PROPOSAL: SUBMISSION TWO

National Law Enforcement Museum – Washington, D.C.

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Executive Summary

The purpose of this document is establish an outline for progress to be made for the Department of Architectural Engineering's Senior Thesis. After going over the National Law Enforcement Museum's project background and overviewing the mechanical system, the design objectives are outlined. These include a desire for energy efficiency, use of free cooling, management by building automation system and power management system, and sound propagation from the air handling units.

Alternatives to the existing design are then considered. These include chilled beams and a variable refrigerant flow system. Both these systems are likely to decrease the energy and noise level. A dedicated heat recovery chiller is also discussed. It has measured success in some hospitals and museums. Finally, a change in the pavilion architecture is discussed: specifically a reduction of glazing on the roof and façade. This would reduce energy loads into the structure.

Going forward, the two proposed mechanical depth topics will be a system redesign with a variable refrigerant flow system and a redesign of the pavilion façade. With these changes, it is expected to reduce the energy consumption and reduce overall noise in the building. The breadth topics in relation to these changes are architecture and acoustics.

This process will recover several tools to complete a succinct analysis. These tools include Trane Trace 700, a load and energy modeling software, Dynasonics AIM, an HVAC noise modeling software, Autodesk Revit, a building modeling software, and IES Virtual Environment, another building energy modeling software. A schedule is printed on the final page of this document showing the expected process of analysis.

PROJECT BACKGROUND

The National Law Enforcement Museum is a 54,000 SF museum will be located in Washington, D.C. between 4th and 5th Street on E Street NW. This structure will complement the Law Enforcement Officer's Memorial and complete the overall aesthetics of the Courthouse Complex of Judiciary Square.

The defining architectural element of the structure are the two glass pavilions that function as the entrance to the museum. Upon entry, the guests will be lead via escalator to the two museum floors. The museum will hold a ticketing area, exhibit space, a research space, café, gift shop and a theater. The third floor below ground will be contain the central plant and utility connections for the structure.

This $50 million dollar project is expected to take 28 months of construction beginning June 2014 and ending September 2015. The contract is set up as a Design-Bid-Build. The Architects and Owners worked together to develop the building design. Following this the Engineers, Consultants and Construction Manager were hired. Finally, the project was bid out to specific subcontractors.

The historical location of the project required cooperation and approval of a number of historical and zoning associations such as the US Commission of Fine Arts, the DC Preservation Review Board and others. The building design is also pursuing LEED© Silver status and preparing to meet compliance with the Section 106 Review as an extra Environmental Assessment.

Mechanical System Overview

The museum is designed to be supplied by six air handling units (AHUs) located in various areas and supplying the multiple spaces in the building. Two 5000 CFM AHUs are specifically assigned to the East and West pavilions, another two 33000 CFM air handling units are situated to serve the exhibit area. Two 4000 CFM units serve the theater and the central plant area. The building is cooled using a combination of a chiller and two cooling towers. The water cooled system is the heat sink for the air handling units. A heat exchanger is also part of the system to support partial or complete free-cooling should the building conditions meet certain criteria.

Air is supplied from the air handling units at a temperature ranging from 50-56 degrees Fahrenheit and then ducted to variable air volume units. The air supply system is separated into three major components: the East & West pavilions, the exhibit areas, and the theater. The theater air handling unit varies its supply to the space with a variable frequency drive at the AHU. Heating in the building is supplied with electric heat at the air handling units and electric reheat at the VAV boxes. Air is returned using a return air plenum for each area and then ducted to be mixed with outside air intakes. Fifteen fan coil units are also used to supplement minor areas such as the café, gift shop and research center.

The entire system is controlled by a direct digital control (DDC) building automation system (BAS). The entry pavilions, theater, and exhibit space each have different control algorithms within the BAS. This control system will use the inputs from various carbon dioxide, oxygen and occupancy sensors. The occupancy schedule is set by the owner with the engineers confirming this with site visits in the one year after construction. Temperature sensors are located within the space and input information to the variable air volume boxes to supply adequate heating or cooling to the spaces. Humidity is maintained at the air handling units from information received by humidity sensors within the return ductwork.

Design Objectives

Being a museum, there is high traffic during the summer and the very cold parts of winter. Therefore, energy efficiency is very important as well as efficient maintenance of comfortable indoor climate. The environment can be maintained with an advanced building automation system with access to multiple sensors throughout the space. Energy efficiency is achieved by effectively using the equipment and allowing it to run at their maximum efficiency. The glass pavilions also use shading devices to reduce the solar load and reduce energy consumption. These can also be used to provide solar heat in the winter months.

The free cooling is an optimal way of decreasing energy use and any addendum to the design should try to keep this design feature. Any other system that could be applied to the museum should utilize free cooling as well. Additionally, an energy recovery component can be used to further enhance the mechanical system.

From an electrical viewpoint, this building solely uses LEDs and fluorescents in all areas outside of the theater. This reduces the energy load by having a lower watts per square foot. The building operators also use a web based Power Monitoring System to monitor the power consumption in the building. This system monitors all the electrical loads in the building from the lights to the HVAC equipment and plug loads.

Sound propagation is very important design objective for the National Law Enforcement Museum. In the theater, the HVAC noise must be limited. This can be difficult because the placing of its air handling unit is in a room directly adjacent. This causes excessive noise that is managed by the use of a duct silencer. The original mechanical design utilizes 24 duct silencers. These are for all of the air handling units, the variable air volume boxes in the exhibit area and for the J. Edgar Hoover Research Center.

ALTERNATIVES

This section discusses the various options that may improve the design and operation of the building mechanical system. These options may augment the system by increasing its efficiency, allowing for increased ceiling height as well as providing the ability to utilize free cooling and decrease noise levels.

CHILLED BEAMS

The use of chilled beams would effectively reduce the noise within the exhibit space. Active chilled beams would continue to duct the noise from the air handling units but the space would no longer have the extra fan noise from the current design's variable air volume units. Since there is no boiler in the building, the chilled beams would only have coolant piping within them. This presents a problem as the current design contains electric heaters at the VAVs as supplemental heat. With chilled beams, the supply air would have to be heated to a higher supply temperature and then sent to the space where the chilled beam would cool the air as required. This method would mimic the utilization of chilled beams in the interior areas of commercial office buildings.

This alternative would be more costly to the construction budget, but its long term benefits may outweigh the initial costs. Another negative aspect is the long lead time on the chilled beams themselves. Most of the manufacturers of these products are in Europe and Australia with only a few from the United States. This may be problematic should specific changes be required.

VARIABLE REFRIGERANT FLOW SYSTEM

A variable refrigerant flow system is similar to the chilled beam system. The refrigerant flow varies within the units as the supply air from the air handling units go through the terminal VRF units. Several manufacturers are proficient in this system type including Daikin, Mitsubishi and LG. It is important to consider the manufacturer when choosing a variable refrigerant flow system because each company has a different way of controlling and piping to each unit. The three major manufacturers' distribution and control style will be compared to determine the best fit for the museum.

Like the chilled beam system, this design would require more energy input from the air handling units but also reduce fan noise. Although VRF systems are costly, the long term benefits will outweigh the initial investment. Because the digital control is so extensive on VRF systems, the controls and sensors will easily interface with the building's power management system.

DEDICATED HEAT RECOVERY CHILLER

This piece of equipment functions as a chiller but utilizes the wasted heat from the compression cycle to provide for elements of the building that require heat such as domestic hot water, for humidity control, or variable units. Multistack DHRC's have effectively been used in conjunction with chillers and boilers at hospitals, commercial buildings and museums. To add this to the mechanical design of the National Law Enforcement Museum, it would have to be integrated into the refrigerant loop and space will need to be allocated for it in the mechanical room. This unit can be modular so energy and load analyses will need to be constructed to determine its efficiency and the best application.

The addition of a dedicated heat recovery chiller may reduce energy costs because of its ability to produce hot and chilled water for building processes. This type of equipment may interfere with the free cooling process because it is most efficient when running at all times.

Pavilion Façade Redesign

The design for the east and west pavilions of the National Law Enforcement Museum include curved glass roofs and facades. Though they allow for a large amount of daylight to enter the levels below, they also input a large solar load on the building mechanical system. By reducing the amount of glass, augmenting the shading devices or adding fritting to the glass, the overall load may be decreased.

In the long run, this would reduce energy loads and therefore costs. Also, less glass in the building may reduce cost by replacing some of the walls with more conventional materials. Some aesthetic might be lost in the changing, but the overall flavor of the design could remain.

Proposed Alternatives

Depth 1: Variable Refrigerant Flow System

The variable refrigerant flow system will replace the variable air volume system currently in the design. It will utilize the existing air handling units and other equipment. The use of this system will reduce energy consumption in the building and reduce the noise in the exhibit areas. This may reduce cost by removing a number of duct silencers from the design and perhaps allowing for smaller ducts. The cost may increase, however as the VRF system will be more costly than the conventional VAV system.

A challenge that may arise during this addendum is humidity control. The presence of electric heaters at the VAV units allowed for better humidity control in the system. This load will likely have to be addressed elsewhere in the design. Also, the author does not have any prior experience with variable refrigerant flow systems so a large amount of research will need to be conducted and a variety of modeling techniques employed to facilitate an educated redesign.

Depth 2: Pavilion Façade Redesign

Reducing the amount of glass in the roof and façade would reduce the solar energy load on the building. The ideal in changing the design is to allow a good portion of daylight to enter into the lower levels and accentuate the architecture of the space and maintain the aesthetic quality of the structure. However, redesigning this element to reduce the amount of glass will decrease the façade cost and the energy load into the building.

In order to analyze the redesign, there will need to be a daylight model using either AGI32 or IES Virtual Environment to show that adequate daylighting is provided to the first level below grade. This can be further explored as a breadth topic. The shading devices currently in the structure must be optimized and connected somehow with the building automation system to regulate the amount of solar gain. The façade will also have to be adjusted, either by reducing the amount of glazing or by adding fritting to diffuse the light and solar energy.

Breadth Topics

Breadth 1: Daylighting

By changing the amount of glazing on the façade and roof, the transparency of the structure will be reduced. The amount of daylight entering the entrance and ticketing areas will be reduced. However, the redesign of the façade can allow daylight to enter the space more efficiently. By modeling the façade redesign in IES VE or AGI32, daylighting levels can be measured within the spaces and the results may allow for reduced use of electric lighting during some hours of the day. This would reduce energy use in the building. To more effectively show the infiltration of daylight, a section cut of the structure will be used.

Breadth 2: Acoustics

The specification of over twenty duct silencers within the mechanical system dictates there is an acoustical concern. The most important spaces to analyze will be the theater, exhibit space and the Hall of Remembrance. The noise from the air handling units will need to be analyzed. The use of the variable refrigerant flow system will reduce the noise by removing the excess fans from the existing variable air volume units. The reduction of glazing in the pavilions will also likely reduce the amount of ambient noise present in the space.

Project Methods & Tools

Trane Trace 700

This is a building load and energy modeling software from the manufacturer Trane. During the Technical Reports phase, a Trane Trace model was created for the National Law Enforcement Museum. Analysis of the model revealed it to have a significant difference to the engineers' calculations. This will have to be amended so that this tool can be used to tabulate the changes in building energy loads and consumption after the proposed changes are implemented.

Dynasonics AIM

Dynasonics AIM is an HVAC acoustic modeling software from Dynasonics, a manufacturer of duct silencers and other noise reduction elements. This program will be used to ascertain the existing noise levels in the important spaces listed in the above section, Breadth 2: Acoustics. The program will be used to determine the sound at the diffuser for this existing system with and without the duct silencer. Following this, a calculation of the noise level while using the variable refrigerant flow system will be analyzed.

IES Virtual Environment

This program from Integrated Environmental Solutions is a very good at displaying the effect of the climate on a structure. It easily models surface temperatures and room daylight diffusion from three dimensional models. This software will help to analyze the infiltration of daylight into the pavilion spaces from the existing design and the redesign with less glazing.

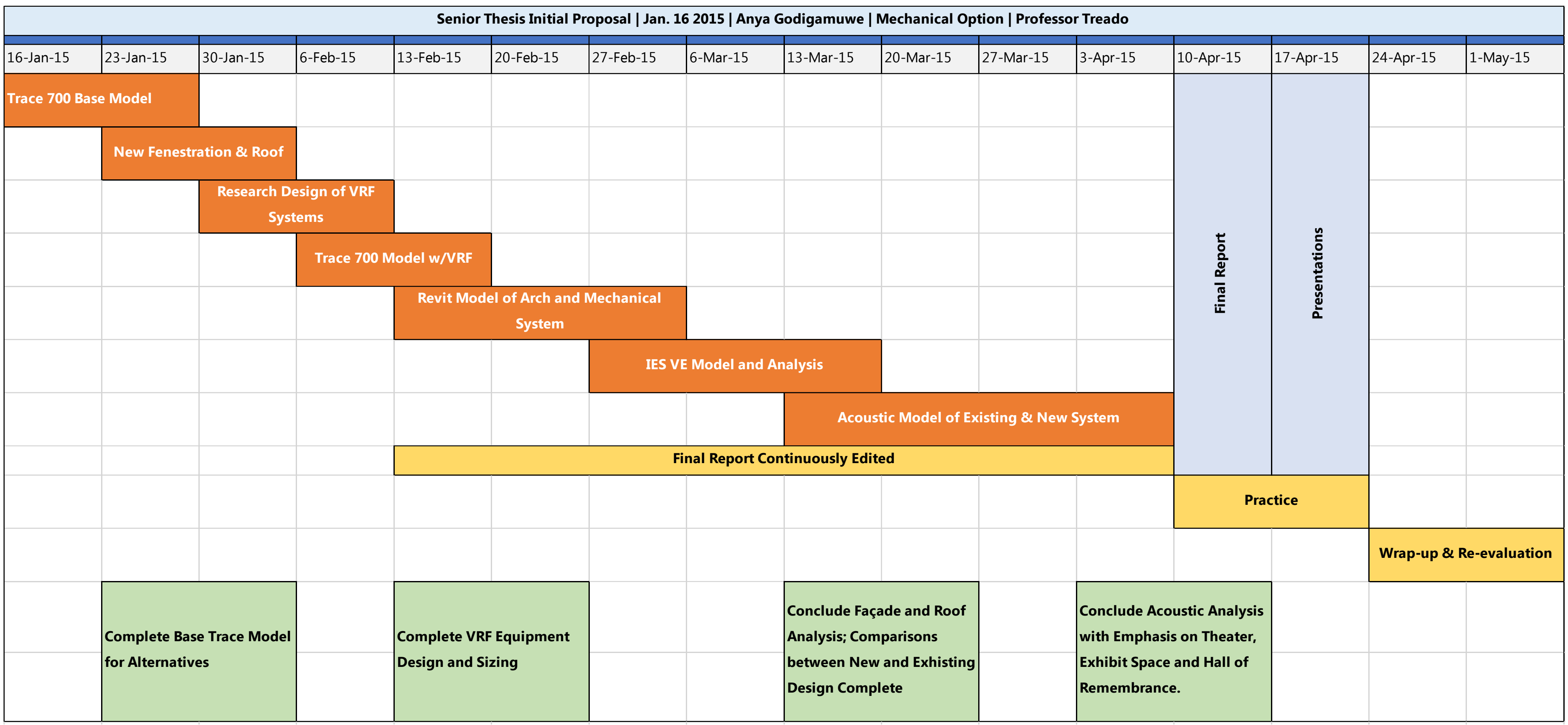
Autodesk Revit

A common building design software, this program will be utilized to augment the daylight analysis completed in IES Virtual Environment. The mechanical design will also be drafted within this program and its duct sizing and analyzing feature will be used to its maximum efficiency.

AGI 32

This program is a lighting program that displays intensity of light from electrical and natural sources. The program yields easy to read, color gradient displays that showcase the lighting levels at various surfaces and heights.

SCHEDULE


Senior Thesis Initial Proposal | Jan. 16 2015 | Anya Godigamuwe | Mechanical Option | Professor Treado
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6-Mar-15
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10-Apr-15
17-Apr-15
24-Apr-15
1-May-15
Trace 700 Base Model
New Fenestration & Roof
Research Design of VRF Systems
Trace 700 Model w/VRF
Revit Model of Arch and Mechanical System
IES VE Model and Analysis
Acoustic Model of Existing & New System
Final Report Continuously Edited
Final Report
Presentations
Practice
Wrap-up & Re-evaluation
Complete Base Trace Model for Alternatives
Complete VRF Equipment Design and Sizing
Conclude Façade and Roof Analysis; Comparisons between New and Exhisting Design Complete
Conclude Acoustic Analysis with Emphasis on Theater, Exhibit Space and Hall of Remembrance.

RESOURCES

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2. Mehta, M., & Johnson, J. (1999). *Architectural acoustics: Principles and design*. Upper Saddle River, N.J.: Prentice Hall.
3. Kreider, J., & Curtiss, P. (2010). *Heating and cooling of buildings: Design for efficiency* (Rev. 2nd ed.). Boca Raton: CRC Press/Taylor & Francis.
4. Grimm, N. (1998). *HVAC systems and components handbook* (2nd ed.). New York: McGraw-Hill.