1.0 PROJECT DESCRIPTION:

A capstone experience provided by the Department of Civil and Architectural Engineering at University XXX has allowed the Architectural Engineering student design teams to establish a project type, size, approximate budget, and determined goals under consideration of a chosen client. Team 5 of the capstone course had established a project that would be designed and developed for Oakland University, a highly recognized university, with high aspirations to become a fifth-tier school in the state of Michigan in terms of containing a strong research and scholarly environment focused on creative endeavors and on the discovery, dissemination and utilization of knowledge. This capstone project had been separated into three phases among the two semesters the course spans which includes a schematic design (SD), design development (DD), and finally a construction documentation (CD) phase. Three technical reports were submitted throughout the design process by all engineering disciplines which concluded each design phase of the project. The design team had begun the SD phase in September, 2020 and completed the CD phase in April, 2021. The design team worked collectively to deliver all reports and design documents which adhere to all Oakland University standards, local, state, and national codes and standards, and the responsibility and competence of all team members.

Currently ranked eleventh in research and development in the state of Michigan, Oakland University established a master plan in 2016 that defines a strategic vision, goals, space needs and requirements, guidelines, sustainability, utilities and parking for its enrolled student body of 20,000 individuals. This context allows for the overall outline of all major developments, plans, and suggestions for future growth of the university. The master plan calls for an undeveloped section of the campus to be developed as the new Innovation District which provides new multi-level parking structures and a fleet of research and development buildings in three quadrants which would be phased in construction based on funding, demand, and program development. Through the understanding and analysis of the Oakland University Master Plan of 2016, Team 5 expanded on the knowledge and background that is understood in order to establish a plan to assist the University in their growth and recognition.

Team 5 comprises of six students in the Architectural Engineering program as well as one of those students dual enrolled in the School of Architecture at University XXX. The team is specialized in five main design and engineering categories as well as seven sub-categories:

- Architectural Design
- Structural Engineering
- Mechanical Engineering
  - HVAC
  - Geothermal
  - Plumbing
  - Fire Protection
- Electrical Engineering
  - Power
  - Lighting
  - Solar Photovoltaics
- Construction Engineering

This architectural and engineering design team have worked collectively over two academic semesters to deliver a comprehensive and rigorous set of architectural engineering construction documents and design intents for the development and construction of Oakland University's newly proposed Interdisciplinary Research Center costing the university and their industry partners a

total of $40 million. Both the interior building program design and exterior façade design intents were established for the project. The building contains approximately 140,000 square feet of gross floor area among three floors and a basement mechanical space. The building was designed such that it would result in a 160,000 square foot total gross floor area after the construction of a future phased addition on the third floor of the building. The anticipated use and occupancy of this building is designed for programs such as bioengineering, computer science, cyber security, environmental science, fastening and joining, and robotics. Individuals of the University such as students, faculty, industry partners, and general visitors would occupy the various spaces in the building which consist of dedicated laboratory spaces, classrooms, individual workspaces, meeting spaces and exhibit areas. This project is all-inclusive in design-development comprising of building architectural design, structural, mechanical, and electrical engineering design work as well as construction engineering including construction project management from ground break to building occupancy.

ARCHITECTURAL

The Oakland University Interdisciplinary Research Center establishes an expressive program in respects to its linear function. The building main entry leads into a wide-open lobby designated for seating, meeting and gathering spaces. The design concepts persuade the building to a relatively narrow and elongated plan that allows for a core laboratory space at the center of the building at each floor level which contains movable and flexible arrangements for specific laboratory needs. Support office and workrooms flank the core laboratories providing dedicated workspace for additional research, analysis and synthesizing. A research high-bay laboratory is provided for extensive field testing and analysis. The upper levels of the building similarly contain additional laboratory spaces, work spaces, meeting areas and classrooms. The second-floor core laboratory roof is designed and prepped for a future third floor building addition per the project phasing requirements of Oakland University. This space allows for temporary photovoltaic panels that would be located a floor level above in the future. Building elevations, modeling and material selection are all coordinated with the Master Plan standards and guidelines to establish a cohesive building design appearing as a fluid member of the campus building population.

STRUCTURAL

In coordination with the building architecture, the structural design student who also acted as the project architect was able to integrate the building's structure with the design and flow that is anticipated for the buildings program. Inspired by Louis Kahn's Salk Institute for Biological Studies in La Jolla, California, the Interdisciplinary Research Center for Oakland University is designed such that the structure allows for wide open spaces while providing a strong and durable shell to support all the occupant's activities. It was the responsibility of the structural engineering student to develop and provide these designs in respect to the following scope of work:

- Structural Framing Layout
- Environmental Loads
- Lateral Force Resisting System Design
- Masonry Wall Design
- Steel System Design
- Foundation Design
- System Connection Design
- Structural Drawings and Details

The building is constructed utilizing structural steel framing over poured concrete foundations including: trenched, column pads, formed walls with continuous pad footings. The ground floor of the structure is provided with 6-inch reinforced concrete floor slabs. All floor decking above the ground floor is designed for 100 PSF live load utilizing 12-inch thick pre-stressed ultralight hollow-core precast concrete planks and a 2-inch concrete topping for a level and aesthetic floor finish. The precast floor system allowed for the reduction of infill beams ultimately allowing for greater

ceiling heights and plenum space for the research environment, mechanical and electrical systems. The building is designed to resist lateral loads with two systems: braced frames and reinforced concrete masonry block walls. Braced frames are located in the longitudinal direction of the building while reinforced masonry shear walls are located in the transverse direction from the top of the foundation to the third floor of the building approximately 50-feet above finish floor. The ground level of the building is continuously constructed of reinforced masonry walls while the second and third floor levels are provided with cold formed light gauge metal framing. The roof framing for the vast majority of the structure contains steel beams while two long span locations of building are provided with open web steel roof joist combined with a joist girder.

MECHANICAL – HVAC AND PLUMBING

The design of the Oakland University Interdisciplinary Research Center's mechanical system focused on sustainability, energy efficiency, and occupant comfort. It was the responsibility of the mechanical engineering students to develop and provide these concepts in respect to the following scope of work:

- Design Heating/Cooling System
- Design Ventilation System
- Design Hydronic System
- Design Domestic Water System
- Design Rain Catchment System
- Design Sanitary System
- Design Fire Protective Sprinkler System
- System Integration
- Clash Detection and Coordination
- Design Ground Source Heat Pump System

The mechanical systems as a whole are designed based on induced building loads including thermal, water supply, fire suppression, drainage, and sanitary discharge. Through the process of evaluation, a hybrid system primarily composed of a Variable Air Volume (VAV) system with a perimeter baseboard hydronic system. The VAV system will contain reheat coils controlled by the hydronic hot water system and Air Handler Units (AHU). The AHU's will contain cooling coils which are controlled by the hydronic chilled water system supplied by the air-cooled chiller. The hydronic system will receive aid from a proposed geothermal bore system along the perimeter of the building in available green areas. The building's plumbing design is primarily for toilet rooms, laboratories, and rainwater collection. Sanitary discharge and domestic water supply is provided to all fixtures specified on the project as required. The rainwater collection is sourced from roof sumps that connect to a filtration system and holding tank. Furthermore, fire suppression is integrated both concealed and exposed per code in the building. A Class I standpipe is implemented to the project with an automatic wet pipe sprinkler system. Smoke control dampers are coordinated with the architect and placed in-line with the ventilation system.

ELECTRICAL – POWER AND LIGHTING

The electrical design for the Interdisciplinary Research Center is such that it provides excellent power quality, reliability, system redundancy, and ease of operation utilizing safety methods per code. The lighting design, both interior and exterior, is driven by energy efficiency, lighting quality, and daylight integration. It was the responsibility of the electrical engineering students to develop and provide these concepts in respect to the following scope of work:

- Power Distribution Plans
- Special Systems Plans
- Lighting and Control Plans
- Riser Diagram and One-Line Diagrams
- Renewable Energy System Design
- Electrical Lighting Concept Design
- Lighting Fixture Selections
- Sensors and Control Device Design
- Daylighting Analysis and Integration
- Sustainable Power Distribution Design

The power supply to the building is received underground from a nearby campus substation at 13.2 kV which transforms the voltage down to 480Y/277V to service the building. A double ended substation is designed for a 938 kVA demand or approximately 1,500 Amps. The total power requirements of the building concluded to be an estimated 8.23 watts per square foot. A renewable energy system comprised of a 342 kW, 250 module, solar array located on the flat roof areas of the building provides approximately 40 percent of the buildings total energy consumption each year of use. The power system in conjunction with the solar array results an Energy Use Intensity (EUI) of 98.25 kBTU/SF/yr. The lighting design of the project incorporated methods in design to assist in the total EUI demand. The philosophy of design was keen on “students, faculty, and the community to advance together”. Bringing this philosophy to light, each space was analyzed to determine adequate light levels, temperature, control, and fixture finishes. All fixtures are lamped with LED’s and are to be circuited such that they work in conjunction to occupancy sensors, switches, and photocells. Fixtures in daylight determined zones are circuited to photocells and lighting sequences which manage the percentage of light provided, if any, during a time of daylight infiltration. Daylighting integration is a key design factor for Oakland University. Spaces with daylight zones were analyzed and provided with electrochromic glazing for automatic glass tinting based on the daylight exposure at a specific time of day to ultimately provide shading and reduce intrusive glare into the perimeter and center spaces of the building.

CONSTRUCTION AND SUSTAINABILITY

In coordination with the engineering disciplines of structural, mechanical, and electrical, the construction engineering student of the project was in charge of the scheduling, construction design, cost estimation, overall scope of work, and determine and develop the main source of communication between subcontractors and the owner. It was the responsibility of the construction engineering student to develop and provide these designs, schedules, and documentation in respect to the following scope of work:

- Cost Management Plan
- Schedule Management Plan
- Sustainability Management Plan
- Scope Management Plan
- Safety Management Plan
- Logistics Management Plan
- Permitting & Approval Plan
- Risk Management Plan
- Communications Management Plan
- Quality Management Plan

The project contains a conceptual estimated cost for the 140,000 square foot facility which results to be $39,651,484 or approximately $40 million. The cost of the project was determined by material breakdowns compared to typical square foot costs for the local area. To maintain the project on-budget it was important to establish a Construction Phase Bar (Gantt) Chart and its related Construction Project Management (CPM) Network Diagram. The schedule denotes being tentative due to unforeseen events on the University campus, weather advisories, financial deficit, or change orders at the Owners request. Management and logistic plans were compiled for the project for construction clarity, transparency, safety, standards and guidelines, and overall success in completing the project on schedule in a safe, adequate, and efficient manner. As an important to Oakland University, all new projects constructed on campus are to be of LEED certification such as their most recent buildings: the LEED Platinum Human Health building or the LEED Gold Engineering Center. The construction engineering student produced a LEED checklist in the sustainability management plan that totaled a quantity of 83 points. The quantity of points qualifies the Team 5, Interdisciplinary Research Center, as a LEED Platinum project achieving 80 or more LEED points. The act of designing a sustainable structure relied heavily on the buildings water efficiency, energy and atmosphere, materials and resources, and finally the indoor environmental quality.

2.0 COLLABORATION OF FACULTY, STUDENTS, AND LICESNED ENGINEERS:

Over the course of the project, Team 5 collaborated in various ways in respects to teamwork, coordination, and consulting with University XXX faculty, Oakland University faculty, and licensed professional engineers. The capstone course is held such that various meetings and presentations were held throughout both semesters which allowed for valuable feedback to the teams in regards to their presentation quality, graphics, technical information, and response to questions regarding that technical information. As each team contains a minimum of at least one student per discipline, a faculty member of University XXX with the specialty of that discipline acts as a mentor and advisor to discuss methods of achieving the scope of work goals as well as staying on task. Team 5 made many efforts to work collectively as a team while undergoing various safety precautions over the previous year due to the COVID-19 pandemic. In person meetings were conducted at the beginning of the first semester while switching over to many more phone calls, text messaging, emails, and online video-call meetings. All file sharing was conducted through online server-based storage accessible by all Team 5 members anywhere they chose to work independently. The team specifically collaborated to provide a fully integrated design project among all project disciplines. In order to do this, it was important to share and discuss the methods and systems that are to be applied to the project with complete validation or an open mind to allow flexibility and change. The most important areas of collaboration include system specifications, clearances, and sustainability. Specifications such as structural loads, power demands, or thermal loads are required to be known among the disciplines where required. Clearances of those implemented systems must be identified and coordinated with other systems such as structural members, ductwork, piping, conduit, and devices for their overall quality, install, and usability. Finally, sustainability had to be coordinated in regards to specifications on system performance, demands, material specifications, embodied carbon emissions in the structure, and efficiency of the building for optimum performance and payback to the owner.

3.0 PROTECTION OF PUBLIC HEALTH, SAFETY, AND WELFARE:

The design of the Oakland University Interdisciplinary Research Center was analyzed for the protection of the public health, safety, and welfare of all of those who occupy the building and those who are in the surrounding community. Each discipline: structural, mechanical, electrical, and construction, all made efforts to provide these crucial design applications in their own way that most economically, ethically, and accurately depicts the safety and security of the people and the environment.

HEALTH

The collective efforts of the mechanical engineering students of Team 5 provide the protection of the health for occupants in various ways. The design of the HVAC system provides effective ways of moving air throughout the building while treating the air with filters and UV protection. Extensive research in the effects of particulate matter in the air as well as effective air distribution and supply methods were conducted most inspired by the response and experience living in a period during a global pandemic. The airside mechanical system provides nearly double the Air Change per Hour (ACH) for all spaces to induce greater air flow and overall circulation in the building allowing old air to be purged from the space. Additionally, the mechanical system is designed and specified to run two hours pre- and post-occupancy in order to purge stale or contaminated air. Disinfection is to be provided in-line with mechanical ducts that contain Ultraviolet (UV) lamps as well as HEPA filters in-line with the source mechanical units as well as in-line with ducts near terminal units.

SAFETY

All disciplines found ways to implement safety into their designs whether it's the system equipment, installation methods, or protection of general building occupants. The mechanical engineering discipline has provided the Interdisciplinary Research Center with a complete fire suppression and detection and alarm system. The protection of the people, building service equipment, as well as laboratory equipment and occupant experiments are taken into consideration to determine the necessary hazards that take place. The electrical engineering discipline has provided emergency power systems as well as specialty systems such as CCTV security throughout the building at all entrances, exits, major hallways, laboratories, and commons. Furthermore, the electrical equipment designed for the buildings power supply was fully analyzed for three bolted fault short circuit analysis, Hazard Risk Category levels (HRC), and overcurrent coordination through Time Current Curve (TCC) plots. The lighting design student has also provided adequate emergency egress lighting to safety exit the facility in case of an emergency. The structural design student designed the buildings structure to the most extreme case for laboratory and classroom induced loads and vibration criteria as well as to minimize building sway from impact of lateral loads. Multiple design safety factors and loading combinations using ASD and LRFD were applied to structural calculations to identify and provide the most adequate and economically justified structural members. Finally, the construction engineering student provided various planning stages to the construction processes of the project to give order and direction for all stages of construction. Safety and logistic plans are graphically posted for the owner as well as contractors to clearly identify plans and protocols.

WELFARE

Welfare of the public and those in the surrounding community of Oakland University are taken care of through design considerations for personal health, impact to the environment, and life span of the proposed project. Impacts to the environment and life span of the project share a major factor: material choice. The materials chosen on the project will ultimately determine the life span of the building as well as the amount of environmental impact including embodied carbon. Strictly directed to the structural engineering, building structures typically account for greater than 50 percent of embodied energy. It was the structural students' task to determine the estimated embodied carbon of the proposed building while identifying methods to reduce that quantity in effective ways. Extensive research and analyses were conducted and identified the project to contain 17.6 million kgCO2e embodied carbon production in the buildings concrete and steel structure. Through optimization and redundancy, utilizing the LEED CLF 2021 baseline for sustainable buildings, the student designed the building to be produced with a total of 10.8 million kgCO2e. The 24 percent reduction came from ultralight precast concrete planks as well as optimized steel member design and utilizing bolted connections.

4.0 MULTIDISCIPLINE AND ALLIED PROFESSION PARTICIPATION:

The capstone presentations of each team allowed for open communication between those teams and University XXX faculty and licensed professional engineers. Approximately forty (40) licensed professional engineers have attended the capstone presentations as well as industry partner break-out sessions. Break-out sessions provided slotted time for all capstone teams to meet with industry partners, licensed engineers, who could provide more input in a smaller meeting session with all similar discipline team members. Specific input provided by the industry partners allowed for concise and realistic applications and advice in the design process of the capstone projects. Information regarding costs, construction methods, design approaches, and general design rules

were shared among the various disciplines. Licensed professional engineers that have attended these presentations and meetings are involved in fields such as:

- Structural Engineering
- Geotechnical Engineering
- Civil Engineering
- Mechanical Engineering
- Electrical Engineering
- Lighting Design
- Construction Engineering
- Transportation Engineering

It was the discretion of the individual team members to take the advice and information received from the industry partners and apply that into their project. Where a situation occurs that a student applies that information to their project, yet needing further assistance in that design, the students were able to contact the professional for additional resources or information pertaining to the requested assistance.

5.0 KNOWLEDGE AND SKILLS GAINED:

Over the course of two semesters the advancement of knowledge and skills gained from the capstone project of Team 5 for the Oakland University Interdisciplinary Research Center had reached great strides. This team grew together utilizing the support and independence of each other and as a group to complete a comprehensive integrated design project. All members of the team have had prior real-life industry exposure through job opportunities and internships; though, in most cases the students may not experience every aspect of design, decision, and execution. The capstone experience allowed for all those aspects to be practiced and understood.

Approximately forty (40) total national, state, local, and Authority Having Jurisdiction (AHJ) codes, standards and ordinances were consulted in the design and development phases of the Interdisciplinary Research Center. Interpretation of the codes and the implementations are of the responsibility of the design students and their teams to create accurate, code compliant, and safe drawings and documentation.

Additionally, each discipline had exposure to utilize professional grade software provided by University XXX to incorporate and assist in their designs. Experience in real world professionally used design software is an important feature in university academics to prepare and expose students to practice over background and theory taught in the classroom. Programs utilized for this project include:

- Adobe Acrobat
- Adobe Illustrator
- Adobe Fresco
- Adobe Photoshop
- AutoDesk 3DS MAX
- AutoDesk AutoCAD
- AutoDesk Revit
- AutoDesk Visual Lighting
- Bentley RAM Structural System
- Bluebeam Revu
- Google Earth Pro
- Microsoft Excel
- Microsoft Teams
- Microsoft Word
- Navisworks Manage
- NCMA Masonry
- RSMeans Estimating
- SkyCIV Platform
- SKM System Analysis
- Sensor Placement Optimization Tool
- Trane Trace 3D Plus
- Trimble Sketchup
- Visual Studio
- Zoom Communications

Ultimately, the capstone experience was an academic real-life-based project with real-life challenges and decision making. The students have learned various problem solving, technical skills, coordination and integration within a team with strong communication, and specifically a greater understanding of their particular discipline and its application in the specific project choice of the individual teams.