CornellEngineering
Systems Engineering

SYSTEMS Magazine

Winter 2021

ALKAABNEH BECOMES FIRST SYSTEMS PH.D. GRADUATE

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MESSAGE FROM OUR DIRECTOR

I'd like to begin by introducing myself. I am H. Oliver Gao, the director of the Systems Engineering Program and professor in the School of Civil and 2Environmental Engineering. I am more than excited to serve in this role at a time when the Cornell Systems Engineering Program is experiencing an exciting amount of change and growth.

One of the most exciting announcements in Systems Engineering is that Faisal Alkaabneh became our first student to earn a Ph.D. in Systems. In 2015, Faisal was one of the first 10 students to enter our program, and we are proud to have such an outstanding person be the first graduate.

We are also excited to invite a number of Ezra Scholar Speakers to campus. The Ezra Systems Scholars Program provides an intellectual platform for established premiere systems thinkers to collaborate and examine many of the world's complex issues. We are inviting leading scholars from industry, academia and government who will be on the forefront of systems thinking in areas such as healthcare, energy, transportation, defense, finance, food, climate change, and smart cities, etc.

I would also like to congratulate Fengqi You, the Roxanne E. and Michael J. Zak Professor in Energy Systems Engineering in the Smith School of Chemical and Biomolecular Engineering, for winning the 2020 Curtis W. McGraw Research Award by the American Society for Engineering Education (ASEE). This annual award recognizes the significant achievements of engineering researchers and educators with outstanding research abilities, trajectory, and potential.

Finally, we would like to acknowledge our Systems Engineering faculty newcomers, Professor Tim Sands, Professor Francesca Parise, Dr. Antonio Pugliese and Dr. Faisal Alkaabneh.

Tim Sands joined Cornell University this fall and focuses his research and teaching on astronautical engineering and systems engineering. From 2010 through 2020, Dr. Sands was an executive leader of both military postgraduate universities (the Air Force Institute of Technology and the Naval Postgraduate School).

Francesca Parise came to Cornell after holding a postdoctoral research fellow position at MIT's Labratory for Information and Decision Systems.

Antonio Pugliese joined us as a lecturer starting this fall. Dr. Pugliese is a researcher in systems engineering with a background in aerospace systems.

As mentioned earlier, Dr. Alkaabneh received his Ph.D. in systems from Cornell this past May. He joined the faculty at Cornell in July 2020 as a lecturer in the Systems Engineering program and will join the Edward P. Fitts Department of Industrial & Systems Engineering at North Carolina State University as a tenure-track assistant professor in the spring.

As you can see, these are exciting times in our program and we welcome you as a part of our alumni family to reach out

with your ideas as to how this program should continue to evolve.

H. Oliver Gao
Director, Systems Engineering

Winter 2021

Systems Magazine is published by the Systems Engineering Program at Cornell University

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Editors: Jessica Best, Chris Dawson, Patrick Gillespie, H. Oliver Gao, Dawn McWilliams

Designer: Patrick Gillespie

Photography: E. Jacob Cornelius, University Photography, Robyn Wishna

ON THE COVER
Faisal Alkaabneh became the first student to receive a Ph.D. in systems from Cornell in May 2020.

THE SYSTEMS MISSION
The mission of the Cornell Systems Engineering Program is to educate students and to stimulate intellectual achievement in the discipline of systems engineering across numerous application domains.

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FAISAL ALKAABNEH BECOMES FIRST STUDENT TO EARN PH.D. IN SYSTEMS AT CORNELL

Back in 2015, Faisal Alkaabneh was one of the first 10 students to enter the Systems Ph.D. Program at Cornell University. This weekend, he becomes the first student to earn a Ph.D. in Systems.

"Faisal's research was driven by and reflects the vision of Cornell Systems Engineering. He studied several important management and policy-analysis problems in food supply-chain systems utilizing large-scale optimization, stochastic resource allocation, and data-analytics methodologies," said H. Oliver Gao, director of the Systems Engineering program and Alkaabneh's advisor. "We are very proud to have such an outstanding person as Faisal be the first Ph.D. graduate of the program."

Who inspired or influenced you during your time at Cornell?

As far as professors goes, the answer is definitely Professor David Williamson from the ORIE department. I took his class ORIE 6330: Network Flows during my first semester at Cornell and I learned a lot in that class and from him personally. Aside from the technical knowledge I learned in his class, he is very humble, nice and dedicated to his students. I consider Professor Williamson as a role model and he changed my way of thinking and behavior in many ways. I cannot thank him enough for his efforts and support.

Outside of the classroom, I would pick Yasin Ahmed, the Muslim Chaplain at Cornell. Yasin is a great person in all ways and I definitely learned a lot from him. I appreciate his hard work, dedication, and support for all student groups at Cornell.

What will you miss the most about Cornell?

I will miss the people—professors, students, staff and everyone in Ithaca.

What surprised you most about your Cornell experience?

I found that students here are very kind and, at the same time, they are brilliant and hard workers. To find a group of students who truly combines those qualities is rare; nonetheless, all students at Cornell are kind and brilliant. That is what surprised me the most.

What accomplishment as a Cornell student makes you most proud?

1. Getting the Outstanding Teaching Assistant Award from the Systems Engineering Program back in 2017. I felt very proud when I read the comments of students. It was truly amazing to see how much students appreciate my dedication and support. I am very grateful to all students I worked with.

2. High-quality, impactful research I did during my Ph.D. Part of my research was in collaboration with the Food Bank of the Southern Tier to help them better manage the supplies they receive to better serve people. We developed a decision support tool and a website that food bank stakeholders can use to increase the efficiency of food banks' operations. When I demonstrated my work to the food bank managers, I felt very proud that my research will be making difference on the ground and helping people.

Faisal Alkaabneh

3. Indeed, getting the Ph.D. degree itself. The journey was intense and full of challenges, so I feel proud that I made it with good research outcomes.

SYSTEMS RECEIVES INCOSE ACADEMIC EQUIVALENCY AWARD

The International Council on Systems Engineering (INCOSE) has presented Cornell University with an Academic Equivalency Award for students to meet the knowledge requirement for the INCOSE Associate Systems Engineering Professional (ASEP) and Certified Systems Engineering Professional (CSEP) certifications. INCOSE first awarded this academic equivalency in July 2018. Now that this equivalency is in place, students who demonstrate knowledge of systems engineering through approved coursework will not have to take the INCOSE Knowledge Exam to get certified. There are 130 students who met requirements in fall 2018 who are now eligible to become ASEPs or CSEPs upon meeting the other certification requirements.

"At INCOSE, we are pleased to have the Systems Engineering Certification Academic Equivalency in place with Cornell University," INCOSE Garry Roedler stated. "Academic equivalency demonstrates the strength of specific university systems engineering programs to meet the knowledge requirements for the systems engineering certification. It also shows the strength of universities working closely with INCOSE to embrace and evolve the requirements in their systems engineering programs toward meeting the accepted competencies for systems engineering."

To learn more about Academic Equivalencies for INCOSE Certification, visit https://www.incose.org/systems-engineering-certification/certification-agreements/equivalency-programs.

About the International Council on Systems Engineering

The International Council on Systems Engineering (INCOSE) is a not-for-profit membership organization that promotes international collaboration in systems engineering practice, education and research. INCOSE's mission is to "address complex societal and technical challenges by enabling, promoting and advancing systems engineering and systems approaches." Founded in 1990, INCOSE has more than 70 chapters and over 17,000 members worldwide. For additional information about INCOSE visit www.incose.org.

AACC AWARDS PROFESSOR FENGQI YOU THE 2020 SCHUCK AWARD

The American Automatic Control Council (AACC) has awarded Dr. Fengqi You, Roxanne E. and Michael J. Zak Professor in Energy Systems Engineering in the Smith School of Chemical and Biomolecular Engineering, and CBE Ph.D. student Chao Ning the prestigious 2020 O. Hugo Schuck Award.

The AACC, formed in 1957, represents the United States to the world automatic control community. Nine professional societies are current members of the AACC—the American Institute of Aeronautics and Astronautics (AIAA), American Institute of Chemical Engineers (AIChE), American Society of Civil Engineers (ASCE), American Society of Mechanical Engineers (ASME), Institute of Electrical and Electronics Engineers (IEEE), the International Society for Automation (ISA), the Society for Modeling & Simulation International (SCS), the Society for Industrial and Applied Mathematics (SIAM), and Applied Probability Society as a subdivision of the Institute for Operations Research and the Management Sciences (INFORMS APS). AACC is a federation of these professional societies.

The O. Hugo Schuck Award is one of the most prestigious awards in the control/automation community. It recognizes one paper emphasizing contributions to fundamental theory and one emphasizing significant or innovative applications. Criteria for selection include the quality of the written and oral presentation, the technical contribution, timeliness, and originality.

This award to Professor You and Chao Ning is in recognition of their research work on a novel hybrid framework combining machine learning and mathematical programming methods for data-driven robust optimization of electric power systems control under renewable energy generation uncertainty.

You receives 2020 ASEE McGraw Research Award

Professor Fengqi You, Roxanne E. and Michael J. Zak Professor in the Smith School of Chemical and Biomolecular Engineering, has been selected to receive the 2020 Curtis W. McGraw Research Award by the American Society for Engineering Education (ASEE).

The Curtis W. McGraw Research Award was established in 1957 with the initial assistance of the McGraw-Hill Book Company to recognize outstanding achievements by engineering college research workers and to encourage the continuance of such productivity. The annual award recognizes the significant achievements of engineering researchers and educators with outstanding research abilities, trajectory, and potential. Two awards are made annually—one to the top applicant from a Ph.D. granting program and one to the top applicant from a non-Ph.D. granting program. Professor You is this year's award recipient in the Ph.D. granting program category.

TIMOTHY SANDS JOINS SYSTEMS FACULTY

Professor of Practice Timothy Sands joins the faculty in a joint position with Systems Engineering and the Sibley School of Mechanical and Aerospace Engineering, where his research and teaching focus on astronautical engineering and systems engineering.

From 2010 through 2020, he was an executive leader of both military postgraduate universities—the Air Force Institute of Technology and the Naval Postgraduate School—serving sequentially as chief academic officer, associate provost, dean, associate dean, and research center director in addition to serving as a fellow of the Defense Advanced Research Projects Agency (DARPA). His work with the military included collaborations between the military services and academia, forming new education programs integrating courses from Harvard, Stanford, and King's College London into the education of military members. He also executed the DARPA Challenge for digital manufacturing analysis, correlation, and estimation (DMACE), investigating the science behind the burgeoning field of digital manufacturing.

During nearly three decades of active duty service in the U.S. Air Force, he performed space mission design and space experimentation for the Department of Defense (DoD) Space Test Program (STP) including the middle atmosphere high resolution spectrograph investigation (MAHRSI) flown in the pallet system on space shuttle mission STS-66. He also worked on the polar ozone and aerosol measurement (POAM) geophysical research mission flown on the French SPOT-4 satellite, in addition to the beryllium induced radiation experiment flown on Russian RESURS satellite.

Professor Sands' other interesting space experiment missions include the polar orbiting geomagnetic survey flown on the defense meteorological satellite program; the remote atmospheric and ionospheric detection system on TIROS-J; and the solar wind interplanetary measurement flown on the NASA WIND satellite. He was the propulsion engineer of the Atlas space launch vehicle, the reliability engineer of the Centaur upper stage, and an electronic warfare engineer and operator, having flown over 600 hours in combat in four countries, being decorated three times for combat gallantry and bravery in addition to other decorations for achievement and meritorious service.

His areas of academic expertise include space mission design; Spacecraft Guidance, Navigation and Control (GNC); estimation; adaption and learning; and nonlinear systems, His minor fields include electrical engineering topics of electronic warfare and automatic controls. His background represents a breadth of leadership experience in space experimentation across academia, the aerospace industry in general, and particularly the defense department. His research has been funded by DARPA, Office of Naval Research (ONR), Air Force Global Strike Command (AFGSC), and Air Education and Training Command (AETC) and has been awarded one patent in spacecraft guidance, navigation and control (GNC).

Recognized for his teaching and mentorship at the Naval Postgraduate School and Air Force Institute of Technology, Professor Sands remains broadly interested in social sciences disciplines of deterrence, command and control communications, and international relations as well as technical translation, particularly of engineering developments written in Chinese.

Professor of Practice Timothy Sands

FRANCESCA PARISE NAMED ASSISTANT PROFESSOR

Francesca Parise has joined the faculty of Cornell's School of Electrical and Computer Engineering (ECE) and Systems Engineering as an assistant professor. Most recently, Parise held a postdoctoral research fellow position at MIT's Laboratory for Information and Decision Systems (LIDS) with Professor Asuman Ozdaglar.

Dr. Parise describes her research as focusing on "problems that arise in the analysis and control of multi-agent systems composed by a large number of users that make autonomous and selfish decisions while interacting with each other, with application to transportation, social, and economic networks." A main goal of her work is to be able to accurately model and predict the outcomes of these complex systems in the limit of large populations and under partial or inaccurate network information.

A second ambitious goal of her research is to have an effect on these systems. "Given a prediction about the outcome, how can we best intervene?," asks Parise. "Maybe there is a constraint of limited resources. If so, how could we optimally allocate these resources in the network to achieve some social goal?"

Parise has always aspired to be a teacher. "When I was growing up in Italy, I always wanted to be a teacher for the level of schooling I was at," she says. "By the time I got to the University of Padua it was already my goal to become a professor and researcher—there was no doubt in my mind that this would be my career."

Parise earned her B.S. in information engineering and her M.S. in control engineering from the University of Padua. She also earned a completion certificate from Padua's Galilean School of Higher Education, which is a special unit of the university open to just 30 students per year and designed to foster an intellectually stimulating environment where students from many disciplines can live and study together. "I wanted to be part of the Galilean School so that I could take classes from a variety of disciplines," says Parise. "Being able to take additional math, physics and biology classes during my engineering degree was particularly important to me. I am also very fortunate to have had great mentors during my studies such as Professors Giorgio Picci and Maria Elena Valcher, who inspired me to pursue a degree in control."

Parise then went to Switzerland to pursue her Ph.D. in control engineering at the Swiss Federal Institute of Technology (ETH) in Zurich. At ETH Parise worked with Professor John Lygeros in the Automatic Control Laboratory. "I liked working with John very much," says Parise. "He always allowed me to follow my research passions and gave me the opportunity to work on a broad range of topics." Over her time at ETH Parise's work evolved from looking at cultures of light-sensitive cells (trying to find the optimal pattern of light exposure to optimize their production of a certain compound), to looking at systems where the participants have agency and are able to make rational decisions.

This interest in multiagent systems with selfish participants then led Parise to her postdoc with Professor Asuman Ozdaglar's group at MIT. "She (Ozdaglar) is a world expert on the interactions between engineering, economics and game theory," says Parise, "and a role model for the type of advisor that I aspire to be. Interacting with her and Professor Daron Acemoglu at MIT inspired me to explore the exciting field at the boundary of game theory and network science: During my Ph.D. I was looking at systems where you have a lot of people that influence each other in generic ways," says Parise. "In my postdoc I started to get interested in systems where the decisions made by some people have bigger effects than those made by others. I started to include network effects." Parise goes on to say that this is one of the reasons she decided to come to Cornell. "There are so many experts on networks here," she says, "and I want this topic to be central to my research as a faculty member."

Professor Francesca Parise

By Chris Dawson

Please see bit.ly/3opqwTc for the full article.

SYSTEMS WELCOMES ANTONIO PUGLIESE

Antonio Pugliese joined the Cornell Systems Engineering Program as a lecturer this fall. Dr. Pugliese is a researcher in systems engineering with a background in aerospace systems. He holds a Ph.D. in systems engineering from Stevens Institute of Technology, a M.Sc. in systems engineering, and a M.Sc. and B.Sc. in aerospace engineering from the University of Naples Federico II. Prior to joining Cornell, Dr. Pugliese was a research associate at Stevens Institute of Technology and assistant professor at Embry-Riddle Aeronautical University.

His past research projects include re-entry vehicles (Italian Aerospace Research Center and UniNa), satellite attitude control (OHB Systems), low gravity experiments (European Space Agency, UniNa, and Université libre de Bruxelles), complexity in cyber-physical systems (Acquisition Research Program at Naval Postgraduate School), and natural language processing (DoD SERC UARC).

At Cornell, Dr. Pugliese is starting a new research track focused on autonomy and its effects on orbital assembly of space systems. As space systems become more sophisticated, and the capability to build systems in orbit does not require direct human intervention such as with the International Space Station, the way to develop these systems is going to change. The introduction of highly autonomous systems will create the need for new systems engineering processes that while taking into consideration the peculiarity of these systems, such as the impossibility of on-ground system-level verification activities, will guarantee low risk in the outcome of the development process. This might lead to heavy reliance on model-based analysis for verification, including the need to simulate the interaction of the system components with a large number of autonomous agents.

Antonio Pugliese

RECENT PH.D. GRAD ALKAABNEH NAMED LECTURER

Faisal Alkaabneh joined the faculty at Cornell in July 2020 as a lecturer in the Systems Engineering program. He received his Ph.D. in Systems from Cornell in 2020 and his M.S in engineering systems and management at Masdar Institute of Science and Technology (currently part of Khalifa University) in 2014. His research interests include large-scale optimization, supply chain management, logistics and inventory management, and applied probability.

Dr. Alkaabneh served as a referee for several international journals such as *Arabian Journal for Science and Engineering*, *Computers & Operations Research*, *Computers & Industrial Engineering*, *Journal of Manufacturing Systems*, *Journal of Cleaner Production*, and *Transportation Research Part D: Transport and Environment*.

Back in 2015, Alkaabneh was one of the first 10 students to enter the Systems Ph.D. program at Cornell University. He also became the first student to earn a Ph.D. in Systems.

"Faisal's research was driven by and reflects the vision of Cornell Systems Engineering. He studied several important management and policy analysis problems in food supply chain systems utilizing large-scale optimization, stochastic resource allocation, and data-analytics methodologies, said H. Oliver Gao, director of the Systems Engineering program and Alkaabneh's advisor. "We are very proud to have such an outstanding person such as Faisal be the first Ph.D. graduate of the program."

Alkaabneh will join the Edward P. Fitts Department of Industrial & Systems Engineering at North Carolina State University as a tenure-track assistant professor in the spring.

Faisal Alkaabneh

USING A SYSTEMS APPROACH TOWARD A BETTER PLANET

Consumers are paying increasing attention to their impact on the planet—and therefore, so are retailers. Now a study by Faisal Alkaabneh, a recent graduate of Cornell Engineering's Ph.D. in Systems program, contributes a systems perspective to solving important last-mile logistic problems, taking both environmental and economic metrics into account. Recently accepted for publication by the journal *Computers and Operations Research*, the resulting paper will appear under the title "Benders decomposition for the inventory vehicle routing problem with perishable products and environmental costs."

Every day grocery stores and similar businesses—under pressure from the rapid rise of online grocery shopping—face critical logistics decisions on inventory management, vehicle routing, and scheduling of vehicles for delivery. Responding to consumer demand for greener practices adds an additional dimension to their operational systems. "But the existing literature in this space tends to focus only on either the economic or the environmental metrics," said Alkaabneh, who conducted the research with co-authors Ali Diabat, professor of civil and urban engineering at NYU Abu Dhabi, and H. Oliver Gao, professor of civil and environmental engineering at Cornell and director of the Systems Engineering Program. "Instead, we developed a complex system to model inventory-routing problems where greenhouse gas emissions are calculated as a function of fuel consumed, and fuel consumption levels are accurately calculated as a function of vehicle speed, load and traveled distance."

Applying two different algorithms—Benders decomposition and a two-stage meta-heuristic—to various experimental analyses, the researchers demonstrated that this more comprehensive modeling of fuel costs saves companies 2-11% on fuel expenditures, compared to traditional systems that model fuel cost as a function of the distance traveled during delivery.

"This information-driven, data-based systems approach that we take to address the key societal challenge lying at the core of food systems, distribution and supply chain, and sustainable development is a good fit to *Computers and Operations Research*," said Gao. "It is a leading journal in the fields of operations research and computers."

He is happy to have placed the third paper of his Ph.D. career—two more theoretical articles are under review in other leading journals—in such a fitting outlet. "I will be applying to different schools, and that will significantly support my application," he said.

By Olivia M. Hall

WEBSITE CHARTS COVID-19 SPREAD ACROSS NEW YORK STATE

A website developed by a Cornell team offers insight into the rate of coronavirus infections across New York state over days, charting daily and cumulative totals of new cases to help users see whether they're flattening the curve.

The site, updated daily with data from all 62 of the state's counties, provides easy-to-use interactive visualizations depicting the virus' spread or slowdown by county or statewide.

Cornell impacting New York State

"When we had to shut down our lab (temporarily last spring), we wanted to see what we could do with our expertise in systems engineering to help the public and provide timely information," said Fengqi You, the Roxanne E. and Michael J. Zak Professor in Energy Systems Engineering in the Smith School of Chemical and Biomolecular Engineering, who is leading the effort. "We're viewing this as a citizen science project, but one where accuracy and primary data are paramount."

The site includes a play button and a slider where users can watch how infections spread day by day across New York state, as well as interactive charts offering different ways of viewing the outbreak statewide or by county. Users can view the total number of new infections by county, as well as a chart showing the numbers of infections per 100,000 residents for each county since the first COVID-19 case was reported in New York state on March 2.

"We wanted to make sure the website was readable and of interest to the public," You said. "Visualization is a useful and powerful tool."

When he began the project in March, You reached out to the researchers in his lab and the students in his Industrial Big Data Analytics and Machine Learning class—as well as colleagues in the College of Engineering, Computing and Information Science and the College of Veterinary Medicine (CVM)—to see who wanted to help.

He quickly assembled a team of students to help both with compiling data and building a nimble and accessible website, as well as experts in other fields to help determine which data points to use and how to visualize them. He collaborated with Joe Guinness, assistant professor of statistics and data science, about data collection, Daryl Nydam, professor in CVM and faculty director of the Cornell Atkinson Center for Sustainability, and Renata Ivanek, Ph.D. '08, associate professor in CVM, on the overall cyber-infrastructure idea and design of the website.

What emerged was a cross-college radical collaboration comprising students and faculty eager to contribute to the public good. The project is being supported by Cornell's Office of Engagement Initiatives and Cornell Atkinson, where You is a fellow.

CORNELL IMPACTS NEW YORK STATE

Radical Collaboration

"Even students who are home—some in California, some in Texas—are still Cornell students, and they still care about New York," You said. "We all feel like we have a mission to help with this crisis."

At first, students collected the data manually from county health departments—a complicated process because each county posted the numbers of daily infections in different formats and at different times of day. Now, the process is automated, though students still manually check the numbers.

"We need to make sure the data are correct and consistent," You said.

The team is making improvements and adding to the site, hoping to soon add hospital bed and fatality data. Major student contributors include doctoral students Akshay Ajagekar and Ning Zhao and master's student Yanqiu Tao, on the website development; and recent graduate Abdulelah Alshehri, master's students Karthik Suresh Menon, Lesley Sun and Khalid Fihat Alanazi, and Shreya Vaidya '22, on data collection and processing.

By Melanie Lefkowitz

COVID-19 Cases in New York State
https://covid19.cheme.cornell.edu/

CORNELL FARM TRACTOR GETS CLEAN, GREEN BIODIESEL MAKEOVER

A week before the Ithaca campus temporarily shut down due to the COVID-19 pandemic, members of an engineering student group converted a university-owned diesel tractor into a clean, green farming machine.

Instead of emitting the notoriously noxious black diesel smoke, the tractor now emits a much lighter colored exhaust with a smell more reminiscent of French fries than farm implements. That's thanks to its soy-based biodiesel fuel, as the updated tractor helps the university take another step toward its goal of carbon neutrality by 2035.

"A carbon-neutral campus is an inspiring vision," said H. Oliver Gao, professor of engineering and director of Cornell's Center for Transportation, Environment and Community Health, which helped create the project. "This was a good opportunity to engage engineering students, to gain hands-on experience, in a Cornell Living Laboratory project."

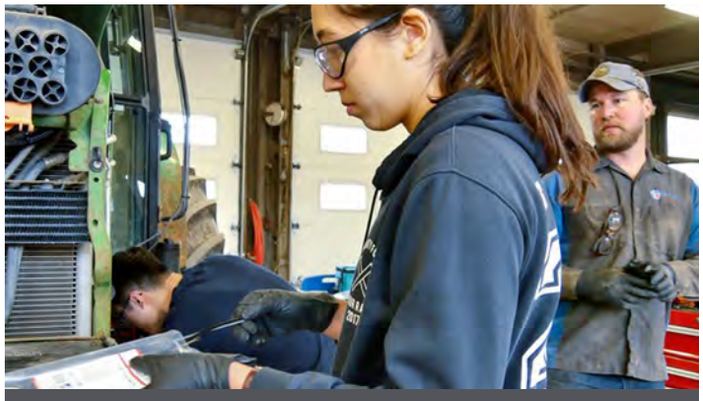
As Jared Hibshman '19 helped to set up the project last year, members of the Engineers for a Sustainable World group—Gregory Brumberg '21, Lawrence Li '21, Sophia Openshaw '23, Sai Mallipedhi '21 and Ian Starnes '20—spent the first weekend in March converting the 2005 John Deere 6715 tractor in the Farm Service Shop, operated by Cornell's College of Agriculture and Life Sciences, and Cornell's Ithaca Agricultural Experiment Station. The tractor is used in the university's compost operation and for agricultural research support.

The biodiesel tank and its fuel-switching kit—called the Vector System—was developed by Optimus Technologies, a Pittsburgh startup that makes biodiesel conversion systems for medium- and heavy-duty trucks. This was the company's first conversion of a tractor; Jonathan Ewing, Optimus' engineering manager, joined the students to supervise the system's installation.

Biodiesel fuel can gel or solidify in cold weather, but the Vector System is designed to reduce the problem. The engine starts with traditional diesel, and as the engine warms, heat is delivered via the coolant system to the biodiesel fuel in a separate tank. The engine will automatically switch from diesel to biodiesel, once this renewable fuel reaches a specified temperature.

The Vector System bolts onto the engine area, reducing modification costs, and enables the tractor to run on new clean fuels as they become available.

Another biodiesel benefit: breathing easy. Because the tractor uses a soy-based biodiesel, Ewing said, there is 60% to 70% reduction in particulate matter, with the same energy efficiency as diesel. The use of biodiesel may reduce up to 80% of carbon emissions into the atmosphere, he said.



Sophia Openshaw '23, of the Engineers for a Sustainable World student group, works to convert a 14-year-old diesel tractor to allow for biodiesel, as Jonathan Ewing from Optimus Technologies looks on.

Charissa King-O'Brien/Provided

The project started three years ago with an email from John Swanson '61, B.M.E. '62, M.S. '63, to then Dean Lance Collins. Swanson suggested that one step toward a carbon-neutral campus would be to convert diesel vehicles into those run on biodiesel.

Collins contacted Gao, who consulted Francis Vanek, senior lecturer in civil and environmental engineering and faculty adviser to Engineers for a Sustainable World. The project took about two years to plan and two semesters to execute. Swanson funded the project; Optimus Technologies provided the system.

"Installing the system provided a valuable opportunity to execute a project and the critical experience of bringing it to fruition," Brumberg said.

"For the university, the year 2035 is not far away," Gao said. "We are engaging and training our students today so that they can contribute now to Cornell's carbon-neutral future."

By Blaine Friedlander

SATELLITE CONSTELLATIONS HARVEST ENERGY FOR NEAR-TOTAL GLOBAL COVERAGE

Think of it as a celestial parlor game: What is the minimum number of satellites needed to see every point on Earth? And how might those satellites stay in orbit and maintain continuous 24/7 coverage while contending with Earth's gravity field, its lumpy mass, the pull of the sun and moon, and pressure from solar radiation?

In the mid-1980s, researcher John E. Draim proposed what is generally considered to be the ideal solution: a four-satellite constellation. However, the amount of propellant needed to keep the satellites in place, and the ensuing cost, made the configuration not feasible.

The Aerospace Corporation

Patrick Reed collaborated with researchers from The Aerospace Corporation to determine the right combination of factors that would enable a four-satellite constellation to maintain nearly continuous 24/7 coverage of almost every point on Earth.

Now, a National Science Foundation-sponsored collaboration led by Patrick Reed, the Joseph C. Ford Professor of Engineering, has discovered the right combination of factors to make a four-satellite constellation possible, which could drive advances in telecommunication, navigation and remote sensing. And in an ingenious twist, the researchers accomplished this by making the forces that ordinarily degrade satellites instead work in their favor.

"One of the interesting questions we had was, can we actually transform those forces? Instead of degrading the system, can we actually flip it such that the constellation is harvesting energy from those forces and using them to actively control itself?" Reed said.

Their paper, "Low Cost Satellite Constellations for Nearly Continuous Global Coverage," published Jan. 10, 2020 in *Nature Communications*.

The AI-based evolutionary computing search tools that Reed has developed are ideally suited for navigating the numerous complications of satellite placement and management.

For this project, Reed collaborated with researchers from The Aerospace Corporation, combining his algorithmic know-how with the company's expertise in cutting-edge astrophysics, operational logistics and simulations.

By David Nutt

Please visit bit.ly/39I05DT for the full article.

SMART INTERSECTIONS COULD REDUCE AUTONOMOUS CAR CONGESTION

In the not-so-distant future, city streets could be flooded with autonomous vehicles. Self-driving cars can move faster and travel closer together, allowing more of them to fit on the road—potentially leading to congestion and gridlock on city streets.

A new study by Cornell researchers developed a first-of-its-kind model to control traffic and intersections in order to increase car capacity on urban streets, reduce congestion and minimize accidents.

"For the future of mobility, so much attention has been paid to autonomous cars," said H. Oliver Gao, professor of civil and environmental engineering and senior author of "Optimal Traffic Control at Smart Intersections: Automated Network Fundamental Diagram," which published Dec. 15, 2019 in *Transportation Research Part B*.

"If you have all these autonomous cars on the road, you'll see that our roads and our intersections could become the limiting factor," Gao, director of the Systems Engineering Program, said. "In this paper we look at the interaction between autonomous cars and our infrastructure on the ground so we can unlock the real capacity of autonomous transportation."

The researchers' model allows groups of autonomous cars, known as platoons, to pass through one-way intersections without waiting, and the results of a mircosimulation showed it increased the capacity of vehicles on city streets up to 138% over conventional traffic signal systems, according to the study. The model assumes only autonomous cars are on the road; Gao's team is addressing situations with a combination of autonomous and human-driven cars in future research.

Car manufacturers and researchers around the world are developing prototypes of self-driving cars, which are expected to be introduced by 2025. But until now, little research has focused on the infrastructure that will support these driverless cars.

Autonomous vehicles will be able to communicate with each other, offering opportunities for coordination and efficiency. The researchers' model takes advantage of this capability, as well as smart infrastructure, in order to optimize traffic so cars can pass quickly and safely through intersections.

"Instead of having a fixed green or red light at the intersection, these cycles can be adjusted dynamically," Gao said. "And this control can be adjusted to allow for platoons of cars to pass."

Models exist to optimize today's intersections in order to ease the flow of traffic, but these aren't directly applicable to autonomous vehicles. The number of cars that can operate on urban streets depends on the precision and speed of sensors, vehicle-to-vehicle and vehicle-to-infrastructure communication, and the system that actually controls the machines.

Most models assume that, for greater efficiency, autonomous vehicles will travel in platoons, heading in the same direction for a period before peeling off and joining different platoons. The researchers' framework

determines the optimal traffic configuration—the number of cars traveling in each platoon approaching intersections—as one of its primary variables.

However, mathematical errors associated with this coordination can cause operational failures or accidents. To counter this, the researchers developed a formula that considers the probability of failures and, accordingly, adds a time gap of an optimal length between crossing platoons.

"By coordinating the platoon size and the gap length between cars and platoons, we can maximize the flow and capacity," Gao said. This allows platoons of self-driving vehicles to pass through intersections that don't have traffic signals without interruption, limiting congestion.

The paper's first author is postdoctoral associate Mahyar Amirgholy; Mehdi Nourninejad of the University of Toronto also contributed. The research was supported by the U.S. Department of Transportation; the Center for Transportation, Environment and Community Health; the National Science Foundation; and the Lloyd's Register Foundation.

By Melanie Lefkowitz

CURBING DIESEL EMISSION COULD REDUCE BIG CITY MORTALITY

Cities across the U.S. could see a decline in mortality rates and a related beneficial reduction in healthcare costs through midcentury if federal and local governments maintain stringent air pollution policies and diminish concentrations of diesel freight truck exhaust, according to Cornell research published in the journal *Environment International*.

"The U.S. must reduce emission in the transportation sector. By improving air quality through better policies and technology in the freight transportation sector, we can breathe better and save lives," said senior author H. Oliver Gao, professor of civil and environmental engineering and director of the Systems Engineering Program.

Freight transportation is a pillar of the U.S. national economy, but while long-haul trucks account for less than 6% of the vehicle miles traveled over U.S. highways, they account for about 40% of the emissions of air polluting particulate matter and about 55% of nitrogen oxides – the precursor to ozone in the atmosphere, the study said.

"People use their family cars some 10 to 12 years, and log about 120,000 miles over the car's lifetime," said Gao. "A diesel truck can stay on a fleet about 25 to 30 years and easily log a million miles."

To reduce emissions by midcentury, the researchers said, truck manufacturers need to add advanced pollution-reduction technology to new trucks and retire older, highly polluting vehicles.

Freight trucks primarily use diesel engines, which are efficient and durable but emit fine-particulate exhaust, which poses a cancer risk 7.5 times larger than all other air toxins. Diesel exhaust is classified as a Group 1 (highest level) carcinogenic, according to the World Health Organization's International Agency for Research on Cancer.

Gao and his colleagues modeled the public health impacts of restraining particulate matter, based on emission change for future air quality. They estimated improved health outcome (preventing 3,600 premature deaths nationally each year) and $38 billion annually in reduced healthcare expenditures.

In order to achieve emission reduction goals and the benefits in public health, stringent emission standards and fuel policies should be continuously and effectively implemented, the study said.

In addition, the societal benefits of reduced freight emissions are expected to largely exceed the implementation costs of such standards and policies. For instance, the total compliance in particulate restraint costs from 2011 to 2050 would be about $1.8 billion annually, which is about 5% of their calculated yearly health savings, $38 billion.

The researchers point out that employing a carbon tax on freight serves to increase oil prices and shifts at least 15% of freight to energy-efficient rail, reducing overall emissions and obtaining 9% more health benefits nationally.

While current federal regulations have emissions limits on new vehicles, the regulations do not affect vehicles already in use, Gao said. Aging trucks, however, can easily degrade from normal to high-emitting conditions. Eliminating super-emitting vehicles completely could further reduce long-haul freight emissions by nearly 70% and provide 20% more health benefits, the researchers said.

"Getting rid of the particulate matter is an important part of reducing air pollution from diesel truck emissions," said Gao.

By Blaine Friedlander

"By improving air quality through better policies and technology in the freight transportation sector, we can breathe better and save lives."

—H. Oliver Gao
Director, Systems Engineering

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