WINNERS OF THE SENIOR DESIGN COMPETITION

First Place - $1,300
Multi-disciplinary Project Representing Department of Mechanical Engineering & Mechanics
Remote-Controlled Underwater Camera System for Real-Time Monitoring of Fatigue Damage in Fuselage Panels
Team: Andrew Bergan, Prince Codjoe, David Schubert, Mark Shuck, Ross Staszak, Arudra Venkat
Advisors: Dr. Jonathan Awerbuch, John Bakuckas, Dr. Timothy P Kurzweg, Dr. Karkal Prabhu, Dr. Tein-Min Tan

The Aviation Safety Research Act of 1988 directs the FAA to develop technologies and conduct data analyses for predicting damage tolerance of aircraft structures. The FAA performs testing at the William J. Hughes Technical Center's Full-Scale Aircraft Structural Test Evaluation Research (FASTER) facility in Atlantic City, NJ. Fatigue cracks are monitored both on the exterior and interior of the fuselage panel. Aircraft flight loads from takeoff and landing are simulated on the test panels as cyclic loading up to 25psi using water as the pressurization medium. During the testing, crack propagation is monitored with an underwater camera mounted on an analog controlled crawler. The poor quality images, manual measurement, and outdated analog controls of the existing system provided motivation for an improved underwater crack monitoring system. The current system provides a 5-DOF support structure, two high resolution cameras with a custom CNC machined camera enclosure, an integrated windows control software, and machine vision image analysis for crack measurement. The current system provides the FAA with positioning accuracy of 0.002 inches, point and click crack measurement accuracy of 0.014 inches, and imaging area of 30 inches by 84 inches, all of which exceed the FAA's requirements.

Second Place - $1,000
Project Representing Electrical & Computer Engineering
Orchestral Performance Companion Using Real-time Audio to Score Alignment
Team: David Grunberg, Alex Hrybyk, Matthew Prockup
Advisor: Dr. Youngmoo Kim

Many people enjoy live orchestral performances, but those without musical training may find it daunting. We have developed a system that guides a listener through the performance in real-time by providing contextual information about the music as it is performed. Through partnerships with musicologists and the Philadelphia Orchestra we generate this contextual information, such as music theory concepts or the music's historical significance. Using acoustic features and dynamic time warping, we align the live performance audio with that of the previously annotated recording. The aligned position is transmitted to users' handheld devices, presenting time-relevant annotation information in a manner similar to that of a personal museum guide. Several constraints include the vagaries of live performance, real-time operation, and system unobtrusiveness. To satisfy these constraints, the system has been tested at four concerts, and will continue to be deployed it in the future.

Third Place - $700.00
Project Representing Chemical & Biological Engineering
Microchannel Reactor Technology: Acrylic Acid Production
Team: Dominic Ciccimaro, Lisa Leone, Chern-Hooi Lim, Jared Lucchesi
Advisor: Steven Schon, Arkema Group

MicrOx Chemical, a start-up company located in Philadelphia, PA, has designed a world class scale acrylic acid plant using microchannel reactor technology, and has performed an economic comparison to the established state of the art in acrylic acid production. Microchannel reactors are well suited to acrylic acid production, a highly exothermic process involving flammable reaction mixtures. The unique properties of the microchannel reactor allow safe operation of flammable mixtures, as well as increased heat transfer capability over shell and tube reactors. These qualities have translated to improved product selectivity (4.7% selectivity gain) and shorter reactor residence time. For the purpose of comparison two world scale acrylic acid plants producing 400 MMlb/yr of technical grade acrylic acid in Cilegon, Indonesia have been designed. The microchannel reactor plant as a whole has a capital cost of $71.6MM and manufacturing cost of $182MM/yr, versus capital and manufacturing costs of $99.5MM and $198MM/yr respectively for the shell and tube plant of the same scale. Assuming a 20 year project life, 40% tax rate, propylene price of $0.51/lb and acrylic acid price of $0.59/lb, the microchannel reactor plant has a net present value of $138MM (versus $87.6MM), a discounted cash flow rate of return of 38.5% (versus 27.3%) and payback period of two years (versus 3.6 years.) Based on this initial work, we have concluded that the microchannel reactor is a promising and profitable technology in future acrylic acid production and worthy of further study.

Runners Up - $400.00

Project Representing Materials Science and Engineering
Design and Fabrication of Carbon Nanotube Tipped Pipettes
Team: Matthew Herbert
Advisor: Dr. Yury Gogotsi

Many cellular and sub-cellular processes remain largely unexplored due to a lack of suitable probes that inflict minimal stress and damage to the cell. Such tools would revolutionize cell biology, enabling in-situ studies of cellular processes. Assembled nanopipettes are multi-functional biological probes consisting of carbon nanotube (CNT) tips with the ability to transfer materials. The purpose of these nanoscale probes is for single cell investigations in which desired molecules are permitted to pass in and out of an individual cell, nuclei or organelle through a CNT opening. Here we describe the design and development of two assembly methods to position CNTs at glass pipette tips before sealing with epoxy: (1) capillary-driven fluid flow and (2) dielectrophoretic trapping. This work led to manufacturing the smallest and most versatile tools for intracellular studies ever reported. The assembled CNT-tipped nanopipettes have demonstrated the capability of accessing intracellular organelles without disrupting the cytoskeleton network. These devices feature magnetic tips permitting remote manipulation; are capable of transferring attoliter volumes of fluids or delivering single particles, extracting cellular material, and monitoring chemical processes in a living cell. Since CNT probes are assembled at the tip of a conventional glass pipette, they can be used in every cell biology laboratory, creating opportunities for minimally invasive intracellular probing, drug delivery and single-cell surgery, thus having a potential to revolutionize cell biology research and drug discovery.

Project Representing Department of Mechanical Engineering & Mechanics
Energy Absorbing Composite Structures to Improve Rotorcraft Crashworthiness
Team: Gary Henderson, Doug Mikita, Kevin Mirarchi, Ryan Park, John Smolko
Advisors: Dr. Tein-Min Tan, Dr. Jonathan Awerbuch

An important design aspect of rotorcraft structures is its crashworthiness. Primary emphasis is placed on occupant protection against sudden deceleration and high energy imparted during crash landing. The objective of this project is therefore to design a sub-floor structure that could reduce high initial loads exerted during crash landing while absorbing impact energy transmitted to the occupants. A primary constraint of the design is the weight limit of the rotorcraft structure. Graphite/epoxy tubes were selected due to their high strength-to-weight ratio and good energy absorption during crush. Effect of diameter-to-thickness ratio was investigated using tubes of elliptical cross-sections whose results were compared with those of circular crosssections. Specimen material and curing was provided by The Boeing Company. Various internal and external trigger mechanisms, to initiate progressive failure of the graphite/epoxy tubes, were investigated to identify which would result in the lowest initial load while providing the highest energy absorption. Failure initiation along the edges of the tubes was carefully examined using a photogrammetry system provided by Trilion Quality Systems. Based on results obtained through an elaborated test matrix, an integrated tubular structure that meets the weight constraint and provides the best energy absorption capability was designed, fabricated, and tested.

Project Representing Department of Biomedical Engineering
Hybrid Design for a Biomimetic Bottle-Brush Aggrecan Molecule Utilizing a Synthetic Polymer Backbone and Bio-Based Bristle Attachments
Team: Xu Mingming Chen, Elizabeth Dreher, Aykan Karabudak, Krista Szymborski, Kim Trasatti
Advisors: Dr. Michele Marcolongo, Ms. Sumona Sarkar

The leading cause of lower back pain is the degeneration of the intervertebral disc due to degradation of the proteoglycan aggrecan in the nucleus pulposus (NP). Aggrecan allows the NP to cushion the vertebrae in response to compressive forces and to restore disc height in the absence of those forces. We propose to design a hybrid structure utilizing a synthetic polymer backbone and bio-based bristle attachments in order to mimic natural aggrecan's chemical characteristics while resisting enzymatic degeneration. A successful, synthetic molecule will fulfill the following criteria: viscosity range of 0.4 - 0.6 Pa, stability in a pH range of 7.4 - 6.3, a bristle density of 0.25 –0.5 bristles/nm, and a molecular weight of 300 kDa.
Our deliverable is the previously described macromolecule which will be synthesized utilizing a stepgrowth process to bind chondroitin sulfate bristles to epoxide groups of a polymer backbone and lyophilized to produce a white powder. This molecule will be demonstrated to fulfill the set forth criteria through viscosity testing, differential scanning calorimetry and a primary amine assay. For clinical use, it will be reconstituted in the appropriate media and injected into degenerated intervertebral discs to restore disc function.

Project Representing Department of Computer Science
Mash-up Visual Programming (MVP) Environment

Team: Timothy Cheeseman, Daniel De Sousa, Jordan Osecki, Ngoc-Tung Nguyen, Martin Piecyk
Advisor: Dr. William Regli

Mashup Visual Programming (MVP) Environment is a system that allows users to create, compile, and run mashups of different services. The graphical user interface supports multi-touch manipulation as well as the traditional mouse and keyboard for easy, intuitive operations. This allows the software to be effectively used by scientists, the military, and others who may not be able to access traditional computer peripherals easily. The construction of mashups employs the use of intuitive visual programming concepts, geared for use by non-programmers.

This project focuses on the user interface, compiling, and running of service mashups. Both the mashups and the services can be stored and retrieved by the user from a registry service. The mashup engine is a separate component which actually compiles and creates results for a mashup. Within the mashup editor application, the user can create mashups and associate them with projects that can then be published to websites.

The MVP system uses OWL, RDF, and SOAP messages to ensure interoperability with other programs and advance the Semantic Web. An OWL reasoner and OWL ontology are used to ensure that only valid connections can be made for a mashup. Security is in place to ensure that mashups and services are kept safe throughout the entire process. The end user result is a website containing one or more mashups, consisting of information from unrelated web services combined together through joins and customized through filters that is displayed on a single output medium.

Project Representing Department of Civil, Architectural & Environmental Engineering
The Reading Viaduct Project

Team: Rob Battelbort, Tyler Carson, Matt Perkins, Kyle Simmons, Pasqualina Tirro
Advisor: Dr. Robert Brehm

In the 1890's the Philadelphia and Reading Railroad companies constructed a Viaduct line to transport patrons from Broad and Callowhill Streets through West Manayunk. Service on the Viaduct was discontinued in 1984 as a result of the opening of the Center City commuter tunnel. Since then, foliage and trees have overtaken the Viaduct's four elevated tracks due to lack of maintenance. Years of vegetative, chemical and mechanical erosion has compromised the structural integrity of structural steel sections and arched masonry bridges.

In response to community interest, the purpose of this Senior Design Project is to restore the structural adequacy of the Viaduct as well as provide recreation/residential opportunities to an area devoid of such amenities. In addition, a development plan for the Viaduct and the surrounding area is considered. The movement set forth by residents of the area (the Reading Viaduct Project) demonstrates the Philadelphia populace's common desire for improvement. Redevelopment of the Viaduct will not only ensure public safety, but will also provide civic areas, residential space and commercial development throughout the surrounding neighborhoods.