Thesis Proposal

Revised Proposal for Investigation of Alternative Systems

Delaware County Community College

STEM Center

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Mechanical Option

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Table of Contents

List of Figures

Executive Summary

(All Photos Provided by Burt Hill)

The Delaware County Community College Science, Technology, Engineering, and Mathematics (STEM) Center is a new addition to their Marple Campus, and is part of the two-building STEM Complex. At 105,000 square feet and four stories it is a focal point for the campus, and stands out with both architectural and sustainable features.

The purpose of this report is to propose alternative systems in relation to the mechanical system design as well as two additional breadth topics. The main areas to be studied will be radiant heated flooring for the ground floor, passive solar heating through the south side glass façade, and the implementation of natural ventilation capabilities.

It is proposed that radiant heating and passive solar heating will provide needed relief for the heating loads in the STEM Center, which lies in a relatively cold climate. These techniques should aid in the lowering of operating utility costs as well as energy usage and subsequent harmful emissions.

Natural ventilation is suggested to be an improvement of the already excellent building sustainability and quality. Study of natural ventilation techniques will include analysis in the way of computational fluid dynamics.

Through implementing passive solar heating and natural ventilation, there will most likely be several potential alterations to the existing building architecture. General building design and key architectural features and elements will be kept, however analysis of this breadth topic will include possible redesign of doors and windows, and study of the building enclosure as a whole.

With the use of radiant heated flooring, the construction implications will be assessed as a breadth analysis. This will include modification of floor insulation and construction processes. Upon completion of all of these areas, a full life cycle cost analysis will be performed to assess the overall financial effects of the proposed systems.

SECTION 1 – Existing Mechanical System

Design Objectives

The STEM Center is a part of new construction located adjacent to the existing buildings that make up the Delaware County Community College campus. It was decided early on that for the STEM Complex there was not much capacity to utilize nearby existing systems, and that significant mechanical systems design were necessary for both the STEM Center and Technology Building. The considerations going into this all new mechanical design varied in degree, but included low initial and/or operating costs, excellent air quality, adequate heating and cooling, and high energy efficiency. A goal for the project from the very beginning was to achieve LEED certification to show achievement of high building sustainability.

Special considerations for this building, specifically, mainly stemmed from the occupancy and space types that were included in such a science-based building. Room types such as laboratories and preparation rooms, as well as other standard educational spaces, meant heightened requirements for air quality, ventilation, and exhaust. Laboratories for the building include physics, biology, anatomy/physiology, earth and space, CAD, and both organic and general chemistry.

Of course a major concern was placed on the operating cost of the mechanical system. For a college such as DCCC, the hope was to be capable of maintaining the building systems with ease and as little expense as possible. Considerations were taken to provide energy efficient equipment to potentially decrease utility bills.

Figure 1: Site Plan Aerial View

Overall, limiting factors on the STEM Center design were minimal. With the site being on the DCCC Marple Campus, in the greater Philadelphia area, it was obvious that there would be a slightly higher emphasis on heating than cooling, but a need for good balance and control altogether. The building design and architecture itself, containing a sizeable glass façade on south side at all four levels, suggested a concern for high amount of solar gain as well. The orientation of the building is suitable though, as the majority of the glazing won't receive the significant glare they might if facing east or west.

SECTION 2 – Mechanical System Evaluation

Existing System Design

Two air handling units that serve the entire building are roof mounted and have a capacity of 89,500 cfm apiece. Each of these units contains a heat recovery coil, pre-heat coil, and a chilled water coil. Ductwork traveling down vertically through four different mechanical shafts lead to variable air volume (VAV) terminal units that are equipped with heating coils, with capacities ranging up to 4400 cfm. Fans for supply and return are all provided with variable frequency drives and full economizer capabilities. In terms of control, flow measuring stations are also used for outdoor air control.

While the supply and return paths for the air side mechanical system are relatively simple and straight forward, the exhaust system for the building is slightly more unique in order to cater to the laboratory and preparation spaces located on the top three floors. In total, there are 13 science labs, most of which have dedicated preparation or storage rooms that require adequate exhaust of air. To comply, fume hoods are located in each lab and preparation room in the building. These are ducted vertically to the roof mounted exhaust fans, which are equipped with refrigerant coils for heat recovery systems. Pressure is controlled using a space pressurization monitoring system, and each exhaust fan is provided with a variable frequency drive.

On the water side of the mechanical system, a 700 ton water cooled chiller accounts for the chilled water. This is arranged with (2) 25 hp primary chilled water pumps and (2) 125 hp secondary chilled water pumps to make a primary/secondary chilled water system. All primary/secondary pumps are equipped with variable frequency drives.

With the construction of the STEM Center, the intent in the mechanical design was to replace the existing cooling tower, and this was done with the addition of (4) 600 ton induced draft crossflow cooling towers. The new chiller and cooling towers are adequately served by the new 40 hp in-line condenser water pump.

For the hot water system, (2) Bryan 250 BHP dual fuel heating hot water pumps account for the hot water heating using natural gas. For the heating hot water system, a primary/secondary arrangement is utilized as well, consisting of (2) 7.5 hp pumps. Additionally for the hot water system, and also located in the boiler room, are two pumps for the heat exchanger, two for the reheat coils, two for the preheat coils, and also two in-line pumps for the fin-tube radiation heating that is utilized for the exterior glass façade on the south side of the building to prevent condensation.

System Evaluation

The mechanical system designed for the STEM Center is effective and appropriate for the needs outlined above. The first cost for the mechanical system was able to be decreased with the partial use of existing plants and equipment from the campus, along with the addition of larger, consolidated equipment. Operating cost analysis was conducted with the help of Trane TRACE™ 700 software, and a yearly cost of $177,286 was calculated. The use of heat recovery, variable frequency drives, and economizers aids the operating cost to a degree, and further investigation will be taken to determine where the yearly totals can be decreased even more.

Altogether, the centralization of the equipment to the roof and the adjacent building helps to alleviate the loss of usable floor space, and also contributes to the easier maintainability of the building as a whole. Obviously a great deal of mechanical shaft space is needed to ensure proper ventilation and exhaustion of air for various science-related rooms, and this usage is largely unavoidable.

As is summarized in Technical Report 3, with discussion of the LEED credits awarded, great steps have been taken by the design team to ensure high quality of air and environmental control. The pursuit of LEED Silver certification accurately summarizes the sustainability and excellence of the building systems as a whole. There is potential, still, for improvement and a higher level of achievement on the LEED scale.

SECTION 3 – Proposed Alternative Systems

As mentioned above, the current mechanical design for the STEM Center is very effective and sufficient to fulfill the design requirements and considerations, and the LEED Silver certification is proof of a fully sustainable design. However, there appear to be areas in which energy consumption is higher and efficiency is lower than it could be, particularly in regards to the atrium and lobby space on the ground floor. A handful of alternative solutions will be analyzed for mechanical system improvement, and those are Radiant Heated Flooring, Passive Solar Heating, and Natural Ventilation.

Radiant Heated Flooring

At present, the air handling for the ground floor is a cause for concern, particularly in the grand lobby space where ceilings heights are relatively high and even exceed 40 feet in some places. A good alternative to the existing space conditioning arrangement may be to utilize radiant heated flooring. Radiant flooring is particularly useful in instances such as high ceilings, space with increased foot traffic, and site locations with potential for snow and ice entering with occupants. In the event of high ceilings, it is important to focus on conditioning the occupants instead of the space itself that has unoccupied volume. With the current layout of the lobby and atrium, there is a significant amount of foot traffic at nearly all levels, as students, faculty, and other occupants utilize the building. Additionally, being in the greater Philadelphia area and having four vestibules on the ground floor in the lobby general area, there is potential for snow and ice to be tracked in. In this case, radiant heating is desirable to keep the floor surfaces at an ideal temperature to ensure both safety and comfort.

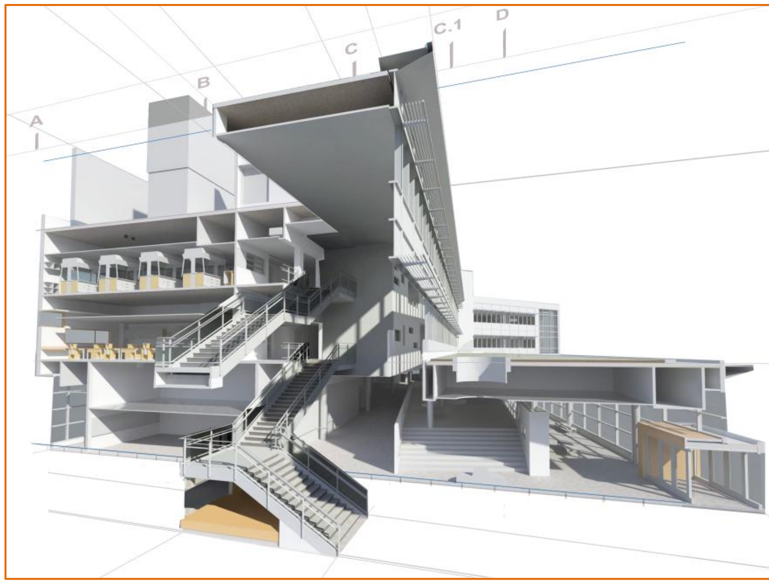

Figure 2: Section View of Lobby and Atrium

This alternative will require significant assessment to see if it is feasible, as there is no basement in the STEM Center and this analysis will be from the ground up. For coordination with the building's existing mechanical system and equipment as a whole, it is noted that radiant heating is provided using hot water carried in flexible PEX tubing. The source for hot water in radiant flooring is typically a gas-fired boiler, just like the existing boilers the STEM Center already employs. Therefore a significant change in equipment should not be necessary, although resizing will potentially be needed to ensure accurate and efficient heating supply for such an alternative system.

Passive Solar Heating

A forefront architectural feature of the STEM Center is the glass curtain wall façade on the south side of the building. There are two sections to this glazing: the portion at the ground floor level and the portion above the green roof at the 2nd and 3rd levels, which is shown in Figure 3. These factors and more make this building a prime candidate for a possible alternative system in passive solar heating.

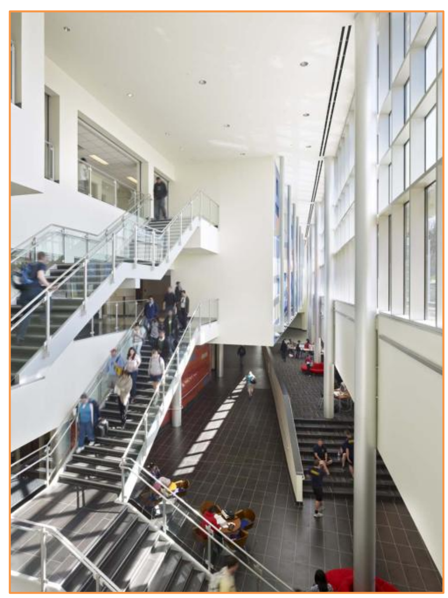
Figure 3: View of Lobby and Glazing

The building orientation is ideal for passive solar design, as it is elongated east to west, has the curtain wall on the south façade, and has more important and higher occupied spaces on the south side. It is also good to maintain the daylight achieved by the glazing while harnessing the heat it provides as well. This can be accomplished through a few different methods: direct gain, indirect gain, and isolated gain. For the STEM Center, it would be most appropriate to not use isolated or indirect gain, which would alter the architecture significantly. However, direct gain is achievable through the use of the right sort of material for thermal mass storage.

The existing design uses a cheaper and less effective sheet rock on the opposite side of the glass curtain wall. However, by using a more expensive material such as stone or brick for a thermal mass wall, passive solar heating may be attainable. A variety of methods and materials will be studied for its effectiveness within the framework of the current building design.

By implementing a passive solar heating system, heat would be absorbed during the day hours through the thermal mass wall and then would radiate at night resulting in saving air handler energy needed for heating. These alternative systems, passive solar and radiant floor heating, are proposed solutions to increase the effectiveness of the mechanical design in the way of heating for the STEM Center, which is suitable for being in a climate where combatting the cold weather is crucial.

Natural Ventilation

The existing design has 100% mechanical ventilation and does not use any natural ventilation. With the need for adequate air exhaustion for lab spaces, the two rooftop air handlers used for ventilation are substantial and could benefit from the assistance that comes from natural ventilation. Using natural ventilation alongside the current mechanical design could potentially decrease operating and energy usage.

Exceptional ventilation is crucial in educational facilities to keep air fresh and lower CO_2 levels that can have an adverse effect on learning and studying. For educational buildings, natural or hybrid ventilation systems are very common, and full analysis of an alternate ventilation system will be conducted as a potential solution.

Main concerns by the Burt Hill design team initially were the possibilities of naturally creating a wind tunnel due to the relation to the adjacent D.C.C.C. buildings. It has been suggested by the team that by altering placement of doors it is possible to solve this problem, and this will be the main issue moving forward in the analysis of this alternative solution.

SECTION 4 – Breadth Topics

Construction Management

Implementing a radiant heated floor system with the current building design will be significant from the construction standpoint, and will include the need for proper installation of the necessary piping and flooring. The configuration of floor insulation will change to work with the PEX tubing containing the heating water. Floor systems, such as the Crete-Heat™ Insulated Floor Panel System allow for this modification to be accomplished practically and easily. A full analysis of the construction management implications will be conducted to explore this proposed mechanical system.

Acoustical

In coordination with the proposed mechanical changes, the potential improvements in the acoustical consequences of mechanical equipment in the building will be assessed. It is proposed that by implementing radiant heating, natural ventilation, and passive solar heating, mechanical equipment may be reduced in size in accordance with the decreased building load. With decreased equipment sizes, it is hoped that mechanical-related noise will decrease, and this possibility will be analyzed. Additionally, a study will be conducted regarding any potential floor changes associated with using radiant floor heating to ensure no acoustical disadvantages to using radiant floor heating.

Systems Integration

The combination of the proposed alternative systems is a part of a goal to maintain the key architectural characteristics of the existing STEM Center building design while lowering the operating costs and site emissions caused by the mechanical design. The main focus of this improvement will be in regards to heating systems, with the aforementioned methods. As passive solar heating is studied, considerations will be taken at all times to ensure only positive effects on the building envelope and its relation to the overall mechanical system performance.

Radiant flooring and passive solar heating should contribute to the energy usage due to heating, and likewise decrease the utility cost of natural gas to the site. The use of natural ventilation should also decrease the load on the rooftop air handlers that at present handle 100% of the ventilation for a building that requires a significant amount of air exhaustion and quality. Fluid dynamics analysis will show the feasibility of this alternative that also makes the STEM Center more sustainable than it already is.

The effect these systems have on the overall construction process and acoustical climate will be assessed and analyzed in regards to long term cost implications. As a whole, the combination of some or all of these proposed alternatives will result in a more cost effective, energy efficient, maintainable, and sustainable STEM Center.

SECTION 5 – MAE Course Related Study

In regards to naturally ventilating the STEM Center, a full study of the wind and fluid dynamics of the site and surrounding buildings will need to be conducted to ensure its effectiveness. Knowledge and methods learned through masters-level coursework in AE 559 Computational Fluid Dynamics will allow for an accurate study. Additionally, the in-depth knowledge of heating concepts in AE 558 Centralized Heating Systems will be utilized in the analysis of implementing alternative heating systems for the building.

SECTION 6 – Tools and Methods

STANDARDS

Throughout the processes described above, attention will be paid to ASHRAE Standards and other necessary requirements to ensure a successful and appropriate redesign. This will be specifically applicable in the implementation of natural ventilation, and the assurance of air quality.

ENERGY MODELING

As per the analysis completed for the existing mechanical design, load simulations will be necessary to assess the alternative systems, as well as calculations of operating costs and emissions due to energy usage. Modeling will be conducted using appropriate software, such as Trane TRACE™ 700, which has been used in analysis to this point.

CALCULATION METHODS

Altogether, to accomplish necessary calculations for redesign, programs such as Engineering Equation Solver (EES) and Microsoft Excel will be utilized. These programs, and other similar ones, are appropriate for engineering related calculations.

APPENDIX A – Preliminary Research

Radiant Heated Flooring

"Comfort from the Ground Up - Versatile In-Floor Radiant Hydronic Systems." *Energy Solutions for Commercial Buildings* 2006: 10-12. *Energy Solutions For Commercial Buildings*. Energy Solutions Center. Web. 7 Dec. 2010.

This article written by the Energy Solutions Center highlights the versatility of radiant heating systems, and outlines common and acceptable building applications. Also, links to appropriate other resources and manufacturers related to radiant heating are included at the end of the article.

Hayden, Gary, and Brian King. "Radiant Floor Heating For Commercial & Industrial Buildings." *PMEngineer*. BNP Media, 29 Aug. 2000. Web. 7 Dec. 2010.

In this article by Hayden and King of Burnham Radiant Heating Co. the ideal candidates for a radiant heated floor are discussed along with the history of the heating method. The use of PEX pipe are touched on, as well as information on cost considerations.

Passive Solar Heating

Fosdick, Judy. "Passive Solar Heating." *Whole Building Design Guide*. National Institue of Building Sciences, 17 June 2010. Web. 7 Dec. 2010.

This article, as supplied by the Whole Building Design Guide, gives a complete overview of the concepts of passive solar heating, discussing fundamentals as well as relevant codes and standards. Included at the end of the article is a case study for the University of Wisconsin as well as additional publications on passive solar heating systems.

Guyer, J. Paul. "Introduction to Passive Solar Buildings." *CED Engineering*. Continuing Education & Development, 2009. Web. 7 Dec. 2010.

Information on daylighting and thermal storage walls are especially useful in this article published by CED Engineering. Also discussed is solar availability and climate considerations, which is information that will be useful in full site analysis.

Haglund, Bruce, and Kurt Rathmann. "Thermal Mass in Passive Solar and Energy-Conserving Buildings." *Vital Signs*. UC Berkeley College of Environmental Design, 9 Sept. 2002. Web. 7 Dec. 2010.

In this article, faculty for the University of Idaho discuss energy-conserving principles in the use of passive solar heating. Most of the discussion is related to the thermal mass necessities of passive solar, including materials and placement strategies.

Natural Ventilation

Guardigli, L., and M. T. Cascella. "Integration of Hybrid Ventilation System in Educational Buildings." *Alma Mater Studiorum*. University of Bologna. Web. 7 Dec. 2010.

This article, written by faculty from the University of Bologna in Italy, discusses case studies for hybrid natural ventilation systems in educational buildings as well as the computational fluid dynamics implications with natural ventilation. As a CFD study will be performed for the analysis of a natural ventilation system, this information and case study will provide a good guide for effective redesign.

Settlemyre, Kevin. "Passive/Hybrid Ventilation Strategies." Integrated Environmental Solutions, Nov. 2007. Web. 7 Dec. 2010.

This discussion is conducted by members of the team at IES, an excellence program for energy modeling. It contains many tips to natural ventilation design as well as discussion of hybrid systems and the integrative design process.

APPENDIX B – Work Plan

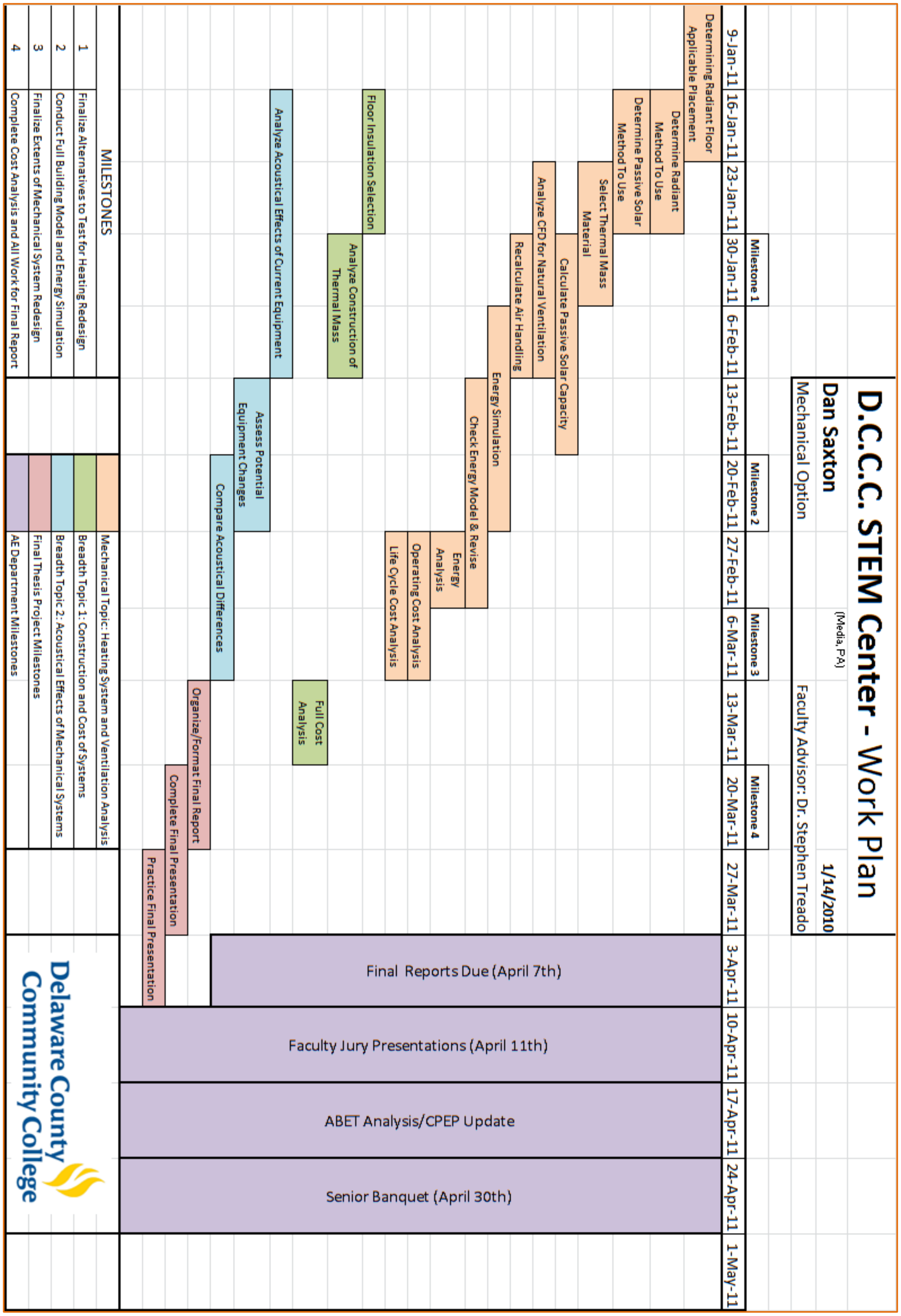

Figure 4: Preliminary Work Plan for Spring Semester