Worcester Polytechnic Institute

Mechanical Engineering Department

2012 Project Presentation Day
April 19, 2012
Schedule for Project Presentation Day
Mechanical Engineering Department
April 19, 2012

Refreshments 8:00 AM Outside HL116 (students) HL102 (judges)

Morning judges assemble 8:00 AM HL102

MORNING SESSION: 8:30 AM – 11:00 AM

Biomechanical Higgins Labs Rm154
Design Higgins Labs Rm218 Higgins Labs Rm234
Redesign and Fabrication of a Formula SAE Race Car Washburn Rm108
Manufacturing/Materials Washburn 1st Floor
Robotics Atwater Kent 1st Floor
Autonomous Blimp Washburn Rm108
Thermofluids Higgins Labs Rm202

Morning judges assemble 11:00 AM HL201

Morning finalists announced at 11:45 AM in HL218

Lunch 12:00 – 1 PM Students HL116 Judges HL102

AFTERNOON SESSION: 1:00 PM — 3:30 PM

Afternoon judges assemble 11:00 AM - 11:45 HL102
Afternoon MQP award competition HL218 & HL234
Afternoon judges caucus 3:30 PM – 4:30 PM HL102

Winners announced 4:30 PM – 5:00 PM HL116
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Design of Medical Device

John Dunbar, Christopher Farren, Mari Freitas

An interventional cardiologist (IC) performs procedures using a transesophageal echocardiogram transducer (TEE). The TEE is positioned by an echo cardiologist who is present for the entirety of the procedures. The purpose of this project was to redesign the user interface of the TEE in order to minimize the role of the echo cardiologist and give more control to the IC. This was accomplished by creating an extension of the TEE control system that can remotely control the TEE from a distance of five feet. Preliminary designs were created using cable and fluid hydraulic systems; however, both types of systems were problematic. A pseudo fluid system consisting of tubes filled with ball bearings was developed to capture the positive aspects of the cable and fluid systems. The user interface of the new system consisted of two rotatable knobs that actuate rack and pinion gear sets, which push the pseudo-fluid balls through tubes. At the distal ends of the tubes, the balls move the racks of rack and pinion gear sets that in turn rotate shafts in the current TEE. The resulting user interface has similar ergonomic and mechanical properties as the original TEE.

Advisors: A. Hoffman, H. Ault

Sponsor: Philips Healthcare
Biomechanical
Room 154 Higgins Labs

Device to Dynamically Stretch Cells During Microscopic Visualization

Brent Duoba, Joseph Lombardo, Kyaw Thu Minn, Juan Rodriguez

Cells in the physiological systems are constantly subjected to mechanical forces in the form of tension, compression and shear \textit{in vivo}. Research has indicated that such mechanical forces are responsible for regulating cell growth, reorientation, differentiation, proliferation, remodeling and gene expression. Additionally, mechanical forces play a significant role in pathologies. Different cells in the physiological system will respond differently depending on the type and profile of mechanical strain exerted on them. Therefore, it is important to understand how different mechanical forces dictate cellular functions of different cell types. In order to study cellular responses to substrate strain \textit{in vitro}, several commercial devices have been developed. However, major setbacks of these devices include the failure to allow “real-time” analysis of cellular responses, inability to provide uniform uniaxial and equibiaxial strains as well as limited operation time. In order to overcome such shortcomings, a novel stretch device using four linear motors to apply cyclic mechanical stretch to cells was developed. In addition, a unique Polydimethysiloxane (PDMS) substrate was fabricated to translate mechanical forces from the motors and apply uniform strain to the cells seeded on the substrate. This new system will facilitate mechanobiology by enabling cyclic stretching of cells biaxially at variable strains (0 – 20%), directions (pure uniaxial to equibiaxial) and frequencies (0.1 – 1Hz) for a minimum of 6 hours as well as allowing “real time” analysis of cells under a standard inverted microscope while stretch is applied.

Advisors: K. Billiar (BME), D. Granquist-Fraser (BME)
Developing a Three Dimensional Finite Element Model of the Anterior Cruciate Ligament to Examine the Risk Factors for Women during the Sidestep Cutting Maneuver

Sandy G. Wu

Anterior cruciate ligament injuries have been increasing throughout the years and close to one billion dollars are spent annually on ACL injuries. Women are 4 to 6 times more susceptible to ACL injuries than men. Many researchers have proposed risk factors that are related to the higher incident rates seen in women. There currently isn’t enough research to verify these risk factors. It is important to find prevention methods to reduce the instances of ACL injuries. The goal of this project is to examine how risk factors affect the ACL during a sidestep cutting maneuver. A three dimensional finite element model of the ACL and knee was developed and combinations of loads are applied. Using the finite element analysis program ANSYS, the stresses on the modeled ACL are examined. The model is tested against risk factors that are proposed to be related to the increase in incident rates in women compared to men, such as difference in ligament size, quadriceps angle, and muscular strength.

Advisor: C. A. Brown
Rehabilitative Robotic Glove

Michael Delph, Sarah Fischer, Philip Gauthier, Carlos Martinez Luna

Stroke affects thousands of people annually, and a large percentage of people are left with weakened hands. Repetitive hand movement is used as a rehabilitation technique in order to regain hand movement and strength. In order to facilitate this rehabilitation, a robotic glove was designed to aid in the movement and coordination of gripping exercises. This glove utilizes a cable system to open and close a patient’s hand. The cables are actuated by servos, mounted in a backpack. The glove can be controlled in terms of finger position and grip force through switch, program, or EMG inputs. This project developed a working prototype of the rehabilitative robotic glove which is capable of actuating finger movement.

Advisors: G. Fischer, E. Clancy (ECE)
Mapping the Histology of the Human Tympanic Membrane by Spatial Domain Optical Coherence Tomography

Cory Rutledge, Michael Thyden

The tympanic membrane is one of the major structures of the ear that aids in the hearing process, giving humans one of the five major senses. It is hypothesized that sound induced displacements of the membrane, which allow humans to hear, are directly related to the membrane’s medial layer. This medial layer is comprised of a network of collagen fibers. Limitations in available medical imaging techniques have thus far inhibited the further study of these fibers. In this paper, we detail an imaging system that we developed with the capability to quantitatively and noninvasively image the internal structures of biological tissues in vitro through spatial domain optical coherence tomography (OCT). By utilizing spatial OCT, we can correlate the characteristics of internal collagen fibers to sound induced displacements in the tympanic membrane. This will eventually lead to improved modeling of the middle-ear and a better understanding of hearing mechanics.

Advisor: C. Furlong

Sponsor: Massachusetts Eye and Ear Infirmary - John J. Rosowski and Jeffery Tao Cheng
The Development of a Radial Artery Line Placement Simulator

Likuvi Chebelyon-Dalizu

Currently, there are many medical simulators that provide a means to train medical practitioners on various medical procedures like arterial or venous access, surgeries, and patient care. There are many factors that determine the efficacy of a particular medical simulator in teaching a medical procedure. This project reports the details in developing a medical simulator for teaching arterial access into the radial artery. The objective was to learn the aspects of creating a model feasible for teaching this procedure, and a comprehensive study was conducted evaluating the kinematics, anatomy, and physiology of the human arm. A model of a radial arterial placement simulator was produced and presented to our clients and further validated by medical practitioners.

Advisor: G. Gaudette (BME), B. Savilonis
Dynamic Knee Device for Real Time Acquisition of Angular Flexion of the Knee Joint During Race Walking

Corrie Avila, Eric Dickinson, Brian Moore, Kayla Rayworth

This project report describes the design, construction, and testing of a device that measures knee flexion angle for the competitive sport of Race Walking. The goal is to provide the sport with a means of indisputable angular measurement for the purpose of improved rule enforcement. Our device is designed to aid both judging officials and competitors alike in their respective training through real time accurate angular readout with both visual and audible alerts. Data analysis compares the three angular measurement mediums: the human eye, our device, and high-definition video recording. The results of this analysis show a general agreement for all modes, complemented by personal recommendations for future improvements.

Advisor: B. Savilonis
Headgear for Soccer Players

Isaac Barbour, Nikole Connor, Elisabeth Jeyaraj

Participation in sports greatly increases the chance of concussion, and in a study on soccer it was determined that 62.7% of players experienced at least one concussion during a season. The goal of this project was to address existing gaps in the efficacy of available soccer headgear. Design considerations included reducing head accelerations during collisions, thermal regulation, and size adaptability, while not limiting the users’ mobility during game play. Tests showed that the headgear prototype decreased average linear accelerations by 14% when compared to a bare head-form, while only increasing head exterior temperature by 2.9 °F during exercise. Feedback from university soccer athletes showed positive results for comfort and fit. Overall, the prototype addressed the existing gaps in the effectiveness of competing products and met the team’s objectives.

Advisor: B. Savilonis
Biomechanical Evaluation of the Restrainer Component in a Horse Leg Protective Device

Xiaolin Zhen, Xiaowen Zhen

A restrainer band is often used to minimize hyperextension of tendons in racing horses. The current restrainer band design does not enable constant tension in the restrainer band and therefore provides insufficient protection of the horse leg from injuries. In this project, a static analysis of the fetlock joint was performed, and the required restrainer band tension was determined based on the band elastic elongation and the joint statics. It was found that the suspensory ligament tendon tension contributes to most of the fetlock joint moment, and the restrainer band should be designed to produce counter tension to suspensory ligament tension. The restrainer band can be redesigned to obtain minimum and maximum restraint tensions of 87N and 1620N to reduce 10 percent fetlock joint moment.

Advisors: S. Shivkumar, A. Hoffman

Sponsor: Cummings School of Veterinary Medicine at Tufts University
Enteral Feeding Connector Redesign

Talha Riaz, Kushi Sellahennedige

Enteral feeding is an important daily task for patients that are unable to consume food orally. However, the lack of unique medical connectors in healthcare delivery mechanisms for various liquids and gases has resulted in misconnections, some of which proved fatal. The International Organization for Standardization formulated ISO 80369-1, a standard that specifies general requirements for small-bore connectors, which conveys liquids or gases in healthcare applications. The standard provides the methodology to assess non-interconnectable characteristics of small-bore connectors based on their inherent design and dimensions in order to reduce the risk of misconnections between medical devices. The team developed a variety of design concepts to replace existing devices used for enteral feeding. These designs were subject to critical design reviews coupled with augmentations which culminated in a unique rotatable connector design for enteral feeding. The feeding system has a two layer mechanism attached to the abdomen with a unique connector that fits and locks into the feeding system. The device contains seals that ensure the connector does not leak. Prototypes were also built throughout the design review process to test the various design functionalities. The final prototype unit, which satisfies all specifications of the new international standard, is trim in size so users can wear it comfortably and confidentially and it can be operated easily by elderly users with a single hand.

Advisors: J. Sullivan

Sponsor: Boston Scientific Corporation
Design of a Rowing Foot Stretcher

John Madura, Daniel Pierson

In crew racing shells, the foot stretcher attaches the shoes to the shell and provides a surface to push off. Significant advancements in rowing foot stretcher technology have not been made in several decades. The background research, collected from patents, rower input, and international safety requirements identified several aspects of the foot stretcher that could be improved. A working design was developed and analyzed using solid modeling, axiomatic design, and finite element analysis. A prototype was then created and assembled for user testing. Testing was conducted using a modified ergometer and consisted of power workouts to ensure ergonomic and power requirements were met. Based on the results of testing 8 rowers and design analysis, this project’s design was found to make the rower more comfortable, regardless of gender, ability, and rower size. Furthermore, it improves the rower’s ability to adjust to their own physiology, without decreasing the performance of the foot stretcher and power output of the rower.

Advisors: H. Ault, A. Hoffman
Joining Method for Mass Production of Bamboo Bicycle Frames

Joshua Chan, Kyle Hobin, Ero Iordanou

Bamboo bicycles are currently in production for sale in both domestic and foreign markets. In third world countries such as Ghana and Ecuador bamboo bicycles are targeted to be an inexpensive and sustainable method of transportation. Prior technology uses a time and labor-intensive composite layup to join frame tubes. This project set out to improve the production method for these bicycles by developing a more efficient method to create the joints. To facilitate production of the bicycle, fixturing and manufacturing procedures were also developed.

Advisor: C. A. Brown
ACL Protective Footwear Design

Michael Doyle, Nicholas Workman, Jessica Shelsky

ACL tears that are not the direct result of contact with another player are a regular occurrence in athletes. The reduction of such tears would keep more athletes on the field participating in their respective sports. The objective of this project is to design a load mitigation device that will reduce the occurrence of non-contact ACL injuries in athletes. Research has already been conducted on the causes of ACL injuries. Using this data and further research into preventing ACL tears we created a system that mitigates the forces associated with non-contact ACL tears. A prototype design was realized using Axiomatic design principles. A mold for the prototype was modeled in SolidWorks then created using CNC machining. The prototype was tested using a force plate analyzed using Netforce software for data acquisition and Bioanalysis software for gait, balance and power; and with a uniaxial tensile test on an Instron machine. Through testing the prototype exhibited characteristics that would reduce the occurrence of ACL injuries.

Advisors: C. A. Brown, G. Gaudette (BME)
Design
Room 218 Higgins Labs

Redesign of a Dental Mirror

Joshua Bernier, Steven Knapp

Dental mirrors allow for dentists or hygienists to view parts of the mouth that would otherwise be difficult or impossible to see. During dental procedures this mirror can become soiled with debris which causes the mirror’s reflectivity to be reduced. The current solution to this problem involves removing the mirror from the patient’s mouth to be cleaned. The goal of this MQP is to develop a method of effectively removing debris from the dental mirror surface while remaining inside the patient’s mouth. A disposable wiper attachment for existing dental mirrors was developed through a process of ideation, design, and analysis. The attachment consists of a rod with a wiper at the end that is pushed through a casing which is attached to the mirror handle. By pushing a thumb grip connected to the rod, the wiper deflects up the mirror surface and cleans off the debris in the process.

Advisors: E. Cobb, A. Hoffman
Design and Demonstration of a Heat Exchanger for a Compact Natural Gas Compressor

Jessica Holmes, Calvin Lam, Bradford Marx, Andrew Nelson, Christopher O’Brien

As natural gas is compressed, the temperature increases significantly and must be cooled before it can be processed further. However, current heat exchangers for this application are rather large and inefficient. The goal of this project was to design a more efficient and compact heat exchanger to be used in conjunction with OsComp’s rotary-positive displacement natural gas compressor. The design incorporated heat pipes as a means to improve the efficiency of the overall heat transfer. The design has a total footprint of 0.364 m² and a volume of 0.849 m³. The footprint is 65.5% smaller than the average heat exchanger currently available on the market (0.555 m²) whereas the volume is 154% larger (0.55 m³). A scale model was constructed and tested using the exhaust of an internal combustion engine as the source of hot fluid.

Advisor: S. Evans

Sponsor: OsComp Systems
Ambulance Universal Chassis Analysis and Suspension Design to Improve the Efficiency of Care

Nicolas Gardiner, Doug Griesbach, Connor McCann, Nicholas McDonald

The pre-hospital work conducted by EMTs in an ambulance vehicle is very important. Patients of all kinds can receive a wide range of pre-hospital care; from diagnosis, CPR and stabilization to transportation to medical hospitals. Surface road vibrations are known to influence the quality, efficiency and safety of care in an ambulance. This MQP focuses on understanding the mechanics of the chassis of an ambulance in order to design a new chassis that can sustain the weight of a typical ambulance and also be able to suppress the surface road vibrations. We investigate all alternative suspension designs to implement and analyze the most accommodating design. Furthermore, we chose hydropneumatic suspension as the best alternative to current suspension systems in ambulances. We designed a bolt-on kit for aftermarket installation of hydropneumatic suspension into current ambulances using our 2004 Ford F-350 ambulance as a template. Our proposed chassis provides better ambulance ride quality compared to existing ambulance vehicles.

Advisor: M. Fofana
Renewable energy cooking environments have evolved since humans learned to utilize fire as a tool. The purpose of this project is to update this technology to assimilate into a modern kitchen. The process involves modifying an antiquated, wood-burning stove’s combustion chamber, cooking surface, and exhaust system. With the correct modifications, a modern cooking stove can use renewable resources to efficiently and safely cook a meal for a full size family. Testing was done to ensure the newly-designed safety measures functioned as intended, while allowing the user to prepare a meal within similar time constraints of other modern stoves.

Advisor: M. Fofana
**Design**  
Room 218 Higgins Labs

**Water Filtration by Reverse Osmosis Device**

Shane Bellingham, Robert Flaherty, Daniel Metcalf, Alex Pittera, Jose Sosa, Garrett Yablonski

The purpose of the report is to analyze the most promising methods for distilling pure water from otherwise unusable water: Reverse-Osmosis with preprocessing. By forcing the water through a fine membrane the system removes the need for heat to purify the water. High pressures in the filtration process allow use of salt water, which comprises the majority of the water on the planet, and waste water to create a distillate which is safely consumable and for use in electronic cooling systems. Eliminating fuel consumption in the system decreases cost and creates an environmentally friendly system out of a process usually responsible for the release of large quantities of greenhouse gases. Preprocessing allows even the most polluted waters to be passed safely through the membranes without the destruction normally caused by chemical pollutants often found in water. Additional processing can also be performed to refine the water into deionized water without significant impact on water production. To increase the efficiency of the system, the fluid dynamics through the pipes and pump were analyzed to search for areas of weakness in the design. The ultimate goal of the project is to decrease electricity consumption and increase the total water output of the system. These improvements are vital as they will make fresh water more readily available throughout the third world as well as decrease the environmental impact of a lifesaving process. The availability of fresh water is one of the greatest challenges facing many developing nations all over the world and the improvement of Reverse-Osmosis water purification system shows the greatest potential for making fresh water available to all people cheaply and efficiently.

Advisor: M. Fofana
Design
Room 218 Higgins Lab

Impulse Turbine Medical Cutting Device

Nicholas Mercurio

Tissue sampling is becoming a more common diagnosis method in the clinical field because of its diagnosis accuracy; however, some current methods involve at least two medical instruments for cutting and sampling, which makes procedures time consuming, invasive, and expensive.

To overcome these imperfections our group has designed a millimeter scale medical device, which can cut and suction tissue samples simultaneously at a high rotation speed. The device can be broken into three portions: power, cutting, and sample delivery. The impulse turbine, a major component of the power portion, is used to generate a high-speed rotation to the shaft. With a high rotation speed, the cutting tip of the shaft can cut the tissue with the required torque and cutting force. This project focuses on the structural analysis of the existing device by analytical and experimental methods to draw conclusions that could help in future designs.

Advisor: C. Furlong
Link Conveyor Modeling

James Alleva, Kathryn Byorkman, Samantha Dubois, Stephanie Klegraefe

The aim of this project is to provide the sponsor with a dynamic computer model that accurately approximates their solid-link, index-dwell conveyor belt and can be adjusted to test alternate scenarios. Using background information including research into index-dwell conveyor systems, mathematical models, relevant computer models, past research, and data provided by the sponsor, the team developed their methodology. The cam profiles were created in Dynacam and the link was tested using finite element analysis. The team then created scripts in MATLAB to solve the differential equations for the one, two, and 85 degree of freedom (DOF) cases. The 1 DOF model was verified using Dynacam and The modified sinusoid cam profile was determined to be the best because the displacement, velocity, and acceleration had the smallest discrepancies from the theoretical for the 85 DOF model.

Advisors: R. L. Norton, D. Lados

Sponsor: P&G Gillette
Vibrational Modeling of Bat-Ball Collision

Brandon Boucher, Gregory Mannke, Mitchell McClune

The purpose of this project is to develop a mathematical model of a bat-ball collision which takes into account the energy lost due to vibration experienced when the bat is struck at varying points along its length. The method we propose is to subtract the kinematic losses due to vibration from the existing rigid body model for bat-ball collisions. By comparing the rigid body model to the model we construct during vibration analysis, we will be able to find the “sweet spot” of the bat in terms of the modes of vibration. This allows us to compare our vibrational “sweet spot” to the rigid body velocity model to examine how the two models simultaneously relate to outgoing ball velocity. In turn, we were able to determine that a “sweet spot” of a bat is the location where outgoing ball velocity is at a maximum due to minimal kinetic losses due to vibration.

Advisor: M. Richman
Enhanced Strobe Reflector

Chrystian Dennis, Alexandra Sanz-Guerreo

It is necessary to warn the hearing impaired in case of an emergency, however, each strobe light requires immense power and current. By maximizing the efficiency of the power input, it will be possible to connect more strobe lights to the fire protection system. To do this there is a need to find a working ray tracing program for testing, specify requirements for the new design, create a method of statistical analysis, and finally make a 3D model. According to the simulation results, about 40% of the power supplied to the fire alarm can be saved along with a 5% efficiency increase.

Advisor: Y. Rong

Sponsor: Tyco International Ltd.
Stability of Three Wheel and Two Wheel Bicycles

Dimitri Lurie

The goal of this project is investigation of the stability of some non-trivial transportation devices, such as motorcycle with a side car, and a two-wheel bicycle, under various dynamic conditions.

The first approach is a theoretical study of the stability in the motion of a motorcycle with a sidecar. Its specific feature is its lack of symmetry. In the project, conditions were obtained that guarantee directional, lateral, and, most importantly, rollover stability.

The project also studies the dynamic control maintained over a bicycle through the course of its motion.

The first dynamic topic concerns the self-stability of a bicycle where the gyroscopic effects have been removed. Only recently (2011) has it been realized that an uncontrolled bicycle without any gyro effects can demonstrate self-stability due to an appropriate feedback from the steering column alone. In this project, we find values of some parameters that maximize the forward velocity range for uncontrolled stability.

The second dynamic topic concerns the controlled stability of a moving bicycle. Its vertical position is then maintained by a rider who properly operates the handlebar. A bicycle is similar to an inverted pendulum acted upon by an additional force created through rotation of the handlebar. The main idea is to operate the handlebar so as to make this force mimic the force that appears when fast vertical oscillations of a pivot stabilize an inverted pendulum. As a consequence, the bicycle can be stabilized for small forward velocities. This is an improvement compared to uncontrolled stabilization.
Design
Room 218 Higgins Lab

Redesign of a Single Screw Extruder

Stephen Jenkinson, John Kreso

This project involved the redesign of a two decade old plastic extruder. Diagnostics and many forms of troubleshooting were needed to progress with our revamping of the extruder. The biggest setback during our project was the lack of information on the model. Without the proper name plates or the existence of the company moving ahead took time and use of many recourses. A cooling method was needed to maintain the structure of the extruded plastic and a platform for the plastic to continue moving on which we decided to design a water bath and roller system.

Advisor: S. Shivkumar
Design
Room 234 Higgins Lab

Self-balancing in Rotating Machinery

Cody Harrop, Eric Montague, Vu Nguyen

In rotating machinery, mass imbalances are unavoidable and can lead to large vibrating forces and displacements. These imbalances, which in many cases are unknown, can be corrected by a passive balancing system, which is more advantageous than an active balancing system in terms of complexity, as it does not require a sensor-actuator system. The project will investigate the method of passively correcting mass imbalances in a rotor operating above its critical speed using ball balancers. This passive balancing phenomenon will be described theoretically and a working model will be fabricated to demonstrate this principle. The device will also be used to test the ability of the ball balancers to achieve a stable balancing position under different conditions including rotation speed, number of ball balancers, addition of damping fluid, and critical speed of the system. Ball position will be observed with stroboscopic illumination and the vibration of the rotor will be measured using a dual-axis MEMS accelerometer.

Advisors: M. Dimentberg, J. Hall
Redesign and Materials Optimization of the Nor'Easter Engine

Daniel Brundige, Stanley Mui, Peter Osswald

The design team was assigned the task of redesigning the Nor’Easter helicopter engine for O’Neill Motor Company. Three engine configurations (Diesel powered, high power gas, and low power gas) were optimized to minimize size and weight while producing the highest possible power to weight ratio. The engine alleviates the need for a tail rotor by powering cam-driven concentric counter-rotational shafts that need neither a transmission nor crankshaft to operate. Composite steel-aluminum cams were designed to minimize weight while maximizing fatigue life. Bonding methods for conjoining the dissimilar metals were researched and tested. To reduce surface fatigue on the cams, followers with logarithmic profiles were developed to eliminate stress concentrations. The engine achieved a power to weight ratio of roughly 1:2 which is a competitive output for unmanned aerial vehicle applications.

Advisors: D. Lados, R. L. Norton

Sponsor: O’Neill Motor Company, Inc.
Design
Room 234 Higgins Lab

Product Insertion Fixture

Chao Lian, Blake Reeves, Catherine Shea

The sponsor utilizes a manufacturing process that requires the insertion of a product into a housing slot. This stage of the assembly has been a significant source of scrap however, the primary cause is undetermined. This project focuses on the design of a testing fixture to simulate the product insertion process and to induce a variable offset between the tooling and housing to determine the effects of misalignment on the success of assembly attempts. The tooling is actuated using a linear servo motor to simulate the tooling path used in the assembly machine. The nest holding the housing is mounted to a two axis, micrometer-driven linear stage that is used to induce an adjustable offset between the housing and tooling in the plane perpendicular to the tooling approach direction. Sensors are used to align the product with the housing slot and to measure the geometric characteristics of the product prior to the assembly attempt. The nest and tooling are mounted on intermediate plates that allow more than one product line to be accommodated.

Advisors:  R. L. Norton. D. Lados

Sponsor: P&G Gillette
Design
Room 234 Higgins Lab

Product Transfer Tooling Redesign

Stephanie Hoag, Matthew Kellas, Antonia La Bella, Mark Vanacore

Procter and Gamble’s cartridge transfer station utilizes a gripper loading mechanism to transfer their finished products from the assembly conveyor into their shipping and storage containers. Currently, this gripping mechanism is actuated by physical contact with the product, causing undesired surface deformations, shear marks and chipped product housings within the finished product. The project team developed and designed a new gripper loading mechanism which utilizes a spring dampened toggle-linkage gripper to pick and place the product. This new linkage system is actuated by a pneumatic cylinder, a method currently being utilized by Procter and Gamble. This new mechanism does not contact the product during its loading, completely eliminating the chance of physical deformation in the finished products.

Advisor: R. L. Norton

Sponsor: P&G Gillette
Design of Residential Solar Power Mounting System

James Rossman Anderson, Cody Anthony Beckel, Mariela Lizet Castillo, Michael E. Osley, Samantha R. Sinapi

Small, residential solar power can be part of the solution to the energy crisis. However, there are very few options for a homeowner to purchase household solar mounting systems. To meet this need, a single solar panel ground mounting system has been designed that is functional, economical and easy to install. The design includes a base with a detachable center square pole and an angle adjuster allowing residential use throughout the US. The retail price is less than $1,500 and has easy to follow instructions for installation.

Advisor: R. Sisson
Redesign and Fabrication of a Formula SAE Race Car

Krysten Carney, Richard Davis, Jonathan Leith, Anton Kirschner, David Piccioli

The purpose of Formula SAE is to provide students an opportunity to design, fabricate, and then demonstrate the performance of a prototype race car. This project focused primarily on the redesign of the previous WPI Formula SAE car by addressing the strengths and weaknesses of the previous car. The areas addressed include the chassis, front suspension components and geometries, tuning the continuously variable transmission (CVT), the air intake, exhaust system, engine mounting, fuel tank, braking components, and the uprights for the front suspension. With weight reduction in numerous systems of at least ten percent, careful design of the intake and exhaust, and increased height of the chassis roll hoops and length between the front roll hoop and bulkhead, the final product is lighter, more efficient, and more spacious than its predecessor.

Advisor: D. Planchard
Development of a Visual Humidity Indicator for 3D Printed Cores for Metal Casting

Tiffany Chau, Paul Finn, Jesse Ouellette

During metal casting, cores are emplaced in the mold. Cores with high moisture content give rise to porosity in the cast part therefore impairing quality. The project goal was to create a visual humidity indicator to determine moisture content of a 3D printed core. We accomplished this by successfully incorporating phenolphthalein into sand based powder in the printing process. The success of our project will optimize digital manufacturing and metal casting by ensuring high quality cast products and improved productivity.

Advisors: D. Apelian, N. Kazantzis (CHE)

Sponsor: Viridis3D
Adhesion of Silver Nanoparticles

Robert Cakounes, Michael Judelson

To better understand the life-cycle of a nanoparticle it is important to study how nanoparticles adhere to substrates. This project implemented various removal techniques to study the adhesion strength of silver nanoparticles to carbon substrates with various surface chemistries. TEM characterized the size, distribution, and agglomeration of the nanoparticles. IR confirmed the surface chemistry. This project developed a semi-quantitative method to determine adhesion strength. A brush is run along the surface and the change in concentration is measured using AAS. Our project shows a correlation between the force of adhesion and the surface chemistry.

Advisors: D. Brodeur (CHE), N. Burnham (PH), J. Liang

Sponsor: Grant-In-Aid from the National Academy of Sciences, administered by Sigma Xi, The Scientific Research Society
Roughness and Reflectivity of Mass Finished 6061 T6 Al Surfaces

Nicolas Allen, Jeffery Laun

The objective of this Major Qualifying Project is to study surfaces produced by mass finishing. To better understand the basic mechanisms we have determined the normal forces between a surface and a sample mass finishing media by measuring scratch depths from brief mass finishing times on polished surfaces, testing the micro-hardness of the surface, and measuring the shape of the abrasive particles in the media. We also studied how the surface produced by mass finishing effects the shininess of the surface. In particular scale-sensitive fractal analysis allowed us to identify the scales at which the surface roughness and surface reflectivity correlate the best. There appears to be limited literature on both the texture and reflectivity of mass finished surfaces. The results of this work should support product and process design for mass finishing.

The parts were machined using HAAS CNC machines. The finishing machine used is a BelAir centrifugal disk finishing machine. The surfaces were measured using an Olympus LEXT 4000 laser (409 nm) scanning confocal microscope. The surface reflectivity was measured using an Olympus USPM-RU III micro spectrophotometer.

Hardness and scratch depth tests show that for a pyramid type abrasive media the forces on machined and polished cylindrical aluminum alloy (6061 T6) parts (r=0.5 in., length=1.0 in.) are 16-19 mN. Regression analyses have shown a correlation coefficient $R^2$ of 0.95 between relative area and surface reflectivity in the scales of 2-5 µm², at a wavelength of 405 nm.

Advisor: C. A. Brown

Sponsor: WPI Surface Metrology Laboratory
Surface Metrology for Quantifying the Difference in Surfaces

Jessica Booth, Mackenzie Massey

The objective of this work is to compare six rolling die specimens based on surface characteristics and material properties and to use these comparisons to make hypotheses about improving the lifetime of similar dies. These hypotheses are important in providing insights into why some tools perform better than others which can give manufacturers a competitive edge when improving their tools. This comparison can also help identify differences in wear mechanisms, which can demonstrate variations in operating behavior or potential material weaknesses. Surface characteristics were quantified by measuring the new and used portion of the thread surfaces of six die specimens. These measurements were compared using F-tests of conventional parameters in addition to similar tests done on Area-scale and Complexity plots. Material characteristics were compared by examining the alloy, microstructure, and microhardness profiles on threads. Failure modes on each die were identified by visually inspecting the surface of failed threads. It was found that the alloy and hardness were different for each die, and an alloy change could potentially be used to improve die life. It was also found that it is possible to discriminate between the surfaces of most of the dies. This leads to the conclusion that there is a likely connection between the surface characteristics of the threads and the lifetime.

Advisor: C. A. Brown
Synthesis and Characterization of Tin Oxide-Supported Platinum for Cathode Catalysts of Direct Methanol Fuel Cells

Manish Chawla, Tony Chou, Kevin McCarthy, Xi Geng

It is imperative to reduce society’s reliance upon the limited supply of fossil fuels. Direct methanol fuel cells (DMFC) possess immense potential as an alternative to current energy generation methods, especially in portable applications because of their high energy density, low operating temperature, and ease of handling. Several obstacles encountered by contemporary carbon-supported catalysts, however, are preventing widespread adoption of the technology, including prohibitive materials cost and relatively abbreviated life cycles due in part to inefficient Pt-catalyst loading and cathode degradation resulting from methanol crossover. The following research investigated the potential of tin oxide as a DMFC electrocatalyst support due to metal oxides’ high electrical conductivity, good corrosion resistance, and resistance to the effects of methanol crossover. In this paper, two synthesis methods to prepare tin oxide-supported platinum are reported: the impregnation process and the colloidal process, relying primarily on ethylene glycol as the reduction solvent. Platinum particle size, loading, and surface distribution on the tin oxide support were characterized by TEM, SEM, and XRD, while its electrochemical properties were determined by electrochemical tests. It’s physical and electrochemical properties were compared with conventional Vulcan XC-72 carbon black-supported platinum.

Advisors: R. Datta (CHE), J. Liang
Manufacturing/Materials Engineering  
1st Floor Washburn Shops

One Machine One Tool

Evan Molenda, Rockwell Shortlidge

Milling is an important manufacturing process that has been used since the start of the industrial revolution. Milling is utilized in a variety of industries, able to handle mass manufacturing to one of prototypes. This project focused on analyzing new techniques applied to milling. Research in the areas on high speed/efficiency milling provided many techniques from which to improve material removal rate, surface finish and part tolerance. Next the project compared various CAM software available at WPI, analysis of new cutting techniques available from the different packages was taken into consideration. The project’s case study focused on solving chatter problems in 4 axis machining of pistol barrels, with the intent of increasing tool life and surface finish quality as well as reducing time required to manufacture. The engineering drawing’s details are essential to understanding the requirements of the process, each feature was broken down to analyze the requirements of each tool in the machining process. The project analyzed surface finish of finished parts to understand potential causes of chatter. A redesign of fixturing assured maximum stability when cutting the part. Audio analysis determined locations of chatter, focusing the areas needing adjustment in the CAM files. The MQP project analyses new ways to systematically perform milling, while reducing manufacturing time and increasing part quality.

Advisor: M. Fofana

Sponsor: Saeilo
Material and Design Optimization for an Aluminum Bike Frame

Forrest Dwyer, Adrian Shaw, Richard Tombarelli

Fatigue is a prominent failure mechanism for mountain bike frames, and can lead to serious accidents, costly recalls, and poor product image for bicycle frame manufacturers. The team collaborated with a local bike company, in the process of developing a new 6061-T6 aluminum mountain bike, to investigate the fatigue behavior of the new frame and optimize the material/heat treatment and frame design. The fatigue testing was done in-house using a test rig specifically built for this project according to the ASTM standard F2711-08 for horizontal loading. A solid model of the frame was created and a finite element analysis (FEA) was conducted using the ASTM standard as a guide, with appropriate mechanical properties for various sections of the bike and the joining welds. The FEA model enabled the team to predict fatigue failure locations and cycles to failure, and was further validated using the experimental fatigue testing results obtained from the prototype frames. On the physical frames tested, thorough fractographic examinations were conducted to identify the fatigue crack initiation locations and crack propagation mechanisms using optical and scanning electron microscopy. To complete the project, systematic studies were performed to optimize the frame’s design, materials and heat treatment for improved fatigue resistance.

Advisor: D. Lados
Synthesis of Silicate Based Lithium-Ion Battery Cathodes

Andrew Boucher, Michael Ducey, Nathan McNeff

As technology advances, the need for alternative sources of energy arises. Batteries have been studied by many different research groups as a proper way to power everything from small devices such as cell phones to large units such as cars and factory machinery. Specifically, lithium-ion batteries have been vigorously studied due to their numerous benefits such as high energy density, high voltage and a low self-discharge rate. Thin-film lithium-ion batteries have been researched, but not many successful prototypes have been developed. These prototypes have incorporated active materials such as LiCoO2, LiMn2O4 and Li2MSiO4 (where M=Mn, Fe, Ni, etc.). Based on prior research, many of these materials vary in properties such as theoretical capacity, conductivity and cycling life. Lithium silicates, with two lithium atoms in each molecule have been proposed as candidates with higher theoretical capacity. Pure phase compounds with a general formula of Li2MSiO4 (M=Mn, Fe, Co) have been tested and each has manifested unique drawbacks. In this project we want to test the hypothesis that Li2MSiO4 with mixed M of Fe and Mn might provide superior performance to the pure phases as observed in the case of the layered LiMO2 cathodes. We first studied the synthesis of Li2FexMn1-xSiO4 through a sol gel process. Li2FexMn1-xSiO4 materials with different Mn to Fe ratios have been synthesized. Carbon coating was used to increase the active material’s conductivity. We then characterized the composites through an array of tests, including XRD, SEM and coin-cell battery testing. The results are discussed in this presentation.

Advisors: J. Liang, D. DiBiasio (CHE)
Fire Fighter PPE

Ricardo Belmontes, Barbara Hall

The objective of this Major Qualifying Project was to determine the thermal limit of a polycarbonate facemask material used by firefighters and compare it to an alternative high temperature material, polyethersulfone. The effects of repeated heat stresses on Self Contained Breathing Apparatus facemask failure were studied. A series of tests were conducted at the product level on polycarbonate and polyethersulfone samples by exposing both materials to convective and radiant heat sources. The final test recorded the time to failure of a new and used polycarbonate facemask that had extensive use by firefighters in training exercises. The results of the tests were compiled and presented to the National Fire Protection Association 1981, Standard for Open Circuit Self-Contained Breathing Apparatus for Use in Emergency Services, Technical Committee. These results may be used in the process of updating the current standard for the 2013 edition.

Advisor: K. Notarianni (FPE)
Manufacturing/Materials Engineering
1st Floor Washburn Shops

**Magnetic Braking**

Michael Scanlon

This Major Qualifying Project (MQP) is directed at creating an integrated electric motor and eddy current brake. This combination is designed to be used in the automotive industry as an electric all-wheel drive system that can be managed by available traction and stability control technology. This project does not address the control aspect of the control system; it addresses the physical concept of using an induced electromagnetic field to slow the proposed vehicle. The goal is lessening the lifetime maintenance of a vehicle and eliminating several high maintenance items. This system is designed as a “frictionless” system and although it is not completely frictionless it eliminates the need for standard hydraulic brake pads and rotors which wear and fail due to friction material loss. This saves the consumer time and money in maintenance.

Advisors: D. Planchard, A. Emanuel (ECE)
ACES characterization of damping in micro-beam resonators

Xiuping Chen, Vu Nguyen, Jason Parker

Recent advances in microelectromechanical systems (MEMS) technology have led to development of a multitude of new sensors and their corresponding applications. Great many of these sensors (e.g., microgyrosopes, accelerometers, biological, chemical, etc.) rely on vibrations of either sensing elements or elastic suspensions that resonate. Regardless of their applications, sensors are always designed to provide the most sensitive responses to the signals they are developed to detect and/or monitor. One way to describe this sensitivity is to use the Quality factor ($Q$-factor). Most recent experimental evidence indicates that as physical sizes of sensors decrease (especially because of advances in fabrication by surface micromachining) the corresponding $Q$-factors increase. This project develops a preliminary model of $Q$-factors of MEMS resonators using Analytical, Computational, and Experimental Solutions (ACES) methodology to investigate the effects of various damping mechanisms on the $Q$-factor of micro mechanical resonators. We have focused on the contributions of air damping, thermoelastic damping (TED), and surface damping to the $Q$-factor. Laser Doppler Vibrometry (LDV) and Michelson Interferometry were used to characterize the damping of tipless atomic force microscopy (AFM) probes through ring down tests. Tests were performed at various levels of vacuum with different beam geometries and coatings. COMSOL was used to model the TED as well as resonance characteristics of the beams and the computational results were compared to analytical and experimental results. It was found that as surface area to volume ratio increases beyond approximately 1 $\mu$m$^{-1}$, surface damping becomes the dominant damping mechanism. Additionally, air damping was significant at a vacuum level greater than approximately 0.1 $\mu$bar. It was also found that the surface damping was much greater with a 28 nm Au-Pd coating as compared to a 30 nm Al coating and damping increased with coating thickness. Finally, the dissipation term in the analytical approximation of surface damping was calculated for the above coatings.

Advisor: R. Pryputniewicz
Process Simulation of Mono-Layer Super Abrasive Grinding Wheels

Yann-Frederic Schoenhagen, Jonathan Vasquez

Grinding is a machining process where complexity of the process lies in the microscopic interaction within the wheel-work piece contact zone. Understanding the microscopic interaction can lead to many advancements in the area of grinding. These advancements can be very beneficial for companies designing and developing grinding wheels and grinding tools for the field. Saint-Gobain had given the opportunity to study the grinding process, specifically the interactions and performance of super abrasive wheels. Experiments were created around changing the input factors (grain geometry, cutting depth, and wear) to gain results in the outputs (force and side flow) to be able to define a quantitative relationship. Using design of experiments to reduce the number of experiments needed, 50 experiments were able to define the range needed, from which quantitative equations were derived for the Force in the X & Y direction as well as Side Flow Height and Width. Using this data, it will be possible to update current grinding parameter to simulate an entire grinding wheel interacting with a work piece material.

Advisor: Y. Rong

Sponsor: Saint Gobain
Retainable Rack Design for Large Fabrication Parts

Ryan Anderson, Melissa Chung, Richard Nazzaro

This project, in collaboration with Shanghai University, established a new rack design to help transport large fabrication parts for Caterpillar Suzhou, China. This project was completed by first gathering necessary information from Caterpillar to allow for design criteria to be established. Using the design criteria, a convergent design process was followed to narrow down three initial designs to one final optimum design. The most optimum design was then validated before being offered to Caterpillar for future use.

Advisors: Y. Rong, A. Zeng (MG)

Sponsor: Caterpillar, Inc. and Shanghai University
Dynamic Evaluation of Forces during Mastication

Justin McGarry, Anthony Spangenberger

Mastication simulators are a powerful tool for the dynamic evaluation of mechanical properties in food. A simplified reproduction of the human masticatory system is presented here to evaluate mechanical properties of foods, relevant design elements of a simulator, and the practicality of the system. The model incorporates a cam-driven linkage system moving a set of dentures, whose reaction forces are measured with strain gauges on two axes to record real-time changes in food structure that cannot be analyzed accurately in vivo. Experimental outcomes include texture profiles for a range of foods, comparison of the masticatory simulator to conventional food testing procedures, and evaluation of necessary design criteria. Ideally it will be shown that a simulator provides superior data acquisition to both traditional mechanical testing and human experimentation at a similar or lesser cost.

Advisor: S. Shivkumar
Manufacturing/Materials Engineering
1st Floor Washburn Shops

Real-Time Process Monitoring and Statistical Process Control for an Automated Casting Facility

Daniel Lettiere

In the metal casting industry, defects increase cost of production, expand required labor hours, and decrease overall productivity. Better understanding of process variables allows for successful reduction of defects. Utilizing real-time data logging technology and statistical process control software creates the framework for an effective process monitoring system. To establish a correlation between mold temperature and casting defects, a unique data logging system, capable of withstanding high temperatures, was designed. The beneficial results of this project will not only impact the process today, but will help improve future innovations in the industry.

Advisor: S. Shivkumar

Sponsor: Hitchiner Manufacturing Company
Heat Treatment Optimization of Cold-Sprayed Aluminum Alloys

Caitlin Kelley, Lauren Ketschke, Baillie McNally

Cold-sprayed aluminum 6061 alloy test samples were heat treated at several solutionizing temperatures, aging temperatures, and aging times to determine the effect of heat treatment on microstructure and hardness. The cold-spray process sprays 10-100 micrometers particles of the aluminum alloy, at velocities of 400-1200 m/s onto a substrate to form a coating of the highly cold worked aluminum alloy. The as-cold sprayed samples were solution heat treated at 530 °C, and aged at 200 °C for 30 minutes to 4 hours. In addition, as-cold sprayed test samples were heat treated at temperatures from 200 to 400 °C for times ranging from 15 minutes to 4 hours. Vickers and Knoop hardness values were compared to determine the effects of heat treatments on the microstructure and hardness.

Advisor: R. Sisson

Sponsor: Army Research Lab
Low Speed Motorcycle Stabilization Device

Adam Sears, Alexander Segala, Jessica White

The objective for this Major Qualifying Project was to create a low speed motorcycle stabilization device for a partially handicapped client. The system would remove the need for the rider of the motorcycle to place his feet on the ground at low speeds or stops, but allow uninhibited motorcycle riding at standard to high speeds. The final design focused on three major aspects, the mechanical assembly, fluid power, and microprocessor control. The outrigger deploys at 14 miles per hour with some compliance for low speed turns and becomes increasingly rigid until 4 miles per hour when the device locks to keep the motorcycle steady at a stop. The finished system was installed on a Harley Davidson Sportster.

Advisors: K. Stafford, T. Bergstrom
Pneumatic Robot Actuation System for MRI-Compatible Devices

Grant McDonald, Kellen Pastore, Gregory Overton

Modern medicine promotes the design and creation of innovative ideas. The goal of this project is to further the research in MRI compatible actuators. The proposed actuator design, known as the PRiSM, uses directed pneumatic pressure to generate rotational motion. To confirm the validity of this idea, multiple tests were designed and conducted. These tests showed that, at 60psi, the PRiSM can operate open-loop with an angular velocity of 7deg/s, while exerting a torque of 435N/mm. Optimized conditions yielded an overall maximum angular velocity of 178deg/s and an overall maximum torque of 747N/mm.

Advisors: G. Fischer, G. Cole
Robotic Kayak

Clark Bakstran, Scott Brooks, Gregory Sletterink, Nicholas Solarz, Thomas Womersley

The goal of this project was to design and manufacture an Autonomous Surface Vehicle (ASV) in collaboration with Santa Clara University (SCU) that would integrate with their existing ASV fleet. The team was responsible for designing a universal chassis that enabled it to attach to several different kayak hulls, and upgrading the electronics to a modern microcontroller architecture. The vessel is propelled by two motors and controlled by a microcontroller located onboard. The microcontroller receives commands from an off board base station, which facilitates communication between other ASVs in order to perform complex group maneuvers. The chassis and the electronics were successfully designed and implemented on the kayak, demonstrating the overall integration of the teams design to the existing fleet.

Advisor: M. Gennert (CS/RBE)

Sponsor: Santa Clara University
Lizard Inspired Tail for Dynamic Stabilization of Robotic Bodies

Michael Berlied

The purpose of this project was to determine the feasibility of a lizard inspired tail for the dynamic stabilization of robotic bodies through aerial or aggressive maneuvers. Matlab was used to create a mathematical model which was designed to test the effects of various tail designs. A physical model of one tail design was created and used to determine feasibility of the design as well as prove the accuracy of the mathematical model.

Advisor: S. Nestinger
Parallel Kinematic Manipulator

Spenser Brouwer, John Cushion, Elizabeth DeZulueta, Joshua Jannsen, Sean Townsend

Our project was to design, fabricate and implement a parallel kinematic manipulator robot with open architecture to be used in the ME/RBE 4815 curriculum for inverse kinematics and other classroom projects. The robot was designed using solid modeling software and manufactured in the WPI machine shop with use of computer aided manufacturing techniques. We developed our own programming architecture to allow control of the robot via a touchscreen GUI.

Advisor: S. Nestinger
Multi-MAV Deployment

Adam Campisi, Samuel Daley, Joseph Danner, Samantha Hilerio, Alexander Hindley, James Kirk, John Pearsall, Christopher Sanchez

The goal of this project was to develop a coordinated micro aerial vehicle along with an unmanned ground vehicle in order to advance the development of collaborative systems. The design objectives were to maximize flight time and mobility of a quad-rotor and to minimize the size of the system. During the course of the project, analysis, design, construction, and testing of the quad-rotor and ground vehicle were completed and the resulting system was capable of deployment and hover.

Advisors: S. Nestinger, M. Demetriou
Self-Reconfigurable Modular Robots

Paul Heslinga, Kyle Padelford, Stephen Poppa, Caleb Swienson

The goal of this project was to design and build a self-reconfigurable modular robot. Each module was designed to move independently, identify and connect with other modules, and travel as a collective system. This project investigated both mechanical and electrical connection mechanisms as possible system assembly methods. Each module was designed to have three degrees of freedom to allow for high individual and system mobility as well as overall system configurability. The module was designed as 3.125” x 3.125” x 6.375’ in size. For structural strength and weight reduction, the module was custom machined out of aluminum. The modules were designed to operate untethered and therefore contained an onboard microcontroller, wireless communication, and rechargeable battery. Two individual modules with external connection mechanisms were manufactured.

Advisors: S. Nestinger, F. Looft (ECE)
Design of an Autonomous Platform for Search and Rescue UAV Networks

Catherine Coleman, Joseph Funk, James Salvati, Chris Whipple

In this report, we present a system of modular unmanned aerial vehicle (UAV) drones capable of semi-autonomous/autonomous flight for search and rescue applications, to improve the speed, efficiency and safety for both the victims and the rescuers alike. This system also alleviates the need for large teams of rescuers to divide up to search vast areas of land were a stranded victim could be. To accomplish this, the system was designed to incorporate light, long endurance UAVs, equipped with specialized search and rescue sensors to aid humans in the search for lost hikers in mountainous areas. The ability to search from the area, without putting additional humans at risk is invaluable for search and rescue. All UAVs in the system utilize the paparazzi autopilot system, which is an open source, Linux based autopilot package for flight stability and autonomous control. The system was engineered to follow a centralized command structure, revolving around a specially outfitted UAV, the mothership. The mothership communicates with the other UAVs, dictating tasks and coordinating the efforts of the UAVs to be as efficient as possible. The mothership also communicates with the ground station, where rescuers on the ground can relay commands to the network, and vital information can be passed down from the UAVs. To date, the system is comprised of a mothership which has flown under RC control, as well as a drone model which has flown under assisted autopilot.

Advisors: T. Padir (ECE), A. Wyglinski (ECE)
Automated Refueling for Hovering Robots

Nigel Cochran, Janine Pizzimenti, Raymond Short

Small-scale, battery-powered unmanned aerial vehicles (UAVs) suffer from short mission times before they must land for manual refueling, making the UAVs not truly autonomous for extended periods of time. This solution aims to be an innovative approach to a more refined iteration of previously proposed refueling solutions, while adding the novel functionality of being universal for many UAVs that are battery powered and can perform vertical takeoff and landing. The proposed design is a base station that positions the landed UAV to a known orientation, then exchanges and charges the UAV’s battery. This solution allows for persistent flight of the UAV by maximizing its in-air duty cycle.

Advisors: K. Stafford, W. Michalson (ECE)

Sponsor: Lincoln Laboratory
ORYX 2.0: A Planetary Exploration Mobility Platform

Joseph Amato, Jon Anderson, Thomas Carlone, Michael Fagan

ORYX 2.0 is a modular mobility platform designed for operation on rough terrain to facilitate space related technology research and Earth based exploration missions. Currently there are no low-cost rovers available to academia or industry, making it difficult to conduct research and testing related to surface exploration missions. ORYX 2.0 fills this gap by serving as a platform that can operate in analog Martian or lunar environments, and can withstand harsh Earth conditions while also providing users with many features to simplify payload integration. A standard mechanical and electrical interface aids in this process, and the use of Robot Operating System (ROS) provides a well-known software architecture for research platforms. A passive kinematic averaging suspension provides excellent mobility over obstacles in addition to improving stability and even weight distribution. The rover chassis is sealed to provide all electronics with environmental protection from dust and water. Extended field testing was done to evaluate both the mobility aspects of the rover and its ability to integrate and transport payloads. Mobility performance far exceeded expectations, with ORYX 2.0 climbing obstacles up to three times its intended limits. Multiple teleoperated field testing trials on a variety of terrains validated the rover’s ruggedness and ability to operate soundly over long periods. Lastly, a sample payload in the form of a deployable camera boom was designed, built, and tested in order to demonstrate the effectiveness of payload integration features.

Advisors: T. Padir (ECE), K. Stafford
Autonomous Blimp MQP

Daniel Lanier, Marcus Menghini, Daniel Sarafconn

The purpose of this project was to design and build an autonomous lighter-than-air vehicle for the demonstration of outdoor navigation functions and multi-mission capacity. The platform was designed to carry and interface with a variety of mission specific hardware through a standard interface. The project team created a custom designed hardware platform and propulsion system with integrated GPS, altimeter, magnetometer, and IMU. A proportional controller was implemented to navigate between GPS coordinates. Multiple rounds of ground level testing were undertaken to determine sensor performance and the capabilities of the navigational programs.

Advisors: S. Nestinger, F. Looft (ECE)
Development of a Flame Spread Screening Tool for Fiber Reinforced Polymers

Valerie Boutin, Andrew Eng, Michael Gorgone, Matthew Guilfoyle, Craig Mitchell, Chelsea Tuttle

The International Building Code (IBC) is often referenced in the United States to establish requirements for new construction. Based on performance criteria established in the IBC, interior finish materials are rated Class A, B, or C, and exterior cladding materials are classified as pass or fail. The uses of materials are limited to particular building applications according to their classification. To obtain a classification, materials must undergo various full-scale standardized tests (ASTM E 84, NFPA 286, NFPA 285), which impose a potentially significant economic penalty for material development. Currently there is no IBC process for screening materials based on economical bench scale standardized testing (ASTM E 1354) to assess materials’ performance in full-scale tests.

This project studied the relationship between bench-scale material properties of fiber reinforced polymers (FRPs) and their performance in full-scale tests. These materials are a growing interest in building construction due to their customizability. A flame spread model was developed relating cone calorimeter (ASTM E 1354) test data to full-scale test scenarios in the Tunnel Test (ASTM E 84), Room Corner Test (NFPA 286) and Multi Story Building Test (NFPA 285). Initial evaluation shows the model to be a useful tool for screening materials. Fourteen FRP systems, each with a change in a component (e.g. resin type, aggregate type, etc.) were screened using the model. How component changes affect performance is detailed. In going forward, manufacturers will be able to use this model to screen materials relative to full-scale standardized test performance, and determine in which applications their material can be used. This will enable them to make changes to the material to obtain optimum performance without wasting time and resources on multiple full-scale tests.

Advisor: N. Dembsey (FPE)
Sponsor: Kreysler and Associates
Modeling the NorEaster Engine

Malena Lund, Daniel Mullen, Matthew Rosen, Daniel Sullivan

As robotic technology develops, the United States Military has increased their demand for engines that can fly in Unmanned Aerial Vehicles (UAVs). These UAVs are typically designed for combat or reconnaissance missions, so the engine must be powerful enough to carry the appropriate equipment but also be light enough to maximize the aircraft’s efficiency. The objective of this project is to model the dynamic behavior of the O’Neill Motor Company, Inc.’s innovative coaxial counter-rotating cam engine called the NorEaster engine. Using this Mathcad model, the team identified the power to weight ratio of the NorEaster. The military’s desired minimum power to weight ratio for the NorEaster engine is 0.5. In order to calculate the power to weight ratio, the team performed dynamometer tests and pressure tests on the existing NorEaster engine prototype, and they developed Mathcad models for both gasoline and diesel NorEaster engine designs. The team worked closely with another MQP team that is focused on designing a new NorEaster engine and used the weights from the new engine designs to calculate the most accurate power to weight ratio of the NorEaster engine. A future NorEaster engine that operates on gasoline has a 4 inch bore, a firing temperature of 2000 K and a compression ratio of 10 will have a power to weight ratio of 0.46. Similarly, a future NorEaster engine design that operates on diesel fuel, has a 4 inch bore, a cut off ratio of 2.75 and a compression ratio of 20 will have a power to weight ratio of 0.49. Based on these results, the team recommends further development of an eight cylinder diesel engine at the specified parameters.

Advisors: R. L. Norton, J. Hall

Sponsor: The O’Neill Motor Company, Inc.
The integration of antifreeze and water mist systems raises system performance concerns based on the size of the droplets discharged through water mist nozzles at high pressures relative to traditional sprinkler systems. There is a lack of scientific knowledge about the interactions of the antifreeze solutions and the unique conditions of a water mist system. This project will demonstrate the feasibility of using select antifreezes in water mist systems. Four antifreezes solutions: propylene glycol, glycerine, potassium acetate, and betaine, were selected to be studied as representatives of different classifications of antifreezes. Three classes of variables were used to study the antifreezes. These classes include spray performance variables (viscosity, density, and surface tension), standing system failure variables (corrosion and volumetric expansion coefficient), and agent-fire interactions (heat release rate). Both spray performance variables and standing system failure variables were measured using bench scale experiments while agent-fire interactions were tested in a standard size compartment. Extensive testing demonstrated that no antifreeze solution behaves ideally when analyzed by all three classes of variables. Solution flammability was proven to be a function of solution concentration and droplet size, as shown in comparisons between low pressure and high pressure systems. These preliminary results are indicative that future testing should focus on droplet size. This will more definitively prove the feasibility of using specific antifreezes in the design of water mist systems.

Advisors: K. Notarianni (FPE), D. DiBiasio (CHE)
Enclosed Vertical Axis Wind Turbines

Julie Eagle

This project studies vertical axis wind turbines (VAWT) to be mounted on the roofs of residences and public buildings. Vertical axis wind turbines were tested in the WPI closed circuit wind tunnel with different blade numbers, blade configurations, and enclosures to determine which variations could increase the efficiency of the turbine. The desired product of this research is a turbine design that would generate as much energy as possible given normal inland wind conditions. Enclosures were designed and tested with the goal of accelerating the wind through the turbine and blocking wind that would act against the direction of rotation. Wind turbines were made with thin, flat plate blades at angles of 30, 37.5, 45, 52.5, and 60 degrees. At a blade angle of 45 degrees, turbines were made with 2, 3, 4, 5, 6, 7, and 8 blades. Additionally, one turbine was made with an S1223 airfoil shape. All the turbines were tested at wind speeds from 0 to 34.9 mph and their performance was evaluated based on rotations per minute. Without an enclosure, the turbines with a higher number of blades had a higher number of rotations per minute (rpms). The 2-bladed turbine with 90 rpms was the slowest performance and the fastest rotation was the 8-bladed turbine with 1254 rpms. The first enclosure had outlet approximately 210 degrees after the inlet. With the first enclosure, all turbines increased their rotational velocity by at least 34.9% with the largest increase being 2325%. Turbine with more blades showed a smaller increase in velocity than turbines with fewer blades. The smallest increase was shown by the 8-bladed turbine, while the largest increase was shown by the 3-bladed turbine. The second and third enclosures, an enclosure with the outlet directly across from the inlet and a simple 90-degree arc, blocking wind on the negative half of rotation, had similar results to the first enclosure. Based on the performance of these prototype turbines with and without enclosures, it is apparent that enclosures increase the rotational velocity of the vertical axis wind turbines.

Advisors: D. Olinger, J. O’Shaughnessy (CEE)
Large hydro-power extraction systems such as hydroelectric dams can be very expensive to construct and maintain, and could have a negative impact on the environment. An alternative, less intrusive hydro-power extraction system based on the vortex-induced vibration phenomenon is a viable solution to the problem. Our project seeks to maximize vortex induced vibrations to efficiently convert flow energy into mechanical energy. The goal of this project was to develop a shedder geometry that would provide a greater energy conversion rate (power output) than a cylinder. We performed computational fluid dynamic (CFD) analyses on a cylinder and various T-shapes at a range of Reynolds numbers. To compare these CFD results to physical experiments, a flow test facility was constructed to provide an environment in which to test the various geometries. The geometries under test were mounted to a pivoting beam oscillator that was designed to have an adjustable natural frequency. The results confirm agreement between oscillation theory, computational fluid dynamics, and experiment, showing that the lock-in condition occurs at a specific resonant frequency and results in the greatest power output.

Advisor: B. Savilonis
Absorption Refrigeration

Joseph Kajano, Doug Lucas, Glorius Muyuka

This project focuses on the construction of a Gas Absorption Refrigeration unit that operates at ambient temperature and pressure with a compartment temperature of three degrees celsius. Gas absorption systems are similar to vapor-compression systems, but use a heat source to facilitate refrigeration. The gas absorption refrigerator uses no electricity and no moving parts, such as pumps and compressors, and operates at a single system pressure, unlike the vapor-compression cycle which utilizes pressure gains and drops to produce refrigeration. The gas absorption cycle uses the principle of partial pressure between two fluids to create the cooling effect. Extensive analysis of the thermodynamics, heat transfer, and chemical properties was conducted to design and construct the model shown in the report. The model was pressure tested for structural integrity and leakage, and a safety analysis of the fluids involved was undertaken. Although construction and thorough analysis of the system was completed, operation of the refrigerator was not possible.

Advisor: J. Sullivan