



SENIOR DESIGN PROJECTS 2019

industry sponsors

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

2009-2010

DePuy Orthopedics, Inc. Warsaw, IN
GE Healthcare, Waukesha, WI
3M, St. Paul, MN

2008-2009

DePuy Orthopedics, Inc., Warsaw, IN
Siemens Medical Solutions, Hoffman Estates, IL
GE Healthcare, Waukesha, WI
ACTRA Rehabilitation Associates, Brookfield, WI
Gauthier Biomedical Inc., Grafton, WI
Stevenson Industries, Simi Valley, CA

2007-2008

3M, Saint Paul, MN
Siemens Medical Solutions, Hoffman Estates, IL
Baxter Healthcare, Deerfield, IL

ON THE COVER:

A team of students collaborate on the design and construction of a device to safely transfer a young boy with mobility challenges from his wheelchair to the family car, reducing the potential for injury to him and his caregivers. More information about this project can be found on page 18.

to our industry partners

We are pleased to present the Biomedical Engineering Senior Design Projects completed during the 2018-2019 academic year with the new joint department between Marquette University and the Medical College of Wisconsin.

The Department of Biomedical Engineering at Marquette University 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 third year of our new joint Department of Biomedical Engineering between Marquette University and the Medical College of Wisconsin. This year we continued our 14-year collaboration with the Milwaukee Institute of Art and Design (MIAD). Five of our project teams collaborated with industrial design students from MIAD during the spring semester. This was the eighth year of external funding for service learning, assistive technology, and other projects. We appreciate this support made possible by R25 EB013070 from the National Institute of Biomedical Imaging and Bioengineering and the Marquette University Strategic Innovation Fund.

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.
Clinical Professor of Biomedical Engineering
Senior Design Course Instructor

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

industry sponsorship

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
- 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:

Benefits to companies sponsoring design projects include:

- 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 of industry-sponsored projects:

- 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 issues involving customer needs, provide technical expertise and advice, and approve design concepts and prototypes. Faculty advisors will be responsible for administrative issues (grading, meeting deadlines, 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 in-person or by phone, e-mail or video conference. The advisor determines the frequency of communications.

Travel: The sponsoring company 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 trade secret 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 (414) 288-6059 or jay.goldberg@marquette.edu.

We look forward to working with you.

projects

CT GROUND-TRUTH PHANTOM

Project Team: Connor McColl
Dan Ostrander
Kristen Cardoza
Kiko Ramos
Dan Butler

Faculty Advisor: Dr. Taly Gilat-Schmidt

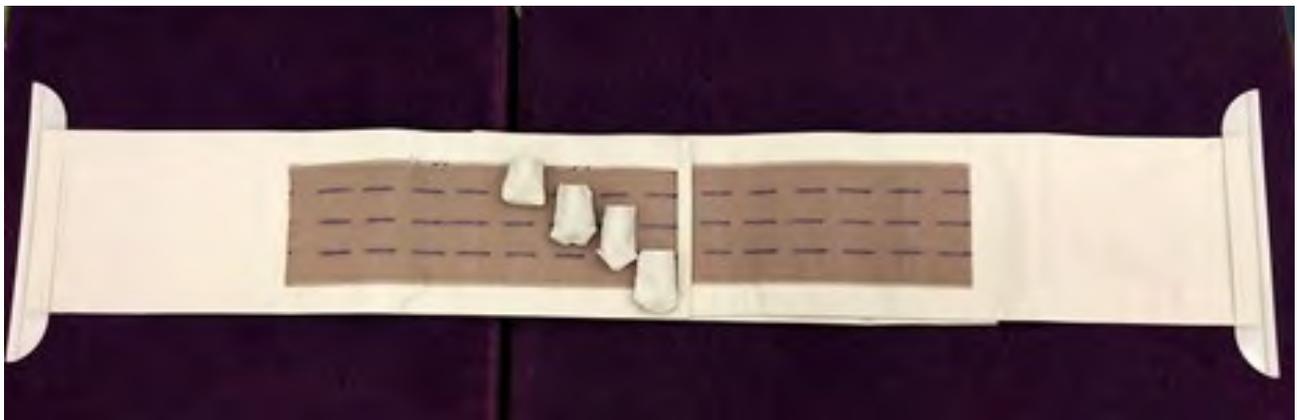
Sponsor: Scott Slavic
GE Healthcare

Traditional diagnostic applications for Computed Tomography (CT) scans revolve around a qualitative analysis of the tissue of interest and the surrounding areas. In many cases, the regions of interest— whether it be a tumor, a mineral deposit, or other abnormalities—are only differentiable by the apparent density of the tissue. The density differences between healthy and unhealthy tissue are represented as the difference in contrast present in the resulting DICOM image. This means that even with improvements in scanning technology, many

of the decisions made by radiologists are determined by simply comparing the contrast values present in an image without a baseline of how dense that tissue is.

The scope of this project was to develop ground-truth reference points within the field of view of a CT scan. These points provided the contrast values representing a range of concentrations of the material of interest. The ground-truth points themselves were created using Gammex Multi-energy solid core phantoms. The phantoms were required to maintain contrast accuracy compared to other phantoms of the same density, minimize the number of artifacts created, and be distinguishable from other tissue in a scout scan. In addition, the workflow of a standard CT scan needed to be minimally affected, the apparatus had to be comfortable to the patient, and the cost had to be kept below \$5,000.

Testing consisted of taking CT scans of a variety of shapes and sizes of phantoms across a range of different concentrations of iodine and calcium. The contrast numbers collected using the ImageJ open source DICOM image viewer had an error of less than 5%. User survey ratings determined a higher average aggregate score for patient comfort and workflow compatibility.



FERRUGAUGE: NON-INVASIVE TESTING FOR IRON DEFICIENCY

Team Members: Witor Eng
Rosemary Florido
Timothy Rittenhouse
Alyssa Sanchez
Joshuah Solito

Faculty Advisor: Dr. Bing Yu

Sponsor: Dr. Maggy Sikulu-Lord
Spectroscopy and Data
Consultants, Pty. Ltd.,
Brisbane, Australia



Iron deficiency affects approximately 1 out of 4 (~1.62 billion) people and is currently the number one global nutritional disorder. Of those affected, it is more common in pregnant women. It is approximated that 42% of women in non-industrialized countries are iron deficient. Coupling iron-deficiency anemia with the physically high demands of pregnancy introduces many risks to the mother and baby, such as perinatal, prenatal, and maternal mortality, and the increased likelihood of premature delivery. Approximately 70% of iron is located in the circulating erythrocytes (via hemoglobin (Hb)), 20% of iron is stored as ferritin (dominantly in the liver), and the remaining 10% of iron can be found coupled with other proteins.

This project aimed to create a solution for a noninvasive method to determine iron-deficiency through an indirect measurement of hemoglobin and the comparison of the standard range according to the user's age, sex, and pregnancy period. The device

was required to monitor the amount of hemoglobin present in the blood by using an 800-nm LED and photodiode to take the measurement of the finger spectra inside an enclosed probe. The device consists of three components: circuit, software, and CAD design. The circuit was designed to process and amplify the electrical signal from the sensor. An Arduino was used as the processor of the data acquired from the sensor and the interface between the user and the system functions, and the finger probe was designed with a cave concept through CAD to block all external light.

Verification tests showed that the accuracy of Ferrugauge was only 9% with the calibration accuracy of 82%, while the newest calibration showed an accuracy of 96%. The design and the results of the testing have demonstrated the feasibility of non-invasively detecting iron-deficiency. With more improvements and further development, Ferrugauge has the capacity to generate accurate, safe, and understandable results regarding iron levels.

ASSISTIVE WALKING TO CONTROL FOCAL SPASTICITY OF THE FOOT

Project Team:	Joseph Evanoff Elizabeth Bobeck Drew Neubauer John Baltz Russell Emmett
Faculty Advisor:	Dr. Jessica Fritz
Sponsor:	Shawn Paterson Resolution Medical, LLC

Over the years, researchers have conducted numerous studies of patients with normal gait, as well as a variety of pathologies that affect gait. Normal gait can be broken down into many components. A limb, muscle, or joint abnormality may affect one or multiple components depending on the specific condition. An individual's gait analysis may be compared to the average analysis of normal gait to determine sources of abnormalities and potential corrective treatments. Depending on a person's gait condition, one or more of the kinematic, kinetic or EMG outputs would be the primary focus in diagnosis and treatment with secondary effects elsewhere in the body.

While several lower extremity conditions exist that effect gait, the focus of this project included focal spasticity of the foot and drop foot. Focal spasticity of the foot is a condition in which a muscle controlling ankle motion is overactive. Drop foot is a condition in which the user has inadequate muscle activity for plantar flexion during gait, resulting in a toe drag and risk of tripping. The team's customer was a 56-year-old woman who began noticing the onset of her condition about six

years ago. She experiences excessive and forceful plantar flexion during the swing phase of gait and has full control over dorsi and plantar flexion when she is not walking. However, her



control of her plantar flexion muscles diminishes as soon as she begins to walk. She has been clinically diagnosed with focal spasticity in the plantar flexor muscles of her right foot and has been administered numerous ankle foot orthotics (AFOs) designed for treatment of drop foot and focal spasticity. These solutions have not worked for her as they are uncomfortable, and she pushes out of the AFOs while walking. Thus, the goal of the project was to design a device that was strong enough to resist the force generated by plantar flexion muscles to keep her foot in dorsiflexion during swing phase, and be comfortable and effective with repeated use.

The team developed customer needs and target specifications based on interviews with various stakeholders throughout the fall semester. Verification testing of the prototype indicated that all target specifications and customer needs had been met. The final design implemented a resistive band mechanism that holds the foot in dorsiflexion during swing phase. The mechanism attaches to the foot with s-biner clips and a shoe cover and attaches to the calf muscle with a cuff and D-rings. The team designed a tailored, external orthotic to resist excessive plantar flexion during the swing phase of gait, and allow her to walk with comfort and relative ease and carry out her daily activities.

TENSIOMYOGRAPHY DEVICE FOR ATHLETIC TRAINING AND REHABILITATION

Project Team:	Mohammad Assad Abbas Amer Margaret Bellinder DJ Seline
MIAD Partners:	Jade Akim Alexandra Upadhyaya
Faculty Advisor:	Dr. Brian Stemper
Sponsor:	Dan Kant-Hull Marquette Track and Field

Sports-conditioning coaches and rehabilitation facilitators are limited when it comes to routine, objective evaluation of muscle and tendon fitness. Currently, all muscle and tendon fitness evaluation routines are subjective physical tests which can result in varying diagnoses between different clinicians and physical therapists. Thus, there is glaring need for an objective test which is able to accurately and reliably quantify the fitness of muscles and tendons. At the moment there is no wide-spread solution to this need. Tensiomyography devices do exist but are currently expensive enough to be outside the budget for a majority of amateur sports teams.



The objective of this project was to design and build a diagnostic tensiomyography device for use in the Marquette Athletic Department. The hand-held device uses an indenter to compress the muscle or tendon and a load cell to quantify a variety of passive mechanical outputs related to muscle and tendon fitness. The device was designed for a minimum accuracy of 95%, to yield reproducible data, and to be affordable for amateur sports teams. When completed, this device will provide a single-step solution to the diagnosis of muscle and tendon fitness.

Preliminary testing incorporating test phantoms indicated that the prototype tensiomyography device failed to produce accurate or reproducible data. The final design was affordable as its cost fell within the project budget which was less than half of the typical market price for a tensiomyography device. The device operated using a single-step process.

RESCUE MANNEQUIN NECK TO SIMULATE SPINAL CORD INJURIES FOR FIRST RESPONDER TRAINING

Team Members: Alisa Beduhn
Kevin Dolick
Claire Gunderman
Madeline Rose
Zach Wilcox

Faculty Advisor: Dr. Frank Pintar

Each year, an average of six million car crashes occur in the U.S. resulting in injuries to three million people. Two million of these people experience permanent injuries each year. About 17,500 new spinal cord injuries occur each year in the U.S. as a result of vehicle crashes, falls, violence and sports-related incidents. Vehicle crashes account for 38.4% of spinal cord injuries. Currently, there is no cure for spinal cord injuries and therefore it is imperative to prevent further spinal injury from occurring. According to the EMT community it is well known that movement of the neck after a potential spinal cord injury could cause more harm, and therefore a patient's neck should be stabilized by using C-spine immobilization techniques or a cervical collar.

The purpose of this project was to create a manikin neck and head that provide immediate feedback on neck positioning during a training exercise. The manikin neck and head were designed to retrofit the current Rescue Randy extrication manikin currently on the market. The silicone neck creates a more biomechanically similar neck to that of a human. The immediate electronic feedback system allows for



position changes in four directions to be detected. If the neck sensors exceed thresholds in bending in the lateral and/or anterior/posterior directions the LED array is engaged. The LED system is a red, yellow, and green light feedback system which is used commonly in triage situations. For the purpose of this design green indicates good positioning and red indicates poor positioning. The immediate feedback system is also able to record data with a time stamp so that positioning data can be referenced after training.

The design required the mechanical neck to be able to bend to 45 degrees, which was confirmed through verification testing. The electrical feedback system needed to have an adequate battery life to last the length of an entire extrication training session which is at least two hours. The average battery life was determined to be 4 hours and 16 minutes which was twice the desired value. The device can also be used with a cervical collar as desired by EMTs. All requirements were met; thus the Rescue Manikin Neck is ready for use.

LARYNGEAL NERVE MONITORING IN INFANTS TO PREVENT VOCAL CORD PARALYSIS DURING SURGERY

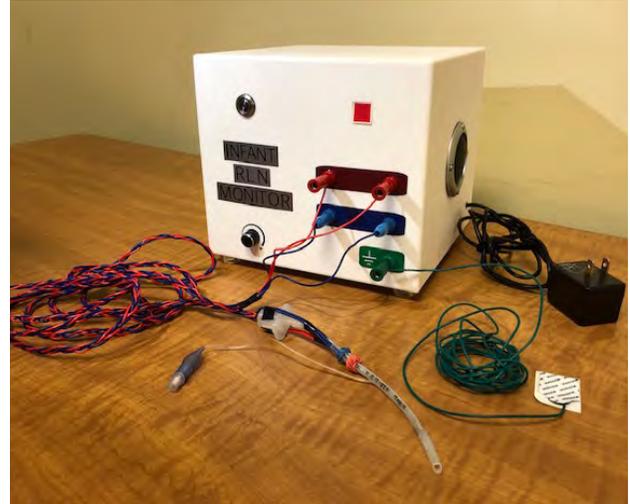
Team Members: Lesley Arant
Leah Chambers
Nicole Lundeen
Lauren Miller
Kaitlyn Nordmeyer

Faculty Advisor: Dr. Guilherme Garcia

Sponsor: Dr. Thomas Robey
Medical College of Wisconsin

Infants undergoing congenital heart surgeries are vulnerable to vocal cord paralysis, an iatrogenic injury that results from the surgeon damaging or severing the recurrent laryngeal nerve (RLN). The RLN loops under the arch of the aorta and provides motor innervation to the intrinsic muscles of the larynx, including the vocal cords. In infants who suffer from RLN injury, only 25% of these patients recovery fully while half of the remaining 75% are symptomatic for years. These symptoms can include breathing complications, difficulties swallowing, problems with aspiration, and a hoarse voice. While a RLN monitoring device exists for older children and adults, there is no such solution available for infants due to size constraints.

The purpose of this project was to design a method to monitor the RLN in infants to prevent vocal cord paralysis and its associated symptoms. The device was required to monitor the nerve reliably during surgery using easy to operate equipment, while also avoiding interference with other surgical protocols. The Infant RLN Monitor contains two major components: the endotracheal tubes instrumented with electromyography



electrodes, and the monitor to alert the surgeon via an auditory and visual stimulus. The use of this integrated system allows the surgeon to monitor the nerve at critical times throughout the surgery without a significant adjustment to the surgical procedure. This will benefit not only patients and their families by preventing vocal cord paralysis, but it will also benefit surgeons by avoiding surgical malpractice and damage to their professional reputation.

Using replicated in vivo conditions for testing, the device was found to have a 98.33% sensitivity and 100% specificity for detecting and alerting for simulated vocal cord muscle activity. The device was also created with an accessible, straightforward user interface for ease of use. The next steps in the development process include using biocompatible electromyography electrodes and in-vivo testing in animal models. Overall, the Infant RLN Monitor is the first step toward preventing the negative medical, financial, social, and emotional impacts of RLN injury in infants, which will improve the quality of life for patients and their families.

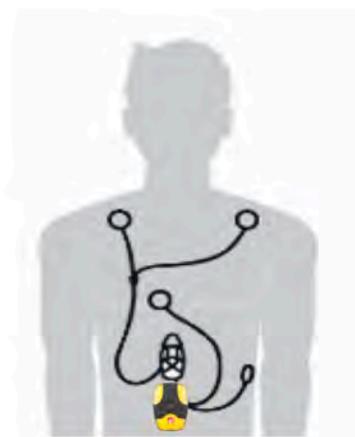
REAL-TIME HEART RATE VARIABILITY FEEDBACK DEVICE

- Project Team:** Luis Jimenez Gonzalez
 Alex Heigl
 David Newman
 Jason Hubler
- Faculty Advisor:** Dr. Said Audi
- Sponsor:** Dr. Thomas Chelimsky
 Medical College of Wisconsin

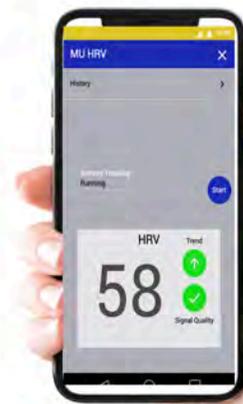
Chronic and severe pain affect more than 50 million American adults. Current approaches for managing chronic pain are “one size fits all” solutions. The most common approach for treating chronic pain is through prescription drugs, and most

of them are opioid prescriptions. This has contributed to the increasing dependency on opioids in the United States. Over the past few years, significant research has been devoted to developing more personalized approaches to chronic pain management. One such approach takes advantage of the correlation between heart rate variability (HRV) and the state of the nervous system.

The project sponsor has been exploring how HRV can be used to better manage chronic pain. He currently sends his patients home with a heart rate monitor, and data is collected over a 24-48-hour period. Data is then brought back to him and analyzed so that feedback can be provided. We have addressed this long feedback loop by creating a mobile application that analyzes the data in real-time. The data is sent from the portable heart rate monitor to the mobile device through Bluetooth. The mobile application is then able to provide HRV feedback within 30 seconds. This shorter feedback loop allows individuals to adjust daily activities to manage their HRV and in turn their chronic pain.



Bittium Pharos Monitor



HRV Monitor Android Application

HUMAN MOTION ANALYSIS MODEL VALIDATION TOOL

Project Team:	Rayann Jaber Arlaeth De Jesus Ferrusquia Lopez Jeffrey Weaver Kelly Wachholz Josey Benandi
Faculty Advisor:	Dr. Jessica Fritz
Sponsor:	Adam Graf Shriners' Hospital for Children, Chicago, IL

Children afflicted with neuromuscular disorders or orthopaedic deformities may experience gait deficiencies. Medical professionals can treat such pathologies through targeted rehabilitation and surgical or conservative interventions. However, determining the most appropriate treatment may be difficult without a clear understanding of what is occurring during gait at the biomechanical level. Quantitative gait analysis can provide an in-depth look into joint movements. Three-dimensional motion capture technology is used to describe the motion of joints in all three planes and can help clinicians determine the most effective treatment plan to improve functional mobility and efficiency. Infrared cameras are used to track the motion of reflective markers placed over bony landmarks on the skin of the subject. The musculoskeletal model's output from gait analysis is dependent upon placement of the markers and the mathematics used to calculate the joint kinematics (motion) and kinetics (forces, moments, and powers). Despite the utility of gait analysis in clinical decision making, there is no commercially available tool to validate these dependencies. Inaccuracies in measurements or

calculations can lead to inappropriate treatment recommendations. The device developed as part of this project will help in verifying the reliability of motion capture models used in clinical gait analysis.

The unit validates sagittal plane movement as most of the motion during gait occurs in this plane. It uses servo-motors to model and actuate joint movement at the hips, knees, and ankles. The servo-motor movement is controlled using six potentiometers. An Arduino Mega reads the positions from the potentiometers and translates the positions into joint angles. These joint angles are printed to an LCD. The angles are verified using goniometers centered at each joint's axis of rotation. The servo-motors joints are connected using a combination of acrylic, 3D- printed materials, and PVC tubing. The system is enclosed with moldable plastic.



Verification testing showed that the validation unit meets the four key customer needs. First, the device has repositionable joints which are actuated through servo-motor joint interfaces. Second, the device displays metrics to verify the angular positions of the joints. This is done using goniometers to provide visual verification and potentiometer readings which are fed to an LCD providing automatic readings. Third, the device is easy to use. This was implemented using potentiometers to allow joint repositioning and the LCD to make readings of angles easy. Fourth, the device is portable. Portability was achieved using lightweight materials and designing it short enough for easy storage.

This project was supported by R25 EB013070 from the National Institute of Biomedical Imaging and Bioengineering.

PORTABLE POSITIONING DEVICE FOR STANDARD CHAIRS

Project Team:	Sucharita Doddi Tiffany Echols Liya Moolayil Walter Wilson
MIAD Partners:	Ignacio Garcia-Casas Tron Alyssa Felix
Faculty Advisor:	Dr. Scott Beardsley
Clinical Advisor:	Dr. Anne Pleva



The purpose of this project was to design and develop an assistive seating device for a ten-year-old boy with Spinal Muscular Atrophy (SMA) and scoliosis. Spinal muscular atrophy is a disease that affects the motor nerve cells in the spinal cord, resulting in muscle weakness throughout the body. For an individual living with SMA, daily life is a challenge. As the client has grown it has become increasingly difficult to find a non-restrictive solution to assist seating outside of a wheelchair. The increasing restriction to a wheelchair has impacted his confidence and sense of independence. To address these issues the team was tasked with developing a portable, non-restrictive, and adaptable positioning device that increases the client's sense of independence, improves balance and encourages strengthening of his postural muscles.

The final design consists of a foldable aluminum framed positioning device that can be placed on chairs and has side panels to provide positioning

support for the client's scoliosis. The side panels include hinged attachment points that allow the device to be quickly folded for transport. The positioning device is height adjustable to accommodate growth, has a foam core to provide stability and durability, and is upholstered with cushion overlays to provide comfort to the back, buttocks, and thighs while the client is seated. Adjustable straps are attached at the bottom of the device that allow it to be securely fastened to a chair and which also serve to lock the folded device during transport. The positioning device can be easily transported by caregivers and can be attached to any chair to enable him to sit safely and comfortably for prolonged periods of time. The low-profile form and use of racing colors make the device aesthetically pleasing, and provide him with the unobtrusive functional support needed to interact independently outside of his wheelchair.

MODIFIED PEDIATRIC WALKING DEVICE

Project Team: Jordan Amedio
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Amanda Ezzell
Evelyn Granados Centeno
Louie Hawkins

MIAD Partners: Sheila Hernandez
Gabrielle Dyke
Autumn Lundberg

Faculty Advisor: Dr. Jay Goldberg



There are many pediatric medical conditions that require equipment to help carry life sustaining devices. However, many current pediatric walkers on the market are not intended to cater to specific cases. Many devices do not have the proper storage for devices or are not designed for children. Pediatric walkers that may be useful to children are extremely expensive and therefore are not always accessible. A walking device that provides storage and meets the needs of a specific client with a specific need is desired.

The project team was tasked to create a modified pediatric walking device for a four-year-old boy with several medical conditions. The specific goal of this device was to hold his total parenteral nutrition bag (TPN) to eliminate the need for a caretaker to hold it as he walks. Through research and interviews with our advisors and our client's medical team, we were able to address specific customer needs as well

as target specifications to use in our design process. Through several iterations and trials, we created a final device that focused on our customer needs and target specifications. This device involves a front pushing cart with a low carbon steel frame and polycarbonate box. The frame is corrosion resistant, lightweight and sturdy to accommodate the load of the medical equipment. It encompasses an adjustable handle so the device can be used for years to come. The second part of the design is a removable storage bin that holds his TPN bag. The storage bin is covered with black fabric; however, it can be customized with Velcro pieces to add images of our client's favorite characters (such as Peppa the Pig and Ninja Turtles). We offered this option to make the device discrete when desired but also fun and youthful. Verification testing of our device indicated that our final design meets the needs of our client and is safe and user friendly.

This project was supported by R25 EB013070 from the National Institute of Biomedical Imaging and Bioengineering.

BINARY CHOICE DEVICE

Project Team: Hasan Barakat
Olivia Bellatin
Olivia Dau
Allison Kehn
Jamie Wiszniewski

MIAD Partners: Van Heyer
Eve Berndt

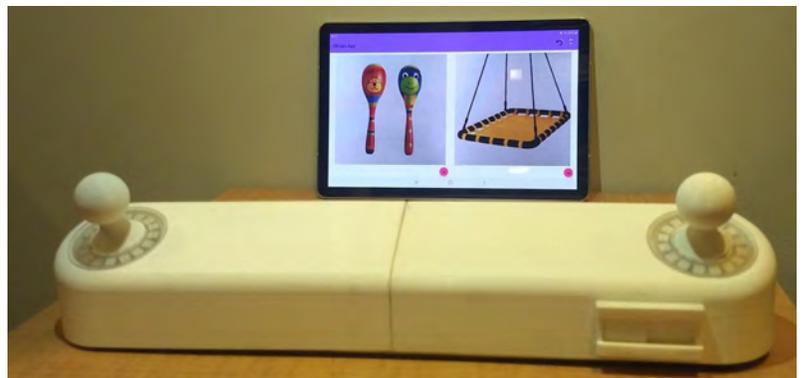
Project Advisor: Dr. Scott Beardsley

Our client is a seven-year-old girl with Emanuel Syndrome, a chromosomal disorder that interrupts motor skill and verbal development. Due to her condition and extensive medical history, the development of her communication skills was placed at a low priority up until this point in her life. Her support team, including her mother, teachers, and therapists feel that she does not realize that she can make decisions for herself because of this. While she is unable to verbally communicate a choice, or select a choice on a touch screen using fine motor skills, she does show interest through body language and sounds. It is believed that she often desires one option over another, but it is not clear if her choices are deliberate. Her team faces uncertainty every day when they attempt to decipher her sounds and movements into decisions or actions.

Current technology for patients with impaired communication skills include eye-gaze systems, which follow the user's eyes to make selections and type letters. She is visually impaired and often has uncontrolled head movements, so it is difficult to determine how effective eye-gaze systems could be for her at this time. Direct select devices and

applications also exist, where she selects the option that she would like on a touch screen. While she may be able to use these types of technologies in the future, she does not yet have the fine motor skills to use a touch screen. Our goal was to create a device that bridges the gap between her current capabilities and the communication devices on the market. Additionally, the product was to be motivating for her to use, through colorful lights and specific textures, and easy for her team to set up and use.

Our product consists of a knob-and-base system and a tablet with a personalized application. The system has a slanted base that can be used on the floor, at a table, or on her wheelchair. Two knobs, with interchangeable covers made of textured materials, are located on either side of the base and correspond to two picture options presented by the application. Her team can choose which two pictures are presented by selecting them from existing categories or by taking new pictures with the camera. With the press of a button in the application, the tablet connects to the knob-and-base system using Bluetooth. Hall effect sensors under the knobs, which contain a magnet, are used to detect the absence of the knob, light up an LED, and signal the chosen option to the tablet app. When she lifts one knob, an LED ring light surrounding that knob lights up bright pink, and the unchosen option disappears, leaving the chosen option present on the tablet screen. She then receives the option, such as a book, toy, or snack, that she chose.



GO BABY GO!

Project Team:	Ben Wrucke Pedro Lopez Mohammad Saleh Syed Hussain Kyle Perez
Faculty Advisor:	Dr. Jacob Rammer
Sponsor:	Dr. Benjamin McHenry

GoBabyGo! is an international, multi-team, research, design, and outreach initiative that modifies ride-on cars for children with mobility restricting disabilities. Disabilities that affect a child's mobility can prevent them from exploring the world in the same way that other children do, and this can ultimately lead to issues in development and forming mental associations.

The problem associated with this project was twofold. First, children that typically use GoBabyGo! cars can have a wide range of needs that require specific modifications to provide a suitable riding experience. Second, many children who use GoBabyGo! cars may be candidates for electric wheelchairs, and the process for receiving one is long and expensive.

This project aimed to develop a trial vehicle that would act as a template to help the builders of GoBabyGo! cars better identify the needs of each child so that the car gifted to them would be more accurately fitted to the individual. Additionally, this project aimed to produce a vehicle that both mimics the controls of an electric wheelchair and accommodates the needs of many different children to shorten the time associated with being without a car while waiting to receive an electric wheelchair.



The resulting GoBabyGo! car design includes multiple improved features including 1) a manual kill switch, 2) caster wheels, an Arduino, and a joystick for power wheelchair mimicry, 3) adjustable joystick arm, 4) electronic speed controllers (ESCs) for variable speed control, 5) tire traction, 6) 5-point seat harness, 7) lateral trunk supports, and 8) head support. The use of this GoBabyGo! car offers a safe alternative for mobility impaired children to explore the world around them while also allowing a GoBabyGo! team to perfectly fit them for an appropriate car for their specific needs. Additionally, physical therapists can train these children in the driving mechanics of an electric wheelchair in a fun and familiar environment.

Testing to verify this design indicated a successful transition in driving mechanisms with the implementation of the adjustable joystick. Additionally, with multiple tests completed in the Curative Pediatric Physical Therapy Clinic, the reduced speed as well as multiple supports have proven to ensure a safe and fun device that can be adjusted to address a multitude of children and their various needs.

This project was supported by a Marquette University Strategic Innovation Fund grant.

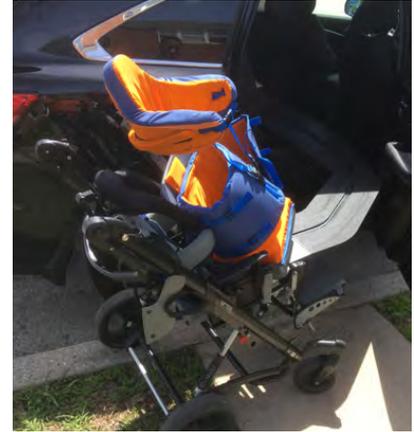
WHEELCHAIR-TO-CAR ASSISTIVE TRANSFER DEVICE

Project Team:	Austin Mangelsdorf Benjamin Sylvester Karlie Hornberger Katelyn Dausman Ryan Serfas
MIAD Partners:	Brendan Sanna David Gabriel
Faculty Advisor:	Dr. Jay Goldberg
Clinical Advisor:	Dr. Christine Schindler Children’s Hospital of Wisconsin

The client for this project is a nine-year-old boy with advanced cerebral palsy, which is a motor disability that provides him with severe mobility challenges that affect his muscle coordination. He cannot move independently or support his head, neck, and limbs, which requires his mother to carry him. Because she is a very petite woman, this puts a great deal of strain on her back and places her son in an uncomfortable position. The goal of this project was to create a device to transfer the client from his wheelchair to their car to reduce the amount of effort required by his caregiver. The current solution of a mobility conversion to a car is costly, and other options of a simple transfer board or gait belt require the user to move independently.

The wheelchair-to-car assistive transfer device is a two-part system that consists of a transfer seat and a transfer board and is designed for use specifically with the client’s wheelchair and vehicle. The seat is equipped with ball bearings that allow for bidirectional transfer and slide along a groove machined within a high-density

polyethylene board. Cutouts on the underside of the board make it lightweight and an adjustable leg folds out from underneath the board to provide stability. A harness that includes an adjustable neck



support and buckles around his torso is securely strapped into the transfer seat. At one end, the transfer board is connected to the car’s seatbelt receiver. The other tapered end of the board is secured around the wheelchair seat cushion.

To operate the device, the subject is placed in the transfer seat that is already within his wheelchair and strapped into the harness. With the wheelchair oriented parallel to the car, the board is connected to the seatbelt receiver and the leg is unfolded and locked in place. The other end of the transfer board is slid underneath the client’s legs. The caregiver grasps the transfer seat by the side handles that allow for positive control, rotates him to the proper orientation, and slides him into the middle seat of the car. The client remains in the transfer seat while in the car, and the transfer board is easily stored in the car trunk.

Verification testing showed that the board met all functional and technical requirements, which ensures that it will safely support the subject’s anticipated weight and resist environmental deterioration. The time to complete the transfer was less than 90 seconds, which satisfies the target specification requirement and is anticipated to decrease as familiarity with the system is established. This device allows the client to be moved between his wheelchair and car with minimal caretaker effort and provides safety and support.

This project was supported by a Marquette University Strategic Innovation Fund grant.

MOBILITY ASSIST DEVICE

Project Team: Tara McNutt
Kyle Beyers
Joshua Schneider
Connor Fitzgerald

Faculty Advisor: Dr. Jay Goldberg

Tetra-amelia is an extremely rare congenital disorder that is characterized by the absence of all four limbs at birth. There are only five recorded cases worldwide. Children that are fortunate enough to survive with the condition are physically dependent on their caretakers. Whenever the child desires to get to a different height (for various activities of daily living), the caretaker has to physically lift him or her up. The force that the caretaker must lift can be quite heavy depending on the child, and even worse, the child is then robbed of independence to get to varying surface levels on their own.

The purpose of this project was to design a device to help a four-year-old boy with Tetra-Amelia move from one height to another by himself, providing him with an increased level of independence during his day-to-day routine. The device needed to raise a load of 60-lb to a height of 36" in a timely and safe manner. To accomplish this, the device included a linear actuator, powered by a control box and rocker switch, that raises and lowers an aluminum seat covered with padding. Use of an actuator that can provide a force of 400-lb allowed the client to be easily moved safely and quickly. Testing of the prototype verified that it is capable of moving a 60-lb load to a height of 36" at a speed of roughly 0.65 in/s.



PROJECTS • 2018-2019

DYNAMIC HAND STRETCHING DEVICE

Project Team:	Imani Burns Andrew Cedillo Ryan Henry Annie Williams
Faculty Advisor:	Dr. Brian Schmidt
Sponsor:	Dr. Brian Robertson-Dick Medical College of Wisconsin

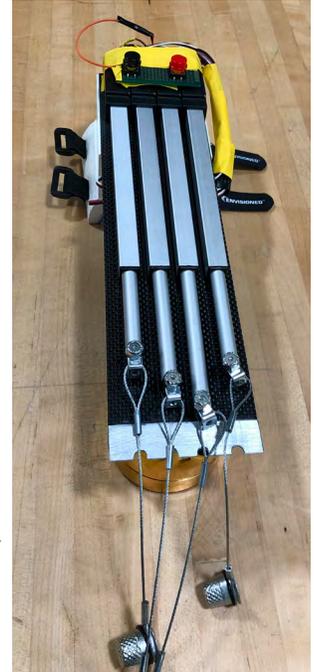
Spasticity is a condition which occurs due to an imbalance of signals from the nervous system to the muscles, resulting in an unregulated increase in muscle activity. It is a common lasting effect of many neurological disorders and ailments, including traumatic brain injury, spinal cord injury, brain damage, stroke, meningitis, cerebral palsy and many more. Post-stroke patients frequently suffer from muscle stiffness and uncontrollable muscle contractions to varying degrees of severity. Hand spasticity is a common manifestation of this, in which the forearm flexors are constantly contracted, causing stiffness and tightness in the finger flexors. A common way to treat this condition is to attend physical therapy in an attempt to regain the normal range of motion.

Post-stroke patients will go to a physical therapist and spend many hours stretching their muscles and performing exercises designed to help offset the effects of spasticity. This process is completed alongside botulinum toxin injections, which help relax the muscles. This can become inconvenient for the patient and caregiver having to constantly travel to the therapist and various physicians. However, in most cases, if patients do not go to the

therapist every day, they are unlikely to stretch on their own at home.

The goal of this project was to create a device to dynamically stretch the finger flexors to aid in the physical rehabilitation of patients with spasticity. This device allows patients to stretch at home with minimal effort to guarantee that they stretch properly and frequently, and is intended to be used in conjunction with the Botox injections and physical therapy. It is convenient and easy to use for both the patient and the physical therapist, and can be used at home or anywhere patients see fit, increasing the likelihood and ease of stretching outside of physical therapy. The device stretches the desired muscles using four linear servos powered by a battery and secured to a beam running parallel to the forearm. The desired range of motion is set through calibration of the device. By simple programming of an Arduino, the device begins by slowly pulling an individual finger back and when the patient feels that he/she has reached the maximum stretch, the black button is pressed. Once calibration is completed, the full 10-15 minute stretching program is implemented. Not only is this device dynamic, but it can also be programmed to hold a static position. The hand-stretching device is different than what is currently available.

Various verification tests indicated that the device met all target specifications. The manufacturing cost of the Dynamic Hand Stretching Device is \$562.61. It is cost effective, user-friendly, and will aid patients during their rehabilitation process.



ANKLE FOOT ORTHOSIS WITH IMPROVED INVERSION CONTROL

Project Team:	Molly Lindway Michael O'Connell Brian Pacilio Daniel Rivera
MIAD Partners:	Martin Solis Eddie Grinwald
Faculty Advisor:	Dr. Tanya Onushko
Sponsor:	Dr. Brian Robertson-Dick Medical College of Wisconsin

Individuals who have experienced strokes or other episodes involving significant nerve damage (e.g. traumatic brain/spinal injury, cerebral palsy, multiple sclerosis) will often experience muscle spasticity (i.e. uncontrolled muscle contraction). Muscle spasticity is categorized by the tendency of a muscle to contract involuntarily, caused by miscommunication between the brain and the muscle being told to relax. Muscle spasticity in a patient's lower extremities during normal activities such as walking or climbing stairs can pose a serious problem due to the risk for a trip and fall. A spastic muscle tone in the leg can cause the foot to uncontrollably plantarflex ("drop foot") with additional ankle inversion, making it difficult to walk and can lead to falls. The current duration treatment for lower extremity spasticity is an Ankle Foot Orthosis (AFO) that serves to support the foot and keep it at a neutral angle during gait, reducing the risk of falling. Typical orthoses are successful in preventing the foot from involuntarily plantarflexing but lack the support necessary for other spastic muscle tones such as foot inversion. Foot inversion causes the foot to turn up and in towards the body and is often unrecognized or explicitly

treated using current orthoses. Untreated foot inversion causes improper biomechanics in lower extremities, heightening the risk for joint damage and deterioration. Patients are frequently unable to obtain a specialized orthosis that treats for both spastic drop foot and foot inversion, indicating an unmet customer need that can be addressed with a novel, biomechanically engineered orthoses treatment.



The purpose of this project was to develop a novel Ankle Foot Orthosis (AFO) that is capable of effectively mitigating both drop foot and inversion tendencies. The device was required to correct spastic plantar flexion and inversion of the foot, be comfortable to wear, and be customizable for each patient. The modified AFO contains three main components: a thermoplastic AFO, a thermoplastic "tongue" which rests upon the dorsum of the foot, and an integrated Boa® Fit lacing system. The Boa® reel is fixed to the thermoplastic tongue and is situated approximately two-inches above the ankle joint. The modified AFO distributed functional, compressive forces across dorsal surfaces of the patient's midfoot to constrain ankle supination tendencies during gait. The integration of the micro-adjustable Boa® Fit system within the modified AFO design allows each patient to dynamically adjust the amount of compression supplied by the AFO.

Verification testing indicated that the design and design components surpassed the required tensile strength and cyclic tensile strength, validating the functionality and claims of the prototype. The device was able to be worn and effectively correct for intentional foot inversion by one of the project team members. Patient studies have not been conducted but will be required for commercialization with performance claims.

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Biomedical Engineering is a discipline that advances knowledge in engineering, biology and medicine to improve human health.

Students in biomedical engineering participate in cross-disciplinary activities that integrate the engineering sciences with the biomedical sciences and clinical practice. Biomedical engineers develop strategies to effectively solve challenging problems in medicine and biology.

Most graduates secure employment working in the medical device/biotechnology industry. Some graduates use our “renaissance” training as a stepping stone for careers in fields such as medicine, law, healthcare management, and academics.

Distinctive Features of Biomedical Engineering at Marquette University and the Medical College of Wisconsin

Marquette University has the largest engineering school at a Jesuit University. The new joint department formalizes the long-standing relationships with the Medical College of Wisconsin and the Zablocki Veteran’s Administration Medical Center. We also have strong ties to the Rehabilitation Institute of Chicago, and manage a number of Centers including the Orthopaedic Rehabilitation and Engineering Center (OREC), the Falk Neurorehabilitation Engineering Research Center and the Rehabilitation Engineering Research Center on Accessible Medical Instrumentation.

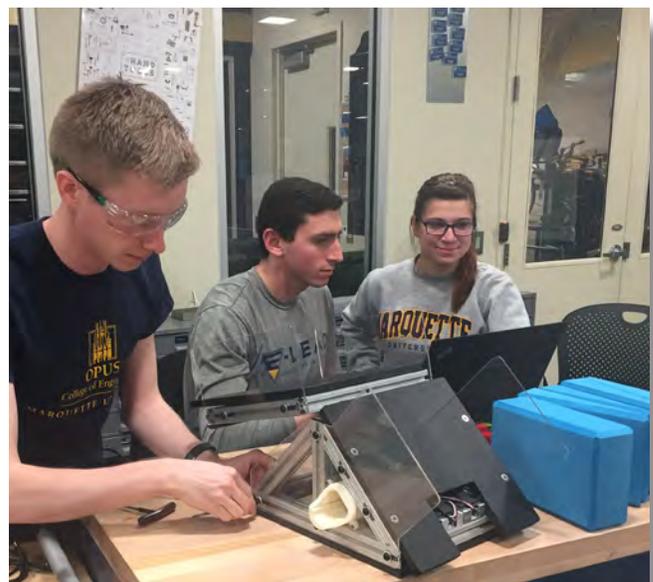
The department has unique laboratory capabilities including CT and SPECT microfocal imaging, biotelemetry, implantable devices, telerehabilitation, and neurorehabilitation robots, in areas including neurorehabilitation, imaging systems, and cardiovascular technologies.

The joint Biomedical Engineering department offers degrees at the bachelors, masters and doctorate levels.

Co-op and Internship Program

Marquette University has developed one of the leading co-op/internship programs among Biomedical Engineering Departments in the nation. More than half of the undergraduate biomedical engineers gain co-op or internship experience before graduation. The Biomedical Engineering department has forged partnerships with many major medical device companies in the Midwest who rely on the excellent reputation established by our students as co-ops, interns and permanent employees. The Co-op and Internship Program offers students the opportunity to gain meaningful practical and professional experiences in the health care industry, in addition to their on-campus educational experiences.

Marquette University began its Engineering Co-op Program in 1919. Students usually enter the Co-op program at the end of their sophomore year and complete three to four terms of off-campus employment.



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The employment experience is alternated with semesters of on-campus study, extending graduation by only one year. Internships, in comparison, are summer-only engineering experiences.

Les Aspin Center for Government (FDA Internships)

The Les Aspin Center for Government at Marquette University and the Department of Biomedical Engineering offer internships on biomedical research and regulatory issues. The Les Aspin/Biomedical Engineering Internships began in 1997 with Biomedical Engineering undergraduates participating in this innovative program in Washington, D.C. To date, more than 100 biomedical engineers have completed Les Aspin Biomedical Internships. The internships are completed at the Food and Drug Administration, Office of Science and Technology in Rockville, MD.

Undergraduate Offerings

Choose from Three Specializations

The Biomedical Engineering Department offers a strong undergraduate education. There are three tracks in the Biomedical Engineering curriculum:

- Bioelectronics
- Biomechanics
- Biocomputing

All undergraduate tracks in Biomedical Engineering are compatible with other programs offered by the Opus College of Engineering. Each track contains the requisite humanities courses, and requires 132 credit hours for graduation. Students automatically earn a minor in biology, and can earn an optional minor in areas such as mathematics, electrical, mechanical, or computer engineering. In addition, all tracks retain most of the core courses of the initial year, which allows the student flexibility to transfer to other curricula if so desired. The Biomedical Engineering curriculum is



interdisciplinary in nature, incorporating courses in biology, chemistry, physics, mathematics, computer science and engineering.

We provide a solid foundation in the mathematical, physical, and life sciences necessary for the engineer to function effectively in a medically or biologically oriented problem solving environment. Social science and humanities courses prepare students to deal with contemporary ethical, cultural, and social issues.

In addition, we prepare biomedical engineers to communicate with life scientists, physicians and other health care providers to describe and model complex biological systems, collect and analyze experimental or clinical data, understand the capabilities and limitations of sophisticated instrumentation, and understand the principles of design.

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Undergraduate Design Curriculum

Biomedical engineering students in our Department learn about design throughout the four year curriculum.

Freshman Year:

Students first gain experience with the design process in the freshman year during BIEN 1100 and 1110 (*Introduction to Biomedical Engineering Methods I and II*). In these courses, they participate in several team design challenges such as:

- Physiological monitoring: Design of an algorithm for analysis of ECG, blood pressure, and other waveforms
- Medical imaging: Design and testing of an imaging phantom
- Entrepreneurship: Semester-long team-based medical device design project including a business plan and elevator speech

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.

During BIEN 1110, students learn about basic business concepts and entrepreneurship (as part of their design projects) culminating in a presentation of their new product ideas to students, faculty, and industry representatives at the college-wide Design Day event.

Sophomore 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 with practice.



In the junior year, students can take BIEN 3400 *Clinical Issues in Biomedical Engineering Design*, an elective in which students observe procedures in the clinical environment and learn to identify unmet clinical needs and opportunities for new product development. Their final project proposals can serve as the basis of their senior capstone design projects.

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 and value creation, 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 validation (per ISO 9001 and 13485) and gain experience in generating the same project deliverables as required in industry.

Five Year B.S./M.S. Program

This program allows qualified students to receive a Bachelor of Science Degree and a Master of Science Degree in Biomedical Engineering in just five years. Students with qualifying grade point averages apply to the program during their Junior year. They begin their thesis research the summer between their Junior and Senior years, and continue their research during the summer between their Senior and fifth years and throughout their fifth year, culminating in the preparation of a written thesis and defense.

Research in Biomedical Engineering

Biomedical Engineering faculty and students at Marquette and the Medical College of Wisconsin are engaged in a wide range of research activities, with many opportunities available for students at both the graduate and undergraduate levels.

Research-oriented Faculty

More than 70 faculty who are active in research have primary (25), secondary (22), or adjunct (>30) appointments in our department, and are available for supervision or co-supervision of students.

Research Laboratories and Centers

The number of research laboratories and centers within our department has been growing dramatically, with the Biomedical Engineering Department now housing 21 research laboratories and three centers.

Most recently, the NIDRR awarded our department a **Rehabilitation Engineering Research Center on Technologies for Children with Orthopedic Disabilities (TECH4POD)**. Faculty, students, clinicians,

and researchers from six area institutions are developing a national center with a focus on advancing engineering research and development based on innovative technologies addressing children with orthopedic disabilities.

Externally Funded Research

More than \$8.7 million/year in externally funded research, the largest of any department on campus, flows through the Department of Biomedical Engineering. Research and training grants are managed by Biomedical Engineering core faculty and support research projects for more than 50 graduate students.

Strong Partners

We are a member of the **Clinical and Translational Science Institute of Southeast Wisconsin**. Supported by a \$20M grant from NIH, this consortium of eight Milwaukee institutions is dedicated to transforming biomedical research in southeast Wisconsin, accelerating the translation of research discoveries, and advancing patient care and education. The eight member organizations include the Medical College of Wisconsin, Marquette University, Milwaukee School of Engineering, University of Wisconsin-Milwaukee, BloodCenter of Wisconsin, Children's Hospital and Health System, Froedtert Hospital, and the Clement Zablocki VA Medical Center.

Targeted Areas of National Leadership

While our students and faculty are engaged in many areas of research, three areas of excellence stand out: Functional Imaging, Rehabilitative Bioengineering, Systems Physiology, Cardiovascular Physiology, and Biocomputing.

faculty

Pintar, Frank, Ph.D.

Professor and Chair

Biomechanics of traumatic brain and spine injury, motor vehicle crash trauma

Audi, Said H., Ph.D.

Pulmonary mass transfer, tracer kinetics, pulmonary hemodynamics

Beardsley, Scott, Ph.D.

Neuroengineering, computational modeling, perceptual learning, functional imaging

Dash, Ranjan, Ph.D.

Computational biology and bioinformatics

Garcia, Guilherme, Ph.D.

Respiratory fluid mechanics

Gilat-Schmidt, Taly, Ph.D.

Medical imaging, image processing and reconstruction, systems engineering

Goldberg, Jay R., Ph.D., P.E.

Medical device design and innovation, biomaterials

Greene, Andrew, Ph.D.

Cardiovascular physiology

Harris, Gerald F., Ph.D.

Quantitative assessment of neuromuscular function, human motion analysis, orthopedic biomechanics, data acquisition and control, real time analysis

Hoffmann, Brian R., Ph.D.

Metabolism

Jeutter, Dean C., Ph.D., P.E. (Emeritus)

Implantable transcutaneous radio frequency power transfer, biotelemetry, biomedical instrumentation, radio frequency circuit design and development

Joshi, Amit, Ph.D.

Optical imaging

LaDisa, John F., Jr., Ph.D.

Cardiovascular biomechanics, adult and congenital heart disease, stent design and development

Olson, Lars E., Ph.D.

Optical instrumentation, tissue engineering, biological transport and circulation physiology, mathematical modeling of physiological systems, biosensors

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, systems identification, rehabilitation engineering, embedded systems, product development

Schmit, Brian D., Ph.D.

Spinal cord injury, human neurophysiology, neurorehabilitation, instrumentation, biomechanics

Shimoyama, Mary E., Ph.D.

Analytics, informatics, software engineering

Silver-Thorn, M. Barbara, Ph.D. (Emerita)

Prosthetic limbs, soft tissue mechanics, rehabilitation engineering, orthopaedic and dental biomechanics

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 and pulmonary physiology

Winters, Jack M., Ph.D. (Emeritus)

Neuromuscular control systems, movement and tissue biomechanics, rehabilitation engineering, telehealth, neurofuzzy computing

Wang, Bo, Ph.D.

Stem cell engineering, heart tissue engineering, 3-D bioprinting, cardiovascular tissue engineering, imaging, modeling, and simulation

Yu, Bing, Ph.D.

Optical imaging

ASSOCIATE FACULTY**Ackman, Jeffrey, M.D.**

Orthopedic surgery

Cariapa, Vikram, Ph.D.

Rapid prototyping, process controls, neural networks, design of experiments

Carroll, Joseph, Ph.D.

Ophthalmology

Clough, Anne V., Ph.D.

Mathematical and computer modeling of biomedical systems, image processing and analysis, modeling of pulmonary hemodynamics, integral equations

Connelly, Jennifer, MD

Neurology

Fritz, Jessica, Ph.D.

Human motion analysis, orthopedic biomechanics, computer modeling

Koch, Kevin, Ph.D.

MR imaging

Krenz, Gary S., Ph.D.

Mathematical modeling of hemodynamic properties of the lung, microangiographic measurements, pulmonary vascular morphogenesis

Kurpad, Shekar, M.D., Ph.D.

Neurosurgery

LaViolette, Peter, Ph.D.

MR imaging, cancer

Liebenthal, Einat, Ph.D.

Functional neuroimaging

Liu, Yu, Ph.D.

Radiology

Marklin, Richard W., Ph.D.

Ergonomics in office and industrial settings, human factors, cumulative trauma disorders

Meier, Timothy, Ph.D.

Neurosurgery

Nagurka, Mark L., Ph.D., P.E. (Emeritus)

Biomechanics, vehicle dynamics and controls, and control system design

Nencka, Andrew, Ph.D.

Radiology

Pawela, Christopher, Ph.D. Anesthesiology**Schminda, Kathleen, Ph.D.**

MR imaging, cancer

Stowe, David, Ph.D.

Anesthesiology

Terhune, Scott, Ph.D.

Microbiology, molecular genetics

Toth, Jeffrey, Ph.D.

Biomaterials

Tugan Muftuler, Lutfi, Ph.D.

MR imaging, neurosurgery

Voglewede, Phillip A., Ph.D.

Lower limb prostheses, dynamics, kinematics

Yoganandan, Narayan, Ph.D.

Neurosurgery

opus college of 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.

DEPARTMENT OF
**BIOMEDICAL
ENGINEERING**



www.marquette.edu/engineering/biomedical