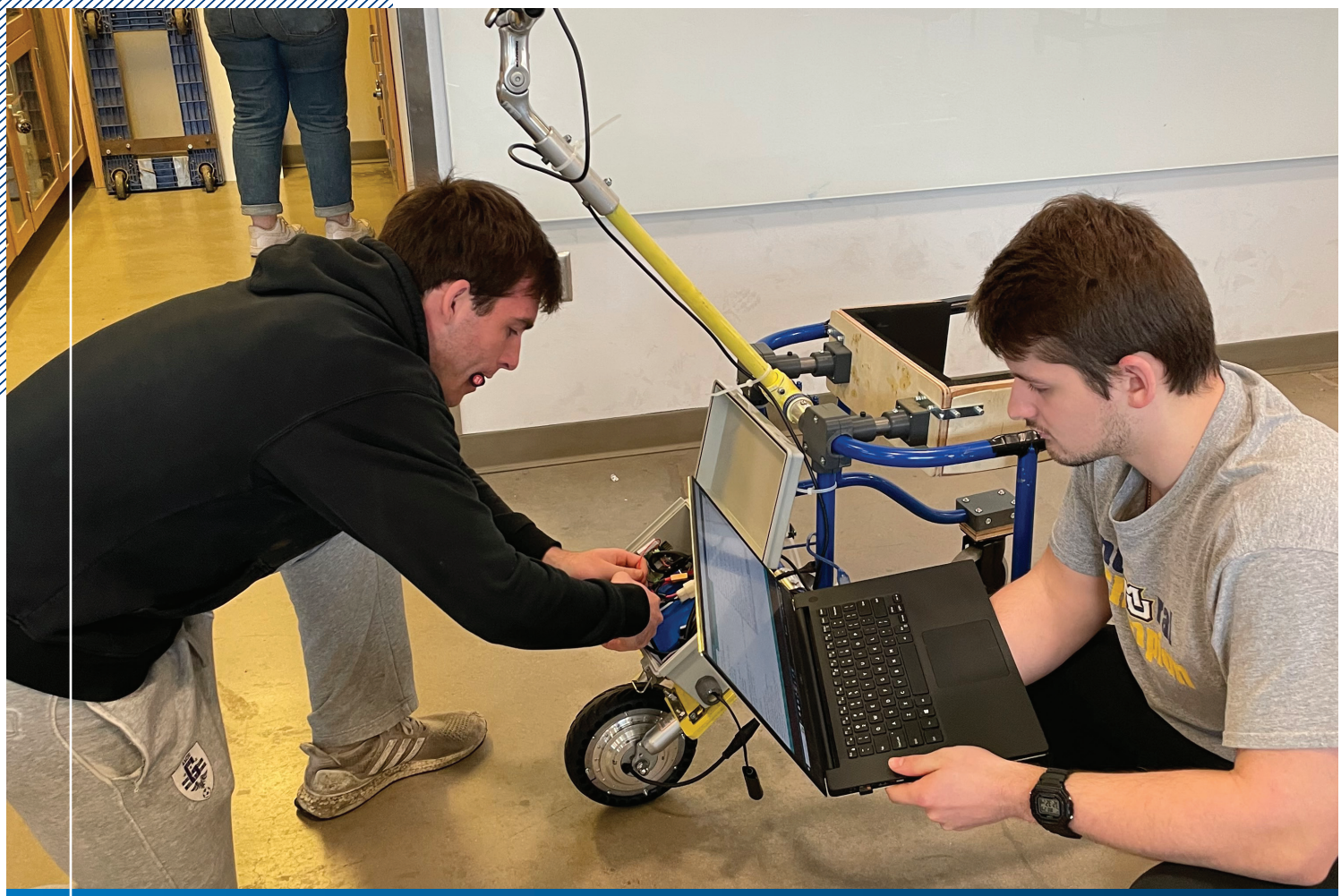

Senior Design Projects

2024

JOINT DEPARTMENT OF
BIOMEDICAL ENGINEERING

MARQUETTE UNIVERSITY

MEDICAL COLLEGE OF WISCONSIN

Contents

On the cover
Two project team members assemble the prototype of an assistive walking device that will enable their young client with a disability to safely maneuver grass, woodchips, and other currently challenging terrains.
See page 14 for more information.

Senior Design Projects
2024

To our Industry Partners

We are pleased to present the Biomedical Engineering Senior Design Projects completed during the 2023-2024 academic year with the joint department between Marquette University and the Medical College of Wisconsin.

The Joint Department of Biomedical Engineering at Marquette University and the Medical College of Wisconsin is dedicated to preparing students for their professional and personal lives after graduation. Undergraduate students can specialize in biomechanical, bioelectrical, or biocomputer engineering. In addition to courses in engineering, mathematics, and the life sciences, students are required to complete several design challenges in the freshman year and a year-long project-based capstone design course in the senior year. Students develop their teamwork skills, learn about the product development process used in industry, and are made aware of the unique requirements and constraints of medical device design. They consider legal and regulatory issues, use standards where applicable, conduct economic analyses, and learn about packaging, sterilization, and testing of medical devices. Several project deliverables, similar to those used in industry, are required. This capstone design experience provides students with the knowledge base and skill sets needed to be effective contributing members of a medical device company, clinical engineering department, or academic research laboratory, and create value for their customers.

This was the eighth year of our new Joint Department of Biomedical Engineering between Marquette University (MU) and the Medical College of Wisconsin (MCW). Department faculty from MU and MCW served as advisors to project teams. This year we continued our 19-year collaboration with the Milwaukee Institute of Art and Design (MIAD). Four of our project teams collaborated with industrial design students from MIAD during the spring semester.

In our Biomedical Engineering Department, students may enhance their design experience and preparation for careers in the engineering profession through work experience. At the Les Aspin Center for Government Studies, students can work as interns for the US Food and Drug Administration and learn first-hand how the FDA functions and what is required to market a regulated medical device. Students participating in our highly popular and nationally recognized Cooperative Education Program gain work experience at medical device companies prior to graduation.

As you read through this report and learn of the benefits of industry sponsorship of senior design projects, please consider becoming a sponsor. We recognize the value to our students and program of strong ties to industry, and we are interested in working with additional companies to help us prepare our students for careers in biomedical engineering.

Respectfully,

Jay R. Goldberg, Ph.D., P.E.
Professor of Practice in Biomedical Engineering
Senior Design Course Instructor

Frank Pintar, Ph.D.
Professor and Chair
Joint Department of Biomedical Engineering

Requirements for Industry Sponsorship of Senior Design Projects

Senior Design Course Sequence

At Marquette University, all senior biomedical engineering students are required to successfully complete a set of project-based capstone design courses (BIEN 4920 Principles of Design, and BIEN 4998 Senior Design).

At the end of these courses, students will demonstrate

- the ability to connect and apply the knowledge and skills developed in previous engineering (and other) courses towards a design solution (to a specific problem) that creates value for a customer,
- the ability to plan and produce a product or service that will meet customer needs,
- the ability to work effectively in teams, and
- written technical and oral communication skills.

Senior Design Project

The major component of the course is a design project that is managed by a multidisciplinary team of three to five students for an entire academic year. During the year, project teams identify customer needs, develop potential designs, construct and test prototypes, and deliver a design and/or working prototype to their industry sponsors. Project teams develop project schedules, maintain project notebooks, conduct economic and risk analyses of their design solutions, and develop and present written and oral project proposals and final reports.

Many of the projects are industry sponsored and provide students with an opportunity to learn about the needs of the medical device market and the operations of a company. Experience gained from industry sponsored projects helps prepare students for careers in the medical device industry. Teams are advised by a biomedical engineering faculty member and a representative from the sponsoring company.

Benefits of Sponsorship of Senior Design Projects

Benefits to companies

- Additional resources at little cost to company. Three to five senior engineering students will be dedicated to each project for two semesters. The sponsoring company can specify the composition of the project team (biomedical, electrical, computer, and mechanical engineering students). This can be very beneficial to companies with limited engineering resources and can allow companies to focus efforts on higher priority projects.
- Involvement and participation in the training of new engineers and potential employees.
- On-campus advertisement of the sponsoring company.

Involvement in the senior design project will provide the company access to and a higher profile among graduating engineers.

Benefits to students

- Opportunity to work on real-world problems important to industry.
- Exposure to the medical device industry and market.
- Experience with project management and product development.
- Familiarity with requirements and constraints of medical device design.

Requirements for Industry Sponsorship

Personnel

Sponsoring companies must identify at least one company representative to act as an industry advisor to the project team. The industry advisor would be the company contact for the project team, advise students on customer needs, provide technical expertise and advice, and approve design concepts and prototypes.

Faculty advisors will be responsible for administrative issues (grading, monitoring progress of teams, dealing with team personnel issues, etc.) and providing guidance to the team.

Time

At a minimum, industry advisors must be available to discuss project requirements, customer needs, and potential designs. Communications can be virtual, in-person, or by phone or e-mail. The industry advisor determines the frequency of communications.

Travel

The industry advisor determines the need for travel.

Funding

Depending upon the needs and expectations of the sponsor, a fund of $1000–$1500 may be necessary to pay for prototypes and testing.

Other

Students have access to Marquette University's computer network, libraries, Discovery Learning Laboratory (machine shop, collaboration space, 3D printers, prototyping resources), faculty expertise, and engineering laboratories. Sponsors may want to provide additional resources (prototyping facilities and/or personnel, laboratories, etc.) to their project teams if desired.

Types of Projects Appropriate for a Senior Design Project

- Lower priority projects for which the company lacks resources.
- Projects that can be completed in nine months or less.
- New products (hardware or software).
- Product improvements (new features, packaging, materials, etc.).
- Process improvements.
- Development of test procedures and/or test equipment.

Protection of Proprietary Information

Sponsors can request that members of their project teams sign non-disclosure agreements to protect confidential and proprietary information.

To Sponsor a Biomedical Engineering Senior Design Project

If you have any questions about our senior design program or if you are interested in sponsoring a senior design project please contact **Dr. Jay Goldberg at jay.goldberg@marquette.edu.**

We look forward to working with you.

Industry Sponsors

2023-2024
Visionary League, Milwaukee, WI
Tecomet, Inc., Kenosha, WI

2022-2023
eClusion, Milwaukee, WI
GE Healthcare, Waukesha, WI
Medtronic USA, Minneapolis, MN
Fresenius Kabi, Lake Zurich, IL

2021-2022
GE Healthcare, Waukesha, WI
eClusion, Milwaukee, WI
Spectroscopy and Data Consultants, Pty. Ltd., Brisbane, Australia

2020–2021
SeaSpine, Carlsbad, CA
Spectroscopy and Data Consultants, Pty. Ltd., Brisbane, Australia

2019–2020
SeaSpine, Carlsbad, CA
Medtronic USA Inc., Minneapolis, MN
GE Healthcare, Waukesha, WI
Spectroscopy and Data Consultants, Pty. Ltd., Brisbane, Australia
FreedomTrax, Waukegan, IL

2018–2019
GE Healthcare, Waukesha, WI
Spectroscopy and Data Consultants, Pty. Ltd., Brisbane, Australia
Resolution Medical, LLC, Minneapolis, Minnesota

2017–2018
Mortara Instruments, Milwaukee, WI
3M, Minneapolis, MN
GE Healthcare, Waukesha, WI

2016–2017
Siemens Medical Solutions USA Inc., Hoffman Estates, IL
Safe Place Bedding, LLC, Conesville, OH
9 Degrees of Human, Milwaukee, WI

2015–2016
Medtronic USA Inc., Minneapolis, MN
Trek Bicycle Corporation, Waterloo, WI
Cardiac Profiles Inc., Franklin, TN
Zimmer Biomet, Warsaw, IN

2014–2015
GE Healthcare, Waukesha, WI
Medtronic USA Inc., Minneapolis, MN
Rowheels, Fitchburg, WI

2013–2014
Cytophil, Inc., East Troy, WI
DesignWise Medical, Loretto, MN
GE Healthcare, Waukesha, WI
Siemens Healthcare, Hoffman Estates, IL
Medtronic USA Inc., Minneapolis, MN

2012–2103
NeoCoil, LLC, Pewaukee, WI
Gauthier Biomedical, Grafton, WI
3M, Minneapolis, MN

2011–2012
GE Healthcare, Waukesha, WI
Medtronic USA Inc., Minneapolis, MN
Innovator of Disability Equipment and Adaptations, LLC, Pewaukee, WI

2010–2011
Cardiac Science Corporation, Deerfield, WI
DePuy Orthopedics, Inc., Warsaw, IN
GE Healthcare, Waukesha, WI
Medtronic USA Inc., Minneapolis, MN

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Faculty Advisor and Sponsor
Dr. Guilherme Garcia

Research Device for Obstructive Sleep Apnea

Obstructive sleep apnea is a breathing disorder where relaxation of pharyngeal muscles during sleep leads to upper airway obstruction and airflow limitation. The recurrent episodes of airflow limitation are associated with snoring, poor sleep quality, daytime sleepiness, cardiovascular and neurocognitive complications, and a higher mortality. Research studies have shown that obstructive sleep apnea patients have higher upper airway collapsibility than healthy controls, thus the goal of treatment is to improve the mechanical stability of the upper airway. To measure upper airway collapsibility, researchers use commercial continuous positive airway pressure (CPAP) devices to modulate airway diameter. However, this method does not allow researchers to fully characterize pharyngeal collapsibility because commercial CPAP devices can only generate positive pressures and in some patients complete collapse is only observed at negative (subatmospheric) pressures.

The purpose of this project was to develop a modified CPAP device that can generate both positive and negative pressures. The target specifications included providing ±20 cmH2O pressure with high precision (< 0.2 cmH2O) through a face mask, maintaining patient safety, and allowing researchers to easily control and export device pressure data. The designed device utilizes 2 blower fans, one to generate positive pressures and another to generate negative pressures, with the pressure magnitude being controlled by the fan speed. The device displays the current pressure on a LCD screen and allows the user to control the pressure through push buttons on the case. The device is connected to a laptop computer via a USB serial connection. A MATLAB software application displays the current pressure, allows the user to control the pressure, and records the pressure data.

Testing to verify the design demonstrated that the device can successfully achieve the target pressure range of ±20 cmH2O and be controlled by the buttons on the case and the software. While the device met these specifications and safety standards, the device was loud when operating at high pressures (>10 cmH2O) and low pressures (< -10 cmH2O). Future versions could include sound insulation materials inside the case to reduce noise. The market size for CPAP devices that generate subatmospheric pressures is limited to a few research labs, but therapeutic CPAP devices have a large market size given that 2 to 7% of adults in the United States are affected by obstructive sleep apnea.

Projects

2023-2024

Project Team
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Sponsor
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iMRI Cranial Stabilization System

Intraoperative magnetic resonance imaging (iMRI) is a crucial procedure enabling real-time brain imaging during surgery. The methodology of iMRI is becoming increasingly more common in the operating room. However, the scarcity of effective MRI-compatible cranial stabilization systems impedes the efficiency of the procedure. Current MRI compatible stabilization systems are difficult to adjust and use during surgery, lacking essential range of motion. Difficulty in making small but critical adjustments to current systems often results in prolonged surgeries and increased fatigue for the operating room team.

To address these challenges, the team was tasked with creating an improved cranial stabilization system for future use in iMRI procedures. Priority was given to redesigning the device to have an increased range of motion and flexibility by adding pivot points and increasing the resolution relative to current designs. The designed adjustment points increased overall flexibility of the device and added translational motion that current models lack.

A key feature of our design includes push and twist locking hinges capable of withstanding considerable force, ensuring rigid head fixation during neurosurgery. Testing verified that the device could provide all necessary range of motion of the head for use during surgery. Furthermore, the main locking systems are easy to adjust and do not require additional tooling.

Further material analysis is required to ensure compatibility with MRI machines. Additionally, patient studies are necessary prior to commercialization to validate device safety and effectiveness. In summary, our design of a cranial stabilization system successfully improves the capabilities of patient positioning for iMRI procedures and demonstrates feasible methods to provide rigidity.

Device to Allow Use of Two Hands During Endoscopic Procedures

Project Team
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Sponsor
Dr. Michael Harris

Optical devices are critical in the surgical setting to allow surgeons to better see what they are doing during a procedure. The microscope is the most widely used optical device during surgery but can be limiting. Endoscopes, such as the Zeiss QEVO offer additional viewing capabilities that microscopes do not, including seeing around corners in the body and providing a wider field of vision, which is particularly useful in neurosurgery and otolaryngology procedures.

These capabilities are not being taken advantage of as often as they could be because the Zeiss QEVO endoscope is designed to be handheld, which, in effect, limits the surgeon to the use of one hand to operate on the patient. Not only does this make it more challenging and less likely for the surgeon to use this tool, but it also means the patient may not be receiving the optimum care during surgery.

This project involved design, construction, and testing of a device that will secure the endoscope so that it will not move during a surgical procedure. This will allow the surgeon to use two hands to operate other surgical tools during the procedure. This is achieved through a clamp-like device that secures the endoscope in place and can attach directly to the existing DORO LUNA Retractor System. Together, this system ensures that the endoscope can be adjusted to different positions depending on where it is needed during surgery but once in position, will remain locked in place and stabilized to ensure the safety of the patient and efficiency of the surgery. It is easy to adjust, learn how to use, and sterilize, which are critical requirements for integration into the surgical environment.

2023-2024

Projects

2023-2024

Project Team
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MIAD Partners
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Sponsor
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Ann & Robert H. Lurie Children's Hospital of Chicago

Heart Kart IV

The Heart Kart IV is a four-wheel push-bike designed to assist in mobility and rehabilitation of pediatric patients needing a new heart. While each patient has a different set of circumstances that require them to need a new heart, pediatric patients waiting for heart transplants often lose the opportunity for movement and exercise, which are important for improving surgical outcomes. In particular, pediatric patients on a heart transplant waiting list will sometimes have major surgery to install a ventricular assist device (VAD) or para-corporeal VAD (pVAD) and need to recover for their next major surgery when a donor heart becomes available. These devices are cumbersome and require assistance by clinical staff for the patient to leave the room, limiting the patient's opportunity to exercise. Moreover, delicate tubing and lines, small battery life of the VAD, anticoagulation medication, and infection risk can further prevent the patient from exercising.

For this project, we redesigned the Heart Kart IV to better suit the needs of our client, Dr. Casey Vogel, and the Lurie Children's Hospital Heart Center. This year's Heart Kart IV project was focused on increased adjustability and manufacturability to make the cart more accessible to more patients. The cart is composed of aluminum extrusion forming an I-shaped frame. A novel seat slide mechanism was developed to achieve a minimum seat height without sacrificing ground clearance. An adjustable footrest was included allowing clinical staff to safely transport their patient back to their room. The front handlebars were also streamlined with simple movement mechanisms, both for adjustment to the patient and for loading and unloading. This cart also includes a fun design geared towards children and low rolling resistance for ease of use. These designs are simple and easily reproducible, improving upon the Heart Kart IV's manufacturability compared to previous designs.

Project Team
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Clinical Advisor
Jared Koser

Device to Prevent Injury While Crawling

Paraplegia is an impairment of the lower extremities. This form of paralysis occurs from the waist down and is typically due to a spinal injury. For children, this condition can pose significant problems during the crawling stages. In the early childhood years, children tend to spend a lot of time on the floor. Children that are able bodied most efficiently move by crawling before they begin to walk. Children who are paraplegic don't crawl in the same way but can get their upper bodies to be mobile on the floor.

The goal of this project was to reduce the injuries a paraplegic toddler faces due to dragging her legs when she moves around on the floor or ground. Our primary customer, a 4-year-old girl, uses her arms to crawl around at home, playgrounds, and parks. However, since she has no use of her legs, she has to drag them behind her. When doing this for prolonged periods of time, bruises and rashes start to form, and her clothes tear from the friction between her clothes and the floor. The family reported that the girl would ruin one pair of leggings every single day. This not only causes more pain, but also incurs additional costs to the family. Commercially available solutions have been made to try and fix this problem, but none have worked due to the lack of muscle in her legs to properly support existing solutions such as knee pads. The goal of this project was to design a protective knee device that paraplegic children can wear while moving on the ground.

The protective knee device design included both padding and a low friction covering with groups of Velcro straps to hold it in place. The knee pads underwent several verification tests as well as functional tests on our client. The device functions as intended: it protects our client's knees, remains attached during movement, decreases the friction with the floor or ground, and can be worn inside or outside.

2023-2024

Projects

2023-2024

Project Team
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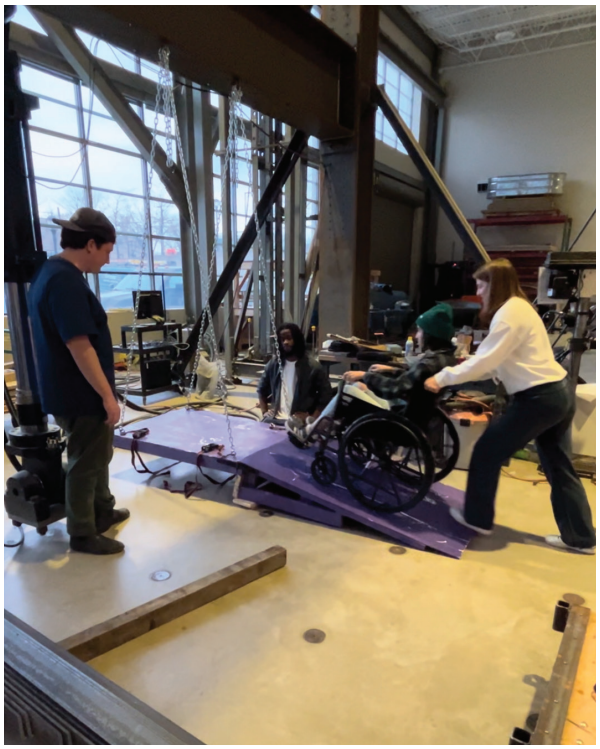
Improved Design of a Wheelchair Swing

Cerebral palsy is a condition that limits movement and posture, caused by abnormal development of the brain before birth. This movement limitation can affect the ability to perform daily tasks that require mobility and independence. It can also cause muscle stiffness which limits the range of motion in joints. Depending on the severity of cerebral palsy, getting outside and staying active can be very difficult, especially for those with limited mobility.

The purpose of this project was to allow our client to safely use an outdoor swing while remaining in her wheelchair. The current solution required the client's parents to transfer her to and from a seated swing. The new solution reduces physical strain on the parents by allowing one of them parents to load the client into the swing while remaining in her wheelchair.

This solution has two main components, a platform on which the client and her wheelchair sit while swinging, and a ramp that is used to transport her onto and off the platform. Testing was performed to ensure the components could support more than the desired weight limit. Testing was also conducted to validate the safety of the wheelchair during swinging. The device uses ratchet straps to stabilize the wheelchair onto the platform while also using an integrated wheel-locking mechanism within the wheelchair itself. This design offers a simple and safe solution for the client to remain comfortably in her wheelchair while enjoying her favorite activity, swinging.



Project Team
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Sam Andriacchi

MIAD Partners
Duncan Kenny
Jada Slagle

Faculty Advisor
Dr. Jay Goldberg

MKE CRIBS

This senior design project focused on addressing the specific needs of a three-year-old girl with neurological impairments including seizures and sleep apnea. Her condition presents challenges during sleep, as she struggles to breathe lying flat and is at risk of falling out of bed due to seizures or rolling movements. Currently, she sleeps with her mother, but this arrangement is not sustainable in the long term.

Current products on the market do not meet the child's needs, as standard beds and cribs lack adequate safety features and are difficult for the mother to manage due to the child's non-ambulatory status. Therefore, we aimed to design a solution that focused on the safety of the child, an easy way for the mother to use, and a cost-effective solution.

Our project involved constructing a twin-sized bed tailored to facilitate effortless lifting for the child's mother. As stated before, safety was a priority in the design, ensuring a secure sleep environment for the child. The mattress includes a built-in incline at the head side which will help address her sleep apnea. The bed frame is made from maple and pine wood assembled with nuts and bolts, which offers strength and practicality with easy disassembly and reassembly. Overall, our project delivers an inclusive bed design that meets the safety and accessibility needs of a child with disabilities and her caregiver, providing enhanced support and peace of mind.

2023-2024

Projects

2023-2024

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Children's Wisconsin

All-Terrain Walker

Joshua is a five-year-old boy with a partial sixth chromosome deletion. He uses both a walker and a wheelchair to assist him in movement. A sixth chromosome deletion can have many effects, including difficulty with stamina in balancing and walking. These issues are normally addressed by the use of a walker to provide support and balance to users as they walk. A common problem that Joshua and his family experience is the inability of his walker to maneuver through grass, woodchips, or other uneven terrains. This limits the use of his current walker to hardwood floors and flat cement surfaces.

The purpose of this project was to provide Joshua with an assistive walking device that enables him to maneuver grass, woodchips, and other currently challenging terrains. The device was required to help Joshua move through these terrains safely and autonomously while allowing him to continue developing his walking ability. The all-terrain walker is a three-wheel, motorized device that provides a structure for balance, a system that moves with the user to reduce his effort while walking, and a place for the user to sit. Distance sensors were implemented to detect user movement and engage the motor, which allows the user to walk without needing to pull the walker forward. Safety sensors built into the handlebars detect user hand placement and act as an emergency shutoff for the motor if the user were to fall. A handlebar with a throttle is also included to provide the ability for a secondary user to control the motor activity and push the walker when the user is seated. The walker acts as an assistive device for walking and includes a detachable seat to provide the function of a wheelchair, so that the family does not have to transport two separate devices.

Testing verified the ability of the walker to provide balanced support to the user and assistance in maneuvering multiple terrains, including grass and woodchips. The all-terrain walker was able to provide safe and functional autonomous walking while eliminating the need for multiple assistive devices for mobility.

Making Shopping with a Disabled Child Safer and Easier

Project Team
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Thomas Leonard
Gretchen Pfeiffer
Sophia Schinke

MIAD Partners
Sophia Mazzolari

Faculty Advisor
Dr. Frank Pintar

Clinical Advisors
Amy Morgan
Dr. Christine Schindler
Children's Wisconsin

For the everyday person, grocery shopping can be a dreaded Saturday afternoon task. For our client, though, the task is herculean. The client is the mother of five children, and her youngest daughter, a five-year-old, suffers from left-sided hemiplegia due to an underlying diagnosis of cerebral palsy. Left-sided hemiplegia leaves her unable to control the left side of her body due to damage to the right hemisphere of her brain. As a result, she must be carried by hand, or a wheelchair must be used.

Because the client cannot control a wheelchair and a grocery cart simultaneously, she currently shops for groceries by carrying her daughter on one arm and using a reusable shopping bag on the other for her purchases. She must support the weight of her daughter, who weighs 45 pounds, and the groceries, and is limited by the volume of a single bag to shop for her family of seven. This forces her to shop for groceries several times a week to obtain enough food for the household.

The project team developed a shopping solution for the client's family. The device consists of a collapsible wagon made from a metal frame with attached wheels and an interior compartment to hold at least four bags of groceries. The wagon attaches to the base of the wheelchair, the Ki Mobility Lil Wave, with ease and enables the client to shop more easily. The device increases the volume of groceries she can buy, eliminates the need to carry her growing daughter, and decreases stress while at the store.

Testing to verify the design proves the device increases grocery storage by at least four times. It folds compactly and fits within the trunk of the client's car, attaches to the wheelchair in less than 10 seconds, and can support more than 120 lbs of groceries. Currently the device has only been tested with the client's wheelchair, but the team anticipates that with only small changes in the attachment mechanism the device can be adapted to other wheelchairs.

2023-2024

Projects

Project Team
Alejandro Ortiz
Jospeh Nudelman
Zachary Cotter
Bianca Rodriguez

Faculty Advisor
Dr. Audi Said

Clinical Advisor
Dr. Rose Tilton

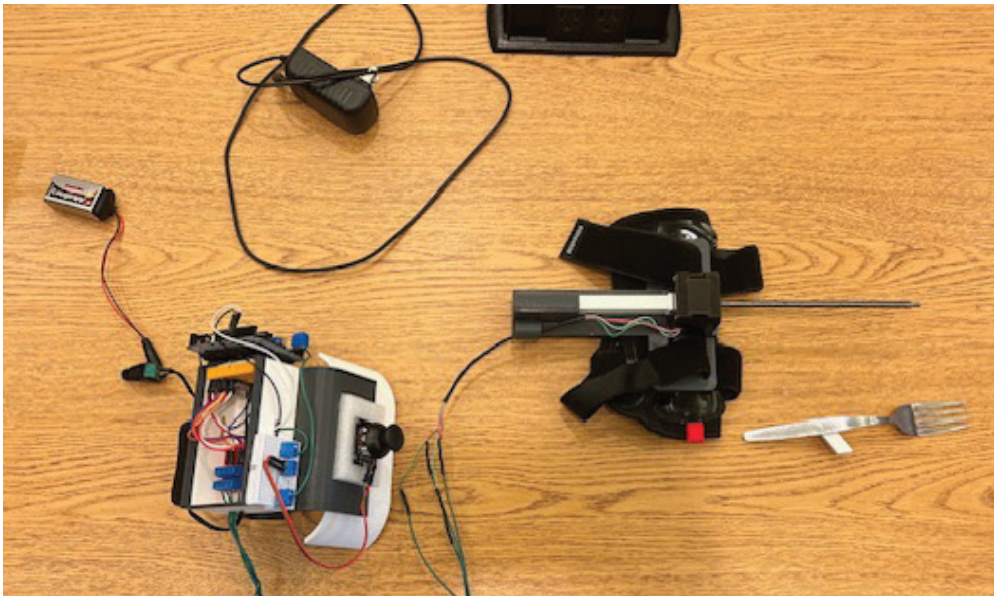
Adapted Utensil to Allow for Independent Feeding

2023-2024

The C5 nerve is the cervical nerve that is responsible for controlling all deltoid muscles of the biceps and shoulders, as well as providing sensation to the arm. An injury to the C5 can severely impact a person's life. Particularly, it can affect the upper and lower limbs, which limits the range of motion a person has, and can even result in the loss of independent mobility. This injury affects any movement from the elbow down in the arms, which leaves patients dependent on others for important daily life activities, such as eating and drinking.

Our client suffered a C5 injury two years ago and was left wheelchair bound and with only limited movement in his right hand from his biceps down. The objective of this project was to design and build a device that would allow him to eat independently, completing the action of taking food from a plate and getting it to his mouth. Our final solution utilized a wrist brace with an attached linear actuator that permits him to extend and retract an attached utensil by clicking a button.

The verification tests performed on our device showed that it currently meets all customer needs and functional requirements. The device is safe for our client but would require more testing before it could be produced commercially.



Project Team
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Elaina Kobal
Kamryn Brockman

Sponsor and Faculty Advisor
Dr. Lars Olson

Cost Effective Neonatal Respirator

There is a higher mortality rate in pediatric patients (0 – 5 years old) with lower respiratory infections (LRI) in developing countries compared to developed countries. Common LRIs in neonates (2 – 6 months) are viral pneumonia and respiratory syncytial virus (RSV). The treatment process involves mitigation of symptoms using a ventilator when the neonate experiences respiratory distress. Currently, the most common treatment device is an AMBU bag which requires a manual ventilation technique. This contributes to the high mortality rate because the ventilation technique lacks reliability, due to the requirement for human operation over multiple hours. It also increases the likelihood of ventilator induced lung injury (VILI), due to the lack of control over the output pressure and volume levels.

This project established an automatic method of delivering air at a regulated level of pressure and volume to a patient. A major goal of the project was to make a cost-effective final product that could be distributed to developing countries.

The prototype built achieves the goal of establishing a low-cost methodology to ventilate neonates. It incorporates the use of a Raspberry Pi microcontroller that controls a fan that supplies the system with airflow and pressure. Multiple sensors have been integrated into the system to allow for proper regulation of the fan's output. This is a preliminary design that with future iterations is hoped to impact lives across the globe.

2023-2024

Projects

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Faculty Advisor & Sponsor
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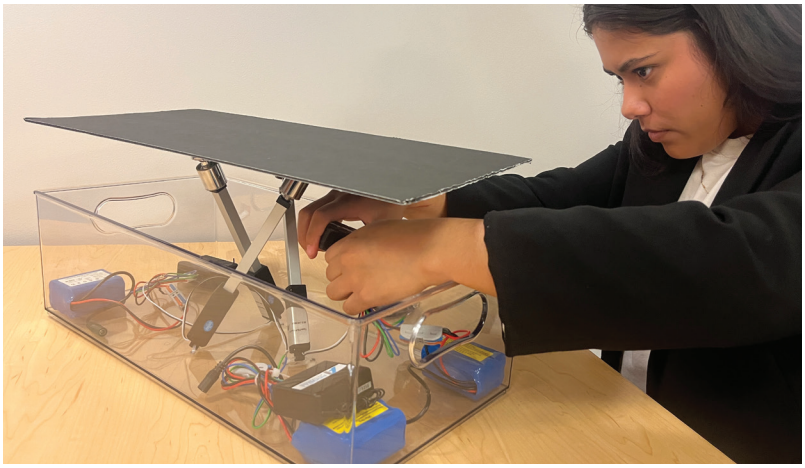
Terrain Simulating Treadmill Tray

2023-2024

Strokes, traumatic brain injury or conditions such as multiple sclerosis and Parkinson's disease have the potential to disrupt neurological function, negatively impacting the balance of individuals. Rehabilitation from physical therapy clinics is often needed, in which the subject works to improve their muscle conditioning and sense of balance over time. One utilized therapy involves walking on treadmills in controlled environments in which walking on floors and flat, ideal surfaces is simulated. However, when exposed to real world situations such as walking on grass, uneven sidewalks or angled surfaces, patients are unprepared and may lose their balance. These patients are limited to the surfaces on which they can walk and must often use assistive devices to aid their balance.

The purpose of this project was to create a tray to place a treadmill on top of that could accurately simulate walking on imperfect surfaces. The tray was required to simulate three degrees of freedom, be accessible to individuals of all capabilities, and be adaptable for physical therapy clinics. The tray can incline and decline (pitch), rotate to either side (roll), or move up and down (vertical displacement). By utilizing these different movements and rotations, the patient's lower extremities will become more familiar with various situations and surfaces encountered in daily life.

The components of the device include a base, three actuators in an equilateral triangle formation, and the tray. The actuators utilize a 3 RPS joint system, complete with a hinge, ball screw actuator, and ball and socket joint for each member. Using this system, the desired three degrees of freedom were achieved for dynamic motion while maintaining device stability. A life-size, fully functional prototype was unable to be built due to the large amount of research and validation required. As a substitute, a fully functional and accurate SolidWorks model, transformation matrix and statics code, miniature prototype, and required design specifications were provided.



Game Board to Evaluate Children's Motor Function

Project Team
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Eric Yang

MIAD Partners
Desharr Saddler
Alynn Schaus

Faculty Advisor
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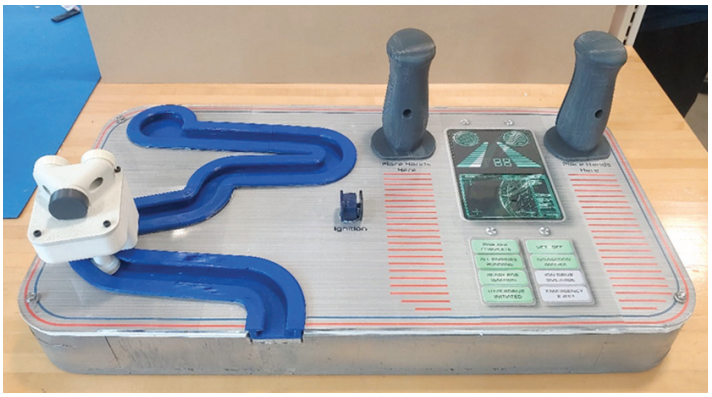
Sponsor
Dr. Sam Nemanich

Cerebral palsy significantly impacts muscular development in children, affecting their dexterity and ability to perform complex tasks. Current research into the upper extremity development of children with cerebral palsy is predominantly limited to two-dimensional data focusing on finger movements. The project sponsor sought to expand this research to include three-dimensional analyses of how affected children manipulate and grip physical objects over time.

The aim of this project was to develop a device that engages children aged 5-12 in various tasks that require distinct grip articulations, enabling the collection of movement and force data. Our solution involved creating an interactive game board featuring three specific tasks: navigating a path using a modified tripod grip, turning a key with a pinch grip, and using two hands to grip vertical stationary objects with a neutral grip. This device interfaces with an iPad app, being developed by the project sponsor, which records the data and issues prompts to research participants.

Extensive testing ensured the device's functionality as a research tool. Mechanical testing assessed device durability when subjected to child-generated forces. Sizing tests compared the device components to average children's hand sizes to ensure accessibility. Electrical tests verified the device's capability to accurately collect and transmit data via Bluetooth for research purposes.



A collaborative effort with students from the Milwaukee Institute of Art and Design enhanced the device's appeal and ergonomic design, making it suitable for children. This partnership not only improved usability but also integrated space-themed aesthetics, making the device more engaging for its young users.

This project represents a significant advancement in the study of muscular development in children with cerebral palsy, promising to enhance both the scope and depth of future research in this vital area.

Confidential Projects

Project 1

Sponsor
Arlando Monk
Visionary League, Milwaukee, WI

Faculty Advisor
Dr. Brandon Tefft

Project Team
Courtney Zanon
Natalie Zintchenko
Katie Knizner
Alexander Giblin
Melanie Long

Project 2

Sponsor
Christopher Melnick, Nayan Kondakalla
Tecomet Inc., Kenosha, WI

Faculty Advisor
Dr. Brian Stemper

Project Team
Michael Helm
James Greene
Matt McKenna
Luke Marciniak
Matt Cimaszewski

Faculty

Pintar, Frank, Ph.D., Professor and Chair
Biomechanics of brain and spinal cord injury, mechanics of spine surgical techniques, motor vehicle crash trauma

Audi, Said H., Ph.D.
Acute lung injury, acute respiratory distress syndrome (ARDS), lung transplantation, pulmonary hemodynamics

Beardsley, Scott, Ph.D.
Neural coding/decoding, neuroplasticity and learning, human visuo-motor processing, functional neuroimaging

Cooper, Robert F., Ph.D.
Photoreceptor mosaic structure and function, image processing, automated analysis tools, clinical imaging

Dash, Ranjan, Ph.D.
Computational systems biology & bioengineering, computational biology and bioinformatics

Fan, Lei, Ph.D.
Computational biomechanics: cardio-cerebrovascular mechanics, cardiac-electro mechanics

Garcia, Guilherme, Ph.D.
Respiratory physiology, fluid mechanics of respiratory airflow, virtual surgery planning

Goldberg, Jay R., Ph.D., P.E.
Medical device design and innovation, biomaterials

Greenberg, Adam S., Ph.D.
Cognitive neuroscience of attention, human psychophysics and computational modeling of perceptual phenomena

Guillory II, Roger, Ph.D.
Cellular and molecular interactions of bioactive materials, bioabsorbable metals, vascular medical devices

Hokanson, Jim A., Ph.D.
Urologic function/dysfunction, electrical stimulation/ neuromodulation therapies, neural engineering

Joshi, Amit, Ph.D.
Molecular image-guided and remote-triggered therapies, breast cancer imaging and therapy, optical imaging

Kruger, Karen, Ph.D.
Orthopedic biomechanics, pediatric gait kinetics and kinematics using motion analysis techniques

Olson, Lars E., Ph.D.
Mathematical modeling, biomedical instrumentation and optics, cell engineering/cardiopulmonary physiology

Pawela, Christopher P., Ph.D.
Brain connectivity, neural plasticity, cerebrovascular structure and function, neurovascular coupling

Ropella, Kristina M., Ph.D., Professor and OPUS Dean
Signal processing, cardiac and neuro-electrophysiology, functional magnetic resonance imaging

Scheidt, Robert A., Ph.D.
Human motor control, rehabilitation engineering, human psychophysics of sensorimotor adaptation and learning

Schmit, Brian D., Ph.D.
Spinal cord injury, neurorehabilitation, human neurophysiology, biomechanics

Somasundaram, Karthik, Ph.D.
Motor vehicle crash trauma, pedestrian safety, computational modeling of dynamic events.

Stemper, Brian, Ph.D.
Biomechanics of traumatic brain and spine injury, biomechanics of the cervical and lumbar spine, automotive safety

Tefft, Brandon J., Ph.D.
Cardiovascular regenerative engineering and device design, tissue engineered vascular grafts and heart valves

Wang, Bo, Ph.D.
Stem cell engineering, hard tissue engineering and 3D bioprinting, cardiovascular tissue engineering, imaging

Williams, Jordan J., M.D., Ph.D.
Peripheral optogenetics for motor stimulation, brain-machine interfaces and neural prosthetics, motor learning

Yu, Bing, Ph.D.
Optical imaging and spectroscopy, optical endoscopy, cancer detection and therapeutic monitoring, global health

Marquette University and Medical College of Wisconsin Joint Department of Biomedical Engineering

Undergraduate Program

The Marquette University and Medical College of Wisconsin Joint Biomedical Engineering program is founded on one of the longest accredited biomedical engineering programs in the nation and was developed in collaboration with active industry professionals. We offer three selective undergraduate majors to better prepare students for competitive, career-building roles within the biomedical engineering profession. These include biocomputing, bioelectronics, and biomechanics.

Our undergraduate program offers students all the educational opportunities and campus community experiences of Marquette University along with access to the libraries, laboratories, lectures, faculty and clinical settings of the Medical College of Wisconsin and its clinical partners.

Accelerated Degree Program (ADP)

Our Accelerated Degree Program allows qualified students to receive a bachelor's and a master's in biomedical engineering in five years. Students with qualifying grade point averages enroll in the program during their junior year and begin thesis research the summer between their junior and senior years. Research laboratory experiences will continue during the summer before their senior year through their fifth year, culminating in a written thesis and defense.

Graduate Programs

For those considering advancing their career in biomedical engineering by pursuing a master's or doctoral degree, our graduate programs provide engaging clinical and research experiences designed to shape students into leaders in their chosen field.

Graduate School Programs

- Doctoral Program
- Master of Science in Biomedical Engineering
- Master of Engineering in Biomedical Engineering
- Certificate in Clinical Immersion in Medical Device Design

Featuring more than 30 dedicated labs designed to facilitate the transfer of new knowledge into innovations directly impacting patient care, our joint program supports student education with a rigorous research practice that offers a dynamic range of novel opportunities for the world's next generation of biomedical engineers. With a focus on collaboration, our research brings together world-class engineers and faculty physicians within state-of-the-art facilities to create solutions for the greater good.

Research Themes

Research themes are provided to help students drive their academic experience, ensuring they are well prepared to pursue their interests upon graduation.

- Biomechanics and Rehabilitation Engineering
- Biomedical Imaging
- Computational Systems Biology and Medicine
- Medical Devices and Bioinstrumentation
- Molecular, Cellular and Tissue Engineering
- Neural Engineering and Neural Rehabilitation

Clinical Partners

The Marquette University and Medical College of Wisconsin Joint Biomedical Engineering programs deliver far more than the reputation of two world-renowned institutions. We also offer valuable opportunities for students, faculty, and staff to conduct research with four equally reputable clinical partners, all located within minutes of campus:

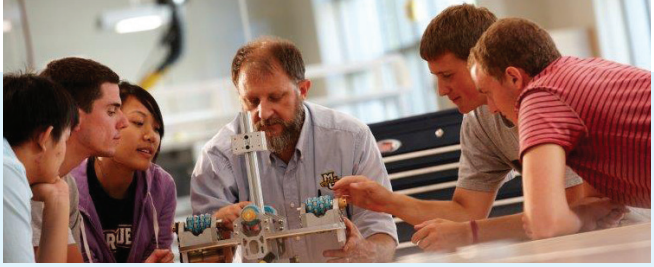
- Children's Wisconsin
- Clement Zablocki VA Medical Center
- Froedtert Hospital
- Versiti Blood Center of Wisconsin

Sponsored Research

Both Marquette and the Medical College of Wisconsin have longstanding histories of successfully partnering on sponsored research supported by federal agencies, for-profit and non-profit entities.

Industry Relations

As one of the first of its kind in the country, Marquette has sustained a proud tradition of connecting students with opportunities for transformative, real-world work experience since our co-op engineering program was founded in 1919. Today, Marquette works with more than 200 leading engineering and technology companies to help students build skills, gain invaluable professional experience, and make key connections that will help them thrive in their careers.



Partnering with Industry

To benefit patients and the future of health care, our joint department fosters collaboration with industry leaders, including such innovators as GE Healthcare, Medtronic, Baxter, and many others.

Collaborations include
- hiring undergraduate students for paid internships and co-op employment opportunities,
- working with senior design and freshman groups on innovative medical device projects,
- joining forces on translational research, and
- developing curricula that respond to industry needs.

Our industry partners value working with us to advance research for their health care products and services while seeking biomedical engineering students and graduates to join their workforces as valued members of their organizations. Our Industry Advisory Board is comprised of active and engaged alumni who are focused on helping to ensure our students are learning industry-leading skills to better prepare them for today's workforce.

The Marquette University and Medical College of Wisconsin Joint Department of Biomedical Engineering stands apart in that it is a true partnership between two institutions with a longstanding history of collaboration and innovation reaching back nearly a century. With unmatched cutting-edge clinical research and benefits and funding that allow students more opportunities for advancement, our joint department is dedicated to delivering an extraordinary educational experience designed to empower the next generation of biomedical engineers, scientists, and physicians.

Undergraduate Design Curriculum

Biomedical engineering students in the Joint Department of Biomedical Engineering learn about design throughout the four-year curriculum.

Freshman Year

Students first gain experience with the design process in the first year during BIEN 1100 and 1110 *(Introduction to Biomedical Engineering Methods I and II).* In these courses, they participate in several team design challenges. These experiences help develop teamwork skills, and teach students about the engineering design process, including technical, legal/ethical, regulatory, and economic design constraints. Students learn to identify customer needs, develop a list of performance requirements and specifications, convert requirements into design concepts, and build and test prototypes. They also learn about basic business concepts and entrepreneurship.

Sophmore and Junior Years

During the sophomore and junior years of the biomedical engineering curriculum, students take courses that include individual and team-based design projects which allow them to apply what they are learning in the course to the solution of a related problem. This helps them relate theory to practice.

In the junior year, students take BIEN 3400 *Clinical Issues in Biomedical Engineering Design*, in which they observe procedures in the clinical environment and learn to identify unmet clinical needs and opportunities for new product development. They hear various stakeholder perspectives on the design and use of medical devices and learn about the regulatory requirements of medical device design, including those of the FDA and ISO standards.

Senior Year

During the senior year, students are required to take BIEN 4920 *Principles of Design* and BIEN 4998 *Senior Design*. These courses require students to apply what they have learned during their previous years of the undergraduate curriculum in a multidisciplinary team-based project experience. They further develop their design, analytical, project management, communication, time management, and teamwork skills. They learn about the product development process, the medical device industry, testing for safety and efficacy, design validation, standards and regulations, risk management, project scheduling, patent issues, and a variety of design issues. Students complete a design project from problem definition to design verification (per ISO 9001 and 13485) and gain experience in generating the same project deliverables as required in industry.

Joint Department of Biomedical Engineering
Marquette University
1515 W. Wisconsin Ave.
Milwaukee, WI 53233

For more information about the Marquette University and Medical College of Wisconsin Joint Department of Biomedical Engineering, scan the QR code or visit **mcw.marquette.edu/biomedical-engineering**

Opus College of Engineering

JOINT DEPARTMENT OF BIOMEDICAL ENGINEERING
MARQUETTE UNIVERSITY
MEDICAL COLLEGE OF WISCONSIN

mcw.marquette.edu/biomedical-engineering

Since 1908, the Marquette University Opus College of Engineering has been uniquely blending professional engineering preparation with a liberal arts education to provide the world with well-balanced leaders in their profession.

Our mission
The mission of the College is to excel in four critical areas:

- To prepare all students for successful careers based on a strong moral and ethical foundation
- To advance the state-of-the-art in engineering
- To serve our professional and technical communities
- To contribute to our global society

The Opus College of Engineering offers six undergraduate degrees in eleven programs/majors through four departments: Biomedical Engineering; Civil & Environmental Engineering; Electrical and Computer Engineering; and Mechanical Engineering. Marquette also offers a wide range of graduate and doctoral programs.

Accreditation
All undergraduate programs offered by the Marquette University Opus College of Engineering are accredited by the Engineering Accreditation Commission of ABET, 111 Market Place, Suite 1050, Baltimore, MD 21202-4012, 410-347-7700.

The University
Founded in 1881 in Milwaukee, Wisconsin, Marquette University has been educating people of faith to be leaders in their professional lives, their communities and in society. Since the first graduating class of five men were awarded bachelor of arts degrees in the 1880s, Marquette has grown into a modern coed campus of more than 11,000 students who learn and grow through nationally admired undergraduate, graduate and professional programs.