senior design
THERE'S NO STOPPING YOU!
DÉMONSTRATION DAY APRIL 29, 2016
The capstone Senior Design Project Program is a hallmark of success for engineering seniors. In this one or two-semester course, senior students are mentored by faculty and industry engineers as they work to solve real-world engineering problems for company sponsors. Students learn about the principles of design, how ethics affect engineering decisions, how professionals communicate ideas and the day-to-day implications of intellectual property.

**REAL DESIGN CHALLENGES: REAL RESULTS**

Each year, dozens of leading manufacturing companies, pharmaceutical and medical firms, consulting practices and utilities present the School of Engineering with design challenges or problems they are encountering in their business. For a modest fee, the companies suggest a particular problem and assign a technical representative from their company who will help guide and mentor the senior engineering students as they work to properly frame the problem and develop meaningful solutions.

The students research and analyze the problem, conceptualize alternate solutions, design and refine one device or method, construct a working prototype, and provide the sponsoring company with regular reports plus a working prototype. This true design experience allows the students to apply the technical skills they have acquired during their undergraduate years, and to stretch their abilities in analysis-based innovation and decision making.

Visit our website for more details about our programs.

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GREETINGS!

I am delighted to welcome you to our Engineering Senior Design Demonstration Expo.

You join us in an important year for our school; the centennial anniversary of UConn Engineering. While learning about the impressive work our students are doing, consider the scope of what we have achieved. From a small program designed to promote agriculture to the premier public engineering school in New England, we’ve made impressive strides.

Perhaps more than any other academic area of study, engineering is an applied discipline aimed at solving real-world challenges—from the nano to vast astronomical scales, inventing new products and processes, and enhancing the quality of life for humans across the globe.

Senior Design is the pinnacle learning experience of an engineering student’s undergraduate education, a year-long process during which principles and theories gain substantive form and relevance to societal needs.

Students learn and apply the principles of design; the complex interplay among engineering solutions and societal, environmental, economic and ethical considerations; the language of industry; and the power of engineering to catalyze new solutions to entrenched problems such as sustainable energy, access to clean water, agriculture, transportation and health.

As you stroll through the exhibits displayed here today, described succinctly within the pages of this booklet, I encourage you to engage our students to better understand the problem-solving tools they employed in developing their prototypes and simulation models. Their answers will afford you rare insight into the issues they encountered and the exceptional quality of their engineering skills.

Within days, they will embark on their engineering careers or perhaps graduate school. They are our future, and I take great pride in the role UConn Engineering played in preparing them to become industry leaders, entrepreneurs and innovators, and technology visionaries of the 21st century.

Cordially,

KAZEM KAZEROUNIAN
Dean
Anh Nguyen ’15 (ENG), left, Anson Ma, assistant professor of chemical and bimolecular engineering, Leonora Yokubinas ’15 (ENG) and Nicholas Fleming ’15 (ENG) taste a test batch of reduced sugar ice cream at the UConn Creamery on April 8, 2015.

(Peter Morenus/UConn Photo)
Chronic diseases are projected to account for three quarters of all deaths by the year 2020. Within that group, the number of patients afflicted by chronic heart diseases is estimated to be 16.7 million. In order to combat this crisis, this design project focused on developing a novel, wearable phonocardiograph device that can continuously monitor the heart in real time. Phonocardiography is a diagnostic technique that creates a graphical representation of the sounds and murmurs produced by the heart - a phonocardiogram (PCG). These sounds stem from valvular events such as the closing of heart valves, myocardium contraction, vascular events, and vibrations caused by acceleration and deceleration of blood. On the human body, there are four primary areas of auscultation where the acoustic sounds coming from each valve are best transmitted.

The primary component in the wearable phonocardiograph device is the sensing unit and to accurately detect the heart sounds with minimal noise, a high sensitivity contact microphone was used. The CM-01B contact microphone (TE Connectivity Sensor Solutions) uses a polyvinylidene fluoride (PVDF) piezo film combined with a low-noise electronic pre-amplifier, which minimizes external acoustic noise - making it ideal for sensing body sounds. In order to further amplify the heart sound signal, a simple op-amp circuit was built on a printed circuit board. In this circuit, resistance values were calculated and implemented so as to maximize gain and function in the low frequency range of the heart sounds. Using a LabVIEW program along with a microcontroller and Bluetooth® tandem, data is transmitted wirelessly from a patient and displayed on a mobile device or tablet/PC. The sensors are fitted into an adjustable strap that can be worn in a fashion similar to a five-point seatbelt. All necessary circuitry, microcontroller components, and rechargeable power supply are fitted into a small casing. To minimize motion artifacts, the device is firmly secured and insulated from external noise and utilizes a reference sensor to subtract any residual noise from the primary signal. This device enables patients and their medical professionals to be aware of the patient’s health - providing for an accurate and immediate response and diagnosis. This device also presents great potential for research purposes through the study of how specific conditions affect heart sounds.
An estimated 80 percent of the US population suffers from back pain, with improper posture being the leading cause of the pain. Bad posture leads to not only back pain, but also neck pain. Poor posture can also lead to tension in the shoulders and neck that can eventually cause headaches. When an individual stands or sits with poor posture, an excessive amount of stress is introduced in his or her muscles. Over time, poor posture becomes a habit, and the muscles must work harder than normal to keep a person upright and balanced with proper posture. This can result in an impairment of the body’s ability to deal with forces, and cause wearing and tearing of joints and ligaments. Overall, this can increase the chances of harmful accidents and organ problems. There are several products in the market that attempt to correct poor posture, but these products can be bulky, or difficult to use and tend to be expensive.

This project has produced an accurate, durable device that can be worn discreetly and comfortably at all times in order to enhance posture and reduce neck and back pain. The device is small, lightweight, cost effective, and will detect improper posture. This novel design relies on two gyroscopes to determine the relative angle of the upper body compared to the waist. These two gyroscope components each utilize a LilyPad arduino. One gyroscope will be attached near the shoulder and the other will be worn on the waist. The relativeness of the angle ensures that the device works even when the user is lying down or slouching with their lower back rather than their upper back. Bluetooth has been implemented as the method of communication between the two gyroscopes in an effort to reduce the size of the device and eliminate unnecessary wires which can impede movement. Rechargeable batteries have been used in the device. The device has the ability to alert the user when his or her posture is incorrect, allowing the user to correct his or her posture. This feedback will be given to the user via a buzz motor attached to the gyroscope worn near the shoulder.
Epilepsy is a neurological disorder characterized by sudden, recurring seizures, which are the result of excessive and synchronous electrical discharges of a large number of neurons. Epileptic seizures occur in over 1% of the world’s population, making it the second most common neurological disorder after stroke. Currently the most precise method of epileptic seizure detection involves utilizing three certified clinicians to analyze a patient’s EEG signal data and establish a consensus as to where the beginning and end of each episode takes place. The purpose of this project is to design and prototype a microcontroller-based system that interfaces with iEEG data for automatic detection of an oncoming seizure. This system will raise an alarm when a seizure is detected and, by means of its graphical user interface (GUI), will plot the filtered iEEG data and show a brain map on an external monitor. The GUI will assist the clinician in better understanding the onset and spread of the imminent epileptic seizure. The real-time component of this design will be a novel contribution to existing systems and is of critical importance because added detection lag will delay clinician response time before seizure onset.

The system’s first stage of processing will transmit iEEG signals from a virtual patient’s intracranial electrodes within the brain to a set of microcontrollers. Second, the signals will be frequency filtered into four separate frequency sub-bands. Then, signal features will be calculated for each frequency sub-band to assist in determining seizure events. The features our system utilizes are kurtosis, power, line length, and number of maxima and minima. Once the features are extracted, the third step in processing is to use a Support Vector Machine to linearly separate the data into seizure and non-seizure classes. The classification decision will be sent from MCU 1 to MCU 2, and ultimately displayed on the GUI (see figure below). The graphical user interface will present the raw iEEG data in real-time alongside a brain map that will visually show seizure propagation on the electrode grid.
For most, the action of standing from a seated position is an automatic response that occurs with ease; however for millions this action is not so simple. The act of going from sit to stand (STS) requires lifting body weight and placing a large strain on the knees. With this strain created on the knee joint, it is natural for the decomposition of the cartilage during the aging process. The National Institute of Aging estimated that by 2050, the number of people 65 and older will triple, only making a device which aids this process necessary. In addition to the elderly, a STS device can be used among those with knee injuries, arthritis and individuals with a neuromuscular disorder. A variety of options are accessible for people who struggle with walking, but there are only a few STS devices on the market. Currently, there are large STS devices available to hospitals and residential use, but these devices are expensive and heavy and do not allow the user to maintain an independent lifestyle. Smaller devices are available, but they are too flimsy and unreliable. We saw the need for such a device and have developed a functional STS device which is efficient, affordable and portable.

The main component of the STS device is its scissor lift. The scissor lift is controlled by the device’s sensors, electrical components and actuator which together aids in the process of raising and lowering the user. In order to determine the proper angle and height the platform should reach, the device was simulated in multiple programs. The device was created in Working Model 2D to test its spring properties and later a SolidWorks representation of the device was created and tested in AnyBody Technology software to further understand how the device will interact with the user. Once the optimal angle of the platform was determined, the model was implemented into ANSYS. ANSYS allowed for the forces acting on the device to be analyzed ensuring longevity and determining safety precautions. Results from these simulations dictated that the height and angle of the seat needed to be adjustable depending on the height of the user. Together these modifications created a polished product.
Team 5: Characterizing Osteoblast Cell Morphology during Bone Formation

Sponsored by: University of Connecticut Biomedical Engineering Department, Sponsor Advisor: Dr. Wendy S. Vanden Berg-Foels

Studying endochondral ossification, the process of bone formation, is important in developing cures for osteoporosis and other instances of bone deterioration. As endochondral ossification proceeds, trabecular bone replaces cartilage on both ends of the long bone; hypertrophic chondrocytes die, leaving a network of pores behind which then becomes the foundation for trabecular bone. Trabecular bone has previously been imaged in 2-dimensions using light microscopy and 3-dimensions using micro-CT. Although providing a glimpse into the process, neither the 2D nor the 3D rendering of trabecular bone details the transition from blind pores to an intricate network of bone at the cellular level. The aim of this study is to investigate how hypertrophic chondrocytes determine the 3D structure of trabecular bone using nano-resolution images, compiled in three-dimensions.

This project consisted of three sequential stages: tissue preparation, image acquisition using a focused ion beam scanning electron microscope (FIB-SEM), and image processing. First, a modified tissue preparation technique used to embed a temporomandibular (TMJ) joint taken from a 12-week old mouse. The TMJ was used because of its small size and its unique fibrocartilage structure. Ruthenium hexamine trichloride (RHT) was used on several samples to enhance the fixation of proteoglycans within the cartilage. Second, a series of nano-scaled images of this tissue were taken using a FIB-SEM. The FIB-SEM used a “slice and view” technique to repeatedly image and slice off the surface of a tissue. Finally, a 3D image processing pipeline was developed and tissue features—hypertrophic cells, proliferating cells, the extracellular matrix—were segmented. This pipeline provides in depth imaging of the tissue, rather than just at the surface. The extracted features were then analyzed for directionality, orientation in space, and varying shapes, to understand how these blind pores led to trabecular bone formation.
Cell culture and monitoring is a crucial part in most tissue engineering experiments. However, this process can become tedious and, sometimes, problematic. In many experiments, it is necessary for researchers to study cell behaviors in various conditions. Some of these conditions can endanger the cells, requiring proper attention to be given and adjustments to be made in order for the cells to survive. This level of involvement makes it so that researchers will have to be present in the laboratory. However, this is not always conducive due to many limiting factors such as geography, accessibility, incommodity, or finance, and hence give rise to the need of wireless monitoring system. To facilitate this process, a device that is able to create an ideal, sustainable and controlled environment for cell culturing as well as provide wireless adjustment, manipulation, and monitoring is highly desirable.

In this project, we want to focus on creating an affordable and simple cell culture system that is accessible to students and researchers. The goals are to allow all users, whether members of a lab or students, to have the ability to study cell behavior in various culture conditions, and under physical stimulation by built-in micromanipulator over the web. Magnets control the manipulator movement, shown on the bottom left, and the legs can be moved in directions shown by the arrows. When the legs move outward, the probe rises. When the legs move inward, the probe lowers. Using a Raspberry-Pi and an Arduino, a web server is created that has live video feed and command window where user can control the micromanipulator and view the auto-regulated temperature and CO2 concentration inside of the incubator. In addition to those features, the device is also incorporated with an inverted microscope which will allow the cells to be viewed and manipulated safely outside of the lab.
Team 7: Shoulder Sliding Platform: A Rehabilitation Device to Safety and Effectively Increase Shoulder Range of Motion in Post-Operative Patient

Sponsored by: UConn Health Center
Sponsor Advisor: D.P.T. Gregg Gomlinski

In the world of orthopedic surgery, many of the complications arise not from the surgery itself, but in the rehabilitation stages that follow. After surgery the patient is enrolled in a series of physical therapy sessions, which are meant to increase the strength and mobility of the recovering muscles in slow increments. Current improvised methods of postoperative physical therapy are proven to work and help patients regain strength, however, other novel exercises and devices can help make the rehabilitation process more successful.

Our group proposed creating a novel device, which can be used in early stage rehabilitation of the rotator cuff. This device facilitates an assisted range of motion exercise (AROM) for the shoulder, an exercise that has been extensively tested and confirmed to be most beneficial for early stage rehabilitation. Our client, Gregg Gomlinski D.P.T. from UConn Health Center’s, Department of Rehabilitation and Sports Medicine (UCHC), offered an idea in creating a permanent early stage rotator cuff therapy device which could be easily installed in any physical therapy specialized gym. The goal of this project was to develop a reliable device that specializes AROM exercises of the rotator cuff, which can be used earlier in the rehabilitation process. The device consists of a safe, low-friction sliding platform, which is pushed along a supporting rail with the use of the patient’s hand. The device allows the patient to exercise from either a seated or standing position and offer a large range of incline angles for the sliding platform. Lastly the device is also able to fold up against the wall to which it is attached, minimizing the space it occupies when not being used.

Upon the completion of the project, the device was installed at UConn Health Center’s Department of Rehabilitation and Sports Medicine. Through cooperation with James Noel, aluminum alloy parts for the device were designed, purchased and sent to UCHC. The device was assembled and installed easily on the premises. Furthermore testing was performed to confirm the accuracy, reliability and safety of the device and its use in early stage rehabilitation.
Team 8: Design and Testing of Exercise Equipment for People in Wheelchairs

Sponsored by: Hospital for Special Care
Sponsor Advisor: Dr. Krystyna Gielo-Perczak

The purpose of this project is to design and test a form of exercise equipment for people in wheelchairs in order to perform stationary, safe, indoor exercise. It is apparent that exercise has many benefits to the body, and the lack of exercise in one’s life can lead to weight gain as well as many secondary conditions. According to our client, Janet Connolly, at the Hospital for Special Care, many individuals with spinal cord injuries tend to be less physically active. In addition to their physical limitations, people with disabilities face environmental barriers, like limited access to accessible equipment, especially during certain times of the year when weather conditions are not suitable for outdoor activity. It is a vicious cycle since lack of exercise leads to inevitable weight gain, and weight gain leads to poor sense of self and the inability to fit into wheelchairs that can be utilized for exercise. In order to reverse this cycle, new equipment for cardiovascular exercise for people who use wheelchairs is in dire need. In order to accommodate for larger patients, exercise equipment with the capacity to hold wider chairs is a must.

Rollers are a stationary device, which function similar to how a treadmill does for running. The wheelchair rests on the rollers and allows the person to roll in place for exercise. Currently on the market there are various forms of wheelchair treadmills and rollers. These devices allow for stationary aerobic exercise, yet are often unstable, unsafe, or highly expensive. Our purpose was to create low-cost, safe device which allows wheelchair users to exercise indoors independently. In addition, our project is meant to be usable by as wide of a range of people as possible, including those in a wide weight range and those who use various types of wheelchairs. Our optimal design includes a ramp, steel rollers, 80/20 frame, and flywheel with a mechanical disc brake. The design allows the user to independently roll backwards onto two steel rollers supported by an 80/20 frame and roll themselves in place to perform exercise, with the option of increasing difficulty through added resistance.
Dr. Syam Nukavarapu at the University of Connecticut Health Center in Farmington, CT, requires a device that will create gradient osteochondral (i.e., bone-cartilage interface) scaffolds. His research group is focused on developing advanced scaffold systems for bone and bone-cartilage interface regeneration. In regenerating osteochondral tissue, or the transition area between bone and cartilage tissue, the porosity of the scaffold on which stem cells are seeded onto plays an important factor in stem cells’ differentiation. With the help of this device, a mass production of varyingly porous scaffolds will help create gradient porous scaffolds suitable for bone-cartilage interface regeneration. Currently, the method to generate these scaffolds is to manually layer concentrations of salt and polylactic co-glycolic acid (PLGA) microspheres for sintering, then washing the salt out to create porous scaffold. This process is time consuming and inconsistent.

This project sets out to optimize a previous developed device and expand its capabilities. This device has been expanded from its initial ability to create various step or gradient porosities in scaffolds. This device has the capability of being programmed to create a scaffold between 0% salt to 40% salt, by weight, and can measure up to 20 layers. In addition, it can produce several different layering schemes that are representative of osteochondral tissue regeneration theories. A LabVIEW Virtual Instrument (VI) that allows the user to determine how many scaffolds to make and their specifications automate the function. The VI then interacts with an electronic balance and a series of stepper motors that drive augers to dispense PLGA and salt from their respective reservoirs onto a weigh-plate. Upon dispensing the appropriate amount of each material for an individual layer onto the weigh-plate, the stepper motors cease the dispensing of material and a solenoid triggers the plate to drop the microspheres and salt down a chute equipped with slalom-style protrusions causing the layer’s material to sufficiently mix on its way to the scaffold mold. After this step is complete, the weigh-plate resets and the process repeats for the next layer of the scaffold. Upon completion of an individual scaffold the mold is repositioned automatically and the next scaffold is filled. This process reiterates until the specified amount of scaffolds have been produced.
Photochromic lenses, also known as transition lenses, were a great innovation when they were invented back in the 1960’s. These lenses are optical instruments designed to change opacity based on the exposure of the ambient light. When light is prominent, the lens gradually shifts towards a darker opacity and the lens becomes clear when light is scarce. However, when light rapidly changes in an environment, the transition lens often cannot do enough to prevent a short period of blindness and discomfort in the subject. In this regard, the user may become subject to danger. The purpose of this project was to develop a lens capable of shifting opacity instantaneously with varying ambient light. This works by creating a circuit in which a photocell is coupled in series to a voltage supply and LCD screen. Imminent light alters the photocell’s resistance, thereby changing the voltage drop across the LCD screen and allowing more and less light to enter the subject’s eye.

An LCD screen with liquid crystals sandwiched between the two polarizers was used to selectively alter the opacity of the lens. When a voltage is applied to the liquid crystals, they reorient themselves. This reorientation process allows for the modulation of light, which affects the overall opacity of any lens utilizing liquid crystals. The process is gradual depending on the applied voltage, therefore allowing a quick and steady change in opacity of the lens. The LCD lens of Panasonic™ 3-D shutter shade eyeglasses were removed and tested using a DC power supply. Results showed that the LCD lens begins to dim at approximately 3.3 volts and reaches maximum opacity at approximately 5 volts. From this information, a circuit was designed in order to apply a voltage between 3.3 and 5 volts to the LCD when exposed to any light sources. The primary components of the design included LCD’s, a power supply, a photoresistor, various resistors, and a transistor. As the intensity of a light source increases, the voltage across the photoresistor decreases, thus increasing across the load resistor of the circuit. This change in voltage drop essentially alters the opacity of the lens. The resistance range of the photoresistor and therefore the amount of light to be regulated by the photoresistor is tested utilizing a DC power supply, a digital multimeter, and multiple light sources of varying intensities.
Currently there are over 30 million amputees residing in developing countries, most of whom do not have access to decent prosthetics. The prosthetics used in developing countries tend to fail within the first year and a half due to a combination of factors including: extreme environments, inferior manufacturing methods, and limited design capabilities. The average annual income of a person living in a developing country is $300 USD, while the average cost of a durable prosthetic ranges from $125 to $1,875 USD. Ultimately, an affordable prosthetic should cost 3% of an individual’s annual income (in this case, about $9 USD) [1].

Normally an amputee in a developing country needs to perform daily tasks such as farming or retrieving water, which requires the individual to carry loads up to 100 lbs. Prosthetics currently on the market have a load range of approximately ±15-30 lbs. When additional loads exceed this limit, the prosthetic cannot store and return energy. An ideal prosthetic must be load variable in order to allow for the individual to preserve their livelihood in these demanding conditions. Of all the prosthetics currently used in developing countries, only the Niagara Foot® has passed ISO Structural Testing of Lower-Limb Prostheses (ISO-10328). This certification process consists of four tests: a static proof test, a static strength test, a cyclic loading test, and a cut test [1]. The Niagara Foot® is also the most expensive prosthetic available in these countries at a cost of $35 USD.

The proposed design consists of two main parts: a thermoplastic base and polyurethane inserts of varying densities. As seen in left figure below, the base is designed to imitate natural gait and provide energy storage capabilities. The split toe allows the base to adjust to uneven terrains, as each “toe” can deform individually. The large cutout in the base houses the polyurethane inserts, which can be interchanged by the user. By varying the densities of the inserts, the effective load range of the prosthetic can be adjusted as needed. With an approximant raw material cost of $3 USD and affordable manufacturing options, such as plastic injection molding, this proposed design is a step in the right direction towards improving low-cost prosthetics.

Team 12: Optimizing the interface between electrode array and peripheral nerve axons

Sponsored by: University of Connecticut Biomedical Engineering Department
Sponsor Advisor: Dr. Bin Feng

Researchers in the fields of neuroscience, pharmaceuticals, and the newly termed “electro-ceuticals” rely on the study of peripheral nerves in-vitro to gather data on axon signals under varying desired experimental conditions. Today, the researching party often individually manufactures the chambers used to stimulate and record nerve axon signals in-vitro. There lacks a standardized and accessible chamber that would open research to laboratories that do not have the ability to fabricate and manipulate independent non-proprietary hardware. Therefore, the goal of this study is to develop a stand-alone in-vitro system that allows for simultaneous multi-channel recordings of action potential activities from individual nerve axons in the mouse sciatic nerve. Further, the goal is to increase the efficiency of nerve action potential recordings by creating a robust and reliable environment that is easily accessible by researchers while providing high signal-to-noise ratio impulse readings and long-term nerve compatibility.

An in-vitro fluid system chamber that houses the nerve fibers during the application of selectable drug and electrical conditions was designed and developed. The chamber was designed with two main areas, comprising of a stimulating and testing section and a recording section. Stimulation of the nerve was accomplished through an electrolyte filled hollow glass pipette to deliver low-noise, isolated signals while providing mechanical stability to the recording. The nerve was preserved with oxygenated media. Drug delivery through the chamber was accomplished through lamellar flow to reduce noise and increase media mixing. A barrier between the two sections consisted of a hollow frame and tunnel, allowing solely the nerve to pass through. The void in the center of the barrier was filled with a hydrophobic and biocompatible sealant. ANSYS Fluent software was used to examine the fluid dynamics of the design, and 3D printed PLA prototypes were created to physically test the fluid flow. Preliminary results in fluid simulation showed promising low velocity and low turbulent flow. Dye tests in PLA prototypes showed sufficient dyed media mixing and prevalence in the testing section. There was a high fraction of used solution removed during the influx of new media.
Team 13: Lung Injury Prediction from Underwater Primary Blast

Sponsored by: Naval Submarine Medical Research Laboratory
Sponsor Advisor: Michael Qin, Ph.D.

In many underwater naval applications, primary blast injury is a significant part of the decision making process. The most lethal primary blast injuries are incurred by the lungs, making a model to predict such injuries especially important. The primary objective of this project was to build upon previous research to create this model, connecting each step between a user defined explosive event and the probable outcome for a diver.

The overall model was divided by the scope of the relevant works. There was documentation to define the explosive event and correlate it to a pressure in time wave at the location of the diver, several models accepting this pressure wave and predicting the resulting chest wall velocity, and another series of papers focusing on how chest wall velocity can predict injury and mortality. The resulting tool is unique, as underwater environments have not been the primary focus of studies on this topic.

It was found that the underwater pressure wave could only be predicted through the first two pulses. As opposed to air, the more heavily studied medium, water demonstrates incompressibility and a higher acoustic impedance. One parameter of injury prediction is taken by integrating the area under each pulse, as this impulse provides a reliable indication of injury. This pressure in time is then used to predict chest wall movement. While previous work required the use of a physical model of the torso, outfit with four transducers, to generate the input data, we utilized a model taking the pressure history at a single point. This simplification comes with a higher uncertainty, but allows for sufficient data to be generated in a numeric environment. These velocities and displacements are used in conjunction with the impulse from the pressure wave to predict the extent of lung injuries. Users can set their own risk tolerance to inform decisions and determine acceptable standoff distances. Furthermore, each aspect of the model can be isolated for further refinement as more research on the subject is pursued.
The goal of this project is to create a reusable cell plate which will enable application of uniform and reproducible ES to scaffold materials in vitro and optimize ES parameters, promoting cell differentiation. Dr. Kumbar’s laboratory has synthesized novel ionically conductive (IC) materials that address redox instability and provide very stable electrical conductance in physiological environment will serve as the matrix. Human mesenchymal stem cells (hMSCs) will be seeded on IC materials placed in the designed plate to apply ES and study changes in cell morphology and neuronal phenotype expression using various analytical techniques. Studies are designed to identify optimal ES parameters that lead to higher neural phenotype expression, including β-III tubulin and microtubule-associated protein-2, by hMSCs. The novel device configuration focuses on relatively easy use to provide uniform stimulus while striving to mitigate current density loss due to media interaction. Electrode dimension can be changed to fit variable graft sizes. Additionally, we have designed circuits to percutaneously apply ES to tissue and evaluate permeation of stimulation through tissue.

Team 14: Electrical Stimulation Plate for Neuronal Tissue Regeneration

Sponsored by: Dr. Kumbar Laboratory, UCHC
Sponsor Advisor: Sangamesh G. Kumbar, Ph.D.

UCONN HEALTH

Twenty million Americans suffer from peripheral nerve injury constituting ~150 billion health-care dollars annually. Axonal regeneration is extremely slow process that occurs at a rate of ~1mm/day, requiring at least 12-18 months for muscle reinnervation and functional recovery. Current procedures involving biological and synthetic grafts focus on defect repair, however, the clinical outcomes in terms of functional recovery, time, and quality of regenerated tissue are suboptimal. Tissue engineering approaches involving growth factors and cells have shown benefits in preclinical settings, but face significant challenges for clinical translation, with no currently marketed products.

Electrical stimulation (ES) of injured peripheral nerves has been shown to accelerate axonal regeneration and functional recovery in laboratory animals and human clinical trials. Electrically-conducting, non-degrading polymers and their composites enable ES, presenting an appropriate scaffold for housing cells and directing regeneration. However, these materials face significant challenges in terms of degradation, biocompatibility, and reliable electrical conductivity in vivo. Popularly used polymers PANI and PPY are brittle, non-degradable or slow-eroding, and tend to exhibit deterioration of electrical conductivity under physiological conditions due to oxidation-reductions (redox) reactions. Therefore, development of alternative approaches for enhancing peripheral nerve regeneration that achieve and surpass the performance of the current gold standard autograft is currently an unmet need.
**Team 15: Use of Surface-Mount Strain Gauges to Quantify Linear Laparoscopic Reload Compression**

Sponsored by: Medtronic  
Sponsor Advisor: Matthew Eschbach, Marisha Godek  
UConn Advisor: Patrick Kumavor

**LET’S TAKE HEALTHCARE FURTHER, TOGETHER**

**Project Description:** There is significant clinical relevance to understanding the interaction of linear laparoscopic surgical staplers with their target tissues to help maximize positive results during post-surgical tissue healing. Specifically, one aim of this project was to quantify compressive force applied to tissue during clamping and firing in an efficient and reliable way. Medtronic’s Endo GIA™ stapler with Tri-Staple™ technology is a linear laparoscopic stapler most commonly used in abdominal and thoracic surgical procedures when tissue must be resected and/or sealed. This project utilized strain gauges mounted to the surface of the Medtronic Tri-Staple™ Endo GIA™ reload to accurately measure strain and covert these values to pressure applied by the jaws of the stapler onto tissue. While surgical results using the current Medtronic Endo GIA™ stapler with Tri-Staple™ technology are generally favorable, it is advantageous to develop a reliable method of quantifying actual compression values to more thoroughly understand the effect of the device on tissue in this unique way.

A small, portable tool was designed to standardize the application of strain gauges to the anvil of the reload to minimize test set-up and data collection variability. A user-friendly LabVIEW program was developed, and a “black box” device was produced to process and analyze raw data in an intuitive manner. The applicator tool for applying five 350-ohm linear strain gauges to the reload anvil was designed in SolidWorks and fabricated via 3D printing with PLA (Polylactide, a biodegradable thermoplastic polyester). A quarter bridge circuit was implemented to acquire the raw difference signal for each strain gauge along the anvil, which was then digitized by a LabVIEW DAQ and processed and analyzed with the LabVIEW program. The circuit and external components were housed in a shielded box. The gathered data may serve a role in correlating varying degrees of pressure from the stapler to any visible bruising or tearing inflicted upon the tissue. The results of this experiment provided a range of pressure values relating to varying levels of tissue compression from the stapler for potential use in future product development and improvement. The issues of quantifying compression of linear staplers on tissue and developing a deeper understanding of the biomechanical interactions between stapler and tissue were in part solved through the development of this novel standardized testing process. *Representative images are shown below.*
Cartilage is a connective tissue within the human body that provides the cushioning and lubrication needed for joints. Osteoarthritis is a degenerative disease that affects the cartilage of the knees. There is currently no approved cartilage regeneration treatment in the United States. Osteoarthritis causes debilitating pain depending on the stage of degeneration and it is the leading cause of decreased or impaired mobility in the elderly. Around 700,000 people each year in the United States receive a knee replacement surgery. Many recipients of these surgeries are patients who suffer from osteoarthritis. However, these procedures are invasive and can have complications such as implant loosening.

Adipose derived stem cells (ADSCs) are a multipotent stem cell that is found within the fat of most species. These stem cells have been shown to have great potential in terms of healing and improving tissue regeneration. ADSCs are more readily available and ethically favorable when compared to embryonic stem cells. ADSCs are easier to isolate than mesenchymal stem cells (MSC) from bone marrow. Obtaining stem cells from adipose tissue is a much more attractive prospect for patients in terms of non-invasiveness, comfort, availability, and expendability than obtaining them from the bone marrow. ADSC’s have the ability to differentiate into chondrocytes which has immense potential as a cartilage regeneration option. In order to utilize the potential of ADSC’s, they need to be isolated from the body tissue and then replanted to the desired location.

This project seeks to create a method to rapidly harvest adipose tissue and adipose derived stem cells that can be used within a patient to help regenerate the cartilage. The most prevalent method to isolate ADSCs utilizes collagenase to breakdown the extracellular matrix. Due to the FDA guidelines, this method has limited clinical applications. Therefore, experimentation will be done to determine the efficacy of utilizing freeze and thaw cycles, ultrasound radiation, and vibrations to break down collagen. These methods will be developed into a rapid closed looped sterile system to increase the clinical potential of a cartilage regeneration treatment.

Once adipose-tissue harvesting and stem cell isolation procedures are developed, an induced osteoarthritis model will be created in rats to mimic what occurs in humans. The isolated ADSC’s viability (proliferation and differentiation) will be examined by implanting them in the osteoarthritic-induced joint. This project has the potential to improve human health as it is aimed at regenerating deteriorated cartilage which affects a multitude of patients.
Diabetes is among the many diseases that diminish the quality of life for many individuals. According to the National Diabetes Statistics Report, in 2014, 29.1 million individuals in the United States already had diabetes with an additional 21.0 million individuals being newly diagnosed. The achievement of a tight glycemic control for diabetic patients is pivotal in mitigating the effects of such a widespread disease.

Continuous glucose monitoring (CGM) technology provides users with an abundance of data that can help tailor interventions and changes in lifestyle specific to each individual. CGMs provide nonstop readings of glucose levels, which is a significant advantage to the finger sticks method that only provides a glucose level at one time point. Some current CGMs utilize a subcutaneously implanted biosensor that comes in contact with the blood to record the individual’s glucose levels. However, the slow transport of glucose molecules from capillaries to the sensing element of the biosensor can cause delays of up to 20 minutes. The transfer of glucose through matrices can be explained by two constituent mechanisms. By modeling these two mechanisms separately with relation to the sensing element of a CGM, the computational algorithm of the CGM can be optimized to provide a more accurate measurement of blood glucose levels.

The purpose is to develop a standalone biosensor testing pod allowing for corresponding microgravity experiments to be conducted at the International Space Station U.S. National Laboratory to segregate the two constituent mechanisms. The testing pod consists of individual biosensor pods containing Biorasis' Glucowizzard™, a light-based detector, microdialysis tubing, a heating element, a temperature sensor, and an Arduino based control. Each biosensor testing pod is encased in gel made from polyvinyl alcohol with a three-dimensional printed skeleton to support the pod and suspend the biosensor. Full automation of the biosensing testing module will exemplify the gold standard for quality assurance for the biosensor. With the execution of the experiment through the assistance of the Glucowizzard™, diabetic patients will benefit from improved accuracy that will result in tighter glycemic control to significantly reduce hyper- and hypo-glycemic incidences. Improved diabetic management will help individuals live longer and healthier lives.
Controlled drug delivery is a necessity for pharmaceutical companies and their consumers as it allows for the sustained release of the active pharmaceutical ingredient within therapeutic range for a specific duration of time. This is important to increase a drug’s bioavailability, especially with hydrophobic, class II drugs, which have characteristics of low solubility and high permeability. This project’s main goal is to characterize foam molded tablets and to understand how their physical characteristics affect bulk tablet degradation and release kinetics. Foster Delivery Science created tablets with different physical characteristics by altering manufacturing parameters during hot-melt extrusion (HME) and injection molding (IM) so that the effects of the processing parameters on the tablets characteristics could be correlated. The physical characteristics such as, skin thickness, degree of foaming, and density, were changed to create an optimal release profile. The design element of the project includes analyzing the results of the tests and correlating the physical characteristics and release kinetics of the tablets to be able to eventually manufacture a tablet with controlled drug delivery properties. The drugs and polymers used in this experiment cannot be disclosed for proprietary reasons.

Due to availability and feasibility, optical microscopy was performed for imaging the tablets. After the images were acquired, they were processed in ImageJ, an Open-Source program from the National Institute of Health (NIH), to measure the skin thickness, pore size, and porosity. After the physical properties of the tablets were characterized, the chemical properties of the samples were examined using powder x-ray diffraction and Fourier transform infrared spectroscopy. Dissolution testing was then done to determine the release kinetics of the tablets. High Performance Liquid Chromatography (HPLC) was used to analyze the dissolution media for API levels.

A Design of Experiment (DoE) is a statistical tool that can be used to correlate a response based on changing input factors. For the first round of testing, 5 factors were changed to create a binary DoE with 32 different sets. The responses were input to MiniTab and analyzed so that concrete relationships between the processing parameters and physicochemical characteristics of the tablets could be created. A second round of testing was then be done using the information about the processing parameters from the first round of testing to create tablets with ideal physicochemical properties and release kinetics.
Titanium is widely used as dental and orthopedic implants due to its biocompatibility and mechanical properties. However, titanium is bioinert and does not promote bone growth around the implant, which may lead to implant loosening. To remedy the bioinertness of titanium, hydroxyapatite is commonly used to promote bone ingrowth. Hydroxyapatite encourages new bone growth, and by coating titanium with hydroxyapatite, the implant can be firmly fixed through new bone growth. The most common method of coating titanium with hydroxyapatite is through plasma spraying, but the high heat of the coating process and post-coating heat treatments are undesirable in many applications. In contrast, biomimetic deposition is a low temperature, mild pH process that mimics the conditions found in the human body. Therefore, there is no need for post-coating heat treatment, and the coating process can be used to incorporate growth factors and other proteins within the coating. However, the biomimetic deposition produces a coating with relatively poor bond strength to the titanium substrate. Therefore further analysis of variables in the coating process and their effects on the bond strength of the coating will be conducted to provide the optimal conditions to produce a hydroxyapatite coating with a strong bond strength to the substrate.

The biomimetic coating process mimics the conditions found within the body and is done by first surface treating Ti6Al4V cylindrical substrates by sandblasting and acid treating. Afterwards a simulated body fluid (SBF) solution is produced. This solution’s pH is afterwards fixed and the substrates are then immersed in it. Afterwards the solution is kept for a day at 37°C and afterwards dried cautiously. Once this process is complete characterization techniques such as electron microscopy, X-Ray Diffraction or Fourier Transform Infrared Spectroscopy will be used to study the coat and qualitatively determine its structural integrity. The mechanical bond strength of the hydroxyapatite coatings will be tested with the use of a Focused Ion Beam (FIB) to create micropillars of hydroxyapatite coatings. Afterwards, the micropillars will be subjected to a shear force normal to the pillars to determine its failure point. This testing method will produce more quantitative measure of the bond strength between the hydroxyapatite and the titanium, when compared to the current standard of ASTM-C633 pull off test.
CHEMICAL & BIOMOLECULAR ENGINEERING

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Team 1: Modeling of Corrosion Protection Schemes for Aircraft Systems

Sponsored by: UTC Aerospace Systems
Sponsor Advisor: Marc E. Gage
Faculty Advisor: Dr. Kelly Burke

UTC Aerospace Systems, a division of the United Technologies Corporation, designs several systems for commercial and military aircraft. During the design of these systems, careful material selections are made based on different material properties for specific applications. In general, two of the most influential properties that affect design in the aerospace industry are weight and strength. Many components would be manufactured out of steel if strength were the only material property consideration, however, lighter materials are often substituted to decrease weight and to save on fuel costs. Therefore, there are many dissimilar metal interfaces on aircraft systems, especially between stainless steel and aluminum. This dissimilar metal interface can lead to galvanic corrosion.

Galvanic corrosion can deteriorate the structural integrity of parts and components. To prevent damage to dissimilar metal interfaces, various corrosion protective materials are used by the aerospace industry. The protective materials are applied in between the two dissimilar metals to seal out water and to break the electrical circuit. The ideal protective material should be cost-effective, easy to apply, and environmentally safe, while still providing adequate corrosion protection. Currently, in order to qualify a new corrosion protective material, UTAS performs extensive testing that is costly and time consuming.

The goal of this project is to design a model in COMSOL, a finite element simulation software, to predict the degree of galvanic corrosion on dissimilar metal interfaces with or without any protective material. This model will be verified through physical testing of stainless steel-aluminum test specimens by placing the specimen in a salt spray cabinet for 48 hours and 500 hours. After analysis with a white light interferometer, deformation profiles, corrosion pit sizes, and overall material volume loss will be obtained for each test assembly. The test data will be compared to the COMSOL model and our model can be fine-tuned in an iterative design process.

Although salt spray testing will never be completely eliminated, an accurate model will be able to screen a larger set of materials and configurations in a shorter amount of time, which will decrease testing necessary for UTAS to perform. In the years to come, qualifying new materials will be of great importance due to the pressure on manufacturing companies to use more environmentally friendly materials.
In just this past year, Mars exploration and research has exploded with new discoveries. Scientists have found flowing liquid water, and have even discovered how the Martian atmosphere was stripped by solar winds, creating the climate it has now. While robotic explorers have studied Mars for that last 40 years, NASA has announced its intention to send humans to the planet by 2030. Many have long since advocated for such a mission, and now is the time to start developing the technology and processes to survive in an alien world.

The objective of our Capstone Design project is to develop a closed-loop, self-sustainable habitat that allows for the survival of four humans on Mars for sixty days. The primary obstacle in this project is that the Martian biome does not provide food, potable water, oxygen, or many of the necessary resources needed for human survival. Bringing everything needed from Earth is generally considered infeasible, as there are major weight constraints involved in launching a rocket with heavy supplies. Thus, the design aspect of our project is to model a habitat that contains closed-loop systems and chemical reactions for the production of needed resources in-situ.

The Sabatier reaction and the electrolysis of water, both of which would provide a continuous source of oxygen, water, and methane for fuel will be utilized. The Martian atmosphere contains roughly 96% Carbon Dioxide, which will be harvested by an absorption system and combined with a minimal amount of hydrogen brought from Earth. These feedstocks will be used as the reactants in the Sabatier reaction, to produce methane and water, via the reaction:

\[
\text{CO}_2 + 4\text{H}_2 \rightarrow \text{CH}_4 + 2\text{H}_2\text{O}
\]

Methane can be used directly as a fuel source, and water can also be used directly, or electrolyzed to produce oxygen and hydrogen. This multistep process will ultimately be optimized in terms of component weight and production of resources in order to keep the launch costs as low as possible, while maintaining the necessary output of resources. As it is anticipated that launch costs will be the dominant cost driver in this process, economic considerations will be factored in by attempting to minimize process weight, and by extension, launch costs.
Team 3: Design of an Illuminated Bioreactor

Sponsored by: UCONN School of Engineering
Faculty Advisor: Dr. Yongku Cho

Light utilization of microorganisms has been a developing research field in recent years. These microorganisms utilize light energy to produce biomass through photosynthesis. Photoreactors are also commonly utilized to break chemical bonds using high energy ultraviolet light. The potential for photoreactors to produce goods on an industrial scale has been recognized, but practical application has been limited by the difficulty of supplying light evenly and controlling temperature during operation.

This project aims to design and build a bench scale reactor for light activated protein cultivation that can overcome the issues commonly faced by photo-reactors. The unit is to operate at 37°C, the temperature that bacteria produces the highest relative mass of proteins. The biomass in the reactor will be exposed to a maximum light intensity of 1mW/mm², shown to activate the least sensitive light activated proteins to be studied. This will be supplied by a light emitting diode, because LEDs offer high light intensity with a low relative heat output, making them perfect when temperature control is a concern.

Isothermal operation and deliverance of a controllable uniform light intensity are the key constraints that were considered throughout the length of the project. Temperature control was achieved by designing a specialized bacteria growth plate, that is completely hollow except for 24 aluminum tubes intended for biomass growth. Water is pumped through this hollow area, turning the plate into a high efficiency heat exchanger, allowing for rapid and effective response to any deviation from the designated temperature set point. To create an even light density profile collimator lenses were used to turn the light emitted from the LEDs into a beam with a diverging angle of 3 degrees. The low angle reduces the rate at which the light expands outward, thus creates a more even light profile up the reactor. The brightness of the LED was controlled using a variable resistor coupled with a variable voltage power supply to control the electrical current in the LED circuit.

This product provides a platform for researchers to study photon sensitive microorganism behavior on a more affordable price in comparison to the industry model. Its reliable heat control mechanism keeps the temperature in the optimal range. The design works for small scale research and is built with a closed system to prevent contamination.
Team 4: Eco-Friendly Car Wash and Water Reclamation Process

Sponsored by: UConn School of Engineering
Faculty Advisor: Dr. Doug J. Cooper
Industry Advisor: David Eckhardt, AIChE Fellow

The objective of this project is to invent an innovative water reclamation process to minimize the amount of fresh water used in each car wash cycle. Our above ground water reclamation system will be retrofittable with current car washes that have sub-par reclamation technology. Research suggests nearly 20% of water is lost by evaporation and carry off alone, and is unrecoverable. This system will reclaim at least 90% of the recoverable water used in each wash by purifying and recycling.

The purification process consists of four steps, each improving the purity and the functionality of the wash water. The first step is the separator which is responsible for removing heavy particles including grit, grease, dirt, sludge, and oil. The oil is skimmed off the top of the tank using a belt mechanism and the heavier particles will settle to the bottom and be removed as needed. The wash water stream enters the bio-digester next, which uses bacteria to break down excess oil and grease and to remove the foul smell. The bio-digester uses anaerobic digestion which involves four steps, all utilizing different types of bacteria, to reduce complex compounds down to methane and carbon dioxide. The produced methane can then be used to heat our bio-digester to between 30-38°C. The filtration step uses a fine membrane filter to remove any small particles. This step is important because small particles can clog high pressure nozzles and damage the exterior of a vehicle. The final step is reverse osmosis filtration which uses a semipermeable membrane to remove unwanted molecules and ions. The water exiting the process will be the quality of drinking water.

Our business plan revolves around the savings from the water reclamation system outweighing the initial installation cost. Assuming a water cost of $0.005 per gallon, an average water usage of 60 gallons per car, an average rate of 200 cars per day, and a reclaim rate of 75% of all water, the annual profit from water savings alone will exceed $16,000. We are currently estimating a price of $40,000 for the water reclamation system itself and its installation. Therefore, our water reclamation system will pay itself back in just over two years of operation.
In 2015 the National Cancer Institute funded well over $17 million in bio-nanotechnology research grants. Bio-nanoparticles have a wide range of applications within the pharmaceutical market, from scaffolding for biocompatible implants to nanostructures for cancer drug delivery.

The major challenge facing in bio-nanoparticle production industry lays within the separation of the target molecule. Standard practice for most separation involves ultrafiltration using a selective membrane with nano-scale pores. Overtime particles adhere to the surface of the membrane and will block the pores, this is called fouling. Fouling greatly reduces the performance of a membrane by either directly blocking a pore or by creating a concentration gradient along the membrane surface, a phenomenon called concentration polarization. The effects of fouling increase with smaller pore sizes.

The focus of this project is to minimize the effects of bio-fouling through the use of heat activated differential separation. Elastin Like Polypeptides (ELP) are unique in that they are soluble in water under a certain transition temperature. Above this transition temperature the ELP motifs become hydrophobic and aggregate, thus becoming water-insoluble. The transition temperature of a particular ELP is a function of its amino acid sequence and can be set in protein design. By aggregating the target bionanoparticles through heating, filtration with only micron scale pore-size membranes can be achieved. Simulations in Aspen Plus were created to model the biomanufacturing process of outer membrane vesicles (OMVs) decorated with engineered ELPs produced by genetically engineered E. coli as an example of the implementation of this universally applicable method of separations. Basal strain OMV productions rates were determined experimentally and adjusted using multipliers in literature from high OMV producing mutants.
Flexible sensors are increasing in demand over the past few years due to their ability to conform to non-flat surfaces. The functions of these sensors include monitoring the temperature and pressure of structures along with monitoring human conditions. One of the main issues at the forefront of flexible sensors production is delamination. Delamination usually occurs during the flexing process, causing the metal-based interconnects to separate away from the polymer base. When the flexing occurs micro fractures may also develop within the metal interconnects causing the resistance to increase irreversibly, leading to the malfunction of the sensor.

Delamination is mainly due to the fundamental difference in modulus between the conductive metal traces and polymers. The modulus of metal is usually higher than that of the polymer substrate, meaning that the metal traces do not deform as much as the polymer when subject to the same stress. For example, silver has a Young’s modulus of about 70 GPa versus 3 GPa for polyimide. Polyimide is a typical substrate material used for flexible electronics due to its relatively high temperature stability as a polymer.

Our initial idea was to develop a multiple-layer interconnect structure by varying the ratio of metal to polymer in each layer using inkjet printing. The goal was to create a functionally graded structure with a more gradual change in modulus and thus a smaller chance of delamination. However, producing a proper mixture of metal and polymer is challenging as polyimide does not dissolve easily in readily available solvents and silver inks. The solvents will also have to be compatible with the electronics of the inkjet printer.

Given the time constraints, other materials capable of producing a conductive trace were investigated. Poly(3,4-ethylenedioxythiophene) polystyrene sulfonate (PEDOT:PSS) was chosen as a replacement. PEDOT:PSS is a conductive polymer mixture, with an electrical conductivity of about 100 S/cm and a Young’s modulus of about 2 GPa comparable to the polymer substrate. As a proof-of-concept study, PEDOT:PSS is applied using screen printing to form the conductive traces. Electrical conductivity of these traces were benchmarked against silver traces and measured as a function of flexing cycles.
In an industrial world where water is becoming increasingly regulated and scarce, it is necessary to find ways to manufacture goods while consuming less water. This is accomplished by either reducing the water use in manufacturing or reclaiming water for reuse. Our project sponsor, Unilever™, is interested in options for reclaiming water in its manufacturing of a number of personal care products. In particular, of their equipment cleaning processes they use a cleaning-in-place (CIP) system which generates a wastewater stream with numerous contaminants including salts and surfactants. Applying a strategy to recycle the water could dramatically reduce water use for CIP systems across Unilever manufacturing.

The scope of this project was to explore the feasibility of using forward osmosis and membrane distillation together to purify wastewater into high quality water for industrial reuse. The forward osmosis (FO) portion of the system can effectively remove water from difficult waters, such as industrial wastewaters like CIP blowdown, by using a polymeric membrane. The separation is driven by generating an osmotic pressure difference with a concentrated draw solution that can be regenerated using some secondary process.

We have chosen membrane distillation (MD) to reconcentrate the draw solution. Direct contact MD operates by exploiting a vapor pressure difference between two aqueous streams. Water vapor transports across a hydrophobic porous membrane and condenses into a colder permeate stream while the dissolved salts from the draw solution are left behind to be reused by the FO system.

This project involved the construction of the Direct Contact MD system using the X40 hollow fiber membrane contactors provided from 3M™. These membranes are hollow fiber polypropylene membranes and are designed for liquid-gas contact, but should function for MD as well. The newly constructed MD system was then connected to an existing forward osmosis system for demonstration of wastewater treatment with Unilever CIP blowdown.
Alkaline batteries are one of the world’s most popular and effective forms of energy storage. These batteries consist of a zinc anode and electrolytic manganese dioxide (EMD) cathode. Since the size and shape of alkaline batteries cannot change, internal improvements are crucial to producing higher capacity batteries. Our project focuses on improvements to the production and characterization of the EMD cathode. Currently, EMD contains impurities that are embedded during its production process; these impurities lower the achievable amount of energy and shelf life of the battery. Thus, our project aims to characterize impurities and determine the optimal conditions for EMD production.

The goals of this capstone design are to: 1) understand how specific variables of the EMD production process influences the purity of the final product; and 2) design a state-of-the-art industrial-scale EMD manufacturing process that minimizes the number of plant workers through automation. This new facility will produce higher quality EMD while significantly reducing the burden of this typically labor-intensive production process. As proof-of-concept we have implemented a fully automated bench-scale reactor in order to show the effectiveness of the new plant design.

To achieve these design goals, our team has performed a wide array of computational & experimental work. Experimentally, many different combinations of current density, acidity, and manganese content have been tested to find optimal conditions under which to make EMD. The results of these experiments, allowed for the optimal process control of our bench-scale reactor. The group has also spent a considerable amount of time on plant design, optimization and automation processes. These improvements to the overall process, will allow for higher quality EMD to be produced, resulting in significantly improved batteries.
Energy storage technologies play a pivotal role in powering our modern, everyday lifestyles. From cell phones to automobiles, a great portion of the world’s technology runs on battery power. The continual development and improvement of battery technology allows for a more advanced world. Ohmic Innovation is a mock engineering consulting company created by our design team to provide expertise to companies in the growing energy market. After speaking with over 15 experts in the energy and engineering sector, we determined that Ohmic Innovation will focus on providing full service battery testing as well as battery fundamentals and data analysis training to energy companies. Ohmic Innovation will be distinguished from its competition as it would be the first and only such testing facility in New England.

Our first client, BST Systems, is an engineering company located in Plainfield, CT that develops, produces, and manufactures silver-zinc batteries (Figure 1). This type of battery has high energy density and can function well in extreme climates. For these reasons, silver-zinc batteries are widely used in aerospace and military applications. Despite the many capabilities of silver-zinc batteries, a major limitation of their performance is that there is no way to determine their state-of-charge. State-of-charge is determined with many battery chemistries (i.e. Li-ion) by measuring a voltage change over time. However, the voltage in silver-zinc batteries remains mostly constant throughout its discharge (Figure 2). Therefore, using DC methods to analyze state-of-charge is not possible with these batteries.

In order to improve BST’s product quality and customer satisfaction, Ohmic Innovation partnered with BST Systems to design a new way to measure state-of-charge. Using alternating current and electrochemical impedance spectroscopy, Ohmic Innovation set out to determine a descriptive parameter that correlates to state-of-charge for BST’s silver-zinc batteries.

Through this project, Ohmic Innovation will be able to improve the reliability and marketability of BST’s batteries. This state-of-charge correlation will have broad practical impact – for instance it would reduce the chance of batteries failing during covert missions. The uncertainty in the state-of-charge leads to frequent, unnecessary charging before and after missions. This unnecessary charging leads to degradation of the battery over time, and eventually premature failure. Therefore, we are working to provide a safer environment for our Navy servicemen and women operating the vessels powered by silver-zinc batteries (Figure 3).
Targeted drug delivery is on the cutting edge of modern medicine and has applications in anti-cancer, antibiotic, and anti-inflammatory therapies. Treatments using targeted drug delivery systems are more efficient and can have less damaging side effects for the patient. One such system uses spherical phospholipid nanoparticles called liposomes as vehicles to increase drug uptake in diseased tissue. The current processes for producing liposomes are costly, energy intensive, and time consuming. As a result, these safer and more effective treatments are significantly more expensive.

Our goal is to design a process to manufacture liposomes that has a higher production rate and is more energy efficient than currently employed processes. The novel feature of our process is the implementation of a dialysis membrane in a continuous reactor. The dialysis membrane is used to filter short lipids out of a phospholipid feed stream. This causes the remaining larger lipids to spontaneously form into liposomes. Some potential benefits of a continuous process are higher production rates, lower cost, and increased consistency in our liposome product.

The design strategy was to maximize liposome production rate in the reactor by developing a predicative model. This approach required the use of computational modeling software such as COMSOL to determine optimal operating conditions. Experimental data was used to determine model constants such as the diffusivity of small lipids through the dialysis membrane. Some parameters of interest were the phospholipid solution flowrates, pure water flowrates, and dialysis membrane surface area. Different reactor designs were tested in order to determine the optimal configuration for the formation of liposomes. With the ability to produce liposomes at a higher rate and lower cost, liposomal drug delivery systems can become more readily available for patients. These systems can greatly enhance treatments and improve a patient’s quality of life.
The students at the Spring Valley Student Farm have received a grant for the purposes of constructing an aquaponics system. By doing this, they hope to prove the feasibility of a sustainable method of producing organic fruits and vegetables for UConn Dining Services. Aquaponics is the combination of fish farming and growing plants hydroponically. Without soil, the plant roots need to extract their nutrients from the water. The fish excrete ammonia (NH₃) via their waste and through their gills. Through a series of biological processes, the ammonia in fish waste is converted into useful nutrients available for the plants. Naturally occurring bacteria (nitrosomonas) first convert the ammonia into nitrite (NO₂). Other bacteria (nitrobacter, nitrospira) convert nitrates into nitrates (NO₃), which is an essential nutrient for plant growth.

As an engineering team, our role is to provide as much information to the student farmers as we can on the operation of an aquaponics system. The best way to accomplish this was to build a working pilot scale system. We decided to treat this system as a chemical engineering problem, where a “black box” will be drawn around the fish tank and the hydroponics system. Our goal is to make a mass balance between the fish food that we put in and the lettuce we are able to harvest. There is a relationship between the number of lettuce heads and the number of fish in the system. This parameter will be optimized and implemented in the greenhouse built at Spring Valley Farm. This relationship is being determined by collecting data on the water quality of the system as well as a mass analysis of the filter present in the fish tank.

The water is tested for pH, nitrite, nitrate and ammonia as these are the most critical indicators of system performance. Nitrogen is the key element of interest as it enters via protein in the fish food, transforms through various processes, and is ultimately removed by the plants. By monitoring nitrogen levels in the system, and keeping track of how much we put in, we hope to establish relationships and operating parameters. These can then be scaled up and applied to the large system being put in place at the student farm.
Team 12: Design of an Integrated Smart Resource Microgrid Research Greenhouse

Faculty Advisor: Dr. Leslie M. Shor
In Collaboration with the UConn College of Agriculture, Health, and Natural Resources

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In Connecticut, the agricultural industry is worth $3.5 billion and is responsible for 20,000 jobs. With unique facilities including a state of the art water reclamation facility, fuel cells, and a biomass gasifier, UConn can become the world leader in sustainable food-water-energy nexus research. The ability to use wastewater for crop production provides relief for areas of high water scarcity and allows food to be grown locally. The use of wastewater is not universally accepted and impact on greenhouse irrigation systems is unknown. A major greenhouse concern is biofouling or clogging of irrigation lines due to bacterial growth in pipes and tubing. Biofilm is a collection of microbial cells, organic and inorganic material enclosed in a hydrated, extracellular polymeric substance that adheres to a surface. Biofouling causes pipe, pump, and filter fouling, forcing commercial growers to replace necessary parts for greenhouse operation. There is currently no economically feasible method to remove biofilm in irrigation lines, so emitters and sometimes entire pipe networks must be removed and replaced every few years. The chronic presence and spread of bacteria can also adversely impact plant health reducing the number, size, or quality of greenhouse products. The impacts of alternative irrigation sources including reclaimed water and secondary effluent on the biofouling issue has never been investigated.

The goal of this Capstone Design project was trifold: (1) model the integration of key components such as water and energy into a functional and feasible greenhouse design, (2) characterize biofouling for different water sources, and (3) develop novel, practical, integrated food-water-energy nexus technology to combat biofouling in commercial greenhouses. Our integrated smart resource microgrid research greenhouse facility design will showcase the gasification of food waste to provide heat to the facility and the mechanism for sanitizing irrigation pipes, and can draw from multiple water sources for research.

Biofilm was grown inside copper pipe segments in nutrient-rich media based on either synthetic secondary effluent or UConn tap water in a recirculating laboratory system emulating a commercial greenhouse irrigation system. Alternative treatments aimed at eradicating biological growth inside pipe segments were evaluated as a function of biofilm severity and irrigation water source. These methods included dry thermal treatment, chemical treatment, and physical abrasion with a sand slurry. Experimental results were compared with finite element simulations of heat transport, chemical diffusion and reaction, and physical disruption. This work provides practical information to growers in Connecticut of novel methods to combat biofilm and the practical implications for implementing alternative irrigation water sources in commercial greenhouses.

Figure 1: Flower benches in Connecticut Greenhouse
Figure 2: Diagram of energy, water, and ventilation systems within greenhouse
Figure 3: Biofilm buildup in PVC pipe
Roasting raw coffee beans currently emits several pollutants; including carbon dioxide, volatile organic compounds, and particulate matter. According to Class One Technical Services (an environmental consulting firm), a roasting facility that produces 12.5 lbs/hr of roasted coffee generates approximately 3,240 lb/yr of carbon dioxide and about 43 lb /yr of particulate matter. It is our objective to combine current environmental initiatives within the roasting industry into a single system that will result in an eco-friendly coffee bean. We will model the process of roasting coffee as well as the attempts to clean the emissions, then we will optimize the system while maintaining a reasonable sale price for the coffee.

The coffee roasting process is regulated by federal agencies, as well as at state and local levels. The Environmental Protection Agency (EPA) has set regulations for roasters on the amount of particulate matter, volatile organic compounds, organic acids, and combustion products that can be emitted during the roasting process. Our objective is to have our process emissions well below the EPA regulations, so we will not have to worry about them. In addition to the EPA constraints, we are limited by the price for which coffee companies, like Starbucks, can sell the beans. In order to remain competitive in the coffee market, our goal is to sell the whole bean coffee at no higher than $12.50/lb.

Simulating the coffee roasting process has been our biggest feat, as coffee is not commonly modeled in software programs. We represented our coffee substance in Aspen by defining its elemental composition. In our simulation, we sent the coffee through a drier, then heated it to a uniform temperature between 250°C - 450°C depending on the type of roast wanted. These roasted beans are then cooled with either water or air, screened to remove debris, and packaged for consumers. We have looked into several methods of dealing with the emissions produced from roasting that are currently practiced. These approaches included exhaust fans, chaff collectors, afterburners, scrubbers, and UV scanners. In order to optimize our process, we have taken the most eco-friendly and economically sound components and combined them into a green coffee roasting process.
Food Packaging is a necessity that can be seen on shelves all over the country. There is currently one dominant material used to produce chip bags for the food industry and it is aluminum. The aluminum is used by a process of aluminum vapor deposition, which requires the vaporization of aluminum at very high temperatures to coat the plastic substrates. The reason to use aluminum is because of the excellent oxygen and water vapor transmission rates. These low rates are what keeps the chips fresh and crisp for a long shelf life. Our project is to take a newly designed polymer/inorganic hybrid nanocomposite coating that does not require high operating conditions to apply, but still meets the transmission rates required for food packaging.

The goal of this Capstone Design project was to take this newly designed coating, using clay and polyvinyl alcohol, to coat a biocompatible and biodegradable film made of polyactic acid. This project is to design a scaled up process that will effectively coat substrates to be used for packaging in the food sector. One of the keys to designing this process was to maintain a homogenous composition throughout and ensure an even coating across the polymer film. Constraints such as temperature, pressure, speed and viscosity were taken into account using experimental data and literature.

Our proposed process is a gravure coating method because it allows for a continuous stream of fluid to be applied to the substrate film and it allows good and controllable alignment of the nanosheets, which is crucial for oxygen and water barriers. Our proposed method is composed of an engraved roller running through a coating bath that is continuously filling the engraved lines of the roller with the coating solution. In order to remove any excess of the solution on the film, a doctor blade wipes off the excess and a pressure roller is used to control the gap between the gravure roller and the substrate. This process could potentially reduced contamination to the environment because it uses biodegradable materials in replacement of metal coated plastics such as Aluminum based packaging, which takes much longer to degrade. It also reduces the high energy cost of the industrial process compared to its current industry competitor.

Within the next few years, crude oil refineries in the United States will be required to observe the EPA’s increasingly stringent fuel regulations. The new regulations will stipulate further reductions in the sulfur content of diesel to less than 10 ppm. The EPA regulates the sulfur content of fuels to protect the public, crops, and water supplies from dangerous pollutants like sulfur and nitrogen oxides. Sulfur can poison the catalysts used in vehicle exhaust systems, as well as those used in large scale industrial processes. The current method of sulfur removal from diesel is hydrodesulfurization (HDS), which relies heavily on hydrogen to react away sulfur containing compounds. The problem with producing ultra-low sulfur diesel by this method is that, at lower product sulfur concentrations, the amount of hydrogen gas required increases exponentially. The increase in hydrogen consumption this necessitates makes treating in this fashion very costly. By introducing an adsorption step post-HDS, the process has the potential to be more environmentally friendly and less expensive.

Adsorption of refractory sulfur compounds will be achieved through the use of ion – exchanged zeolites. Their value lies in their ability to remove compounds HDS struggles with. These include large and unreactive compounds such as benzothiophene and dibenzothiophene. Zeolites with metal ions work well as adsorbents for these compounds, using the metal ions as active sites for molecular attraction. In particular, copper (II) – Y zeolites provide the most promising performance of the metal ion zeolites available. These same zeolites can be relatively inexpensive, compared to catalysts already used in HDS. Therefore, zeolite adsorption is well suited for sulfur removal after the majority of sulfur containing compounds are treated in HDS.

The viability of an adsorption process rests heavily on the cost of sorbent, packed bed size, adsorption kinetics, and regeneration. The practicality of the post-HDS treatment of highway diesel was determined with a MATLAB simulation, used to optimize system energy, mass, and momentum balances. The comparison of this model to that of an HDS simulation, capable of producing less than 10 ppm sulfur diesel, served as the basis for the proposed system’s potential market and efficiency. This process is still being explored for use on a large scale, but further refinements would be required before full implementation could be considered.

Figure 1: Adsorption column with copper (II)-Y zeolite is shown producing 10 wppm sulfur diesel. http://www.co2crc.com.au/research/demo_precomb_adsorption.html

Figure 2: Experimental breakthrough data and modeled curve used in MATLAB simulation. Courtesy of Kevin X. Lee
Open, wood-burning fireplaces are commonly used for heating and aesthetic purposes worldwide. Despite this, the public is generally unaware of the amount and effect of emissions created by the incomplete combustion of wood in an open fireplace; this includes particulate matter that cause a variety of respiratory and cardiovascular illnesses and polycyclic aromatic hydrocarbons (PAHs) which are known carcinogens. These emissions are worse in unregulated wood-burning fireplaces than in coal burning power plants. An economical solution in the form of an improved fireplace grate and chimney filter device may convince more fireplace owners to adhere to the voluntary EPA regulations for decreasing fireplace emissions, thus improving the air quality and health of communities who enjoy the comforts of traditional fireplaces.

The objective of our project is to design and model a consumer and environmentally friendly product that can be retrofitted into wood burning fireplaces to reduce particulate matter and PAH emissions, while maintaining heat and fuel efficiency. In addition, this product must be consumer friendly, aesthetically pleasing, easy to install and maintain, comply with fire and building codes, and prevent backflow of air into the home, all for a low purchase price and maintenance cost.

Our product consists of two separable devices. The first is a newly designed grate that encourages more complete combustion of the wood by improving the time, temperature, and turbulence within the fireplace, thereby reducing particulate matter and PAH emissions. The second is a chimney cap containing a filter apparatus to remove any particulate matter and PAHs that do get created. The use of these two devices will decrease emissions from a wood-burning fireplace while maintaining the pleasing aesthetics of an open flame.
Gasoline is currently mandated to contain at least 10% volume of ethanol as a way to oxygenate gasoline for a more complete combustion. However, water enters the gasoline through the atmosphere due to the attraction from ethanol causes the gasoline to phase separate into two layers: one comprising primarily of ethanol and water, and the other composed primarily of gasoline. The ethanol layer promotes the growth of acetobacter bacteria which consumes ethanol, producing acetic acid as a byproduct that causes corrosion to the aluminum engine blocks. As such, the ethanol content in the gasoline should be reduced to decrease the harmful effects from the acetobacter and the corrosive damage from ethanol and water.

The goal of this Capstone Design project is to design a process to remove ethanol from gasoline so that the ethanol consists of less than 1% volume per volume of gasoline product. Our approach consists of using a batch multistage liquid-liquid separation process. Water is added to E10 gasoline to produce a two layer phase system: a gasoline rich phase and a water-ethanol mix layer. After removing the water-ethanol phase, more water is then added into the gasoline layer to extract more ethanol into the water-ethanol phase. This new phase is then removed and the process continues until the ethanol content is below 1% volume per volume of gasoline product. Once the desired ethanol volume content is achieved, sorbents are used to absorb residual water left in the gasoline phase to leave an ethanol-free gasoline product safe to be used in small engine systems. Aspen Plus was used to simulate the results of our process.

In addition, a small plant was evaluated and designed to assess the economic viability of our process when used in a small scale operation to provide ethanol-free gasoline to customers with small engines. An economic analysis was performed to consider capital and operating costs as well as our relations to customers.
Liquid hydrocarbons are attractive chemicals, polymer precursors and fuels because of their high energy density and transportability. Some of the most valuable liquids are aromatics, such as benzene, toluene and xylene (BTX), with many industrial applications such as conversion to plastics. BTX are most commonly produced through naphtha reforming, which is an energy-intensive and expensive process requiring many processing steps and units in petroleum refineries. Moreover, petroleum refineries and BTX production have been shown to contribute substantially to greenhouse gas emissions.

One of the most promising methods for the production of BTX, with parallel mitigation of the greenhouse gas emissions of the process, is the direct conversion of methane over a molybdenum catalyst. This process also takes advantage of the abundance of natural and shale gas in the United States, while presenting a solution to overcome the transportation challenges of gaseous fuels. The one-step process of methane to BTX eliminates the need for extensive unit operations, petroleum refining and our dependence on foreign oil. This process can be carried out in the absence of oxygen, generating virtually zero in-stream CO₂. It is a modern response to the recent advancements in horizontal gas drilling technologies, which have vastly increased available natural gas reserves in the United States, significantly complicating the future landscape of CO₂ capture. However, the process of methane conversion to BTX is not without challenges. Limitations imposed by the thermodynamics and reaction kinetics of the process make it difficult to be economically viable and require advancements in the fields of process and reactor design.

The goal of this Capstone Design project is to optimize the conversion of methane into BTX through a novel reactor design. Specifically, the aromatization of methane also generates hydrogen as a product. A hydrogen membrane reactor is explored as a promising option to selectively remove hydrogen from the products pool and allow for higher reaction conversions by relaxing the thermodynamic limitations. As the concentration of H₂ in the reactor decreases, equilibrium is driven towards the products, overcoming the thermodynamic barrier of the original system. This increases the conversion and selectivity to BTX from a methane feedstock in a one-step reaction-separation system.
Team 1: Electrical Conductivity Investigation in Groundwater Flows

Sponsored by: United States Geological Survey (USGS)
Sponsor Advisor: Dr. Martin Briggs
Faculty Advisor: Dr. Amvrossios C. Bagtzoglou

The United States Geological Survey (USGS) investigates the natural world to better understand and protect natural resources for current and future generations. Access to clean water is critical, both for human use and ecosystem function. Every being on our planet needs water to survive, therefore we need to understand and communicate the physics of fluid flow. When water is flowing underground, it cannot be directly visualized like when in streams and rivers, and it is inherently more difficult to understand. Groundwater is simply the water that lies beneath the soil surface and is present within the pores and cracks in the ground, and is derived ultimately from precipitation. Along with groundwater flow, there is a plethora of reactivity occurring between the sediment, water, carbon, and chemical elements. One key process that needs illustration is the different rates that water and heat propagate under various heterogeneous sediment distributions. The goal of this project is to demonstrate groundwater flow dynamics in aquifers with heterogeneous sediments using electrical conductivity (salt) and heat as water tracers.

A physical flow model was designed to display these concepts. Embedded in the multi-layered sand of the physical groundwater flow model are three sensors that can measure electrical conductivity, temperature, and water content. When flow is present, the sensors will read all three of these parameters and collect the data to a data logger. To analyze the data, we will use software that organizes what is being recorded into one summary graph, which in turn allows us to make sense of transport along the entire flow path.

This project stands out compared to other flow model designs due to the incorporation of digitally-monitored tracers that traditional teaching models do not include, but rather rely on colored dyes and visual interpretation. These new digital advancements, including the use of smart-phone infrared, will aid students who are accustom to consuming digital information. The design will help to better understand the complicated coupled movement of groundwater and heat without the need for expert interpretation and explanation.
The Town of Thompson looks to extend a paddling route outlined by the multi-state conservation group, The Last Green Valley. The route along the French River reaches far into southern Massachusetts, but ends abruptly at a dam in North Grosvendorale, preventing kayakers from continuing on down river. The purpose of the proposed design is two fold: 1) to allow kayaks and canoes to portage around the dam, and 2) to provide residents of Thompson and North Grosvendorale additional access to the paddling trail.

The site is located in North Grosvendorale, Connecticut off State Highway Route 12. It is a small town owned parcel situated between Route 12 (Riverside Drive) and the French River. The front of the site (closest to Route 12) will be a parking area. A trail with ample space for transporting canoes and kayaks will lead from the parking area to the river, where these can be launched safely from the proposed small boat launch. The front of the property currently serves as a driveway to the neighboring property. The parking lot will be designed in such a way to allow an existing residential driveway on site to remain in use. The site is currently, littered with garbage, glass, fallen trees, and an old foundation.

The design is split into three parts. The first part to be designed is the trail starting at the parking lot, winding through the property where it ends at the boat launch. Next, the boat launch will be designed. The boat launch shall be designed with input from the local kayakers who currently use the paddling route. The final design approval will come from The Town of Thompson. Third, the parking area will be designed last to minimize imported or exported fill.

The Town of Thompson intends for the project to be designed and constructed using a minimal amount of money. The topographic survey was self-performed by Team #2 group members. In addition, the site design will show that Team #2 placed emphasis on simplicity, cost efficiency, and ease of construction. The initial vision was to provide a safe, accessible, and efficient way for kayak and canoe enthusiasts to launch their vessels into the French River.
The Town of Thompson, Connecticut assigned the task of designing new sewer and water pipelines in an undeveloped area. The new system starts at the industrial park on Reardon Road and travels through a forested area to Route 12. The French River and a rail line owned by Providence and Worcester Railroad Company run perpendicular to the direction of flow for the water and sewer lines.

In order to overcome the obstacles, directional bores will be used to install the system under the river and railroad tracks. Directional boring, also known as horizontal directional drilling is a method of installing underground infrastructure along a predetermined bore path with minimal impact on the surrounding area. This is the ideal method to install the system due to the onsite obstacles. It allows for less surface disturbance than any other installation method. It also allows for a wider variety of pipe materials to be used. The directional bore installation method makes the system’s design more cost-effective.

Since the new pipelines are being designed to carry the capacity produced by the industrial park, the design capacity is set at 20,000 gallons per day. This is an overestimate of the actual output to account for future capacity increases. A low pressure system will be used because it is an effective and low cost solution. The smaller pipe diameter requires a depth just below the frost line. This makes the directional bore process simpler and it allows the system to follow the terrain. A grinder pulverizes the sewage into small particles, allowing the system to accept solid particles without clogging. This is a sealed, pressurized system which ensures the safety of the river, groundwater, and the rail line.
The site of interest is located in a residential neighborhood in the town of Pittsfield, MA. It consists of an upland watershed, 1000 feet of roadway along Mountain Drive, and a lower wetland. The upland watershed features a stream that flows downhill along the existing terrain and then abruptly changes direction to the west; a design intended to create more useable land for residential properties. During intense rainfall events and snowmelt, however, the stream overflows both at the existing embankment where the stream was rerouted, as well as at the inlet culvert due to clogging debris. The excess runoff flows downhill along the grade, ultimately causing undesired property damage. The goal of this design is to solve both of these flooding problems with minimal disturbance to surrounding residential homes.

An analysis of the surrounding water shed was conducted to calculate the surrounding watershed area and the peak volume of the stream from a hydrologic modelling program (GIS). A cross sectional area was then calculated to determine the peak flow entering the culvert inlet using the TR-55 method for a 25-year storm. Bearing the necessary intake to the system in mind, several culvert options were then compared to determine the appropriate inlet. After replacing the culvert, the embankment was reinforced by utilizing a cut & fill volume calculation in order to determine the amount of soil needed to reinforce the bank and account for potential erosion. The river was re-graded to minimize erosion damage and to better control the flow of the water. Finally, a wetland restoration plan has been implemented to repair any damage caused during the construction process.
The objective of this project is to rehabilitate Bridge No. 02934 in Stonington, Connecticut. Bridge No. 02934 carries Route 234 (Pequot Trail) across Anguilla Brook. The bridge is a single span reinforced concrete slab bridge carrying two lanes of bidirectional traffic. It was initially constructed in 1941 with reconstruction in 1986. The existing superstructure consists of a 16” reinforced concrete slab, overlain with a waterproof membrane and a minimum of 2.5” of bituminous concrete. The existing substructure consists of reinforced concrete cantilever abutments with a U-shaped wingwall at the northwest corner, and flared wingwalls at the other three corners. The existing bridge has a span length of 20’ and a curb-to-curb width of 31.24’. The concerns with the existing bridge include the serious condition of the concrete deck and significant evidence of scour along the abutments, despite the installation of a scour wall during the 1986 repairs. Additionally, the existing bridge is unable to pass a 100-year storm without flooding of the road, deeming it hydraulically inadequate.

Based on the current condition of the bridge, a full bridge replacement is recommended to become structurally and functionally adequate. Replacing the entire 74-year old existing structure will be the best long-term investment because it has the longest estimated service life, requiring less future rehabilitation. Furthermore, the proposed design addresses the concerns of the existing bridge. The new bridge will consist of steel beams and a reinforced concrete deck spanning 47’ with a 40’ clear span to meet the hydraulic requirements of a 100-year storm. The deck will also have an increased curb-to-curb width and out-to-out width which will improve the Deck Geometry rating and will accommodate staged construction. The original abutments will be left in place and be used as cofferdams to provide additional scour protection for the proposed abutments and to lessen the amount of necessary water work. Bridge design will follow the AASHTO LRFD Bridge Design Specifications and the ConnDOT Bridge Design Manual.
Bridge No. 02932 carries Route 2A over the Dickerman’s Brook in Preston, CT. The current bridge is a single-span reinforced concrete slab structure that was built 1928 and has no records of rehabilitation since then. The structure is 14 feet long and the hydraulic opening is inadequate. The bridge sits on a curve with a radius of 295 feet, whereas the standard requires a curve with 345 feet that has traffic moving at 35 mph. The insufficient hydraulics, horizontal alignment, as well as the deterioration have deemed this bridge structurally deficient. The goals of this project include designing and detailing the new reinforced concrete deck and steel girders spanning 40 feet with 12 foot lanes and 5.75 feet shoulders. Construction staging and the maintenance and protection of traffic were also considered during the design process. The construction of the bridge will utilize two construction stages where one half of the bridge will be constructed during each stage, and traffic will be handled using one lane of alternating one-way traffic. Some tasks also include the horizontal and vertical roadway alignments, construction sequence, maintenance and protection of traffic that meet the Connecticut Department of Transportation and Federal Highway Administration standards.

The superstructure being proposed is a steel girder design with a single-span reinforced concrete deck. It will be supported by concrete integral abutments and it will have a span of 40 feet in order to allow better water flow under the bridge and improve the horizontal sight distance around the road curve where the bridge currently lies. Appropriate load factors were applied to the bridge to design the components of the superstructure so it would meet all AASHTO design requirements. The horizontal alignment was designed with a radius of 345 feet to meet the ConnDOT requirements and the vertical alignment was designed to provide a hydraulically adequate waterway. Plans that detail the superstructure and highway geometry were developed using MicroStation. The construction sequence and the maintenance and protection of traffic precautions are outlined in plans developed in MicroStation. Based on the design plans, a final construction cost estimate for the project was created.
Team 6: Complete Street Design for a Section of Maple Road in Mansfield, CT

Sponsored by: Town of Mansfield
Sponsor Advisor: Derek Dilaj
Faculty Supervisor: Amvrossios Bagtzoglou

Our team was tasked with doing a complete streets design for Maple Road in Mansfield Connecticut. This connector road is a link between Route 275 and Route 195. Located at the intersection of Maple Road and Route 275 there is the Mansfield Housing Authority and the Mansfield Senior and Wellness Center. Halfway down the road there is the Mansfield Middle School, and just northwest of the site is the University of Connecticut. This area experiences a fair amount of bicyclists who use the existing shared road with motor vehicles. The road has some strong curves that make for unsafe conditions when it comes to cars sharing the space with cyclists. We will be focusing our design on one section of Maple Road running from Davis Road to Lodi Drive. Within this area there is an existing culvert below the road. There is a water hole that builds up on the east side of the road that drains over a dam and through the culvert. This section of road is also very narrow and cars tend to pass through with higher speeds than posted. The town also has a 15-foot ROW from the center of the road and the homes along the road are sparse.

Our approach to this will be to redesign the outdated culvert, implement an exclusive right of way multi-use path off to the east side of the road, as well as widen and realign the road where necessary. We are considering removing the dam on the east side of the culvert so as to allow for more room to create a 6-foot bike path. On the west side of the culvert, there is sufficient room to possibly realign the road outward thereby providing more space on the east side for the bike path. Running a quick drainage analysis through StreamStats to see if the culvert could be removed, we saw that there is a sufficient amount of water flowing, so the existing size of the culvert will remain the same to handle drainage. We are considering adding in speed bumps before and after this narrow section to introduce speed calming. We also will be adding curbing along both sides of the road, as there is currently no existing curb.

Figure 1: West end of culvert passing under road.  Figure 2: Water hole on east side of road.  Figure 3: Google maps aerial view of Maple Rd.
Teams 7 & 8: Hunting Lodge Rd. Bikeway and Culvert Redesign; Bonemill Rd. Conversion

Sponsored by: Town of Mansfield
Sponsor Advisor: John Carrington, Town Engineer
Client Supervisor: Derek Dilaj, Assistant Town Engineer
Faculty Supervisor: Amvrossios Bagtzoglou

Our project consists of three distinct parts: the design of a bicycle/walking path connecting Separatist and Hunting Lodge Road, the design of a culvert spanning a section of Hunting Lodge Road and the design and development of nearby Bonemill Road.

For the design of the bike/walkway, we plan to make use of the southern portion of Hunting Lodge road to create an on street shared lane up to the culvert. From this point on, our design incorporates an elevated boardwalk looping out into the wetlands and terminating at the Hunting Lodge Rd and North Eagleville Rd intersection. Our design focuses on providing users with access to wetlands as a transportation corridor, as well as a bridge into the natural environment of the wetlands.

The second part of our project involves the replacement and redesign of a local corrugated metal pipe culvert. The culvert will be redesigned with the intent of replacing it with a box culvert, but other design alternatives will be presented. The culvert site is just south of the Hunting Lodge Road and North Eagleville Road intersection in Storrs. In order to design the culvert, we will use various methods to estimate peak flows of Eagleville Brook. Using the maximum calculated peak flow, as well as worst-case traffic conditions, the culvert will be designed according to water height and maximum expected loads.

Bonemill road is located between N Eagleville Rd and Route 44 in Mansfield, CT. The existing road is currently a two way unimproved dirt road that is too narrow for traffic in both directions to pass comfortably and safely. The design we selected will consist of a conversion from the existing two lane road into a single-track road that will allow traffic in both directions. Strategically placed pull over spots and speed bumps will be placed along the road to allow vehicles to pass each other safely. In addition to this, shoulders will be placed on both sides of the road to accommodate pedestrian access. The expansion will include a dry grass swale that will extend along the north edge of the road and tie in to the existing cross road culverts.
Team 9: Conceptual Redesign of I-384 Interchange in Manchester, CT

Sponsored by: CONNDOT
Sponsor Advisor: Jordan Pike, P.E.

The Connecticut Department of Transportation (CONNDOT) is interested in a conceptual redesign of the I-384 interchange between Hartford Rd. and Keeney St. in Manchester, CT. This design needs to address the problems of safety for Charter Oak Trailway users and pedestrians as well as conflicts due to peak hour traffic congestion in the area.

The area gained attention from CONNDOT after a patron of the Charter Oak Trailway expressed his concern with safety for pedestrians and trail users. The Keeney St. bridge overpass along with trees at the left of the ramp creates a poor line of sight for cars exiting on the westbound ramp. As a result of this, cars are forced to extend into the crosswalk if waiting to make a turn. This also creates a threat to pedestrians and trail users as they anticipate using the crosswalk on the exit ramp. Further investigation from CONNDOT uncovered problems with traffic congestion at the nearby intersections. Dunkin Donuts experiences heavy volumes during the morning commute. Similarly, the eastbound off ramp exit onto Wetherell St. as well as the intersection at Keeney St. and Wetherell St. experience the heavy congestion due to inefficient traffic flow at the Hartford Rd. and Keeney St. Intersection.

In an effort to address the problems described above, a high cost and a low cost alternative were developed. The high cost alternative is a complete redesign of the affected intersections. This includes shifting the Hartford Rd. and Keeney St. south to create space for parking, combining both westbound off ramps into one, and implementing a 5-legged roundabout at the intersection. The low cost alternative includes optimizing the traffic signals, relocating a bus stop on Wetherell St., adding in crosswalks and signage where the Charter Oak Trailway crosses the I-384 ramps, as well as eliminating one of the westbound off ramps. Both alternatives include moving several business driveways, particularly Dunkin Donuts on Harford Rd., to create better traffic flow and pedestrian safety.

All alternatives will be designed for the year 2036, estimating a 1% population growth rate per year, and simulated using Vistro. In the end, we will have a full report for each alternative that will include a traffic analysis, a conceptual redesign of the area, a cost analysis, and a safety-impact analysis.
We are HASE engineering, the “Highway And Street Experts.” Our team consists of four members: Seth Stevens, Adriaunna Towle, Ethan Donecker, and Hojung Jang all of whom are expecting to graduate in May of 2016 with a Bachelor of Science Degree in Civil Engineering. We have been selected by the Civil Engineering Department at the University of Connecticut to work with the Connecticut Department of Transportation and the Town of Thompson to create a unique conceptual redesign of Interchange I-395 and Route 193 in the Town of Thompson, CT. Our team's academic background, coupled with our wide range of work experience, have given us the tools and the skills necessary to manifest real value and professionalism to this project, and ultimately to the State of Connecticut’s highway system and to the Town of Thompson’s road network and economic development efforts.

Currently there is an industrial park under construction in the Town of Thompson near the Interchange of I-395 and Route 193 that the town wants to increase access to. The current interchange does not offer an easy route to the industrial park from I-395 and also operates with an undesirable left hand exit from the Interstate. At this time the only way to access the industrial park is by traveling in a circuitous pattern on small back roads that are not currently designed to accommodate the increased volume of large trucks that will be using them soon.

The primary objective of this project is to improve access to the industrial park from I-395 to ensure an improved, safer route. In order to accomplish this we will be redesigning the interchange into a conventional full diamond (pictured below, bottom middle). Furthermore, in order to address the risk of collision from speeding cars coming off the interstate we will be redesigning an intersection (pictured below, bottom left). We will also be increasing the curb radii of another intersection to accommodate larger trucks (pictured below, bottom right). These improvements will succeed in both increasing access to the industrial park and ensuring safety.
Conventional reinforced concrete (RC) columns are very common in bridge construction, yet they possess many shortcomings that must be addressed. The construction of cast-in-place reinforced concrete columns is time-consuming, costly and complicated. In addition, RC columns are not sufficiently resilient to environmental hazards and extreme events. In the course of the lifetime of a bridge, there is a high likelihood that a flood, fire, earthquake, blast or other extreme event will pose a significant test to the resiliency of the structure. Since columns are typically the most vulnerable members of a bridge structure, they are often a key determining factor in the longevity and durability of the bridge.

Minimally reinforced concrete-filled fiber reinforced polymer (CFFT) columns have been proposed in order to meet the demand for a system that is superior to conventional reinforced concrete columns. This innovative column system has proven—both in laboratory experiments and in field applications—to be more simply constructed, more resilient, and more cost-effective over the course of the lifetime of the bridge with less environmental impact than conventional reinforced concrete columns.

To conduct a comprehensive comparison between the RC and CFFT column systems, the columns of two bridges with reinforced concrete columns – Bear River Bridge in California and Townsend Bridge in Connecticut – were redesigned while maintaining the superstructure and other aspects of the bridge. First, SAP2000 was used to model the existing RC columns and determine their capacities. These values were then used to design CFFT columns with comparable capacities. Models of the two bridges – one using RCs and one with CFFTs – were generated using CSIBridge. Once the design was determined, AutoCAD was employed to generate new bridge plans for the proposed redesign using CFFT columns.

In addition to redesigning the columns, a comprehensive comparison of both the lifetime cost and environmental impacts of the two systems was conducted. All of these analyses demonstrated the superiority of the CFFT system in terms of multi-hazard resilience, lifetime cost and environmental impact.
Team 12: Small Scale Irrigation Project at Abba Samuel River Watershed, Ethiopia

Sponsored by: Engineers Without Borders
Sponsor Advisor: Dr. Jonathan Mellor

This senior design team is assisting Engineers Without Borders UCONN with the design of an irrigation system for a community near to Woreta, Ethiopia. As is the case in many communities in Africa, agriculture is essential for both sustenance and economic development. The nine month dry season experienced in the Woreta region leads to food insecurity since communities do not have adequate irrigation. The current irrigation system in the village consists of a small cement dam and diversion channels along the northwest side of the Abba Samuel River. The dam and channels lose a substantial amount of water to leaks, infiltration, and evaporation. The southwest side of the river does not have any access to the river water for irrigation. The team’s goal is to design an irrigation system for the fields on the southwest side of the river by diverting a portion of the seasonal Aba Samuel River for storage in ferrocement tanks. The stored water from the wet season will be distributed to fields in the dry season via a pipe distribution network. This water will then be used to irrigate fields using furrow irrigation.

The design consists of four major sections: watershed modeling, storage design, distribution design, and irrigation planning. The watershed model uses precipitation data, calculated infiltration rates from soil samples, and land surface topography to characterize the surface water balance in the region. The resulting mathematical model provides estimated expected water volumes that assisted in the design of the storage system. To store this capacity of water, the team decided to design ferro cement tanks, which are common as a means of harvesting rainwater accumulated from storms. The watershed model also enabled the team to determine the most beneficial area to place the distribution system based on a calculated point of highest accumulation, as well as surrounding elevations. All of the systems, including the distribution network and irrigation, needed to be gravity fed. Therefore, knowing the elevations between points of accumulation, as well as the steepness of slopes along the river and cross slopes out from either side of the river, were essential in determining their placement. Regular PVC piping was used in the distribution network to divert water from the main river outward, where furrow irrigation channels were implemented to provide water to the designated fields for agricultural purposes.
This senior design project involves the design of a refueling pier in order to replace an existing structure that is no longer adequate for use. The pier is to be designed and built in two segments. The first part of the structure consists of timber piles and pilecaps with a steel walkway. The second is a steel pier and platform that will extend from the end of the timber portion at an angle and will include a steel canopy. The design of the new structure will be performed entirely in U.S. customary units while remaining within the standards of codes such as ASCE 7-10, the AISC Steel Construction Manual, 14th Edition, and NDS 2015 Edition.

The project includes obtaining environmental loads along with specified dead and live loads that have been provided for use in the design. The walkway will be subjected to uniform distributed live load of 100 psf or a concentrated load of 500 lbs. The platform will be able to withstand a uniform distributed live load of 250 psf. Earthquake loads are to be found using the United States Geological Survey Earthquake Maps, and wind loads are to be calculated with site location data, the Applied Technology Council website, and ASCE 7-10. Wave loads are to be 1000 lbs acting on each pile towards the North. Next, structural adequacy is determined by the worst case load combinations using either Allowable Strength Design (ASD) method or Load and Resistance Factor Design (LRFD) method depending on the material and section. This involves structural analysis using hand calculations, excel spreadsheets, and using SAP2000 software for modeling and analysis. The project is sponsored by COWI Marine North America, located in Trumbull, Connecticut. We thank our faculty advisor Dr. Zhang and sponsor advisor Mr. Alex Mora for advice and support our project.

The final project will be dedicated to the memory of our teammate and friend Gregory Colla who tragically left us this semester. He will be remembered and missed as a vital member not only to us and our group, but also to UCONN and his friends and family.
Team 14: The City of Bridgeport Streets Program: Route 130 Conceptual Redesign

Sponsored by: City of Bridgeport
Sponsor Advisor: Norman Garrick

The City of Bridgeport gave us the opportunity to collaborate on one of their Better Street Program projects. The Better Street Program strives for the safety and accessibility for all modes of transportation on a City of Bridgeport road to reduce pedestrian, bicyclist, and motor vehicle fatalities. The project we are collaborating on with two City of Bridgeport representatives is to create concepts for a 30% design of the approximately 3.6 mile section of Fairfield Avenue (Route 130) that connects several areas of Bridgeport: Downtown, West End, Black Rock and the Fairfield Metro Metro-North train station.

Recently, downtown Bridgeport has experienced a revitalization period with new businesses and residents migrating into this vibrant culture. The preservation of historic buildings, modification of existing structures, and redesign of street structures to increase walkability and biking were the main factors for the transformation of downtown Bridgeport’s image and activity. Downtown is home for the city’s art, cultural festivities and entertainment, most notably the Barnum Museum and Downtown Cabaret Theatre. Downtown intrigues many individuals to see the city’s art, cultural diversity, restaurants, and other various shops. We are attempting to improve this section of road which is so vital to the community in order to enhance all the great aspects of a city that Bridgeport has to offer.

Our goal for this project is to design various solutions in order to improve traffic flow, safety for all modes of transportation and green infrastructure in certain sections of Fairfield Avenue. Researching the vehicle, pedestrian and bicyclist traffic volumes at every intersection on this 3.6 mile section will show us which branches of Fairfield Avenue are considered dangerous or problematic. We have discovered the problematic areas, investigated traffic calming methods, intersection improvements, bike lanes and storm water drainage techniques. We are now deciding which design plans for each section of our route are most beneficial to the area in all aspects. To further solve the issues on Fairfield Avenue we are using the concept of complete streets to help us understand the underlying principles in order to produce safe and accessible modes of transportation throughout the entire roadway.
The complete design of a street must take driver and pedestrian safety into account. The layout of a street and its surrounding aspects like sidewalks, guard rails, and signs must be constructed with the absolute assurance of individual well-being. In the case of Furnace Avenue in Stafford, CT, a lack of safety measures has caused major accidents and because of this the Director of Public Works, Richard Zulick, and the Town of Stafford requested our services to assess the existing conditions of the road and propose a new design to solve the issues at hand. Furnace Ave. runs from the center of Stafford Springs for just under three miles where it then intersects with Rt. 319. In addition to the safety problems, there is wear and tear all along the road surface, there are major problems with the drainage system along certain sections, and there are sightline issues at multiple locations. A redesign of Furnace Ave. is necessary to provide a more enjoyable driving experience while keeping the surrounding community safe.

The documented results from the assessment of the existing conditions of Furnace Ave. helped single out the problem areas along the road. To address the safety problems, traffic markings like a painted center line and various crosswalks will be added to the road. There will also be sidewalks, signage and guardrails introduced in the necessary areas. A complete regrading and repaving of the road will be suggested to eliminate the defects in the asphalt. To reduce the issues dealing with braking distance and line of sight for drivers, the horizontal and vertical alignment will be addressed as well as the inconsistencies in lane width. In regards to the drainage issues solutions are offered including the option of constructing swales at certain locations. All of the effort put in to redesigning Furnace Ave. is geared towards eliminating accidents, providing pedestrian security, and improving the overall well-being of downtown Stafford, CT.
After storms occur, such as Hurricane Sandy, flooding indoors can affect thousands of people, and the mold that develops can contribute to a very unhealthy environment. There are many different types of mold that thrive on building materials and in temperatures usually found in homes. With moisture present, mold can grow exponentially, becoming a danger to those who clean up after storms. Since mold and other biological materials that grow with the mold in flooded homes can cause severe health issues, such as asthma attacks and lung diseases, it is important to reduce exposures and remove mold safely.

The goal of this project is developing a smartphone app, called Mold Response, which assists mold removal and informs the public on mold, particularly after a storm. The app takes a highly complex diagram designed by UConn Health and breaks it down into a simpler form. This simpler form can help people quickly and successfully decide whether they are healthy enough to participate in mold cleanup. If an individual is healthy enough to be around mold, the app then explains how to correctly use safety equipment so the individual can successfully and safely remove mold from a location without causing any harm. The app also informs users certain directions on what they can do if they have a certain health issue.

The application also can be used for testing the individual on their knowledge for mold. The application has numerous quizzes that the individual can take, and each quiz is based on pamphlets also designed by UConn Health. With the application questions being connected to a database, UConn Health can then add and change the quizzes accordingly when they need to either update the information on existing quizzes or add new quizzes entirely.

The application is being designed on an Android environment using Android Studio with the intent to make it portable to Apple IOS in the future. The database uses a MYSQL server with Apache supporting the web interface for the data entry. The whole project’s backend is being designed in an orderly fashion so the project can be continued later with a different team if the sponsors wish to expand on the application and its capabilities.
Team 2: Wireless Electroencephalographic Device Incorporation into Gameplay

Sponsored by: UConn CSE Department
Faculty Advisor: Professor Jeffrey Meunier

Electroencephalographs (EEGs) are input devices available as commercial wireless headsets which are capable of picking up signals associated with facial expressions, emotions, or even focused thoughts. These could be used by physically impaired people (e.g., paraplegics or victims of ALS) to control prostheses or wheelchairs, restore mobility, and increase independence. Alternatively, they can be used by people including the non-disabled to control external devices or software such as video games.

The goal of this project is to create a new paradigm of gaming using EEG input via an Emotiv headset. This makes the game more psychologically involved through the use of mental commands, such as spell-casting, by thinking or concentrating rather than the conventional usage of a keyboard and mouse or console controller. This could make the gaming—or any—experience more intuitive, not requiring the user to click when they want something, but instead just thinking about it. This could also be useful in a psychological sense: it could be used to monitor a person’s emotions in a non-intrusive way, and could be used as a therapeutic tool, or simply an interesting way to teach people more about what signals their brains are sending, while providing an entertaining experience in the process.

The game is made in Unity and interacts with the Kinect through RUIS, Reality-based User Interface System. A client-server connection is used to obtain data from the EEG headset which determines the player’s actions within the game. Players are able to use their mind with the EEG headset to control certain actions, and move their body in front of a Kinect One to control the character’s movements. This provides a more immersive experience where users aren’t just pressing buttons to progress through a storyline. EEG gaming is a largely unexplored field of gaming, so much of what this project explores is unprecedented, making it a great problem-solving experience. The main goal is to engineer a more immersive and healthy gaming experience in which the player can interact directly with the environment without the use of traditional inputs.
Manufacturers today face a very real problem: thousands and thousands of industrial sensors are creating millions of data points, with no systems in place to effectively monitor them and indicate possible problems in real time. Solving this big data problem has the potential to save companies tremendous amounts of money, as well as increase their efficiency and reduce waste. Furthermore, companies seek to save even more by running their big data solutions in the cloud, offsetting the cost of expensive hardware and the maintenance costs associated with that hardware, such as electricity and personnel.

Our solution utilizes several technologies to meet those manufacturers’ needs. Among them are the Hadoop NoSQL database solution, which can efficiently store and query the millions of data points being sent by sensors throughout the manufacturer’s system; PostgreSQL for clustered relational storage of sensor metadata; Apache Spark for advanced, distributed data analytics, and a custom JavaScript web application for data visualization. The data analytics are written in Java, and the framework for storing new data is written in Python, both of which, as languages widely adopted in industry, allow for extreme flexibility and customization to fit the manufacturers’ needs with minimal time and expense.

These technologies work together to make a speedy and robust data analytics system, allowing one to monitor an industrial environment from afar, and even be alerted when things go awry. This elegant and versatile solution to data analytics could be applied to just about any modern day industrial environment.
Team 4: Resource Management and Data Analytics in 6TiSCH Networks

Sponsored by: Emerson Process Management  
Sponsor Advisor: Mark Nixon  
Faculty Advisor: Professor Song Han

With the proliferation of small, low-power, wireless embedded devices, commonly referred to as the "Internet of Things," comes a need for standardized communication protocols. Currently, multiple competing standards are in use around the industry, with two of the most popular being 6TiSCH and WirelessHART. Though the industry is moving towards 6TiSCH, which uses IPv6 on top of the new IEEE 802.15.4e specification, we expect to see many mixed-protocol networks in the future. In this senior design project, we designed a fully-featured network manager for embedded devices that can handle both the 6TiSCH and WirelessHart protocols.

The nodes in an IEEE 802.15.4e 6TiSCH network communicate by following a time Division Multiple Access (TDMA) schedule. A timeslot in this schedule provides a unit of bandwidth that is allocated for communication between neighbor nodes. The allocation can be programmed such that the predictable transmission pattern matches the traffic. This avoids idle listening and extends battery lifetime for constrained nodes. Channel-hopping improves reliability in the presence of narrow-band interference and multi-path fading.

WirelessHART derives its physical layer protocol from the IEEE 802.15.4 standard. Using a subset of the IEEE standard with modifications, it operates only in the 2450MHz ISM band, though the data link layer can employ 15 channels of the band to increase reliability. As in 6TiSCH, the data link layer utilizes superframes and TDMA scheduling.

Our manager provides a GUI representation of the currently running network, in addition to graphical elements to help the user monitor the current network state, monitor traffic patterns, and manage the devices on the network. Link strength, packet loss, and latency information are presented to the user, who can then manage the devices in the active network. Designing for scalability from the beginning, we ensured that our manager could handle hundreds of simultaneously connected devices while still preserving acceptable network performance.
The problem we aimed to solve was simple: how do you play chess online with a friend and still keep the charm and ease-of-use of having a physical chess board in front of you? The result is a physical chess board that can connect to the internet via Wi-Fi. Like a normal game of chess, each player takes turns moving their pieces on the board. Our board then reads the move the player makes, translates the move into an encoded message, and sends the message to the opposing player’s board. With that message, the board automatically moves the pieces into place.

Each board consists of a microcontroller, a Wi-Fi module, and an XY gantry underneath the surface of the board. The microcontroller is responsible for driving the motors and gantry that move pieces. Each piece contains a small magnet, which trigger small Reed sensors that reside just underneath every square. Since every game of chess can be defined entirely by its current state, this allows the microcontroller to know where every piece is at any given time.

The two boards both connect to a server, which is in charge of managing the connection, judging the legality of moves, relaying movement messages, and keeping track of the game state. The server was programmed in Python and can run on any modern laptop or desktop computer. This allows one player to use their computer as the host for their game.
Team 6: Pins
- A Society Network on A Map
Know Your Surrounding Better

Sponsored by: UConn CSE Department
Faculty Advisor: Professor Yufeng Wu

We have built a mobile social network application, called “Pins”, with geolocation features. It allows users to share information in certain categories, events, exploration and deals. This information is in the form of an anonymous post that is pinned to their current spatial location on the map. Users are able to browse the information not only in their surrounding area, but also in other areas that they are interested in. Users are also able to upvote or downvote the pins. Additionally, our application provides filter and search options for users to customize their “map”. One goal of our app is to let people share what they see, discover, and think in a specific location on the map anonymously. The ultimate goal of this application is to let people know their surroundings better by allowing them to quickly get current local news as well as the points of interest in their neighborhood.

Our application was developed for the iPhone and iPad. When the application is initially opened, the user will be prompted to create an account, using their phone number or an email, or to log in to an existing account. A map with multiple pins will be shown after logging in. When a user taps a pin, a bubble will pop out above it showing the post attached to it. Tapping the post will expand the bubble allowing the user to view the full text as well as a larger picture. The popularity level of each post will be determined using an algorithm which will give more weight to earlier votes and less to later votes. The popularity level will also decay with time. The more popular posts will be more visible. Users will also be able to filter what they see using date/time, location, and our three main categories. Furthermore, users will be able to search for posts using keywords. Searching for certain keywords will filter out the pins without those keywords. Users who want to make a post just need to press the pin button. The user will then be allowed to upload a picture as well as write a short text. This post will then be pinned to their current location.
When a voter goes to the polls, a poll worker must check a paper list to see if they are eligible to vote. This simple process is meant to ensure “one voter, one vote,” or the idea that each voter should be able to vote, should have his or her vote count, and he or she can only vote once. Using a paper poll book, while effective, is time consuming and error prone. An electronic system can potentially reduce paperwork, increase the speed of voter check-ins, and reduce errors. It would provide a way to quickly look up a voter’s information and mark them as having voted in the current election.

Yet, an electronic poll book is not as simple to create as it seems. Two critical challenges are security and fault tolerance. The system must prevent attackers from recovering any voter information and cannot violate the “one voter, one vote” policy. It should also be resilient against data losses from a single point of failure, such as a centralized server or a single poll book. In addition, the system should be inexpensive, have a small form factor, and be highly usable.

This Senior Design Project addresses all of these concerns with an Electronic ePoll book application for the Android platform. The application can be installed on affordable Android tablets and can be configured as the sole application on the tablet, reducing the risks of attacks. The key insight into a robust solution is the extensive reliance on fault tolerant technologies. Instead of traditional methods of data storage replication, our system uses distributed shared memory to reliably and dependably store all necessary data fragments. Transient or even permanent failures of one or more tablets do not jeopardize the ability of the surviving tablets to fulfill their tasks, without any data losses. In addition, the system is very scalable as replacement devices can be safely and easily added during an election to accommodate more concurrent check-in lines and preserve fault tolerance.
$tockr is a mobile-friendly web application that is geared towards newcomers in the business of stock trading, specifically teenagers, and those who are in their 20s. Using our software, users can add stocks to their portfolio, where the details regarding their stocks are updated automatically. Users can also create investment scenarios that enable users to see the return that would have yielded from past investments for different combinations of stocks, depending on their date of purchase, price, and other details.

$tockr utilizes various techniques to engage users and enhance the user experience with the system. For example, in addition to providing a captivating but simple user interface, the system incorporates a community-powered education platform. In this platform, users can submit content that educates other users regarding various aspects of stock trading. The submitted content is presented in a manner that is easily accessible. Furthermore, submitted content is up-voted or down-voted by the community, therefore identifying the most helpful and informative submissions.

Due to the benefits offered by online platforms, that are accessible to anyone with a modern browser and Internet connection, the system is implemented as a web application using JavaScript. JavaScript is chosen for several reasons. For example, JavaScript runs on all modern browsers, which allows for applications to run in-browser without requiring users to download external programs, such as Java or Silverlight. Furthermore, JavaScript recently earned its popularity from the development of frameworks such as Node.js and MongoDB which provides open-source libraries for server-side implementation and database management functionalities. Alongside front-end frameworks, such as Bootstrap.js and Express.js, full stack web application development is made possible solely with JavaScript as well. Finally, AmCharts.js library is used to display stock information that supports rendering interactive graphs and charts, allowing users to manipulate the views.
Pratt & Whitney makes jet engines for both commercial and military applications. These engines have an embedded electronic engine control (EEC), which is essentially a computer that controls all the major systems and functions of the engine. The Controls and Diagnostics Systems (CDS) Group at Pratt & Whitney have traditionally used a wired interface during the testing phase in order to monitor and maintain normal operation of the engine and EEC. The current interface allows a connection to be made between the EEC and a testing computer over Ethernet. The data read from the EEC allows the CDS team to find problems that may be occurring within the engine’s components.

This connection has several limitations, such as being restricted to computers with an Ethernet port, and being near the EEC. Our senior design team was tasked with designing and developing a wireless system to replace the wired system that is currently in place, while still providing all former capabilities and functions. Our wireless interface will be accessed remotely through Wi-Fi, which will support the use of other monitoring devices such as tablets and smartphones.
The concept of ranking participants in an activity stems from the inherent human desire to compete. Assigning ranks to participants caters to this innate human desire as top competitors are motivated to maintain their status, while lesser competitors feel a greater sense of involvement and an incentive to improve. This project develops Rank Management APIs that allow users to easily manage and choose from multiple ranking algorithms such as Elo, Microsoft Trueskill, and Glicko, and apply them to create application specific ranking for different types of activities and competitions that result in a win, loss, or draw. For example, competitions can range anywhere from traditional sports such as football and baseball to competitive video games and academic challenges. In addition to enabling ranking and managing events, the API enables presentation of key statistics such as participants’ progress over time and analysis of an opponents’ performance.

Our developed API can be used by groups of friends as well as groups of competitors to effectively record and update statistics based on the group activity performance. In our developed prototype, users have multiple facets for interacting with the system. For example, developers can install an external library (Node.js module) to communicate with our API from their own application whereas non-technical users can leverage the web and mobile interface support to manage rankings and events.
Team 11: Speakr, or the Pursuit of Audio Synchronization

Sponsored by: UConn CSE Department  
Faculty Advisor: Professor Bing Wang

Speakr is an application for Android phones that will allow users to transform multiple phones within a close vicinity into a combined speaker system. The phones will connect through an ad hoc network using either Bluetooth or WiFi. Once connected, all of the phones will be able to stream audio synchronously in real time. Consider a simple use-case: three users want to play music but do not have access to a speaker system. Rather than just play music through only one phone, the users connect all of their phones together through our application. Then, a shared queue will be formed to which any member of the group can contribute. Any music in this queue will be played simultaneously by all phones connected to the ad hoc network. Similar to the functionality of Chromecast, each phone in the network should have control over the audio being played, there is no group leader.

The main purpose of developing Speakr is to provide useful functionality to users and also gain experience developing for Android, using networking technologies, eliminating latency, and implementing material design standards to make an application look professional. The challenges involved in developing this application are many. First, simply learning to understand the Android documentation and use the API’s for WiFi direct has been a challenge due to the lack of clear documentation. Second, only one of us actually has Android programming experience and none of us have any experience in using networking technologies. Therefore, our group may have to turn to subject matter experts to assist us in development. Lastly, because the human ear is extremely sensitive to subtitle differences in music, it is crucial to eliminate perceivable offset in the tracks, which is another major challenge. Despite these challenges we hope to have a functional prototype of our application by the end of the year.
The goal of the project is to create mobile iOS and Android applications that tracks and provides information on shellfish harvest areas to be used year round in an attempt to protect and preserve their population. The major features of this app are real time harvest area status (depicted on an interactive map interface), tidal information, and harvesting regulatory information. The app has been created to solve the obsolete strategy of posting information related to shellfish harvesting. Currently, users have to call a hotline to retrieve information on whether or not a harvest area is closed due to hazardous conditions (mostly bacteria). This is a hassle for harvesters considering the information may not always be readily available. This app electronically manages all of the information and makes it easily accessible to fishermen.

The map interface utilizes a user’s current location or has them input a town they are in or near. Once the user's location is known, a map is displayed showing the area in which they are in and nearby harvest areas. The harvest areas will be distinguished by different shades on the map interface. The harvest areas will be listed below the map, allowing another medium of selecting desired areas. The Connecticut Department of Agriculture’s Bureau of Aquaculture’s database provides real time harvest area statuses. The frequency at which the data will be updated has yet to be decided. The tide information will be found from the National Oceanic and Atmospheric Administration (NOAA) site. The site has all of the information about tides, and is accessible from the map since some harvest sites are only accessible during certain tides. We have utilized API’s to make this data retrieval possible (for example, Java, SOAP, and WSDL implementations at dap.co-ops.nos.noaa.gov/axis/).

The regulatory information is important as it contains information about how one can go about harvesting shellfish from the designated area. This information is available currently in a PDF/Word doc with all the information. The information includes specifics for each town. The specifics are such as species, shellfish size limits, quantities, seasons, permits and permit costs, and hotline numbers. This information is provided in the app without the need to download the source document.

From left to right: Jianxing Ke, Conner Gates, Craig Goyette, Steven Weldon, and Robert Gworek
Hydra is an affordable elbow-down prosthetic that restores dexterity and muscle control for basic hand functionality. At a far lower cost than alternative high-end prosthetics, it allows for dynamic motion and static hand positions essential for daily tasks. The package provides patients with a 3-D-printed forearm and hand, STL’s for printing, supplies and directions for installing an Arduino board, Servo’s, and a Bluetooth receiver. An Android phone application will give the user control over movement settings and the various functions. The total price is estimated to be under $300.

The problem we aim to solve is availability and cost of modern prosthetics. The most complicated and expensive part of modern upper body prosthetics is the mechanical control essential for finger movements. Generally, this requires translating the single radial motion of a Servo to a complex jointed bend at the fingertip, which can be done in two ways. The first is purely mechanical finger movement. This has several advantages including exact structured movement for the fingers as well as giving power to flexion and extension equally. However, these designs are complex, heavy, and usually expensive. The second method of finger construction is non-mechanical, where elastics or springs are used in between the joints to return the fingers to an extended position. Flexion of the fingers is achieved by applying a single force pull to the fingertip. This method is lightweight, low cost, and easy to build or fix but is less precise. The strength of the extension is also subject only to the springs in the joints, which must be balanced against the torque of the Servos. Our project aims to find a medium between these two methodologies, allowing the user to specify which type of movement they want at minimal cost. A prosthetic that is capable of emulating multiple gestures would typically require super precise (and expensive) sensors capable of measuring miniscule differences in muscle flexion. By introducing an easy to use phone and smartwatch application, we are able to accurately simulate many common gestures using only two muscle states: flexed and relaxed.

Hydra is scalable, open-source, economically advantageous, and easily reprintable. We want to give the users as much or as little customization as they are comfortable with. Our goal is to merge the various branches of CSE into a unified project that will benefit our education as well as the others in need.
OnIt is a service that adds a new level of interaction to users’ favorite applications. OnIt is putting the power of a programmer into the hands of a common user by allowing the user to make applications interact in a manner that previously had to be done manually. Using this service, it is possible to create interactions between two applications that are activated conditionally. These interactions are called recipes. The basic flow of these recipes is as follows; if something occurs in the “trigger” application, then execute something in the “action” application. These somethings are to be set by the user and each application comes with a wide selection of triggers and actions to choose from.

Here is a simple example of a useful recipe. The user can select the weather application from the list of available trigger applications and make a trigger that activates when tomorrow’s high rises above 90° F. Then the user can attach this trigger to the email application to send out an email saying, “Soccer training will be cancelled tomorrow due to the heat.” This is simple, yet saves the coach some of his time.

Ingredients can also be added to recipes. Ingredients are pieces of information that get passed from the trigger application to the action application. Since this specific trigger action uses location, date, and temperature as pieces of information, they can be passed on to the action as well. A potential email using these ingredients could turn out written like this, “Soccer training will be cancelled tomorrow, 7/16/2015, due to the expected high of 95° F.” This recipe is far from the only one that can be created by the user. Due to the large list of available and planned applications, as well as the triggers and actions associated with these applications, users are only limited by their creativity.

Our Senior Design group has been tasked with creating additional channels for the OnIt system to expand the application’s capabilities. Our goal is to have five functional channels by the end of the academic year. These include two trigger channels which consist of a Weather Monitor and a Stock Exchange Monitor, and three action channels, consisting of an Email Digest, WeMo Switch, and LIFX.
Aircraft software and systems must adhere to guidelines outlined in the “DO-178 Software Considerations” texts, while also satisfying requirements particular to the manufacturer (or customer) entity, in order to be deemed compliant and eligible for certification by the parenting bodies: Federal Aviation Administration (FAA), European Aviation Safety Agency (EASA), etc.

To achieve these ends this project is focusing on the development of software tools which will allow automation of test case generation and system design verification for aircraft systems. These utilities will reduce the rigorous testing and verification process from a tedious manual endeavor to an efficient, hands off application; this will allow faster product delivery, a higher degree of quality consistency, and higher revenue.

The project software performs several primary functions which are composed of several sub-utilities; these are described as follows:

1) Analysis of provided documents via a parsing system
   - Detect and correct variable, function, formatting, and other textual specification irregularities or errors
2) Generation of test cases from the software specifications outlined in documents
   - Create complex truth tables for each of the textual cases described
   - Validate all generated and manually composed test cases with each other
   - Verify adherence of total system to DO-178C guidelines.
3) Selection and interaction via comprehensive graphical user interface
   - Customize function input and operation
   - Provide feedback via interactive console and generated report
Land Trusts are nonprofit organizations whose mission is to preserve open space properties. There are 137 land trust organizations in Connecticut that own both properties and easements throughout the state. Monitoring these annually is essential to ensure the properties are neither being encroached on nor violated. This has typically been done on paper, but Land Trusts have been expressing a strong interest to digitize this process. In this senior design project, we developed a cross-platform Android and iOS app for the UConn Extension program that allows Land Trust Volunteers to visit a property and collect information needed to assess the condition of the property, or identify any areas of concern. The application integrates forms stored on a volunteer’s Google Drive with an open-source mapping platform to facilitate data collection and sharing.

When using the application, the user first authorizes their Google Drive account and selects a form for use in the monitoring session before opening a map centered on their current GPS location. The map supports the import of overlays from Google Drive or local storage, which will usually be property boundaries in GPX or KML format. This helps users to locate and navigate the property and record information about its condition and any areas of concern. If the user finds an area of concern (point of interest, violation, updated boundaries) they can choose to either create a waypoint or track with details regarding the concern. Additional media such as audio, pictures, or video is able to be attached to the waypoint or track to help detail the issue. Once the user has finished their survey, they have the option to export waypoints and tracks as layers to GPX or KML files and upload the files to Google MyMaps, along with any associated media. The Google Drive MyMaps URL is be stored as a field in the form upon export. If the user does not have a wireless connection, the data is saved locally.

This application was built with the Apache Cordova mobile application development framework, using the open-source Mapbox and Leaflet Javascript mapping libraries and a Model-View-Controller design pattern.
College is a large financial burden on many students, especially those who live on-campus. Even so, many students moving into new living arrangements will need to purchase furniture, textbooks, and supplies. Additionally, many of the items purchased for dorms or housing near campus is temporary and is not needed after graduation. These conditions lead many students use word of mouth, fliers in their dorm, and even Facebook groups to buy, sell, and trade items with other students. Services such as craigslist create a feeling of insecurity for college students due to the open nature of the platform. Many people would prefer to stay within their on-campus network for their transactions.

We have decided to take this opportunity and create an online classifieds platform targeted at UConn college students. The theme of our site is friendlier than those of other services on the web and to fix the feeling of insecurity, we require login with a valid UConn email address to use the site. We will allow for searching, browsing, and filtering the items posted on the site and we have created a user interface that is both intuitive and easy to use on both mobile and desktop platforms.

From an engineering standpoint, we have made it a goal to use many new technologies in the web development industry. While developing the front-end of the website we have been using many frameworks such as React.js with a Flux architecture, which is Facebook’s new variation on the traditional Model-View-Controller (MVC) software design pattern. On the back-end we are using Python with Flask to create a well-structured RESTful API for our front end. For the entire design of the site we are keeping in mind good design practices for a scalable solution that would allow us to expand and add features to the site relatively easily.

Over the course of the semester we have built the site using many developer tools used in industry today such as Webpack, Git, and Heroku. Because we have multiple developers working on the site at the same time, we have multiple development branches set up in Git as well as a full staging site that allows us to check for integration errors before deploying changes to the production server.
UnitedHealth Group is the most diversified health care company in America that serves its clients and consumers through two distinct platforms: UnitedHealthcare and Optum. UnitedHealthcare provides health care coverage and is the single largest health carrier in America. Optum provides information technology enabled health services. This project focuses on a UnitedHealthcare business called UnitedHealthcare Military & Veterans which proudly serves the health care needs of service members, military veterans, and their families. The company is partnered with the Department of Defense and their TRICARE health care program. Our team has been asked to create a special purpose application store for UnitedHealthcare to allow for the management of multiple (existing and future) apps from multiple sources. Our team has worked with the project leads from Optum to deliver an app store that implements a generic framework, supports flexible branding and multiple channels, supports management of an evolving list of app content, and provides a user interface that is easy to navigate. UnitedHealthcare has existing apps that aim to improve the health of service members and their families. Some of these apps allow users to monitor their emotional health, cope, relax, manage their stress, and browse information on many health topics. One of the reasons the company wants an app store is so they can place all of these existing apps in one location. The ultimate goal of this project is to improve the health and well-being of those who currently serve and have served in the past.

Our team created a static version of the app store website using HTML and CSS. We implemented a framework called bootstrap to make the pages for the site responsive so that they could be scaled for different devices including phones, tablets, and desktops. We used a content management system (CMS) application to maintain the websites content from a central interface. UnitedHealthcare wanted an app store with many of the technical features that existing app stores have. Some features required include, but are not limited to, the ability to add/remove/edit apps within the mobile store, flexible branding, ability to display in mobile and desktop browsers, ability to search for applications within the store, ability to gather user feedback, ability for users to download and share applications, and ability for users to preview applications.
Team 19: Population and Occupancy Tracking System (P.O.T.S.)

Sponsored by: UConn CSE Department  
Faculty Advisor: Professor Yufeng Wu

The Population and Occupancy Tracking System (abbreviated P.O.T.S.) is designed to easily track either a single person, or multiple people entering or exiting an area. The system is composed of three major components; a sensor module (for every entrance and exit of a building or area), a central server, and a web server. The first component is the sensor module, which contains an array of sensors attached to a microcontroller. These sensors detect people entering and exiting the designated facility, logs the detection, and sends the data to the central server. Once it has arrived at the central server, the data is aggregated and displayed via the web client to any users who wish to view it, either by live occupancy, or recorded and predicted occupancies stored on the server. Through this flow, the system is able to accurately and reliably report real-time data to the user base.

The ultimate goal of P.O.T.S. is to be able to analyze a facility's capacity at certain times of the day, and to provide this data in a clear interface to anyone who wishes to find the least populated times to visit a certain location. By doing this, we predict that informed people will visit the location at low-traffic times which will eventually lead to a similar capacity level for all times of the day. An endless number of facilities can make use of this technology: restaurants, movie theaters, grocery stores, parking garages, just to name a few.
Team 20: The Integrated Pest Management (IPM) Mobile Application

Sponsored by: UConn Plant Science & Landscape Architecture
Sponsor Advisor: Ms. Donna Ellis
Faculty Advisor: Professor Steven A. Demurjian

The IPM mobile app (iOS and Android versions) supports the work performed by the UConn Integrated Pest Management (IPM) Program (http://ipm.uconn.edu/root/) which provides training and outreach education on managing plant pests for commercial producers of diverse agricultural cropping systems - fruits, vegetables, ornamentals (nursery and greenhouse), and landscapes. There are many pests that attack agricultural crops, including insects, mites, diseases, weeds, and invasive plants. The IPM app provides direct access in the field to a database of information on plant pests, help the user identify the plant pest by comparing photos of the pest itself and damage caused by the pest on the crop, and resources about the pest and how to manage it using photos, videos, text, and links to online resources. The IPM provides capabilities that include: pests that are found in Connecticut, with applicability to New England and the Northeastern US; pests that are found on vegetables (sweet corn, tomatoes, peppers, etc.), fruits (apples, peaches, blueberries, strawberries, etc.), and ornamentals (greenhouse crops: poinsettias, herbs, and annuals; and nursery and garden center crops: trees, shrubs, and perennials); and damage on plants caused by specific pests.

Using the IPM app, a grower takes a photo of a plant pest or crop damage caused by the pest. They select a crop grouping (vegetables, fruits, or ornamentals) and then a particular plant species within the crop grouping. They further select where the pest and/or damage is found on the plant, such as leaves, stems, flowers, fruits, or roots and match the pest and/or damage to images in the database to help identify what is causing the problem. The images in the app database include possible pests that may cause the damage and various types of damage that can occur on the crop. The causal factors include biotic (cause by living organisms) or abiotic (caused by other factors such as weather, nutritional disorders, pollution, or pesticide toxicity). Once the identification of the pest is determined, the user is linked to additional information on the pest and its life cycle, along with control recommendations, such as the UConn IPM website, the New England Vegetable Management Guide, etc.
Pitney Bowes is a global technology company that powers billions of physical and digital transactions in the world of commerce. The current focus at Pitney Bowes is enabling data-driven marketing, parcel shipping and logistics, and statements, invoices, and payments. The shipping of items sold on eBay is powered by tools built by Pitney Bowes. Of the many tools Pitney Bowes provides, they have a Global Shipping Program that companies use to effortlessly ship their products all over the world. All international packages that are shipped from the United States through the Global Shipping Program are first sent to Pitney Bowes’s hub in Kentucky. While at the hub, all the necessary work is done on the package to prepare it to be shipped internationally. Once the appropriate steps are taken for the country it is being sent to, Pitney Bowes ships the package out to its designated destination. Our group will be working with Pitney Bowes and the data they provide us to tackle two use cases that address the complicated process of mass shipping both domestically and internationally.

The first project given to us by Pitney Bowes to tackle has been that of carrier performance analysis. Pitney Bowes uses its Instant Online Postage tool to provide domestic shipping and tracking to eBay sellers. Our goal is to create a model that chooses the optimal carrier for a given package by training this model with 12 months of Pitney Bowes shipping data and the major US carriers. The features used to select the optimal carrier include parcel destination, origin, physical dimensions, and weight.

The second project concerns selecting an optimal “hub” location. Currently, all parcels are shipped to the Kentucky Hub before they are sent overseas. It may be beneficial to expand this process by adding one or more hubs within the United States. We will study 12 months of shipping data to select a new location for an additional hub to be built. Factors that will be considered include physical location within the US, labor and shipping costs from that location and state-by-state shipping routes.
Team 22: Fite-Bit “Exercise Videogame App”

Sponsored by: Team Members
Faculty Advisor: Professor Chun-Hsi Huang

From left to right: Jinesh Mehta, Yilun Chen, Erik Green, Benjamin Keen, Santiago Galarza, and Jezreel Jardeleza

Our Mission Statement: “Provide motivation and encourage a healthy lifestyle through a competitive and entertaining mobile video game application.”

Information technology undoubtedly has an enormous impact in our daily lives. Over the past few decades, it has enabled us to gain access to massive amounts of data and information from all over the world, created countless new businesses, and even brought a new breed of millionaires along the way. In general, such advances in technology have allowed us to become more productive and efficient, leading to many breakthroughs in business, medicine, science, and various other fields. However, as the inevitable growth of technology continues, we are now starting to see a new emerging trend in technology and it is no surprise that most of us, if not all, have already experienced it one way or another. Although some may say it’s well overdue, technology has finally begun to target our quality of life rather than just our productivity in the workplace. Motivated by the development of the internet and fueled by introduction of cellular phones, we have seen applications that help us cope with depression, applications that allow us to keep in touch with loved ones half across the world, and now even applications that with the integration of wearable technology, like the Fitbit® for example, can help us monitor our own body and ultimately our well being.

Observing these current trends in technology and the direction that we are headed, our team’s project will be to develop a mobile application, in particular a video game, whose main objectives are to entertain users while promoting a healthy lifestyle. Our team goal is simple. We will work with these new technologies, exploit their capabilities, and present a product that will not only bring a new flavor to the way people play video games, but will also have a significant and positive impact for today’s technologically inclined society.

The idea of the game is simple, yet addictive. While the user exercises, information will be collected and seamlessly sent to our servers for analysis and interpretation. Once data has been processed, and the user opens our App, an addictive game will be presented and your character strength will be a measure of how much exercise has been done.
The STORMWISE program at UConn (http://www.stormwise.org) is intended to mitigate damage associated with power outages caused by large storms (hurricanes, snow, etc.). The Stormwise mobile app with iOS and Android versions provides the ability for an expert professional (arborist, utility worker, etc.) and layperson (homeowner, concerned citizen, etc.) to assist in this process by supporting three capabilities: failed/broken tree data collection, tree risk assessment, and communication of the broader STORMWISE program.

The tree risk assessment and damage report components of the Stormwise mobile app allow a user to submit a detailed self-assessment of potentially problematic and failed trees. The assessment of tree risk has become more precise, but it is largely unknown how accurate the assessments are. Tracking the fate of assessed trees through follow-up damage reports can reveal the accuracy of assessments. The Stormwise app engages the layperson in the process of looking at their trees as something that could fail, and the dangers therein. It provides a vital educational tool, giving agency to the layperson in recognizing tree safety. To accompany this, a primer in tree risk assessment including documentation and photographs curated by professionals will be included. This widespread awareness of tree-related risk will also be valuable to the broader implementation of the STORMWISE program. As a crowd sourced activity, contributed data of tree hazard and risk can be georeferenced on a map visible to the user. This would provide a powerful perspective on the level of tree health in the neighborhood, town, state or even country. Users of the app can register, or sign in as guests. Those with accounts will see more interactive features such as ticket history, and verified expert users will have access to more precise reporting criteria.

A web app will also be included for the town services managing STORMWISE services. This will provide a complete view of all tickets submitted, with options to sort, produce info graphics, and comment on reports.
Team 24: Backpack
Electronic Guidance and Informational Application

Sponsored by: Highper Computing, LLC
Sponsor Advisor: Professor Sanguthevar Rajasekaran
Faculty Advisor: Professor Reda Ammar

Backpack is an informational mobile application that offers a menu of options and features to optimize any travel experience. The purpose of Backpack is to guide users in a new environment by providing access to an extensive library of electronic tours and multimedia information. The portability and user-friendly interface increases the efficiency of traveling to locations that may be unfamiliar. Backpack can eliminate the inconvenience and expenditures associated with a physical tour guide, as well as the hassle of carrying paper maps and brochures. The tours consist of verified user-generated content that provides users with a uniquely designed and detailed description of any facility. The main advantage is the application’s access to local insights on locations, which may not be available on the web or other resources. Local business owners and managers can increase revenue by focusing on immediate consumers. Backpack is an invaluable asset for local business owners and managers since it is a more cost-effective approach to marketing than most other methods of advertisement.

The application’s home screen consists of a Place Search Box with the default input set to the current location of the user. Upon entering a location, existing tours are displayed on the screen for selection. Each tour is separated into pages with left and right arrows, allowing the user to easily traverse through the sites. Each tour includes text descriptions as well as optional multimedia. When progressing to each site, the user is prompted with a “Start Route” option. This feature implements the Google Places API and provides directions to the next location in the tour.

Tours can be generated and viewed on a corresponding website implemented using the Bootstrap web framework. The website is synchronized with the same database used for the mobile application. Backpack’s data are stored on a cloud database, which is hosted on DigitalOcean’s cloud servers. The Django framework was used to develop back-end server operations used for both the application and the website. The Google Identity Toolkit API gives users of Backpack with existing Google accounts a convenient way to gain login access. Although the current version of Backpack supports most Android phones, any device with web access capabilities can use the application. The Google Places API also gives Backpack the capability to provide basic information on nearby points of interest such as restaurants, metro stations, airports, hospitals, fire and police stations, retail stores, art galleries, museums and more.
The Live Local Mobile App for UConn Extension is both an iOS and Android mobile application used to engage local residents and business to support local farms and working landscapes. UConn Extension is a department within the College of Agriculture, Health, and Natural Resources devoted to connecting the power of UConn research to solve local problems. One of our growing projects is engaging residents to support local farms and working landscapes. Through the CT 10% Campaign, residents and businesses are invited to take a pledge to spend 10% of their food and gardening dollars on locally grown products. The 10% Campaign is an online tool of agriculture service providers that are working together to help consumers discover local Agriculture, based at www.buyctgrown.com.

In August 2014, the CT 10% Campaign recruited 400+ people and 115 businesses to take the pledge with cumulative tracking of over $700,000 spent on locally grown products. As of August 2015, the commitment has increased to 1000+ people and 220 businesses taking the pledge, spending over $2,200,000 on locally grown products and these numbers continue to grow. The development of a Live Local Mobile App for the Android platform will further momentum for the campaign. The Live Local app allows users to: Discover information with users about opportunities to discover and experience local agriculture (calendar, season’s top ten, featured trails (e.g. beer trail); Track and share their progress toward their 10% pledge; and, Maximize social media opportunities for users, such as sharing pictures, sharing progress toward the pledge, joining a Facebook group of mobile app users, etc.

The Live Local Mobile App has been designed for CT residents as well as tourists/visitors to CT who want to discover CT-grown food and experience local agriculture (calendar, seasons top ten, featured trail). The app lets users browse upcoming events to find an activity that will be fun for the family. Users take a pledge to spend 10% of their food and gardening dollars on locally grown products and then may use the app to track and share their progress with friends on Facebook. The Live Local Mobile App also helps to build an online community of local food and farm enthusiasm through Facebook.
ELECTRICAL AND COMPUTER ENGINEERING

www.ee.uconn.edu
Magnetic circuit breaker calibration is traditionally achieved manually with a procedure that is implemented on the production line. The method currently involves the doubling of rated current to bring the iron core within the dashpot of the breaker to the trip-point required. This process may be repeated numerous times in order to come within a small window around the desired trip current value where adjustments can be made. Tripping the breaker at the necessary level requires slow adjustments around the point of tripping.

Carling has assigned this project in an effort to reduce the time required with manual calibration in both production and when needed in testing. A device capable of automating the process of calibration was created to increase the efficiency of the manufacturing plant. This device allows production line workers and technicians to remotely set or adjust circuit breakers. Ultimately, the device brings circuit breakers within their specified trip points more rapidly and with a certain repeatability that is time consuming with current methods.

The device is capable of being set to a specified current level and in approximately 20 seconds have adjusted a brand new breaker to its specified trip point. The calibration device operates using a programmable chip to read and detect current levels. Current levels are stepped down for the analysis of current with respect to time. Concurrently, adjustments are made with a stepper motor making adjustments to the circuit breaker. Minor adjustments are made until satisfactory levels have been met. The process is repeated to ensure proper adjustment of trip point and for accuracy purposes. The calibration device will create repeatable consistency among all breakers going through production so that each product is adjusted to specification.
The purpose of this project is to develop a proof-of-concept system for remotely powering, controlling, and monitoring an electric motor entirely through fiber optics. Currently there are no fiber-based motors available in industry, so our system must be able to do the conversion between the fiber optics and the copper signals. There are a variety of benefits which can be derived from incorporating fiber optics into the system of an electric motor. Namely, fiber optic systems are resistant to electromagnetic interference (EMI) and operate more efficiently, in terms of both temperature and speed of transmission.

To ensure proper operation of the motor, a variety of sensory devices have been selected. These sensors will be powered through a commercially-available, power-over-fiber system and will provide remote feedback on the status of the motor’s operating condition.

The power-over-fiber system takes an electric power supply, to modulate a laser system, and transmits over fiber optic cables. The light is converted back to electrical power, at the output end of the fiber optic cable, to drive the motor. The conversion from fiber optic light to standard electronic power uses photodetectors (or photovoltaic cells) and is based on a mechanism similar to solar energy conversion using solar panel.

The development of entirely fiber-based systems serves to increase the efficiency and speed of transmissions, particularly through noisy or insecure mediums, prevents electrostatic and electromagnetic interferences, and provides an alternative to copper in various applications.
Team 1603: Dynamometer for Testing Frequency Inverter Performance

Sponsored by: Lenze
Sponsor Advisor: Christopher Johnson
Faculty Advisor: Prof. Ali Bazzi

A frequency inverter, or frequency drive, is an essential device used to operate motors by manipulating the voltage magnitude, as well as, the frequency at the motors terminals. These controls allow the user to set a motor to a desired speed or torque level. The motivation for this project is drawn from the prevalence of electric motors in today’s society and the importance of frequency drives in their operation for flexible control and high efficiency. Lenze is seeking a control solution that integrates two motor drives, which run in tandem and act as a test bench for their equipment. By utilizing Lenze control equipment, Team 1603 distilled their existing test setup into a single interface that not only allows the manipulation of all the elements involved but also the compilation of the performance data, including current, torque and speed, into easily interpreted graphs.

This project strives to improve Lenze’s capability to test the performance of their drives’ efficiency and reliability. Currently, Lenze tests drives using a test setup that is multi-platform and uncoordinated. The project utilizes two frequency inverters, one to run the dynamometer (dyne) which acts as a load, and a second “drive under test” (DUT) which controls the other motor. The motor and the dyne are mechanically coupled together with a torque transducer for torque measurements. Current is measured using external hardware, and speed readings come from the dyne. The entire control scheme takes the form of a graphical user interface implemented on a touch screen Human Machine Interface (HMI).

New opportunities arise from implementing a control scheme that can synchronize measurements precisely from multiple sources. Lenze will be able to try out new hardware, software, and techniques to enhance motor-drive performance and efficiency. All of the equipment including power supplies, cables, drives, motors, sensors, analog and digital PLC modules, connectors, and the HMI have been generously provided to UConn by Lenze for this project. The UConn team is integrating all of the hardware, and writing the HMI based program to control the system and extract performance data.
Wireless communication is an essential component to life in the modern world. Advances in recent years has lead to a seamless integration of wireless technologies in our daily lives. The demand for greater bandwidth and faster speeds drives research and development. One such advancement is in the area known as multiple-input-multiple output (MIMO) systems. This system model is in contrast to the more traditional single-input-single-output system. By utilizing a MIMO architecture some of the most hostile communication environments can be operated in quite effectively. This is due to the fact that MIMO turns the apparent disadvantage of channel fading to its own advantage.

Since any communication system may possibly benefit from such an approach, being able to easily test such an augmented system for gains in bandwidth and reliability is an important capability for communication engineers. It is to this end that our project is focused. We employ the software-defined-radio (SDR) platform GNU Radio to design, build, and test such MIMO enhanced systems. Traditional radio signal processing is usually done in hardware; while reliable, this is not easily configurable. GNU Radio allows us to build a communication system in a modular manner at the software level and utilizes SDR hardware with modern field-programmable-gate-arrays (FPGAs), providing fast yet configurable implementations. Similarly, we can take pre-existing models and reconfigure them through many of the built-in capabilities of the GNU Radio platform.

The MITRE Corporation is a not-for-profit federally funded research and development center (FFRDC) that provides systems engineering and practical solutions for many of the critical challenges we face today. Currently, GNU Radio has no built-in MIMO functionality. The aim of our project is to design and build such MIMO capable software to be integrated into the GNU Radio platform and be able to run and verify our algorithm with the Ettus Research USRP hardware in order to provide our customer and project sponsor, MITRE, with a convenient tool for the purpose of design and testing. The long-term goal of the software-defined MIMO project is to develop new and more flexible communication systems for applications such as air-to-ground transmission for emergency service vehicles and drones.

This research was supported by The MITRE Corporation ® as an independent research project. The views, opinions, and findings are those of the authors and are not intended to convey or imply an official position of the The MITRE Corporation ®.
Team 1605: Elevator Wire Rope Inspection Device using Resistance Measurement

Sponsored by: Otis
Sponsor Advisors: Rich Fargo, Peter Liaskas, Marty Hardesty
Faculty Advisors: Rajeev Bansal, Brice Cassenti

As Otis elevators run their course in service, the wire ropes that hoist the car degrade. Breaks and stretches can adversely affect the braided steel ropes as they repeatedly bend over the elevator sheave during motion. While all roped elevators have backup safety systems to support the elevator and protect passengers if the ropes were to fail, such a failure, or a failure to pass a manual rope inspection, could cause the elevator to be taken out of service until the ropes are replaced. It is a goal of this system to provide an advanced indication of rope wear, so that new ropes can be ordered, and the old ropes replaced, with minimal disruption to the customer.

Today, the primary method of inspection is a thorough visual inspection as stated in the American Society of Mechanical Engineers (A.S.M.E.) guidelines. This method, however, only accounts for what can be seen on the rope’s exterior surfaces and does not take into account the interior conditions of the cable. Furthermore, a visual inspection is extremely time-consuming and costly which leads to an increase in the elevator’s downtime as it cannot be in operation while maintenance personnel inspect the shaft. For these reasons, we need to develop an inspection method with higher accuracy, thoroughness, and efficiency.

Our approach is the resistance based inspection (R.B.I.) method which checks the condition of a steel rope by comparing the current electrical resistance of the cable to the resistance of the same cable when it was newly installed. Throughout a rope’s lifetime, wire strands abrade and break causing the cross-sectional area to decrease. This in turn increases the resistance so it is useful to monitor this value over time. By using the Kelvin resistance measurement technique, the contact resistance for the measurement leads becomes negligible so the low resistance of the cable can be accurately determined. Then the measured rope resistance can be compared with the baseline value to provide a reasonable indication of cable wear. The device will sample on each floor to obtain a resistance profile of the rope since wear is not distributed evenly across the full length. From this data, we can monitor the cables over time to analyze the correlation between cable resistance and remaining strength.
Phonon Corporation needs a specific type of calibrated AC/DC current measurement system to test their Surface Acoustic Wave (SAW) devices. The current measurement system can attach to any DC power supply to measure current, with low internal series impedance (<1 Ω), and output as much as 30 volts and 5 ampere. Furthermore, the current measurement system must integrate with existing data acquisition equipment already present in the lab, with software to drive and calibrate said equipment. The focus should be on developing a flexible device which can acquire, process, and track accurate data. The device is designed to allow easy expansion using a modular design principle.

Besides the basic design, we are tasked with adding additional design features should time allow. These new features include transient current spike detection, voltage sensing, and a range selector to record data at different current ranges for increased accuracy. The project will encompass circuit building and a hardware component with a software component which will be used to gather data.

Our iteration of the Current Monitor benefits from a large supply voltage (5-30). Furthermore, the DAQ allows for easy switching between different ranges. The software developed is a complete solution which will interface with our current monitor as well as other equipment which use the same DAQ.
In today’s modern world of advanced computational design, sensing technology has expanded into many different areas of applications. Linear Variable Differential Transformers (LVDTs) are at the forefront of position sensing technology. For close to half a century Trans-Tek has provided the best linear, angular, and linear velocity transducers in the industry. Each transducer is made and crafted with pride here in the USA, with LVDTs being Trans-Tek’s main product.

An LVDT measures linear-displacement through the interaction of two excitable coil-forms and a ferromagnetic core. First, the primary coil, of the LVDT, is excited with a sinusoidal signal. Then, when the ferromagnetic coil experiences displacement, the secondary coil is excited, due to electromagnetic induction. The signal from the excited secondary coil is analyzed and utilized for a variety of applications. Trans-Tek offers a multitude of LVDT’s, of different shapes, sizes, and design, in order to provide sensing technology for all possible applications.

The objective for this project is to re-design the control circuitry for a standalone unit that drives AC transducers. This system will provide a seamless interface between the LVDT and the user, which will make implementing a transducer in an existing design much easier. The design will generate sinusoidal signals, at adjustable amplitudes and frequencies, to excite the primary coil of the LVDT, and will also demodulate the output sinusoidal signals from the secondary coils, to a DC voltage that can then be easily read by a microcontroller or other circuitry.

We have realized this functionality by implementing a microcontroller to generate the sinusoidal waveform via a Digital-to-Analog Converter (DAC). We have also employed a DAC and Analog-to-Digital Converter (ADC) to demodulate the secondary signal. Finally, we have designed amplification circuitry for both our primary-side and our secondary-side in order to condition the signals to meet specifications.

For further product information please visit http://www.transtekinc.com/
Triumph Engine Control Systems (TECS), based in West Hartford, CT, is a leading manufacturer of fuel pumps, metering units, and digital electronic control systems for aerospace gas turbine engines. The Full Authority Digital Engine Control (FADEC) is the controlling unit of the aircraft engine that converts the pilot’s commands from the cockpit along with sensor data of the engine itself to decide the best response to the necessary effectors. The FADEC is also responsible for collecting large amounts of flight performance and fault data, which is used for engine maintenance and diagnostics. Despite its enormous importance to recording data, current FADEC technology utilizes rugged Flash Memory that is quite small, providing limited fault and crash data.

The goal of this project is to test possible Next Generation FADEC memory which would have an increased memory. Research into the most current non-volatile memory storage devices led us to choose industrial grade microSD cards for this application. MicroSD cards have a high memory density, are very lightweight, and are rated to operate in a temperature range of -40 to 85°C. FADEC’s operate in high vibration and variable temperature environments which the memory device must be able to withstand. In order to verify that the microSD cards can function properly and reliably in an airborne environment a highly accelerated life testing (HALT), frequency response characterization and endurance testing will be performed in Triumph’s Thermotron HALT chamber, which is a thermal chamber integrated with a six axis vibration table. A microcontroller was programmed to communicate with the microSD card via SPI bus to ensure proper data transmission. The results of the test will demonstrate whether the microSD card, mounted at various points on the memory board, could survive under the vibrational and thermal environment the FADEC must endure.

If the microSD proves to be a viable alternative to the current rugged Flash Memory, TECS will be able to integrate it into the Next Generation FADEC and utilize the increased memory to provide enhanced data analysis potential to their customers.
UI is an electric transmission and distribution company that delivers power from centralized generating facilities to its customers. Everyone in a certain geographical area receives power that is supplied by the same circuit. In any given neighborhood a customer might install a small rooftop photovoltaic (PV) system and start a chain reaction where all of their neighbors do the same. A situation like this will eventually cause problems since there will be a large amount of uncertainty as to when and how much power the PV systems will be injecting into the grid.

By injecting intermittent PV power into the grid, the grid supply changes from being predictable and constant to unpredictable and periodic. This will cause issues for the distribution network since there will now be the potential for bidirectional power flow and islanding. By artificially creating these issues through modeling we hope to understand the impacts and provide a solution as to how to mitigate them.

A simulated experiment will be conducted on a distribution feeder with moderate solar photovoltaic (PV) penetration within UI’s territory. The feeder circuit will be manipulated to investigate the potential impacts on the distribution network. The study will include a power-flow analysis in MATLAB Simulink of the current circuit as well as various potential problem scenarios. The result of the study will be a report documenting the findings of network power quality and stability problems and a recommendation for how to alleviate or mitigate the hazards caused by high penetration of distributed PV generation if and when they arise.
Team 1610: Command and Control of Unmanned Autonomous Vehicles

Sponsored by: LINKS Lab
Sponsor Advisor: Professor Shalabh Gupta

A quadcopter is a very simple machine, meritng it as the most common aerial platform used for research and recreation. In accord, the base of UAV (Unmanned Autonomous Vehicle) is a quadcopter. The primary application for our UAVs is to have them operate in areas too dangerous for humans. One potential area, for example, is a collapsed mine. It is much safer for a quadcopter to assess damages and locate survivors in the mine than to send in a traditional rescue team for the job. The advantages are limitless. Suppose there is a fire in a tall building. UAV sensors are useful for not just navigation, but for three-dimensional map generation and target detection as well. The ability to identify human whereabouts and visualize the layout of the building will prove invaluable to fire-rescue missions.

In order for the UAVs to be successful in these missions, it is critical that they function accurately in GPS-denied environments. The device must not depend on circumstance. Rather, it must be reliable in any environment. From the tallest buildings to the deepest tunnels, wifi accessibility may range from inconsistent to entirely absent. Hence, the capability of our UAVs must operate invariably.

The three-dimensional maps are generated through an algorithm called SLAM (simultaneous localization and mapping). As the UAV is flying, the algorithm compares adjacent frames to estimate the change in position. Using the estimated changes in positions and the corresponding frames at those positions, a 3D map of the environment can be constructed.

The generated three-dimensional maps are only useful if they are correct. At present, techniques of validating a map’s accuracy independent of GPS, wifi, or expensive sensor networks does not exist. We have developed and extensively tested an inexpensive technique to verify the accuracy of the generated maps.
This goal of this project was to design and develop a network of sensors for data collection and algorithm implementation. This consists of creating an array of sensor motes that will report information back to a database. These motes also have the ability to pull and analyze data from the database in order to operate intelligently. The final goal of this project is to create a hardware and software platform for this sensor network so that it may be appropriated by other uses for network algorithm testing and verification. Possible applications for this project include border surveillance, patient monitoring in hospitals, urban environment target tracking, and general situation awareness.

A mote is defined as a single node in a sensor network comprised of multiple different sensors of varying degree of power consumption. These sensors include PIR and US sensors at low power, and a SONY camera, Microsoft Kinect, and a laser range finder for high power sensing. One project goal was to redesign and replicate multiple motes and connect them in a decentralized network. The network of motes is designed to record data to a database for access by lab personnel only. The design also allows for the access of data from one mote by other motes on the network. In order to control how these sensor’s work and interact with each other, we designed a software environment to allow for a user to implement their algorithm. Specifically, we designed the software to allow each sensor on a mote to be controlled independently of the other sensor/motes. The network hardware was also designed to be modular (sensors can readily be changed for others) and to be both durable and easily deployed in a lab environment.
Team 1612: Sit-to-Stand Rehabilitation Device for Cerebral Palsy Patients

Sponsored by: University of Connecticut
Department of Electrical Engineering
Department of Biomedical Engineering
Sponsors Advisor: Dr. Shalabh Gupta,
Dr. Krystyna Gielo-Perczak
Graduate Assistant: Shariel Bowen

This project involved the development of a motorized Sit-to-Stand platform. The finished device will be able to assist the rehabilitation of patients with neuromuscular disorders like cerebral palsy and other patients with injured, or weakened, lower limbs, such as the elderly. The device implements a linear actuator, sensors, microcontrollers, and measuring devices as well as springs to assist in vertical force while the device is at low angles. These components were used for real-time data acquisition and mechanical output, such as force applied to the seat platform and velocity of vertical lift. The models chosen were determined by musculoskeletal modeling and simulations, and computer-aided design (CAD) using the AnyBody Modeling System and SolidWorks respectively. Working Model 2D was also used to simulate the design and help choose variables.

To determine the best base design of the device, current devices on the market were analyzed, with close attention paid to improvements that can be made. The best improvement that was made, and what sets this device apart from others, is the joint translational and rotational movement of the platform. In order to choose and validate the optimal design, force platform testing was performed with people of differing heights and weights. A control system is made using the sensors, microcontroller, and measuring devices mentioned above to linearize vertical velocity by controller input velocity.

A SolidWorks model was constructed to test the overall device after the implementation of actuator and springs. AnyBody software was used to determine the angle of the seat platform that corresponded to minimum activity in the knee. The goal is to allow the user to still use part of the knee in conjunction with the device to prevent any type of muscle atrophy from occurring.

Upon completion of the project, further modifications will be made to the device in the future to establish a product that will be patented and put into publication. The ultimate goals of this device is for it to be eventually used in a home or clinical setting and that it will be able to give patients a means of gaining greater mobility, more independence, and a better quality of life.
With the growing popularity and quantity of rechargeable battery devices and systems, such as personal electronics and electric vehicles, there is a growing need for more efficient ways to recharge these batteries. Current, conventional battery charging algorithms do not consider the time-varying electrochemical properties of these batteries. The ever-changing electrochemical properties make for very complex and computationally demanding algorithms. By utilizing an adaptive algorithm, the potential benefits include increased cycle life, energy savings, faster charging times, and reduced costs.

Our goal is to design a sinusoidal ripple current algorithm and battery charger that takes into account time varying electrochemical properties of rechargeable lithium-ion batteries. By understanding the processes of lithium plating, the formation of solid electrolyte interphase (SEI), and limited exchange current, we can create an algorithm that minimizes these negative effects. The foundation of the charging algorithm and battery charger design is in electrochemical impedance spectroscopy (EIS). This process allows us to use a frequency sweep to experimentally determine the frequency with the lowest impedance through the battery. This gives us the critical charging parameters such the optimal charging frequency and ripple current amplitude.

We developed a synchronized buck converter to supply and adjust the current and voltages to a battery array consisting of, 14.6V LiFeMgPO4 batteries in a 1x4 or 4x1 arrangement. The monitoring and control of the battery charger was done with dSpace. The development of the PCB components were done via Altium.
Team 1614:  
High Power Density  
AC-DC Converter  

Sponsored by: ECE department  
Faculty Advisor: Prof. Sung-Yeul Park

The IEEE International Future Energy Challenge (IFEC) is an international undergraduate students competition in the power electronics societies. It will provide members of the team with invaluable experience in the design, testing, and critical thinking necessary to meet and exceed the goals set by the challenge. For this year’s upcoming IFEC 2016 our objective is to design an Ultra-High Power Density AC-DC Power Converter. AC-DC power converter is to convert ac outlet input to regulated dc voltage in order to supply constant dc voltage to either dc load or motor drive. The usages of the AC-DC converter has a wide range from a few Watts ~ a few kilo Watts.

Designing for the IFEC involves a significant amount of work and desire to engineer solutions to everyday problems. We have done our schematic, simulation testing, printed circuit board (PCB) design, 3D model, and have started assembly. During these design activities, we learned the software we are using such as Altium, Power Simulation (PSIM), and SolidWorks. A second revision of the PCB will be necessary after our first pass of testing. This is because the volume requirement is crucial even if our first board’s testing fulfills the converter goals.

As a part of the School of Engineering, the team representing UCONN will need to step up and take on this engineering challenge in order to display what we have learned both through instruction and through personal endeavors of design. UCONN have been finalists at IFEC in 2011 and 2015. Winning the grand prize would be a great accomplishment for the team and the university.
Wireless power transfer (WPT) is the transmission of energy from a power source to an external device or system with the absence of a direct connection. Inductive charging is the most popular method used. Induction systems operate similarly to a transformer where current is sent through a primary coil creating a magnetic field which induces a current in a secondary coil. This current is then used to charge the target device. The goal of this project is to design a closed loop WPT that will deliver a constant supply of electricity under changing conditions such as distance or orientation of the receiver.

The advantage of wireless power transfer is the ability to keep the system fully enclosed and protected. One of the most common places a consumer would interact with a WPT device would be in an electric tooth brush. This allows the device to be changed without the danger of damage from water. The technology is also used in charging pads for smart phones and tablets. Mobile devices on these pads can positioned in different orientations relative to the source coils. The source will change the amplitude of the signal delivered to account for any loss due to non-ideal orientation. This project aims to combine these two principles to create an inductive charging system that could be applied to a device such as an embedded sensor underwater where pitch and orientation could fluctuate consistently. The prototype consists of two Atmega328p microcontrollers connected using SPI communication, and transmitting using two copper plated coils. The transmitter generates a sinusoid which changes dynamically with feedback from the receiver to provide a constant level of power within the transmission range of the coils. This allows a device to charge uninterrupted under the non-ideal conditions that could be experienced in an underwater environment.
The University of Connecticut plans to utilize autonomous underwater vehicles (AUVs) in order to monitor the aquatic environment on Long Island Sound. These vehicles are battery powered and require frequent charging which is unavailable when in use underwater. The goal of the Wave Energy Converter (WEC) is to generate power for the AUVs to use. The WEC stores the electrical energy that it generates in its own battery and wirelessly transmits the power to the AUVs. This allows the AUVs to continuously operate without needing to stop and charge, as well as removing the need for undersea cables to charge them.

The Wave Energy Converter was initially designed with a direct-drive linear generator consisting of one coil attached to a buoy, and three permanent magnets in a spar. The Spar’s vertical movement is dampened by a heave plate which keeps it relatively stationary. This allows the system to generate electricity using the relative motion of the buoy to the Spar. This year, the coil was replaced by a set of three coils and a power conditioning circuit was added. Electricity from the three phases (coils) is rectified, then passed through a PI (Proportional-Integral) controlled Buck-Boost Converter. The Buck-Boost Converter is set to output 13.8 volts in order to charge the 12 volt Lead Acid batteries. Our system is designed to output 100 Watts continuously with peaks of 300 Watts.
Team 1616: WEC - Underwater Wireless Power Transfer

Sponsored by: University of Connecticut
Sponsor Advisor: Peng Zhang, Taofeek Orekan

UCONN
SCHOOL OF ENGINEERING

Senior Design Team 1616 is focused on the design of a generator buoy that can capture wave energy for use in Autonomous Underwater Vehicles (AUVs). Currently, AUVs are powered by batteries that are charged by expensive on-site teams. In the marine environment mechanical connections are rigid, and also prone to corrosion. Wireless power transfer allows two electrically isolated systems to transfer energy. This will allow untethered AUVs to be charged as they station near the generator, or even as they carry out assigned tasks. Our subgroup of team 1616 is focused on the testing and design of a wireless power transfer system capable of functioning in a marine environment. It will be coupled with wave energy generation to simplify AUV deployment, removing the need for repeated human interaction.

The marine environment is not friendly to any form of EM power transfer. This is the reason that sonar is used in place of cameras for seabed mapping, and submarines are so difficult to talk to by radio. Even in waters with low turbidity, directed beam or other far field transmission methods perform poorly. However, a new type of near field transfer may be much more effective. Resonant inductive coupling allows two intermediary coils with the same resonant frequency to couple strongly to each other at longer ranges, extending the near-field effect. While immersed in salt water the efficiency and power transfer rate is affected by the distance the coils are separated. This is due to the natural attenuation by the salt water, and the decrease in coupling efficiency. With adequate source and load control, power transfer rate and efficiency can be controlled even as distance changes. Our testing has focused on fully describing the effect salt water has on transfer efficiency at different frequencies, and includes digital source and load control to improve efficiency over a range of distances.

Figure 1. Resonant circuits connected to transmitting and receiving coils.
Team 1617: Autonomous Firefighting Robot

Sponsored by: University of Connecticut
Sponsor Advisor: Professor John Ayers

The Autonomous Firefighting Robot was in conjunction with the Trinity College International Robot Contest, which took place April 2-3, 2016 and is an annual, not-for-profit event that promotes innovation and creativity in the STEM field. The main requirement of this project was to design and create a fully autonomous robot, meaning that once initiated by the user, the robot can navigate, search for, and extinguish a fire on its own, with no external input or assistance from the user. The principles used in the design of this robot were implemented with the intent to be extendable to a more robust system used to combat actual fires in residential or commercial settings. In order to meet this criteria, many critical decisions were made involving part selection, mechanical and electrical design, and control for the robot. The ultimate goal was to not only accomplish all of the above listed criteria, but also to create a robot that works quickly and accurately.

This is a complex system with many different parts that must function in unison. The main operations are broken up into navigation, which involves finding where the robot is relative to its surroundings and deciding where to go next, movement, which involves robot actuation, and flame extinguishing. The flame extinguishing is ultimately the main goal of the robot, but the other operations are essential to accomplishing this task.

The navigation sensor used is a 360° laser scanner that records and sends data to a Raspberry Pi, running ROS (Robot Operating System), to process and perform localization and path planning calculations. A secondary Arduino board was used with a motor control shield to receive velocity commands from the Pi and transfer them into pulse-width modulation signals to drive the motors. A thermal array sensor was used to monitor for the flame and if a significant heat difference is detected, it overrides the path planning to navigate toward the fire. A small tire inflator with compressed CO₂ was used with an extended nozzle to extinguish the flame. Once in position, the robot initializes a servomotor used to press the button of the inflator to release the gas and extinguish the flame. The images below show the robot body, the model contest arena, and the fully equipped robot, respectively.
Working dogs are commonly used to aid military and police units. Part of their training involves bite strength conditioning. To condition a working dog’s bite, trainers will use a bite sleeve or sometimes a large tug, which is held with two hands by the trainer. There are currently many varieties of bite sleeves and tugs which vary in toughness; however, there are none that can measure the pressure of the dog’s bite. Thus, the U.S. Army tasked UConn to create a device that is able to measure and display the bite force of the Military Working Dog (MWD). Our device will ultimately help with validating training methods used for conditioning bite strength, enable trainers to keep record of health issues, and help with identifying muscular problems. The ECE team was paired with a Mechanical Engineering team to create a non-intrusive product that will fit inside a standard bite tug.

To achieve the above goal, the team is constructing a tug with an air bladder containing a pressure sensor, which connects to a microcontroller-contained PCB with Bluetooth capability. During training, when the dog bites the tug the pressure measurements travel from the microcontroller to a Bluetooth dongle connected to a computer. Using software created for our device the measurements are saved and displayed in a graphical format so that the dog bite data is easily readable. Additionally, because multiple dogs will be biting the tug in one training session, configurable profiles within our software are available. Trainers can store the graph of bite force over time, raw sensor data, and webcam footage of each dog’s bite. In addition to storing the data, the trainer can review the dog’s performance by playing back the video footage with a synchronized graph of the bite force over time. This will allow trainers to determine how different stimuli affect the dog’s bite.

To calibrate the pressure sensor data, the team placed different weights on the device noting the corresponding values that were output. The bite force was determined by creating equations from the known weight applied to the sensor. We were able to work with local K-9 units to perform initial testing of our device.
Embedded devices are not always manufactured with security in mind. As a result, many of commercial devices today have vulnerabilities that provide attackers with a means to maliciously exploit them. This presents an even larger problem because of the phenomenon commonly referred to as the Internet of Things (IoT). IoT describes a scenario in the near future where interconnection between devices will be a very common occurrence. Information being leaked by any one of the devices within a system of interconnected devices could be dangerous if it gets into the wrong hands.

Today, some devices still retain their test ports and communication headers even after manufacturing and testing. This is unsafe because it gives attackers a backdoor into sensitive parts of device such as the memory and firmware. Access to these could ultimately alter a device’s functionality and compromise the users of the device.

Our project is to design a probe capable of interacting with embedded devices, identify what type of communication protocol is being used (RS232, JTAG, SPI, I2C, etc.) and analyze the data being sent and received from the device. Our probe should work effectively as a debugger without any prior knowledge of the pinout or protocols utilized by the device. This probe will be very useful for debugging and testing devices with greater ease. With this accomplished, signals can be further analyzed in order to improve the way these devices allow information to be accessed and thus, make them safer from malicious exploitation. Our probe will be able to identify the two communication protocols; RS232 and JTAG. We expect this to eventually grow to encompass more protocols.
In the aerospace industry, Field Programmable Gate Arrays (FPGA) are employed extensively to provide hardware that allow complex systems that perform critical to mission tasks in environments of high energy radiation. Flash-based FPGA’s are one technology that have shown concrete evidence in their ability to provide hardened hardware to high energy radiation and lower the single events upsets (SEU) in these embedded systems. SEUs occur due to a high energy particle passing through the depletion region of a transistor. This causes an error due to a state change in that transistor, thus triggering a system failure on the rest of the design. However, the trade-off using Flash-based FPGA for protection against SEUs is the high performance offered by other memory types, such as RAM-Based FPGAs. Although RAM-based FPGAs have higher performance, they also have higher susceptibility to SEU’s.

Investigated were ways to reduce RAM-based FPGA’s susceptibility to SEU’s. One way was with Triple Modular Redundancy (TMR). TMR works by triplicating design logic whose 3 outputs are passed to a majority voter. This method allows the system to continue running because error in from one output is masked by the two agreeing outputs. Along with the TMR, a single error mitigation module (SEM) was investigated to repair the masked errors in the design. This module works by scanning through the design for any errors and corrects them. This SEM module operates in the background while the FPGA operates, further increasing the uptime of the system.

Existing design was migrated from a Flash-Based Microsemi FPGA to a RAM-based Xilinx FPGA. A number of changes had to be done such as replacing proprietary code from Microsemi with Xilinx IP cores. Once the code migration was complete, a series of test-cases provide by our sponsor, UTC Aerospace Systems (UTAS), were done to validate the design at pre- and post-implementation.
Modern commercial aircraft contain a Fuel Metering Unit (FMU) that is responsible for metering fuel to the engine. In order to calculate the burn flow (how much fuel is required by the engine in order to operate at peak efficiency), the FMU uses a generic performance map that may not be perfectly calibrated to the engine’s parameters. This map is generally created by averaging the performance data of many different FMU’s of the same make and model. As this generic map is based on the performance data of many different units, it will never perfectly model the performance of any individual unit. Therefore, any burn flows calculated using this generic map will fall short of achieving the best possible burn flow given the current environmental conditions. UTC Aerospace Systems (UTAS) is looking to improve the efficiency of their burn flows. To do this, UTAS will map the performance data of each individual FMU rather than an average of multiple FMU’s.

In order to accomplish this, a memory chip will be permanently attached to each FMU, storing its own performance parameters to be recalled later by the Electronic Engine Control (EEC). Our solution is 3 fold: acquisition of performance data, extracting good data, and determining how to meaningfully store that data on the memory chip. The acquisition involves operation of a test rig to capture 5 key parameters, FMU temp, pump speed, pressure out, resolver position and metered flow. Extraction of good data requires removing unstable data and the use of data which exhibits the most steady state. In order to store the data on the memory chip, a combination of mapped values using a lookup table and coefficients which produce a regression fit. Both of these tools must be used to achieve the desire 0.1% accuracy and have the data read by the EEC in less than 0.5 seconds.
Nutrient pollution is an increasing problem in global water sources. Human waste contains larger amounts of nutrients - most importantly phosphorous and nitrogen - which can have negative effects on ecosystems. Therefore, it is important to have nutrient removal systems at wastewater treatment plants in order to lower concentrations before the waste stream enters natural water bodies. The Water Pollution Control Facility in Waterbury, Connecticut treats municipal wastewater from the city of Waterbury for nutrients, metals, suspended solids, etc. They currently have an effluent total phosphorus concentration limit of 0.7 mg/L before the treated wastewater can be pumped into the Naugatuck River. This will soon change, as by the year 2020 new EPA regulations will require the seasonal discharge limit of phosphorous to decrease to 0.2 mg/L. The plant has a design capacity of 27 MGD but averages around 21 MGD throughout the span of a year.

This group has been tasked with exploring all possible removal methods and technologies that could remove enough phosphorous to reach the new limit. The facility presently uses a process of chemical addition, which adds aluminum sulfate and magnesium hydroxide to react with phosphorous-containing compounds, creating solid particles that will precipitate the phosphorous out of the waste stream. This project examines the cost and ability to continue running chemical processes in larger doses to account for the additional removal required. Other biological methods, such as enhanced biological phosphorus removal (EBPR), are also examined to compare the efficiency of biological removal with chemical removal. The budget for the upgrade is approximately $30 to $50 million dollars.

The project also considers the removal of biosolids created in phosphorus removal. Currently, biosolids are incinerated on site, but alternatives for biosolid management are examined as well. These alternatives must also consider the new regulations set by the EPA; modifying the chemical process increases the amount of precipitate formed, while the biological process produces more biofilm. As part of the goal of this project, increasing treatment process efficiency and exploring options to increase energy efficiency and sustainability are considered.
The Town of Vernon Water Pollution Control Facility services five surrounding areas including the Towns of Vernon, Tolland, Ellington, Manchester, and South Windsor. The design flow is 7.1 MGD, however the plant averages about 3.9MGD. Treated effluent water is discharged into the Hockanum River located to the east of the plant. In the past, the plant treated industrial wastewater from various industries including a textile dye house, currently not in operation, and was the main driving force for the implementation of the now 40-year old Zimpro-PACT secondary treatment system. This process includes the addition of powdered activated carbon to the activated sludge tanks followed by regeneration through oxidation in the wet air oxidizer (WAO) unit located on the site. The Zimpro-PACT system is special in that it provides odor control which benefits residential and commercial areas surrounding the plant. However, the Zimpro-PACT system does not allow for efficient phosphorus removal. Under a new Municipal National Pollutant Discharge Elimination System (NPDES) permit, the plant is required to treat for phosphorus to a seasonal average of 0.14 mg/L in its effluent, which they must meet within five years. The plant is also currently purchasing nitrogen credits due to excessive nitrogen concentrations in their effluent.

Two methods of phosphorus removal have been considered in order to comply with the NPDES permit. This includes tertiary chemical addition and sedimentation as well as enhanced biological phosphorus removal (EBPR). Our EBPR design would replace the existing activated sludge tanks, thus also removing the PACT system; which would bypass many problems that arise with the corrosion of the wet air oxidizer by chemical coagulants. Typically, lower levels of phosphorus effluent can be achieved through EBPR alone, however lowest levels are achieved via a combination of processes. In order to reach an effluent phosphorus concentration as indicated in the NPDES permit, a tertiary polishing step is needed in order to further reduce phosphorus concentrations. Determination of our final design takes into consideration sizing constraints, budget, removal efficiency, current infrastructure, as well as potential for nitrogen removal.
Waypoint Spirits is a start-up craft micro-distillery located in Bloomfield, CT. Dedicated to supplying hand-crafted and high quality distilled spirits, Waypoint mashes, ferments, distills, and flavors its products on site, creating a unique product, and with it, a unique waste. Along with providing high-quality craft spirits, Waypoint is dedicated to sustainability. From using locally sourced grains to using green energy for their building, they are looking to reduce their carbon footprint and reduce energy costs at the same time. Our design goal is to utilize the nutrient-rich waste produced onsite in a small scale anaerobic digestion process which can produce usable by-products. Anaerobic digestion produces methane gas which can then be used to supplement their current natural gas stream feeding their boiler. After digestion, the solid waste can then be sold to local farmers as fertilizer.

This project requires testing and analysis of waste samples to determine its compatibility with a digester and its potential to produce a significant amount of methane gas. Next, the available water quality analyses of the Waypoint waste stream are matched to a microdigester with design specifications that fit the parameters. Preliminary designs of the infeed system of the waste into the digester as well as a design for the infeed of the methane into the boiler are made. Treatment of the gas for the removal of unwanted impurities is also accounted for in this plan. Using the estimation of methane production, information on the microdigestor, and necessary design modifications, a cost-benefit analysis was done to estimate a return on investment of the project. Based on the cost-benefit analysis, Waypoint will purchase the microdigestor, implement our input designs, and begin facilitating the digestion process. Overall, our project entails testing the waste in order to choose a compatible microdigestor, designing a transport network to carry the waste and digestion byproducts, and designing a methane cleaning system with a reasonable rate of return for Waypoint Distillery.
Team 4: Remediation of an expired chromic acid storage sump

Sponsored by: GZA GeoEnvironmental, Inc.
Sponsor Advisor: Karen Kinsella and Tom Stark

The 0.75-acre site manufactured rotogravure printing rollers for thirty years in a 1,500 square foot building beginning in 1980. Manufacturing continued until digital printing technologies made rotogravure printing obsolete. Some of the manufacturing processes included plating with copper and hexavalent chromium. These chemicals have been released into the surrounding groundwater and soil. The release of these metals is regulated by the United States Environmental Protection Agency (USEPA) and the Connecticut Department of Energy and Environmental Protection (CTDEEP). Hexavalent chromium is more toxic than the naturally occurring trivalent chromium. Trivalent chromium is an essential nutrient for humans while hexavalent chromium is a known carcinogen. Hexavalent chromium has been linked to respiratory and gastrointestinal damage. Also, hexavalent chromium can accumulate on fish gills increasing mortality rates. High copper concentrations are mostly dangerous for aquatic biota in free surface waters, so the copper release could affect a wetland located 1,200 feet west of the site. Due to wording of the lease agreement with the landlord, the client removed a 4 by 4 by 6 foot deep in-ground concrete sump with a polyethylene liner, used for storing chromic acid. The sump was unlined from 1980 to 2000, and continued to store chromic acid during that time. When the liner was removed, there was yellow coloration of the concrete, concrete degradation, and a black liquid in the bottom of the sump. A sample was taken of the black liquid, which was suspected to be groundwater, and was determined to have a total chromium concentration of 800 mg/L. State and federal regulations and the lease language indicate a need for remedial action to return the site to pre-lease conditions and ensure regulatory compliance (0.05 mg/L).

A few remediation techniques were explored. The first is a permeable reactive barrier containing zero-valent iron. The effluent after the barrier should have reduced levels of chromium and copper. Another possible technique is well injections using iron and calcium polysulfide or sodium meta-bisulfite. These chemicals would be injected into the groundwater to precipitate chromium and affix it to the aquifer media where the regulations on chromium in soil are less stringent. To reach compliance of chromium and copper concentrations in the vadose zone, excavation is the main method for remediation. A detailed sampling plan must be completed to ensure the extents of the soil contaminations have been thoroughly addressed through remediation.
The Connecticut Stormwater quality manual sets runoff standards that a site that meets certain criteria must follow. In our case the site meets the criteria of the disturbance of greater than 1 acre of land. Therefore in developing a stormwater management plan we must bring our site to compliance with specific parameters set by the manual. The manual focuses specifically on two standards that must be met through the management plan. The first one addresses the pollutant reduction in the water quality volume (WQV) of the rain event. The WQV is defined as the volume of stormwater runoff generated by the first inch of rainfall on the site. This value is based on the fact that one inch accounts for the treatment of 90% of average annual storm events. The second standard of the stormwater plan is to store the WQV on site before releasing it to a water body or a treatment plant. Both of the standards can be met through the implementation of best management practices (BMPs) on the site. The overall goal is to reduce the impact that stormwater runoff has on water bodies as well as treatment facilities that deal with an increase flow during storm events.

The site is located at the confluence of the Hockanum and Connecticut Rivers, adjacent to highway 2 and floodplains. The 3.6-acre plot is 90% impervious cover, and is mainly comprised of a large building and two parking lots; therefore there is a high amount of runoff during storm events. The lack of pervious cover leaves very little space for the implementation of best management practices (BMPs) on site. To better understand the flow of stormwater runoff on our site we used Bentley StormCAD software to develop a stormwater model. We first designed a site plan on AutoCAD using elevation data collected while surveying the site and plans obtained from the town of East Hartford engineering department. We also worked alongside a team of landscape architecture students who provided input on visual design of the BMPs we selected. A series of rain gardens were strategically placed to capture runoff from the parking lot, and a modular green roof was applied to the membrane roof. Any associated water diversions necessary to re-route runoff are detailed in the designs.
MANAGEMENT & ENGINEERING FOR MANUFACTURING

www.mem.uconn.edu
Commercially Licensed Cooperative Kitchen, Incorporated (CLiCK) of Willimantic, Connecticut is a non-profit 501c3 organization that serves the needs of the local community through its continual allegiance to a locally-based, sustainable, and healthy food system. They provide food preparation education and certification for the local community through their teaching kitchen as well as a rentable commercial kitchen for food entrepreneurs to use for production of legally merchantable food products. One of their foremost needs is increasing the membership and retention of their commercial kitchen users to increase revenues and fund their ongoing operations. The focus of this project is to generate new demand for the commercial kitchen by increasing awareness of CLiCK in the local community and improve retention of current commercial kitchen users by creating and modifying resources that assist them through registration/certification, production decisions, and safe and efficient use of the commercial kitchen.

The project consists of three components that aim to make CLiCK’s commercial kitchen more attractive and accessible to farmers and small food manufacturers. The first component is an informative manual to guide users through the lead-up to and production of several common categories of food items in the kitchen. The manual collects and integrates state licensing walkthroughs, regulatory information, safety procedures, and best practices into an illustrative and easily readable form. The second component is a software program that provides current and prospective kitchen users with information about their proposed production efforts. The product costing software will be used by CLiCK personnel to consult users about selling prices, production volumes, and capital necessary to profitably produce in the commercial kitchen. The final component is a marketing campaign to spread awareness of CLiCK in the local community. The marketing campaign will highlight CLiCK’s unique capabilities and encourage food entrepreneurs and small farmers to consider using CLiCK’s most lucrative services, including its commercial kitchen.
Team #2: Frito Lay Former Cleaning Process Improvement

Sponsored by: Frito Lay
Sponsor Advisors: Christopher Eber, Benjamin Sharpe

(From left to right) Tyler Markert, Caitlin Hewes, Raza Butt, Grace Lynch, Anders Mattisson

Project Description
During the packaging process at Frito Lay, product is channeled through a device called a “former”. This device is a piece of equipment that controls product flow and also makes product specific packages. Due to the high volume of product the plant produces, seasoning and product build-up occurs inside the former, especially for specific flavors. As part of Frito Lay’s commitment to excellent food safety and quality, formers must be removed and thoroughly cleaned after batches with color and allergen changes. Due to space constraints in the packaging department, employees must manually carry formers to be cleaned, resulting in high physical exertion and safety risks.

The primary objective of this project is to design, produce, and deploy a cart for transportation of formers. The cart should minimize employees’ time spent off of the packaging floor as well as minimize physical effort in the former cleaning process. The secondary objective is to provide a recommendation for a washing station and/or permanent dishwasher-style machine to efficiently clean multiple formers simultaneously. Both the cart and washing station will enable employees to clean the formers with higher efficiency and in an ergonomically friendly way.

A House of Quality was created to ensure the product fit the customer’s requirements. Four operational definitions were defined to measure the performance of the new cart. The definitions are ergonomic quality, cleanliness of former, efficiency of system, and employee satisfaction. The design of the new cart was constructed in Solidworks to ensure safety and reliability. Time studies and a computer model were created to evaluate the efficiency of the system and to examine the overall impact in terms of time and safety.
Team #3: Vehicle Travel Time Prediction Analysis

Sponsored by: Departments of Management and Engineering for Manufacturing & Civil Engineering
Sponsor Advisor: Dr. Diane VanScoter & Dr. Karthik Konduri

A multitude of companies and varied software firms utilize crowd-sourced data to predict travel times. These systems are generally propriety and the actual crowd-sourced data is not available to the public. If access to this data was not restricted, more firms could design and build better, more efficient and less congested infrastructure for our society.

Dr. Karthik Konduri and his team in the Department of Civil Engineering at the University of Connecticut, in coordination with the New England University Transportation Center, developed hidden Markov model (HMM) algorithms based on GPS tracking data to predict travel times for the bus transit system on the Storrs campus here at the University of Connecticut. The purpose was to develop a non-proprietary system that could be used for multiple applications without involving larger proprietary systems.

This project, between the Departments of Management and Engineering for Manufacturing and Civil Engineering is to conduct a feasibility study to see if the algorithms developed by Civil Engineering can be used to predict the travel times of personal vehicles. If the algorithms can correctly predict these times, the number of uses for the algorithms and systems in general increases. Additionally, this project will validate the results of the current algorithms by comparing them with actual results from the ground. Clustering analysis will be used to explain discrepancies between the two.
TEAM 4: TYCO SIMPLEXGRINNELL ELECTRICALLY ACTUATED VALVE

Sponsored by: Tyco SimplexGrinnell
Sponsor Advisor: James Williams
Zachary Magnone

(From left to right) Kenneth Miller, Anthony Nguyen, Bozun Wang, Dennis Aguilar

PROJECT DESCRIPTION

SimplexGrinnell, a subsidiary of Tyco International, is a market leader in the global fire protection industry. A subsystem within their fire protection valves is the main drainage valve. The purpose of the drainage valve is to drain the fire suppression system after actuation due to fire or a required test.

Technology is constantly advancing and Tyco is evaluating the automation of their entire line of fire suppression systems. The purpose of this project is to design an electrically actuated valve by automating the open and close functions of the valve. The goal is to construct an innovative and viable alternative to the current models on the market for electrically actuated valves. With an emphasis on low cost, environmental friendliness, and energy efficiency, this design will allow for remote draining of the system after a remote test. Eventually, this design will support the company’s goal of implementing computers within their future fire suppression systems.
Team 1: Accelerated Separator Aging Test

Sponsored by: BST Systems
Sponsor Advisor: Dr. Bryan Hirschorn

BST Systems produces silver-zinc batteries for specialized applications such as underwater submersibles and space exploration, including the Mars Pathfinder Program. Compared to lithium-ion batteries, silver-zinc batteries have a higher power density and are utilized where battery weight, volume, and safety are primary concerns. However, increasing constraints on performance, longevity, reliability, and operating conditions lead to battery failure often due to internal short circuits. Most commonly these stem from metallic dendrite growth that plates onto the anode and pierces the polymer separator which lies between the anode and cathode. Therefore, improving the separator material to resist dendrite penetration can extend battery life. Four candidate replacement materials were provided by BST Systems that may provide longer lifetimes for future silver-zinc batteries. This study aims to qualify which of the four candidates best resist the effects of the operating environment in a battery.

The polymer candidates are exposed to a KOH solution with AgO particulates as a simulant of the conditions within a packaged battery. KOH is a strong base, which is corrosive and therefore it is important to take the necessary safety precautions including proper labeling, disposal, and handling. Furthermore, since actual lifetime tests would be time inefficient, the polymers and solution are heated to several hundred degrees Fahrenheit for accelerated aging, effectively simulating battery life in hours instead of months or years. Before, during, and following these tests, multiple materials properties are measured to assess the candidate materials. Tensile strength is compared to previously gathered baseline information to determine how the KOH environment affects mechanical properties. Fourier Transform InfraRed (FTIR) analysis identifies any changes in the chemical composition due to KOH attack. Density measurements reveal swelling and uptake. Optical and electron microscopy resolve changes in microstructure. In this manner, recommendations can be made for targeted future scaleup testing by BST Systems and ultimately improved battery performance, reliability, and lifetime.
Currently it has been estimated that 250,000 people in the United States have had hip replacement surgery in their lifetime. Not only that but it has been estimated that if this trend continues, by the year 2030 there will be a 180% increase of people undergoing this surgical procedure. This is quite problematic because it has also been noted that the number of physicians who can perform these surgeries has been steadily decreasing in the past decade. It is because of this increasing demand that a need for longer lasting and more efficient prosthetics is needed. Studies throughout the years have stated that the reason for failure of these prosthetics over the years is due to its lack of biocompatibility. Meaning that there is no interaction and fusion of the prosthetic and the bone, which eventually leads to aseptic loosening and ultimately failure. One route that has been taken in accomplishing that goal is by coating a titanium alloy prosthetic with hydroxyapatite, the mineral found in human bones. It is through this method that one hopes are bone ingrowth within the coating. This will provide mechanical stability for the prosthetic implant and a longer duration. The goal of this study is to study the biomimetic coating method for this purpose, study the effects that pH, temperature, surface treatments and drying methods have on the coating’s integrity and develop a mechanical test to quantitatively measure the adhesive strength between the coating and the substrate.

The experimental approach involved the biomimetic coating approach, which is the concept of mimicking the body’s method of producing hydroxyapatite. This is done by first surface treating Ti6Al4V cylindrical substrates by sandblasting and acid treating. Afterwards a simulated body fluid (SBF) solution, which contains the principal ions needed to produce the coating, is produced. This solution’s pH is afterwards fixed and the substrates are then immersed in it. Afterwards the solution is kept for a whole day at 37°C and afterwards dried cautiously. Once this process is complete one can use the many different characterization techniques such as electron microscopy, X-Ray Diffraction or Fourier Transform Infrared Spectroscopy to study the coat and qualitatively determine its adhesive bond strength and structural integrity. It is the goal of this research group to develop a mechanical test that will accurately reveal the coating’s true adhesive bonding strength.
KX Technologies is making the world a better place through innovation in the water industry. Consumption of pollutants in water is a hazard that many people in advanced societies do not even consider because of the regularity effective filtration. KX Technologies is a leader in water filtration research and development. This development of a large line of product offerings aids the well-being of the humans globally. These filters are typically either carbon block or carbon paper based filters employing the use of activated carbon fibers. To produce an activated carbon fiber, the source material is fibrillated and carbonized. Such a fiber will extract micro and macro pollutants from water. At the simplest level cellulose is a polysaccharide composed of gluten monomer chains. It is a main component in plant cells and is completely insoluble. Fibrillation of cellulose samples will result in fibers that have an extremely high aspect ratio. The ability to maintain a high aspect ratio upon fibrillation is a pivotal variable when it comes to deciding what specific cellulosic fiber source to use. From there the fibrillated fibers are carbonized. This process allows for most of the non-carbon components of the fibers to be burned off. This causes the samples to create new carbon-to-carbon bonds, which in turn causes the formation of carbon plates that will stack on one another to give an extremely high specific surface area per unit volume. This gives water running along the fibers far more material to extract any pollutants that may be present. The fibers are then ‘activated’ by addition of a combustible compound into the carbonization mechanism. This creates both micro and macro pores that are the part of the fiber are the basis of the mechanisms behind pollutant removal.

The scope of this project is to examine potential biomass substitutes for filter production that will be more economically viable. Through extensive literature search the materials selected for testing were cotton, coir, hemp, and rice husks. These different cellulosic fibers were processed through fibrillation, carbonization, and activation. Samples were then subjected to testing and characterization. Surface morphology was monitored at the raw, fibrillated, and carbonized steps using visual light microscopy, scanning electron microscopy, and transmission electron microscopy. Raman spectroscopy was used to monitor chemical composition. The filter specific surface area was tested with a BET test. The project benchmark is a chloroform absorption test to test the source material as a viable filter.
In locations with high concentrations of people, there exists a need to maximize exit time in the event of an emergency. Marmon Innovation and Technology Group produces cables used in transportation infrastructure, and is working to gather and analyze data about how their cables perform in fire scenarios. The cables are constructed with an inner metal conductor and an outer insulation, which Marmon provided 3 different types for evaluation. Two are halogenated cables, a full thickness and a half thickness wall, made of Polyvinylidene Fluoride (PVDF), a cross-linked fluoropolymer that has high corrosion resistance, but can emit carcinogenic gases. The third is a non-halogenated cable, made of cross-linked polyolefin, which is an extrinsically flame retardant polymer. The three cables will be tested in a cone calorimeter at three different heat fluxes: 25 kW/m², 50 kW/m², and 75 kW/m². The cone calorimeter was developed at NIST and provides benchmark data on the burn performance, ignition time, and smoke density of the materials tested. The major tasks of this project are to design a method for interpreting and analyzing the data generated by the cone calorimeter and to present this data in a way that is informative to both Marmon and the fire engineering community.

The results will be used to determine the trade-offs between cable materials, thickness, and burn performance characteristics of the cables. The desired cable will take the longest time to ignite, and once it has caught fire, emit the least amount of smoke with the lowest heat release rate and peak heat release. These parameters will be used to establish an index for burn performance which can be used to rank differing cable materials and geometries. This index may be useful as an input to fire models, which can be used to predict conditions for increasing the egress time in fire emergencies.
Team 5: Alternative Non-Metallic Materials for Transfer Pump End Cap

Sponsored by: Stanadyne LLC
Sponsor Advisor: Keith Simpson

Project Description
The transfer pump end cap is an important component in Stanadyne’s model DB diesel fuel pumps, used in heavy equipment and trucks. The end cap holds the transfer pump components to the fuel pump head and contains the fuel inlet port. It is currently machined from 1018 bar stock steel and carbonitrided. The part’s thin walls and low tolerance internal and external threads leads to difficult machining and potential distortion during heat treatment, resulting in defective parts. As a result, Stanadyne sought to replace the material for the end cap. The project goal was to identify and propose non-metallic materials that are compatible with the diesel environment, meet the structural needs, and are economically feasible. Prototypes were fabricated and tested by Stanadyne for their functionality and long term durability.

Through extensive research, it was determined that a polymer would be the best option to replace the metallic end cap. PEEK, PAI, FEP, and PTFE were deemed the four best polymeric options due to their mechanical properties, working temperature ranges, chemical compatibility, and cost to manufacture. Several tests were then carried out including fluid immersion, tensile testing, and toughness testing. An immersion test was performed on these materials to find the rate of absorption and property changes after being soaked in water, kerosene, and a mixture of fuels at elevated temperatures. Samples of each material were cut into 1” diameter disks and placed in separate glass jars filled with each testing fluid. The jars were then put in a furnace at 100-120°C and the samples’ mass and volume were collected every 12 hours until steady state was reached. Tensile and toughness tests were performed before and after immersion testing to study how soaking the materials changed their mechanical properties. The top two performing materials were officially proposed to Stanadyne for them to begin prototyping.
UTC Aerospace Systems provides heat exchanger assemblies to air framers. The Lower Recirculating Heat Exchanger is installed in the Liquid Cooling System (LCS) and is used to cool recirculated air from the airplane cabin and provide cooling to the Pack Control Unit (PCU). Part of the component design includes plastic mock inlet and outlet ducts being fabricated through fused deposition modeling (FDM), an additive manufacturing process. The mock-ups will be used for rig testing before implementing final, expensive metallic materials.

This project aims to design a plastic mock-up air duct that can withstand the environmental conditions of the LCS. One of the biggest issues with FDM and additive manufacturing in general is the porosity caused by the layer by layer fabrication process. The porosity leaves FDM parts susceptible to liquid and/or gaseous environments, like the LCS, where the fluids will permeate the parts. While additive manufacturing is advantageous in terms of schedule and cost, the mock-ups are not useful unless they can be tested without permeation. To prevent permeation, this project will design a coating to be applied to the FDM parts that will make the additive manufacturing process feasible for fabricating air ducts.

Success of this project will be based on preventing permeation of fluids into additively fabricated plastic parts. To accomplish this, multiple FDM materials and coatings were investigated. Three materials produced by Stratasys; ASA, Ultem 9085, and Nylon 12, were coated with three coatings; an epoxy (BJB-TC-1614), a polyurethane (ANAC 58 Series), and an adhesive (Loctite RTV Silicone). The merits of each coating-material combination was quantified by two main metrics, the adhesion between the coating and substrate, and the amount of permeation allowed into the part. Adhesion testing was accomplished using a cross-hatch tape test to observe the bond strength of each test piece. The permeability was tested by submerging the parts in fluids from the LCS environment (60/40% mixture of propylene glycol and water) for varying exposure times and recording the change in mass due to permeation. Mechanical testing was then used as a supplementary metric to quantify the structural integrity of each test combination. Tensile and hardness tests were carried out to accomplish this as well as provide a characterization standard for future research conducted by UTC Aerospace Systems on FDM materials and practices.
Aluminum is preferred for Air Management Systems components due to their favorable strength to weight ratio and affordability. Aluminum heat treatments are characterized in a series of abbreviations posted after the aluminum series number. As the set system of abbreviations for temper designations follow, -O is a full soft or annealed sample, -T stands for heat treated to produce stable tempers. The objective of this project is to investigate the varying levels of plastic strain imparted prior to heat treatment on the mechanical properties of –T62 aluminum. It’s crucial to know how the microstructure changes throughout the process of plastic deformation before heat treatment as during the heat treatment process precipitates will develop and try to alleviate the stress developed through pre-straining. This will be compared to known values of, UTS (42ksi) and for yield strength (36ksi) for 6061-T6 plate (thickness .4in.). Strain levels in excess of 15% will be of particular interest as they have not been tested previously. The general thought is that if the materials can be strained above 15% that other methods and parts can be produced using this form of cold working. If the material is a success at strains above 15% it companies can save money and time producing air management system products. We will be testing 24 samples, with 3 samples each corresponding to a specific pre-strain (0%, 5%, 10%, 15%, 20%, 22%, and 24%). Microstructure of each pre-strain before and after heat treatment will be examined.

Changes in the mechanical properties of the Aluminum are measured through tensile tests for each pre-strain percentage. Samples are pulled to failure, and the corresponding ultimate tensile strength, yield strength, and maximum elongation was found for each pre-strain based on corresponding stress-strain curves. Scanning Electron Microscopy and Visual Light Microscopy were employed to see changes in microstructure based on the pre-strain percentage before and after heat treatment. The aging process of for –T62 Aluminum involves the formation of β Mg2Si phases that strengthen the Aluminum. Imaging is important in visualizing differences in the precipitation of phases amongst the different pre-strains. Being able to confirm little to no reduction in mechanical properties of 6061-T62 Aluminum based on testing results and imaging would be largely valuable for improving efficiency at UTC Aerospace Systems.
Computational materials sciences are quickly gaining traction in industrial applications in order to explore volatile and obscure processes as well as to guide experimentation, avoiding blind, trial and error approaches. Unfortunately, limitations to computational resources prevent the large scale, high accuracy calculations needed to truly revolutionize the industry. In an effort to unite highly accurate density functional theory calculations to much larger scale (but less accurate) molecular dynamics calculations, a data driven scheme to predict interatomic force fields using a training data set of density functional theory calculations has been developed. The method allows for molecular dynamics calculations to be done with the accuracy of density functional theory by generating an interatomic force field using a statistical model trained on density functional theory data. As with any statistical model, the force field is not accurate for any situation sufficiently outside of the dataset and no testing has been done to explore the domain as of yet.

The objective of this work is to stress test the “machine-learning” force field by using it to run molecular dynamics calculations for a range of atomic environments. This data is then checked with density functional theory calculations in order to improve the data set of the statistical model. The experimental procedure for testing the machine learning generated force field is broken down into structure selection and generation, molecular dynamics using the generated force field, first-principles (DFT) molecular dynamics and comparison/recommendation. To evaluate the success of the force field, the magnitude of the force on each atom as predicted by the force field and first-principles is calculated. These values are plotted against themselves in a parity plot for qualitative assessment. If a low correlation between the two methods is seen, the structure is placed directly into the training data for the force field. Atomic environments tested include a sigma-3 grain boundary in equilibrium and strained 0.1, 0.3 and 0.5 Angstroms. The comparisons for the grain boundary configurations proved accurate, serving as validation for the machine learning force field. Testing of bulk systems in uni-axial and bi-axial tension and compression along with vacancy clustering are currently in progress. All configurations are defined for an FCC Aluminum crystal structure.
Team 9: Hexavalent Chromium Chromate Replacement Product Performance Verification

Sponsored by: General Electric – Industrial Solutions
Sponsor Advisors: Peter Greenwood, PE and Leonardo Mascarenhas
Faculty Advisors: Pu-Xian Gao, Ph.D. (MSE) and Zbigniew Bzymek, Ph.D. (ME)

General Electric - Industrial Solutions (GE) is a company that provides a wide variety of products and services in the electrical distribution business. GE has tasked us with identifying a suitable replacement for Hexavalent Chromium Chromate passivation. This material is plated on many components in GE electrical equipment due to its corrosion resistance. However, due to changing regulations and the health risks of HCC, the sponsor has determined that it is necessary to remove the plating from production by 2019.

In order to determine the viability of potential substitute materials, the team of Material Science & Engineering (MSE), and Mechanical Engineering (ME) students produced custom testing rigs to evaluate material wear and corrosion performance. The construction of these rigs and the fabrication of the 400+ testing coupons were the primary physical deliverables of this project. The wear rig allowed the team to determine mechanical performance on the basis of mass loss. In the evaluation of mechanical performance, the coated test coupons were revolved on a testing plate while a flat, coated column contacted the surface to wear the plating. After a certain number of cycles, the coupons were subjected to environmental testing. The corrosion rig was designed to provide aggressive corrosion on the worn coupons, and was modeled after the industry standard salt fog test. The worn test coupons were immersed in a humid salt fog test chamber and held at temperature until corrosion started. A series of calibration checks were completed to evaluate the UConn test severity to ASTM standard testing.

The team examined three different plating materials (JS 600, trivalent chromate, and zinc phosphate) and compared their performance to that of the original HCC plating. Optical microscopy, scanning electron microscopy, profilometry, and surface metrology techniques were employed to determine which plating was likely to meet the consumer standards necessary for replacement. The large set of data on volume loss, mass loss, and surface degradation provided good metrics for the evaluation of material suitability. These tests were done before and after the corrosion process. The resulting comparative analyses drove the final recommendation of the best candidate material for the sponsor on the basis of mechanical and environmental performance.
X-Ray micro-CT machine is capable of performing high cost resolutions scans on various specimens allowing one to give an in-depth study of the scanned specimen. However, there exist multiple challenges with the X-Ray micro-CT machine such that an alternative analysis technique is sought after. The common challenges of utilizing the X-Ray microCT are the fact that it involves a high amount of time, cost, and that there are limitations on sample size and the corresponding scan resolution. The goal of this project is to compare micro-CT analysis to Archimedean method for measuring porosity of a sample which contains both “open” and “closed” pores. To ensure liquid penetrates into the “open” pores of the specimen and that “open” and “closed” pores are distinguished, a modified Archimedean method, “Archimedean Freeze”, is pursued with a Potassium Iodide+Iodide Solution instead of water. Once the Potassium Iodide+Iodide solution infiltrate the pores, it will stain the specimen, leaving a trace behind in the open pores of the specimen. This trace left behind can be detected through the X-Ray micro-CT, where observations can be made in regards to the viability of the “Archimedean Freeze” method by measuring and distinguishing between “open” and “closed” pores. This method can help assess whether the difference in porosity measured by the Archimedean method as compared to micro-CT is due to the closed pores not being infiltrated. If the “Archimedean Freeze” method proves to be successful, one would be able to test for porosity on a multitude of specimens at significantly low costs and lower lead time.

*Figure: Photo of micro-tomography analysis instrument.*
Team 11: Quantum Mechanical pKa Predictions of Drug-like Molecules

Sponsored by: Pfizer Inc.
Sponsor Advisor: Geoffrey Wood

One of Pfizer Inc.’s goals is to improve their ability to predict molecular and solid state properties in order to aid drug design and delivery. A molecule’s degree of dissociation in solution is a vital characteristic that determines a number of key properties such as, formulation, stability, bioavailability, absorption, and salt formation. The pKa defines a molecule’s extent of ionization in solution and in the pre-formulation stage the pKa value assists in deciding which salts are viable targets for drug design. Empirical methods for pKa determination are fast but potentially produce large errors. In these situations ab initio quantum mechanical investigations may present a more accurate alternative for pKa determination for drug-like molecules because these calculations do not depend on training sets or experimental information. Although using quantum mechanical computations to predict the pKa value leads to marginal increases in the cost of research, it is advantageous to use when faster and less accurate approaches produce inconsistent pKa results or crucial design decisions are being made and more certainty is needed.

A variety of ab initio quantum mechanical calculations and statistical analysis of the obtained results were preformed to establish the accuracy of currently used conventions for pKa predictions in drug-like molecules. An understanding of the advantages and disadvantages of each method was obtained. To conduct this investigation, computational research was done using the Gaussian code. This program was used to predict energetics, structure, and thermodynamic properties of molecules in the gas and solution phases. These energies were then used to calculate the molecule’s pKa, which was then compared with the corresponding experimental data.

The thermodynamic cycle shown in the figure below is a strategy that was employed to calculate the pKa value of a molecule of interest (propionic acid in the example). It was concluded that the choice of reference base (Ref- in the figure) plays a critical role for achieving high accuracy. However, further research is being conducted to discover a reliable way of identifying these references.
Team 12: Additive Manufacturing Processing Design for 17-4PH Stainless Steel

Sponsored by: Medtronic
Sponsor Advisor: Dr. William Powers

Medtronic is a medical device company whose mission is “to contribute to human welfare by application of biomedical engineering in the research, design, manufacture, and sale of instruments or appliances that alleviate pain, restore health, and extend life.” There has been recent interest in researching the viability of utilizing the additive manufacturing process in the design and creation of various parts for medical instruments. Some biomedical devices require high tolerance parts as well as quality surface finish. The interest in additive manufacturing is the potential to create complex and intricate parts while maintaining minimal surface roughness.

The aim of the design project was to utilize the Direct Metal Laser Sintering Process (DMLS) found in the 3D Systems ProX 300 system using 17-4PH stainless steel to manufacture samples at variable parameters. The samples were generated based on a computer aided design model that focused on the faces of the sample at various angles. The surface roughness of the resulting samples was then analyzed using the aid of a Zygo 3D Optical Scanning Interferometer profilometer. The core objectives were to improve the surface roughness of samples in addition to establishing a qualitative relationship between the laser parameters and the surface roughness parameter.

The variable parameters that were being explored include the laser beam power, laser speed, and beam overlap distance. These 3 factors will have 2 levels which will result in the creation of 8 samples. For consistency, each sample will be duplicated, resulting in 16 samples. One sample will be fabricated with default settings as a control which will result in a total of 17 samples. Because each sample had 6 faces (0°, 10°, 30°, 50°, 70°, 90°) and a total of 17 samples, 102 Zygo measurements were necessary in order to effectively observe the relation between the parameters of the 3D Systems ProX 300 system and the surface roughness parameters of the samples.
Team 13: Electron Beam Welding of Additive Manufactured 17-4PH Steel

Sponsored by: PTR-Precision Technologies, Inc.
Sponsor Advisor: Dr. Amber Black

PTR-Precision Technologies, Inc. specializes in electron beam welding and is interested in the performance of additive manufactured stainless steel components when subjected to this joining technique. Determining how electron beam welding affects the strength of the material can identify whether or not additive manufactured parts can be safely welded by PTR for their clients. With additive manufacturing becoming more common in industry, PTR needs to have a certain level of confidence that they can weld these parts, or at least know how to adjust manufacturing or welding parameters to safely do so. By developing guidelines for welding additive manufactured parts, PTR can be assured that they can continue to serve a wide range of customers in a variety of industries. In order to assure customers that electron beam welding can be used on additive manufactured components, PTR must have data regarding how the strength of additive manufactured parts change when welded. If there is no significant change in the properties of these components, it will be safe for customers to have their parts electron beam welded. If not, PTR can suggest methods for manufacturing so that they can be safely welded. By developing these guidelines, PTR will be able to maintain a diverse customer base including manufacturers who utilize additive manufacturing.

This studied additive manufactured 17-4PH stainless steel powder using selective laser melting; both being common a material and processing technique used in additive manufacturing. This experiment will determine how much of a variation in strength this material has from traditional wrought 17-4PH steel. In testing the mechanical properties, both tensile and hardness testing were performed on both fabrication techniques in welded and non-welded conditions. Microstructural analysis was also done to determine how processing changed mechanical properties. Finally, the materials were compared in their varying processing states in order to calculate a percentage difference between them and determine whether additive manufactured steel is safe to use in industrial applications when electron beam welded.
Team 14: Ultra-High Pressure Tube Encapsulated Conductor (TEC) Development

Sponsored by: RSCC Wire & Cable, LLC
Sponsor Advisor: Scott Magner

RSCC Wire & Cable provides an array of engineered cables to clients in a variety of industries. More specifically, many of their cables function as tube encapsulated conductors (TECs). Tube encapsulated conductors are conducting wires (often copper) surrounded by a polymer shell and bonded to a metallic tube covering. As RSCC is one of few companies that offer such products, high quality must be guaranteed. One industry where their products thrive is in oil and gas production. These products serve as information lines between sensors found in oil wells, and operators found at the surface. Such sensors provide readings like well temperature, pressure, and composition. These sensors are extremely important, as without them companies would be blindly drilling into wells. The demand for these products is large, and as stated before, high quality must be nothing short of guaranteed.

The purpose of this project is to fabricate a stronger cable capable of withstanding extremely high working pressures (30,000psi) with a large working range (yield at 125,000psi at .2% offset). Using Inconel-825 as an alloy, a strengthening mechanism must be chosen so that the product meets the given specifications. The chosen mechanism must be both cost effective and practical in order to keep costs at a minimum.

Conventional materials science gives four general options for strengthening a metal; precipitation hardening, work hardening, solid solution treatment, and grain size reduction. Nickel-based alloys (like Inconel-825) often don’t use grain size reduction for strengthening, so this process should be avoided. Additionally, the composition of the material cannot be altered, so solid solution treatment is eliminated. Precipitation hardening is tough for this application, as the alloy must be treated before the welding process. Once welded, the polymer binder cannot withstand typical aging temperatures, so any precipitation hardening would have to occur prior to the rolling and welding of the material on site. RSCC receives this specific alloy in an annealed state, so cold working is the leading candidate for strengthening. By conducting tests on both annealed and cold rolled samples, an ideal rolling technique will be developed for the strengthening of this alloy.
Ulbrich Stainless Steels and Special Metals is a family-owned company headquartered in North Haven, CT which is relied on by the medical, aerospace, automotive, and electronic industries along with many others. Ulbrich is having difficulty cooling wire coming out of their annealing furnace. To make up for this, the wires are being drawn through the furnace at low speeds in order to allow proper cooling at the end of the unit. In order to run the wires through at an acceptable speed, the cooling apparatus must be altered such that the wires can run through quickly but also exit the cooling system at safe handling temperatures. This project was aimed toward an evaluation of the current annealing process for both round and flat wires, some made of stainless steel and others nickel alloys. The focus is to improve the efficiency of the annealing process by altering the cooling apparatus and beneficially adjusting wire speeds. Ideally, proposing a formula for speeds of both round and flat wire will allow effective production and improve ease of furnace operation and adaptability. When implementing this new formula to increase annealing speed, safe handling temperatures when leaving the cooling system are paramount. Maintaining physical and mechanical properties to match customer specifications are other essential constraints.

Mechanical testing was performed on wire samples before and after annealing in order to determine customer specifications for the product. Stress-strain relationships, Rockwell hardness, and grain size were determined for each sample. The parameters for successful annealing were determined as an increase in elasticity and toughness, and a slight increase in grain size. These property changes, brought on by annealing, increase the lifetime and performance of the finished product and must be held by the new annealing process. In order to properly anneal the wire running at a higher speed, the hydrogen unit should be moved closer to the exit in order to allow proper heating over a shorter amount of time. In order to cool the annealed wire using less time, a water spraying system should be implemented in order to allow safe handling without quenching the material into a martensitic state. Testing of the new finished wires is crucial to ensure the results of annealing have not strayed from customer specifications.
As composite materials begin to replace metals in many structural components in rotorcraft, a reliable and adaptable method must be developed to repair damaged composite parts. Traditional methods typically used for the repair of metal parts such as welding are not viable repair options for composites. Instead, the damaged area will be scanned and translated into a 3D computer model. A customized mold could then be 3D printed which would be used to lay up and cure the composite patch. Then, the cured patch could then be used to repair the damaged composite.

High dimensional fidelity of composite patches is required since they must fit precisely into the damaged area. Thus, the mold must be thermally stable and keep its shape constantly during the patch curing process at an elevated temperature. The glass transition temperature of polymer mold needs to be higher than 350°F to avoid softening of mold. Also, the thermal expansion coefficient needs to be minimal. Furthermore, since resources will be limited during field repair scenarios, the mold material must be recyclable so that it can be ground up and used to create a new mold. Thus, thermo-plastic would be a good candidate.

The mold material that was chosen was a polyetherimide based polymer, ULTEM 1010. It was chosen because it meets the requirements listed above. An additively manufactured mold was produced in the shape of a cylinder. This shape was chosen as it has only one direction of curvature and will be easy to visually inspect for dimensional inaccuracies. The composite was laid up using this mold between 6 and 18 layers thick. This was done as this is an industry standard for the composites used in rotorcraft. Residual stresses within the composite patches were analyzed to determine the effectiveness of the 3D printed molds for composite patch production. Visual inspection was also done to study any changes in dimension of the mold itself due to thermal expansion during the curing process as this could affect the dimensions of the final patch.

(1) 3D Printed Mold

(2) CAD model of composite laid up on 3D printed mold

(3) Sikorsky S-97 Raider Helicopter, relies heavily on composite parts
GE Power became a leader in power generation with the acquisition of Alstom’s energy businesses in November 2015. With operations in 70 countries worldwide, approximately 25% of the world’s power production capacity depends on the products and services of GE Power. One of these products is the Radially Stratified Flame Core (RSFC) Burner, which has primarily been used for coal combustion. Now that the industry is switching over to natural gas as a primary fuel source, the gas gun utilized in this burner requires reexamination. The nozzle in the RSFC Burner is nearly 30 years old, and the current operating data is not fundamentally reliable. Both a low-momentum and high-momentum version of the nozzle are utilized in this burner configuration. These nozzles release the natural gas into a swirling, three-layered air zone produced by the RSFC Burner to create fuel-rich combustion within a boiler.

The objective of this project is to produce usable velocity, pressure, and fuel-air mixedness data for both nozzle designs. To accomplish this, SolidWorks and ANSYS Fluent Computational Fluid Dynamics (CFD) software are employed to model and simulate flow through the applicable geometry. A scaled model of the air zone-nozzle configuration gives a visual representation of the phenomenon seen in the simulations. This experiment verifies the fluid mixing and swirl components that are vital to the performance of the RSFC Burner configuration. Numerous modules were done in preparation to familiarize the team with ANSYS Fluent. The deliverable cases involve turbulent flow, viscous behavior, swirl factors within the air zones, and fluid mixedness at the outlet. The team ran simulations with these conditions in ANSYS both independent and combined with one another to gain familiarity with relevant geometries and ANSYS principles. Velocity, pressure, and mixedness values are the focus of the final RSFC Burner simulation. These values are crucial in the implementation and performance monitoring of the RSFC Burners, utilizing both the low momentum and high momentum nozzles. With the values obtained, the team produced suggestions for a mid-range nozzle design that would maximize power output while minimizing emissions. Moving forward with the use of natural gas as an energy source, these suggestions will help GE Power implement efficient, practical designs.
General Electric Power is one of the leading energy companies in the world, providing energy to over a quarter of the homes across the world through a variety of power generation. General Electric Power has recently transitioned from coal to natural gas burners, and is developing new natural gas burners. An important component of the natural gas gun is the orifice plate which is used to control the flow rate of the natural gas. Our team was tasked to perform both computational and experimental analysis on seven orifice plate designs. The designs differed by hole size, chamfer of the holes, and surface finish. A single hole orifice plate was used as the control. We compared the results of each design to find which orifice plate provides the optimal flow configuration. We achieved this by studying the velocity contours and pressure drops across each of the respective orifice plates. A series of increasingly complex simulations were run in Ansys Fluent in order to work towards a final model to analyze how each aspect affects the overall flow. A test rig was then designed to experimentally validate the computational simulations. The test rig was also designed with increasing complexity to correspond with the computational simulations. This way each set of data had something to be compared to. These results were given to General Electric so that they could garner a better understanding of how their new natural gas powered system operates.
Team 03: Sealing Solution for Solas Thermal Receiver

Sponsored by: General Electric
Sponsor Advisor: Pedro Inigo, David McGrane, and Pushpal Swarnkar
Faculty Advisor: Dr. Ugur Pasaogullari

Solar thermal power generation systems capture solar energy by using heliostats to redirect solar radiation towards a heat transfer surface atop a tall central receiving tower. The redirected solar radiation heats the molten salt working fluid, which is then pumped down the tower into storage tanks. The heated working fluid is moved through a heat exchanger where water is vaporized and used to run a steam turbine. The power generated is then sent out into the grid to power nearby homes and businesses. The efficiency of this system is dependent on how effectively the receiver can capture and retain solar radiation during the day, and how well it can store the solar energy at night, when the system is pumped down. A key area for potential heat loss is the manifold which collects the molten salt from one set of receiving tubes before routing the working fluid to the next set of receiving tubes. Unlike the receiving tubes, the manifold does not receive solar radiation and therefore needs to be insulated in order to prevent heat loss to the surrounding air. The operating temperature of the manifold goes as high as 600°C but must be kept above 300°C to prevent the molten salt from crystallizing and impeding the flow in the pipes. Insulating the manifold retains heat during daytime operation which increases efficiency as well as retaining heat overnight. This helps minimize the use of electric heaters in the morning to reheat the manifold to 300°C before the molten salt is introduced to the system. The goal of project is to design an oven box enclosure to insulate the manifold as well as design a seal to minimize air infiltration at the interface between the receiving tubes and the oven box.

ANSYS was utilized to model the manifold oven box system. Convective heat losses from the manifold and air infiltration rates were calculated using the model. A seal criterion for air infiltration vs. convective heat loss was created to evaluate the heat loss of different sized air gaps. This criteria was used to decide the largest allowable air gap to minimize heat loss at the interface between the receiving tubes and the oven box. Various oven box designs were proposed and evaluated based on the sealing criterion to identify the most effective design. A scale model of the oven box was designed using Buckingham Pie Theorem in order to test air infiltration rates since the tests were limited to 300°C for safety purposes. The measured air velocity at the inlet and outlet gaps along with the air temperature were used to find the heat loss due to air infiltration as well as conductive heat loss through the oven box walls. This data was used to validate ANSYS data and refine the oven box design.
ASML is a multi-national company that is the world leader in the design and manufacturing of lithography machines used by the semiconductor industry. Due to low heat tolerances found in microchip manufacturing, ASML used microfluidic cooling to control possible damaging temperature increases inside their machines. However, flow through microfluidic channels tends to have a laminar or transitional profile, which is not ideal for heat transfer. Team four’s task was to improve and optimize heat transfer inside a microfluidic water channel by increasing turbulence with speed-bump-like “turbulator” features that disrupt the flow. Team four was required to work within the constraints of pre-existing channel geometry, size, and working conditions, and could no more than double the total pressure drop through the channel.

Team four tackles the problem using ANSYS-Fluent CFD simulations and two physical test rigs. After initially simulating ASML’s original featureless channel design to determine baselines for pressure drop, turbulent kinetic energy, and heat transfer, Team four moved on to investigating the effect of turbulators. Team four Investigated turbulator shape, height, length, spacing, and orientation. Simulations were built using ANSYS-Fluent, and the turbulator design was optimized by comparing simulation results when a single variable was changed. The final design incorporates square-cross-sectioned turbulators oriented orthogonally to the flow, and produces a measurable increase in heat transfer with twice the pressure drop experienced by the smooth channel.

The two physical test rigs, on with no turbulator and one with Team four’s optimized design, were used to verify CFD results. Both rigs consisted of two stainless steel plates with the channel profile machined into the contacting faces. The channel assemblies were held together using a gasket, support boards, and several c-silicone clamps. The test consisted of pumping water at a controlled temperature into the channel assembly where a silicone heating pad was used to apply a steady heat input of 10W/in² to one plate. Temperature was measured using thermocouples at the inlet and outlet, as well as embedded in the steel along the length of the channel. Pressure and flow meters were also used to measure these values at the inlet and outlet of the channel. This test data allowed for the test rigs to be compared to each other for heat transfer improvements, and helped to verify CFD simulations.
Barnes Aerospace machines and grinds complex aerospace components for turbine engines, air frames, and industrial gas turbines. Barnes employs many processes to grind and machine exotic and high temperature metals such as EDM, electron discharge machining, 5 axis milling, 5 axis grinding, and vertical turret lathes.

To machine jet engine parts, Barnes Aerospaces designs and manufactures unique tool fixtures to accompany each process. The main purpose the fixture is to locate the tool, secure the tool for machining, and increase the efficiency of tool machining. Currently there is no standardized process in designing these fixtures, rather they are created using methods that designers have proven effective through experience. Due to the lack of a standardized process, these fixtures are often designed with little analysis for optimization. The tools end up bulky, heavy, inconsistent, expensive to produce, and difficult to set up. The task for Team 6 in this senior design project is to document the workflow of the tool design process currently employed at Barnes Aerospace. After analyzing the traditional tool design process and current fixture designs, Team 6 created an improved workflow. This improved workflow is projected to yield optimal fixtures that are lighter weight, easy to use, and less expensive than the traditional tool fixtures.

To test the improved workflow, Team 6 has applied it to an actual part that Barnes Aerospace will be machining using EDM. Using CAD modeling, multiple designs have been created by applying the improved workflow. From these designs, Team 6 has built prototypes to demonstrate the functionality of the tool fixtures and also to physically explore additional improvements in the tool design process such as modularity, standardization, and manufacturing with non traditional materials such as plastic.
Barnes Aerospace is a Manufacturing Repair and Overhaul (MRO) company that specializes in jet engine casings. The company receives used jet engine casings that are to be overhauled and used in a rebuilt engine assembly. Due to the high cost of a new casing, it is more economical to repair and re-machine these used casings. In particular, this project focuses on the Pratt and Whitney 4000 series 94 inch turbine exhaust casing (PW4000). After thousands of hours in flight the flange surfaces of these casings can warp and become rough, not allowing for other engine components to correctly align during reassembly. During the overhaul of these parts, it is desired to have this surface machined to a smooth finish, to allow plating to restore the needed thickness of the flange. The machining of this flange is a lengthy and expensive process because of use, the casings can become bent, and are no longer a perfectly round circle (out-of-round). If there is no constant diameter, the casing cannot be machined on a vertical lathe without significant modification. The company currently has a tedious, bulky and expensive process to fix these casings, which we are asked to expedite and streamline. The process involves manually forcing the casings into round after they have been distorted during operation of the engine. After the engine casing has been forced into round then and only then can the engine flanges be cut to the proper thickness. Our product will revolutionize this process by doing away with the first step entirely. By utilizing a custom copier, the pre-machining step can be eliminated, as roundness does not need to be restored for final machining. The thickness of plasma needed to be applied to the flange will be reduced by at least 50% (.015”), leading to cost savings for materials and labor. The design is an electromechanical copier, consisting of a ball screw actuator and contact DVRT measurement sensor, utilizing a DAQ system to control the components. The copier is designed to attach to the VTLs at the Windsor Airmotive Division without any modification to the lathe. The electromechanical copier uses the measurement sensor in conjunction with the actuator to make a cut according to the real time measurement of the sensor. The system is able to cut within a 0.0005" inch tolerance.
Team 07: Heat Transfer and Pressure Drop Coefficients for Compact Heat Exchanger

Sponsored by: BGR Radiator
Sponsor Advisor: Todd Parcinski
Faculty Advisor: Dr. Amir Faghri

Compact heat exchangers are widely used in the process industry where cooling or heating systems are needed. The performance of a compact heat exchanger can vary depending on the surfaces used in the core of the radiator. In most applications, the air-side heat transfer coefficient is significantly smaller than the liquid side. Therefore, the air side heat transfer rate can be enhanced by creating a high area density in the core. A concern for BGR radiator was that they did not have in house testing capabilities to determine the performance of different core geometries. Previously, they relied on data obtained from a supplier when sizing the radiators for a customer. This data was modified in their performance analysis software known as Instinctcode. However when sizing a radiator, a 30-40% safety factor is added for reassurance. This safety factor potentially led to oversized radiators which did not meet the demands of the customer. Team 7 has worked closely with BGR to minimize this safety margin by providing reliable and accurate data for several compact heat exchanger cores.

Performance data of a compact heat exchanger can be shown through the relationship between the heat transfer and pressure coefficients at different flow rates (Reynolds number). In order to obtain performance data on the various core geometries, a test rig was developed. A wind tunnel was used to simulate ambient air flow while a coolant in the form of hot water was delivered through the heat exchanger. Testing was divided into two phases. In the first phase, hot tap water was fed into the inlet of a heat exchanger with known performance data. Once it was shown that the experimental data matched with a known core geometry in Instinctcode, the second phase was initiated. In the second phase, the cores with unknown performance data were tested. In the end, performance data was obtained on several core geometries. The heat transfer and pressure coefficient data was saved in Instinctcode for BGR to use in the future.
Team 08: Automatic Electrode Sleeve (“Viskase”) Cutting Machine

Sponsored by: BST Systems, Inc.
Sponsor Advisor: Tom Terjesen
Faculty Advisor: Dr. Vito Moreno

BST Systems specializes in designing, developing, and manufacturing high energy cells, batteries and support electronics for the space and defense industries. In these cells, a “Viskase” sleeve is placed between the positive and negative electrodes to separate the opposite polarities. This material is purchased in large rolls from an outside vendor. Currently, each piece has to be measured, cut, and inspected by hand. In order to improve efficiency, the team was asked to create an automated machine to unwind, align, and cut the material into segments of specific lengths. Reducing labor time was the main concern, however other factors that were addressed was the amount of waste after each cut along with the inconsistency of the sleeve’s shape and dimensions. Testing was completed in order to understand the properties of the “Viskase” and how to best account for the natural arc of the material.

After completing research, a wooden prototype was constructed in order to demonstrate feasibility. Using data collected during prototype testing, several design modifications were made. The prototype was broken down into four main systems; a material holding system, a guide system, a drive system, and a cutting system. Methods were incorporated that would reduce the time to produce a single piece with high accuracy and repeatability while also minimizing waste. A final 3D Model was created using Autodesk Inventor and included each of the four systems mentioned above. The machine was then fabricated and tested to ensure these four systems performed as expected. After this had been accomplished, another system had to be added to the machine; an automation system. This machine has to be fully automated and able to withstand several thousands of cycles without failure. In order to achieve this, a linear actuator and a stepper motor were used. The final design is an automated cutting machine that will ultimately save BST time and money due to its accuracy and repeatability.
Capewell Aerial Systems specializes in robust landing platform solutions designed to facilitate safe delivery of valuable cargo and equipment. The cargo is deployed via an airdrop application in both military and civilian assignments around the world. Currently, a single platform design is used for all airdrops independent of total weight and weight distribution considerations for the payload. As part of an initiative to develop the next-generation of airdrop platform to be reusable, Capewell requires a means to acquire reliable test data for each platform’s performance. This data collection is centered around tracking the acceleration of the payload as it impacts the ground as well as the internal pressure of the airbag cushion system.

To fill this need, Capewell has tasked Team 9 with the design and fabrication of a high speed instrumentation system that records pressure and three-axis acceleration during impact. Our goal was to design two systems which are robust enough to withstand repeated high-acceleration impacts as well as large static loads, including supporting the weight of a 10,000 pound truck. The enclosure design includes a quick-release feature that allows technicians to readily access and download data as well as exchange power supplies. In addition, the system adheres to strict military standards for electromagnetic interference, requiring extensive use of shielding and complete sealing of the enclosure within a Faraday cage.

The stringent requirements for data recording rate necessitate the use of laboratory grade sensors and fabricating a custom circuit board and enclosure, as well as validating these designs using extensive simulation and real-world testing. The data acquisition system, sensor integration, protective housing, and mounting system are successfully developed in time for the first real-world tests of Capewell’s prototype landing platform system. The first delivered design was verified in the field with a drop from twelve feet under a three thousand pound analogue of a real payload. The improved final design was further optimized for ease of use and delivered to Capewell for their developmental use.
Team 10: Integrated J-hook and Spring

Sponsored by: Clarcor EMS
Sponsor Advisor: Staffan Linnersten
Faculty Advisor: Dr. Julian Norato

Clarcor has developed a new state-of-the-art diesel fuel filter system to replace its older filter, patent-expiring filter. The problem with this new design is that a hook used to latch the filter into the fuel system and hold the filter in place inside the vehicle causes resonance of the filter and yields when experiencing extreme temperature conditions. Therefore the objective of this project is to create a new hook design that experiences none of these problems. A compression gasket from the original design has also been removed, so the new hook needs to not only have the functions of the original hook, but also have the functions of the gasket integrated into the design as well. This means that the new hook needs to act like a spring, which will allow the filter to be tightened into place. General requirements for the J-hook design include its size, simplicity in design and manufacturability.

Due to the new design having the function of a spring and the shape of a hook, it has been dubbed the “sprook.” This design resembles a vertically stretched letter “C” and will be manufactured from stainless, corrosion-resistant steel. The sprook is exceptionally small; at only about 2.4 inches (60 mm) tall, it needs to stretch to exert 400 pounds of force on the filter. This force will ensure that the first natural frequency of the assembly is above the natural frequency of the vehicle in which the filter is installed. Furthermore, the sprook needs to exert this force by deforming only 0.07 – 0.11 inches (2-3 mm). The majority of the work on this project was spent optimizing the sprook design to these various constraints. The trade-off between stress and deformation was exceptionally challenging, as most designs that would deform appropriately would yield under the stress, and most designs that did not yield would not deform appropriately when experiencing 400 lbf. Finite elemental analysis in ANSYS was used extensively throughout the project to run simulations of stress and deformation. It was ultimately determined that modifications would have to be made to the existing filter cap design in order to accommodate the sprook, so the team also performed analysis of several other filter components.
Team 11: Cook Stove
Combustion Chamber Design

Sponsored by: Biomass Controls, LLC
Sponsor Advisors: Jessica Peterson, Jeff Hallowell
Faculty Advisor: Dr. Baki Cetegen

Biomass Controls is a biomass appliance control company. Their technology is able to control the various electronic components that comprise an individual biomass system. Through the use of various actuators and feedback from a variety of sensors, their control systems are able to adjust parameters automatically to maintain a desired air-fuel ratio within the heating system, improving overall efficiency and reducing emissions.

The purpose of this project was to produce an environmentally friendly stove at an affordable cost. Approximately two billion people still rely on fires to cook their meals. Many of these makeshift cook stoves are constructed using the “three stone method”, in which wood, or another readily available fuel, is placed at the center of three stones and the cooking pot is placed on top. Because of the minimal amount of engineering involved, this method of cooking is often inefficient and can produce significant emissions. Without an efficient design and adequate airflow, it is hard to maintain a hot fire without using a lot of wood at once. Also, because the wood rests on the ground as it burns, combustion is often incomplete. This produces significant amounts of carbon monoxide and particulate emissions, which can lead to health complications and even death.

After analyzing various cook stove design features, the team developed their own, novel cook stove using principles that would result in both a clean and thermally efficient burn. Naturally convective and forced draft models of the stove were fabricated and tested. Using results obtained from Ansys FLUENT simulations and data acquired from testing, the stove’s geometric and operational parameters were adjusted in order to optimize performance. Numerous accessory considerations were made in the designing of this stove, including material costs and the moisture content and energy densities of the various fuels that may be used in the stove.

The stove’s performance was analyzed by measuring carbon monoxide and particulate matter over a 15 minute test, with the goal being to meet EPA and OSHA standards. Thermal efficiency was measured using an industry standard test in which the time it takes the stove to boil 5 liters of water is measured.
Team 12: Measuring the Bite Force of a Military Working Dog

Sponsored by: Major Sean McPeck of the U.S. Army
Faculty Advisor: Dr. David M. Pierce

Major Sean McPeck, a veterinarian associated with the United States Army, has tasked the University of Connecticut with developing a specialized system designed to measure the bite strength of a military working dog. The device needs to be designed in such a way that it is easily integrated into current training methods, requiring little if any additional training to both the K-9’s and handlers. The purpose of this device is to verify and improve upon current methods of training for the animals. Methods for verifying other aspects of k-9 performance, such as speed and overall conditioning already exists; but a quantitative method of measuring the bite force still needs to be designed.

This project requires a team of mechanical and electrical engineers to conceptualize, design, and prototype a product that is not currently in existence. This end goal of this project is to develop a product that has been thoroughly tested by the military working dog community, and is ready for manufacturing. The teams identified many methods of determining the forces of the bite force such as a mechanical device that measured spring displacements, a system that created a pressure distribution map, or utilization of electrical sensors to determine changes in pressures. These initial designs were assessed and rated based upon complexity, costs, manufacturability, or overall consistency and accuracy of the device.

Team 12, in conjunction with electrical engineering team 1618, has developed and tested a system that meets the critical guidelines of the project. Utilizing electrical sensors to monitor changes in pressure of a rubber bladder housed inside a Kevlar sleeve, the team is able to determine and analyze the bite forces of working dogs. Housing this system into a training tool known as a “tug” the military and other working dog communities are able to easily test the compressive forces of the K-9’s bite. This implementation allows the dog handler to easily place the system allowing for consistent and repetitive data. The electrical engineering team has developed the accompanying circuitry and software that allows the user to track each dog individually so improvements in bite strength are verified.

The team is currently applying for a design patent, and awaiting final prototypes to arrive from production that are able to be shipped and tested by several military and police units.
Team 13: Validate Simsmart Simulation of Flow through Fittings

Sponsored by: General Dynamics: Electric Boat
Sponsor Advisor: Dave Eggler and Kristi Shrestha
Faculty Advisor: Dr. Wilson Chiu

Electric Boat is a company that designs, builds, and maintains lifecycle support for the majority of U.S. Naval submarines. They are involved in the production of all components within a submarine, including the ship’s fluid systems, heating and ventilation systems, structural integrity, and electrical components. Within their fluid systems are pipe fittings such as a tee connector and pipe reducer. These components suffer from pressure changes due to a change in fluid direction and velocity. In order to accurately model their systems it is important to have a strong understanding of how these simple components contribute to the total change in pressure. Currently Electric Boat is using a mathematical model standardized within the company to predict the pressure changes within these components and would like to transition to a modeling software called Simsmart Engineering Suite. During use of the software Electric Boat has found a discrepancy in how the software calculates the pressure differentials across tee connectors and pipe reducers upwards of 40%.

In order to validate the use of the software the team has used mathematical models that help describe the expected pressure differentials across these pipe fittings as well as conducting an experiment to obtain data that can help validate the Simsmart Engineering Suite. The experiment was composed of a closed pipe system where a pump pushed water at 5 GPM through ¾ inch PVC pipes. By measuring the flow rate before and after the tee connector the pressure differential was calculated. Based on the experimental results and mathematical calculations performed it was seen that the pressure differential across the tee is closer to Simsmart model than it is to the previous model Electric Boat used. The results of the experiment have shown results within 10% of the pressure differentials predicted by the Simsmart models. Further experiments conducted to check the validity of a system composed reducers also supported the Simsmart Engineering Suite’s simulations.
The purpose of this project was to diagnose and repair a point of failure occurring in a residential elevator motor from a home in Greenwich, Connecticut. By reintroducing this component back into service, the homeowner was able to avoid installation of a new elevator. This saved over two-hundred and fifty thousand dollars and weeks of work occurring in his home. Upon starting this project, the team found themselves with a partially disassembled electric motor and transmission assembly, a box of parts, and a matchbook containing a crude wiring schematic drafted by the contractor responsible for removal and disassembly. Prior to the motor coming into possession of the University, two regional elevator repair companies had inspected the issue and deemed it a lost cause, only offering to upsell the homeowner on a complete replacement. After a period of research, it was found that the motor had originally been installed in the home in 1908, making the device 107 years old at the time of failure with no known previous maintenance.

Due to the nature of this project, the only deliverable asked for by the sponsor was a working elevator. Despite this seemingly simple task, a prodigious amount of work had to be completed to meet this goal. In the first period of testing and analysis, it was found that the cause of failure in the device was a faulty relay board. Dozens of parts including the main relay board and retention pegs had to be precisely machined, and the relay arms and point-contacts had to be fabricated by hand. After the relay system was assembled, a test rig was designed in order to check the proper function of the device. Following this the motor was assembled completely, delivered to its residence, and installed by an independent contractor under the supervision of the team.
General Electric Industrial Solutions (GE) is a company that provides a wide variety of services in electrical appliances, power, and home and business solutions. GE has tasked us with identifying a suitable replacement for Hexavalent Chromium Chromate passivation. This material is plated on many components in GE electrical appliances due to its resistance to abrasion and corrosion. However, due to changing regulations and the health risks of HCC, the sponsor has determined that it is necessary to remove the plating from production by 2019.

In order to determine the viability of potential substitute materials, the team produced custom testing rigs to evaluate material wear and corrosion performance. The construction of these rigs and the fabrication of the 400+ testing coupons were the primary physical deliverables of this project. The wear rig allowed the team to determine mechanical performance on the basis of mass loss. In the evaluation of mechanical performance, the coated test coupons were revolved on a testing plate while a flat coated column contacted the surface to wear the plating. After a certain number of cycles, the coupons were subjected to environmental testing. The corrosion rig was designed to provide aggressive corrosion on the worn coupons, and was modeled after the industry standard salt fog test. The worn test coupons were immersed in a humid salt fog test chamber and held at temperature until corroded. A series of calibration checks were completed to evaluate the UConn test severity to ASTM standard testing.

The surfaces before and after the corrosion process were analyzed in a number of ways. Optical microscopy, profilometry, and surface metrology techniques were employed to determine which platings were likely to meet the consumer standards necessary for replacement. The large set of data on volume loss, mass loss, and surface degradation provided good metrics for the evaluation of material suitability.

The team examined three different plating materials (JS 600, trivalent chrome, and zinc phosphate) and compared their performance to that of the original HCC plating. The resulting comparative analysis drove the final recommendation of the best candidate material for the sponsor on the basis of mechanical and environmental performance.
The objective of this project was to reduce process-induced deformations in angle bend composite parts. When resin-based composites cure, inter-laminar stresses are generated between the shrinking resin and the rigid fiber. As a result, parts with an angled shape deform after removal from the mold. This generates a part with a slightly different angle than the mold. Our team was asked to devise a new heating process for manufacture that reduces this undesirable deformation. Specifically, we looked at altering the temperature profile and gradient.

To study this problem, we ran simulations of the composite part using the program Abaqus and the plugin Compro to better understand what factors most influence the curing process and the buildup of internal stresses, such as when in the process alterations should be made and to what degree. Applying this analysis framework, we devised and simulated heating processes that intentionally generated high deformations. Using the results of these simulations, we devised a process with the aim of reducing deformations. In order to test this process, we designed and built a mold tool which we then used to fabricate test parts to verify the accuracy of our simulations.

This mold tool was designed in Solidworks and analyzed in Abaqus to be sure it could withstand the pressure of resin injection without notably deforming. We fabricated several test parts with the mold. They included one based on GKN’s standard process, which we used as a control, and one made using our alternative process. The physical testing showed us ways to improve the robustness of our simulations, which we used to produce a final process that reduced the final deformation of the angle bend part. Finally, we fabricated an angle bend part using our improved process in order to validate our analysis framework and to show the overall improvement.
Team 17: Bolted Joint Optimization for Leakage and Thermal Gradient

Sponsored by: Infotech Aerospace Services (IAS)
Sponsor Advisor: Roger Paolillo
Faculty Advisor: Dr. Eric Jordan

Infotech Aerospace Services (IAS) was incorporated and began operations in Puerto Rico in 2003. At their main facility IAS designs, evaluates, and supports Gas Turbine Engines, Airframe Systems, and other Aerospace Products. Infotech Aerospace Services provides engineering and supply chain services for United Technologies (UTC) as well as many other non-UTC companies. The Pratt and Whitney PW 4000 is a group of high-bypass turbofan aircraft engines that IAS has been working with. In the combustor section of this engine, the flange between the combustor and the turbine experiences large loads due to thrust and a high thermal gradient due to ignition. The loads experienced by the two connected flanges causes a separation of the structures resulting in a leakage of hot air out of the turbine engine.

While the leakage negatively impacts the engine by decreasing the efficiency, a positive side effect is that the leakage decreases the thermal gradient across the flange. This decrease in thermal gradient extends the life of the flange resulting in less need for maintenance. IAS has tasked us with developing a method to experimentally model this scenario and develop a method of finding an appropriate leakage rate which decreases the thermal gradient in this flange while not hampering the efficiency of the engine to drastically. Our solution was to construct two separate scaled down rigs to model the behaviors within the combustor of the engine. Each model was constructed out of two pipes with flanges on each of the four ends. All of these were made of stainless steel to mimic the thermal conductivity of the engine. One rig was designated as the control “non-leaky” rig, while the other was designated as “leaky” and had small leakage grooves machined into the flanges. Tests were then performed on each rig to analyze how the thermal gradient across the flanges changed with the introduction of specified leakage rates within the experimental model.
Infotech Aerospace Services (IAS) is a Pratt and Whitney joint venture established in 2003 in Isabela, Puerto Rico. IAS serves as an aerospace technical services center with a focus in providing top industry support of aerospace products in the areas of engineering design, analysis, information technology, and supply chain. Gas turbine engines, which experience temperatures between 3000°F-4000°F, are made of Nickel alloys withstand temperatures between 2000°F-2100°F for static parts (vanes and cases) and 1350°F for rotary parts (rotors and blades). It is imperative to cool down these parts using lower temperature airflow taken from the compressor in order for the engines to operate efficiently at high temperatures without failure. The path between the compressor’s cooler air and the turbine parts that require cooling is modeled as a one-meter long insulated pipe with heat sources applied to its walls. This model is then analyzed theoretically with hand calculations and computationally with ANSYS Fluent. The results of these analyses show that the model requires 170W of power to obtain a temperature rise of 56K at a laminar flow speed of 0.3 m/s.

A rig modeling the system is built to validate theoretical and computational results. The test rig includes airflow from a compressed air cylinder that travels through a hose, passes through a pressure gauge, a flow orifice, and a sintered plate before it enters the main test duct (1-meter long steel pipe), providing laminar flow. The flow is heated in multiple sections along the pipe by power controlled heat cables and temperature measurements are taken by multiple thermocouples. The experimental results show that the temperature gradient along the duct closely matches the analytical results, validating our theoretical and computational model. Further testing was performed to determine how the output temperature was affected by a step change in the input temperature under a given heating load. These analyses and test results provide useful information for how moving air responds to various heating conditions in a duct, which can be used by IAS to engineer more effective and efficient jet engines.
Jacobs Vehicle Systems is a leading manufacturer of diesel engine compression-release brakes. A compression-release engine brake effectively switches a power-producing heat engine into a power consuming air compressor. The exhaust valve is opened immediately after the compressions stroke of the diesel cycle, and fuel ignition never occurs. The engine now has to do work to compress the fuel-air mixture, without any of the energy returning to the piston, thus slowing the vehicle. This takes a substantial amount of load off of the traditional friction brakes on the vehicle. In the Cummins-ISX series, up to negative 600 horsepower of retarding power can be achieved. The key component of the engine brake is a rocker arm - bushing assembly which is responsible for transferring the rotational motion of the engines camshaft to the translational opening and closing of the exhaust valves. The rocker arm-bushing assembly “rocks” back and forward on a journal bearing. High pressure oil is introduced at the interface, and as velocity increases an oil film develops that prevents metal-to-metal contact between the journal and rocker arm. We were tasked with accurately modeling the lubrication characteristics of the assembly in order to understand why bearing wear is present, and use this information as a design benchmark for the future in order to minimize friction at the interface. Desirable results include localized film thickness, pressure distribution.

Our team began by studying tribology, or friction, as a means to understand the dynamic and static characteristics of lubrication and friction reduction. The next step was to begin modeling. To do that, GT-Suite, a leading CAE software by Gamma Technologies, was used. Breaking down the task into multiple smaller problems was done in order to get a better understanding of the program as well as to ensure accuracy of modeling. A simple journal bearing was modeled with some specific geometry, forces, and other characteristics provided by JVS. Some of these characteristics were journal groove depth and width, oiling hole location. This geometry was used for a finite element analysis, done in GT-Suite.

Finally, we modeled the set up from rocker arm to cam shaft. Once we were happy with our results of the assembly, we began testing how different variations of the characteristics like groove depth would impact our key results, i.e. film thickness and pressure distribution.
As Otis elevators run their course in service, the wire ropes that hoist the car degrade, lose strength, and eventually become unsafe to function. Breaks and stretches can adversely affect the braided steel ropes as they repeatedly bend over the elevator sheave during operation. Serving as the main support structure in elevator systems, a failure in even one cable can be catastrophic for the entire system as well as any human occupants inside the car. Therefore, it is imperative for these hoisting cables to be periodically inspected to ensure safe and functional operation.

Today, the primary method of inspection is a thorough visual inspection for breaks and wear, as stated in the American Society of Mechanical Engineers (A.S.M.E.) guidelines. This method however, only accounts for what can be seen on the rope’s exterior surfaces and does not take into account the interior conditions of the cable. Furthermore, a visual inspection is extremely time-consuming and costly which leads to an increase in the elevator’s downtime as it cannot be in operation while maintenance personnel inspect the shaft. For these reasons, it is desired to develop an inspection method with higher accuracy, thoroughness, and efficiency.

Our approach is the resistance based inspection (R.B.I.) method which checks the conditions of a steel rope by comparing the electrical resistance of the cable to the resistance of the same cable when it was newly installed. Throughout a rope’s lifetime, wire strands flatten and break causing the cross-sectional area to decrease and the resistance to increase. Monitoring this value over time gives insight onto the condition of the ropes as they degrade. By using the 4-Wire Kelvin resistance measurement technique, the contact resistance for the measurement leads are negligible and the low resistance of the cable can be accurately determined. The measured rope resistance can then be compared with a baseline value to provide a reasonable indication of cable wear. The baseline values are determined by measuring the resistance of varyingly worn rope samples and determining the remaining strength of those samples through tensile testing. The device will sample on each floor to obtain a resistance profile of the rope since wear is not distributed evenly across the full length. From this data and the correlation between cable resistance and remaining strength can be used to monitor the condition of hoisting cables over time. Ultimately, this data can be used to aid maintenance scheduling and maintenance personnel to improve the inspection regiment and indicate when a rope needs to be replaced.
Team 21: Automated Stem Deburring System

Sponsored by: PAS Technologies
Sponsor Advisor: Gene Flenke
Faculty Advisor: Dr. David Giblin

PAS Technologies is a multinational Original Equipment Manufacturer (OEM) and Maintenance, Repair, and Overhaul (MRO) application and component provider. One product that PAS Technologies produces is threaded stems that are used in oil field applications. The process used to cut the 5-ACME threads on these stems leaves a burr, which then needs to be removed. PAS currently utilizes a hand deburring process that is time consuming, inconsistent, and provides a safety risk to the operator. PAS has tasked team 21 with designing a prototype system to automate their stem deburring process.

The most important deliverable of the automated deburring process is to eliminate the safety risk by reducing operator exposure to sparks from manual grinding. The prototype will also free up the operator and improve the overall quality of the final deburred stem. It was designed to be completely separate from the existing process, which will facilitate a seamless integration into the current production line.

A focus was placed on simplicity in the design of our automated system. After evaluating numerous design ideas, we decided on a design that utilizes the preexisting threads on the oil field stems to control the motion of the deburring wheel. This system includes a pin connected to the deburring brush assembly which travels along the inside of the threads as the stem rotates, making it possible to drive both the rotational motion of the stem and the linear motion of the deburring wheel with a single motor. Another important feature of this design is that it is compatible with stems of different diameters and lengths, since the deburring wheel will always travel along the length of thread that needs to be deburred.
Team 22: Automation of a Taping Process

Sponsored by: PAS Technologies
Sponsor Advisor: Donald Spriggs
Faculty Advisor: Dr. Vito Moreno

PAS Technologies is a leading original equipment manufacturer and part refubbisher to the aerospace and oil industry. At their Phoenix Arizona location, PAS overhauls parts that will be exposed to high heat, high wear and corrosive environments. Many of the parts they refubish require electroplating and anodizing to protect the outer layer of the part. As of now, PAS prepares parts for electroplating by manually applying chemical resistant tape to the areas that should remain unplated. Our team was tasked with automating this taping process, reducing cycle time and eliminating the ergonomic strain of manual labor. One of the major challenges in automating this taping process is variability of parts. The basic geometry of the parts is cylindrical, but any automation approach would have to be able to accommodate a wide variety of part diameters and lengths.

After exploring alternative possibilities, our team settled on a CNC “Lathe Style” design. Our approach was to create a two degree of freedom CNC machine that would rotate parts lying on their sides, while simultaneously applying tape along a horizontal axis. Electric stepper motors, governed by an Arduino microcontroller, were used to drive the rotation of the parts and the motion of the tape. A Graphic User Interface was developed to accept inputs from the user and communicate these inputs to the Arduino controller. The entire system was fabricated on an anodized aluminum base plate, with adjustable endplates and rollers to account for the wide range of part shapes. Using our machine, PAS technologies will be able to significantly decrease the time needed to tape parts and eliminate the ergonomic strain associated with manual labor.
Pratt & Whitney, a sub-division of United Technologies Corporation, is a world leader in the design and manufacturing of commercial and military jet engines. In gas turbine engines, performance is a key factor, especially in military applications. To achieve the necessary performance, engines must be designed to run hotter, reaching temperatures beyond the melting point of the materials that the engines are made of; thus, engine cooling is necessary to achieve greater performances. External heat exchangers (HEXs) are therefore crucial in engine design. However, another factor in achieving high performance is weight. This leads designers to compact engine components together, ultimately blocking the air flow to the HEXs. The goal of this project is to help Pratt & Whitney in the design process of the location, size and shape of external parts around the HEXs to reduce effects on HEX performance. For instance, should a cooling pipe have a standard cylindrical shape, a rectangular shape, or a teardrop shape, how big should it be and how far away from the HEX should it be located?

Using computational fluid dynamics software and experimental testing, it was concluded that cylindrical and teardrop-shaped obstructions are more desirable obstruction shapes, dropping HEX effectiveness by only 9-12% and 8-12% respectively. Rectangular obstructions drop HEX effectiveness by up to 50%, making them undesirable to place in front of HEXs. Along with these results, for the cylindrical obstructions, any sized obstruction, between 2 and 4 inches can be placed up to 3 inches from the HEX inlet without effecting the HEX performance. For the tear-drop shaped obstruction, the larger it is, the farther way it should be placed from the HEX inlet. Using these results, Pratt & Whitney can incorporate design rules at early stages in engine development, allowing for less redesign at later stages in the development process.
Currently, low cycle fatigue (LCF) spin rigs are very large, time consuming, and costly. Spin tests are necessary to collect adequate material data on jet engine disks and characterize a material’s fatigue properties. A typical tensile test demonstrates material properties axially along a cylindrical or dog bone specimen. A spin test shows the biaxial stresses (hoop and radial) under centrifugal load of a disk shaped specimen, which more realistically simulates the mechanical conditions seen when in use in the engine. It is important to know and understand the material properties of an engine disk because its failure in an engine cannot be contained and can endanger the lives of everyone on board an aircraft. Team 24 was responsible for the complete design, building, and testing of a benchtop sized spin rig that is capable of performing these material tests.

A test of three hundred cycles on an optimized aluminum disk specimen with a 1.2 radial to hoop stress ratio was done to demonstrate the viability of a benchtop sized rig. The motor was programmed to ramp up to the speed required to induce 110% of the specimen material’s yield stress so that the part does not have infinite life. This speed was approximately 34,500 rpm. Success was defined by being able to ramp up the disk specimen to this maximum speed and back down in a timely manner for three hundred cycles. The team was able to ramp up and down in less than 9 minutes for each cycle. By demonstrating that this idea works, the sponsor will be able to save money and space by using the desk top version of a spin rig. Because of the low cost of the rig, more machines can be produced and a number of tests can be run simultaneously, therefore improving the current process of evaluating fatigue properties.
Pratt & Whitney is a world leader in the design, manufacturing and service of aircraft engines and auxiliary power units. With the advancements in aerospace technology, the need for new high-performing materials has increased. Ceramic matrix composites (CMCs) are thermodynamically efficient, reduce combustion emissions and have a high heat tolerance. The porosity of CMCs is of particular interest as it affects the strength, endurance, and other durability properties. The measurement of this property is the focus of this project using two main processes: a micro-CT scan and the Archimedean Method of submerging the material and calculating the volume difference. The scan is then repeated following the submersion into a dye to note the holes in the material that were already accounted for versus those that were not. It is necessary to quantify the difference in measurements between the two methods to compare the practicality of them in application.

The imaging software Avizo was used to create a 3D image of the image slices produced from the micro-CT scan. The method was able to account for both open and closed pores within the CMC, however the disadvantages were that one scan would take anywhere from 8-10 hours and it is expensive to use the machine for that amount of time. The Archimedean method was able to account for most of the open pores within the material, however as expected it was unable to account for the closed pores. This makes this method less accurate; however it is much less expensive, as it uses fewer resources and takes less time to execute. Following the results of the porosity measurement, the 3D model was exported to Abaqus software and a deflection simulation was run to evaluate the effect porosity had on strength. In the simulation, a load was applied to the center of the beam of material until failure occurred. It was concluded that the more porous a material, the more likely it was to fail under a predetermined load. The results from this test were then validated, by comparing to the results of a bend test run by Pratt & Whitney.
Pratt & Whitney, a UTC company, is a leader in the manufacturing of commercial and military gas turbine engines and have been in business for nearly a century. Pratt & Whitney supplies engines for a wide variety of applications including commercial transportation, power generation systems, and military aviation; they are also one of the major employers in the state of Connecticut. The goal of this project was to model the rotating/static seal pressure ratio inside a gas turbine engine as a function of geometry and flow rate. This specific seal, known as a honeycomb knife edge seal, is located throughout the engine and is used to seal the interface between the primary gas path and secondary flow when both rotating and non-rotating hardware are present. Sealing effectiveness is imperative to ensuring not only high engine efficiencies, but safe operation as well. The previous methods used to predict the performance of these seals are derived from older test rig results and are no longer representative of the current, state of the art sealing designs. Specifically, three different geometries were tested using three dimensional computational fluid dynamics (CFD): two knife edges in series, two knife edges with a step up design, and a knife edge with an instatic groove. These three varying geometries were each modeled in SOLIDWORKS, meshed in Star-CCM+, and then ran in ANSYS Fluent. Two physical rigs were also created to validate the CFD results, one with a single knife edge and one with two knife edges in series. The results that were obtained allowed for the team to provide Pratt & Whitney with functional relationships of flow versus pressure ratio for all three of these geometric configurations.
Technologies Corporation (UTC). They are one of the world’s primary manufacturers of commercial and military gas turbine engines. At the celebration of their 90th anniversary in 2015, Pratt & Whitney currently employs over 4,000 engineers and continues to be the market leader in innovation for gas turbine technology. As UTC’s most coveted company, Pratt & Whitney has never failed to deliver ground-breaking technology in their products. One advancement in manufacturing methods has been Additive Manufacturing, better known as 3D printing. Today, Pratt & Whitney owns and operates some of the most advanced 3D printers in the world. The technology we are discussing is Direct Metal Laser Sintering (DMLS).

Since this technology is relatively new, errors in the manufacturing process still occur. One of these errors is the occurrence of a build failure. Due to the high cost and limited resources of 3D printing, it is in Pratt and Whitney’s best interest to eliminate build failures from the manufacturing. The objective of this project is to create a predictive tool which can calculate the probability of a build failure for that part during the direct metal laser sintering (DMLS) printing process. Currently, build failure is predicted by using approximate ‘rules of thumb’ based on aspect ratio (height/width) of the printed part. This method only takes the physical dimensions of the part into consideration, and is inaccurate and unreliable. Using the dimensions of the planned build part, along with the orientation of the part on the build plate, the thermal and vibrational properties, and the physical specifications of the printer, this new predictive tool will allow Pratt & Whitney to better understand build failure, and operate the EOS 270/280 series printers at its performance limit without build failures.
Pratt and Whitney, a United Technology Corporation subsidy, is a world leading designer, manufacturer, and aftermarket supplier of turbine engines. In the current engine market, fuel efficiency, and replacement part/repair costs are large factors to making an engine supplier competitive and profitable. Today’s aircraft take-off and land all over the world, experiencing various environmental conditions which reduce engine component life, affecting reliability and ultimately company profitability. Selling to airlines that operate in harsh environments with sand laden air has created the need for sand separation in jet engine applications. Sand is composed of calcium magnesium aluminosilicate (CMAS), a low melting eutectic. Upon ingestion from ground vortexes and dust clouds, CMAS causes internal damage to the combustor and airfoils through impingement, coating spallation, and cooling hole blockage. Ultimately the life, efficiency, and reliability of the engine decline.

Current particle separation and removal techniques include centrifugal force and bleed methods to separate the particulate from the gas path. Unfortunately, while effective on large debris, these methods do not efficiently remove the fine sand particles. The team researched current state of the art separation techniques across all fields focusing on fine, micron sized particle separation. Potential concepts were evaluated based on pressure drop and flow path effects, size, weight, cost, reliability, and collection efficiency. Down selection yielded inertial and electrostatic separators as the most viable fit; a complimentary combination of these two methods was chosen for further evaluation and optimization.

Fundamental analytical and computational studies were done to understand the sensitivity of particle motion to inertial, electrical, and aerodynamic effects. It is concluded that particles under 30 µm require an additional external body force independent of their inertia to be separated from the flow conditions, such as an electric force. Inertial particle separator (IPS) geometry studies were performed using CD-Adapco’s Star-CCM+ computation fluid dynamics software package. Geometric optimization for collection efficiency relative to total pressure and mass flow loss was performed. After finalizing the IPS geometry, the device is enhanced by providing an electric potential and charging the particles prior to the inlet, creating an electrostatic inertial particle separator.

An adjustable, low cost IPS was experimentally tested for various geometries to draw direct correlations between design parameters, collection efficiency, and pressure drop. Data was also compared to the CFD simulations.
RBC Bearings has made it a point to investigate, analyze and improve the skidding phenomena that occurs when a cam interacts with a cam follower bearing. Skidding is the result of differences in the relative velocity of two surfaces and their interaction when they initiate contact and adjust to match their velocities. There has not yet been an effective method for predicting when the skidding will occur and how this affects the life of the follower bearing.

In order to perform the analysis on the relationship between the cam and follower, the team utilized a three-step approach with two theoretical analyses and a physical test rig with data acquisition. The theoretical analyses consisted of SolidWorks Motion Study and Matlab code. The prediction was verified when the results from both programs matched. In the analyses, the angular velocity of the follower bearing was calculated while rolling against a step-profile cam. This cam profile was used because it causes the bearing follower to constantly increase velocity before losing contact over the step of the cam. The loss of contact between the cam and follower forces a difference in relative velocities, resulting in skidding. As the follower reinitiates contact, the angular velocity rapidly adjusts to the relative angular velocity of the cam. The time that the follower takes to adjust is the time skidding will occur. By adjusting the speed of the cam, force on the follower, and design of the bearing, the time of skidding was minimized. The third step was to create a test rig that physically creates this interaction between the cam and follower. We were able to build a test rig that can utilize multiple cam profiles, cam follower geometries, speed variation and force variation to accurately show that the prediction of how long and when the skidding will occur are correct.

This proof of concept for analyzing and predicting the skidding between the cam and cam follower will allow RBC Bearings to prolong the life of their bearings. It will be applicable across many disciplines, including the canning industry, automotive, and trucking industries where cam followers and tappet rollers are commonly used.
Sikorsky Aircraft, subsidiary of Lockheed Martin, is a civilian and military helicopter manufacturer headquartered in Stratford, Connecticut. Commercially available collision warning systems improve helicopter safety by alerting the pilot to long to mid-distance terrain features which may cause a collision with the aircraft. These systems are not designed to reliably detect near-distance discreet obstacles such as buildings, trees, or other aircraft. Additionally, these systems rely on the pilot's reaction to the threat, rather than operating the vehicle autonomously, which can lead to collision during low visibility or high workload conditions. Sikorsky Aircraft tasked Team 30 with customizing a commercially available quadrotor Unmanned Aerial System (UAS) to perform autonomous obstacle avoidance in hover and low forward speed flight.

The flight control inputs required to demonstrate autonomous obstacle avoidance were modeled in Simulink as a 6-DOF system. The desired position and heading of the quadcopter serve as inputs whereas the actual position and attitude are outputs. PID controllers were designed and implemented to stabilize the quadcopter and achieve aggressive and robust avoidance of obstacles by controlling the roll, pitch, yaw, and thrust. The control logic allows the quadcopter to reject disturbances in the form of wind and track its commanded attitude and position to within a small margin. Ultrasonic sensors are used to scan the surroundings of the UAS for obstacles during flight. Appropriate sensor scheduling is utilized to ensure maximal situational awareness of the UAS at all times, as well as verifying threats before alerting the flight control system of an imminent collision. Scheduling and sensor analysis is performed by a secondary microcontroller which communicates the distance and direction of the obstacle to the onboard flight controller. Once the flight controller is alerted to the presence of a threat the custom flight control software maneuvers the quadcopter to a safe location. During these maneuvers the Inertial Measurement Units (IMUs) are monitored to ensure that the aircraft operates in a manner that would be practical for a full scale aircraft.
Sikorsky Aircraft Corporation is a Lockheed Martin company headquartered in Stratford, Connecticut, and is one of the world leaders in the design and manufacturing of both military and commercial helicopters. One way Sikorsky is looking to improve their future aircrafts is by moving to high performance composite structures as the primary content of their airframes as opposed to the typical aluminum material. However, there are some issues that come with using large integrated composite structures, it becomes difficult to replace the entire structure, and instead the structures would need to be repaired in situations with limited facilities in order to remain operational. In order to repair the damaged composite structure it would be necessary to fabricate a composite patch which would then be applied to the structure itself. Both additive manufacturing and out of autoclave composite systems will be utilized in the process of creating the composite patch. The ultimate goal of this project was to determine a thermoplastic material which could be 3-D printed into a mold for use in the out of autoclave composite manufacturing process.

Initial research was conducted on different thermoplastic materials to determine any materials that would be able to withstand the pressure and thermal conditions the mold would need to be placed under during the composite curing process. A half-cylinder mold was designed as the contour shape for which to create a composite patch. After determining the best candidates for use, Finite Element Analysis (FEA) models were created in an attempt to simulate the curing conditions in order to predict the deformation of the composite during curing. Molds were acquired made out of one of the top candidates; a PEI based thermoplastic material, ULTEM 1010. Using pre-preg composite fibers, composite patches were manufactured using the 3-D printed molds and the patch dimensions were ultimately compared both to the original design definition of the mold, and also to the FEA results in order to determine the validity of the simulations. All of the information gathered regarding the composite repair patches and their processes, was able to be submitted to Sikorsky for them to make the proper decisions when it comes to the future progression of the airframe manufacturing processes.
Team 32: Alternate, Non Metallic, Materials for Transfer Pump End Cap

Sponsored by: Stanadyne LLC
Sponsor Advisor: Keith Simpson
Faculty Advisor: Dr. Horea Ilies

Stanadyne LLC was founded over 135 years ago and they manufacture fuel pumps for gasoline and diesel engines. Stanadyne developed the first Diesel Model Rotary Pump in 1952, which has evolved into a major product of theirs today. Since then, Stanadyne has developed the smallest available Gasoline Direct Injection Pump. Stanadyne manufactures the diesel fuel injection pump, which delivers fuel at precise timing to each cylinder of the engine. The fuel pump allows for increased performance, efficiency and power. The DB model is very reliable. The pump currently has a metallic end cap, of which there are four varieties available for the 1,041 DB models. The current metallic end cap has a very thin-walled cross section and current production using AISI 1018 or SAE 1215 steel often experiences various failures. This also makes machining the end cap a difficult task. The part has many small dimensions with tight tolerance requirements and any distortion during production requires the entire batch of (900-3000) parts be scrapped and reproduced. Therefore, there is a need for an alternative, non-metallic, material that is compatible with the diesel environment, meets the structural needs, is comparable in cost with the current material used as well as being able to be mass produced (around 150,000 a year). Multiple material categories were whittled down to just polymers due to their pricing as well as physical and chemical properties. Tensile, fluid absorption, impact and compression tests were developed and performed on four candidate materials in order to determine the best functioning polymer. Two of the best performing polymers were then sent to Stanadyne for prototyping as well as other various tests that are performed on the original steel end cap. The best performing and most cost effective material will be presented to Stanadyne as the final selection for the end cap.
Stanley Access Technologies, a division of Stanley Black & Decker, specializes in manufacturing automated commercial door packages. Included in their diverse line of products is their Magic-Force operator. In the past the Magic-Force operator featured rubber isolation mounts, however they began finding the isolation mounts helped contribute to excess rotation of the operator.

A prototype was developed which modified the casting of the operator to eliminate the need for the isolation mounts resulting in reduced production cost and excess rotation. To identify potential issues, Stanley provided us with prototypes to perform a risk analysis on the now rigidly mounted operators. Our group decided to use a two pronged approach to perform our analysis.

The team utilized SOLIDWORKS 3D modeling and finite element analysis to perform computer simulations on the prototype. Based on required safety limitations, calculations were performed in order to determine the forces acting on the internals of the operator. These forces were then applied in SOLIDWORKS to the 3D models in order to get preliminary results for the apparent stresses, strains, and displacements on the system. In order to validate this computer simulation our team used strain gauges in addition to a Vishay data acquisition system to collect experimental data. This experimental data was then compared against our SOLIDWORKS simulation in order to confirm the accuracy of our results. To account for potential failures occurring due to fatigue over a longer period of time, a cycle test was performed in tandem to the previous analysis strategy. To facilitate testing fixtures were developed and constructed as a means to support the required hardware to perform the testing.
Team 34: Boost Pump Performance Enhancement

Sponsored by: Triumph Engine Control Systems
Sponsor Advisor: Nancy Miller, George Bennett
Faculty Advisor: Dr. Wilson Chiu

Triumph Engine Control Systems is an aerospace fuel system supplier dealing mostly with helicopters and business jets. Due to helicopter maneuvers, the main fuel pumps typically have an added boost pump to maintain performance. One of these added boost pumps is a high lift, side channel pump called LOLA (Liquid, or Light Ends, Air), pictured in Figure 1, that is used to increase the pressure of the fuel before entering the main fuel pump of a Bell-type helicopter.

The challenge that Triumph is having with LOLA is that there is backflow recirculation at a portion of the pump inlet which decreases the performance of the pump. The reason for the backflow is due to a small region of larger pressure at the inlet. Triumph has run initial simulations on the pump using ANSYS CFX and found a possible yet non-manufacturable solution. The solution disrupts the backflow, but it does not alter the pressure gradient at the pump inlet. The task given to Team 34 was to manufacture, into an actual LOLA pump, a solution to the backflow recirculation challenge using Triumph’s idea as a starting point, and to test the pump at the Triumph test rig to show improved performance and decreased backflow recirculation.

We began the project by creating a mesh for the LOLA pump in ANSYS CFX, with pump models given by Triumph. The next step was adding a manufacturable modification and running simulations, varying the dimensions and features. Table 1 shows how different simulations changed the outlet pressure as well as backflow velocity at the inlet.

The design was finalized after running many simulations using variations of the initial modification concept. Data from CFX shows that the backflow recirculation velocity was reduced by 37 percent with the final design. Figure 2 shows the before and after fluid velocity contour at the interface between the inlet and impeller. The modification was manufactured from Al 7075 at the UConn Machine Shop and was added to the pump with the high strength epoxy. The modified pump was then taken to Triumph to test the vapor/liquid pumping capabilities. These results along with the analytical data were submitted for comparison to other Triumph pumps. Alongside the testing and manufacturing, other modification ideas were run in ANSYS CFX to find different options for a modification. We were able to generate useful data as well as a prototype so that Triumph can continue backflow reduction studies.
Triumph Engine Control Systems (TECS), based out of West Hartford, CT, is a leading manufacturer of fuel pumps, metering units, and digital electronic control systems for commercial and military gas turbine engines. The Full Authority Digital Engine Control, FADEC for short, is a device mounted on the engine of jets and helicopters that converts the pilot’s commands in the cockpit to the necessary effectors to obtain the desired response. The FADEC is also responsible for collecting large amounts of flight, performance, fault, and crash data which is used for engine maintenance and diagnostics. Despite its enormous importance to recording data, current FADEC technology utilizes rugged Flash Memory that is quite small, provides limited fault and crash data, and goes obsolete in just a few years. The re-engineering costs of the FADEC memory board have proven to be very costly. Thus, the goal of this project is to design and test a prototype Next Generation FADEC memory board with an increased non-volatile memory (NVM) storage capability and lifespan, using commercially available technology.

Research into the most current NVM storage devices led us to choose industrial grade micro SD cards as the best choice for this application. Micro SD cards have a high areal density, or quantity of stored information in a physical volume, are very lightweight, and are rated to operate in a temperature range of -40 to 85°C. FADEC’s operate in high vibration and variable temperature environments which the memory device must be able to withstand. In order to verify that the micro SD cards can function properly and reliably in an airborne environment, HALT (highly accelerated life testing), vibration qualification and endurance testing were performed in Triumph’s Thermotron HALT chamber, which is a thermal chamber integrated with a six axis vibration table. A computer program was written by our electrical engineering counterparts which communicated with the micro SD cards during testing to ensure proper data transmission. The results of the test demonstrated that the micro SD card system, mounted at various points on the memory board, could survive under the vibrational and thermal environment represented throughout the FADEC’s lifespan. With this memory board prototype, TECS can now integrate it into the Next Generation FADEC and utilize the increased NVM to provide enhanced data analysis potential to their customers.
Team 36: Laser Cutting System
Vacuum Optimization

Sponsored by: Trumpf
Sponsor Advisor: Walter Kampitsch
Faculty Advisor: Dr. Ugur Pasaogullari

TRUMPF

Dr. Ugur Pasaogullari, Alexander Trotman,
Alexander Dumschott, Clement Lee.

Trumpf is the largest manufacturer of fabricating equipment and industrial lasers in North America. They offer customers innovative, high-quality products and solutions in the areas of sheet metal processing, laser-based production processes and electronic applications. The TruLaser series of laser cutting machinery is currently sold by Trumpf in the global market, which performs high capacity 2-axis laser cutting of sheet metal. The machine removes the cutting byproduct using a vacuum assembly which tracks laterally below the laser cutting operation. The principal objective of this project is for Team 36 to optimize the performance of the current vacuum system through baseline performance analysis, design and physical testing of proposed changes. The modifications must meet the fluid, structural and thermal requirements based on the current machine environment, and cannot disrupt the accuracy of the cutting process. The initial assessment performed by Trumpf determined a desired goal of uniform air velocity along the length of the debris catcher, and an increase of average air velocity to at least 0.8 meters/second at the work piece.

The team began by modeling the internal system in Solidworks, and importing the components into ANSYS Fluent to perform CFD simulations. The team also constructed an experimental rig to test varying vacuum slot sizes and suction source locations. The results of these simulations and tests were used to understand which modifications would be the most beneficial to both the flow capability of the vacuum system, and the velocity profile along the length of the sheet metal work piece. It was found that the cross-sectional area of both the debris catcher and the coupling component yielded the highest losses with respect to pressure drops. The team was able to separate the fluid and structural functions of these components and redesign with a more favorable internal geometry. The final design is a model which meets both the power and uniformity goals presented by Trumpf during the initial system assessment.
Lyophilization is tremendously important to the preservation and distribution of pharmaceutical products. When the aqueous solution of the product is not stable and the product cannot be crystallized in bulk, lyophilization is the preferred method of preservation because it is less destructive to the product than other methods, especially for proteins. Freeze-drying (lyophilization) is a pharmaceutical process by which a drug solution in some form, often in vials, (i) is loaded onto a temperature-controlled shelf, (ii) is lowered in temperature to freeze all but the non-crystallizable solutes that persists in a glassy freeze-concentrate, (iii) has the frozen water removed by sublimation, (iv) has the non-frozen water removed by desorption, and (v) is stoppered in place to maintain sterility of the product. While the shelves in the freeze-dryer are temperature-controlled, many other surfaces are not. Therefore, the product in the vials in a batch often experience a variation in temperature history. Experimentally, vials along the edges of the tray near the hotter walls often experience elevated heat transfer. In some cases, this may produce a variation in mass transfer of H2O, and subsequently influence the product quality. The goal of this project is to understand the roles of different heat transfer modes in a lyophilization process and to mitigate, or at least account for, unwanted heat sources.

Experiments testing the variation of heat transfer to the outer edge vials and walls within the chamber were performed. Temperature variation was expected due to the possibility of heat sources from electrical panels outside the vacuum chamber. Temperatures within the vials were measured by a thermocouple located at the bottom center of the vial, and temperatures on the wall were measured by taping the thermocouple to the wall at precisely measured points. Due to a limited number of thermocouples, repetitive runs with the exact same settings were conducted to generate the data sets so that thermal behaviors of the lyophilizer can be characterized. A theoretical model of the sublimation process was developed to predict the experimental results.
The Power and Energy Systems Laboratory (PESL) at the University of Connecticut, directed by Dr. Peng Zhang, specializes in developing reliable, intelligent, and sustainable solutions for power grids. The Wave Energy Converter (WEC) being developed by the PESL generates electricity from the vertical motion of the waves. The specific design of the WEC is called a direct drive linear generator. It works by using the motion of the waves to move a set of coils up and down an axis that contains magnets. The change of magnetic flux flowing through the wires is what generates the electricity. The body of the WEC, called the spar, contains the magnets, and the buoy containing the coils moves relative to the spar. The spar has to maintain neutral buoyancy in the seawater and resist moving due to the various wave forces. The Smart Ocean Wave Generator System team has been tasked to design a more stable spar and heave plate system, as well as design and build a mechanical wave simulator to test power generation capabilities of the system.

Currently the sponsor does not have an easy, reliable, and repeatable means to test the power output of the electric coil designs. The team must design and build a test rig for the electronics that can be used in a controlled environment such as a laboratory setting. The primary goal for the project was to make the test rig inexpensive, adjustable, and dry. The test rig will be used to test current electrical configurations as well as others for years to come. The secondary goal was to design a more stable, waterproof, and economic spar/heave plate system for the WEC.

The solution to these problems was to develop multiple designs for each. For the stability of the spar, the design was focused around lowering the center of gravity while maintaining a center of buoyancy near the center of the magnets. To retard vertical and horizontal motion, circular heave plates were added to the bottom of the system. Analysis of the design concepts was done using statics and dynamics, while testing was done via CAD software and its built in tools.

The test rig was developed with two main designs utilizing a user controlled oscillator attached to the coil. After analyzing and testing the costs, practicality, and robustness, a scotch and yoke mechanism was determined to be the best design. This mechanism creates a sinusoidal oscillation from a rotating motor. This is perfect for simulating ideal waves, and allows for adjustable speed and displacement.
Infectious bacteria and viruses are prevalent in frequently used facilities such as public restrooms. Additionally, healthcare facilities, such as hospitals, also suffer from the same risks of infection. This often results in more fatal complications due to the weakened immune systems of patients. Unfortunately, these areas tend to be difficult to keep clean regularly without obstructing the functionality of the facility. This is an important issue, which needs to be addressed more thoroughly in order to further improve the quality of life and life expectancy of people across the United States. The solution being proposed in this project is an intelligently designed, self-regulating, cleaning system that is able to be retroactively fitted onto a variety of toilet seats. The device must be childproof, waterproof, and powerful enough to eliminate 99% of harmful bacteria and viruses on a toilet seat surface in a reasonable working time as to not inhibit the functionality of the facility.

UV germicidal irradiation was chosen as the primary method to eliminate germs for this device for several reasons. Using a UV light allows for efficient and effortless elimination of germs compared to conventional cleaning methods. The light encourages hands off operation, meaning that the user will not have to physically touch the toilet seat to clean it. Additionally, it allows the toilet seat surface to be cleaned continually throughout the day and in between uses, which is an unrealistic task to replicate with methods currently being employed.

Multiple experiments were conducted that tested the ability of the UV light to reach all surfaces on a toilet seat. The germicidal effectiveness experiment tested the sanitation capability of the light under its intended operating conditions. Finally, the durability test indicated that the device would be able to withstand the conditions of the working environments commonly associated with bathrooms. Results from each of these experiments aided in the creation of the Cleanlight design.
Team 40: Smart Fuel Metering Unit

Sponsored by: United Technologies Aerospace Systems
Sponsor Advisor: William Rhoden
Faculty Advisor: Dr. Horea Ilies

Dr. Horea Ilies, Samson Velpula, Otto Holda, and Kenneth Looby.

UTC Aerospace Systems

United Technologies Aerospace Systems (UTAS) is a leader in commercial and military aerospace systems. Among the products that UTAS develops are fuel control systems. The focus of this project is on the Fuel Metering Unit (FMU) of an aircraft. The FMU is responsible for controlling how much fuel is sent to the combustor as well as the hydraulics of an aircraft. Currently the FMUs produced by UTAS use a generic performance map based upon computer models and calculations in order to determine the amount of fuel to be sent to the combustor and hydraulics. It is the purpose of this project to develop a method for creating a performance map that is specific to a particular FMU using test data.

Our joint electrical and mechanical engineering team’s goal is to create a method for converting raw test data into a useful performance map. This performance map will be stored onto a memory chip that will use the map to make more optimal decisions on the amount of fuel to be sent based off of temperature, pressure, pump speed and position of the resolver on the pressure regulating valve. Some of the possible benefits include shorter calibration times, more accurate FMU performance and less of a reliance on highly calibrated and expensive components in the fuel system. The team developed a test plan to be run on a UTAS test rig. The team also produced a mapping algorithm to remove erroneous raw data and create a performance map for the FMU tested on the UTAS test rig. This performance map was stored into a memory chip mounted on a printed circuit board designed by the electrical engineers for reading data within time frame specified by the UTAS. The ability of the chip to retain data at temperatures similar to what the FMU experiences was also investigated. Through a trade study the team was able to determine the best location and housing for the printed circuit board to protect the board from vibration and electromagnetic interference. A validation test of the team’s performance map was performed to verify the map’s accuracy. The team provided UTAS with a feasibility analysis of the Smart FMU from an electrical and mechanical engineering perspective.
Team 41: Passive Control Accumulator for Two Phase Flow Loop

Sponsored by: UTC Aerospace Systems
Sponsor Advisor: Dr. Wei-Lin Cho
Faculty Advisor: Dr. Vito Moreno

UTC Aerospace Systems

United Technologies Aerospace Systems (UTAS) is a world leader and supplier of advanced aerospace and defense products. Formed by a merger in 2012 between Hamilton Sundstrand and Goodrich Corporation, they employ over 42,000 professionals in 26 countries.

A current research area at UTAS focuses on the capability of passively separating two phase flow and ensuring liquid output from flow loop accumulators during transient heating conditions. Such a device contains no moving parts, is capable of function in both near Earth and microgravity environments, will prevent pump cavitation and be capable of functioning for long periods of time without servicing. In order to aid UTAS by providing a proof of concept for such a design, simulations of phase separation were run and various designs were assembled and tested.

Design concepts for such an accumulator were produced using additive manufacturing techniques to produce a phase separating environment housed in a steel pressure tank. A test rig has been constructed, from which data was collected. After several revisions to the design, a proof of concept for the passive accumulator was developed, a valuable deliverable expected by UTAS. Significant data concerning the design was collected from both tests and simulations, providing UTAS with information to aid in further development of flow loop accumulators.
Team 42: Extrusive Feed Throat Redesign

Sponsored by: Web Industries
Sponsor Advisor: David Morgan
Faculty Advisor: Dr. Zhaoyan Fan

Web Industries is an employee owned company specializing in the conversion of plastics, and various other materials. These materials are supplied to Web Industries in large rolls or are extruded by web industries and then cut to various lengths and widths. Their products can be found in electrical cables, airliner hulls, and medical supplies. Their goal is to provide their customers with the converted materials in the most efficient and time effective manner.

The Dayville Connecticut facility performs the extrusion and slitting of plastic sheets. In the extrusion process resin stored in a hopper is fed into an extrusion screw. The resin is extruded through a die to create a web which is later slit to the desired width and thickness that the customer demands. During this process the edge pieces were not used because they do not meet the dimensional requirement. This excess trim was collected and had to be re-pelletized in a separate process before being recycled back into the extruder. Team 42 was given the task of redesigning the extrusion feed throat to include a trim reclaim system and a powder feeder system.

Through the use of a full scale test rig team 42 was able to design a feed throat that incorporates a controlled rate trim reclaim feeder and a controlled rate powder feeder. The team also used FEA to ensure the feed throat is able to support the weight of a fully loaded hopper and new components added to the system. The team built, delivered and installed the working system on the extrusion line at Web Industries. The addition of the powder feeder increased the variety of products that can run on the extrusion line and the trim reclaim system helped increase the final yield of the product by almost 10%.
Team 43: Extrusion Slitting System Redesign

Sponsored by: Web Industries
Sponsor Advisor: David Morgan
Faculty Advisor: Dr. Ying Li

Web Industries is a global leader in flexible material converting and end product contract manufacturing. Web has requested that we complete a redesign of an extrusion slitting system that was having a lot of failures. The machine we were asked to work on is one that extrudes polypropylene into a sheet, which is then slit into thin pieces less than 1/10th of an inch thick. When one of these slits snaps and loses the tension that was pulling it along, the plastic will wrap around the blades and cause the entire system to be shut down. The second aspect to our project was to gather the outer edges of the plastic that was being scrapped and feed it back into the hopper to increase yields up to 1.5x. This required our team to integrate our designs with Team 42, who was responsible for the feed throat hopper redesign.

Our approach to the problem was to brainstorm possible causes of the failure. After discussing the list with our sponsor we determined that the best way to fix the issue would be to flip the orientation of the system. Previously, the polypropylene was fed into the slitter in a horizontal orientation. When a cut would drop out the orientation would allow the material to wrap around the blades. Changing the system to a vertical feed orientation would prevent this.

We have created detailed models of the entire system in AutoCAD Inventor in order to ensure precision in our designs. After much deliberation over our proposed designs, we have converted the system to include a vertical feed orientation to keep the cuts from jamming the slitters. We have also implemented a vacuum pickup system in order to increase yields, reduce scrap and clutter on the floor and to catch slits that drop out. To validate our project we researched and tested the polypropylene to make certain that the tension in the material will be within specification. We have also optimized our designs according to our research on the entry and exit angles of the material on the rollers. This resulted in a successfully installed system where there has been significant improvement in the uptime of the system as well as the elimination of scrap material.
Team 44: Analytical Model of Cooling Coil Air-Side Fouling

Sponsored by: Zachry Nuclear Engineering
Sponsor Advisors: Hannah Skinner, Shera Singletary and Jeff Lundy
Faculty Advisor: Dr. Tianfeng Lu

Zachry Group is a privately held company serving the power, energy, chemical manufacturing, and industrial sectors. Zachry Nuclear Engineering, based in Stonington, Connecticut, is one of 400 Zachry Group locations nationwide and provides analysis and design services to the U.S. commercial nuclear power plant fleet. The design project that Zachry Nuclear approached us with concerns heat exchangers in nuclear power plants. A typical nuclear power plant utilizes air to water heat exchangers in both safety related and non-safety related applications. Heat exchangers are relied upon to maintain safe pressures and temperatures in containment, and to maintain acceptable temperatures in rooms housing specialized equipment. Since heat exchangers are important components in a nuclear power plant, it is desirable to understand their performance degradation over time. Heat exchanger performance typically becomes poorer over time due to the accumulation of debris (fouling) inside the cooling coils and on the outside heat transfer surface. In typical performance analysis of air to water cooling coils, it is assumed that performance degradation occurs inside the heat exchanger coils, thus all fouling resistance is accounted for on the water side of the heat transfer area. This simplified analysis scheme assumes that air coming into the heat exchanger containment structure is well filtered.

Due to the finned construction of a water to air heat exchanger, much of the surface area for heat transfer is present on the air-side. As a result, heat exchanger performance is sensitive to fouling accumulation on the air-side. Under operating conditions that cause air-side fouling, lumping all of the fouling resistance on the water side is not a valid assumption and performance can be impacted in a manner that is difficult to estimate.

Zachry has tasked us with developing an analytical model which predicts time dependent heat exchanger heat transfer performance subject to variable particulate loading. This model was established based on empirical data collected from a heat exchanger test rig designed and built in-house. Relationships among test variables were evaluated using computer aided regression analysis. The final analytical model incorporates user defined inputs for particle concentration, particle type and air flow rate. This model will allow Zachry to estimate heat exchanger service intervals to ensure systems are running at optimal efficiency.
Since 1979, Zeeco has been advancing the technology of combustion processes and cleaner, more energy-efficient systems. One service they offer is to improve the emissions in existing combustion technology, such as the oil-burning auxiliary boilers at UConn Power. Due to more stringent emissions regulations, it is not likely that these boilers will pass the next inspection in 5 years.

In the combustion process, fuel is combined with air (mostly oxygen and nitrogen) and ignited. The most efficient combustion creates the highest temperatures, which unfortunately cause the nitrogen in the air to combine with oxygen and create NO and NO2, commonly referred to as NOx or “nox”. These gases are known to deplete ozone and form acid rain, respectively. Team 45’s goal was to implement two methods to improve the emissions working with the existing burner technology.

The first of these methods is to better control the airflow into the burner. This is accomplished by installing baffles in the existing wind box and ducts. Burners have 2 criteria to be met before they work most efficiently. At the burner exit, the air must have uniform velocity and no axial rotation or “spin”. Additionally, care must be used when implementing baffles as pressure head losses in the system may exceed the ability of the intake fan to work effectively. Team 45 found a solution through physical testing of a ¼ scale model and verified the results using computational fluid dynamics (CFD).

The second of these methods is to develop an oil atomizer that discourages emissions production. This involves a careful balance between efficiency and high temperatures that produce NOx emissions. This is controlled through placement, quantity and size of ejection ports in the atomizer tip. Zeeco is known to develop ultra-low NOx producing atomizers, so Team 45 was given the task of making a Zeeco proprietary tip, as well as the opportunity to develop their own.
Biorasis, Inc., founded by two UConn professors, Fotios Papadimitrakopoulos and Faquir Jain, has been developing a needle-implantable continuous blood glucose monitoring system for over 10 years. The core of this technology is the GLUCOWIZZARD™, an ultra-small implantable biosensor measuring just 0.5 x 0.5 x 5 mm. This sensor is implanted by a needle into the subcutaneous tissue of the dorsal forearm where it reads glucose levels in the blood and transmits the information to a specialized watch that sits just above the chip. The watch can then send the information wirelessly to a glucose pump for glucose level regulation or to a smartphone or personal computer for analysis.

The project assigned to Team 46 was to design a system to implant and extract this sensor that was repeatable and usable by a person with minimal training. A quick and easy implant and extract of the sensor is crucial to the success of the system, as the chip must be changed every three months. By making the implant and extract system as easy to use and error proof as possible, the procedure can be done properly by a pharmacist or even a home user, instead of a doctor, significantly reducing costs.

The sensor must be located at 3mm below the surface of the skin. This location is below the lowest extent of the dermis and above the underlying muscle. For the implant system, the design implemented a system using a 30mm diameter flat disk with medical adhesive on its end that lifted an area of skin to a predetermined height. A spring loaded needle with the sensor already placed inside its tip is allowed to move 2mm into the side of the bulge in the skin. The sensor which has a sharpened tip is pushed out of the end of the needle via a plunger. The needle and plunger are then retracted from the skin, leaving the sensor at the proper depth.

For the extract system, hall effect sensors are used to precisely locate the chip under the skin. The extract needle is positioned using stepping motors so that it aligns its long axis with the long axis of the chip. The needle is then allowed to slowly move forward and make contact with the end of the chip to which a permanent neodymium magnet is mounted, attaching to it. The chip is then slowly pulled out of the skin.
The ultimate goal researchers hope to achieve is to harness the properties of the carbon nanotubes (CNTs) via the creation of a composite material. The Carbon Nanotube-Copper composite material (Cu-CNT) will hopefully provide a better conductance of current without thermal anomalies so that this material can replace copper in interconnects within computer chips.

This technology will create a stronger device that can conduct electricity more efficiently. Another hope is that the material will allow for the cross sectional areas of interconnects to be minimized while maximizing the current flow through the material. Finding a way to optimize the size and current carrying capacity of interconnects is necessary in order to allow engineers and manufacturers to keep up with the demand for smaller and more capable electronic devices.

This research statement is defined based on the interest of UConn in copper/Carbon Nanotube composite materials. UConn is interested in knowing the electrical behavior of these composite materials. Custom CNTs samples will be grown in the MTL laboratory at the MIT. Copper will be deposited on these CNT samples using electro and electro-less plating techniques. The primary goal of this project is to evaluate the electrical properties of the resulting composite. An understanding of the electrical properties of the composite material is needed for future applications of this material, including the ability to replace pure copper interconnects in electronics as a smaller and more efficient conductor.

The objective of this project is to model electrical behavior of the Cu-CNT composite material through experimentation and through theoretical modeling. The theoretical model of the electrical resistance is based on literature review and simulated via COMSOL software. The experimentation to determine the electrical resistivity was taken by using a four probe machine.
Currently humans and robots interact through computer programs, which direct robots to perform a set of specific, pre-designated tasks. This system, although effective, severely limits our ability to control robots for more spontaneous or fluid tasks. Relatively few people in the world know how to program, and an even fewer know how to program robots. Creating a more natural and versatile interface between humans and robots would open up many more possibilities for increased interactions between the two.

A communication tool such as a Leap Motion already has a gesture-based interface that can recognize intelligent gestures and can act as a motion interpreter. The device applies two cameras and three infrared LED lights to track the movement of user’s hands. The proposed research will study the integration and design of control systems for training-free mixed-reality-based communication as a natural interface between humans and robots.

To achieve this goal, the Leap Motion device will act as a hardware platform for proof and evaluation of the concept. The research will explore the integration between this device and several robotic devices, creating a new way for people to communicate with technology. In more details, the research will entail pairing and integrating the sensor with state-of-the-art educational and industrial robots in the Manufacturing Automation and Control Systems (MACS) lab at the University of Connecticut, and designing algorithms that relay natural commands from the human operator that can be applied to different robots.

After the robots can all be individually paired with the Leap Motion device, two robotic hands will be created and will be able to mimic the users hand motion when in range of the Leap Motion device. Many robots have singular armatures, which limits their functions. Dual arm robots increase the ability of a robot to perform bimanual tasks as well as decrease physical space needed to perform the tasks. The possibilities for an application with a more naturally interfacing robot are extensive. The concept is to allow the user to have an easier yet more capable experience with the robotic machine.
Team 49: Scientific Instrument for Characterization of Thermoelectric Properties

Sponsored by: Accelerated Masters Program
Sponsor Advisor: Dr. Michael Pettes
Faculty Advisor: Dr. Michael Pettes

A type of material called thermoelectrics is able to directly convert a temperature difference into electricity. Its potential for applications, however, is limited by the relatively low conversion efficiency. Thus one of the research conducted in the lab of Dr. Michael Pettes is the manufacturing of thermoelectric materials with higher conversion efficiencies. In order to actually characterize the materials, however, an instrument is necessary to measure the electrical conductivity, the thermal conductivity, and the Seebeck coefficient to obtain the thermoelectric figure of merit. This instrument must be able to measure at high temperatures (600~700°C) in which a thermoelectric device may utilized. It is critical that the instrument minimizes any inaccuracies and errors so that the measurements are reliable. These inaccuracies can be caused by multiple factors, such as parasitic heat losses, contact resistances, and uneven temperature distribution. The goal of this project is to analyze these possible sources of inaccuracies and to create a design for such an instrument.

A basic design was formulated using similar instruments and measurement setups. To measure the thermal conductivity and the Seebeck coefficient, a temperature gradient is formed across the sample while the voltage drop and required heat input are recorded. To measure the electrical conductivity, a current is passed through the sample and the voltage drop is recorded. Multiple sources of error were then analyzed using the ANSYS software, and the design was adjusted with those in consideration. In order to avoid any convective losses, the system was placed within a vacuum. To prevent any radiative losses, a radiation shield was placed around a central measurement portion. The radiation shield temperature was also set at the upper temperature of the gradient, as the heat input only needs to be measured at one side. An axial thermocouple probe was also designed to touch on a uniform surface, while being spring-loaded to reduce contact resistances. One of the wires of the thermocouple also serves as a voltage probe. Grafoil sheets are also used to reduce contact resistances and to ensure a uniform temperature distribution. Other factors such as radiative shunting between heat spreaders, parasitic losses through wires and supports, and sizes and outputs of potential heaters were also considered and accounted for.
3M
ASML
Barnes Aerospace
BGR Radiator
BioFibers, LLC
Biomass Controls, LLC
Biorasis, Inc.
BST Systems, Inc.
Capewell Aerial Systems
Caring Technologies
City of Bridgeport, CT
Clarcor EMS
CME Associates, Inc.
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CONNDOT
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