MAEnews

School of Engineering and Applied Science
PRINCETON

MECHANICAL AND AEROSPACE ENGINEERING

Spring 2020

Dear Friends of MAE,

Another fall semester has passed, and we are now experiencing the last time Princeton's final exams will take place in January. The new academic-year calendar will take effect in the fall of 2020 and bring Princeton's calendar in alignment with that of our peer institutions. The past semester has been filled with activities, accomplishments from our students and faculty, and new initiatives, some of which are highlighted in this newsletter. In September, Jesse Jenkins, an expert in energy systems, including the role of electricity in economy-wide decarbonization, and public policy, joined MAE and the Andlinger Center for Energy and the Environment. Sadly, in mid-December, we lost Emeritus Professor Irv Glassman who was associated with Princeton for more than 50 years. He contributed broadly and extensively to applications-inspired fundamental science and technology involving combustion and propulsion. Also, in late Spring 2019 we lost Emeritus Professor David Hazen who was an expert in subsonic and high-lift aerodynamics. Many of you may have fond memories of Professors Glassman and Hazen. There is much happening in the halls, classrooms, and laboratories of MAE, and we hope you will visit us if you are in the area.

With best regards, Howard Stone

In this issue...

student spotlight

Daniel Ruth
Finding the Key to the Highway and Bubbles

As a kid, Daniel Ruth enjoyed flying his remote-controlled airplane and watching it dance through the air with almost wave-like movements. Little did he know that hobby would lay the foundation for his future in fluids research.

Dan's fascination with airplanes was about as strong as his interest in music. As a classically trained pianist, he was an accompanist for the Penn State University School of Music. Now that he is a third-year grad student at Princeton, Dan spends most of his time focused on studying the way bubbles break up in turbulence, and then uses that knowledge to better understand how gases are transferred between the atmosphere and the ocean.

"When waves break on the ocean's surface, they draw many bubbles into the water, which can break apart due to the turbulence from the wave breaking. Understanding how these

...continued p. 2

grad program info

IN OUR PhD PROGRAM

All PhD students are fully supported with tuition and a living expense stipend during the entire program. A First Year Fellowship covers tuition and stipend in year one. The remaining years of the program are fully funded through a combination of teaching and research support provided by the student's adviser. As a candidate for the doctoral program, the student, in consultation with a faculty adviser, develops an integrated program of study which culminates with a dissertation showing technical mastery of their chosen field and contribution to the advancement of knowledge, followed by a public presentation of the material. Princeton's Department of Mechanical and Aerospace Engineering has played a leading role in propulsion, combustion, aerospace dynamics, and fluid dynamics over the past half century. In recent decades the Department has extended its reach as a leading presence in dynamics and control, robotics, biomechanics, applied physics, and materials science. By exploiting its multi-disciplinary character and stressing science and engineering fundamentals, the Department seeks to educate the very best students – undergraduate and graduate - for future positions of leadership in areas of rapidly evolving technology.

GET MORE INFO

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mae.princeton.edu

faculty spotlight

Alexander Glaser

Using Vintage Electronics as Verification Tools

Details about nuclear weapons remain among the world's most highly guarded secrets. An expert dismantling a weapon, or even witnessing its destruction, can learn much about the warhead. On the other hand, without examining the weapon, it's difficult to convince inspectors that a real weapon was destroyed. This has long been considered a problem for disarmament—how can countries convince others that a nuclear weapon is gone without revealing details about its arsenal?

Scientists have yet to design a trusted verification device for use in nuclear disarmament. Early prototypes were complicated, making authentication of the device and its results difficult to verify. But Alexander Glaser, PhD, associate professor of mechanical and aerospace engineering at Princeton, and Moritz Kütt, PhD, a former post-doctoral research associate, have found that an unlikely technology may be the key to solving this decades-old problem: vintage electronics, specifically, simple 6502 microprocessors from the 1970s. It's the same chip used in early home computers and arcade machines that ran games like Pac-Man.

Professor Glaser—a vintage video game collector who teaches a class on nuclear disarmament—and Kütt paired a simple radiation detector with a 6502 microchip and programmed the device to confirm that an item's radiation signature matches an expected result by displaying a green light. Their prototype system accurately detected subtle changes in gamma-radiation signatures from standard sources that simulate warheads. All of the researchers' designs are open-source and cost about $250.

"In terms of computing power, this is all you need," Kütt said. "Because the processor is so primitive, scientists can literally check every transistor in the circuit, which could help confirm that the chip is authentic."

Some 14,000 nuclear weapons exist in nine countries today, down from a high of around 60,000 weapons in the late 1980s. If further reductions are to be achieved, negotiators will likely need tools to verify that the U.S. and Russia are reducing their stockpiles as promised. Those two countries account for 90 percent of the world's nuclear weapons. For now, Glaser and Kütt see their device as a simple proof-of-concept, but one that they hope starts a broader conversation within the international community. ¤

student spotlight *continued*

bubbles break up will enable better estimates for how much of the gases in the air can dissolve into the ocean water, which is an essential process in the transfer of carbon dioxide between the atmosphere and the ocean," he says.

Dan's image processing skills helped him design experiments writing codes for the high-speed Vision Research camera used in capturing the air bubbles breaking away from the neck of the needle under water. The camera, positioned outside of a large aquarium, films 100,000 frames per second. Dan then plays the data back as either individual photos or video. The code can tell him the speed and direction the bubble is growing, breaking, and releasing. He also tracks "how fast water rushes in and the asymmetry induced by the turbulence."

His work has real-world applications. "Understanding how the bubbles break apart in turbulence, where the turbulence is caused by the wave breaking, can enable us to improve models for the global carbon cycle," he explains.

For relaxation, Dan turns to music. He is part of the blues and classic rock band called Bad Tiger. The study of bubbles is like a classic blues song they like to play: "Key to the Highway." Bubbles have been studied countless times over the years, but Dan is attempting something new with his research. "We are taking something that has been studied in the past—how an air bubble detaches from a needle underwater—and adding something new, which is turbulence in the water," he says.

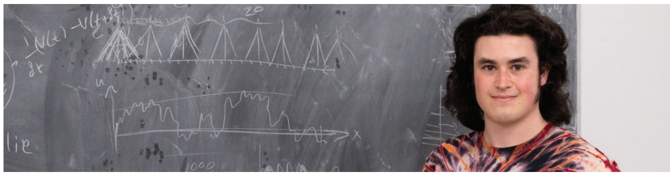
Building on previous work and combining various fields of study is something Dan tries to do in his music as well. "Each field," he says, "has a lot of room for creativity in how you make use of the fundamentals, whether that is in coming up with a solo during a performance or designing an experiment to learn something new." ¤

a word from the lab

APPLIED PHYSICS ▫ DYNAMICS & CONTROLS ▫ FLUID MECHANICS ▫ MATERIALS SCIENCE ▫ PROPULSION & ENERGY SCIENCES

Sam Otto

An Interdisciplinary Approach to Modeling Turbulence



For most people, turbulence is what causes bumpy airplane rides. But Sam Otto will tell you that turbulence is hardly confined to airplanes—and that it's one of the most common, and complex, pattern-forming behaviors in nature.

Turbulence remains one of the most challenging behaviors to understand, predict, and model. Engineers who are designing airplane wings lose significant design time waiting for turbulence simulations to run. Sam's research looks at ways to improve the current modeling techniques by using machine learning. "In order to speed up our simulations and advance our understanding, we need to develop a large-scale picture of turbulence that reduces the number of variables involved while still capturing the essential features resulting from small-scale motion in the fluid."

His approach is interdisciplinary and involves breaking down the complexity of modeling turbulence into simple parts. "Ultimately what we are doing is using machine learning for pattern identification—and if we start with one of the most complex pattern-forming behaviors in nature, we will be able to apply what we have learned to other patterns," he explains. *Faculty advisor:* Clancy Rowley ¤

Nikita Dutta

From Childhood Inventor to Materials Scientist

Ever since she was a little girl, Nikita Dutta has been coming up with solutions for the problems around her. Back then, Nikita would take apart old toys and sift through the recycling to find spare parts. Today, as a materials scientist and third-year PhD student in MAE, she finds ways to repurpose materials by changing their properties and structures to make them work in new or more efficient ways.

Her research focuses specifically in solution processing materials that are used for optical devices. Nikita tries to understand how materials change when they are dissolved in a certain type of solvent. Since materials are difficult to study in a dissolved state, researchers often use reverse engineering to determine how solution processing affects final material properties. Nikita, however, is looking to gain more control over the process with a forward-thinking strategy by adding knowledge of the material structure.

By better characterizing these materials, researchers can learn how changing their structures affects properties that make them work better. These devices, which use light to transmit information or store energy, have applications in fiber optic networks, chemical sensors, and more. *Faculty advisor*: Craig Arnold ¤

Xinyi Minnie Liu

MAE Research Day Winner Overcomes Adversity to Build Better Batteries

Xinyi Minnie Liu has been challenging stereotypes ever since she checkmated her chess master grandfather. Today, the fifth-year PhD student, stands out in a male-dominated industry by winning first prize at the MAE Research Day.

When batteries degrade, a dangerous phenomenon called lithium plating occurs. Minnie describes "using modified separators to create transport non-uniformities and show that certain geometric features lead to more vulnerability to plating, and localization strongly depends on size." Her findings have important applications for product control and battery safety. *Faculty advisor:* Craig Arnold ¤

awards and honors

Alexander Smits
receives Fluid Dynamics Prize

Richard Miles
elected Senior Member of the
National Academy of Inventors (NAI)

Andrej Kosmrlj
receives Alfred Rheinstein Faculty Award, SEAS

Craig Arnold
appointed the Susan Dod Brown Professor of
Mechanical and Aerospace Engineering

For full stories, visit: http://mae.princeton.edu/about-mae/spotlight

PRINCETON UNIVERSITY

Mechanical & Aerospace Engineering
Engineering Quad - D Wing
Princeton University 08544

Visit **mae.princeton.edu/about-mae/events** for event updates and location information. Events are free and open to the public.

Newsletter Editor: Carolyn Sayre

events: spring 2020

February 7, 2020 – 12:30 pm
ISABEL HOUGHTON, University of San Francisco

February 14, 2020 – 12:30 pm
CHRISTOPHER HART, Former Chariman of the National Safety Transportation Board

February 21, 2020 – 12:30 pm
DIONISIOS MARGETIS, University of Maryland

February 28, 2020 – 12:30 pm
JOHN KOLINSKI, EPFL

March 27, 2020 – 12:30 pm
KAREEM AHMED, University of Central Florida

April 3, 2020 – 12:30 pm
JOHN DABIRI, Standford University

April 10, 2020 – 12:30 pm
CHLOE DEDIC, University of Virginia

April 17, 2020 – 12:30 pm
PHILIP BAYLY, Washington University

May 1, 2020 – 12:30 pm
SONIA MARTINEZ DIANZ, UC San Diego Jacobs School of Engineering

In Memoriam

DAVID COMSTOCK HAZEN

David Comstock Hazen, ’48, ’49, Professor of Mechanical and Aerospace Engineering, Emeritus, passed away on April 27, 2019. A distinguished researcher of subsonic and high-lift aerodynamics, David received the Navy’s highest civilian honor, the Distinguished Public Service Award. David was the son of William Gardner Hazen, ’10, and Anna Ewing Hoover Hazen. He was 91 years old.

IRVIN GLASSMAN

Irvin Glassman, the Robert H. Goddard Professor of Mechanical and Aerospace Engineering, Emeritus, died on December 14, 2019. Irvin was a leading authority on combustion and propulsion. A member of the Princeton faculty for 49 years, Irvin was affectionately known among his colleagues and former students as the “Grand Old Man of Combustion.” He was 96 years old.