Sibley Graduate Research Symposium

Friday, October 5, 2018

Mechanical and Aerospace Engineering Department
Cornell University
Ithaca, NY

Committee:

Carlos Diaz-Ruiz

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Maura O'Neill

Ryan Snodgrass

Erik Taylor

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Welcome!

Welcome to the 2018 Sibley Graduate Research Symposium! We look forward to an engaging afternoon exploring all of the research being conducted in the Mechanical and Aerospace Engineering Department at Cornell University.

As the planning committee for this year's Sibley Graduate Research symposium, our goal was to plan a conference-style event that encourages students to explore the vast array of research topics being explored within the Mechanical and Aerospace Engineering department and enhance the cross-disciplinary scientific community in the Sibley School. With these goals in mind, we chose a recent alumnus of our graduate program, Dr. Riley Schutt, to give the keynote address at the beginning of the research symposium. We are honored to have Riley back on campus to tell us more about his academic career here at Cornell as well as his exciting work with the U.S. Sailing Team since graduating from Cornell University.

In this document, you will find the presentation abstracts for our Keynote Address in addition to that of each student presenter. I encourage each and every attendee to take a step outside of their comfort zone at this research symposium: attend a presentation on a research topic that is outside of your realm of expertise, maybe even expand your academic network!

All in all, I truly hope that this will be an interactive and educational experience for everyone involved! Enjoy!

-Maura O'Neill

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Schedule of Events

Friday, October 5, 2018

11:00-11:30 Coffee (Half)Hour..Duffield Atrium

Coffee, snacks, and other refreshments available in 106 Upson Hall.

11:30-12:30 Keynote Address..Upson Lounge

Riley Schutt, PhD, U.S. Sailing Team

12:30-1:15 Buffet Lunch..Duffield Atrium

Buffet lunch served in 106 Upson Hall. Seating in Duffield Atrium.

1:15-2:45 Student Presentations Session #1 ....Upson Lounge

Reece Kearney, *Experimental Fluid Dynamics*	1:15 PM
Jacob Shapiro, *Optics and Space Telescope Design*	1:25 PM
Ronald Heisser, *Fracture Mechanics and Fragmentation*	1:35 PM
Marysol Luna, *Biomechanics*	1:45 PM
Dan Houck, *Experimental Fluid Dynamics*	1:55 PM
Patricia Xu, *Soft Robotics*	2:05 PM
Jeffrey Sward, *Power Systems and Uncertainty Modeling*	2:15 PM
Autumn Pratt, *Soft Robotics*	2:25 PM

2:45-3:00 Coffee Break ....Duffield Atrium

Coffee, snacks, and other refreshments available in 106 Upson Hall.

3:00-4:30 Student Presentations Session #2 ....Upson Lounge

Doga Yucalan, *Space Navigation*	3:00 PM
Xiangkun Elvis Cao, *Biomedical Technology*	3:10 PM
Lam Vu, *Computational Fluid Dynamics*	3:20 PM
Erik Taylor, *Biomechanics*	3:30 PM
Cameron Aubin, *Soft Robotics*	3:40 PM
Suwon Bae, *Mechanics for Polymer Design*	3:50 PM
Josh McCraney, *Fluids*	4:00 PM
Kyle Wellmerling, *Microfluids*	4:10 PM
Kevin O'Brien, *Prosthetics*	4:20 PM

5:00-7:00 SiGMA Happy Hour..Upson Lounge

Keynote Speaker: Riley Schutt, Ph.D.

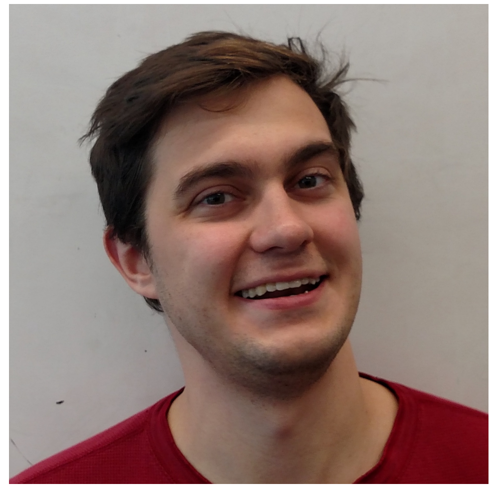
Biography

Riley Schutt is the Innovation, Research & Development Performance Analyst at the US Sailing team, working to win gold at the 2020 Olympics. Riley received his PhD in Aerospace Engineering working with Professor Charles Williamson in the Fluid Dynamics Research Laboratories at Cornell University. After growing up sailing on Cayuga Lake, Riley has pursued a career in the performance modeling and design of racing yachts. In addition to his current Olympic work, he has worked as a designer in the America's Cup, Volvo Ocean Race, Vendée Globe, and on numerous one-off record breaking ocean racers.

Abstract: The Engineering of Olympic Sailing

The US Sailing team is enthusiastically preparing for the 2020 Olympics in Tokyo Japan. In 2017 the US Team created an Innovation, Research & Development group to focus on creating technical advantages for the team. Concepts that started with research at Cornell University are now being used to increase coaching effectiveness, identify fast sailing techniques, and increase boat performance. In this talk we explore how PhD research into the vortex dynamics and working for an Ithaca area startup have turned into a career focused on the design and analysis of high performance sailboats. Additionally we present opportunities to partner with the US Sailing team for collaborative research and on student projects that will help in the team's quest for gold in 2020.

Presentation Abstracts



Reece Kearney

4th-Year PhD Student
Experimental Fluid Dynamics
PI: Greg Bewley

Measuring Particle Collision Rates

Collisions between particles in turbulent flow are important in a variety of natural and industrial processes, including rainfall and combustion. A great deal of work has been done to predict and simulate the interactions between particles, though no one has yet measured collision rates with well-understood uncertainties in such settings. We introduce a new computer algorithm to track particles and measure particle collision rates. We characterize the uncertainty of the method by testing it on synthetic data and then use the new method to measure collision rates of real water droplets in a simple benchtop experiment. In this experiment, we vary the diameters of the droplets between 10 and 300 microns and observe collisions varying the impact parameter between 0 and 1 and the Weber number from 0.1 to 20.

Jacob Shapiro

4th-Year PhD Student
Optics and Space Telescope Design
PI: Dmitry Savransky

Preliminary Optical Design of a 30 Meter Segmented Space Telescope

Space observatories have many advantages over ground-based telescopes. However, constructing and launching large space telescopes remains a significant challenge. A solution to this problem lies in autonomous, in-space assembly. To gain benefits from efficiencies of scale and mass production, a modular telescope assembled in space should be constructed from identical mirror segments. This work examines the optical feasibility of such a project, using a 31 meter Ritchey–Chrétien telescope composed of about 1,000 1-m mirrors as a case study. In particular, this work examines the shape of the telescope optics through Zernike decomposition, determines a realistic actuator design to achieve the desired shape, and computes the physical optics propagation of such a system to analyze the resultant PSF with simulation in Zemax OpticStudio.

Ronald Heisser

2nd-Year PhD Student
Fracture Mechanics and Fragmentation
PI: Robert Shepherd

Breaking Spaghetti to Control Fracture and Fragmentation

Fracture fundamentally limits the structural stability of macroscopic and microscopic matter, from beams and bones to microtubules and nanotubes. Despite substantial recent experimental and theoretical progress, fracture control continues to present profound practical and theoretical challenges. While bending-induced fracture of elongated rod-like objects has been intensely studied, the effects of twist and quench dynamics have yet to be explored systematically. Here, we show how twist and quench protocols may be used to control such fracture processes, by revisiting Feynman's observation that dry spaghetti typically break into three or more pieces when exposed to large pure bending stresses. Combining theory and experiment, we demonstrate controlled binary fracture of brittle elastic rods for two distinct protocols based on twisting and nonadiabatic quenching. Our experimental data for twist-controlled fracture agree quantitatively with a theoretically predicted phase diagram, and we establish novel asymptotic scaling relations for quenched fracture. Due to their general character, these results are expected to apply to torsional and kinetic fracture processes in a wide range of systems.

Marysol Luna

4th-Year PhD Student
Biomechanics
PI: Christopher Hernandez

Changes in Bone Tissue Strength Caused by Disruption of the Gut Microbiome Depend on Stage of Skeletal Growth

The gut microbiome influences bone morphology and density. Recently, we demonstrated that disruption of the gut microbiome throughout life (4-16wks of age in mice) reduces the mechanical performance of whole bone at skeletal maturity by modifying bone tissue material properties. However, it is unclear if disruption of the gut microbiome alters all bone tissue or only affects bone tissue at the time of formation. To test the idea that the microbiome influence bone tissue at the time of formation, we disrupted the microbiome at different stages of growth and determined the effects on whole bone strength at skeletal maturity. Male mice (B6.129S1-Tlr5tm1Flv/J) were divided into groups (n=11-15/group, 37 total): disrupted microbiome from 4-10wks, disrupted microbiome from 10-16wks, and untreated. Whole bone strength was determined with 3-point bending to failure. Disruption of the microbiome from 4-10wks resulted in a 17.2% reduction in tissue strength as compared to untreated mice. The difference in tissue strength among groups was likely due to the amount of bone tissue formed during disruption of the microbiome. Our findings demonstrate that an impaired gut microbiome at a crucial point in skeletal growth can have a long lasting effect on bone tissue strength at skeletal maturity.

Dan Houck

6th-Year PhD Student
Experimental Fluid Dynamics
PI: Todd Cowen

Can You Accelerate Wind Turbine Wake Decay with Unsteady Operation?

Wind farms are adversely affected by the very wakes that are a necessary by-product of their energy extraction process. In this presentation, I will focus on an experiment with one turbine in which a novel method of accelerating wake decay was tried. Rather than operate the turbine at its best efficiency point, a dynamic set point was used and the turbine alternated between two points on its power curve varying both the amplitude and frequency for different treatment cases. The goal was to resonate with the characteristic frequencies of existing instabilities and thereby amplify them or to seed new instabilities. Results are compared to steady operation cases.

Patricia Xu

3rd-Year PhD Student
Soft Robotics
PI: Robert Shepherd

Stereolithography 3D Printing of Left Atrial Appendage Occluders

Stroke is a major leading cause of death in the world and is even more deadly in patients with atrial fibrillation due to stagnant blood flow in the heart. While anti-clotting medication is successfully used to prevent stroke in many patients, not everyone can use it due to other medical conditions or medications. For these patients, an option is to block off the left atrial appendage (LAA), a remnant sac to the side of the left atrium since many clots are formed there. To this end, we present a 3D printed, custom fit LAA occluder based on CT scans of a patient's heart.

Jeffrey Sward

3rd-Year PhD Student
Power Systems and Uncertainty Modeling
PI: Max Zhang

A data-driven approach for maximizing solar PV capacity at the distribution feeder level under existing operational paradigms

Recent rapid growth in solar photovoltaic (PV) marks a shift away from conventional generation, providing a strategy for stemming carbon emissions emanating from the electricity sector. However, solar PV often appears within distribution systems where existing infrastructure was designed under a central-station paradigm. Fortunately, smart grid technologies can aid integration of distributed energy resources through better characterization of how these resources affect the grid. Using a New York utility service territory as a test bed, we present a data-driven Monte Carlo framework that estimates the maximum installed solar PV capacity at the distribution feeder level subject to existing network constraints. Working with representative days that closely match a feeder's load profile, we probabilistically select PV systems according to current New York trends and stochastically model hourly electricity generation.

Autumn Pratt

2nd-Year PhD Student
Soft Robotics
PI: Robert Shepherd

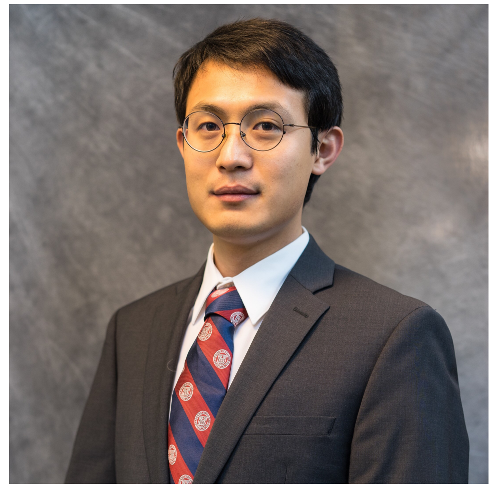
[Sometimes] Soft Robots: Making Robots both Soft and Strong

Doga Yucalan

3rd-Year PhD Student
Space Navigation
PI: Mason Peck

Towards a Relativistic Navigation Algorithm

Physical exploration of deep space is an inevitable next step to current space missions; however, the limitations of existing space propulsion systems overshadow other details of such a breakthrough. The fastest spacecraft ever built would take over 18,000 years to reach the closest star to the Sun if it could travel constantly at its peak velocity for that duration. Future spacecraft will need to travel much faster, with speeds that are a significant fraction of the speed of light, to realize extrasolar exploration. State-of-the-art navigation techniques rely on reference-frame-independent physical laws and treat relativistic effects as perturbations to the classical theories of motion and gravity. Moreover, most methods are Earth-based and would lack the bandwidth to navigate a spacecraft through the interstellar medium. Given the unprecedented amount of sources of uncertainty that interstellar space will introduce, the only feasible way of handling these challenges is to automate the means of navigation. This talk will investigate the design of an innovative method of autonomous navigation for spacecraft traveling with relativistic speeds that uses Einstein's special theory of relativity as a baseline dynamics model.



Xiangkun Elvis Cao

3rd-Year PhD Student
Biomedical Technology
PI: David Erickson

FeverPhone: Fever Diagnosis on Your Phone

Acute undifferentiated febrile illnesses are responsible for substantial morbidity and mortality globally. Our goal is to develop a technology called FeverPhone, a smartphone based molecular diagnostics platform for point-of-care differential diagnosis of six common causes of acute febrile illness (namely: Dengue, Malaria, Chikungunya, Leptospirosis, Typhoid fever, and Chagas). In parallel with technical development, this system will be fully validated at our existing field site in Ecuador and be ready for FDA approval by the end of the effort. The system has significant advantages over the state-of-the-art as it will enable: (1) Quasi-unbiased detection of causative agent behind cause of febrile illness in a single test on a familiar platform requiring little or no training; (2) Simplified patient and spatiotemporal tracking; (3) Demonstrated inter-device repeatability; (4) Health care advice and ability to immediately contact or alert a health-care provider if needed; (5) Low-cost.

Lam Vu

3rd-Year PhD Student
Computational Fluid Dynamics
PI: Olivier Desjardins

Studying the Effect of Momentum Flux Ratio on the Primary Breakup Dynamics of a Canonical Coaxial Atomizer

Sprays are ubiquitous in engineering systems and the ability to control them would lead to significant improvements in technology. To determine the optimal avenue for control of these systems, a comprehensive characterization of spray formation is needed. To this end, we perform high fidelity simulations of an atomizing jet exiting from a canonical coaxial air-blast atomizer. These simulations focus on the near-field region where the initial destabilization of the liquid core occurs. The simulations are performed at various co-flowing gas velocities, varying the gas Reynolds number and momentum flux ratio while keeping the liquid Reynolds number fixed. We compare volume fraction statistics from simulations to experimental X-ray attenuation data, enabling quantitative comparisons of radial liquid volume fraction profiles. X-ray data was obtained by our collaborators at the University of Washington and Iowa State University using Argonne National Lab's Advanced Photon Source.

Erik Taylor

4th-Year PhD Student
Biomechanics
PI: Eve Donnelly

Sequential treatment of osteoporosis with anti-resorptive and anabolic therapies alters bone collagen matrix composition

Osteoporosis is a disease characterized by the loss of bone mass and affects men and women worldwide. Current FDA approved treatments for osteoporosis are anti-resorptives and anabolic therapies (PTH), which suppress bone resorption and stimulate bone formation, respectively. The different mechanisms of action of these treatments has motivated their use in sequence to produce better results than monotherapies alone. Sequential treatment with anti-resorptives and PTH increases bone mass and strength relative to monotherapies alone. However, changes in the bone mineral and collagen matrix chemical composition with sequential therapies has not been investigated. Thus, the objective of this study was to compare bone chemical composition in rats treated with anti-resorptive or PTH monotherapies to rats treated with sequential therapies. Rats treated with sequential therapies had a lesser extent of collagen crosslinking than rats treated with monotherapies. This is consistent with stimulation of bone formation with PTH treatment and suggests that sequential therapies increase bone mass and strength without embrittling the collagen matrix. Together, these results suggest that sequential anti-resorptive and PTH therapy is a promising approach for the treatment of osteoporosis and in the future these findings should be confirmed in clinical studies.

Cameron Aubin

3rd-Year PhD Student
Soft Robotics
PI: Robert Shepherd

A Biologically-Inspired Aquatic Soft Robot with a Synthetic Vascular System

Suwon Bae

6th-Year PhD Student
Mechanics for Polymer Design
PI: Meredith Silberstein

Single chain polymer nanoparticles as building blocks for a new class of polymers

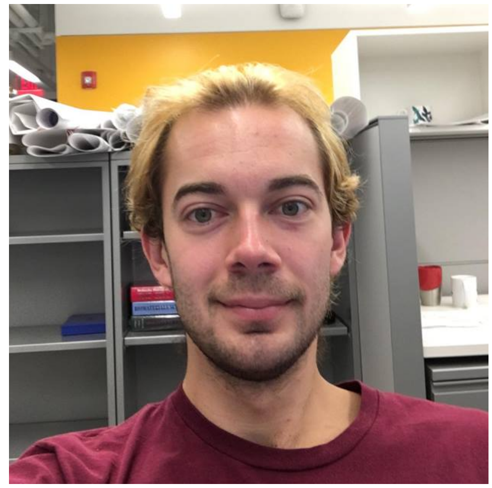
Incorporating intra-chain crosslinks into a single macromolecular chain is a powerful way to tailor the thermo-mechanical properties of the chain. Intra-chain crosslinks restrict the motion of constituent monomers and modify chain configuration. When induced under moderate to poor solvents these crosslinks lock the polymer chains into collapsed conformations, forming single chain polymer nanoparticles (SCPNs). A large number of SCPNs are assembled together to build a bulk polymer. Due to intra-chain crosslinks, SCPNs are not unfolded and nearly entangled among each other, resulting in thermo-mechanical properties different than those of a linear bulk polymer. The glass transition temperature increases and the material becomes stronger and more brittle with increasing crosslinking ratio at the glassy state. Our group has conducted both molecular dynamics simulations and experiments in order to rationalize the relationship between microstructure and thermo-mechanical properties.

Josh McCraney

3rd-Year PhD Student
Fluids
PI: Paul Steen

Capillary Stability and Low-G Drains

In space, residual accelerations (crew-docking, orbital maneuvers) can hamper life support equipment and fuel/cryogenic management by ``sloshing'' the stored fluid, inducing capillary surface instabilities that can preclude fluid availability when required. Here we consider an ideal fluid interface held in equilibrium by surface tension. Small perturbations induce dynamical changes governed by the equations of motion, which are reduced to an operator equation. An overview is provided and ISS data reported.



Kyle Wellmerling

4th-Year PhD Student
Microfluidics
PI: Brian Kirby

Teratoma-forming Potential in Neural Progenitors derived from human-induced Pluripotent Stem Cells

Human induced pluripotent stem cells (hiPSCs) represent a promising strategy to derive patient-specific neural progenitor cells (NPCs) for therapeutic transplantation of neurodegenerative diseases. However, teratoma currently limits transplantation potential of hiPSC-derived NPCs. Current cell-sorting technology such as Fluorescent activated cell sorting (FACS) cannot adequately prevent teratoma formation. Therefore there is an urgent unmet need for a simple, high-precision device that remove teratoma-forming cells. To this end we have characterized a microfluidic immunocapture device to remove teratoma-forming cells form hiPSC-derived NPCs.

Kevin O’Brien

5th-Year PhD Student
Prosthetics
PI: Robert Shepherd

The ADEPT Hand

We present an Elastomeric Passive Transmission (EPT) for tendon-driven robotic systems which increases maximum output force and actuation speed and acts as a series elastic element. The EPT achieves these improvements with minimal impact to the size, weight, or cost of the system. Each EPT is composed of a 3D-printed polyurethane (PU) composite: a circular array of soft PU struts cured to a hard PU core to form a hybrid spool with a material cost of ~$1 and a mass ~2 grams. Using tension applied by the tendon to strain the elastomeric struts toward the center of the motor-mounted spool, the EPT passively adjusts the effective gearing ratio of a motor; the diameter of the EPT spool narrows as the tension is increased. This allows a tendon-driven actuator to move with high speed when unimpeded, and with high-force under load. Our EPTs can be used with low-cost motors to achieve the performance (high force and speed) of a high-cost motor at a drastically reduced price, or they can further improve the performance of higher quality, more expensive motors.

Thank You