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39 Y Yttrium 88.906	60 Nd Neodymium 144.242
57 La Lanthanum 138.905	61 Pm Promethium [145]
58 Ce Cerium 140.116	62 Sm Samarium 150.36



63 Eu Europium 151.964	67 Ho Holmium 164.930
64 Gd Gadolinium 157.25	68 Er Erbium 167.259
65 Tb Terbium 158.925	69 Tm Thulium 168.934
66 Dy Dysprosium 162.500	70 Yb Ytterbium 173.045
	71 Lu Lutetium 174.967



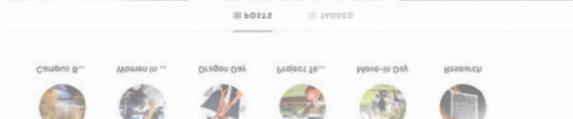
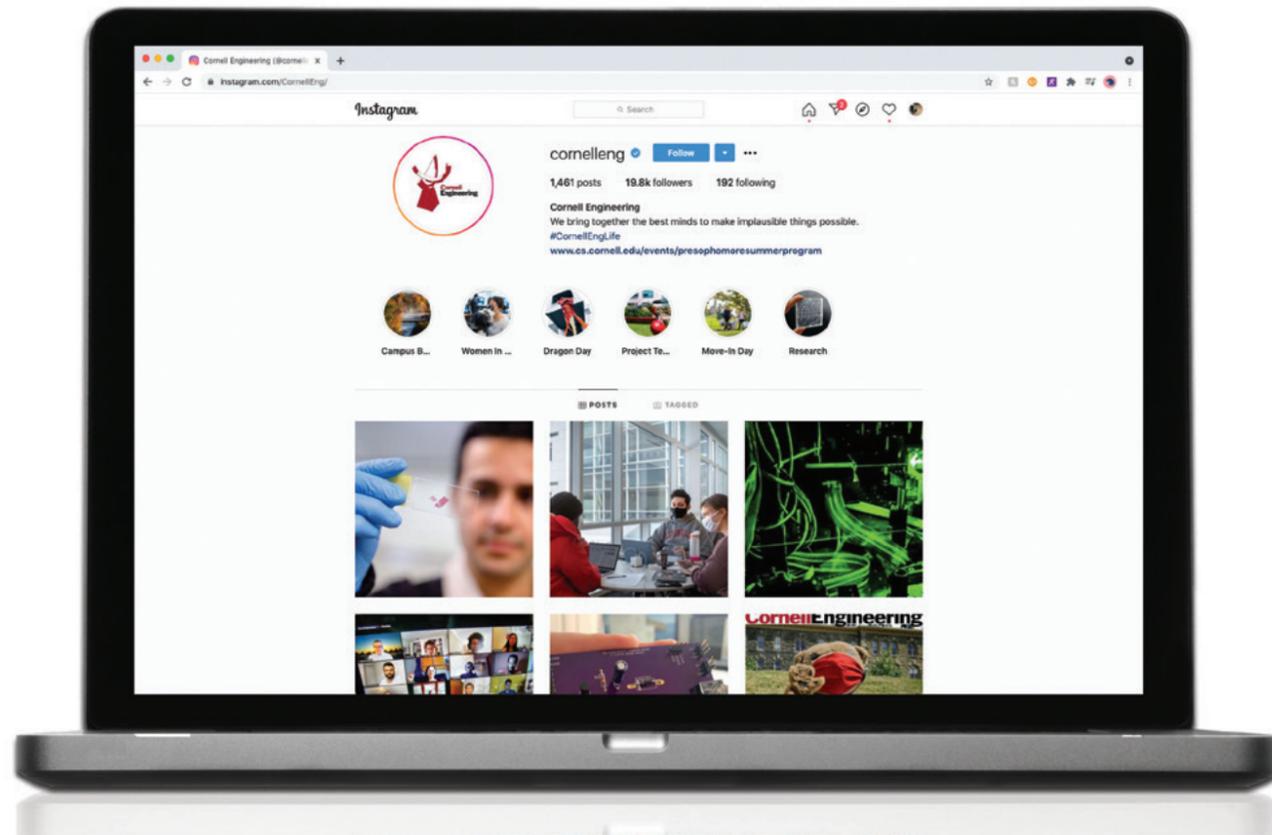
BIOMINING RARE EARTH ELEMENTS

Cornell engineers are pioneering a novel method for mining metals that are key to unlocking a sustainable future

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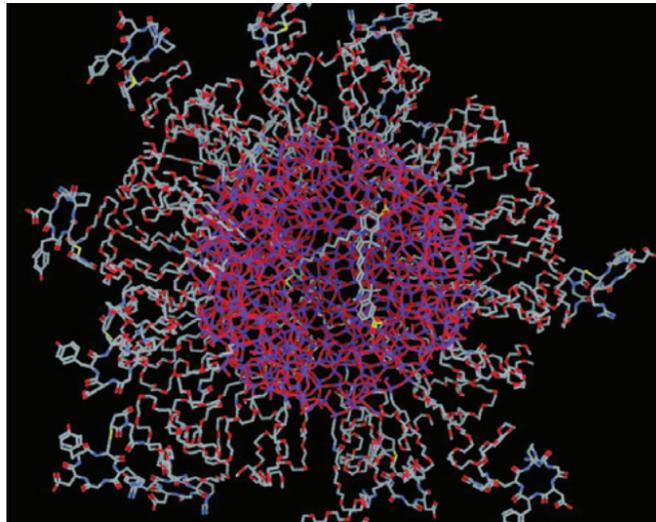
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CORNELL STARTUP RAISES \$44M TO ADVANCE 'C DOTS' BIOTECH

Elucida Oncology, a biotechnology company based on C Dots – ultra-small nanoparticles developed at Cornell that show promise in identifying and fighting cancer – recently secured \$44 million in financing, in addition to \$28 million raised in 2018.

C Dots, originally called Cornell dots, were created more than 15 years ago in the lab of Uli Wiesner, the Spencer T. Olin Professor of Engineering in the Department of Materials Science and Engineering. Wiesner has been working to put C Dots to use in the fight against cancer ever since.

As a result of their size, C Dots proved safe and effective for use in human beings as both an imaging and a diagnostic tool in early clinical



A rendering of the molecular structure of a Cornell dot, which is smaller than 10 nanometers.

studies. The new funding will help the company gain regulatory approval as a targeted cancer therapeutic, and to expand its management

team and its laboratory capabilities. “This vote of support from investors means a lot to me,” Wiesner said. “Given C Dots’ broad applicability, I have been pushing efforts in health care-focused startups since 2005 to commercialize this technology. At the beginning it was a reagent company. Then we started a company focusing on diagnostics, and now we have a company emphasizing therapeutics.”

Elucida was founded in 2014 and co-founders include Wiesner, Kai Ma, Ph.D. ‘15, and Dr. Michelle Bradbury, director of intraoperative imaging at Memorial Sloan Kettering Cancer Center and professor of radiology at Weill Cornell Medicine.

Elucida is planning to start clinical trials this summer; by the spring of 2022, the company expects to have the first data from those trials.

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Ferrets, similar to humans, generate antibodies against COVID-19, yet display limited clinical signs.

NASAL SPRAY BLOCKS COVID-19 INFECTION IN FERRETS

Researchers at Cornell, Columbia University Irving Medical Center and Erasmus Medical Center in the Netherlands have developed a nasal formulation that blocks the spread of COVID-19 among ferrets – and are hopeful the formulation could have the same effect on humans, and potentially generate therapeutic treatments as well.

Ferrets are one of the best animal models for COVID-19, because they take the virus quite readily, and undergo both direct contact and airborne transmission. Ferrets, similar to humans, also generate antibodies against the virus, yet display limited clinical signs.

“This is a simple nasal formulation that we think can prevent the transmission of SARS-CoV-2 in humans,” said Chris Alabi, associate professor of chemical and biomolecular engineering and a co-senior author of the research paper, which published in Science. “The beauty of the research is its simplicity. The ultimate goal is to create a nasal spray drug product that can be made widely available, one that can be kept readily in a purse or pocket. A key feature of this research is that it’s a plug-and-play platform technology that can be adapted and applied to other viruses or mutations.”

In recent years, the collaborators have been using the technique to

develop antiviral peptide-lipid conjugates that prevent measles and Ebola. When COVID-19 emerged and scientists identified the sequence of the viral proteins, the Columbia and Cornell groups were able to adapt their approach, because all three viruses share a similar fusion mechanism. They swapped out the measles or the Ebola peptide for the HRC peptide in SARS-CoV-2 and tagged it with a cholesterol lipid.

Researchers at Erasmus Medical Center in the Netherlands tested the formulation on ferrets, which turns out to be an ideal model for replicating the way SARS-CoV-2 spreads among, and

proliferates inside, humans. “It’s the best of both worlds,” Alabi said. “They mimic the disease indication seen in humans, but they can recover at a given dose. It’s a similar mechanism that allows certain cohorts of the human population to also clear the virus.”

The Erasmus Medical Center team found that the lipopeptide fusion inhibitors successfully prevented transmission of the SARS-CoV-2 virus. The collaborators are currently studying the spray’s effectiveness as a therapeutic treatment for subjects who are already infected, as well as its ability to combat other strains and viruses.

On the Web

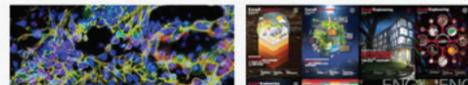
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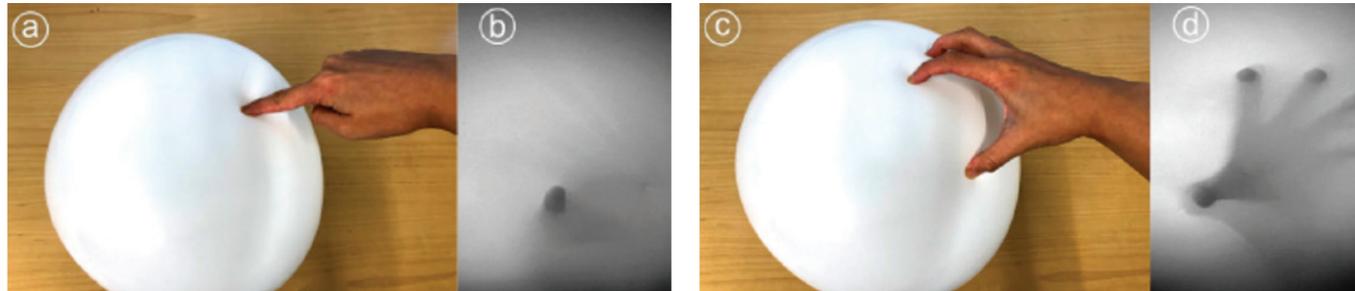
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SOFT ROBOTS USE CAMERA AND SHADOWS TO SENSE HUMAN TOUCH



ShadowSense can turn an inflatable skin into a touch-sensitive device by using a camera and image classification. (a) and (c) show two tactile gestures; (b) and (d) show the device's view of the shadows generated by these gestures.

Cornell engineers have created a low-cost method for soft, deformable robots to detect a range of physical interactions, from pats to punches to hugs, without relying on touch at all. Instead, a USB camera located inside the robot captures the shadow movements of hand gestures on the robot's skin and classifies them with machine-learning software.

The new ShadowSense technology is the latest project from the Human-Robot Collaboration and Companionship Lab, led by Guy Hoffman, associate professor and the Mills Family Faculty Fellow in the Sibley School of Mechanical and Aerospace Engineering.

"Touch is such an important mode of communication for most organisms, but it has been virtually absent from human-robot interaction. One of the reasons is that full-body touch used to require a massive number of sensors, and was therefore not practical to implement," Hoffman said. "This research offers a low-cost alternative."

The technology originated as part of a collaboration with Hadas Kress-Gazit,

professor in the Sibley School of Mechanical and Aerospace Engineering, and Kirstin Petersen, assistant professor of electrical and computer engineering, to develop inflatable robots that could guide people to safety during emergency evacuations. Such a robot would need to be able to communicate with humans in extreme conditions and environments. Imagine a robot physically leading someone down a noisy, smoke-filled corridor by detecting the pressure of the person's hand.

Rather than installing a large number of contact sensors – which would add weight and complex wiring to the robot, and would be difficult

to embed in a deforming skin – the team took a counterintuitive approach. In order to gauge touch, they looked to sight.

The prototype robot, designed by Petersen's Collective Embodied Intelligence Lab, consists of a soft inflatable bladder of nylon skin stretched around a cylindrical skeleton, roughly four feet in height, that is mounted on a mobile base. Under the robot's skin is a USB camera, which connects to a laptop. The researchers developed a neural-network-based algorithm that uses previously recorded training data to distinguish between six touch gestures – touching with

a palm, punching, touching with two hands, hugging, pointing and not touching at all – with an accuracy of 87.5 to 96%, depending on the lighting.

The robot can be programmed to respond to certain touches and gestures, such as rolling away or issuing a message through a loudspeaker. And the robot's skin has the potential to be turned into an interactive screen.

By collecting enough data, a robot could be trained to recognize an even wider vocabulary of interactions, custom-tailored to fit the robot's task, according to the researchers.



A CAMERA INSIDE THE ROBOT'S BODY CAPTURES THE SHADOW CREATED BY TOUCHING ITS SKIN

A camera inside the robot's body captures the shadow created by touching its skin.

RESEARCHERS CREATE 'BEAUTIFUL MARRIAGE' OF QUANTUM ENEMIES

Cornell scientists have identified a new contender when it comes to quantum materials for computing and low-temperature electronics.

Using nitride-based materials, the researchers created a material structure that simultaneously exhibits superconductivity – in which electrical resistance vanishes completely – and the quantum Hall effect, which produces resistance with extreme precision when a magnetic field is applied.

"This is a beautiful marriage of the two things we know, at the microscale, that give electrons the most startling quantum properties," said Debdeep Jena, the David E. Burr Professor of Engineering in the School of Electrical and Computer Engineering and Department of Materials Science and Engineering. Jena led the research with doctoral student Phillip Dang and research associate Guru Khalsa.

The two physical properties are rarely seen simultaneously.

The research is the latest validation from the Jena-Xing Lab that nitride materials may have more to offer science than previously thought. Nitrides have traditionally been used for manufacturing LEDs and transistors for products like smartphones and home lighting, giving them a reputation as an industrial class of materials that has been overlooked for quantum computation and cryogenic electronics.

"The material itself is not as

perfect as silicon, meaning it has a lot more defects," said co-author Huili Grace Xing, the William L. Quackenbush Professor of Electrical and Computer Engineering and of Materials Science and Engineering. "But because of its robustness, this material has thrown pleasant surprises to the research community more than once despite its extremely large irregularities in structure. There may be a path forward for us to truly integrate different modalities of quantum computing – computation, memory, communication."

Such integration could help to condense the size of quantum computers and other next-generation electronics, just as classical computers have shrunk from warehouse to pocket size.

"We're wondering what this sort of material platform can enable because we see that it's checking off a lot of boxes," said Jena, who added that new physical phenomena and technological applications could emerge with further research. "It has a superconductor, a semiconductor, a filter material – it has all kinds of other

components, but we haven't put them all together. We've just discovered they can coexist."

Potential applications for the material structure include more efficient electronics, such as data centers cooled to extremely low temperatures to eliminate heat waste. And the structure is the first to lay the groundwork for the use of nitride semiconductors and superconductors in topological quantum computing, in which the movement of electrons must be resilient to the material defects typically seen in nitrides.



Doctoral students Phillip Dang (left) and Reet Chaudhuri at the National High Magnetic Field Laboratory, where measurements were made on a material structure that concurrently has superconductivity and the quantum Hall effect.

REED AWARDED \$1.4M GRANT TO ADVANCE HUMAN-NATURAL SYSTEM MODELING

A Cornell engineer is advancing the field of ‘multi-sector dynamics’ with a new \$1.4 million grant from the U.S. Department of Energy that will focus on techniques for better projecting the outcomes of human interactions with the natural world.

Patrick Reed, the Joseph C. Ford Professor in the School of Civil and Environmental Engineering, received the grant in collaboration with the Pacific Northwest National Laboratory’s Integrated Multisector Multiscale Modeling project.

As scientists and policy makers increasingly turn toward mathematical modeling to help inform their decision making, the project aims to better predict how human systems – such as the economy, urbanization, technology, and agriculture – co-evolve with Earth systems, such as climate, natural resources and wildlife.

For example, Reed’s prior research has modeled how the complex dynamics

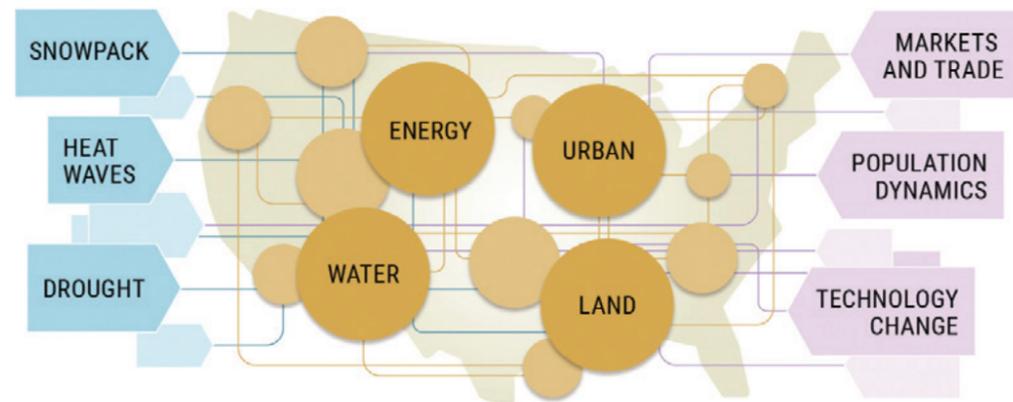
between snowmelt, reservoirs, and water rights affect the availability of irrigation water to farmers in the Yakima River Basin, and how hydropower dams constructed along the Mekong River affect ecological systems.

Reed said the core objectives of the new grant include: Developing flexible, open-source, and integrated modeling capabilities that capture the structure, dynamic behavior and emergent properties of the multiscale interactions

within and between human and natural systems; using these capabilities to study the evolution, vulnerability and resilience of interacting human and natural systems and landscapes from local to continental scales, including their responses to the compounding effects long-term influences and short-term shocks to natural and socioeconomic systems; and advancing the understanding the implications of uncertainty in data, observations, models, and model coupling

approaches for projections of human-natural system dynamics.

“We want to promote a deep integration across scientific disciplines, where new modes of analysis can rapidly emerge and be synthesized into decision relevant insights,” said Reed. “Accelerating our ability to make these insights is critical for societal systems that are facing acute shocks while simultaneously trying to deal with the pressures from long-term changes.”



Flowchart depicting the research field of multi-sector dynamics.

GLOBAL ‘WIND ATLAS’ PROPELS SUSTAINABLE ENERGY

Cornell wind energy scientists have released a new global wind atlas – a digital compendium filled with documented extreme wind speeds for all parts of the world – to help engineers select the turbines in any given region and accelerate the development of sustainable

energy.

This wind atlas is the first publicly available, uniform and geospatially explicit (datasets tied to locations) description of extreme wind speeds, according to the research, “A Global Assessment of Extreme Wind Speeds For Wind Energy

Applications,” published in Nature Energy.

“Cost-efficient expansion of the wind-energy industry is enabled by access to this newly released digital atlas of the extreme wind conditions under which wind turbines will operate at locations around the world,” said

Sara C. Pryor, professor in the Department of Earth and Atmospheric Sciences, who authored the paper with Rebecca J. Barthelmie, professor in the Sibley School of Mechanical and Aerospace Engineering. Both are faculty fellows at the Cornell Atkinson Center for Sustainability.

“This kind of information will ensure the correct selection of wind turbines for specific deployment,” Pryor said, “and help ensure cost-efficient and dependable electricity generation from those turbines.”

Knowing extreme wind speeds is key to turbine design for cost effectiveness, proper turbine selection and structural integrity on any given site, said the researchers. Before, in many locations, extreme wind-load estimates on projects were

uncertain due to limited on-site measurements.

Development of this research product was motivated by a need from the wind-energy industry, Barthelmie said. Quantifying extreme winds may also be useful in civil engineering applications and in structural reliability analyses for tall buildings and transportation systems – including long-span bridges – as well as for electricity generation and distribution.



Cornell wind energy scientists have released a new global wind atlas – a digital compendium filled with documented extreme wind speeds for all parts of the world.

DIMENSIONAL ENERGY EMERGES AS \$20M CARBON X PRIZE FINALIST

Dimensional Energy – a Cornell McGovern Center startup company that can capture industrial carbon dioxide and then convert it by way of sunshine into an environmentally friendly products like aviation fuel – has emerged as one of two finalists in the \$20 million Carbon X Prize competition. The contest’s winner will be announced this summer.

After developing small-scale models on the laboratory bench at the McGovern Center, Dimensional Energy brought their pilot reactor to Gillette, Wyoming, last fall for a long stretch of scaled-up testing. The group successfully demonstrated their technology with a 10-ton per year scale proof-of-concept solar fuels reactor that can turn carbon dioxide into a carbon-neutral

fuel.

“We found that our conversion had percentage numbers that were high and successful, validating the whole process for the Carbon X Prize finals,” said Jason Salfi, Dimensional Energy’s cofounder and chief executive officer. “We have validated all the modeling we’d been doing for years, but now at a larger scale. The reaction ran as close

to equilibrium conversion as we modeled the entire time – for about 10 weeks – without any degradation in catalytic performance. We got it done.”

Tobias Hanrath, the Marjorie L. Hart ’50 Professor in Engineering, in the Smith School of Chemical and Biomolecular Engineering; and David Erickson, the S.C. Thomas Sze Director of the Sibley School of Mechanical and Aerospace Engineering, are cofounders and partners in the company.

In 2018, Dimensional Energy joined the McGovern Center and began pioneering artificial photosynthesis to produce environmentally green polymers and chemicals. Before the gaseous, industrial waste carbon dioxide ends up in the atmosphere, it is captured. After adding hydrogen and sunlight to the carbon dioxide in a reactor, it can emerge as a useful liquid fuel for aviation and surface transportation, or if desired, more durable products like plastic.



Dimension Energy demonstrates their reactor where carbon dioxide meets sunlight to create environmentally friendly fuel.

SLOW MOTION PRECURSORS GIVE EARTHQUAKES THE FAST SLIP

At a glacier near the South Pole, earth scientists have found evidence of a quiet, slow-motion fault slip that triggers strong, fast-slip earthquakes many miles away, according to Cornell research.

During an earthquake, a fast slip happens when energy builds up underground and is released quickly along a fault. Blocks of earth rapidly slide against one another.

However, at an Antarctic glacier called Whillans Ice Plain, the earth scientists show that “slow slips” precede dozens of large magnitude 7 earthquakes. “We found that there is almost always a precursory ‘slow slip’ before an earthquake,” said

lead author Grace Barcheck, research associate in Earth and Atmospheric Sciences, in the College of Engineering.

Barcheck said that these slow-slip precursors – occurring as far as 20 miles away from the epicenter – are directly involved in starting the earthquake. “These slow slips are remarkably common,” she said, “and they migrate toward where the fast earthquake slip starts.”

Observations before several large tsunami-generating magnitude 8 and 9 earthquakes on subduction zone faults suggest a similar process may have occurred, according to Patrick Fulton, assistant professor and Croll

Sesquicentennial Fellow in the Department of Earth and Atmospheric Sciences.

As these faults are mostly offshore and deep underwater, and because it is difficult to know when or where a large earthquake will occur, the start of large earthquakes is generally hard to observe.

To overcome these challenges, the scientists placed GPS sensors above an icy glacial fault at Whillans Ice Plain, where large magnitude 7 earthquakes occur nearly twice a day over a 60-mile-wide area of the glacier.

Within a period of two months in 2014, the group captured 75 earthquakes at the bottom of the Antarctic

glacier. Data from GPS stations indicated that 73 – or 96% – of the 75 earthquakes showed a period of precursory slow motion.

The data from the GPS tracking stations and surface seismometers allowed the team to identify how the slow precursory slip triggers the fast earthquake slip.

“Before we pored over the data, I thought that if we saw any precursors before the earthquakes, they would be rare and in the same place as the earthquake epicenter,” Barcheck said. “Instead, we found many slow-slip precursors – starting miles from the epicenters and migrating across the fault.”



Matthew Siegfried, forefront, and seismologist Marino Protti, of the Observatorio Vulcanológico y Sismológico de Costa Rica, prepare to move equipment at Whillans Ice Plain. The Transantarctic Mountains are in the background.

CELL-FREE BIOTECH ENABLES SHELF-STABLE VACCINES ON DEMAND



A collaboration between Cornell and Northwestern University has led to the creation of iVAX, which uses extracts derived from bioengineered bacteria to create shelf-stable vaccines on demand.

Researchers from Cornell and Northwestern University have devised a new method of using extracts derived from bioengineered bacteria to create vaccines that protect against life-threatening infections caused by pathogenic bacteria.

Because the technology can be easily reconfigured for different pathogenic foes and freeze-dried for portability and refrigeration-free storage, it could be a game-changing approach to fighting infection, especially in locations where access to such medicines is limited.

The project is the latest iteration of an ongoing collaboration between Matthew DeLisa, the William L. Lewis Professor in the Smith School of Chemical and Biomolecular Engineering and director of the Cornell Institute of Biotechnology, and Michael Jewett, a professor of chemical and biological engineering at Northwestern University and director of Northwestern’s Center for Synthetic Biology.

In 2018, their team jointly pioneered a method for cell-free biomanufacturing in which engineered *E. coli* bacteria are used as a kind of chassis. The bacteria are equipped with biosynthetic machinery for protein glycosylation – the process of attaching a complex carbohydrate to a protein – which is something that *E. coli* cannot do naturally. These bacteria are then used to source cell-free extracts, which are enriched with all of the ingredients for making bespoke glycoproteins. The technology opened the door to the cell-free production of COVID-19 therapeutics. Importantly, eliminating the need for living cells affords many advantages, including lower cost-of-goods and faster production.

“This new [research] is the next conceptual leap for the technology,” DeLisa said. “By changing the composition of the carbohydrate structures that are made, we can – by design – create glycoproteins that have the potential to protect against infectious disease.”

All the reaction components, including the polysaccharides, are derived from the engineered *E. coli* chassis, which itself is non-pathogenic. Therefore, there is no need to ever handle or cultivate a pathogen, making the process far safer than the conventional method. In addition, while the extracts can be used immediately following their preparation to mass produce vaccine doses, they can also be preserved for future use by freeze-drying, which reduces their storage volume and increases their shelf-life at ambient temperatures.

The technology, which the team calls iVAX (short for in vitro bioconjugate vaccine expression), has already attracted the support of the Bill & Melinda Gates Foundation, which last year awarded the researchers a \$100,000 seed grant to develop the technology to address diarrheal diseases in developing countries.

“We hope to make a universal vaccine candidate against diarrheal pathogens using the technology,” DeLisa said. “We have a firm understanding of how to make these conjugates, so now we’re starting to shift our focus to more of the biomanufacturing aspects. We’re also really excited about the opportunity to use our expertise to tackle a really profound problem that is global in terms of the scope.”



A new research project led by Cornell will seek an integrated approach to turning waste from steel manufacturing plants into valuable materials.

\$1.5M GRANT TO EXPLORE INTEGRATED REUSE OF INDUSTRIAL WASTE, CO2

Sludge, slag and other waste produced by the steel industry are not only hazardous to the environment, but can be expensive for companies to discard. A new research project led by Cornell will seek an integrated approach to turning that waste into valuable materials using a \$1.5 million grant from the U.S. Department of Energy.

Steel production is a messy business. Blast furnaces reduce iron ore into pig iron, which is then converted into steel using a variety of processes and materials. Each step of the way produces a variety of by-products such as flue

dusts and slag – waste matter containing a mixture of chemicals and metals.

The steel industry has sought methods to reuse those by-products for steel and other manufacturing processes, however, efforts have mainly focused on treating waste materials independently of each other.

A group of academic and industry experts led by Greeshma Gadikota, assistant professor in the School of Civil and Environmental Engineering, proposes a new approach that would synergize the recycling of industrial steel waste by improving the recovery and quality of by-

products using carbon dioxide generated during the iron and steel-making process.

“Our interest is in developing holistic solutions that harness all the metal-bearing residues and carbon dioxide generated in iron and steel making processes to produce nano-scale calcium carbonate and iron oxide and remove heavy metals,” said Gadikota. “A key differentiator of this approach from existing pathways is the use of regenerable solvents for capturing carbon dioxide directly from flue gas to produce nano-scale carbonates at much lower temperatures in a process-intensified manner.”

The group, which includes

investigators from Columbia University, research and development firm Reaction Engineering International, and engineering management company HATCH, will focus on three specific areas: The synthesis of uniform nanoscale calcium carbonate from slag using regenerable solvents; iron oxide recovered from the alkaline residues will be reused in the steel making process; and recovered silica will be functionalized to separate the undesirable metal constituents such as lead, copper, and nickel.

ANTIBIOTIC TOLERANCE STUDY PAVES WAY FOR NEW TREATMENTS

A new study identifies a mechanism that makes bacteria tolerant to penicillin and related antibiotics, findings that could lead to new therapies that boost the effectiveness of these treatments.

Antibiotic tolerance is the ability of bacteria to survive exposure to antibiotics, in contrast to antibiotic resistance, when bacteria actually grow in the presence of antibiotics. Tolerant bacteria can lead to infections that persist after treatment and may develop into resistance over time.

The study in mice, “A Multifaceted Cellular Damage Repair and Prevention Pathway Promotes High Level Tolerance to Beta-lactam

Antibiotics,” published Feb. 3 in the journal *EMBO Reports*, reveals how tolerance occurs, thanks to a system that mitigates iron toxicity in bacteria that have been exposed to penicillin.

“We’re hoping we can design a drug or develop antibiotic adjuvants that would then basically kill off these tolerant cells,” said senior author Tobias Dörr, assistant professor of microbiology in the Weill Institute for Cell and Molecular Biology in the College of Agriculture and Life Sciences.

Co-authors included Ilana Brito, the Mong Family Sesquicentennial Faculty Scholar and assistant professor in the Meinig School

of Biomedical Engineering in the College of Engineering, and Lars Westblade, associate professor of pathology and laboratory medicine at Weill Cornell Medicine.

Some bacteria, including the model bacterium used in the study, *Vibrio cholerae*, which causes cholera in humans, are remarkably tolerant to penicillin and related antibiotics, known as beta lactam antibiotics. It has been known for a long time that beta-lactam antibiotics break down bacterial cell walls, but how bacteria survive loss of their cell walls was poorly understood.

In the study, the researchers developed a *V. cholerae* mutant that lacked a two-component damage repair response system that controls a gene network encoding diverse functions. Without the system, known as VxrAB, when the cell wall is damaged by antibiotics, the transfer of electrons across the cell membrane goes awry, leading to electrons ending up on the wrong molecules. This misdirection causes hydrogen peroxide to accumulate in the cell, which changes the oxidation state of cellular iron and disrupts signals for the cell to tell how much iron it has.

In the presence of hydrogen peroxide, the mutant bacteria cannot sense how much iron has been acquired, and it behaves as if it is iron-starved and seeks to acquire more iron. Left unchecked, these circumstances cause iron toxicity, which will kill

the cell, according to the experiments the researchers conducted. In further tests with mutant *V. cholerae* bacteria, both in test tubes and in mice, the researchers showed that reducing the influx of iron increased the bacteria’s tolerance to beta lactams.

Fortunately for normal *V. cholerae*, exposure to antibiotics and the breakdown of the cell’s walls activate the VxrAB system, which works to repair cell walls and downregulates iron uptake systems, and thereby creates antibiotic tolerance. More study is needed to understand what triggers the VxrAB system in the presence of beta-lactam antibiotics.

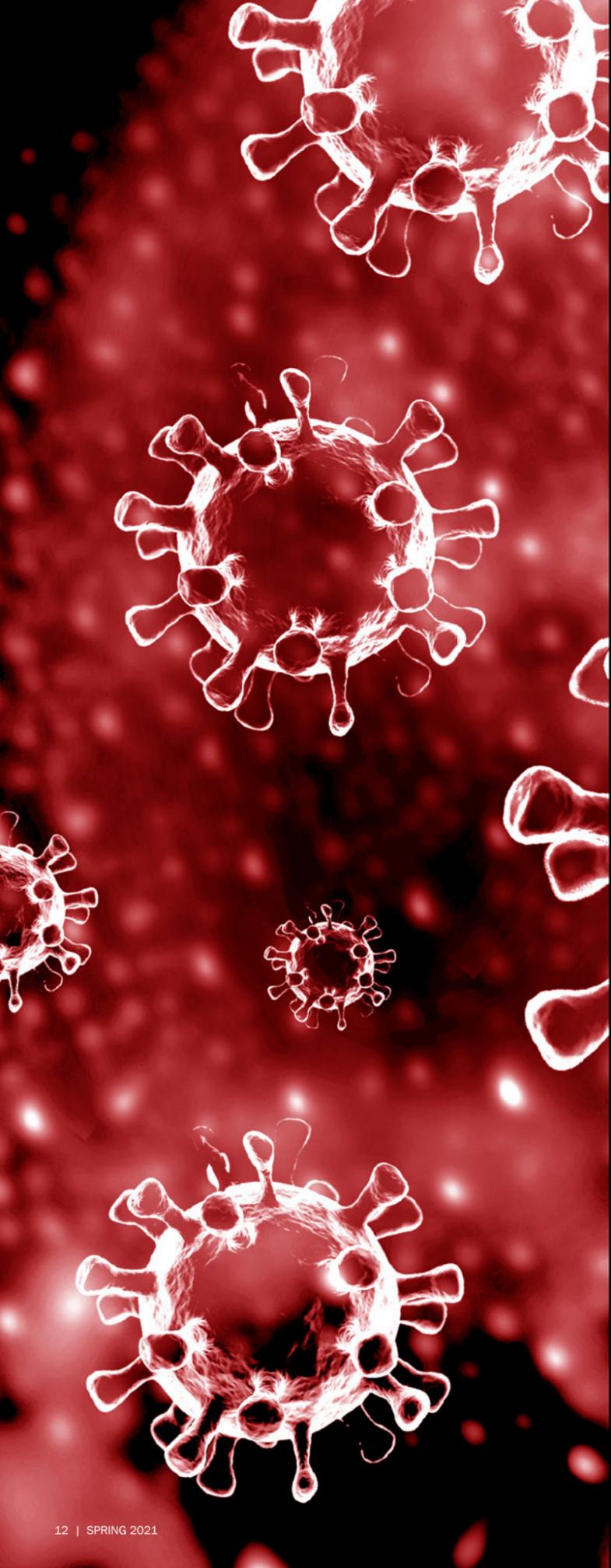
The research opens the door for developing new drugs that could be combined with antibiotics to exploit oxidative damage and iron influx in tolerant bacteria. In future work, the researchers will search for parallel mechanisms of tolerance in other bacterial pathogens.

Jung-Ho Shin, a postdoctoral researcher in Dörr’s lab, is the paper’s first author. Co-authors include researchers from the Korea Advanced Institute of Science and Technology and the Intelligent Synthetic Biology Center in Korea.

The study was funded by the National Research Foundation of Korea and the National Institutes of Health.



Stock image of antibiotics



CONTAINING COVID-19 AT CORNELL

By Syl Kacapyr

**THE MODELING
BEHIND CORNELL'S
SUCCESSFUL FALL
SEMESTER AND
THE ENGINEERS
WHO SKILLFULLY
CRAFTED IT**

“In God we trust. All others must bring data.” The words spoken by the late engineer and statistician William Edwards Deming imply the importance of translating data into information for decision making.

It is a notion that Cornell University understood as the fall 2020 semester approached. Whether or not to bring tens of thousands of faculty and students back to campus amid a deadly pandemic was a decision that could not be left to sheer judgement. It needed science.

Fortunately, the university is home to the School of Operations Research and Information Engineering, internationally recognized for its experts who use advanced analytical methods to help make better decisions.

“In late March, the world was turning upside down,” said Shane Henderson, the school’s Charles W. Lake, Jr., Professor in Productivity. “It was clear there were a lot of choices that the university was facing along with the rest of the nation, and we wanted to help. We knew that our ability to apply science to decisions could be important and we were trying to figure out how to have the most impact.”

Faculty and students began thinking about logistical aspects of the pandemic, such as how to optimize transportation of ventilators needed to treat COVID-19 patients. But it was an interest in an epidemiological approach used in World War II to help curb the spread of syphilis that would eventually bring the school’s capabilities to the university’s attention.

What came next was a Herculean operation to mathematically simulate the months to come and inform university leadership of the best path forward, according to science. The results would capture the attention of the academic world and provide Cornellians with a semester they would never forget.

Pooled testing and a path forward

During World War II, an outbreak of syphilis among U.S. troops forced health officials to develop a creative solution to prevent its spread. Regular testing of every soldier would have been expensive and inefficient given testing methods at the time. Instead, multiple blood samples were pooled together to reduce the total amount of required tests.



Clockwise from top left: Christopher Wofford of eCornell; Provost Michael Kotlikoff; Sharon McMullen, assistant vice president of student and campus life for health and well-being; Gary Koretzky, vice provost for academic integration; Diego Diel, Cornell COVID-19 Testing Laboratory; and Peter Frazier, associate professor in the School of Operations Research and Information Engineering, during the COVID-19 Summit, a 2-day event featuring researchers from across Cornell.

Peter Frazier, associate professor of operations research and information engineering, had taken an interest in this “pooled testing” technique, and envisioned its application for curbing the COVID-19 pandemic.

“We know most of the people we’re going to be testing will be negative, so what you can do in a situation like that is instead of testing each sample – each swab of the nose – individually, you dissolve those nose swabs into some fluid and run one chemical reaction in order to test for the presence of the virus,” said Frazier, who specializes in Bayesian optimization and simulation. “If it tests negative, you can rest assured that all who participated in that pool are negative. If it tests positive, then you do follow-up testing on each of the individual samples.”

As fate would have it, Cornell Provost Michael Kotlikoff had independently taken an interest in pooled testing, and began exploring the idea by contacting a close colleague of Frazier’s – David Shmoys, the Laibe/Acheson Professor of Business Management and Leadership Studies.

“I knew that Peter had been looking for an opportunity to work on developing pooled testing as a means to achieve regular asymptomatic screening on a national scale, but the possibility of helping Cornell would be a way to have a more immediate impact,” said Shmoys, who is also director of the Center for Data Science for Enterprise and Society. “I put Peter in touch with the provost, and this led to the formation of the Cornell Covid Modeling Team.”

Wondering if this technique could be a path forward to having in-person instruction during the pandemic, Frazier, supported by Henderson and Shmoys, launched a full-fledged effort to mathematically model Cornell’s options for the fall. What their simulation modeling revealed was a counterintuitive finding that was met with a healthy mix of curiosity, hope and skepticism.

Scouring the literature... and cruise ships

Working as part of a university committee to support decision making for university leadership, Frazier and his team enlisted the help of a talented roster of students. Their goal was to provide data-driven options as leadership considered whether and how to bring students back for an in-person fall semester.

“We thought quite hard about not opening Cornell and instead going to virtual instruction in the fall, but the challenge that we faced was there were a number of students who said they would come back anyway,” said Frazier, referring to a university survey in which 31% of respondents said they were likely to return despite virtual-only instruction. That translated to roughly 5,000 students. “We were worried that if students weren’t officially on campus, then the mechanisms by which Cornell could enforce testing compliance would essentially be voluntary.”

In order to determine which option would produce the fewest COVID-19 infections and, hence, be the safest, the team wanted to know how COVID-19 might spread among the Cornell and greater Tompkins County communities. To do this, they used a stochastic compartmental simulation, a type of mathematical model frequently used in epidemiology. The simulation tracks people based on the state of their disease – susceptible, exposed, infectious, symptomatic or recovered – and by length of time in each of those states. The population was compartmentalized into groups including undergraduates in high-density housing, undergraduates living off campus, graduate students, and faculty and staff.

“A simulation model is a representation of reality, where you try to mimic what would happen in real life,” said Henderson, “and you build in as many realistic assumptions as you feel like you need for the decisions you’re facing.”

Simulating how Cornell’s entire semester might play out during a pandemic was a massive undertaking, recalled J. Massey Cashore, doctoral student in Frazier’s research group.

“The number of parameters in this kind of simulation becomes really huge – things like disease length, length of time it takes to incubate, how many contacts a person has per day. We were scouring the literature on COVID-19, trying to get these answers.”

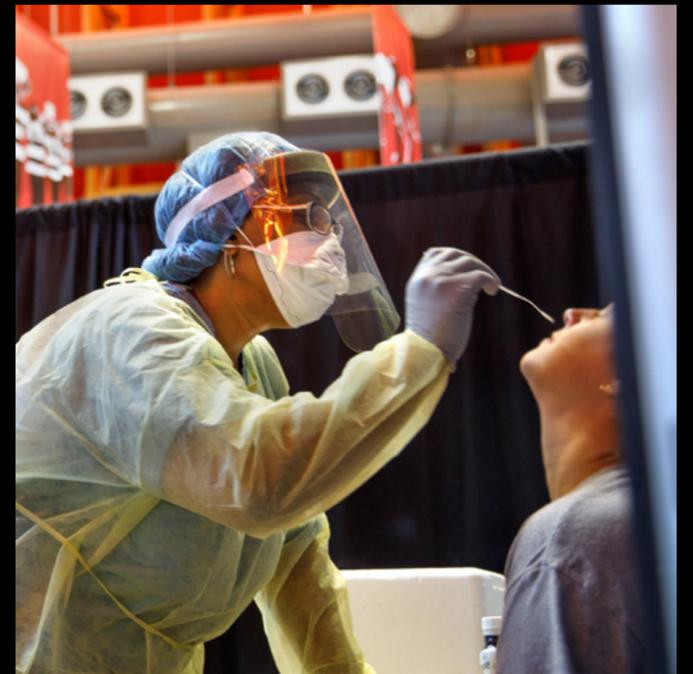
Knowing that models are only as good as the assumptions built into them, the group began searching the Centers for Disease Control and Prevention website for reports and statistics on the disease, which was still relatively new at the time. They were also contacting epidemiologists and other experts, trying to find as much data as they could to build their models.

“We cobbled together I don’t know how many different sources, trying to get some estimates of infection and hospitalization rates as a function of age,” said Henderson. “In those early days, I think for the asymptomatic rate we saw estimates ranging from 20% to 85%. That’s an enormous range.”

Another doctoral student, Alyf Janmohamed, found data from an unlikely, but helpful, source – cruise ships that experienced COVID-19 outbreaks.

“The ships had good, comprehensive data about whether or not passengers had COVID and whether or not they were asymptomatic,” said Janmohamed. “People in these data sets had vastly different ages, different races, and different geographies that we were stitching together to get our initial estimates of asymptomatic percentage.”

Added doctoral student Yujia Zhang: “In turn, we needed to apply that data to the different separation of the age levels we



A test sample is taken at Cornell’s COVID-19 testing site at Fischell Band Center.

see on the Cornell campus. That was another set of parameters we needed to get, using enrollment data.”

In the end, the group’s model for infection rate was remarkably accurate considering what little information about COVID-19 was available at the time. They estimated that around 50% of COVID-19 patients are asymptomatic. Nearly a year later, the CDC has determined the rate to be roughly 40%.

The team’s effort continued. They needed more data.

Close contacts and Cashore’s coding

One of the most important numbers the group sought to model was the number of people that, on average, a single infected person could transmit the disease. They would have to consider the number of close contacts per day, the chance of transmitting the virus during those contacts, and the amount of time that person would be at large before being isolated.

Based on the scientific literature, the group expected individuals to have an estimated 8.3 close contacts per day.

“But we really had a lot of uncertainty about that number,” said Frazier, “and we knew if, in reality, the true number of expected contacts per day was much larger, then we would likely see much larger numbers of positive cases on campus. That’s a really dangerous thing we wanted to avoid and so that’s what kept me and a lot of us up at night.”

And there were other estimates that concerned the group, according to doctoral student Jiayue Wan.

“For instance, the accuracy of COVID-19 tests using different sampling methods – nasopharyngeal, oropharyngeal, saliva – and I remember that the team and I were reading dozens of papers that were fresh-off-the-shelf just to find evidence for one single parameter,” said Wan.

To counter this and other uncertainties, the group performed sensitivity analyses in which they varied data



Students wait in line to submit test samples as part of Cornell’s COVID-19 surveillance testing program.

parameters to see how the simulations would respond. If a simulation showed potentially dire consequences for small variations in the data, the group would use the most conservative estimates they had in order to be safe.

"We'd have a small change of the parameter settings, but it would launch an avalanche of additional work we had to do to rerun the set of simulations," said Cashore. "By the end, we got really good at automating the sensitivity analysis runs, because this is something we had to do so frequently."

There was a considerable amount of coding to be performed as the group continued to find information about COVID-19. More data. More simulations. Repeat. The main software script used to run the simulation models eventually reached about 700 lines of programming code, according to Cashore.

The group was closing in on a final simulation that would help inform university leadership which option – having an in-person or virtual-only semester – would be the safer option. But first, the group had to go back to where it all started – Frazier's idea of pooled testing.

Moving heaven and Earth

The cornerstone of Cornell's ability to have in-person instruction amid the pandemic is the Animal Health Diagnostic Center at the College of Veterinary Medicine, home to the Cornell COVID-19 Testing Lab. The lab already had experience testing for COVID-19 in dairy cows, and university leaders wanted to know if it could be modified for screening the campus population.

But because of the lab's limited size, the goal for Frazier and the group was to find the sweet spot in which the number of daily tests would be within the lab's limits, but enough to contain the spread of the disease on campus. So the group simulated different percentages of the campus population it might test each day, from zero all the way to everyone.

"Each run of the simulation produces a percentage of the population that becomes infected," said Frazier. "What you see is that in most runs of the simulation, if I test everyone once every five days, I usually have about 5% of the population infected. If I don't do asymptomatic screening, I often have as much as 50% of the population infected."

Using this data, a number range that stood out to Frazier was 6,000 to 7,000 tests per day. The simulations showed that infections exponentially rise as the number of tests per day dip below that range, but as testing rises above that range, no dramatic shift in infection rates occurs.

And with Frazier's pooled testing plan, screening 7,000 people per day would mean only performing about 1,500 tests – a measure that would make testing economically feasible.

"The testing lab moved heaven and Earth to get to that number," said Frazier. "The people in that lab, every day they open 7,000 tubes by hand, and then they close 7,000 tubes by hand. They do that every weekday and then run 4,000 or 5,000 tests on Saturday and Sunday. We're really appreciative of those people."

More data. More simulations. More sensitivity analyses.

The work culminated in a 54-page report that the group published on June 15, 2020. In it, the modeling results suggested that a combination of contact tracing and pooled testing, among other measures, could achieve meaningful control over



Test samples are processed at the Cornell COVID-19 Testing Lab.

COVID-19 outbreaks on Cornell's campus.

The report also detailed how the group's simulations predicted that the number of infections for a virtual-only semester would be approximately 7,200 during a 16-week semester, while an in-person semester with the protocols recommended by the group would produce only 1,200 infections, an estimate that was later reduced to 900 based on refined models.

It was a counterintuitive finding, but it was one based on data and science. Having students on campus, according to the report, would enable testing compliance and other key factors in limiting spread of the disease. A virtual-only semester risked large outbreaks that would have endangered not just the Cornell campus, but the surrounding community in Tompkins County and beyond.

After reviewing the report, among many other considerations by university leadership, the decision was made – Cornell would have an in-person semester beginning Sept. 2.

The moment of truth

The anticipation. That's what Henderson remembers most about the start of the fall semester. The anticipation of whether or not the simulation models would accurately reflect reality. After all, epidemic modeling is fundamentally imperfect, as the group's report stated, and it was impossible for their models to fully capture the intricacies of the real world.

"Everybody was watching," said Henderson. "We put in a lot of effort to try to make the estimates conservative, but accurate. But at the end of the day, there's going to be some uncertainty."

One of the main parameters the group was watching was testing compliance, according to Janmohamed.

"Everyone had been in quarantine for five, six months at that point and it was hard to predict what people were going to do when they came back to campus and had a little bit more freedom," said Janmohamed. "But seeing the way that Cornell students took it upon themselves to follow the social distancing guidelines and make sure the semester went well, it was really inspiring to see."

As it turned out, Cornell saw a 97% compliance rate with its testing protocol. But before regular testing could begin in earnest, cases began to spike. By Sept. 4, the university saw a new high of 14 cases in one day, adding to the 24 cases it had seen the previous two days.

"During this period, there were clusters of cases that started in off-campus apartments," said Frazier, "and when the asymptomatic screening started, that's when we found all the cases. This was a scary period, but over the course of about a week and a half, we were able to drive down this cluster."

On Sept. 13, the university reported its first day with zero new cases. That was followed by two consecutive days of no new cases, and through the end of October the university was finding three or fewer cases per day.

Cornell's success gained national attention. Some universities began modeling their protocols after Cornell's, while many of those that didn't were experiencing outbreaks. In the case of Michigan State University, the county in which it resides saw a major jump in infections despite the university not opening its campus – 640 cases one week in September. It was exactly what Frazier and others had feared for the Ithaca community had Cornell not opened its campus.

Beating the models

By the end of October, Cornell had reported a total of 155 COVID-19 cases, much fewer than the 900 Frazier and team had estimated in their report.

Frazier attributes the discrepancy to a number of factors, including the conservative data the team used out of an abundance of caution, and a lower prevalence of the disease among students returning to campus, likely due to a high compliance to the university's request to quarantine before leaving.

"I really do believe – and I've seen the data – that students at Cornell are doing a much better job at complying with social distancing and masking restrictions as compared to other universities," said Frazier. "I think that's a big part of why we've had success – because our students are great, but also because of a number of innovations that the administration put in place and designed quite effectively."

Another reason infections were much lower than the models predicted was because of adaptive testing, according to Frazier. Adaptive testing is the concept of testing everyone in the social circle of an infected individual, not just those identified through contact tracing.

"For example, if a student who is on the wrestling team tests positive, we would test the entire wrestling team. If a student who lives in a dormitory tests positive, we would test all people who share a bathroom with that student," said Frazier, who also points to Cornell's strong partnership with Cayuga Health System and the Tompkins County Health Department as reasons for the successful fall semester.

Never losing hope

Based on lessons learned from the fall and new challenges that have emerged during the pandemic, university officials have made adjustments to its policies and protocols for the spring semester. But for the most part, the spring is mirroring the fall – a semester backed by data, science, operations research and information engineering.

"There's an introductory course I always start by presenting a few applications of what operations research can do," said Shmoys. "This year was so completely different – in a few minutes one could explain the broad outlines of how mathematical modeling enabled the students to be on campus, taking this class in person."

For all their hard work – the all-nighters, the seemingly endless modeling and coding, the thoughtful approaches and careful attention to detail – the faculty and students from the School of Operations Research and Information Engineering said there was just as much in it for them as everyone else.

"It's been a fantastic experience working with such incredible people, pouring their heart into this. I think it's been the highlight of my academic experience," said Janmohamed. "In terms of personally dealing with the pandemic, going through this exercise of how you control the virus was something that helped me process everything that was going on."

Zhang added: "It's the sense of control that we are building up, and in a more abstract sense, it's never losing hope. We know that the efforts we make actually contribute to making the situation better, at least in the scope of the Cornell campus."



Staff process test samples at the Cornell COVID-19 Testing Lab.



By Chris Dawson

BIO MINING RARE-EARTH ELEMENTS

21 Sc Scandium 44.956	59 Pr Praseodymium 140.908
39 Y Yttrium 88.906	60 Nd Neodymium 144.242
57 La Lanthanum 138.905	61 Pm Promethium [145]
58 Ce Cerium 140.116	62 Sm Samarium 150.36

63 Eu Europium 151.964	67 Ho Holmium 164.930
64 Gd Gadolinium 157.25	68 Er Erbium 167.259
65 Tb Terbium 158.925	69 Tm Thulium 168.934
66 Dy Dysprosium 162.500	70 Yb Ytterbium 173.045
	71 Lu Lutetium 174.967

CORNELL ENGINEERS ARE PIONEERING A NOVEL METHOD FOR MINING METALS THAT ARE KEY TO UNLOCKING A SUSTAINABLE FUTURE.

“BUZ AND HIS TEAM ARE RUNNING EXPERIMENTS TO EXTRACT RARE-EARTH ELEMENTS FROM ROCKS USING ACIDS PRODUCED BY MICROBES. AND IN ORDER FOR THEM TO QUANTIFY THE EFFICIENCY OF THEIR MICROBES, THEY NEED TO QUANTIFY THEIR INPUTS AND THEIR OUTPUTS PRECISELY.”

— **Assistant Professor Megan Holycross**

In the search for more sustainable energy technologies, many of the solutions humans are turning to – rechargeable batteries, massive wind turbines, electric cars, LED lighting – rely on what are known as rare-earth elements. There are 17 rare earths on the periodic table, ranging from the lightest, scandium, to the heaviest, lutetium, and they are highly valued for their unique physical and chemical properties that make them useful in sustainable energy technologies.

As is so often the case, solutions to existing problems can create their own, new problems. This is certainly true of our reliance on rare earths to make technologies greener. The industrial processes used to isolate them from their naturally-occurring ores often rely on strong acids or bases that can pollute the environment. Harmful effects of the mining include contaminated soil and water, deforestation and negative health impacts on humans and other animals. These processes also require large amounts of energy.

Our reliance on rare earths is not going to end any time soon, so researchers have begun to look for ways to obtain them in less environmentally harmful ways.



BEE Assistant Professor Buz Barstow in his lab.

A multidisciplinary team at Cornell is on the leading edge of this push to help green technologies get even greener. Between the Department of Biological and Environmental Engineering and the Department of Earth and Atmospheric Sciences – units shared between the College of Engineering (ENG) and College of Agriculture and Life Sciences (CAL S) – faculty, postdocs and graduate students have all come together to tackle this problem.

Led by Buz Barstow, assistant professor of biological and environmental engineering (CAL S), the team is looking at ways to “program” microbes to produce organic acids that can leach rare-earth elements from crushed ores or from recycled electronics components. These microbial acids will be far safer than the acids and bases used in existing industrial processes.

Altogether, the processes Barstow and the team of engineers are pioneering can be called “biomining,” and if proven scalable, will have a major impact on the sustainability of future electronics as well as on the health of people and the environment.

‘Risky, cutting-edge work’

Postdoctoral researcher Alexa Schmitz joined Barstow’s effort when, as a Cornell grad student earning her doctorate in plant pathology and plant-microbe biology, she was in a biofuels seminar presented by Barstow. But in the discussion afterward, he also talked about bioleaching and its potential in the mining and recovery of rare earths.

“It felt like risky, cutting-edge work,” says Schmitz, “but at the same time I thought ‘Yes. This can definitely work.’” Schmitz was finishing her Ph.D. and looking for a postdoctoral position, and Barstow was looking for help on his biomining project

after receiving an Academic Venture Fund seed grant from the Cornell Atkinson Center for Sustainability.

Schmitz got to work right away with a bacterium called *Gluconobacter oxydans*. It had already been shown to have potential as a bioleaching microbe through initial work done at the U.S. Department of Energy’s Idaho National Laboratory. Schmitz used a method developed by Barstow called Knockout Sudoku to selectively inactivate one gene at a time and then build a collection of several thousand variants of *G. oxydans*. Each of these variants will be tested as a bioleaching agent for rare earths, and then those that perform best will be further developed.

As she gathers data, Schmitz – who is continuing the work with help from the Cornell Atkinson Small Grants Program – says she will be compiling a roster of genes that could be key to the development of an efficient and sustainable system to extract rare earths.

Mutant bacteria

Monazite is one of the ores known to contain rare earths in sufficient quantities to be worth mining. Schmitz can’t just throw a chunk of monazite and some bacteria into a beaker and wait to see what happens. Rather, the initial screening for genes that may be related to leaching of rare earths will happen in microplates that can be read spectroscopically.

Schmitz explains, “Once we know which genes are most important for bioleaching, we will target those genes – and genetic elements controlling those genes – for mutagenesis. This can be done in combination, targeting several genes at once, and the resulting modified strains are screened for changes in bioleaching.”



Each variant of *G. oxydans* will be tested as a bioleaching agent for rare earths. Those that perform best will be further developed.

BEE postdoc Alexa Schmitz

Mutagenesis is a process whereby the genetic information of an organism changes by mutation. That mutation can be spontaneous or it can be controlled in a laboratory. Schmitz and Barstow will force mutations on the genes that are most involved in bioleaching and then measure how effective the mutated organism is at gathering available rare earths. Their hope is that with a high-throughput method for evolving *G. oxydans*, they will be able to engineer an organism that can leach rare earths more efficiently and sustainably than existing industrial methods.

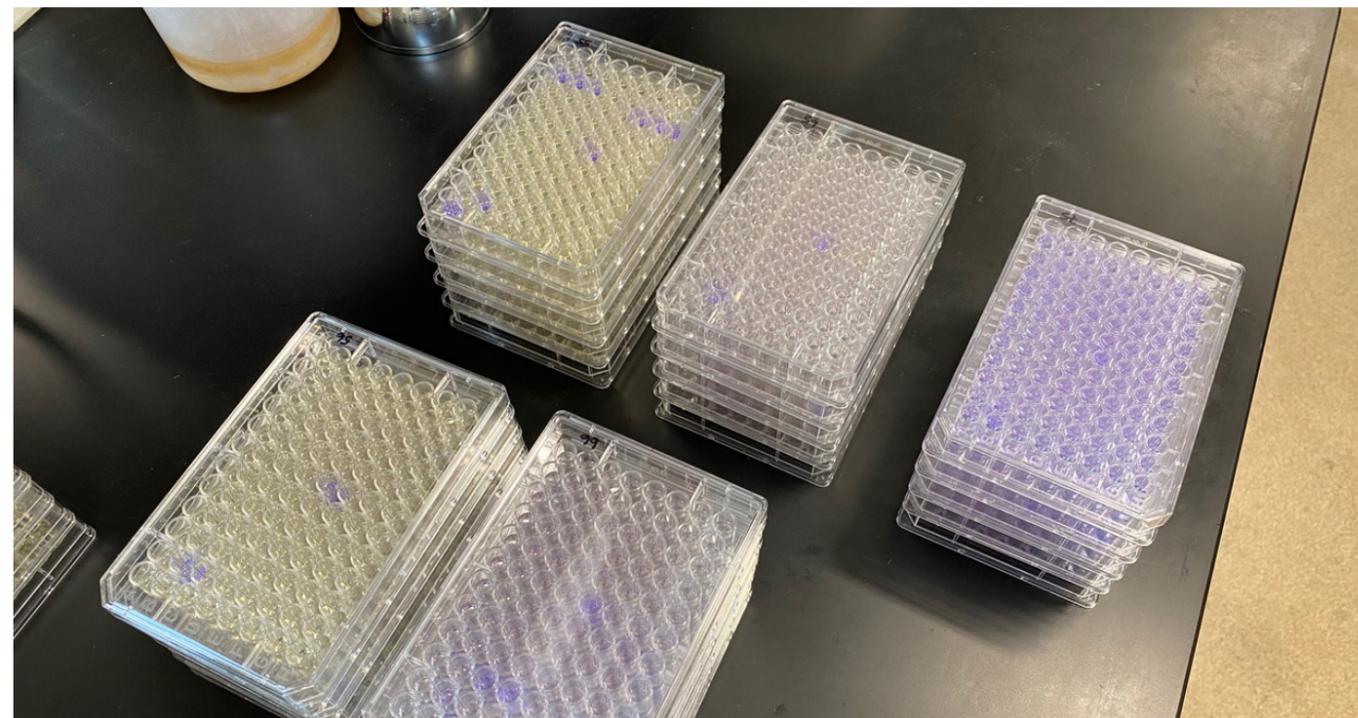
This is where Mingming Wu comes in. Wu, a professor of biological and environmental engineering (CALS), is an expert in microfluidic devices. Traditional methods of identifying, isolating, and mutating microbes are labor and time intensive, requiring a lot of careful and repetitive pipetting.

“Buz and I started to talk about his work,” says Wu, “and we realized that in microfluidics there already exists an established way of identifying and selecting ‘super-bugs’ that exhibit a desired characteristic.”

This existing process is called directed evolution. Together with Sean Medin, a second-year Ph.D. student in Barstow’s lab, the team is in the process of designing a microfluidic device that forces individual bacteria through a channel, with several “stations” along the way.

“We can put sensors in the device so that when a bacterium binds with a rare-earth element, it changes color and we can see it,” says Wu. “Those that bind will be sent down one route in the device, and those that don’t bind will be sent down another route.”

The bacteria that worked will be directed back through the device to a station where they will be mutagenized and then sent through the device again. In this way, Barstow’s team can create an improved variant of the bacterium that Medin will be using to adsorb rare earths.



The initial screening for genes that may be related to leaching of rare earths will happen in microplates that can be read spectroscopically.

Recycling electronics and waste products

In addition to helping to craft the microfluidic device the group will use in their process, Medin is also working on an essential step in biomining rare earths – separation.

Once the rare earths have been leached out of the monazite or other ores, they still need to be separated from each other and from the impurities that make it through the leaching process. Current methods of separation, such as liquid-liquid solvent extraction and the ion-exchange process, are energy-intensive and result in large amounts of dangerous waste products.

Medin will instead use a bacterium called *Shewanella oneidensis* MR-1, and he will subject it to a similar directed evolution process that Schmitz is using with *G. oxydans*. Medin will be selecting for variants that show higher than average ability to adsorb rare earths. These variants will be subjected to several rounds of mutagenesis with the aim of creating a bacterium that is able to adsorb specific rare earths in high quantity.

Medin joined the Barstow Lab with the express intent of working on this project, and he hopes to someday start a company to commercialize some of the processes honed in the lab. However, his focus would be on recycling existing rare earths from electronics, mine tailings and fly ash, which is one of the waste products of coal combustion.

“Ideally,” says Medin, “I’d like to be able to take fly ash or permanent magnets or other recycled sources of rare-earth elements, bioleach them, and then extract the rare earths out for reuse. And I’d like to do all of that in the U.S. and make sure it is environmentally friendly.”

Currently, the United States imports most of the rare earths it uses, and recycles just a tiny percentage of rare-earth-containing products.



Sample of monazite ($NdPO_4$) synthesized by EAS post-doc Brian Balta.

The right tools for the job

Sabrina Marecos, a first-year Ph.D. student in the Barstow Lab, is working to validate the genetic models being used. Previous research at Cornell and elsewhere supports the theory that Barstow’s Knockout Sudoku process should work with *Gluconobacter oxydans*.

“At the moment,” says Marecos, “I am working on the verification of the knockout of the membrane-bound glucose dehydrogenase gene. This would confirm that it is possible to knock out genes in *Gluconobacter*. After that, I will proceed to try and validate the over-expression of another gene to confirm it can be done and which method is most suitable.”

Once Marecos validates the methods Barstow, Schmitz and Medin plan to use, the resultant tools will supplement the relatively few that already exist. “This would allow us to engineer the bacteria using data indicating that some genes are more involved than others in the production of important acids,” says Marecos. “By modifying the bacteria and observing its behavior, we will better understand the bioleaching process and how to enhance it.”

‘An idea that can only happen at Cornell’

Barstow makes a point of highlighting the importance of Cornell’s culture of collaboration in enabling biomining research. In addition to his lab member’s individual projects, there is one pivotal piece of the work none of them can do: synthesize monazite containing precisely quantified amounts of various rare earths.

In order to know exactly how effective and efficient the bacteria are at leaching and separating rare-earth elements, the team needs to know exactly how much of each element there is in the initial ore. After all, it does not help to know how many grams of lanthanum have been collected through bioleaching if you have no idea how many grams were there to start.

Lucky for Barstow, there are two recent faculty hires who can synthesize and characterize monazite in exactly the way he requires. It was a chance encounter at a Cornell Atkinson brown-bag lunch that would eventually bring the three Atkinson

Faculty Fellows together.

Assistant Professor Megan Holycross’s (ENG) specialty is understanding the processes that have differentiated the chemistry of earth’s solid interior. “The instruments in my lab in Snee Hall are capable of achieving temperatures and pressures that recreate the conditions up to 120 kilometers deep in the earth,” says Holycross. “I am studying what happens in the lower crust and the upper mantle of the earth.”

Serendipitously, some of Holycross’s lab equipment can also be used to create homogeneous samples of ores. “Buz and his team are running experiments to extract rare-earth elements from rocks using acids produced by microbes,” says Holycross. “And in order for them to quantify the efficiency of their microbes, they need to quantify their inputs and their outputs precisely.”

Holycross is growing synthetic monazite samples with Associate Professor Esteban Gazel (ENG) and postdoc Brian Balta. Gazel will use his geochemical expertise to characterize the samples, and he will also carry out mass balance calculations to help Barstow determine which mutant version of *G. oxydans* is most efficient – and therefore most commercializable.

“This is an idea that I believe could only happen at Cornell,” says Gazel. “There is this culture of interdisciplinary collaboration here that is very hard to find elsewhere. Buz and Mingming knew as little about monazite as Megan and I knew about synthetic biology before collaborating.”

Holycross agrees. “This is why I came to Cornell – to do interdisciplinary things like this and work on exciting problems with colleagues.”

“The powerful perspective of our work is not only the fact that we are open to crossing the boundaries of disciplines,” Gazel says, “but that we are all open to learning new areas and communicating with each other. It is in these interdisciplinary spaces where solutions to old and new problems can be found.”



Postdoc Alexa Schmitz and M.Eng. student Don Flood.

THE MODERN TA

By Eric Laine

UNDERGRADUATE TEACHING ASSISTANTS ARE CHANGING THE CLASSROOM THANKS TO CORNELL ENGINEERING'S OUTSTANDING TRAINING PROGRAMS

The role of teaching assistants is no longer limited to basic classroom and lab administration such as answering questions and grading assignments. Today's TAs are responsible for the ambitious task of creating a positive sense of community where students feel comfortable and ready to learn.

Cornell Engineering recognizes the importance of this and invests heavily in substantive training programs through its office of Engineering Learning Initiatives (ELI). The office applies the latest research on pedagogical practices to its TA training, expanding beyond the traditional model of relatively static knowledge transmission from teacher to learner. The goal is to excite and engage students by giving TAs a sophisticated understanding of how human learning occurs – along with administrative management and interpersonal skills – to create an educational environment that works for all students.

Emphasizing peer education, student-centered learning,

and a shared understanding of diversity and inclusion have placed Cornell Engineering at the forefront of modern classroom practices.

Investment in training

Hundreds of students work as TAs at Cornell Engineering each year, and these days, many of those TAs are undergraduates. The expanding number of undergraduate TAs is not unique to Cornell but represents a growing recognition of the value of peer-facilitated learning nationally, particularly at large universities.

One indicator of the value teaching assistants provide is the considerable resources Cornell Engineering devotes to their training and compensation. In some departments, the budget allocation for TA positions can reach over a million dollars each academic year.

"TAs are an absolutely critical part of our education

model," said Jed Dove, director of administration for the School of Electrical and Computer Engineering (ECE). "Particularly for large enrollment courses, if we didn't have TAs it would just be impossible for our professors to teach."

Recognizing the need for a focused training experience for undergraduate TAs, in 2013 ELI collaborated with engineering departments to create a half-day program, drawing upon the educational content developed for Ph.D. TAs, but tailored to the work undergrad TAs do.

The ELI training gives TAs practical strategies for getting students talking to one another, answering each other's questions, and building a sense of community through active learning, a core guiding philosophy of the TA development program.

ELI's TA development programs are but one angle from which Cornell Engineering, and university, focus on teaching. The James McCormick Family Teaching Excellence Institute

works with engineering faculty to develop dynamic teaching methods and improve course design, and the Center for Teaching Innovation provides a wealth of teaching resources for both faculty and TAs across the university, including the Teaching Assistant Online Orientation, developed last year.

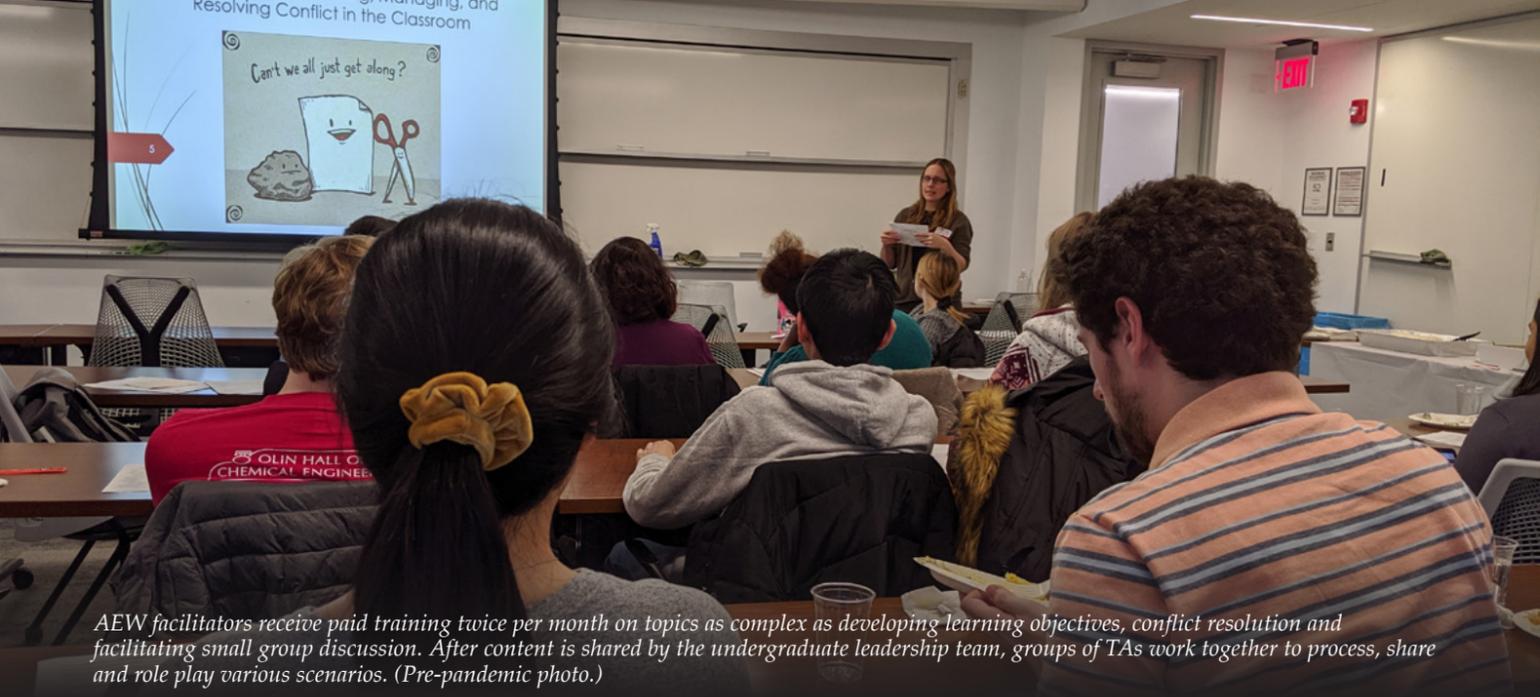
A classroom for everyone

One of the very first considerations of the modern TA is ensuring that the learning environment is engaging and inclusive, according to Lisa Schneider-Bentley, director of ELI.

"And when I say inclusive, I'm talking about awareness of the diversity of learners along all kinds of social identity dimensions and backgrounds, as well as understanding how to use an array of teaching strategies to reach students who come in with a broad variety of learning strengths and challenges," said Schneider-Bentley.



In a large lecture hall, TAs are incredibly valuable for helping clarify, redirect and support idea development during group work segments. (Pre-pandemic photo.)



AEW facilitators receive paid training twice per month on topics as complex as developing learning objectives, conflict resolution and facilitating small group discussion. After content is shared by the undergraduate leadership team, groups of TAs work together to process, share and role play various scenarios. (Pre-pandemic photo.)

“People have different ways they process material,” said Celia Evans, ELI’s associate director. “They have different ways they express themselves and different ways they engage mentally and emotionally with material. We have a really diverse student body and it’s very important that everybody feels like they can interact, contribute and ask a question.”

Strategies for creating engagement, belonging and equity are integrated throughout ELI’s training components. For example, the session on fair and effective grading includes guidance and practice in creating consistent rubrics so students know how their work is evaluated, employing anonymous grading to guard against unconscious biases and giving clear and usable feedback so students can learn from their mistakes.

Ultimately the TA training is intended to frame a shared understanding of diversity and inclusion at Cornell, and the best teaching strategies to facilitate effective learning.

“Undergraduate TAs contribute diversity to the teaching team,” said Aaron Wagner, professor and associate director of electrical and computer engineering. “While an introductory ECE class typically will have one instructor and, at most, two Ph.D. TAs, it might have several undergraduate TAs who represent a wider range of identities and lived experiences, better reflecting the composition of the student body.”

Active learning and adapting to COVID-19

Once a welcoming and inclusive environment is developed, then the complex task of engaging students through active learning can begin, providing avenues for students to construct their understanding and ask questions.

Active learning is a teaching approach that is learner-centered as opposed to traditional lecture in which content is unidirectional from teacher to student. Teaching with active learning means designing activities that require interaction. The idea is to get students thinking, talking and writing about what they are doing. It emphasizes the importance of students controlling their own learning process with structured, guided discovery.

“Active learning is teaching the TAs to facilitate and not teach, essentially,” said Evan Austin ’21, a student in materials science and engineering. “It’s very collaborative and structured around activities instead of just sitting around and watching a lecture.”

Concepts like active learning are explained, modeled and infused throughout ELI’s TA training programs. Activities such as “Think-Pair-Share” – in which students consider an instructor’s question, meet with a partner to discuss answers, then share their solutions with others who might have reached different conclusions – are modeled in the interactive training sessions. Meanwhile, TAs are encouraged to utilize such techniques in their own teaching.

Some of the most important tasks that TAs in Cornell Engineering perform are in course labs. Like most courses during these pandemic semesters, labs have moved online, but the critical role of the TA has not diminished.

“We had the students remote desktop into the lab computers,” said Hadas Kress-Gazit, professor of mechanical and aerospace engineering. “But we had one TA in the lab that was moving robots around. We set up cameras in the lab and had a livestream of the field where the robots are moving.”

Other labs were conducted entirely through Zoom video conferencing, with parts kits being shipped to engineering students working at home, which presented new challenges for the TAs.

“The hardest part was if there was a defect, or if a student was running into a software or hardware issue, it was much harder to debug, it was a lot harder to visualize their setup,” said TA Andrew Tsai ’21. “We had to say, please point your camera at this, or take a screenshot and then share it.”

Students and TAs alike adapted to labs over Zoom and soon some positive aspects of the remote learning setup emerged. “One cool thing was being able to see the code on your own screen,” said TA Nicole Lin ’20. “Usually, you have to bend over a student’s computer to see what’s happening on their screen, but with screen sharing and being able to control the student’s screen, some of the workflows are easier.”

“The lab environment tends to be a bit stressful for students,” said Hunter Adams, lecturer for the popular ECE 4760 microcontrollers course. “For many of them, it may be the first time that they’ve attempted to build something themselves.”

Students often feel more comfortable with their TAs than with their professors. That’s one of the strengths of the peer education model. “Student-to-student communication is often more casual,” said Lin. “I think some students feel a little bit intimidated about asking professors questions during a lecture. But when it’s just students in the room, I feel like they have no problem asking questions.”

“Students can bounce ideas off the TAs; there’s a lot of back and forth. As the semester progresses and the students become more competent, the TA role shifts more and more to that of a sounding board,” Adams said. “They’re the experienced voice that can suggest a better direction.”

Winning with workshops

Realizing the value of peer education decades ago, Cornell Engineering created a program to supplement the regular course structure which offers a peer-facilitated, collaborative learning experience for first- and second-year students in core engineering courses. These Academic Excellence Workshops (AEWs) are optional 1-credit courses taken in conjunction with core engineering courses in math, computer science, chemistry and statistics. AEWs are led by trained undergraduate engineering students and focus on active, collaborative problem-solving.

Students who enroll in an AEW workshop section benefit from an educational environment where working together on concepts, problems and projects gives them a deeper understanding of the course material. The engineering students who serve as AEW facilitators also report their own knowledge of the coursework is enhanced.

“I fell in love with that course material,” said Austin, an

AEW facilitator for Multivariable Calculus. “One of my favorite things about teaching is what you learn from the material. I get a lot of energy out of teaching. Every time I come out of a facilitation session, I feel energized and I have a lot of curiosity about many other things.”

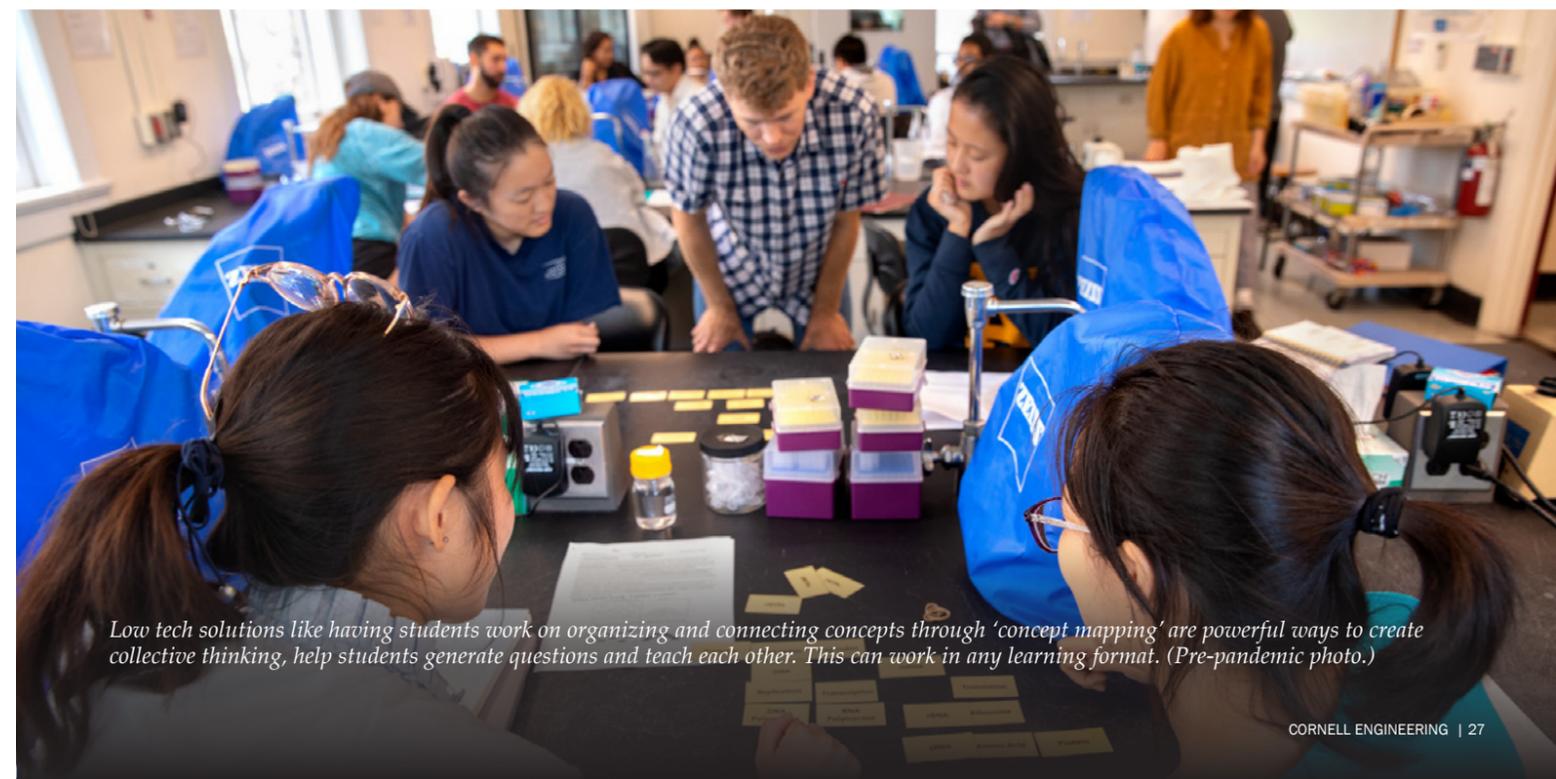
Other impacts from the experience of being a TA are even more personal. “As a freshman coming in, I was probably one of the most shy students at Cornell,” said Juan Berrio ’20, who now has several years’ experience as a TA and AEW leader. He says that being a peer educator forced him to break out of the shell he had. “As a result, I never get nervous in interviews. I have so much experience teaching and talking to students that I just don’t get nervous public speaking anymore.”

The emphasis on peer education helps to build a sense of community. Lin, who was the electrical team lead for Cornell Racing in addition to being a TA, spoke about this. “A really big part of it is just getting to meet a lot of other students in engineering,” she said. “You’re working with them in a context where it’s more collaborative, and those interactions help you meet other students in the college and lead you to a stronger understanding. It goes beyond the coursework.”

Students who work as TAs and AEW facilitators enjoy long-lasting benefits. Some see themselves pursuing academic careers, where an understanding of different learning modalities and experience teaching and collaborating with students will serve them well. Some also value the opportunity to teach or facilitate because it cements their own understanding of core content, especially as they move into advanced courses.

“You really understand the material and the bigger picture, how it fits together, after you have started teaching it,” said Evans. “So the gains for TAs are professional development, public speaking and a much better command of that material than they had before.”

“It’s just something I’m passionate about,” said Berrio. “A friend asked me, ‘why are you teaching so much?’ It’s because I enjoy it. That was my first gut reaction. It’s just something I really enjoyed doing.”



Low tech solutions like having students work on organizing and connecting concepts through ‘concept mapping’ are powerful ways to create collective thinking, help students generate questions and teach each other. This can work in any learning format. (Pre-pandemic photo.)

AWARDS AND HONORS



Lynden Archer



Iwijn De Vlaminck



Greeshma Gadikota



Ziv Goldfeld



Huili Grace Xing



Debdeep Jena



Alyosha Molnar



Atieh Moridi



Kirstin Petersen



David Putnam



Jerry Stedinger



Madeline Udell

SCHOOL AND DEPARTMENT ABBREVIATIONS

AEP – Applied and Engineering Physics
BEE – Biological and Environmental Engineering
BME – Biomedical Engineering
CBE – Chemical and Biomolecular Engineering
CEE – Civil and Environmental Engineering
CS – Computer Science
EAS – Earth and Atmospheric Sciences

ECE – Electrical and Computer Engineering
MSE – Materials Science and Engineering
MAE – Mechanical and Aerospace Engineering
ORIE – Operations Research and Information Engineering

Awards and honors received from January to March 15, 2021. Honors received outside of this timeframe appear online.

Lynden Archer, the Joseph Silbert Dean of Engineering, was featured in Chemical & Engineering News’s Trailblazer profile series, in which he discussed research, entrepreneurship and opportunity with the publication.

Iwijn De Vlaminck (BME), was elected associate professor with indefinite tenure by the Cornell University Board of Trustees.

Greeshma Gadikota, assistant professor (CEE), is part of a group of researchers to share a 1.15 million grant from the Research Corporation for Science Advancement, the Alfred P. Sloan Foundation, and the Thistledown Foundation as part of the Scialog: Negative Emissions Science initiative.

Ziv Goldfeld, assistant professor (ECE), received an NSF CAREER Award for his proposal, “Smooth statistical distances for a scalable learning theory.”

Debdeep Jena, the David E. Burr Professor of Engineering (ECE, MSE); Huili Grace Xing, the William L. Quackenbush Professor (ECE, MSE); and Alyosha Molnar, associate professor (ECE), received a 2020 Intel Outstanding Research Award for their project “Wide-Bandgap pFETs: Materials, Devices, and Circuits.”

Atieh Moridi, assistant professor (MAE), received an NSF CAREER Award for her proposal “In Operando Investigation of Laser Powder-fed Directed Energy Deposition: Process Physics, Microstructure Evolution, and Mechanical Properties.” She was also one of three faculty to receive a 2021 Schwartz Research Fund from Cornell.

Kirstin Petersen, assistant professor (ECE), received and NSF CAREER Award for her proposal “Environmentally-Mediated Coordination in Natural and Robot Swarms.”

David Putnam, professor (BME, CBE), was named the inaugural associate dean for innovation and entrepreneurship at Cornell Engineering - the first dean-level position at Cornell University dedicated solely to innovation and entrepreneurship. The termed position will oversee all activities in the college related to technology transfer and entrepreneurship, and elevate the college’s stature as a nationally-recognized institute for innovation and commercialization.

Jerry Stedinger, the Dwight C. Baum Professor of Engineering (CEE), has been approved for emeritus status. Stedinger, a fellow of the National Academy of Engineering, has focused his research on statistical issues in hydrology and optimal operation of water resource systems.

Madeline Udell, assistant professor (ORIE), was selected for the 2021 Sloan Research Fellowship from the Alfred P. Sloan Foundation.



Jefferson Tester

Lance Collins

Tester, Collins elected to National Academy of Engineering

Jefferson Tester, professor of chemical and biomolecular engineering, and Lance Collins, professor emeritus of mechanical and aerospace engineering and the former Joseph Silbert Dean of Engineering, are among the new class elected to the National Academy of Engineering.

Election to the academy is among the highest professional distinctions for an engineer, with membership honoring those who have made outstanding contributions to “engineering research, practice, or education... and to the pioneering of new and developing fields of technology, making major advancements in traditional fields of engineering, or developing /implementing innovative approaches to engineering education,” according to an announcement by the academy.

Tester, the David Croll Sesquicentennial Fellow, was elected for his “leadership in development of novel renewable energy systems.” He is considered one of the leading experts in the world on the thermodynamics, reservoir science, and techno-economics of geothermal energy systems.

Collins was elected to the academy for “contributions to understanding turbulent processes, leadership in engineering, and contributions to the diversity of the profession.” He left Cornell in 2020 to become the inaugural vice president and executive director of Virginia Tech’s Innovation Campus, but remains an emeritus faculty member and was elected to the academy under his title as the former dean of the College of Engineering.

ALUMNI

PROFILE

FROM CORNELL TO NASA TO AN ICY MOON OF JUPITER

LAURA JONES-WILSON, PH.D. '12

By Olivia Hall

Laura Jones-Wilson, Ph.D. '12, has long had her sights set on outer space. "I learned about space at an Earth Day celebration when I was five, and as soon as I found out that people had left the planet, I was like, 'I'm in, let's do this!,'" she remembered. "I got the word 'aerospace engineer' from watching Star Trek episodes, and by early middle school, that's what I was convinced I was going to be."

Indeed, that early enthusiasm and determination have carried the graduate of Cornell's Sibley School of Mechanical and Aerospace Engineering (MAE) right to the forefront of today's space exploration. At NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California, she currently serves as the payload verification and validation lead for the Europa Clipper mission, expected to launch in the mid-2020s. Jones-Wilson is tasked with ensuring that a variety of scientific instruments are properly tested and ready to study the surface of an icy moon of Jupiter as the 20-foot-high spacecraft makes approximately 45 close passes to determine its habitability.

"There's a certain romance about aerospace engineering," said Jones-Wilson. "Space lets us see how small we are in the universe and the variety of worlds that are out there. Many of us in the industry are really taken by the idea of the 'exploring the final frontier' aspect of our work."

Internships at NASA's Wallops Flight Facility in Virginia and the Ames Research Center in California during her undergraduate years at Virginia Tech first introduced her to the problem-solving skills required to work at the cutting edge of the unknown. "These NASA internships cultivated a can-do attitude and willingness to 'MacGyver' a project into working," Jones-Wilson said.

She brought both to her doctoral work at Cornell, attracted not only by the opportunity to work with her advisor, Mason Peck, the Stephen J. Fujikawa '77 Professor of Astronautical Engineering, whom she calls "a visionary in the field," but also by a supportive student body that shared her love for tackling challenges with team work. "Ithaca's gorges also helped," said Jones-Wilson, who enjoys hiking, biking and skiing.

Armed with funding from the National Science Foundation

and National Defense Science and Engineering Graduate Fellowship program, Jones-Wilson was free to explore a wide range of projects and technologies with Peck, from small satellites to control moment gyroscope steering laws. For her dissertation, she settled on studying how the phenomenon of magnetic flux pinning might be applied to maintain a specific close-proximity position and orientation between spacecraft without mechanical contact.

"When a type-II superconductor interacts with magnets," she explained, "you can build a magnetic potential well that maintains a stable, pre-selected relative position and orientation between the magnet and superconductor. We can use this phenomenon to levitate the magnet against a gravity field on earth, but in space we can use the fact that the effect works in all six degrees of freedom to maintain relative position and orientation between spacecraft without the need for an active control system."



Laura Jones-Wilson, Ph.D. '12, stands in front of a modified Boeing 727 used by NASA to conduct microgravity experiments.



Laura Jones-Wilson, Ph.D. '12, prepares a microgravity experiment to gather data on magnetic flux pinning.

Jones-Wilson constructed spacecraft analogues to collect data and better model the flux pinning interface. After first hovering them on a testbed consisting of a sheet of glass with compressed air, she expanded her tests to two microgravity flights at NASA's Johnson Space Center in Houston, Texas, where a modified aircraft temporarily creates a space-like experience of weightlessness during freefall dives from around 30,000 feet. "When you're not constrained by gravity in the same way, you can actually measure the subtle cross-coupling in the dynamics across degrees of freedoms that we were looking to characterize in this interface," she said.

To make it happen, Jones-Wilson drew on a broad pool of undergraduate and master's-level talent at Cornell Engineering, from experts at soldering and machining to students focusing on mechanical and electrical design work. "I think at one point I had 20 students working for me," she said, "and we were all focusing on different parts of the project. I couldn't have done it without those teams. It was really empowering to have access to such smart people who were all really interested in the research."

Jones-Wilson was benefitting from a form of experiential learning – at all levels – that Mason Peck calls a hallmark of Cornell's programs in aerospace engineering. "As an undergraduate you might expect your time here to include four years, or maybe more if you stick around for the M.Eng. degree, of continuous engagement in a particular project, which I think is rare," he said. Students get to contribute and take on leadership positions at the level of their abilities, regardless of seniority.

His advisee, for one, "really took ownership of her project," Peck recalled. "Part of our mission here in advising Ph.D. students is to give them the freedom to be successful – or, I suppose, to fail – on their own terms. And Laura's tendency to just go ahead and wrestle a problem to the ground is clearly one of her strengths."

Jones-Wilson also took advantage of the close relationships that exist between MAE and Cornell's Department of Astronomy in the College of Arts & Sciences. For example, Peck points out, faculty regularly collaborate on large research ventures, and astronomers and engineers come together for summer programs on spacecraft projects.

Like many aerospace engineering doctoral students, Jones-Wilson took classes such as optical astronomy and planetary science and invited an astronomy faculty member, Professor Terry Herter, to sit on her special committee. "Having access to a world-class engineering program and world-class scientists in one space makes Cornell unique," she said. "It's the perfect incubator for what JPL, in particular, is looking for: scientists who understand engineering, and engineers who understand science."

As a result, "the folks who come out of our program are highly sought after," Peck said, pointing to the fact that both established companies in the industry, such as Northrup Grumman or SpaceX, as well as newer startups, such as Ithaca-based Ursa Space, actively recruit Cornell graduates. Through research collaborations with faculty, these businesses also help to ensure students' exposure to the practical considerations of contemporary space technology. "One thing that characterizes our program is being at the cutting edge," Peck said.

For Jones-Wilson, these connections meant a foot in the door with her dream employer. A visit from JPL leaders to Cornell led to conversations, an interview, and ultimately her first job on the Pasadena campus. For the first five years with NASA, she pursued guidance and control work for small satellites. "A lot of what I found most interesting was talking to the scientists about how to effectively get the science they wanted," she recalled. She found herself looking increasingly for positions in systems engineering, which brought her to a number of different roles for the Europa Clipper mission.

Now, as the payload verification and validation lead, Jones-Wilson finds that her time at Cornell prepared her well for her job. "Being sensitized to a scientific point of view really enriches the work I do today," she said. For example, the team was having trouble translating the requirements for scientific data collection at Europa in a way that would allow systems engineers to make informed decisions about how to build the flight system. So Jones-Wilson and a colleague developed a framework for these conversations, a kind of "periodic table" of requirements. By mapping science objectives onto the way measurements need to be collected to achieve them, it shows useful patterns that support analysis and reveals potentially missing requirements to ensure a complete set. "The framework ended up really successfully facilitating key science and systems engineering decisions across the whole project," Jones-Wilson said. "It's probably the work I'm most proud of to date."

And while Jones-Wilson thoroughly enjoys her day-to-day work of meetings, talking to colleagues, writing code, conducting analyses and attending science lectures, what ultimately inspires her efforts is an understanding of what they contribute to. "Figuring out in meetings how you're going to timestamp a data packet really does come out to – how do you know if there's a saltwater ocean under the ice shell of Europa? Is this a place that could have been habitable? There are a lot of cool questions we can answer if we get this right," she said.

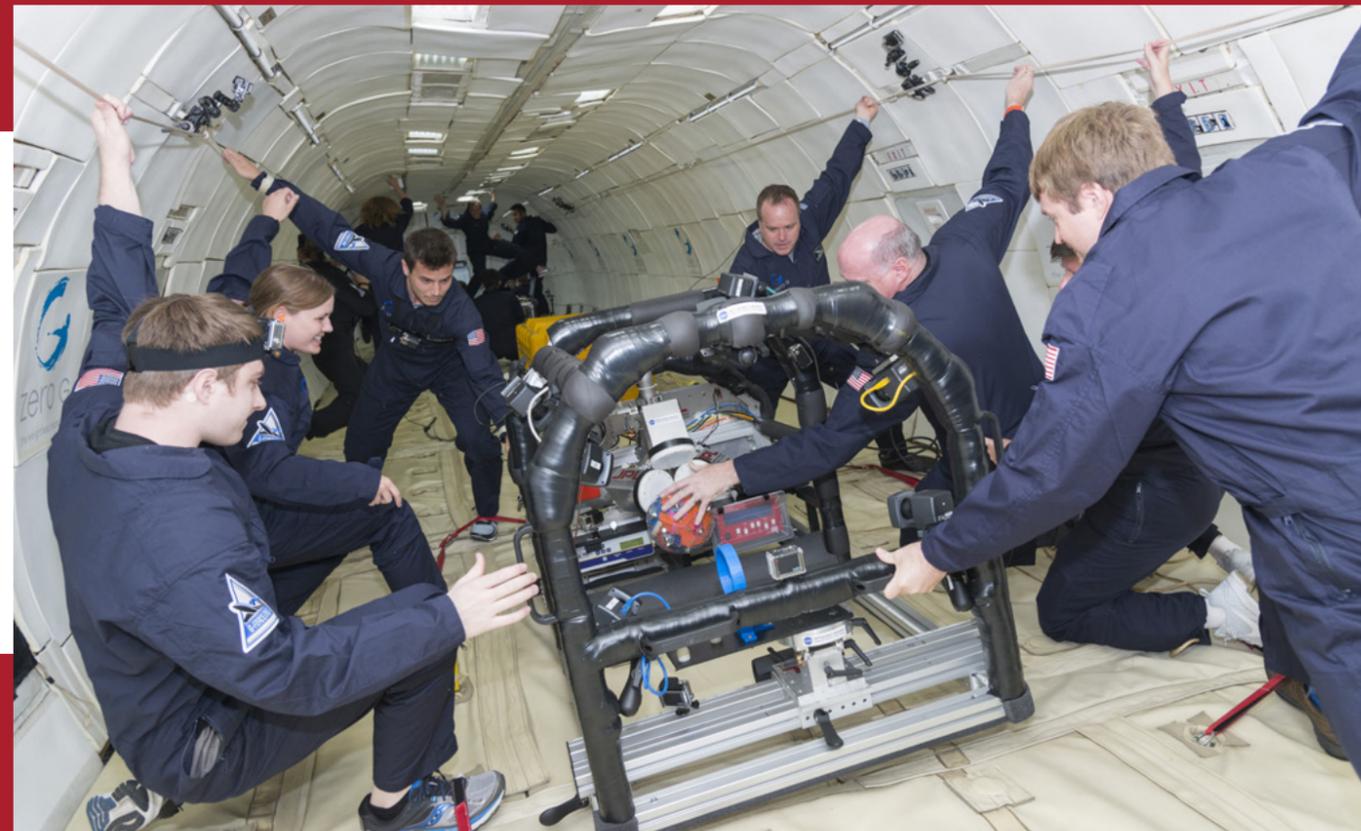
Bitten by the planetary science bug, Jones-Wilson plans to continue helping to find those answers. "The scientists have been cooking up some really exciting missions I hope get funded," she said. "I know that Mars sample return is going to be a big thing – being able to get actual rocks back from another

surface and put them through the laboratories we have on Earth would be really exciting. Being involved in that project would be pretty cool."

By then, she may have already advanced to working as one of the JPL supervisors, who typically split their time between administration and engineering projects. "I could see myself doing that," said Jones-Wilson. So could her former advisor. "The key features I'd say that make Laura successful are her dogged insistence on getting things right and being very detail-oriented and thorough," Peck said. "She's terrific as an organizational leader, and I'm confident that in the years to come she'll continue to rise through the ranks of JPL or whatever organizations she finds herself part of."

Jones-Wilson herself is curious to discover where she may end up. "A lot of careers at JPL are made by just following your heart and doing what's exciting to you at the time," she said. For now, that is the Europa Clipper mission, though somehow she also finds time to get trained to serve on JPL's Team A, a kind of brainstorming group of experts to solve "crazy problems;" occasionally stop into the Small Satellites Dynamics Testbed that she co-founded at JPL with fellow Cornellian Swati Mohan '04; continue to collaborate on projects with Peck; and help to pave the path for the next generation of aerospace engineers.

"I'm really grateful to the Cornell community for all the opportunities they've given me, so I like mentoring students and bringing them over to do internships at JPL to see what it's actually like to work on big engineering projects at the scale Clipper has," Jones-Wilson said. "It's what I wanted when I was five and thought about exploring the cosmos, and now here we are."



Laura Jones-Wilson, Ph.D. '12, and her colleagues conduct microgravity experiments aboard an aircraft that simulates weightlessness during freefall dives.

SWANSON '61, M.ENG. '63, TO RECEIVE 2021 CORNELL ENGINEERING DISTINGUISHED ALUMNI AWARD

By Amy Horner

John A. Swanson '61, M.Eng. '63, internationally recognized authority and innovator in the application of finite-element methods of engineering, will be honored with the 2021 Cornell Engineering Distinguished Alumni Award.

The award, established in 2018, celebrates the accomplishments of graduates whose leadership and vision have been truly transformative and who have brought great pride to their alma mater. Swanson will be presented the award by Lynden Archer, the Joseph Silbert Dean of Engineering, at an on-campus ceremony on Thursday, Oct. 14.

Swanson, elected a member of the National Academy of Engineering in 2009, is founder and former president and CEO of ANSYS Inc. Founded in 1970 as Swanson Analysis Systems Inc., ANSYS develops and globally markets engineering simulation software and technologies widely used by engineers and designers across a broad spectrum of industries. The company was awarded the CAD/CAM Leader Award by Machine Design in 1991-1993, and Manufacturing Systems ranked it among the "Top 50" software companies. Among Swanson's numerous honors are the American Association of Engineering Societies John Fritz Medal, the Computers in Engineering Award, and the Pittsburgh Entrepreneur of the Year in High Technology.

After selling ANSYS in 1994, Swanson focused on engineering education and the training of future generations of practicing engineers. He founded the Swanson Engineering Simulation Program at Cornell, and joined the Engineering

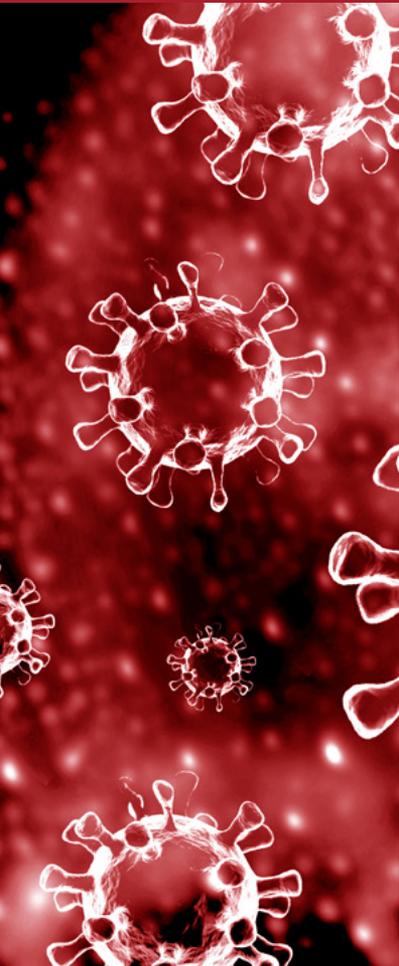
College Council. More recently, he has shifted his attention to renewable energy, including solar and bio-diesel enterprises; he is a developer of Green Key Villages in Lady Lake, Florida, the only "net zero energy" home development in the area.

Swanson received his bachelor's and master's degrees in mechanical and aerospace engineering from Cornell, and his Ph.D. from the University of Pittsburgh, where the Swanson School of Engineering is named in recognition of his involvement and support. He began his career at Westinghouse Astronuclear Laboratory, where his discovery that "developing the tools was more fun than solving the problems" led to his founding of Swanson Analysis Systems.

Swanson and his wife Janet are among Cornell's foremost benefactors. They have given generously to the College of Engineering and the College of Veterinary Medicine, with gifts to programs – including Engineering Student Project Teams – faculty support, scholarships and capital projects.



John and Janet Swanson



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CONTAINING COVID-19 AT CORNELL

**THE MODELING BEHIND CORNELL'S
SUCCESSFUL FALL SEMESTER AND
THE ENGINEERS WHO SKILLFULLY
CRAFTED IT**

