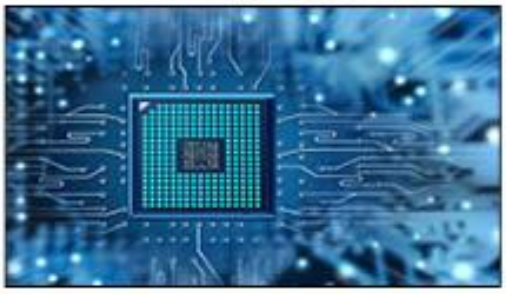
THE 3RD ANNUAL

SENIOR DESIGN EXPO








THURSDAY, MAY 5, 2016
12:00-3:00 PM

ROONE ARLEDGE AUDITORIUM, LERNER HALL
COLUMBIA UNIVERSITY, MORNINGSIDE CAMPUS

COLUMBIA | ENGINEERING
The Fu Foundation School of Engineering and Applied Science

Senior Design Expo

THURSDAY, MAY 5, 2016
12:00 - 3:00 PM
ROONE ARLEDGE AUDITORIUM
LERNER HALL

COLUMBIA | ENGINEERING
The Fu Foundation School of Engineering and Applied Science

THE SENIOR DESIGN EXPO IS POSSIBLE THIS YEAR THROUGH GENEROUS SUPPORT FROM TURNER CONSTRUCTION.

Expo: Departmental Guide

Applied Physics and Applied Math……..……Champagne
Biomedical Engineering……..……White
Chemical Engineering……...……...…….Gold
Civil Engineering…….....……...…….Burgundy
Computer Science…….……..Navy Blue
Earth and Environmental Engineering……...…….…….Teal
Electrical Engineering…….……Royal Blue
Industrial Engineering and Operations Research……...Black
Mechanical Engineering……...Columbia Blue

PROJECTS

Applied Physics and Applied Math Department

1. **Nanostructure Enhanced Polymer Coatings to Induce Passive Cooling**
   Dillon Kraus
2. **Protocol Development for Analysis of Microbial Biodegradable Polymer Production from Waste Feedstock**
   Ramya Ahuja
3. **Self-Assembly of Iron Oxide Nanoparticles at Liquid Interfaces**
   Kathleen Kennedy
4. **Size Dependent Lattice Expansion and Bulk Modulus of Co_3O_4 and MgO**
   Yuxuan Xia
5. **Towards a Graphene Oxide Membrane Made Impermeable to Water**
   Adam Jaffe
6. **Using High Energy X-rays to Watch Milk Sugar Crystallize**
   Daniel Puttmann

Biomedical Engineering Department

1. **AQubeI**
   Jorge Santiago Pena, Easter Thames, Mayra Velazquez, Ludan Zhang, Nanbin Xia
2. **CatheCARE**
   Aonnicha Burapachaisri, Charles Pan, Aishwarya Raja, Chanond Sophonpanich
3. **cerVIA**
   Jahrane Dale, Olachi Oleru, Ritish Patnaik, Stephanie Yang
4. **Frontinus Nebulizer**
   Anna Bystran, Francesca Fasullo, William Smith, Manuel Tamargo, Shirley Zhang
5. **HelioCure**
   Jason Kang, Bryan Wang, Vivian Zhang, Jennifer Zhu
6. **HipsDL**
   Dennis Bienstock, Paul Custodio, Michael Dermksian, Hanbin Wang Jr.
7. **LIfeHug**
   Natalie Chee, Danielle Cooke, Jiyoon Kim, Xuan Ha Nghiem, Tayler Reynolds
8. **NeoInfuse**
   Bret McCarthy, Steve Rwema, Gurbani Suri, Eamon Thomasson
9. **Oculus Prime**
   Joshua Bazile, Jaime Castro, Elizabeth Dente, Andrea Ortuno
10. **Resistaderm**
    Lauren Cardenas, Shannon K. Haynie, Jamila K. Martin, Tessa M. Kroll
11. **SafenSound**
    Christopher Farley, Chuqiao Huyan, Arnesh Jajoo, Adam Pluchinsky, Ai Phuong Tong
12. **SafeStep**
    Ajit Singh, Eric Tong, Anthony Yang, Wenlan Zheng

Civil Engineering Department

1. **Blue Lion Skyway**
   Alex DuVall, Andrew Young, Antonella Landaeta, Deborah Owolabi, Isaac D'Auria, Jacklyn Uniza, Jane Manley, Jessica Sacks, Kylie White, Matt Dalrymple, and Muhammad Ahsan
2. **South Poughkeepsie Canoe Club Crossing**
   Omar Arafa, Frank Fang, Alexandre Issa-El-Khoury, Tyler Mattingly, Jumari Robinson, Idris Sardharwala, Etsub Ketema Tadesse, Walter Trumbull, Ji Hoo Woo, Zachary Wyche, Joseph Zaragoza
3. **Sunfish Cove Crossing**
   Andrew Chapman, Nick Durham, Akiva Goldstein, Maria Idrovo, David Jacobs, Colby Johnson, David Kornbluth, Steven Lowinger, Suyesh Thapa, Mark Wang
4. **The Teller's Point (TP) Bridge**
   Ivy Lin, Fumin Li, Yoojin Kim, Peter Swanson, Roberto Bravo, Jintong Yan, Inuri Illeperuma, Matthew DeMasi, William Bambury, Ishaan Nagpal, Thomas Dougherty

Computer Science Department

1. **Dice Programming Language**
   David Watkins
2. **Note Hashtag**
   Kevin Chen, Brian Kim, Edward Li

Earth and Environmental Engineering Department

1. **Life Cycle Analysis of Organic Hydroponic Fertilizer Production**
   Akiko Shimizu, Christine Djan, James Geddis, Shirin Dey
2. **Optimization of Pharmaceutical Waste Treatment**
   Elizabeth Adkins, Fazena Bacchus, Aine Chalmers, Mounir Ennenbach
3. **Solar Power and Distributed Energy Storage in New York City for Storm Resilience**
   Gabriella LoConte, Karmina Padgett, Elline (Yiwei) Zheng

Electrical Engineering Department

1. **Auto-Powered Water Meter**
   Nazli Tuncer and Gayathri Ganesh
2. **BCMI**
   Nathan Gubser, Andrew Jorquera, Charles Yolen and Dominique Evans
3. **ClearChat**
   Caleb Fujimori, Jeffrey Yuan, Harrison Liew
4. **Dynamic Guitar Effects Pedal**
   Hayley Ekle, Nicole Grimwood, Nicolo Montecalvo
5. **Jumping Robot (cross-listed with Mechanical Engineering)**
   Daniel Garcia, Rienzi Gokea, Andrew Vogel, Steve Jaycox, and Diego Song
6. **KeyHand**
   Galen Mack-Crane, James (Cedric) Mayer, Daniel Sawyer, and Julian Wong
7. **Light-Emitted Drum Set (LED)**
   Saleil Bhat, Syed Mohsin
8. **Pool Playing Robot (cross-listed with Mechanical Engineering)**
   Stefan Boyce, Amogh Kumar, Michael Trietsch, John Del Latto, and Dennis Mars
9. **Quadruped Robot (cross-listed with Mechanical Engineering)**
   Gwendolyn Archambault, Neil Orzechowski, Sydney Sherman, and Chad Tarpley

10. **Remote Water Management System**
    Felipe Vargas, Robert Viramontes, Jessica Zhao
11. **Thermal Imager**
    Barry Xu
12. **USCN**
    Yi Wu, Yizhou Shen, Yutao Gu, Yuxin Yang

Industrial Engineering and Operations Research Department

1. **Operations Research for Humanitarian Logistics: A Recent Review**
   Andelyn Russell
2. **Statistical Analysis on the Overnight and Intraday Returns of Emerging Market ETFs**
   Xiao Xu

Mechanical Engineering Department

1. **Baby Instron Machine**
   WuJoon Cha, Sydney Garay, Jun Guo, and Dami Lee
2. **Braille Teacher**
   Marco Nedungadi, Stephanie O'Gara, Ravish Rawal, Jason Tsui, and Sigal Winfield
3. **Compensated Cable Gantry**
   Christopher Bolger, Brett Harrington, Leslie Hill, and Alexander Mango
4. **Equine Therapy Chair**
   Kirsten Arnell, Matthew Heartney, Claudia Moreira, and Matthew Sheridan
5. **Jumping Robot (cross-listed with Electrical Engineering)**
   Daniel Garcia, Rienzi Gokea, Andrew Vogel, Steve Jaycox, and Diego Song
6. **Knitting Machine**
   Laiya Ackman, Cynthia Hajal, Zhaoxin Hu, Alexandra Pan, and Megan Patoskie
7. **MicroGravity Chip Collector**
   Damien Chang, Javier Rodriguez, Luis Torres, and Andy Yang
8. **Pool Playing Robot (cross-listed with Electrical Engineering)**
   Stefan Boyce, Amogh Kumar, Michael Trietsch, John Del Latto, and Dennis Mars
9. **Quadruped Robot (cross-listed with Electrical Engineering)**
   Gwendolyn Archambault, Neil Orzechowski, Sydney Sherman, and Chad Tarpley
10. **Regenerative Baby Stroller**
    Tracie Brown, Christine Capper, Andrei Shylo, and Thomas Snyder
11. **Robotic Gold Putter**
    Turki Alrashed, Andrew Arredondo, Spencer Hobson, and Rebecca Stussman
12. **Spider Robot/Stewart Platform**
    Ty'Quish Keyes, Vasu Rabaib, Jacob Simmonds, and Shajie Zang
13. **Tennis Ball Fetcher**
    Gerardo Cervantes, Devon Harvey, Eric Simmons, and Nicolas Sun
14. **Tensegrity Snake Robot**
    Taryn Bailey, Bryan Cao, Rosemarie Murray, and Joshua Woods

Applied Physics and Applied Math

Nanostructure Enhanced Polymer Coatings to Induce Passive Cooling

Dillon Kraus
Advisor: Professor Nanfang Yu

The research entails creating a very thin coating comprised of polymer embedded with nanostructures of various materials, which has been designed to maximize reflectivity in the visible region of the electromagnetic spectrum, so as to reflect high intensity sunlight, as well as emissivity in the mid-infrared region of the spectrum, i.e. the region of most thermal radiation on earth. The motivation for this is to minimize the amount of heat the coated object will absorb, and maximize the amount of heat it releases, ultimately enabling a passive cooling effect. This has been done by carefully selecting the nanoparticle material compositions, as well as shapes, in addition to picking the best polymer for this type of function.

Keywords: Nanoparticles, polymer science, metamaterial, emissivity, reflectivity, passive radiative cooling

Protocol Development for Analysis of Microbial Biodegradable Polymer Production from Waste Feedstock

Ramya Ahuja
Advisor: Kartik Chandran, Mark van Loosdrecht (Professor, Delft University of Technology)

Both research projects focused on production of biodegradable polymers accumulated by bacteria within their cells using organic waste as feed source. The objective was to maximize accumulation capability of microbial culture by applying feast-famine selection pressures that allow enrichment and growth of PHA accumulating bacteria. This sub-study focused on identification and optimization of methods for rapid measurement of accumulation during experiments to characterize the process. A related question was how the errors (systemic and human) could be quantified to determine reliability of the final measurement. Samples collected from different stages of the PHA production process were esterified and the monomers extracted to be analyzed using gas chromatography. For protocol development tests were undertaken to confirm effective drying of biomass by oven, accurate estimation of any remaining fluid as percentage of dried sample, release of intracellular PHA before esterification and consistency of preparation and measurement. Information regarding percentage of PHA was obtained over the cycle of enrichment and accumulation. This enabled the creation of a feedback loop with the design and operation of the pilot, informing future experimentation with the set-up. Data obtained was compared to that of thermogravimetric (TGA) analysis of the same biomass samples. A supplementary method for qualitative *in situ* analysis of intracellular PHA was developed based on selective staining by Nile Blue A and fluorescence imaging with DsRed (ex 558nm, em 583nm).

Keywords: biodegradable plastic, waste, resource recovery, biotechnology

Self-Assembly of Iron Oxide Nanoparticles at Liquid Interfaces

Kathleen Kennedy
Advisor: Professor Irving P. Herman

Self-assembly of nanoparticle monolayers at liquid interfaces using immiscible solvents is a fairly well established technique. In this project, certain miscible solvent pairs were also found to result in ordered monolayers. The assembly processes of immiscible and miscible systems were investigated and compared using optical microscopy. Samples were then taken from each system and characterized using transmission electron microscopy (TEM) and grazing incidence small angle x-ray scattering (SAXS). Further work has begun investigating how these assembly techniques can be adapted for use with superatoms and nanosheets.

Size Dependent Lattice Expansion and Bulk Modulus of Co_3O_4 and MgO

Yuxuan Xia
Advisor: Professor Siu-Wai Chan

Uniform crystalline nanoparticles ranging from 7nm to over 100nm were prepared for the Co_3O_4 and MgO oxide systems using an aqueous precipitation method and a sol-gel synthesis method respectively. The nanoparticles were characterized by transmission electron microscopy (TEM) and x-ray diffraction (XRD). Analysis of diffraction patterns to obtain lattice parameter shows lattice expansion for smaller nanoparticles: 0.47% expansion from bulk for 7nm MgO and 0.15% expansion from bulk for 9nm Co_3O_4. Bulk modulus measurements were taken for MgO using high pressure xrd up to a pressure of 10GPa with a pressure medium of 4:1 Methanol: Ethanol. Bulk Modulus for nanoparticles increased then decreased from bulk with decreasing crystallite sizes. A maximum is reached around 14nm.

Keywords: nanoparticle, lattice parameter, bulk modulus, Co3O4, MgO

Towards a Graphene Oxide Membrane Made Impermeable to Water

Group Name: Herman
Adam Jaffe
Advisors: Professor Irving Herman, Datong Zhang

Graphene oxide has been shown to be permeable to water, even while it is impermeable to other liquids, vapors, and gases, including helium. The goal of the project was to design a layered material, based on graphene oxide, which would be impermeable to water as well as the other liquids, vapors, and gases.

Using High Energy X-rays to Watch Milk Sugar Crystallize

Daniel Puttmann
Advisor: Professor Billinge and Maxwell Terban (MSE)

Amorphous dispersions are critical to improving the performance of food and pharmaceutical products. However, they are highly unstable and tend to turn back to their crystalline counterparts. In this study, a high energy X-ray probe is used to watch the structural development as amorphous lactose molecules begin to order and crystallize. By understanding this behavior, processes can be designed to enhance the shelf life of life saving drugs and taste-bud saving foods.

Keywords: Total Scattering pair distribution, Phase composition

Biomedical Engineering

AQubeI

Jorge Santiago Pena, Easter Thames, Mayra Velazquez, Ludan Zhang, Nanbin Xia
Advisor: Professor X. Edward Guo

Asthma is the world's leading chronic respiratory disease, with a worldwide prevalence of 300 million people. Pollutants such as ozone, sulfur dioxide, and particulate matter have been found to increase the risk of asthma attacks. The best approach that asthmatic patients and their doctors can employ to deal with these triggers is to manage exposure, which can be done through robust, personalized air quality monitoring. There is a need for a device or platform that provides accurate, spatiotemporal air-quality information. Our solution, AQubeI, senses the aforementioned pollutants, providing accurate real-time measurements of their concentrations and warning users when they are in areas where environmental pollutants may trigger their asthma. Initial prototype testing shows that AQubeI accurately monitors the relevant air pollutants and can rapidly clear its volumetric space for repeated air quality examinations.

CatheCARE

Aonnicha Burapachaisri, Charles Pan, Aishwarya Raja, and Chanond Sophonpanich
Advisor: Professor X. Edward Guo

Each year in the U.S., 3 to 5 million central venous catheters (CVCs) are implanted into patients suffering from cancer, kidney failure, and Crohn's disease. CVCs administer chemotherapeutic drugs, infuse nutrients, and remove vascular waste. Despite the prevalence and usefulness of CVCs, catheter-related bloodstream infections (CRBSIs) are one of the leading causes of hospital-acquired infections. The primary source of CRBSIs is exogenous bacteria on catheter hubs that migrate into the catheter lumen. CRBSIs, which can lead to fatal sepsis, have an associated mortality rate of 25% and an annual cost of over $5 billion. CatheCARE is an attachable device that administers germicidal doses of ultraviolet light directly onto the hub. Unlike existing competitors such as ethanol caps and antimicrobial catheters, our device eradicates 99.99% of bacteria, continuously sterilizes even during line access, and does not contribute to bacterial resistance. CatheCARE is a unique, compatible, and easy-to-use device that can sterilize hubs, preventing the complications that arise from catheter-borne infections.

cerVIA

Jahrane Dale, Olachi Oleru, Ritish Patnaik, Stephanie Yang
Advisor: Professor Katherine Reuther

Cervical cancer devastates lives if not detected early; however, early diagnosis is often not possible in low- and middle-income countries (LMICs). 90% of the 555,000 cases and 310,000 deaths due to cervical cancer in 2008 occurred in LMICs. Visual inspection with acetic acid (VIA) is a common method of cervical cancer screening in these settings; however, VIA shows poor diagnostic sensitivity (67-79%) and specificity (49-86%) due to inadequate lesion identification training, inconsistent lighting conditions, and the inherent subjectivity of diagnoses. The cerVIA system meets the need for improved pre-cancerous lesion detection in LMICs in a manner that increases both sensitivity and specificity of VIA. The system combines a speculum-fitted camera that produces high-quality images of the ectocervix with a screening algorithm that analyzes these images for lesions and provides this information to clinicians. Initial testing demonstrates that the cerVIA system captures images appropriate for analysis and achieves levels of diagnostic sensitivity and specificity that are higher than conventional VIA.

Frontinus Nebulizer

Anna Bystran, Francesca Fasullo, William Smith, Manuel Tamargo, Shirley Zhang
Advisor: Professor Henry Hess

Asthma affects over 200,000 infants in the United States. Infants having an asthma attack, which is characterized by rapid, shallow breathing due to constriction of the airwaves, are treated using the blow-by method, wherein the nebulized albuterol is delivered through a mask that is wafted in front of the patient's face. The blow-by method of indirect drug delivery severely reduces efficacy of treatment, with less than 1% of nebulized albuterol delivered to the bronchioles. This results in increased treatment time, drug wasted due to diffusion, and additional stress to the children receiving therapy. Patients and their caregivers, both in home and emergency settings, require a treatment that increases drug deposition and minimizes loss as well as stress on the child. Our system uses a breath actuated focusing array to direct the flow and increase drug deposition. Preliminary testing shows that deposition and focusing are significantly increased when using our device compared to the blow-by method. Ultimately, the Frontinus Nebulizer will provide more efficient treatment for pediatric asthma patients.

HelioCure

Jason Kang, Bryan Wang, Vivian Zhang, Jennifer Zhu
Advisor: Professor Clark Hung

Hyperbilirubinemia, which leads to jaundice in newborns, accounts for 10% of neonatal mortality worldwide. Although jaundice is easily treatable, annually over 5.7 million neonates in South Asia and Sub-Saharan Africa do not receive treatment. The current standard of care is blue light phototherapy. However, sunlight phototherapy is prescribed in areas where blue light units are unavailable. There are significant risks associated with unprotected sunlight exposure, and administration is limited to daylight hours. HelioCure is a hybrid phototherapy device that treats neonatal jaundice using blue light from the sun when it is available and LEDs in low-light conditions. It mitigates risks from sunlight exposure by filtering out >99% of UV rays and >65% of IR rays, allows for continuous phototherapy, and costs <$50 per device. Through its ease-of-use, portability, and cost, HelioCure addresses the gap in care for neonatal hyperbilirubinemia in under-resourced settings.

HipsDL

Dennis Bienstock, Paul Custodio, Michael Dermksian, Hanbin Wang Jr.
Advisor: Professor Sunil Agrawal and Dr. Rami Said

After hip surgery, mobilization of the hip joint is recommended to promote recovery and restoration of full range of motion. In the first few post-surgical weeks, passive mobilization is required otherwise the patient can develop stiffness, adhesions, and atrophy in the repaired joint. The current methods of passive mobilization are physical therapy (PT) and the knee continuous passive motion (CPM) machine. However, these methods both fall short in that PT can only be sustained in the therapist's office and costs an average $558 per session. The knee CPM only takes the hip partially through one plane of motion. There is a clear need for an affordable and portable method of hip mobilization with a higher range of motion. Our device achieves these goals by passively taking the hip through 120 degrees of flexion and 30 degrees of abduction, theoretically improving mobilization for patients who have had hip replacements or arthroscopic procedures.

LifeHug

Natalie Chee, Danielle Cooke, Jiyoon Kim, Xuan Ha Nghiem, Tayler Reynolds
Advisor: Professor Elisabeth Olson

In low resource hospitals, such as Mulago Hospital in Kampala, Uganda, there is a dearth of neonatal vital signs monitors. This lack of monitors can result in under-detection of dangerous events, such as bradycardia, apnea, or abnormally high or low body temperature. Vital sign monitoring in low resource hospitals is often done via manual, periodic measurements in overcrowded wards, which presents a significant burden to healthcare professionals and makes it likely that infant distress will be missed. LifeHug has created an easy-to-use, comfortable monitoring band that continuously measures a neonate's heart rate, respiratory rate, and temperature. The LifeHug monitor produces audio and visual alerts when it detects an abnormal vital sign measurement. A portable display monitor will allow for quantification of measurements. Our device provides a means for healthcare workers to better care for babies in low resource settings.

NeoInfuse

Bret McCarthy, Steve Rwema, Gurbani Suri, and Eamon Thomasson
Advisors: Professor Barclay Morrison

In third world countries, where hospitals are significantly understaffed, the electrical grid is unreliable, and resources are limited, standard intravenous (IV) drug delivery via infusion pumps for neonates is largely unavailable. For example, the neonatal unit at Mulago Hospital in Kampala, Uganda, currently serves around 70 neonates while employing only two nurses, and there are not enough infusion pumps to adequately support every neonate. Mulago also lacks the resources to repair infusion pumps or replace parts when technical problems arise. Commercial infusion pumps costs range from $1000 to $7000, which is cost-prohibitive for many low-funded clinics and hospitals, including Mulago. Drugs can be delivered via bolus injections; however, this can be dangerous, particularly for low birth weight infants. NeoInfuse proposes a low-power infusion device which supplies IV fluids and drugs continuously, allowing for fluid and drug therapy for neonates in low-resource clinics. Compared to convention infusion pumps, our device is user-friendly, self-regulating, and more affordable. It is also safer than bolus injections that would otherwise be administered.

Oculus Prime

Joshua Bazile, Jaime Castro, Elizabeth Dente, and Andrea Ortuno
Advisor: Professor Tal Danino

Inhabitants of poor, rural communities lack access to formal eye exams and tend to live with uncorrected refractive error (URE), a major cause of treatable blindness. URE affects more than 625 million people worldwide, 94% of which live in developing countries. Vision impairment due to URE is responsible for $202M in productivity losses. Diagnosing refractive error requires trained optometrists and costly equipment to provide testing that are not readily available in rural settings. Oculus Prime is an eye examination device for health workers, both trained and untrained, who cannot afford expensive equipment. The device utilizes an estimation retinoscopy technique to diagnose URE and provide a corrective eyeglass prescription. Operating within 1.5 Diopters of accuracy, the device is low-cost, portable, and durable. Oculus Prime aims to provide accurate prescriptions for different refractive errors to patients in low-resource settings.

Resistaderm

Lauren Cardenas, Shannon K. Haynie, Jamila K. Martin, and Tessa M. Kroll
Advisor: Professor Clark T. Hung

The transmission of skin infections in contact sports like wrestling or mixed martial arts is a problem with no current course of management adequately ameliorating the issue. Cutaneous infections are perceived as an inherent risk by contact sport athletes. Herpes, Impetigo, Ringworm, and MRSA are the most notable skin infections affecting athletes and can lead to lifelong management of outbreaks, psychological distress, and in severe cases, kidney failure and death. There are over 5 million contact athletes in the U.S. alone, with 10-20% of them developing skin infections per year. To combat these issues, Resistaderm has developed a bioplastic seal to prevent transmission of cutaneous infections during contact sports. The seal will be appropriate for both competition and practice, providing an impermeable, flexible, and sweat resistant physical barrier over the site of infection, preventing transmission. Our product provides an affordable, safe, and simple barrier method to reliably protect contact sport athletes from skin infections.

SafenSound

Christopher Farley, Chuqiao Huyan, Arnesh Jajoo, Adam Pluchinsky, and Ai Phuong Tong
Advisor: Professor Paul Sajda

Magnetic resonance imaging (MRI) is one of the most powerful imaging methods in medicine, but the acoustic noise generated by MRI scanners can reach up to 130dB, a level 10 times as loud as thunder. Patients are continuously subjected to this noise during a scan, risking tinnitus and permanent hearing damage. Noise at these levels causes inflammation in the ear, contributing to a 75% misdiagnosis in scans of acoustic nerves and auditory centers areas of the brain. MRI centers currently utilize passive noise reduction techniques -- earplugs or headphones -- but these hearing protection devices do not reduce the noise to safe levels. Active noise cancellation (ANC) headphones, which can sufficiently attenuate the noise, are available only at a cost-prohibitive price (greater than $10,000) precluding widespread adoption. SafenSound has developed a low cost (less than $500) ANC headphone using a novel laser microphone system to protect patients hearing during MRI scans.

SafeStep

Ajit Singh, Eric Tong, Anthony Yang, and Wenlan Zheng
Advisor: Professor X. Edward Guo

Falls can cause significant injuries and result in exorbitant medical costs, especially in the geriatric population. Falls are most devastating and common among the geriatric population due to a combination of factors including age-related musculoskeletal frailty, deficits in sensory perception, and neurological diseases. Despite an increase in the use of walkers amongst elderly people susceptible to falls, they are still vulnerable due to insufficient training and overreliance on the walker for support and balance. The SafeStep walker addresses this deficit by monitoring and providing feedback on the patient's walking performance. SafeStep detects and warns of postural instability through real time collection and processing of pressure data obtained from the walker and the user's feet. This system can effectively train the patient to use the walker in a safer and non-intensive manner.

Civil Engineering

Blue Lion Skyway

Alex DuVall, Andrew Young, Antonella Landaeta, Deborah Owolabi, Isaac D'Auria, Jacklyn Uniza, Jane Manley, Jessica Sacks, Kylie White, Matt Dalrymple, and Muhammad Ahsan
Advisor: Tom Panayotidi, Lecturer

The Blue Lion Skyway is a network tied arch bridge designed to cross the Hudson River just south of Albany, NY. The proposed structure is to be constructed using structural steel and concrete and will have a span length of 650'. The orthotropic steel deck, X-bracing along the top of the arch, and crossed suspension cables provide an efficient, sturdy, and aesthetically pleasing design. The bridge will provide a connection between Albany and Rensselaer counties allowing for two lanes of traffic travelling in each direction, as well as providing an elevated pedestrian walkway for the community.

Keywords: Albany, Arch Bridge, Blue Lion Skyway, Hudson River, Network Arch Bridge, Rensselaer County

South Poughkeepsie Canoe Club Crossing

Omar Arafa, Frank Fang, Alexandre Issa-El-Khoury, Tyler Mattingly, Jumari Robinson, Idris Sardharwala, Etsub Ketema Tadesse, Walter Trumbull, Ji Hoo Woo, Zachary Wyche, and Joseph Zaragoza
Advisor: Tom Panayotidi, Lecturer

The challenge proposed to our group was to design a cable-stayed bridge crossing over the Hudson River. Several factors need to be considered before deciding where and how to build a bridge of this size, including the surrounding traffic flow, river span length, river depth, land elevations on either side of the river, and proximity of nearby highways. We chose a site in South Poughkeepsie that met all our criteria, and designed a six-lane cable-stayed bridge to meet the demands of the location. The bridge will consist of two concrete towers positioned close to the shoreline, with a main span of 2250 feet from tower to tower, and a total length of 4500 feet. The towers are reinforced concrete "A" frames that are 676 feet tall. The cable stays are positioned 50 feet apart on the deck in two planes, and 10 feet apart on the towers in two planes. We also made a hypothetical construction schedule and Gantt Chart. The bridge would cost about $1.7 billion.

Sunfish Cove Crossing

Andrew Chapman, Nick Durham, Akiva Goldstein, Maria Idrovo, David Jacobs, Colby Johnson, David Kornbluth, Steven Lowinger, Suyesh Thapa, and Mark Wang
Advisor: Tom Panayotidi, Lecturer

Sunfish Cove Crossing traverses the Hudson River just south of the Mid-Hudson Bridge, connecting Route 9W on the New Jersey side with Route 9 on the New York side. The need for this fixed-crossing arose due to the increasing urbanization of the New York Metro area. By supporting six lanes of traffic, Sunfish Cove Crossing will alleviate congestion on both the Mid-Hudson Bridge and the Newburgh-Beacon Bridge.

The cable-stayed design will maximize structural efficiency with a main span length of 2,250 feet, while also minimizing environmental impact through off-site construction and the application of LEED principles. Designed with strict adherence to AASHTO, AISC Steel Manual, and ACI, and constructed through the cantilever method, Sunfish Cove Crossing will provide a safe and minimally disruptive solution for a vital regional link. Further, the striking tower height of 800 feet above water level will offer a signature landmark for all of the Northeast.

Keywords: Bridge, Cable-stayed, Sunfish Cove, Hudson River, New York, New Jersey, LEED, AASHTO

The Teller's Point (TP) Bridge

Ivy Lin, Fumin Li, Yoojin Kim, Peter Swanson, Roberto Bravo, Jintong Yan, Inuri Illeperuma, Matthew DeMasi, William Bambury, Ishaan Nagpal, and Thomas Dougherty
Advisor: Tom Panayotidi, Lecturer

The Teller's Point (TP) Bridge is a suspension bridge that is 1.4 miles (7392 feet) long from anchorage to anchorage, with a main span of 0.83 miles (4382 feet) and side spans of 0.26 miles (1373 feet). The remaining 0.05 miles (264 feet) of the bridge lies between the end of the cable support on the eastern side and the anchorage on the eastern shore. The TP Bridge features 680 ft tall steel towers with aesthetic innovation, and an enclosed aerodynamic deck design that reduces vertical vibration due to wind loads. The bridge is comprised of approximately 144 spanning orthotropic box girder deck units that are 50 feet long and 80 feet wide and constructed with deck erection sequence from mid-span to pylons.

The project criteria states that the suspension bridge is to be situated at a location between Tappan Zee Bridge and Bear Mountain Bridge. The bridge is situated in an opportune area of the river that narrows from its more consistent width of approximately 3 miles. The chosen site for bridge construction is the area that extends from Croton Point Park in Westchester County to Hook Mountain in Rockland County. They are both fairly populated areas that do not have any connectivity. The Teller's Point Bridge will reduce commute time between the two locations by 50%. The bridge is to be made of steel and have reinforced concrete piers and anchorages with a roadway at a height of 212 feet above the water level. The proposed design, supported by pile foundations and anchorages, accounts for dead and live loads as well as ice and extreme event loadings and is verified by AASHTO, AISC and SDI code standards. The design was modeled in Rhino and tested using SAP2000, and the photographs of the bridge were rendered in Maya. An environmental impact assessment was developed, and construction management techniques of project scheduling and cost estimating were also performed.

Keywords: Suspension bridge, aerodynamic deck design, steel towers

Computer Science

Dice Programming Language

David Watkins
Advisor: Professor Stephen Edwards

Dice is a general purpose, Java-like programming language. It was built using the LLVM as its backend and features useful programming language features such as inheritance, file-inclusion, cross-platform support, objects, and arrays. This project was done as part of the COMS4115 Final Project.

Keywords: Programming Language, Java, LLVM

Note Hashtag

Kevin Chen, Brian Kim, and Edward Li
Advisor: Professor Stephen Edwards

We created a language optimized for exploring and composing music. The syntax facilitates writing snippets of music. Standard library functions transform and combine these snippets, allowing the programmer to take advantage of the repetition found in many songs. The song can then be written to an audio file (WAV).Our language revolves around the concept of tracks. A track is a variable length sequence of chords, each with a list of pitches and a length, plus metadata such as key signature, tempo, time signature. Tracks are the building blocks of a composition, because they allow the user to specify a few snippets of music, and then concatenate, overlay, transform, or otherwise reuse them while creating a song.

Note Hashtag is also a modern language that provides type inference, static typing, low-overhead memory safety, and a clean, readable syntax. Users can simply concentrate on writing a great song, and let the compiler take care of the rest.

Keywords: compiler, music composition, music synthesis, type inference, OCaml

Earth and Environmental Engineering

Life Cycle Analysis of Organic Hydroponic Fertilizer Production

Akiko Shimizu, Christine Djan, James Geddis, and Shirin Dey
Advisor: Professor of Professional Practice, Robert Farrauto

This senior design project explores a life cycle analysis (LCA) on the production process of organic hydroponic fertilizer products manufactured by the partnering company, Re-Nuble Inc. The life cycle analysis was conducted on a per unit basis of generated fertilizer, taking into account energy inputs at various points in the manufacturing process. The derivatives of this LCA were used to quantify the environmental impact of the process by interpreting energy consumption in terms of carbon footprint and greenhouse gas emissions. The overall objective of this quantification is to evaluate the company Re-Nuble as an environmentally friendly alternative to other hydroponic fertilizers on the market, whether organic or not. When this analysis was conducted Re-Nuble's product was found to emit up to 44% fewer emissions than potential alternatives. However, there was still room for improvement in Re-Nuble's manufacturing process, such as sourcing materials from a more local supplier and increasing the amount of vegetable waste that is incorporated into their product. In addition to this, it was found that the potential emissions savings from pursuing urban farming in New York City would be the equivalent of taking over 1,000,000 cars off the road.

Optimization of Pharmaceutical Waste Treatment

Elizabeth Adkins, Fazena Bacchus, Aine Chalmers, Mounir Ennenbach
Advisors: Eric Auerbach, P.E., ARCADIS Consulting- Environmental Engineer; Robert Farrauto, Professor of Practice, and Dr. Kartik Chandran, Associate Professor

Given the increased attention to the scarcity of accessible and clean water, water treatment has become an especially salient task for environmental engineers. The main objective of this project is to evaluate the accuracy of computer modeling software in characterizing pharmaceutical wastewater treatment. Based on the assessed utility, the group makes recommendations of whether ARCADIS Consulting (the partnering organization in Queens, NY) should purchase *Envirosim* modeling technology. Additionally, the group completed an exploratory analysis on plant modifications that could minimize costs and increase efficiencies.

Keywords: Computer modeling, computer simulation, waste water treatment, environmental technology, environmental consulting

Solar Power and Distributed Energy Storage in New York City for Storm Resilience

Gabriella LoConte, Karmina Padgett, Elline (Yiwei) Zheng
Advisors: Professor of Professional Practice, Robert Farrauto, Chris Neidl- Director of Here Comes Solar at Solar One

After Hurricane Sandy, New York City realized that it must implement a storm resiliency plan for the future, especially with the expected increase in drastic storms due to global warming. The Governor's Office has asked Solar One to work on improving storm resilience through the use of solar photovoltaics, which would increase access to electricity in emergency situations. Through this report, we will explore the potential for using solar photovoltaic systems paired with battery technology for emergency relief in New York City. Suitable battery and solar panel technologies were identified through an extensive comparison process, narrowing the scope to 10 batteries and solar systems. However, once an analysis on the appropriate approval processes in New York City was included, American Vanadium was selected for implementation on the site. American Vanadium is ideal because of its proven success in the NYC market and MTA project as well as its ability to meet the necessary storage capacity for the Manhattan Beach Jewish Center's demands. More specifically, the FB10-100 model was recommended as it has a lifetime of 20 years, and a low replacement rate allowing for low overall project costs. The ideal location and system for solar panels was determined after considering a range of conditions including roof status, solar availability, and labor restrictions. Next steps for Solar One include submitting a Review for Proposal (RFP) in order to be approved by all the appropriate government bodies including the NY Fire Department and Department of Buildings. The timeline for battery approval process varies, due to lack of familiarity with the technologies. But due to the promising future of solar and storage in New York City, the approval processes will most likely become more structured and uniform. Thus, more New York City residents will have access to the economic and storm resilience benefits that solar and storage systems offer.

Electrical Engineering

Auto-Powered Water Meter

AUWM
Nazli Tuncer and Gayathri Ganesh
Advisor Name: David Gidony, Graduate Research Assistant

Our wireless energy-harvesting water meter can be installed in the main water supply pipe of any home. When requested by the resident, the device transmits water consumption data for viewing using an app. Real time monitoring, as opposed to the current system of receiving a monthly bill, could significantly improve water stewardship by offering the resident detailed information about consumption associated with specific activities (showers, dishwashing, and so on).

Keywords: Energy harvesting, wireless data transmission, water conservation

BCMI

Nathan Gubser, Andrew Jorquera, Charles Yolen, and Dominique Evans
Advisors: Dr. Nima Mesgarani and Alexander Gazman

The Brain Computer Music Interfaces (BCMI) is a step toward an instrument which enables mind-controlled musical composition and even live performance. Through this system we hope to offer individuals with restrictive neurological conditions the opportunity to participate in the joy, self-expression, and community of music.

Keywords: neuroscience brain computer interface BCI BCMI electrical engineering EE prosthesis medical music audio sound art

ClearChat

Caleb Fujimori, Jeffrey Yuan, and Harrison Liew
Advisor Name: David Vallancourt, Senior Lecturer

ClearChat is a revolutionary directional hearing aid which greatly enhances the user's ability to hear desired sounds and voices without amplifying other sounds. For example, ClearChat brings the conversation at one's table in a noisy restaurant to the fore, with other voices and noise from the sides and behind suppressed. ClearChat consists of a microphone array mounted on the frame of eyeglasses and a digital signal processor (DSP) that performs beamforming on the microphone signals. The user has the freedom to choose a beam direction. After processing, the desired voices are heard clearly above all interfering sources of speech and noise.

Keywords: directional listening device, beamforming, signal processing, audio signal processing, noise reduction, speech filtering, hearing enhancement, cocktail party problem

Dynamic Guitar Effects Pedal

My Electrical Romance
Hayley Ekle, Nicole Grimwood, and Nicolo Montecalvo
Advisor: David Vallancourt, Senior Lecturer

The Dynamic Guitar Effects (DGE) pedal packs multiple effects (distortion, phasing, reverb, and more) into a single space-saving device. While some other products do this, the DGE is unique in combining both digital and analog effects in a single package, improving tone quality and versatility at the same time. Tweakable via traditional knobs and switches, it also features wireless control and a microphone input that can be used for beat-synching effects such as echo. Robust and musical, the DGE is a pedal for both beginners and professionals.

Keywords: Guitar, Digital Signal Processing, Effects, Raspberry Pi, IoT, Music, Beat-Tracking, Analog Circuits

KeyHand

Galen Mack-Crane, James Mayer, Daniel Sawyer, and Julian Wong
Advisor: Alexander Gazman

The KeyHand is a glove equipped with an array of sensors providing information on hand movement, orientation, and finger position. To demonstrate the KeyHand's capabilities, we use it to control a 3D hand model set in a virtual environment. Our aim is to provide subtler and more dexterous manipulation of virtual objects than is possible with usual digital interfaces such as keyboards and touchscreens.

Keywords: wearable, virtual reality, IoT, biosensor, Arduino, motion tracking, games

Jax - Hopping Robot (cross-listed with Mechanical Engineering)

The Jaxon 5
Daniel Garcia, Rienzi Gokea, Steve Jaycox, Diego Song, and Andrew Vogel
Advisors: Senior Lecturers David Vallancourt and Fred Stolfi, Brian Jones, and Michael Fernandez

Jax is a research testbed for the development of machines that use legs to run and jump. Our hopping robot is able to achieve continuous locomotion by recycling its elastic potential energy. It uses a pneumatic system to minimize energy losses while allowing for a simple means to add more. It maintains balance through a control system in Matlab that calculates the best course of action based on environmental inputs detected with an Arduino. Working with Jax can help us understand animal locomotion as well as build useful legged vehicles.

Keywords: Jumping, hopping, robot, monoped, locomotion, mechanisms, biomimetics, dynamic motion, pneumatics, Arduino.

Light-Emitted Drum Set (LED)

Saleil Bhat, Syed Mohsin
Advisor: David Vallancourt, Senior Lecturer

The light-emitted drum set is a portable, flexible, and novel approach to making music. It uses an LED projection system to display a virtual drum set. By striking these virtual drum pads with wireless accelerometer-equipped drumsticks, the user can produce a variety of dynamic sounds. The light-emitted drum set's small form factor, customizability, and ability for use on multiple surfaces make the system an exciting musical medium. But don't just take our word for it; come over and try it out for yourself!

Keywords: LED projection, infrared lasers, wireless transmission, microcontroller, image processing, music, drums

Pool-Playing Robot (cross-listed with Mechanical Engineering)

The Hustlers
John Dellatto (EE), Dennis Mars (EE), Michael Trietsch (ME), Stefan Boyce (ME), and Amogh Kumar (ME)
Advisors: Senior Lecturers David Vallancourt and Fred Stolfi, Brian Jones, and Michael Fernandez

Our autonomous pool cue stick can detect a pool ball, move into proper position, and sink the ball into the pocket chosen by a human user. An overhead camera, several Arduinos, and a laptop control the stick in two dimensions as well as lift it between shots. We will demonstrate proof of concept for our robot by having it clear a table of pool balls directly on its own.

Keywords: Pool, Billiards, Robot

Quadruped Robot (cross-listed with Mechanical Engineering)

The Quad Squad
Neil Orzechowski, Gwedolyn Archambault, Chad Tarpley, and Sydney Sherman
Advisor Name: David Gidony, Graduate Research Assistant

The quadruped robot is a compact, mechanically stable, four-legged walker. Each leg has two degrees of freedom, driven by two DC motors. The eight overall degrees of freedom are controlled simultaneously by an on-board PID system. This is one sure-footed bot.

Keywords: Robot, Quadruped, Control System, DC motor

Remote Water Management System

Felipe Vargas, Robert Viramontes, and Jessica Zhao
Advisor: Alexander Gazman

Our project is a collaboration with the Morocco program of Columbia Engineers Without Borders. We have designed a robust, self-powered system that monitors the level inside of a community water tank and wirelessly controls a pump at the source (two miles distant) to refill the tank when needed. The goal of our design is to further the EWB Morocco program's efforts in reducing barriers to water accessibility.

Keywords: water, EWB, wireless

Thermal Imager

Barry Xu
Advisor: David Vallancourt, Senior Lecturer

The Thermal Imager is designed to be a mobile, infrared imaging device that employs a longwave infrared imager to provide an easily accessible real time thermal imaging system. Powered by a Raspberry Pi, the imager is designed to be able to easily interface with any monitor or Android device with HDMI or USB capabilities. The intent is to provide a simple, compact device that can be used for home projects, lab work, or any inquisitive endeavor.

Keywords: imaging, camera, infrared, thermal

Ultrasonic Cane

USCN
Yi Wu, Yizhou Shen, Yutao Gu, and Yuxin Yang
Advisor Name: David Gidony, Graduate Research Assistant

The Ultrasonic Cane addresses several limitations of the traditional walking cane for the visually impaired. Unlike the traditional cane, our ultrasonic cane can alert the user to obstacles well beyond its mechanical reach, objects at chest or head height, and can even provide estimates of a moving obstacle's velocity. Audible and tactile feedback give a user the clear and reliable information needed to navigate with confidence

Industrial Engineering and Operations Research

Operations Research for Humanitarian Logistics: A Recent Review

Andelyn Russell
Advisor: Professor Ward Whitt

Operations Research for Humanitarian Logistics: A Recent Review" is a sample of two articles described within "Review of Literature on Humanitarian Data Analysis for Operational Decision Making," an independent project completed in Fall/Winter 2015. The highlighted papers present real problems faced by humanitarian organizations and the formulation of operations research models to find optimal solutions. The scope of the review was limited to articles written after 2009 and cases in which real data were applied to models.

Statistical Analysis on the Overnight and Intraday Returns of Emerging Market ETFs

Xiao Xu
Advisor: Professor Tim Leung

This project studies three emerging market ETFs, FXI, EEM, and VWO, and compares them with the benchmark ETF, SPY.

We design a volatility ratio between the intraday returns and overnight returns of those ETFs in order to visually observe the relations between them, and find some difference and similarities among the patterns of the volatility ratios. Then we conducted statistical analysis to both visually and quantitatively compare two distribution models for the returns of the ETFs.

Keywords: ETF, statistical analysis

Mechanical Engineering

Baby Instron Machine

WuJoon Cha, Sydney Garay, Jun Guo, and Dami Lee

The development of an interactive and affordable miniature tensile tester to help high school level students explore fundamental engineering concepts and material properties (stress versus strain). Material testing samples that they can be tested to failure will be provided.

Braille Teacher

Marco Nedungadi, Stephanie O'Gara, Ravish Rawal, Jason Tsui, and Sigal Winfield

The Braille Box is an affordable product aimed to promote Braille literacy, awareness, and self-learning. The portable device is capable of providing feedback in reading and writing braille that would otherwise require trained or professional teachers.

Compensated Cable Gantry

Christopher Bolger, Brett Harrington, Leslie Hill, and Alexander Mango

Modeling the dynamics of a gantry crane and using the model to design a control system that damps undesirable sway in the payload. The model and control system have been validated through implementation on a scaled model of a gantry crane.

Equine Therapy Chair

Kirsten Arnell, Matthew Heartney, Claudia Moreira, and Matthew Sheridan

The development of an equine therapy chair to emulate the motion of a horse for the benefit of people with spinal cord injuries and neurological disabilities. The physical motion developed in the human spine while riding a horse (hippotherapy) has been shown to improve the motor function and alleviate spasticity of patients with these disorders.

Jax - Hopping Robot (cross-listed with Electrical Engineering)

The Jaxon 5
Daniel Garcia, Rienzi Gokea, Steve Jaycox, Diego Song, and Andrew Vogel
Advisors: Senior Lecturers David Vallancourt and Fred Stolfi, Brian Jones, and Michael Fernandez

Jax is a research testbed for the development of machines that use legs to run and jump. Our hopping robot is able to achieve continuous locomotion by recycling its elastic potential energy. It uses a pneumatic system to minimize energy losses while allowing for a simple means to add more. It maintains balance through a control system in Matlab that calculates the best course of action based on environmental inputs detected with an Arduino. Working with Jax can help us understand animal locomotion as well as build useful legged vehicles.

Keywords: Jumping, hopping, robot, monoped, locomotion, mechanisms, biomimetics, dynamic motion, pneumatics, Arduino.

Knitting Machine

Laiya Ackman, Cynthia Hajal, Zhaoxin Hu, Alexandra Pan, and Megan Patoskie

The knitting machine is capable of human-like knitting using two straight needles controlled by a set of cams and motors. The goal of the project is to create a personalized machine for in-home use where users can program the type of knitted fabric they want to create.

MicroGravity Chip Collector

Damien Chang, Javier Rodriguez, Luis Torres, and Andy Yang

NASA's Micro-G Next Competition includes a need for a microgravity chip collector. The device must be able to break off chips of an asteroid, collect them and store them without cross contamination between different sites. The device is subject to several other constraints detailed in the competition guidelines.

Pool-Playing Robot (cross-listed with Electrical Engineering)

The Hustlers
John Dellatto (EE), Dennis Mars (EE), Michael Trietsch (ME), Stefan Boyce (ME), and Amogh Kumar (ME)
Advisors: Senior Lecturers David Vallancourt and Fred Stolfi, Brian Jones, and Michael Fernandez

Our autonomous pool cue stick can detect a pool ball, move into proper position, and sink the ball into the pocket chosen by a human user. An overhead camera, several Arduinos, and a laptop control the stick in two dimensions as well as lift it between shots. We will demonstrate proof of concept for our robot by having it clear a table of pool balls directly on its own.

Keywords: Pool, Billiards, Robot

Quadruped Robot (cross-listed with Electrical Engineering)

The Quad Squad
Neil Orzechowski, Gwedolyn Archambault, Chad Tarpley, and Sydney Sherman
Advisor Name: David Gidony, Graduate Research Assistant

The quadruped robot is a compact, mechanically stable, four-legged walker. Each leg has two degrees of freedom, driven by two DC motors. The eight overall degrees of freedom are controlled simultaneously by an on-board PID system. This is one sure-footed bot.

Keywords: Robot, Quadruped, Control System, DC motor

Regenerative Baby Stroller

Tracie Brown, Christine Capper, Andrei Shylo, and Thomas Snyder

In a world of environmental awareness and emerging regenerative technology, such as bikes and skateboards, this project investigates a regenerative stroller. Power your stroller while walking and jogging to get uphill assistance -- a parent and child have never been greener!

Robotic Golf Putter

Turki Alrashed, Andrew Arredondo, Spencer Hobson, and Rebecca Stussman

A miniature, mecanum wheel, autonomous robot will play mini-golf. Utilizing image processing and omni-directional drive capability, this robot will approach the golf ball and putt completely on its own!

Spider Robot/Stewart Platform

Ty'Quish Keyes, Vasu Rabaib, Jacob Simmonds, and Shajie Zang

A custom built 6-legged robot (hexapod) with integrated balancing functionality. Will walk and simultaneously balance a ball on a touchpad plate.

Tennis Ball Fetcher

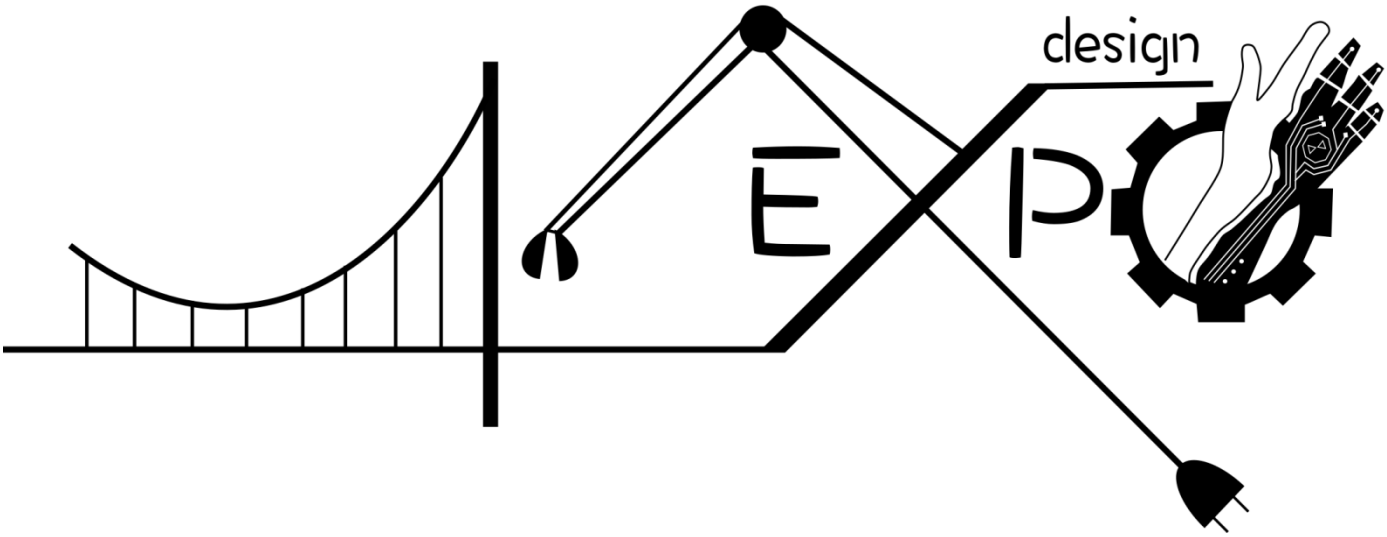
Gerardo Cervantes, Devon Harvey, Eric Simmons, and Nicolas Sun

Courtmate is an autonomous tennis ball retrieval robot meant to decrease downtime during tennis training sessions. It uses machine vision to identify tennis balls and calculates the optimal retrieval path to take to collect all of them and bring them to the ball thrower machine so that the person being trained doesn't have to.

Tensegrity Snake Robot

Taryn Bailey, Bryan Cao, Rosemarie Murray, and Joshua Woods

A biologically-inspired, tensegrity robot uses peristaltic motion to generate forward movement. By combining this unique method of locomotion with tensegrity design principles, this flexible, lightweight, and robust robot is well-suited to the exploration of unknown terrain, with applications in space-exploration, pipe monitoring, and search-and rescue.



Thanks to Antonella Gutierrez ’16 for designing the first Senior Design Expo t-shirt

Columbia Engineering
The Fu Foundation School of Engineering and Applied Science
500 W. 120th St.
New York, NY 10027