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INTEGRATION EXECUTIVE SUMMARY

Synergy is a multi-discipline team comprised of Structural, Mechanical, Lighting/Electrical, and Construction that utilizes an integrated design approach guided by the design themes of value, resiliency, performance, and versatility. Collectively, Synergy’s discipline teams assume the role of the architect. For the 2017 AEI Student Design Competition, Synergy committed to designing an athletic performance center for Texas Tech University that caters to the Texas Tech student athletes and surrounding community while striving to aid in student athlete development by promoting healthy lifestyles. Synergy identified three areas of the project’s design and construction that serve as the leading points of integration and collaboration: the building’s core, the depressed roof, and the building’s enclosure. Within each integrative design focal point, Synergy delivered final designs that achieve the overarching project themes and goals.

BUILDING CORE
- Optimized building floor plan
- Enhanced occupant flow
- Centralized tornado safe room (occupancy: 516 people)
- Improved separation of space between the athlete/spectator
- Centralized facilities with shorter, more efficient service runs
- Creation of a grand lobby & more prominent building entrance
- Permanent seating for 2,100 spectators
- Partial second level added for improved viewing angles
- Communal showers provided for community shelter

DEPRESSED ROOF
- North-facing clerestory glazing creates uniform daylight distribution
- 17% volume reduction of main athletic spaces & 5% of heating/cooling loads
- Permits use of displacement hybrid ventilation which saves 30% source energy and 50% on site fan energy
- Automatic operable windows in tandem with mech. vent. demands
- Modularized glass panes based on custom radial mullion configuration
- Truss assembly erection sequencing saves 14 days of schedule
- Coplanar long-span roof trusses provide diaphragm continuity and lateral bracing

BUILDING ENCLOSURE
- Impact-resistant façade
- Modularized wall assemblies
- Prefabricated wall assemblies
- Prefabrication of wall assemblies reduces schedule by 29 weeks
- R-32 wall (20% above original design and 210% above code min.)
- R-25 roof (25% above code min.)
- Enhanced moisture performance and water shedding detailing
- FM-Approved roof assembly for wind uplift pressures
- FT laminated insulated glass
1.0 PROJECT INTRODUCTION

The Texas Tech University Sports Performance Center, located in Lubbock, Texas, comprises a 200m competition indoor track and an 80-yard football practice field. The performance center is located adjacent to the Jones AT&T Stadium in the northern corner of the Texas Tech University campus. With its iconic bell tower, the sports performance center embodies Texas Tech traditions while serving as an investment towards the future of the university’s athletic programs.

2.0 SYNERGY’S MISSION

Backed by the ideals of collaboration and innovation, Synergy’s mission was to deliver Texas Tech University a sports performance center that caters to the needs of their student athletes as well as keeping in mind the safety and resiliency of the surrounding community. Through a robust and dynamic team atmosphere partnered with sustainable thinking, Synergy was able to generate a building that offers enhanced value to the university, optimized performance, adaptability, and superior resiliency features.

3.0 DESIGN CHALLENGES AND PROJECT GOALS

Synergy considered the owner-defined project challenges that served at the forefront of the generation of the project team’s design goals and criteria. By breaking down the owner’s set challenges and requirements, Synergy was able to develop their own project goals and criteria critical to deliver on the owner’s expectations. The owner-defined challenges are highlighted in the following subsections while a breakdown of the design goals and criteria may be observed within Drawing I-1.0. Synergy decided to pursue all three owner-defined challenges, and all challenges were achieved by Synergy’s design as referenced throughout this report.

3.1 RESILIENCY AND SECURITY

Synergy was tasked with designing a facility that would serve as a community shelter in the event of a natural disaster. As a minimum, the entire facility had to be designed to withstand an EF3 tornado. The design team was required to further enhance the building through the implementation of a tornado safe room designed to withstand an EF4 tornado. The entire facility was intended to operate off-grid for seven days with only essential critical systems that will allow the community shelter to function with a minimum of 48 hours of built-in capacity.

3.2 HIGH PERFORMANCE AND WELL

The design team was committed to improving occupant health and wellness by obtaining (at minimum) the Silver level certification of the WELL Building Standard. Synergy’s design will reduce energy by at least 50% over the 2012 International Energy Conservation Code.

3.3 SCHEDULE ACCELERATION

Synergy had been asked to reduce the construction schedule by eight months so the project will reach substantial completion in July 2019 before the fall semester commences. The project team provided an innovative, safe, realistic, and cost effective manner to achieve such a schedule acceleration without compromising the finished quality.

4.0 PROJECT THEMES

Through the characterization of the project’s goals and criteria devised by Synergy, overarching project themes were developed to align with the owner’s vision of creating a performance center that serves the athletes by encouraging positive health and mental practices. Since the project themes encapsulate every defined challenge, project goal, and criterion, satisfying all project themes throughout design and construction meant that all design challenges and project goals were achieved. Four project themes serve as the areas of focus throughout the design process and delivery: value, resiliency, performance, and versatility. A visual of the formation of the project themes may be referenced in Drawing I-1.0.
Synergy strived to install their four project themes within every aspect of the project. Through a value-added approach to design, Synergy delivered a safe and secure structure that outperforms expectations while offering a versatile, economically feasible project.

4.1 VALUE

Synergy has designed and constructed a facility that procures the added benefits of minimized supplementary cost while assisting in making operation and maintenance easier and less costly. In addition, Synergy strived to deliver value to the owner through an accelerated schedule that did not jeopardize the project budget.

4.2 RESILIENCY

Synergy has ensured protection to the athletes, facility employees, and the surrounding community by carefully designing a tornado-resistant structure that provides safety and sanctuary during times of extreme weather events. By focusing on the theme of community resiliency in the aftermath of a natural disaster, Synergy aimed to generate a building that will continue to serve as a community anchor and example of revival and resurgence.

4.3 PERFORMANCE

Synergy has engineered an innovative building that goes beyond traditional output of design by reducing energy consumption by 61% against the 2012 International Energy Conservation Code, improving the wellness of the athletes, and delivering the most cost-effective solution to the building owner through generous building life-cycle payback.

4.4 VERSATILITY

Synergy has delivered a flexible and versatile project that will allow Texas Tech University to evolve with new innovations while continuing to serve at the forefront of sports performance and technology nationwide. Synergy’s design offers diversity and convenience in future building adaptations.

5.0 DESIGN INFLUENCES

With every decision that affected the design development of the Sports Performance Center, Synergy returned to the needs and demands of the major project design influences in order to help guide the decision-making process and yield the best desired outcome for the project.

5.1 OWNER AND STAKEHOLDERS

The Sports Performance Center is a privately funded project commissioned by Texas Tech University. Synergy defined the key stakeholders as the Board of Trustees at Texas Tech University, the athletic department, the donors, the athletes, and the NCAA. The design team developed an overarching goal on the basis of overlapping stakeholder’s values critical to the project: to maintain the traditional Texas Tech architecture while also promoting the excellence of all athletes on the field and in the classroom by supplementing Texas Tech’s “Fearless Champions” campaign. Figure 1 represents the influence Texas Tech University had on the outcome of design.

5.2 COMMUNITY

The university is comprised of campus educational institutions, dormitories, and athletic facilities. Synergy’s project recognizes the university community by maintaining the traditional Texas Tech architecture. The community outside of the university is home to the local residents of Lubbock. Synergy strived to not only provide security to the university but also to the surrounding community, by designing a building that operates as a community shelter in the event of a natural disaster. The community shelter offers temporary accommodation for 1,636 members of the university and community that are left without housing or resources in the aftermath of a natural disaster. More information regarding the community shelter planning is referenced on Drawing I-4.0.
6.0 DESIGN FACILITATION AND COMMUNICATION

In effort to promote the best design, Synergy identified and executed several design facilitation and communication methodologies that resulted in a superior final design.

6.1 DECISION MAKING PROCESS

As Synergy is a 10 person multi-disciplinary team, it was vital that each discipline aligned with the project goals and themes to ensure consistency and to reduce ineffective discussion time during collaborations. In order to guide the integration process, Synergy developed a decision matrix that utilized a weighted criteria based on the critical areas of the project (Table 1). The decision matrix served as a tool that guided rational thinking based on project themes and criteria objectively. A weighted system allowed unbiased decisions across all disciplines. It was inevitable that with each decision every discipline did not benefit equally, but the purpose of the matrix was to decide what was best not for individual disciplines but what was best for the outcome of the project. The categories within the matrix align with the project themes previously stated in Section 4. A detailed example of the decision matrix can be referenced in Integration SD-A.

Table 1: Sample of Decision Matrix

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<tr>
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6.2 CONVERGENT DESIGN STRATEGY

Prior to finalizing designs for any integrative design focal point of the project, Synergy explored several design iterations. Based on the pros and cons of each, Synergy’s design team was able to advance designs after each iteration until final designs were achieved. In effort to track discipline tradeoffs and enhance integrative design after each iteration, Synergy implemented a team-coined Convergent Design Strategy. With every new design iteration, each discipline was responsible for rating the iteration based on discipline-specific pros and cons. Discipline tradeoffs were able to be identified and Synergy was able to work collaboratively in attempt to resolve any discipline-specific concerns prior to producing a subsequent iteration. A final design iteration was deemed most successful by the team if the ratings of each discipline converged to positive values, minimizing the negative effects of discipline tradeoffs. A sample representation of the use of Convergent Design Strategy may be observed in Figure 2. Reference Integration SD-C for detailed use of Convergent Design Strategy with accompanying design iterations of the integrative design focal points of the project. The same design strategy was utilized in assessing and improving the tradeoffs and effectiveness of the project themes on the basis of design iterations (Drawings I-6.0 through I-8.0).

Figure 2: Sample of Convergent Design Strategy

6.3 COLLABORATIVE ENVIRONMENT

Synergy created an integrated collaborative environment that facilitated communication and fostered interaction between team members. The design team collectively decided that a central space was necessary for developing a strong link between disciplines. This collaborative environment is one room equipped with several work stations with double-screen computers. A separation of space existed to create a conference area designed for team meetings.

The conference area is stationed with a large conference table and chairs, a projector, and a SmartBoard projector screen. The open layout of the room permitted open interaction amongst team
members and allowed for quick relay of information. To maintain a flexible workspace, no area was claimed by any member. Synergy wanted the space to adapt to what the design team needed at any given stage of the design process. For example, work stations shifted and combined to house both Synergy’s mechanical team and Structural team in one area during periods of heavy collaboration in resolving clashes regarding the structural grade beams and the in-ground mechanical ducts (Reference Section 8.3.5).

6.3.1 TEAM BUILDING

Prior to the formation of Synergy, the team members had previous experience working together in smaller group environments. A strong team dynamic was already established before collaborating as a project team on the Sports Performance Center. Through a combination of personality tests and a written team agreement, an environment was supported where each member was comfortable expressing himself/herself and his/her opinions. To foster personal interaction, the design team devoted time each week before entering every meeting to share personal victories and acknowledge individual values outside of Synergy in order to build trust and personal connections. Team bonding activities took place throughout the duration of design development to strengthen team interaction, which had direct positive effects in the workplace.

6.3.2 INTER-DISCIPLINARY COLLABORATION

Within each discipline, partners established their goals for the day and were able to work separately but in close proximity in order to improve productivity. Tasks were divided among discipline colleagues to expedite completion. Working in close proximity allowed quick sharing of the most up-to-date information and prompt diagnosis of any issues with the support of the collaborative partners. Effective structuring of inter-disciplinary collaboration made successful cross-disciplinary collaboration possible.

6.3.3 CROSS-DISCIPLINARY COLLABORATION

Because effective communication is essential to design development, Synergy strived to develop innovative methods to transfer information across disciplines. For communication within the design team, Synergy created an Integration Log (IL). A detailed visual of the IL may be referenced in Integration SD-C. The log documented the activities performed by each discipline on a daily basis. If any discipline discovered that a component of their system’s design was affected by the design decisions of other disciplines reported in the IL, a statement of the changes and the impacts would be documented. A color-coding system within the IL allowed disciplines to identify areas of acknowledgement and no concerns, areas of caution in need of addressing comments, and areas in need of immediate discussion. Even though the design team occupied the same space, collaboration across disciplines was still challenging. To address this challenge, Synergy dedicated a portion of every weekly meeting towards briefing the team on how each discipline has progressed over the span of a week.

6.4 COMMUNICATION

6.4.1 NON-VERBAL COMMUNICATION

While face to face communication was encouraged, it was not possible at all times. In order to facilitate digital communication, Synergy primarily resorted to Google Drive, Box (an online cloud), and the GroupMe app. Synergy’s benefits from using each form of non-verbal communication is referenced in Integration SD-B.

6.4.2 TEAM MEETINGS

Once a week, Synergy met as a team to discuss progress updates of the design and to decide upon critical project matters. Synergy found value in the role of an individual. To ensure that no voice was overlooked, the team felt an even distribution of leadership responsibility was important in enhancing the collaborative environment. One member was designated as the meeting leader prior to each weekly meeting. If the meetings were becoming inefficient or disorganized, the meeting leader was responsible for refocusing the team. During every weekly meeting, every member was responsible for presenting any information on how the project was progressing as well as points of integrative design in an effort to ensure consistent project development.

Synergy values the importance of creating a learning environment for each member within the team. To make sure that every member was well-versed in all facets of the design progression, a weekly Lunch and Learn was held. During each Lunch and Learn, all disciplines presented information related to their discipline and their most current designs.
The Lunch and Learn Program created an educational environment that facilitated open discussion while teaching all members of the team discipline-specific information that would be important to know and understand in order to help influence other areas of design (Figure 3).

6.4.3 TEAM PLANNING

The design team was able to track progress and plan workflow based on the design milestones using pull planning. Pull planning is a look-ahead scheduling technique that tracks progression towards predetermined milestones. The milestones were based upon system design advancement established in the design schedule. The process of pull planning is deciding what supportive tasks and actions are required to reach any given milestone. The design team worked backwards by designating Post-It notes on a schedule explaining each task to be completed and the required action necessary to complete each task. Each week, the schedule was adjusted based on in-progress tasks to detect areas causing delays. Pull planning helped the team identify what was needed from each discipline. For more information regarding pull planning, see Section 3.3.1 of the Construction Report.

7.0 EARLY DESIGN ITERATIONS

Early design iterations for the representative design focal points of the project (including the building core/floor plan, the roof, and the enclosure) are sampled through the highlighted subsections. More detailed design information regarding each iteration, including detailed pros, cons, and tradeoffs, may be found in Drawing I-5.1 through I-5.3.

7.1 BUILDING CORE ITERATIONS

Synergy’s first iteration involved rotating the floor plan 90 degrees counterclockwise with reference to due north. All auxiliary spaces were repositioned along the western perimeter of the building. Though this first iteration was advantageous to the mechanical team, the Lighting/Electrical team and the architecture were negatively impacted. Synergy’s second design iteration introduced the building core by splitting the building apart along its north-south central axis. A wider footprint was created, and the tornado safe room was centralized in the building core. Though the Structural team benefitted from a centralized tornado safe room, site restrictions negatively impacted the construction team and the architecture still lacked optimized occupant flow. Synergy’s third design iteration condensed the building core and created a grand entry/lobby space. With this, a partial second level was created which negatively impacted cost, schedule, and system servicing. Synergy’s final design (Detailed in Section 8.1) reduces the square footage and minimizes the boundary of the second level while extending the tornado safe room on the ground level to create an emergency exit corridor.

7.2 ROOF ITERATIONS

Synergy’s first design iteration of the roof added skylights. Though this modification slightly helped the Lighting/Electrical team (yet introduced glare issues), the three other disciplines suffered from the design decisions. Iteration 2 introduced curved extrusions spaced along the profile of the roof that contained north-facing clerestory glazing. The Lighting/Electrical team benefitted from indirect daylighting, but significant challenges surrounding the Structural team and the Construction team were created. The third design iteration slightly modified the second iteration by replacing the curved extrusions with rectangular extrusions. The windows were designed to be operable to allow for natural ventilation and other innovative mechanical design strategies. Synergy’s Lighting/Electrical and mechanical teams took advantage of the benefits supplied by the third design iteration, though there were still major issues regarding structural support of the rectangular extrusions and the added cost and maintenance of the added assemblies. Synergy’s fourth design iteration was prompted in effort to add more value to the project by depressing the roof at various locations. This still created north-facing clerestory glazing with operability yet minimized building volume. Planar roof trusses were positioned within the full-depth of the roof high points for main roofing support, though stability issues still existed. Synergy’s final design (detailed in Section 8.2) builds upon the positive aspects of previous design iterations and addresses major tradeoff concerns.
7.3 ENCLOSURE ITERATIONS

Synergy’s first design iteration of the building enclosure implemented masonry walls, a concrete roof structure, and polycarbonate windows in order to improve impact performance and mitigate roof tear-off in the event of a severe natural disaster. Iteration 2 replaced the masonry-backed walls with a combination of precast concrete wall panels (lower wall) and an EIFS wall system (upper wall). A lightweight roof structure equipped with innovative roof vents to alleviate roof uplift pressures substituted the heavy concrete roof. The poor-transmittance polycarbonate windows were replaced with fully tempered laminated glass (single-lite). Synergy’s third iteration was the same as the second only the entire wall assembly was comprised of precast concrete wall panels. Synergy’s final design (detailed in Section 8.3) was selected after analyzing and addressing discipline and project theme tradeoffs under the Convergent Design Strategy.

8.0 INTEGRATIVE DESIGN FOCAL POINTS AND FINAL DESIGNS

Synergy identified three areas of the project’s design and construction that serve as the leading points of integration and collaboration: the building’s core, the depressed roof, and the building’s enclosure. Within each integrative design focal point, Synergy delivered final designs that achieve the overarching project themes and offer the university superior performance through innovative, value-added efforts.

Each integrative design focal point corresponds to directly satisfying one or more of the owner-defined challenges. Synergy is aware that Texas Tech may not be able to afford all incurred costs of achieving all three owner-defined challenges. In response, Synergy has categorized the added costs to the initial project budget into packages based on owner-defined challenges: Resilient Cost Package, WELL/Energy-Savings Cost Package, and Schedule Acceleration Package. Some design features overlap, thus making components of the packages mutually dependent. Synergy recommends selecting overlapping packages which in turn offer the most value to the university. The full breakdown of the cost packages are referenced in Integration SD-E and cost package selection recommendations are supported in Section 7.2 of the Construction Report.

8.1 BUILDING CORE

Figure 4: Building Core Longitudinal Section

The implementation of a centralized core to the building’s design was essential in establishing a safe and secure divider between the building’s main functional spaces. By creating a separate core, Synergy was able to initiate design strategies and install systems unique to their design in order to achieve improved performance and enhanced resiliency while offering an optimized building layout. A summary of building core achievements is highlighted in Table 2. A detailed added cost for the addition of the building’s core may be referenced in Drawing C-6.0. In summary, the building’s core contributes added cost to the Resilient Cost Package represented on Integration SD-E in exchange for an optimized building layout, centrally-located high-performance facilities, and a tornado safe room designed to withstand an EF4 tornado and protect the lives of building occupants.

Table 2: Building Core Project Theme Achievements

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<th>Enhanced construction sequencing</th>
<th>Improved occupant flow</th>
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<td>Centralized tornado safe room (Occupancy 516)</td>
<td>Resilient building core with motorized emergency shutters</td>
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<tr>
<td>Performance</td>
<td>Centralized MEP for shorter runs</td>
<td>Create separation of space for systems design</td>
</tr>
<tr>
<td>Versatility</td>
<td>Ability to reprogram space within core, improved ADA accessibility</td>
<td>Permanent seating of 2,100 spectators for large events</td>
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8.1.1 ARCHITECTURAL ENHANCEMENTS

Through the addition of the building core, the building’s architecture was enhanced by providing optimized athlete, spectator, and building occupant flow through the building’s main spaces. A more prominent entryway was created which invites athletes and spectators into the building. Within the entryway is a lobby decorated with athlete inspiration art pieces, a student athlete performance recognition wall, and a WELL Building Standard achievement wall (Figure 5). The building owner is provided with a grander, more attractive lobby space that will be utilized as an athlete recruiting tool. From both the interior and the exterior of the building, the strip of the building’s core clearly designates a separation of space from the general public and
athletes while also emphasizing an area of safeguard and protection in the event of a natural disaster or emergency. Drawing I-5.1 showcases the architectural evolution of the floor plan through design iterations.

8.1.2 OPTIMIZED BUILDING LAYOUT

The building’s core provides 40’ of separation between the fields and has a height of 33’. The floor plans of the building core are referenced in Figure 6 while the full building floor plans are on Drawing I-2.0. On the ground floor of the building’s core, one set of permanent concrete bleachers (main bleachers) with a capacity of 1,100 spectators is centered about the indoor track. Within the main indoor track space along the western wall, there is another set of permanent concrete bleachers (supplemental bleachers) that holds an additional 1,000 spectators. The west seating is only to be open to spectators during large NCAA track events, and the seating will otherwise be blocked off to encourage spectator seating within the main bleachers. Approximately 2,400 SF of space beneath the supplemental bleachers will be utilized as additional storage if needed for future building adaptation. The space beneath the main bleachers is programmed for the Fueling Station, a nutritionist’s office, facility storage, and the tornado safe room. A corridor also exists beneath the main concrete bleachers, offering through-access from the northern end of the building to the southern end that is equipped with men’s and women’s restrooms and men’s and women’s showers. The men’s and women’s showers were added to the program to offer convenience and amenity to community members when utilizing the building as a community shelter. Two additional men’s and women’s bathrooms exist adjacent to the bleachers west of the track facility so that spectators do not need to cross the track in order to access facilities.

The sports medicine room and the hydrotherapy room are located on the northern end of the building’s core, allowing shared, quick access from both the track and the football practice field. At the very northern end of the building’s core exists a prominent main entryway to the building with an interior lobby space decorated with an Encouragement Wall that highlights the athletic and academic successes of Texas Tech University athletes. In addition to the Encouragement Wall, a WELL Wall is positioned within the lobby space that illustrates the building’s successes in achieving the Gold certification of the WELL Building Standard. Interior renderings of the lobby space may be seen on Drawing I-3.0. Synergy’s mechanical and structural designers identified the significance of incorporating a vestibule space in the main entryway to the building’s core. Not only would a vestibule space help to improve the thermal performance of the building, the vestibule would serve as a double-layer of protection against wind-borne missiles in the event of a tornado or other security-related risks. Furthermore, by creating a lobby space with a vestibule entrance, doors do not immediately open to the athletic spaces as originally designed. This maintains a secure and
resilient building in defending against man-made threats (particularly to the performing athletes) in addition to the threats of natural disasters.

As the permanent concrete bleachers extend vertically 16 vertical feet, a second level to the building’s core offers another means of accessing the spectator bleachers (Figure 6). An adjacent elevator allows ADA accessibility to more premium viewing spaces at the second level. The second level also offers a team meeting room with viewing angles of the track beneath. A press box exists on the second level, providing clear viewing angles to all track events.

Though the addition of the building’s core adds 18,120 SF (11 %) to the original square footage of the building, the optimized floor plan offers an improved division of space with enhanced occupant flow. Labeled floor plans which highlight the building core addition and occupant flow may be referenced in Drawing I-4.0.

### 8.1.3 CENTRALLY-LOCATED FACILITIES

Immediately adjacent to the southern end of the building’s core is the building’s mechanical and electrical rooms. By positioning these in the building core’s southern end along an exterior wall, utility access is readily available to the electrical room at an exterior face. The electrical room is within close proximity to emergency generators positioned outside nearby the south side of the building. The team instituted an enclosure around the emergency generators for security of equipment. Since the roof of the building’s core is flat, Synergy’s Mechanical designers were able to take advantage of the placement of four rooftop air handling units, easily receiving air intake from predominant southern wind in order to supply air for their dedicated outside air system with return. Synergy’s Structural and Mechanical designers collaborated to design an enclosure to protect the exposed rooftop air handling units against EF3 and EF4 tornado wind speeds and missiles. The mechanical room itself is host the Mechanical system’s pumps and heat exchanger and is oversized to accommodate future growth. By positioning the air handling units along the core’s vertical axis, the duct run length is minimized and the overall efficiency of the air distribution is enhanced. The ductwork is able to run down the spine of the building and branch out to service the building’s main athletic and auxiliary spaces as seen in Figure 7.

### 8.1.4 TORNADO SAFE ROOM

The building’s tornado safe room is centralized and integrated into the building’s floor plan and serves as the anchor point of the building’s resiliency and security features. Designed to withstand an EF4 tornado and protect the lives of all building occupants, Synergy aimed to centralize the safe room such that it is most easily accessible for all building occupants no matter what their location in the building. In effort to minimize mechanical and electrical penetrations that would have the potential of compromising the structural integrity of the tornado safe room, Synergy’s Mechanical and Lighting/Electrical teams worked with Synergy’s Structural team in locating the safe room in plan in order to avoid creating a major obstacle in servicing adjacent spaces. The reinforced concrete structure of the main bleachers doubles as the structure of the tornado safe room (Figure 8). Ten-inch-thick walls surround the area beneath the concrete bleachers, encapsulating the space during an EF4 tornado. Synergy’s Structural team collaborated with Synergy’s Construction team to prefabricate the reinforced concrete structure of the main bleachers and the tornado safe room (excluding the walls). Utilizing precast concrete segments to construct the main bleachers and the tornado safe room improved quality, saved one week of construction time, and saved cost by eliminating complex formwork.
Because the Structural team relied on the walls to act as continuous shear walls to resist lateral loads, Synergy’s Structural and Construction teams determined it was best to cast the concrete walls in place for continuity and robustness.

The total occupancy of the tornado safe room designed for is 516 people, more than double the anticipated typical daily occupancy of the building. The increased tornado safe room capacity was designed for in case of larger occupancy numbers of the entire building at the time of the natural disaster. Any through-openings within the EF4-tornado-designed structure will employ Qompact StormSafe automatic shutters designed for impact resistance and EF4 tornado wind speeds in order to seal off the concrete structure. Examples of these shutters can be found on Drawing I-6.0. By centralizing the tornado safe room, the amount of emergency shutters required was reduced to only two since the safe room was away from any windows and glass doors, promoting a faster procedure for securement in the event of a natural disaster.

The tornado safe room structure is designed to take the impact loads and gravity loads of any host structure collapsing on the tornado safe room. In order to provide an emergency exit from the tornado safe room, Synergy decided to implement a straight-line exit path from the safe room that is also designed for EF4 tornado impact loads and wind pressures. The entire area designed to withstand an EF4 tornado occupies 4,674 SF which is illustrated in Figure 9. Because Synergy’s discipline teams collaborated to increase the footprint and area of the EF4-tornado-resistant structure, building occupants do not need to funnel to one specific location within the designated tornado safe room. Building occupants are able to more quickly and more freely move to the safe area of the building in the case of an emergency.

FEMA 361 and ICC 500 do not require the heating and cooling of the tornado safe room. For the 516 occupants of the safe room, 258 SF of venting area is required per ICC 500 Section 702.1.1. The natural ventilation openings within the safe room will use storm-rated Greenheck AFLS01 louvers. An on-site emergency natural gas generator is incorporated into the electrical distribution system and will provide two hours of built-in capacity for critical systems. All lighting located within the tornado safe room boundary is on an emergency circuit. A detailed breakdown of the added cost of the tornado safe room addition may be observed in Drawing C-6.0.

8.2 DEPRESSED ROOF

The roof emerged as a critical design area with opportunity of enhancement of the building’s performance on the basis of all disciplines. Integrated focus in Synergy resulted in increased building performance through an enhanced roof design providing value to the building owner while improving the well-being of building occupants. Synergy implemented operable, north-facing clerestory windows. A balanced distribution of north-facing glass across the roof profiles created a uniform daylighting scheme while the operable windows equipped with roof-hung Haiku fans allowed for the utilization of displacement hybrid ventilation, reducing energy consumption and costs. Rather than extruding the roof at various locations to create the clerestory windows, Synergy decided to depress the roof in tandem with the predetermined truss spacing in order to create the clerestory windows. By positioning the long-span roof structure within the full-depth of the high-points of the depressed roof, the minimum height requirements of the main athletic spaces were always maintained. In addition, the volume of the main building spaces was able to be decreased by 17% (Figure 10), saving on exterior perimeter façade area and mechanical ventilation demands (5%). A summary of the project theme achievements is highlighted in Table 3. In summary, the depressed roof contributes added cost to the Resilient Cost Package and the WELL/Energy-Savings Cost Package described on Integration SD-E.
8.2.1 ARCHITECTURAL ENHANCEMENTS

The depressed roof design serves as an iconic feature of the building’s architecture by making the roof profile more dynamic. Synergy’s discipline teams worked together to enhance the building’s architecture and provide Texas Tech University with a unique building appearance that would serve as a signature look for the university’s athletic program. The new roof design is an integrated component of the architecture by serving as a living feature of the building: taking in a uniform distribution of natural daylight, exhausting warm air and air contaminants, and serving as a means of natural ventilation.

8.2.2 CLERESTORY GLAZING

The original design employed large north-facing windows along the northern façade of the building creating an unbalanced distribution of daylighting. In order to introduce a uniform distribution of natural light into the main track and football spaces, Synergy’s Lighting/Electrical designers took the lead in coordinating north-facing clerestory windows to complement the large windows of the northern façade. Because more daylight was introduced into the building, Synergy’s Lighting/Electrical team was able to reduce the area of the large curtain walls of the north facade by 47%. This helped the Construction team save cost of the curtain wall glazing and helped the Structural team minimize the vertical and horizontal curtain wall spans. A uniform daylighting distribution creates well-lit spaces that decrease the amount of electric light required (Figure 12).

Furthermore, a uniform daylighting distribution provides natural lighting for the athletes and building occupants, satisfying requirements of the Light section of the WELL Building Standard. For a detailed summary of how the clerestory windows achieved WELL Building Standard requirements, refer to Integration SD-D as well as Lighting/Electrical SD-B. The electric LED lighting of main daylight spaces are operated by photosensors that employ daylighting dimming. When there is sufficient daylight in the space, the lights dim, thus reducing the output on average in those spaces by 44 percent and reducing energy consumption by 17 percent throughout the year. Details of this system are found in Drawings E-1.0. Since the Mechanical team required operable windows along a curved profile, Synergy’s Structural and Mechanical team devised a mullion configuration as seen in Figure 13. The radial mullions were spaced at 6’-3” to align with the panel points of the truss while horizontal mullions were configured to create 48 operable windows along the roof profile (12 additional operable windows along the track-side roof profile). The mullion arrangement was determined based on impact performance, deflection...
criteria, and visible transmittance. In coordination with the Construction team, Synergy ensured that the same constant radius was maintained between the roof profiles of the track-side and the football-side. Because of this, Synergy was able to standardize the glazing sizes to five different sizes, allowing for ease of installation and convenience of stock and replacement (Figure 13).

8.2.3 DISPLACEMENT HYBRID VENTILATION

By making the clerestory windows along the high-points of the depressed roof operable through automatic controls, Synergy’s Mechanical designers were able to take advantage of displacement hybrid ventilation. Through collaborative efforts with Synergy’s Mechanical and Structural teams, operable windows were implemented that may be automatically sealed off with electromagnetic locks. Since the volumes of the main building spaces are very large, the Mechanical designers were concerned with offering the best thermal comfort at the occupant level. The remaining volume of warmer air above occupant level would naturally rise and be able to be drawn out of the building by the roof-hung Haiku fans that do not impede upon the minimum height requirements of the athletic spaces. Coordination with minimum height requirements also discouraged overhead air supply which is ineffective in high bay areas. Contaminants would also be removed from the spaces by flooding fresh air at the ground level of the track and football spaces and forcing contaminates up and out of the building (Figure 14). Utilizing displacement ventilation, the Mechanical designers were able to take advantage of a ventilation effectiveness multiplier which helps to reduce the volume of air needed to handle the mechanical loads. In total, displacement ventilation saves 30% source energy and 50% on-site fan energy which together translates to a yearly cost savings of $3,300 (approximately 25%). Additionally, achieving improved ventilation effectiveness satisfies an Air section requirement of the WELL Building Standard.

effectively utilize natural ventilation during the months of April, May, September, and October. Utilizing natural ventilation allows the mechanical systems to completely shut off, saving up to 50% site energy and 30% source energy with 25% reduction of yearly operation costs. Additionally, tornadoes are most likely to occur during the same months that natural ventilation is able to be utilized. Thus, the community shelter may be ventilated by means of natural ventilation. Natural ventilation is made possible with the addition of mechanical louvers on the lower areas of the southern walls, facing the direction of the prevailing winds. Air enters the spaces through the louvers, creating a negative pressure at the roof which helps to draw displaced air from the building, naturally cooling the spaces at occupant level and ridding of air contaminants. More information regarding the advantages of displacement hybrid ventilation may be found in Section 8.2 of the Mechanical Report.

8.2.4 LONG-SPAN ROOF STRUCTURE

Because areas of high points exist along the depressed roof profile, more area is exposed to increased EF3 tornado horizontal wind pressures. In order to not jeopardize the lateral stability of the high points along the roof profile, Synergy’s Structural designers decided to design a coplanar roof truss positioned within the full-depth of the roof high points that was capable of better resisting the horizontal wind pressures. Angled members of the coplanar roof truss (Figure 15) provide lateral rigidity to the roof structure and are able to adequately transfer the horizontal wind loads into the lower roof diaphragm.

Figure 15: Long-span Coplanar Roof Truss

Synergy’s Structural designers maintained the minimum height requirements of the athletic spaces by positioning the roof trusses within the high points of the roof. By doing so, the bottom of the structure matched the depressed roof profile which provided necessary clearance for the athletic spaces while also reducing building volume by 17%. After the Structural team’s consultation with Synergy’s Lighting/Electrical team, it was determined that a maximum window pane height was limited to 10'-0". In effect, Synergy’s Structural designers limited the height of the long-span roof structure to be 10'-0", and they controlled excessive deflection by pre-cambering the roof truss profile. A
shallower roof truss helped to maintain an appropriate proportion between the height of the roof high points and the overall height of the building. Furthermore, a shallower roof truss created less building volume to heat, cool, and ventilate. Through collaborative efforts to depress the roof, not only was building volume saved but the clerestory glazing was positioned closer to the playing surfaces which increased the effectiveness of daylight distribution. Any depth less than 10’-0” was not able to be achieved in the Structural design as deflection criteria dictated the minimum depth.

In order to help accelerate the construction schedule, Synergy’s Construction team worked with the Structural team in order to eliminate the need for temporary shoring of the long-span trusses during construction. All welded truss connections are to be completed during fabrication in the shop. Truss segments would be shipped in 50’ to 60’ segments, eliminating the need for special transportation permits. Once on-site, the truss segments would be lifted into construction cradles spaced approximately 50 feet apart. All segments would then be bolted together to form the entire-span truss, eradicating the need for field welding, welding inspections, and temporary vertical shoring.

Since a singular truss is unstable in torsion due to its geometry, the Structural team and the Construction team devised a manner to connect two trusses on the ground with the high-point roof purlins which provide stability. By ensuring that one Manitowoc 16000 Crawler (Figure 16) is to be on site during the roof truss erection sequencing, the two trusses and their roof purlins are able to be lifted and erected as an assembly unit. This construction method eliminates the need for horizontal shoring and accelerates the erection sequencing of the long-span roof trusses by approximately 3 weeks. The Structural designers verified the performance of the truss assembly during construction by modelling the truss assembly under exposed loads during erection. Details of construction are represented in Construction SD-D.

### 8.3 BUILDING ENCLOSURE

Tasked with designing a building enclosure to resist wind-borne missiles, Synergy developed a structurally robust facade and roof assembly with improved thermal and moisture performance. Though structural performance was critical in the enclosure design, Synergy devised a design that would not compromise glazing for daylighting schemes, that would be thermally efficient for mechanical performance, and that would be modularized and prefabricated such that construction methods were accelerated and quality-assured. A summary of the project theme achievements may be observed below in Table 4. In summary, the building enclosure contributes added cost to the Resilient Cost Package and the Accelerated Schedule Cost Package described on Integration SD-E.

![Figure 16: Critical Pick of Truss Assembly](image)

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<td><strong>FIR-laminated glass protects building occupants</strong></td>
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<td><strong>Performance</strong></td>
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<td><strong>Versatility</strong></td>
<td>Continuous thermal insulation, maintained window openings</td>
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<td><strong>Facade assembly materials are easily replaced if damaged</strong></td>
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<td><strong>Watersheding strategies tested long term through WFI modeling</strong></td>
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The newly designed building enclosure complements the architectural style of Texas Tech University, offering a signature brick-veneer look on the lower bounds of the exterior walls accompanied with an innovative soft gray terracotta rain screen on the upper bounds of the exterior walls. The building’s enclosure goes beyond its aesthetics and serves as a shield in protecting building occupants in the event of a natural disaster while aiding in keeping them comfortable and well-living.

### 8.3.2 IMPACT-RESISTANT FACADE

Though the entire building was meant to be designed to withstand an EF3 tornado, no specified guidelines existed for designing for the impact loads of an EF3 tornado. Instead, the design team referenced FEMA 361, a design document which specifies tornado safe rooms designed to withstand an EF4 tornado. Synergy set out to develop a facade which would resist the impact loads of an EF4 tornado, creating a safer and more structurally-robust building envelope. In order to develop an impact-resistant facade, Synergy resorted to test data from Texas Tech University. For more information and data regarding the testing procedures for the impact resistance of wall assemblies, refer to
In summary, an approved wall assembly passed testing from the impact of a 15 pound 2x4 wood stud with a missile speed of 100 mph. Synergy intended to maintain the architectural style of the lower brick façade that wrapped around the entire building in the original design. However, to expedite construction and to improve impact performance, Synergy decided to utilize brick-stamped, insulated concrete panels. The precast concrete panels’ composition may be observed in Figure 17. Impact tests indicate a threshold missile speed of 102 mph, prior to damaging the first 3” of concrete of the insulated panel. The panels’ thermal performance is dictated by an R-value of 32, 20% above the R-value of the original wall assembly and 210% above code minimum.

In effort to minimize weight of the wall assembly to reduce structural sizes, Synergy selected a different façade composition to stack on top of the precast concrete panels and extend the remaining height of the building. To achieve superior impact performance and pass impact tests, the upper wall assembly relies on a double stud wall with layers of plywood and steel. A continuous layer of 3” rigid insulation lines up with the 3” rigid insulation layer of the insulated concrete panels beneath, providing a continuous thermal barrier. An exterior finish of the upper wall assembly is a terracotta rain screen, designed to improve the moisture performance of the wall assembly. Though the terracotta rain screen is not tested for impact, the rain screen system is rated for wind pressures up to 190 psf, enough to resist wall wind pressures and suction experienced during an EF3 tornado. Synergy selected terracotta panels as the exterior cladding of the upper wall assembly for easy maintenance and replacement if a tile happened to be damaged by impact during an extreme weather event and also superior moisture performance. The entire wall assembly and its make-up may be referenced in Figure 17. The R-value of the upper wall assembly is 32, similar to that of the concrete wall panels, providing thermal continuity of the wall assemblies. To combat moisture penetration, Synergy’s Construction, Mechanical, and Structural teams worked together to detail the wall assemblies (specifically near the joint of where the two different wall assemblies meet) in order to properly rid the walls of any moisture through weeps and flashing. A detail of where the two wall assemblies join along with other enclosure design information may be seen in Drawing I-8.0. Synergy also ran a moisture analysis of the wall assemblies using WUFI to verify moisture performance.

Synergy’s Structural designers coordinated with Synergy’s Lighting/Electrical and Mechanical designers in order to select a fully tempered, laminated and insulated glazing type by Viraco with an overall thickness of 1-5/16". Synergy’s Mechanical team did not want to compromise the thermal performance of the clerestory glazing, so they worked with the Lighting/Electrical and Construction teams to select a glazing type with a U-value of 0.28. Through collaborative efforts, the enhanced thermal performance of the glazing was achieved while still having suitable light transmittance and minimized cost. Synergy’s Structural team worked with the Lighting/Electrical team to select a fully tempered, laminated glass type to achieve optimal performance resisting impact loads and increased wind pressures. By selecting a laminated glass type, building occupants will not be at risk of falling glass shards. Furthermore, the building is protected from being breached since any broken windows will be held intact with the PVB interlayer.

### 8.3.3 PREFABRICATED WALL ASSEMBLIES

The precast concrete panels have the appearance of brick and are modularized in 12’-0” by 30’-0” sections, structurally spanning from horizontal wall girts spaced 12’-0” vertically. The panels are also attached at column locations spaced 30’-0”. Panels extend vertically 24’-0” all around the perimeter of the building in order to match the height of the architectural bump-out of the northern elevation. The upper wall assembly...
is prefabricated in 10'-0" tall by 30'-0" wide panels. Upper wall panel seams are disguised by the terracotta rain screen. The track attachments of the terracotta rain screen will be prefabricated on the upper wall assembly panels, though the system’s track and terracotta panels themselves will be later added during construction. By pre-fabricating the wall assemblies, higher quality is achieved when compared to on-site fabrication. Synergy’s Construction team has implemented a Quality Assurance Program and rigorous on-site inspection testing to ensure a high-functioning building enclosure.

Pre-fabricating the entire wall assembly costs an additional $2.3 million, including the cost savings of a schedule reduction of 29 weeks. Furthermore, the owner is provided with a safer façade with enhanced thermal and moisture performance as verified by WUFI results (Reference Drawing I-8.0). Pre-fabricating the wall panels in a controlled facility increases quality and reduces the number of workers on site during exterior façade construction.

8.3.4 UPLIFT-RESISTANT ROOF ASSEMBLY

Synergy’s Structural designers identified the importance of developing a light roof assembly that would also resist uplift and roof tear off in the event of an EF3 tornado. This meant that the fastening design would be critical, and the depth of the roof would need to be minimized for the sake of adequate fastening attachment and securement. Collaborative efforts from Synergy’s Structural, Construction, and Mechanical teams ensured a high-quality, uplift-resistant roof assembly under EF3 tornado wind pressures that is able to achieve the desired thermal performance as specified by the Mechanical team.

In selecting a roof assembly, Synergy’s design team referenced RoofNav, a complimentary design tool from FM Approvals that provides access to the most up-to-date FM Approved roofing products and assemblies. Synergy was able to select a Factory Mutual Approved roof assembly that is approved for an uplift of 180 psf, providing a factor of safety of 2 against EF3 tornado wind roof uplift pressures. The composition of the FM Approved roof assembly may be observed in Figure 18. Synergy’s Structural and Mechanical teams sorted through the FM-Approved roof assemblies to find an assembly that allows for at least four inches of rigid insulation in order to achieve the desired R-value for the roof assembly. The R-value of the roof assembly is 25, 25% over the specified code minimum. Referencing testing results from Texas Tech University and the University of Florida, a similar roof assembly experienced no penetration or perforation at a threshold speed of 74 mph which is larger than the FEMA 361-specified missile speed of 67 mph for horizontal surfaces.

8.3.5 WALL AND GRADE BEAM COORDINATION

Heavy collaboration existed between Synergy’s Construction, Mechanical, and Structural teams in integrating the Mechanical team’s in-ground ducts with the Structural team’s foundation system in clashed areas. Through integrative efforts, Synergy was able to lower the grade beams in the conflicted areas by five feet and allow three 40-inch-diameter duct penetrations spaced 8'-0" O.C. to occur within the base of the concrete shear wall that was extended downward to meet the grade beam (Figure 19). The track space did not have similar issues as there were not grade beams at supply locations since a transfer truss spanned the opening of the main bleachers. More information on the grade beam coordination may be referenced in Section 7.2.1 of the Structural Report.

Figure 18: FM-Approved Roof Assembly Composition

Figure 19: Grade Beam and In-ground Duct Coordination
9.0 LESSONS LEARNED

Throughout the design process of the Sports Performance Center, Synergy developed as a team and took advantage of experience gained through lessons learned. Such lessons encompassed all levels of professional and personal growth including the independent level, the collaborative level, and the level of the overall design process. Synergy's greatest takeaway from the completion of the project revolves around the superior outcome generated from an integrated design. By working as a collaborative team in an open colocation space, information was readily available and easily shared among all team members. Challenges encountered during the design process were able to be quickly resolved through interdisciplinary and cross-disciplinary creative thinking. Learning about the designs and processes of other disciplines creates a well-rounded designer equipped to provide solutions in an unlimited realm of innovative problem-solving. Additionally, understanding the work of other disciplines helps to better design with inter-reliant relationships and design outcomes in mind. Synergy exemplified the benefits of a collaborative design approach in their final designs. See Integration SD-C for detailed Lessons Learned.

10.0 CONCLUSION

Synergy instituted a collaborative design approach that was enhanced through the interaction and cooperation of a multi-discipline team that produced a combined output of design of the Texas Tech University Sports Performance Center greater than the sum of individualistic discipline efforts and ideas. By focusing on a Convergent Design Strategy, Synergy was able to yield the most desired outcome of design by tracking discipline and project theme tradeoffs and effectiveness throughout the design process as multiple iterations of the integrative focal points of the project were executed. Ultimately, Synergy provided Texas Tech University with a sports performance center that adds value to the university and the athletic program through enhanced operation and maintenance, provides security and resiliency to student athletes and community members in the event of a man-made threat or natural disaster, implements high-performing systems that promote sustainable and healthy lifestyles, and versatile features of the building which may conveniently adapt alongside future growth and advancement in technology and building function. Strong efforts were made to minimize added cost to the owner, though Synergy was accepting of additional cost in order to deliver on all three owner-defined challenges. In exchange for a minimized added cost to Texas Tech University, the university and athletic program is provided with increased value, an accelerated construction schedule, and superior building performance specifically in the realm of promoting the WELL Building Standard and safeguarding the public from man-made threats and natural disasters. A summary of how Synergy delivered a superior project that accomplished all project themes with credit given to a collaborative design, refer to Figure 20. Within the figure, discipline symbols appear next to achievements where significant contributions were made by the given discipline team.

Figure 20: Project Theme Design Accomplishments
Supporting Document A | Design Process and Decision Making

Decision Matrix

Synergy’s decision matrix is a tool utilized by each discipline to develop an unbiased solution to every decision that affects the overall project. The subsections are based on a combination of the team goals and project themes. Each section is uniformly weighted to balance the more discipline specific goals with the overarching project goals. For more detailed information about design iterations, see I-5.1 through I-5.3.

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Additional Comments:
The final design utilizes a centralized core space that separates the football and track spaces without extending beyond the site limits. The core offers versatility for future reprogramming of spaces. By optimizing the square footage on the second level, Synergy minimized added cost and maintenance. The roof safe room is centralized and is accompanied with an E4A rated emergency egress path.

Additional Comments:
The final design utilized the energy consumption analysis by reducing the original volume via depressing the roof structure at predetermined mass spaces to create operable, north-facing clerestory windows. The windows allowed for a uniform distribution of natural light into the football and track space. Synergy incorporated bullpen fans to facilitate the displacement hybrid ventilation by exhausting air through the operable windows.

Additional Comments:
The final design produced a robust EF3 tornado shield that is designed to enhance thermal and moisture performance. Synergy maintained Texas Tech University's tradition by utilizing secure precast brick-stamped concrete panels, on the lower wall area, and prefabricated terracotta skin, on the upper wall area, that mimic the architectural style of the campus infrastructure.

Decision Making Process

1. **Define the Challenge**: Identify the challenge that directly impacts the design or any discipline on the team. A working definition of the scope is necessary to be defined to ensure that all parties involved understand any of the components of the problem.

2. **Determine All Affected Disciplines**
   - Determine all disciplines that are affected by the decision outcome. Each discipline must be educated on the challenge to accurately assess the effects it will have on the design.

3. **Devise Possible Solutions Based on Calculations**
   - Devise possible solutions based on calculated results that will develop an unbiased decision. Each discipline is responsible for acquiring all necessary materials.

4. **Utilize the Decision Matrix**
   - Utilize the decision matrix to measure the options based on the solutions devised in Step 3. The matrix weighs each option based on a pre-defined criteria established by using the project goals.

5. **Organize an Implementation Plan for All Disciplines**
   - Organize an implementation plan that can be used by all disciplines to establish a plan of action on how to integrate the solution into the project. The plan is organized strategy centered around the project goals.

6. **Implement Plan**
   - Implement the proposed strategy into action by monitoring the critical components involved in the change. Ensure that all disciplines are educated on how to successfully execute the plan.

Pieces to an Integrated Design

To successfully develop a final project, it is essential that Synergy utilized a decision making plan to ensure that the proper amount of coordination and collaboration went into evolving the final design. The decision making plan serves as a guideline that each discipline can repeatedly utilize for every design decision. By creating a plan, Synergy produced a standard set of instructions that contains the principles that Synergy values as important for producing unbiased calculated decisions.

Understand the Project Components

Understand the 2017 AEI Student Competition guidelines to determine what components of the project will be the team’s main focus.

Detailed Analysis & Calculations

Collect detailed information based on system analysis and calculations.

Discuss & Collaborate

Facilitate communication with organized meetings that allows exchange of information and ideas.

Establish Team & Project Goals

Develop project goals that incorporate the established team goals to serve as guidelines for all design decisions.

SIM = EXECUTION PLAN

Foster a plan that enriches communication and organizes how the team exchanges information across disciplines.

Decision Matrix

Formulate a matrix that will serve as the standard for making all design decisions concerning the project.

Project Systems & Construction Design

Utilize industry research, code standards, and professionals to assemble information that will aid design.
**Team Structure**

**Non-Verbal Communication**

**Google Drive**
Google Drive provided the group with a network that stores information. Each discipline had designated folders containing documentation developed during the design phases. The documents contained in Google Drive were supportive data, figures, and calculations that were used to develop design iterations. Synergy benefited from using Google Drive by creating a file storage location that allowed collaborative file editing and information sharing.

**The Box**
Synergy utilized an online cloud (Box) for large documents and model sharing since the database has an unlimited capacity. Because Box does not share many of the collaborative functions of Google Drive, the design team chose to use the server only as a final storage location. The team benefitted from utilizing Box by having final versions of calculations and models readily available without having to sort through archived versions with non-updated information and data.

**GroupMe**
Synergy utilized the GroupMe app to facilitate group communication when the design team was operating remotely from the collaborative space. The conversation within the app was in relation to information that needed to be distributed to the entire group such as any design suggestions and/or changes that required notifying the team prior to proceeding. Synergy benefitted from quick relay of information to the entire team away from the collaborative space.

**Program Interoperability**

Interoperability is defined as the ability for software to exchange and make use of information. Each discipline utilized the programs illustrated above to produce the final design. Revit serves as the central model that incorporates all analyzed components produced from each of the programs. Synergy utilized a central model to ensure cross-disciplinary communication. Synergy’s Structural, Mechanical, and Lighting/Electrical design teams inputted information into the Revit central model while Construction extracted dimensions and qualities. Collectively, Synergy utilized Artlantis and Photoshop to acquire graphical representations of Synergy’s focal points of the final design. WUFI, a moisture and thermal performance software, provided Synergy with methods for testing the proposed wall sections.
Integration Log

Synergy created an Integration Log as a resource that required daily documentation of all activities performed by each discipline. The structure of the log is oriented so once a discipline completes a task, that discipline inputs any information about the task that might be of immense importance for the other respective disciplines under the specified sections. An Integration Log was created for each discipline to ensure that a communication link existed for relaying information. By utilizing the Integration Log, Synergy realized that a distinct level of communication must exist between all disciplines to ensure that all disciplines are well versed in all aspects of the project.

Lessons Learned

Synergy treated every opportunity as a learning experience to evolve the team dynamic. The Texas Tech University Performance Center challenged the team’s skills individually and as an integrated group. Synergy realized that this project served as a test of the real challenges that are faced in industry. The figure below illustrated the challenges that Synergy experienced by addressing the positives and negatives.

Convergent Design Strategy

The purpose of the Convergent Design Strategy is to track each discipline’s tradeoffs and enhance integrative design after each iteration which is illustrated by the adjacent graphs. Synergy showed how each design progression affected the project theme as well as each discipline. Synergy utilized the strategy to control iteration tradeoffs and ultimately benefit all the project themes and disciplines.

Integration Supporting Documentation
Synergy's goal is to cater to the health and wellness of the athletes. The WELL performance board is an information tool that provides a detailed breakdown that athletes can use to monitor their health intake. The board contains beneficial topics specific to the athlete, like nutrition facts and sleep schedules.

**WELL Performance Board**

Synergy strives to incorporate healthier material options during construction. By utilizing an underground duct system, Synergy is providing a low volatile organic compound (VOC) system that promotes increased ventilation effectiveness.

**BlueDuct System**

Synergy implemented a cork turf field to reduce the health risk that accompanies a rubber turf. The cork is an organic substitution that performs at optimal levels while providing a 100% environment-friendly, non-toxic material for the athletes.
### Cost Packaging

Synergy developed a cost package that offers the owner pricing for each proposed add-alternate within the project. The all-inclusive design includes each of the three add-alternates (WELL, Resilient Design, and Reduced Schedule). Synergy has equipped the baseline design with the necessary system components to implement any of the add-alternates. The baseline design provides the owner with Synergy’s proposed cost of the reformed design. The owner then has the option of adding any add-alternate for the specified price.

### Schedule Acceleration

<table>
<thead>
<tr>
<th>Original Schedule Duration</th>
<th>Integrated Design Team</th>
<th>Steel Sequencing</th>
<th>Precast Concrete Panels</th>
<th>Pre-Assembled Metal Stud Panels</th>
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</thead>
<tbody>
<tr>
<td>01</td>
<td>Original Schedule Duration</td>
<td>The original duration encompasses design, documentation, preparation, approvals, construction, and coordination of all interior sports venues. The anticipated full project time frame is 3 months with a design start date of May 2017.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Synergy’s Recommended Design

- Drilled Belled Piers
- Grade Beams
- Reinforced Concrete Safe Room
- EF4 Rated Interior Walls
- Drilled Belled Piers
- Reinforced Concrete Safe Room
- Co-planar Truss
- EF4 Rated Interior Walls
- Prefabricated Co-planar Truss
- Concrete Walls

#### Packaging Combination Breakdown

<table>
<thead>
<tr>
<th>Synergy’s Recommended Design</th>
<th>$54M</th>
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<tbody>
<tr>
<td>Base plus WELL</td>
<td>$46M</td>
</tr>
<tr>
<td>Base</td>
<td>$42M</td>
</tr>
<tr>
<td>Base plus WELL</td>
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<tr>
<td>Base plus Reduced Schedule</td>
<td>$50M</td>
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<tr>
<td>Base plus Reduced Schedule</td>
<td>$50M</td>
</tr>
<tr>
<td>Base plus WELL</td>
<td>$54M</td>
</tr>
</tbody>
</table>
The facility must be designed to serve as a community shelter in the event of a natural disaster or emergency. As a minimum, the entire facility must withstand a EF3 tornado. The team must also design a tornado safe room for building employees and typical building occupants. The tornado safe room design must withstand an EF4 tornado. The facility must operate for a minimum of 7 days "off grid" with only essential critical systems. The tornado safe room must have 48 hours of built-in capacity.

The facility must be designed to reduce energy by 50% over the 2012 International Energy Conservation Code. The building must also improve occupant health and wellness. To quantify occupant health and wellness, the design team must meet the Well Building Standard Silver Certification at a minimum.

The anticipated full project timeframe is 34 months with a design start date of May 2017. This includes design, document preparation, approvals, construction and completion of all interior sports venues. Substantial completion is currently set for March 2020. As part of the schedule acceleration, the design team must accelerate the substantial completion date to July 2019, prior to the start of the fall semester (8 month reduction in schedule).

By evaluating Texas Tech University's definition of value, Synergy designed and constructed a facility that has added value at a minimized cost. Additionally, the schedule was accelerated and operation and maintenance techniques were enhanced. Synergy committed to adding value to the project that will satisfy Texas Tech University wishes and improve upon the user experience.

A main priority when designing and constructing the Sports Performance Center is life safety and resiliency. The Sports Performance Center is to be built to accommodate any change in the plan of use, as well as new requirements from the University. The Resiliency theme encompasses the need for safety and redundancy in response to natural disasters and emergencies.

The end users of the Sports Performance Center is one of Synergy's greatest design influencers. Making the space comfortable for the athletes and coaches will ensure that Texas Tech University will be at the forefront of athletic programs for the nation. By putting the needs for the athletes first, the Sports Performance Center will standout as one of the best sporting facilities in the country.

The sports industry is constantly changing and adapting to new technology and advancements. Synergy has designed the Sports Performance Center to evolve alongside the future development of Texas Tech University and their athletic program by offering versatile design features. Ranging from adding more spectator seating to updating mechanical equipment and design methodologies, Synergy has made commitments to a timeless design.
ATHLETE & SPECTATOR FLOW

1ST FLOOR PLAN

During large NCAA track events, the supplemental bleachers of the west side of the track may be accessed through any of the three separate doorways along the west elevation. The spectators should not have to leave the west side of the track since they are provided their own restrooms in the northwest corner of the building. This helps to improve spectator/athlete RESILIENCY and separation.

2ND FLOOR PLAN

After being directed up the stairwell, spectators may fill the main bleachers from the top down. If needed, spectators and/or athletes may access the second level via the elevator located adjacent to the stairwell. Area is allotted on the second level to provide premium viewing angles for disability spectators. Athletes will occupy the second level when needing to access a meeting room that overlooks the competition track.

ATHLETE FLOW

SPECTATOR FLOW

Since the outdoor football practice field is located immediately adjacent to the indoor football practice field, it was important to maintain maximum openings along the east elevation. Four double doors provide a direct means of entrance and exit while five 14'-8" x 18'-4" operable doors may be opened at any point to provide a connection between the two practice areas.

At the location of the main entrance, two ticket booths are positioned to allow spectators to purchase event tickets outside to avoid congestion in the lobby. Once inside, spectators are directed by a receptionist to go up the stairs and fill the main bleachers from the top down. Athletes may move freely in the building depending on their target destination. Through access is provided within the building’s core in case an athlete wanted to travel from one end of the building to the other.

EMERGENCY & SAFETY PLANNING

TORNADO SAFE ROOM

The tornado safe room area (the area of the building designed to withstand an EF4 tornado) is highlighted in blue. Dotted arrows indicate occupant flow into the centralized safe room. Synergy centralized the tornado safe room for superior protection from wind-borne missiles and so occupants may funnel toward the secure central anchor of the building quickly and easily regardless of their location in the building at the time of an emergency or natural disaster. The total occupancy of the tornado safe room is 516 based on a gross area of 4,674 SF that was reduced for egress (15%) and un-concentrated furnishings (35%) in order to calculate maximum occupancy. Synergy provided a maximum tornado safe room occupancy more than double the anticipated typical occupancy of the entire building on a non-event day. The tornado safe room includes the emergency exit corridor that allows safe exit from the safe room in the event that the host structure collapses on top of or surrounding the tornado safe room.

LIFE SAFETY PLAN

The toxic free area is bound by the maroon line while the total gross SF of the community shelter is shaded in purple. Occupants may move freely within the area bound by the maroon line, including the area of the building’s core. All exits from the shelter are indicated by the green triangles. Since the track curves are permanently banked, that area was not counted as usable SF to determine shelter occupancy. The total occupancy of the community shelter is 1,636 people based on providing 60 SF per person since the shelter is designed to accommodate cots for stays longer than 24 hours. The gross SF was reduced by 15% when calculating occupancy to account for egress. Synergy provided community showers and vanity sinks at the southern end of the building’s core for occupants use when the building is serving as a community shelter. Synergy has presented the owner with the option of implementing hydraulic banked curves for the track at an additional cost. The added cost will add 200 people (12%) to the shelter maximum occupancy.

The life safety plan verifies that there is at least 200'-0" from any location in the building to an exit. Because the second floor area is less than one-third of the total square footage of the building, the second level does not require its own fire-rated stair. In the event of an emergency, there is a stair tower at the north and south end of the second level. The bleacher steps may also serve as a means of egress in the event of an emergency.
**DESIGN ITERATION 1 | 90 DEGREE ROTATION**

Synergy's first design iteration of the building's form concept included rotating the building 90 degrees counterclockwise with reference to due North. All auxiliary spaces were repositioned along the western building façade. The existing architectural style remained consistent with the revised building façades. The first design iteration was prompted as an attempt to apply synergy by identifying synergies by aligning column systems.

**DESIGN ITERATION 2 | INTRODUCTION OF THE BUILDING'S CORE**

The second iteration introduced the concept of a building core. The building core is a central space utilized for both the fitness center and core services. The building core serves as a nucleus for the building, allowing for a more centralized and efficient building design. The building core is designed to provide access to core services and amenities throughout the building.

**DESIGN ITERATION 3 | SUMMER CORE WITH PASSAGE**

The third iteration focused on introducing a new concept for the building's core. The concept of a "summer core" was introduced, which would integrate a new central space for the building. This space would serve as a hub for the building, providing access to core services and amenities. The new central space would be designed to be a focal point for the building, allowing for a more dynamic and engaging building design.

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**Table 1: PERFORMANCE**

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**Table 2: DISCIPLINE**

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**Table 3: VALUE**

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<tr>
<td>Sustainability</td>
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**Figure 1: ORIGINAL FLOOR PLAN LAYOUT**

The original floor plan layout was developed to establish the basic framework and initial design concept for the building. This layout served as a foundation for further iterations and modifications.

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**Figure 2: STRATEGY MOVING FORWARD**

The strategy moving forward is focused on maximizing the building's potential by implementing various design solutions. The goal is to create a building that is both functional and efficient, while also being attractive and engaging. This will be achieved through a combination of thoughtful design and innovative solutions.
**DESIGN ITERATION 1 | MAGNIFY WALLS, CONCRETE ROOF, AND POLYCARBONATE WINDOWS**

In order to find design solutions, a number of initial concepts was developed by the design team. The concept wall panel was designed with a combination of precast concrete and panels lower wall and an EIFS wall system upper wall. The precast concrete walls were designed to look a standard brick appearance. The second iteration utilized the same wall panel system with a lightweight metal structure. In the second iteration, wall panels were utilized to isolate wall uplift pressures. The glass transmittance polycarbonate was replaced with laminated glass for light-only.

**DESIGN ITERATION 2 | PREFAB CONCRETE/EIFS WALLS, METAL ROOF, AND LAMINATED SINGLE PANE GLASS**

In order to find design solutions, a number of initial concepts was developed by the design team. The concept wall panel was designed with a combination of precast concrete and panels lower wall and an EIFS wall system upper wall. The precast concrete walls were designed to look a standard brick appearance. The second iteration utilized the same wall panel system with a lightweight metal structure. In the second iteration, wall panels were utilized to isolate wall uplift pressures. The glass transmittance polycarbonate was replaced with laminated glass for light-only.

**DESIGN ITERATION 3 | FULL PREFAB CONCRETE WALLS (NO EIFS SYSTEM)**

In order to find design solutions, a number of initial concepts was developed by the design team. The concept wall panel was designed with a combination of precast concrete and panels lower wall and an EIFS wall system upper wall. The precast concrete walls were designed to look a standard brick appearance. The second iteration utilized the same wall panel system with a lightweight metal structure. In the second iteration, wall panels were utilized to isolate wall uplift pressures. The glass transmittance polycarbonate was replaced with laminated glass for light-only.
StormSafe shutters that pass strict approval

BUILDING CORE FEATURES

1. CENTRALIZED FACILITIES

Four air handling units are positioned on the southern roof of the building’s core. Since the roof of the building’s core was designed to be flat, the units were able to be positioned in a centralized location without giving up square footage within the building. The southern end of the flat roof is lowered several feet in order to hide the air handling units as observed from the north elevation. By centralizing equipment, the duct run length is minimized and the overall efficiency of the air distribution is improved. The ductwork is able to run down the spine of the building and branch out to service the building’s main athletic spaces and auxiliary spaces. Confining the majority of the mechanical ductwork along a central axis minimizes potential areas for system clashes.

2. TORNADO SAFE ROOM & EMERGENCY EGRESS PATH

With an occupancy of 516 people, Synergy designed a 10"-thick concrete tornado safe room that withstands an EF4 tornado and protects the lives of all building occupants. The tornado safe room occupies 4,674 SF and includes an emergency exit corridor for a clear exit path if the host building were to collapse around the safe room. Referencing FEMA 361 and ICC 500, the tornado safe room structure has been designed to withstand EF4 tornado wind pressures corresponding to a wind speed of 250 mph. FEMA 361 instructs the designer to design for the gravity loads and impact loads resulting from the host structure’s collapse onto the tornado safe room. For the 516 occupants of the safe room, 258 SF of venting area is required per ICC 500 Section 702.1.1. The natural ventilation openings will use storm rated Greenheck AFL501 louvers. An on-site emergency natural gas generator is incorporated into the electrical distribution system and will provide two hours of built-in capacity for critical systems. All lighting located within the tornado safe room boundary is on an emergency circuit.

3. MOTOR-OPERATED EMERGENCY SHUTTERS

In order to provide through access within the building’s core without compromising the protection of the tornado safe room, Synergy has specified Qompact StormSafe shutters that pass strict approval tests using wind speeds up to 250 mph (EF4 tornado threshold) for shutters up to 19'-6" wide. Within the boundary of the tornado safe room and the emergency exit corridor, two Qompact StormSafe shutters each 19'-6" x 12'-6" are to be installed. The shutters are also tested to withstand impact tests.

4. GRADE BEAM & IN-GROUND DUCT INTEGRATION

The grade beam along the shared foundation line of the building’s core initially served as a major obstacle for in-ground ducts routed to service the football field. As a solution, Synergy lowered the shared foundation five feet between two drilled belled piers within the conflict area. Three 40" diameter in-ground ducts penetrate the base of the concrete wall of the tornado safe room in order to attach to diffusers servicing the football field. Lowering the grade beam ensured that the structural loads distributed to the soil would not crush the in-ground ducts if they needed to be re-routed underneath of the grade beam. Additionally, Synergy’s solution decreases the amount of duct and excavation required during placement.

5. TRANSFER TRUSS OVER MAIN BLEACHERS

In order to provide an unobstructed view of the competition track, some of the long-span roof trusses could not bear directly on columns that extend to the foundation. To promote versatility, Synergy designed a transfer truss that is 20'-deep and spans 210' to pick up the load from eight of the long-span trusses of the track-side. The transfer truss was designed to be concealed within the two-foot-thick exterior wall, allowing for finishes and any future artwork to enhance the lighting and aesthetics. Any need for a transfer truss along the supplemental bleachers was eradicated by Synergy’s decision to extend the track-side roofline an additional 20’ and bear the trusses on columns located behind the bleachers.

6. INTERIOR LOBBY & MAIN ENTRANCE

By adding the building core, Synergy created a prominent entryway that makes the architecture more pronounced and inviting. Within the main entrance is a grand lobby space that features Texas Tech University student athletes on a signature, interactive Performance Wall. Also highlighted in the grand lobby is the building’s WELL Gold Achievements on a WELL Wall. The grand lobby is designed to be an attractive feature of the building in order to impress athletes and recruits. A receptionist helps direct occupants flow during events and normal use.

TEXAS TECH SPORTS PERFORMANCE CENTER
LUBBOCK, TEXAS 79409

BRIAN REED
February 22, 2017
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DATE
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TEAM NO.

TEXAS TECH

BUILDING CORE
DEPRESSED ROOF FEATURES

DEPRESSED ROOF FEATURES

MAIN ATHLETIC SPACE VOLUME REDUCTION

Rather than extruding the roof profile in order to allow for north-facing clerestory glazing, Synergy's discipline teams collaborated to depress the roof in alternating column bays. By integrating the long-span roof trusses within the high points of the depressed roof profile, the minimum clearance from the playing surface to the bottom of structure was able to be maintained even at the locations of the roof depressions. The structural design of the trusses saves 5'-0" of building height while an additional 10'-0" of building height is saved at locations of the depressions. In total, 17% of main athletic space volume is saved with Synergy's depressed roof design. This translates to a 5% reduction in heating and cooling loads.

COPLANAR LONG-SPAN ROOF TRUSSES

Synergy designed innovative, coplanar long-span roof trusses comprised of square A500 Gr. C HSS members. Truss depth was optimized to be 10'-0", and a roof framing configuration permitted roof depressions in the roof profile while still maintaining minimum height restrictions over the athletic spaces. The lower roof is supported by secondary framing that frames into the bottom chord of each truss while the upper roof is supported by secondary framing that frames into the top chords of each truss. The coplanar geometry of the long-span trusses aids in providing diaphragm continuity and lateral stability.

UNIFORM DAYLIGHT DISTRIBUTION

A uniform daylighting scheme is created with Synergy’s depressed roof design. The difference in daylight distribution illustrated in the figure to the left clearly demonstrates the improved daylight uniformity from the original roof design to Synergy’s integrated clerestories. Serfas calculations computed the Daylight Autonomy for 460 lux, given the field illuminance requirements. In the final design, the football field has an average of 55% DA, and the track and field an average of 72% DA. Improved Daylight Autonomy allows for daylight harvesting and corresponding energy savings.

TRUSS-ASSEMBLY ERECTION

In order to expedite construction, all roof trusses will be fabricated in shop with welded connections. Trusses will be shipped to site in 50’ to 60’ segments, eradicating the need for special transportation permits. Once on site, the truss segments will be connected with high-strength bolts, eliminating the need for field welding and on-site weld inspections. Synergy’s structural and construction teams collaborated to erect two adjacent trusses together by connecting them with their upper purlins. An entire truss assembly consisting of two complementary trusses and their upper purlins will be erected as one system, avoiding the need for temporary vertical and horizontal shoring. This saves 14 days in construction.

TRUSS-MOUNTED FLOOD LIGHTS

The main athletic spaces implement high output SpecGrade LED floodlights in order to provide uniform light onto the playing surfaces. The fixtures are spaced evenly along the trusses, providing uniform illumination. The fixtures are mounted to the bottom chord of each truss using a custom clamp attachment, with all wiring running within conduit attached continuously along the truss’s bottom chord. For both the football field and track & field floodlighting design, all fixtures mounted to the same truss are placed on the same branch circuit, reducing wiring which inevitably reduces cost.

AUTOMATIC OPERABLE WINDOWS

The operable clerestory windows are controlled to open and close as desired. A compact device to open the windows was required in order to integrate best with the roof trusses. The SE Controls Two SECO Ni 24 40 was chosen to meet this requirement. Two chains are used to open the window a maximum of 30’. Synergy ensured that before a tornado, the windows would close and lock automatically. This fully encloses the structure and mitigates the risk of a structural breach. Electromagnetic locks will be used to seal the gap and hold the windows in place during an emergency or natural disaster.

DISPLACEMENT HYBRID VENTILATION & HAIKU FANS

Synergy’s depressed roof design enables a seasonal control cycle for the building varying between natural ventilation and forced displacement ventilation. When outdoor air conditions do not allow for natural ventilation, displacement ventilation is utilized to provide ventilation and occupant comfort. Displacement ventilation allows for a lower supply air temperature in the space because supply air is at occupancy level. In tandem with operable windows, warmer air may be drawn from the building. Contaminants may also be removed by flooding fresh air at the ground level of the main athletic spaces and forcing contaminants up and out of the building. Haiku fans positioned within the high points of the roof profile contribute to forcing warm air and contaminants out of the building. In total, displacement hybrid ventilation saves 30% source energy and 50% on-site fan energy.

MODULARIZED GLASS PANES

Since operable windows were required in order to implement displacement hybrid ventilation, Synergy devised a radial mullion configuration. The radial mullions are spaced 6'-3” apart to align with the panel points of the truss. Synergy ensured that the same constant radius was maintained between the roof profiles of both main athletic spaces. By doing so, the glass panes were standardized to five types for the clerestory glazing.

COPLANAR LONG-SPAN TRUSS ASSEMBLY

Synergy's discipline teams collaborated to depress the roof in alternating column bays. By integrating the long-span roof trusses within the high points of the depressed roof profile, the minimum clearance from the playing surface to the bottom of structure was able to be maintained even at the locations of the roof depressions. The structural design of the trusses saves 5'-0" of building height while an additional 10'-0" of building height is saved at locations of the depressions. In total, 17% of main athletic space volume is saved with Synergy’s depressed roof design. This translates to a 5% reduction in heating and cooling loads.

CONNECTING TRUSSES

Synergy's depressed roof design enables a seasonal control cycle for the building varying between natural ventilation and forced displacement ventilation. When outdoor air conditions do not allow for natural ventilation, displacement ventilation is utilized to provide ventilation and occupant comfort. Displacement ventilation allows for a lower supply air temperature in the space because supply air is at occupancy level. In tandem with operable windows, warmer air may be drawn from the building. Contaminants may also be removed by flooding fresh air at the ground level of the main athletic spaces and forcing contaminants up and out of the building. In total, displacement hybrid ventilation saves 30% source energy and 50% on-site fan energy.

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A uniform daylighting scheme is created with Synergy’s depressed roof design. The difference in daylight distribution illustrated in the figure to the left clearly demonstrates the improved daylight uniformity from the original roof design to Synergy’s integrated clerestories. Serfas calculations computed the Daylight Autonomy for 460 lux, given the field illuminance requirements. In the final design, the football field has an average of 55% DA, and the track and field an average of 72% DA. Improved Daylight Autonomy allows for daylight harvesting and corresponding energy savings.

TRUSS-ASSEMBLY ERECTION

In order to expedite construction, all roof trusses will be fabricated in shop with welded connections. Trusses will be shipped to site in 50’ to 60’ segments, eradicating the need for special transportation permits. Once on site, the truss segments will be connected with high-strength bolts, eliminating the need for field welding and on-site weld inspections. Synergy’s structural and construction teams collaborated to erect two adjacent trusses together by connecting them with their upper purlins. An entire truss assembly consisting of two complementary trusses and their upper purlins will be erected as one system, avoiding the need for temporary vertical and horizontal shoring. This saves 14 days in construction.

TRUSS-MOUNTED FLOOD LIGHTS

The main athletic spaces implement high output SpecGrade LED floodlights in order to provide uniform light onto the playing surfaces. The fixtures are spaced evenly along the trusses, providing uniform illumination. The fixtures are mounted to the bottom chord of each truss using a custom clamp attachment, with all wiring running within conduit attached continuously along the truss’s bottom chord. For both the football field and track & field floodlighting design, all fixtures mounted to the same truss are placed on the same branch circuit, reducing wiring which inevitably reduces cost.

AUTOMATIC OPERABLE WINDOWS

The operable clerestory windows are controlled to open and close as desired. A compact device to open the windows was required in order to integrate best with the roof trusses. The SE Controls Two SECO Ni 24 40 was chosen to meet this requirement. Two chains are used to open the window a maximum of 30’. Synergy ensured that before a tornado, the windows would close and lock automatically. This fully encloses the structure and mitigates the risk of a structural breach. Electromagnetic locks will be used to seal the gap and hold the windows in place during an emergency or natural disaster.

DISPLACEMENT HYBRID VENTILATION & HAIKU FANS

Synergy’s depressed roof design enables a seasonal control cycle for the building varying between natural ventilation and forced displacement ventilation. When outdoor air conditions do not allow for natural ventilation, displacement ventilation is utilized to provide ventilation and occupant comfort. Displacement ventilation allows for a lower supply air temperature in the space because supply air is at occupancy level. In tandem with operable windows, warmer air may be drawn from the building. Contaminants may also be removed by flooding fresh air at the ground level of the main athletic spaces and forcing contaminants up and out of the building. In total, displacement hybrid ventilation saves 30% source energy and 50% on-site fan energy.

MODULARIZED GLASS PANES

Since operable windows were required in order to implement displacement hybrid ventilation, Synergy devised a radial mullion configuration. The radial mullions are spaced 6'-3” apart to align with the panel points of the truss. Synergy ensured that the same constant radius was maintained between the roof profiles of both main athletic spaces. By doing so, the glass panes were standardized to five types for the clerestory glazing.
FULLY TEMPERED, LAMINATED INSULATED GLASS UNITS

The Viracon 1.2M was chosen for its significant light to solar gain ratio of 1.8. This material maintains high visible transmittance, while drastically improving thermal performance and preserving durability. The clerestory glazing selection is the same as the north facade, while all other building glass is a laminated IGU with less visible transmittance, to comply with the ASHRAE stipulation of SHGC < 0.25. This glazing type, all other building glass is designed to be resistant wall assemblies.

IMPACT-RESISTANT FAÇADE

In order to develop an impact-resistant façade, Synergy selected a Factory Mutual Approved roof assembly. In summary, an approved wall assembly passed testing from the impact of a 15 pound 2x4 wood stud with a missile speed of 100 mph. A version of each selected wall assembly and its corresponding test threshold speed may be observed in the above table. Though the terracotta rain screen is not rated for impact, it is rated for wind pressures up to 190 psf, enough to resist wind pressures and suction experienced during an EF3 tornado.

FM-APPROVED ROOF ASSEMBLY

In selecting a roof assembly, Synergy referenced RoofNav, a complimentary design tool from FM Approvals that provides access to FM Approved roofing products and assemblies. Synergy was able to select a Factory Mutual Approved roof assembly that is approved for an uplift of 180 psf, providing a factor of safety of 2 against EF3 tornado wind roof uplift pressures. Referencing testing results from Texas Tech University and the University of Florida, a similar roof assembly experienced no penetration or perforation at a threshold speed of 74 mph which is larger than the FEMA 361-specified missile speed of 67 mph for horizontal surfaces. The roof R-value is R-25 (25% over the specified code minimum).
0.0 EXECUTIVE SUMMARY

Integration
Synergy utilized an Integrated Design Build delivery method for the Texas Tech University Sports Performance Center project. The Synergy team worked in a co-location work area to maximize design input and reduce future change orders. The team also participated in events outside of the work environment to strengthen the comradery and relationships between members. Having the Construction team on early in the design process proved to be very beneficial. The Construction team was able to offer constructability, cost, and schedule information that helped the Design team create the most optimal facility for Texas Tech University. The use of Lean Tools such as Last Planner System and Cross-Disciplinary Communication allowed the members of Synergy to exchange information in the most efficient way possible.

Owner Defined Challenges
Synergy was able to reach Texas Tech University’s target goal of $46 million even after adding 17,000 SF to the building. While the building enclosure is rated to withstand an EF3 tornado, an EF4 rated tornado safe room was incorporated into the core. The exterior wall assembly created a secure shell that will resist a 100 mph projectile. The new wall assembly also helps decrease the schedule by eight months. If chosen by Texas Tech University the new robust structure and schedule acceleration adds $4.37M. The Sports Performance Center reaches a WELL Gold Standard while also reducing energy usage by approximately 61%. This added a cost of $3.05M but due to the energy savings, will be paid back within 30 years. Synergy has set up cost packages that breakdown each owner defined challenge. The Construction team is confident if any of these packages are selected, the owner can expect a high-quality project.

Constructability
Synergy’s Construction and Design team collaborated to determine the constructability of major components. The truss assembly was designed to be shipped to site in four, 50’ sections that will be bolted below their final location. A clerestory detail was created to show major connections points. The exterior wall assembly connection was discussed so moisture and heat loss does not occur. The Construction team also created a maintenance plan for components like the glazing in the clerestories, the custom AHUs, and the BlueDuct underground ductwork. By working with the design team, the construction team believes that the installation, quality, and maintenance of the entire building will allow the Sports Performance Center to stand as a staple for Texas Tech University.

Technology
The Sports Performance Center is built for the student athletes of Texas Tech University. Synergy will enhance the experience of the athletes and recruits by implementing new technologies. WELL walls, athlete kiosks, and nutrition walls will be used throughout the building. The WELL wall will showcase healthy behaviors and routines that a student athlete should follow. The player kiosks will display past student athletes and their accomplishments for other athletes to be inspired by. The nutrition wall will be placed in the fuel station to show health facts of different food/drink options. Synergy believes the student athletes are the focus of the new building and these technologies will certainly elevate their experiences.

Schedule Reduction
Synergy decreased the schedule by eight months through an integrated design process, innovative construction sequencing, and by prefabricating wall assemblies. When fast-tracking a schedule by a large duration, quality has higher odds of lower however, Synergy’s Construction team is confident in the quality of construction of the Sports Performance Center. By utilizing Advanced Material Tracking, a process that tracks where, when, how far, installation time, and maintenance of all materials, Synergy ensures a high quality product. Also, a detailed Site Specific Safety Plan to address the wellbeing of the community during construction. Synergy will work diligently with the owner to turn over the project eight months ahead of schedule.
1.0 PROJECT INTRODUCTION

1.1 BUILDING BREAKDOWN

The Texas Tech University (TTU) Sports Performance Center is an indoor track and football practice facility in Lubbock, Texas. The facility serves as an investment towards the future of both the football and track & field program. With a state-of-the-art Sports Medicine wing, the Sports Performance Center caters to the athletes and facilitates excellence. With the iconic bell tower, the Sports Performance Center embodies Texas Tech University traditions while introducing a new landmark for the community to enjoy.

1.2 SYNERGY’S MISSION

Synergy was committed to designing a Performance Center that embodied the TTU community and strived to aid in athlete development. Synergy proposed an innovative architectural structure coupled with an impact resistant facade that provides a secure resilient shell for the TTU community. With the addition of a pioneering roof design, Synergy plans to achieve the stakeholders’ goals by producing a facility that not only supports the needs of the athletes, but adapts to future growth.

2.0 PROJECT THEMES

Synergy created project themes of Value, Resiliency, Performance, and Versatility to align with Texas Tech’s vision of creating a project that benefits the athletes and community. The project themes were created from the project goals set forth by TTU, see Integration Report section 3.0. Synergy’s strives to deliver a project of the highest quality while maintaining the budget and fast tracking the construction schedule. For the health of the athletes and community, the construction team will use environmentally friendly materials and put the safety of the community, athletes, and staff as the highest priority.

VALUE

The construction team focused on using innovative scheduling techniques, along with an extensive management system to allow for early occupancy and easy use of the building.

RESILIENCY

The sequence of construction focused on completing a weather resistant safe room as early as possible to act as a safe haven for the community in a disaster situation.

PERFORMANCE

Low volatile organic compounds (VOCs) and environmentally friendly materials were utilized and an innovative distribution system lowered the energy consumed by the project.

VERSATILITY

With the use of virtual reality technologies like Google Cardboard and the HTC Vive, the construction team was able to provide a unique opportunity for the owner to supply input to the design.

3.0 DELIVERY METHOD

Synergy utilized an Integrated Design-Build project delivery method during the design and construction of the Texas Tech University Sport Performance Center. This method allowed for increased collaboration and communication between the members of Synergy and the owner. The contractual relationship between Synergy and the owner can be referenced in Figure 1.

Figure 1. Project Delivery Method Diagram
An Integrated Design-Build approach allowed the Construction team to have early input into all design decisions. The Construction team assisted the Design team to ensure proper constructability of all elements. A more integrated construction method has also been proven to reduce the overall schedule. Changes occur early in the design process rather than during construction which saves time and effort. The integrated method also shifted the design risk to the Synergy team, allowing the risk on the owner to decrease. Synergy believed an Integrated Design-Build project delivery method was the best way to meet the project and owner’s goals. For more information on the chosen Delivery Method see Construction SD – B.

3.1 WORK SPACE

Communication and collaboration are key components in the Integrated Design Build delivery method. To further achieve communication and collaboration between the Design and Construction teams, a co-location workspace was created. This space was utilized throughout the entire design phase and a similar space will be used during construction. The co-location workspace layout referenced in Figure 2.

The layout of the approximate 800 square foot co-location work area lends itself to a collaborative environment. With the Design and Construction team spread throughout the workspaces, any questions or concerns that arise can be communicated to produce a time efficient response. This reduced the amount of RFI’s and change orders that occur within the team. Always working in the same location allowed Synergy to continuously integrate and work towards common goals.

3.2 DECISION MATRIX

Throughout the design process of the Sports Performance Center, there were numerous high priority and critical decisions that needed to be made. It was important to establish a matrix that utilized a weighted criterion based on the Construction team’s critical goals to make unbiased decisions. To do this, a Decision Matrix was created using the four project themes and goals within each theme, discussed in Section 2.0. See Drawing I-1.0 for a detailed breakdown of Synergy’s goals. To view the constructability decision matrix that breakdown decisions concerning construction, see Construction SD-A.

3.3 COMMUNICATION STRATEGIES

Synergy utilized many forms of communication to ensure that accurate information traveled between disciplines. For a full list of communication strategies utilized, see Integration Report Section 6.4. The Construction team oversaw the Last Planner events where the entire team created a look-ahead schedule to track the design progress based on system design advancement. The Construction team also conducted cross-disciplinary checkups where each construction member collaborated with other disciplines to track the work completed. The work completed was then recorded in Synergy’s Integration Log which may be referenced in Integration SD-B.

3.3.1 LAST PLANNER SYSTEM

A great way to open the lines of communication between team members is to use the Last Planner System (LPS), a Lean technique. When using LPS, a team works with the end in mind and establishes different goals that each member needs to meet. By openly discussing what each member requires from the others, a look-ahead schedule can be created. The Last Planner System relies heavily on a network of trust between all members. Each member must promise to accomplish tasks by the agreed upon deadlines. Synergy takes great pride in the trust among its team members, so the Last Planner System lends itself nicely to the Design and Construction teams. A sample of the Last Planner System can be seen in Figure 3.
3.3.2 CROSS-DISCIPLINARY

Synergy felt that having a direct line of communication between disciplines was an important component in creating a cohesive team. The Construction team consisted of three members, each were assigned a discipline to serve as a personal management resource. To ensure that Design team factored in constructability, the Construction team tracked material availability, system cost, delivery, maintenance, and life cycle cost. After meeting with each discipline, the Construction team would meet to discuss possible system constraints that would affect sequencing, material delivery, and budget.

4.0 SITE ANALYSIS

One of the first steps prior to designing a new project is to analyze the site. Understanding all facets of the given site was critical to the overall success of the construction project. The new Sports Performance Center will be located to the North-East of Memorial Circle, the center of the Texas Tech campus, and directly south of Jones AT&T Stadium. A visual representation of where the site is located on campus may be referenced in Figure 4.

Figure 4. Site Map

The site is bordered on the West and South sides by Red Raider and Akron Avenues, both of which are single lane car and bus roads. The North side is a pedestrian only continuation of 6th Street and the East side is bordered by Texas Tech University’s Football Training Facility. Beyond the continuation of 6th Street the North side borders TTU’s Jones AT&T Football Stadium. Being bordered by a heavy traffic pedestrian walkway provides a challenge for the construction team, both in safety and logistics. The solution to these challenges will be discussed in sections 4.3 and 4.4.

4.1 ZONING

Along with the 2012 International Building Code, the City of Lubbock’s Code of Ordinances was utilized to understand requirements on setbacks, building height, lot area, and property lines. TTU’s Sports Performance Center was previously zoned as an Educational Institution and therefore does not need to be rezoned. With thorough code and ordinance review, Synergy was more than comfortable working with City of Lubbock Code Officials to verify zoning and inspection requirements for setbacks, parking, plumbing, electrical, mechanical, fuel and natural gas, and signage. With an intense schedule reduction, Synergy planned to have a City Code Official present at all meetings throughout the design and construction of the project.

Figure 5. Original Footprint vs. Synergy Footprint

During the beginning stages of design, it was important to understand requirements on setbacks and height limitations. According to Lubbock’s District Sec. 40.03.1035 of the Code of Ordinance, there is a minimum “front yard” space of 25 feet and a 10 foot “side yard” requirement for all other sides. With Synergy’s increased square footage, it was important to meet these setback requirements. Currently there is 40 feet of front yard space, 90 feet of west side yard space, 40 feet of space east side yard space, and 20 of rear yard space exist, see Figure 5 for reference. The setbacks of Synergy’s new design meets code requirements but offers logistical challenges to overcome. By coordinating deliveries, solutions can be produced. Due to the limited space between the Football Training Facility and the Sport Performance Center, Synergy planned to utilize the automobile portion of 6th Street for deliveries intended for the East wall. Once the enclosure was completed on the East side the entrance/exit in the North-East corner will return to a construction exit only. The proximity to the South-West sidewalk also posed an aesthetic challenge. Synergy planned to employ unique landscaping to give this corner less of a visual impact.
4.2 EXISTING SITE CONDITIONS

The Lubbock area is known for its flat land and dry climate. These qualities make the area susceptible to dry clay and sand subsurface materials and tornadoes. Lubbock, Texas is known for one of the worst tornadoes in Texas history. In 1970 Lubbock Texas experience a EF5 tornado which caused over $1.5B of damage and took 26 lives. Synergy’s goal was to overcome some of the devastation that is associated with natural disasters by creating a facility that serves as a safe haven during times of distress.

The subsurface conditions of Lubbock also posed challenges. After a thorough Geotechnical analysis, which included 14 geotechnical borings, it was determined that the land where the new Sports Performance Center will be situated possess typical loamy soils with the potential to shrink and swell with moisture changes. However, soils with high shrink-swell potential are not found on the TTU site. The upper 10 feet of soil contains low to moderate clay, which limited substructure design options. The 14 borings were tested to 30 feet beneath the surface. It was determined that the material at 30 feet offers enough strength and resistance to sustain normal building loads. This supports the idea to use drilled piers and grade beams for foundational support throughout the new Sports Performance Center. For further detail, see Structural Report section 10.1 or Structural SD-C. The drilled pier substructure is more costly and time consuming than a typical foundation. However, the Construction and Structural team spent extensive amounts of time optimizing the piers to reduce cost and installation time.

4.3 SITE SAFETY

As stated in the Site Analysis Section, the Sports Performance Center will be located in the Northeast corner of the TTU campus. It neighbors highly populated buildings and roadways and it is Synergy’s job to keep everyone safe at all times. To ensure the safety of the workers and pedestrians Synergy created a Site-Specific Safety Plan (SSSP), seen in Construction SD-C. At the North end of the site sits Texas Tech University’s Jones AT&T Football Stadium. To secure the North side of the site, Synergy used continuous wire fencing with no entry/exits to the site. The fencing will also offer a full-size marketing banner that will stop or subside large gusts of wind that could potentially carry dirt or debris onto the sidewalk. Along Red Raider Ave and Arkon Ave Synergy utilized a jersey barrier enclosure. The barrier will be 3 feet of concrete topped with 5 feet of wire fence. The jersey barrier and wire fence combination was chosen to prevent any disruptions from construction equipment onto the busy Avenues. During anytime of the construction schedule Synergy maintained a minimum of 2 vehicular and foot entry/exit points. Throughout construction Synergy will have full time site surveillance with the use of multiple OxBlue cameras and worked with Texas Tech University’s campus police to further ensure safety on and around the site during off hours.

4.4 SITE LOGISTICS

To understand site logistics, Synergy worked with Texas Tech University to determine the best possible way to transport materials to and from the site. Extensive research was put into determining methods that would affect the normal operations of campus as little as possible.
three certified flaggers to ensure pedestrian and driver safety. Synergy’s on site office trailer was located on the R24 Parking Lot just South of the site. This parking lot has just under 70 parking spaces each of which cost $3,000 to rent per calendar year. Locating the site trailers in this area throughout the duration of the project will cost Synergy an additional $420,000. However, due to limited site space and tight deliveries, Synergy believed that the additional cost was necessary to allow the maximum amount of space for construction.

4.5 SITE PHASES

The new Sports Performance Center will be constructed in four main phases: substructure, track, auxiliary, and football. The auxiliary phase will include the construction of the center core space, which is where the safe room is situated. Once the substructure is completed, construction will begin in the North end of the football side and work South. Once the football structure is complete, the track will follow the same sequence. The center core area will be constructed concurrently with the track side so it can be utilized in the chance of natural disaster during construction.

Synergy will utilize two large mobile cranes to construct the superstructure. To fast track the schedule, a third smaller crane will be used to construct the structure of the auxiliary space. This crane will also be used throughout the project for exterior wall panels and material picks. Adding an extra crane increases general condition cost by $225K but allowed the construction team to optimize the sequencing plan. By adding a second crane, the schedule was decreased by approximately 3 weeks. The large mobile crane chosen, associated cost, critical pick, assembly, max load calculations, and other information can be viewed on Construction SD – D.

5.0 DESIGN CHANGES

5.1 PROGRAM CHANGES

The overall floor plan for the Texas Tech Sports Performance Center was changed to better meet the TTU and Synergy project goals. The new floor plan also helps meet the challenges set forth in sections 8.0, 9.0, and 10.0. The transformation of the floor plan can be seen on Drawing I-5.1. Moving the auxiliary spaces and other areas that are not the track or football field into the new core space allows for more flexibility for the owner. It also creates a better flow through the building and centralizes the nourishment and restrooms for the athletes and spectators. The spectators who come to the events also have an easier time getting through the spaces. The changes create a more secure and resilient building for all occupants. Synergy kept the sizes of each area the same but added a second floor in the core to meet our goals.

The additions increased the square footage of the building by 17,000 square feet. This added an initial cost of $2.4 million to the original target value. Even though these changes increased the initial target value, the Construction and Design team collaborated to optimize systems to still reach the target value of $46 million. This breakdown is discussed in section 8.0. The new layout also creates a better building overall and allowed for a more efficient schedule, discussed in section 8.2.

5.2 EXTERIOR ENCLOSURE

The enclosure for the building was an innovative focal point of Synergy. The enclosure must be rated to withstand resilient enough to withstand an EF3 tornado, resist an impact load from a projectile traveling at 100 mph, meet an R-Value of 20, and adhere to the Texas Tech University architectural style. The following changes were made during the design phase.

5.2.1 ROOF

Synergy found the roof to be a perfect area for integration between the design and construction teams. The roof will need to withstand not only the impact load of a projectile but also the uplift created by an EF3 tornado. For these two goals to be met, the composition of the roof must be heavily considered,
with emphasis on the quality of connections between the roof materials and the structure. A 3D schematic of the roof composition can be seen in Figure 9 and fastener spacing can be seen on Drawing S-9.0.

The clerestories offer operable windows on the North of the clerestories; allowing natural light to enter the track and football field and helping create a natural flow with the help of haiku fans. The addition of these clerestories added a cost of $469K to the project. To decrease the impact of this substantial cost the Construction and Design team worked together to lower the overall roof height, while still maintaining the 65 foot height requirement, to save cost on the exterior enclosure. By lowering the roof, Synergy reduced the exterior wall by 5340 square feet, saving the project $116K. This offset the cost of the clerestories to $353K. With any team decision, it is not guaranteed that every member will benefit. However, Synergy was able to integrate to minimize the cost impact placed on the Construction team due to the clerestories.

5.2.2 Facade

The composition of the facade wall section was one area the construction team felt could accelerate the project schedule, later discussed in section 8.1. The facade is split into two different materials. The lower section (0 feet to 24 feet) is precast concrete panels with a stamped brick face and the upper section is a prefabricated double metal stud, 14 gauge steel sheet, and plywood wall. A 3D schematic can be seen in Figure 10 and detailed sections can be found in Drawing C-1.0.

The panels will extend to 24’ and wrap around the entire building. The sizing and delivery of the panels are very critical for efficient installation.

The size and material layout of the panels can be found on Drawing C-9.0. To ensure that deliveries run smoothly and not take up valuable site area, a Just-In-Time (JIT) delivery method will be implemented. This method will be discussed further in Section 8.2.

The prefabricated double metal stud, 14 gauge steel, and plywood wall section will extend from 24’ to the roof of the track and football areas of the building. The finish on the upper roof will be a terracotta tile rain screen. This wall assembly was chosen from impact testing designs done by Texas Tech University. The structural details of the facade can be found in Structural Report section 11. By choosing to precast and prefabricated our wall panels, Synergy cuts 150 days off the schedule. Not only is the panelized wall sections great for the schedule, they are also able to resist EF3 wind speeds and projectiles, while increasing the R-value of the wall from 27 to 32. Synergy’s new wall assembly perfectly encapsulates the integration between the Synergy team.

6.0 CONSTRUCTABILITY

One advantage of an Integrated Design Build project delivery method is the early involvement of the Construction team. This early involvement allows for constructability review meetings to take place between the Construction and Design teams. These reviews allow the construction team to reduce or prevent major errors from occurring as they are identified in the design phase rather than in the construction phase. This reduces cost overruns, delays, and can provide innovative strategies for construction. Some of the major constructability review meetings are discussed below.

6.1 STRUCTURE REVIEW

One of the most critical aspects of the Sports Performance Center is the massive structure designed to withstand an EF3 tornado. A major point of integration between the Synergy team was the roof and the truss structure. Not only are the trusses on the critical path, but they also control the largest pick size and add a large amount of lead time to the project. To meet the goals of the owner and Synergy, the truss design needs to be Resilient but at the same time constructed easily. The numerous constructability review meetings between the structural design and
construction teams helped the truss design meet both of these goals.

One of the major concerns with the truss design was the amount of connections needed to construct the truss. The Construction team saw an issue with welding the connections on site. Welding would be very unsafe because of the height of the trusses. It would also be very time consuming and increase the overall schedule. To solve this problem, the two teams worked together to optimize sections of the 200’ truss. The trusses were split into four sections, cutting the truss in precise locations to reduce the amount of on-site welds, and the sections were shipped to the site prefabricated with the members welded. By implementing these ideas, the amount of bolted connections on site was greatly reduced. The construction of the trusses can be found on Construction SD - D

Another element of the truss design that was changed during the constructability reviews was the composition of the truss members. Before the reviews, the trusses consisted of round hollow structural steel (HSS) members. Some issues arose when using these members. One issue identified was with the welded connections between the HSS members. With a round member, welding is difficult and attaching the wall and roof materials to the trusses would be an issue. To fix this problem a simple choice was made, switching the members to rectangular hollow structural steel.

6.2 ENCLOSURE REVIEW

When looking at the constructability of the enclosure system, it was important to the construction team that that the connection details were clear. These details would include the connection of the precast concrete panels to the steel structure, the transition between the precast concrete panels and the prefabricated metal stud system, and detailed drawings of the clearstory connections. With clear and concise connection details, the amount of RFIs and change orders will be decreased during the construction of the project. The connection details can be found on Drawing C-1.0.

6.3 MEP REVIEW

Another benefit to moving the auxiliary spaces into a new core area is being able to centralize the mechanical equipment, seen on Drawings M-1.0, 1.1, 1.2. The Design and Construction team found this centralization to be very beneficial. With the mechanical room being between the track and field, the runs for ducts is reduced. This helps with the efficiency of the systems and also reduces costs.

To increase the comfort for the athletes and visitors of the Sports Performance Center, Synergy will be using a displacement ventilation combined with natural ventilation system. This system is further broken down in the Mechanical Report section 8.0. In a large volume space, displacement ventilation provides the opportunity to condition and ventilate air at occupancy levels. This is done by supplying low and exhausting air upward into unoccupied volumes. To accomplish this, the Mechanical team designed a creative, underground duct system. This proposes challenges that the Design and Construction team must solve. The first problem is the upfront cost. The underground duct system was $659K more expensive than the original system. However, the energy savings allow for a life cycle analysis to be performed, see section 8.3. Also, the mechanical ductwork must be installed early in construction and protected from large equipment. Finally, with the ductwork running underground, it must penetrate the substructure. The design and construction team planned the duct layout carefully so as to not compromise the substructure. A 3D coordination model showing the detail can be seen in Figure 11.

Figure 11. 3D Coordination between ducts and substructure

6.4 QUALITY ASSURANCE

To provide the highest quality to the owner, Synergy used a quality assurance checklist. The checklist was utilized when a certain material was installed. For a quality assurance checklist to be successful, the planning must be tracked and kept current with the construction that is currently being done. Due to the flow of events in construction, the day-to-day activities will change and if the plan does not change with it, confusion and delay will occur. The Construction team
tracked the construction process and made changes to the quality assurance checklist as needed. The checklist is a part of Synergy’s advanced material tracking strategy, which can be found on Drawing C-8.0.

7.0 COST BREAKDOWN

The owner, Texas Tech University, set forth three project goals: a tornado resilient structure, meeting WELL silver and reducing energy by 50%, and reducing the schedule by 8 months. Synergy’s Construction and Design teams felt confident that they could provide the owner with all three of these goals. However, an additional cost will need to be added in order to accomplish each goal. Synergy is confident that the benefits of implementing the owner-defined goals greatly outweighs the added cost, $7.42 million.

While not being a direct goal of the owner, the budget of the new Sports Performance Center needed to be carefully considered. In the next sections, the Construction team will break down the approach of tracking the budget. The Construction team understood that the project goals are associated with an added cost and TTU may not have the budget to implement all of the goals to the project.

7.1 BUDGET EVOLUTION

The initial budget for the project was set at $48,000,000. This budget included a $2 million dollar addition for a defining art feature. The construction budget for the project then becomes $46,000,000. This number became the project’s Target Value. The construction team worked with the design team to keep the budget of the project below $46 million. Figure 8 shows the evolution of the project budget through the design. Synergy, even though adding 17,000 square feet, was able to work the budget back to the Target Value. The baseline estimate was formed by a combination of a square foot estimate and comparison estimate. The owner project goals add approximately $7.42 million to the overall budget.

7.2 ADD ALTERNATES: PROJECT GOALS

The complexity of the owner defined goals is best presented in a series of add alternates. Synergy fully utilized the budget given by offering a more efficiently designed Sport Performance Center. However, some of the large costs associated with the owner defined goals cannot fit into the given budget and are thus presented to the owner as add alternates.

7.2.1 EIGHT MONTH SCHEDULE REDUCTION

Reducing the schedule by 8 months allows the Sports Performance Center to be occupied before the 2019 Fall semester. The track and football team can both use the building earlier. Also, construction during the 2019 Fall and 2020 Spring semesters will not occur, which could be a distraction for class and also football games. This helps Texas Tech show off the facility to future recruits, which helps grow their sports programs.

The fast track schedule is made possible by the integration between the Synergy team, an extensive sequence plan, prefabricating materials, and advanced material tracking. The added cost of accelerating the schedule is $2.58 million. However, the decrease in schedule cuts general conditions cost by $318K. This brings the total cost of the accelerated schedule to $2.26 million.

7.2.2 ROBUST STRUCTURE

Constructing a building that can withstand an EF3 tornado requires a stronger structural system, more steel, and impact resistant walls and windows. The EF4 safe room also requires more concrete and rebar to construct. The value of a stronger structure is evident; it will save lives. Having a safe haven for the Lubbock community is immeasurable. The added cost for the more robust structure is $4.37 million. However, this

Figure 12. Target Value Tracking (See Drawing C-6.0)
cost includes $2.26 million for the prefabricated wall panels on the exterior because the new walls offer impact resistance of 100 mph projectiles.

### 7.2.3 WELL & 50% ENERGY SAVINGS

The WELL Building Standard focuses on the health and mind of the occupants. In an athletic facility, the well-being of the athletes is very important. A student athlete spends most of their time working out, participating in events, or going to class/studying. Synergy wishes to give the athletes a space that is comfortable and inviting. The team also would like to reduce the overall carbon footprint of the building by saving 50% energy.

To meet a WELL silver rating and reduce energy, the Synergy team incorporated the use of a fuel cell, a distributive air system, and higher end finishes. The added cost of this project goal is $3.05 million. A benefit of this goal is the payback period of the fuel cell and mechanical system. The lifecycle cost analysis can be found on Drawing C-6.0.

### 8.0 SCHEDULE

#### 8.1 FAST TRACKING

Texas Tech University starts the design phase of the performance center in May 2017. The anticipated full project timeframe is 34 months including design, documentation preparation, approvals, construction, and completion of all interior sport venues. Substantial completion is currently set for March 2020. To challenge the team, Synergy will reduce the construction schedule by eight months so the project will reach substantial completion in July 2019, before the fall semester commences. The overall schedule, with comparison can be further analyzed from Drawing C-2.0 to C-5.0.

### 8.2 STRATEGIES

To reduce the project duration by 8 months, the Construction team will work with the Design team to develop a strategic plan to reduce durations of tasks. Some strategies Synergy plans to use include prefabrication, Just-In-Time Delivery (JIT), and intense construction sequencing.

#### 8.2.1 PREFABRICATION

Prefabrication is the practice of assembling components off site and then transporting the components to site when needed. Just-In-Time delivery is a technique used when there is a lack of storage space on site. Prefabrication and as needed delivery reduces the number of tasks completed on site and thus reduces construction duration. Prefabrication is known for decreasing schedule and labor cost while increasing quality, aspects extremely important to the success of the construction of the new Sports Performance Center. To make prefabrication effective, Synergy’s construction and design teams collaborated on the creation of an intense BIM plan where prefabricated assemblies were determined. Synergy found opportunity to prefabricate exterior auxiliary wall panels and the structural truss assemblies.

The exterior wall panels, precast concrete wall and preassembled metal stud system, help cut the schedule greatly. It was determined that 16 precast concrete panels and 12 preassembled metal stud panels could be installed each day. Just-In-Time delivery will be used for the installation of the panels. This requires a very detailed shipping and installation plan. The panels are very important to the overall success of the project, so the construction team has made a detailed material tracking system for the panels. Figure 13 shows the breakdown of the precast panels on the east facade and the tracking of the panels can be further analyzed on Drawing C-9.0.

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**Figure 13. Precast Panel Delivery Key**

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East Elevation
As stated earlier in section 6.1, Structure Review, the structural trusses used to support the roof will also be prefabricated. The truss sections will be assembled and welded offsite and delivered in four 50-55’ sections. The extreme size and complexity of the roof trusses posed a challenge to Synergy’s design and construction team. However, with effective prefabrication strategies, proper construction sequencing, and advanced material tracking Synergy was confident in achieving the scheduled completion.

### 8.3 LONG LEAD ITEMS

<table>
<thead>
<tr>
<th>Item</th>
<th>Lead Time (weeks)</th>
<th>Procure By</th>
<th>Installed By</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Cell</td>
<td>6</td>
<td>1/7/19</td>
<td>2/18/19</td>
</tr>
<tr>
<td>Transformers</td>
<td>14</td>
<td>8/15/18</td>
<td>2/19/19</td>
</tr>
<tr>
<td>Switch Gear</td>
<td>18</td>
<td>8/15/18</td>
<td>2/19/19</td>
</tr>
<tr>
<td>Structural Steel</td>
<td>5</td>
<td>3/20/18</td>
<td>5/2/18</td>
</tr>
<tr>
<td>Transfer Truss</td>
<td>10</td>
<td>3/20/18</td>
<td>5/29/18</td>
</tr>
<tr>
<td>Coplanar Truss</td>
<td>18</td>
<td>12/28/17</td>
<td>5/3/18</td>
</tr>
<tr>
<td>AHUs</td>
<td>10</td>
<td>7/27/18</td>
<td>10/5/18</td>
</tr>
<tr>
<td>VAV Units</td>
<td>4</td>
<td>3/20/19</td>
<td>4/17/19</td>
</tr>
<tr>
<td>Concrete Panels</td>
<td>16</td>
<td>3/29/18</td>
<td>7/19/18</td>
</tr>
<tr>
<td>Metal Stud Panels</td>
<td>8</td>
<td>4/19/18</td>
<td>6/14/18</td>
</tr>
<tr>
<td>Aluma View Doors</td>
<td>8</td>
<td>4/23/19</td>
<td>6/18/19</td>
</tr>
</tbody>
</table>

An important aspect of Synergy’s schedule is the manufacturing and delivery of major items. Due to the strict schedule, many of these items fall on the critical path and must be ordered at the right time. If any of these items were to be overlooked, the schedule would be impacted. These items can be seen in Table 1 and in Drawing C-2.0.

### 8.4 ADVANCED MATERIAL TRACKING

To ensure materials and equipment are procured, delivered, installed, quality checked, and maintained in the proper fashion, Synergy used an advanced material tracking system. By working with suppliers and providing them with Synergy tags, the Construction team was confident that the project would follow the schedule with minimal delays. To learn more about the system, see Drawing C-8.0.

### 9.0 RESILIENT STRUCTURE

While being tasked with fast tracking the schedule, Synergy looked to provide a facility that could withstand an EF3 tornado and a safe room that could withstand an even greater, EF4. The Sports Performance Center will, in times of emergency, serve as a community shelter, holding up to 1,636 of the Lubbock community. The center of the building, underneath the concrete bleachers, will serve as a safe room that can hold 516 occupants, which will be used in the situation of an EF4 tornado. More details on the safe room design can be found in Structural Report section 8.2. Keeping the community safe is one of Synergy’s highest priorities which is reflected in the project theme of resilience.

### 9.1 CONSTRUCTION IMPACTS

The construction team realized early in the project that constructing a much more robust structure would increase cost and schedule. Working with the Structural team was crucial for minimizing the effects of the new design on the schedule and budget, see section 6.2. Some impacts include more connections between members, more lateral bracing, and more drilled bell piers in the substructure.

### 10.0 WELL IMPLEMENTATION

Synergy’s design team was tasked with creating a WELL Silver Certified building. WELL Building Standard is an evidence-based system for measuring, certifying and monitoring the performance of building features that impact health and well-being. Currently WELL Certification has only been conducted in commercial office spaces. Since the current breakdown of WELL is meant for commercial office buildings, Synergy has adapted some of the requirements to better suit an institutional sports center. A closer look into the materials used for the football and track fields, health and activity improvements for athletes, ADA accessibility, and comfort was taken to account. Synergy designed systems that not only offer an increase in user productivity and performance but also have a greater return on investment for the owner. For a breakdown of the WELL Standards met, see Drawing C-10.0.

### 10.1 WELL BREAKDOWN

The WELL Building Standard is broken up into seven concept areas: air,
water nourishment, light, fitness, comfort, and mind. To achieve the Air concept requirements, Synergy’s Construction team worked together with the Mechanical team to achieve the required ventilation effectiveness by determining cost efficient ways to use air displacement and natural ventilation. Another WELL Air Concept requirement is the need to reduce possible contamination of air handling equipment. For this requirement, the construction team required ducts to be sealed during construction and vacuumed out before grills and diffusers were installed.

To meet all of the requirements of the Nourishment Concept, Synergy took a closer look into the food and drink being served at the Fueling Station. Synergy planned to work with Texas Tech University to ensure 24 hour access to nutrient and protein rich foods and drinks to student athletes. Synergy also provided a 50 inch touch screen where users can learn about the nutritional facts, food allergies, and good food habits.

The Construction team worked together with the Lighting/Electrical team to select interior materials with high reflectivity so space with less light still feels bright. The Construction team also helped the Lighting team with lighting controls. Synergy's Construction team surveyed a handful of University Officials regarding indoor sports space lighting and provided useful information on televised vs. non-televised, daytime vs. nighttime, and event vs. practice lighting requirements. With this information, along with the information spelled out in the NCAA requirements, Synergy’s Construction and Lighting team successfully achieved all of the WELL Light Concept requirements.

Synergy creatively solved the Fitness and Mind Concept requirements by adjusting the floor plan and including subtle health improving features. For example, Synergy created a lobby for the main entrance with a large grand staircase that leads spectators to their seats in the main bleacher area. Synergy promotes health by directing users of the building to the stair case rather than the elevator which is hidden behind the staircase. For a complete WELL Breakdown see Drawing -10.0.

10.2 CHOICE OF MATERIALS

The WELL Standard focuses heavily on materials that are environmentally friendly. Synergy researched and worked with manufactures in order to use low volatile organic compounds (VOC) materials while still maintaining a high end look. Some materials include, low VOC paints, BlueDuct underground ductwork, and, in the wake of recent studies showing rubber turf causes health risks, the use of cork instead of rubber for the football turf field.

The ATHLETE

The main user of the new Sports Performance Center will be student athletes. Throughout numerous meetings and surveys taken from University Officials, Synergy determined ways to offer the absolute best user experience. Synergy found that offering strategies to improve user health by promoting proper nourishment, sleep, and physical activity not only
benefits the student users but will also act as a recruiting tool for the university. By offering top of the line facilities and an experience revolved entirely around student athletes Synergy hopes Texas Tech University will see an increase in student recruits. Figure 16 shows the lobby space which showcases top of the line finishes.

10.4 ADA ACCESSIBILITY

The construction industry is continually innovating to better accommodate the needs of the elderly and disabled. To adopted ADA standards within the building, the design team has restructured the floor plan to include elevator accessibility, an upper level ADA viewing deck, extra wide hallways, and centralized bathrooms. Special equipment will also be installed to ensure equal training opportunities for handicapped athletes.

10.5 COMFORT

The comfort of the user is critical to the WELL Standard. In fact, it could quite possibly be the most important. For the high priority Comfort Category Synergy redesigned the way air is supplied in typical indoor sports centers. To do this, Synergy determined the different users of the space and narrowed it down to be athletes and spectators. For the athlete users Synergy’s Mechanical team worked out a strategy to supply air at the level it is most effective (ground) and naturally ventilating the spent air out of the building through openings in the roof, Figure 17. This strategy is known as air displacement and can improve the comfort of the athlete user dramatically. For the spectator areas Synergy’s Mechanical team utilized traditional overhead air supply. Traditional methods in these areas were chosen because of the differences in activity levels between athletes and spectators. Occupants with lower activity levels (spectators) have different requirements that occupants with high activity levels (athletes).

Figure 17. Air Displacement & Natural Ventilation

Synergy also wanted to improve upon the experience of the user by offering de-stressing areas, encouragement walls, natural lighting strategies, and continuous access to fresh cold water and essential nourishment. For more information on Synergy’s user comfort improvements see Drawing C.10.0.

11.0 FACILITY MANAGEMENT

Along with standard turnover strategies Synergy plans to implement an in-depth Facility Management review. Synergy’s facility management would give Texas Tech University the capability to understand reliability of equipment in the Sports Performance Center at any point in time. Texas Tech University would also be able to identify and isolate potential failures before they occur; to predict and plan for scheduled maintenance and downtime and to reduce unnecessary time-based maintenance operations.

According to Manuel Dias from Microsoft, in order to properly implement Facility Management, an owner needs to have four things:

1. Rich Device Data: In order to predict and influence an equipment’s risk of failure, there must be sufficient data on device behavior to support prediction.

2. Flexible Analysis Environment: An analytics solution can be built incrementally as business needs warrant and allows an increasing range of analytical capabilities to be brought to bear to support maintenance efforts.

3. Ability to Take Action: Existing production work flow such as dashboards, command centers, and technician portals need to be instrumented to receive notifications and to record the actions taken (or not) based on those notifications.

4. Operations Feedback Loop: Once models and recommended actions are created in the analytics environment, their effectiveness needs to be tested.

Synergy plans to work with Texas Tech University to implements the four items listed above. To further explain facility management Synergy took an in depth look at Space Management and Asset Management. For more information on Synergy’s approach to Facility Management see Drawing C.8.0.

11.1 Space Management

Space Management can be simply defined by being the management of building spaces. It is monitoring the users of the spaces, the amount of time the space is used per day, the time of day the spaces are used, the wear and tear of the space after use, etc. Thorough space management monitoring yields a Facility Condition Index (FCI). A Facility Condition Index is the
total estimated cost to complete deferred maintenance projects for the building by its estimated replacement value. The lower the FCI, the lower the need for renovations. Keeping a low FCI also retains the value of the property. Space Management with FCI analysis would give Texas Tech University the information needed to always provide an up to date user experience in the new Sports Performance Center.

11.2 ASSET MANAGEMENT

Asset Management is the management of the building’s operational assets. Operation assets include things like light fixtures, electrical distribution, pumps, generators, air handling units, etc. The purpose of asset management is to improve maintenance effectiveness and efficiency and optimize equipment reliability. An objective of asset management is to maximize return on investment on assets. Preventative Maintenance is an Asset Management strategy that maximizes the asset’s return on investment. Figure 18 is a graph showing the difference between an unmanaged asset (purple) and a managed asset (green). The y-axis is the working condition of the asset and the x-axis is the time in years that the asset is in commission. As the working condition dips below 20%, the asset is typically deemed unusable. The managed asset resembles an asset that utilizes preventative maintenance, which is preforming scheduled inspections and repairs on an asset while the asset is still working, so that it does not breakdown unexpectedly. The inspections and repairs are scheduled and coordinated in the early stages of the assets life and usually take place during the mid-life of the asset. The purple line (the unmanaged asset) becomes unusable 1/3 faster than the green line (the managed asset). This is due to the stages of preventative inspections/repairs that occur during the mid-life of the asset. These mid-life repairs prolong the managed asset from reaching the Asset lifespan thus increasing the return on investment.

To provide large return on investments, Synergy plans to work with TTU in determining, scheduling, and coordinating mid-life repairs for the operational assets used in the Sport Performance Center. See Drawing C-8.0 for Synergy’s recommended inspection/repair schedule.

11.3 TURNOVER

Upon completion of the Sports Performance Center Synergy plans to turnover the building to Texas Tech University with completed Turnover Check lists. Checklist items include completed punch lists, Operation and Maintenance Manuals, confirmed construction test, inventory lists, spare lists, status of extra materials, warranty information, contact list, and preventative maintenance procedures.

Project turnover is Synergy’s final step preformed on the Texas Tech University Sports Performance Center. Any work following project turnover will be considered maintenance/warranty work of which Synergy allotted a period of 24 months. Synergy will complete any additional work that is required if a system is not working to predetermined performance standards.

Inadequate performance reports due to contractor error within the 24 month period warrant maintenance repairs funded by Synergy.

12.0 TECHNOLOGY

To improve upon the design and construction processes Synergy incorporated modern technologies such as Autodesk Navisworks, Google Sketchup, 3DS Max, and Unity. Autodesk Navisworks gave the design team the ability to virtually tour the facility on a desktop to determine problems and clashes. Sketchup was used to create simple geometries to represent different objects. 3DS Max was used to assign different materials to objects and surfaces as well as convert the Revit file (.rvt) to a readable Unity file. Unity was then used to allow for Virtual Reality and Cardboard implementation. Having the ability to virtually tour the model with a one to one scale gave Synergy the owner ability to make huge design decisions such as material selection, color, and scale of objects.

Synergy also created innovative and custom technologies for the Sports Performance Center users. These include the Student Recruitment Kiosk and the WELL Performance Board. To learn more about the technologies used see Construction SD - E.
13.0 CONCLUSION

Throughout the project the Construction and Design team worked in a collaborative environment to produce the most optimal facility for Texas Tech University. Synergy found with the Sports Performance Center, like any project, there was an opportunity to reflect on the design experience. The construction team learned that it would have been beneficial to organize construction tasks to be completed earlier in the design process. When the team started using the Last Planner System, members knew exactly what needed to get done in order for the team to succeed. This helped the team prioritize the important tasks and developed a plan to complete sequentially. Also, each Construction member was given a role at the beginning of the design. Those roles transformed over the design process. Knowing the specifics of these roles early would have been in the best interest of the team. If these strategies were implemented in the early weeks of design, time would have been used more effectively. The Construction team will use these reflections to better Synergy and future project endeavors.

At the end of the project Synergy compared the design of the Sports Performance Center to the four project themes created at the beginning of the design (listed below). Upon review, Synergy is confident that the project themes were exceeded and the Sports Performance Center will be a staple in the Texas Tech University community for years to come.

**1. RESILIENCY**
With strong integration between disciplines Synergy determined robust cost effective systems that will keep the occupant and community safe in a time of disaster. All of the FEMA requirements for a structure that can withstand an EF3 tornado, as well as a safe room that can withstand an EF4 tornado were met. If selected, the total cost required to make the changes needed while maintaining the 8 month schedule acceleration is roughly $4.37M.

**2. PERFORMANCE**
To improve upon the user experience Synergy analyzed all of the materials used and selected the most environmentally friendly. The turf field for example, a low VOC cork material was chosen to improve upon the indoor air quality. Combining an advanced material analysis with Synergy’s air displacement strategy improves the indoor air quality dramatically. If selected, the user experience advancements paired with a 60% energy reduction would cost Texas Tech University an additional $3.05M.

**3. VERSITILITY**
Synergy has implemented modern technologies such as Virtual and Augmented Reality to improve upon the design and construction processes. This increased owner involvement in making critical design decisions. Synergy also created technologies to improve upon the user experience with the use of a Performance Board and a Recruiting Kiosk. Synergy has provided Texas Tech University with interactive strategies to recruit more students and promote a healthy lifestyle.

**4. VALUE**
As a result of innovative schedule techniques such as prefabrication and Just-In-Time Delivery, Synergy’s design gives the option to decrease the construction schedule. If selected, Synergy will turnover the Sports Performance Center with turnover documentation as well as the Asset Management system on July of 2019. Synergy explored all of the Owner Defined goals and presented Texas Tech University with a thorough Add Alternate Package. Synergy will save 8 months while minimizing added cost.
Synergy created a decision matrix in the earliest stage of design. To create the decision matrix Synergy first decided four overarching themes that are important to the project: Performance, Security, Versatility, and Value. However, the team did not want to limit project potential to just these four themes so within each of these themes goals were set (for more on the creation of the Decision Matrix see Drawing I-1.0). The Constructability Decision matrix below was used to make decisions regarding the Mechanical System, Exterior Perimeter Enclosure, and the Clerestory Windows respectively.

**Decision Matrix**

The Decision Matrix Analysis yielded positive results for the Mechanical Decision and the Exterior Perimeter Enclosure however, the Roof Clerestory Windows decision matrix lead to an unfavorable response constructability. Finally the addition of clerestory windows raises issues with the large cost increase, schedule increase, and greater operation and maintenance cost associated with the clerestories. However, the system was selected because of the benefits it bring to other disciplines.

**Program Interoperability**

The Program flowchart above lays out the steps Synergy took to produce the Final Design of the Sports Performance Center. In the center is Autodesk Revit where the architectural, mechanical, lighting/electrical, and structural models were located. The Construction team mainly utilized the programs listed in the green section, above. The dotted green line represents an output relationship with Revit to the other programs. The Construction team also assisted in creating photorealistic renderings using Artlantis and Photoshop. Finally the Construction team checked the wall makeup by analyzing the moisture and thermal performance using WUFI.

The Construction team also assisted in creating photorealistic renderings using Artlantis and Photoshop. Finally the Construction team checked the wall makeup by analyzing the moisture and thermal performance using WUFI.
Synergy will be utilizing the Integrated Design-Build project delivery method during the design and construction of the Texas Tech Sport Performance Center. This method allows for an increase in collaboration and communication between all team members within Synergy and the owner. The best way to explain Integrated Project Delivery is to compare it to Traditional Delivery Methods.

**Traditional Project Delivery**

With traditional project delivery methods an Owner is contracted with multiple parties. In the figure above the Owner is Contracted with a Designer (Architect) and a Contractor. Each of these parties are then contracted with other parties; consultants and subcontractors. These types of contract heavy delivery methods are often chosen due to the decrease of risk taken on by the parties.

**Integrated Project Delivery**

Synergy will be utilizing the Integrated Design-Build project delivery method during the design and construction of the Texas Tech University Sport Performance Center. Integrated Design-Build leverages the power of design and construction to provide an understanding of cost, schedule and scope of work earlier in the process. This approach delivers tangible benefits to clients from design to completion with quality built in to each stage.

**Project Team**

The core project team includes Synergy Designers, Synergy’s Construction Management Team, and Texas Tech University Representatives from their Building Maintenance and Construction Division and the Facilities Planning and Construction office.
Supporting Document C | Decision Making and Software Interoperability

Site Specific Safety Plan (SSSP)

Synergy’s Site Specific Safety Plan is a review of all work tasks and expected hazards associated with the work performed at Texas Tech’s Sports Performance Center. Synergy cares deeply about every individual that steps foot onto our construction sites and large amounts of resources were dedicated towards improving site safety, industry wide.

In efforts to improve site safety Synergy requires all contractors to review all tasks and hazards and provide a brief analysis on how the contractor will address each hazard in a safe and timely manner. Contractors are required to submit Site Specific Safety Plans to Synergy prior to beginning work and shall update the Site Specific Safety Plan as drawings and work scopes develop throughout the entire duration of the project. Due to the high pressure and accelerated schedule of the Sports Performance Center Project, Synergy mandates SSSP updates on a monthly basis. All up to date Site Specific Safety Plans (SSSPs) as well as Safety Data Sheets (SDSs) are located in the Synergy Trailer across Arkan Ave (location shown in blue on the site plan to the right).

Along with strict record keeping Synergy’s Designated On-Site Safety Representative is responsible for each workers safety orientation. Upon arrival on-site each worker is to report to Synergy’s Office Trailer to undergo a 35 minute Safety Orientation. The safety orientation is offered in both Spanish and English and is mandatory for anyone who steps foot onto a Synergy Site. Synergy’s Safety Representative is responsible for monitoring the watching compliance of the safety orientation and to make sure there are no questions or discrepancies with it’s content. Every individual who watched the safety orientation will sign a document stating that the content was clearly understood and will be used throughout the work performed while on site. After the safety orientation is watched an additional 30 minutes is allotted for the Safety Representative’s review of important site specific hazards. The Sports Performance Center Important Hazards Include:

- Fall Hazards
  As a requirement of OSHA all workers must be tied off when working at elevations greater than/equal to 6 feet however Synergy requires workers to be tied off at elevations greater than 4 feet. Synergy also requires all holes/ penetrations greater than 2 inches to be visibly marked and flagged.

- Struck-by Hazards
  With multiple mobile cranes on site Synergy requires an English and Spanish speaking qualified person to flag and ensure crane safety. All work under a lift must be halted until the area is cleared by the crane operator. Prior to any heavy lift a horn will sound alerting all workers of the activity.

- Electrical Shock Hazards
  Synergy has a zero tolerance policy towards all electrical deficiencies. This policy includes daily inspections on all electrical cords and ground pins, extra protection for all electrical cords, enforced lock-out/tag-out practice for all large electrical utilities, and weekly safety inspections by the electrical subcontractor.

- Designated On-Site Safety Representative
  Throughout the construction of Texas Tech’s Sports Performance Center, Synergy will employ one on-site safety representative. This person is responsible for all major and minor accidents occurred throughout construction, head count of people on site at any given time, documenting safety deficiencies and resolutions, etc. The on-site safety representative is OSHA-30 Hours trained and certified as well as CPR trained and certified. See contact information below for issues related to any of the items listed above:

  Name: John Doe  
  Phone: (488) 926-889  
  Email: johndoe@synergy.com

*In extreme safety situation request the help of any certified individual and immediately call 911.

Safe Plan of Action (SPA) & Safe Zones

Synergy developed an Emergency Plan for two different scenarios: a natural disaster (i.e. tornado) and a construction related disaster. The construction sites have designated areas as Safe Zones. If a tornado or other natural disaster were to occur during construction, workers are to follow the green arrows into the safe zone where they can be accounted for and wait out the storm.

American Red Cross serving the Lubbock Area
2201 19th St
Lubbock, TX 79401-4507
Phone: (806) 765-8534
1.5 miles from construction site (6 minutes with normal traffic)

UMC Emergency Room
Located in Texas Tech University Health Sciences Center 3603, 4th St
Lubbock, TX 79415
1.4 miles from construction site (7 minutes with normal traffic)

Revised: 11-2017
Critical Pick
To determine the type of crane to be used on the Sports Performance Center Project, Synergy first had to determine the sites critical pick. Due to the accelerated schedule goal Synergy has proposed most truck member connections to be made off site while the main truss segment connections will be made in the field. The trusses will be divided up into four 50 foot sections and delivered to the Sports Performance Center Site. Synergy proposes to connect a “truss assembly” (shown below) on the ground and once all of the connections are made the entire assembly can be lifted into place. Having the trusses prefabricated off site in sections that will fit on a delivery truck saves a large amount of time and for this project, time is critical.

Each co-planer truss weighs about 43 tons and has a total of 166 fixed connections. Two of these long span trusses will be connected together with 35 purins. Each purin weighs 780 pounds.

When all of the members are connected together the 200 foot spanning truss assembly will weigh about 109 tons. This truss assembly is the Sports Performance Center projects critical lift.

The Construction team has worked with the Structural Design team to determine the number of points and determine the locations the truss assemblies will be picked from. The Construction team was then able to find a sling that can accommodate these picks.

Truss Assembly

Transfer Truss
Due to the size of the transfer truss panels, each 15’x20’ panel will be fabricated in shop and shipped individually to site. Once on site, the panels will be bolted together in the field in order to eliminate the need for field welding and welding inspections. Shipment of the 14 panels will require two truckloads. The 15’x20’ panels exceed the width of a truck by three feet, resulting in special transportation requirements. Following Lubbock City transportation requirements, the delivery of these panels will be limited to any time before 7am and any time after 6pm.

Crane Assembly
The Manitowoc 16000 will be rented through Bigge Crane and Rigging Company in Houston, Texas. The crane will arrive on site in a series of pieces. The trucking company used to transport the pieces and assemble the crane will cost $64,000 per way. So in total the Manitowoc 16000 will cost just under $130K to be deliver/removed as well as assembled/disassembled from the Sports Performance Center site. The 12 step assembly process (right) is shown for reference.

Manitowoc 16000 Crawler w/ Mast
To determine the type of crane capable of lifting the large lift load Synergy requested the help of Bigge Crane and Rigging Company located in Houston Texas. After a conference Tim Reed, Manager of Business Development, quoted the Manitowoc 16000 Crawler Crane with a mast and a boom length of 236 feet. The Manitowoc 16000 offers Manitowoc’s EPIC system (Electrically Processed Independent Control system), FACT Connectors (Fast Aligning Connection Technology), and closed loop hydraulics.

Quote Details:
Rent: $600/hr (straight time) and $675/hr. (overtime)
Labor: $400/day (includes a competent operator and flagger)
(40) Mat Pads: $130/month/ mat
Synergy estimates the Manitowoc to be on site for a total of 40 days (320 hours), which brings the total to just under $225K. This total does not include delivery and assembly fees as discussed in the Crane Assembly Section.

Reference:
Tommy Reed
Manager of Business Development
Bigge Crane and Rigging Co.
Email: treed@bigge.com
Office: (832) 786-5201
Direct: (832) 547-0624
Student User Technology

Student Athletes are a major factor in Synergy’s Performance project theme. The needs and requirements (from WELL Building Standard) of student athletes have pushed Synergy to create innovative technologies that improve upon the user experience. These technologies include the Student Recruitment Kiosk and the WELL Performance Board.

Virtual Reality Design Review

In today’s modern world there are many new technologies at our finger tips. To improve upon the traditional design review process Synergy decided to offer Texas Tech University Virtual Reality design reviews throughout the Conceptual, Schematic, and Design phases of construction. Using Virtual Reality Synergy was able to produce a 1:1 model of the Sports Performance Center and invite third party individuals (meant to represent Texas Tech University Owner Representatives) into the space. Their feedback resulted in positive design changes. The flowchart below shows the process Synergy used to make Virtual Reality Design Reviews possible. First the model was exported from Revit and imported into 3DS MAX. From 3DS MAX the file was saved in a readable Unity file where the model was adjusted to become as photorealistic as possible. From the Unity engine the model is viewable in two options: the HTC Vive or the more portable Google Cardboard.

WELL Performance Board

Navisworks Clash Detection

To complement the overall 3D Revit model, Synergy combined all of the 3D models into a single Navisworks file. Once all of the models were combined a clash detection was performed with a tolerance of 1/4 inch. The clash detection rendered over 350 clashes, most of which were trivial clashes while others were undetected major issues. For example in the image to the left an air duct penetrates a steel W-Shape in the lobby space of the Sports Performance Center. Navisworks identified all of the major clashes between different building components. Synergy’s team was able to work together to solve all of the clashes. Being able to solve problems before they occur onsite by using Navisworks adds a great deal of Value to the project and saves Texas Tech University a substantial amount of money in potential change orders.

Virtual Reality Design Review

In today’s modern world there are many new technologies at our finger tips. To improve upon the traditional design review process Synergy decided to offer Texas Tech University Virtual Reality design reviews throughout the Conceptual, Schematic, and Design phases of construction. Using Virtual Reality Synergy was able to produce a 1:1 model of the Sports Performance Center and invite third party individuals (meant to represent Texas Tech University Owner Representatives) into the space. Their feedback resulted in positive design changes. The flowchart below shows the process Synergy used to make Virtual Reality Design Reviews possible. First the model was exported from Revit and imported into 3DS MAX. From 3DS MAX the file was saved in a readable Unity file where the model was adjusted to become as photorealistic as possible. From the Unity engine the model is viewable in two options: the HTC Vive or the more portable Google Cardboard.

WELL Performance Board

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Synergy’s Design vs. Original Design

In the early stages of the design, Synergy focused on the layout of the building. The team looked to optimize the layout to create a better building for the athletes and the TTU community. The changes can be seen to the right and also in Drawings 1, 5.1, 5.3. Synergy and the owner were able to benefit in different ways by adding the 17,000 SF core space. The biggest advantage is centralizing the safe room and placing it under the bleachers. Other advantages include being able to add a grand lobby space, centralizing the fuel station so all athletes could use it, centralize the mechanical and electrical rooms to shorten runs, and creating a second restroom area. Restrooms on both sides of the track will prevent spectators from walking through the track during events. Even though the 17,000 SF adds initial cost, $2.4 million, Synergy was able to still hit the target value of $46 million. Synergy believes the additional space will create a more inviting area for the athletes, community, and recruits.

Other large design changes were the roof and exterior wall makeup. The roof design evolved from a simple curved roof to a curved roof with twelve clerestories. The clerestories were an area of integration for all members of Synergy. The team was able to lower the roof height and reduce the volume of the building. This lowered exterior enclosure cost and loading for the mechanical and electrical team. The clerestories windows allowed for natural light to enter the space and create an exhaust point for the natural/displacement ventilation. The exterior wall assembly was also changed to resist impact, increase the R-value, and decrease the schedule. Synergy discussed many options throughout the design phase and the team is confident that the changes will make the Sports Performance Center a great new addition to the Texas Tech University campus.

WUFI Analysis

The exterior wall assembly was a great integration point for the Synergy team. The assembly was able to withstand a projectile of 100 mph, increase the R-value from 27 to 32, help accelerate the schedule, and stay true to the campus architecture. The construction and mechanical team also ran a WUFI analysis to determine if moisture would accumulate in the assemblies. The two graphs below, separated by the two wall types, show the heat transfer, humidity, and moisture content in different parts of the wall assembly. The left side of the graph is the exterior and the right is the interior of the building. Oklahoma City was chosen because it is located in the same climate zone as Lubbock. The red line is a representation of heat transfer and it shows that heat is not lost to the exterior in both assemblies. The walls also slow the heat transfer into the space, creating less heat transfer. The green line represents humidity and within the wall assemblies the humidity does not reach 100%. This illustrates that no moisture will accumulate in the wall. The blue line is the moisture content which is limited to the outer layers of the assemblies. For the upper wall section, there is moisture in the terracotta rain screen area. The air gap behind this layer allows the terracotta to dry, so moisture accumulating here is fine. Synergy strongly believes that the two wall assemblies chosen are the best option for Texas Tech University.

Section Cuts

The construction team found it very valuable to work with the design teams to create detailed sections of important locations. The details shown represent these areas. Synergy was concerned with the transition between the precast concrete and metal stud wall assemblies. The connection between wall assemblies were detailed to show how the transition would be sealed and how moisture would be treated. The clerestory detail was made for a similar reason. Also, this connection was the most difficult connection for the project because of the interaction of the trusses and clerestory windows. The detail was carefully considered.

The construction, mechanical, and structural team worked to detail the penetrations of the underground displacement ducts through the substructure. The two details to the right showcase how the ducts will interact with the substructure. The BlueDuct system also does not need to be maintained due to the tight seal of the ductwork. Once installed and buried, the manufacture guarantees no mold or debris will accumulate in the ducts. To learn more about the displacement duct system integration with the substructure, see Mechanical Report section 8.0 and Structural Report section 12.5.

Connection Between Wall Assemblies

The connection between wall assemblies was also changed to resist impact, increase the R-value, and decrease the schedule. Synergy discussed many options throughout the design phase and the team is confident that the changes will make the Sports Performance Center a great new addition to the Texas Tech University campus.
Final CPM Schedule for Synergy’s Design of The Sports Performance Center

Synergy was able to save a total of 167 days or 33.4 weeks. This was possible due to the collaboration of all Synergy team members. Saving time during design, creating a great sequence plan, and prefabrication helped meet the owners’ goal of finishing in July of 2019. Turnover of the Sports Performance Center to Texas Tech University will occur on July 19th, 2019. This allows construction to be completed before the 2019 Fall semester. Synergy is confident of turnover on this date because of precise planning and an advanced material tracking system.

Long Lead Items

Major items and equipment on projects take time to approve and procure. Listed below is the long lead items Synergy must procure early. To ensure a smooth schedule and delivery, all of these items will be part of our advanced material tracking system. Next to each item is a colored circle that can also be seen on the final CPM schedule above. These circles indicate when each item needs to be procured. The dates are written in the table below. Finishing the Sports Performance Center in July 2019 can only happen if the communication between the construction/design team, the owner, and manufacturers is open and clear. Synergy has provided the project with many unique solutions to scheduling and delivery. The construction team completely believes that the Sports Performance Center will be finished on a fast tracked schedule but will still provide a high-quality product.
Design Comparison

By using an integrated Design-Build project delivery method over a more traditional approach, Synergy was able to save 55 days on the design of the project. Having the Construction team on the project at an earlier time allows for a faster design. The Construction team assisted the design by giving their input to the design team early in the schematic phase. In a traditional project delivery approach, there are many RFIs between the design and construction team. Synergy was able to eliminate the need for RFIs by establishing all team members in one integrated team co-location. This is where the savings in the schedule to place.

Substructure Comparison

Synergy was faced with designing a structure that could withstand an EF3 and EF4 tornado. This caused the new substructure to be more robust, adding piers to the design. The amount of piers added was approximately 40. With the addition of more piers, a long duration task, the schedule for the new design was increased by 25 days. Though the new substructure added cost and schedule, which were lowered due to optimization, Synergy feels that making the structure EF3/EF4 tornado resistant could save many lives in the future.
The construction team saw an opportunity to fast track the schedule during the structural steel erection. Synergy saved 14 days or 3 weeks of the project by acquiring a second mobile crane. This added a cost of $225K to the project’s general conditions but because the structure is on the critical path, Synergy felt saving 3 weeks of the schedule outweighed the added cost. Using a second crane allowed the construction of the columns/girders and the truss assemblies to be concurrently. This overlap shortened the completion of the track and football structure, which also allowed the exterior to begin earlier. Due to a large amount of concrete being poured in the auxiliary space and the safe room, the auxiliary duration was larger in Synergy’s Design schedule. The total durations for the football, track, and auxiliary spaces are highlighted to the left.

### CPM Schedule For Synergy’s Design of The Superstructure

<table>
<thead>
<tr>
<th>Task Name</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Football Structure</td>
<td>39 days</td>
</tr>
<tr>
<td>Track Structure</td>
<td>41 days</td>
</tr>
<tr>
<td>Auxiliary Structure</td>
<td>42 days</td>
</tr>
</tbody>
</table>

### CPM Schedule For The Original Design of The Superstructure

<table>
<thead>
<tr>
<th>Task Name</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Football Structure</td>
<td>50 days</td>
</tr>
<tr>
<td>Track Structure</td>
<td>54 days</td>
</tr>
<tr>
<td>Auxiliary Structure</td>
<td>23 days</td>
</tr>
</tbody>
</table>
Prefabricating the exterior wall panels saved the project the largest duration. The precast concrete wall panels and preassembled metal stud system, comprised of metal studs, 14 ga steel, and 2 layers of plywood, saved on labor cost, $514K and cut the schedule by 148 days. However, the new wall assembly added a material cost of $3.09 million. This means the wall assembly added a cost of $2.58 million. Even though this is a high additive, the new wall types provide a more resilient building, faster installation, and less workers on site, which is much safer for the overall project. Synergy gives the owner the option to add the new exterior wall assemblies to the project.

Synergy was tasked with creating the Sports Performance Center while keeping the WELL standard in mind. Along with higher end materials, the team needed to decrease energy usage by 50%. This increased the duration for the interior space by 45 days. Some items that lead to the increase are the installation of underground duct work to reduce energy and higher end finishes to comply with WELL. Synergy stands behind the increased schedule and cost because it creates a better environment for the athletes and community.
The Uniformat table and Tracking figure, shown to the left, are a representation of Synergy’s estimate changes through the design phases. A target value of $46 million was set due to owner requirements. The Baseline Estimate, Level 1, was determined using a square foot and comparison estimate. Synergy’s Estimate, Level 2, was an assembled/detailed estimate created during the Design Development phase of design. The construction team worked with the design team to lower the estimate during the construction document phase of design. Synergy’s Optimized Estimate, Level 3, was a detailed estimate of the entire design. Synergy’s Add-Ons is the detailed price of each Uniformat area when considering the three owner defined challenges. The exact cost comparisons between Synergy’s Optimized Design and Synergy’s Add-Ons can be analyzed in the tables to the right.

**Life Cycle Analysis**

By using innovative and integrative design approaches Synergy was able to save 61% of the overall energy usage. This is higher than the owner defined challenge of 50%. Meeting this goal was very important for Synergy but the strategies to save energy must be in a reasonable price range. A life cycle analysis was performed to see the payback period of the add-ons. The total cost of the fuel cell and the electrical and mechanical systems was an additional $2.04 million. The yearly cost savings from energy reductions and switching to natural gas was $102K. This yielded a payback period of roughly 20 years. Synergy feels this is well within the life span of the building and is a recommended investment for Texas Tech University. To see fuel pricing data for Lubbock, see Electrical SD – C.

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The figure above is the expected budget the owner will pay each month. The majority of the cost will occurring during the exterior façade, months 12-16, and interior, months 18-23, construction.
The Sports Performance Center will be secured by two types of fencing: traditional and a jersey barrier fence combination. The traditional fencing is represented as a red line and the jersey barrier is represented as yellow in the plan above. Due to the limited site space, Synergy decided to locate the site trailers in the R24 Parking lot across Arlon Ave.

**Site Securement** — The Sports Performance Center will be secured by two types of fencing: traditional and a jersey barrier fence combination. The traditional fencing is represented as a red line and the jersey barrier is represented as yellow in the plan above. Due to the limited site space, Synergy decided to locate the site trailers in the R24 Parking lot across Arlon Ave.

**Excavation** — Excavation equipment will be stored across Arlon Ave in a paved lot where Texas Tech University held a dumpster. The South equipment entry will be used to transport equipment to and from the site and the North entry is where the spoil trucks will enter and exit the site. This was chosen because Synergy is trying to limit heavy vehicular road use to the Drive of the Champions road.

**North Football Truss Erection** — The erection process will begin on the Football side of the Sports Performance Center. During truss erection Synergy plans to have two Manitowoc cranes on site. One of the cranes will start with column and girder erection and the other will assist in truss assembly connections.

**South Football Truss Erection** — The progression of truss erection will proceed Southward down the football side of the building. Once the columns and girts are connected and the truss assembly is finished, one crane will be used to lift each assembly into place. The other crane will assist with taking materials off of the delivery trucks while also continuing erecting columns and girts. During this phase the center core space will remain free of any debris and will be used as a transportation path for material delivery.

**North Track Truss Erection and Start of Auxiliary Steel** — Once the football side columns, gists, and cross members are placed the cranes will move to the North track side to begin column and girder erection as well as assembling truss assemblies. Similar to the football side, one crane will be used to erect columns and girts while the other will be used to take materials off delivery trucks and assist in the truss assembly connections. As truss erection begins auxiliary steel is erected with a smaller mobile crane.

**South Track Truss Erection** — As in Phase 5, the west side of the site will remain free of debris and be used as a material delivery path. Deliveries will enter from the North-West gate located off of the Drive of Champions and exit from the South-West gate onto Arlon Avenue. Before auxiliary steel can be erected down the core, the preassembled metal panels must be installed along the two interior walls. After installation, the Auxiliary steel progresses into the core space where the structure is beefed up due to the creation of the safe zone.

**Start of Large Roof and Finish of Core Steel** — Once all of the columns, girts, cross members, and truss assemblies are placed the large cranes are disassembled and removed from the site. As this happens two additional small cranes are brought on site and used to lift materials onto the roofs of the football and track. The west travel path remains for track roof material deliveries and an additional travel path from the Southern most entrance will be used for football roof material deliveries. For this entrance trucks will back into the entrance from Arlon Ave with the help of 3 certified flaggers to assist in traffic redirection.

**Large Roof and Start of Aux Roof** — In Phase 8 the core steel is complete and the third small crane is used to lift materials for the auxiliary and core roof. The other cranes progress in their respective directions (south for the track side and north for the football side) to continue football and track roof assembly. During this phase an additional entry/exit point is created in the North-East corner. This access point will be used for delivery trucks exiting from auxiliary roof and delivery trucks entering/leaving from the progression of the football roof.

**Finish of All Rooves** — The core roof finishes as the final materials are lifted onto the roofs of the football and track. The West side of the site will remain as the primary delivery travel path and the North-East entry/exit will remain until the football roof is completed.

*Interior work starts as soon as the 1st layer of insulation is placed throughout the roof.
Step 3
the act of fixing and restoring an already failed asset to a previously recommended asset inspections to occur during the ½ life of the asset to monitor the energy usage of the assets
Every two months, looking for loose screws
recommends conducting an immediate Arrival
Twice a year and directly after a severe
allotted 30 days for the team to approve Monthly Management
Step 5 recommends Texas
Lighting Delivering Roof Diagnosis
Visual once per month, cable and conduit
Step 7 with Management strategy is
– recommends Texas Tech University employ
3 Advanced Material Tracking
Construction Application
Submittal Submission
Using Synergy’s powerful Construction Application, the Construction team members are able to markup and instantly share submittals for approval. Synergy allotted 30 days for the team to submit submittals.

Material Tracking Label
Large quantity materials, like the rigid insulation, will all be delivered to the site with a tracking label. When the item arrives on site, it is checked in with Synergy’s construction application. When scanned, the iPad displays a screen with an item description tailored to the Sports Performance Center project. Information like the items specific application/use, safety warnings, spec. sheet, storage strategies, installation guidelines, and installation time and date can all be found. This breaks down silos between the on and off site team members by giving every member access to information that is commonly inaccessible.

Material Ordering
Within the Construction Application on-site team members are able to place requests for additional materials and check the status of long lead items.

Arrival Check-in
The image below is rigid insulation with Synergy’s tracking label attached. This is an example of how materials will be delivered to the Sport Performance Center Site.

Lifespan Extension
The graph to the right is a representation of Synergy’s maintenance plan if preventative and corrective maintenance is utilized. The graph shows an increase in maintenance frequency in the unmanaged asset compared to the managed asset. The unmanaged asset sees an increase because problems are solved after they occur and as the lifespan increases the maintenance frequency increases. The same correlation is seen with the managed asset however because of the scheduled inspections the managed assets maintenance frequency is slightly less and the lifespan is increased by 1/3.

If Texas Tech University follows through with Synergy’s recommendations the assets used in the Sports Performance Center will potentially last 1/3 longer than they would if they were unmanaged.

System Management Software
Texas Tech University utilizes UtiliVisor, an energy metering service that measures the consumption of energy for all major assets on campus. This exports a more accurate bill at the end of each month where TTU can determine large energy consumers and make changes to increase asset efficiency. Synergy recommends Texas Tech University uses UtiliVisor with a Management Software that tracks the usage and performance of the services provided at the Sports Performance Center to effectively increase asset lifespan.

1 Inspection
The first step to Synergy’s Management strategy is inspection. Representatives from Texas Tech University’s Maintenance and Construction Division would be required to conduct inspections at varying intervals for differing building components.
• Roof - Twice a year and directly after a severe storm.
• HVAC - Every two months, looking for loose screws or latches, gasket deterioration, lack of lubrication,
• Lighting - Visual once per month, cable and conduit checks per year.

2 Diagnosis
If a problem or issue was determined after an inspection the next step is to Diagnose. Rather than simply doing what is thought to be correct to fix the issue, Synergy recommends a short Diagnosis stage where the issue can be greater understood and the best possible solution can materialize. A previous problem is more likely to reoccur when the solution chosen is “quick fix” and there were no additional steps taken to completely fix the piece of equipment.

3 Monthly Management
Synergy recommends Texas Tech University employ a monthly management strategy where the energy usage is tracked with UtiliVisor and inspections for potential failures are conducted. Along with the interval inspection, Texas Tech University can use UtiliVisor to monitor the energy usage of the assets located in the Sports Performance Center. If inconsistencies are found or the services are not preforming to Synergy’s predetermined output, Synergy recommends conducting an immediate inspection and diagnosis.
Procuring Panels

The precast concrete panels will be procured from Speed Fab-Crete Inc. outside of Fort Worth. The map to the left shows the distance and time of the deliveries. Four panels can be delivered on each truck bed. This means that four trucks need to be used each day. This requires detailed coordination with Speed Fab-Crete Inc.

Temporary Store Panels 4 & 5

- Thursday, July 19, 2018
- Tuesday, July 24, 2018
- Tuesday, July 24, 2018
- Monday, July 30, 2018

North-East Site Entry/Exit

Prefabricated Wall Panel Installation

The section cut below is for the area where the brick wall meets the precast concrete panels Encore. The section cut is for the area where the brick wall meets the precast concrete panels. The precast concrete panels will begin on the East Façade, the red labeled panels, and run in a clockwise manner. On July 18th and 19th, panels 4 and 5 will not be installed. They will be temporary stored within the structure. This was done so deliveries trucks could deliver materials within the football and track area. These areas will be used as storage spaces for the project. To properly insure that the panels will be installed correctly, the connection details will also be attached to each panel when delivered, shown below. This will hopefully increase the quality of the installation. The final challenge when installing the panels was the limited space of the site near the East Façade. The crane and delivery trucks being used to install the panels have approximately 40 feet to work with. To solve this problem, the crane will be placed within the 40 feet between the Sport Performance Center and the Football Training Facility. To get material to the East façade delivery trucks will back into the space thought a gate located in the North-East corner of the site. This allows the trucks to enter and exit the north-eastern gate without interfering with the crane picks, depicted to the right.

To account for any delays in procuring or shipping, the construction team has built 6 extra days into the schedule. This same process will be used to install the preassembled metal stud wall panels.
The health and well-being of the Sports Performance Center occupants is a crucial component of the Synergy plan. By meeting a WELL Gold Standard, Synergy has proven that the design and construction will be done with the occupants’ best interests in mind. WELL is broken into seven categories, with preconditions and optional features. To meet the lowest WELL Standard, silver rating, all of the preconditions must be met. Synergy went beyond the 41 preconditions and pursued 29 optional features. This allowed the Sports Performance Center to reach a WELL Gold Standard.

**WELL Implementation Summary**

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**Air**

**Precondition = 12/12 Optional = 8/17**

- **Air Movement**
  - The innovative usage of both displacement, supplied from the occupants level, and natural ventilation allowed Synergy to meet ASHRAE 62.1-2013.
  - The displaced and natural ventilated air will force unwanted air particles out of the occupant zone and exhausted through the operable windows in the clerestories. Humidity levels will also be kept between 30-50%.

- **Air Filtration**
  - To rid the air of contaminants, the mechanical systems will be sized with extra filters, the ambient outdoor PM0.3 and PM2.5 are below the limits set in WELL, and maintenance of the filters will be done during occupancy.

**Water**

**Precondition = 5/5 Optional = 3/3**

- **Water Quality**
  - Turbidity of water samples from the 2014 Lubbock Water Quality Report is 0.15 NTU which is lower than the 0.3 NTUs set forth in WELL.
  - All finishes and paints will be low in VOC. The underground duct system, below, is low in VOC and could be harmful, disease causing organisms, were not detected in the 2014 Lubbock Water Quality Report.

- **Pesticide Free**
  - All water being delivered to the site has been confirmed to have an amount of herbicides, pesticides, and fungicides under the allowed limit in WELL.

**Nourishment**

**Precondition = 8/8 Optional = 2/7**

- **Healthy Options**
  - The Sports Performance Center will house a fueling station where athletes can restore their energy by eating healthy options. These options include types of fruits and vegetables, snacks high in protein, and foods/drinks with less than 30 grams of sugar per container.

**Light**

**Precondition = 4/4 Optional = 2/7**

- **Sunlight Exposure**
  - Augmented healthy sunlight exposure was achieved through increased north-oriented glazing. The spatial daylength autonomy (dA300, 50%) is achieved for 72.6% of regularly occupied spaces. Undesirable direct sunlight glare is minimized due to the predominantly north facing glazing. The annual sunlight exposure (ASE 1000, 250) is less than 3%, and this affected space is the perimeter of the football practice field.

**Fitness**

**Precondition = 2/2 Optional = 3/6**

- **Stair Promotion**
  - While only having two sets of stairs, one set is one of the first objects viewed when entering the Sports Performance Center. The stairs are used by spectators to get to the center bleacher area. By being one of the first views when entering, the stairs are promoted to be used instead of the elevator. The stairs also have artwork wrapping around them to promote stair use even further.

**Comfort**

**Precondition = 5/5 Optional = 4/14**

- **Thermal Comfort**
  - The use of displacement and natural ventilation in the football and track spaces provide a relaxing air flow feel. The use of the two strategies allow Synergy to meet ASHRAE Standard 55-2013 Sections 5.3 and 5.4.

- **Sound Levels**
  - An acoustic plan was developed for locations of quiet areas and areas with noisy equipment. All dB levels that WELL set were meet.

**MIND**

**Precondition = 5/5 Optional = 5/14**

- **Health Awareness**
  - The health of the athletes and community is important. Including a WELL, nutrition, and workout wall will emphasize healthy options.
  - Sleep patterns, food/beverage consumption, and workout routines will all be tracked.

- **Owner Involvement**
  - Texas Tech will be a crucial member of the design and construction team. Synergy held charrettes to determine owner goals. New technologies, like the Google Carpool and VWC Wash, will be used to give the owner a better understanding of the space during construction.

- **Survey Plans**
  - Surveys about comfort, acoustics, etc. will be completed by the athletes and other occupants to see if any changes need to be made.

**Lower Carbon Footprint**

Lowering the overall carbon footprint of any project is always a goal of Synergy. Certain strategies were used to accomplish this goal on the Sports Performance Center. One example is the use of a fuel cell to produce electricity rather than relying on the grid. Along with the fuel cell, Synergy has cut total energy usage by 80%. The table below breaks down the reduction of CO\textsubscript{2}, NO\textsubscript{x}, and SO\textsubscript{2}. These savings can be compared to saving 4 million miles driven by a vehicle or recycling 557 tons of waste.

**VOC Materials**

Synergy has worked with suppliers to use the most environmentally friendly materials. Volatile organic compounds (VOC) creates smog which can cause health risks to the eyes, liver, kidneys, and in extreme conditions, cause cancer. Low VOC materials will be used throughout the project. All finishes and paints will be low in VOC. The underground duct system, below, is low in VOC and will not distribute contaminants into the air. With new studies the rubber in turf fields could be harmful, Synergy will use a newer cork based turf field.

**Turf Field with Cork**

**BlueDuct System**

**PB Materials: Concrete**

**Beck Steel Inc: Structural Steel**

**Lubbock Glass & Mirror Co: Glass**

**C.H.E Incorporated: BlueDuct**
0.0 EXECUTIVE SUMMARY

GENERATOR
Generac Bi-fuel generators were selected to provide necessary power to the Texas Tech University Sports Performance Center in the event that the electrical grid becomes disconnected. Surrounded by a Lonestar Prestress Inc. EF4 enclosure, natural gas lines would be tapped into and utilized. This eliminates harsh emissions and pollutants, satisfies the building’s need to be off the electrical grid for seven days, and makes the overall campus a much better environment for the athletes, faculty, and community.

MAIN ELECTRICAL ROOM
The fuel cell, switchgear and other vital panelboards and switches are located in the Electrical room. Situating the room on the south façade allows for shortened distance to the utility line. Similarly, locating the room near the center core of the building allows for shorter runs to panels and other equipment.

ENERGY PRODUCTION
Incorporating a 200 kW Bloom Energy Server Fuel Cell into the generation system decreases the Sports Performance Center’s reliance on the electrical grid. The fuel cell operates using natural gas, which is a much more reliant source. The fuel cell not only produces electricity, but minimizes the ecological footprint, reducing thermal loads due to the fuel cell’s heat given off as a result of the chemical reaction to produce electricity.

LIGHTING DESIGN
In conjunction with the mechanical and lighting controls designs, Synergy achieved a 60.25% reduction in total building energy consumption, compared to ASHRAE 90.1 2010 standards. Efficient LED lighting not only contributed to these savings, but also increased reliability in all fixtures chosen with regards to lumen output, maintaining color temperature and highlighting all artwork displayed throughout the Sports Performance Center to motivate and inspire athletes and other visitors.

LIGHTING CONTROLS SYSTEM
Implementing a Lutron Vive wireless lighting controls solution introduces the ability to harvest daylight. With photosensors, vacancy sensors and occupancy sensors installed, this controls system contributed to the reduced lighting energy usage of 70.16% over ASHRAE 90.1 – 2010 standards.

CLERESTORY DESIGN
Synergy collaborated to construct several clerestory structures in the track and football spaces. These clerestories were developed through coordination with the mechanical team’s natural and displacement ventilation design, the structural team’s long-span coplanar truss design, and the accelerated schedule challenge. A modular window Viracon insulated laminated glass system incorporated operable windows while also welcoming ample amounts of daylight into the space. The design not only provides a healthier environment for the athletes, but also reduces artificial lighting energy consumption significantly.
1.0 PROJECT INTRODUCTION

1.1 SITE LOCATION

The Texas Tech University Sports Performance Center is an indoor track and football practice facility in Lubbock, Texas. The facility is located adjacent to the Jones AT&T Stadium in the northern corner of the Texas Tech University campus. With the iconic bell tower, the performance center embodies Texas Tech traditions while introducing a new landmark for the community to enjoy.

1.2 BUILDING FUNCTION

The Sport Performance Center houses a competition indoor track and an 80-yard football practice field. The facility serves as an investment towards the future of the football and track & field programs. With state-of-the-art Sports Medicine and Strength & Conditioning spaces, the performance center caters to the athletes in order to facilitate excellence.

1.3 SYNERGY

Synergy is committed to designing a performance center that embodies the Texas Tech community and strives to aid in athlete development. Synergy proposes an innovative architectural structure coupled with an impact-resistant facade and building enclosure that provide a secure and resilient shell to ensure public safety. With the addition of a pioneering roof design, Synergy plans to achieve the stakeholders’ goals by producing a facility that not only supports the needs of the athletes, but adapts to future growth and advancement.

2.0 TEAM MISSION

The goals based on the owner and stakeholders serve as the foundation for the goals of the project. At Synergy, we strive to give our clients the greatest amount of value through a hard working team atmosphere, innovative design, sustainable construction, and superior maintenance capabilities.

3.0 PROJECT SCOPE

Synergy set Lighting/Electrical goals to design an efficient building by selecting cost-effective and sustainable systems and creating an inviting space and surrounding campus for staff, athletes, and spectators through daylight implementation, lighting design and electrical distribution. The main goals were to reduce the energy use by 50%, meeting the WELL Building Standard, maintain building operation for 7 days off grid, and utilize prefabrication and modularization where possible.

VALUE

Synergy strived to design efficient daylighting, lighting and electrical systems while considering both initial and life-cycle costs through several cost analyses. In addition, the artificial lighting design utilizes 100% LED fixtures, reducing the need for maintenance.

RESILIENCY

Synergy created lighting designs that provided a safe and secure area inside and outside the Sports Performance Center. Incorporating a redundant electrical distribution system assured that all building occupants are protected during emergency events.

PERFORMANCE

Synergy’s clerestory design added uniform daylight into the track and football spaces, thus creating an environment where all athletes could enjoy daylight while still being indoors. All artificial lighting complemented the artwork and memorabilia throughout the Sports Performance Center. The Lighting/Electrical team also coordinated with the Mechanical team to assure the space would be environmentally friendly.

VERSATILITY

Synergy explored the opportunity for lighting controls to be installed as well as security ID swipes at the appropriate door locations throughout the building. Lighting designs were also created for flexibility such as NCAA broadcasting requirements.
4.0 FINAL DESIGN

The Synergy Lighting/Electrical team, through full team coordination, created designs that are energy efficient, serve the occupant, provide redundancy, and support the Campaign for Fearless Champions. The final design features the following systems:

1. Integrated Building Clerestories
2. Stimulating Lighting Design
3. Fuel Cell Power Generation
4. Redundant Power System
5. Sustainable Design and Construction

4.1 CLERESTORY DESIGN

Figure 1. Enlarged Exterior Rendering Displaying Mullion and Clerestory Design

Synergy designed integrated clerestory structures along the roof span of both the track and football spaces. These clerestory structures create improved daylight distribution throughout these spaces, which form a more inviting atmosphere for the athletes, as well as provide for daylight harvesting energy savings. The added clerestories contribute to solidifying the building as a campus icon, and additionally aids in the mechanical system design of natural ventilation.

4.2 LIGHTING DESIGN

Synergy’s lighting designs aid in recruitment of Texas Tech athletes while providing a comfortable, secure and welcoming atmosphere for all athletes.

4.3 FUEL CELL POWER GENERATION

Synergy implemented a solid oxide fuel cell powered by natural gas to provide the building with 200kW of clean energy at all times. Utilizing a fuel cell minimizes reliance on the electrical grid while reducing harmful emissions. The fuel cell fulfills an added bonus for the university to be used for research purposes, and the system also has the potential to grow and serve a greater section of the university in the future.

Figure 2. Lobby and Track & Field Renderings

Figure 3. Bloom Energy Server Fuel Cells

4.4 REDUNDANT POWER SYSTEM

Synergy focused on a primary goal of resiliency in the electrical system design to ensure reliability and safety for the building occupants. The power distribution system will reliably satisfy the demands of a sports performance center, while also providing ancillary redundancy and stability during a natural disaster.

4.5 SUSTAINABLE DESIGN

Synergy placed a focus on integrating energy efficient solutions to reduce building energy consumption and costs through the lifetime of the building. The design features the Lutron Vive control system, and a focus on daylight harvesting that takes advantage of the architectural redesign to generate savings. The implementation of a fuel cell allows the university to capture excess generation on the campus grid in times of overproduction.
5.0 DAYLIGHTING DESIGN

5.1 SOLAR CONSIDERATIONS

The Sports Performance Center sits directly south of the football stadium across Sixth Street. The facility is bordered by football practice fields to the east, Red Raider Ave to the west, and Akron Ave to the south. The available sunlight is not obstructed by any neighboring buildings, therefore the building is exposed to natural daylighting and solar heat gain throughout the day. The area of Lubbock, Texas receives an average of 262 sunny days per year. Reference Mechanical Report Section 5.0 for detailed climate analyses.

5.2 DAYLIGHTING PERFORMANCE BENEFITS

In the conversation of enhanced building performance with a focus on occupant well-being, daylighting strategies are an important feature in all building types. Specifically in sports performance centers, the benefits of natural light can have a significant impact on athlete performance.

Track and field athletes and football players can spend up to 4 to 5 hours per day practicing in their indoor facilities. It is important that these athletes receive adequate daylight exposure throughout the day to help align their circadian rhythms. Exposure to daylight can help athletes get more restful sleep, which allows them to have more energy throughout the day, and can consequently improve their mood and performance.

In light of these studies, Synergy sought to enhance conditions inside the athletic spaces that would improve the health and experience for student athletes. Coordination between the Structural, Mechanical, Lighting/Electrical, and Construction disciplines began early in conceptual design, to assure that the architectural layout would aid the delivery of natural light into regularly occupied spaces. The Lighting/Electrical team specifically analyzed the daylight exposure and researched methods to improve daylighting in critical spaces.

5.3 DAYLIGHTING REDESIGN

The Lighting/Electrical team ran a daylight analysis on the original building layout to identify potential areas of improvement. Sefaira is a daylighting analysis tool that was used by Synergy to gather daylighting metrics on the building, such as Spatial Daylight Autonomy (sDA) and Annual Sunlight Exposure (ASE). Initial modeling of the building daylighting demonstrated the uneven distribution of daylight throughout the spaces in the original building design. The sizeable north glazing on both athletic fields allowed a significant amount of daylight into the space while minimizing direct sunlight and potential glare. While the existing north glazing provided substantial light and exterior views from the athletic fields, Synergy desired to optimize the daylighting throughout the entirety of the fields, not just at the north end, to create a more uniform distribution and more comfortable environment.

5.4 INTEGRATED CLERESTORY DESIGN

Investigation into architectural daylighting strategies produced several iterations of roof redesign. The various roof design iterations are summarized in Integration Report Section 7.2. Input from all disciplines shaped the roof design progression, focusing on daylight benefits, thermal performance, EF3 structural stability, and overall cost. The Convergent Design Strategy, outlined in Integration Report Section 5.2, indicates the factors, decisions, and tradeoffs that contributed to the final design resolution.
Synergy’s roof design established an integrated clerestory construction. This design created 15,000 SF of additional north facing glazing on the roof, spread out along the depth of both the football field and the track & field spaces. The overall amount of glazing did increase, however, the redesign reduced the front north facade glazing by 47%, while maintaining the look of the exterior facade and views out to the stadium. Creating the clerestories and minimizing the north facade glazing allowed the entire daylight distribution to become more uniform, and reduced the panel sizing, making the north facade glazing more resistant to high winds and projectiles.

![Synergy Clerestory Design](image1)

![Original Building Design](image2)

**Figure 5. Daylight Autonomy Comparisons**

The difference in distribution, illustrated in Figure 5 clearly demonstrates the improved daylight uniformity from the original roof design to Synergy’s integrated clerestories. Sefaira calculations computed the Daylight Autonomy for 460 lux, given the field illuminance requirements. In the final design, the football field has an average of 55% DA460lux, and the track and field an average of 72% DA460lux. Energy savings calculations from this progressive daylighting design can be seen in [Drawing E-1.0](https://example.com).

### 5.5 GLAZING SELECTION

Material selection played an integral part in the new roof design. It was important to the team to not only maintain, but improve the building envelope performance, while increasing the amount of glazing on the building.

The Lighting/Electrical team sought to maintain high visible transmittance for the glazing selection. Given that all glazing panels were placed on the north facade, there was little concern for glare problems with direct sunlight. Therefore, a visible transmittance above 60% was desired.

All disciplines in Synergy were heavily involved in the glazing selection. Considerations included meeting the stringent ASHRAE 90.1 2013 code requirements for glazing performance, maintaining the glazing during natural disasters, minimizing cost, and positively influencing interior daylight penetration. These variables were all analyzed by the Synergy team to come to a decision, which is summarized in Lighting/Electrical SD-D.

These collaborative decisions resulted in a north facade glazing change from polycarbonate to an insulated laminated glass panel. Specifically, the Viracon VE 1-2M was chosen for its significant light to solar gain ratio of 1.81. This maintained high visible transmittance while drastically improving thermal performance and preserving durability. The clerestory glazing selection is the same for the north facade, while all other building glass is a laminated insulated glass unit with less visible transmittance to comply with the ASHRAE stipulation of SHGC < 0.25. This glazing type, Viracon VNE 7-63, has a reduced VT of 20%. This selection also helped to regulate the daylight uniformity on the north end of the building, while achieving the lower SHGC requirements for glazing under 2.1 meters.

### 6.0 LIGHTING DESIGN

Throughout all spaces, Synergy created lighting designs that highlight all important memorabilia, to produce a safe and welcoming building environment with innovative technology, while acknowledging the importance of overall expenses.

All lighting fixtures were selected through Texas Lighting Sales linecard to ensure that they would be available in the Lubbock, Texas area.

In addition, all of Synergy’s lighting designs incorporate LED fixtures to meet WELL requirements and incorporate energy efficient building strategies.
The discussion of lighting control systems and implementations with the respective spaces will be mentioned in Lighting/Electrical Section 9.0. For details regarding a specific fixture, see Drawing E-6.0.

6.1 LOBBY DESIGN

When entering the Texas Tech University Sports Performance Center, one will first notice the electronic media wall that accents the north elevator wall. By providing images of track and football athletes making successful plays on these Planar RA Series LCD video wall displays, this feature sets the tone for athletes to complete successful practices and competitions.

Recessed downlights located in close proximity to the perimeter of the space will satisfy both ambient lighting criteria as well as highlight other art displays and additional features that draw focus to the athletes' achievements.

The lobby space is the first interaction that a spectator has inside the Sports Performance Center; therefore Synergy wanted to exhibit a huge feature that displays TTU pride. The team incorporated a 14 feet by 16 feet TTU logo, which drops down from the ceiling about 6 inches. Cove lighting fixtures were then utilized to produce a glow, bringing the logo to life.

The elevator was purposefully located in the lobby to accommodate those with disabilities. Elevator lighting at the base and top of the shaft was included in the design for maintenance needs. These fixtures and certain downlights in the lobby space are on emergency power to provide proper egress illumination.

Refer to Drawing E-6.0 for final calculations of the space as well as Drawing E-3.1 & E-3.2 for circuiting information.

6.2 STRENGTH & CONDITIONING

When one first enters the lobby space, the strength and conditioning room is visible on the left through a series of glass panes and double doors. The wall opposing the glass door entrance is covered in an art feature that further motivates the athletes. In addition, above the free weights and mirrors on the back wall is another art installation that features the Texas Tech University Track & Field team. Synergy highlighted these features with recessed linear wall washers. The north facade is largely glass, which allows the space to receive ample amounts of natural daylight. Wall washers along the southern wall subdue the contrast in brightness from one side of the weight room to the other.

On the same wall as the entrance to the gym, several different LCD screens will be provided to include recommended workouts & exercises for the day, depending on the athlete type and their position (football) or event (track).

A comfortable ambient lighting design was desired by the Synergy Lighting/Electrical team. A common complaint from athletes working out in strength and conditioning centers is the harsh direct light seen when looking up in the room. Specifically for athletes that are horizontal to execute certain exercises, this is a significant issue. Unfortunately, a ceiling height of 20 feet posed a challenge for using strictly indirect lighting. Therefore, suspended direct/indirect lighting was incorporated into the design of this space, with the shape of the fixture mimicking the unique glass arches in the north facade of the space.
See Drawing E-6.0 to view detailed calculations and fixture specifications as well as Drawing E-3.1 for circuiting layouts. For each row of suspended fixtures, the fixtures on either end are on emergency power. Refer to Drawing E-1.0 to understand how these fixtures work with lighting control implementation.

6.3 SPORTS MEDICINE

For this space, the Lighting/Electrical team created a relaxing and comfortable environment for the athletes, considering that the space is utilized for healing and dealing with injuries. This space maintained a similar design strategy as the strength and conditioning room, reducing the amount of direct light. The team chose largely indirect fixtures, which would ameliorate discomfort glare for athletes being attended to on treatment tables.

It should be noted that fixtures closest to the three doors in the space are on emergency power to provide illumination in the event of an emergency.

6.4 OFFICES

The WELL Building standard has a main focus on office buildings; therefore Synergy desired to maintain the lighting design focus on the occupant experience. Indirect suspended linear lighting dominated the lighting design for all office spaces in order to eliminate possibilities of glare on computer screens and harsh reflections from furniture surfaces. The indirect lighting scheme meets criteria, while also providing a satisfying space for employees to work in. Lighting designs for the office spaces remained the same throughout the building in order to reduce cost and create simplicity in repeatable design and construction delivery.

6.5 CORRIDOR DESIGN

The core of Synergy's building design consists of two long corridor spaces. One of these corridors was designed as part of the Tornado Safe Room; therefore it was crucial that these light fixtures were protected appropriately. Linear recessed wall washers, located in the dropped gypsum ceiling, were utilized adjacent to the wall with a dual column line on a shared foundation. This allowed for suitable illumination while concurrently highlighting more memorabilia pertaining to the athletes.

Refer to Drawing E-3.1 for circuiting and the lighting fixture layout. Synergy anticipates this space to be a high-traffic area for occupants with regards to egress, so every fourth fixture is on emergency power to assure all occupants can safely exit the building. This satisfies Tornado Safe Room criteria per ICC 500 to provide at least 1 footcandle of average illuminance.

6.6 PRACTICE FOOTBALL FIELD

![Figure 9. Interior Safe Room Corridor Rendering](image)

![Figure 10. Interior Rendering of Football Field Area](image)
The practice football field incorporates high output SpecGrade LED floodlights in order to provide uniform light onto the field. The fixtures were spaced evenly along the trusses, providing uniform illumination. The fixtures are mounted to the bottom chord of the trusses using a custom angle attachment. For fixture mounting details, see Drawing E-3.2. The fixtures have an IP65 rating which makes them extremely durable to impact. Each floodlight is a 300 Watt LED fixture, which is equivalent to a 750 Watt Metal Halide fixture. With the reduced wattage consumption and wide distribution, this lighting design proved to be under ASHRAE 90.1 criteria – from 0.21 W/SF to 0.17 W/SF – prior to any implementation of lighting controls.

With regard to emergency and egress, a total of six fixtures were placed on emergency power. These six floodlights were strategically chosen based off of door locations that gave access to the campus outside.

Refer to Drawing E-3.2 and E-4.0 to see circuiting configurations, renderings and calculations.

6.7 TRACK & FIELD

Figure 11. Interior Rendering of Track & Field Area

The track and field space also incorporated SpecGrade LED floodlights. The fixtures are spaced evenly mounted to the trusses as designed for the football field, but needed to fulfill the additional requirement of illumination that would meet NCAA broadcasting requirements. The fixtures at 100% output meet broadcasting requirements, but would only need to be at 80% output for all other instances. Other lighting controls were implemented into this space, shown on Drawing E-6.0.

For both the football field and track & field floodlighting design, all fixtures mounted to the same truss were placed on the same branch circuit, reducing wiring which inevitably reduced our cost for this design. With regards to emergency power, six fixtures were placed on emergency power. All fixtures were carefully considered after looking at all possible egress paths in the event of an emergency. Please refer to Drawing E-3.2 for circuiting and lighting layout of the track & field floodlighting design.

6.8 SUPPORT & UTILITY SPACES

One unique space for the Sports Performance Center is the meeting room located on the second floor of Synergy’s architectural design. The Lighting/Electrical team chose a unique lighting layout with the assumption that track athletes and coaches would be in this room often. Direct/indirect suspended lighting was used to create the curve of a track and its boundary lines with their mounting locations. With the fixtures curving toward the track & field area, the Lighting/Electrical team felt this would subconsciously draw the athlete’s attention back towards the track & field area in the building.

Industrial fixtures were used within mechanical & electrical rooms, telecommunications, and security and video control rooms. All of these spaces have emergency powered lighting to allow maintenance access with no visibility issues in the event of an emergency or loss of power.

All other ancillary spaces incorporate industrial, protected linear LED fixtures. Please refer to Drawing E-6.0 for details on the fixture types within these additional spaces.

6.9 SAFE ROOM DESIGN

The Tornado Safe Room within Synergy’s enhanced design required a specialized lighting design. Lighting located in the auxiliary spaces under the bleachers, known as the safe room, have certain fixtures on a dedicated emergency circuit, which would be powered by the emergency generator. Since the generator is enclosed in an EF4 rated protection, the emergency lighting meets the needs of the Safe Room at all times.
6.10 EXTERIOR LIGHTING

Within the Texas Tech University System Facilities Planning & Construction Design & Building Standards, Metal Halide fixtures have been standard for exterior campus fixtures. However, Synergy incorporated LED fixtures for all building facade and site lighting designs due to the improved efficiency.

![Figure 12. Exterior Rendering of North Façade of Sports Performance Center](image)

To provide secure pathways around the building perimeter, Lumiere bollards were placed where all pathways existed in Synergy’s site design. In addition, the small parking lot integrate d McGraw-Edison decorative post-top fixtures to provide additional security around the building’s exterior.

Lastly, io-LED linear asymmetric fixtures were selected to highlight the columns on the north facade adjacent to the north glazing apertures as well as to showcase the clerestories the Synergy team designed. These io-LED linears are RGB, and can be tuned to be Texas Tech red during football games and other events. Please see Drawing E-3.0 for the exterior lighting plan.

7.0 POWER CONSIDERATIONS

Synergy analyzed many options for the electrical design to ensure that the best generation solution was implemented. Throughout the course of the schematic design phase, Synergy researched the following options for electrical system design:

1. Photovoltaic Power Generation
2. On-Site Battery Storage
3. Fuel Cell Power Generation
4. Fully DC System Operation
5. Bi-Fuel Generators

7.1 ELECTRICAL DESIGN DECISIONS

In an effort to develop the best electrical system for the Sports Performance Center, Synergy weighed the pros and cons of several generation, distribution and emergency power options. Factors that influenced the system selection included cost, environmental benefits, maintenance requirements, and payback period. For an analysis on all electrical system options, see the decision matrix on Lighting/Electrical SD-A which demonstrates how Synergy was able to determine which systems would be best to investigate during the system selection phase of the project.

Photovoltaic power generation was considered very early on in schematic design, due to the project location. The city of Lubbock experiences 262 sunny or partly sunny days per year. Looking at the campus site, the Sports Performance Center is not shaded by any neighboring buildings or vegetation, making it a prime contender for photovoltaic panel location. While the building rooftop provided ample space for panel installation, the curved roof structure posed a challenge for mounting photovoltaic panels that would withstand an EF3 tornado. These stipulations caused Synergy to investigate the use of photovoltaic membranes that would maintain a low profile by being attached to the roof with adhesive. These membranes would not experience the uplift that would tear regular solar panels off the roof in high wind speeds.

Another technology considered for power generation was a fuel cell system. Synergy analyzed the use of solid oxide fuel cells to power all building loads. Fuel cells convert chemical energy from natural gas fuel into electricity through a chemical reaction. Fuel cells have additional advantages over the electrical grid. Energy generated from fuel cells release less emissions than the grid. Decreasing reliance on the electrical grid reduces peak demand charges, contributes to a lower payback period on the technology, and lessens the strain on the grid in Texas.
Synergy compared the fuel cells versus the photovoltaic system through a discussion summarized in the Decision Matrix in Lighting/Electrical SD-A. The Lighting/Electrical team collaborated with the Construction team to study the capital and lifecycle costs, which were a significant contribution to the final decision. After in depth analysis of the two systems, the team decided that due to low efficiency from the membranes and an undesirable lifecycle cost, photovoltaic membranes would not be recommended to the client. Ultimately, the system chosen for the power generation was a fuel cell with electrical grid backup. Synergy analyzed the benefits detailed above, and determined that a fuel cell would be the best recommendation as a worthwhile investment for the university. Not only would TTU be recognized for using pioneering sustainable energy generation, the system can be used for research at the university, and would be open for future system growth.

![200kW Bloom Energy Fuel Cell](image1)

![Electrical Utility Line](image2)

![200kW Generac Bi-Fuel Generators](image3)

**Figure 13. Building Power Sources**

Initial fuel cell system designs incorporated two 200kW fuel cells to service the building maximum load of 400kW. Excess generation would be supplied to the campus grid and utilized for other campus buildings. However, through load calculations and an analysis guided by the electrical decision matrix, Synergy realized that the most beneficial arrangement was downsizing the fuel cell closer to the building’s typical loading. This change would lower capital cost and restrict the surplus generation, which will only be required once a year during large track & field events.

**Figure 14. Main Electrical Room 3D Layout**

### 7.2 ALTERNATE FUEL CELL PLACEMENT DESIGN

Through the Mechanical and Lighting/Electrical system design, Synergy realized the potential of a more efficient arrangement for the fuel cell system. Use of a molten carbonate fuel cell as opposed to a solid oxide fuel cell would allow for heat recovery and transferred to domestic hot water, or heating water. This utilization of waste heat from the fuel cell could be achieved by locating the fuel cell at CHACP I (Central Heating and Cooling Plant near the Sports Performance Center). This solution would require additional coordination with the client as well as specifying a new fuel cell specification, however, this would provide benefits not only to the Sports Performance Center, but also the entire campus. This updated fuel cell location would allow for energy recuperation year round, which is detailed in Mechanical Report Section 7.2. This alternate power generation proposal is being investigated to develop the best solution for a combined heat and power generation system.

### 8.0 BUILDING ELECTRICAL SYSTEMS

#### 8.1 FUEL CELL

A 200kW Bloom Energy Server solid oxide fuel cell services lighting, plug, mechanical and emergency loads, which is supplemented with the electrical grid when necessary. The fuel cell is connected to the natural gas line for input, and the electricity produced runs through Switchgear which inherently distributes power to all panels. Refer to Drawing E-5.0 for the
distribution system breakdown of Synergy’s design through the riser diagram.

8.2 EMERGENCY POWER

Synergy supplied two 200kW Generac Bi-Fuel Generators to service emergency loads in the event that connection to the electrical grid, natural gas line, or both were removed. One generator fulfills all building emergency loads, while the other acts a standby generator. Specific emergency loads that will be powered include fire pumps, fans, emergency egress lighting, safe room, some office receptacles, and telecom. Please refer to Drawings E-2.0, E-2.1, E3.0, E3.1, for power and lighting plans, as well as Drawing E-7.0 for Synergy’s emergency panel loads. Given that the emergency generators were needed to provide power to the Safe Room, they were also required to withstand an EF4 tornado. Synergy opted to keep the generators outside to avoid acoustical exhaust, fuel handling issues indoors. The resulting design is a collaboration between all disciplines, to ensure that the generator can withstand an EF4 tornado, is exhausted properly, and can be constructed on site maintaining the structural stability. The generators are enclosed within a Lonestar Prestress Enclosure, detailed in Drawing E-2.0.

8.3 SYSTEM REDUNDANCY

Synergy placed significant focus on redundancy and safety for the electrical system. The electrical design employs two reliant levels of redundancy to ensure that the building maintains operational in all situations. The majority of regular use building loads are supplied by the fuel cell that receives natural gas from the utility lines. The first level of redundancy is the system connection to the electrical grid for building loads surpassing 200kW, and as system backup if the natural gas line were to be disrupted for any reason. For both a second line of backup and for all emergency purposes, the building supplies two 200kW Generac Bi-Fuel generators – one of the two being on standby. These generators are started initially with diesel fuel, and can then run off of natural gas. Synergy coordinated to make sure the proper amount of diesel fuel would be on-site and ready to be utilized in the case of an emergency where neither the fuel cell, grid, nor natural gas lines are functioning properly.

The generator can utilize diesel fuel until natural gas lines come back up to fully functioning. Therefore, 700 gallons of fuel will be stored in a tank under the EF4 enclosure that will be housing the bi-fuel generators. This provides the Sports Performance Center with 48 hours of fully reliable emergency power generation. The generator consumes 14.4 gallons of fuel per hour, which means that the generator can run off of diesel fuel at 100% for at least 48 hours. This provides redundancy, and also a more environmentally friendly alternative to exclusively diesel fuel generators. See Drawing E-5.0 for a riser diagram breakdown of electrical operation.

9.0 SUSTAINABLE STRATEGIES

Energy usage can be reduced through electrical and lighting design in a number of ways. Synergy focused on an advanced lighting controls system that utilizes daylight harvesting in the building lighting design. The daylighting strategies and LED lighting selections combined to reduce the yearly lighting energy consumption by 70% over ASHRAE 90.1 2010.

The electrical design provides opportunities for advanced research, increased energy efficiency, and decreased emissions.

9.1 DAYLIGHT HARVESTING

Synergy placed significant value on integrating daylight into the architectural design due to the added benefits for athlete experience in the space. This encompassment provided opportunity for additional advances in energy savings. All spaces that feature significant natural light throughout the day employ daylight dimming to reduce the electric light in the space when adequate natural light is present. Closed
loop dimming operates for multiple daylight zones in offices and auxiliary spaces, while open loop operates in the field spaces. The daylight dimming saves an average of $1,598.65 per year, which is 12.8% of the entire building yearly energy consumption costs. Specifically, the biggest advantage in daylight harvesting lies in both field lighting applications. During daylight hours 8AM-6PM, the football and track & field receive an average daylight autonomy of 55% and 72% respectively, which allows the electric light to be dimmed at the same average throughout the day. This equates to energy savings of $1,538.11 per year from the field lighting alone, which is made possible through the clerestory installations. See Drawing E-1.0 for a summary of daylight dimming energy savings.

9.2 LIGHTING CONTROLS

In addition to daylight harvesting, the Lighting/Electrical team employed additional lighting control strategies to provide ease of lighting operation for the occupants, as well as minimizing energy consumption in the building. The Lutron Vive™ is an intelligent wireless control system that manages lighting controls for the entire Sports Performance Center. The system features scalability through wireless devices and BACnet protocol communication to allow connection to other campus buildings in the future. The lighting controls system ensures that the appropriate amount of light is available within each space at all times, and reduces lighting levels when spaces are unoccupied. Bilevel control, timeclock scheduling, and automatic on/off contribute to lighting spaces where required by ASHRAE 2013 Standard and other additional spaces. Refer to Drawing E-1.0 for the controls narrative for each space type within the building and control layout diagrams.

Vive wireless hubs are installed within each room, and PowPak modules are installed for every lighting control zone. These devices communicate via Clear Connect radio frequency to employ timeclock scheduling, automatic on/off, and daylight harvesting. The lighting controls system utilizes BACnet/IP protocol, which allows it to communicate to Texas Tech University’s campus energy metering system, UtiliVisor. The Vive also has the capability to communicate via WiFi to smart devices. This will be advantageous for staff at the Sports Performance Center, as they can adjust lighting for recruits or make quick changes to timeclock scheduling when required.

9.3 FUEL CELL EFFICIENCY

The implementation of a fuel cell provides several benefits in sustainable design. The fuel cell runs off of natural gas, which make it more efficient than the electrical grid, which operates at an efficiency of 33%. Generating power from the fuel cell reduces both reliance and strain on the electrical grid, and also lowers the university’s peak demand charge per month. During times where the fuel cell is generating more power than the building requires, this excess generation can be supplied back to the campus grid, and used in other areas of campus. Fuel cells convert natural gas into electricity through an electrochemical reaction, which is a combustion-free process that produces virtually no pollutants. Refer to Lighting/Electrical SD-C for system emissions comparisons.
The alternate proposal for the fuel cell system location and specification provides additional efficiency to the power generation system. If Synergy was able to run a molten carbonate fuel cell at CHACP 1, heat recovery could take place throughout the entire year. This would save energy overall through the CHACP 1 system.

10.0 SPECIAL SYSTEMS

10.1 FIRE ALARM SYSTEM

The Texas Tech Sports Performance Center is classified as building type A-4, assembly uses for indoor sporting events with spectator seating. In accordance with NFPA 72, a manual fire alarm system will be installed. The Fire Control Instruments line by Honeywell will be utilized in the design of the Sports Performance Center.

All smoke detectors shall utilize photoelectric obscuration smoke detection. With these detectors being line-type, all large areas will be secure with a detector having a greater coverage area. With the Synergy team also believing in complying strongly with the American Disabilities Act, the team wanted to provide fire alarm/visual type horns with strobes throughout the building so all occupants are aware of an emergency.

The fire alarm control panel is located in the lobby, close to the entrance for convenience for the fire department, and protected from the public in an enclosed space under the lobby staircase.

Figure 17. Gamewell Fire Control Instruments From left to right: Fire Alarm Control Panel, Photoelectric Fire Alarm, and Manual Pull Station

Several manual pull stations will be located at the main entry, corridors, and equipment rooms. Heat detectors will also be installed for the elevator in the lobby area, as well as flow switches and tamper switches for the sprinkler system where required. Activation of any heat detector in the elevator machine room, elevator pit, or elevator shaft shall shunt trip the circuit breaker serving the associated elevator.

It should also be noted that Synergy’s fire alarm system shall be tied into and monitored at the Central Heating and Cooling Plant 1 emergency maintenance facility and Texas Tech Police Department through Synergy’s Telecommunications system.

10.2 SECURITY SYSTEM

Synergy’s design implements several security strategies to ensure safety for visiting patrons and athletes. The welcome desk in the lobby is staffed from 7AM-6PM, and directs those who enter to their desired destination. The main entry doors are locked at all times and visitors must either swipe in or be granted access by the desk staff. In addition to the entrance personnel, card swipe admittance at other doors prevent people from entering prohibited spaces. Athletes, coaches, trainers, and managers will have swipe access to their respective facilities on their university IDs.

10.3 TELECOMMUNICATIONS SYSTEM

The Main Distribution Frame (MDF) communications room shall provide the service provider with a demarcation point. Texas Tech currently utilizes Cat5e for horizontal cabling with Cat6 available as an upgrade. Cat6 horizontal cabling provides a wider bandwidth at 250MHz over the Cat5e 100MHz bandwidth. Therefore, the Lighting/Electrical team decided to utilize Cat6 horizontal cabling. This decision kept in mind that Synergy wished to create a building that considered future possibilities.

All horizontal cabling imposes a 296 feet length restriction before the cabling must be terminated. Therefore, an Intermediate Distribution Frame (IDF) communications room was incorporated into the new building program to assure the cabling does not exceed these limitations. The Sports Performance Center is 400 feet in length, so this issue had to be evaluated by the team.

10.4 BROADCASTING REQUIREMENTS

The track & field is designed to support televised championship events from high school to collegiate level. This increased design requirements to be able to provide sufficient lighting for NCAA broadcast requirements. Incident lighting, or the light striking the subject, needed to be increased to fulfill the design criteria of 1000 horizontal and vertical lux and 1.7:1
horizontal and vertical uniformity. For broadcast lighting compliance calculations, refer to Drawing E-6.0. In advance of a Big 12 Championship event, the facility will submit the NCAA Lighting Performance Checklist to the championship administrator to be approved for broadcast lighting requirements.

10.5 LIGHTNING PROTECTION

A UL 96A Standard Lightning Protection system was installed on the building after reviewing UL and NFPA 780 recommendations. Lightning risk assessment calculations, shown on Lighting/Electrical SD-E, determined that lightning protection should be installed at the facility. Air terminals were spaced using the standard grid placement scheme, at 20 feet apart along the roof perimeter. Class II air terminals, cable conductors, and ground rods will be used, due to the highest roof height exceeding 75 feet. The mechanical rooftop equipment will be intentionally bonded to the lightning protection system to ensure that side flashes do not occur.

11.0 CODES & STANDARDS

The following codes were referenced as the basis for the Competition design:

1. 2012 International Building Code
3. ASHRAE 90.1 2010/2013
6. TTUS FP&C Design & Building Standards: Division 16 - Electrical

12.0 WELL CERTIFICATION

Synergy developed a design that meets WELL Gold Certification Standards. A summary of the entire checklist can be found in Lighting/Electrical SD-B, with specific lighting/electrical compliance calculations. Synergy acknowledged that the WELL Building Standard guide was centered on an office building, so additional strategies were considered to tailor the health and well-being motives to a sports performance center. Synergy recognized that the main focus for the Sports Performance Center was athlete performance, and sought to maximize this facet through implementation of the WELL Standard.

13.0 CONCLUSION

Synergy’s Lighting/Electrical designs are innovative and modern, but still consider the end value brought to the owner. All systems were evaluated with consideration of capital costs and payback periods. The team also sought to provide value through an efficient design, with ease of use and maintenance for building occupants. A simple and adjustable lighting control system was used, in addition to an innovative and secure building power design.

Synergy’s design reliably accommodates for the building occupants and the community through redundant power generation. The fuel cell and electrical grid provide power for the building, with Bi-Fuel generations as emergency backup that operate on either natural gas or stored diesel fuel. Patron and athlete safety is prioritized through building access security measures.

The focus on the WELL Building Standard allowed Synergy to not only have a high performing building, but also one that positively impacts the athletes. Synergy developed an integrated clerestory construction that allowed more natural light into the athletic spaces. The building lighting design focuses specifically on athletes and future recruits, highlighting the artwork and features that motivate the athletes.

Synergy’s design allows for future expansion of systems. The fuel cell serves as an innovative power generation source that can be utilized for university research and be expanded upon in the future. The building also features scalable lighting controls that can be integrated into campus wide control systems. Synergy’s broadcast design in lighting and telecom capacity allows the university to use the Sports Performance Center as a championship meet venue.
Supporting Document A | Decision Making and Program Interoperability

**Electrical Decision Matrix**

Synergy created a decision matrix during the schematic design phase to serve as a guideline for major project evaluations. This guide helped to center the decisions around Synergy’s four overarching themes: Performance, Resiliency, Versatility, and Value. The decision matrix below was used to make decisions regarding the Electrical system decisions. Proposed solutions were rated on a 1-5 scale, with 5 being the best. The results of these matrices served as a method to ascertain which systems to pursue further.

**PROGRAM GOALS:**
- Participants: Lighting/Electrical Team
- Weighting Explained:

**DECISION MATRIX: LIGHTING/ELECTRICAL**

<table>
<thead>
<tr>
<th>PROJECT GOALS</th>
<th>VALUE</th>
<th>RESILIENCY</th>
<th>PERFORMANCE</th>
<th>VERSATILITY</th>
<th>TOTALS</th>
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</thead>
<tbody>
<tr>
<td>Cost</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Design &amp; Maintenance Schedule</td>
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<td>2</td>
<td>3</td>
<td>4</td>
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<tr>
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<td>4</td>
<td>5</td>
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<td>4</td>
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<tr>
<td>Community</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
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</tr>
<tr>
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<tr>
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<td>Environment</td>
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<td>5</td>
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</table>

For example:

**POWER GENERATION**

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<th>4</th>
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<tr>
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<tr>
<td>Diesel Generator</td>
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<td>3</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Bi-Fuel Generators</td>
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<td>3</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Fuel Cell Parallelled with Grid</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>4</td>
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</table>

**EMERGENCY POWER SUPPLY**

<table>
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<th>5</th>
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<th>2</th>
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</thead>
<tbody>
<tr>
<td>On-Site Battery Storage</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
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<tr>
<td>Diesel Generator</td>
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<td>4</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Bi-Fuel Generators</td>
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<td>2</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>2</td>
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</table>

**ELECTRICAL DISTRIBUTION**

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<th>4</th>
<th>5</th>
<th>4</th>
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</thead>
<tbody>
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<td>4</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>DC Distribution</td>
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<td>3</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

**Program Interoperability**

The Program Interoperability lays out the programs utilized by the Lighting/Electrical team for developing the Final Design of the Sports Performance Center. In the center is Autodesk Revit, where the architectural, mechanical, lighting/electrical, and structural models were centrally located. The Lighting/Electrical team mainly utilized the programs highlighted above. The calculations produced from these programs were entered into the Revit model to produce an accurate representation of the building. Lighting/Electrical created a Sketchup model to use within Sefaira, an energy and daylight analysis Sketchup plugin. Sefaira produced an overall energy use index and various daylighting metrics that the team used to design the building fenestration. To calculate illuminance, Lighting/Electrical modeled the building’s room geometry within AutoCad to input into AGI32. AGI32 produced illuminance calculations to verify adherence to established IES criteria.
Supporting Document B | WELL Light Checklist

**Feature 53. Visual Lighting Design**

<table>
<thead>
<tr>
<th>Feature</th>
<th>P</th>
<th>✓</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual Acuity for Focus</td>
<td>P</td>
<td>✓</td>
</tr>
<tr>
<td>Brightness Management Studies</td>
<td>P</td>
<td>✓</td>
</tr>
</tbody>
</table>

- Ambient lighting at desks maintains an average of 300 lux in offices and sports medicine room.
- Even daylight distribution throughout the fields is achieved through integrated roof clerestory construction. Contrast concern exists in the designated core space, where auxiliary spaces and corridors do not have daylight exposure. Consideration for higher electric light levels were executed in this space to mitigate the steep contrast between heavily daylit spaces and core areas.

**Feature 54. Circadian Lighting Studies**

<table>
<thead>
<tr>
<th>Feature</th>
<th>P</th>
<th>✓</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melanopic Light Intensity for Work Areas</td>
<td>P</td>
<td>✓</td>
</tr>
</tbody>
</table>

- Electric lights at work stations achieve melanopic lux recommendations greater than or equivalent to the Vertical Targets as follows: Lobby Reception Desk: 50 lux, Office Desks: 150 lux, Meeting Room: 100 lux. These values were achieved through the overhead indirect fixtures in the offices and meeting room, and achieved with undercabinet task lighting at the reception desk. Melanopic lux was calculated using the 4000K LED multiplier of 0.76, taken from the WELL Building Standard V1.

**Feature 55. Electric Light glare Control**

<table>
<thead>
<tr>
<th>Feature</th>
<th>P</th>
<th>✓</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lamp Shielding</td>
<td>P</td>
<td>✓</td>
</tr>
<tr>
<td>Glare Minimization</td>
<td>P</td>
<td>✓</td>
</tr>
</tbody>
</table>

- Maximum luminance values from all lighting fixtures (summarized to the left), fall under the 19,507cd/m² required.
- At workstations and desks, all lighting is both lensed, and at least 80% indirect, which maintains less than 8,000cd/m².

**Feature 56. Solar Glare Control**

<table>
<thead>
<tr>
<th>Feature</th>
<th>P</th>
<th>✓</th>
</tr>
</thead>
<tbody>
<tr>
<td>View Window Shading</td>
<td>P</td>
<td>✓</td>
</tr>
<tr>
<td>Daylight Management</td>
<td>P</td>
<td>✓</td>
</tr>
</tbody>
</table>

- All glazing less than 2.1 m above the floor is located in athletic spaces. Workstations will not be disrupted.
- The daylight management for all glazing greater than 2.1 m above the floor is achieved by limiting all glazing to be north facing only. In addition, this glazing is located in athletic spaces, so occupants are not likely to be disrupted by the incoming daylight as they would be in an office setting.

**Feature 57. Low Glare Workstation Design**

<table>
<thead>
<tr>
<th>Feature</th>
<th>O</th>
<th>✓</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glare Avoidance</td>
<td>O</td>
<td>✓</td>
</tr>
</tbody>
</table>

- All computer screens are located beyond 4.5 m of view windows. Indirect lighting is used for office spaces.

**Feature 58. Color Quality**

<table>
<thead>
<tr>
<th>Feature</th>
<th>O</th>
<th>✓</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color Rendering Index</td>
<td>O</td>
<td>✓</td>
</tr>
</tbody>
</table>

- All electric lights achieve a CRI Ra of 80 or higher, and a CRI R9 of 50 or higher (see E-6.0 Lighting Fixture Schedule).

**Feature 59. Surface Design**

<table>
<thead>
<tr>
<th>Feature</th>
<th>O</th>
<th>✓</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working and Learning Area Surface Reflectivity</td>
<td>O</td>
<td>✓</td>
</tr>
</tbody>
</table>

- All ceilings in the space are white and have an LRV>95%. The average wall LRV falls below 80%, due to the TTU scarlet and black painted walls, in addition to the large posters that fill some walls in the spaces. Synergy has not specified all building furniture, and therefore cannot confirm that the average furniture LRV falls above 50%.

**Feature 60. Automated Shading and Dimming Controls**

<table>
<thead>
<tr>
<th>Feature</th>
<th>O</th>
<th>✓</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automated Sunlight Control</td>
<td>O</td>
<td>✓</td>
</tr>
<tr>
<td>Responsive Light Control</td>
<td>O</td>
<td>✓</td>
</tr>
</tbody>
</table>

- All workstations are located beyond 4.5 m of view windows. Indirect lighting is used for office spaces.
- All workspace lighting is controlled via ultrasonic or PIR occupancy sensor to switch to full off 20 minutes after a space has been vacated. All workstations are located beyond 4.5 m of view windows. Indirect lighting is used for office spaces.

**Feature 61. Right to Light**

<table>
<thead>
<tr>
<th>Feature</th>
<th>O</th>
<th>✓</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lease Depth</td>
<td>O</td>
<td>✓</td>
</tr>
<tr>
<td>Window Access</td>
<td>O</td>
<td>✓</td>
</tr>
</tbody>
</table>

- Less than 75% of regularly occupied area is within 7.5 m of view windows, due to the size of the athletic fields. Added clerestory lighting provides daylight into playing field spaces, and perimeter auxiliary spaces feature view windows. Some core spaces (less than 25% of regularly occupied area) do not feature daylighting due to tornado safe room reconfiguration.

**Feature 62. Daylight Modeling**

<table>
<thead>
<tr>
<th>Feature</th>
<th>O</th>
<th>✓</th>
</tr>
</thead>
<tbody>
<tr>
<td>Healthy Sunlight Exposure</td>
<td>O</td>
<td>✓</td>
</tr>
</tbody>
</table>

- a. Spatial daylight autonomy (sDa300, 50%) is achieved for 71.5% of regularly occupied space.
- b. Annual sunlight exposure (AEI1000, 250) is achieved for less than 3% of regularly occupied space.

**Feature 63. Daylighting Fenestration**

<table>
<thead>
<tr>
<th>Feature</th>
<th>O</th>
<th>✓</th>
</tr>
</thead>
<tbody>
<tr>
<td>Window Sizes for Working and Learning Spaces</td>
<td>O</td>
<td>✓</td>
</tr>
<tr>
<td>Window Transmittance in Working and Learning Areas</td>
<td>O</td>
<td>✓</td>
</tr>
</tbody>
</table>

- a. Wall-to-wall ratio is 12% for external elevations, which is less than the suggested 20%
- b. 90% of window area is at least 2.1 m above the floor.
- a. All glazing located higher than 2.1 m above the floor has VT of 67%.
- b. All glazing located 2.1 m or lower from the floor has VT of 47%.

**Feature 64. Circadian Lighting Studies**

<table>
<thead>
<tr>
<th>Feature</th>
<th>O</th>
<th>✓</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uniform Color Transmittance</td>
<td>O</td>
<td>✓</td>
</tr>
</tbody>
</table>

- All windows used for daylighting have a visible light transmittance that falls within a factor of 1.42.
BloomEnergy Solid Oxide Fuel Cell

1. **Improved Efficiency**
The fuel cell is more efficient than the electrical grid, due to the fact that it uses natural gas.

2. **Reduced Emissions**
Since the fuel cell produces electricity without combustion, the emissions produced are negligible, making them much better for the environment.

3. **Redundancy**
These fuel cells operate off of the natural gas line, which is much more reliable than the electrical grid.

The BloomEnergy solid oxide fuel cell consists of an electrolyte, an anode, and a cathode. At high temperatures, air enters the fuel cell, and steam mixes with fuel to make reformed fuel. Once the reformed fuel passes the anode, it attracts oxygen ions from the cathode, which combine with the reformed fuel to produce electricity, water, and small amounts of carbon dioxide.

Generac Bi-Fuel

1. **Redundancy**
The natural gas operation allows for less reliance on stored diesel fuel and extended running times during an emergency event.

2. **Reduced Emissions**
Bi-fuel generators emit 30% less nitrogen oxides and 50% less particulate matter than the average diesel generator.

3. **Lifetime Costs**
Natural gas is significantly cheaper than diesel fuel, therefore operational costs over the lifetime of the generator will be reduced.

The Generac Bi-Fuel generator runs primarily on natural gas, and can also run off of diesel fuel. The generator requires 100% diesel to start, then natural gas enters into the system as the coolant reaches a minimum temperature. As the generator begins to accept load, the amount of natural gas is increased and diesel fuel is decreased.

Cost Analysis

<table>
<thead>
<tr>
<th>FUEL CELL CONSUMPTION: BLOOM ENERGY SERVER ES5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Baseload Output (kW)</strong> 200</td>
</tr>
<tr>
<td><strong>Cost per kW</strong> $5,500</td>
</tr>
<tr>
<td><strong>Initial Cost</strong> $1,100,000</td>
</tr>
<tr>
<td><strong>Efficiency of Fuel Cell (%)</strong> 0.52</td>
</tr>
</tbody>
</table>

**INPUTS**
- Natural Gas Flow Rate (MMBtu/hr) 3.11538462
- Gallons of Water Required at Startup 120
- Natural Gas Fuel Cost (per MMBtu) $1.09

**TOTAL COST**
- Initial Cost $1,100,000
- Cost of Natural Gas (per year) $12,535.56

**ELECTRICAL GRID**
- Service Availability Charge (per month per meter) $37.85
- Energy Charge (per kwh) $0.04
- Demand Charge (per kW) $12.28
- Total Building Load (kW) 200
- **TOTAL COST** $105,382.78

Emissions Analysis

<table>
<thead>
<tr>
<th>Carbon Footprint Reduction</th>
<th>Electrical Grid</th>
<th>Synergy Fuel Cell</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Energy used (kwh)</td>
<td>1,829,413.12</td>
<td>713,788.80</td>
</tr>
<tr>
<td>CO₂ Pollutant Factor (lbm/kwh)</td>
<td>1.71</td>
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<tr>
<td>NOx Pollutant Factor (lbm/kwh)</td>
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<td>SO₂ (lbm/yr)</td>
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</table>

References
1. Lubbock Power & Light Electric Rate/Tariff Schedule, Rate 15, Purchased Power Recovery Factor
2. Bloom Energy ES-5700 Product Datasheet

FUEL CELL PAYBACK PERIOD 11.85 years
Synergy used Sefaira to conduct daylighting schematic design. The Sports Performance Center was modeled in Sketchup, and the original building architecture was investigated. Daylight Autonomy renderings to the right show the daylight distribution of the original building. Synergy sought to improve upon the non-uniform daylight within the field spaces. Once the clerestory design had been developed (detailed in Integration Drawing I-5.2), Synergy ran an analysis on several glazing types with several different areas to determine which configuration was optimal for the clerestory windows. Considerations included impact on heating and cooling loads, spatial daylight autonomy improvement, resiliency during an EF3 tornado, and cost of the system. The graph to the left showcases comparisons of varied glazing heights and the subsequent impact on daylighting and energy use index.

After analyzing 10 glazing configurations that complied with ASHRAE and tornado resiliency requirements, Synergy determined that laminated insulating glazing was the most optimal configuration for both thermal performance and uniform daylighting. Given that glazing within the building had varied ASHRAE requirements, Synergy settled on two versions of Viracon laminated insulating glass. The glazing for the north elevation panels and clerestories is VE-2M, which allows for significant visible light transmittance. The glazing located within 7m of the ground had more stringent ASHRAE requirements, and therefore required a higher performance coating that lowered visible light and achieved higher light to solar gain.

Synergy complied with ASHRAE 2013 for glazing requirements. The conditions for the vertical fenestration envelope are summarized to the right.

The Sefaira daylight calculations above show the daylight autonomy for both the original building design and Synergy’s redesigned building with clerestory extrusions. The analysis was run at 460 lux, due to the illuminance requirements for the athletic fields. Synergy’s design provides an average daylight autonomy of 72% for the track and 55% for the football field.

The entire Sports Performance Center was designed to withstand an EF3 tornado, which required the glazing to be resilient in high winds and against airborne projectiles. The glazing was designed to resist winds of up to 200mph, and the impact of a 2x4 traveling at 50 FT per second. To achieve this endurance, the glazing is comprised of laminated lites, which are fully tempered and bound by a Stormguard polyvinyl butyral (PVB) interlayer. This material is specifically designed for large missile hurricane-resistant applications, boasting improved tear resistance and minimal deflection over standard PVBs, which parallel the design requirements for an EF3 tornado.

The strength of the glazing was crucial to the enclosure design. The graphics to the right depict the importance of strong glazing for a building. If the building enclosure was breached due to broken windows, the wind forces would enter into the building, causing an increase in pressure and uplift forces, which could cause the building to collapse. Synergy’s laminated glazing will ensure that the lites remain intact, preserving the building during a weather disaster.
Voltage Drop & Short Circuit Calculations

**SHORT CIRCUIT CALCULATION**

<table>
<thead>
<tr>
<th>Name</th>
<th>FLA</th>
<th>%Z</th>
<th>Short Circuit Amps</th>
<th>Feeder Length</th>
<th>&quot;F&quot; Factor</th>
<th>&quot;M&quot; Multiplier</th>
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**VOLTAGE DROP CALCULATION**

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<tr>
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<td>480</td>
<td>1.18</td>
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Lightning Protection Calculations

**ENVIRONMENTAL & TOLERABLE RISK FACTORS**

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<th>Value</th>
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<tr>
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</tr>
<tr>
<td>Structure Operations (C&lt;sub&gt;5&lt;/sub&gt;)</td>
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</tr>
</tbody>
</table>

**Voltage Drop**

\[ N_C = \frac{1.5(10^{-3})}{C_2C_3C_4C_5} \]

\[ N_D = N_2A_2C_3(10^{-6}) \]

\[ N_C = 24.18 \]

If \( N_D > 1 \), LPS is required

Electrical Room Layout

One-Line Diagram

Lighting/Electrical Supporting Documentation

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Synergy's efficient lighting, mechanical, and controls designs saved **60.25%** over ASHRAE 90.1 2010 Standard.

ASHRAE 90.1 2010 Yearly Energy: **1,194,264 kWh**

Synergy LPD Energy Savings: **579,855 kWh**

Synergy LPD + Daylighting Energy Savings: **356,333 kWh**

### Synergy's Energy Usage

- **ASHRAE 90.1 2010 Building Energy Usage**
  - **Total Energy Usage:** **56%**
  - **Synergy Energy Savings:** **43%**

### Lighting Controls

- **Room Name:**
  - **Local Control**
    - **9.4.1.1(a)** Manual On
    - **9.4.1.1(b)** Automatic Full On
    - **9.4.1.1(c)** Bilevel Control
    - **9.4.1.1(d)** Receptacle Control
    - **9.4.1.1(e)** Timeclock Programmed for Full On During Regularly Occupied Hours 5AM-7PM. Automatic Full On/Partial Off During All Other Hours by Ultrasonic Occupancy Sensor.
    - **9.4.1.1(g)** Automatic Full On/Partial Off by Ultrasonic Occupancy Sensor. Multilevel Scene Control, With On, Off, Evening, and Recruit Scenes.
    - **9.4.1.1(i)** Automatic Full On/Full Off by Ultrasonic Occupancy Sensor.

### Energy Savings

- **Operational hours assumed 14 hours/day.
- Receptacle load average daily operation assumed 4 hours/day.
- *Daylight tracking energy measured from typical IES requirements, not broadcast load.
- **Daylight autonomy values are 0.4-0.40 for athletic spaces, and 0.4-0.30 for all other spaces.
- **Daylight savings in non-office spaces utilize a 71% adjustment factor for an assumption of 30 daylight hours out of 14 operational hours.

Synergy performed a life-cycle analysis on both the electrical and mechanical systems. These analyses took the energy savings into consideration, and resulted in a total savings per year of **$9,248.08**. These savings allowed the payback period of the fuel cell to be lowered, and is at a manageable timeframe for the university at **11.85 years**.

### Lighting Controls Summary – Lutron Vive

- **Minimizing wiring reduces installation time by 70% and creates a more flexible system.**
- **Daylight Harvesting**
- **High performance dimming for LED fixtures; zone and individual fixture control**
- **BA.Net Integration**
- **Ability to connect with mechanical, IT, security systems; potential for future campus growth**

---

**Legend:**
- **Lighting Load**
- **Mechanical Load**
- **Receptacle Load**
- **Savings**
Synergy worked to design an enclosure to protect the emergency Generac bi-fuel generators. These generators serve the safe room and all other emergency loads, therefore needing to be protected during a tornado. The structure is prefabricated at Lonestar Prestress Inc. in Houston, Texas. Synergy worked to create an enclosure that can withstand an E4 tornado, equating to withstanding a 100 mph projectile. The enclosure will also be assembled with louvers to help with emissions from the generator. The exhaust louvers will be located away from the natural ventilation louvers on the south wall.

In order to anticipate the event of needing the Sports Performance Center to act as a community shelter, the electrical team designed all perimeter receptacles in the track and football spaces to be quadruplex receptacles.
**Electrical Equipment Naming Abbreviations**

- **CTRL** – CONTROL
- **VAV** – VARIABLE AIR VOLUME
- **SF** – SUPPLY FAN
- **RF** – RETURN FAN
- **AHU** – AIR HANDLING UNIT

**Mechanical & Electrical Coordination Schedule**

<table>
<thead>
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<th>Tag</th>
<th>Voltage/Phase/Hz</th>
<th>Supply Fan (Hp)</th>
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<th>Return Fan (Hp)</th>
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</table>

**Electrical Naming Convention Key**

- **XX** - **X**
  - **X**
    - **PREFIX**
    - **CIRCUIT NUMBER(S)**

**Electrical Power & Equipment Symbols**

- **DUPLEX RECEPTACLE**
- **JUNCTION BOX – CEILING MOUNTED**
- **MOTOR & CONNECTION**
- **FUSED DISCONNECT SWITCH**
- **MOTOR STARTER**
- **VARIABLE FREQUENCY DRIVE**

**Keynotes**

- All VFDS & FUSED/DISCONNECT SWITCHES in outdoor areas are to be NEMA-3R ENCLOSURE TYPES.
- Weather shields shall also be provided for all VFDS & FUSED/DISCONNECT SWITCHES that are located outdoors.
When athletic events are being held, whether in the Sports Performance Center or the adjacent Jones AT&T Stadium, all of the exterior uplights – Fixture SC – will be set to emit red light to further exhibit school spirit and get spectators excited for the meets.

Bollards are utilized for all pathway areas to assure proper light levels are achieved. When moving farther away from the building footprint, a more traditional fixture commonly seen on Texas Tech’s campus is utilized for the parking lot and other areas where needed.
The tornado safe room has two dedicated branch circuits: circuit 29 on LP-1 and circuit 9 on EMLP-1.

Lighting Symbols
- Ceiling Mounted Occupancy Sensor
- Ceiling Mounted Vacancy Sensor
- Wall Mounted Occupancy Sensor
- Wall Mounted Vacancy Sensor
- Fixture Type Designation
- Wall Mounted Exit Light
- Lighting Zone
All SpecGrade LED fixtures were fastened to the hollow structural steel – HSS – trusses located in the clerestories of the track and football spaces.
The Sports Performance Center is serviced through a combined heat and power cogeneration system. The primary building load is powered by a BloomEnergy solid oxide fuel cell. The fuel cell is directly serviced by the natural gas line, and creates combustion-free power at a high efficiency. The building is supplemented by the electrical grid, which powers the building when the loads surpass 200kW. The fuel cell operates at 100% at all times. When the building load is less than 200kW, the excess generation is sent to the campus grid, to be utilized in other buildings, or to be sold back to the grid.

In the event that the building loses connection to the electrical grid, all loads can be serviced by the natural gas line. During times of lower building loads, the fuel cell itself can provide enough power to the building. Should the building load surpass 200kW, the additional loads will be powered by the bi-fuel generator, which will be started by diesel fuel and will continue to run off of natural gas.

In the event that the natural gas line is disconnected, the entire building load will run off of the electric grid. There are no concerns about capacity, as the grid will be able to serve all building loads.

In the event that the building is completely cut off from all utility lines, the emergency building loads will be serviced by the EF4 resilient bi-fuel generator running off of diesel fuel. The 200kW generator has enough on site diesel stored to supply the building for 2 hours. An standby 200kW generator exists on site for redundancy.
0.0 EXECUTIVE SUMMARY

Displacement Ventilation
The large volume athletic spaces are mechanically ventilated and conditioned using displacement ventilation. Integration with architectural features and other disciplines allowed for an underground supply air duct system.

Natural Ventilation
Building location, orientation, and architectural design presented opportunity for seasonal free ventilation and cooling. The integration of south wall louver controls and an operable window scheme in the clerestory allowed for natural ventilation in the large volume rooms.

Energy Savings
System integration of fuel cell technology and hybrid ventilation design in the building exceeded ASHRAE 90.1 energy reduction of 50%. The total energy reduction yearly was 60.25%. Synergy was also able to meet WELL Gold and LEED Gold certifications.

Occupant Comfort
Acoustical considerations, thermal comfort, and occupant wellness influenced design of major building systems. Sound control and air distribution strategies are tailored to the occupants. The building interacts with users to positively influence work flow, exercise regimens, and life style decisions.

Building Enclosure
The enclosure is a highly resilient assembly. A precast wall and terracotta rain screen assembly provide a high R-value performance. The building is able to resist heat gain and loss, which reduces mechanical system loads.

Safe Room
A centralized core shelter protects the occupants in emergency situations. The safe room design provides comfort and reliability to occupants. Occupant safety is the main priority.
Synergy plans to achieve the stakeholders’ goals by producing a facility that not only supports the needs of the athletes, but adapts to future growth and advancement.

2.0 TEAM MISSION

The goals based on the owner and stakeholders serve as the foundation for the goals of the project. At Synergy, we strive to give our clients the greatest amount of value through a hard working team atmosphere, innovative design, sustainable construction, and superior maintenance capabilities.

3.0 PROJECT SCOPE

Synergy set mechanical goals to design an efficient building by selecting cost-effective and sustainable systems while also creating a comfortable space for staff, athletes, and spectators. The main goals were to, at a minimum, reduce the energy use by 50%, meet the WELL Building Standard, maintain building operation for 7 days off grid, and utilize prefabrication where possible to advance the building schedule.
4.0 FINAL DESIGN

Synergy approached design schemes for Texas Tech University Sports Performance Center by analyzing the architectural potential to enhance overall building performance as the first step in mechanical design. Opportunity for design innovation began with an understanding of the site and climate conditions. The final design split the large athletic spaces and added a two-floor multipurpose core. For complete architectural design iterations, see in Drawings I-5.1 to I-5.3.

The final mechanical design for the Texas Tech University Sports Performance Center includes the following:

1. **Building Enclosure**
   The building envelope was optimized to have a higher R-value and provide protection from tornados.

2. **Central System Design**
   The central system design accounts for utilities and innovative future applications for the current university central plant.

3. **Hybrid Ventilation**
   The hybrid ventilation system combines the use of natural and displacement ventilation and is used in the athletic and auxiliary spaces.

4. **Safe Room & Shelter Design**
   Natural ventilation was designed into the tornado safe room and community shelter in case of an EF-3 or an EF-4 tornado.

5. **Fire Protection**
   The fire protection system for the athletic spaces is integrated into the roof design.

6. **Acoustic Design**
   The acoustical design takes into account critical spaces and their adjacent spaces; including reverberation time and STC partition analysis.

5.0 SITE ANALYSIS

Texas Tech is located in climate zone 3B characterizing the location conditions as hot and dry. To analyze the potential use of natural ventilation and rainwater harvesting, an analysis of the wind conditions, temperatures, and precipitation was performed.

5.1 WIND ANALYSIS

Wind patterns were analyzed to determine the ideal building orientation in order to properly use natural ventilation. Figure 1 shows the wind rose for Lubbock, Texas from Lakes Environmental’s WR PLOT. The most significant sources of wind come from the south and southwest with speeds most frequently between 8-19 mph. The design team found the southern building face to be the most beneficial for natural ventilation for the TTU Sports Performance Center. This consideration aided in choosing an orientation of the building to work for all disciplines.

![Lubbock, Texas Wind Rose](image)

5.2 CLIMATE ANALYSIS

The climate conditions for Lubbock, TX are referenced from ASHRAE 2013 Fundamental using data from Lubbock international Airport weather station data.

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<thead>
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<th>Design Conditions</th>
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<tr>
<td>Wet Bulb</td>
<td>73.2</td>
</tr>
<tr>
<td>Heating Dry Bulb</td>
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Table 1. Outdoor Temperature Design Conditions
The weather condition extremes were used to select and size equipment. The monthly weather data from IES VE, shown in Figure 2, demonstrates the typical temperature averages for both daytime and night. The climate in Lubbock has a comfortable temperature range for a sizable portion of spring and fall leading to further research of natural ventilation as an option.

![Figure 2: Outdoor Temperature Stresses, TX from IES](image)

Natural ventilation addresses the design challenge of a seven-day shelter space in the event of tornado in the community. Primary tornado season, in accordance with Texas Tech University, is from late spring through early summer. In the event that Texas Tech University’s Sports Performance Center is called into service as extended shelter, the favorable climate conditions offer the opportunity for thermal comfort and ventilation without forced ventilation or mechanical cooling.

Lubbock historically experiences low precipitation annually. The yearly average rainfall is 19.18 inches and snowfall is 9 inches. Therefore, water recovery is difficult to justify for this facility.

6.0 BUILDING ENVELOPE

Envelope and roof design are critical parts of the infrastructure that impact mechanical loads. Synergy’s approach to these components of the building are developed from the design for EF-3 tornado winds. With this in mind, the team choose to implement highly impact resistant materials to prevent damage from flying debris. The design team collaborated to find impact resistant materials that also provided thermal resistance to benefit the assemblies’ R-value. Calculations for the wall assembly R-Values can be found in Mechanical SD-D.

6.1 FACADE

The façade is split into two section types, as shown in Figure 3. Two wall assembly types are used to reduce wall weight on the grade beam. The bottom 24’ of wall is precast wall construction used to meet accelerated schedule goal. See Drawing C-4.0 for information on the precast wall construction. The wall assembly above 24’ is a terracotta rain screen. This lighter assembly is equipped with 2 plywood boards and a 14 gauge metal sheet for EF-3 material impact. The team chose terracotta tiles for the exterior material for ease of maintenance and repair. Tile can be easily replaced in the event of damage. The total thermal performance of the both wall compositions increased to R-32. This increased performance wall reduced 70% of the thermal loading from conduction. The energy performance was increased due to continuous insulation around building. This allowed for minimum thermal bridging in the wall assembly. In addition, the assembly faces have a layer of massive material outside the insulation to absorb and delay solar gains. The terracotta is also vented. This reduces solar heat gain from transmitting to interior.

![Figure 3. Envelope Wall Section & Materials](image)

6.1.1 MOISTURE CONTROL

Moisture control in the wall was considered when designing a varied building enclosure. The joint connection between the precast wall assembly and the terracotta wall assembly was an area of high concern. Synergy’s solution used sequencing of construction to provide a continuous water barrier at the seam.
Synergy used a moisture transport analysis program called WUFI. The program analyzed moisture content, showing that the building’s wall assemblies were capable of water shedding. Both wall sections were modeled in the program and environmental impacts were entered into the system. When the analysis was run, it was determined that both the precast and terracotta wall assemblies allowed for the wall to dry permeated water in the outer materials. Behind the vapor barrier, no moisture was present within the metal studs and batt insulation, the crucial parts of the wall assemblies, because neither the dew point nor 100% relative humidity was reached. The program also shows heat transfer through the assemblies. The wall resists wall conduction effectively which reduces energy loss through the building envelope. Synergy is confident in the two designed wall assemblies. Details of the WUFI models can be found in Drawing C-1.0.

6.2 Roof

The roof design was coordinated to withstand uplift from tornados, provide proper daylighting, and improve the overall R-value. Factory Mutual (FM) roof assemblies showed that the structural connections would allow for 4” of insulation to meet uplift requirements. For more information on the structural roof connections, see Structural Report section 11.2. ASHRAE standard require a minimum of an R-20 roof for zone 3B. Considering design criteria, 4” of polyisocyanurate rigid insulation panels (R-7.25/in.) were selected for the roof assembly. The complete assembly can be seen in Figure 4.

![Roof Section](image)

The depressed roof design added additional glazing and façade material. In order to maintain a consistent envelope, the structure and glazing values were selected to optimize reductions energy lost. The façade in the depressed roof maintains an R-value of 20, meeting ASHRAE code for zone 3B. The large amount of glass incorporated posed two challenges: energy performance and durability of the windows. The clerestories withstand EF-3 tornado conditions and exceed ASHRAE window performance parameters. The glazing selection meeting both conditions is a triple-pane laminated glass assembly. The glass thermally performed with a U-value of 0.3 in combination with a low-E fill to reduce solar heat gain. For more glazing details see Lighting/Electrical SD-D.

7.0 CENTRAL SYSTEM DESIGN

Texas Tech University runs and maintains two centralized power plants that distributes steam and chilled water throughout the campus. Distribution methods for these utilities have also been developed within the campus master plan.

7.1 NORMAL USAGE

With a central steam and chilled water plant available, Synergy focused on the building’s effective use of these utilities instead of creating a separate central plant on site. A decision matrix with Synergy’s values was used to confirm this decision as shown in Mechanical SD-A. Chilled water from the central plant is brought into the facility’s mechanical room through utility lines located near the south west corner of the site. Reference Mechanical SD-B for the utility plan.

The chilled water supply is distributed at an assumed 40°F. Two variable frequency chilled water pumps (CHWP) provide proper GPM flow rate to the cooling coils. The pump will cycle to reduce strain on a single pump while also providing redundancy. The chilled water is fed to air-handling units (AHU) providing required ventilation in the facility. Steam is provided at a known 80 psi, which is used to heat hot water via a heat exchanger. Hot water is then distributed to AHU coil by two pumps, also allowing for cycling and redundancy. High temperature steam condensate (200°F) from the heat exchanger is routed through a secondary water-to-water to preheat hot water supply (HWS), as shown in Figure 5.

---

1. BEMO 305 Aluminum Standing Seam Metal Roofing
2. BEMO Hook Clip spaced 30” O.C. with row spacing of 30”
3. Polystyrene Vapor Retarder
4. 4” Polyiso Rigid Insulation
5. 1.5B 16 ga. (min. 60 ksi) Steel Decking
6. Deck laps 0.19” Hilti fasteners at 30” O.C.
7. Hilti fasteners at 6” O.C. with row spacing of 72”
8. W10 roof purlins at 6’-0” O.C.

Figure 4. Roof Section
In Synergy’s design, the building is powered by a combination of a 200 kW fuel cells and supplementary grid power, for detailed distribution see Drawing E-5.

7.2 ALTERNATE CENTRAL PLANT DESIGN

Synergy saw an opportunity to use the waste heat from the fuel cell rather than wasting it. In order to get the most heat out of the system, the fuel cell can be moved to Central Heating and Cooling Plant (CHACP I). Ideally, fuel cell waste heat can continuously be captured throughout the year. Locating fuel cell at the central plant allows year-round energy recuperation. In Synergy’s first design, the fuel cell wastewater at 140°F is used to preheat domestic hot water that is used in the building. When that demand is not there, heat is wasted. Summer season has little thermal demand. Instead, the waste water can be used to preheat boiler feed water in the central plant. This waste water from the fuel cell does not need to be returned. The electricity can be distributed into the campus grid and the thermal energy can be recuperated into central plant distribution. Overall, this results in a higher efficiency for the combined heat and power system as a whole.

This alternate design would require further coordination with Texas Tech University. Available space at the current central plant would have to be determined. Synergy found moving the fuel cell to CHACP I to be an integrative solution benefitting the entire campus. For a detailed diagram of the proposed alternate, see Mechanical SD-B.

8.0 HYBRID VENTILATION

TTU’s Sports Performance center can be view as two large volume athletic spaces, football and track, plus auxiliary spaces. These athletic spaces are seasonally and sporadically used through the year. This situation presents opportunities for innovative and integrative design solutions. Synergy’s proposed solution involves a hybrid system, combining natural ventilation and displacement ventilation in the space condition design. The hybrid ventilation system greatly contribute to meeting the owner’s challenge of 50% energy reduction and WELL Building Standard. Refer to Drawing I-5.1 for more details of the architectural redesign integrating natural ventilation, daylighting and structural improvements.
8.1 NATURAL VENTILATION

In order to reduce energy on the air-side design, Synergy decided to use natural ventilation during the part of the year when conditions are favorable. This will allow the building to directly take in outside air for savings in cooling and fan energy.

8.1.1 NATURAL VENTILATION SCHEDULE

Synergy optimized the schedule for use of natural ventilation by first analyzing annual temperature profile and heating/cooling degree days. Figure 6 shows the heating and cooling degree days for Lubbock, Texas. The spring months of April and May and the autumn months of September and October were found to be the optimal times for use of natural ventilation due to favorable outside temperature.

The next step was to analyze the average temperatures and the corresponding wind directions for these months. Figure 7 shows the temperature curve with average high and low and corresponding monthly wind rose. The months previously identified from the heating and cooling degree days are shown highlighted in gray. In order to use natural ventilation and still maintain a comfortable space, the outdoor air temperature can range from 55ºF to 72ºF. The given range corresponds with the average temperature outdoors during the optimal months, as shown highlighted in purple. This air can be used directly by modulating the amount of air flow based on air temperature. This range also allows for opportunity to use natural ventilation outside of the displayed schedule during the described conditions. During these months, a significant portion of wind comes from the south direction as shown in the wind roses.

8.1.2 SYSTEM DESIGN

Given the results of the site analysis, louvers for natural ventilation were placed on the tall south facing walls of the indoor track and football facilities. The positive pressure on the south wall provides ample airflow to the louvers. To supply air equal to the primary system cooling, over 200 SF of open area with supply at 500 FPM was necessary. The dampers control on the louver can be adjusted to match the needs of cooling and ventilation. The louvers will receive ample air supply due to southern winds and minimal building interruption. Refer to Mechanical SD-C for calculations and elevations.
Louvers are not typically designed for natural disaster threats. In the case of tornado event, the Sports Performance Center will maintain the enclosure to survive an EF-3 tornado. In order to meet the challenge of having a community shelter and survive an EF-3 tornado, the enclosure must meet FEMA 361. The AFL501 Aluminum Louver from Greenheck was chosen to meet these standards. This louver will be able to withstand the wind load from the tornado and impact from wind-borne debris. For more information on louver performance, see Mechanical SD-C.

The average relative humidity in Lubbock, Texas typically lies between 40-50%. For the occupants and athletes to be as comfortable as possible, additional humidification can be added to the space when the air is dry.

8.1.3 ROOF DESIGN

To facilitate the air movement in the space from the south side, the design team optimized the roof to include clerestories with operable windows. The new design was a coordinated effort between all disciplines to aid air flow, improve daylighting, reduce volume of the space, and maximize the use of the roof trusses. Figure 8 shows Synergy’s design with the green representing the volume removed from the original. For more information on the integration of the roof, see Drawing I-3.0.

As the air flows into the space from the louvers on the south side, the air moves across the building along the north-south axis. Windows located in the low pressure undulated roof serves to draw air through zone of ceiling. Fans are added to aid forced ventilation and provide relief out through the operable windows. The natural ventilation is additionally used for night purge to reduce loads during start up time. Also, the operable windows can be closed and secured in extreme weather conditions by magnetic latches.

The operable windows are controlled to open and close as desired. A compact device to open the windows was required in order to integrate with the roof truss. The SE Controls Two SECO Ni 24 40 was chosen to meet this requirement. Two chains are used to open the window a maximum of 30°. This angle creates enough open space for the number of operable windows to be optimized to 8 per clerestory and 48 per Athletic Space. The assembly can be seen in Figure 9.

![Figure 8. Roof Structure with Depressed Roof to Reduce Building Volume](image)

![Figure 9. Clerestory Operable Window Section](image)

With the operable windows located high within the spaces, Synergy ensured that before a tornado, the windows will close and be locked automatically. Electromagnetic locks will be used to seal the gap and hold the windows in place during an emergency and to ensure a tight enclosure. A further description of the lock system, controls, and assembly can be found in the Drawing M-6.0.
8.1.4 THERMAL COMFORT
In order to confirm the use of hybrid ventilation for the athletic spaces, the thermal comfort was analyzed. Due to these spaces being meant for activity, the metabolic rate (MET) was 3.0 at a minimum, and the clothing value (CLO) was small due to the athletes wearing light clothing. This criteria does not match the requirements set forth in ASHRAE Standard 55, but the given inputs with a set point of 70°F and 50% relative humidity falls in the comfort zone defined by the MET, CLO, and operative temperature as shown in Figure 10.

To fit the ASHRAE 55 standard, a time-averaged MET value was used with a higher CLO value. Instead of assuming constant hard work out in the spaces, the average MET includes hard work out, walking, and standing still. This MET value can reduce the previous 3.0 MET to 2.0 MET. For more information on thermal comfort, see Mechanical SD-C.

8.2 DISPLACEMENT VENTILATION
The integrated roof design enabled a seasonal control cycle for the building varying from natural ventilation to forced displacement ventilation. When outdoor air temperature conditions limit natural ventilation’s ability to provide thermal conditioning, displacement ventilation starts managing internal loads. To meet the owner defined challenge of 50% percent energy reduction and WELL silver standard, Synergy focused on optimizing systems in the large spaces of the building. Displacement ventilation supplies air for on the occupant level and reduces conditioning of unused air in the higher volume.

8.2.1 SYSTEM SELECTION
Synergy developed a displacement ventilation system through coordination of all disciplines. The mechanical system needed to provide a high quality indoor environment, while maintaining building feature points. The key points for system selection included coordination with roof design, operation and maintenance, cost, performance, and integration into the building. Synergy explored various distribution systems including air rotation units (ARUs), overhead duct supply, and displacement ventilation. Using the decision matrix of team goals, displacement ventilation proved to provide the most opportunity to all options. The decision matrix can be found in Mechanical SD-A.

8.2.2 DISPLACEMENT VENTILATION: ATHLETICS
The displacement ventilation system is designed to run for both heating and cooling cycles. Cooling coils are modulated to meet the loads. The coil utilizes chilled water from the campus central plant. The heating cycle uses hot water produced from the campus steam through an on-site heat exchanger.

Displacement ventilation uses the natural bouncy of air to flood air across the ground plane. The constant ventilation air also forces used air out of the occupancy zone to the return system. Cooler air is introduced at the perimeter as supply air to the occupied zone. As the air absorbs the room loads it becomes buoyant and rises. Heating conditions require control sequencing with haiku fans located in the high point of the depressed roof. Heating air will naturally rise into unoccupied volumes directly after being supplied to the space. The haiku fan can reverse to help mix the air to create thermally constant zone.

The football and track space have zones of 200’ by 400’. The air distribution system needed to have high throw capability. Displacement ventilation achieves high performance in these parameters by supplying at occupant level and conditioning the most critical air in the volume. A computational fluid dynamics (CFD) model was used to analyze the air movement and to ensure supply air would reach the center of the space as shown in Figure 11. The air in the volume stratifies from the temperature set point at occupant level to warm air in the high bay. This helps remove contaminated/used air out of the breathing zone. The sensible and latent load from athletes and solar gain create thermal rise of air.
Typically, displacement ventilation has an air supply range of 30 ft. from the diffuser face. Synergy’s design proposes an alteration to the standard airflow speeds. The activity level and use of each space was used to determine new airflow standards. Typical displacement air supply is 50 FPM. The modified air speed was supplied at 100 FPM from the diffuser face. The occupants are typically moving at or faster than this speed. This relative speed difference will prevent the occupant from experiencing a draft sensation.

As shown in Figure 11, the increased air flow provides even distribution across the span of room of 100’ in to center of floor.

8.2.3 DISPLACEMENT VENTILATION DESIGN

Displacement ventilation allows for lower temperature supply air temperature in the space because supply air is at occupancy level. See temperature set points and building schedules in Drawing M-5.0. The temperature control for the large space will use numerous thermostats around the perimeter of the space and average the read outs. This will provide the most realistic room temperature. The sensible heat ratio in the athletic spaces is .66. The higher supply air temperature can handle the load because of the high latent load. This lowers demands on the cooling and heating cycles. The air in Lubbock, Texas is very dry and has average low humidity profiles. This created a high humidity loading condition in the track and football space. The design controls for the space are used to maintain a range of relative humidity between 30% and 50%. On critical days, for example BIG 12 NCAA track meets, the system will be aided by a direct humidifier design. This is to ensure high performance and safety for the athletes competing.

The displacement ventilation system runs off a modularized system of air handling units. This allows for cycling of equipment and better efficiency in part load conditions. The modularized system was used because the building occupancy varies greatly throughout year. There are two air handlers dedicated to each athletic space located on the south end of the core roof. The south prevailing winds will provide ample air to air handler equipment. To enter the building, a mechanical shaft is located in the core with access to the football and track spaces.

8.2.4 DISTRIBUTION METHOD

Both the Track and football spaces have a requirement of 50,000 CFM for sensible cooling load. The duct size to deliver this amount of air (60’Ø) limited duct routing solutions. Synergy wants to maintain low height for the depressed roof line for energy savings and construction material reduction of enclosure. The restricted site space also reduced wall area potential for duct runs. To have duct span across the football field and track, Synergy implemented an underground duct supply system to provide air to zones. This distribution was coordinated with the architecture, mechanical, and structural systems.

The air supply distribution routed down a mechanical shaft to the underground ductwork, refer to Drawing M-1.0. The underground supply is the Blue Duct system. This is a pre-insulated duct system from AQC Industries, shown in Figure 12. The team was able to integrate duct supply into the track and football
8.2.4.1 Track and Field Distribution

To distribute to the track, the mechanical and structural team coordinated space underground. Due to the transfer truss over the bleachers in the core, there is no grade beam resting under the slab because of no wall loading condition. Reference Structural Report section 10.5 for more information on this coordination effort. Synergy took advantage of this underground space to route the blue duct underneath the main and supplemental bleachers. With the bleachers rising three feet above ground level, the space under the walkway can be used to distribute air low in the space, as seen in Figure 13. Air will be supplied with 2.5’x6’ diffusers at 100 FPM. See the displacement duct layout plan in the Mechanical Drawings 1.0.

8.2.4.2 INDOOR FOOTBALL DISTRIBUTION

The football side proposed a new challenge. The perimeter included a continuous grade beam to support the safe room wall and football column line. The blue duct system could not penetrate or go under the grade beam. Synergy found a solution by dropping the grade beam and concrete wall between a column span. By dropping the structure, the blue duct was able to penetrate the concrete wall that is part of safe room, shown in Figure 14. The main duct for distribution branches off into 18’ Ø branches that meet plenum boxes underground. These plenum boxes then supply air to a diffuser box that sit in the wall assembly, as shown in Figure 15.

8.2.5 RETURN & RELIEF AIR SYSTEM

The return air system uses a duct run for both the track and football spaces. The duct return height is above 30’ to meet displacement ventilation schemes as shown in Figure 16. The core functions as the main duct path for the return to the air handlers located on south end of the core roof. The return will be able to meet air handlers with no roof penetration, which reduces potential exposure in the building envelope. The return system was sized to have a higher friction loss at max air return due to lower roof plenum height. Synergy coordinated duct size in this manner due to high part load conditions. The optimized air return condition was applied to the track space specifically due to additional bleacher space next to the zone. In order to host BIG 12 national competitions, the east and west bleacher areas have individual zone control to accommodate large crowds. See Drawing M-1.2 for the air supply path. The excess air for spectator loading will be handled by using operable windows as a pressure relief system for the air.
8.2.6 AUXILIARY SPACE DESIGN

Synergy focused on applying owner defined challenges to all space in the sports performance center. The auxiliary spaces, defined in Drawing M-2.0, are ventilated and conditioned with an economizer Dedicated Outdoor System (DOAS) system with Variable Air Volume (VAV) room control. The returns for these zones supplied by the DOAS unit will have plenum returns. This exhaust air while removing loads from the plenum. Coordination with the Construction and Lighting/Electrical teams ensure proper fire protection coatings and assemblies for plenum return. The return air will duct back to the DOAS unit before exhausting to transfer energy to a recovery wheel.

The auxiliary spaces have a more consistent occupancy schedule. By giving individual zone control, the common users of the spaces can be thermally comfortable and effective in work space. Each zone is slightly different in design in term of air distribution.

The current WELL Building Standard focuses on the occupants of the space and is typically used for office buildings. Synergy recognized the main occupants of the building and their work spaces to provide them with the comfort desired. The office spaces and sports medicine room will use a displacement ventilation system similar to that in the athletic spaces. For more information on displacement ventilation for the WELL Building Standard, see Drawing M-8.0.

9.0 SAFE ROOM & SHELTER DESIGN

The design challenges for a tornado safe room and a community shelter have driven many of Synergy's decisions for architectural layout. The concrete structure in the core will allow the tornado safe room to withstand an EF-4 tornado. It also allows a maximum of 516 occupants to exit the building even if the building collapses around it. The community shelter will withstand an EF-3 tornado and house up to 1636 occupants in the aftermath.

9.1 SAFE ROOM DESIGN

When designing a space for the tornado safe room, Synergy had to consider the requirements from all disciplines. This space is located in the central core of the building under a permanent set of bleachers to improve security. The final design of the core includes an open space for congregation, the fuel station for food, restrooms, and a hallway to the outside. These spaces will be used for their stated purpose during normal hours, so access to food and water over the period of a tornado is available.

9.1.1 AIR DISTRIBUTION

Tornado season in the Lubbock Area is typically during April and May. As mentioned in section 7.1, these months typically show less demand for heating and cooling, so natural ventilation can be used in case of emergency. For the 516 occupants of the safe room, 258 SF of venting area is required per ICC 500 Section 702.1.1. The natural ventilation openings will use the Greenheck AFL501 louvers that are storm rated.

Figure 17. Shelter Location & Air Distribution

To supply the rooms regularly with air, the DOAS system will come into the EF-4 structure in a concrete box to meet ICC 500 for impact routes of materials. This will limit any potential flying debris from entering into the safe room during a tornado. A natural gas generator will be on site to provide electricity to the critical mechanical systems for ventilation. For more information on the generator emergency electric distribution, see Drawing E-5.0. Figure 17 shows the distribution methods for the safe room.

9.1.2 SANITATION REQUIREMENTS

In accordance with ICC 500 Section 702.2, the tornado safe room will include two restrooms and two sinks.

9.2 SHELTER DESIGN

The shelter space includes all spaces in the safe room, bathrooms, showers, football, and the indoor track. The indoor track space, see Integration SD-A. Synergy designed these spaces and systems to be able to run off grid for seven days. The community shelter will continue to run off of the campus distribution for steam...
and chilled water in order to condition the space if necessary. The utility will also be used for domestic water. As these utilities are underground in a non-seismic area, they were assumed to survive the disaster. A natural gas generator will be on site to aid in providing electricity to lights and critical mechanical systems in the space. Utilities not supplied underground, such as diesel fuel, food, and water will be stored for 48-hour usage until further distribution can be arranged.

9.2.1 AIR DISTRIBUTION

With the same idea as the safe room design, natural ventilation can be used during the tornado season. The shelter space will use the same design as the system for the normal schedule. Heating and cooling are not required, in accordance with FEMA P-361. Forced ventilation will be supplied through the displacement ventilation system with use of the generator in case of uncomfortable conditions.

9.2.2 SANITATION REQUIREMENTS

The restrooms currently designed for the building are included in the shelter space. One set is located in the main track space and another is located in the core of the building. Showers are also included for the occupants for regular and 7 day shelter use.

10.0 ENERGY ANALYSIS

Synergy exceeded the owner defined challenge of reducing energy use by 50% in accordance with ASHRAE standard 90.1. The baseline for energy modeling includes prescribed wall assemblies and mechanical systems from ASHRAE code. See Mechanical SD-E for more baseline details. Synergy strategically enhanced architecture to improve building energy utilization. These changes included a reduction in volume, increased envelope performance, and allowed for the use of natural and displacement ventilation.

With internal loading reduced, cooling and heating loads were reduced from peak operating points throughout the year by 30% as shown in Figure 18. For detailed load analysis see Mechanical SD-E. The displacement ventilation, in combination with lower load conditions, allowed for reduction of 50% HVAC energy usage throughout the year. This includes the potential saving from natural ventilation. The large opportunity in savings came from the reduction in fan power required through the year in design and controls coordination with the Lighting/Electrical team. The overall building met 60.25% savings over ASHRAE 90.1. For a more detailed energy analysis, see Drawing E-1.0. This combined savings provided a lifecycle cost analysis of a 20 year payback period for Texas Tech University.

11.0 FIRE PROTECTION

Synergy worked to provide the safest space possible for the occupants in every situation. When changing the floor plans and architectural design of the building, fire protection and life safety was a main concern. A curved roof with clerestories required an integrated sprinkler design, and the addition of a second floor required research on egress pathways.

The athletic spaces includes both upright and pendant sprinklers. Pendant sprinklers will be used in the clerestories as there is little risk for damage, and upright sprinklers will be used elsewhere. For the auxiliary spaces, downright sprinklers were chosen to provide egress protection. This decision was made to provide versatile spaces for any sport to be able to use this facility. The fire protection systems is a coordination between fire detection, suppression and egress.

11.1 ATHLETIC SPACES

The maximum distance between two sprinkler heads is 15 feet according to NFPA 13. The column spacing and clerestory spacing for Synergy’s design is 30 feet. This allowed for an ideal spacing of two rows of sprinklers in the clerestories, and two rows between the purlins. The sprinklers run on an automatic control to manage flames at the source. Automatic sprinklers demand a smaller pipe size requirement for pump to maintain pressure. Where air borne objects are able to hit sprinklers, the sprinklers will be upright with cages around them. The high bay and open space clearance of the athletic spaces require two type of smoke detection. Laser sensor smoke detectors were placed on the walls at 20 ft. apart for early smoke detection.
Smoke detectors also placed in the return air system. The sprinkler layout can be found on Drawing M-6.0.

### 11.3 AUXILIARY

Smoke detection and sprinkler system will be place in the auxiliary spaces as well. The main focus on sprinkler design was to provide fire protection in the safe room. A detailed layout in the auxiliary spaces can be found on Drawing M-6.0.

### 11.2 LIFE SAFETY

In the event of a life safety situation, Synergy has complied with code to provide exit for occupants of the buildings. As shown in the diagram below, all occupants in the building are within 250' of a designated exits. The second floor corridor and rooms are less than one third of the SF of the entire building. In this case, the bleachers are permitted to be a means of egress out of the building.

![Life Safety Egress](image)

**Figure 19. Life Safety Egress**

### 12.0 ACOUSTICS

The Sports Performance Center includes a variety of spaces with significantly different acoustical requirements. Offices, meeting rooms, and sports medicine will require lower noise criteria (NC) levels while the reverberation time (RT) in the athletic spaces must be adequate for large event days. Loud and quiet zones were then identified for Synergy’s design. The acoustic zone plans and further calculations can be found on Drawing M-7.0.

### 12.1 ATHLETIC SPACES

The reverberation time (RT) in the athletic spaces was calculated to ensure athletes will adequately hear announcements on event days. The original spaces had high RT times at lower frequencies but close to acceptable RT times at the higher frequencies. Synergy proposed solutions to reduce the reverberation times to be less than two seconds. A summary of the changes can be found in Table 2.

**Table 2: Reverberation Time Summary**

<table>
<thead>
<tr>
<th>Space</th>
<th>Frequency (Hz)</th>
<th>250</th>
<th>500</th>
<th>1000</th>
<th>2000</th>
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<tr>
<td>FB Original</td>
<td>4.06</td>
<td>1.63</td>
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<td>Modified</td>
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<td>Modified</td>
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<td>1.04</td>
<td>0.77</td>
<td>1.04</td>
<td></td>
</tr>
</tbody>
</table>

The absorption coefficients were used to analyze the surfaces in each athletic space. The wall materials were the focus for more absorptive materials. To match the facility function and current materials, AlphaPerf Metal Acoustic Panels were implemented. These panels are able to reduce the reverberation, improve speech intelligibility and are impact resistant. Results and calculations can be found on Drawing M-7.0.

### 12.2 AUXILIARY SPACES

**Table 3: Reverberation Time Summary**

<table>
<thead>
<tr>
<th>Space</th>
<th>NC Requirement</th>
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<td>Nutritionist Office</td>
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<td>Sports Medicine</td>
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<tr>
<td>Sports Medicine Office</td>
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</tr>
<tr>
<td>Consult Room</td>
<td>30</td>
</tr>
<tr>
<td>Hydrotherapy Room</td>
<td>35</td>
</tr>
<tr>
<td>Weight Room Office</td>
<td>35</td>
</tr>
<tr>
<td>Meeting Room</td>
<td>30</td>
</tr>
</tbody>
</table>

The partitions in the auxiliary spaces were improved to ensure the regular occupants of the building can work comfortably. Synergy evaluated critical space in the building and used the WELL Building Standard to define NC requirements as seen in Table 3. Synergy’s partitions were analyzed to ensure they met the criteria.
defined based on the noise in the surrounding spaces. The lobby space was chosen for analysis because of the proximity to the street and athletic spaces. The outdoor noise into the Lobby should not exceed 50 dBA according to WELL. The windows and exterior wall were analyzed to find the transmission loss due to outdoor noise, and the interior walls were analyzed for noise from surrounding spaces. The lobby space is able to meet and exceed the requirements of NC-40. Synergy’s design includes the lobby at NC-35.

The sports medicine room was then analyzed as it is located between the two main athletic spaces. The current partition was tested according to the transmission loss to each of the large athletic spaces. The sports medicine room is able to achieve an NC-34 value without any changes to the interior partitions.

13.0 WELL & LEED

Design for mechanical systems is important but the main goal is to provide a high quality building for athletes, coaches and observers. The owner defined challenge to achieve WELL Certification: Silver was exceeded with Synergy’s design. Through integration of design with occupant wellness, WELL Certification: Gold was achieved. In coordination with the WELL certification, Synergy took the opportunity to meet LEED GOLD certification. For detailed point break down of mechanical incorporated WELL Standards and LEED, see Drawing M-8.0.

14.0 LESSONS LEARNED/CONCLUSION

Design of Texas Tech’s Sports Performance Center was an opportunity to integrate design in a confined space and large volumes. The natural layout of sports fields introduced innovative solutions to reorganize the architecture to benefit building systems as the first step in the design process. Integrating with designs of other disciplines allowed the mechanical team to find creative solutions to meet Synergy’s goals.

Synergy has added value by providing a functional shelter and safe room space, an effective hybrid air distribution method that lowers energy consumption throughout the year, and the highly developed building for the occupant wellness. These elements integrated with and architecturally dynamic building elevation and floor plan.

The Sports Performance center acts as an important center piece for the community. The event of a tornado can cause havoc on a community. Synergy’s design of the critical systems for a safe room and 7 day shelter produce a low energy cost solution. Natural ventilation of shelter and safe room is used from the hybrid ventilation system. Synergy ensured protection of all openings and equipment to best suit the owners need.

Performance design was integral part of Synergy’s design scheme. Using architectural detailing, the building was optimized to perform better than owner expectations. The system saves 60.25% energy in reference to the ASHRAE 90.1 baseline. By effectively integrating mechanical design with focus of the occupants, the system selection best fits the changing occupancy through the year. Hybrid Ventilation increased thermal performance and fan effectiveness of large athletic spaces with lowered energy consumption requirements.

This type of building type is dynamically changing with upcoming technologies and trends. Synergy need to design for future use, as well as intended use. When designing systems, the team created space that could easily be changed and adapted to needs. As seen in the mechanical rooms, considerations for future expansion of systems and program space by leaving dedicated space. The systems do not define the building but simply make them functional.
### Project Goals:

#### Participants: Mechanical

<table>
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<tr>
<th>Campus Central Plant</th>
<th>On-Site Plant</th>
<th>Outcome of Discussion:</th>
<th>Additional Comments:</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 4 3 2 5 3 2 5 4 4 2 2</td>
<td>1 2 2 3 2 2 3 4 3 4 2 2</td>
<td>Displaced Ducts via Buried Ducts</td>
<td>The campus central plant was chosen for the main building utilities. The central plant already has lines to the site and will be able to provide chilled water and steam for heating and cooling. The use of the current campus systems will save on cost, schedule, and improve the resiliency of the building.</td>
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#### Ventilation

<table>
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<th>Poor</th>
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#### Heating

<table>
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<th>Outcome of Discussion:</th>
<th>Additional Comments:</th>
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<tbody>
<tr>
<td>AHU Heating Coils</td>
<td>AHU Heating Coils proved to be the best option for the Value theme, but struggled in meeting the Performance theme. Overall, this option was best for cost and further maintenance of the central plant. Radiant panels could still be an option at an additional cost to supplement the heating by displacement ventilation.</td>
</tr>
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### Decision Matrix: Mechanical

<table>
<thead>
<tr>
<th>Performance</th>
<th>Versatility</th>
<th>Resiliency</th>
<th>Value</th>
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<td>On-Site Plant</td>
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<td><strong>Displaced Ducts via Buried Ducts</strong></td>
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</tr>
<tr>
<td><strong>Displacement and Natural Ventilation</strong></td>
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<tr>
<td><strong>Displacement Ventilation</strong></td>
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<td>5 4 5 5 5 5 5 5 5 3 4 5</td>
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<td>177</td>
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</tbody>
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#### Codes, Standards, and Programs

- ASHRAE Standard 62.1 – 2013
- ASHRAE Standard 90.1 – 2013
- ASHRAE Standard 55 – 2013
- International Energy Conservation Code (IECC) - 2012
- WELL Building Standard – New and Existing Buildings
- Lake's Environmental WRPLOT

### Software Usage

- EXCEL
- SKETCHUP
- REVIT
- TRANE TRACE
- STAR CCM+
- REVIT MEP
- ARTLANTIS
- PHOTOSHOP
- WUFI

### References

- CBE Thermal Comfort Tool. Comfort.cbe.berkeley.edu
- Bell & Gossett's Selection Tool
Supporting Document C | Hybrid Ventilation Analysis

### Example Duct Run Specifications

<table>
<thead>
<tr>
<th>Type</th>
<th>Material</th>
<th>Size</th>
<th>Length</th>
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<th>FPM</th>
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<td>30'</td>
<td>50000</td>
<td>2000</td>
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<td>60&quot;x64&quot; to 60&quot; ø</td>
<td>~50000</td>
<td>2000</td>
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<td>Round</td>
<td>Blue Duct</td>
<td>60&quot; ø</td>
<td>~20'</td>
<td>50000</td>
<td>2000</td>
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<td>Tee Branch</td>
<td>Blue Duct</td>
<td>60&quot; ø to 48&quot; ø</td>
<td>~25000</td>
<td>2000</td>
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<tr>
<td>Round</td>
<td>Blue Duct</td>
<td>48&quot; ø</td>
<td>116'</td>
<td>50000</td>
<td>2000</td>
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<tr>
<td>Long Radius Elbow</td>
<td>Blue Duct</td>
<td>48&quot; ø</td>
<td>~25000</td>
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</tr>
<tr>
<td>Round</td>
<td>Blue Duct</td>
<td>48&quot; ø</td>
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<tr>
<td>Tee Main</td>
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<td>40&quot; ø</td>
<td>~12000</td>
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<tr>
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<td>30&quot; ø</td>
<td>7'</td>
<td>6000</td>
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<tr>
<td>Reducer</td>
<td>Sheet Metal</td>
<td>30&quot; ø</td>
<td>7'</td>
<td>4800</td>
<td>1000</td>
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<tr>
<td>Round</td>
<td>Sheet Metal</td>
<td>30&quot; ø</td>
<td>7'</td>
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<td>18&quot; ø</td>
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1. Maintained 0.08 Friction Loss per 100 ft. of Duct

### Natural Ventilation Louvers

The Greenheck AFL-501 Louver will be used on the south facing walls of both the track and football spaces for natural ventilation. This louver will comply with the FEMA 361 code for storm shelters and the ICC 500 debris impact standard. The design consists of V shaped aluminum blades to help air performances and reduce water penetration to the space. Shown below are the calculations to find the open area required. After calculations, Synergy took the opportunity to allow for double the open area in order to get the required ventilation with a smaller change in temperature. This method allows for natural ventilation to be an option during more of the year with the same thermal comfort conditions. To maintain consistency, each space will include 8 - 108"x76" louvers. The open area will account for 53% of the total louver area to meet these requirements.

<table>
<thead>
<tr>
<th>Equation</th>
<th>Football</th>
<th>Track</th>
</tr>
</thead>
<tbody>
<tr>
<td>Required Air Volume</td>
<td>607,000 BTU/1.1°F = 55,181 CFM</td>
<td>642,000 BTU/1.1°F = 58,363 CFM</td>
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<tr>
<td>Open Area</td>
<td>234 SF</td>
<td>222 SF</td>
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### Thermal Comfort

**Constant Activity: Athlete**
- Operative Temperature: 70°F
- Air Speed: 300 FPM
- Relative Humidity: 50%
- Metabolic Rate: 3.5 MET
- Clothing Level: 0.2 CLO

**Intermediate Activity: Athlete**
- Operative Temperature: 70°F
- Air Speed: 100 FPM
- Relative Humidity: 50%
- Metabolic Rate: 2.0 MET
- Clothing Level: 0.6 CLO

Thermal comfort for the athletes was determined through two models. The top model is for an athlete during a hard workout or event in light clothing. The bottom model is for an athlete with intermediate activity levels. The time averaged MET rate calculated as shown below. The clothing level also increased to allow for a sweatshirt during rest periods.

**MET Assumption**

<table>
<thead>
<tr>
<th>Activity</th>
<th>Duration</th>
<th>MET Value</th>
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<tr>
<td>Exercise</td>
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<tr>
<td>Walking 2.0 MPH</td>
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<td>Standing, Relaxed</td>
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<td>Time Averaged MET</td>
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</table>
Supporting Document D | Building Envelope and Storm Drainage

### Material R-Value

<table>
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<tr>
<td>Outside Air Film</td>
<td>0.17</td>
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<td>Terecotta brick</td>
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<tr>
<td>1 1/2 &quot; Air Gap</td>
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</tr>
<tr>
<td>3&quot; Rigid Insulation</td>
<td>14</td>
</tr>
<tr>
<td>5/8&quot; Plywood</td>
<td>0.77</td>
</tr>
<tr>
<td>1/16&quot; Steel Plate</td>
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</tr>
<tr>
<td>6&quot; metal studs 16&quot; OC and BATT infill</td>
<td>15</td>
</tr>
<tr>
<td>5/8&quot; Corrugated metal deck</td>
<td>0.5626</td>
</tr>
<tr>
<td>Interior Air film</td>
<td>0.68</td>
</tr>
<tr>
<td><strong>Total</strong> BTU h * ft²</td>
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### Upper Wall Assembly

#### Brick Face Precast Assembly

**24'- Roof Elevation**

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<td>5/8&quot; Plywood</td>
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<tr>
<td>1/16&quot; Steel Plate</td>
<td>0</td>
</tr>
<tr>
<td>6&quot; metal studs 16&quot; OC and BATT infill</td>
<td>15</td>
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<tr>
<td>5/8&quot; Corrugated metal deck</td>
<td>0.5626</td>
</tr>
<tr>
<td>Interior Air film</td>
<td>0.68</td>
</tr>
<tr>
<td><strong>Total</strong> BTU h * ft²</td>
<td><strong>32.25</strong></td>
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</table>

### Storm Drainage

The rain water management system for the Sports Performance Center includes two different systems. The flat roof core requires slightly graded sections of roof to meet low drainage points for water removal. The secondary system manages rain water falling on the curved roof of the building. The depressed roof system splits the gutter system required to capture roof runoff. Detail one shows the flow path of rain water from the high roof section to the low roof gutter system.

**Detail one** shows the flow path of rain water from the high roof section to the low roof gutter system.

### Upper and Lower Wall Assembly Connections

9' Precast Panel (Panel Dimensions 12'-0" X 30'-0")

1. 3" Reinforced Concrete Layer w/ Stamped Brick Finish
   - #4 Rebar @ 12" O.C. each way

2. 3" Polysioyanurate ISO Insulation 14 ga. Steel
   - #4 Rebar @ 12" O.C. each way

3. 2x6 Double Metal Stud 16" O.C. with 6" of Batt Insulation
   - Connected to W-16 Girt

4. W-16 Girt
   - 9' Precast Panel Assembly
   - 3" Precast Concrete With Brick
   - 3" Polysioyanurate ISO Insulation
   - 3" Precast Concrete
   - W Shape with Horizontal Slotted Inserts
Synergy’s Design largely increases the performance of the envelope in comparison with ASHRAE 90.1. This provided significant reduction of internal loading conditions from the baseline model to synergy’s final design, as shown in heating and cooling coil pie charts. ASHRAE 90.1 energy baseline prescribes the system type for air distribution. The system required is a package air terminal unit with a bowl thru fan configuration. The air path is directly ducted to zone and the coil location is at zone level. Primary fan supply for the system consists of a centrifugal fan with constant volume supply.

The baseline requirements for building assembly in zone three is listed in construction baseline comparison table above. Synergy’s design largely increases the performance of the envelope in comparison with ASHRAE 90.1. This provided significant reduction of internal loading conditions from the baseline model to synergy’s final design, as shown in heating and cooling coil pie charts. ASHRAE 90.1 energy baseline prescribes the system type for air distribution. The system required is a package air terminal unit with a bowl thru fan configuration. The air path is directly ducted to zone and the coil location is at zone level. Primary fan supply for the system consists of a centrifugal fan with constant volume supply.

The system selection of energy production and consumption devices for the Sports Performance Center are the key components for life cycle cost analysis. The pay back period of 20 years encompasses the integration of underground displacement ventilation and fuel cell technology. A university owned building life cycle is typically longer than the average commercial building. The Sports Performance Center will maintain operation for the duration of Texas Tech University’s student athletic program.
The Blue duct system provided by AQC Industries is an underground ductwork solution. Made up of high-density polyethylene Synergy implemented this product because of the ability to directly bury the duct underneath slabs. Guaranteed and warrantied to not rust, mold or crush. The only requirement is a backfill soil. Requiring no concrete housing, the blue duct is a long-lasting durable system. The system contains a built-in R-10 insulation and resists mildew and corrosion.

To best supply air to the football space, Synergy dropped the grade beam and safe concrete wall 5' between columns, then allow ducts to penetrate through the shelter to distribute to wall of football space. This allowed for less excavation and for a shallower ducts runs throughout space. For this reason supply duct for the football space is divided into three 40" Ø ducts to coordinate with the structural grade beam. Sizing to 40" round required three equal distribution ducts to divide 50,000 CFM and maintain .08 friction.
Haiku fans are used in the Sports Performance Center to circulate air during cooling and heating cycles and promote relief air to exhaust through the operable windows in the clerestory.
### Ventilation Calculations

<table>
<thead>
<tr>
<th>Room Name</th>
<th>Occupancy Category</th>
<th>A&lt;sub&gt;r&lt;/sub&gt; (ft&lt;sup&gt;2&lt;/sup&gt;)</th>
<th>P&lt;sub&gt;r&lt;/sub&gt; (cfm/ft&lt;sup&gt;2&lt;/sup&gt;)</th>
<th>P&lt;sub&gt;p&lt;/sub&gt; (people)</th>
<th>R&lt;sub&gt;p&lt;/sub&gt; (cfm/person)</th>
<th>V&lt;sub&gt;in&lt;/sub&gt; (cfm)</th>
<th>E&lt;sub&gt;i&lt;/sub&gt;</th>
<th>V&lt;sub&gt;ex&lt;/sub&gt; WELL Exceed ASHRAE by 30% (cfm)</th>
<th>V&lt;sub&gt;ex&lt;/sub&gt; (cfm)</th>
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**Total Required CFM:** 90,464

### Exhaust Calculations

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<th>Room Name</th>
<th>Occupancy Category</th>
<th>Air Class</th>
<th>Exhaust Rate (cfm/ft&lt;sup&gt;2&lt;/sup&gt;)</th>
<th>Units (quantity)</th>
<th>Exhaust (cfm)</th>
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**Total Required CFM:** 74539

### Mechanical Equipment Zoning

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<th>Cfm Baseline</th>
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<td>Zone 1</td>
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<td>50000</td>
<td>64000</td>
</tr>
<tr>
<td>Zone 2</td>
<td>Track and Field</td>
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<td>61000</td>
</tr>
<tr>
<td>Zone 3</td>
<td>Indoor Bleachers, Locker, Corridor, Fueling Station, Nutrition Office, Meeting Room, Sports Medicine, Sports Medicine Office, Musculoskeletal Office, Athletic Training</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zone 4</td>
<td>Strength and Conditioning, Office, Equipment, Televisions &amp; Office, Video Control Room</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zone 5</td>
<td>West Bleachers</td>
<td></td>
<td>10000</td>
<td>10000</td>
</tr>
</tbody>
</table>

**Note:** M-2.0
### AIR HANDLING UNIT SCHEDULE

<table>
<thead>
<tr>
<th>Tag</th>
<th>Zone</th>
<th>Max Supply Air [cfm]</th>
<th>Min Air supply [cfm]</th>
<th>OA%</th>
<th>Nominal Tons</th>
<th>Supply Fan [hp]</th>
<th>Cooling Coil EWT (F)</th>
<th>LAT (F)</th>
<th>Heating Coil EWT (F)</th>
<th>LAT (F)</th>
<th>Return Fan [hp]</th>
<th>Volts/Phase/Hz</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>AHU-1</td>
<td>1</td>
<td>25000</td>
<td>15000</td>
<td>50</td>
<td>80</td>
<td>27.5</td>
<td>40</td>
<td>50</td>
<td>180</td>
<td>160</td>
<td>50</td>
<td>430/3/60</td>
<td>Trane</td>
</tr>
<tr>
<td>AHU-2</td>
<td>1</td>
<td>25000</td>
<td>15000</td>
<td>50</td>
<td>80</td>
<td>27.5</td>
<td>40</td>
<td>50</td>
<td>180</td>
<td>160</td>
<td>50</td>
<td>430/3/60</td>
<td>Trane</td>
</tr>
<tr>
<td>AHU-3</td>
<td>2</td>
<td>25000</td>
<td>15000</td>
<td>50</td>
<td>80</td>
<td>27.5</td>
<td>40</td>
<td>50</td>
<td>180</td>
<td>160</td>
<td>50</td>
<td>430/3/60</td>
<td>Trane</td>
</tr>
<tr>
<td>AHU-4</td>
<td>2</td>
<td>25000</td>
<td>15000</td>
<td>50</td>
<td>80</td>
<td>27.5</td>
<td>40</td>
<td>50</td>
<td>180</td>
<td>160</td>
<td>50</td>
<td>430/3/60</td>
<td>Trane</td>
</tr>
<tr>
<td>AHU-5</td>
<td>3</td>
<td>20000</td>
<td>20000</td>
<td>100</td>
<td>65</td>
<td>22</td>
<td>40</td>
<td>50</td>
<td>180</td>
<td>160</td>
<td>20</td>
<td>430/3/60</td>
<td>Trane</td>
</tr>
<tr>
<td>AHU-6</td>
<td>4</td>
<td>8000</td>
<td>8000</td>
<td>100</td>
<td>35</td>
<td>8.8</td>
<td>40</td>
<td>50</td>
<td>180</td>
<td>160</td>
<td>22</td>
<td>430/3/60</td>
<td>Trane</td>
</tr>
<tr>
<td>AHU-7</td>
<td>5</td>
<td>10000</td>
<td>10000</td>
<td>100</td>
<td>45</td>
<td>11</td>
<td>40</td>
<td>50</td>
<td>180</td>
<td>160</td>
<td>15</td>
<td>430/3/60</td>
<td>Trane</td>
</tr>
</tbody>
</table>

1. ASHRAE 90.1 Table 6.5.3.1-1 used to approve fan power limitations.

### STEAM TO WATER HEAT EXCHANGER SCHEDULE

<table>
<thead>
<tr>
<th>Tag</th>
<th>Location</th>
<th>Type</th>
<th>Steam Inlet Condition</th>
<th>Steam Outlet Condition</th>
<th>Heating Water Inlet</th>
<th>Heating Outlet Water</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>HX-1</td>
<td>Mech Room</td>
<td>Steam to water</td>
<td>Steam</td>
<td>Water</td>
<td>200</td>
<td>160</td>
<td>Maxitherm</td>
</tr>
</tbody>
</table>

### PUMP SCHEDULE

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>HWP-01</td>
<td>7.5</td>
<td>150</td>
<td>5.49</td>
<td>3550</td>
<td>69.32</td>
<td>70.87</td>
<td>52</td>
<td>5.25</td>
<td>210</td>
<td>Bell &amp; Gosset</td>
</tr>
<tr>
<td>HWP-02</td>
<td>7.5</td>
<td>150</td>
<td>5.49</td>
<td>3550</td>
<td>69.32</td>
<td>70.87</td>
<td>52</td>
<td>5.25</td>
<td>210</td>
<td>Bell &amp; Gosset</td>
</tr>
<tr>
<td>CHWP-01</td>
<td>15</td>
<td>300</td>
<td>9.93</td>
<td>3550</td>
<td>77.03</td>
<td>76.04</td>
<td>71</td>
<td>5.5</td>
<td>5.5</td>
<td>Bell &amp; Gosset</td>
</tr>
<tr>
<td>CHWP-02</td>
<td>15</td>
<td>300</td>
<td>9.93</td>
<td>3550</td>
<td>77.03</td>
<td>76.04</td>
<td>71</td>
<td>5.5</td>
<td>5.5</td>
<td>Bell &amp; Gosset</td>
</tr>
</tbody>
</table>

1. Variable speed drive will be installed
2. All equipment on concrete pads with vibration isolation for structure borne noise.

### VARIABLE AIR VOLUME SCHEDULE

<table>
<thead>
<tr>
<th>Tag</th>
<th>Zone</th>
<th>Floor</th>
<th>Room</th>
<th>CFM</th>
<th>HP</th>
<th>GPM</th>
<th>MBH</th>
<th>Volts / Phase</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>VW-1</td>
<td>3</td>
<td>1</td>
<td>Safe Room</td>
<td>1000</td>
<td>1</td>
<td>2</td>
<td>17.7</td>
<td>120 V / 1</td>
<td>Daiken</td>
</tr>
<tr>
<td>VW-2</td>
<td>3</td>
<td>1</td>
<td>Fueling Station</td>
<td>500</td>
<td>1</td>
<td>2</td>
<td>11.7</td>
<td>120 V / 1</td>
<td>Daiken</td>
</tr>
<tr>
<td>VW-3</td>
<td>3</td>
<td>1</td>
<td>Nutritionist</td>
<td>200</td>
<td>1</td>
<td>2</td>
<td>7.8</td>
<td>120 V / 1</td>
<td>Daiken</td>
</tr>
<tr>
<td>VW-4</td>
<td>3</td>
<td>1</td>
<td>Sports Medicine and Consulting Room</td>
<td>2500</td>
<td>1</td>
<td>2</td>
<td>39.3</td>
<td>120 V / 1</td>
<td>Daiken</td>
</tr>
<tr>
<td>VW-5</td>
<td>3</td>
<td>1</td>
<td>Hydrotherapy</td>
<td>600</td>
<td>1</td>
<td>2</td>
<td>12.5</td>
<td>120 V / 1</td>
<td>Daiken</td>
</tr>
<tr>
<td>VW-6</td>
<td>3</td>
<td>2</td>
<td>Meeting Room</td>
<td>800</td>
<td>1</td>
<td>2</td>
<td>16.4</td>
<td>120 V / 1</td>
<td>Daiken</td>
</tr>
<tr>
<td>VW-7</td>
<td>3</td>
<td>1</td>
<td>Lobby</td>
<td>1000</td>
<td>1</td>
<td>2</td>
<td>17.7</td>
<td>120 V / 1</td>
<td>Daiken</td>
</tr>
<tr>
<td>VW-8</td>
<td>4</td>
<td>1</td>
<td>Video Control Room</td>
<td>300</td>
<td>1</td>
<td>2</td>
<td>9.5</td>
<td>120 V / 1</td>
<td>Daiken</td>
</tr>
<tr>
<td>VW-9</td>
<td>4</td>
<td>1</td>
<td>Strength and Conditioning Room</td>
<td>7100</td>
<td>3</td>
<td>2</td>
<td>89.6</td>
<td>120 V / 1</td>
<td>Daiken</td>
</tr>
<tr>
<td>VW-10</td>
<td>4</td>
<td>1</td>
<td>Office and Equipment Room</td>
<td>350</td>
<td>1</td>
<td>2</td>
<td>10.1</td>
<td>120 V / 1</td>
<td>Daiken</td>
</tr>
</tbody>
</table>

### EXHAUST FAN SCHEDULE

<table>
<thead>
<tr>
<th>Tag</th>
<th>Location</th>
<th>CFM</th>
<th>RPM</th>
<th>Drive</th>
<th>Electrical Amps</th>
<th>Volts / Phase</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>EF-1</td>
<td>Restroom M &amp; W</td>
<td>700</td>
<td>1100</td>
<td>Direct</td>
<td>3.2</td>
<td>480/3/60</td>
<td>Greenheck</td>
</tr>
<tr>
<td>EF-2</td>
<td>Showers M &amp; W</td>
<td>420</td>
<td>900</td>
<td>Direct</td>
<td>0.82</td>
<td>50.1</td>
<td>Greenheck</td>
</tr>
<tr>
<td>EF-3</td>
<td>Restroom M &amp; W</td>
<td>800</td>
<td>1150</td>
<td>Direct</td>
<td>3.3</td>
<td>480/3/60</td>
<td>Greenheck</td>
</tr>
</tbody>
</table>

1. ASHRAE 90.1 Table 6.5.3.1-1 used to approve fan power limitations.

### FIRE PUMP SCHEDULE

<table>
<thead>
<tr>
<th>Tag</th>
<th>Location</th>
<th>GPM</th>
<th>Speed</th>
<th>Impeller Diameter [in]</th>
<th>Motor HP</th>
<th>Max WP [PSI]</th>
<th>Manufacturer</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>FP-1</td>
<td>Mech Room</td>
<td>500</td>
<td>1100</td>
<td>Direct</td>
<td>40</td>
<td>175</td>
<td>Xylem</td>
<td>4x4x7F</td>
</tr>
</tbody>
</table>

1. ASHRAE 90.1 Table 6.5.3.1-1 used to approve fan power limitations.
When all utilities are available to the building, CHACP I will provide chilled water and steam to the site for heating and cooling purposes. Electric will be provided by the natural gas fuel cell and the grid for the full load. Heat exchangers will be used to capture heat from the condensate for the hot water system.

When natural gas is not available for use, the boilers and chillers are not available from the central plant and the fuel cell can not be used. Domestic water will still be available from the local utility, and the grid can be used to support part loads in the building.

When the electric grid is not available for use, the building will run as normal at part loads. The fuel cell is able to supply power to the pumps and fans in the building to stay functioning.

When the natural gas and electric utilities are not available, the domestic water supply is still available and a diesel generator will be used to support critical systems in the building including the fire pump, emergency telecom, and lighting.
### TEMPERATURE SET POINTS

<table>
<thead>
<tr>
<th>Space</th>
<th>Type of heating/cooling</th>
<th>Cooling Supply air</th>
<th>Heating Supply Air</th>
<th>Unoccupied Setpoints</th>
</tr>
</thead>
<tbody>
<tr>
<td>Football Field</td>
<td>Constant Volume AHU</td>
<td>60</td>
<td>72</td>
<td>65</td>
</tr>
<tr>
<td>Track and field</td>
<td>Constant Volume AHU</td>
<td>60</td>
<td>72</td>
<td>65</td>
</tr>
<tr>
<td>BLEACHERS EAST</td>
<td>DOAS with VAV Reheat</td>
<td>51</td>
<td>75</td>
<td>70</td>
</tr>
<tr>
<td>STRENGTH AND CONDITIONING</td>
<td>DOAS with VAV Reheat</td>
<td>51</td>
<td>75</td>
<td>70</td>
</tr>
<tr>
<td>Equipment Work Room</td>
<td>DOAS with VAV Reheat</td>
<td>55</td>
<td>75</td>
<td>70</td>
</tr>
<tr>
<td>Equipment Office</td>
<td>DOAS with VAV Reheat</td>
<td>55</td>
<td>75</td>
<td>70</td>
</tr>
<tr>
<td>Sports Medicine</td>
<td>DOAS with VAV Reheat</td>
<td>55</td>
<td>75</td>
<td>70</td>
</tr>
<tr>
<td>Consulting</td>
<td>DOAS with VAV Reheat</td>
<td>55</td>
<td>75</td>
<td>70</td>
</tr>
<tr>
<td>Hydrotherapy</td>
<td>DOAS with VAV Reheat</td>
<td>50</td>
<td>70</td>
<td>65</td>
</tr>
<tr>
<td>Sports Medicine Office</td>
<td>DOAS with VAV Reheat</td>
<td>55</td>
<td>75</td>
<td>70</td>
</tr>
<tr>
<td>Safe Room</td>
<td>DOAS with VAV Reheat</td>
<td>55</td>
<td>75</td>
<td>70</td>
</tr>
<tr>
<td>Nutritionist</td>
<td>DOAS with VAV Reheat</td>
<td>55</td>
<td>75</td>
<td>70</td>
</tr>
<tr>
<td>Fueling Station</td>
<td>DOAS with VAV Reheat</td>
<td>55</td>
<td>75</td>
<td>70</td>
</tr>
<tr>
<td>Meeting Room</td>
<td>DOAS with VAV Reheat</td>
<td>55</td>
<td>75</td>
<td>70</td>
</tr>
</tbody>
</table>

5. Room thermostat set points will have a dead band of +/- 2°F

### OPERABLE WINDOW CONTROLS

The operable window controls can be adjusted based on the season and usage of the space. They can be controlled through the building automation system.

### BUILDING OCCUPANCY SCHEDULES

Building occupancy schedules were documented in order to find how often the building would be at full capacity for large events as opposed to practice days and normal operation. Eight cases were developed based on the assumed usage of the main athletic spaces as defined left. The eight cases represent the varied occupancies from being at full capacity in both spaces to both being unoccupied.

This analysis shows the frequency of specific events. For example, the full occupancy with full team football practice and a major event for track is assumed to only occur if a weekend practice in November or December lines up with a track meet. The analysis also showed how the occupancies lined up with the season for natural ventilation. The highlighted months represent those proposed for natural ventilation use. They both also line up with sports seasons where the space will be frequently used.

Building hours were approximated based on typical morning and evening practice times as well as typical track and field event days. The weekly schedule assumes practices on weekdays and event days on weekends. Sundays are assumed to be closed for athletes. The monthly schedule was then based on the sport seasons.

Other occupancies can be controlled separately as needed. These could include special events, other athletic teams borrowing the space, or a natural disaster.
### Indoor Football Field Modified Reverberation Time

<table>
<thead>
<tr>
<th>Surface Description</th>
<th>Surface Area (m²)</th>
<th>Material Description</th>
<th>α</th>
<th>S*α</th>
</tr>
</thead>
<tbody>
<tr>
<td>South Wall</td>
<td>1824.00</td>
<td>Gypsum Board, Material 8</td>
<td>0.14</td>
<td>0.08</td>
</tr>
<tr>
<td>East Wall - Glass</td>
<td>2430.00</td>
<td>Glass, Ordinary window</td>
<td>0.25</td>
<td>0.18</td>
</tr>
<tr>
<td>East Wall - Wall</td>
<td>3560.00</td>
<td>Gypsum Board, Material 8</td>
<td>0.14</td>
<td>0.08</td>
</tr>
<tr>
<td>North Wall - Glass</td>
<td>4575.00</td>
<td>Gypsum Board, Material 8</td>
<td>0.14</td>
<td>0.08</td>
</tr>
<tr>
<td>North Wall - Glass</td>
<td>4249.00</td>
<td>Glass, Ordinary window</td>
<td>0.25</td>
<td>0.18</td>
</tr>
<tr>
<td>West Wall - Glass</td>
<td>4760.00</td>
<td>Glass, Ordinary window</td>
<td>0.14</td>
<td>0.08</td>
</tr>
<tr>
<td>West Wall - Glass</td>
<td>4760.00</td>
<td>Glass, Ordinary window</td>
<td>0.25</td>
<td>0.18</td>
</tr>
<tr>
<td>West Wall - Glass</td>
<td>10800.00</td>
<td>Glass, Ordinary window</td>
<td>0.25</td>
<td>0.18</td>
</tr>
<tr>
<td>West Wall - Glass</td>
<td>14412.00</td>
<td>Gypsum Board, Material 8</td>
<td>0.14</td>
<td>0.08</td>
</tr>
<tr>
<td>East Wall - Glass</td>
<td>6468.00</td>
<td>Turf Grass</td>
<td>0.24</td>
<td>0.18</td>
</tr>
<tr>
<td>East Wall - Glass</td>
<td>6000.00</td>
<td>Metal Roof Deck, Volcraft</td>
<td>0.18</td>
<td>0.12</td>
</tr>
<tr>
<td>East Wall - Glass</td>
<td>3800.00</td>
<td>AlphaPerf Metal Acoustic Panel</td>
<td>1.13</td>
<td>1.33</td>
</tr>
<tr>
<td>East Wall - Glass</td>
<td>5200.00</td>
<td>Fabric Covered Panel</td>
<td>0.68</td>
<td>1.00</td>
</tr>
</tbody>
</table>

### Outdoor Football Field Reverberation Time

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>α</th>
<th>S*α</th>
</tr>
</thead>
<tbody>
<tr>
<td>250</td>
<td>0.37</td>
<td>0.63</td>
</tr>
<tr>
<td>500</td>
<td>0.71</td>
<td>0.65</td>
</tr>
</tbody>
</table>

### Sound Absorption Coefficient, α

- **South Wall**: 0.14
- **East Wall - Glass**: 0.25
- **East Wall - Wall**: 0.14
- **North Wall - Glass**: 0.14
- **North Wall - Glass**: 0.25
- **West Wall - Glass**: 0.14
- **West Wall - Glass**: 0.25
- **Clerestory - Glass**: 0.25
- **Clerestory - Glass**: 0.14
- **Floor**: 0.24
- **Climbing**: 0.24
- **Wall Panel - Metal**: 1.13
- **Mats**: 0.68

### Calculated RT

- **Average α**: 0.37
- **Air absorption constant for 20°C and 40% RH, m²/Hz**: 0.00E+00, 1.83E-04, 3.26E-04, 7.66E-04
- **Sabine RT (s)**: 2.47, 1.41, 1.17, 1.29
- **Norris-Eyring RT (s)**: 1.98, 0.90, 0.63, 0.82
- **Calculated RT (s)**: 1.98, 0.90, 0.63, 0.82
Ventilation rates comply with the requirements in ASHRAE 62.1-2013. A study was completed based on the outdoor air quality to achieve natural ventilation. See Mechanical Drawing 2.0 for full calculations.

The naturally ventilated spaces are also the athletic spaces. This analysis can be found in Mechanical SD-C.

Total coliforms are not detected from the 2014 Lubbock Water Quality Report.

An acoustic plan defining loud zones, quiet zones, and locations of noisy equipment can be found in the Mechanical Drawing M-8.0.

Building Product Disclosure and Optimization - Environmental Product

Humidity levels will be maintained between 30% and 50%. For major event days when the air will become more dry, extra humidity can be justified with view of these spaces.

The athletic facilities will have access to outdoor air and daylight at all times. With the exception of two offices, all regularly occupied spaces are adjacent to an exterior wall for easy access. With the close proximity to the sports facilities, the outdoor air and daylight can be justified with view of these spaces.

Ventilation Design P

Increased Outdoor Air

Feature 24. Combustion Minimization

Displacement

Feature 21. Displacement Ventilation

Humidity Control O

Window Operation

Feature 19. Operable Windows

Operable windows will be used for natural ventilation. CO2 levels are able to be monitored.

ASHRAE outdoor air supply rates will be exceeded by 30% to bring in more outdoor air in order to remove unwanted contaminants in the air. See Mechanical Drawing 3.0 for full calculations.

Steam generating equipment will be checked upon construction.

The athletic facilities will have access to outdoor air and daylight at all times. With the exception of two offices, all regularly occupied spaces are adjacent to an exterior wall for easy access. With the close proximity to the sports facilities, the outdoor air and daylight can be justified with view of these spaces.

Seating and Balancing will be completed for the hybrid ventilation system at completion.

A study was completed based on the outdoor air quality to achieve natural ventilation. See Mechanical Drawing 2.0 for full calculations.
0.0 EXECUTIVE SUMMARY

Coplanar Roof Trusses
The long-span coplanar roof trusses are composed of HSS tubes and integrate with the depressed roof clerestory windows. Geometry was optimized for architecture, deflection, gravity load, and amplified tornado wind load.

Lateral System
Because the building is separated with an expansion joint, the lateral system is divided into two separate systems. Moment frames and braced frames resist EF3 tornado wind loads and control building deflection within H/400 criteria.

Tornado Safe Room
Centralized in the resilient building core is reinforced concrete safe room designed for a maximum occupancy of 516 people. The safe room is integrated with the main spectator bleachers and is designed to withstand an EF4 tornado.

Drilled Belled Piers and Grade Beams
The foundation primarily consists of 30'-0" deep drilled belled piers. Grade beams distribute all building loads evenly across the piers. The belled geometry of the piers lock into the soil and resist uplift under amplified wind loads. Coordination with the Mechanical team permits proper in-ground duct placement.

Integrated Enclosure
The enclosure is capable of resisting wind-borne missiles generated from an EF3 tornado. An FM-approved roof assembly mitigates the risk of roof tear off. A laminated fully tempered glass type was selected for optimal performance. Through prefabrication efforts, 29 weeks of the construction schedule were saved.
1.0 PROJECT INTRODUCTION
The Texas Tech University Sports Performance Center comprises a 200m competition indoor track and an 80-yard football practice field. The main structural challenges designed for include supporting a long-span roof that spans approximately 200’ over each athletic space, designing the entire structure and enclosure to withstand an EF3 tornado, and integrating a tornado safe room that must withstand an EF4 tornado and protect the lives of all building occupants.

2.0 SYNERGY’S MISSION
Backed by the ideals of collaboration and innovation, Synergy’s mission was to deliver Texas Tech University a sports performance center that caters to the needs of their student athletes as well as keeping in mind the safety and resiliency of the surrounding community. Safety and resiliency are exemplified in the Structural team’s implementation of the tornado safe room designed to withstand an EF4 tornado and protect the lives of all building occupants. Prefabricated design elements increase quality and efficiency while shortening the total time of construction.

3.0 PROJECT THEMES
The four project themes that serve as the areas of focus and achievement throughout the design process and delivery are value, resiliency, performance and versatility. By achieving all project themes in the structural designs, Synergy is able to deliver on all of the owner-defined challenges and Synergy-developed project goals and criteria.

VALUE
Synergy has designed a robust structure that prioritizes constructability and allows for rapid and simplified construction methods, ultimately saving 32 weeks in the construction schedule.

RESILIENCY
With an impact-resistant structural enclosure equipped with a centralized tornado safe room, Synergy has designed a resilient structural system that protects the lives of all building occupants in the event of an emergency.

PERFORMANCE
Through collaborative efforts, Synergy has integrated its structural designs with the designs of other disciplines to produce an energy-efficient building that promotes healthy lifestyles for athletes and building occupants. Synergy also exceeded code minimums in their structural design in order to achieve a robust and resilient building.

VERSATILITY
Synergy’s structural designs allow openness in layout and accommodate potential future adaptations and new building developments, based on life cycle analysis projections.

Synergy designed the Sports Performance Center’s structure as a means of protecting building occupants, and as a method of enhancing the building’s iconic features while facilitating system integration.

4.0 SYSTEM GOALS
Synergy’s structural system goals prioritized safety, security, and resiliency in design yet stress the importance of an integrative design across all disciplines to produce a high-performing, versatile building that adds value to the owner through quality-controlled, accelerated construction methods. A complete list of the system goals of Synergy’s Structural team corresponding to various design features is referenced on Drawing S-1.0.
5.0 DESIGN METHODOLOGY

5.1 DESIGN CODES AND STANDARDS

Lubbock, Texas adopts the IBC 2012 with 2009 Lubbock provisions, which references ASCE 7-10, as the local building code. These codes were used in the application of loading conditions and combinations. Tornado wind design considerations were determined from Texas Tech University’s Wind Science and Engineering Center report on the Enhanced Fujita Scale and FEMA P-361. The Structural team compared the design criteria of the safe room presented by both FEMA P-361 and ICC 500. The more stringent requirements of each were utilized for design. FEMA P-361 was also referenced in regard to code wind speed comparison for impact resistance, cost benefit analysis between certain sizes and system types, egress requirements, essential features, and fire safety.

5.2 FIRE PROTECTION

Prior to any design, Synergy’s Structural team determined the construction type to be I-B in accordance with IBC 2012. The primary structural system was required to have a 2-hour fire rating, the floor system was required to have a 2-hour fire rating, and the roof system was required to have a 1-hour fire rating. A complete list of fire rating requirements and how Synergy’s structural design achieved all fire ratings, reference Drawing S-2.0.

5.3 DESIGN AND ANALYSIS SOFTWARE

Synergy structural designers completed the project designs using a combination of hand calculations and software. Synergy’s Structural team utilized a variety of computer software to check and calculations and optimize the various components of the building’s structural designs. Primary software used was SAP2000, SP packages, and RAM Structural System. A summary of the software and corresponding structural design elements are included in Structural SD-A.

6.0 STRUCTURAL OVERVIEW

Synergy’s structural design integrates innovative, coplanar long-span roof trusses with a unique roof design. A resilient building core is supported with composite steel framing. Precast reinforced concrete coupled with cast-in-place reinforced concrete shear walls make-up a centralized tornado safe room. The lateral system of the building employs concentric steel braces and steel moment frames for strength and drift control under amplified tornado wind speeds. An integrative structural enclosure is impact-resistant and high-performing across all disciplines. Drilled belled piers equipped with grade beams serve as the main foundation system that resist wind uplift and adequately transfer all loads to the supporting soil.

7.0 LONG SPAN ROOF TRUSSES

Included in the project scope, Synergy’s Structural team was responsible for the design of the long-span roof structure over the two main athletic spaces. A minimum height restriction of 65'-0" at the center of the football field needed to be maintained for kicking clearance (45'-0" center span minimum height restriction for the track). The span of the typical roof truss over the football field is 196'-0", rising 20'-0" from end-to-end. The span of the typical roof truss over the competition track is 224'-0" (25'-0" rise). The increased length allowed the truss to span over the supplemental bleachers of the building’s west side.
7.1 MODIFIED ROOF PROFILE

Through collaborative purpose and efforts, Synergy modified the profile of the roof as seen in section in Figure 3. Though the new roof geometry posed to be challenging to Synergy’s Structural team, an integrative design approach yielded a long-span structural system that ultimately saved 17% of building volume of the main spaces (seen in green) while aiding in achieving a uniform daylight distribution. As influenced by the manipulated roof profile, Synergy implemented coplanar roof trusses within the high points of the undulated roof to support the structural loads while providing stiffness and continuity between the roof diaphragm (Figure 4).

7.2 LOADING

The roof trusses were designed for a dead load of 12 psf and a calculated snow load of 16.5 psf. The clerestory windows introduce snow drift, increasing snow loads by as much as 36 psf at the drift locations. Because of drift loads, snow loads governed over a code-specified roof live load of 20 psf. Wind uplift loads on the roof purlins were designed for components and cladding wind pressures based on an EF3 tornado wind speed of 165 mph. The main trusses were designed for wind pressures of the MWFRS as tributary area was greater than 700 psf. Synergy’s structural designers decided to conservatively increase the wind pressures by 50% as per recommendations by “Building Design for Tornadoes” Presentation at the ATC OKSEA Conference in 2013 backed by testing and research done for tornado design of buildings. Since the roof trusses are positioned within the full depth of the roof high points, the roof trusses needed to also be designed for horizontal wind pressures. Because the complex roof geometry complicates the wind loading on the roof structure, Synergy recommends a wind tunnel test to provide more accurate design wind pressures. Full loading diagrams and calculations are referenced on Drawing S-5.0.

7.3 DESIGN PROGRESSION

During the early stages of design, Synergy’s Structural team explored several long-span structural systems based on the original roof profile. Preliminary designs were performed and all alternate systems were objectively compared within Synergy’s decision matrix, which aligns with the team’s goals and project themes (See Structural SD-A). Selection was narrowed down to two options to optimize the designs: planar and coplanar trusses. Planar roof trusses were unstable out of plane in resisting horizontal wind loading while the coplanar roof trusses were stable and provided continuity between the roof diaphragm (Figure 4). Synergy’s Structural team pursued the optimization of the coplanar roof trusses.

7.4 FINAL DESIGN

In effort to enhance the aesthetics of the exposed structure and to simplify any structural and non-structural connections to the roof truss members, square HSS section sizes were designed. In order to optimize the coplanar roof trusses, A500 Gr. C steel was selected, offering an increased yield strength with no added cost. The web configuration was selected to be an isometric version of the Warren truss to implement an equal balance of tension and compression members (Figure 5).

The coplanar roof trusses were designed to be 5'-0" wide between the two top chords. The trusses taper in width to a single bottom chord. Truss depth was optimized to be 10'-0" (governed by deflection criteria), permitting a reduction in building height by 5'-0" while still maintaining minimum height restrictions over the athletic spaces. Synergy’s Structural team decided to pre-camber the profile of the roof trusses by 80% of the
dead load in order to optimize the structure’s depth and save steel tonnage. To provide additional lateral stiffness, vertical x-braces spanning one truss to another were added at truss quarter-points to aid in one truss bracing the adjacent truss laterally. Horizontal lateral x-bracing spans the bottom chords of two adjacent trusses to provide additional continuity between the roof diaphragm. Final designs and sizes of the roof trusses are summarized in Table 1. Synergy’s long-span roof truss designs were optimized and verified utilizing SAP2000 (Figure 6).

Table 1: Truss Design Details

<table>
<thead>
<tr>
<th>Descriptor</th>
<th>Football Truss</th>
<th>Ratio</th>
<th>Track Truss</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Span</td>
<td>190'-0&quot;</td>
<td>NA</td>
<td>224'-0&quot;</td>
<td>NA</td>
</tr>
<tr>
<td>Depth</td>
<td>10'-0&quot;</td>
<td>NA</td>
<td>10'-0&quot;</td>
<td>NA</td>
</tr>
<tr>
<td>Width</td>
<td>5'-0&quot;</td>
<td>NA</td>
<td>5'-0&quot;</td>
<td>NA</td>
</tr>
<tr>
<td>Top Chords</td>
<td>HSS12x12x3/8</td>
<td>74%</td>
<td>HSS12x12x1/2</td>
<td>90%</td>
</tr>
<tr>
<td>Bottom Chords</td>
<td>HSS16x16x1/2</td>
<td>96%</td>
<td>HSS16x16x5/8</td>
<td>97%</td>
</tr>
<tr>
<td>Web Size</td>
<td>HSS5x6/5/16</td>
<td>53%</td>
<td>HSS5x6/5/16</td>
<td>78%</td>
</tr>
<tr>
<td>Tonnage</td>
<td>32.4 tons</td>
<td>NA</td>
<td>36.0 tons</td>
<td>NA</td>
</tr>
<tr>
<td>L/380 Limit</td>
<td>6.5&quot;</td>
<td>NA</td>
<td>7.5&quot;</td>
<td>NA</td>
</tr>
<tr>
<td>Live Load Defect</td>
<td>4.4&quot;</td>
<td>67%</td>
<td>5.5&quot;</td>
<td>73%</td>
</tr>
<tr>
<td>Camber</td>
<td>6.8&quot;</td>
<td>80%DL</td>
<td>0.2&quot;</td>
<td>80%DL</td>
</tr>
<tr>
<td>L/240 Limit</td>
<td>9.8&quot;</td>
<td>NA</td>
<td>11.2&quot;</td>
<td>NA</td>
</tr>
<tr>
<td>Total Defret.</td>
<td>6.1&quot;</td>
<td>62%</td>
<td>7.8&quot;</td>
<td>70%</td>
</tr>
</tbody>
</table>

7.5 CONSTRUCTABILITY

In order to expedite construction, all roof trusses will be fabricated in-shop with welded connections. Trusses will be shipped to site in 50’ to 60’ segments, eradicating the need for special transportation permits. Once on site, the truss segments will be connected by high-strength bolts, eliminating the need for field welding and on-site weld inspections. Because a single truss is unstable in torsion under its own self weight, Synergy’s Structural and Construction teams collaborated to erect two adjacent trusses together by connecting them with their upper purlins. An entire truss assembly consisting of two complementary trusses and their upper purlins will be erected as one system, as seen in Figure 7, avoiding the need for temporary vertical and horizontal shoring. Synergy’s Structural team verified the truss assembly’s design under construction loading. See Construction SD-D for more information regarding crane selection and steel erection.

7.6 ROOF TRUSS SUMMARY

As part of the roof profile modifications, Synergy designed innovative, coplanar long-span roof trusses comprised of square A500 Gr. C HSS. Truss depth was optimized to be 10’, and a roof framing configuration permitted roof depressions in the roof profile while still maintaining minimum height restrictions over the athletic spaces. The long-span structural system helped to save 17% of building volume of the main athletic spaces which translates to a 5% yearly energy savings of the mechanical system. Through well-thought out truss geometry and collaborative efforts made with the Construction team, a creative means of truss erection eradicated the need for temporary vertical and horizontal shoring of the trusses which expedited the schedule by three weeks.

8.0 RESILIENT BUILDING CORE

After evaluating the original floor plan’s effectiveness in achieving the project themes, Synergy decided to implement a resilient building core that splits the building apart along its north-south central axis. The core provides 40'-0" of separation between the track and the football field and has a height of 33'-0". Serving as the anchor point of the resilient building core, the building’s tornado safe room is centralized in plan and is positioned beneath the main spectator bleachers of the track. The structure of the bleachers
doubles as the structure for the tornado safe room. By treating the resilient building core as a separate building with separate structural design solutions, Synergy’s Structural team added value for the owner by delivering a versatile, high-performing structure with prioritized safety and resiliency. Synergy also integrated with the architecture by designing a transfer truss over the bleachers, permitting optimal viewing.

8.1 LOADING

The resilient building core has structural loading unique to the rest of the structure, encompassing increased wind pressures and roof live loads for the tornado safe room, second-level live load for the auxiliary framing, and large point loads on the main bleacher transfer truss.

8.1.1 TORNADO SAFE ROOM LOADING

Referencing FEMA P-361 and ICC 500, the tornado safe room was designed to resist EF4 tornado wind pressures corresponding to a wind speed of 250 mph. The safe room was considered fully exposed, as the host building is not designed for an EF4 tornado. As per FEMA P-361, Synergy designed the safe room for the gravity loads and impact loads resulting from the host structure’s collapse onto the tornado safe room. ICC 500 recommends a minimum roof live load of 100 psf to account for the host building’s collapse. However, Synergy’s Structural team designed for double the code-recommended roof live load since the weight of the surrounding long-span structure was deemed heavier than the typical structure of a host building. Loading recommendations from FEMA P-361 and ICC 500 are referenced on Drawing S-8.0.

8.1.2 AUXILIARY FRAMING LOADING

As the only area of the entire structure with second-level loading, the auxiliary framing of the main spaces within the resilient core is designed for a dead load of 68 psf and an unreducible live load of 100 psf. This allows spaces to be re-programmed in the future, offering versatility to the university. More information regarding the loading of the auxiliary framing is referenced on Drawing S-4.0.

8.1.3 TRANSFER TRUSS LOADING

To allow for unobstructed viewing of the track from the main spectator bleachers, Synergy’s Structural team designed a transfer truss to support eight point loads from the higher ends of the track-side roof trusses. A loading diagram is referenced on Drawing S-7.0.

8.2 TORNADO SAFE ROOM

Offering versatility to the owner, Synergy decided to integrate the tornado safe room with the main spectator bleachers. The integration allowed the area under to bleachers to serve as a location for the tornado safe room, provide a passageway through the resilient building core, and exist as a gathering area for athletes near the Fueling Station. Designing the location for the tornado safe room was highest priority to the project theme of Resiliency, but Synergy’s Structural team collaborated with the other discipline teams in order to accomplish all goals and functions of the tornado safe room. Synergy designed a multi-functioning tornado safe room that withstands an EF4 tornado and protects the lives of all building occupants. The tornado safe room occupies 4,674 SF and includes an emergency exit corridor for a clear exit path if the host building were to collapse. Synergy designed the tornado safe room for an occupancy of 516 people, more than double the anticipated typical daily occupancy of the entire building. A maximum occupancy calculation was completed for the safe room by required gross floor area reductions. The occupancy calculation and applicable area reductions considered are referenced on Structural SD-E.
8.2.1 DESIGN PROGRESSION
In order to meet the amplified wind loads beyond ASCE7, the two most viable options considered by the Structural team were reinforced concrete and a combined masonry/moment frame system. In an effort to separate the safe room from the rest of the structure, reinforced concrete was chosen as it did not rely on the surrounding framing of the resilient building core that would not be designed for an EF4 tornado. Reinforced concrete offered more robust design features, specifically in resisting impact loads. In collaboration with the Construction team, Synergy’s Structural team designed components of the tornado safe room to be precast concrete, allowing for faster and cheaper construction with better quality control. The only components of the tornado safe room not designed to be precast concrete are the reinforced concrete shear walls, which were designed to be cast-in-place to provide continuity in their behavior.

8.2.2 FINAL DESIGN
The final design of the tornado safe room is designed to consist of five reinforced concrete components: 10”-thick cast-in-place shear walls, a 12”-thick precast bleacher slab, an 8”-thick precast roof slab, (4) 16”x36” precast ridge beams, and (5) 12”x16” precast columns. The emergency exit corridor of the tornado safe room is designed only to consist of 10”-thick cast-in-place reinforced concrete shear walls and an 8”-thick precast reinforced concrete roof slab. Reinforcement and clear cover details of the design elements and detailed schematics with supporting calculations are referenced on Drawing S-8.0. Figure 10 illustrates the framing configuration of the tornado safe room. All designs were completed by hand and verified with SP software (See Table 2 for designs).

### Table 2: Safe Room Design Details

<table>
<thead>
<tr>
<th>Feature</th>
<th>Span</th>
<th>Size</th>
<th>Reinforcing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Bleacher Slab</td>
<td>10’-4”</td>
<td>12”-thick</td>
<td>Top: #4@12” O.C. Bot: #6@8” O.C.</td>
</tr>
<tr>
<td>2) Roof Slab</td>
<td>11’-0”</td>
<td>8”-thick</td>
<td>Top: #4@12” O.C.</td>
</tr>
<tr>
<td>3) Ridge Beam</td>
<td>28’-0”</td>
<td>16”x36”</td>
<td>Top: (2) #4 bars Bot: (10) #8 bars</td>
</tr>
<tr>
<td>4) Columns</td>
<td>16’-0”</td>
<td>12”x15”</td>
<td>(4) #8 bars</td>
</tr>
<tr>
<td>5) Shear Walls</td>
<td>115-0”</td>
<td>10”-thick</td>
<td>Horiz: #4@13” E.F. Vert: #4@18” E.F.</td>
</tr>
</tbody>
</table>

8.2.3 THROUGH-OPENINGS
In order to maintain a flexible and versatile space while offering through-access between the resilient building core and the two main athletic spaces, Synergy implemented two 19’-6”x15’-0” openings within the tornado safe room. The openings will be protected in case of an emergency by motor-operated shutters designed to withstand EF4 tornado wind pressures and impact loads (refer to Drawing S-8.0 for specified shutters). During typical building use, the shutters will be in the up position, allowing through-access between the main spaces of the building.

8.2.4 CONSTRUCTABILITY
Designing many of the tornado safe room components as precast elements offered significant benefits to Synergy’s Construction team and the overall project by eliminating the need for complex formwork, reducing cost, accelerating construction, and improving quality control and assurance. Simple support conditions of the precast concrete elements simplified the design and reinforcement detailing by eliminating the transfer of moments between the majorities of the tornado safe room structural components.

8.3 AUXILIARY FRAMING
Separate from the long-span structural system yet integrated with the tornado safe room, the structural framing of the auxiliary spaces within the resilient building core and its adjacent areas offer composite steel framing. Composite steel framing promotes an open floor plan that adds value and engages versatility for future adaptations while ultimately saving cost and expediting construction.

8.3.1 DESIGN PROGRESSION
Steel framing was selected over the design alternatives on the basis of achieving Synergy’s project themes. When compared to alternative gravity systems, steel framing differentiated itself from the other options on the main criteria of value and versatility (see Structural...
After SD-A for the decision matrix, once steel framing was selected, a cost analysis was performed between the designs of composite and non-composite steel framing. Overall, the composite steel design saves approximately 9,300 lbs of structural steel within the resilient building core (approximately 25% of the structural steel tonnage of the non-composite design).

### 8.3.2 FINAL DESIGN

Steel W-shape columns are spaced typically at 30'-0" in order to maximize tributary area and reduce the number of required columns. Intermediate W-shape composite beams are typically spaced at 15'-0" O.C. In order for this spacing to be feasible, a composite 3VLI 16 ga. deck with 3.5” of lightweight concrete topping was selected. The composite deck is designed for a two-span loading condition with a maximum unshored clear span of 15'-2" under construction loading which eliminates the need for temporary shoring. The Structural team’s calculations and referenced Vulcraft catalog tables are included on Drawing S-4.0.

Since the main lobby and weight room are double-height spaces, the columns for these spaces were designed for a total unbraced length of 30'-0". Column spacing is still maintained at 30'-0" for flexibility in the layout of the lobby and weight room. Columns supporting the roof overtop the location of the tornado safe room bear on the walls of the safe room, eliminating the need for separate foundations for the columns. The typical column over the tornado safe room is a W10x33, ensuring that the dimensions of the column may adequately bear on the 10"-thick concrete walls of the safe room. This design coordination minimizes any load eccentricities on the wall.

### Table 3: Typical Bay Details

<table>
<thead>
<tr>
<th>Descriptor</th>
<th>Typ. Beam</th>
<th>Typ. Girder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>W21x44</td>
<td>W21x44</td>
</tr>
<tr>
<td>Studs</td>
<td>20</td>
<td>14</td>
</tr>
<tr>
<td>Span</td>
<td>32 feet</td>
<td>30 feet</td>
</tr>
<tr>
<td>Flex. Capacity Ratio</td>
<td>79%</td>
<td>85%</td>
</tr>
<tr>
<td>Composite Action</td>
<td>26%</td>
<td>26%</td>
</tr>
<tr>
<td>L/360 Limit</td>
<td>1.06’</td>
<td>1&quot;</td>
</tr>
<tr>
<td>LL Deflection</td>
<td>0.66*</td>
<td>0.55*</td>
</tr>
<tr>
<td>LL Deflect. Ratio</td>
<td>62%</td>
<td>55%</td>
</tr>
<tr>
<td>L/240 Limit</td>
<td>1.6&quot;</td>
<td>1.5&quot;</td>
</tr>
<tr>
<td>TL Deflection</td>
<td>1.42’</td>
<td>1.07*</td>
</tr>
<tr>
<td>TL Defect. Ratio</td>
<td>89%</td>
<td>71%</td>
</tr>
</tbody>
</table>

### 8.3.3 CONSTRUCTABILITY

Synergy’s Structural team optimized beam spacing and carefully selected a composite deck type that allows for a maximum clear span under construction loading that does not require temporary shoring. Because the tallest column within the auxiliary framing is 30'-0", no columns need to splice. The maximum beam span is 40'-0", eradicating any need for splicing and/or special transportation permits.

### 8.4 TRANSFER TRUSS

In order to provide an unobstructed view of the track, some of the long-span roof trusses could not bear directly on columns that extend to the foundation. To promote versatility, Synergy’s Structural team designed a transfer truss that spans 210’ and picks up the load from eight of the long-span trusses of the track-side (Figure 12 and Figure 13). The transfer truss was designed to be concealed within the exterior wall, allowing for finishes and any future artwork to enhance the lighting and aesthetics of the track.

### 8.4.1 FINAL DESIGN

The design of the truss consists of (57) A992 Gr. 50 W-shape members, spans 210’ over the main bleachers, and is optimized to be 20’-deep. The 20’ depth was selected to accommodate strict total load deflection criteria of L/600 in order to avoid noticeabled sag and increased deflection of the long-span roof trusses.

**Figure 11:** Walkway Area Bay
Furthermore, the 20’ depth occupies the full-depth of the wall that extends from the roof of the resilient building core to the upper portion of the track-side roof. This allows the planar truss to be laterally braced by the track-side long-span roof trusses at the top chord and by the structural framing of the resilient building core along the bottom chord.

Vertical members were added to add stiffness at the locations of high point loads and to reduce the unbraced length of the top chord in compression under gravity loading. The Warren configuration of diagonals provided additional stiffness while maintaining an equal number of tension and compression members in resisting reversible in-plane lateral wind load when integrated into the whole building’s lateral system. The profile of the transfer truss was modified in order to camber 80% of the dead load. The total weight of the transfer truss is 78.5 tons. Relatively square W-14’s were selected for the member design in effort to reduce slenderness ratios. The full geometry, all member sizes, and all capacity design ratios are referenced on Drawing S-7.0. The transfer truss design was verified utilizing SAP2000. A sample of the design and capacity ratios may be observed in Figure 14.

**8.4.2 CONSTRUCTABILITY**

Due to the size of the transfer truss panels, each 15’x20’ panel will be fabricated in-shop and shipped individually to site. Once on site, the panels will be bolted together in the field in order to eliminate the need for field welding and welding inspections. Shipment of the 14 panels will require two truckloads. The 15’x20’ panels exceed the width of a truck by three feet which requires special transportation as coordinated with the Construction team. In order for the transfer truss to adequately fit within the width of the exterior wall, Synergy optimized section sizes with flange widths no larger than 16”.

**8.5 GRAVITY CONNECTIONS**

In effort to eliminate the need for field welding and weld inspections, Synergy’s Structural team collaborated with the Construction team to design and implement simple bolted connections for all design elements of the gravity system. More information regarding gravity connections is on Drawing S-2.0.

**8.6 BUILDING CORE SUMMARY**

The addition of the resilient building core provided opportunity to centralize the tornado safe room. The reinforced concrete tornado safe room is designed to resist EF4 tornado wind pressures and gravity and impact loads from the collapse of the host structure. Auxiliary framing of the resilient building core offers a versatile, open floor plan by implementing composite steel framing to maximize beam spans and spacing. A transfer truss over the main spectator bleachers provides unobstructed views of the track while adequately transferring the loads of the long-span roof trusses to the foundation.
9.0 LATERAL SYSTEM

The whole building’s lateral system is separated into two lateral systems by means of a building expansion joint. Each lateral system is designed for strength and drift under amplified wind loading and calculated seismic loading. Synergy’s lateral system design employs moment frames in locations of large windows and door openings while utilizing concentric and eccentric braces in all other required locations. Lateral system elements are positioned such that the torsional moment is minimized. Both lateral systems are designed to control drift within two inches.

9.1 BUILDING EXPANSION JOINT

As per AISC Steel Manual, 14th Edition and NSA Tech Report 65, an expansion joint is needed in the Sports Performance Center because the building is 460’ wide. The calculation for determining the size of the joint is referenced in Structural SD-C. The selected location for the joint is along the column line separating the football field and the resilient building core due to the column line’s continuity along the entire length of the building (Figure 15). The addition of an expansion joint created two separate lateral systems: one for the football-side structure and one for a combination of the resilient building core and the track-side structure. Each lateral system was separately designed and optimized for strength and drift. Synergy’s Structural team coordinated with Synergy’s other discipline teams to ensure that the building’s service systems were designed to accommodate differential movement across the expansion joint.

9.2 LATERAL LOADING

Wind and seismic loads were calculated with reference to ASCE 7-10. MWFRS wind load calculations corresponded to a wind speed of 165 mph (EF3 tornado maximum wind speed). Seismic load calculations were in correspondence with Seismic Design Category A. Since the expansion joint separated the building into two, lateral loading was calculated independently for each building portion on either side of the expansion joint. Wind loading governed the lateral system’s design, though strength and drift values were verified for seismic loading. Lateral loading calculations are supplied in Structural SD-B.

Figure 15: Expansion Joint Location

Figure 16: Football-side Lateral System

Figure 17: Track-side Lateral System
9.3 DESIGN PROGRESSION

The large size of the structural bays and the overall height of the building negatively affected the feasibility of utilizing shear walls (concrete or masonry) in the athletic spaces. Furthermore, through discussion with Synergy’s Construction team, concrete and masonry shear walls were both deemed non-optimal due to severe cost and schedule implications. Synergy’s Structural team decided to implement a combined lateral system of braced frames and moment frames.

9.4 FINAL LATERAL DESIGN

Steel braced frames and steel moment frames were selected as the ideal combined system for the MWFRS due to cost benefits, ease of construction, and integration with the architecture. All lateral frames are comprised of A992 Gr. 50 W-shapes. Together, the frames’ designs are optimized for strength while controlling building drift through virtual work within 2” (H/400 criteria). Drift optimization results are included in Structural SD-D.

Moment frames primarily exist along the northern facade as many door and window openings decorate the facade. Synergy’s Structural team did not want to compromise the placement of large, north-facing windows that offer superior daylight into the building’s main spaces. The typical column size is a W12X53, and the typical gir is a W12x72. A sample of moment frame elevations and sizes are summarized on Drawing S-6.0.

In all other locations aside from the north facade, concentric bracing is primarily utilized to resist lateral loads. The typical column size of a typical braced frame is a W24x131. The typical column is also designed to support the axial compression loads from the long-span roof trusses. The typical gir size is a W12x72. The girts are designed to take axial load from the MWFRS, support vertical load from the dead load of the wall panels, and resist out-of-plane wind loading. The girts are designed to experience bi-axial flexure, and they are oriented about their weak axis as the increased out-of-plane wind pressures governed the design over the vertical dead load of the wall panels. The typical brace size is a W12x120. The braces are designed to take similar axial compression and tension load due to reversible wind loading. A sample of concentric braced frame elevations and sizes are summarized on Drawing S-6.0.

Typical gir spacing was selected to allow for modularization of wall panels for attachment. Wall panels on the project are prefabricated in two heights, 10’-0” and 12’-0”.

The transfer truss located above the main spectator bleachers is also incorporated into the lateral system. In order to relieve stress from the two end columns of the transfer truss, the next two bays are designed to be lateral frames. Additional moment frames within the resilient building core run perpendicular to the bottom chord of the transfer truss, providing bracing that resist out-of-plane wind loads.

9.5 LATERAL CONNECTIONS

A typical braced frame connection is designed as a pinned-pinned connection, allowing the brace to take only axial loads. Due to reverse loading conditions, the typical braced frame connection was designed for similar axial tension and compression loads.

Though more complicated to design to transfer moment, an all-bolted moment connection was selected in order to reduce the amount of field welds and weld inspections needed on the project, translating to savings in the schedule. The typical moment frame connection is illustrated in Figure 18.

All typical lateral connection details are provided on Drawing S-2.0.

Figure 18: Typical Moment Frame Connection
9.6 LATERAL SYSTEM SUMMARY

The whole building's lateral system is separated into two systems due to the addition of a building expansion joint. Synergy's lateral system design employs a combination system of steel braced frames and steel moment frames to control building drift within two inches to fall within the allowable drift criteria for EF3 tornado wind loading. Thus, building drift in accordance with typical design wind pressures is well within the deflection limits. The combination system's design is governed by increased wind loads corresponding to a maximum wind speed of 165 mph of an EF3 tornado.

10.0 FOUNDATIONS

Synergy's foundation system is the recommended system of the project's geotechnical engineer, Dyess-Peterson Testing Laboratory, Inc., and is designed to adequately transfer the significant loads from the long-span roof structure to the supporting soils through use of drilled belled piers. The drilled belled piers offer superior performance in resisting uplift of amplified wind design loads.

10.1 SITE ANALYSIS

Preliminary research into a soil survey of the Lubbock County subsurface conditions indicated typical loamy soils with the potential to shrink and swell with moisture changes. A concern of the Structural team was exposure to clays with high plasticity (CH in the Unified system of Classification) due to its potential to cause damage to concrete foundations. The provided geotechnical investigation outlines the soil types on site as SC, CL, and SM and describes the soil as well drained, not flooded or ponded, with a low shrink-swell potential. The report also recommends grade beams supported by drilled belled piers due to the depth at which suitable soil is found on the site.

10.2 DESIGN PROGRESSION

Based on the geotechnical investigation results, a deep foundation system with a slab on grade was considered to be the most efficient design option for the substructure of the Sports Performance Center. Comparing the options of piles, drilled piers with and without a bell, and stone columns, Synergy evaluated each option's performance experiencing uplift as well as its ability to spread load to soil of a suitable bearing capacity. Synergy's Structural team ultimately selected drilled belled piers and grade beams to meet this criteria.

10.3 SHARED FOUNDATION

The Structural team employed the grade beams providing lateral support to the drilled piers to also support the dual column line resulting from the building expansion joint. An expansion joint through the foundation was not necessary due to the assumption that minimal movement will be seen by the substructure compared to the superstructure.

This shared foundation will carry loads from both the columns supporting the long-span trusses over the football field as well as the reinforced concrete wall enclosing the tornado safe room. Grade beams of a 5'-0" width are centered under the two walls and span between 6'-0" diameter drilled piers which will be spaced at the same locations as the columns. The 6'-0" diameter drilled belled piers support the grade beams along the shared foundation and were designed using the loading described on Structural SD-C.

10.4 FINAL DESIGN

Synergy's Structural team final foundation system of the Sports Performance Center consisted of drilled belled piers ranging from 2' to 5' in shaft diameter with a depth of 30' and a rebar cage extending into the bell with a total area of steel of 11.44 in². The diameter of the bells were designed to be three times the diameter of the shaft with a 70° angle. With the application of large lateral forces to the superstructure, the drilled piers are tied together with grade beams spanning between the drilled piers along the perimeter walls of the building and in select areas throughout the building core. The grade beams provide necessary lateral support as well as carry the weight of the exterior walls to the drilled piers. They were
designed to withstand the dead load of the walls, compression due to lateral loads, and the soil pressure calculated from the potential vertical rise value of 0.56” provided in the geotechnical report. The typical perimeter grade beams were designed to be 3’ wide by 2’ deep with a total longitudinal area of steel of 16 in² and typical transverse steel of #4 bars spaced at 10”.

The foundation system utilizes 4000 f’c concrete.

The typical slab on grade to be placed in all areas of the Sports Performance Center except under the synthetic turf field will be 6”-thick with #4 bars at 16” O.C. in both directions placed at the bottom of the slab. This design was determined by comparing the maximum live load applied to the slab to the calculated allowable live load that 6”-thick concrete of 600 psi flexural strength may withstand.

### 10.5 GRADE BEAM AND IN-GROUND DUCT COORDINATION

In order to efficiently utilize the displacement ventilation system and increase occupant comfort in the athletic spaces of the Sports Performance Center, Synergy’s Structural team worked together with the Mechanical and Construction teams to propose a solution for the underground ductwork placement. For further details of the underground mechanical system, refer to Section 8.2.4 of the Mechanical Report. The room where the ductwork will traverse vertically from the mechanical equipment to the slab on grade is located within the central core between two foundation lines. Due to the transfer truss above the bleachers eliminating the need for columns and therefore drilled piers and grade beams, the ductwork can easily span from under the slab of the mechanical room in the core to the diffusers on the far side of the track space. However, the ducts extending underneath and across the football field from that same mechanical room posed a challenge due to the grade beams spanning between drilled piers along the shared foundation. By leaving the grade beams and drilled piers in their positions unchanged, the duct would need to be buried deeper to adequately clear the depth of the substructure, requiring greater excavation and backfill and longer duct runs for air to travel. Synergy’s solution to this challenge is to lower the shared foundation between the columns in the area of the tornado safe room by a depth of 5’. This allows the mechanical ductwork to be closer to the underside of the slab in the resilient building core and decreases the amount of duct and excavation required during placement. With this solution, the cost of the foundation is increased slightly (4%) to account for the additional foundation in that area. However, the benefits of the integrated solution outweigh the minimal cost addition to the foundation.

![Figure 20: Foundation and In-ground Duct Coordination](image)

### 10.6 FOUNDATION SUMMARY

Synergy’s Structural team applied the information and recommendations of the provided geotechnical report to design a foundation system capable of supporting heavy building loads and large lateral forces, as well as meet the integrated project themes for the Sports Performance Center.

### 11.0 INTEGRATED STRUCTURAL ENCLOSURE

Tasked with designing a structural enclosure to resist wind-borne missiles while adequately transferring increased design wind load to the main building structure, Synergy developed a structurally robust facade and roof assembly with improved thermal and moisture performance. Though structural performance was critical in the enclosure design, Synergy’s Structural team devised a design that would not compromise glazing for daylighting schemes, that would be thermally efficient for mechanical performance, and that would be modularized and prefabricated such that construction methods were accelerated and quality-assured. Synergy’s Structural team recommends comprehensive performance testing of the designed enclosure.
11.1 IMPACT-RESISTANT FACADE

Though the entire building was meant to be designed to withstand an EF3 tornado, no specific guidelines existed for designing for the impact loads of an EF3 tornado. Instead, the design team referenced FEMA P-361 for design recommendations for resisting the impact loads of tornado wind-borne debris. In order to develop an impact-resistant façade, Synergy utilized test data from Texas Tech University. For more information and data regarding the testing procedures for the impact resistance of wall assemblies, refer to Drawing S-9.0. In summary, an approved wall assembly passed testing from the impact of a 15 pound 2x4 wood stud with a missile speed of 100 mph. While considering constructability and enhanced thermal and moisture performance, Synergy’s Structural team selected 9”-thick precast brick-stamped, insulated concrete panels. The concrete panels have 3” of rigid insulation sandwiched in between two layers of 3” of reinforced concrete. Impact tests indicate a threshold missile speed of 102 mph without damaging the first 3” of concrete of the panel.

In effort to minimize weight of the wall assembly to reduce structural sizes, Synergy selected a different façade composition to stack on top of the precast concrete panels and extend the remaining height of the building. To achieve superior impact performance, the upper wall assembly relies on a double 2x6 metal stud wall with two layers of ¾” structural plywood laid over one layer of 14 ga. steel. Testing indicates a threshold missile speed of 130 mph. The exterior cladding of the upper wall assembly is a terracotta rain screen, designed to improve the moisture performance of the wall assembly. Though the terracotta rain screen is not tested for impact, the rain screen system is rated for wind pressures up to 190 psf, enough to resist EF3 tornado wall wind pressures and suction.

11.2 UPLIFT-RESISTANT ROOF ASSEMBLY

Synergy’s structural designers identified the importance of developing a light roof assembly that would also resist uplift and roof tear off in the event of an EF3 tornado. This meant that the fastening design would be critical, and the depth of the roof would need to be minimized for the sake of adequate fastening attachment and securement.

In selecting a roof assembly, Synergy’s design team referenced RoofNav, a complimentary design tool from FM Approvals that provides access to the most up-to-date FM Approved roofing products and assemblies. Synergy was able to select a Factory Mutual Approved roof assembly that is approved for an uplift of 180 psf, providing a factor of safety of 2 against EF3 tornado wind roof uplift pressures. The composition of the FM Approved roof assembly may be observed in Figure 22. Referencing testing results from Texas Tech University, a similar roof assembly experienced no penetration or perforation at a threshold speed of 74 mph, which is larger than the FEMA P-361-specified missile speed of 67 mph for horizontal surfaces.

![Figure 21: Wall Assembly Composition](image1)

![Figure 22: Roof Assembly Composition](image2)
11.3 CONSTRUCTABILITY

Synergy’s Structural team collaborated with Synergy’s Construction team to prefabricate and modularize all wall assemblies in order to accelerate the construction schedule by 29 weeks. More information on the prefabrication of the wall assemblies may be referenced in Section 8.2.1 of the Construction Report.

11.4 GLAZING AND MULLION DESIGN

Synergy’s Structural team coordinated with Synergy’s Lighting/Electrical and Mechanical teams in order to select a fully tempered, laminated and insulated glazing type with an overall thickness of 1-5/16” inches (Figure 23). By selecting a laminated glass type, building occupants will not be at risk of falling glass shards. Furthermore, the building is protected from being breached since any broken windows will be held intact with the PVB interlayer. Glazing design was performed in accordance with ASTM E-1300. Calculations and corresponding design charts are supplied on Drawing S-9.0.

Typical mullions were designed to be 2.5” wide by 7.5” deep in order to resist the components and cladding wind pressures corresponding to EF3 tornado wind speeds. Details on the mullion design are referenced on Drawing S-9.0.

![Figure 23: Typical Impact-Resistant Glass](Image)

11.5 ENCLOSURE CONNECTIONS

The precast wall panels and the prefabricated upper wall panels are designed to be connected on four sides (spanning two horizontal wall girts and two adjacent columns). Synergy’s Structural team also detailed a typical connection of the clerestory glazing and surrounding facade to the top and bottom chords of the coplanar roof trusses. This detail is supplied on Drawing S-9.0.

11.6 ENCLOSURE SUMMARY

Resorting to test data from Texas Tech University, the Structural team designed an enclosure capable of resisting wind-borne missiles generated from an EF3 tornado. By employing an FM-approved roof assembly for a specified uplift load greater than the design load, Synergy’s Structural team mitigated the risk of roof tear off. A laminated fully tempered glass type was selected for optimal performance. Through collaborative efforts with Synergy’s Construction team, the Structural team was able to aid in saving 29 weeks of the construction schedule by prefabricating the wall assembly.

12.0 LESSONS LEARNED

In reflecting upon the design process of the Sports Performance Center, the Structural team learned an immense amount related to design through failures and triumphs. The main takeaway from the Structural team is learning how to adapt their designs to accommodate the designs of other discipline teams and achieve overall project goals. Understanding the designs of other disciplines helps to devise creative structural solutions that complement the execution of other discipline goals and ideas.

13.0 CONCLUSION

Value was added to the project through prefabricated design, optimization of truss systems, and reduction of members. The building enclosure met impact resistance and increased the rate of construction. The trusses were designed consistently for easy construction and cambered to reduce member size. The core space was optimized to reduce the total number of members.

Synergy designed a structure that can remain intact through an EF3 tornado and a safe room that can withstand an EF4 tornado. The impact resistant façade and the combination of lateral systems provide the resiliency against the EF3 tornado. The precast concrete safe room provides the lateral strength and impact resistivity to protect building occupants during an EF4 tornado.

Synergy’s integration of the structural system allowed the whole building to perform above code standards. Synergy integrated the clerestories for reduced building height and increased daylighting. The lateral system exceeds code limits for deflection, providing increased performance in unpredictable emergency situations.

Versatility is achieved through the structural system by allowing the building to adapt with time. The auxiliary spaces have open layouts allowing for a variety of uses. Because many designs are controlled by deflection, the building can be used for different events as seen fit, including those that would use decorations that add extra loads to the structure.
### Decision Matrix

#### PROJECT GOALS:

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<tr>
<th>VALUE</th>
<th>RESILIENCE</th>
<th>PERFORMANCE</th>
<th>VERSATILITY</th>
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<tr>
<td>Cost</td>
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<td>Operation &amp; Schedule</td>
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#### LONG SPAN ROOF STRUCTURE

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<td>Additional Comments:</td>
<td>Composite decking allows for longer spans, lighter self-weight and a more cost-effective solution to the mid-floor framing of the building core.</td>
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#### FOUNDATION SYSTEM

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<td>1</td>
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<tr>
<td>Additional Comments:</td>
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</table>

#### Codes and Standards

Lateral Loading

Lateral seismic loads were found for the original iteration design of the building using ASCE 7-10 Chapter 11 (Seismic Design Criteria) and Section 1.4.3. It was found that wind pressures would control over seismic for the design of the lateral system and seismic loads were not adjusted further. Lateral wind loads were determined by following ASCE 7-10 Chapters 26 (General Requirements) and 27 (Directional Procedure) and modifying the basic wind speeds presented in Figure 26.5-1B to correspond to the wind speeds of the enhanced fujita tornado intensity scale. The pressure calculations for these scaled wind speeds were also altered using suggested tornado design methods and code requirements respectively. Due to the complexity of the building size and shape, wind pressures were calculated for the separate lateral systems utilized by the building.

Flat Roof Snow Load

The ground snow load was obtained from ASCE7-10, and the resulting flat roof snow load was calculated to be 10.4 psf. The code minimum flat roof load is 16.5 psf, so 16.5 psf is the controlling snow load.

Snow Drifts

Seams:

Sand: 0.9, 1.95, 2.95, 3.95
W: 3.02, 3.05
W: 3.02, 3.05

Components and Cladding

Components and Cladding wind pressures were used to design mullion spacing and sizes on the glazing, individual truss elements, roof joints, and wall girts. Further calculations can be found on Drawing S9-D.
Expansion Joint Location

Structural Supporting Documentation

Load Determination
The deep foundations were designed for the worst case load in each area of the building in order to increase their constructability on site. The code driven minimum area of reinforcement was used for the rebar cage, which extends to within three feet of the bottom of the pier.

Grade beams tie the tops of the drilled belled piers together to provide lateral support while also acting as a wall foundation for the lower 1/2 of the precast façade. The grade beams were also designed to withstand soil forces equivalent to a 0.56″ displacement.

The slab on grade, present in all areas except under the football field, was designed according to the load allowed for a 600 psi flexural strength concrete. The slab of the building core was designed to the same live loading conditions as well as to withstand the weight of the tornado safe room wall. Minimum reinforcing steel was used in the slabs and met the requirements presented in the FEMA document for foundation design.

Drilled Belled Piers
Pier analysis of capacities and sizes were determined through the creation of a spread sheet.

Critical column reactions used to design piers (kips).

Grade Beams
Typical 3′x2′ grade beam design verification with spBeam.

Grade Beam Loading
Shear Capacity Curve
Moment Capacity Curve

Expansion Joint Calculation

Slab On Grade

<table>
<thead>
<tr>
<th>6″ REINFORCED CONCRETE SLAB</th>
</tr>
</thead>
<tbody>
<tr>
<td>#4 @ 16″ O.C. EACH WAY</td>
</tr>
</tbody>
</table>

VAPOR BARRIER
12″ COMPACTED FILL
SANDY LEAN CLAY (CL) OR CLAYEY SAND (SC)

FLEXURAL STEEL:
#4 @ 6″ O.C. each way
ASHC 14th Edition

FLEXURAL CONCRETE STRENGTH:
FLEXURAL STRENGTH = 0.2 x 5900 psi = 1180 psi

Typical 3′x2′ grade beam design verification with spBeam.
Supporting Document D | Lateral Analysis

Strength and Drift Optimization
Synergy’s initial lateral system design employed full building use of braced frames, moment frames, and concrete shear walls. With the addition of an expansion joint the column line between the building core and football space, individual lateral system analyses were performed.

The track and football lateral systems were then designed to limit drift to 2", or a drift criterial of L/400. Once the drift met the stated criteria, Synergy continued the design with the optimization of braces and members. The maximum drift occurs under the load combination of 1.2D+0.5L+1.6W.

The girder spacing was chosen in conjunction with the design of the prefabricated wall panels. Girts are spaced at either 10 feet or 12 feet. Each wall panel weighs 65 psf, resulting in a uniform load of 780 plf across a 30 foot girt, and a moment of 87.5 ft-k. Taking into account the unbraced length of the girt and deflection criteria of L/240 for dead load, a W12x72 was chosen as the typical girt size.

Because the size of the girts are controlled by deflection and the lateral elements are controlled by drift, many of the girts have more strength than is required by the loading. This can attribute to the buildings extra resiliency in the case of a natural disaster. The increased capacity of the members also allows for flexibility in the usage of the space. Should Texas Tech University decide to use the space for an unforeseen event, such as a student gathering, that requires additional materials to be hung from the exposed wall girts, there will be no issue in overstressing the members.

Detailed elevations can be found on Drawing S-5.0.

Specific user defined factors for wind load cases were input into RAM in order to accurately model the proposed EF3 winds seen by the building lateral systems.

Drift Optimization is shown for the track in the east-west wind direction due to use of only braced frames resisting the lateral load.

A combination of concentric braced frames and moment frames surround the football field and are optimized for 2" of drift.

The braced frames were optimized for strength by decreasing the amount of bays and increasing the brace sizes.
Tornado Safe Room Occupancy

Calculations for the reinforced concrete elements of the tornado safe room were completed by hand and verified using various Structure Point concrete design software. The slanted bleacher slab was designed for impact loading, EF4 tornado wind pressures, and live loads of spectators. The walls of the safe room were loaded axially from the 2nd floor walkway above them as well as the EF4 lateral wind pressures. Interior columns and beams spanning them were designed to withstand the loading from the 2nd floor and allow the roof slab to span the length of 115' in the North – South direction.

**Tornado Safe Room Location**

**Tornado Safe Room Section**

**Columns**

- 12 x 15 in
- 1.65% rein.

**MATERIAL:**
- f’c = 4 ksi
- Ec = 3605 ksi
- fc = 3.4 ksi
- H0 = 1.85
- fy = 60 ksi
- Es = 29,000 ksi

**SECTION:**

- Aq = 132 in²
- Ix = 4056 in⁴
- fy = 2304 in⁴
- Xo = 0 in
- Y0 = 0 in

**REINFORCEMENT:**

- 4 #8 bars @ 1.646%
- As = 3.16 in²

Confinement: Tied

Clear Cover = 1.68 in

Min Clear Spacing = 6.25 in
System Goals Summary Chart Graphic

<table>
<thead>
<tr>
<th>Disciplines</th>
<th>Goal</th>
<th>Design Feature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Architecture</td>
<td>Reduce overall building height and create open viewing areas</td>
<td>Coplanar and transfer trusses</td>
</tr>
<tr>
<td>Lighting Design</td>
<td>Provide support for clerestory window, allowing maximized daylighting</td>
<td>Trusses located in clerestories</td>
</tr>
<tr>
<td>MEP Systems</td>
<td>Protect emergency equipment in event of emergency</td>
<td>Concrete center core</td>
</tr>
<tr>
<td>Construction</td>
<td>Allow for prefabrication</td>
<td>Steel structure and depressions between clerestories</td>
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<tr>
<td>Lateral System</td>
<td>Integrate with façade features that connect to campus</td>
<td>Moment Frames</td>
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<td>Lighting Design</td>
<td>Allow for daylighting</td>
<td>Moment Frames</td>
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<td>MEP Systems</td>
<td>Protect emergency equipment in event of emergency</td>
<td>Concrete center core</td>
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<tr>
<td>Construction</td>
<td>Allow for ease of erection</td>
<td>X-braces along exterior</td>
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<tr>
<td>Foundation System</td>
<td>Reduce the probability of differential building settlement</td>
<td>Addition of a building expansion joint</td>
</tr>
<tr>
<td>MEP Systems</td>
<td>Protect underground ductwork for displacement ventilation system</td>
<td>Addition of the foundation wall</td>
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<tr>
<td>Construction</td>
<td>Ensure the ease of construction by decreasing the types of foundations</td>
<td>Single system selection</td>
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<td>Building Enclosure</td>
<td>Keep the traditional architecture look</td>
<td>Stamped brick concrete panels</td>
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<td>Lighting Design</td>
<td>Provide opportunities for daylighting</td>
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<td>MEP Systems</td>
<td>Maintain an R-Value of 27</td>
<td>Whole wall section</td>
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<td>Construction</td>
<td>Prefabricate the wall sections</td>
<td>Brick-stamped concrete panels</td>
</tr>
</tbody>
</table>

Lessons Learned
Integrative Design Through Discipline Understanding
Synergy was able to achieve integrated design by communicating effectively to gain an understanding of the goals of other disciplines in relation to the overall project themes. Designing these areas were considerably easier and done more efficiently due to the continuous communication which led to a higher quality design.

Routine and continuous discussion of the multiple iterations for the clerestory windows transpired with all of the members of Synergy. By understanding the goals for daylighting, the Structural team was able to minimize the amount of members creating shadows. Through discussions with the Construction team about erection and prefabrication, the Structural team designed the trusses for strong prefabricated construction, hassle-free shipping, and simple on-site connection and erection. Lastly, working with the Mechanical team to create operable windows helped define the mullion spacing.

The building enclosure was driven structurally by impact resistivity due to the project theme of resiliency. After finding potential assemblies that could withstand the impact requirements, Synergy discussed prefabrication options with the Construction team while simultaneously working with the Mechanical team to achieve high R-values. The Lighting team was involved with selecting interior finishes to create the best setting for lighting the spaces in order to promote WELL and occupant wellness in the building.

System understanding was gained through use of the Semester Integration Log. This log was intended to be filled out weekly by each discipline with progress updates and coordination details. The other disciplines then would note the changes and comment on the magnitude that the change would affect their design. With consistent use of the integration log, issues and coordination were brought up and discussed immediately. However, lax updating of the integration log hindered the movement of ideas between disciplines during off times outside of normal working hours.

Team Design Summary
Synergy’s structural team worked to continuously develop the Sports Performance Center design based on the progress and results of each individual structural feature. Major features were designed in an overlapping manner in order to accommodate changes made during the design process. Open communication and knowledge of the other design teams’ work lead to a resilient, efficient, and integrated project.

Architecture Changes
Long Span Trusses
Lateral Design
Foundation Design
Gravity Design
Enclosure Design
Safe Room Design
Synergy utilized the decision matrix to choose all of its major systems. This included the long span roof system, the framing system of the auxiliary spaces, the foundation system, and the lateral system. The use of the decision matrix allowed the Structural team to illustrate concrete evidence as to why certain systems would prevail over others during full team discussions.
Connections

Simple Shear Connection

Simple shear connections are utilized in the auxiliary spaces and building core framing. The driving factor for using this connection was constructability. The plate can easily be shop welded and the bolts can be quickly assembled in the field. The loads for the one story building core and auxiliary spaces are such that larger connections with heavy welds and multiple rows of bolts were not necessary.

Moment Frame Connections

For the moment frames in the lateral system, all bolted connections were chosen over connections involving welds. In order to accelerate the building schedule and follow the project goals, prefabrication of as many elements as possible to bring onto site was the most effective. Fewer field welds were far more preferable when deciding the type of moment connection.

Brace Frame Connections

This typical connection will be used in the braced frames found throughout the lateral system. The connection is designed to behave as a pin, permitting only axial loads to go into the braces. While the brace size does change from frame to frame, the connections are designed to use the same size plate and bolts throughout, with the number of bolts potentially changing. Because the lateral system is controlled by drift more often than strength, the plate size controls the connection more often than the brace size, permitting the consistency of connections.

Fire Ratings

The 3VLI lightweight concrete composite framing system chosen for the auxiliary spaces meets the necessary 2 hour fire rating required by the IBC for floors and ceilings as well as lessens dead load on the building core and allows for more flexibility in the floor plan due to its ability to span longer distances.

Exposed interior structural steel also meets the 2 hour fire rating by being protected by sprayed intumescent coating which allows for a more aesthetically pleasing surface finish than typical spray fireproofing.
The Sports Performance Center's structural resiliency relies on a foundation system consisting of drilled belled piers, grade beams, and a slab on grade. The decision to take advantage of the recommended foundation system proposed by the geotechnical engineers resulted from the desire to utilize a system with sufficient uplift capacity as well as the ability to disperse heavy building loads onto suitable soil. A bearing capacity of 8000 psf was outlined in the geotechnical report at a depth of 30' below grade.

### Drilled Belled Pier Schedule

<table>
<thead>
<tr>
<th>Shaft Diameter</th>
<th>Length, L (ft.)</th>
<th>Reinforcing</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>2'-0&quot;</td>
<td>39'-6&quot;</td>
<td>11.86</td>
<td>10</td>
</tr>
<tr>
<td>3'-0&quot;</td>
<td>39'-6&quot;</td>
<td>24.46</td>
<td>61</td>
</tr>
<tr>
<td>4'-0&quot;</td>
<td>39'-6&quot;</td>
<td>42.06</td>
<td>12</td>
</tr>
<tr>
<td>5'-0&quot;</td>
<td>39'-6&quot;</td>
<td>48.87</td>
<td>2</td>
</tr>
</tbody>
</table>

*Reinforcing cage to be placed within 3'-0" of the bottom of the bell.

### Grade Beam Schedule

<table>
<thead>
<tr>
<th>Size</th>
<th>Reinforcing</th>
<th>Stirrups</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>H</td>
<td>Bottom</td>
</tr>
<tr>
<td>24</td>
<td>24</td>
<td>9in</td>
</tr>
<tr>
<td>36</td>
<td>24</td>
<td>13in</td>
</tr>
</tbody>
</table>

*Shared Foundation

Typical Grade Beams
Full design lateral load calculation values can be found on Structural SD-A.
Design Methodology

Preliminary truss design options and basic geometry were first modeled in AutoCAD and analyzed in Staad.Pro in order to ascertain the desired deflection and capacity ratio would be met. In-depth modeling of the final coplanar truss design and assembly was completed in SAP 2000, which more accurately distributed applicable loads and created a more realistic model for the long-span structure. Final member sizes of the coplanar trusses were optimized to the controlling deflection criteria.

Deflection Criteria

The coplanar roof truss was designed for a typical long span roof deflection criteria of L/240 for the total load and L/360 for the live load. With the applied loading (described on Structural SD-A) and large deflection output, it was decided that 80% of the dead load would be pre-cambered from the profile of the coplanar trusses. Resulting deflections with camber due to live load and total load were 4.4" and 6.1" respectively. The use of horizontal bracing also reduced the out-of-plane deflections in the clerestories due to the depressed roof shape.

Deflected Shape of Truss Bays Under Lateral Loading

Deflected Shape of Truss Bays Under Dead and Snow Loading

Deflected Shape of Truss Bays Under Lateral Loading

HSS Chord Members Optimized for Strength and Deflection

Typical Roof Truss Bays

Football Truss

<table>
<thead>
<tr>
<th>+</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Span</td>
<td>22' 0&quot;</td>
</tr>
<tr>
<td>Top Chord</td>
<td>HSS 12 x 12 x 1/2</td>
</tr>
<tr>
<td>Bottom Chord</td>
<td>HSS 10 x 10 x 3/8</td>
</tr>
<tr>
<td>Web Members</td>
<td>HSS 6 x 6 x 1/16</td>
</tr>
</tbody>
</table>

Track Truss

<table>
<thead>
<tr>
<th>+</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Span</td>
<td>19 6' 0&quot;</td>
</tr>
<tr>
<td>Top Chord</td>
<td>HSS 12 x 12 x 1/2</td>
</tr>
<tr>
<td>Bottom Chord</td>
<td>HSS 10 x 10 x 3/8</td>
</tr>
<tr>
<td>Web Members</td>
<td>HSS 6 x 6 x 1/16</td>
</tr>
</tbody>
</table>

Typical Roof Truss Bay (Deflected Shape of Truss Bays Under Lateral Loading)
Comfort and application of the WELL building standard lead to the design of the 210'-0" transfer truss spanning over the open bleacher area. In order to restrict the use of columns in the lines of sight of the spectators, the transfer truss supports eight point loads from the coplanar truss roof assemblies and distributes the load to the foundation. The transfer trusses location is within the wall over the bleachers with a deflection criteria of L/600. Due to the length of the span and high deflection output during optimization in SAP 2000, it was decided that 80% of the dead load will be pre-cambered from the profile of the transfer truss, similarly to the coplanar roof trusses. This camber helped produce an acceptable deflection of 4.2".
Impact Resistant Storm Shutters

To protect the openings of the tornado safe room in the event of a natural disaster, the Qompact shutter system was specified for protection. With a maximum occupancy of 516 people in the safe room, at least three exits were provided in accordance with IBC 2012 and protected with the mechanically operated shutter system.

**Strength**
The single wall extruded slats are very strong and have been subjected to study the forces impacts and hurricanes impact tests. These products are hurricane-tested, and even with Qompact's small cell requirements, provide the utmost hurricane and security protection. Stad image exceeds 2000 lbs (179 kip) pull apart strength excellent for security.

**Operations**
Gear, low voltage, and motor driven with spring assisted. Spring assist manual operation for up to 150 sq. ft (16 square metres). Manual operation up to 160 sq. ft (16 square metres) saves money over other shutter owners who must motors and pay for electrical hookups. Spring assisted gear drives make for smooth and easy operation. Our E2 drive system: a low voltage battery power, gives you more flexibility plus a simple motorization installation.

**Life Cycle Tested**
To 15000 operations (42 years) and counting. Each shutter part has been enhanced for maximum durability and to reduce warranty service. Our Compact customers will experience carefree operation for many years. Keeping the ratio balanced of durability and opening them often will extend their life and provide maximum protection.

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**Preliminary Storm Shelter Model**
In order to secure the everyday occupants of the Sports Performance Center, the reinforced concrete tornado safe room was designed and optimized to be the anchor point of the building core.

The attached corridor leading to the exterior of the building from the south safe room wall is designed with reinforce concrete in the same fashion as the east and west wall so that the occupants can safely exit the building in the event of a natural disaster.

**Final Tornado Safe Room Design**

**FEMA P-361 Safe Room Requirements**
Within the building core, the tornado safe room was designed with both ICC 500 minimums and FEMA P-361 requirements. The FEMA document "describes the criteria for any safe room to be constructed so that it is capable of providing near absolute protection for its occupants during tornadoes and hurricanes." (FEMA P-361) in order to do just that. Synergy chose to exceed the minimum standard put forth by the ICC and NSSA (ICC 500-08) and utilize FEMA P-361 recommendations for design.

One major difference in the design of the safe room was in terms of lateral pressure design. FEMA P-361 requires all safe rooms to be designed for a wind pressure of 250 mph regardless of location. Even the most critical wind speed for an EF4 tornado (165-200 mph) is 50 mph less than the design requirement, illustrating the resiliency of Synergy’s tornado safe room.
Clerestory Detail

The total height of the clerestory glazing was maximized to be 7'-0" after taking into consideration the depth of the roof, the depth of the secondary framing, and the 14" vertical sill height that prevents snow build-up and direct water penetration. Since the slope of the curved roof profile is no greater than 1/2" per foot at any location, the standing seam metal roof did not need to be waterproofed.

Impact Resistance

The upper and lower wall sections for the Sports Performance Center have been optimized to FEMA impact resistance requirements courtesy of research performed by the Wind Science and Engineering Research Center at Texas Tech University.

The lower 24' of the wall section consists of the 3" precast concrete panel and the height from 24' to the roof consists of two plywood layers and a 14 ga. steel layer. The large missile impact criteria outlined in FEMA P-361 were tested by Texas Tech University using a compressed air cannon to launch a 15 lb 2x4 wood stud 100 mph into the assemblies.

Glazing Calculations

Typical mullions were designed to be 2.5" wide by 7.5" deep. The values on the typical mullion design charts were extrapolated to exceed the necessary design load of 185 psf (Line J).

<table>
<thead>
<tr>
<th>Design Load</th>
<th>180 psf</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panel Size</td>
<td>5' x 4'</td>
</tr>
<tr>
<td>Glass Type</td>
<td>1/2&quot; FT Laminated IGU (Exterior Lite)</td>
</tr>
</tbody>
</table>

Deflection

<table>
<thead>
<tr>
<th>Exterior Lite</th>
<th>1/2&quot; FT Laminated IGU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deflection</td>
<td>0.005&quot;</td>
</tr>
</tbody>
</table>

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