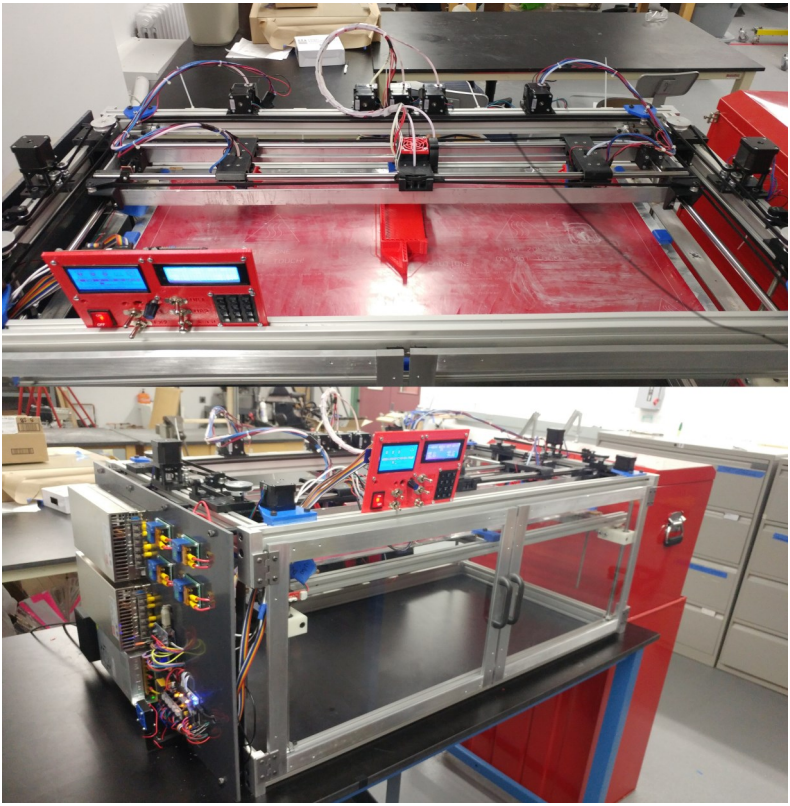
Worcester Polytechnic Institute

Mechanical Engineering Department



Project Presentation Day
April 20, 2018

Schedule for Project Presentation Day
Mechanical Engineering Department
April 20, 2018

8:00 AM	Judges Assemble	Higgins Labs 102
8:00 - 8:30 AM	Breakfast	
	Judges	Higgins Labs 102
	Students	Alden Hall
8:15 - 8:30 AM	Judges Instructions	Higgins Labs 102
8:30 - 11:30 PM	Presentations	Alden Hall
12:00 - 1:00 PM	Lunch	
	Judges	Higgins Labs 102
	Students	Alden Hall
1:00 - 1:15 PM	Winners Announced	Alden Hall

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Biomechanical

Equine Lung Function Testing

David Frederick, Brandon Hoghaug, Justin Shanahan,
Aaron Weeks

The Cummings School of Veterinary Medicine at Tufts University is the only facility in New England with a non-invasive device for diagnosing equine respiratory problems. Their first rendition of the device, while functional, was very cumbersome and expensive, leading to a partnership with Worcester Polytechnic Institute (WPI) to improve the aspects of this design. Following the work of a previous WPI design team and that of Dr. Mazan of the Cummings School of Veterinary Medicine, our team refined the display and functionality of LabVIEW code for analysis, and developed significant improvements to the mask design to house a Rev C sensor, which is used for data acquisition. The result of this project is a lightweight, cost effective, and reproducible mask design capable of producing consistent and accurate measurements of respiratory function.

Advisors: Robert Daniello, Songbai Ji (BE)

Sponsor: D.VM. Melissa Mazan: Tufts Cummings School of Veterinary Medicine

Biomechanical

Dynamic Correction of Postural Kyphosis

Kirsten Herchenroder, Spenser Martin, Connor Mastropoll,
Maria Manuela Perez Luna, Silvio Torres Betancur

Many American adults in today's society spend extended periods of time hunched over a computer or phone. This hunched position weakens the upper posterior muscles that support the shoulder and neck prompting muscle imbalance. Specifically, the lower trapezius and clavicle flexor muscles become too weak while the pectoral and upper trapezius muscles become too tight leading to the condition known as Postural Kyphosis or, more commonly, Rounded Shoulders. Our project aimed to design, build, and test a device able to treat and correct Postural Kyphosis through sensorimotor training. A user guide for the device as well as a supplementary exercise list was produced for the benefit of the user. While the effectiveness of this device was determined through a biomechanic validation processes, we recommend further testing to gather the long term effects of use.

Advisors: Gregory Fischer, Tiffiny Butler (BE),
Loris Fichera (CS)

Biomechanical

Cough Counter for Dogs

Michael Hellmich, Allie McCarthy, Larissa Naidoo

The purpose of this project was to design and build an automatic cough counting device for small canines. In collaboration with veterinarians from Tufts Cummings School of Veterinary Medicine, we developed a device that uses sound analysis to distinguish coughing from barking, and automatically displays the number of coughs on a digital display. The device is protected by a custom printed casing, which is water resistant, drop proof, and can withstand loads upwards of 50 N. To optimize comfort and mobility, the device is worn in the form of a harness that can be easily interchanged with various sizes. The results of our test conclude that the device has a sensitivity and specificity of 85.7% and 88.8%, respectively. This project was successful in its goals of distinguishing coughing from barking, and automatically detecting and displaying the total number of times the dog coughed without interfering in its daily activities.

Advisor: Songbai Ji (BE)

Sponsor: Tufts University

Biomechanical

Humanoid Walking Robot

Kenneth Colpritt, Andrew Curran, Shannon Moffat,
Mariah Sullivan

This project is focused on research and development of the application of Hydro Muscles to bipedal robots. Our team designed, researched, and developed a bio-inspired, bipedal walking robot to simulate the human gait cycle. The walking motion is actuated by Hydro Muscles, which are soft, fluidically actuated, artificial muscles that contract and expand longitudinally while being constrained radially. These artificial muscles were placed in anatomically accurate locations on a lower limb skeletal model to create a biologically lifelike gait. Further extensions of this project would explore this robot's potential for clinical, prosthetic, military defense, and other applications involving biomechanics and gait analysis.

Advisors: Marko Popovic (PH), Selcuk Guceri

Biomechanical

Impact Reduction Design

Priscilla Cole, Nicholas Maio, Dan Salisbury, Joseph Silva, Lucas Zuccolo

The objective of this project was to design a new type of headgear for field hockey that reduces the injuries caused by the field hockey ball's facial impacts. The protective abilities exceeded the protective abilities of field hockey headgear that is currently utilized. Consisting of an aluminum frame with a layered foam lining, this facemask design was found to reduce HIC values from impact by as much as 75%. This was tested by using a pendulum with an attached field hockey ball that could achieve the same momentum as an average field hockey ball impact. The pendulum's repeatability allowed for several testing trials that swung against a designed model head wearing the facemask with a simulated neck; this allowed the testing of the headgear to be as close as possible to the real world scenario while providing enough data to confirm the initial results.

Advisor: Brian Savilonis

Biomechanical

Sea Turtle Prosthetic

Maura Buckley, Katelyn Chagami, Kara Martin, and Julia Veitch

This project focuses on Rocky, a green sea turtle located at the Key West Aquarium, who lost his front right flipper in a boating accident. In addition to a missing flipper, Rocky has a buoyancy disorder in the rear of his shell, which inhibits him from diving for food, swimming in a straight line, and breathing properly. This project aims to develop a floatation device to counteract Rocky's buoyancy disorders as well as a prosthetic flipper to imitate his healthy flipper. The flipper was fabricated using 3D printing and molding processes. Adapting from previous projects' calculations, a flipper was developed that will work as effectively as a healthy fin. The attachment mechanisms were designed by the project team and will be developed in collaboration with Hanger Prosthetics in Orlando, Florida. The team also created a generalized process, demonstrated in an instructional pamphlet and video, that can be used to assist in making prosthetics for other sea turtles.

Advisor: Brian Savilonis

Biomechanical

Self-Sustaining Cooling System

Michael Bahnan, Kristen Bender, James Mosteller,
Joseph Tomellini

The rucksack loads that military, law enforcement, and hiking enthusiasts need to endure can be excessive and may lead to heat exhaustion. Cooling strategies have been proposed in the past, but there are significant constraints associated with these concepts. This MQP aimed to cool the body by pumping cooled water around the upper torso and releasing body heat into the cooling water. The closed-system of cooled water flows to the back of the rucksack where heat is exchanged to an evaporative cooling system using a separate, non-potable water system. Field tests of the unit have documented significant quantitative cooling using this process.

Advisors: John Sullivan, Ryan Madan (HU)

Biomechanical

The Design and Prototyping of a Medical Lifting Device

Alvaro Galindo, Aaron Hartford, Jasmine Higuera, Colin Mashack

The goal of this project was to design and prototype an affordable, mobile and more compact medical lifting device that can safely lift an immobile patient from a bed to a wheelchair or restroom without requiring an electrical power source. This project also aims to decrease the number of back injuries reported by nursing assistants, completing the lifting process mechanically opposed to manually. Continuously, the final design was manufactured into a prototype made of Aluminum 6061 to decrease costs of fabrication. Load testing was completed to simulate the lifting of a patient, determining weak points in the design. In conclusion, the Medical Lifting prototype can lift up to 275 lbs. Additionally, the overall price of this device is approximately $1,000 and when stored, fits inside a 33 in. X 25 in. X 60 in. cube. Ultimately, to increase the strength and safety of this device, the team made recommendations to redesign a more durable model in the future.

Advisor: John Sullivan

Design

Automated Fish Feeder

Mackenzie Banker, Charlie Brooks, Jake Halverson,
Rachel Huntley

It is not feasible for fish owners to leave extra food in their fish's tank before leaving for an extended period. This creates the need for a device that can automatically and reliably feed a fish. The purpose of this project is to design an automated fish feeder for household use. The device was developed to feed a single goldfish for at least 14 days without any additional input from the user. Using an Arduino unit to control two stepper motors, the multi-stage design feeds the fish while avoiding failures that could result in too much food being dispensed. The compact design attaches directly to the tank for easy setup.

Advisor: Eben Cobb

Design

Automated Salt Shaker

Harrison Czajkowski, Matthew Lenthall

Our project was focused on automating the application of seasonings in a fast food setting. We created a linear zero-offset four-bar slider crank design that uses a motor to drive the mechanism. Before constructing our design, we conducted various analyses to determine torque necessary to run the mechanism and limit potential mechanical failures. We determined that our mechanism would require a maximum torque of approximately 30 in-lb. We used aluminum T-slotted frames, 6063 aluminum bars, custom 3D printed ABS plastic parts, a motor, servo motor, raspberry pi controller, relay, and various fasteners to construct and assemble our mechanism. Our mechanism was able to translate along the full slider path, although its motion was not as smooth as desired. Our salt dispersal mechanism functioned adequately and was able to control the flow of seasonings across the designated area.

Advisor: Eben Cobb

Design

Development of a Modular Seesaw Safety Device

Samuel Bickham, Matthew Eaton, Matthew Garcia

The goal of this project was to develop a device to improve the safety of playground seesaws. Seesaws can cause injury or discomfort due to the jarring impact experienced by the user when the seesaw hits the ground because of the other user dismounting the seesaw. To address this issue, we designed, built, and tested a modular shock-absorption system that applies a braking force to seesaw motion, thus limiting seesaw acceleration, and consequently, preventing large impact forces. The device can be attached to a variety of seesaw geometries. Testing shows that the device successfully reduces the likelihood of user injury without impeding normal seesaw operation.

Advisor: Eben Cobb

Design

Water Cooler Bottle Loader MQP

Nicolas Martin, Marlon Matthews, Benjamin Schooler

The project goal was to create a device that loads five-gallon water bottles into water cooler dispensers, eliminating the need to manually lift the bottle. Our device incorporates a four-bar mechanism to lift a bottle from a low platform to a level above the dispenser. In a final step, the operator manually tips the bottle from its supported position, inverting the bottle to rest in the dispenser and allowing the seal on the bottle to be punctured.

Advisor: Eben Cobb

Design

Show & Tell: What Fun Can Do

Franklyn Bucknor, Alexis Gamez, Miguel Ortiz

‘Umwelt’ is a German word meaning “environments,” or “surroundings.” In English, we use the word to describe the world as it is perceived by a given organism. Different organisms have Umwelts of different sizes because they rely on varying degrees of one or more senses to interpret their realities. As sighted people, we can only imagine the disconnect that arises when another person’s Umwelt doesn’t include sight.

As humans, we can connect fellow humans to the world that they do not know exists around them through the use of play, and in the process, more intimately include them in society. 80% of the information sighted children learn from the world comes from their vision, which causes a substantial disconnect between blind and sighted children. Play is also crucial to cognitive, social, and emotional development. Toys for blind children are overpriced, under-designed, and fail to use current technology. By designing a toy that acts on all of these things, we created something that will help blind children expand their umwelts and immerse themselves more intimately in society; all while having fun.

Advisor: Paul Cotnoir

Design

Motorcycle Rear Suspension

Jacob Bryant, Allysa Grant, Zachary Walsh

Mechanical Design Motorcycle suspension is critical to ensuring both safety and comfort while riding. In recent years, older CB motorcycles have been becoming increasingly popular. While the demand has increased, the outdated suspension technology has remained the same. In order to give these classic motorcycles the safety and comfort of modern bikes, we designed, analyzed and built a modular suspension system. This system replaces the old twin-shock rear suspension with a monoshock design that utilizes an off-the-shelf shock absorber from a modern sport bike. By using this modern shock technology combined with a mechanical linkage design, we were able to create a system that greatly improved the progressiveness and travel of the rear suspension.

Advisor: Robert Daniello

Design

Automation of Assembly

Marissa Ford, Haruna Okada, Muhammad Ali Shah

MilliporeSigma produces high grade filters used in the medical industry. One of the main components of the filters is a composite membrane that has complex elastic and mechanical properties, which demands manual, complex, and skillful processes for assembly of the filters. Therefore, assembly could benefit from automated solutions. In this project, we evaluated the current manual processes to identify automation points and formulated individual station designs. Multiple design solutions were evaluated with respect to functional specifications and experiments were conducted to approximate membrane properties. For each station, risk analyses and SWOT were used during an iterative design process to define two potential assembling solutions. These two solutions were detailed, which included identification of sensors and actuators together with animations that illustrate the assembly processes. Additionally, critical points of the designs were evaluated with kinematic analysis. It is shown that these designs hold the potential to be further analyzed and implemented by the sponsor.

Advisor: Cosme Furlong

Sponsor: MilliporeSigma

Design

Development of Miniaturized Otoscope for Middle Ear Diagnostics by High Speed Holography

Jessica Grabinsky, Peter Hurley, Ajay King, Benjamin Morton

In the United States, 17% of the adult population suffers from hearing loss. However, the diagnostic tools available to clinicians are imperfect and therefore make diagnosing middle-ear diseases extremely challenging. WPI's CHSLT in collaboration with Massachusetts Eye and Ear Infirmary is developing a high-speed holographic system to provide physicians with a tool capable of shape and displacement measurements of the tympanic membrane (TM) with nanometer-scale resolution. We developed an optical head for the system with a 10 mm field-of-view, a 5 mm depth-of-field, and miniaturized optics to visualize the entire TM through an intact ear canal. The prototype was developed using advanced optical design and analysis tools, validated and tested on a controlled sample, and finally integrated into the high-speed holographic system for measurements on a post-mortem human TM. The prototype met all design specifications and is successfully integrated into the system for future otologic research.

Advisor: Cosme Furlong

Sponsor: Massachusetts Eye and Ear Infirmary

Design

Water Desalination: Designing a Seawater Purification System

Spencer Austin, Trevor Gehring, Michael Wilkinson,
Benjamin Zogby

Water is a fundamental need for all living things. The goal of our project was to design, prototype, and test a portable water desalination unit capable of producing drinkable water in emergency situations. The team elected to use a boiler-condenser system with a thermoelectric dehumidifying unit. This system is unlike others on the market because it is able to produce a higher volume of water using any source, and is personal sized and portable. Testing of the system resulted in the conversion of 1,000 mL of 35 ppm salt water to an average of 820 mL of drinkable water in 40 minutes. This corresponds to an efficiency of 82.0%, and a drinking water production rate of 20.5 mL/min. Being the first apparatus of its kind, there are many possibilities for improvements. The team envisions the system to be powered by a portable source such as solar or battery.

Advisors: Stephen Kmiotek (CM), Robert Daniello

Design

Acrylic Microfluidic Chip

Katherine Comeford, Susan Elliott, Storie Nivers, Emma Ryan

Microfluidics is a field which uses the manipulation of small amounts of fluid to perform certain functions. The small required sample size has led to its growth in popularity. Many of the chips still require off chip equipment to force flow through the chip which can be inconvenient. Most of the current microfluidic devices are fabricated on PDMS which requires access to a clean room and expensive equipment. This project seeks to address these problems by creating a pump to be used for spherical droplet generation using cross flow on an acrylic microfluidic platform. Our team used laser ablation to fabricate chips to determine the optimal parameters to generate spherical droplets. We also worked to develop a handheld pump which produced the flow rates necessary to generate the droplets.

Advisor: Yuxiang Liu

Design

Design of Bicycle-and Solar-Powered Lighting System for Rural Vietnamese Students

Cassondra Dale, Emilee Gancarz, Chau Tran

In many developing countries, electric lighting is still not easily accessible to the rural community. As a result, many students do not have a safe and sustainable light source for nighttime studying, leading to poorer performance in school. At the request of the Southeast Asian Coalition (SEAC) of Worcester, MA, our goal was to develop a sustainable, LED lighting system powered by a battery pack which is charged by a bicycle generator so that rural Vietnamese students would have electric lighting to study at night. The specific objectives were to design, construct, and test a battery charging circuit that is compatible with a multitude of charging inputs across a large voltage input range and also design, create, and test a simple and affordable bicycle generator charging input mechanism for the battery energy storage system. The battery and generator cases were designed to be waterproof, dustproof, and rugged to endure usage in the operating environment of Southeast Asia.

Advisor: Fred Looft (ECE)

Design

Design of a Ferry Kite Powered Water Pump

Megan Errichetti, Xiaozhu Liu, Ronglin Na, Zebulon Shippee

This project focuses on the continued design of the WPI Kite Powered Water Pump for use in developing regions with a lack of clean water access. The final design uses a ferry kite which is designed to be able to change kite orientation between the power phase and stalling phase. During the power phase, the ferry kite rises and transmits aerodynamic forces using another tether to a water pump mechanism on the ground. During the stalling phase, the aerodynamic forces are reduced, and the ferry falls down the main kite line in a controlled manner. The ground system includes a rotary water pump, a bike wheel, a bike winch, a priming system, and a retraction spring. Multiple iterations of the ground system were designed. The new ground system was tested under laboratory conditions. Field testing was conducted on the kite system, and basic operation of the ferry was confirmed.

Advisor: David Olinger

Design

Design and Optimization of a FSAE Vehicle

Andrew Casella, Alex Deneault, Patrick Donaghey,
Mark Lightbody, Jeffrey Robinson, Cote Taylor

The purpose of this MQP was to design and optimize a formula SAE vehicle for use in the FSAE 2018 competition based on a frame designed and built by the 2016-2017 FSAE MQP team. The major goals for this MQP were to improve in competition and to reduce the weight of the vehicle. The 2015-2016 car served as a starting point for this year's design decisions and validations. This vehicle was divided into several subsystems. The suspension and drivetrain subsystems were studied extensively as it was determined that these systems needed the biggest redesigns. The steering subsystem also needed to be significantly modified in order to fit in the new frame, which is smaller compared to the 2016 frame. All of the designs in the car adhere to the 2018 Formula SAE Competition rules. This report will fully detail the car's designs; explain what worked, what did not, and how it can be improved for next year's MQP team.

Advisors: David Planchard, John Hall

Design

Designing a Parametrically Scalable Prosthetic Arm for Low-End Rapid Prototyping Machines

Alessandra Paolucci and Rachael Naoum

Traditionally manufactured prosthetic arms are expensive and unsustainable for children who outgrow their devices each year. To address this issue, engineers have been designing low-cost 3D printed upper extremity prostheses to make them more feasible for these children and their families to acquire. Current designs that are freely available for the general public to manufacture are functional but have room to be improved. More robust hand models exist; however, their designs are not available for anyone to produce. In this project, the team developed a low-cost prosthetic arm that incorporates best practices of alternative 3D printed arm designs. Our design utilizes finger and thumb mechanisms that can be printed as assemblies. Hardware was introduced in areas of the design that needed reinforcement. The design was made to be parametrically scalable so it can be a appropriately sized to fit the wearer. The team fabricated and tested the design to ensure that the people who would want to build this device would be able to assemble it using our instructions. The goal was to produce a device that could be manufactured and assembled at any makerspace around the world.

Advisors: David Planchard and John Hall

Design

Revolver Recoil Reduction

Jacob Grealis, Michael Griffin, Carlos Ordonez

Excessive recoil forces cause individuals to avoid using large caliber revolvers, and individuals who fire such revolvers are often met with pain and inability to fire repeatedly. The Revolver Recoil Reduction MQP aims to reduce the perceived recoil in the Ruger Super Blackhawk revolver by 30%. Baseline force-time data was gathered for individual shots fired from the revolver, using newly designed measurement instruments. After determining the forces and moments acting on the shooter's hand, two devices were designed, manufactured, and tested, to reduce the peak recoil loading imparted in the shooter's hand and wrist. Once deemed safe, the two devices were tested by a small group of 15 firearms enthusiasts to determine the average reduction in perceived recoil.

Advisors: David Planchard, John Hall

Design

Society of Automotive Engineers Baja Vehicle Frame Research and Design

James Muller, Louis Muller

The Society of Automotive Engineers (SAE) hosts the Baja SAE competition each year. The objective of this competition is to design and build an all-terrain prototype vehicle for recreational users. The vehicles are put through a series of tests including endurance races and hill climb circuits, as well as a marketability presentation. Our team researched and designed a Baja vehicle frame that complies with the 2018 Baja SAE Rules and will fit other vehicle components such as the drive-train assembly, suspension, braking, and steering. Our frame and detailed documentation will be used by future Baja SAE MQPs to create a functioning Baja vehicle that is suitable for competition.

Advisors: David Planchard, John Hall

Design

Towards Automated Ear Surgery: Improved Calibration and Registration Techniques

Shannon Harrington, Christopher Salomone

Researchers at the Universitäts Spital Zürich are investigating the acoustic pressure distribution within the cochlea. The objective of this project was to develop an improved procedure for their experiments that would increase the accuracy, which is necessary due to the small scale of the inner ear. This was done by calibrating tools and completing registration and insertion processes. The goal was to achieve an overall accuracy of 250 microns, which was met with a final accuracy of 150 microns, allowing for this procedure to be used in future experiments.

Advisors: Marko Popovic (PH), Cosme Furlong

Sponsor: University Hospital Zurich

Design

Automated Design

Automated Design of Linkages

Jonathan Andrews, Brandon Knox, Brad Leach, Guillermo Rivera

Accurate analyses are necessary for the effective design of planar linkages. The goal of this project was to create a universal methodology by which a planar linkage could be completely synthesized and analyzed without any experience in computer aided design (CAD). To facilitate this process, new features were integrated into an open-source kinematics tool called Planar Mechanism Kinematic Simulator (PMKS). The features include the ability to apply forces, assign materials, set initial dimensions for links and joints, calculate and export static and dynamic joint reaction forces, determine the required input torque, refine link and joint dimensions based on axial and shear stresses, and calculate and plot instant centers of rotation. Additionally, linkages can be designed with three-position synthesis, and CAD files can be automatically generated for subsequent design editing and manufacturing. This tool yields a lot more useful and accurate data, has a faster end-to-end design process than existing kinematics tools, and can help students further their understanding of the design and analysis of planar linkages.

Advisors: Pradeep Radhakrishnan, David Brown (CS)

Design

<u>Automated Design</u>
Automated Generation of SolidWorks Assemblies of Gear-trains and Linkages

Garrett Holman, Oluchukwu Okafor

This project demonstrates the automated generation of Computer Aided Design (CAD) assemblies of gear trains and linkages in SolidWorks. Two standalone programs have been developed; one for generating gear trains and the other for generating planar linkages. Upon detailing sufficient information about individual parts and their assemblies in each case, the programs calculate design details and interfaces with the SolidWorks API to generate all the parts and their overall assembly with all the required mates. In the gear program, spur gears, helical gears, bevel gears, straight shafts and bearings can be generated along with a representative enclosure. In the linkage program, prismatic links, pin joints, spacers, covers and axial constraints can be generated with a backing plate. These programs can generate the models much faster than manually creating them. Detailed processes, benefits and challenges will be discussed.

Advisors: Pradeep Radhakrishnan, David Brown (CS)

Design

Automated Design
Automated Analysis of Gears and Shafts in a Gearbox

Joseph Gallagher, Zhidong Ju

This project details the development process of an automatic gear and shaft analysis tool for a single-input, single-output gearbox. Details critical to the analysis such as input torque, input angular velocity, positions, geometry and material data of gears and shafts are provided as user inputs. These details allow the tool to compute kinematics, gear-tooth bending and surface stresses, and shaft fatigue stress and deflection. The tool adapts the process specified in the Machine Design book by Robert Norton and includes detailed procedures for automatically deriving various constants important to gear and shaft stresses. Significant testing was done to ensure this tool can produce rapid and accurate results. Eventually, this analysis tool will be integrated with a gearbox generation tool that automatically designs gear-train models based on user-defined constraints.

Advisors: Pradeep Radhakrishnan, David Brown (CS)

Design

Vertical Axis Wind Turbine for Remote Power Generation

Jeremy Lane, Theodore Lynn, Saffiyah Rafieck,
Travis Rossen

The goal of this project was to create a working micro wind turbine capable of charging small electronic devices, constructed using materials readily available in off-grid locations, such as developing countries or areas recently affected by natural disasters. Given the target audience, the design was focused on minimizing the amount of machining by modifying off the shelf products to create turbine components. A full scale prototype was constructed and field-tested to determine its performance characteristics under an electric load at various wind speeds. Testing showed that with a resistive load of 20 ohms the turbine has a maximum system efficiency of 13 percent and produced a maximum power of 4 Watts in 6 m/s of wind. Based upon the prototype's performance, with the proper charging circuit the turbine could be adapted to charge small electronic devices such as battery packs or cell phones.

Advisor: Brian Savilonis

Design

Development of Autobody Tool

Justin Mancovsky, Marcus Pritchard

In the automotive repair industry doors are being stripped (removing the handle, mirror, side molding) every day to be repainted. Insurance appraisers will pay for up to one hour for removal and installing door moldings. The process includes removing leftover adhesive tape and re-taping for installation. The current industry practice uses a razor blade by hand to remove the adhesive, which is timely and aggravating for technicians. The goal of this project is to develop a motorized handheld tool that removes double-sided adhesive tape from door moldings in a timely fashion. A focus for this objective was modeling a device to fit the tight constraints of the tool's operating path (<0.3in). A second objective was to explore the different angles for our blade to see its effects on adhesive removal. An analysis of the design and it's several iterations, along with fabrication details are discussed in this report.

Advisor: Joseph Stabile

Design

<u>Low Profile Home Speaker</u>
The Synthesis and Improvement of a Force Balanced, Sealed Double Passive Bass Box for a Low Profile Home Speaker System

Nick Borsari, Brett Carbonneau, Karim Elsayed, Jeremey Honig

Working alongside four other mechanical and electrical engineering teams, this Major Qualifying Project aimed to manufacture a wall-mounted, low profile home speaker system. The main goal of our group was to prototype a force-balanced, sealed, double passive radiator bass box with a low profile and a low frequency response. By conducting background research in parallel with findings taken from in the 2016-2017 MQP, "The Synthesis and Design of a Small Speaker System," initial designs were prototyped using additive manufacturing. Simulation software and test equipment were then utilized to iterate and improve bass response of moving magnet transducers to reach an ideal design. Additionally, mechanically rotating speaker housings were designed for moving coil transducers, to assist in sound steering. The overall work completed in this project was finally incorporated into the wall mounted, low profile home speaker system.

Advisor: Joseph Stabile

Sponsor: Bose Corporation

Design

<u>Low Profile Home Speaker</u>
Resonant Panel

Obianuli Obiora, Drew Sansoucy, David Zielinski

In a landscape that is producing sleeker and thinner products, this MQP is looking to apply this idea to the home entertainment system. The goal of this project was to produce a resonant panel that had a first modal frequency of 40 Hz. Because the volume velocity of the air needs to be much faster for such a low frequency, the panel has to cover a much larger area than a traditional speaker. The resonant panel is driven by a moving magnet transducer on its surface. The mass of the magnet and motor stator moving helps to displace the panel more, causing there to be more surface acceleration, and thus a larger volume velocity. Surrounding the panel are other, smaller moving magnet and moving coil speakers, which cover the mid and high frequency ranges. These designs were all analyzed and modeled with Finite Element Analysis techniques and 3D Computer Aided Design methods.

Advisor: Joe Stabile

Sponsor: Bose Corporation

Design

<u>Low Profile Home Speaker</u>
Moving Coil Transducer

Binh Phan, Ivanna Stuart, Amile Zaaf

Speaker

The goal of our team is to design a low profile speaker that has a high frequency response using a moving coil and a stationary magnet. Our speakers will be a part of a low profile speaker system in which one team is designing a moving magnet speaker to play bass frequencies, one team is designing the signal steering, one team is performing material analysis and one team is designing the speaker case. As the name refers, the total height of the speaker is less than 2.5 cm and the diameter is less than 10 cm. Through research and design process, we use different software to model and test the speaker such as Finite Element Method Magnetic (FEMM), Solidworks (CAD) and Ansys (Frequency response). Our speaker features a doubles surround system, where one flexible rubber surround is stacked above another, for increased stability. We also use FEMM to simulate and pick the best magnet motor design for the speaker optimizing for best force response per unit current. It also has features for manufacturability such as a plastic ring on the top and bottom plastic supports, where the both the coil and magnet reside centered, respectively. Between the top and bottom support there are holes which further stabilize the vibration axially, and provide a way to easily assemble the outer case.

Advisor: Joe Stabile

Sponsor: Bose Corporation

Design

<u>Low Profile Home Speaker</u>
Moving Magnet Transducer

Steven D'Agostino, Raymond DiMestico, Harrison Roy

This report describes the development of a novel moving magnet transducer. Typically, speakers that produce bass have a large footprint because they require a sufficient acoustic volume to deliver quality sound. Our team's goal was to develop a moving magnet transducer capable of generating quality bass while maintaining the slimmest possible profile. This unique moving magnet transducer was inspired by an E-Core transformer and can produce more force per mass of magnet than commonly used moving coil transducers. In our design current flows through coils that are wound around opposing arms of the low carbon-steel stator. The current induces a magnetic flux in the stator that causes it to act as an electromagnet. The permanent magnets centered in our design oscillate up and down as they interact with the electromagnet. In our design the permanent magnets are bonded to the speakers' cone, so as they oscillate, the cone emits sound. The final transducer measured 0.80" tall with a 2.94" diameter. An in-depth breakdown of our design process, manufacturing process, and performance results are contained within our report.

Advisor: Joseph Stabile

Sponsor: Bose Cooperation

Design

<u>Low Profile Home Speaker</u>
Signal Processing

Corey Coogan, Mark Panetta, Suilio Simo, Avik Vimal,

In this project we design a system to beam steer the soundwaves being outputted by a speaker based upon the location of a listener in the room. The concept is modeled after a phased array system which uses a progressive time delay calculated based upon the distance between speakers and the desired steering angle. The desired angle will be determined using infrared sensors to track an individual in front of the speaker and obtain the required delay to steer the sound towards them using the sensor's voltage output. Each time delay value will have a corresponding, unique, resulting steering angle of the beam. The microcontroller chosen to process this information is the Arduino Mega 2560 which will be used to sample the audio and apply the chosen time delays as well as obtain the sensor output voltage and calculate the corresponding delay using a second Arduino Mega. The basic implementation of the system starts with a circuit to obtain the analog audio input from the source which is then sampled and converted to a digital value using the on board ADC. The arduino then manipulates when the samples are played out of each speaker in order to delay them properly. The samples are sent through an 8-bit DAC which converts the samples back to an analog waveform. The waveform is then low pass filtered and amplified before being played through the speaker. For the testing of the audio quality we created a matlab program for purposes of audio testing. The program generates a sine sweep signal and sends the signal to testing speaker and records the speaker's response. The recorded signal is then filtered and analyzed at different frequency points and a plot of the average peak values at different points versus frequency is obtained.

Advisor: Joseph Stabile

Sponsor: Bose Corporation

Design

Conveyor Belt 3D Printer

Shawn McCarthy, Zachary Palanchian, James Whelan

Our MQP problem was to design a 3D printer that had continuous printing capabilities, whether to create longer parts or to rapidly produce multiple parts, while printing at an angle. The goal was to create a 3D printer that could achieve these specifications while maintaining a cheaper price point than the current market options. We designed and created our own 3D printed parts where we could so that we could save on money while not sacrificing the performance of the printer. We also machined custom parts as well because we had to use a pipe for our pulley as many standard pulleys are significantly costly. We also used a 5:1 planetary geared stepper motor to ensure that we would have enough torque to turn our pulleys and belt. While a considerably labor-intensive apparatus, our printer is significantly cheaper than market alternatives while providing a comparable performance.

Advisor: John Sullivan

Design

Harvesting Energy from Roads

Kurt Bilis, Mary Osler, Sam Smith

In this project we designed and created a prototype capable of harvesting kinetic energy normally converted to heat by vehicles during braking and converted it to electrical energy to be used to power nearby streetlights. A slider crank mechanism converted linear motion to radial motion and a permanent magnet generator that we designed and prototyped created a system to accomplish this energy harvest. The system was designed to have minimal impact on vehicle operators and/or passengers.

Advisors: John Sullivan, Alexander Emanuel (ECE)

Design

3D Data Collection Package

Stephen Jendritz, Logan Mendelson, Brad Scuzzarella

This project involves optimizing a work flow for photogrammetry. This includes the design of an existing 3D scanning stage, the use of a raspberry pi and camera for image acquisition, as well as, the selection of the best software and settings to use in order to render the 3D model. Once a 3D model is generated, it will be brought either to a CAD environment or sent directly to a 3D printer. It is our goal to develop a complete 3D data collection package that is easier to use for the general user.

Advisor: John Sullivan

Design

Collapsible Temporary Housing Design and Optimization

Reid Billings, Michael Morlock, Jack Nigro, Ryan Rigney, Nasjela Thodhoraqi

In the wake of a hurricane, relief organizations often provide victims with temporary housing until their original homes are repaired or replaced. Many current temporary housing solutions can accommodate displaced persons for up to one year, but these products can be expensive to manufacture, difficult to set up, and not reusable. This project, sponsored by Deployed Resources, addressed these shortcomings through the development of a cost-effective, semi-collapsible, and reusable temporary housing unit. The design incorporates three nested compartments which extend from an 8 x 10 ft collapsed size to a 10 x 22.5 ft expanded size. The unit is designed to accommodate four persons and includes permanently installed bathroom and kitchen appliances to minimize set-up time. Based on unit dimensions and weight, up to five units may be transported on a single trailer. The estimated manufacturing cost of each unit is $15,000. The team managed construction of a full-scale prototype of the unit at the Deployed Resources facility in Rome, NY.

Advisor: Sarah Wodin-Schwartz

Sponsor: Deployed Resources

Design

Design of Water Delivery System for a Microgravity Environment

Rachel Welch

Human exploration and settlement of Mars poses a wide range of complex challenges for engineers and scientists. Deep Space Ecology, LLC (DSE) was formed to tackle some of these challenges and adapt their solutions to improve life on Earth. One way DSE is accomplishing this goal is through the Functional Astro Agronomy Research Modular (FAARM) Lab, a unit which will grow plants in low Earth orbit to achieve scientific objectives. The purpose of this MQP is to design, build, and test the FAARM water delivery system to accomplish mission objectives while minimizing power consumption. This was accomplished through requirements definition, design, fabrication, and testing of the water delivery system.

Advisor: Jamal Yagoobi

Sponsor: Deep Space Ecology, LLC.

Manufacturing

Portable Power for Arid Regions

Nicole Alves, Rachel Rynazewski, Howard Vance

This MQP designed, manufactured, and tested a proof of concept prototype of a hydrokinetic power generator that functions in slow, low flowing water. This generator was created with the intent that it would be efficient, portable, and could charge small electronics. We decided to design a five-bladed horizontal turbine that could be submerged in 0.25-1.25 inches of water. We manufactured our turbine and other components of the prototype were 3D printed. The device was tested and although it did not function fully due to using the incorrect generator, we were able to gather enough data to calculate theoretical voltage outputs given a proper generator. We were able to calculate that we could achieve 5 volts with a water velocity of 6.0596 ft/s.

Advisor: Torbjorn Bergstrom

Manufacturing

Mechanical Tic Tac Toe Board

Shane Bell, Tim Bill, Abigail McAdams, Taylor Teed

The goal of this MQP was to design, test, and build a fully mechanical computer capable of playing tic-tac-toe against a human being. Although modern computers could solve this problem more efficiently, our team aims to prove that old school technology still has a place in society today. Included in our design are various elements of mechanical motion ranging from racks and pinions to crank shafts to a hydraulic system. The machine was built almost entirely in the Higgins machine shop, except for a couple parts that were either cut with a water-jet or purchased. Our design uses an indexing module to detect position and data stored on a physical punch card to produce the best strategic answer. The user makes the first move; the computer will never lose, only win or tie.

Advisor: Robert Daniello

Manufacturing

Modification of the Microcontact Printing Process for Conductive Ink Printing

Adam Cyran, Michaela Dowling

The goal of this project was to adhere miniature circuit chips to flex prints using conductive epoxy and microcontact printing techniques. To accomplish this goal, the printing process was first optimized. Tool properties were varied to determine their influence on final print quality. Optimized parameters included ideal ranges for inking force and acceptable alignment during inking. The prints created with the optimized parameters were used to bond substrates for shear resistance and electrical conductivity tests. Both tests showed that using microcontact printing to apply conductive epoxy for establishing continuity has potential to become an alternative solution for bonding electrical components.

Advisor: Sarah Wodin-Schwartz

Sponsor: NTB

Materials

Sorting of Automotive Manufacturing Wrought Aluminum Scrap

Shady Zummar

An increase of 250% in wrought aluminum usage in automotive manufacturing is expected by 2020. Consequently, the generation of new aluminum sheet scrap will also increase. Producing secondary aluminum only emits 5% of the CO_2 compared to primary aluminum – a significant 95% decrease. With the advent of opto-electronic sorting technologies, recovery and reuse of new aluminum scrap (generated during manufacturing) is at hand. A series of interviews with industrial experts and visits to automotive stamping plants were performed in order to: *(i)* identify the most common wrought aluminum alloys from which scrap is generated; *(ii)* the present scenario - how scrap is collected today; *(iii)* and the types of contamination that must be accounted for during and after sortation. Recommendations are made herein that will support the development of an optimized scrap management system including sorting criteria that will enable closed loop recycling.

Advisor: Diran Apelian

Sponsor: Metal Processing Institute

Materials

Process Optimization for the Fabrication of Novel Polymer-Metal Composites Using 3D Printing

Justin Coppolino, Ann Kaczowka and Nde Nkimbeng

Additive manufacturing is a breakthrough technology that offers enhanced flexibility in customization of part geometry relative to traditional subtractive manufacturing processes. The major barriers impeding the broader adoption of this process are the lack of materials specifically developed for use with fused deposition modeling (FDM), the most broadly utilized polymer 3D printing strategy, and the need for further optimization of the process parameters. A recently developed fabrication methodology has been utilized in this study to create polymer-metal composites (PMCs) for use with FDM, based on acrylonitrile butadiene styrene (ABS) with additions of stainless steel (SS) powders. Printing parameters, including speed and temperature, were tested and optimized for composites with 0, 5, 10, 15, 20, 25, and 30 wt% SS. The resulting composites were evaluated using differential scanning calorimetry, dynamic mechanical analysis, and mechanical testing. The findings demonstrate the ability of the process to successfully create PMCs with adequate structural properties and increased functionality.

Advisor: Diana Lados, Germano Iannacchione (PH)

Materials

Transport Properties Measurement and Prediction in Cast and Wrought Aluminum Alloys

Andrzej Bielecki and Dexter Gutierrez

In pushing the limits of performance and efficiency in transportation applications such as automotive and jet engines, as well as rocket components, it is critical to utilize materials with optimal thermal and electrical conductivities. Aluminum alloys are widely used due to their high strength and low density in order to reduce weight and increase the fuel efficiency of air, ground, and water vehicles. Thus, novel methods for evaluating transport properties with higher accuracy and efficiency than current methods need to be developed and validated. The goals of this project were to establish a methodology and design a testing apparatus that would provide accurate and reproducible transport measurements. This method was created and validated using various cast and wrought aluminum alloys (A356, 319, 6061, 7075, 2024), and original correlations between the materials' microstructures and conductivities were developed. Furthermore, design guidelines using the correlations were established and will be systematically discussed.

Advisors: Diana Lados, Germano Iannacchione (PH)

Materials

Light Driven Actuators

Jake Kelley, Emily McLean

Light is a clean form of energy. The ability to use light to cause mechanical motion is relatively a new area of research that can bring benefits such as remote control of actuators and micro-machines. Graphene is a 2D nanomaterial that has high mechanical strength, thermal conductivity and broad optical absorption. Graphene nanoplatelets (GNPs) dispersed into a polymer not only improves mechanical strength and thermal conductivity but also enables high performance photomechanical actuators.

In this project, we dispersed (GNPs) into a Polydimethylsiloxane (PDMS) elastomer matrix to test the nanocomposite's mechanical responses after being exposed to near-infrared light (NIR) in timed illumination cycles of on for 90 seconds and off for 50 seconds. Different concentration levels of GNP to PDMS (0.1-2 wt%) nanocomposites were made and varying levels of pre-strain (3%-40%) were applied to each test sample before it underwent the illumination cycle. Highly stretched test samples showed reversible contraction while lowly stretched test samples showed reversible expansion.

Advisor: Balaji Panchapakesan

Materials

Analysis of Shape Memory Properties in 3D Printed PLA

Tsering Dolma, Jesse Kauffman, Andrew Kelly, Emily Perkins

In recent years, 3D printing has become a popular alternative to conventional manufacturing techniques; untapped potential exists for application of 3D printing across various industries. However, additional research on 3D printing technology is still required in order to produce accurate results and to be able to apply the technology to a wide range of industries. This research focuses on verifying relationships between printing parameters and thermal strain accumulated in 3D printed polylactic acid (PLA). Results from raster angle and layer thickness strain experiments were fit to an algorithm for predicting irreversible thermal strain. While experimental data trends agreed with theory in certain cases, magnitudes of strain deviated significantly from expected values. Such deviations required alteration of the set of algorithm equations. This research provides crucial initial steps for future research in developing an accurate method for predicting strain in Material Extrusion (MatEx) printed PLA parts.

Advisor: Amy Peterson

Materials

FGM Soft Actuators

Reynaldo Duran, Jiacheng Liu, Steven Rangel, Adam White

The goal of this project is to design, analyze, and fabricate a pneumatically powered, functionally-graded soft robotic actuator made of a polymer embedded with nanoparticles, and later attach three of them to a hand-sized gripper assembly for object distribution. This was accomplished through finite element analysis, nanocomposite fabrication, and construction of a mechanical arm controlled by a wearable gesture controller.

Advisor: Nima Rahbar (CE), Cagdas Onal

Materials

Flexible Solar Cells

Jason Bugarin, Collin Chen, Jeremiah Leonard, Reese Peterson

The thin film generation of solar cells is a promising alternative to the market-dominating silicon wafer cells. Thin film cells have increased manufacturability by reducing cost and ecological impact, while having recorded efficiencies that rival that of traditional silicon cells. Several Hole Transport Layers (HTL) are available for flexible solar cells limited by effectiveness and price. Our group aims to show that CuSCN, cheaper than several other HTL layers, can be utilized on a flexible substrate. We compared the overall Power Conversion Efficiency of CuSCN cells to known P3HT cells and performed mechanical bend testing to show its viability. Through this we discovered that CuSCN can be used to create a working flexible cell but produces no obvious breakthroughs for the HTL layer in thin film solar cells. Further testing and lab work would be used to determine the potential of CuSCN and how it compares to its more expensive counterparts.

Advisors: Pratap Rao, Cagdas Onal

Materials

Structural Features and Mechanical Properties of Five Species of Seaweeds

Rachel Sudol, Rachel Swanson

Macroalgae and seaweeds are plentiful and simple to cultivate in most coastal areas of the world. Current industrial uses of seaweed utilize chemically extracted polysaccharides and hydrocolloids found in seaweeds, not entire seaweed fibers. The present study investigates various material properties and structural features of seaweeds found in New England and Southern California. The dried samples were analyzed by microscopy, thermogravimetric analysis, and tensile testing. Tensile strength for these samples ranged from .7 to 29 MPa. Strength and the degradation behavior can be directly correlated to the amount of polysaccharides and cellulose in the seaweed. In general, red seaweed, with a highly organized cellular structure, has a greater strength than other types of seaweed with branched cells. These findings suggest a higher strength of cellulose-high morphologic areas of the seaweed due to the higher strength of cellulose compared to polysaccharides. The data obtained in this study can be used to aid future applications and studies of seaweed.

Advisor: Satya Shivkumar

Materials

A Metallurgical Investigation of the Effects of Double Tempering on the Hardness, Impact Toughness and Microstructure of AISI 4140 Steel

Aiden Freeburg, Connor Hoeckele, Connor Ross, Kelly Soldevilla

Low alloy steels are commonly used in industry for a wide range of applications that require high strength and toughness. Each application requires specific properties. In order to modify the alloy's properties to meet the specification, a variety of heat treatment techniques are employed, including annealing, quenching, and tempering. Tempering is a metallurgical process by which toughness and ductility are improved. This procedure is conducted by heating the as-quenched martensitic steel to temperatures in the ferrite plus cementite phase region for several hours. Tempering is generally carried out in a single cycle temperature-time. However, the procedure may be conducted in two cycles with cooling to room temperature between the cycles. This process is known as double tempering. The goal of this project is to investigate the effects of single versus double tempering on the mechanical properties and microstructure of 4140 steel. To achieve this goal, samples of 4140 steel quenched and tempered at 300, 400, 500, and 600 ºC in for the same total heat time in single and double tempers. The samples were machined for ASTM standard impact testing. The Rockwell hardness and Charpy V-notch impact energy were measured. The microstructure was characterized using optical and scanning electron microscopy (SEM), and carbides were extracted from each sample determine their size and geometry. The results are analyzed using the Holloman – Jaffe parameter.

Advisor: Rick Sisson

Materials

Stabilized NMC811 to Enable High Energy Density Lithium Ion Batteries

Yuxin Gao and Logan Visser

Over the past decade, the performance of lithium ion batteries (LIBs) has improved greatly and costs have dropped significantly. However, emerging battery applications (EVs) demand increasingly higher energy density, lower cost, longer cycle life, and higher safety, which cannot be met simultaneously by current LIB technology. Specifically, cathode material is recognized as the key limiting component for both energy density and cost. Commercial cathode materials ($LiCoO_2$, $LiFePO_4$, $Li_2Mn_2O_4$, $LiNi_{1/3}Mn_{1/3}Co_{1/3}O_2$) normally offer a specific capacity in the range of 130-160mAh/g. Currently, both industry and academia are searching for next generation cathode materials with a specific capacity of >200mAh/g for xEV applications, and $LiNi_{0.8}Mn_{0.1}Co_{0.1}O_2$ (NMC811) is viewed as a promising candidate in this space. However, along with the energy density benefits, its high nickel content also poses technical issues including cracking, low thermal stability, cation mixing, and parasitic reactions which result from interactions between the electrolyte and the highly reactive delithiated cathode surface at high potentials. These issues have thus far stalled the commercialization of these materials. In this project, an integrative approach including doping and coating is being adopted to solve the above issues of NMC811.

Advisor: Yan Wang

Materials

Material Processing of a HIPS/AC FDM Filament for Water Filtration

Bryant Babel, Jennifer Day, Chris Massar, Emily Matsco

Additive manufacturing has seen extensive development within recent years, leading to innovations within a variety of industries. New printing technologies enable the incorporation of intricate geometry within a part unachievable using traditional manufacturing methods. These geometries, which can increase the surface area of a part, and the intrinsic high porosity of additive manufactured parts are advantageous to water filtration applications. One of the most common methods of water filtration involves the usage of activated carbon, a common material derived from plant matter. High surface area and unique pore structure make activated carbon a viable filter of organic compounds. In this project, a polymer-filler composite was developed for creating a filament with filtering properties, specifically targeting organic compounds. Fused deposition modeling filament was manufactured through a unique seven-step process. Utilizing the advantages of additive manufacturing and this new composite filament, a water filter was created that removed the organic compound methylene blue, illustrating the potential of this novel technology.

Advisor: Sarah Wodin-Schwartz, Erica Stults

Robotics

Multi-Terrain Wheelchair

Joseph Abinader, Andrew Buley, Alexander Pappas, Victor Pina

Many disabled people struggle to traverse outdoor terrain without specialized equipment. To tackle the outdoors, users have to spend money, time, and sacrifice usability and indoor capability by using bulky assistive devices. This project was carried out by a group of four WPI students to design and construct an assistive device for a fellow student who is paralyzed from the waist down. After initial brainstorming and research, the choice was made to create a multi-terrain wheelchair. Using organizational, financial, manufacturing and design methods, the group was able to design and construct a prototype wheelchair consisting of separate subsystems. Each subsystem attempts to solve a different facet of the overarching problem being addressed. This wheelchair design and prototype aims to not only assist disabled persons, but also serve as a basis for future projects to improve upon and help solve the issue.

Advisor: Torbjorn Bergstrom

Robotics

Telenursing RoboPuppet

Brent Heavey, Matthew Lamare, Evan Stelly

The Tele-robotic Intelligent Nursing Assistant (TRINA), is a retrofitted Rethink Robotics Baxter, designed to improve the work quality for nurses by helping to perform high strain, repetitive tasks and interacting with infectious patients. Previously, it was found that performing nursing tasks with TRINA took significantly longer than it did for a human. There were reported issues with the previous teleoperation controller's intuitiveness and unexpected motions due to geometric differences between it and Baxter. The goal is to improve TRINA's ability to perform common nursing tasks by designing an improved input device. The selected solution was the RoboPuppet, a DH parameter scale model of Baxter's arms, which allows for direct manipulation of Baxter's joint space with one-to-one correspondence. Toggle buttons were implemented to control the grippers, and a dead man switch ensured safe operation. Servo motors on the joints were integrated to provide opportunity for gravity compensation and haptic feedback. The puppet was successful in manipulating Baxter's arms smoothly and precisely, however more testing and refinement will be need to more accurately perform complete nursing tasks with active feedback.

Advisor: Zhi Li

Robotics

Autonomous Campus Mobility Platform

Garrison Hefter, Mitch Read, Dylan Roncati, Shamsur Saikat

The basis for this major Qualifying Project was the development of a robotic vehicle for use in improving mobility. The main objective was for the vehicle to navigate a person or load back and forth from Higgins Laboratory on the Worcester Polytechnic Institute main campus to the WPI Robotics Laboratory at 85 Prescott Street. While there are existing solutions serving similar goals, our design and implementation provides benefits not offered in any other current research, as it is lightweight, compact, and portable. Our autonomous robot was designed to navigate its environment using a unique onboard navigation and sensing system. The custom long board chassis design includes a battery-powered motor for locomotion, a handle for steering, control system, various sensors and LIDAR for environmental orientation. Navigational decisions made by the robotic vehicle are derived through information from various interfaces.

Advisor: Cagdas Onal

Robotics

Aquatic Robotic Recovery Craft (ARRC)

Justin Harris, Alexander Krasa, Patrick Murphy, Alberto Ramirez

In situations where someone is trapped underwater, rescue personnel must attempt a search for the body in question. This task is extremely dangerous for the rescue personnel that attempt to locate the body. Drowning, hypothermia, and decompression sickness are some possibilities that could happen to a diver, while trying to locate a missing person. This project proposes the Aquatic Robotic Recovery Craft (ARRC), which can take the place of a diver during the search for the missing person. This system is capable of powering its thrusters to propel through the water, uses a camera to look at the surrounding area, and uses visual tracking to map the bottom of a body of water. The prototype for the robot could be used by any fire department in order to search for a body under the water in a safe and effective way.

Advisors: Kenneth Stafford, Michael Ciaraldi (CS)

Robotics

Sailbot

Jordan Burklund, Hans Johnson, Travis Norris, Liam Shanahan

The goal of this MQP was to design, build, and program a sailing robot capable of competing in the 2018 International Robotic Sailing Competition (IRSC), also known as Sailbot. Challenges in this competition include a fleet race, station keeping, navigation, payload transportation, collision avoidance, search, and endurance. This project will utilize existing research on control and design of autonomous sailboats, and build on lessons learned from the last two years of WPI's Sailbot entries. The final product of this MQP is a more reliable, easier to control, and more innovative design than last year's event-winning boat. We utilized similar construction techniques, such as fiberglassing, laser cutting, and marine waterproofing. The robot will be designed to sail primarily with a rigid wing sail developed by a previous MQP project, and manufactured in collaboration with the WPI Robotics Club. A new hull design and a functional movable ballast system are complimented by a redesigned NMEA 2000 compatible motor controller and a vision system to significantly improve the boat's ability to round buoys when sailing a prescribed course.

Advisors: Ken Stafford, William Michalson (ECE)

Thermofluids

Waste Heat Turbo Charger

John Bylund, Benjamin Freed, Yiannis Kaparos

Diesel engines are used in a wide range of applications, from passenger vehicles to large scale transportation and shipping. These engines account for roughly 20% of total US fuel consumption, so maximizing their efficiency is paramount. The addition of a turbocharger dramatically increases engine performance and efficiency. Even these devices, however, have their drawbacks. The introduction of a turbine in the exhaust stream creates a restriction that impedes the engine's power. Moreover, there is a delay in developing boost pressure, called turbo lag. Both of these characteristics limit the real-world efficiency and performance. These engines typically have a thermal efficiency of about 40%. This project designed a system that recaptures heat normally wasted through the exhaust and uses it as the heat source for a Rankine cycle that powers the turbocharger. This system aims to improve overall engine efficiency, by reducing the flow restriction in the exhaust stream and the amount of energy wasted as heat through the exhaust.

Advisor: Torbjorn Bergstrom

Thermofluids

Analytical Model for a Modular Geothermal System

Sabrina Guzzi, Brendan Harty, Karina Larson, Amanda Richards

A geothermal heat pump system is a renewable energy source that uses earth's natural ground temperature as a thermal reservoir to regulate the temperature of a building. The focus of this study is to design a modular ground heat exchanger unit for a residential geothermal heating system located in New England. This design utilizes water well technology to account for the low ground temperatures of the New England region. The Engineering Equation Solver program was used to build a mathematical model of the system. An analytical model was created that captures the thermal resistances and calculates the energy transferred throughout the system. The parameters of the model were iterated to determine how they affected the energy output of the system. The final design selected optimized the system yield. Consequently, the final design of the system significantly reduced the size and increased the efficiency of the ground portion of the system.

Advisors: Robert Daniello, Christopher Scarpino

Thermofluids

Deep Ocean Energy Harvesting

Jasmine Feliciano, Nicholas Hernandez, Yao Long, Julia White

In a world where fossil fuels are being steadily depleted, new energy sources are being sought out. Ocean energy is a renewable resource that has yet to be fully utilized. Waves are a consistently available resource, in spite of weather changes or time of day. Wave energy has the potential to supply power for a variety of applications ranging from supplying the grid to remote applications such as marine research and ocean reconnaissance. The goal of this project was to use a point absorber style wave energy converter to harvest the kinetic energy of waves. We designed and built a 1:15 scale model to test the mooring capabilities and power output. In order to calculate the power output, we measured the pressure output and stroke length, which could then be scaled to estimate a full-size wave energy converter.

Advisor: Robert Daniello

Thermofluids

Conceptual Design of an Advanced 10 MW Ocean Thermal Energy Conversion System in Jamaica

Melody Shum, Valentina Vacarez

Ocean Thermal Energy Conversion (OTEC) is a clean energy marine system that utilizes the difference in warm surface temperature and the cool deep temperature of the ocean to produce power. There has been previous investigations in this large-scale ocean energy extraction system however, the small temperature difference in the ocean waters yield inefficient power output. In an effort to design a 10MW OTEC system, extensive research has been done to achieve maximum energy output. An offshore OTEC system powered by an auxiliary energy source located 30 km off the shores of Jamaica with average surface temperature of 27.7C and deep temperature of 10C at 100m. Binary fluids such as ammonia, propane, and inorganic fluids were incorporated into the system to maximize power output. The performance of the conceptual design simulated with auxiliary energy sources and binary fluids have demonstrated to be a potential thermal power source that could assist to meet the energy demands of Jamaica.

Advisor: Selcuk Guceri

Thermofluids

Jet Blast Energy Harvester

Constantine Christelis, William Dziuban, Jessica Norman

The transportation sector is one of the largest energy consumers in the US. Reducing airport energy consumption would benefit the environment. This MQP designed a system to effectively and efficiently harvest energy from jet blast at commercial airports. The system consists of a hydraulically actuated flap to redirect airflow, a funneled duct that leads to a turbine bank, and a diffuser to allow air to exit the system. Positioned at the end of a runway, it is designed to be stowed under the runway surface in order to have minimal impact on regular air traffic operations. Both the mechanical system and the flow were modeled, and testing was performed on prototypes for comparison with some aspects of the modeled behavior. According to our models, if jet blast was captured from all of Logan Airport's flights, our system could produce enough energy to power the equivalent of 730 homes year-round.

Advisor: Fiona Levey

Thermofluids

Computational Fluid Dynamics of a Wind Turbine

Harrison He, Alan Hunt, Charlotte Moore, Theodore Wallach

Currently it is difficult to determine wind speed or power output for a proposed wind turbine without on-site wind speed data and computational fluid dynamics (CFD) analysis software. Our Major Qualifying Project is to compare the results from SolidWorks's Flow Simulation package with data that was collected from an actual wind turbine test rig that was custom designed and manufactured. To do this, air was rotated through modeled wind turbine blades in the CFD simulations. On-site, an anemometer collected the local wind speeds while a free spinning wind turbine test rig measured the RPM. The local wind speed and RPM data was then compared to the predicted results from the CFD simulations.

Advisors: David Planchard, John Hall

Thermofluids

Energy Harvesting from Rainwater

Carolyn Detora, Kayleah Griffen, Nicole Luiz, Basak Soylu

The purpose of the project was to provide electricity that was sufficient for charging cell phones in rainy locations with limited electricity access. A household rainwater energy harvesting system was designed, prototyped, and tested to determine the feasibility of rainwater as a source of renewable energy. The system produced a power of 0.74 Watts and a 14.8% efficiency at 8 GPM. When scaled for a month with higher rainfall intensity, the current system could charge about 1.8 cell phones. This project proved the concept of a rainwater energy harvesting system. The system could be combined with a filtration system and holding tank to collect drinkable water so that the system serves a dual purpose for people with limited access to electricity and water.

Advisor: Brian Savilonis

Thermofluids

Kármán Vortex Street Energy Harvester For Picoscale Applications

James Doty, Christopher Mayforth, Nicholas Pratt

The Kármán Vortex Street, a phenomenon produced by fluid flow over a bluff body, has the potential to serve as a low-impact, economically viable alternative power source for remote water-based electrical applications. This project focused on developing a self-contained device utilizing thin-film piezoelectric transducers to generate hydropower on a pico-scale level. A nozzle was created capable of generating specific-frequency vortex streets through parametric SOLIDWORKS modeling and flow simulation software. The prototype nozzle was verified to produce an increased fluid flow velocity. Piezoelectric testing resulted in a range of measured dominant frequencies and an average power output of up to 100 nanowatts. The output frequencies were inconsistent with predicted values, likely due to an unreliable testing environment and the complexity of the underlying theory. A more stable testing environment, being able to better verify the nozzle velocity, and fine-tuning the piezoelectric circuit would allow for a higher, more consistent power output.

Advisor: Brian Savilonis

Thermofluids

Experimental Study of Flexible Electrohydrodynamic Conduction Pumping

Pavolas Christidis, Nathaniel O'Connor, Nicolas Vayas Tobar

Electrohydrodynamics (EHD) deal with the interaction between electric fields and fluid flow. This interaction can result, for example, in electrically induced pumping, flow distribution control, or mixing of fluids. There are three kinds of EHD pumping mechanisms: ion-drag pumping, induction pumping, and conduction pumping. EHD pumps are advantageous for their small size and lack of moving parts.

This paper presents the design and performance characteristics of a flexible EHD conduction pumping technology in macro- and meso-scales. Specifically, the flow field generated by flexible EHD conduction pumps is measured on a flat-plane and in various internal and external configurations. The results show that the flexible EHD conduction pumps are readily capable of generating significant flow rates in macro- and meso-scales by simply inserting them into the desired setups. Unlike mechanical pumps, flexible EHD conduction pumps are lightweight, can flex into complex geometries such as a cylinder or cone. Additionally, EHD conduction pumps can be scaled down to the micro-scale which is impossible for a mechanical pump. This technology shows potential for use in a wide range of applications, including thermal control of flexible electronics, cooling of high power electrical systems, actuators for soft robotics, and medical devices.

Advisor: Jamal Yagoobi

WPI