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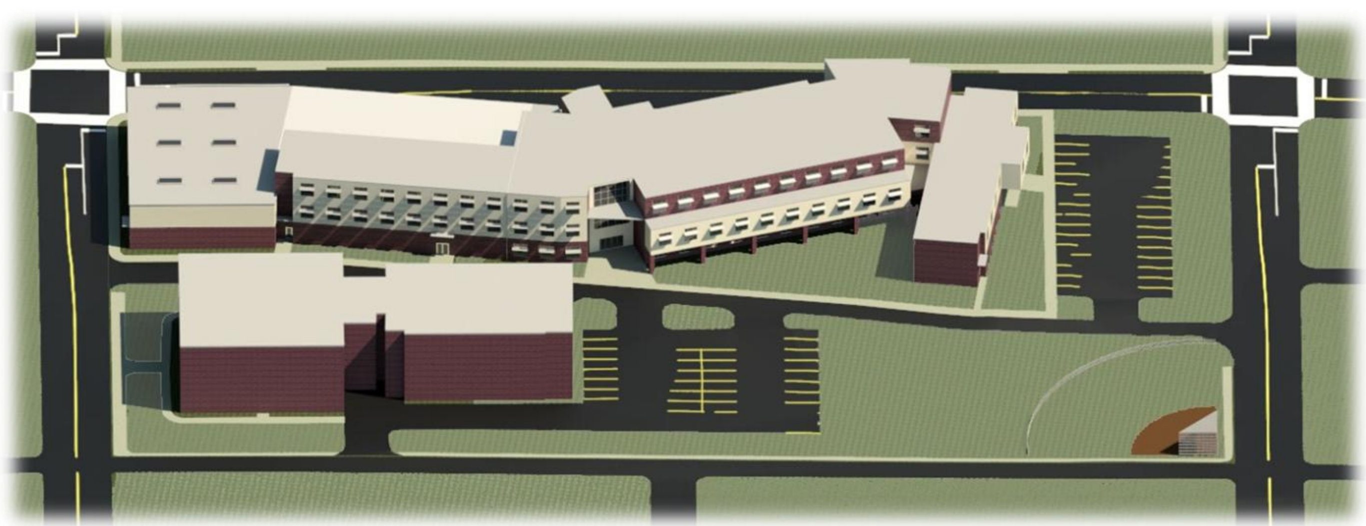
2013 ASCE Charles Pankow Foundation
Annual Architectural Engineering Student Competition

nexus

BUILDING INTEGRATION



Team Registration Number: 02-2013

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The requirements of a typical elementary school, in conjunction with the socioeconomic conditions of the Reading school district, motivated unique design decisions and innovative solutions. To achieve these solutions, a set of categories was created to define the purpose of each function in the school. It was determined that the three major functions of the building included user **Experience**, **Community**, and **Education** spaces. The function of these three categories dictated the integrated design of the various building systems, as well as the manner of dividing the building in terms of system types and discipline coordination. As such, these three sections will be the key areas of discussion and integration in the following content.

1. Executive Summary

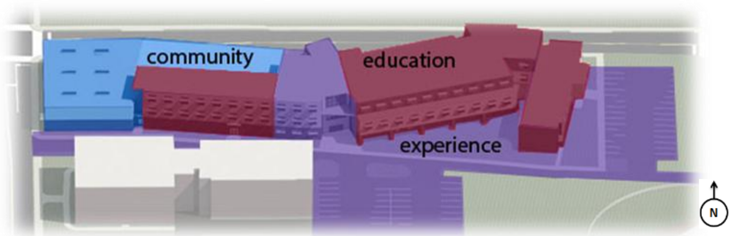

Figure 1: Nexus Defined Building Functions

1.1 Introduction

The **experience** aspect of Nexus' design encompasses the new campus layout, the façade, and main lobby. Through the creation of a new campus, Nexus integrates safety with functionality; both of which need to be emphasized in the overarching design. The integration of insulated concrete form exterior bearing walls and exterior window louvers, with a brick and metal panel facade create a distinctive aesthetic appearance for the new elementary school. Lastly, an inviting three-story lobby will welcome students and community members into the school. This lobby acts as the "hub" of the building, bridging the community and education portions of the school. This is also a critical point for the building systems as different applications were implemented by all disciplines to adapt to the functionality of these very distinct spaces.

Community involvement is an integral aspect of Nexus' school design. The west end of the school contains a 24-hour health center, multi-purpose room, and a proposed second construction phase which includes a pool. These community areas are separated by safety doors from the education portion of the building to ensure student safety and school security after hours. The multi-purpose room also functions as a community shelter in the event of a natural disaster. Lastly, this portion of the building is serviced by separate mechanical and electrical systems along with an enhanced structural system.

As it is the primary purpose of the school building, the **education** portion is the most innovative part of Nexus' design. The main focus of this area was to create a learning environment that is augmented by the building systems. Designing to maximize efficient daylighting and increased ventilation ratios create an enhanced learning environment conducive to elementary education. An open-air feel is heightened by an exposed 14-foot ceiling with a lean interior structural steel system that allows for classroom flexibility. All of these aspects are integrated so the building itself will function as a learning tool.

1.2 BIM Execution Plan

Nexus developed a BIM (Building Information Modeling) Execution Plan to facilitate the integration of the building systems. This execution plan specifically defines the roles to be fulfilled by the construction managers and the structural, mechanical, and lighting/electrical engineers (see page 16 of Supporting Documentation). In creating the BIM Execution Plan, each design discipline created their own objectives to achieve the overall project goals (see page 24 of Supporting Documentation). In addition, The BIM Execution Plan defines the information exchanges (softwares, models) between the four disciplines (see page 17 of Supporting Documentation). All of these processes enabled progress by recognizing the individual discipline decisions comprising the overall building design that were crucial to maintain team progress.

Outlining objectives and goals was necessary to expedite each discipline's ability to work cohesively to create innovative solutions (see page 18 of Supporting Documentation). This prevented the team from having to perform unnecessary or additional work. Increasing the team's efficiency and effectiveness was critical throughout this project in order for each discipline to meet the numerous interim submissions scheduled by Nexus. Thus, the time spent in planning the early phases of this project facilitated productive team communication and progress. As a result, the interrelatedness of Nexus' building systems reduces redundancy and enhances the architecture of the school building.

1.3 Owner Goals

safety & security

Safety is of utmost importance for the Reading School District. Having a sense of 'unseen' security will enhance the feeling of safety for the occupants. This must also address the possibility of dangerous events unfortunately becoming prevalent in today's society.

lifecycle & maintenance

Reading School District desires a building that can endure for 100 years. This building must be adaptable and flexible to accommodate new emerging technologies, learning styles, and teaching techniques. The flexibility of the spaces prolongs the building's lifecycle while the mechanical systems minimize the need for routine maintenance.

cost effective

Reading School District needs a building that is cost effective over both the short and long terms. All design decisions were analyzed by all Nexus team members to ensure that the greatest value was achieved. Nexus' building system and material selections minimize first costs, while maintaining the integrity and affordability in the long run.

Nexus' Mission Statement

To develop a design that merges education with the community in a facility that is safe and cost effective while functioning as a learning tool.

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1.4 Nexus Project Goals

Nexus' project goals were developed to achieve the owner goals and are supported by the individual discipline objectives.

integration

Integration is the all-encompassing goal of meeting the owner's objectives. With the main architectural components of the building already established, Nexus focused on integrating the structural, mechanical, and lighting/electrical designs with the constructability of the building through predefined discipline goals and established information exchanges.

reduce, recover, reuse

This holistic building design was produced through lean practices. These lean practices were achieved by reducing, recovering, and reusing. These are reflected in all four design disciplines' decisions in order to save construction time, initial and lifecycle cost, and energy.

learning tool

Nexus desired to create a building that could be used as a learning tool for the end users. The building has exposed ceilings in order to allow users to understand the function of the exposed structural, mechanical, and electrical elements. All of these items were coordinated through extensive planning to meet the necessary discipline performance requirements.

The six icons above that represent the owner objectives and Nexus goals will be utilized next to section subtitles throughout this report to express achievement of the objectives or goals in that particular section.

2. Experience

2.1 Campus

In order to meet the owner's objectives of safety and flexibility, Nexus deemed it necessary to reposition the building on the site. Prior to developing a learning environment, establishing site safety was imperative to all end-users. Since Reading has one of the highest crime rates in Pennsylvania, Nexus focused heavily on the importance of maintaining the safety and security of the students in the campus design[1]. As seen in Figure 2, the main entrance originally faced a busy road. To improve campus security, Nexus turned the educational campus in on itself to shelter the students (see Figure 3).

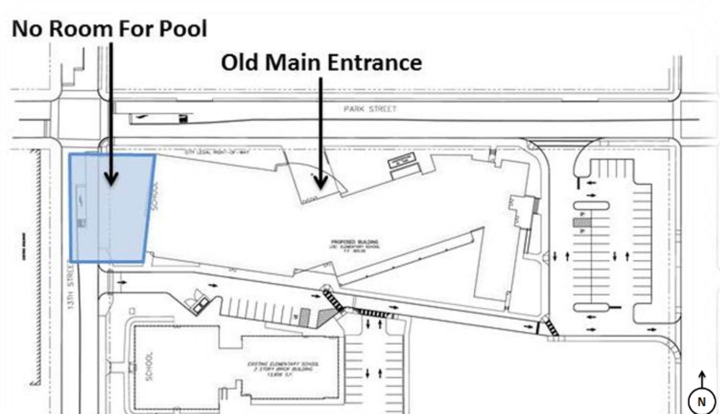


Figure 2: Original Site Plan Provided by the AEI Competition

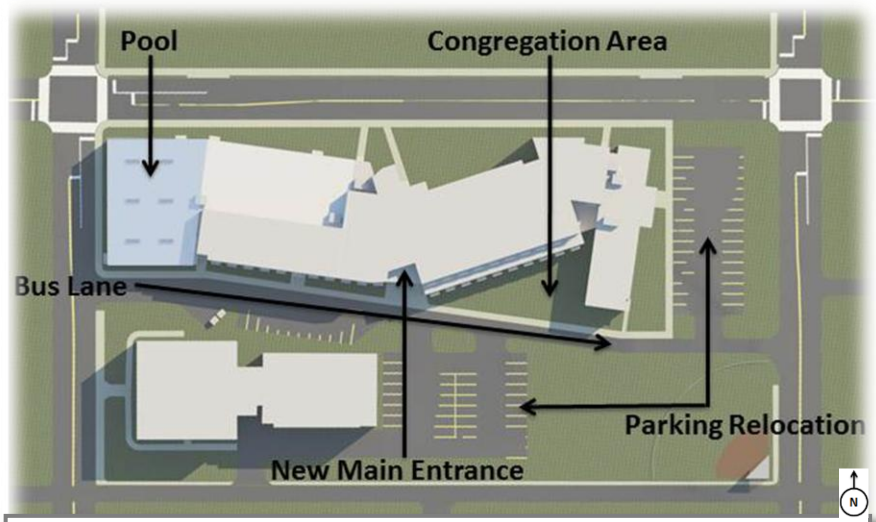


Figure 3: Nexus' Revised Campus Plan (building moved east, parking reallocated, and pool addition)

This inward turn moved the main entrance from the north to the south facade creating a large group congregation space on the inside of the campus. This area allows students to congregate away from the main roads before and after school.

The original site plan also did not provide sufficient space for a pool. Figure 3 shows how the building was shifted east in order to make room for the proposed pool and maintain east to west construction sequencing (see page 21 of Supporting Documentation). This shift displaced some of the parking which has been relocated in the southern lot. This relocation of the parking brings more parking closer to the new main entrance of the building as an added benefit of this design. The baseball field proportions were not affected, thus maintaining the existing playground area. The bus lane will remain one way, with traffic progressing from west to east. This will also be the direction of construction traffic on the temporary gravel road during the 15 month construction schedule (see page 20 of Supporting Documentation). In addition, there will be automatic balusters implemented to prevent unwanted thoroughfare during school hours.

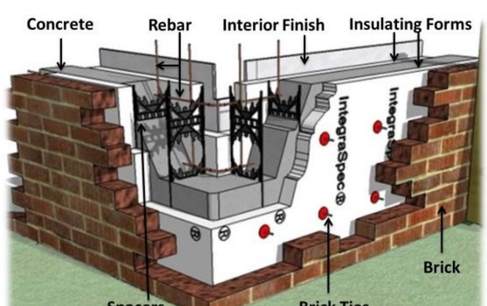


Figure 4: ICF Isometric Section: (www.integraspec.ie)

2.2 Building Envelope

An integrated approach was taken when forming the façade of the building. Ultimately a brick-on-concrete bearing wall system was chosen. The concrete wall is made with Insulated Concrete Forms (ICFs). Insulated Concrete Forms are stay-in-place concrete forms that consist of two pieces of three-inch rigid insulation with six inches of reinforced concrete (see Figure 4). The exterior of the façade will be comprised mostly of brick with some colored aluminum panels. The interior of the façade will be finished with impact resistant gypsum wall board.

2.3 Building Envelope Rationale

The building envelope is a very integrated facet of the integrated design. All discipline performance criteria was taken into consideration to select an effective solution. From a construction management standpoint, ICFs are easily transportable and lightweight in addition to being easily erected. The ICFs also provide different structural purposes. They serve as bearing walls in the gravity structural system in addition to acting as shear walls for the lateral structural system (see Figure 6).

Figure 5: Experience Highlighted on First Floor Plan

A primary focus in designing the façade was ensuring it improved the energy efficiency of the building. The ICF's have an R-value of 24 which is roughly double that of a typical façade system. This greatly exceeds the minimum R-value of 19 recommended by ASHRAE Standard 90.1 for this region. Along with being a good thermal insulator, ICFs are also very airtight which improves energy efficiency by decreasing infiltration rates.

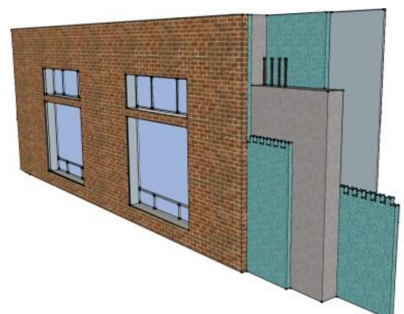


Figure 6: Isometric Section of ICF wall

One of the project goals was to provide plenty of daylight to the classroom spaces to promote an enjoyable learning environment. However, large windows are typically not possible in a concrete bearing wall system. In response to this, a window system was developed to provide enough daylight while maintaining the integrity of the gravity structural system. Seven foot wide windows spaced seven feet apart were implemented into a 28-foot standard bay size. These windows fit seamlessly into the structural system so that only one beam sits above a lintel over each window. Due to the ICF walls, the six inches of reinforced concrete is sufficient to carry the load from the beam. Also, the seven foot horizontal sizing and spacing of the ICF walls creates a repetitive pattern which is desirable for construction by reducing cost through schedule savings. It

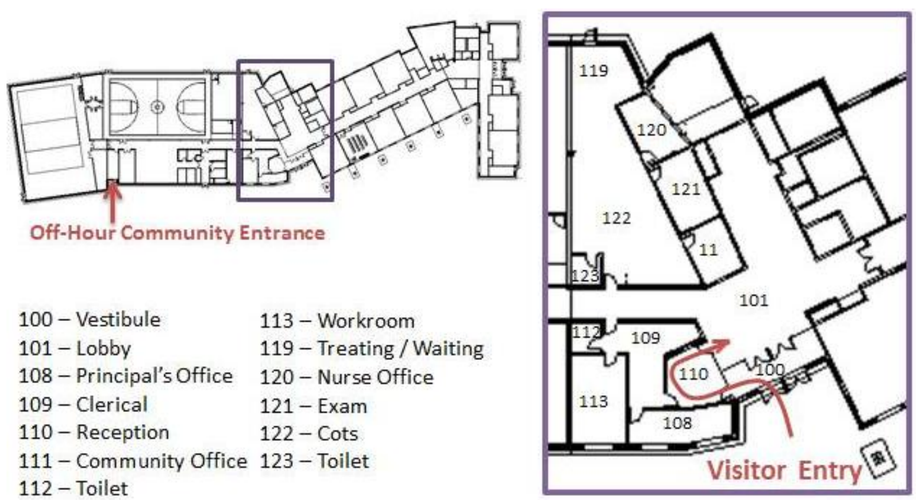


Figure 7: First Floor Plan with Enlarged Image of Redesigned Lobby

should also be noted that Nexus' design minimizes the number of windows at the street level of the building. These windows will utilize bullet resistant glazing to maximize student security by further preventing unwanted access to the school's interior.

In designing the roofing system for the school, it was decided that a white roof be implemented to reduce the "heat island effect." This also earns a LEED Credit for the building. It was decided that this roofing system be implemented in place of a green roof due to the increased cost associated with the additional structural and maintenance requirements. The savings as a result of this decision allowed for the reallocation of funds to be spent on classrooms and other interior spaces.

2.4 Lobby

Relocating the main entrance on the interior part of the site increases the 'unseen' sense of security. The theme of safety was carried into the building by maintaining one secure entrance (see Figure 3). Having one entrance ensures that no unwanted visitors enter the facility, which is crucial at an elementary school full of young children. This is the only secure point of entry into the building during school hours. All visitors must be buzzed in through the double doors and then turn left and check in at the front desk (see Figure 7). The entrance to the community side of the building that is accessible to community members during off hours does not permit visitor access to the classroom wing because of the security doors. The addition of the atrium also created flexible learning space on the second and third floors that was not included in the original scope (see Figure 8). These spaces can be used as a reading nook or allow teachers to get their students out of the classroom and into a new more open space. These spaces are well lit thanks to the hanging pendants and the daylight that filters in through the curtain wall (see Figure 9).

Figure 8: Second Floor Atrium/Lobby Perspective Rendering

Figure 9: Perspective Rendering of Main Entrance on South Facade

The lobby will also house a video display building monitoring hub. This hub will track the energy use and savings of the building by housing the control system that works with both the lighting and mechanical system. This system will show occupants the real time energy use of the building and how the building's systems save energy. This too will act as a teaching tool for students so that they become aware of their own energy use.

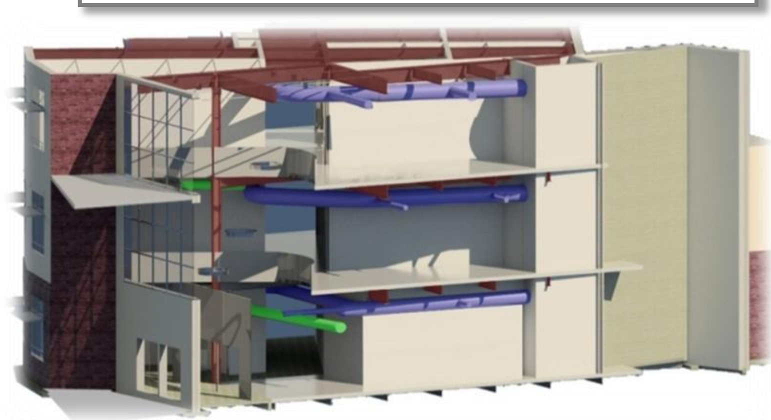


Figure 10: Building System Integration in Lobby

2.5 Lobby Rationale

The cantilever over the entrance serves as an architectural element to welcome students into the building (see Figure 9). It also serves the purpose of blocking direct solar heat gain during the summer. The atrium allows sunlight into the core of the building and further into the corridors (see Figures 9 and 10). This reduces the amount of electric light needed during the day. At night, a combination of downlights and decorative pendants will be used to illuminate the space.

The lobby serves as the "hub" to the building since it is where both the structure and the mechanical system split. This is due to the vast differences in the structural and mechanical designs to meet the varying requirements of the adjacent community and education spaces (see page 29 of Supporting Documentation). The lobby space will also be the only location in the building where acoustic ceiling tile is utilized. This is to improve and reduce the reverberation time of this space. In determining the acoustical integrity of this space, it was assumed that a large amount of traffic would occur through this space periodically throughout the day. It was therefore decided to implement an acoustical drop ceiling to dampen and reduce the transmission of noise between the floors via the three-story atrium.

The central lobby will also conceal a vertical chase which will house the large supply and return ducts from the rooftop air handling units, as well as the piping for the ethylene glycol run around system. This piping will connect all outdoor air units, exhaust air units, and the hydronic unit in the basement (see page 28 of Supporting Documentation). The basement mechanical room will also house all other mechanical equipment including 3 chillers, pumps, and the boiler (see page 27 of Supporting Documentation).

Lastly, the electrical lighting system will be tied into a single control system that works seamlessly with the mechanical system. This system will automatically turn lights off in the lobby space when daylight is sufficient from the south-facing curtain wall.

3. Community

3.1 Multipurpose Room – (Gym, Cafeteria, Auditorium, Shelter)

The multipurpose room is one of the most interesting spaces in the school as it is used in many different ways. During school, this space functions as the cafeteria for the students. One consequence of using the space as a cafeteria is the increased thermal load, which was addressed during the design of the mechanical system.

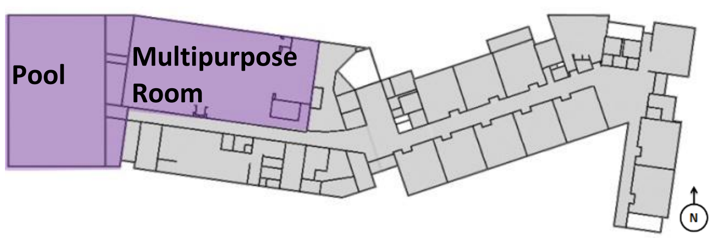


Figure 11: Community Wing Highlighted on First Floor Plan

Another obvious purpose for the room is its use as a gymnasium for classes and after-school sporting events (see Figure 12). The depth of the roof joists was limited to 40 inches, and the mechanical ducts are nestled between the walls and the joists so that they do not interfere with such events. The design for the multipurpose space also includes a stage for performances. Therefore the acoustical design of the space was taken into consideration. To improve the acoustic quality of the space, slotted concrete masonry unit walls and acoustical roof deck will be used. Since the performances in the space will call for versatility in the lighting system, the space uses compact fluorescent lamps that have a short restrike time. This way, the lighting in the space can be adjusted easily depending on how the room is used.

Figure 12: The Multipurpose Room Can Be Used For Stage Performances, a Lunchroom, or Athletic Events

The multipurpose room also acts as an emergency shelter. One of the requirements of the shelter is that it cannot include typical windows in the event of projectiles (see page 32 of Supporting Documentation). The room also requires strong exterior walls, which are adequately provided by the exterior ICF walls. In the case of an emergency, the multipurpose room has two exits to the exterior, two to the interior corridor, and one to the pool.

The multipurpose room is truly a centerpiece of the Nexus triangle of community, experience, and education. It provides members of the community with a place to play pick-up basketball games in the evenings and a safe place to go during emergency situations. It also gives students and parents a place to experience school plays and band performances while also providing increased opportunities for physical health and education.

3.2 Multipurpose Room Rationale

Providing value to the community was one of Nexus' key objectives in designing this building. The multipurpose room is designed to be used in a number of different ways for both students and the community. The implementation of 40 inch roof joists provides space for mechanical ductwork. Since this space is also an emergency shelter, the roof structure of the building must be heavy enough to resist uplift during wind storms. Therefore, a slab and deck system similar to that used for the floors elsewhere in the building is used to achieve the required mass (see Figure 13). A more detailed description and analysis of the requirements for the shelter can be found on page 11 of the Structural Systems Report.

Another difficult decision involved the exclusion of windows from the space. It was determined that the safest and most cost-effective solution for protecting against projectiles would be to exclude windows and skylights from the design. This decision made the need for a flexible lighting system even greater. For this reason a fluorescent lighting system was chosen for the room. Although designing this space as an emergency shelter introduced added costs (such as separate emergency power), these costs will be minimal and will provide value to the community. This also meets the project goals of increasing safety and security of not just the students, but the community as well.

Figure 13: Aerial Plan of Multipurpose Room with Roof Removed

3.3 Pool

The swimming pool functions as a direct link to the community. The pool is six lanes wide and 25 yards long and will be used primarily for recreational purposes (see Figure 14). There are both men's and women's locker rooms along the east wall of the pool, which also connect to the multipurpose room (see Figure 11). The pool equipment room is located south of the locker rooms. The pool deck is larger near the south side of the room to provide space for lines to form behind the starting blocks. Both the pool and multipurpose room are serviced by the community entrance (see Figure 7). The stairs located in this entrance lead to a second floor balcony (see Figure 16). This balcony provides a stadium-style viewing area, with a staircase leading down to the pool deck below.

Figure 14: View of Pool from Balcony

The trusses in this space are similar to the gym, however they are 5' deep and spaced 8.5' apart. This allows for the mechanical ductwork to run directly through the trusses. The conditioned air will be supplied along the perimeter of the pool enclosure. As per ASHRAE HVAC Applications, the pool water will be heated to 80°F and the air temperature will be conditioned to approximately 82°F. This space has a peak heating load of approximately 350 MBh.

There is one large window on the north side of the pool enclosure. This will allow daylight to penetrate the space while not allowing direct glare. Six skylights will be constructed in the ceiling to provide additional daylight. The lighting fixtures will be wall-mounted and placed along the perimeter of the entire enclosure (see pages 33-34 of Supporting Documentation).

3.4 Pool Rationale

The pool is being designed as an add-alternate in the event the school district decides to build it at a later date due to funding restrictions (see section 5.2 of Construction Report). This decision will need to be made by the school district before the project is publicly released for bid so that the subcontractors have sufficient time to properly assess the project. If the school board chooses not to move forward with constructing the pool, the extra $2,012,588 could be saved or allocated to other portions of the project (such as alternative building materials, technology in the classrooms, or teaching resources) at the school board's discretion (see Figure 15). However, if the pool is constructed in a second phase, the cost of the pool would rise to $2,683,654 (a 33% increase) for general conditions costs (overhead, remobilization, site constraints, and inflation).

Pool Phase 1	
SF	8,925
$/SF	$ 225.50
Total Cost	$2,012,588
Pool Phase 2	
SF	8,925
$ / SF	$ 300.69
Total Cost	$2,683,654
Variance	
	$ 671,067

Figure 15: Pool Cost Comparisons

A major decision that had to be made early on was the design of the windows for this space. Concerns included the possibility of direct glare in swimmers eyes and also the heat loss that would occur through the glazing. Therefore, one large window on the north wall was deemed the best solution (see Figure 16). This window will allow daylight to penetrate the space with no direct glare. The glass chosen has a low U-value of 0.28 and solar heat gain coefficient of 0.23. Additional daylight is brought to the space with skylights that will be constructed using diffuse glass to again ensure no direct glare will affect the swimmer's experience (see Figure 17). Wall-mounted metal halide uplight fixtures will be used to illuminate the space indirectly to further reduce the amount of glare on the surface of the pool.

Figure 16: Interior Pool Perspective Rendering

The ductwork layout was designed to keep continuous airflow over the window and perimeter to prevent condensation. This will also prevent drafts from directly hitting the swimmers in the pool, as this creates user discomfort. Another concern of the mechanical design was the chemicals used to treat the pool water. The evaporated tri-chloramines from the pool water can cause air quality problems that link to eye, nose, and throat irritation[2]. The exhaust system is located directly over the pool to prevent occupant discomfort through the immediate elimination of these vapors. These chemicals are also corrosive to the building system and equipment. Protective coatings will be applied to the necessary structure and mechanical systems to ensure the removal of these vapors while protecting the integrity and longevity of the systems. The mechanical system was designed so that the pool could be incorporated at a later date. Should the pool not be built with the rest of the project, the energy efficiency of the mechanical system would decrease slightly due to the reduction in heat recovery.

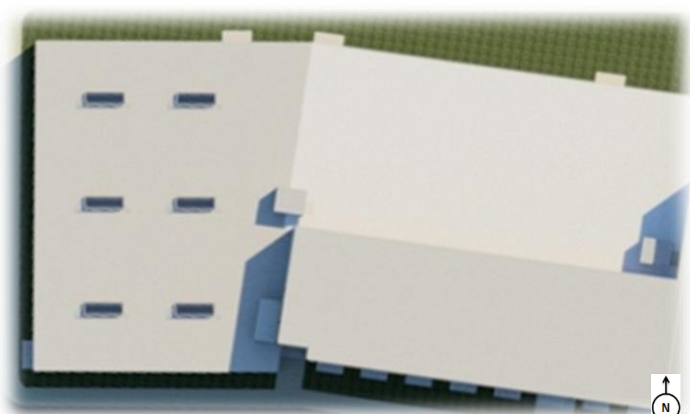


Figure 17: Aerial View of Diffuse Pool Skylights

The lighting scheme was designed with operation and maintenance in mind. No fixtures were placed over the pool surface; there are wall-mounted fixtures lining the perimeter. This will allow for ease of maintenance because no bulbs will need to be changed over the water surface. The pool was one of the spaces that required the most integration between all the disciplines. As previously mentioned, the window design impacted both the lighting and the mechanical systems. The truss structure was sized to provide openings large enough for the mechanical ductwork to run through unencumbered.

3. Education

3.1 Classroom

With education understandably being the most important component of the building, this became the key area of focus in integrating systems to provide an optimized learning environment. This area also presented most of the building's challenges. To ensure the building acts as a learning tool, the decision was made to expose the building systems in the classrooms to facilitate a student's ability to understand how the systems work. This alone presented many challenges in maintaining a practical functionality of the classrooms and balancing system efficiency with architectural aesthetics. To achieve this, Nexus took the approach of reducing the application of unnecessary materials, such as ceiling tiles.

Figure 18: Student Classroom Perspective Rendering

By exposing the ceiling in the classroom, the 14' ceiling height creates a large open feeling (see Figures 18 and 19). As previously mentioned, students will be able to see the color-coded systems that comprise the space, starting with the 20" deep structural steel members that support the acoustic metal decking of the floor above (see page 22-23 of Supporting Documentation).

Figure 19: Teacher Classroom Perspective Rendering

Additionally the students will be able to see the exposed ductwork conditioning the space (see Figure 19). The space will utilize a 100% outdoor air system as studies by the Environmental Protection Agency have shown that increased ventilation rates improve teacher and student performance[5]. Through the use of this system, Nexus was able to decrease the size of the ductwork which allowed for a more compact design. The duct is housed within a lateral chase running along the hallways (see page 30 of Supporting Documentation). One supply outdoor air handler will be coupled with one exhaust outdoor air handler so that they may be turned down or even off when this side of the facility is not being used.

An additional aspect of increasing the quality of this environment was to bring natural light into the space. Studies show that daylighting is an intrinsic part of improving overall learning capabilities of students[3]. Increased daylighting will also save money by reducing electrical lighting costs. Special considerations were made in the functionality of each window to allow for optimized solar penetration at each façade. The south facing windows are designed with both an exterior overhang and an interior light shelf as is shown in Figure 20. The exterior overhang (attached with bolts anchored into the ICFs after the brick or metal panels are installed) will prevent direct penetration into the classroom during the summer. The interior light shelf (constructed of metal studs and gypsum wall board) will reflect the solar rays up and into the space so that it is lit with ambient daylighting. The classrooms will also have manual shades that the teacher can use to control the amount of daylight. The primary lighting sources are the two rows of direct-indirect T5 pendants (see page 35 of Supporting Documentation).The second electrical lighting source is a wall-mounted fixture that runs along the top of the black board to provide more task-specific lighting. Vacancy sensors and dimmers will also be installed to save energy in the classrooms.

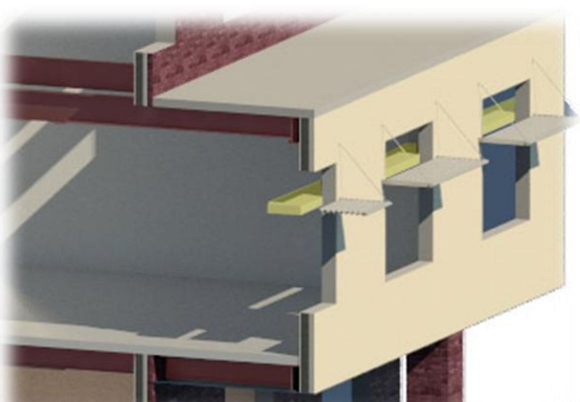


Figure 20: Close-up of Windows with Solar Shading

4.2 Classroom Rationale

As with the other aspects of Nexus building design, Nexus first looked into initial costs and potential savings that could be made from the original drawings. It was determined that a method of pseudo-modularization be developed to decrease construction schedule as well as the associated labor costs. The reasoning for this decision was based on the redundancy and continuity of each classroom on either side of the building. It made sense to standardize these rooms to facilitate and expedite the construction process, as all of these spaces will require the same design considerations. To achieve this, the first unique component was the redesign of the structural system. The original building design called for two rows of interior columns that lined the internal corridor (see Figure 22).

It was determined that a column line could be eliminated to create a standard bay size and an axis of symmetry along the column line (see Figure 23). This standardization of the structural grid will greatly expedite the manufacturing and construction process while reducing the possibility of errors. Additionally, the building requires lateral support for the seismic loads that may act on the building (see pages 25-26 of Supporting Documentation). In order to provide adequate lateral resistance while maintaining sufficient space for the mechanical systems, the building lateral system consists of A-frame ordinary steel concentric braces designed in accordance with the member forces determined through ETABS modeling of the lateral loads.

Figure 21: Education Wing Highlighted on Building Floor Plan with Structural Bay Redesign Called out in Red

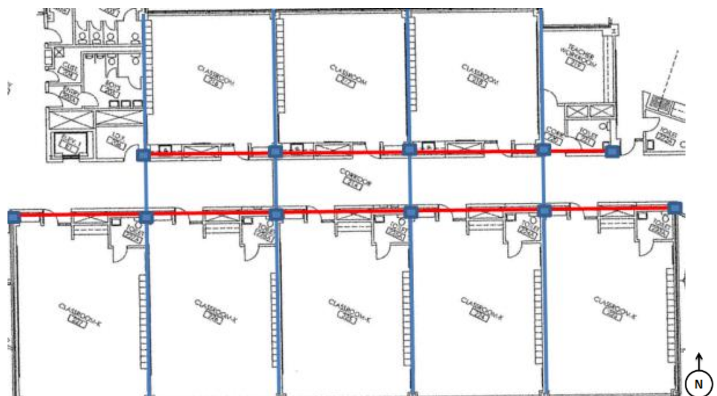


Figure 22: Original Structural Configuration

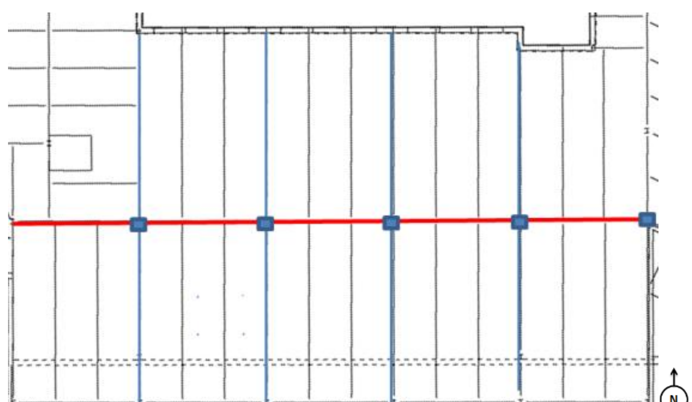


Figure 23: Revised Structural Grid

In order to achieve standardization of the structural grid, several other components had to be taken into account with regards to other disciplines. Although the original structural grid configuration had more columns, connections, and footings (ultimately driving up initial cost and construction time), this initial configuration provided a large plenum space to run the necessary ductwork and piping along the corridors. As such, in continuation of the modularization, lateral mechanical chases were developed to run the supply and exhaust ductwork for the 100% outside air mechanical system. These chases run in the classrooms on the corridor wall and allow for continuous duct runs along the length of this part of the building (see Figure 24). The mechanical system will utilize round duct. Round duct is less expensive to fabricate and install because it can be fabricated to the correct size and length at the manufacturing facility. This will allow for savings in initial construction costs. Additionally, round duct provides more of an aesthetic finish than that of utilitarian rectangular applications. Because of this, it was decided to expose these round ducts in certain areas of the lateral chase to increase the design goal of making the building a learning tool. This will also mitigate the expense of building a bulkhead to house this lateral chase along the span of the corridor.

While the lack of a ceiling will save costs on unnecessary building materials, an acoustic analysis was performed to determine the acoustic environment of the classroom. One specific criterion Nexus looked at was the reverberation time. The reverberation time is a primary descriptor of an acoustic environment. It is based solely upon the size of the room and the amount of sound absorbing materials present in the space. A classroom setting has an optimum reverberation time between 0.4 and 0.8 seconds. For the typical speech frequencies of 125 Hz to 1000 Hz, the reverberation times Nexus calculated using the acoustic metal decking were within this range (see page 31 of Supporting Documentation).

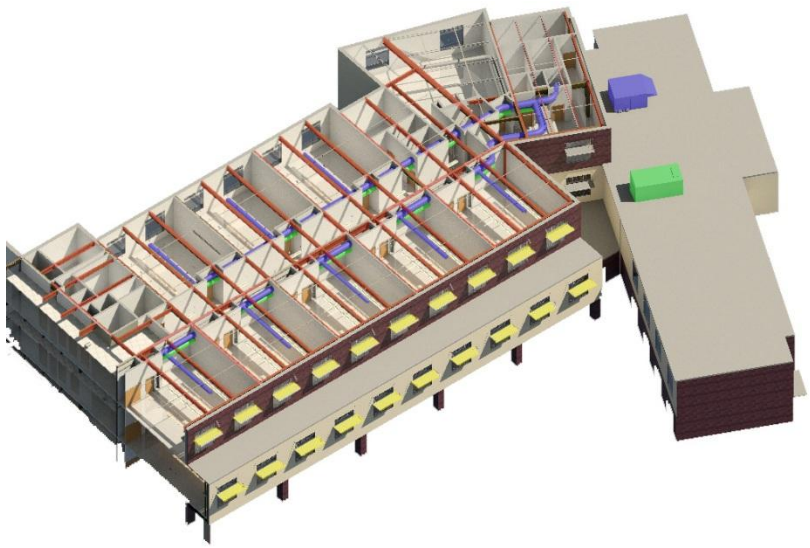


Figure 24: Building Section Showing System Integration in the Classrooms

Another acoustic criterion Nexus considered was the sound transmission class of the building materials present in the classroom. The sound transmission class is the most common sound reduction measurement in use. It is widely used to rate how well a building component attenuates airborne sound. The exterior walls for all classrooms are comprised of insulated concrete forms (ICF). These ICF walls have much lower rates of acoustic transmission than more typical building materials. Standard thickness ICF walls have shown sound transmission coefficients between 46 and 50 compared to 36 for standard fiberglass insulation and gypsum walls.

5. Building Overview

5.1 Building Security and Occupant Safety

With Reading's crime rate 133.52% higher than the national average, along with recent events around the nation, Nexus thoroughly analyzed all possible security and safety precautions for a new elementary school[1]. By moving the main entrance from the north to the south side of the campus, the main entrance became more welcoming and also more secure from a highly trafficked road. Balusters were added to prevent unwanted cross traffic through the center of the educational campus (see page 40 of Drawings). To further ensure student and faculty safety, all windows on the first floor are bullet-resistant glass (see Figure 25).

Nexus' School Security and Occupant Safety Checklist		
Level of Integration	**Significant**	Acceptable
Secure Main Entrance	√	
Safe Main Entrance	√	
Parking Lot Balusters		√
Public Address System	√	
Security Alarms	√	
Intrusion Detection System	√	
Lockdown Security Doors	√	
Manual Window Shades		√
Video Surveillance	√	
First Floor Bullet-Resistant Glass	√	

Figure 25: Nexus' Security Analysis

Safety transitions into the building by providing a single secure main entrance that requires visitors to pass through the reception area prior to entering the school. Nexus provided a sense of unseen security through the use of hidden cameras monitoring the main entrance. Some of the other security features that were integrated include a public address system with speakers in each classroom (not only for daily announcements, but also security purposes), security alarms triggered by an intrusion detection system at all exterior doors, automatic lockdown security doors in the corridors that double as fire doors, and manual shades to cover the classroom door window and sidelight.

Safety will also be the top priority for the project during construction. Safe site working conditions will be achieved largely through contractor work practices. According to the contract, all parties on site must meet, and in some cases exceed, OSHA regulations. Nexus recommends that additional safety precautions be considered such as daily toolbox talks, subcontractor company safety procedures, and a mandatory five foot tie-off rule. A construction fence will be installed to protect the students, teachers, and staff members of the current elementary school, as well as pedestrians on the sidewalks and traffic passengers. The site fence will double as a security fence for the site during construction. Lastly, the building footprint will remain lit at night to prevent vandalism and theft.

5.2 Sustainability

LEED 2009 for Schools	
Sustainable Site	13
Water Efficiency	7
Energy and Atmosphere	14
Materials and Resources	4
Indoor Environmental Quality	15
Innovation and Design Process	2
Regional Priority Credits	0
Total	55

Figure 26: LEED Scorecard Summary

After a thorough analysis of the building design, and the systems Nexus has integrated into it, LEED Silver Certification was recognized with 55 points (see Figure 26). In order for this to become a reality, the construction manager must closely manage the submittal process to ensure that the subcontractors submit the specified materials and systems according to the architect's specifications. Continually tracking the sustainable measures Nexus incorporated into the building, both during and after construction, will be of utmost importance to reap the sustainable features' fullest life-cycle, environmental and cost savings potentials. By achieving Silver Certification, Reading School District will receive a $542,850 credit based on PlanCon calculations that will help offset the building construction costs (see section 5.2 of Construction Report).

Integrating the sustainability features into the learning environment helped Nexus integrate the owner's objective of b lifecycle and maintenance with Nexus' goal of reduce, recover, reuse. For example, in order to create a comfortable learning environment, the mechanical system had to be sized to improve indoor air quality by increasing the amount of outside air provided. The motive for this was improving the learning environment; but in turn, also helped Nexus meet LEED requirements under the indoor environmental quality category. Additionally the mechanical system will have a heat recovery efficiency of approximately 65% percent while the facility is in use during the academic school year. If the school were to be in full use year round the mechanical system would still be able to reduce energy costs associated with the building loads by about 50%. Nexus chose to leave the existing elementary school in place to be reutilized as the Reading School District sees fit. Retaining the building created a significant savings in both cost and schedule. The reuse of a building is also a sustainable principle and helps keep unnecessary waste out of landfills. Lastly, Nexus chose not to implement a green roof due to the increased structural loads, mechanical thermal requirements, and potential high maintenance issues (leaks) and costs.

5.3 Cost Estimate and Schedule

To help offset the capital burden borne by the school district, Nexus explored all possible options for additional funding. Based on PlanCon funding conditions for elementary schools, funding from the state will

Cost Estimate			
	Total Cost	$ / SF	% of Cost
A. Substructure	$ 713,750	$ 8.02	4%
B. Shell	$ 6,516,250	$ 73.22	37%
C. Interiors	$ 1,970,000	$ 22.13	11%
D. Services	$ 6,475,000	$ 72.75	37%
E. Equipment & Furnishings	$ 300,000	$ 3.37	2%
F. Special Construction & Demolition	$ -	$ -	0%
G. Building Sitework	$ 475,000	$ 5.34	3%
Z. General Conditions	$ 997,650	$ 11.21	6%
*Uniformat Categories (A-G, Z)	$ 17,447,650	$196.04	89,000 SF

Figure 27: Whole Building Cost Estimate

total $5,296,915. By allocating approximately $200 per square foot for an innovative school design, the total project cost is roughly $17.8 million (see Figure 27). For further cost justifications, please see page 19 of Supporting Documentation.

Nexus is confident it can build the new school in 15 months (see Figure 28). This fast track project must start immediately following the end of the 2013-2014 school year, continue throughout the following school year (2014-2015), and finally end before the subsequent academic year commences. The construction manager will be responsible for closely managing the subcontractors in order to maintain the schedule, especially getting the building enclosed before the winter months. The interior finishes will be completed in late July so that punch-lists can be executed before the teachers move into their new classrooms in the middle of August. For more details on the project schedule please see page 20 of Supporting Documentation.

6. Concluding Summarization

The distinctive image below represents the union of the experience, community, and education portions of the school building (see Figure 29). Each building section operates amongst itself to service a distinctive function while also supporting its two other building section counterparts. The experience portion welcomes all individuals onto the campus and creates a sense of security. This leads people to the community portion of the school where essential needs are met for the local area. Most importantly, the educational portion of the school is bolstered by the efficient building systems and support areas, while serving as the foundation of each individual student's first learning endeavor, developing them into

ID	Task Name	Duration	Start	Finish
1	**Construction**	**317 days**	**Fri 6/6/14**	**Mon 8/24/15**
2	**Last Day of School - Spring 2014**	**1 day**	**Fri 6/6/14**	**Fri 6/6/14**
3	*Notice to Proceed*	0 days	Mon 6/9/14	Mon 6/9/14
4	*Mobilization*	5 days	Mon 6/9/14	Fri 6/13/14
5	Excavation	25 days	Mon 6/16/14	Fri 7/18/14
6	Utilities	10 days	Mon 7/21/14	Fri 8/1/14
7	**First Day of School - Fall 2014**	1 day	Mon 8/25/14	Mon 8/25/14
8	Foundation	20 days	Mon 8/4/14	Fri 8/29/14
9	Structural Steel	65 days	Fri 8/29/14	Thu 11/27/14
10	ICF Walls	51 days	Tue 9/9/14	Tue 11/18/14
11	Roofing	49 days	Mon 12/8/14	Thu 2/12/15
12	Building Façade	40 days	Fri 2/13/15	Thu 4/9/15
13	MEP Rough-Ins	75 days	Fri 2/13/15	Thu 5/28/15
14	Glazing	33 days	Fri 3/6/15	Tue 4/21/15
15	**Last Day of School - Spring 2015**	1 day	Fri 6/5/15	Fri 6/5/15
16	Interiors	66 days	Fri 4/3/15	Fri 7/3/15
17	Finishes	20 days	Mon 7/6/15	Fri 7/31/15
18	*Commissioning*	55 days	Fri 5/29/15	Thu 8/13/15
19	*Demobilization*	5 days	Mon 8/3/15	Fri 8/7/15
20	**Teacher Move-in / FF&E**	10 days	Mon 8/10/15	Fri 8/21/15
21	*Substantial Completion*	0 days	Fri 8/21/15	Fri 8/21/15
22	**First Day of School - Fall 2015**	**1 day**	**Mon 8/24/15**	**Mon 8/24/15**

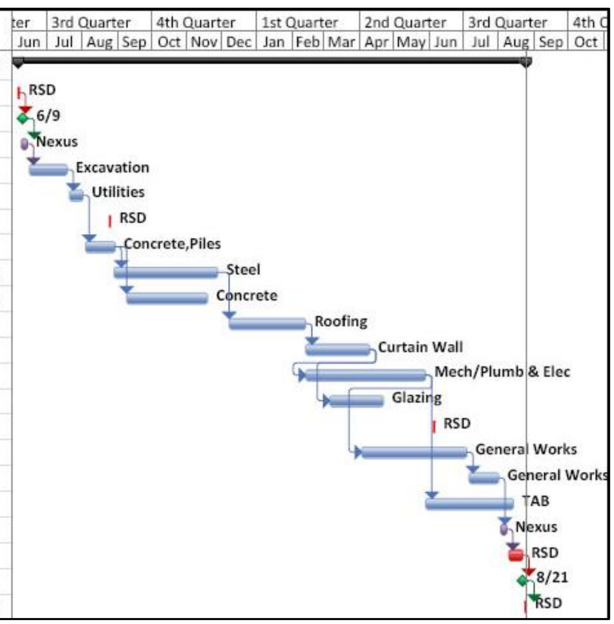


Figure 28: Construction Milestone Schedule

productive community members.

The integrated design process utilized by Nexus was facilitated by a building information modeling process. Executing information exchanges amongst softwares, streamlining communication through linked models, and tri-weekly team meetings enabled each disciplines' work to be seamlessly incorporated into the building. This resulted in a flexible and functional elementary school that is able to suit the individual needs of all students in attendance. The learning spaces were designed so that they can be tailored to the unique student-teacher relationship that develops every year in each classroom. Local residents can rest easy knowing that their children are safe when they go to school thanks to Nexus' design focus on safety and security.

The goals set forth by Nexus were created in order to deliver a building that satisfies the needs of the students, teachers, and community members. Nexus' new proposed Reading Elementary School contains a plethora of examples of innovative design solutions through the integration of each of the disciplines working on the project. Nexus is confident that the proposed elementary school successfully achieves and exceeds the district's objectives. The hidden sense of security far exceeds a typical elementary school's safety protocols, ensuring the building cannot be penetrated and that all occupants are safe from outside dangers. The sustainable features incorporated into the building will lengthen the building's life-cycle and lower the maintenance and operation requirements. Lastly, the integration of the construction, structural, mechanical, and lighting/electrical discipline's systems created a school that acts as a learning tool for the teachers and students, while maintaining a low initial and life-cycle cost, and that will be constructed with fewer conflicts and change orders.

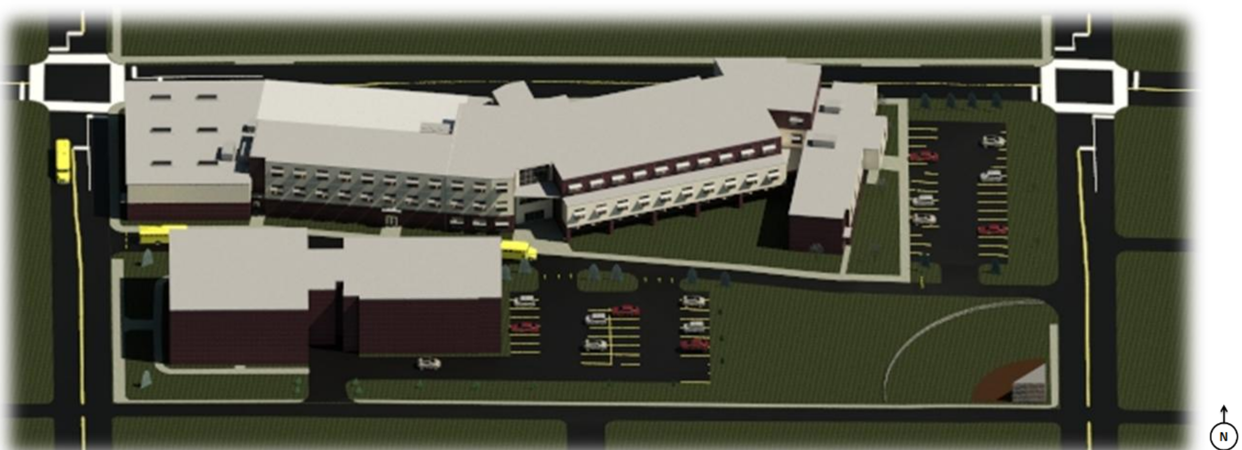


Figure 29: Aerial Rendering of Nexus' New Reading School District Elementary School

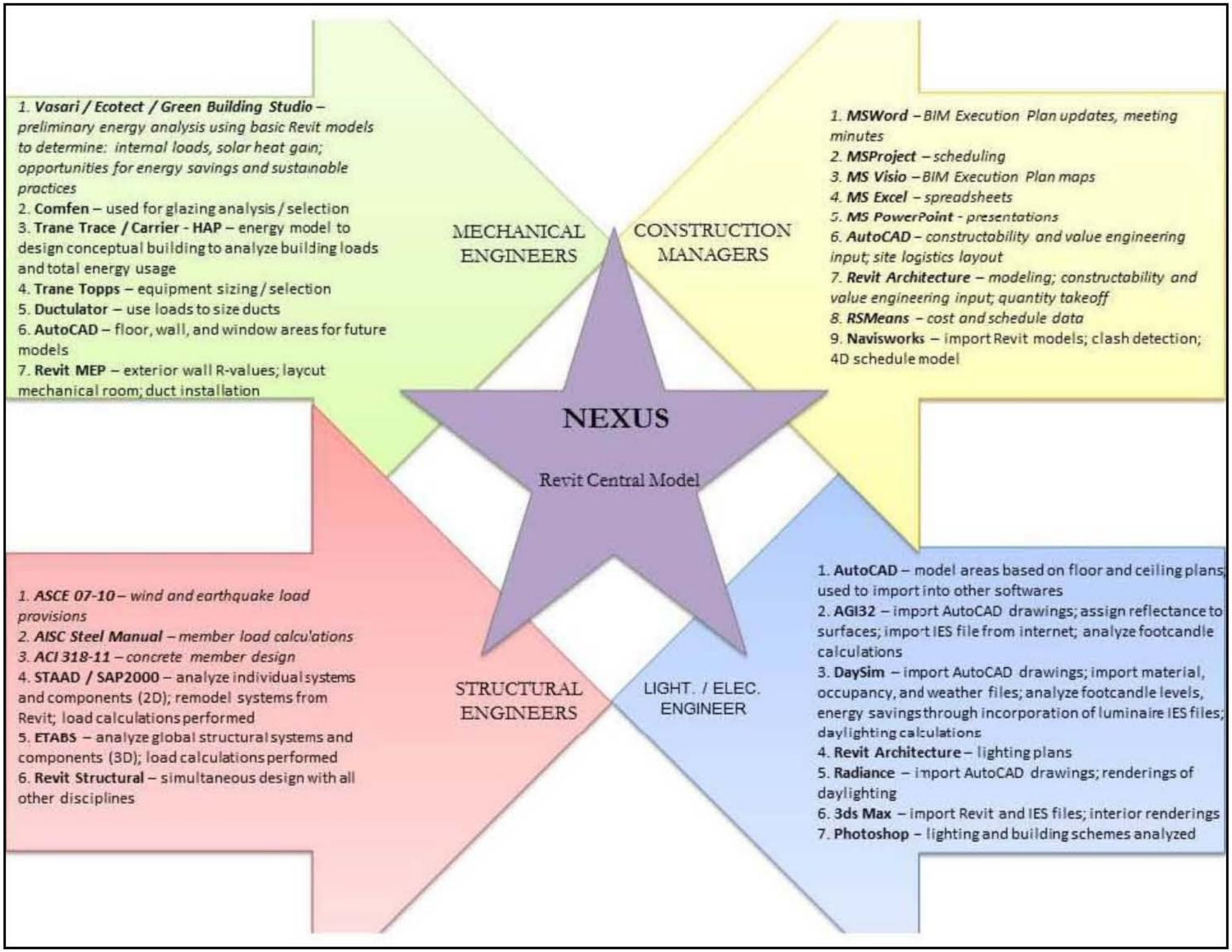
6.1 References

1. Crime Statistics:
<http://www.portal.state.pa.us/portal>
2. Pool Safety Precautions:
<http://erj.ersjournals.com/content/29/4/690.full>
3. Daylighting in Classrooms: <http://architecture.mit.edu/house>
4. School Safety and Security:
<http://www.securityinfowatch.com/article/10577993/>
5. Environmental Protection Agency
<http://www.epa.gov/iaq>

NEXUS DISCIPLINE ROLES AND RESPONSIBILITIES

This figure displays the discipline roles and responsibilities for Nexus' four divisions. Then, Nexus as a whole has roles and responsibilities to fulfill that all team members will contribute to. Many of these roles are in relation to the BIM Execution Plan BIM Uses and Goals. Read each individual report for more information.

NEXUS SOFTWARE INFORMATION EXCHANGES



This figure displays the software information exchange coordination amongst Nexus team members. Each team member is to fulfill their roles and responsibilities through the use of these technologies. Then, when one person has completed a task, the information can flow to the next responsible team member. There is a short description next to each software to describe its use for this project.

NEXUS BIM GOALS USE ANALYSIS WORKSHEET

BIM Goal Use Analysis Worksheet				
BIM Use	**Project Importance**	**Disciplines Involved**	**Discipline Importance**	**Necessary Data**
	High / Med / Low		High / Med / Low	
		Design Phase		
Design Review	High	CM SE ME LE	High High High High	Constructability input to design models Structural design models Mechanical design models Lighting / Electrical design models
3D Coordination	High	CM SE ME LE	High High High High	Design models Design models, ETABS and SAP models Design models Design models, ceiling plans
Structural Analysis	High	SE	High	Local codes, ETABS and SAP models
Lighting Analysis	High	LE	High	AGI and Daysim models
Mechanical Analysis	High	ME	High	Energy model and equipment sizing and selection
Energy Analysis	High	ME LE	High High	Preliminary Vasari model and later more accurate energy model AGI - lighting power density information
Sustainability (LEED) Evaluation	High	CM SE ME LE	High High High High	Materials and energy data Material efficiency data Energy model and IAQ information AGI and Daysim analysis
Phase Planning (4D Modeling)	High	CM	High	Design models, project schedule
S.F. / Detailed Cost Estimation	High	CM	High	Materials, building statistics
Existing Conditions	Med	CM SE	Med Med	Site data Ggeotechnical report
Record Modeling	Med	CM SE ME LE	Med Med Med Med	4D coordinated model Structural and ETABS model Model and equipment selection Analyses and models
Site Utilization Planning	High	CM	High	Site layout, equipment, material laydown, project schedule

This figure displays data information exchanges based on BIM Uses. These BIM Uses are rated based on the importance to Nexus on a project whole, the disciplines involved with each BIM Use, and the importance to the individual disciplines. The necessary data refers to the information required to most efficiently utilize the BIM Use.

UNIFORMAT COST ESTIMATE

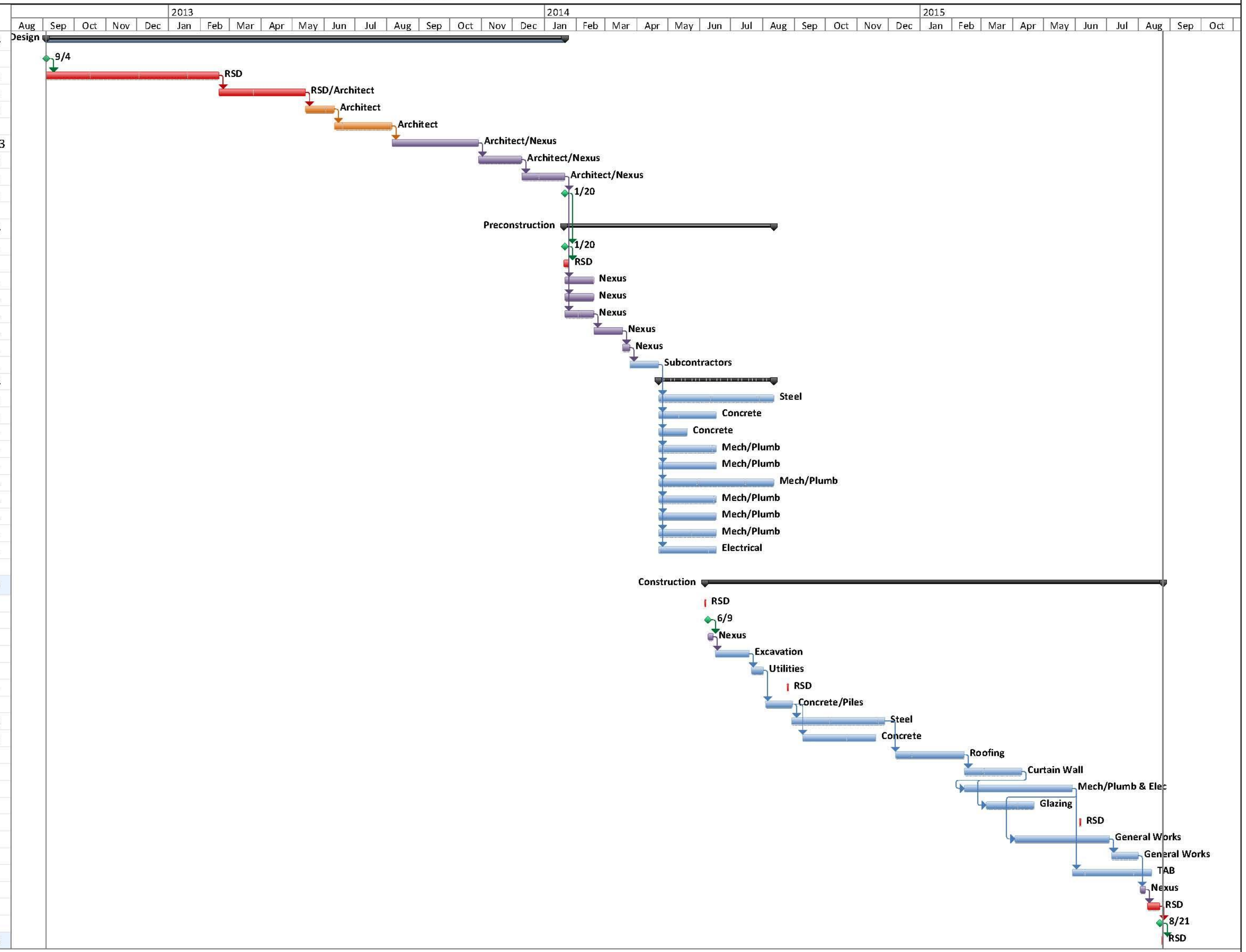
Uniformat Cost Estimate					
A. Substructure	**$ 713,750**	A10 Foundations	$ 459,750	A1010 Standard Foundations	$ 138,500
				A1020 Special Foundations	$ 200,000
				A1030 Slab on Grade	$ 121,250
		A20 Basement Construction	$ 254,000	A2010 Basement Excavation	$ 150,000
				A2020 Basement Walls	$ 104,000
B. Shell	**$ 6,390,250**	B10 Superstructure	$ 1,777,250	B1010 Floor Construction	$ 1,381,000
				B1020 Roof Construction	$ 396,250
		B20 Exterior Enclosures	$ 3,908,000	B2010 Exterior Walls	$ 3,239,000
				B2020 Exterior Windows	$ 629,000
				B2030 Exterior Doors	$ 40,000
		B30 Roofing	$ 705,000	B3010 Roof Coverings	$ 700,000
				B3020 Roof Openings	$ 5,000
C. Interiors	**$ 1,970,000**	C10 Interior Construction	$ 965,000	C1010 Partitions	$ 830,000
				C1020 Interior Doors	$ 75,000
				C1030 Fittings	$ 60,000
		C20 Stairs	$ 110,000	C2010 Stair Construction	$ 103,000
				C2020 Stair Finishes	$ 7,000
		C30 Interior Finishes	$ 895,000	C3010 Wall Finishes	$ 180,000
				C3020 Floor Finishes	$ 500,000
				C3030 Ceiling Finishes	$ 215,000
D. Services	**$ 6,475,000**	D10 Conveying	$ 175,000	D1010 Elevators & Lifts	$ 175,000
				D1020 Escalators & Moving Walks	$ -
				D1090 Other Conveying Systems	$ -
		D20 Plumbing	$ 1,400,000	D2010 Plumbing Fixtures	$ 100,000
				D2020 Domestic Water Distribution	$ 300,000
				D2030 Sanitary Waste	$ 240,000
				D2040 Rain Water Drainage	$ 74,000
				D2090 Other Plumbing Systems	$ 686,000
		D30 HVAC	$ 2,800,000	D3010 Energy Supply	$ -
				D3020 Heat Generating Systems	$ 140,000
				D3030 Cooling Generating Systems	$ 280,000
				D3040 Distribution Systems	$ 520,000
				D3050 Terminal & Package Units	$ 840,000
				D3060 Controls & Instrumentation	$ 360,000
				D3070 Systems Testing & Balancing	$ 200,000
				D3090 Other HVAC Systems & Equipment	$ 460,000
		D40 Fire Protection	$ 175,000	D4010 Sprinklers	$ 105,000
				D4020 Standpipes	$ 62,000
				D4030 Fire Protection Specialties	$ 8,000
				D4090 Other Fire Protection Systems	$ -
		D50 Electrical	$ 1,925,000	D5010 Electrical Service & Distribution	$ 551,250
				D5020 Lighting and Branch Wiring	$ 1,023,750
				D5030 Communications & Security	$ 350,000
				D5090 Other Electrical Systems	$ -
E. Equipment & Furnishings	**$ 300,000**	E10 Equipment	$ -	E1010 Commercial Equipment	$ -
				E1020 Institutional Equipment	$ -
				E1030 Vehicular Equipment	$ -
				E1090 Other Equipment	$ -
		E20 Furnishings	$ 300,000	E2010 Fixed Furnishings	$ 200,000
				E2020 Movable Furnishings	$ 100,000
F. Special Construction & Demolition	**$ -**	F10 Special Construction	$ -	F1010 Special Structures	$ -
				F1020 Integrated Construction	$ -
				F1030 Special Construction Systems	$ -
				F1040 Special Facilities	$ -
				F1050 Special Controls and Instrumentation	$ -
		F20 Selective Building Demolition	$ -	F2010 Building Elements Demolition	$ -
				F2020 Hazardous Components Abatement	$ -
G. Building Sitework	**$ 601,000**	G10 Site Preparation	$ 175,000	G1010 Site Clearing	$ -
				G1020 Site Demolition and Relocations	$ -
				G1030 Site Earthwork	$ 125,000
				G1040 Hazardous Waste Remediation	$ 50,000
		G20 Site Improvements	$ 301,000	G2010 Roadways	$ 127,500
				G2020 Parking Lots	$ 133,500
				G2030 Pedestrian Paving	$ 15,000
				G2040 Site Development	$ -
				G2050 Landscaping	$ 25,000
		G30 Site Mechanical Utilities	$ 75,000	G3010 Water Supply	$ 13,000
				G3020 Sanitary Sewer	$ 15,000
				G3030 Storm Sewer	$ 16,000
				G3040 Heating Distribution	$ 12,000
				G3050 Cooling Distribution	$ 8,000
				G3060 Fuel Distribution	$ 11,000
				G3090 Other Site Mechanical Utilities	$ -
		G40 Site Electrical Utilities	$ 50,000	G4010 Electrical Distribution	$ 10,000
				G4020 Site Lighting	$ 25,000
				G4030 Site Communications & Security	$ 15,000
				G4090 Other Site Electrical Utilities	$ -
		G90 Other Site Construction	$ -	G9010 Service and Pedestrian Tunnels	$ -
				G9090 Other Site Systems & Equipment	$ -
Z. General Conditions	**$ 997,650**	Z10 Design Allowance	$ -		
		Z20 Overhead & Profit	$ 997,650	Z2010 Overhead	$ 685,100
				Z2020 Profit	$ 312,550
TOTAL	**$ 17,447,650**				

This table is a detailed cost estimate based on Uniformat categories. These categories are divided into three levels, as shaded in purple. The levels become more descriptive based on the level of detail required. Where there is no cost listed, that means this aspect is not included in Nexus' new elementary school.

DESIGN, PRECONSTRUCTION, AND CONSTRUCTION MILESTONE SCHEDULE

RSD New Elementary School

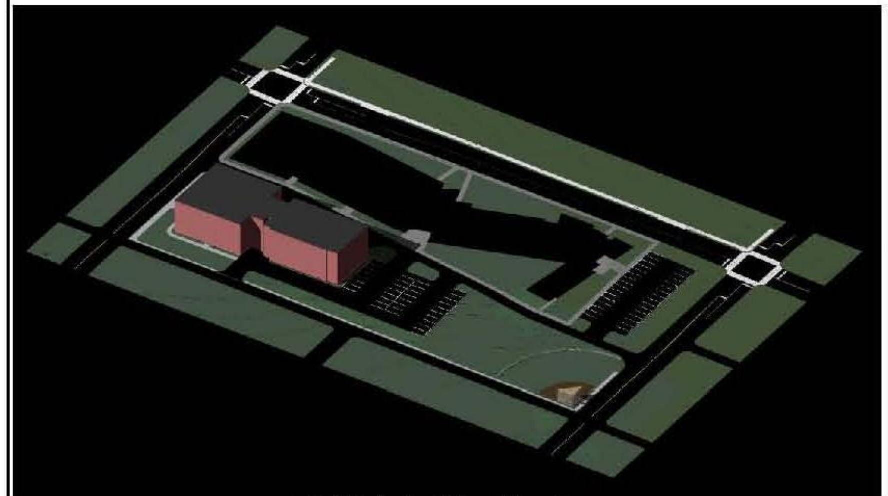
ID	Task Name	Duration	Start	Finish
1	**Design**	**360 days**	**Tue 9/4/12**	**Mon 1/20/14**
2	*Notice to Proceed*	0 days	Tue 9/4/12	Tue 9/4/12
3	Feasibility Study	120 days	Tue 9/4/12	Mon 2/18/13
4	Programming	60 days	Tue 2/19/13	Mon 5/13/13
5	Conceptual Design	20 days	Tue 5/14/13	Mon 6/10/13
6	Schematic Design	40 days	Tue 6/11/13	Mon 8/5/13
7	Design Development	60 days	Tue 8/6/13	Mon 10/28/13
8	50% Construction Documents	30 days	Tue 10/29/13	Mon 12/9/13
9	Construction Documents	30 days	Tue 12/10/13	Mon 1/20/14
10	*Substantial Completion*	0 days	Mon 1/20/14	Mon 1/20/14
11				
12	**Preconstruction**	**146 days**	**Mon 1/20/14**	**Mon 8/11/14**
13	Design Complete	0 days	Mon 1/20/14	Mon 1/20/14
14	*Pool Decision Deadline*	5 days	Mon 1/20/14	Fri 1/24/14
15	Estimate Complete	20 days	Tue 1/21/14	Mon 2/17/14
16	Bid Schedule Complete	20 days	Tue 1/21/14	Mon 2/17/14
17	Scopes of Work Defined	20 days	Tue 1/21/14	Mon 2/17/14
18	Invitation to Bid	20 days	Tue 2/18/14	Mon 3/17/14
19	Subcontractor Awarding	5 days	Tue 3/18/14	Mon 3/24/14
20	Submittals	20 days	Tue 3/25/14	Mon 4/21/14
21	Lead Times - Delivery Times	**80 days**	**Tue 4/22/14**	**Mon 8/11/14**
22	Steel Mill Order	80 days	Tue 4/22/14	Mon 8/11/14
23	ICF Order	40 days	Tue 4/22/14	Mon 6/16/14
24	Concrete Order	20 days	Tue 4/22/14	Mon 5/19/14
25	Sheetmetal	40 days	Tue 4/22/14	Mon 6/16/14
26	Fans	40 days	Tue 4/22/14	Mon 6/16/14
27	AHUs	80 days	Tue 4/22/14	Mon 8/11/14
28	Pumps	40 days	Tue 4/22/14	Mon 6/16/14
29	Cooling Tower	40 days	Tue 4/22/14	Mon 6/16/14
30	Boiler	40 days	Tue 4/22/14	Mon 6/16/14
31	Feeders	40 days	Tue 4/22/14	Mon 6/16/14
32				
33	**Construction**	**317 days**	**Fri 6/6/14**	**Mon 8/24/15**
34	**Last Day of School - Spring 2014**	**1 day**	**Fri 6/6/14**	**Fri 6/6/14**
35	*Notice to Proceed*	0 days	Mon 6/9/14	Mon 6/9/14
36	*Mobilization*	5 days	Mon 6/9/14	Fri 6/13/14
37	Excavation	25 days	Mon 6/16/14	Fri 7/18/14
38	Utilities	10 days	Mon 7/21/14	Fri 8/1/14
39	**First Day of School - Fall 2014**	1 day	Mon 8/25/14	Mon 8/25/14
40	Foundation	20 days	Mon 8/4/14	Fri 8/29/14
41	Structural Steel	65 days	Fri 8/29/14	Thu 11/27/14
42	ICF Walls	51 days	Tue 9/9/14	Tue 11/18/14
43	Roofing	49 days	Mon 12/8/14	Thu 2/12/15
44	Building Façade	40 days	Fri 2/13/15	Thu 4/9/15
45	MEP Rough-Ins	75 days	Fri 2/13/15	Thu 5/28/15
46	Glazing	33 days	Fri 3/6/15	Tue 4/21/15
47	**Last Day of School - Spring 2015**	1 day	Fri 6/5/15	Fri 6/5/15
48	Interiors	66 days	Fri 4/3/15	Fri 7/3/15
49	Finishes	20 days	Mon 7/6/15	Fri 7/31/15
50	*Commissioning*	55 days	Fri 5/29/15	Thu 8/13/15
51	*Demobilization*	5 days	Mon 8/3/15	Fri 8/7/15
52	**Teacher Move-in / FF&E**	10 days	Mon 8/10/15	Fri 8/21/15
53	*Substantial Completion*	0 days	Fri 8/21/15	Fri 8/21/15
54	**First Day of School - Fall 2015**	**1 day**	**Mon 8/24/15**	**Mon 8/24/15**

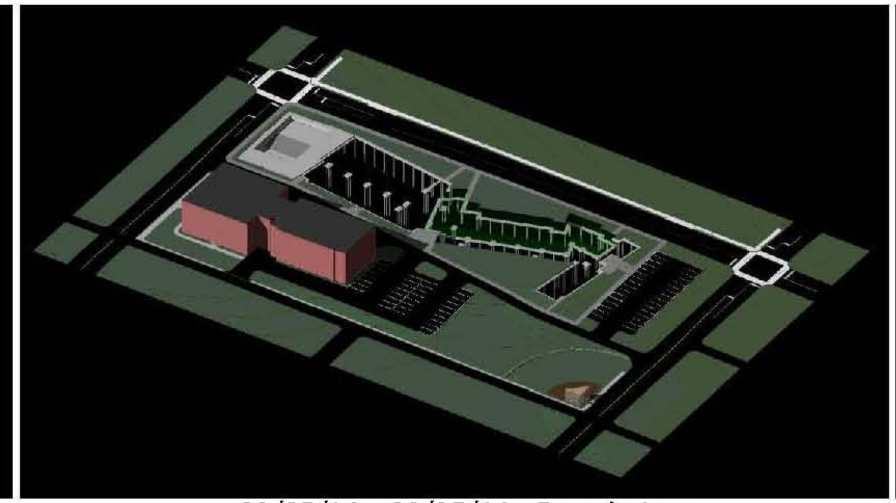


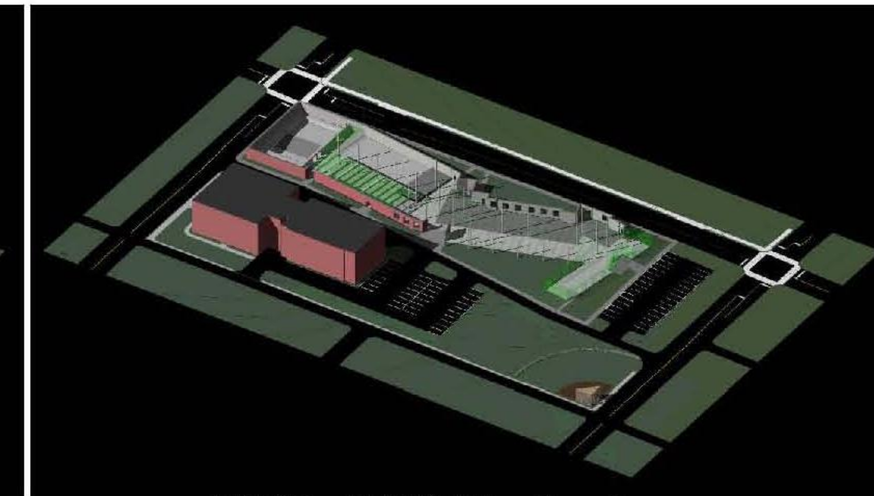
Project: RSD New Elementary School
Team: Nexus
Date: 22 February 2013

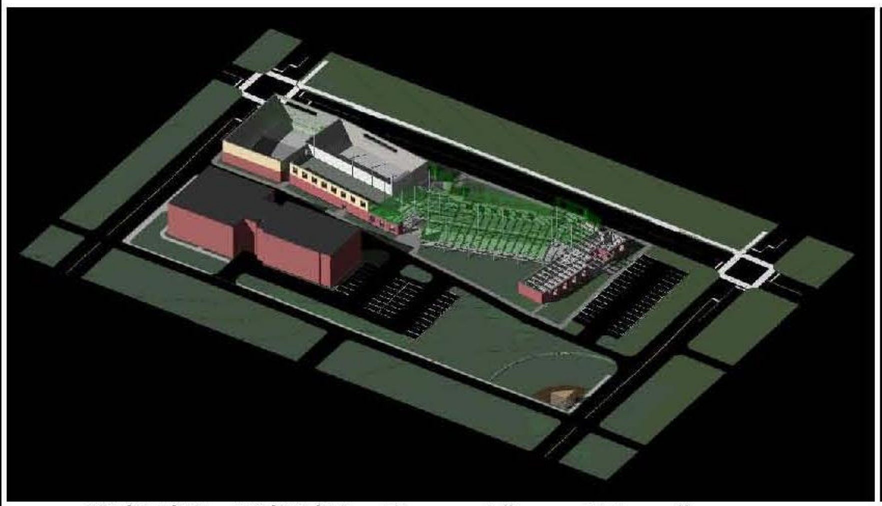
This figure displays a milestone schedule for the project. It is important to note that a design, preconstruction, and construction schedule must be developed to properly plan each phase. The design schedule is largely based on the owner-architect relationship in the planning and design phases. The preconstruction phase involves the owner-architect-construciton manager relationship and eventually the hiring of the subcontractors. Lastly, the construction milestones are listed at the bottom. Nexus has made a point to include all important school dates in their schedule to properly plan for special events both on site and at the existing elementary school.

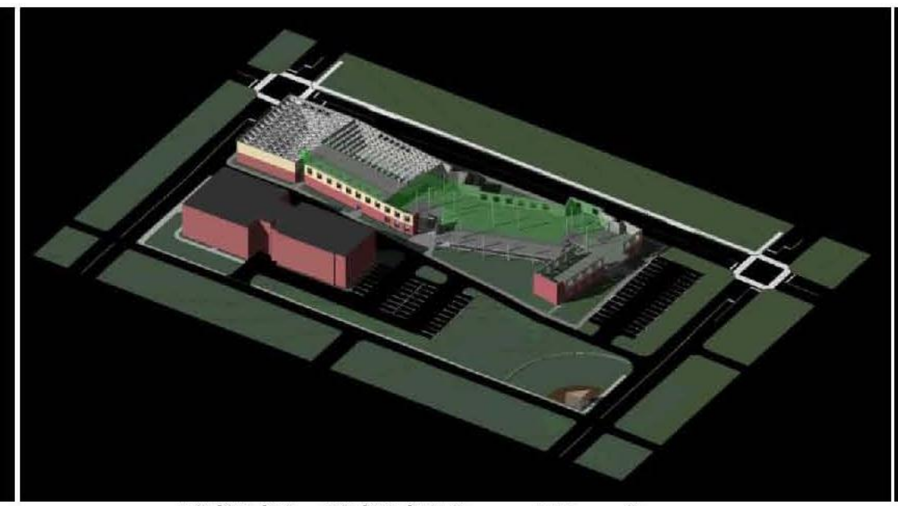
NAVISWORKS 4D MODEL SEQUENCE

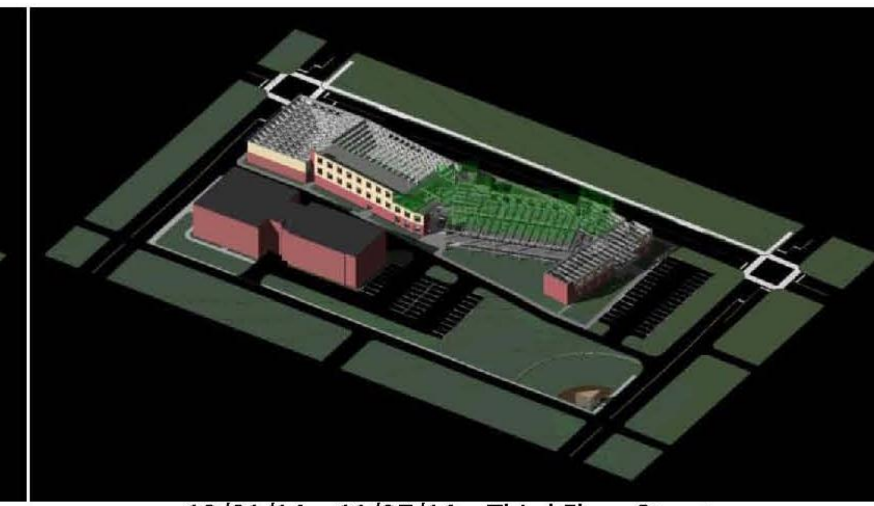

06/09/14 - Mobilization

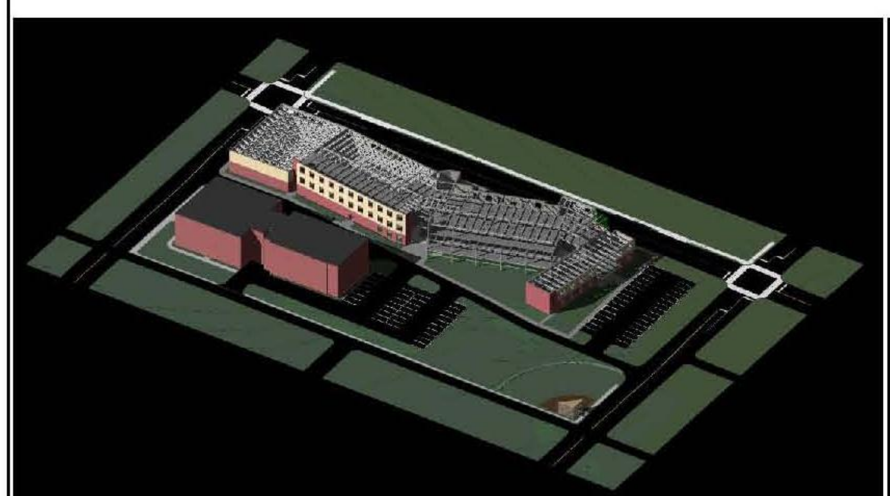

08/05/14 – 08/25/14 - Foundation

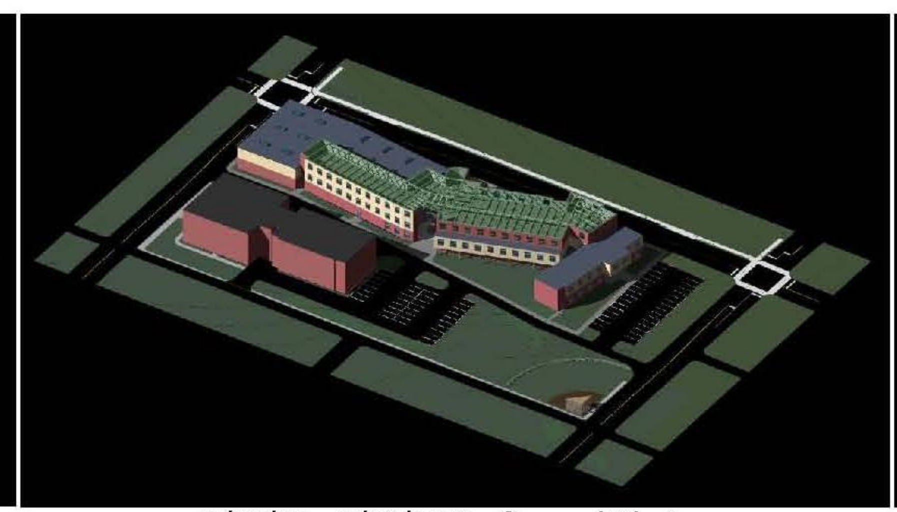

8/29/14 – 09/17/14 First Floor Structure

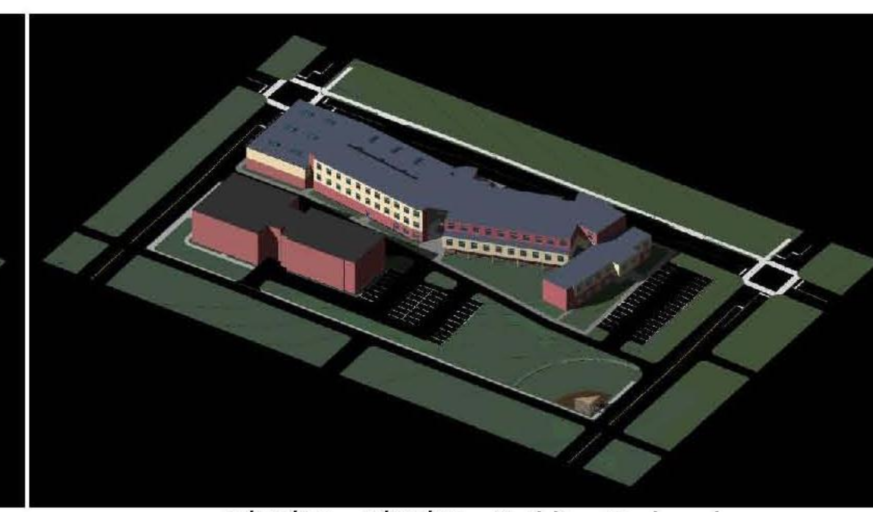

09/17/14 - 10/02/14 – First and Second Floor Structure


10/02/14 - 10/31/14 Second Floor Structure


10/31/14 – 11/27/14 – Third Floor Structure


11/27/14 – 1/21/15 Structure Complete


1/21/15 – 2/12/15 Roofing and Glazing


2/12/15 – 4/21/15 – Building Enclosed

The nine tiles shown here are snapshot images from the Navisworks 4-dimensional model created by Nexus' construction managers. These nine images represent a few of the major milestones that the building will reach while under construction. The Navisworks model helped the construction managers schedule and sequence activities on site to help maintain safety and progress. The model also helped detect and resolve clashes amongst the structural, mechanical, and lighting/electrical trades.

BUILDING FIRE PROTECTION EVALUATION

Since the elementary school is being designed with exposed ceilings, structural members, and mechanical components throughout the building, one important consideration was whether or not fireproofing would be required for the structure. Knowing that fireproofing would be an aesthetic issue, the team evaluated the use of an approved sprinkler system in the building to determine if it would be possible to avoid passive structural fireproofing.

As outlined in Figure A, the design team looked at the options for an “E” classified building (education), and sought to satisfy the requirements for a Type II B construction, which does not require any structural fireproofing. According to the code table, the school would have to be limited to a height of two stories and 14,500 square feet of area per floor. However, the code allows for height and area modifications if an approved sprinkler system is added to the building. The addition of the sprinkler system allows for one additional story to be added to the building, meaning that the proposed three-story design is allowed. Also, the automatic sprinkler increase outlined in Figure B allows for an additional 200% increase in the allowed square footage per floor. This increase results in a new allowable area of 43,500 square feet per floor. The school’s first floor, which has the largest area of any floor, is just under 40,000 square feet. Therefore, the addition of an approved sprinkler system means that Type II B construction is permissible for the building.

According to the code table outlined in Figure C, the use of Type II B construction requires no fireproofing for any structural members of the building. In conclusion, this makes the addition of an approved sprinkler system a logical choice for the design. The sprinkler system provides added fire safety to the building, but it also allows the team to achieve the outlined goals for the classroom spaces.

		TYPE OF CONSTRUCTION								
		TYPE I		**TYPE II**		**TYPE III**		**TYPE IV**	**TYPE V**	
		A	**B**	**A**	**B**	**A**	**B**	**HT**	**A**	**B**
	HEIGHT (feet)	**UL**	**160**	**65**	**55**	**65**	**55**	**65**	**50**	**40**
GROUP	**STORIES(S) AREA (A)**									
A-1	S A	UL UL	5 UL	3 15,500	2 8,500	3 14,000	2 8,500	3 15,000	2 11,500	1 5,500
A-2	S A	UL UL	11 UL	3 15,500	2 9,500	3 14,000	2 9,500	3 15,000	2 11,500	1 6,000
A-3	S A	UL UL	11 UL	3 15,500	2 9,500	3 14,000	2 9,500	3 15,000	2 11,500	1 6,000
A-4	S A	UL UL	11 UL	3 15,500	2 9,500	3 14,000	2 9,500	3 15,000	2 11,500	1 6,000
A-5	S A	UL UL	UL UL	UL UL	UL UL	UL UL	UL UL	UL UL	UL UL	UL UL
B	S A	UL UL	11 UL	5 37,500	3 23,000	5 28,500	3 19,000	5 36,000	3 18,000	2 9,000
E	S A	UL UL	5 UL	3 26,500	2 14,500	3 23,500	2 14,500	3 25,500	1 18,500	1 9,500

Figure A: The 2009 IBC Table 503 showing allowed stories and square footages for each construction type and building group

BUILDING FIRE PROTECTION EVALUATION CONTINUED

$$A_a = \{A_t + [A_t \times I_f] + [A_t \times I_s]\}$$ **(Equation 5-1)**

where:

A_a = Allowable *building area* per *story* (square feet).

A_t = Tabular *building area* per *story* in accordance with Table 503 (square feet).

I_f = Area increase factor due to frontage as calculated in accordance with Section 506.2.

I_s = Area increase factor due to sprinkler protection as calculated in accordance with Section 506.3.

506.3 Automatic sprinkler system increase. Where a building is equipped throughout with an *approved automatic sprinkler system* in accordance with Section 903.3.1.1, the *building area* limitation in Table 503 is permitted to be increased by an additional 200 percent (I_s = 2) for buildings with more than one *story above grade plane* and an additional 300 percent (I_s = 3) for buildings with no more than one *story above grade plane*. These increases are permitted in addition to the height and *story* increases in accordance with Section 504.2.

Exception: The *building area* limitation increases shall not be permitted for the following conditions:

1. The *automatic sprinkler system* increase shall not apply to *buildings* with an occupancy in Group H-1.
2. The *automatic sprinkler system* increase shall not apply to the *building area* of an occupancy in Group H-2 or H-3. For *buildings* containing such occupancies, the allowable *building area* shall be determined in accordance with Section 508.4.2, with the sprinkler system increase applicable only to the portions of the building not classified as Group H-2 or H-3.
3. *Fire-resistance rating* substitution in accordance with Table 601, Note d.

Figure B: Building area modifications allowed for approved sprinkler systems

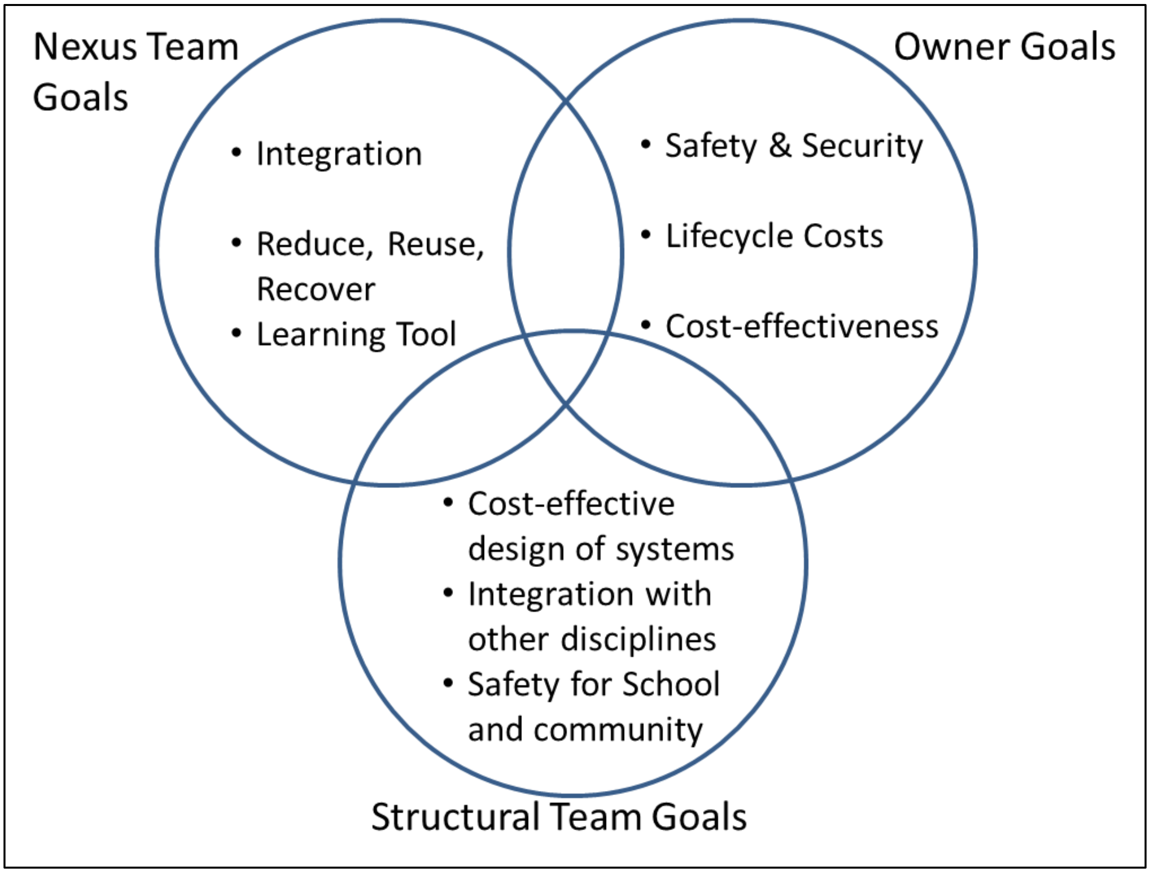
SECTION 601 GENERAL

TABLE 601 FIRE-RESISTANCE RATING REQUIREMENTS FOR BUILDING ELEMENTS (hours)

BUILDING ELEMENT	TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
	A	B	A[d]	B	A[d]	B	HT	A[d]	B
Primary structural frame[g] (see Section 202)	3[a]	2[a]	1	0	1	0	HT	1	0
Bearing Walls Exterior[f,g] Interior	 3 3[a]	 2 2[a]	 1 1	 0 0	 2 1	 2 0	 2 1/HT	 1 1	 0 0
Nonbearing walls and partitions Exterior	See Table 602								
Nonbearing walls and partitions Interior[e]	0	0	0	0	0	0	See Section 602.4.6	0	0
Floor construction and secondary members (see Section 202)	2	2	1	0	1	0	HT	1	0
Roof construction and secondary members (see Section 202)	$1^1/_2$[b]	1[b,c]	1[b,c]	0[c]	1[b,c]	0	HT	1[b,c]	0

Figure C: Fire rating requirements for building elements depending on construction type

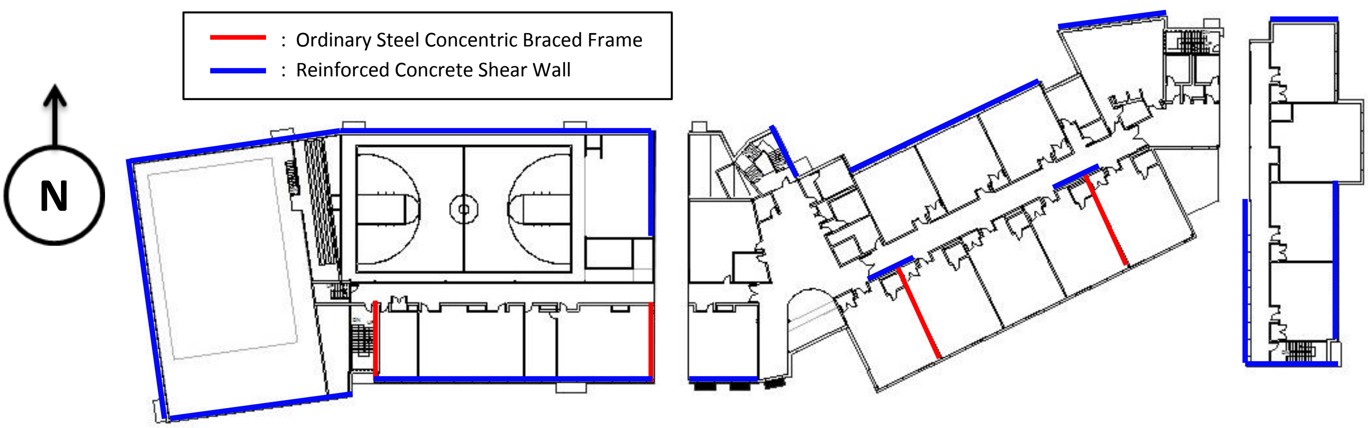
DEVELOPMENT OF STRUCTURAL TEAM GOALS – REPRESENTATIVE EXAMPLE



An important exercise for each of the design disciplines on the project was to focus on certain project goals (see each individual discipline report for their respective discipline goals). As described in the report, six main goals drove the design decisions for the team as a whole. To concentrate efforts, the structural team narrowed in on three of the overall goals to focus on throughout the project. These three goals were cost-effective design, integration, and safety. Most of the design decisions discussed by the structural team focused on these topics, and these ideas are evident in the final design solution.

BUILDING LATERAL SYSTEMS

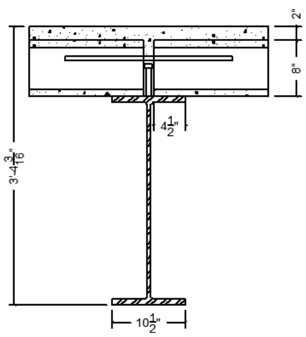
A key focus for the structural design team was the building lateral force-resisting systems. The diagram below shows the building lateral systems and lines of lateral resistance. Ordinary steel concentric braces are used at only four locations in the building. These braces are each designed to sit within the walls and go unnoticed by the building occupants. Since they do provide some small obstruction to the mechanical and plumbing systems of the building, the structural team placed the braces strategically and tried to limit the number of braces used. At the same time, much of the building is constructed with insulated concrete form (ICF) walls. The ICF walls are used as structural bearing walls to help carry floor loads in the building. However, they are also incredibly useful in providing lateral force resistance in the building. Since the ICF walls can be used in most parts of the building, very little additional lateral resistance is required, especially in the east-west direction of the building. In the central wing of the building, two interior shear walls are required since there is no ICF wall available on the south side of the wing. Also, a shear wall in the west wing of the building provides lateral resistance in the north-south direction. This wall is located directly behind the stage area, so it does not interfere with any of the existing spaces in the building.



Another feature exaggerated by the image above is the separation of the building into three independent structures. Since the multipurpose room in the west wing of the building is used as an emergency shelter, the building needs to be designed with an importance factor of 1.5. In order to minimize the effect of this higher importance factor on the rest of the building, the structure was split so that an importance factor of 1.25 (as typical for an elementary school) can be used throughout the rest of the building. However, the “L” shape created by the central and east wings also forms a torsional irregularity that is undesirable for seismic loads. To correct this, the team chose to split the structure again where these wings meet. The final result is the three separate structures shown above. A construction joint between each wing separates the structural members by 1 inch to allow for independent deflections of each structure.

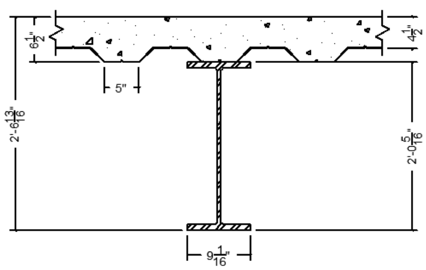
One final important consideration in the design is the question of whether the owner decides to build the pool in the initial construction phase. If the building is constructed without a pool, the lateral system layout is designed to still provide adequate lateral support for the building assuming the ICF wall is still used for the wall on the west side of the gymnasium.

BUILDING LATERAL SYSTEMS CONTINUED



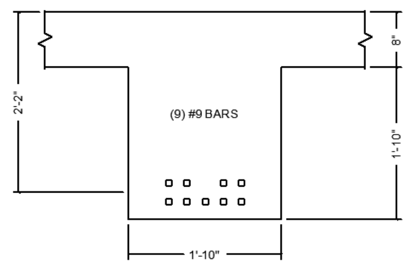
HOLLOW CORE CONCRETE PLANK WITH 2-INCH TOPPING ON STEEL GIRDER

TOTAL DEPTH: 3'-4 3/16"



COMPOSITE DECK ON STEEL GIRDER

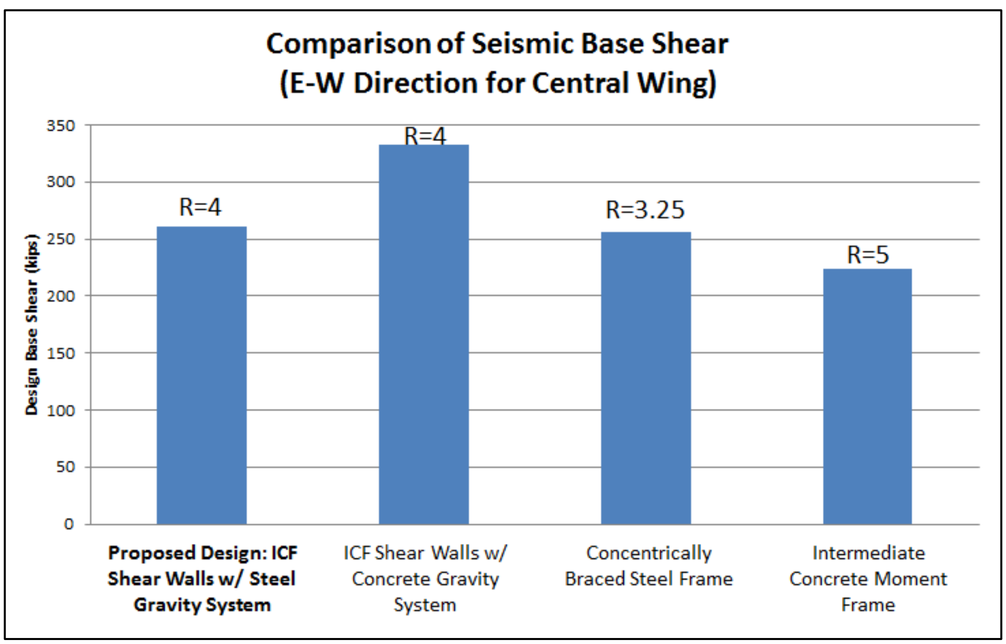
TOTAL DEPTH: 2'- 6 13/16"



CONCRETE SLAB AND GIRDER

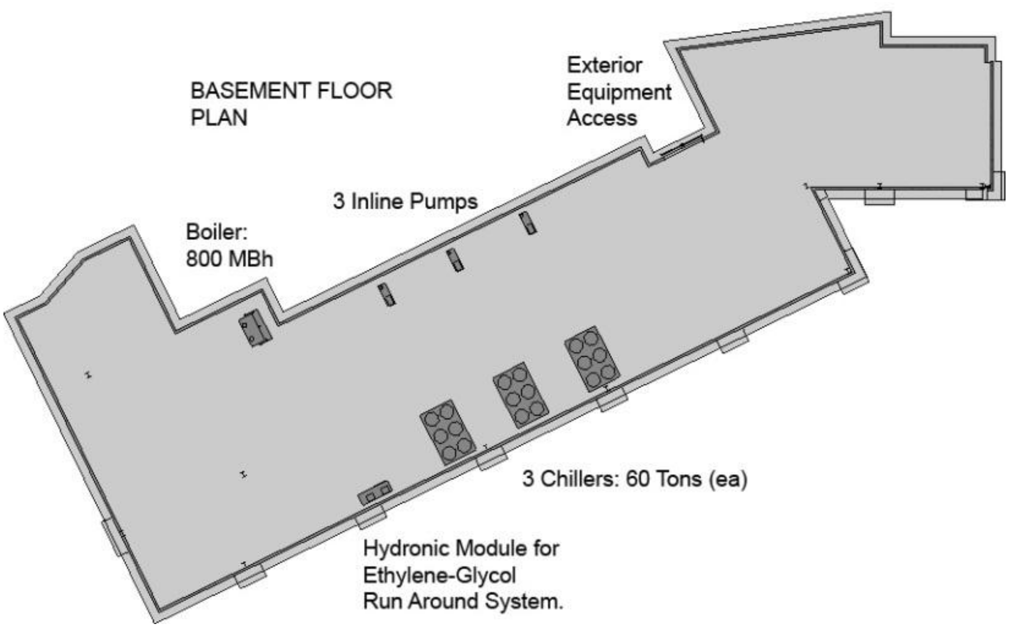
TOTAL DEPTH: 2'- 6"

An important decision for the structural team was the type of gravity load-resisting system to use in the building. Ultimately, the biggest concern for Nexus as a whole was to limit the overall structural depth in order to provide adequate space for the mechanical systems and still allow for an "open" feeling in the classroom spaces. The first option shown – hollow core planks on steel framing – was eliminated early in large part due to the excessive depth of the system. Other concerns for the structural team primarily regarding seismic loads eventually led to the choice of composite deck on steel girder. Although this option is 13/16" deeper than the concrete frame option, the team thought this was an acceptable option. In fact, the steel solution was slightly preferred by the other design disciplines as well as the construction management team. Finally, since the team wants to maintain the opportunity for modifications to the school in the future, it was determined that using a steel structure will provide more flexibility to the building.



As mentioned in regards to the floor system, the steel floor framing option was the final choice for the building for several reasons. Another large factor in this decision was the resulting seismic forces. Since the building uses insulated concrete form (ICF) exterior bearing walls, the building weighs significantly more than a steel frame building with a hung curtain wall. The chart to the left shows a comparison of options for gravity systems and lateral systems in the building. As the chart shows, the steel gravity system has a much lower (and more desirable) base shear than the concrete system. This occurs since the concrete system weighs much more but does not get the benefit of a higher R since the ICF shear walls control the lateral design.

ROOF & BASEMENT MECHANICAL LAYOUT



The majority of the mechanical equipment will be housed in the basement. There are three chillers placed 10 feet apart and 3 inline pumps across from the chillers. The main boiler will be located in the upper left hand corner and the hydronic module for the ethylene glycol system is located in the bottom left. This room will be accessible from the exterior of the building for maintenance purposes from an exterior access panel located along one wall.

MECHANICAL EQUIPMENT BREAKDOWN

Equipment Breakdown			
Equipment	**Description**	**Capacity**	**Price**
Chiller-1	Rotary-Screw Water Chillers	60 Tons	$ 55,300.00
Chiller-2	Rotary-Screw Water Chillers	60 Tons	$ 55,300.00
Chiller-3	Rotary-Screw Water Chillers	60 Tons	$ 55,300.00
Cooling Tower	Axial Fan, Induced Draft	175 Tons	$ 27,375.00
Boiler-1	Gas-Fired Boiler	800 MBh	$ 16,475.00
Boiler-2	Gas-Fired Boiler	350 MBh	$ 7,725.00
OAU-1	Dedicated Outdoor Air	38,000 CFM	$ 172,400.00
OAU-2	Dedicated Outdoor Air	27,000 CFM	$ 163,200.00
OAU-3	Dedicated Outdoor Air	8,000 CFM	$ 54,400.00
EAU-1	Exhaust Air Unit	34,500 CFM	$ 12,320.00
EAU-2	Exhaust Air Unit	24,500 CFM	$ 10,540.00
EAU-3	Exhaust Air Unit	9,000 CFM	$ 5,600.00
Ethylene-Glycol System	Without Pool	65,000 CFM	$ 295,000.00
Ethylene-Glycol System	With Pool	8,000 CFM	$ 355,000.00
Total	**Without Pool**		**$ 863,210.00**
Total	**With Pool**		**$ 990,935.00**

MECHANICAL ZONES

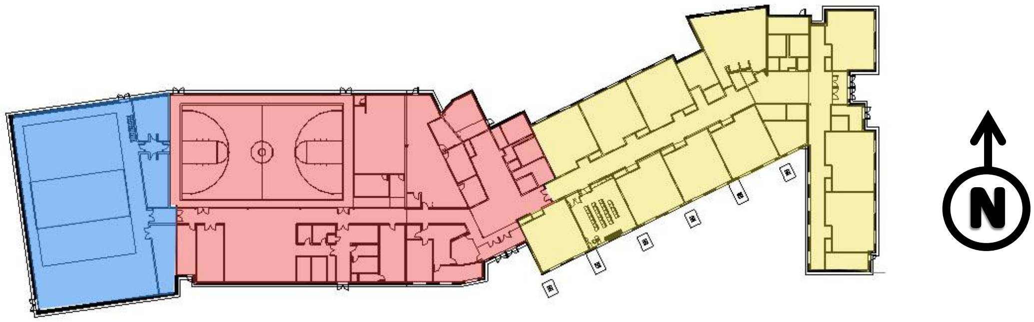


Figure 6: First Floor Plan: Zone Diagram: Pool (Blue), Community (Red), Classrooms (Yellow)

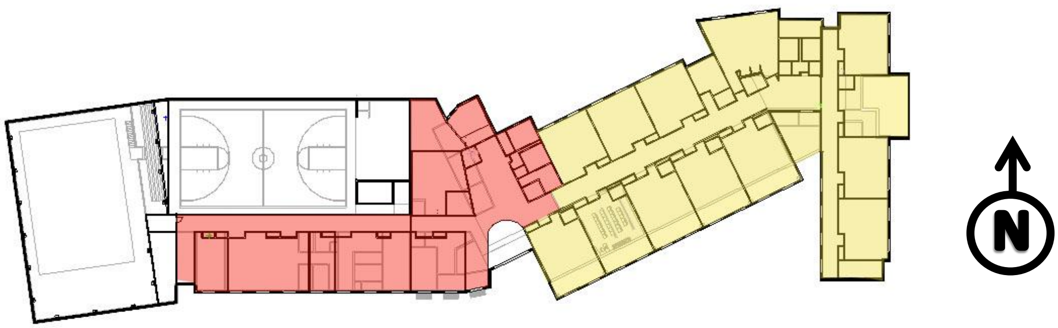


Figure 7: Second Floor Plan: Zone Diagram: Community (Red), Classrooms (Yellow)

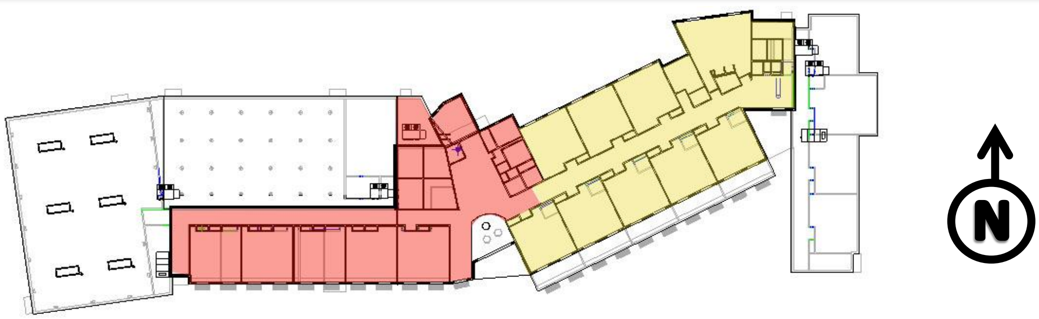
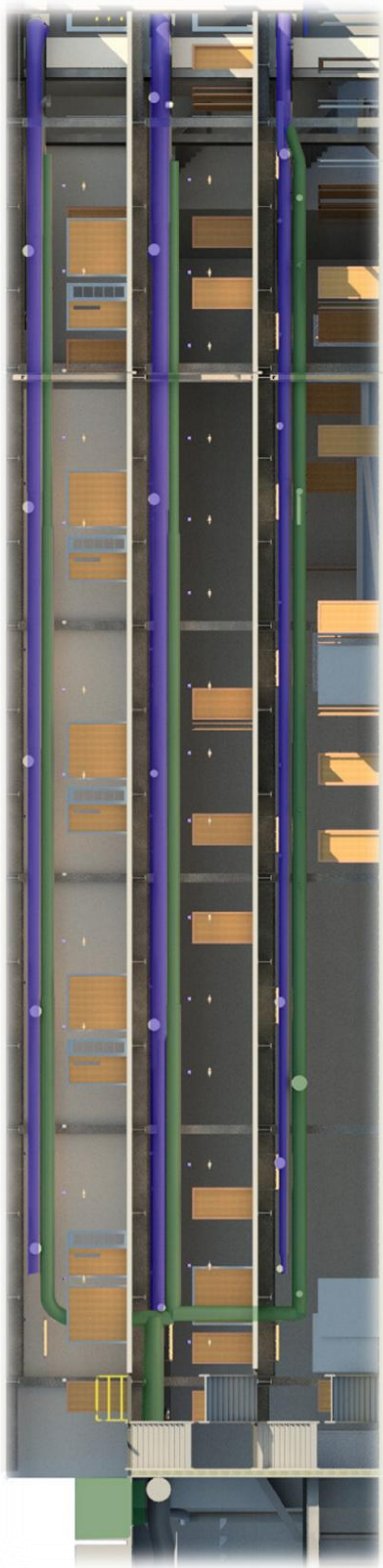


Figure 8: Third Floor Plan: Zone Diagram: Community (Red), Classrooms (Yellow)

The building was broken up into three zones: Academic (right wing), Community (left wing), and Pool (as shown in figures 6-8 below). This building was zoned vertically because all three floor plans are practically identical. These zones were derived in conjunction with the nuances in the structural system with the thought that each zone would have its own pair of outdoor air and exhaust air handlers. This will allow the mechanical system to condition the zones independently of one another. This is important during the summer months when students will not be in the building. This configuration will allow the public spaces to be conditioned while not wasting energy conditioning the classrooms when no students are present. Additionally the system is configured so that the community zone can run independently on emergency power, as this zone houses the multipurpose room that will act as a community shelter in the event of an emergency.

CLASSROOM DUCT DETAIL



In the general duct layout of the classroom spaces, the decision was made to supply from one end of this zone and exhaust from the other as to allow space for the large duct work. Due to this configuration where the supply ductwork is large (on the lobby side by the vertical chase) the exhaust ductwork is at its smallest. Visa versa, at the end of the zone closest to the pool, where the exhaust unit is located, the supply duct work is smallest, having only to condition small office spaces. This can be seen more clearly in this image, which shows how the ductwork for this zone was able to run to each space without conflicting with other discipline systems. The configuration was designed with the input of all Team Nexus members. This layout allows the duct to run just below the structure and out of the way of any light fixtures. As the round duct is more visually appealing than other options, it was also decided to leave the duct exposed which eliminated the need for a bulkhead.

ACOUSTIC ANALYSIS

An acoustic analysis was performed to determine if acoustic metal deck would be necessary for the classrooms to maintain an appropriate acoustic environment. The recommended reverberation time for classroom spaces is between 0.4 and 0.8 seconds. Without the acoustic metal deck, our classroom reverberation time was over 1 second, while with the acoustic metal deck it was approximately half of a second. Therefore, acoustic metal deck was deemed necessary to provide an acceptable acoustic environment in our building.

Acoustic Analysis

Classrooms with Acoustic Metal Deck

Recommended T60 Time: 0.4 - 0.8 s

Dimensions		
Height	13	ft
Width	30	ft
Length	28	ft
Volume	10,920	cf
Window		
Height	8	ft
Width	7	ft
AREA	112	sf

	Material	Composition	Area /Quanity		Absorptivity (α) 125	250	500	1000	2000	4000	A*α 125	250	500	1000	2000	4000
Walls	Gyp	1/2" Thick on 2x4 metal stud 16" O.C.	1396	sf	0.29	0.1	0.05	0.04	0.07	0.09	404.8	139.6	69.8	55.8	97.7	125.6
Ceiling	Acoustic Metal Deck	3VLPA w/Insulation	840	sf	0.4	0.56	1.07	0.78	0.57	0.35	336.0	470.4	898.8	655.2	478.8	294.0
Flooring	Carpet	Carpet, Heavy Tile on Concrete	840	sf	0.02	0.06	0.14	0.37	0.06	0.065	16.8	50.4	117.6	310.8	50.4	54.6
Window	Glass	Double Pane Argon B_ITCH	112	sf	0.3	0.2	0.2	0.1	0.07	0.04	33.6	22.4	22.4	11.2	7.8	4.5
Occupant	Student's Informally Dressed seated in Tablet Arm Chairs		29	per	0.3	0.41	0.49	0.84	0.87	0.84	8.7	11.9	14.2	24.4	25.2	24.4
Treatment	N/A															

Sound Pressure Level (dB)	125	250	500	1000	2000	4000
Classroom	66	72	77	74	68	60

$T_{60} = 0.05V/A$

V	10,920
A_{125}	799.9
A_{250}	694.7
A_{500}	1122.8
A_{1000}	1057.4
A_{2000}	660.0
A_{4000}	503.1

Frequency	$T_{60\,(s)}$
125 Hz	0.6825512
250 Hz	0.7859621
500 Hz	0.48628
1000 Hz	0.5163609
2000 Hz	0.8272853
4000 Hz	1.0853145

Acoustic Analysis

Classrooms without Acoustic Metal Deck

Recommended T60 Time: 0.4 - 0.8 s

Dimensions		
Height	13	ft
Width	30	ft
Length	28	ft
Volume	10,920	cf
Window		
Height	8	ft
Width	7	ft
AREA	112	sf

	Material	Composition	Area /Quanity		Absorptivity (α) 125	250	500	1000	2000	4000	A*α 125	250	500	1000	2000	4000
Walls	Gyp	1/2" Thick on 2x4 metal stud 16" O.C.	1396	sf	0.29	0.1	0.05	0.04	0.07	0.09	404.8	139.6	69.8	55.8	97.7	125.6
Ceiling	Acoustic Metal Deck	3VLPA w/Insulation	840	sf	0.33	0.31	0.3	0.14	0.09	0.01	277.2	260.4	252.0	117.6	75.6	8.4
Flooring	Carpet	Carpet, Heavy Tile on Concrete	840	sf	0.02	0.06	0.14	0.37	0.06	0.065	16.8	50.4	117.6	310.8	50.4	54.6
Window	Glass	Double Pane Argon B_ITCH	112	sf	0.3	0.2	0.2	0.1	0.07	0.04	33.6	22.4	22.4	11.2	7.8	4.5
Occupant	Student's Informally Dressed seated in Tablet Arm Chairs		29	per	0.3	0.41	0.49	0.84	0.87	0.84	8.7	11.9	14.2	24.4	25.2	24.4
Treatment	N/A															

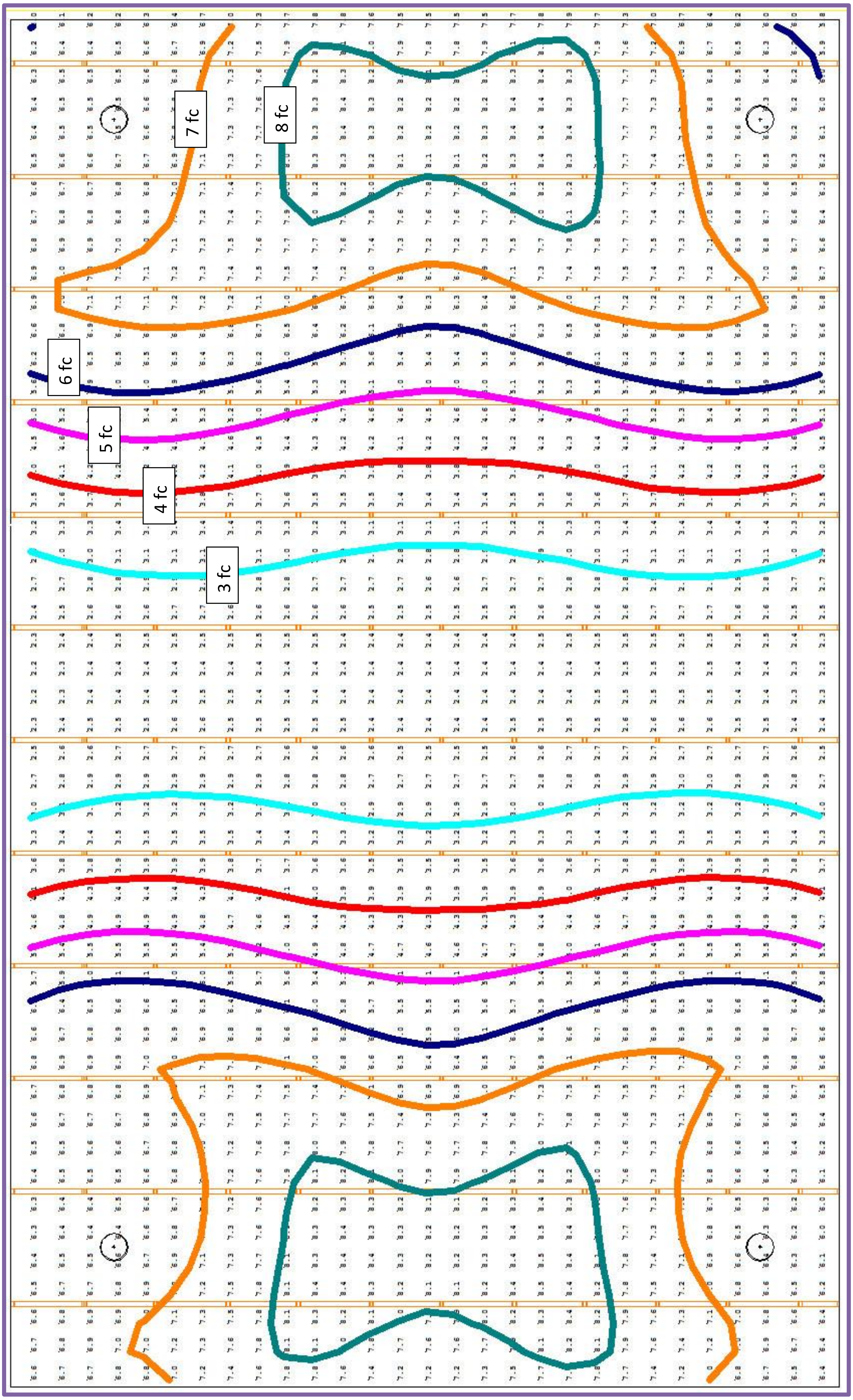
Sound Pressure Level (dB)	125	250	500	1000	2000	4000
Classroom	66	72	77	74	68	60

$T_{60} = 0.05V/A$

V	10,920
A_{125}	741.1
A_{250}	484.7
A_{500}	476.0
A_{1000}	519.8
A_{2000}	256.8
A_{4000}	217.5

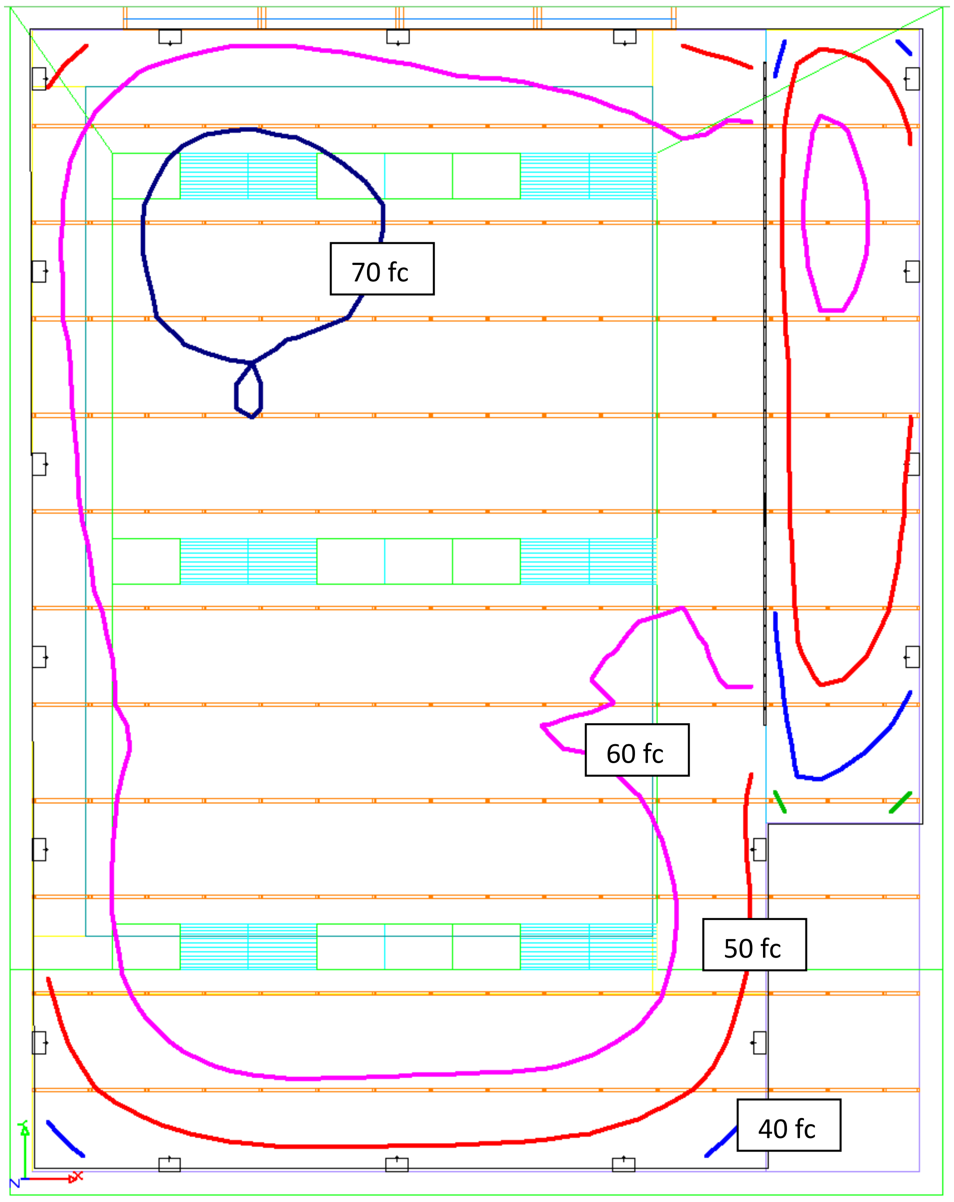
Frequency	$T_{60\,(s)}$
125 Hz	0.7367029
250 Hz	1.1264932
500 Hz	1.1470347
1000 Hz	1.050404
2000 Hz	2.126251
4000 Hz	2.5105757

MULTI-PURPOSE ROOM EMERGENCY LIGHTING

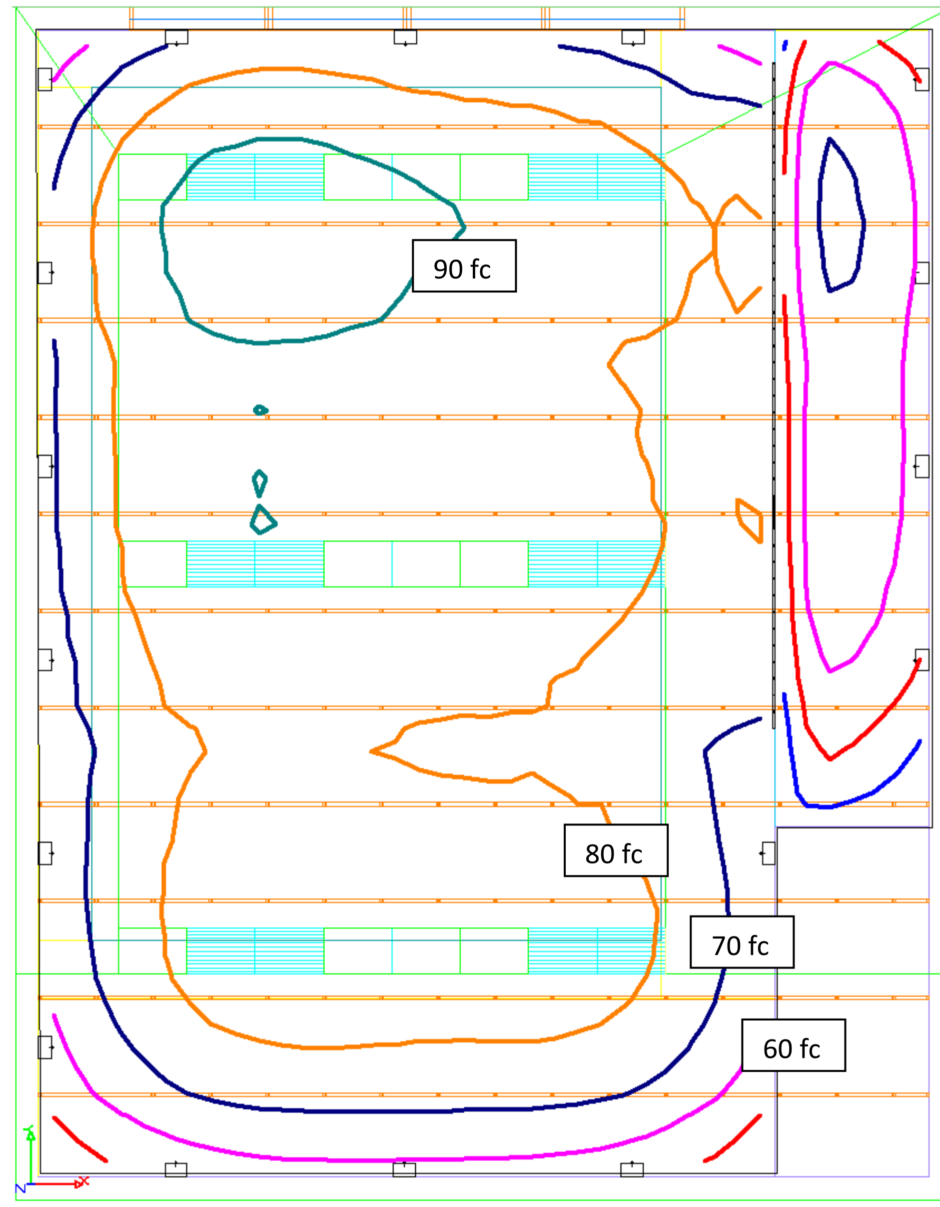


Since another consideration of the gym is nighttime use of the gym as an emergency shelter. There needs to be enough light for safety purposes; however, the levels need to be low enough that the occupants can sleep without affecting their circadian rhythms. The space was determined to have a low degree of hazard, meaning that there is a high enough contrast, and no change of planes, and a high circulation activity; therefore, the IES recommended light level is a minimum of 0.8 footcandles for safety. To achieve this level, 4 luminaires, one in each corner, will also be on emergency power and will remain on when the lights are off or the event of power failure.

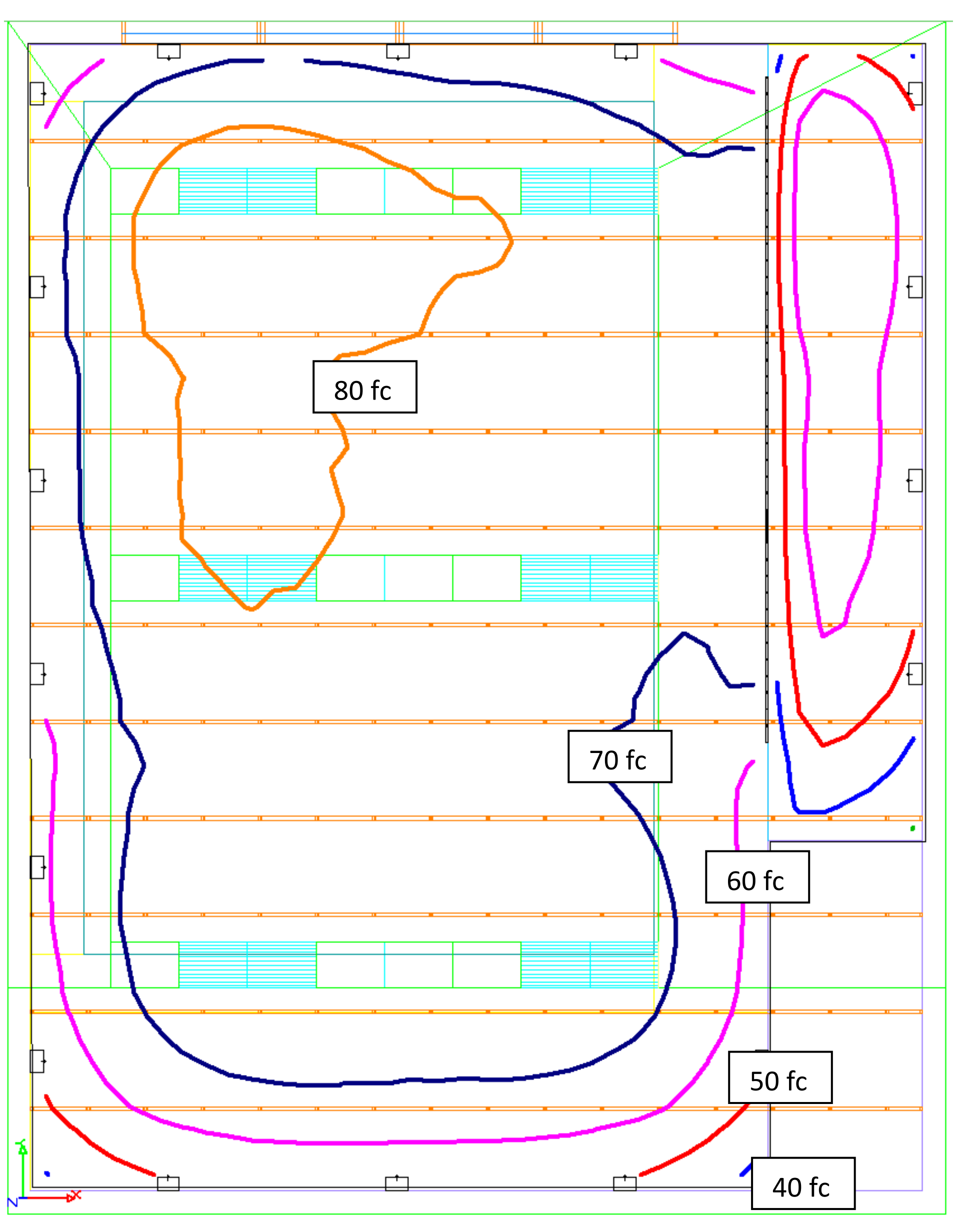
POOL ELECTRICAL LIGHTING AND DAYLIGHTING CALCULATIONS



Winter Solstice



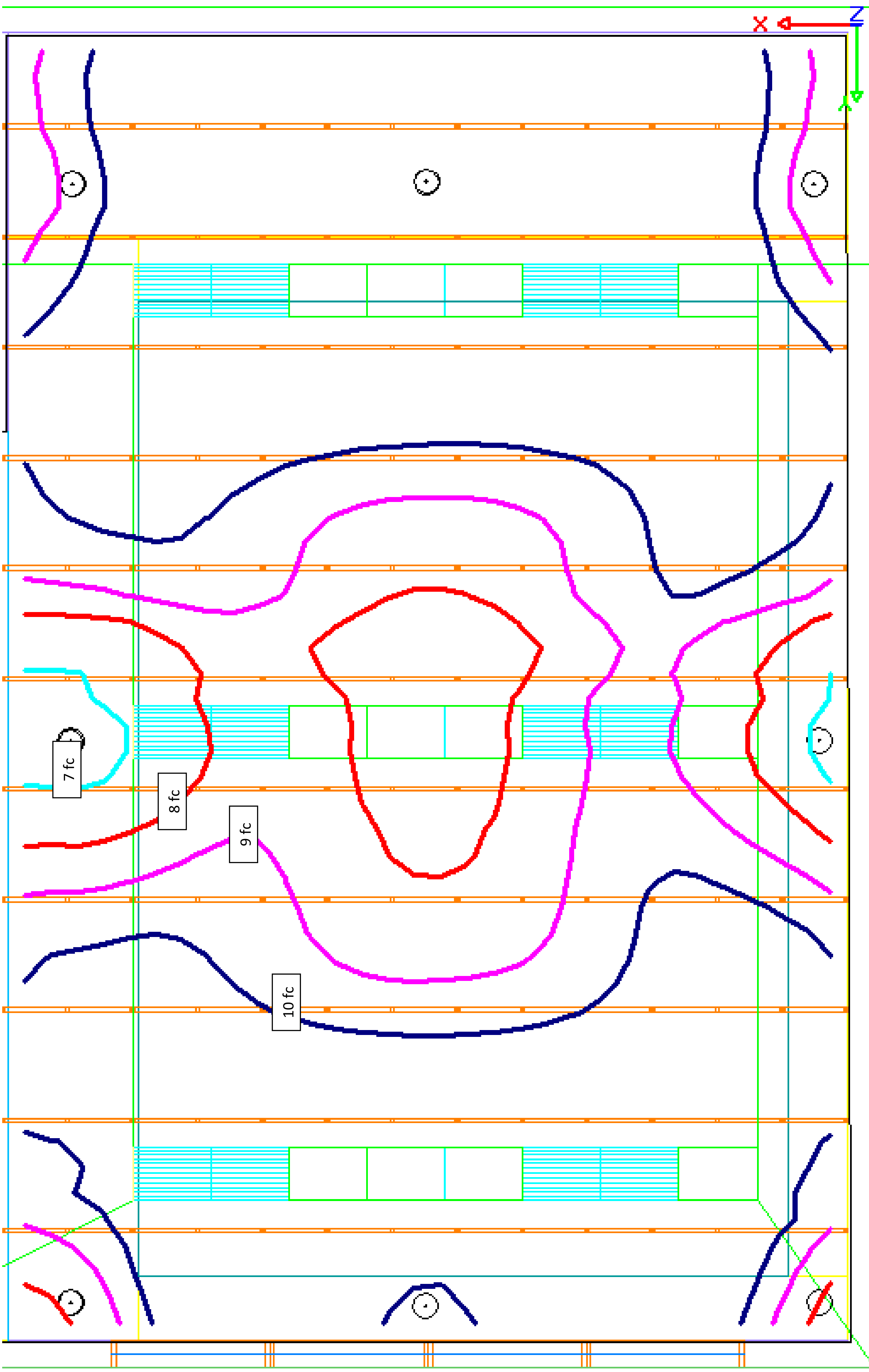
Summer Solstice



Spring/Fall Equinox

In the pool, it was important to coordinate between the lighting/electrical, structural, and mechanical disciplines to ensure that the space will receive enough daylight as well as electric light. Since the ceiling is exposed special care was taken to arrange the skylights and luminaires to ensure that the proper IES recommended light levels are met.

POOL EMERGENCY LIGHTING CALCULATION

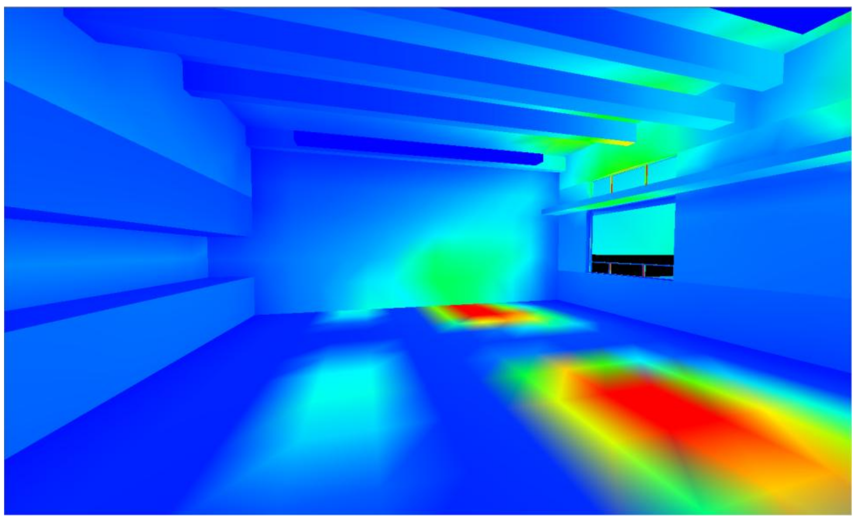


Emergency lighting for pool is extremely important for the safety of the occupants. There needs to be more light concentrated around the edge of the pool to prevent people from accidentally falling in, in the event of power failure. Therefore, compact fluorescent fixtures over the pool deck will be used. Compact fluorescent lamps are capable of immediate switching, which is the reason for their selection over ceramic metal halide. The minimum light level is 4 footcandles; however, the design shown in Figure 12 has a minimum of 6.6 footcandles and an average of 10.21 footcandles. The same fixtures will be used for the emergency lighting in the pool area as in the gym for easy maintenance. Using the same fixtures will also reduce the amount of different lamp types required, which will save the school system money in maintenance costs.

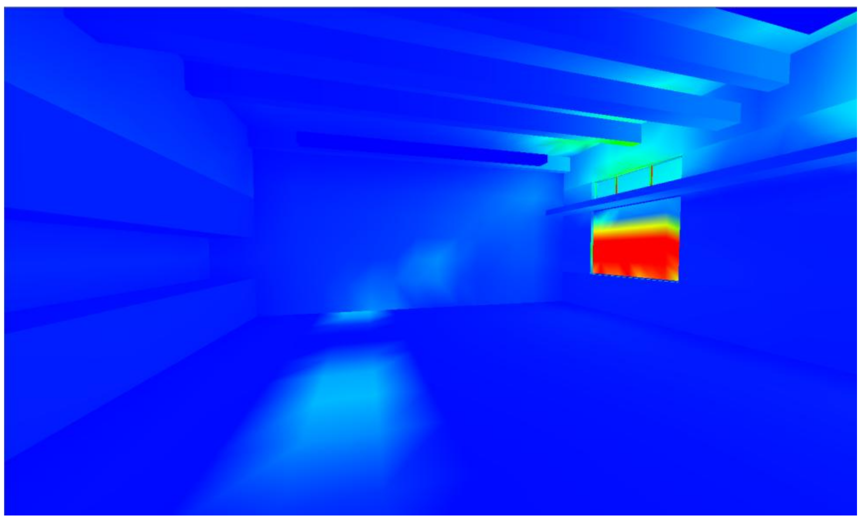
CLASSROOM DAYLIGHTING ANALYSIS

NO SHADES

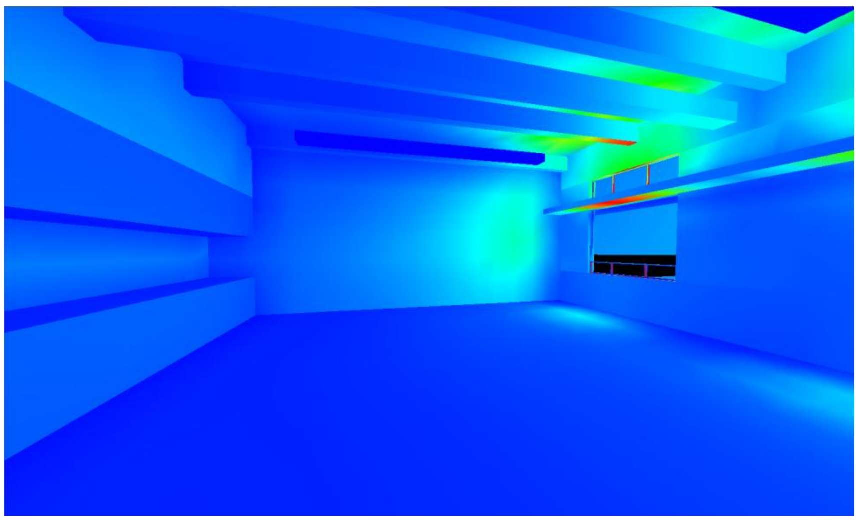
WITH SHADES



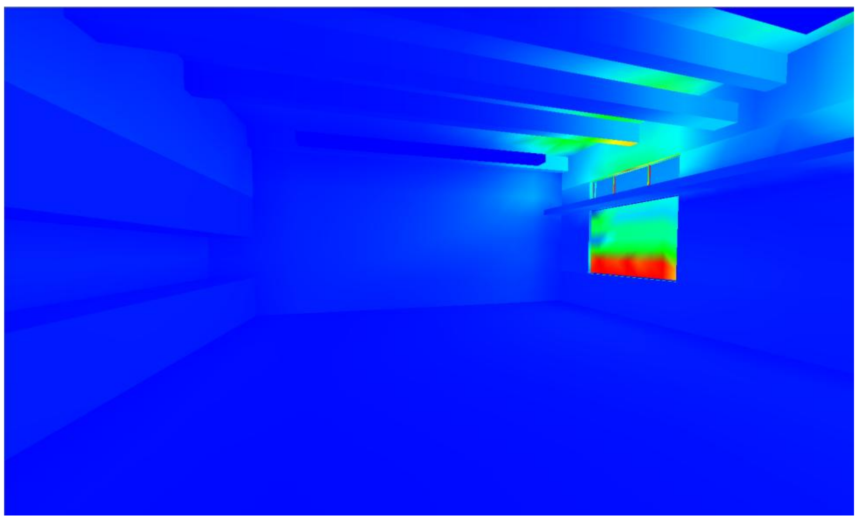
Winter: Maximum – 1823 fc   Average – 287.49 fc



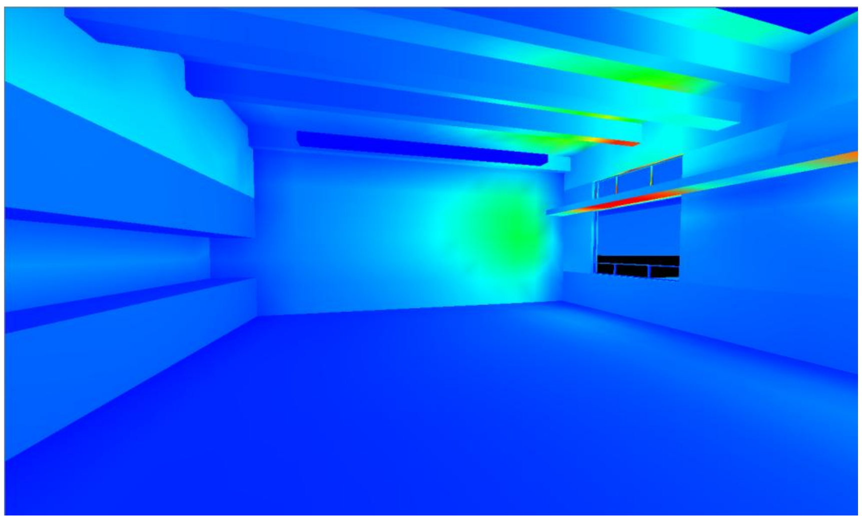
Winter: Maximum – 1661 fc   Average – 65.05 fc



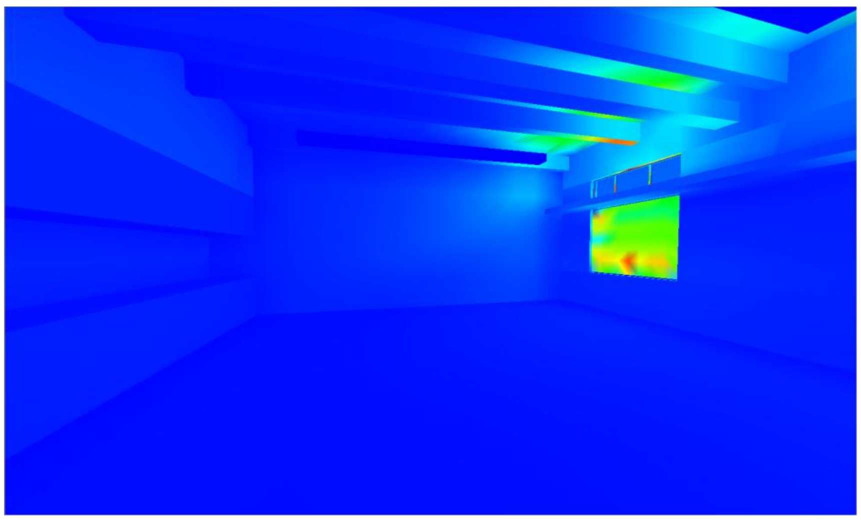
Spring/Fall: Maximum – 191 fc   Average – 49.92 fc



Spring/Fall: Maximum – 60.2 fc   Average – 19.04 fc

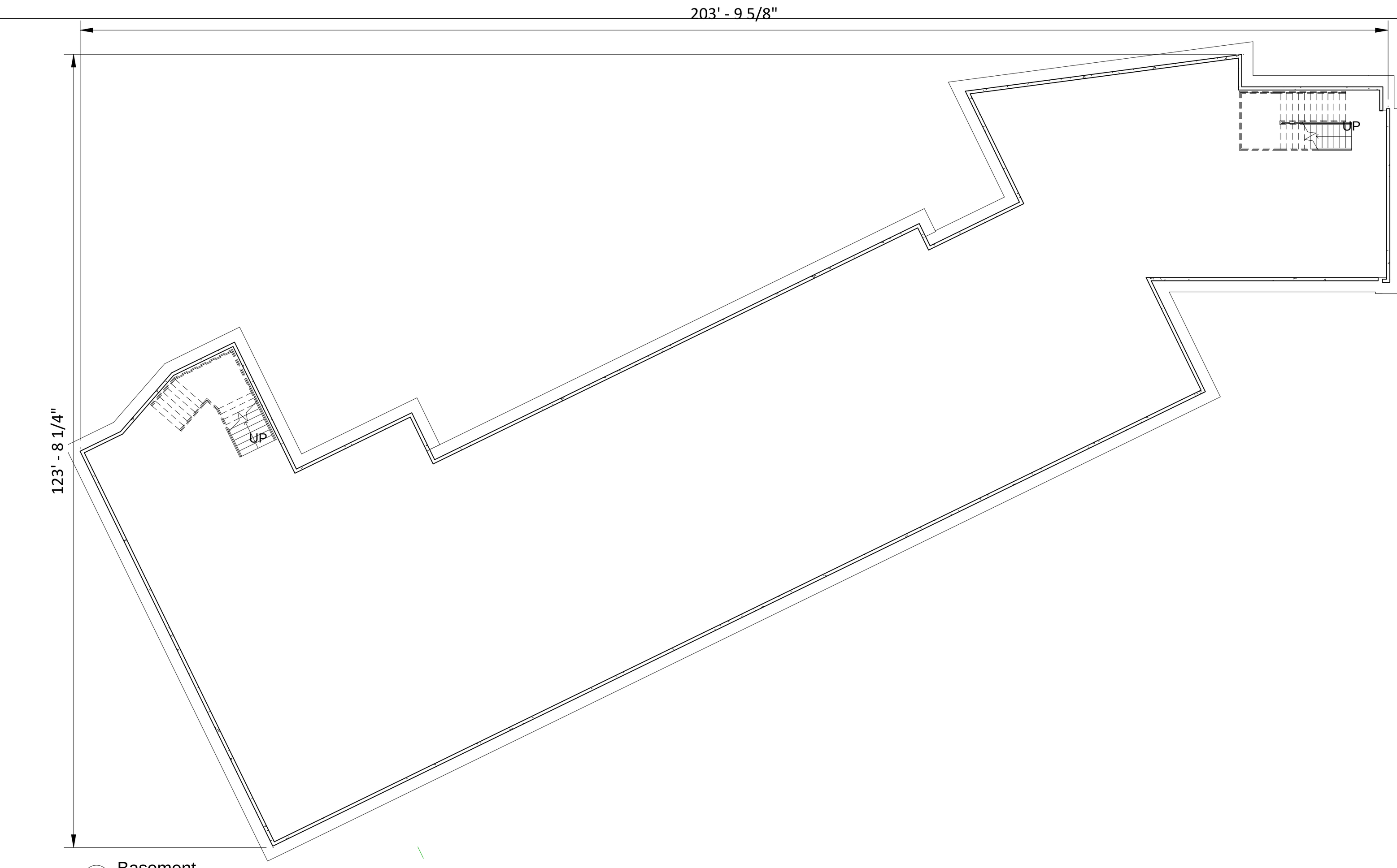


Summer: Maximum – 135 fc   Average – 38.29 fc



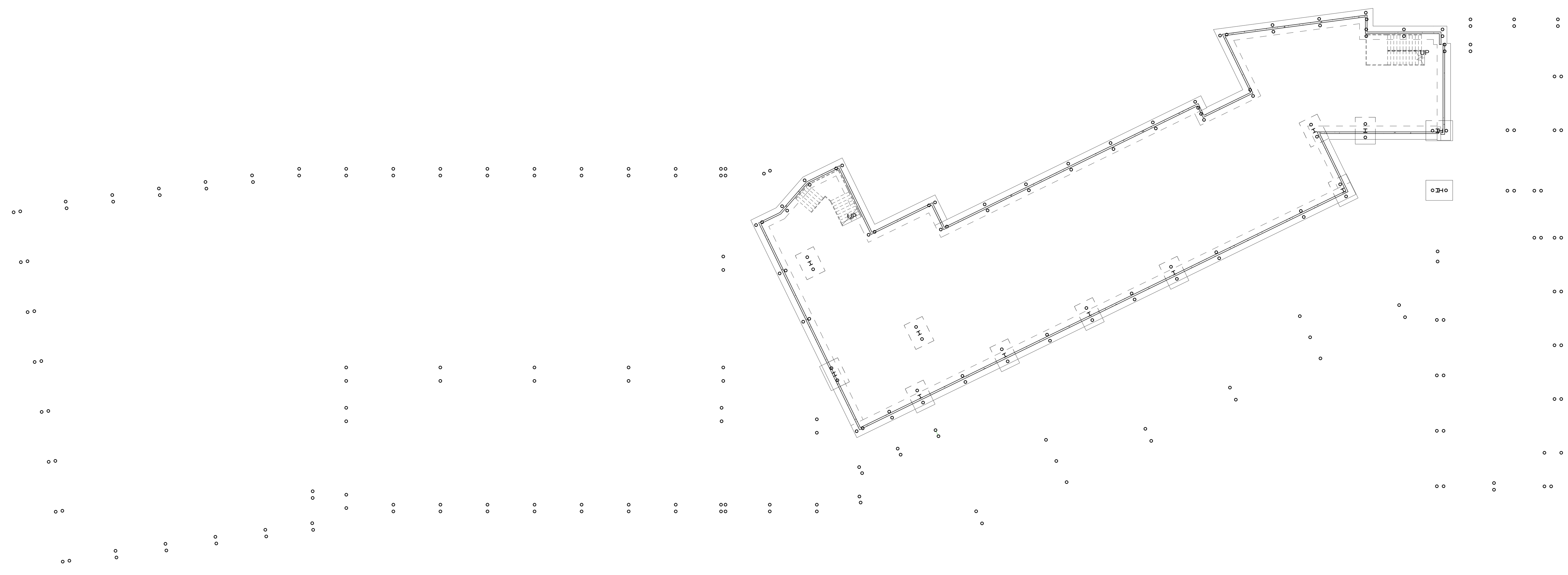
Summer: Maximum – 30.5 fc   Average – 12.88 fc

Since daylighting in the classrooms is important to create a nice environment, all systems had to coordinate to ensure that enough daylight was delivered to the space. The structural team and the lighting/electrical team had to coordinate the most is designing the window system for the building to be suitable for both daylighting and design of the wall system.



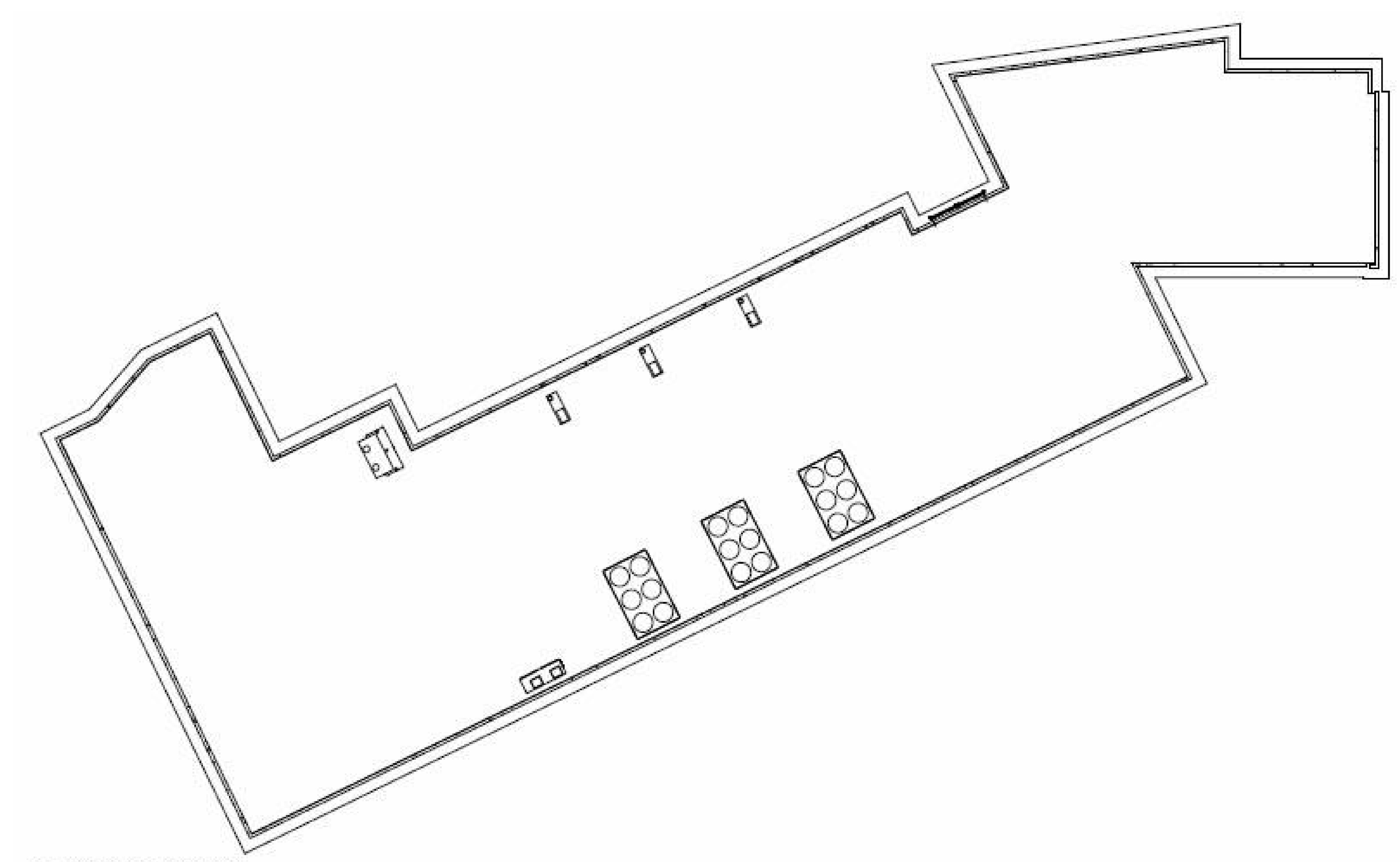
1 Basement
1/16" = 1'-0"

The basement has two points of egress - the main staircase and the northeast staircase. The basement is purposed to house mechanical and electrical equipment. There is an access point for equipment hoisting. Due to safety concerns, only building maintenance personnel will be permitted access.



2 Basement
1/16" = 1'-0"

The structural foundation is built on driven piles and pile caps. The piles are driven until they bear on bedrock approximately 30 feet below the ground surface. A concrete foundation wall extends around the basement while the columns extend down to pile caps at the slab level. The pile caps are braced laterally by the rigid floor diaphragm created by the basement floor slab-on-grade. To ensure the lateral loads can be transferred, the top of the slab-on-grade is cast at the same level as the top of the pile caps. Additionally, the floor slab is constructed with an adequate amount of reinforcement to prevent against cracking in the event that a sinkhole forms in the unstable soil under the structure. Finally, a strip footer runs below the basement walls (and below the exterior bearing walls) to distribute help distribute loads to the pile groups, which are placed every 14 feet along the wall.



1 Mechanical Basement
1/16" = 1'-0"

The majority of mechanical equipment will be housed in the basement. There are three 60 ton rotary-screw chillers, 3 inline pumps, 1 800 MBh boiler, and the hydronic unit which stores the recovered heat from the ethylene-glycol run around heat recovery loop. There is a large garage door for the easy removal or addition of the large mechanical and electrical equipment.

BUILDING INTEGRATION

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Annual Architectural Engineering Student Competition

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Basement Floor Plans

Date 22 February 2013

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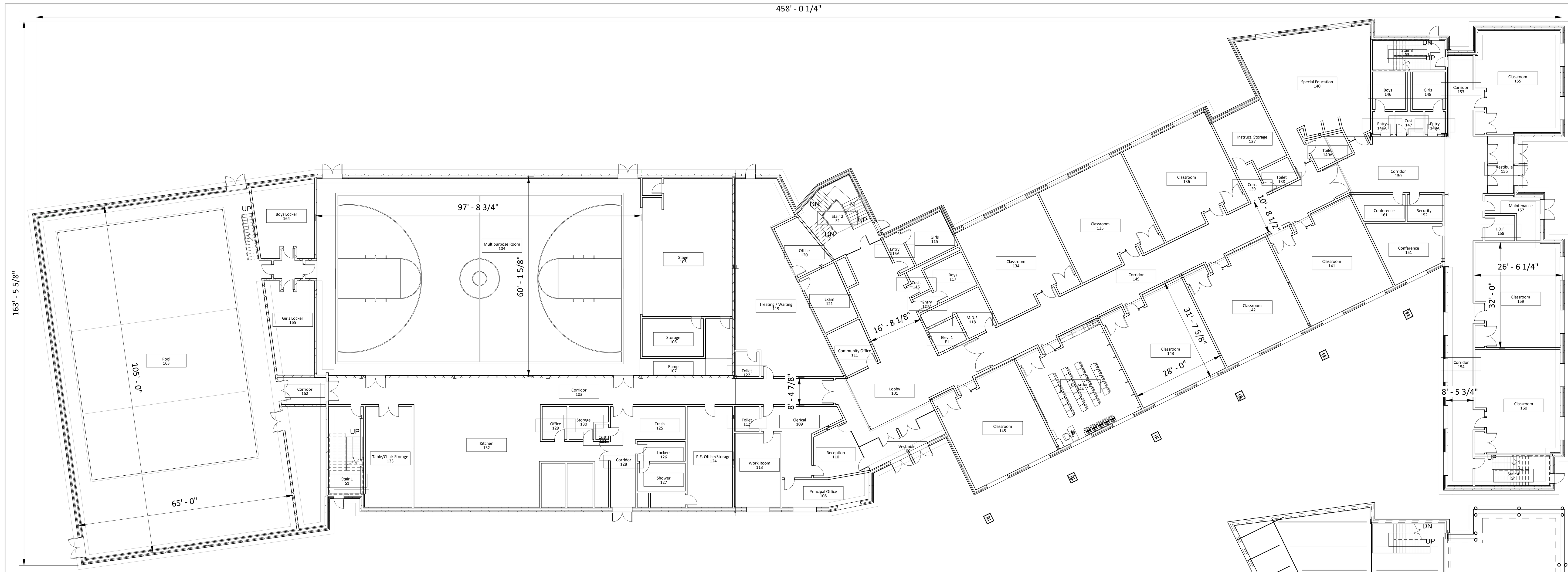
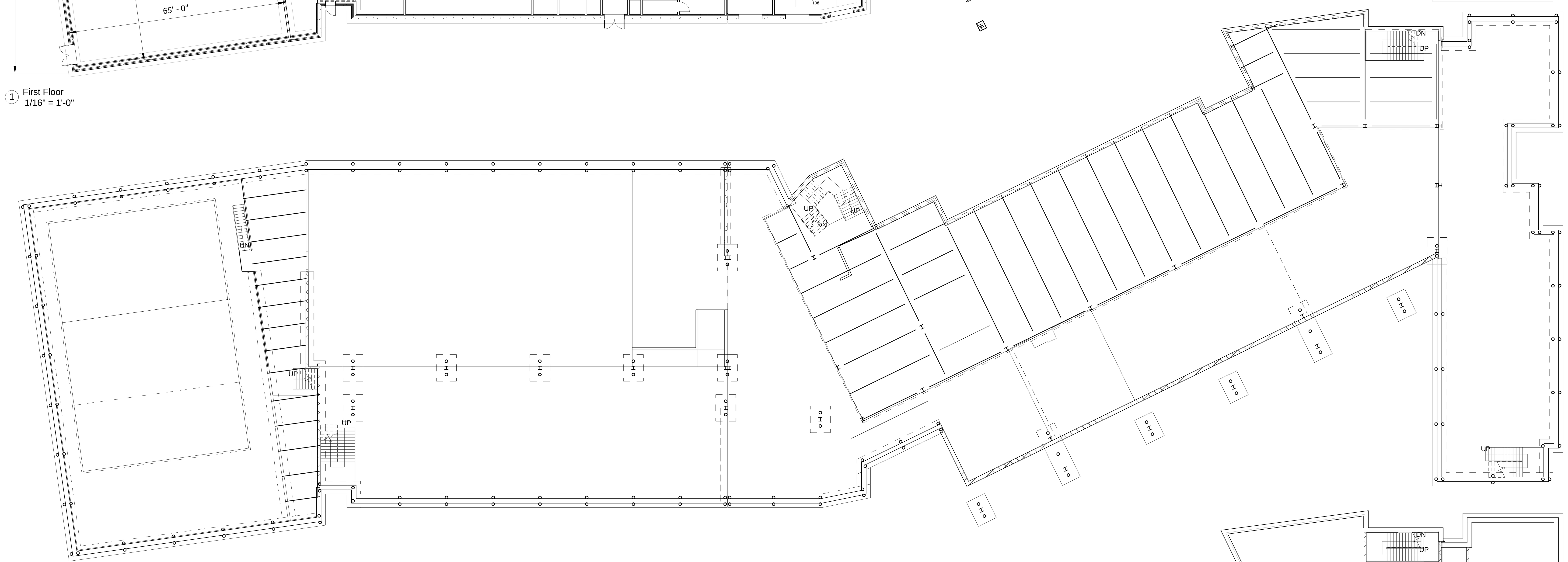
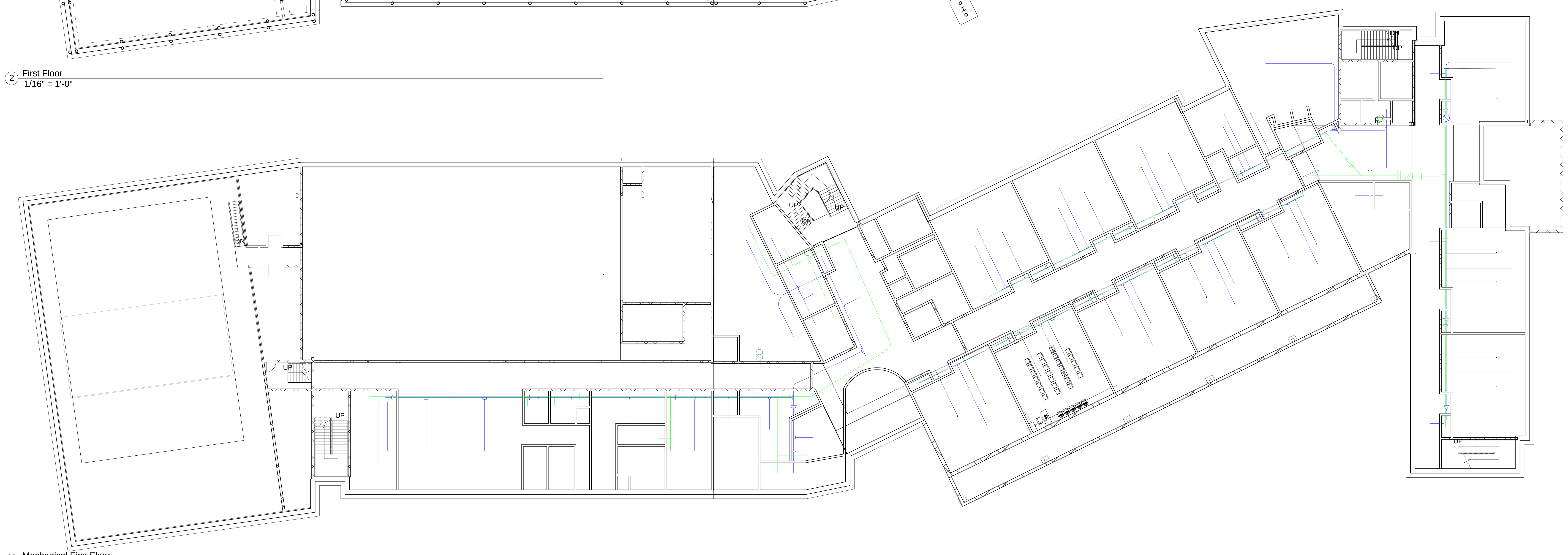
Scale 1/16" = 1'-0"



1 First Floor
1/16" = 1'-0"



2 First Floor
1/16" = 1'-0"



3 Mechanical First Floor
1/16" = 1'-0"

The most noticeable change from the original first floor plan is the modified entrance sequence. The new entrance is on the south facade, with the administration space to the left. Thus, the health center was moved to the north side with an exterior entrance for community members. Three sets of dual security/fire doors were added to the lobby to prevent intruders from gaining access to other parts of the school. The west end of the first floor houses the community spaces such as the pool and multipurpose room. The first series of classrooms are located in the central and eastern portions of the first floor.

Most of the first floor structural system is comprised of the slab-on-grade that is described on the basement floor plan. However, the floor above the basement is supported by a system of steel girders and beams. Although the original design of the building called for four column lines running along the length of the building's central wing, the design team chose to eliminate one of the column lines. Since one of the existing bays is 30 feet long, and the new bay created by eliminating a column line is 32 feet long, the team realized that this was a useful opportunity to provide a more efficient and cost-effective structural system. The drawing also shows the exterior insulated concrete form (ICF) walls reaching around the perimeter of the building. These walls carry vertical building loads and also act as shear walls to provide lateral force resistance.

The main supply and return ducts will be run through large vertical chases in the two lobbies of the building. These chases will allow easy connection of the duct from the interior spaces to the air handlers on the roof. The supply and return ducts that run through the majority of the building will be housed in horizontal chases along the corridor wall in the classrooms.

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BUILDING INTEGRATION

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Annual Architectural Engineering Student Competition

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First Floor Plan

Date 22 February 2013

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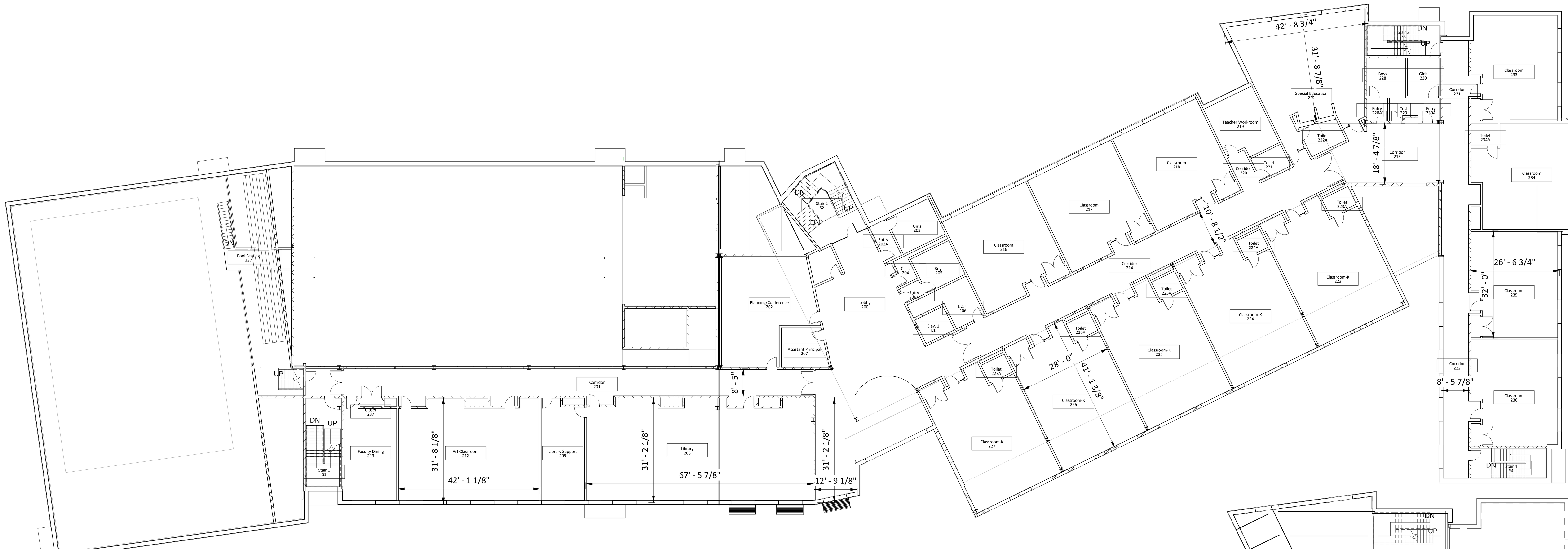
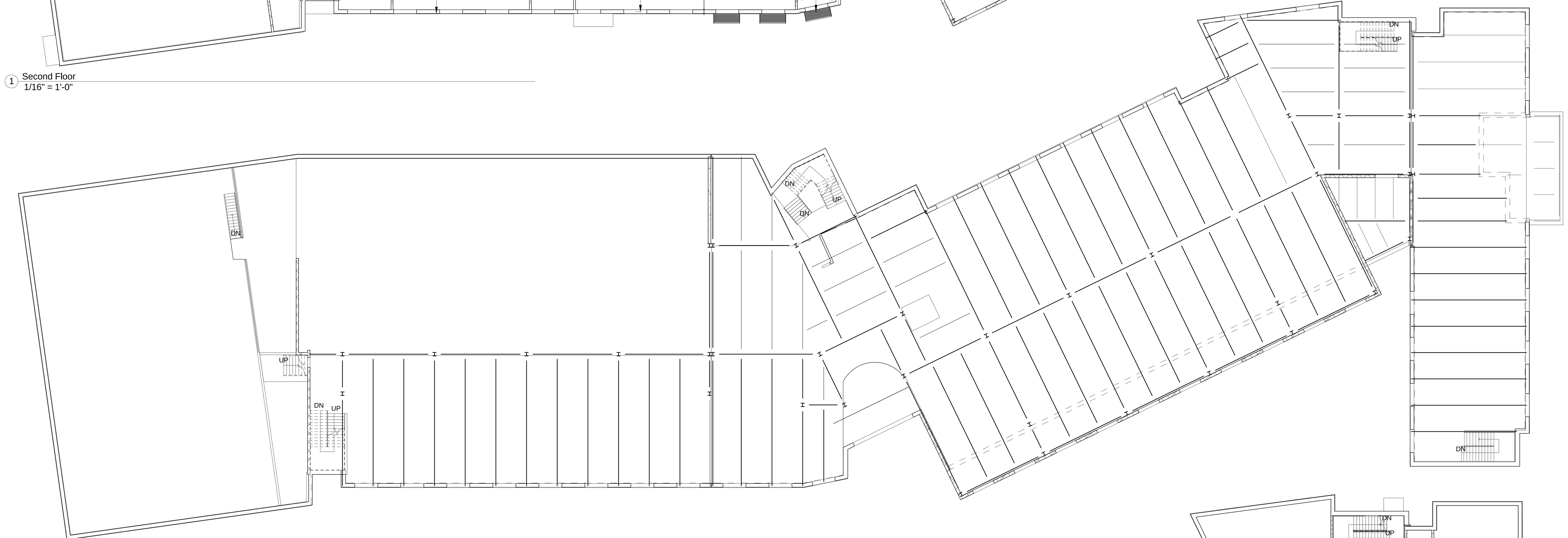
Scale 1/16" = 1'-0"



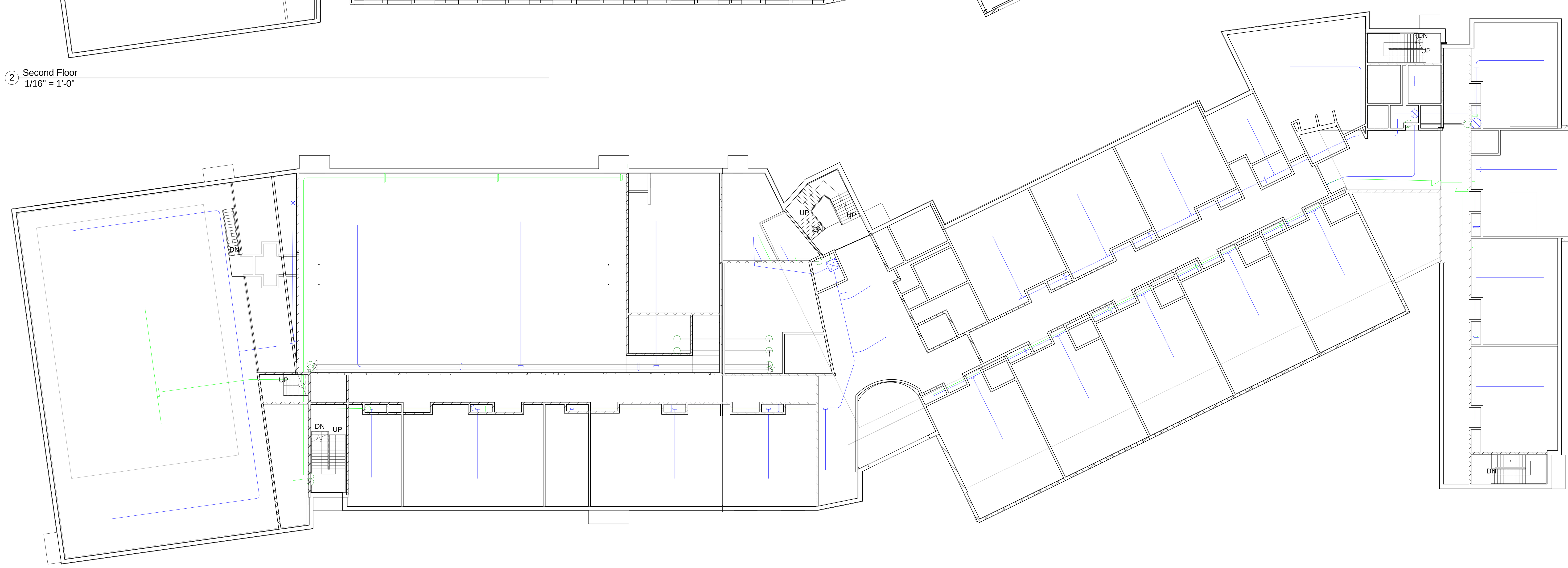
1 Second Floor
1/16" = 1'-0"

The second floor incorporates the teacher's lounge, art room, and library. Moreover, classrooms continue in the central and eastern portions of the floor plan. On the west side of the second floor plan from the community staircase entrance is access to the pool viewing balcony. There is a set of double doors to the right when entering the second level to prevent community access to student-occupied spaces. The kindergarten classrooms are on the south side of the central classroom. These rooms contain larger floor plans for more space for the students along with individual bathrooms.



2 Second Floor
1/16" = 1'-0"

The second floor structural plan begins to show more of the structural features of the building. One key element of the structural design is that the building is separated into three independent structures. This is done in order to make efficient use of the higher importance factor required for the shelter area of the building. It also helps to reduce the effects of accidental torsion due to earthquake loads at the east side of the building where the east wing and central wing make an "L" shape with each other. Since most of the building's perimeter is built of ICF walls, the need for columns in the structure was greatly reduced. As is evident in most of the east wing of the building, no columns are necessary; the W18X35 floor beams are supported on either end by the ICF walls.



3 Mechanical Second Floor
1/16" = 1'-0"

The second floor duct is run similarly to the first. Each classroom has one supply duct that permeates into the room, while the return duct has one grille along the horizontal chase. The gymnasium and pool spaces have the duct run through the structural trusses. The duct layout in the pool area was designed to supply the air along the perimeter to prevent condensation on the windows and prevent drafts. The return duct is centered over the actual pool to easily vent out the evaporated chlorine vapors.

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Second Floor Plan

Date 22 February 2013

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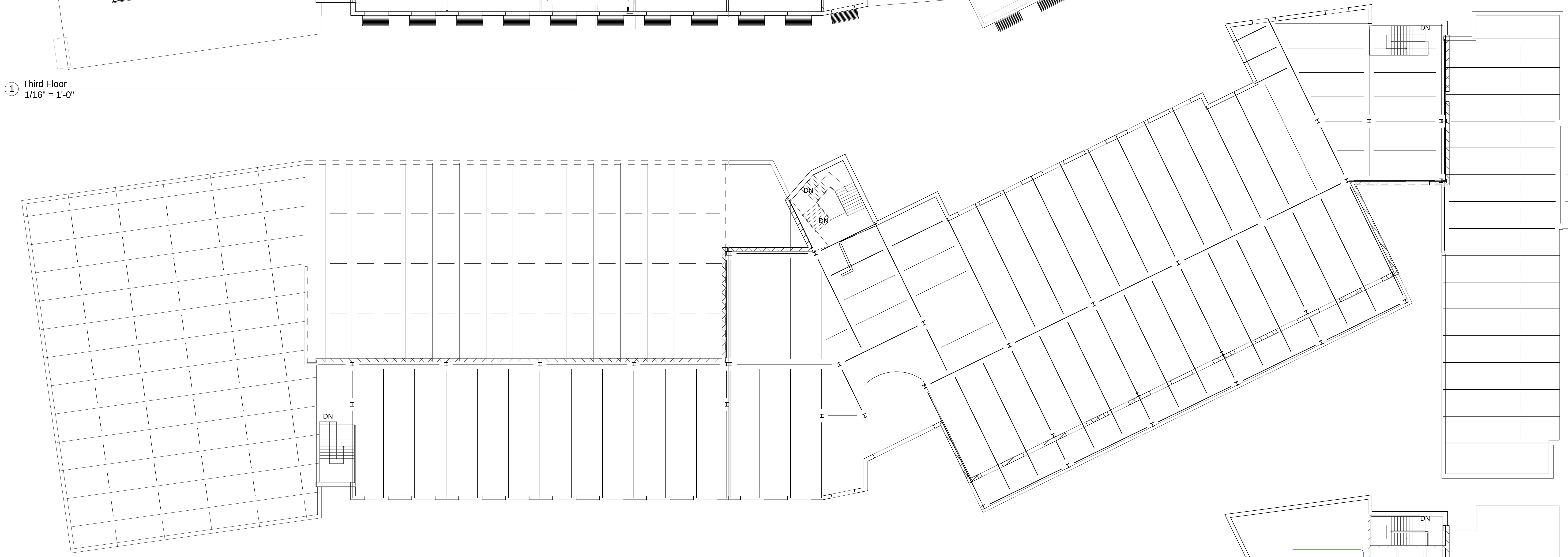
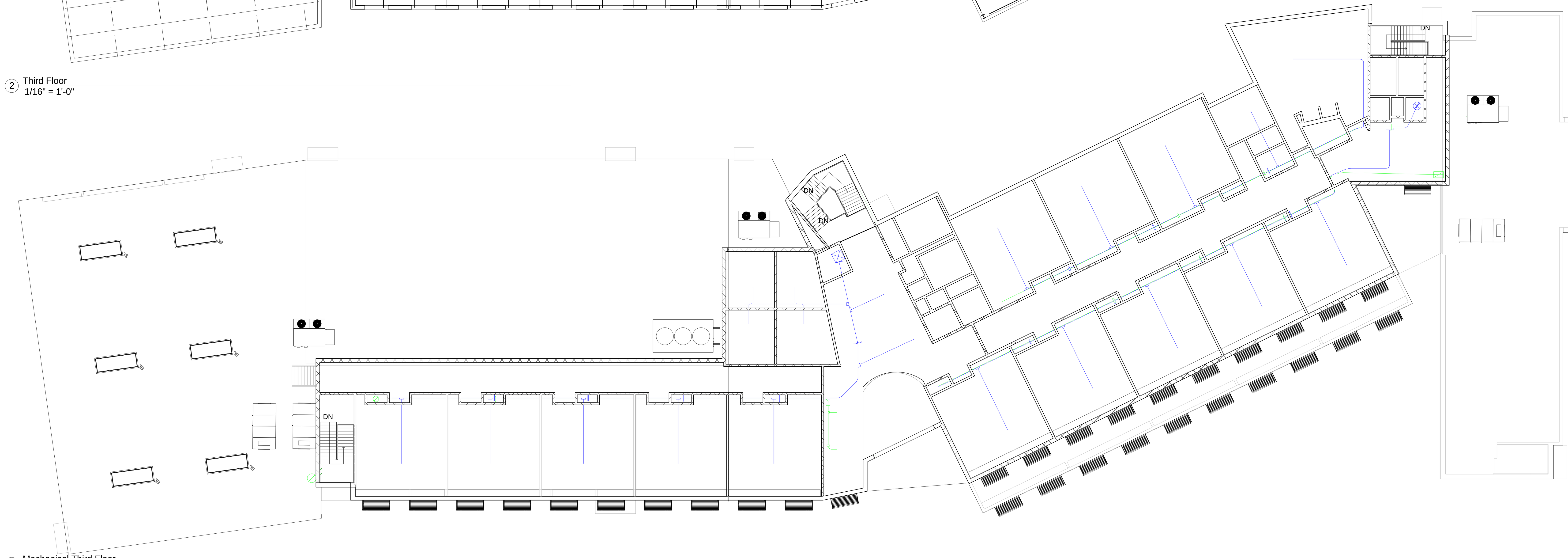
Scale 1/16" = 1'-0"

1 Third Floor
1/16" = 1'-0"



2 Third Floor
1/16" = 1'-0"



3 Mechanical Third Floor
1/16" = 1'-0"

The third floor has the Psychology office, I.S.T. office, Guidance Office, and a Conference room. Moreover, there are no classrooms on the east end because it is only two levels high. Also, like on the first two floors, there is a large special education classroom with its own individual bathroom. In the lobby area, there is a large opening that looks down to the first floor. This atrium allows natural daylight from the curtain wall facade to penetrate deep into the interior of the building. Also, to the left of the atrium is a small group instruction space.

The third floor structural plan also shows the roof systems for the pool and the multipurpose room. The pool roof is supported by 5-foot deep open web steel trusses. The trusses are capable of spanning the maximum required distance of 85 feet, but are also relatively lightweight and allow room for the mechanical system components. In the multipurpose room, the goal is to provide a roof that meets requirements for a community shelter. To do this, the team designed a relatively heavy roof system with a concrete slab on deck supported by 40-inch deep trusses. The 40-inch truss depth was chosen to provide adequate height in the space for basketball games or other gym class activities. Again, the open-web trusses provide room for the mechanical system so that the space remains as open as possible.

The third floor duct layout is similar to the first and second floors. The duct systems are separated into two sections that meet near the central lobby. The return duct for the left section of the building is run vertically in a chase near the pool because the exhaust air unit is housed there.

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Third Floor Plan

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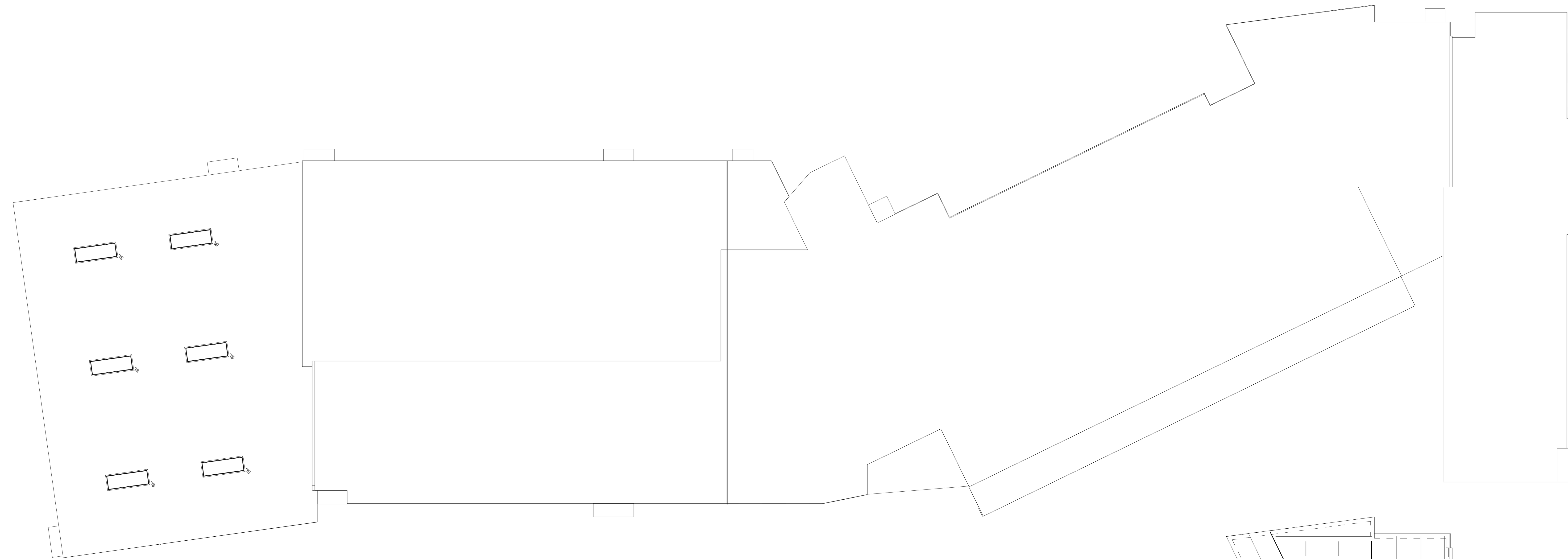
Scale 1/16" = 1'-0"

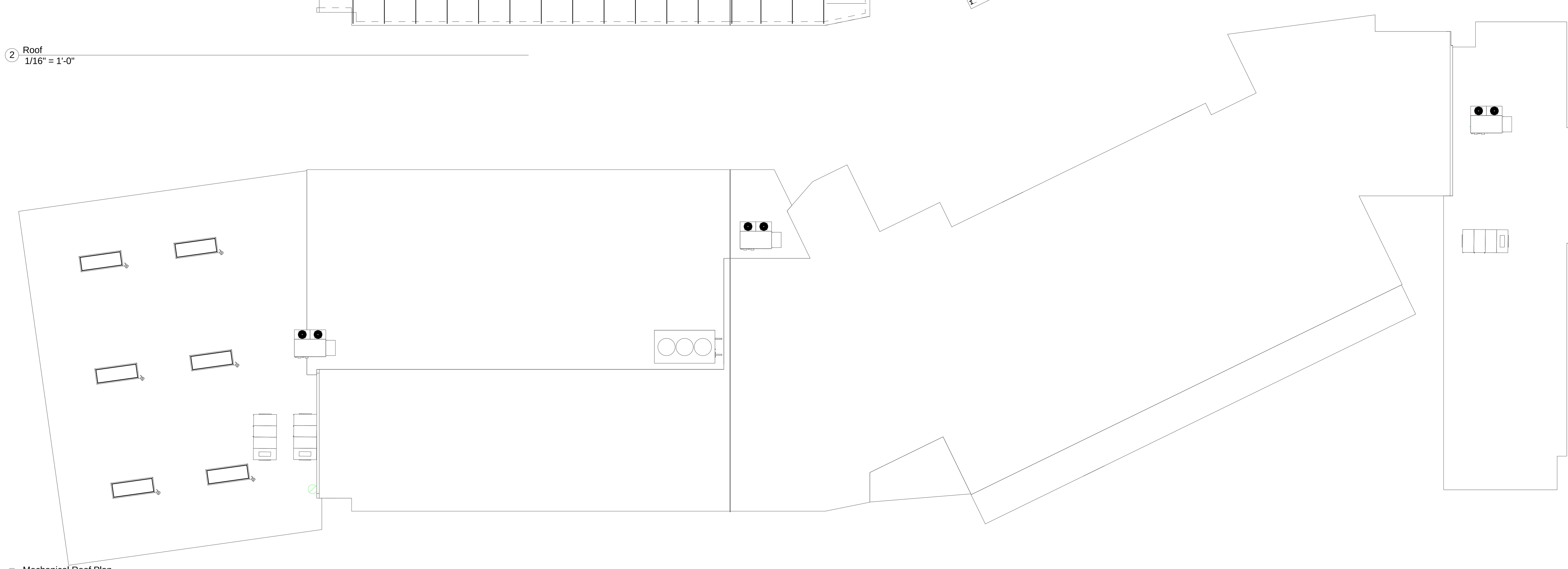


1 Roof
1/16" = 1'-0"

The white roofing membrane helps reflect heat away from the building. This lowers the heat island effect and reduces the mechanical load. There are two roof accesses, one on the east side and one on the west side. However, these accesses are on the roof above the second floors, as no mechanical units are located on the third floor roof. To gain access to the third floor roof, there are ladders on the east and west ends. The gym roof not only has the white built-up membrane, but also concrete on the metal decking. This concrete allows the multipurpose room to act as a shelter in the case of an emergency.

2 Roof
1/16" = 1'-0"

The roof of the building is supported by a system of steel beams and girders. Although the design team considered the use of steel joists, it was determined that the lowest structural depth and least cluttered structure would be with wide flange beams and girders. The roof design at this level account for a 35 psf snow load as dictated by local provisions. Wide flange W18X35 beams and W24X68 girders carry the roof loads to the columns. This structural plan also shows L3X3X1/4 steel angles running across the roof beams throughout the structure. The angles are used to brace the beams that are otherwise unbraced by the roof system, which is not considered to be a purely rigid diaphragm at this level. Instead of a concrete slab on deck, there is a built up roof system on metal roof deck.



3 Mechanical Roof Plan
1/16" = 1'-0"

There are three outdoor air units and three exhaust air units housed on the roof. One pair of these air handlers is specifically for the pool as this is an alternate and might be added later. Another set is for the classroom wing which is placed on roof of the right education wing. The centralized outdoor air unit will supply the left wing of the building which consists of the multipurpose room, health center, and other community features. These two spaces being supplied separately will allow energy to be saved when only one space is in use.

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BUILDING INTEGRATION

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Annual Architectural Engineering Student Competition

Team Registration Number: 02-2013

Roof Floor Plan

Date 22 February 2013

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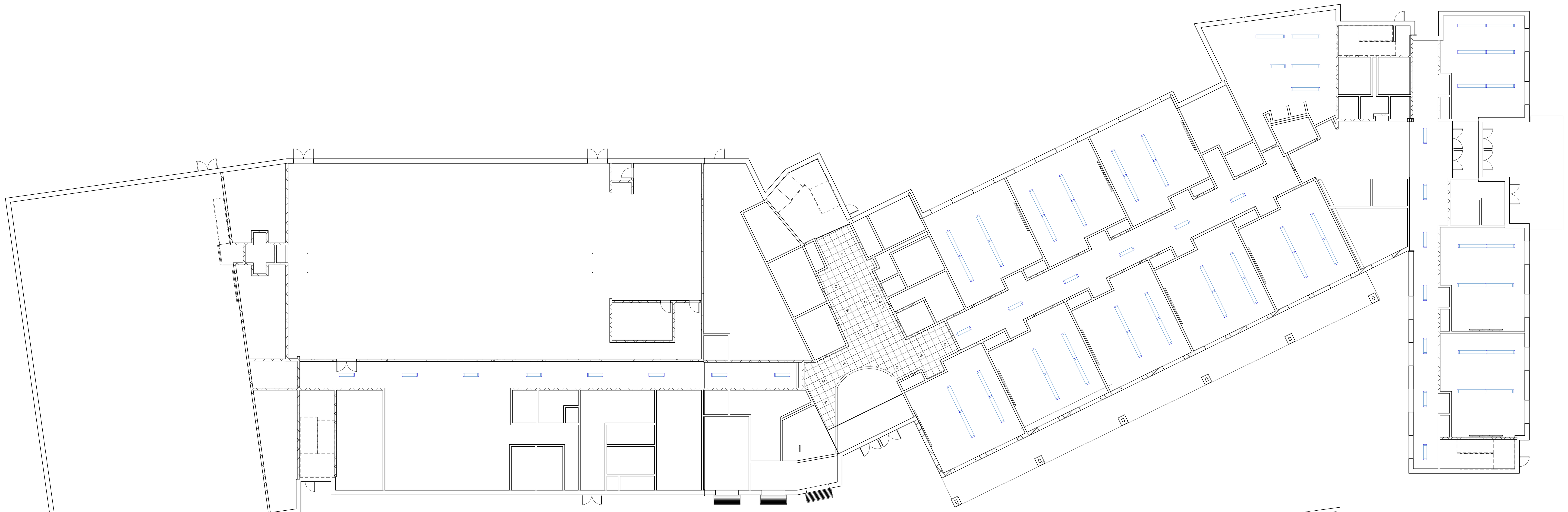
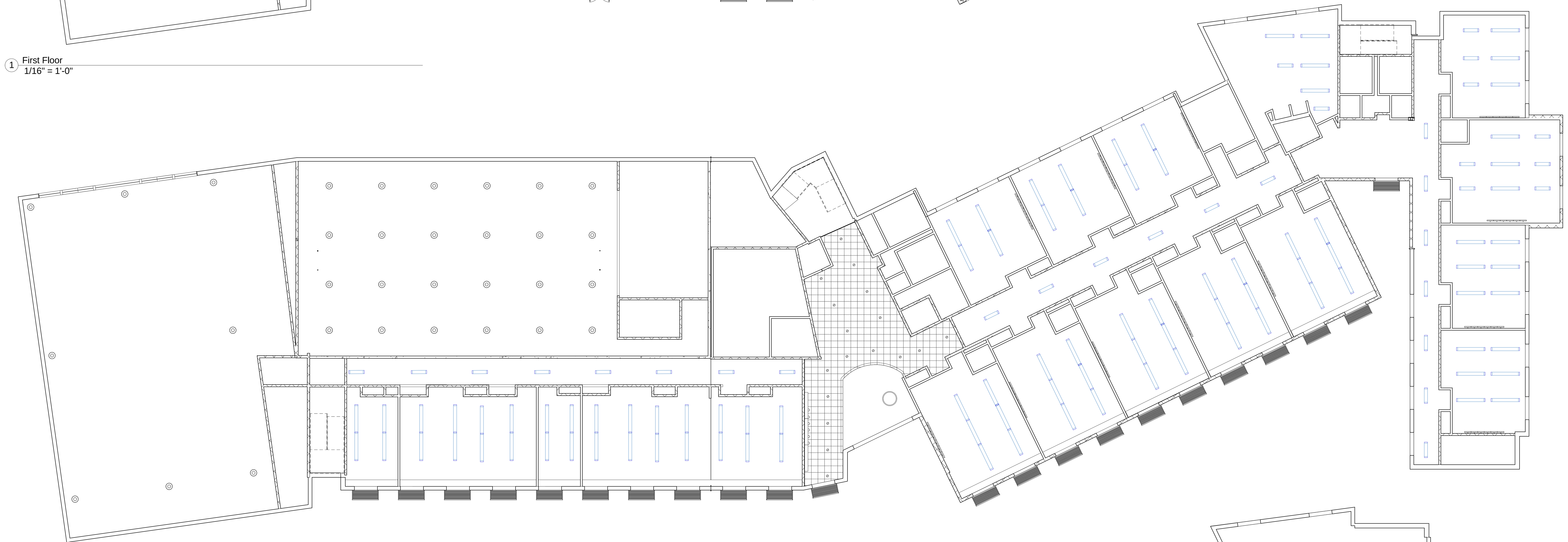
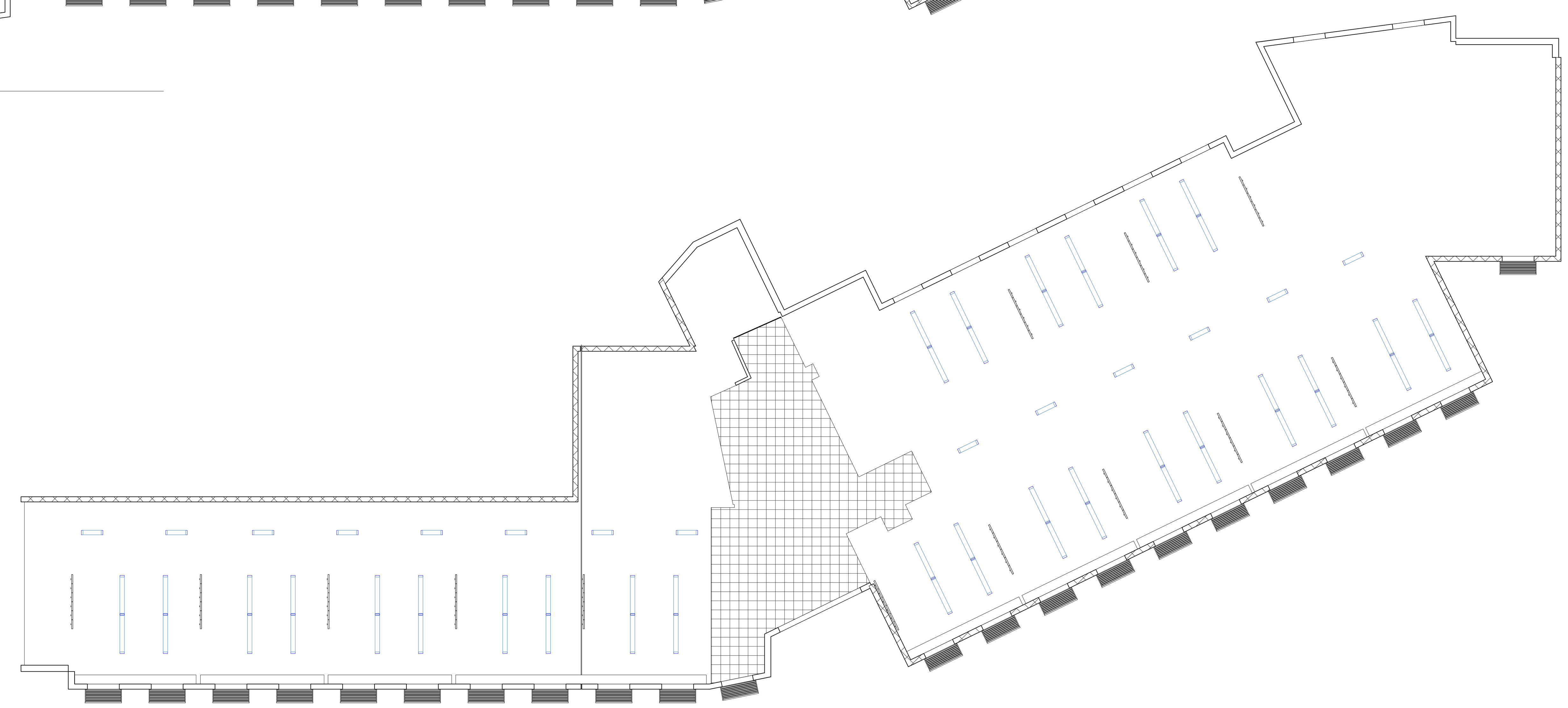
Scale 1/16" = 1'-0"



1 First Floor
1/16" = 1'-0"



2 Second Floor
1/16" = 1'-0"



3 Third Floor
1/16" = 1'-0"

To ensure ease of maintenance, all fixtures in the classrooms and corridors will use the same T5 lamp. The lobby on all three floors will use compact fluorescent lamps for general illumination, as well as for wallwashing. Luminaire layout for the classrooms and corridors was coordinated with the structural and mechanical teams to ensure no clashing between the systems.

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BUILDING INTEGRATION

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Annual Architectural Engineering Student Competition

Team Registration Number: 02-2013

Lighting/Electrical Engineering

Date 22 February 2013

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Scale 1/16" = 1'-0"

1 South Elevation
1/16" = 1'-0"

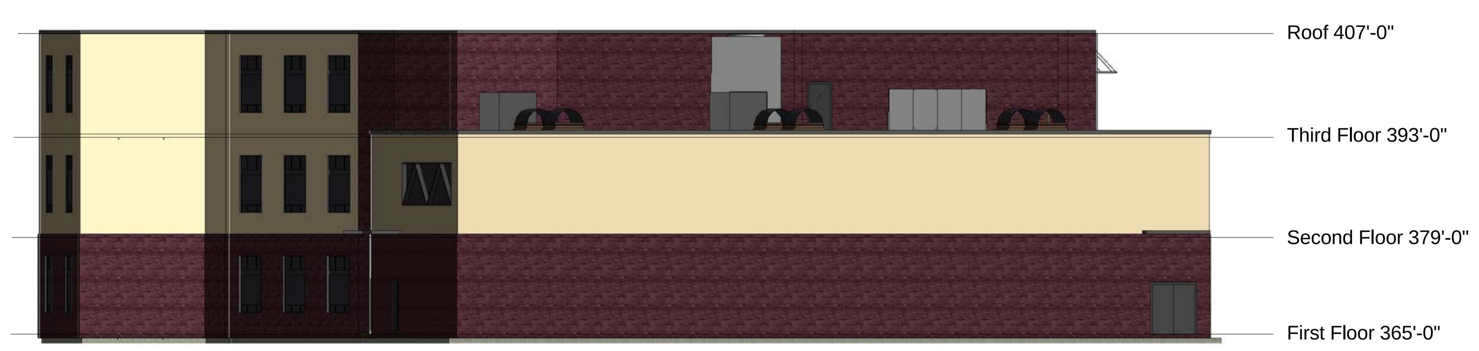
2 North Elevation
1/16" = 1'-0"

Figure 1 shows the South facade of the school building. The main entrance is in the center of the image with two sets of double doors. The auxiliary doors to the left are emergency exists from the kitchen area (double doors). The door to the far left acts as an emergency exit during the school day and the visitor entrance to the gymnasium and pool after school hours.

Figure 2 shows the North facade of the school building. The main entrance used to be on this side of the school, but with safety as the top priority and a busy road along this side, the main entrance was moved to the opposite (South) facade. The left emergency exit door is from the northeast stairwell. The health center entrance is also in this view. The next two sets of double doors are emergency exits from the gymnasium. The last set of double doors is an emergency exit from the pool.

3 East Elevation
1/16" = 1'-0"

Figure 3 displays the East facade of the school building. The doors seen on the first floor are for emergency exit only. The door seen on the third floor leading to the roof is for access to perform maintenance on the mechanical equipment.



4 West Elevation
1/16" = 1'-0"

Figure 4 displays the West facade of the school building. The doors seen on the first floor (right side of the image) are emergency exits from the pool. The door seen on the third floor is for access to perform maintenance on the mechanical equipment above the gymnasium

This image shows the East facade of the school building. The view looks down the bus lane from the traffic exit. Additionally, the teacher's parking lot is seen in the forefront while the existing school is in the background.

This image from a student's perspective riding the bus to school. This is the bus lane entrance on the West side of campus. The yellow security balusters are shown in this view (however, they would be lowered during the morning and afternoon bus times). These balusters will be raised during the school day as explained in the traffic plan and safety sections of the report. The pool is behind the wall seen to the left (with an emergency exit in the foreground.

This image shows the South facade of the school building. The view is taken from the auxiliary parking lot to the West of the playing field. The main entrance is visible in the background to the left.

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BUILDING INTEGRATION

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Annual Architectural Engineering Student Competition

Team Registration Number: 02-2013

Building Elevations and Exterior Views

Date	22 February 2013
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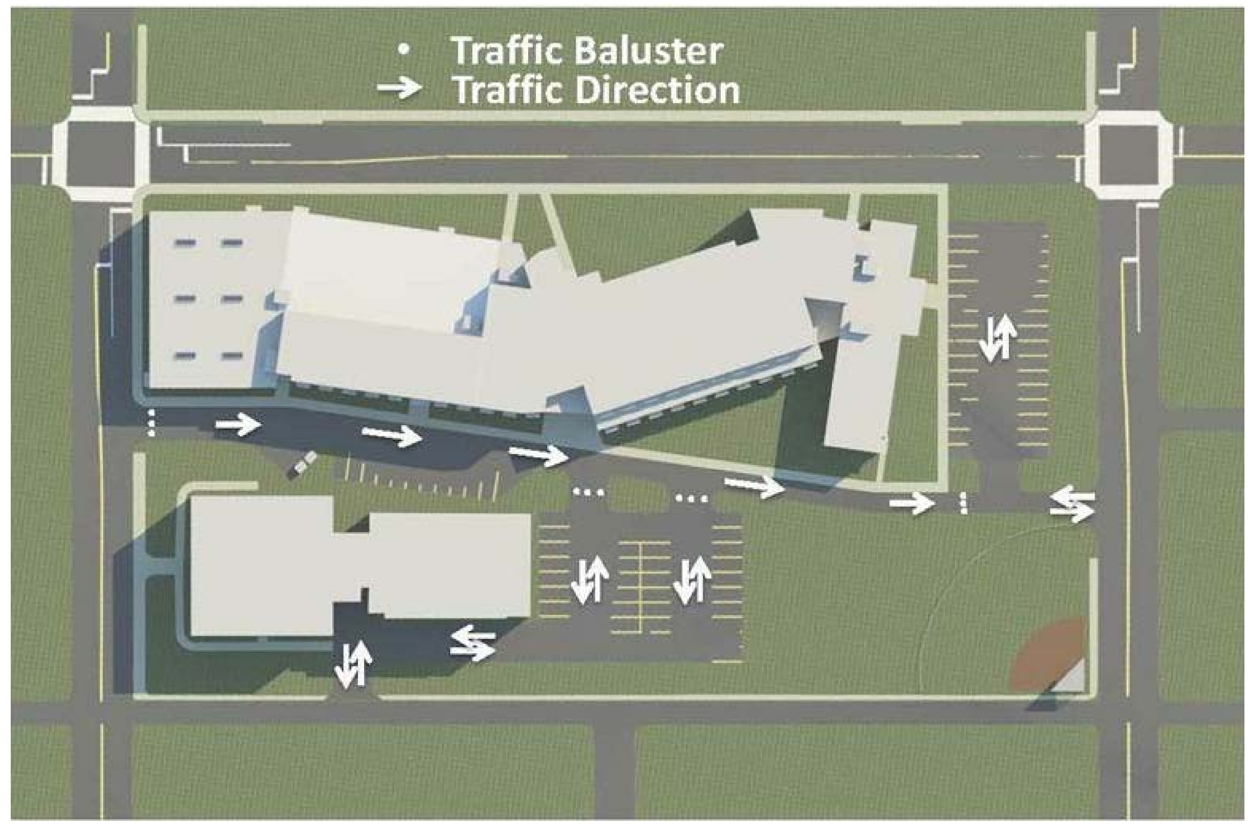
Scale	1/16" = 1'-0"



The safety traffic plan shown in the image above is a description of the site after construction is complete on the new Reading Elementary School. Denoted with white circles, traffic balusters help regulate the flow of traffic during the school day. For example, after school busses drop off the students in the morning and before the busses return in the afternoon, the traffic balusters will be raised. They are made of steel and rise three feet in height with a nine inch diameter. The balusters are strategically placed to prevent vehicles from approaching the school building during the day. Any visitors will have to park in the auxiliary parking lot during the school day.

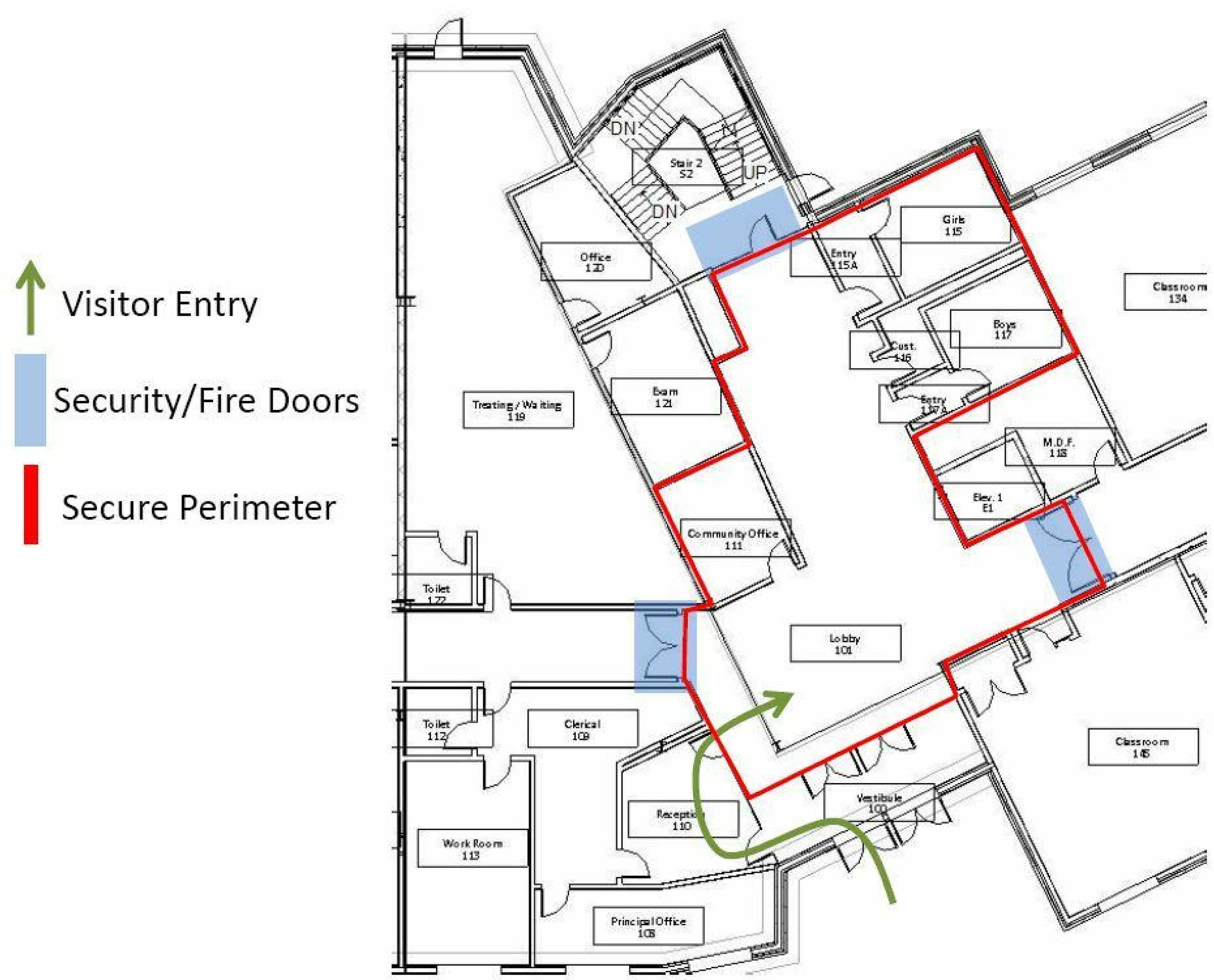
The arrows on this plan denote the flow of vehicular traffic. The bus lane will be maintained as one way at all time, except at the entrance near the teacher parking lot. Maintaining a consistent flow of traffic will decrease the possibility of a traffic accident.

The image above is of the south-facing main entrance to the school building. This entrance was strategically relocated from the north facade to eliminate any possibility of a vehicle accident on the sidewalk while students were entering the school building. The other important thing to note is that all first floor glazing will be made of bullet-resistant glass. This will prevent intruder access through the windows into areas occupied by building occupants. This increase in safety measures aligns with the school district and Nexus' emphasis on building security and occupant safety.

Priority #1

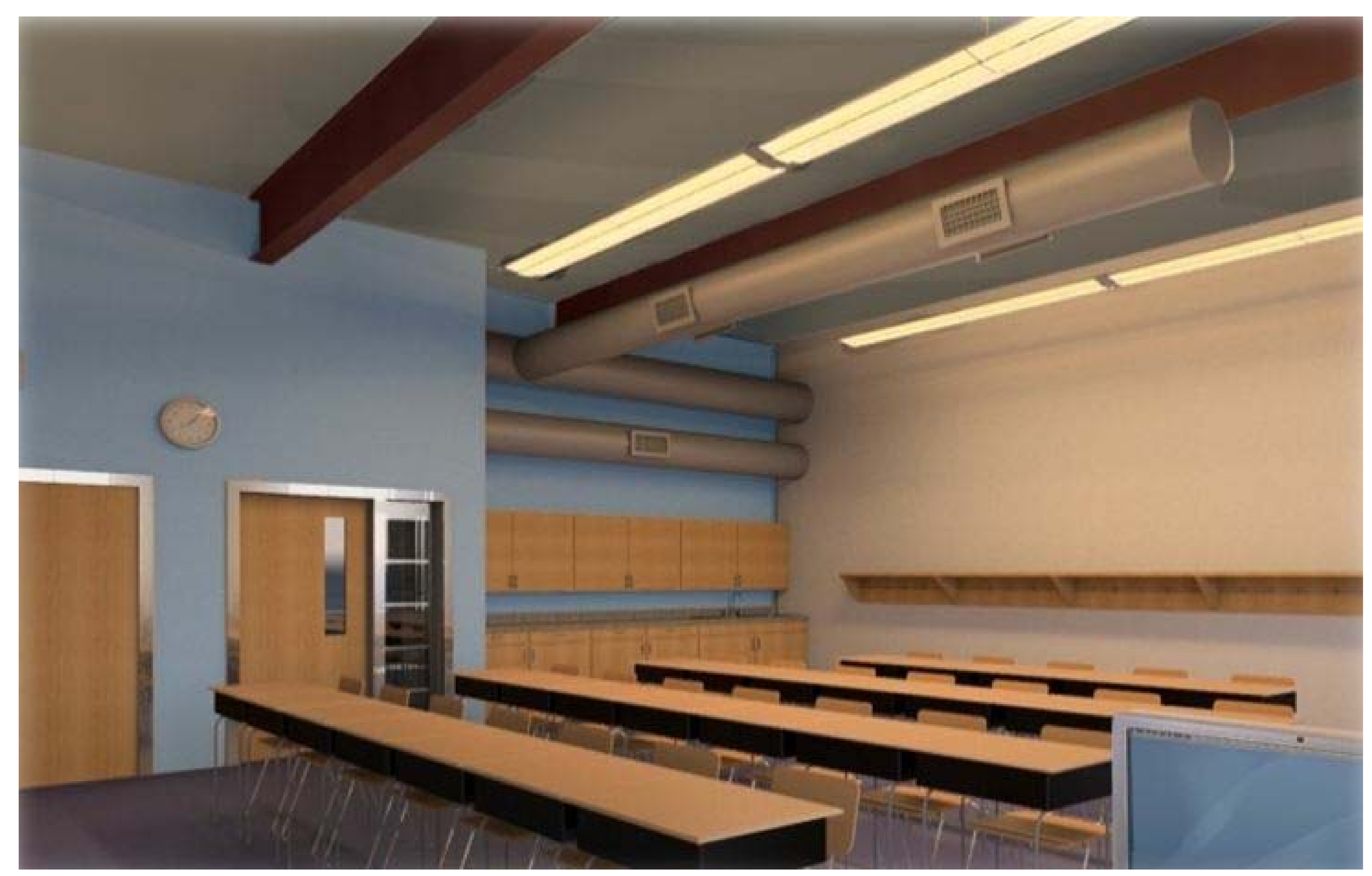
safety & security

The above image is a typical representation of the construction site during the superstructure erection sequences. While under construction, in order to maintain the safety of students and other school members currently in the existing three story elementary school, sidewalks will need to be closed around the construction site. These sidewalks will be closed to protect bystanders from debris, dust, and any other site hazards. Moreover, a crane swing is displayed on this plan to illustrate that the crane will never swing over the existing school boundary, preventing any possibility of an accident. The next important thing to note is the concrete truck and steel delivery truck turns. These turns will be made to increase traffic flow and safety throughout a regular day. The concrete trucks, will shorter lengths, can make right turns in and out of the site; while the steel delivery trucks will need to make left turns across two lanes of traffic due to their larger turning radii.



The floor plan shown to the left depicts the secure perimeter established when the intrusion detection system is activated. Should an intruder make it past the two sets of bullet-resistant doors in the vestibule, the three access points to the remainder of the school will be automatically locked (as shaded in blue). Video surveillance will be maintained at the main entrance, with controls being operated in the reception office. Thus, in the event of a security breach, all students will remain in their classrooms since the intruder will be locked into the first floor lobby until authorities arrive.

The interior rendering of a typical classroom below is included with the safety and security items to demonstrate the incorporation of several measures Nexus provides for occupant safety and building security. First, the public address system will have an integral speaker with the classroom clock to voice alert the teacher and student of an security breach. Security alarms in the corridors will double as an alert system. The intrusion detection system located at all exterior doors will trigger the security alarms and public address system. Lastly, manual window shades will be installed on the classroom door window and sidelight to prevent views into the classrooms from the corridors. Teachers will pull these shades when the alarms are sounded.



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BUILDING INTEGRATION

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Team Registration Number: 02-2013

CONSTRUCTION MANAGEMENT

Date 22 February 2013

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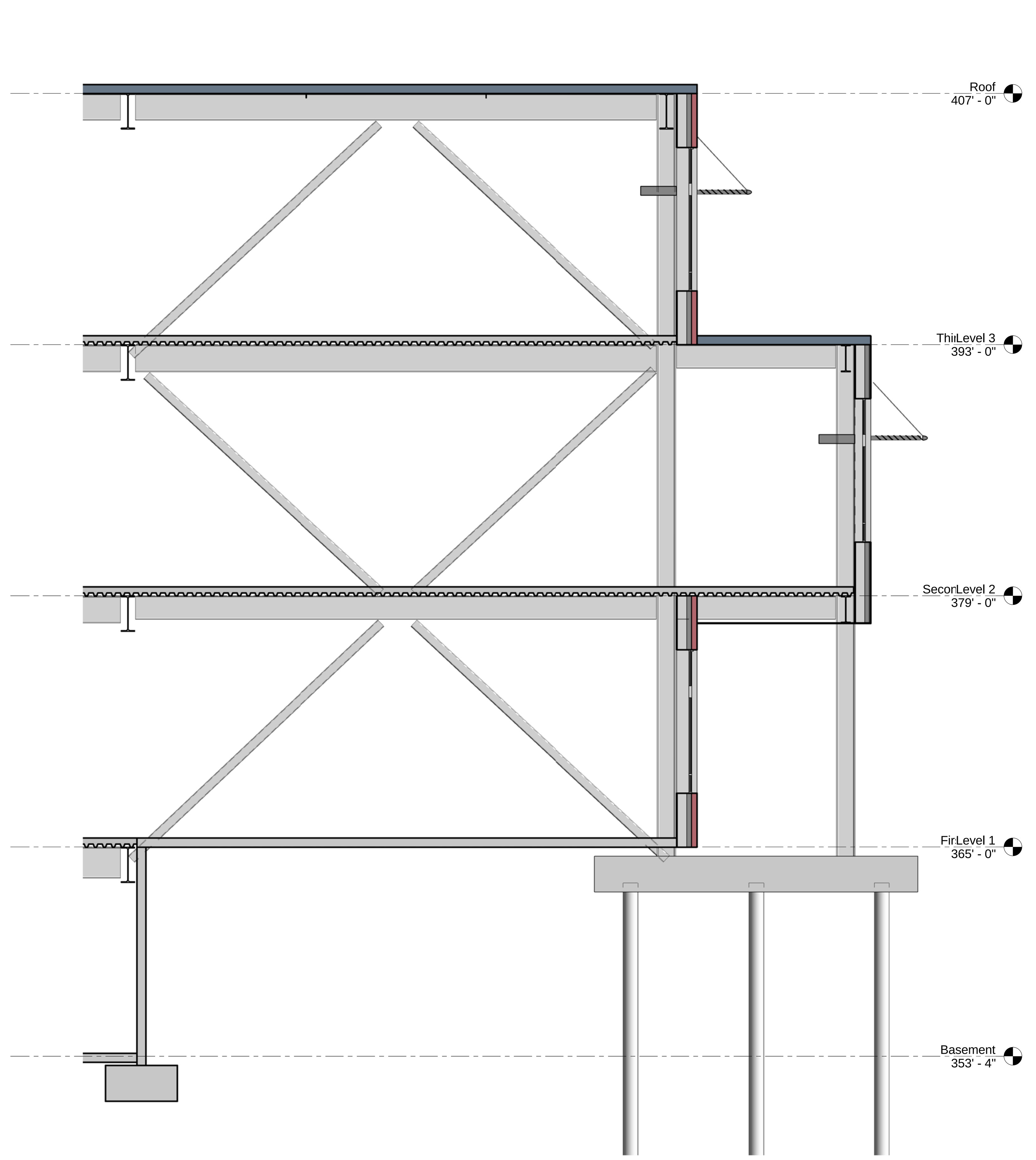
Scale



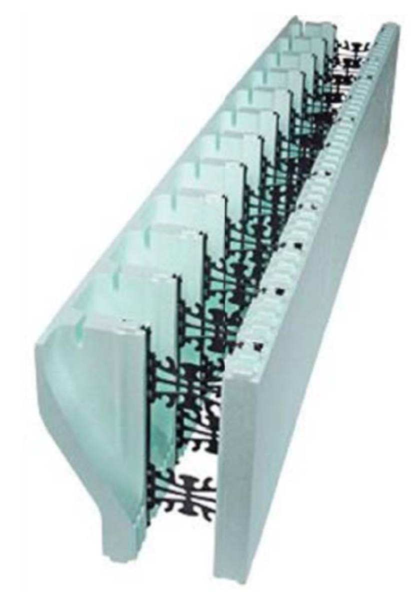
1 Section 11
1/4" = 1'-0"

The building's lateral force-resisting system is one of the most important components of the building structure, but it needs to fit within the building both functionally and architecturally. A key element of the design is the elimination of one column line from the structure. Although this decision saves money by reducing the number of structural members, foundation elements, and connections, it proved to create a difficult situation when designing the steel braces shown in the above section. Since one of the two structural bays crosses the hallway, it was nearly impossible to design a brace that did not interfere with the hallway or mechanical system. Additionally, the shape of the building cross-section is irregular in the other structural bay due to the overhanging second floor (as shown above). Therefore, at each of the two brace locations, an additional column is added to create the framework for the brace. With this design, the HSS 6X6X1/4 hollow tube braces fit within the walls between classrooms without being seen. They also provide adequate space for the mechanical ductwork to run through the room, especially on the first and third floors.

This section also shows a different wall type from what is used in most of the building. Although most of the building is enclosed by insulated concrete form (ICF) walls, the overhanging second floor in this part of the building made it impossible to use a structural bearing wall over the height of the building. Instead, a metal stud curtain wall with brick veneer or painted aluminum panels is used. Although the curtain wall does not have the same thermal advantages as the ICF walls, a layer of rigid insulation provides an adequate layer of thermal protection.

One final feature that is shown in the section is the overhangs used to provide shade to the classroom windows. The aluminum overhangs are lightweight and relatively inexpensive, and they can be easily attached to the exterior of the walls.

The image to the left shows a piece of typical insulated concrete form (ICF) wall. The green insulation foam is used as a stay-in-place form that saves in construction costs since forms do not need to be constructed, removed, and thrown away. The final assembly provides a nearly airtight building envelope that has important thermal advantages over a typical wall. The R-value for the 6-inch thick walls used in this project is 24, which is roughly double that for a standard wall in a similar building. The two foam panels are separated by a spacer that also serves as a chair for steel reinforcement that goes into the walls.



This particular ICF manufacturer has a number of pieces available for order and also builds custom pieces if necessary. The ICF piece shown immediately to the left is used primarily as a brick ledge for buildings with brick veneer facades much like this project. Similar pieces will be used in this project to provide seats on the wall for beams and girders to frame into the walls and transfer gravity loads. Threaded studs will be cast into the form so that the steel framing members will be securely anchored to the walls. Like all of the other ICF segments, these pieces are relatively lightweight and easy to transport. Therefore, they are an attractive option for the contractor due to ease of construction.

Another example of the available ICF pieces includes this T-form. Although an obvious use of this to perpendicularly join to walls, this piece can also be used to form a pilaster by capping the end of one leg of the T. The structural team investigated the slender walls in the pool to determine if these pilasters will be necessary to resist out-of-plane bending in the walls. As designed for the current loads, the wall has enough capacity to resist out-of-plane bending without the use of pilasters. However, the flexibility of the forms to help build these structural components was a large reason that the team believed that ICF walls would be a feasible option for construction.

The rendering shown below includes the structural steel framing as well as the mechanical systems. A key takeaway from this illustration is the relatively open space that the structure provides. The bays are wide, and the clear space from each floor to the ductwork and beams is relatively high as since the depth of the structural members is kept to a minimum. This image is actually useful to help represent the height of each classroom space since there are no dropped ceilings in the rooms.

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BUILDING INTEGRATION

2013 ASCE Charles Pankow Foundation

Annual Architectural Engineering Student Competition

Team Registration Number: 02-2013

Structural Engineering

Date 22 February 2013

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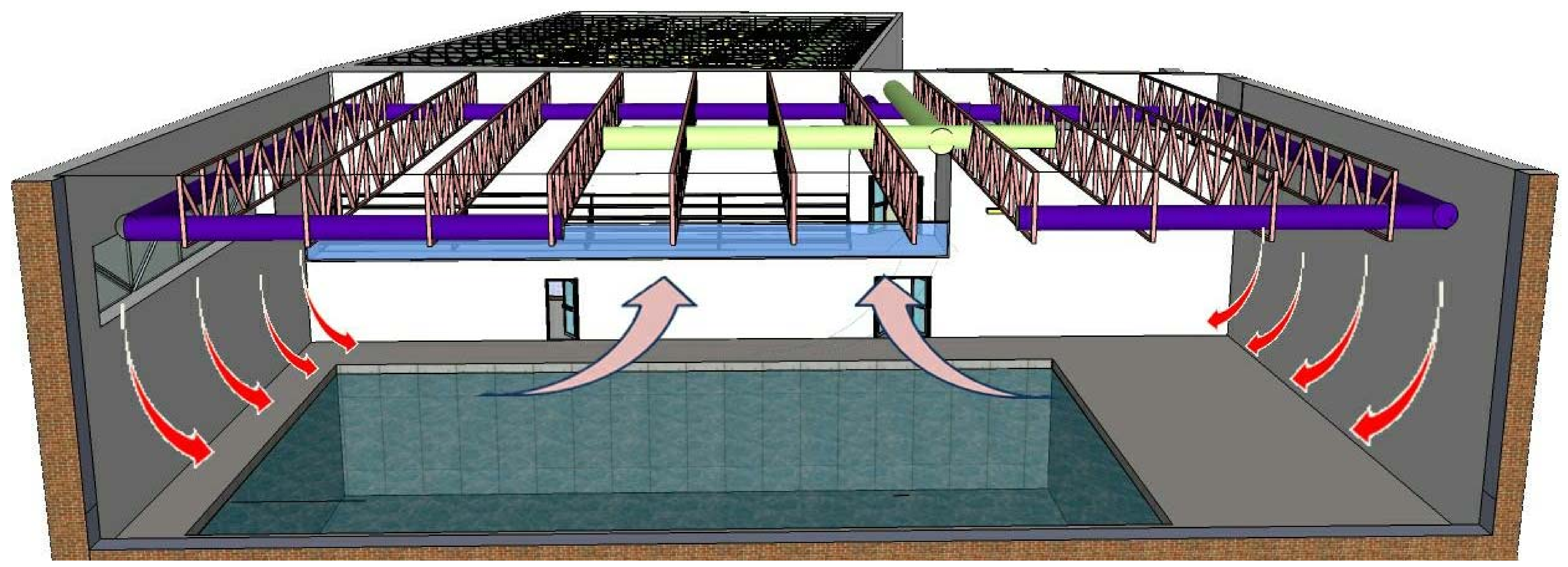
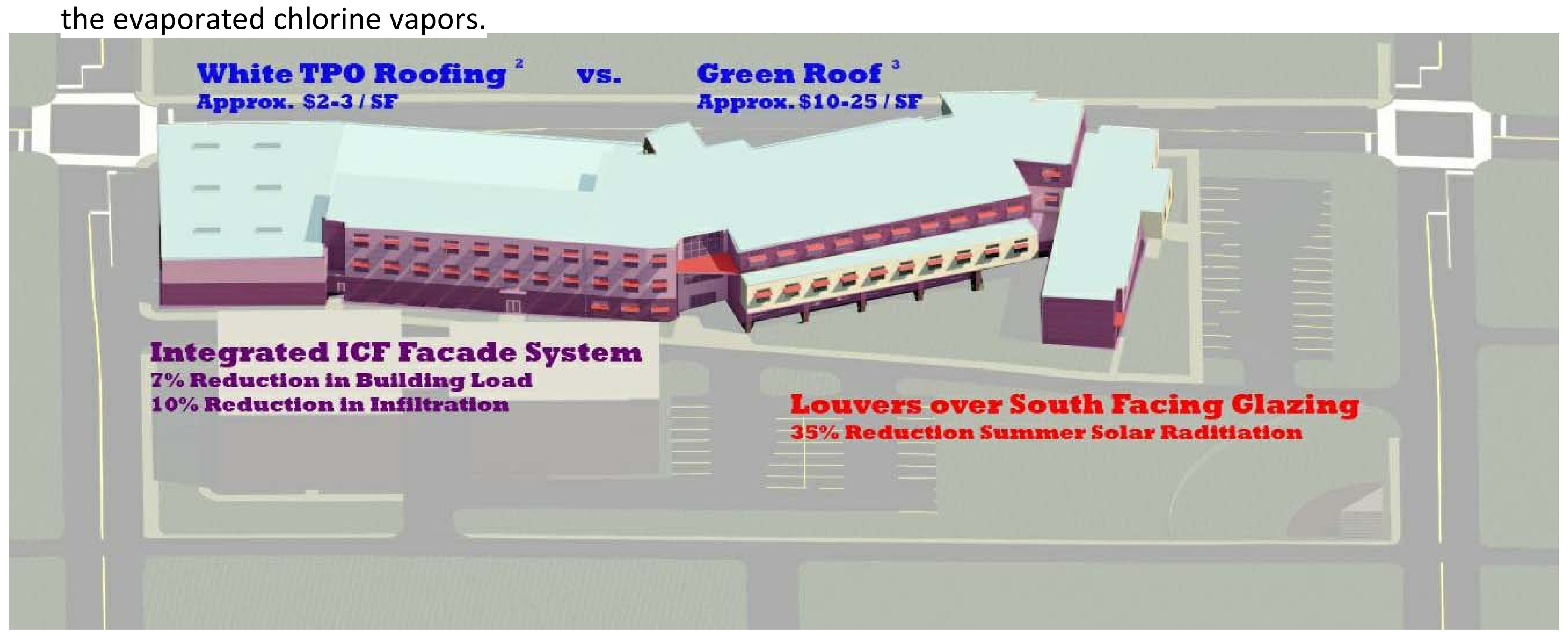
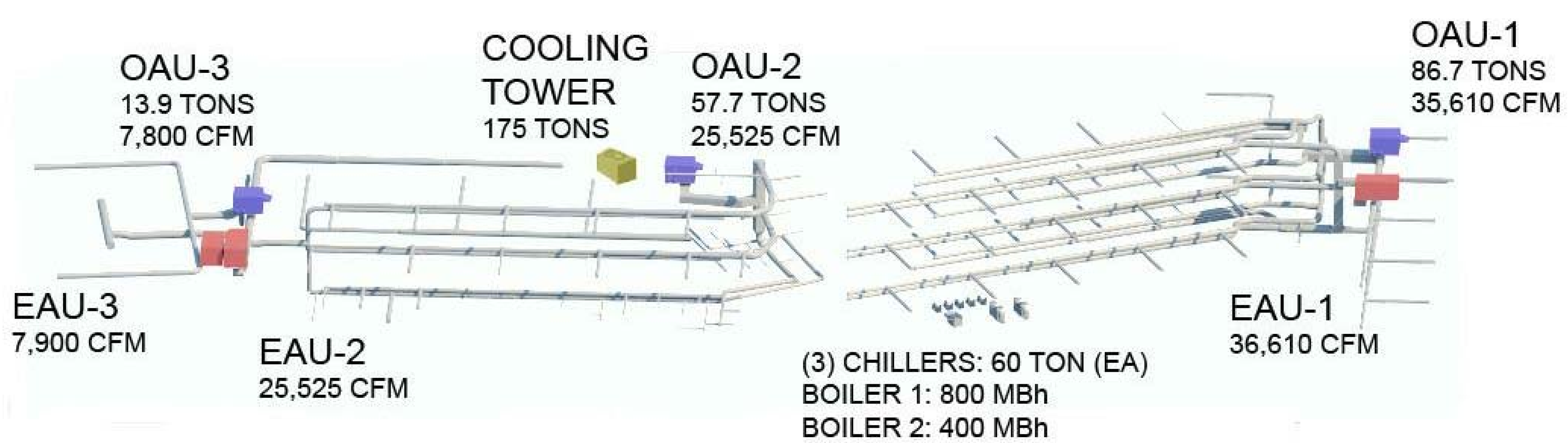
Scale 1/4" = 1'-0"



The duct layout in the pool area was designed to supply the air along the perimeter to prevent condensation on the windows and drafts on the swimmers. The return duct is centered over the actual pool to easily vent out the evaporated chlorine vapors.



Using these modeling outputs in cohesion with the ASHRAE 2010 design criteria, it was determined that an ICF (Insulated Concrete Form) exterior wall construction be implemented. This system provides an R value of 24 and greatly decreases the rate of infiltration of thermal conditioning to the environment as this façade system provides a tighter seal than most. The ICF system too, greatly surpasses the ASHRAE minimum R-Value for Climate zone 5 by almost 20%. Special considerations were also taken into the glazing design for the building. The design goals of the Lighting/Electrical Engineer required that the building utilize as much natural daylighting as possible. In working with the lighting designer a standardized window system was developed with a U-value of 0.28. It too should be noted that this glazing configuration comprises less than 30% of the entire exterior surface area which is well under the ASHRAE 2010 maximum design criteria of 40%. Additionally, the south facing glazing will utilize a three- foot louver that will shield the rooms from direct glare but also excessive solar heat gain during the cooling season. The iteration to the original roofing design was the replacement of the standard black roofing material with white roof on insulated decking. This will prevent the "heat-island-effect" which will allow for additional energy savings especially during the cooling season.



The majority of mechanical equipment will be housed on the roof including three outdoor air units, three exhaust units, and one cooling tower. The basement mechanical room will contain three chillers, inline pumps, two boilers, and the hydronic unit for the ethylene glycol run around heat recovery system.

TYPICAL CLASSROOM ACOUSTIC ANALYSIS

$T_{60}(Reverb\ Time) = 0.05V/A$

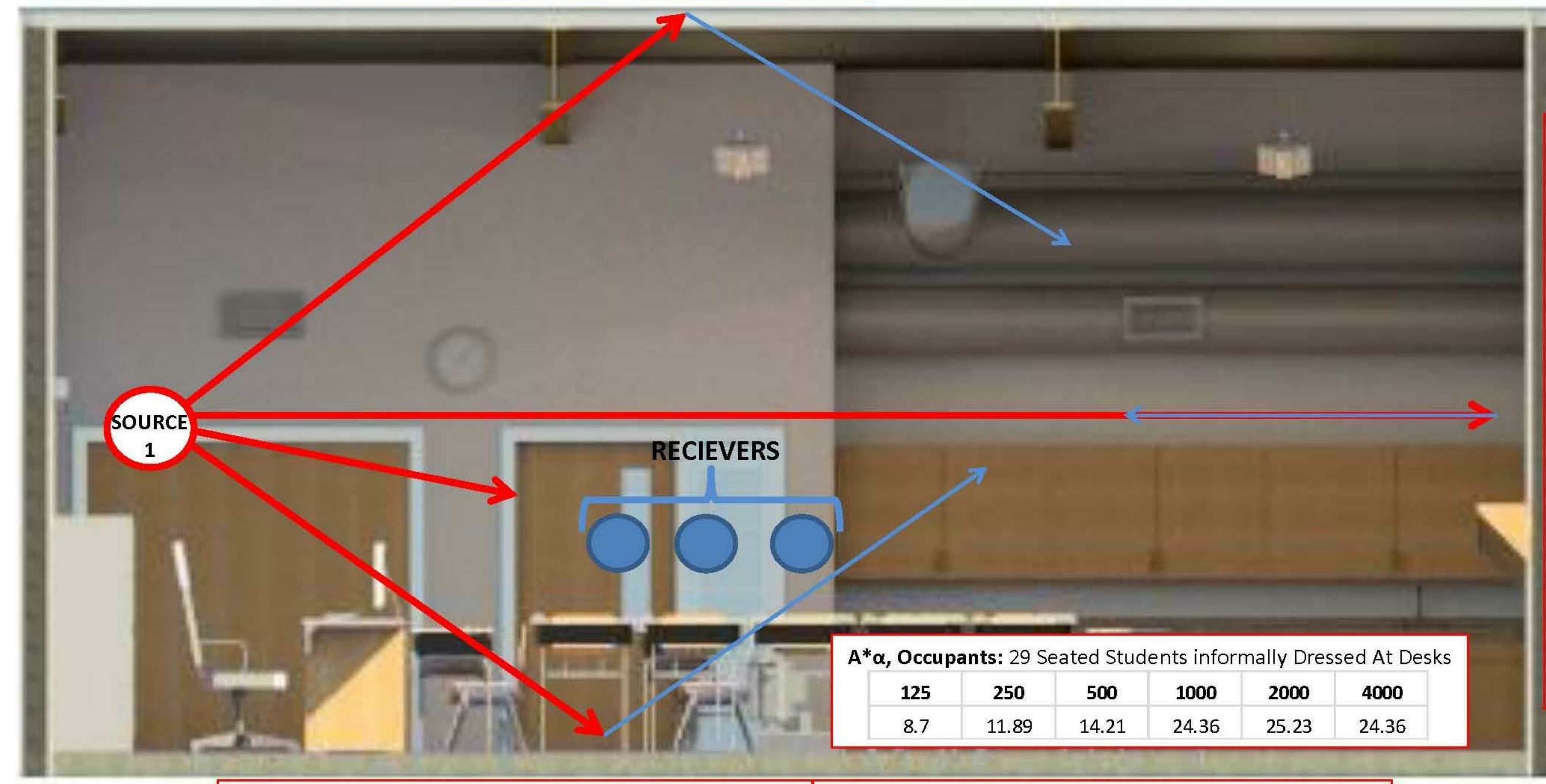
Recommended Time For Elementary School Classrooms: 0.6-0.8 seconds

Frequency (Hz)	125	250	500	1000	2000	4000
Room T_{60} (s)	0.682551	0.785962	0.48628	0.516361	0.827285	1.085314

Room Dimensions
Height: 13 ft
Width: 30 ft
Length: 28 ft
Volume: 10,920 cf

A*α, Ceiling: 3VLPA Metal Deck w/Insulation- 840 sf

125	250	500	1000	2000	4000
336	470.4	898.8	655.2	478.8	294



A*α, Walls: 1/2" Thick on 2x4 metal stud 16" O.C.- 1396 sf

125	250	500	1000	2000	4000
404.84	139.6	69.8	55.84	97.72	125.64

A*α, Occupants: 29 Seated Students informally Dressed At Desks

125	250	500	1000	2000	4000
8.7	11.89	14.21	24.36	25.23	24.36

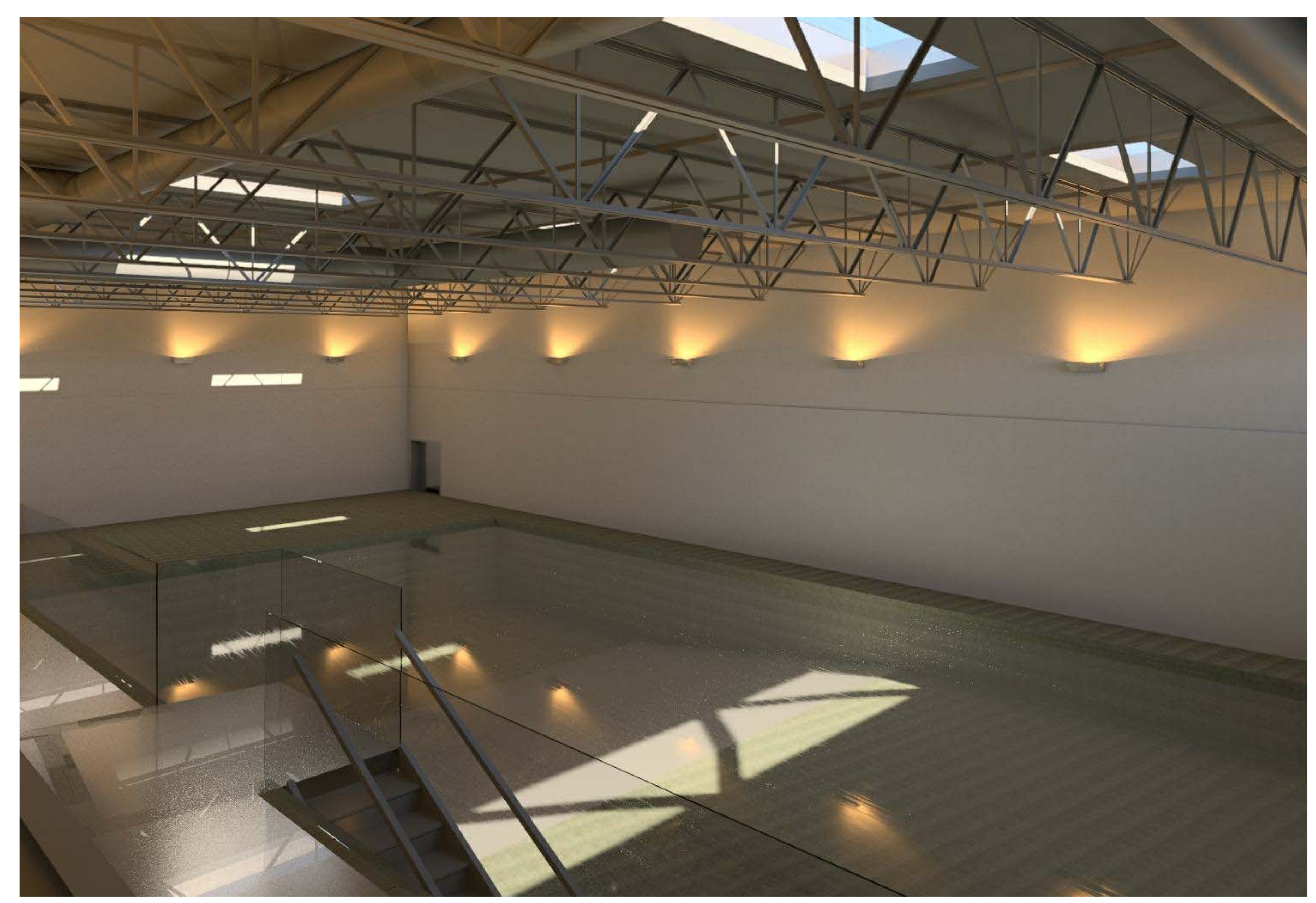
A*α, Flooring: Heavy Traffic Carpet Tile on Concrete- 840 sf

125	250	500	1000	2000	4000
16.8	50.4	117.6	310.8	50.4	54.6

A*α, Glazing: Double Pane Argon – 122sf

125	250	500	1000	2000	4000
33.6	22.4	22.4	11.2	7.8	4.5

Due to the exposed nature of the discipline systems, (as greatly demonstrated in the Team Nexus Integration Documentation) there were primary concerns with the acoustical integrity of not only the classrooms but the lobby, gymnasium and pools as well. To ensure that these spaces met the necessary acoustic criteria, acoustical analyses were done to calculate the reverberation time of each space which guided the selection process of materials based on their reflective and absorption properties. In integrating these considerations with the structural design team, it was decided that a 3VLPA Insulated Composite Acoustical Metal Deck will be used in the construction of the building so that the open ceiling concept could be carried out through the majority of the building. Particularly in the classrooms, it was found that utilizing this system alone allowed reduced our reverberation time from over 1 second to approximately half a second for the 1000 Hz octave band in comparison to a normal metal deck. A reverberation time between 0.6 seconds and 0.8 seconds is desired for a classroom setting.



The duct layout in the pool area was designed to run within the structural trusses to maintain a high ceiling height and not obstruct the light from the six skylights. This allows for a cleaner look while still being fully functional.

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BUILDING INTEGRATION

2013 ASCE Charles Pankow Foundation

Annual Architectural Engineering Student Competition

Team Registration Number: 02-2013

Mechanical Engineering

Date 22 February 2013

Scale