USC Viterbi

MAGAZINE FALL 2021

WELCOME TO THE VITERBI MULTIVERSE

A Historic Graduation

COMMENCEMENT RETURNS TO THE COLISEUM FOR THE FIRST TIME IN 71 YEARS

By Daniel Druhora

A ROW OF CAREFULLY arranged chairs dotted the field of the Los Angeles Memorial Coliseum as graduates from USC's classes of 2020 and 2021 stepped onto the field, in full academic regalia, to celebrate in-person ceremonies for the first time since the outbreak of the COVID-19 pandemic.

The stands were largely empty save for a few tearful family members waving banners and photos. Following California's health and safety guidelines, graduation ceremonies were held twice a day, with limited capacity and distancing requirements, during the week of May 14–20.

In all, 1,125 graduate and undergraduate members of the Class of 2020 returned to their alma mater to celebrate their achievements, some crossing oceans and continents to complete a rite of passage that can never be fully experienced online. The Class of 2021 comprised 2,023 graduates and undergraduates in attendance.

USC conferred a total of 2,754 graduate degrees upon the engineering class of 2020 and 2,765 graduate degrees to the engineering class of 2021. Undergraduate engineering students of the Class of 2020 received 687 degrees, while the Class of 2021 received 829 degrees.

The historic event also marked commencement returning to the Coliseum for the first time in 71 years, as its size and capacity allowed for social distancing. The Class of 1950 was last USC graduating class to enjoy a Coliseum commencement.

"It is so fitting that we are formally certifying the crossing of your graduation finish line in the Los Angeles Memorial Coliseum, home of the Olympics, home of the Trojans," said Yannis C. Yortsos, dean of the USC Viterbi School of Engineering. "Where the lighting of the torch can be taken to also symbolize the saying from Socrates: 'Education is the kindling of a flame, not the filling of a vessel.'"

2021

On May 19-20, as part of USC's historic return to in-person graduation at the Los Angeles Memorial Coliseum, members of the USC Viterbi Classes of 2020 and 2021 received their diplomas on the same ground their predecessors had walked 71 years earlier. After nearly 14 months of remote learning and relative seclusion, it was a bright day, indeed, for graduating students of the USC Viterbi School of Engineering.

PHOTO: MICHAEL BAKER

2020

On May 15, the L.A. Memorial Coliseum sits empty as the university celebrates its first ever virtual conferring of degrees. The USC Viterbi School marked the occasion with a day of online commencement events, including video appearances by Andrew Viterbi, Geena Davis and Larry Ellison.

PHOTO COURTESY OF USC ATHLETICS

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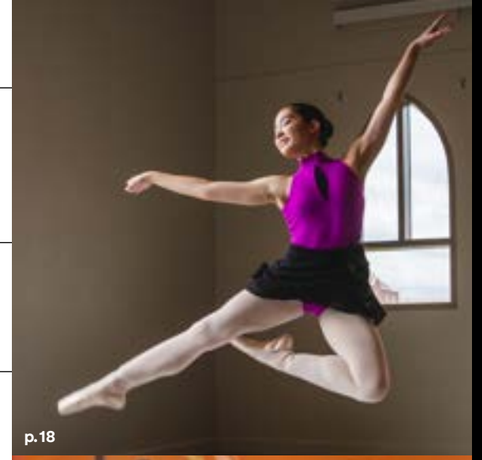

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Find the secret message

Five winners will receive a total of $750 worth of Amazon gift cards. See page 13 for first clue and details.

USCViterbi
Fall 2021
ISSN 2329-0498

Dean
Yannis C. Yortsos

Associate Dean, Communications and Marketing
Michael Chung

Editor
Adam Smith

Managing Editor
Marc Ballon

Art Director
Madelin Lum

Graphic Design
Iña de las Alas

Contributing Writers
Rishbha Bhagi, Caitlin Dawson, Daniel Druhora, Cheyenne Gaima, Greta Harrison, Benjamin Paul, Avni Shah

Photography
Michael Baker, Carolyn DiLoreto, Mike Glier, Hugh Kreschmer, Helen Perez, *Unsplash*/Josh Kahen

Artwork
Antonio Caparo, Laura Catrinella, Chris Kim, Tyler Krantz, Yihyoung Li, Michael Machira Mwangi, Avalon Nuovo, Michael Rogers, Gordon Rowe, Francisco Santoyo

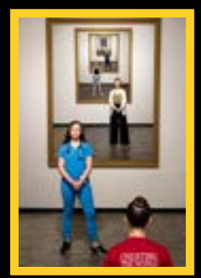
Volume 21, Issue 1
USC Viterbi magazine is published twice a year for the alumni and friends of the Viterbi School of Engineering at the University of Southern California.

Letters to the editor and comments are welcome. Please send them to:
USC Viterbi Magazine
1150 S. Olive Street, Suite 1700
Los Angeles, CA 90015

Or email them to:
viterbi.communications@usc.edu

Development
viterbi.usc.edu/giving

On the cover:



Rhys Richmond, B.S. BME '21, encapsulates many dimensions of the USC Viterbi experience: dancer (Xpressions Dance Company and Trojan Dance Force), co-founder and COO of Duet, undergraduate researcher, and working medical scribe, pursuing a pre-med track.

COVER PHOTOGRAPHY: HUGH KRETSCHMER

Prologue

"On March 15, 2020, in the vocabulary of the many-world theory of quantum mechanics, the 'wave function' collapsed, and essentially, we collectively moved overnight to another world — the COVID world."

— Yannis C. Yortsos, Dean
USC Viterbi School of Engineering

January 21, 2020
First confirmed U.S. COVID-19 case in Washington state.

March 10
USC announces a temporary shift to online classes for the week after Spring Break.

March 11
WHO declares global pandemic. A day when COVID-19 became real for many Americans: actors Tom Hanks and Rita Wilson announce positive tests, and the NBA suspends its season just moments before the tip-off of a game between the Utah Jazz and the Oklahoma City Thunder.

March 15
First confirmed USC student tests positive (not on campus). Dean Yannis Yortsos' memo follows: "Effective tomorrow, and until further notice, all nonessential office functions at Viterbi will be minimally staffed, with most work done remotely and online."

March 19
California issues stay-at-home order.

April 7
USC Viterbi partners with the National Academy of Engineering on a national Call to Action to identify and support engineering solutions for the global pandemic.

May 15
USC commencement goes online. USC Viterbi's celebration features special guests Andrew Viterbi, Ming Hsieh, Larry Ellison, Academy Award-winning actor Geena Davis, actor Jack Black and Megan McCarthy from the National Institute of Allergy and Infectious Diseases.

May 14-20, 2021
USC holds in-person graduation ceremony at the Los Angeles Memorial Coliseum — for the first time in 71 years! — for 2020 and 2021 graduates.

September 10
Dean Yortsos returns to the (online) classroom, kicking off the 11-part "Viterbi vs. Pandemics!" lecture series. The free program immerses students in cutting-edge COVID research from USC Viterbi faculty.

December 11
The U.S. Food and Drug Administration issues the first emergency use authorization for the Pfizer-BioNTech COVID-19 vaccine.

May 19, 2021: "In this historic commencement event, today we are celebrating the passage to a new world: one you are going to shape like no other graduating classes have before."

— Yannis C. Yortsos, Dean
USC Viterbi School of Engineering

PRE-COVID WORLD

COVID WORLD

Which World Do We Choose?

In **MARCH 2020,** when the COVID-19 pandemic became an incredible new reality, I could not refrain from making an analogy to what quantum physicists call the "collapse of the wave function."

The fact that we entered a new world almost instantly paralleled the quantum mechanics process where, from multiple possible real manifestations, only one is selected at the moment when the wave function collapses. Quantum mechanics tells us that moving from one manifestation to another does not preclude that at another time, when the wave function collapses again, one might rejoin the previous world manifestation. Perhaps we are on the cusp of such a transition to a post-COVID world.

A different view can be offered if one considers that our complex world is nonlinear, with myriad choices, and such nonlinear dynamics (often characterized as chaotic) can bring unintended consequences, such that small fluctuations somewhere have a huge effect somewhere else — similar to what is known as the butterfly effect. The 1998 movie "Sliding Doors" creatively embodied both these concepts, wherein a small action — missing a train to work — led to the unintended discovery of a parallel, and very different, world, and in the absence of that action, the more routine world would have unfolded undisturbed.

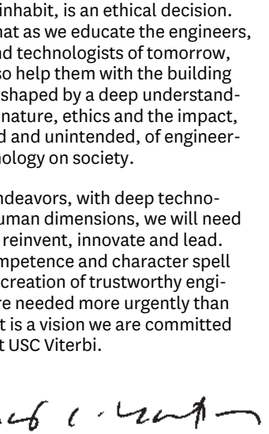
How relevant are these philosophical musings to the current reality? For one, they help us imagine the many options we have for shaping the world, and see that the decisions we make, the vision we elect to pursue, can lead to a better world for all. Such vision will be informed today by the transformative events we experienced over the past 18 months, ranging from the way we adapted technologically during the long COVID-19 seize, to the realization that much remains to be done to address social and racial inequities in our society.

For another, these ideas also warn us of the possibility and relevance of unintended consequences and the underlying need for them to be considered in any decision-making. This is particularly true today: As technology advances at an accelerating rate, so too do advances in adverse, unintended consequences.

Engineering and technology are driving discovery and innovation for practically all disciplines at an unprecedented pace that is certain to accelerate even further with advances in computing of all types and the relevance of AI and data sciences in those endeavors.

At the same time, choosing what problems to focus on, which of the parallel universes we will select to inhabit, is an ethical decision. This means that as we educate the engineers, innovators and technologists of tomorrow, we should also help them with the building of character, shaped by a deep understanding of human nature, ethics and the impact, both intended and unintended, of engineering and technology on society.

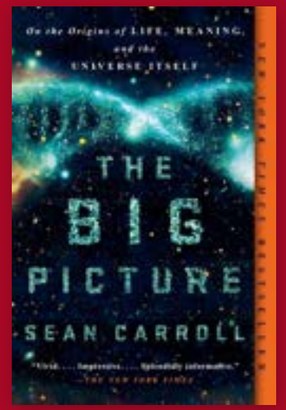
In all these endeavors, with deep technological and human dimensions, we will need to constantly reinvent, innovate and lead. Together, competence and character spell trust and the creation of trustworthy engineers, who are needed more urgently than ever before. It is a vision we are committed to pursuing at USC Viterbi.



What I'm READING, WATCHING, LISTENING

NEVER ONE TO WASTE A SECOND, DEAN YANNIS C. YORTSOS IMMERSED HIMSELF IN AN ECLECTIC SELECTION OF BOOKS, MUSIC, MOVIES AND TV SHOWS OVER THE PAST YEAR. USC VITERBI MAGAZINE ASKED HIM TO LIST SOME THE WORKS HE MOST ENJOYED AND TO SHARE HIS THOUGHTS ON THEM.

By Marc Ballon



***THE BIG PICTURE*, BY SEAN CARROLL** A spectacular treatise on the origins of life, meaning and the universe itself.

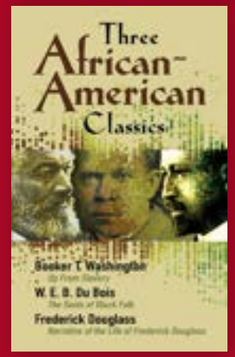
***NOEMA* MAGAZINE (SPRING 2020, ISSUE 1), "THE GREAT ACCELERATION"** Provides great insights on the intersection of technology and society in the context of COVID-19 as well as social change.

***LEADERSHIP IN TURBULENT TIMES*, BY DORIS KEARNS GOODWIN** Learning from history on inspired leadership in difficult times.

THREE AFRICAN-AMERICAN CLASSICS A trio of the most influential African American writings of the 19th and 20th centuries.

***JOURNEY TO THE EDGE OF REASON: THE LIFE OF KURT GÖDEL*, BY STEPHEN BUDIANSKY** A fascinating biography of mathematician Kurt Gödel, his genius, and his life in Austria and then in the U.S. at the Institute of Advanced Studies at Princeton.

***ENLIGHTENMENT NOW*, BY STEVEN PINKER** The case for reason, science, humanism and progress.




Shtisel, *now streaming on Netflix*

ANY AND ALL SOCCER GAMES. And did I mention soccer games? English Premier League (come on, you Spurs!), USC women's soccer (a most talented and well-coached team), and the U.S. Women's National Team (USWNT) and the suddenly looking better U.S. Men's National Team (USMNT).

A number of "whodunit?" mysteries, notably in communities on the coast of England or Ireland, e.g. ***BROADCHURCH*** and the docuseries ***SOPHIE: A MURDER IN WEST CORK*.**

TULSA BURNING: THE 1921 RACE MASSACRE An incredible story.

SHTISEL A Middle East story with human dimensions. Reminiscent in many ways of related cultures in that part of the world, including my own while growing up as a child in the Greek island of Rhodes (of course, with different religious and social backgrounds).


Françoise Hardy

ALL KINDS OF MUSIC, including Enya, Leonard Cohen, Luciano Pavarotti, Andrea Bocelli, Brazilian rhythms (including Bebel Gilberto), Françoise Hardy, Madeleine Peyroux, Sara Bareilles, Smetana, and Italian (Zucchero) and Greek music.

TROJAN DREAMS & MANY WORLDS

FROM MARS TO REFUGEE CAMPS, CONCEPTUAL GLIMPSES OF WORLDS WHERE USC VITERBI RESEARCH IS AN EVERYDAY, APPLIED REALITY

A Crewed Mission to Mars?

USC STUDENTS DESIGN A LIGHTER, MORE ADAPTABLE VEHICLE TO HELP MAKE POSSIBLE A CRUCIAL PIECE OF A HUMAN MISSION TO MARS: BRINGING ASTRONAUTS HOME

By Avni Shah

IN 1971, David Bowie asked, "Is there life on Mars?" echoing the curiosity of people all over the world. Mars has long been a subject of wonder and, in practical terms, a pivotal part of the next chapter in space exploration.

NASA asked student teams to help propel it into this next chapter by solving a core problem: how to bring a two-person crew home from Mars. In response to the 2021 NASA RASC-AL challenge, a team of USC Viterbi students developed the MAVIC (Minimum Ascent Vehicle for Interplanetary Crew). The team was one of 16 finalists out of over 50 teams in the competition, which ended in June.

The project, advised by Anita Sengupta, adjunct associate professor of astronautics at USC Viterbi, prioritized reduction of mass as the key way to reduce entry, descent and landing challenges for the vehicle.

Jessica Yuan, co-lead of the MAVIC team and a mechanical engineering junior at USC Viterbi, explained, "The weight constraints pushed us to innovate away from previous designs for similar missions, which use heavyweight vehicles that hover around 40 tons for a crew of four."

The MAVIC is approximately 20 tons for a crew of two, with a dry mass of 4,976 kilograms and a wet mass of 16,976 kilograms.

To reduce mass, the team had to get creative. A lot of existing design elements were incorporated in new ways.

Yuan and co-lead Albert Sun, a former USC undergraduate and currently a junior studying economics, math and physics at the University of Chicago, pointed to three pivotal aspects of their design that helped reduce the vehicle's weight: a toroidal (doughnut-like) structure for the tank design to reduce the height of the vehicle; a propellant that can be stored at room temperature and does not require heavy temperature-regulating equipment; and a single door (hatch) for entry and docking, versus using two of them.

The project is estimated to take 10 years to complete and cost $7 billion.

A crewed mission to Mars requires many pieces to come to fruition. Said Yuan: "The Mars ascent vehicle is a prerequisite for mission success."

ILLUSTRATION: FRANCISCO SANTOYO

Charting a Course to 6G

ANDY MOLISCH'S TESTS BRING US CLOSER TO A HOLOGRAPHIC, HAPTIC INTERNET

By Benjamin Paul

IMAGINE you're a fisherman living by a lake. Every day, you row out on the calm waters to catch fish. Life is good. But then your family grows and you need more fish, so you go to the river. You can go farther and faster on the river, but you can't take your little rowboat out there — it's not built for those currents. So you learn everything you can about how rivers work and build a better boat. Life is good again — until you realize you need more fish and need to go farther still, to the ocean. But ocean rules are nothing like river rules. Now you have to learn how ocean currents work and then design an even more advanced boat that can handle that those conditions.

Communications frequencies are just like those currents, and the different boats are just like the tools we build to communicate. Before we can build the devices to create the next generation of communications, we have to understand the currents we're working with. Andy Molisch, professor of electrical and computer engineering and the holder of the Solomon Golomb – Andrew and Erna Viterbi Chair, is doing just that for the next communications frontier: 6G.

Molisch's highly detailed measurements of 6G frequencies, which were conducted along with postdoc Naveed Abbasi and several Ph.D. students, as well as undergraduate and master's students, have yielded surprising results.

"Researchers have long believed that as we move up into 6G frequency, the ways in which a signal can reach a receiver will be greatly limited," said Molisch. "Our work shows that that is not always the case."

Think of his calculations as something like early explorers suddenly discovering the Gulf stream. With this new information, engineers can begin to design the tools necessary to make 6G a reality.

This, in turn, is an important step toward realizing a whole host of new applications. Molisch has identified three that he believes will be front and center: haptic (or touch) internet, mobile-edge computing, and holographic communications. All three of these have the potential to change the face not just of communications, but society as a whole.

ILLUSTRATION: FRANCISCO SANTOYO

A Torch Kept Lit

JACOB TOTARO, B.S. '21, AND A TEAM CREATED A PRODUCT TO MAKE TEMPORARY SHELTERS MORE LIVABLE

By Daniel Druhora

IN FEBRUARY 2020, before COVID-19 was declared a pandemic, Jacob Totaro, B.S. CEE '21, and a team of students in the USC Viterbi class "Innovation in Engineering and Design for Global Challenges" traveled to Europe's largest refugee camp, Moria, on the Greek island of Lesvos – then home to 30,000 refugees living in tents and makeshift shelters.

Using Aluminet, a special knitted screen material of metalized polymer used in industrial greenhouses, Totaro's team designed an insulated tent cover, called a Torch Tile, that reflects outside heat while using body heat to thermoregulate the inside. The result is a shelter that increases temperatures by as much as 40 to 50 degrees F in the cold, while the reflective Aluminet bounces heat back on hot summer days and cools the shelter.

Because the material is knitted, it is breathable enough to allow airflow, reducing humidity inside tents by 5% to 10%. Torch Tiles are also ultra-adaptable: they stretch to fit available space, and their geometric design makes them easy to repair or replace.

After eight months of prototyping and 36 iterations, Totaro's team returned to Moria to test their product. They ran out of Torches within a day due to high demand from refugees.

Back in Los Angeles, Totaro realized that what they were working on for the refugee crisis could be applied to the homelessness crisis in their own backyard. And so began a campaign to distribute 2,000 Torches to L.A.'s Skid Row by the end of 2020. He and his collaborators also sent Torches to Las Vegas, Long Island, San Francisco, and to the U.S.-Mexico border, free of charge. In all, over 3,000 tents have been made more livable by Torch as of this writing. They even created a campaign that allows campers to buy a Torch and give a Torch to a refugee or a person experiencing homelessness.

Torch Inc. has since become a community action group whose goal is to distribute Torches all over the world and to grow a network of young innovators whose mission is to develop innovative solutions that improve the lives of people living in temporary shelters.

ILLUSTRATION: MICHAEL MACHIRA MWANGI

A Light (and Colors) at the End of the Tunnel

USC RESEARCHERS ARE USING SUPERCOMPUTERS TO RESTORE PARTIAL VISION TO PEOPLE WITH BLINDNESS

By Cheyenne Gaima

IN 2013, the Argus II artificial retina became the first device approved by the U.S. Food and Drug Administration to help restore sight to the blind. Developed over 25 years by USC Viterbi Professor Mark Humayun — an ophthalmologist turned biomedical engineer whose grandmother lost her sight to diabetic retinopathy — the Argus II has since helped hundreds of people with degenerative eye diseases partially see again.

When light enters the eye, photoreceptors translate that light into electrical pulses that are sent via the optic nerve to your brain. In blind people, the Argus II replaces light by stimulating the cells with electrical pulses directly.

Since then, researchers including Humayun and Gianluca Lazzi, Provost Professor of Ophthalmology and Electrical Engineering at USC Viterbi and the Keck School of Medicine of USC, have been making progress in their studies of retina prosthesis in the hopes of making devices like the Argus II even better.

"Our goal now is to develop efficient biomimetic systems that more precisely mimic the complexities and behaviors of natural neurological cells," said Lazzi, who collaborated on the original Argus II research with Humayun, who is the Cornelius J. Pings Chair in Biomedical Sciences.

Lazzi and his team are working with advanced computational modeling strategies that can run on supercomputers and replicate what happens in the retina to offer an enhanced understanding of the neural system. The revelation: Color perception is a function of waveform and frequency of electrical stimulation.

This next generation of visual prosthetics would offer patients a step up from recognizing shapes and movements to perceiving colors and patterns, and with higher definition. The effects of these discoveries have already been confirmed in clinical trials, where subjects perceived chromatic colors along or nearby the blue-yellow axis in color space.

"Providing different colors — even limited — could greatly enhance vision," said Lazzi. "Even if the vision is still resorting to the same number of pixels, the artificial retina system could detect certain image features, like an image or a door, and differentiate them by color to help a patient identify important features of the image."

There are even discussions of adding artificial intelligence to the Argus II for automated aid in feature recognition.

"My appreciation for the fact that the human body is electrical in nature has grown over time," Lazzi said. "The more we understand electricity, the closer we will be to truly bringing sight to the blind."

ILLUSTRATION: MICHAEL MACHIRA MWANGI

Bot Appétit

WHAT'S ON THE MENU TONIGHT? THIS ROBOT COULD BE YOUR FUTURE CULINARY COMPANION.

By Caitlin Dawson

AFTER a long day at work, an autonomous pod drops you off at your home, sweet home. Your fingerprint opens the door, as the scent of fresh garlic and tomatoes gently wafts toward you.

"What's for dinner?" you call out. The answer: "On the menu tonight: spaghetti bolognese, with lemon tiramisu for dessert. This meal contains 63% of your recommended daily calories."

Your chef is a robot that honed its culinary skills by watching 100 cooking videos on YouTube using technology developed by Stefanos Nikolaidis, a USC Viterbi assistant professor of computer science, and his team.

"If humans could learn to make pancakes by watching videos, why can't robots?," Nikolaidis asked. Cooking is complex in terms of manipulation, the steps involved and the tools used. To cut an apple, for example, you need to take a knife, put it in the right place, make the cut and view the results to make sure you did them correctly.

Early attempts to "teach" robots focused largely on pre-programmed instructions. That led to countless culinary disasters in real-world kitchens. With the robots confused by clutter, and failing to recognize the difference between utensils in unexpected places, people came home to more mashed bowls than mashed potatoes.

Instead, by watching videos on the internet and observing what others do, Nikolaidis's robots are learning complicated grasping and manipulation motions, and recognizing which tool to use for a given action — for instance, a spatula to turn food in a pan, a knife to cut chicken.

Your robot chef uses several key systems: computer vision to "see" the objects, artificial intelligence to process that information and language parsing to help it understand spoken commands.

Since its deployment, the robot chef has learned different cooking styles from cultures all over the world and even adapted its recipe repertoire based on the user's preference. Nikolaidis's top request to his autonomous robot chef? "That's easy," he said. "Ramen."

ILLUSTRATION: FRANCISCO SANTOYO

For Your Eyes Only

NEW USC RESEARCH USES QUANTUM PHYSICS TO SECURE SECRET DATA

By Rishbha Bhagi

EVER WONDERED WHAT'D HAPPEN IF JAMES BOND AND ALBERT EINSTEIN WALKED INTO A BAR? USC Viterbi Professor Todd Brun just might have the answer.

Building upon existing steganography methods, Brun's quantum steganography project explores delivering secret messages in a way that no one but the intended recipient would know that they even existed, using quantum physics to enable highly secure communications. Quantum steganography could potentially be used by governments, militaries, intelligence agencies and multinational banks that place a premium on secret communications.

While steganography is etymologically related to the word "stegosaurus" (*Jurassic Park*, anyone?), Brun's research on quantum steganography for secure transmissions is as futuristic as it gets. Stemming from the Latin word *steganos*, meaning "covered," steganography is the art of hiding information or a message in plain sight, which differentiates it from other secret transmission methods like cryptography.

Aged actor expects message always delivered. Pride betrays Emperor Picard, abominably demolishing perfect democracy. Correspondingly, idealistic deans forgive acceptable avocados. Floating Earths persist.

ILLUSTRATION: TYLER KRANTZ

Cryptography is a way to secure communication by transforming the message into a code that's difficult for unintended recipients or eavesdroppers to decipher; however, since the message looks like gibberish, the eavesdropper will at the very least realize there's something hidden within the communication.

By contrast, steganography conceals the fact that there's even a message in the first place.

In the earliest recorded example of steganography, a message was tattooed on the shaved head of a Greek messenger. By the time he reached the recipient, his hair had grown back and concealed the message with no one the wiser.

Fortunately, there are other methods that don't involve getting a new 'do. Spies, for example, would embed secret messages in letters by using cards with holes cut in strategic locations that show the intended hidden message. In the modern age, digital images can hide secret messages within their pixels.

In both cryptography and steganography, a secret key is shared in advance between the sender and the recipient. Cryptography uses this key to scramble the message, while steganography uses it to trick people into believing that no message exists.

> Steganography conceals the fact that there's even a message in the first place.

QUANTUM (STEGANOGRAPHY) OF SOLACE

Brun's research takes things to the next level by using quantum physics to hide messages for even greater communication security. This method uses quantum channels — a communication channel using quantum states of light like photons or weak laser pulses to transmit information.

"The particular method that we're using is related to an idea called covert communication, where we're disguising our transmissions as an idle channel — that is, a channel where no messages are being sent," Brun explained.

Photons, which are particles of light, are in the background of every communication channel, even if it's an idle one. In quantum steganography, the secret message is transmitted using a series of weak laser pulses that seem like a random pattern of photons in the background; however, the pattern is far from random and actually contains the message itself.

This extra layer of protection can greatly secure sensitive information, which would be useful for government agencies and banks, for example. "The main advantage of quantum steganography over classical [steganography] is that it potentially allows the transmission of quantum messages," Brun said.

These messages enable quantum communication protocols, such as quantum authentication. "The current proposed experiments don't do this, but in the future, this may become possible," Brun added.

To test this theory, Jonathan Habif, quantum physicist at USC's Information Sciences Institute and a USC Viterbi research assistant professor, has begun working with Brun at ISI's Laboratory for Quantum-Limited Information (QLIlab).

Quantum steganography can be used to "watermark" communications, which proves that a transmission is genuine and can prevent eavesdropping attacks. It can also use entanglement for secret communication, which is when two quantum particles are strongly linked in such a way that they can theoretically enable quantum protocols like teleportation.

"This method is a little science-fictional right now, in that there aren't a lot of quantum channels out there and they're mostly used for research," Brun said. "In the future, that's likely to change, however, as quantum channels can be used to share secret keys for cryptography or to share entanglement for a variety of different quantum communication protocols. Secret messages could then be piggybacked on top of those quantum transmissions."

Finally, a Quantum that Mr. Bond can get behind.

FIND THE HIDDEN MESSAGE IN THIS ISSUE

EARN ONE OF FIVE AMAZON GIFT CARDS, A TOTAL OF $750 WORTH OF PRIZES

Sadly, you (likely) do not possess sophisticated equipment for deciphering quantum steganographic messages, à la USC Viterbi professors Todd Brun and Jonathan Habif.

A pity. But despite your relative quantum deficit, we wanted to allow you, dear readers, a chance to discover your own hidden message in this 56 page issue — hidden in plain sight using more standard steganography and cryptography.

For those who discover the hidden message, your efforts shall not go unnoticed — or unrewarded.

There are three connected steganographic messages in this issue. Each one unlocks the next.

Once you discover the third and final hidden message, visit our digital magazine *(magazine.viterbi.usc.edu/secretmessage)*, where you will be prompted to share your answer. The prizes will be awarded based on your time-stamped entries. In other words: first come, first served.

THE PRIZES

1st place	$375 Amazon gift card
2nd place	$200 Amazon gift card
3rd place	$100 Amazon gift card
4th place	$50 Amazon gift card
5th place	$25 Amazon gift card

Where to begin? Our only advice is to scour the pages carefully and thoroughly. Like leaves of grass, the answers might be scattered anywhere. And you might do well to ponder the question: *What hath God wrought?*

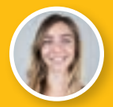
Faculty Accolades

Heather Culbertson
NSF CAREER Award

Jyo Deshmukh
NSF CAREER Award

Xiang Ren
NSF CAREER Award

Constantine Sideris
NSF CAREER Award



Phebe Vayanos
NSF CAREER Award

Stacey Finley
AIMBE Fellow

Rehan Kapadia
Office of Naval Research Young Investigator Award

Qiming Wang
Office of Naval Research Young Investigator Award

Jay Kuo
Television Academy Technology and Engineering Emmy Award

IEEE Charles A. Desoer Technical Achievement Award

Scott Fraser
Society for Developmental Biology Conklin Medal

Shang-Hua Teng
SIAM Fellow

Alan Willner
European Academy of Science and Arts

FIVE CHANGES

Inspired by the USC Viterbi COVID World

THE UNEXPECTED SILVER LININGS OF LIVING THROUGH THIS MOMENT IN HISTORY

By Daniel Druhora

WE LOST A LOT to the pandemic: loved ones, date nights at our local movie theater, passing the microphone at karaoke and blowing out candles on our birthday cakes. But with all the things that COVID-19 took away, we gained some good things, too. Here are five positive changes at USC Viterbi that continue to shape our long-awaited, post-COVID world.

1 RACIAL EQUITY-MINDED ACTION PLAN

The pandemic saw racial inequalities breaking to the surface with millions of people taking to the streets to demand change. In June 2020, USC Viterbi began work on the Racial Equity-Minded Action Plan. With a goal to increase pipelines and pathways to attract and retain Black, Latinx and Indigenous students, faculty and staff, the plan is more than a pledge to remove systemic and structural barriers to diversity and inclusion. It is a detailed plan of action originated by faculty, students, staff and administrators seeking to spark cultural transformation in the STEM fields.

A first indicator of the impact of this initiative is the incoming undergraduate class of Fall 2021, which is projected to consist of 13.8% Black, 27.7% Latinx and 25.4% first-generation students, in addition to being gender-balanced (49.6%) for the third year in a row.

2 CENTER FOR UNDERGRADUATE RESEARCH IN VITERBI ENGINEERING (CURVE) FELLOWSHIP

Last summer, many USC Viterbi students discovered that internships or jobs they had lined up disappeared almost overnight. Some of these opportunities never came back, so USC Viterbi created a new one: the Center for Undergraduate Research in Viterbi Engineering (CURVE) Fellowship. Open to all USC Viterbi undergraduate students, CURVE has admitted more than 110 students so far.

CURVE embeds younger students in USC Viterbi research labs, pairs them with Ph.D. mentors, and allows them to drive research on topics ranging from climate change to space engineering, self-driving vehicles and socially assistive robotics, to COVID-19 misinformation and using AI for social good. They also receive a $1,250 stipend.

3 BLENDED IN-PERSON AND REMOTE WORKING AND LEARNING

Remote work options and flexibility are increasingly important even as more people are getting vaccinated. Through its Distance Education Network (DEN@Viterbi) and other innovations like virtual class meetings, the USC Viterbi community kept the university running from all over the world.

Similarly, the USC Viterbi Human Resources Office and the Office of the Dean have come up with flexible work arrangements under the new Viterbi Workforce Plan. The plan offers three work arrangements — fully remote, hybrid and onsite — to support remote learning as well as the traditional residential campus student life experience that is core to USC Viterbi's mission, including in-person instruction.

4 STUDENT AID FUND

With many students unable to return home during the lockdown, USC Viterbi established the Student Aid Fund to provide financial support to engineering students who had difficulty remaining enrolled. The amount raised was matched with a gift from University Trustee Ming Hsieh, B.S. EE '83, M.S. EE '84, amounting to $241,000 raised to date. The funds helped 365 students with short-term housing, food, internet access, transportation, research on campus, lost wages and supplies.

"Although the fund was initiated to help our students cover short-term food and housing costs, we hope to continue these efforts alongside USC's Basic Needs Office to ensure the physical, emotional and academic well-being of USC students," said Sheryl Koutsis, director of academic services at the USC Viterbi Office of Admission and Student Affairs.

5 VITERBI LIVE AND PANDEMIC LECTURE SERIES

The Viterbi vs. Pandemics lecture series, created by Dean Yannis C. Yortsos, addressed epidemics in a comprehensive way from the perspective of faculty on the frontlines of researching and developing new methods to predict, analyze and combat COVID-19. Open to the USC community and beyond, the 11 lectures ranged from the fluid dynamics of contagion, bioengineering and vaccine development to contact tracing and combating misinformation.

Meanwhile, USC Viterbi's Alumni Relations office hosted a series of Viterbi Live events bringing together students, alumni and staff through a series of faculty, research, leadership and social events.

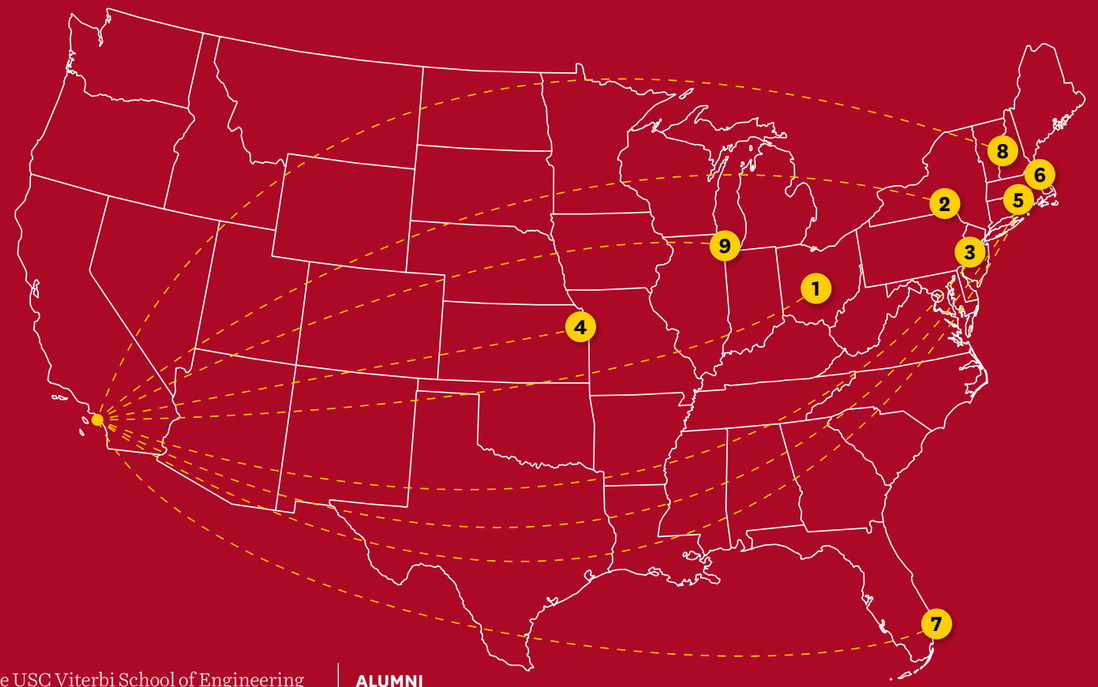
In partnership with USC Viterbi's Marketing and Communications Office, Viterbi Live highlighted the remarkable work of the Trojan Family to adapt to the "new normal," such as Professor S.K. Gupta's "Handling the PPE Shortage Through Innovation, Creativity, and the Maker Movement"; former NASA astronaut and Professor of Astronautical Engineering Garrett Reisman's session, "Working Remotely: Lessons I Learned From Space"; and Professor Andrea Armani's "Innovative 'DIY' PPE Disinfectant Methods."

These global Viterbi Live "E" Day events culminated in a lecture from the school's namesake, Andrew Viterbi, Ph.D. '62, speaking to more than a thousand people on "The Mathematics of Epidemics: A Century-Long Saga."

As the online format evolves from large events to intimate salons, USC Viterbi will continue to bring the engineering community together around the open sharing of knowledge and experience to *engineer a better world for all humanity*.

Trojan Leaders in Academia

LOOK FAR, LOOK WIDE, AND PERHAPS YOU'LL SPOT A FORMER TROJAN LEADING AN ENGINEERING PROGRAM AT AN ESTEEMED INSTITUTION



The USC Viterbi School of Engineering not only empowers the creative thinkers and innovators who help solve grand challenges; it prepares the leaders that educate and inspire the next generation of engineers.

As of July, nine former USC Viterbi students and faculty served as presidents or deans of engineering at some of the nation's top colleges and universities.

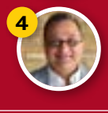
— *Cheyenne Gaima*

ALUMNI

1 **Ayanna Howard**
M.S. EE '94, PH.D. EE '99
DEAN OF ENGINEERING, OHIO STATE UNIVERSITY

3 **Sharon Walker**
B.S., ENVIRON. ENG. '98
DEAN OF ENGINEERING, DREXEL UNIVERSITY

2 **Lyndon Archer**
B.S. CHEM. ENG. '89
DEAN OF ENGINEERING, CORNELL UNIVERSITY



4 **Arvin Agah**
M.S. BME '93, PH.D. CS '94
DEAN OF ENGINEERING, UNIVERSITY OF KANSAS

FORMER FACULTY

5 **Tom Katsouleas**
FACULTY, 1991–2008
PRESIDENT EMERITUS, UNIVERSITY OF CONNECTICUT

8 **Elsa Garmire**
FACULTY, 1975–1995
FORMER DEAN OF ENGINEERING, DARTMOUTH COLLEGE

6 **Richard Miller**
FACULTY, 1979–1992
PRESIDENT EMERITUS, OLIN COLLEGE

9 **Norberto Grzywacz**
FACULTY, 2001–2014
FORMER PROVOST, LOYOLA UNIVERSITY CHICAGO

7 **Jean-Pierre Bardet**
FACULTY, 1983–2011
FORMER DEAN OF ENGINEERING, UNIVERSITY OF MIAMI

More Than Words

EVERY TWO WEEKS A LANGUAGE DIES. LINA BRIXEY, A MEMBER OF THE CHOCTAW NATION AND A USC VITERBI PH.D. CANDIDATE, IS DETERMINED HERS WILL NOT BE NEXT.

By Caitlin Dawson

THOUSANDS OF LANGUAGES are teetering on the edge of extinction. In fact, of the estimated 7,000 languages spoken in the world today, nearly half are likely to vanish in this century, according to UNESCO. For Lina Brixey, a member of the Choctaw Nation of Oklahoma, it's personal.

A linguistics graduate and polyglot who speaks French, Spanish and Portuguese, Brixey didn't start learning Choctaw until she moved to Los Angeles in 2016 to pursue her Ph.D. in computer science at USC Viterbi. "I always came back to one question," Brixey said. "Why don't I speak my own language?"

She's not alone. Like hundreds of Indigenous languages of America, Choctaw is endangered, meaning that without intervention, it is likely to become extinct in the near future. Despite being the third-largest tribe in the U.S., recent estimates suggest only 7,000 Choctaw speakers remain. Crucially, as Brixey discovered, when a language dies, we lose more than just words: We lose cultures, traditions and unique world perspectives.

"Growing up, I had my tribal enrollment card, which is some kind of pedigree, but I never truly felt Choctaw until I could speak the language to a degree," said Brixey. "When I started learning the language and meeting other Choctaw people, I realized the urgency of the situation."

So she decided to do something about it. At USC's Institute for Creative Technologies (ICT), Brixey created the world's first Choctaw language corpus — a collection of written and spoken texts essential for the study of languages — a bilingual chatbot and a dialogue system for language documentation.

Survival Mentality

Brixey is Choctaw on her father's side. (Her mother is of Irish descent.) Her great-grandfather, Noah Frazier, a minister and farmer in Oklahoma, was the last person in her family to speak Choctaw fluently.

"Starting in the 1800s, there was social pressure in schools for Choctaw and Indigenous people not to speak their languages," Brixey said. "I think there was also a survival mentality — maybe my great-grandparents thought it was more important for my grandmother to learn English so she would have access to more opportunities."

Nevertheless, Brixey was curious about her ancestral language. When she was 12 years old, her sister got a special gift from her grandmother: a Choctaw dictionary. Lina and her sister practiced secret conversations in Choctaw, but with no fluent speakers to learn from, their enthusiasm eventually waned.

"That's something that is missing for a lot of us learning Choctaw and other Indigenous languages: We just don't have access to fluent speakers," Brixey said.

Living Avatars

In the decades that followed, Brixey earned an undergraduate degree in journalism; studied abroad in Argentina, Brazil and Belgium; taught English in Spain and France; and received master's degrees in both linguistics and computer science from the University of Texas, El Paso.

She found her niche in natural language processing, a subfield of artificial intelligence that focuses on enabling computers to process and understand human language. After coming to USC, Brixey put her linguistics and computer science skills to work developing a Choctaw language corpus. Named Choco, it now includes more than 300,000 Choctaw words and phrases painstakingly collected by Brixey from written and spoken archival materials.

At the same time, Brixey worked on the USC Shoah Foundation's Dimensions in Testimony, which allows visitors to have one-on-one conversations with "living avatars" of Holocaust survivors. She tinkered around on the system's back end, developed at ICT, and found it works much like a chatbot: When asked a question, the system trawls through a database of potential responses to select the most appropriate answer, simulating a real conversation.

This gave Brixey an idea: If people didn't have access to fluent Choctaw speakers, could she simply invent one?

Fair Skies Ahead

It turned out, she could. Using the same back-end system, Brixey developed a chatbot called Masheli, Choctaw for "fair sky." Working under the supervision of USC Viterbi Professor David Traum, Brixey selected 17 stories to form the chatbot's responses. The conversational chatbot can "speak" in English or Choctaw and read stories in both languages. Brixey hopes it will serve as a resource for schoolchildren and adults with an interest in learning Choctaw.

But practicing the language is only one part of the preservation equation; the other half is documentation. So Brixey created a dialogue system that encourages speakers of endangered languages to converse and tell stories, creating audio recordings to support language research and revitalization. In 2019, she presented the system at the United Nations General Assembly for the International Year of Indigenous Languages.

Brixey is currently working on an automatic speech recognition system, much like the system used for Holocaust survivors. She is also archiving her corpus in Oklahoma-based museums for use by other researchers and language learners. Beyond this?

"The sky's the limit," she said. "Since this is the first and only corpus for Choctaw, I am excited to have laid the foundation to help other Choctaw researchers. I do hope one day we can have a living avatar system for Indigenous people to preserve our languages and stories. There are technical challenges to overcome, of course, but that's the goal."

Seven Generations

It's an Indigenous perspective to talk about seven generations: What can I do today that will positively impact people seven generations from now? "I guess that's something I've embodied," Brixey said.

She and members of the Los Angeles Choctaw Language Community Class have translated five children's books together. Her dream? To see movies translated into Choctaw, and even Choctaw podcasts. Brixey, with countless other speakers of threatened languages, is not ready to let her ancestral language pass into history, even if the road to revival is a bumpy one.

"It feels like a dismissal when someone says it's not worth my effort to work on those languages," Brixey said. "Yes, our languages are endangered. But the fact is, our languages are not dead yet — they are very much alive. There is hope. If conservation efforts can bring wolves back from endangerment, I think it's also true for languages."

To watch storybook animation of Lina's story, visit *magazine.viterbi.usc.edu*

A Brief History of THE CHOCTAW PEOPLE

1500s
The Choctaw people live in what is now the southeastern United States, largely inhabiting the area that became Mississippi. Europeans begin settling America.

1700s
The Choctaw people develop a strong economy based on farming and selling goods and livestock to Europeans.

1801–1830
As a result of several treaties, the Choctaw are forced to cede more than 23 million acres to the United States.

1830
The Choctaw Nation is removed from its ancestral home by the federal government and resettles in Oklahoma.

1860s
The Bureau for Indian Affairs establishes the first Native American boarding school.

1880s
Many students are forbidden to speak their native languages — punishment is often used to enforce this rule.

1900
There is a push for Indigenous people to move out of the reservation areas and find work in big cities — many Choctaw people settle in California.

1945
The Mississippi Band of Choctaw Indians gains federal recognition and forms its own tribal government.

2008
An important cultural site, Nanih Waiya, is returned to the stewardship of the Mississippi Band of Choctaw Indians.

2020
In a landmark case, the U.S. Supreme Court rules that much of Oklahoma's tribal lands had never been rescinded.

ILLUSTRATIONS: CHRIS KIM

The Mechanics of Motion:

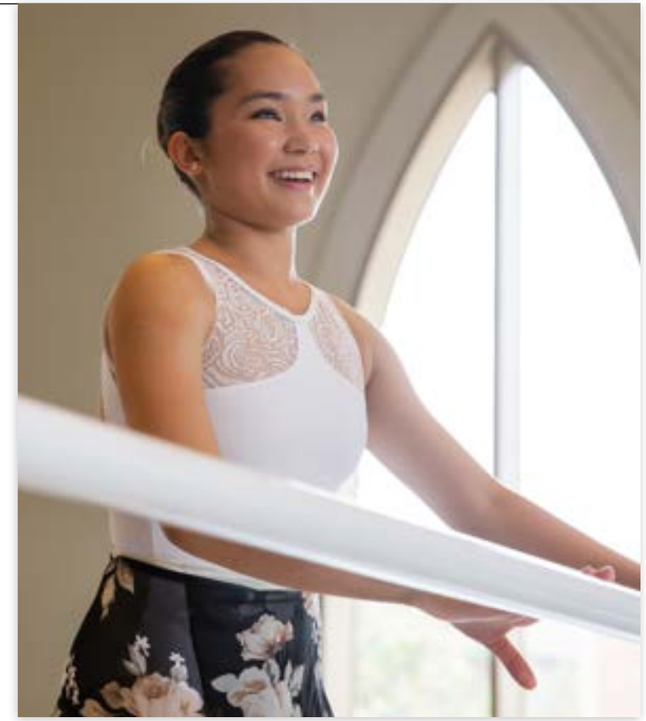
A CONVERSATION WITH A BALLERINA

By Avni Shah

Have you ever wanted to understand the mechanics of motion? As part of USC Viterbi's new "31 Questions" video series, we spoke with sophomore Kaitlyn Kumar about fouettés, jetés and other ballet terms most people can't say, much less do, and how they overlap with her dream job — helping people move through lightweight, adaptable prosthetics.

At USC Viterbi, Kumar studies mechanical engineering while also pursuing another passion: dance. Despite setbacks, like severe scoliosis and a shaky beginning with math, she has learned to advocate for herself, build resilience and recalibrate with ever-changing landscapes. Now she's got her eyes set on changing the world by helping people, including herself, move better.

Here are some excerpts from our rapid-fire video interview with Kumar:



Where did you grow up?

San Jose – in the Bay Area.

What did you want to be growing up?

I wanted to be a paleontologist for one year, and then I decided to become a ballet dancer. That's the profession that's stuck with me for most of my life.

Why did you stop pursuing ballet professionally?

I was diagnosed with severe scoliosis when I was 11, which made it physically impossible to pursue dance professionally without a lot of back pain. Also, scoliosis messes with your lines a bit in ballet, and it frustrated me that I couldn't do everything like my peers.

What's your first engineering memory?

In middle school I experimented a lot with wearable technology, so I sewed electroluminescent wire into a Transformers Bumblebee costume for Halloween. It bridged my interest between fashion and technology.

What do you love about mechanical engineering?

I love how you can take a bunch of different parts and create something with it that can help improve people's lives.

Do you have an engineering playlist?

Anything from Billie Eilish or this Russian playlist I put together on recommendation from my Bosnian friend.

What advice would you give to girls who are curious about engineering?

Get involved. Try to see if you have a local Girls Who Code chapter or a coding club or a STEM club. Even if you are struggling in science or math, or don't think engineering is for you, just give STEM a chance. It won't be easy. I used to coach middle school robotics, and I saw how the girls kept on getting pushed out by the boys into things like marketing and design. These are cool if you want to do that, but the girls wanted to be on the robots.

I would also encourage women in engineering to go back and mentor and help the younger girls, because they need to see you as role models and they need you to stand up for them.

How do art and engineering overlap for you?

Creativity. They are both very detail-oriented. And they both teach you a lot about dedication.

What's your favorite ballet?

Don Quixote. It's full of joy.

To watch the entire "31 Questions" video with Kaitlyn Kumar, visit *magazine.viterbi.usc.edu*.

> "I would encourage women in engineering to go back and mentor and help the younger girls, because they need to see you as role models."

PHOTOGRAPHY: CAROLYN DILORETO

Enabling AI to Use Its "Imagination"

A TEAM OF USC VITERBI RESEARCHERS HELPS AI IMAGINE THE UNSEEN, A TECHNIQUE THAT COULD ALSO LEAD TO FAIRER AI, NEW MEDICINES AND INCREASED AUTONOMOUS VEHICLE SAFETY

By Caitlin Dawson

IMAGINE AN ORANGE CAT. Now imagine the same cat but with black fur. Now imagine the cat strutting along the Great Wall of China. Doing this, a quick series of neuron activations in your brain comes up with variations of the picture presented, based on your previous knowledge of the world.

It's easy for humans to envision an object with different attributes. But computers struggle with the very human skill of imagination.

A USC Viterbi research team including computer science Professor Laurent Itti and Ph.D. students Yunhao Ge, Sami Abu-El-Haija and Gan Xin has developed an artificial intelligence system that uses human-like capabilities to imagine a never-before-seen object with different attributes. The paper, titled "Zero-Shot Synthesis with Group-Supervised Learning," was published in the 2021 International Conference on Learning Representations.

"We were inspired by human visual generalization capabilities to try to simulate human imagination in machines," said Ge, the paper's lead author. "Humans can separate their learned knowledge by attributes — for instance, shape, pose, position or color — and then recombine them to imagine a new object. Our paper attempts to simulate this process using neural networks."

AI'S GENERALIZATION PROBLEM

Say you want to create an AI system that generates images of cars. Ideally, you would provide the algorithm with a few images of a car, and the system would be able to generate many types of cars, from Porsches to Pontiacs to pickup trucks, in any color, from multiple angles.

This is one of the long-sought goals of AI: creating models that can extrapolate, meaning that, given a few examples, the model should be able to extract the underlying rules and apply them to a vast range of novel examples it hasn't seen before. But machines are most commonly trained on sample features, pixels for instance, without taking into account the object's attributes.

In this new study, the researchers attempt to overcome this limitation using a concept called disentanglement. Disentanglement can be used to generate deepfakes, for instance, by "disentangling" human face movements and identity. By doing this, said Ge, "people can synthesize new images and videos that substitute the original person's identity with another person but keep the original movement."

> "We were inspired by human visual generalization capabilities to try to simulate human imagination in machines."

Similarly, this approach takes a group of sample images (rather than one sample at a time, as traditional algorithms have done) and mines the similarity between them to achieve something called "controllable disentangled representation learning." Then it recombines this knowledge to achieve "controllable novel image synthesis," or what you might call imagination.

"Take the *Transformers* movie as an example," said Ge. "It can take the shape of Megatron car, the color and pose of a yellow Bumblebee car, and the background of New York's Times Square. The result will be a Bumblebee-colored Megatron car driving in Times Square, even if this sample was not witnessed during the training session."

This is similar to how we as humans extrapolate: When humans see a color from one object, we can apply it to any other object by substituting the original color with the new one. Using their technique, the group generated a new dataset containing 1.56 million images that could help future research in the field.

While disentanglement is not a new idea, the researchers say their framework can be compatible with nearly any type of data or knowledge. This widens the opportunity for applications. For instance, disentangling race and gender-related knowledge to make fairer AI by removing sensitive attributes from the equation altogether.

In the field of medicine, it could help doctors and biologists discover more useful drugs by disentangling the medicine function from other properties, and then recombining them to synthesize new medicine. Imbuing machines with imagination could also help create safer AI by, for instance, allowing autonomous vehicles to imagine and avoid dangerous scenarios previously unseen during training.

"Deep learning has already demonstrated unsurpassed performance and promise in many domains, but all too often this has happened through shallow mimicry, and without a deeper understanding of the separate attributes that make each object unique," said Itti. "This new disentanglement approach, for the first time, truly unleashes a new sense of imagination in AI systems, bringing them closer to humans' understanding of the world."

The USC Viterbi research team was led by computer science Professor Laurent Itti.

ILLUSTRATION: CHRIS KIM

THE Little Chip THAT COULD

MEET THE POUND-FOR-POUND CHAMPION IN QUANTUM COMPUTING

By Benjamin Paul

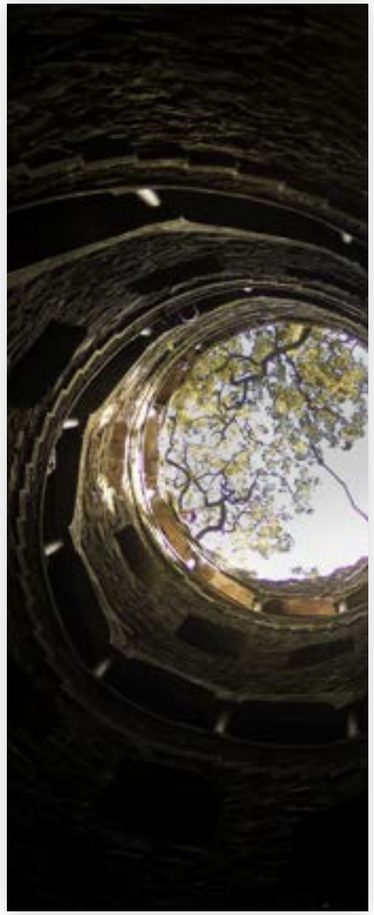
WHEN IT COMES TO quantum computing, less is sometimes more.

Take the new Hydra chip created under the DARPA Quantum Annealing Feasibility Study, directed by Daniel Lidar, USC Viterbi professor of electrical and computer engineering. This chip — which, like all chip generations in this project, is named after a constellation — has 25 qubits. Compared to the 5,000-plus qubits on the well-known D-Wave chip, that might not seem like much. Yet the team led by Lidar, which includes chip designers and fabrication experts from Northrop Grumman and MIT Lincoln Laboratory, has found a way to make the little Hydra chip, by some measures, 100 times more powerful for its size.

How? By improving the "quantumness" of the qubits on the chip. The power of quantum computing comes in part from a qubit's ability to maintain its superposition — essentially existing in an on-and-off state at the same time. The longer a qubit can maintain that state, the more powerful its computing power. When not in superposition, a qubit is no less powerful than an old regular bit.

But the Hydra chip maintains its qubits in superposition much better than anything previously designed — 100 times longer than its D-Wave cousin. (Since 2011, the D-Wave chip has been at USC's Information Sciences Institute, making USC Viterbi the first operational quantum computing center in academia.)

The Hydra is the latest in several generations of chips that the USC-led team has helped design. As part of a DARPA-funded program at USC called Reversible Quantum Machine Learning and Simulation (RQMLS), the goal is to use the 25-qubit chip to demonstrate rudimentary concepts in quantum machine learning and quantum simulation of exotic materials. In time, researchers plan to apply the techniques that give Hydra such staying power to larger chips. If scientists can one day combine Hydra's ability to maintain superposition with D-Wave's sheer number of qubits, we could enter a new phase of quantum computing.



"It's like studying alternative realities..."

USC RESEARCHERS USE RISK ANALYSIS MODELING AND AI TO HELP BUILD CERTAINTY AROUND CONTAMINANTS IN GROUNDWATER

By Avni Shah

ACCORDING TO THE U.S. CENTERS FOR DISEASE CONTROL AND PREVENTION, much of the water we use is sourced below the ground, with about 145 million Americans getting their tap water from a groundwater source. However, groundwater, which is found underneath the surface in spaces between rock and soil, can become contaminated with pathogens and harmful chemicals.

USC Viterbi researchers including Felipe de Barros, associate professor of civil and environmental engineering, have developed a variety of mathematical models to help assess how emerging contaminants disperse, dissolve and ultimately affect water quality and the resilience of aquifers. Such physics-driven mathematical models are needed given the limited information available. These limitations in data are due to the high costs associated with characterizing aquifers.

"The below-ground environment is very complex and challenging to track because we cannot see it," de Barros said. "We don't have detailed information on how deep the contaminants are, how far out they are spread, where they are coming from, what other contaminants they have mixed with or how the geological properties change over a certain area."

Using risk analysis together with a deep understanding of the physical processes involved, de Barros and his colleagues are working on computationally cheap analytical models that can help predict how contaminants behave under different water flow scenarios based on variables in the subsurface environment. By identifying the relationships between different geological parameters — say, how porous the rocks below ground are — the models can predict how a contaminant might dilute and spread, de Barros explained. This information could help apprise public health advisories of a chemical spill, for instance, and help municipal water authorities decide whether to temporarily suspend or continue use of water from a certain source, like a well.

"This modeling can help with questions like, Should I invest more money in public health or in characterizing the geological site? Should I shut down the well — which is very costly — or bring in tap water from another location, or buy bottled water, or is there reasonable knowledge that the water can still be used, once treated?" de Barros said.

> "If you can understand what happens with each different scenario, you can better predict outcomes in real time."

WATER TO WELL

Consider the Central Coast of California, where one of the largest aquifer systems lines a 2,000-mile valley. Sand and gravel beds contribute to different characteristics of the underground and surface terrain, affecting how groundwater moves.

Now imagine that bisphenol A, or BPA, an industrial chemical, has leaked into the groundwater supply. What happens? Below are several scenarios based on the models developed by de Barros and his team.

Scenario 1 A HETEROGENEOUS AQUIFER, WHEREIN THE UNDERGROUND ENVIRONMENT IS RELATIVELY VARIABLE AND INCONSISTENT.

Because the aquifer is made up of so many different types of geological materials, BPA will disperse. By the time the contaminated water makes it to the next city over, the BPA concentration will be much lower because it has been split into so many subsequent streams or flows. While this is good news for potability, it also means that some level of BPA might remain because its residence time in the subsurface environment will be longer and thus show up for a longer period, albeit in lower concentrations.

Scenario 2 A HOMOGENOUS AQUIFER, WHEREIN THE BELOW-GROUND TERRAIN IS CONSISTENT AND UNIFORM, E.G., SMOOTH SOIL.

The BPA will likely remain at a high concentration even when it reaches the city well, introducing a harmful level of the chemical into the water supply for the general population. However, the BPA levels will also fall faster, meaning they are less likely to linger for a long period at an environmentally sensitive location. In this scenario, groundwater supply would probably be suspended from this source for a while to ensure its safety.

Scenario 3 AN OPEN GRAVELED AQUIFER, WHICH ALLOWS WATER TO PASS THROUGH EASILY.

Water passing through gravel will reach the city well quickly, meaning that public officials will need to react quickly after the BPA contamination is reported. At the same time, it should move through quickly dissipating at an equally quick pace, as uncontaminated water flows through the aquifer to replace it.

Scenario 4 A LOW PERMEABLE GEOLOGICAL MATERIAL THAT HAS NO CRACKS OR BREAKS, WHICH MAKES IT MORE DIFFICULT FOR WATER TO FLOW THROUGH IT.

If a BPA contamination is reported in this case, it might take a while to show up at the city well, giving public officials more time to respond. However, it also means that once the water is contaminated in the well, the water source could remain contaminated for a longer period as the slow water flow means that it will take a longer time to flush the BPA from the system.

PHOTO: *UNSPLASH*/JOSH KAHEN

Diving Below the Surface of Cells TO FIGHT DISEASES

NO PATHOGENS ALLOWED: WADE ZENO EXPLORES HOW CELL MEMBRANES MAY HOLD THE KEY TO TREATING SOME OF OUR MOST CHALLENGING DISEASES

By Greta Harrison

WADE ZENO tried to banish any thoughts from his mind.

It wasn't easy with nearly 700 pounds on his shoulders. It was the United States Powerlifting Association Big Tex Open in 2019. The gym was buzzing. Metal guitars blasted from the speakers. If he finished the squat, he would win his class and reach a new personal best. An audience member screamed out, "C'mon, Wade, you got this!"

As he gripped the iron bar, his mind flashed to his research in cellular biophysics. "Are my cells generating enough ATP right now? Is there enough glycogen in my muscle cells to get through this lift?" Zeno was likely the only person in the gym thinking about nutrient transfer and cellular respiration in that moment.

With a roar, he dropped into the squat and heaved the giant weight back up. The crowd erupted.

As a child with a natural curiosity for the world, Zeno was fascinated with how humans work. His mother was a nurse, and he used to snoop through her textbooks, eager to learn more.

Now, as an assistant professor in the Mork Family Department of Chemical Engineering and Materials Science at USC Viterbi, it's no surprise that Zeno is at the cutting edge of biology and engineering, looking closely at the proteins and membranes of human cells to understand how they function and how to create better treatments for debilitating diseases such as Parkinson's and cancer.

A cell's plasma membrane, like the gates of a castle, is designed to keep out dangerous things — think disease-carrying bacteria rather than medieval armies. It also allows safe passage to helpful things like nutrients inside the cell.

"It selectively lets things in and out of the cell," explained Zeno. "The molecules there are mostly composed of proteins and lipids, and their interactions form this interface. Many of the most critical processes that occur in a cell, occur right here."

Zeno, who joined USC Viterbi in the fall of 2020, was recently awarded the USC Provost's Assistant Professor Fellowship. His research has a particular focus on how the curvature of these membranes affects protein-lipid interactions. This curvature is important in allowing the movement of molecules into and throughout the cell.

"Pieces of the membrane get trafficked around the cell for various processes. When there's a defect in that process and it's not functioning properly, this leads to diseases like cystic fibrosis, diabetes, Parkinson's and certain types of cancers," Zeno said. "Membrane trafficking is also one of the routes through which pathogens can get in and hijack your cells."

But membrane trafficking can also be used for good. It's the process used to deliver treatments directly to our cells. "For example, the COVID vaccines use the membrane trafficking route to get the vaccine particles into your cells," Zeno said.

Zeno's latest project is a collaboration with Seoul-based biotech company Biographene on nanoparticles that can interact with proteins and lipids on cell membranes to treat Parkinson's disease.

As Zeno's interest in human biology grew, so did an interest in understanding and pushing the limits of human physical achievement. He fell into the sport of powerlifting during graduate school and has competed in various competitions around the country. His personal-best lifts could see Zeno carrying the equivalent of a large tiger, with a bench press record of 500 pounds, and squat and deadlift bests of 680 pounds.

"During grad school, I noticed that I was just better at lifting weights than I was at running on the treadmill," Zeno said. "I was squatting one day and someone said, 'You're pretty strong. Ever consider doing a powerlifting competition?'" I didn't know what that was, and so I looked it up and thought I could do that for fun."

While the pandemic has put his competition career on hold, Zeno recently ventured back into his COVID-safe gym.

"I've definitely been out of practice over the last year, but it's all coming back. It's all muscle memory," Zeno said.

An emerging leader in the field of cell membrane behavior, Wade Zeno has competed as a powerlifter in competitions around the U.S.

PHOTO: HELEN PEREZ

INFINITE VERSIONS OF US

THE ROADS NOT TAKEN

WE SEE ALTERNATE VERSIONS OF STUDENTS, ALUMNI AND FACULTY IF THEY MADE DIFFERENT CHOICES

CHRIS CANTWELL

By Benjamin Paul

Known World:
QUANTUM GAMES

As a USC Viterbi graduate student, Chris Cantwell, B.S. EE '06, loved playing games on his phone in between classes. One day, he ran into USC Viterbi Professor Berok Khoshnevis, who encouraged him to sign up for his course on invention and creativity in engineering. What started as a fun project for a graduate course credit eventually evolved into the game that is known today as Quantum Chess. Cantwell's game has grown into a full-blown phenomenon, including the 2016 short film "Anyone Can Quantum," starring Keanu Reeves, Paul Rudd and Stephen Hawking.

Now, as CEO and founder of his own game company, Quantum Realm Games, Cantwell has been collaborating with Google on developing the game further. In fact, the two sides recently agreed to a two-year extension to run Quantum Chess on Google's quantum computing hardware.

The beauty of Quantum Chess is how effortlessly it familiarizes people with the concepts of quantum mechanics. In the online game, players can make "quantum moves" where a queen, for example, might be in two different positions simultaneously.

Alternate World:
SPACE FLIGHT FOR THE PEOPLE

But what if Chris Cantwell had never encountered Professor Khoshnevis in an empty classroom that day?

Upon completing his USC Viterbi dissertation, "Assorted Topics in Quantum Computing," Cantwell refocuses on another passion: space exploration. Of course, in this world, he still lives in Southern California — that was a job requirement! With his Ph.D. in hand, Cantwell lands a job working for SpaceX, just down theroad from USC.

As one of the company's star software engineers, Cantwell writes a game-changing code that helps SpaceX develop the first rocket to bring humans to Mars. Cantwell's work on flight control software is key to bringing about the next generation of space travel, eventually allowing people to travel through space in the same way we once boarded transcontinental flights.

In 2030, this Chris Cantwell boards a flight with his wife and two children on one of the first commercial space flights to Jupiter's moon Europa. Coasting above the distant moon's icy surface, Cantwell realizes a lifelong dream and is one of the first to see the recently discovered life flourishing in Europa's ocean below.

ILLUSTRATION: ANTONIO CAPARO

TIM ELLIS

By Avni Shah

Known World:
BUILDING A MULTIPLANETARY EXISTENCE WITH 3-D PRINTED ROCKETS

As a teen, Tim Ellis, B.S. '12, M.S. '13, spent countless hours in Plano, Texas, making short films with his friends. When it came time for college, he chose USC for its proximity to Hollywood and its strong screenwriting program.

But a trip to the Mojave Desert with the USC Rocket Propulsion Laboratory in 2008 changed everything. A rocket engine fired, as did Ellis's imagination for the future of human space exploration. He switched majors to aerospace engineering and worked long hours at RPL to help put a student-built rocket into space.

The USC Rocket Lab is also where Ellis met Jordan Noone, with whom he started Relativity Space in 2015. Their goal: to create the world's largest metal 3-D printer for rockets that could be launched into space. With a vision for a multiplanetary human existence, Relativity Space plans to launch its first 3-D printed rocket, Terran 1, later this year.

In November 2020, the company closed $500 million in funding, an effort buoyed by Ellis's penchant for storytelling to attract investors and space enthusiasts. Indeed, his cold email to billionaire entrepreneur Mark Cuban came with a subject line right out of a Hollywood pitch: "Space is sexy: 3-D printing an entire rocket." Five minutes later, Cuban responded. He then provided the company's initial $500,000 in funding.

Alternate World:
EXPLORING WHAT IT MEANS TO BE HUMAN, WONDER BY WONDER

But what if Tim Ellis had used his storytelling skills to make thought-provoking movies like Darren Aronofsky, the director of *Requiem for a Dream* and *The Fountain*?

In this world, as a student at the USC School of Cinematic Arts, Ellis works on his debut film, a screenplay about a religious man who seeks to prove, concretely, that there is indeed a God. "The character goes into a Starbucks for a highly televised event and drinks hemlock. His soul floats through purgatory and down to hell, where it has a fight with the actual devil," Ellis said.

Following graduation, his screenplay is greenlit with an indie budget of $20 million. The movie debuts at the Tribeca Film Festival, where it wins critical acclaim, and Ellis is written up by Vanity Fair as one of five new writers to watch. His follow-up film, his first big-budget feature, is a love story between two people who have been repopulated to Mars.

Married to his college sweetheart, an artist, he remains inspired by the intersection of art and science and their grand impacts on humanity. "We've always thought if you made a Venn diagram of science and art, the middle section would be wonder," he said. Indeed, his production company would be named Wonder Productions, exploring what it means to be human.

ILLUSTRATION: YIHYOUNG LI

WILLIAM WANG

By Adam Smith

Known World:
THE ENTREPRENEUR

William Wang, B.S. EE '86, is the billionaire founder and CEO of Vizio, one of the most recognizable TV brands in the world. Last March saw the culmination of nearly 20 years with Vizio, as Wang took the company public on the New York Stock Exchange.

But the path was not always smooth. With poor grades at USC, Wang took a job in customer service for a maker of computer monitors, dreaming about the future of TV.

Later, he launched multiple companies, which, although initially successful, ended up losing around $45 million. Wang had just visited his creditors his Taiwan, in fact, to break some bad news in October 2000 when he experienced one of the great "what if" moments of his life: With a typhoon brewing off the coast, the Singapore Airlines pilot turned right instead of left on the rain-soaked runway. Halfway in the air, the 747 hit some construction equipment at 180 miles per hour, detonating 60,000 of jet fuel and killing half the passengers.

Wang survived, and all the mind-swallowing siege of his failed businesses vanished. Within two years, he had moved on to Vizio, backed by those very same creditors and aided, in part, by the $900,000 payout to survivors from the airline.

The young man, who had learned English from TV shows like *Charlie's Angels*, was now making affordable HDTVs on a grand scale.

Alternate World:
THE ARCHITECT

Wang's childhood dream was to be an architect like I.M. Pei, another Chinese American who created buildings like the iconic Louvre Pyramid in Paris: "It's simple and modern, yet timeless....I admired how someone would think about something and then make it into reality for many others to enjoy."

Even in our reality, where Wang chose electrical engineering over architecture, citing the higher pay and approval of his parents, he can't escape architecture. "I helped build a house for my parents, which was a great joy, and have built others, like in San Francisco or the one I am working on in Newport Beach," he said. "I am having a lot of fun because it allows me to pursue my passion that gives me happiness and allows me to express my creativity."

What if Wang had followed the path of his hero, Pei? What if his parents had encouraged him instead to become an architect? And what if the Singapore Airlines flight had never happened and the crushing debts had caused him to reevaluate his life's trajectory?

Said Wang, "I think it would be fascinating to architect hotels, airports and other major structures that people from everywhere could experience. I would likely still infuse my love of new technology and innovation into the buildings I create. I'd probably still be living in Orange County, where the weather and amenities are great."

ILLUSTRATION: YIHYOUNG LI

DARIN GRAY

By Marc Ballon

Known World:
THE K-12 EDUCATOR

When Darin Gray was asked if he'd be interested in leaving his comfortable job as an engineer at Hughes Aircraft to become a full-time math teacher to at-risk youth, he resisted the call. His supervisor told him it would be a terrible mistake.

But Gray saw a lot of really smart kids who had never had a good math teacher. Having grown up among troubled teens himself in Detroit, Gray felt they deserved an opportunity.

He quit his job as an engineer in 1990 — his dream since he was 16 years old — and dedicated the next 31 years to serving students as a teacher, administrator and now as co-director of USC Viterbi's K-12 STEM Center.

As a teacher at the Metropolitan Skills Center, an alternative school in Los Angeles, Gray focused on connecting math to his students' interests — for instance, discussing a song's beats per minute with an aspiring rapper — making him the school's most popular teacher. So talented was Gray — who graduated from USC in 1988 with a triple major in mathematics and biomedical and electrical engineering — that he soon taught every subject except fine arts. Under his direction, graduation at MSC rates tripled, along with the number of students going on to college.

Named the Orange County Engineering Council's 2020 James E. Ballinger Engineer of the Year, Gray has brought that same can-do spirit to USC Viterbi, placing hundreds of Trojan engineering students in area schools as volunteer teachers and training scores of local STEM elementary school instructors.

"The impact I make in the community resonates with me," said Gray, who continues to teach STEM summer school courses. "Teaching is my calling."

Alternate World:
THE AEROSPACE ENGINEER

As a young engineer at Hughes Aircraft in El Segundo, California, in the late 1980s, Darin Gray had it all. The USC Viterbi alumnus earned $35,000 a year ($80,000 year in today's dollars), nearly 50% more than his social worker-mother. He had distinguished himself as a rising star and loved the challenge of solving big, complex problems as an engineer.

In his first two years on the job, Gray worked on a chip that ended up on the radar system of a fighter plane, and created a software program that increased the efficiency and shortened the completion times of his team's circuit design projects. The recipient of several raises, Gray seemed destined for greatness.

"I got called to the carpet by some of my colleagues for making them look bad by working too fast," he said with a laugh.

In 1990, though, Gray left engineering behind and took a full-time job as a teacher at an alternative high school in Los Angeles. But what if he hadn't? Gray believes he would have made a mark in engineering, just as he has as an educator over the past three decades.

Given his career trajectory, Gray would have probably become a senior engineer at Raytheon, which subsequently acquired his unit. He believes he would have continued to volunteer teach and, as a side gig, become a real estate broker with lots of people working for him.

"I would probably be living in Baldwin Hills instead of Whittier and driving a Lincoln instead of a Toyota," he said.

"However, I really love where I am now, the people in my life, the folks I work with, my family, my friends, you know, the people I've built relationships with over the past few decades." Gray added. "I wouldn't trade that at all."

Listen to Darin Gray's story:
Escape Velocity – ***Season 2, Episode 5: "Nobody Wants to Kill the Unicorn."***
magazine.viterbi.usc.edu

ILLUSTRATION: GORDON ROWE

CATHERINE RICAFORT McCREARY

By Greta Harrison

Known World:
FROM THE LIGHTS OF BROADWAY TO A STARTUP STAR

Catherine Ricafort McCreary, B.S. ISE '09, has been a successful Broadway actor for over 10 years. She has booked some of the biggest shows in town, from ***Mamma Mia!*** and ***Honeymoon in Vegas*** to ***SpongeBob SquarePants***, working with the likes of George Takei and Tony Danza.

But frustration with roles that poorly represented the Asian-American experience led her to pivot back to technology in 2015 and again in 2020. She now works as a software engineer at fashion startup Stitch Fix — a job that gave her the stability to buy a home, with flexibility to return to theater if great roles emerged. But the pandemic had other ideas. Right now, she's helping other artists whose careers were paused by the pandemic find job stability as coders, through Artists Who Code, the nonprofit she founded with her husband. They have helped hundreds of people secure their first tech jobs.

Alternate World:
TAKING THE LEAD

What would Catherine Ricafort McCreary's life be like had she landed her dream role, and had the pandemic that devastated Broadway never happened? After moving from ensemble to supporting roles, Ricafort McCreary's main bucket-list item would have been to play a principal role, with more input in originating characters.

"The next thing I wanted," she said, "was to play a character that carries the whole show — from the 'I want' song in the beginning, and conflict in the middle, falling in love, and then the fallout from that and then the resolution at the end."

Also in the cards for Ricafort McCreary would be a creative collaboration with her brother, rapper JD "Super Smack" Ricafort, whose music video, "Choose," she directed and choreographed in 2019.

"There are so many other multiverses down my path," she said. "I would love to help the corporate world reexamine the hiring process, which can close off opportunities for creative people who don't fit the mold."

ILLUSTRATION: LAURA CATRINELLA

NIEMA PAHLEVAN

By Avni Shah

Known World: THE MECHANICAL ENGINEER SAVING HEARTS

Growing up in Iran, Niema Pahlevan was inspired to become a biomedical engineer at the age of 10, when his father's cousin had a heart attack. "My dad and I went to the hospital to visit him," Pahlevan said, "and I got to know about the idea of an artificial heart."

At Caltech, where he earned his doctoral degree in bioengineering and received his postdoctoral training in medical engineering, Pahlevan developed a smartphone-based heart monitoring device to help detect heart failure early on and to measure heart ejection fraction (a measure of heart pumping ability).

Now a USC Viterbi assistant professor of aerospace and mechanical engineering, he is working on expanding the smartphone-based method to diagnose "silent" heart attacks that often go unnoticed.

The technology works by measuring skin vibrations produced by shifts in the dynamics of blood flow. These vibrations can be measured externally, for instance, on the surface of your neck, along the carotid artery, said Pahlevan, who is also assistant professor of medicine in the Division of Cardiovascular Medicine at the Keck School of Medicine of USC.

"A diagnosis and monitoring tool that helps determine if individuals are experiencing a heart event — or if they're on the brink of one — could save lives," he said.

Alternate World: A PROFESSIONAL SOCCER PLAYER TURNED TEACHER

However, even in the known world, Pahlevan had another great and abiding passion: soccer.

At the University of Tehran, he tried out and played for the school's incredibly competitive soccer team. "We had one of the most invincible teams in Iran school history," he said. "We were champions for 13 consecutive years."

Inspired by "Doctor Socrates," who played for the Brazilian national team and had a medical degree, Pahlevan's playing career was cut short with a knee injury his sophomore year, when he was tackled by two defenders during a semifinal game. He had to sit out the final — which ended as the team's first loss in a very long time.

That's how the story ended in our world. But imagine, in an alternate Earth, if Pahlevan had unexpectedly come back faster and stronger, and in his last two years at school, he brought home two more championships. Then, as a part of a university-level national team, Pahlevan competed in Spain against teams from all over the world. A scouting coach there noticed his talent and after graduating, he joined Club Deportivo Tenerife, a second division club team in Spain.

For the next decade, he played for various clubs in Spain and France, and even wore the white and red Iranian national uniform at the 2006 World Cup. Upon retirement, he returned to his love of fundamentals, coaching youth leagues and molding the next generation of greats. "I love teaching kids 10 to 16 years old," he said. "They are really engaged and you can mold them."

ILLUSTRATION: MICHAEL ROGERS

NAJMEDIN MESHKATI

By Daniel Druhora

Known World: THE ACCIDENTAL PROFESSOR

Before the Iranian Revolution, Najmedin Meshkati was shuttling between two worlds. By day, he was an engineering student at Arya-Mehr (Sharif) University of Technology. By night, he concentrated on his other passion — international relations and political science — at the National University of Iran. There he enrolled in a course taught by Iran's legendary diplomat and part-time professor, the late Ahmad Mirfendereski, who was Iran's last foreign minister under the Shah. Mirfendereski suggested Meshkati could pursue both interests to become an engineer-diplomat.

But in 1976, Meshkati's father urged him to leave for the U.S., to study engineering at USC. For the past 35 years, Meshkati has taught and conducted research on ergonomics, safety culture and risk reduction of complex, large-scale technological systems. As a global expert on human factors and safety culture, he investigated the catastrophic events at the Fukushima Daiichi Nuclear Power Plant and the Deepwater Horizon oil spill, and served as a senior science and engineering advisor to the U.S. Secretary of State.

Today, Meshakti, who describes himself as an "accidental professor," regularly appears on news networks as an expert on disaster prevention, achieving the dream seeded by his mentor.

Alternate World: THE DIPLOMAT

But what if Najmedin Meshkati hadn't listened to his father, and what if the Iranian Revolution didn't happen in 1979, and he stayed in Iran to take up Merfendereski's mantle?

Meshkati is propelled into the international diplomatic scene. Rising through the ranks, he becomes ambassador to Russia and later Iran's foreign minister. He is given the enormous task of building diplomatic relations between Iran and the world's superpowers.

He shuttles between Washington, Moscow, Brussels and Tehran, navigating some of the most tenuous periods in Iran's foreign policy history.

As the country's senior global strategist, Meshkati brings his engineering mindset to the negotiating table to craft the Iran nuclear deal. He ushers an era of scientific collaboration with neighboring countries who share the same irreplaceable body of water. Training a new generation of engineer-diplomats, he designs policies that make the region safer and more sustainable.

ILLUSTRATION: ANTONIO CAPARO

MAJA MATARIĆ

By Caitlin Dawson

Known World: THE ROBOTICS PIONEER

When she was growing up in Serbia, Maja Matarić's uncle suggested she study computer science because it was "the profession of the future." Today, Matarić is one of the world's top robotics experts and a pioneer in the field of socially assistive robotics, with more than 665 publications and 41,830 citations to her name.

A Chan Soon-Shiong Distinguished Professor of Computer Science, Neuroscience and Pediatrics at USC and co-director of the USC Robotics Research Lab, Matarić's research focuses on developing robots that provide therapies and care through social interaction, especially for people with special needs. Her USC Interaction Lab has worked with children with autism, stroke patients, people with Alzheimer's and many others. Recently, her research group deployed in-home socially assistive robot tutors for children with autism spectrum disorder in living in Los Angeles' inner-city neighborhoods.

Matarić is passionate about mentoring and empowering others, including K-12 students and teachers, women and other underrepresented groups in engineering. In 2011, she received the Presidential Mentoring Award from President Obama for helping to prepare the next generation of scientists and engineers.

Alternate World: THE ARTIST

But what if Maja Matarić had ignored her uncle's advice? What if she had pursued her childhood dream of becoming an artist like the abstract painters from her native Serbia?

In this world, she immigrates to the United States, receives a prestigious scholarship to the New School in New York, and becomes a pioneer in the field of "empowerment art." Inspired by the Guerrilla Girls, a collective devoted to fighting sexism and racism in art, her work is quickly noticed for its uncompromising take on social and political issues, including gender and racial equality, education and disability rights.

Her deeply layered work would draw on her interest in cognitive science and human behavior to create sprawling, immersive, multimedia digital art exhibitions that stir human emotion and inspire action. She owns a studio that specializes in exhibiting new artists from underrepresented groups and offers art therapy classes to children with special needs.

ILLUSTRATION: GORDON ROWE

We Moved Fast. We Broke Things.

HOW THE USC+AMAZON CENTER FOR SECURE AND TRUSTED MACHINE LEARNING IS RESTORING TRUST IN THE AGE OF AI

By Benjamin Paul

IN 2016, LESS THAN 24 HOURS after coming online, Microsoft's AI-powered Twitter chatbot, "Tay" was taken down for tweeting out a series of less-than-appropriate messages about Hitler and 9/11. Of course, the early-generation bot didn't really think 9/11 was an inside job. It was simply repeating, however clumsily, things real humans had said to it.

While that event was somewhat of a dark comedy, the ways in which artificial intelligence has breached societal trust in the years since are no laughing matter. From leaked personal data to mistreated minority groups to online political echo chambers, AI mistakes have caused significant damage to real people in real ways.

In the past five years, two conflicting facts remain true: AI has grown to play an increasingly important role in how our society functions, yet people have become increasingly distrustful of its ability to do the job right. Indeed, according to a 2018 global survey by IPSOS, only 25% of Americans deemed AI trustworthy, compared to 70% in China and 50% in India.

At the center of this riddle are engineers and their amazing, beautiful, mind-boggling, empowering — and sometimes unempowering — technologies.

The problem has never really been with technology, but rather with us. Humans have a special way of moving too fast. We're the ultimate "early adopter" species. Give us the secret of the atom and we'll make a bomb — immediately. Give us the internet and we'll start trolling each other before you can say "Zuckerberg." But we also have an amazing capacity to adapt. Every time technology has upended society, people have found ways not only to live with it but to thrive with it.

The USC + Amazon Center for Secure and Trusted Machine Learning was established at USC Viterbi in January with exactly this challenge in mind. The center will support a new era of research that is focused on building societal trust in AI and machine learning.

Earlier this summer, the first cohort of USC Viterbi researchers whose work will be supported by the center was announced. Salman Avestimehr, the center's director, said interest among researchers to work on this project was higher than expected.

"We had a very enthusiastic response by USC faculty for the first call for proposals for the USC + Amazon center," said Avestimehr, who is also a Dean's Professor of Electrical and Computer Engineering, and an Amazon Scholar. "We received innovative ideas from our faculty proposing exciting research into various aspects of trustworthy machine learning. The response was so overwhelming that we decided to fund one more project than our original intention, and at the end, we selected the five research projects to be funded for the first year of the center."

The five projects selected are presented on the following pages.

Protecting Patient Data

IMAGINE a federation of hospitals working to understand how a particular disease is spreading and mutating. (Maybe that's not so hard to imagine.) Each hospital has a vast and detailed database of patient information that, when combined, could lead to critical insight. However, for privacy and security reasons, none of the hospitals can share that data with each other. But what if there were a way for these hospitals to use all the data without actually sharing it?

USC's José Luis Ambite, research associate professor of computer science; Muhammad Naveed, assistant professor of computer science; and Paul Thompson, professor of ophthalmology, neurology, psychiatry and the behavioral sciences, are working on ways for multiple large organizations to solve problems that require a lot of data without having them actually share that data.

"Our approach will make it easier for organizations to come together to allow learning over larger datasets by ensuring that local data remains private," said Ambite. "So organizations have an incentive to allow learning over their local data. They can get a better-performing predictor without actually disclosing their private data."

Taking Human Bias Out of AI

IMAGINE a company that, in an attempt to hire a more robust and talented workforce, designs a tool to identify candidates that ends up doing the opposite. Again, perhaps that's not so hard to imagine: Amazon itself struggled with this in 2015 when an algorithm it designed for that purpose unintentionally favored men over women. We know that AI often makes predictions that unfairly target minorities or make lower-accuracy decisions for protected groups.

Keith Burghardt, a computer scientist at USC Viterbi's Information Sciences Institute, plans to update machine learning programs to more fairly benefit everyone. Today, people rely heavily on "decentralized machine learning," that is, many small tools, like smartphones, used together to run machine learning programs more securely and at less expense. But this emphasis on cost and security has come with a big price — equity. These small, disparate devices do not have the built-in tools to address biases.

"We propose complementary methods that help address these issues. First, we will develop a general model that is specialized to particular demographics. Second, we will apply new techniques to reduce biases in the data itself, which can be applied to a large set of commercially available tools," Burghardt said.

AI That Listens Less

IMAGINE asking your virtual assistant to set a reminder to go to the gym at noon. But in addition to setting the reminder, your virtual assistant analyzes your voice to glean all kinds of other information about you: your gender, your geographic location, even your physical or mental state! Suddenly, you're getting ads for everything from homes for sale in your neighborhood to therapy services.

This is called human bio-behavior sensing, and it's a new and at times scary aspect of AI.

Shri Narayanan, University Professor and Niki and C. L. Max Nikias Chair in Engineering, is a leader in signal and image processing who for years has put human-centered approaches to engineering at the forefront of his work. Making sure technology collects the intended information from you — and nothing more — is a huge part of that goal.

Narayanan aims to develop a system that more accurately, sensitively and securely collects bio-behavior data. Of course, collecting the right data is vital — large sets of it are hugely important to modern medicine, for example. But systems could conceivably collect that relevant data while cataloguing so much more about you for future use, all from just your voice.

This project aims to develop methods that can reliably collect the right data from the subject while keeping more private information out of the hands of the companies behind the technology. "Our proposed framework is cognizant of the diversity and subjectivity inherent in the generation and processing of human of bio-behavior data," said Narayanan.

AI That Listens More

IMAGINE you are visiting a doctor for the first time. He or she asks you several questions about your medical history and takes detailed notes. But what if most of the information in those notes wasn't going to good use? What if it was as much as 80%?

When doctors enter their notes into your records, natural language processing (NLP) tools help aggregate the data and make analyses about patient health. But those tools aren't very good at understanding the unstructured data in those notes. Formal information clearly written in a specific place about the date of your last physical?

Easy. The doctor's additional comments, written in his or her own shorthand, about who you share a home with and what support you have in life? Not very easy at all.

Xiang Ren, assistant professor of computer science, is working on ways to automate the processing of this subtler type of data in order to derive deeper insights about patient health on a much larger scale. "By teaching NLPs to 'read between the lines' of someone's medical record, we can provide an extremely useful tool to doctors and hospitals that will help them better understand their patients' needs," he said.

The language that doctors use in their notes can be very different based on their gender, culture or nationality. A poorly designed NLP tool could unintentionally recommend treating one group of people with more care than another simply based on how it interprets the doctor's language. "Because data distribution is often unbalanced with respect to different groups, we end up with biased models that favor certain groups when it comes to things like résumé screening or fraud detection. We hope to remove this major flaw from our current systems," Ren said.

Holding AI Accountable

YOU'VE ALREADY been asked to consider several very real scenarios in which an AI system was unintentionally biased. But how were those biases discovered in the first place? After all, we can't make our systems less biased or more trustworthy if we can't identify where and why they are making mistakes.

Aleksandra Korolova, assistant professor of computer science, is working on better ways to do just that. She audits existing AI systems in a "black box" manner, that is, from the perspective of an outsider. Without being given access to the inner workings of a system, Korolova finds ways to learn about the algorithms used in the models and the data being collected. "It is this auditing of a system — as a total outsider — that allows us to identify mistakes in the design," she explained. "By using this approach, we can better understand the unexpected or undesirable consequences of a complex AI system and find challenges that the company itself did not have the ability or desire to test for."

Once Korolova's audit is complete, she can suggest alternatives to the companies to adjust their algorithms, or recommend to policy makers what to look for or require from designers of AI systems to ensure their accountability. By doing so, Korolova can do more than help make the engineering behind AI more trustworthy and help educate influential decision-makers on how to think about AI in a more holistic and society-focused way.

A New Kind of Trust

INDIVIDUALLY, all of these projects seem like good ideas — and they are. But, as Avestimehr explained, "these projects represent some of the first building blocks of what can be thought of as 'computational trust.' In the same way that institutions of the past needed to earn society's trust before they could reach their full potential, we must now do the same with the tools that are forming the foundations of the future world."

Indeed, the federal government has even gotten involved. The National Institute of Standards and Technology, or NIST, best known for measuring things like time or the number of photons that pass through a chicken, now seeks to measure our trust in artificial intelligence.

NIST, part of the U.S. Department of Commerce, wants to put an actual number to that perceived trust, based on characteristics like accuracy and explainability. Its March 2021 paper suggested, for example, that an AI system used by doctors to diagnose disease should be more accurate than one recommending music.

The era of computational trust cannot come fast enough. "Already, AI is making our lives easier and safer every day," said Burghardt. "But every time an AI system unintentionally targets a certain group or releases sensitive data, distrust in the system reduces progress and makes future research harder. An AI system people fully trust is the only way we can see it truly serve humanity to its fullest potential."

In an increasingly technological world, Yannis C. Yortsos, dean of the USC Viterbi School of Engineering, understands that gaining computational trust is an imperative. "As the interface between technology, society and humanity becomes increasingly intertwined, trust has emerged as a truly fundamental issue," he said. "Trustworthiness must address not just the technology side, but the human side as well. Engineers, perhaps most of all, must have an understanding of intended and unintended consequences and the character, dedication and ingenuity to address them. These themes of trust and human-centered engineering have become extraordinarily relevant to all our engineering education and research."

With the new USC + Amazon Center in place, USC Viterbi has taken that call to heart.

COSMIC POSTCARDS

Scott Willoughby

M.S.'91, VICE PRESIDENT AND PROGRAM MANAGER, NORTHROP GRUMMAN

By Adam Smith
Art by Saharat Tantivaranyoo

*NEW JERSEY, 1977

I CAN STILL SEE MY GRANDFATHER, "POPS," STANDING THERE BEHIND THE L-SHAPED COUNTER, WITH HIS COLLARED SHIRT AND WORK SLACKS.

MUCH OF MY CHILDHOOD WAS AT A BAR.

MY BROTHER AND I WOULD GO TO THE RAVEN'S LOUNGE EVERY DAY AFTER SCHOOL.

THERE'D BE A HAMBURGER AND GINGER ALE WAITING FOR US, AND THE YANKEES GAME ON TV.

I WATCHED POPS.

MAN, HE COULD TALK TO ANYBODY. THE LAWYERS, THE ACCOUNTANTS, THE GUYS FROM THE LOCAL RACETRACK.

POPS LIVED TO SEE ME GO TO COLLEGE AND EVEN GET MY MASTER'S AT USC IN 1991.

BUT HE NEVER SAW HIS GRANDSON BECOME THE VICE PRESIDENT AND PROGRAM MANAGER OF THE JAMES WEBB SPACE TELESCOPE PROGRAM AT NORTHROP GRUMMAN.

TODAY, I OVERSEE THOUSANDS OF ENGINEERS, SCIENTISTS, AND CONTRACTORS ON NASA'S MOST AMBITIOUS SCIENCE PROGRAM.

MY ABILITY TO SPEAK WITH SENATORS, SCHOOL CHILDREN, OR SCIENTISTS, I LEARNED THAT FROM POPS.

THIS FALL, I'LL BE IN THE CONTROL ROOM IN FRENCH GUIANA AS WEBB RIDES A EUROPEAN ROCKET TO LAGRANGE POINT 2 ...ONE MILLION MILES AWAY.

I WASN'T THAT KID WHO LOVED SPACE. BUT I ALWAYS LOVED CHEMISTRY.

IN THE BEGINNING, THE PERIODIC TABLE WAS SIMPLE.

THERE WERE ONLY HYDROGEN AND HELIUM.

THEN THEY SMASHED TOGETHER AND CREATED THE FIRST STARS.

I CAN'T SEE THAT MOMENT. IT WAS 13.7 BILLION YEARS AGO

BUT VERY SOON, WE CAN...

...THROUGH THE INFRARED EYES OF THE WEBB SPACE TELESCOPE

WHERE DID I COME FROM?
EAST RUTHERFORD, NEW JERSEY.

BUT THE ATOMS IN MY BODY, THEY'RE INTERSTELLAR.

THEY'RE ON LOAN FROM THE NUCLEAR FURNACES
AT THE HEART OF THOSE STARS. OR THE SUPERNOVAS
THAT BECAME THEIR TOMBSTONES.

FOR THE FIRST TIME, WE'LL BE ABLE TO
SEE THE ATMOSPHERE OF OTHER
FARAWAY WORLDS. THE CHEMICAL SIGNATURES OF LIFE.

THE WEBB WILL LET US SEE
THOUSANDS OF EXOPLANETS, OTHER EARTH-
LIKE PLANETS LIKE TRAPPIST 1-E...
39.46 LIGHT YEARS AWAY.

I LIKE TO JOKE THAT IN ORDER TO
DETERMINE IF THERE IS INTELLIGENT LIFE,
WE'LL NEED TO SEE A REPLICA OF
YANKEE STADIUM!

OR DISCOVER SOME NEW TRUTH ABOUT THE NATURE OF REALITY...
JUST LIKE THE HUBBLE TELECOPE WHISPERED TO US THE MYSTERIES OF
DARK MATTER AND DARK ENERGY.

AT HOME, I HAVE THE FAMOUS EARTHRISE PHOTOGRAPH...

ONE OF THE MOST ICONIC IMAGES OF THE 20TH CENTURY, SIGNED BY ONE OF THE APOLLO 8 ASTRONAUTS.

THEY SET OUT TO FIND THE MOON AND DISCOVERED THE EARTH INSTEAD.

I'D LIKE TO PUT THE FIRST "COSMIC POSTCARD" FROM WEBB RIGHT NEXT TO IT.

SCIENTISTS SAY THAT AN ALIEN 65 MILLION LIGHT YEARS AWAY WITH A POWERFUL TELESCOPE MIGHT SEE EARTH AS IT WAS...

AND MAYBE,

JUST MAYBE,

SOMEONE NEAR A STAR LIKE CAPELLA (43 LIGHT YEARS AWAY)

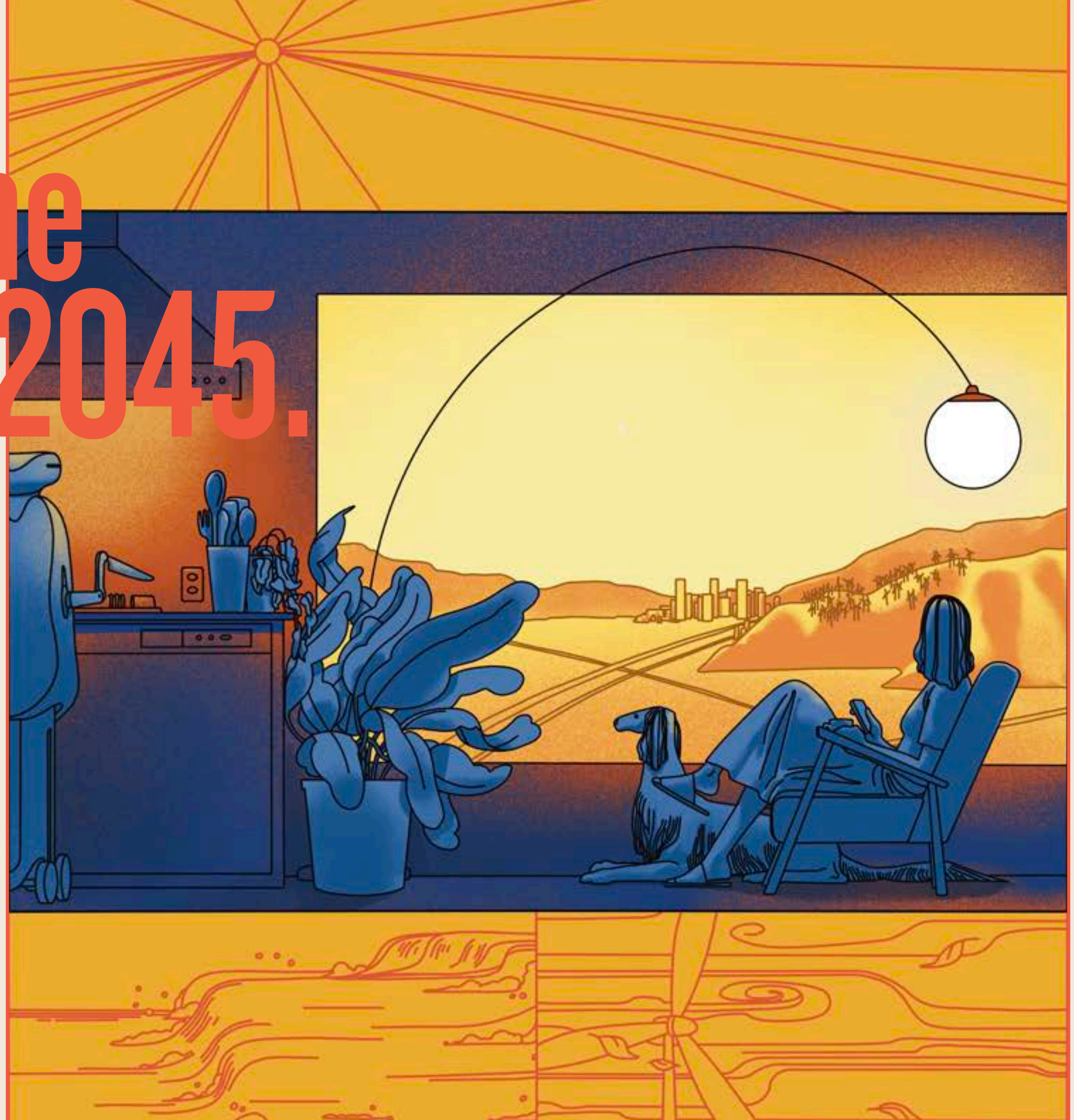
MIGHT SEE A GUY IN HIS COLLARED SHIRT AND WORK SLACKS WAITING OUTSIDE THE RAVEN'S LOUNGE, WELCOMING HIS GRANDKIDS HOME.

SURE LOVE TO GET THAT POSTCARD.

It's the Year 2045.

Los Angeles is Entirely Fossil Fuel Free.

How Did This Happen?



USC RESEARCHERS HELPED CHART A COURSE TO A ZERO-EMISSIONS FUTURE FOR LOS ANGELES WITH THE LA100, ONE OF THE BIGGEST STUDIES OF ITS KIND

By Marc Ballon
Illustration by Avalon Nuovo

THE YEAR IS 2045, and Kelly Sanders has never felt happier, or worked harder.

Sanders, the newly appointed dean of the USC Viterbi School of Engineering, puts in long days balancing her administrative responsibilities with her ambitious research.

On this hot, summer day, Sanders decides to duck out a bit early. She summons her self-driving electric car with an app on her cellphone. Five minutes later, Sanders' Tesla picks her up.

Looking out the window, Sanders marvels at the near ubiquity of self-driving electric cars. Just 25 years ago, toxin-spewing gas guzzlers ruled the roads. No more. About four out of five vehicles now are electric, which has helped improve Los Angeles' air quality. Because of self-driving cars' ability to "talk" to one another to collectively identify the fastest and safest routes, traffic jams have largely become a thing of the past, even though the number of cars and buses has increased since the 2020s.

The Tesla enters the garage of her downtown condominium complex, stopping at a charging station powered by solar and wind energy. Arriving at her penthouse moments later, Sanders receives an alert on her cellphone. Opening an app that connects her appliances to the internet, she sees the following message: "Kelly, solar energy is abundant and cheap right now. You can run your dishwasher and washing machine for half of what it would cost you this evening."

Sanders smiles and remotely turns on the dishwasher, which she leaves full for such occasions. Another notification tells her that the building's solar panels — much smaller, more efficient and aesthetically pleasing than the big, clunky ones that once adorned nearby rooftops — have generated so much energy that some of it has automatically been sold to the power grid. Ka-ching!

Hungry, Sanders texts "Alfred" to prepare dinner. Her robotic assistant goes to the kitchen and begins cutting vegetables and slicing lab-grown chicken that he cooks in an electric wok. All of Sanders' devices, including her water heater, stove, air conditioner, dishwasher, and washer and dryer, are powered by renewable electricity, just like nearly all appliances and buildings in Los Angeles.

Peering out her large bay window, she marvels at the beauty of the San Gabriel Mountains shimmering in the pristine twilight air. Air pollution has diminished in the region, saving lives and billions in health care costs.

Taking a swig of cold water — recycled, of course — Sanders thinks about how far we have come in such a short period of time. With a hint of pride, she also reflects on the role she and other USC professors played more than two decades earlier incontributing to a seminal report that helped move Los Angeles to 100% renewable energy and a brighter, cleaner future.

Toward a Cleaner Tomorrow

LOS ANGELES, filled with emission-producing cars and ports and factories powered by fossil fuels, has long held the dubious distinction as one of America's most polluted cities. The American Lung Association recently gave Los Angeles County and its surrounding areas an F grade for particle and ozone pollution, which can lead to lung, heart and other health problems.

To help combat climate change and improve the air quality of the nation's second-largest city, Los Angeles and the U.S. Department of Energy's National Renewable Energy Lab, or NREL, partnered to produce a path to a zero-emissions future. USC Viterbi and Sol Price School of Public Policy researchers, including Sanders, wrote portions of the report.

The LA100: The Los Angeles 100% Renewable Study, released in March, concludes that the city could be powered completely and reliably by 100% renewable energy by 2045, and perhaps even a decade earlier through an ambitious adoption of solar and wind power, hydropower and improved electrical storage, among other steps. The plan also envisions a surge in the popularity of electric vehicles, the electrification of buildings citywide, and people using energy when it is most plentiful during sunnier and windier hours.

In April, Mayor Eric Garcetti committed to transitioning Los Angeles to a carbon-free power grid by 2035, although it would still include some non-renewables such as nuclear energy, according to Lauren Faber O'Connor, L.A.'s chief sustainability officer. She added that renewables could account for 80% of the grid by 2030.

"The LA100 study shows us that a zero-carbon grid, a renewable energy grid, is achievable, reliable and affordable," O'Connor said.

At present, natural gas and coal generate about 48% of the city's electricity, according to NREL. To move to 100% renewables in the next 24 years or less "is a huge deal," said Sanders, the Dr. Teh Fu Yen Early Career Chair and associate professor of civil and environmental engineering, and the author of the LA100's chapter on water.

"Although some regions might power their grids with high fractions of renewables for short periods of time, there really aren't many that are meeting the majority of their electricity demands with renewables all the time," Sanders said.

"L.A. has already taken the lead by doing the study and committing to achieving a clean energy future. I think this could serve as an inspiration to others," added Paul Denholm, NREL senior energy analyst and chief engineer for LA100 project.

How to Get There

THE MOST comprehensive study of its kind, LA100 offers several different pathways for reaching 100% renewables. To answer questions about each scenario, including the potential environmental and health benefits and economic impacts, NREL and its partners modeled different projections for the Los Angeles Department of Water and Power (LADWP) customer electricity demand, local solar adoption, power system generation, and transmission and distribution networks, among other data.

Additionally, researchers ran millions of simulations of thousands of local buildings to understand how new design elements, equipment or appliances would impact when and how much electricity people use. NREL used sophisticated aerial scans, including LIDAR, and customer adoption models for every rooftop in L.A. to ascertain how much rooftop solar could be installed. The projection: between 22% and 38% of existing single-family homes could go solar by 2045.

In the end, LA100 researchers concluded that the city could indeed reach its 100% renewable goal with limited pain and lots of benefits. That's because solar and wind power, along with lithium ion batteries, have plummeted in price and increased in reliability, a trend that should continue well into the future, Denholm said.

To reach 100% renewables by 2045 would cost an estimated $57 billion to $69 billion. Doing so a decade earlier would cost about $86 billion. "A faster transition to 100% would likely require deployment of technologies at a higher cost, reflecting both technology maturity and commercial availability," according to the report.

However, moving from 90% renewables to 100% remains a big challenge. To meet peak demand just a few times a year, the city must rely on expensive hydrogen-based technologies that are still under development. "We are not there yet," Denholm said.

LA100 Benefits

IF ENACTED, LA100 promises a myriad of benefits, ranging from decreasing greenhouse gases that cause climate change to improving the city's air quality, including in low-income areas with gas-fueled power plants.

"By moving to a zero-carbon clean grid, we will save 150 lives a year from better air quality, and support [thousands] of jobs annually in new investments in the clean energy sector," O'Connor said. "This study shows that by making this transition we can have a tangible, positive impact on our residents."

Under one particularly aggressive LA100 scenario, greenhouse gases produced through power generation could be reduced by 76% to 100% by 2035 compared to today's levels.

Similarly, L.A.'s infamous brown, dirty air could become cleaner, clearer and healthier in the next 25 years, noted George Ban-Weiss, who penned the LA100 chapter on air pollution. Ban-Weiss, the David M. Wilson Early Career Chair and associate professor of civil and environmental engineering at USC Viterbi, said the emissions of fine particulate matter could fall up to 11% by 2045 when compared to 2012. Nitrogen oxides could drop as much as 59% during the same period. Overall, L.A.'s better air could save $1.4 billion in health-related costs in 2045 alone, according to the LA100 report.

"This is certainly moving us in the right direction," Ban-Weiss said. He added that such dramatic pollutant reductions presuppose the widespread use of electric vehicles, the electrification of the Port of Los Angeles and neighboring Port of Long Beach as well as buildings, and the transition of fossil fuel-burning power plants to renewables.

In several LA100 scenarios, Valley Generating Station, located in the low-income, mostly Latino neighborhood of Sun Valley, would transition to clean energy, such as green hydrogen, or shut down and be replaced by a renewable energy facility. For three years, the natural gas-fired power plant leaked methane, which can cause respiratory problems and even convulsions in high enough concentrations, the Los Angeles Times reported. The city would also transition to cleaner renewables or replace its local gas power plants, including Harbor in the Wilmington neighborhood, Scattergood near El Segundo and Haynes in Long Beach.

Equally important, supporters of the city's renewable future argue that the mix of hydropower, solar, wind and other clean energy sources, combined with new technologies, could keep Los Angeles' power on every minute of every day of the year, even during the hottest summer days and coldest winter nights when demand peaks.

"You can have a reliable system with renewables," Denholm said.

The good news: The transition to 100% renewable energy can happen with only minimal impacts on the local economy and jobs, said Adam Rose, a research professor at the USC Price School who co-authored the LA100 chapter about the economy with Dan Wei, a USC Price research associate professor.

"The shift to an all renewable electricity generating capability stimulates both an expansion and contraction of the economy, and they offset each other somewhat," Wei noted. " The L.A. economy is so large, however, that none of the impacts of the LA100 scenarios exceed more than seven-tenths of one percent of the L.A. economic output or employment base."

Five Factoids

48%
THE PERCENTAGE OF NATURAL GAS AND COAL IN LOS ANGELES' POWER GENERATION MIX IN 2019

$1.4B
SAVINGS IN HEALTH-RELATED COSTS IN 2045 BECAUSE OF IMPROVED AIR QUALITY

$57B to $69B
THE AMOUNT IT WOULD COST LOS ANGELES TO REACH 100% RENEWABLES BY 2045

3,800
THE CITY'S ANNUAL JOB LOSSES BETWEEN 2026 AND 2045, MOSTLY IN THE FOSSIL FUEL ELECTRICITY GENERATION SECTOR, ACCORDING TO ONE LA100 SCENARIO

76% to 100%
THE REDUCTION IN GREENHOUSE GASES PRODUCED THROUGH THE CITY'S POWER GENERATION BY 2035, ACCORDING TO ONE LA100 SCENARIO

4,600
THE NUMBER OF NEW JOBS CREATED PER YEAR, LARGELY IN CONSTRUCTION, OPERATION AND MAINTENANCE, ACCORDING TO ANOTHER LA100 PATHWAY

Kelly Sanders Redux

THE YEAR is 2021, and Kelly Sanders is feeling contemplative.

Her mind flashes to March 2020, when the city shut down for several months with the onset of the COVID-19 pandemic. With few cars and trucks on the road, Los Angeles' omnipresent smog lifted, revealing majestic mountain ranges and ocean views. Less than a year later, the dirty brown air returned when the economy reopened.

But not for long, Sanders believes.

With Los Angeles committed to the LA100 goal of powering the city with 100% clean energy, along with the expected widespread adoption of electric vehicles, buildings and ports, Sanders envisions a much cleaner and less congested city in the next 15 to 25 years — a far cry from the "Blade Runner" dystopia that many once imagined.

"Los Angeles is a city that has it all — beautiful snow-capped mountains, gorgeous beaches and interesting architecture. However, it has also been covered in a thick blanket of pollution for decades," Sanders said. "I think people are really going to be amazed in how this transition toward a clean energy future improves our quality of life."

USC & LA100

The following summarizes some of the USC researchers' contributions to LA100:

Water

THE CITY OF LOS ANGELES' Green New Deal aims both to source 70% of the city's water locally and to recycle 100% of its wastewater by 2035. At present, L.A. imports 90% of its water, according to Kelly Sanders, an associate professor of civil and environmental engineering.

Sourcing and treating water locally could increase the amount of electricity LADWP uses on the water system three to five times by 2050. However, the benefits of reaching those water sustainability goals, the increased demand for electricity notwithstanding, far outweigh the costs, she noted.

Creating a local water supply through recycling wastewater and storm water conserves a precious resource. It is also "better from a resilience standpoint," Sanders said. "If a big earthquake came, the city would be less vulnerable to water supply disruptions if water conveyance systems were damaged. It's also more drought-proof."

Moreover, the ability to treat waterwhen solar and wind power are plentiful during sunny and windy days — and store water when it is not — means that energy that might otherwise go to waste is put to good use.

"If we have too much electricity, we treat water," Sanders said. "If we don't have enough, we stop and store it until we need it."

Air Pollution

UNDER THE VARIOUS LA100 scenarios, air quality improvements would cumulatively save billions of dollars in health-related costs, including the prevention of hundreds of pollution-induced deaths and hospital visits.

"This is good," said George Ban-Weiss, an associate professor of civil and environmental engineering. "Pollution in general causes premature death, cancer, Alzheimer's and asthma. It causes a whole host of health issues that are far-reaching."

The big reduction in the emissions in fine particulate matter and nitrogen oxides would come largely from the electrification of the ports, vehicles and buildings. However, tire and brake wear and tear, heavy-duty diesel trucks, airplanes, trains and cooking would still continue to befoul the air.

"What we really need to do is build more sustainable, walkable communities and get vehicles off the road," Ban-Weiss said.

Economy

CRITICS OF renewable energy have long called them "job killers" that would destroy the economy if widely adopted. They are wrong, said Adam Rose and Dan Wei of the USC Price School.

Over the past 12 years, the pair have conducted 10 studies at the behest of the Florida's Governor's Office, the Minnesota State Legislature and NREL, among others, on the economic impact of moving from fossil fuel-generated electricity to renewables. Their findings: "The overall economic impacts were relatively small in percentage terms, and typically they were positive," Rose said.

In one LA100 scenario, the city's average annual job losses could total 3,800 annually between 2026 to 2045, mostly in the fossil fuel electricity generation sector, Wei said. By contrast, another pathway to 100% renewables would add 4,600 positions per year, largely in construction, operation and maintenance.

"A lot of people say we can't afford this," Rose said. "My response is that actually we cannot afford not to do this because of the projected acceleration of climate change and all of the negative impacts it will bring about."

The Great 'What-Ifs' of USC Engineering

SIX ALTERNATE SCENARIOS THAT MIGHT HAVE RESHAPED THE TROJAN ENGINEER-IVERSE

By Adam Smith

What if Zohrab Kaprielian had been left behind as a baby?

One of the most transformational deans in USC Viterbi's history, Zohrab A. Kaprielian — who also served as USC's provost and executive vice president during the 1970s — galvanized the school into a major research institution.

After convincing the U.S. Department of Defense in 1962 to award USC one of the coveted Joint Services Electronics Programs, Kaprielian assembled the school's renowned "Magnificent Seven" communications faculty: Solomon Golomb, Bob Scholtz, Irving Reed, Charles Weber, William Lindsey, Lloyd Welch and Bob Gagliardi. Kaprielian also supported visionary projects like the Distance Education Network (DEN@Viterbi) and the USC Information Sciences Institute.

But it almost never happened.

Born in 1923, Kaprielian, the son of Armenian refugees, was left behind in his crib when his childhood home was attacked by marauders. His family fled in panic, only to remember the missing baby several hours later. When his parents returned to the Turkish city of Aintab (present-day Gaziantep), they discovered the infant Zohrab still in his crib, "surrounded by a hail of bullets," according to Archbishop Vache Hovsepian in his 1982 memorial remarks for Kaprielian. Resettling in Syria, young Kaprielian attended primary school in rags. Despite this, he was always first in his class — though his primary school trustees nearly refused to let such a destitute student deliver the valedictory speech.

He earned his bachelor's and master's degrees in applied physics in 1942 and 1943 from the American University of Beirut. According to his niece, Arpine Deraney, Kaprielian may have been aided by AUB or UC Berkeley in coming to the United States after World War II, where, at Berkeley, he received his Ph.D. in electrical engineering in 1954. He came to USC in 1957, and the rest is Trojan history.

Zohrab Kaprielian, USC Viterbi's fourth dean, played a pivotal role in the school's evolution as a top 10 ranked program. However, as the child of Armenian refugees, he was almost left behind by his parents in southeastern Turkey.

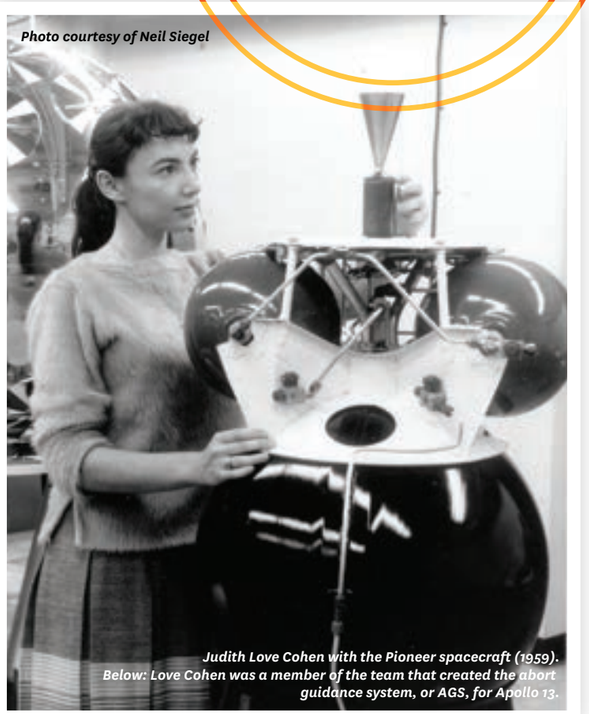


Photo courtesy of Neil Siegel

Judith Love Cohen with the Pioneer spacecraft (1959). Below: Love Cohen was a member of the team that created the abort guidance system, or AGS, for Apollo 13.

Photo: Look Magazine

What if Judith Love Cohen hadn't worked for the space program?

Judith Love Cohen, B.S. '57, M.S. '62, was a celebrated author of children's books like *You Can Be a Woman Engineer*. She was the mother of Neil Siegel, a member of the National Academy of Engineering and a USC Viterbi faculty member, as well as the actor and musician, Jack Black. But perhaps her proudest achievement, according to Cohen's son, Neil, was working on the Apollo space program.

As an engineer for TRW (Thompson Ramo Wooldridge Inc.), a subcontractor on the Apollo missions, Cohen was a member of the team that created the abort guidance system, or AGS, an early digital computer that had a very important job. Much of the maneuvering and flight of the Apollo spacecraft was planned and computed well in advance. But in the event of an aborted moon landing, the AGS could provide the necessary calculations to allow the lunar lander, with its two astronauts on board, to safely return to the command module, where a third astronaut awaited in lunar orbit.

During the Apollo 13 mission in 1970, the oxygen tank exploded, destroying the ship's engine, life support and power systems, and forcing the three astronauts, Jim Lovell, Jack Swigert and Fred Haise, to use the lunar lander as a "lifeboat." With no power for the command module's primary navigation computer, the crew relied entirely on the lander's AGS to plot 238,000-mile trip back to Earth, including two course corrections. In addition, Cohen was part of TRW's "orbitology" team that designed the trajectory paths to get the astronauts from the Earth to the moon and back. Without this, the AGS would have been useless.

Siegel recalled: "After they returned to Earth, the Apollo 13 astronauts came to TRW in Redondo Beach to thank the three TRW teams — orbitology, LEM descent engine and LEM abort guidance system — that also helped get them home. I was just a teenager, but my mom took me to that event."

What if Charlie Bolden hadn't watched *Men of Annapolis*?

Charles Bolden, the 12th NASA chief administrator, spent over 28 days in space over four space shuttle missions from 1986 to 1994.

Growing up in segregated South Carolina, 12-year-old Charles Bolden fell in love with the sharp suits and tradition of the U.S. Naval Academy through the 1957 television series *Men of Annapolis*. Every episode opened with the words: "These are their stories, full of their laughter, their heartache, their tragedies and triumphs ... the stories of the Men of Annapolis!"

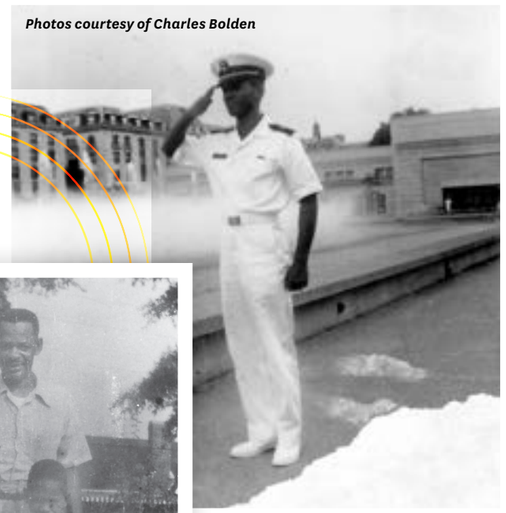
Inspired, Bolden wrote to both his senators and to Lyndon Johnson, then vice president of the United States, seeking a necessary appointment in the academy. Said Bolden, "I wanted them to know, early on, who I was and that I was really serious about this." Unfortunately, the responses from his congressmen, which included the segregationist Sen. Strom Thurmond, made it clear they were "not going to appoint a Black to the academy," Bolden said. Still, he was hopeful that LBJ would appoint him. That is, until November 22, 1963, when he learned — on the way to Charleston to play for the state football championship — that John F. Kennedy had been assassinated, and Johnson was now the president.

"My world stopped," Bolden told the "Consider the Cosmos" podcast in 2020, "and it was selfish. Not only had we lost the president we all loved, but I had lost any hope of going to the Naval Academy. Johnson was going to become president, and I wasn't eligible for a presidential appointment."

Undeterred, Bolden wrote to the new president. Within weeks, a Navy recruiter was knocking on Bolden's door, leading to an appointment from U.S. Rep. William L. Dawson from Chicago.

After graduating from the Academy, Bolden became a Marine aviator and test pilot, eventually earning his master's in systems management from USC in 1977. In 1980, Bolden got the call from NASA and replaced a crisp Marine Corps Nomex flight suit for a spacesuit, which he wore on four Space Shuttle missions from 1986 to 1994. In 2009, Bolden received one more presidential appointment: President Obama nominated him to become the 12th Administrator of NASA. With his Senate confirmation, he became the only African American to hold that post in the agency's 63-year history.

Photos courtesy of Charles Bolden



Bolden, also seen here with family, bottom row, middle; and wearing the coveted white uniform of the U.S. Naval Academy.

What if A.C. "Mike" Markkula did something else on Mondays?

A.C. "Mike" Markkula, a co-founder and key leader of Apple during its first two decades, was credited by Steve Wozniak as being most responsible for the company's early success. Here, Markkula poses with the first Apple II computer and its carrying case, April 1977.

"A lot of people wouldn't invest in Apple, wouldn't even talk to Apple, because Steve [Jobs] was so odd," recalled venture capitalist Don Valentine, founder of Sequoia Capital.

Nolan Bushnell, founder of Atari (where Jobs worked) said no. Tom Perkins, co-founder of Kleiner Perkins, said he "very foolishly didn't even look at Steve and [Apple co-founder Steve] Wozniak." Although Valentine dismissed Jobs and Wozniak as "renegades from the human race," he did refer them to an old colleague from his Fairchild days.

That colleague was A.C. "Mike" Markkula Jr., who was arguably the first to recognize the full potential of the Apple II.

Markkula, B.S. EE '64; M.S. EE '66, a millionaire from stock options as an Intel marketing manager, spent his days teaching himself to read music for guitar and building custom wood furniture for his A-frame cabin in Lake Tahoe.

"Every Monday, I'd help people write business plans and find financing to start companies. I thought it was fun. But I only did it Mondays," Markkula said.

One Monday, he pulled into the driveway of Paul and Clara Jobs' home in Los Altos.

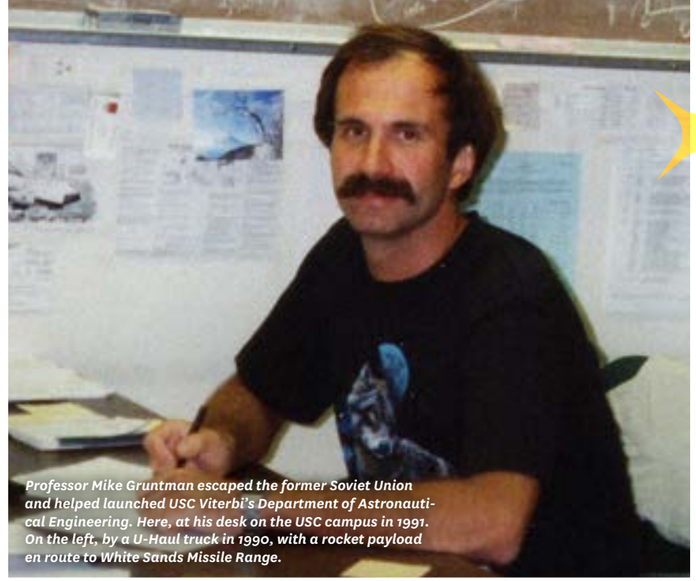
Markkula entered the garage, looked past their unkempt 22-year-old son, Steve, and his buddy, Steve Wozniak, and pondered the machine on the workbench.

Markkula, the USC trained engineer, knew it was "a massive achievement." He came out of retirement and wrote Apple's original business and marketing plans. He made the $250,000 investment that launched Apple and leveraged his professional experiences and relationships to help build Apple into a Fortune 500 company in less than five years. For over 20 years, Markkula led Apple in various capacities, from CEO to chairman of the board, leading to Jobs' ultimate return in 1997.

"Steve and I get a lot of credit, but Mike Markkula was probably more responsible for our early success, and you never hear about him," Steve Wozniak told Failure Magazine in July 2000.

Today, with a market capitalization of $2.1 trillion, Apple is the biggest company in the world. But it might never have existed as the behemoth we know today without Markkula, its lesser-known co-founder.

Images courtesy of Mike Gruntman



Professor Mike Gruntman escaped the former Soviet Union and helped launched USC Viterbi's Department of Astronautical Engineering. Here, at his desk on the USC campus in 1991. On the left, by a U-Haul truck in 1990, with a rocket payload en route to White Sands Missile Range.

What if Mike Gruntman had not escaped the Soviet Union?

Gruntman seen here with his mother, Raya, in Tyuratam, one year after the launch of Sputnik.

Mike Gruntman, USC Viterbi professor of astronautics and aerospace and mechanical engineering, has helped build one of the largest academic space engineering programs in the United States. It's the lifeblood of private space companies like SpaceX and Virgin Galactic. It's the home of the USC Rocket Propulsion Laboratory, which in 2019 launched the first student-built rocket to outer space. It's the first and only university to offer a B.S., M.S. and Ph.D. in astronautical engineering.

It's perhaps no exaggeration to say the department would not exist without Gruntman. But what if he had never escaped the Soviet Union?

In an alternate world, Gruntman should have been a favorite son of the Soviet space program. As a 3-year-old raised in Tyuratam — a secret location deep in present-day Kazakhstan — he was one of the world's few witnesses to the launch of Sputnik in 1957, the first man-made satellite. His father was the chief engineer who built the cosmodrome, or Russian spaceport, from which Sputnik launched.

But though he earned his Ph.D. in physics from the Space Research Institute of the USSR Academy of Sciences and worked as a researcher for the IKI and IPM institutes, Gruntman turned anti-communist at an early age. In 1984, he tasted tear gas for the first time, aiding the Polish Solidarity movement against riot police imposing martial law in Gdansk.

When the "cracks developed in the Iron Curtain," Gruntman found himself in a Dutch airport in March 1990. Three days later, with $80 in his pocket, Gruntman walked into a new office and new life at USC.

Though Gruntman is not ready to share the exact details of his complex escape plan, he relied heavily on the support of colleagues and friends from six countries on three continents. One of these was Darrell Judge '63, Ph.D. '65, professor emeritus of physics and astronomy and astronautical engineering at the USC Dornsife College of Letters, Arts and Sciences. Judge, Gruntman recalled, helped him escape from the former Soviet Union and make the transition to the scientific community at USC.

"Darrell's generosity, hospitality and friendship have touched the lives of many people, including mine," Gruntman said. "As I started my life from scratch in the U.S., he warmly welcomed me to his group at USC and offered the hospitality of his home during my first week in Los Angeles."

Gruntman would go on to map the interstellar frontier of our solar system in 2008 (a project he began at age 24!) as part of the IBEX spacecraft team. But none of it would've been possible without first reaching a new terrestrial frontier in Southern California.

What if UCLA had moved faster the day Keith Uncapher called?

In 1972, technology maverick Keith Uncapher received an unusual offer. His work at Santa Monica, California-based think tank RAND Corp., where Uncapher directed the computer science division, had drawn the attention of the United States' Defense Advanced Research Projects Agency (DARPA). Create and lead a center for emerging technologies, said DARPA officials, and the agency would provide financial support.

Uncapher initially approached the University of California at Los Angeles, where he was told it would take 15 months to receive approval from the UC Board of Regents. But given DARPA's interest, Uncapher felt he had no time to waste.

He appealed to George Bekey, chair of electrical engineering systems at USC and a consultant to RAND. Bekey helped arrange for Uncapher to meet with USC's dean of engineering, Zohrab A. Kaprielian, who wielded considerable influence — and who thought Uncapher's concept had tremendous promise.

USC's Board of Trustees authorized the center just five days later. In less than a month, the Information Sciences Institute, or ISI, launched operations as a largely autonomous arm of USC's School of Engineering. At Uncapher's insistence, the new center was located off campus to maximize its entrepreneurial bent.

From its 12-story, oceanfront building in Marina Del Rey, ISI conceived wonders. In 1972, ISI designed an interface for ARPANET, which became the basis of the internet. In 1981, Danny Cohen created MOSIS, probably the world's first e-commerce site. Two years later, Paul Mockapetris created the internet's Domain Name System (DNS), enshrining .com, .gov and .edu, among others. In 2011, ISI established the USC-Lockheed Martin Quantum Computation Center, the first academic research center in quantum computing. In 2016, Pegasus software, whose development is led by Ewa Deelman, was instrumental in detecting gravitational waves, contributing to a recent Nobel Prize.

Today, ISI is USC's crown jewel research institute. But nearly 50 years ago, it might have been UCLA's.

Nearly 50 years ago, the USC Information Sciences Institute, or ISI, might have become UCLA's crown jewel research institute, if not for the swift and decisive actions of Keith Uncapher, George Bekey, Zohrab Kaprielian and the USC trustees.

Lessons from THE MOUNTAINTOP

HAO WU HAS CONQUERED THE SEVEN SUMMITS, THE HIGHEST PEAKS ON SEVEN CONTINENTS. HERE'S WHAT HE LEARNED ALONG THE WAY.

By Benjamin Paul

IN 1923, FAMED MOUNTAINEER George Mallory uttered one of the most famous quotes of all time when asked why he was attempting to summit Mount Everest. "Because it's there," he said.

Mallory disappeared on Everest the following year, and to this day, no one knows if he ever made it to the top before his demise. Still, his statement might be the most succinct summary of humanity's essential need to be challenged.

In the years since, thousands of climbers have attempted to scale Everest. In 2015, Hao Wu, Ph.D. ECE, '96, hoped to add his name to that list. For Wu, summiting Everest would bring admittance into the Seven Summits Club, a select group of roughly 500 people worldwide who have climbed the tallest peaks on every continent. To put that in perspective, that's fewer people than have been to outer space.

Wu checked the first of these summits off his list when he climbed the highest peak in Africa, Mount Kilimanjaro, in 2005. The next five came in quick succession: Mount Elbrus (Europe) in 2008; Mount Aconcagua (South America) in 2010; Mount Denali (formerly called Mount McKinley, North America), in 2011; Mount Vinson Massif (Antarctica) in 2012; and Carstensz Pyramid (Oceania) in 2015.

For Wu, a talented researcher whose dissertation was on high-energy electronic devices called "gyratrons," preparing for a climb is in some ways second nature. The methodical and detail-oriented approach to engineering research that he learned at USC Viterbi are equally applicable to mountain climbing.

"My experience as a researcher prepared me immensely for the rigors of mountain climbing," said Wu. "When we developed our novel gyratrons in the lab, we had to control all the parameters we could while accepting which ones we could not. Preparing for a climb is exactly the same. You have to have all your equipment in place, your route planned out and your body in top form. Even still, unexpected things will happen. If you can't think this way, you will fail as a researcher and a mountain climber!"

In 2015, halfway up Everest, something unexpected happened.

Wu was resting in his tent at one of the base camps when a shower of ice and snow rained down on him. Moments later the earth began to shake. Someone shouted, "Earthquake!" and everyone took cover. For the next two days, Wu and his team were stranded on the mountain, rationing food and fuel, with nothing to keep them busy except thoughts of their families back home.

They were eventually rescued by helicopter as the path down the mountain had been seriously damaged, but the relief came with mixed feelings. "Emotionally, it was a very difficult experience. You feel equal parts elated at your own survival while knowing that just a few thousand feet below other people had died in that same accident," he said.

Of course, things one learns on the mountain can apply in your professional life as well. "By far the most important lesson I learned while climbing is that the biggest challenge isn't getting to the top — it's getting down safely," Wu said.

That's a lesson Wu applies to his work as a venture capitalist and partner at Sino-Century Investment Management and as a member of USC Viterbi's China & East Asia Advisory Board. He is also the former chairman and CEO of Sky Solar Holdings Ltd., in Shanghai. "Experienced climbers know how to reserve energy and plan for their safe descent even before they begin their climb," he said. "And successful investors likewise plan ahead on how to exit from a position and sell at the right time."

Six years ago on Mount Everest, Wu had to take his own lesson and accept what he couldn't control. Writing in his journal, Wu reflected back on the reason he loves climbing:

In climbing,
we found love,
we found peace
of mind,
we found courage.
We found
perseverance,
we found health,
we found challenge,
we found risk.
In climbing, we found
how to live a life.
In climbing, we found
how to invest.
Climbing is about
the journey not
the destination.

With years of experience climbing some of the most challenging mountains on the planet, the peak that holds the top spot in Wu's heart is the least technical and easiest of all the Seven Summits. "Kilimanjaro is the only one of the seven summits I climbed with my favorite climbing partner — my wife!" he said. Like so many other USC Viterbi alumni before and since, Wu met his future wife, Fan Xing, right here when they were both students.

As for summiting Mount Everest, Wu tried again a few years later. In 2019, he stood on the top of the world and completed the Seven Summits.

Hao Wu, Ph.D., ECE, '96, came to USC to design gyratrons. Today, the venture capitalist is an elite mountain climber who has accomplished a rare feat.

Hao Wu conquered the "Seven Summits," the seven high highest mountains on each of the seven continents, including Mt. Everest in 2019.

PHOTOS COURTESY OF HAO WU

It's a Wonderful *Life*

DURING ONE OF THE DARKEST TIMES OF HIS LIFE, BRYAN MIN FOUND A RENEWED PURPOSE, INSPIRED BY HIS CHRISTIAN FAITH AND A CERTAIN JIMMY STEWART FILM

By Marc Ballon

EVERY CHRISTMAS, Bryan Min, B.S. ISE '86, watches Frank Capra's *It's a Wonderful Life*, one of his favorite movies. In it, a depressed George Bailey, played by James Stewart, contemplates suicide on Christmas Eve. As his thoughts darken, a guardian angel shares a unique gift: a glimpse into an alternative world where he'd never been born. Seeing how many lives had been touched by his existence, Bailey chooses life.

The 1946 classic is more than just a great movie to Min, namesake of the Min Family Challenge, a Navy veteran, a successful entrepreneur, and a member of the USC Viterbi Board of Councilors. Instead, *It's a Wonderful Life* is both a source of inspiration and aspiration."The thought of what George Bailey did moves me so much," said Min, who admits to dissolving into tears every time he watches the movie. "It never gets old. I want to be remembered for the people I've impacted."

Like George Bailey, Min has had his share of challenges that have "shaken me to my core." In the film, Bailey is nearly ruined and wrongfully accused of embezzlement. For Min, it's a scenario he understands all too well.

In September 2015, Min, the CEO and founder of Epsilon Systems Solutions, a San Diego-based defense contractor, learned that the company's chief financial officer — a person Min had trusted, "broke bread" and played golf with, and considered a friend — had misappropriated company funds. For the next year and a half, Min worked to save Epsilon as government auditors and the inspector general's office as well as federal prosecutors swarmed the company. A forensic accountant hired by Epsilon painstakingly dissected the company's finances to find out how much had been stolen. The amount: $825,000.

More urgently, Min worried that the U.S. government would cease doing business with Epsilon. Min literally spent sleepless nights worrying about the future of his business and of his family. In fact, the government designated Epsilon as a "high risk" defense contractor in 2015, 2016 and 2017, which impacted sales.

Instead of sliding into despair, Min opted to bring joy by giving. Amid his personal and professional turmoil, he and his family created the Min Family Challenge, an engineering social entrepreneurship contest that encourages would-be social entrepreneurs to build companies that benefit the underprivileged locally, nationally and even worldwide.

"In the darkest time of my life, when everything I've worked for is about to crumble, the vision of the challenge was something that came alive," Min said. "We were committed to doing something good, to making the world a better place."

In the ensuing years, the federal government not only removed Epsilon from the high-risk category, but also increased its orders. Over the past three years, Epsilon's valuation has increased more than fivefold.

Bryan Min and his wife, Julie, contribute more than 10% of their annual income to philanthropy. "Wealth is just a platform," he said. "What's important is what you do with it to benefit mankind."

The Challenge

Throughout the decades, Min has made a profound impact. Driven by his deep Christian faith and belief in the biblical proverb "Much is required from the person to whom much is given," he has long set aside more than 10% of his income for philanthropy. "Wealth is just a platform," he said. "What's important is what you do with it to benefit mankind."

Indeed, Min feels particular pride in the creation of the Min Family Challenge.

Launched in 2015 with a generous gift from Min, his wife, Julie Min, and their children, the business model competition offers a $50,000 grand prize. Over the years, participating students have traveled to Texas to aid victims of natural disasters like Hurricane Harvey; gone to Lesvos, Greece, to create life-improving innovations to help refugees; and more recently, leveraged entrepreneurship for the benefit of underserved populations.

"It is likely the only such competition nationwide. It gives USC Viterbi students a new way of solving societal problems through the lens of social entrepreneurship using engineering innovation," said Dean Yannis C. Yortsos.

Past participants include Duet, which was featured in the PBS documentary *Lives, Not Grades*. Duet, one of the world's first student-built, micro-philanthropy platforms, uses an algorithm to allow donors to buy refugees needed items available at stores in their host country. Social Benefit, the winner of the 2021 challenge, is creating a digital platform that brings transparency to government benefits for low-income populations and case managers to help end cyclical homelessness and poverty.

At this year's challenge, Bryan Min quipped about how his support for MFC could substantially brighten his long-term prospects.

"I go to the Pearly Gates, and I can see God asking me, 'Bryan, what good have you done?' I think I could point to the Min Family Challenge," he said. "And maybe God will allow me in at that time."

ILLUSTRATION: MICHAEL ROGERS

Class Notes

Oussama Mellouli, of Tunisia, grabs a drink while passing through the feeding station during the men's marathon swimming event at the 2020 Summer Olympics, Thursday, Aug. 5, 2021, in Tokyo. (AP Photo/David Goldman)

Rachel Morford

B.S EE, M.S. EE '07, is the new president of the Society of Women Engineers. She will lead the prominent global organization for a one-year term. Morford became involved with SWE at USC and has remained involved in the organization since, serving in a number of executive positions over the years. Morford is principal director at The Aerospace Corp.

Rachel Morford

Philip Moynihan

M.S. ME '66, published his third book, "Spirit of the Sky Walkers." The book captures the joys, poetries, and adventures of flying by detailing the more than three decades of aviation escapades that took him and his wife, Penny, all over North America. Before his retirement, Moynihan spent 45 years as an aerospace engineer, including 38 years at NASA's Jet Propulsion Laboratory.

Philip A. Iannuzzi Jr.

M.S. Systems Management '89, received a Citation of Honor from the Philadelphia City Council in September 2020 recognizing his commitment to service, scholarship and industry. The retired Air Force colonel and military pilot serves as a workforce development leader for The Boeing Co. Iannuzzi also has a doctorate in education from Delaware Valley University and three other master's degrees.

Oussama Mellouli

B.S. CS '07, competed in the Tokyo 2020 Olympic Games, becoming only the fourth swimmer ever to compete in six Olympics. Mellouli is a three-time medalist, and was the first African male swimmer to win an Olympic gold medal in an individual swimming event (in the 1500-meter freestyle in 2008). He carried the flag for Tunisia in the opening ceremonies for the 2016 Olympics and in the closing ceremonies in 2012. Nicknamed "The Mediterranean Shark," Mellouli still holds the USC record in the men's 400-yard IM (3:39.19, 2003) and both the Uytengsu Aquatics Center 400-meter (3:44.79, 2006) and 800-meter (7:49.02, 2006) freestyle records.

In Memoriam

Thuy Truong

Thuy Truong

B.S. CS '09, passed away Jan. 25, 2020, at age 35, from genetic lung cancer. Truong leaves a legacy as a multilingual businesswoman, a driven computer engineer, a highly successful entrepreneur and a cancer advocate. Born in Vietnam in 1985, Truong and her family moved to the United States in 2003. After graduating from USC Viterbi, Truong moved back to Vietnam, where she launched a number of successful startups, including the country's first frozen yogurt company, Parallel Frozen Yogurt. She also launched the app development company Greengar, which built several popular mobile apps. Truong was dubbed the "Queen of Startups" by the BBC, and was included in the "Forbes 30 Under 30" list by Forbes Vietnam magazine in 2015 and the "50 Most Influential Women of Vietnam" in both 2017 and 2019. Truong also starred in an award-winning documentary about female business founders called "She Started It."

After being diagnosed with lung cancer in 2016, Truong moved back to Los Angeles for treatment at USC and began to devote herself to improving treatment options and quality of life for people with cancer. In 2016, she launched the Salt Cancer Initiative, a nonprofit dedicated to providing support and education to cancer patients and their caregivers in Vietnam. In 2017, Truong hosted USC's first-ever "Hack for Health," a three-day "hackathon" in which teams worked to develop technological solutions for cancer management.

Jason Weinstein

B.S. CE '85, passed away Dec. 15, 2020. Weinstein worked for 34 years at Shoring Engineers, which provides services including drilling, shoring and excavating that are essential for nearly all major construction projects. During his time there, he designed and managed hundreds of shoring projects, including at the Apple headquarters in Cupertino, California, and at the Los Angeles County Museum of Art, along with multiple projects at USC, UCLA, Universal Studios, Disneyland and NBC Studios. During his college career, Weinstein was a member of the American Society of Civil Engineers and twice won concrete canoe engineering competitions.

Robert Melbourne

B.S. CS '51, passed away peacefully of natural causes at the age of 91 at his family home in San Luis Rey, California, on Dec. 24, 2020. After serving as a private in the U.S. Marine Corps Reserve and then as an officer in the U.S. Navy in the Civil Engineering Corps, Melbourne spent 28 years working to develop large-scale water construction projects for the San Diego County Water Authority. Melbourne earned his Ph.D. in history from USC in 1996. He was a life member and proud fellow of the American Society of Civil Engineers.

Q&A

THE MULTIVERSE OF CLIFFORD JOHNSON

ON THE NATURE OF REALITY AND ADVISING THE MARVEL CINEMATIC UNIVERSE

Interviewed by Daniel Druhora

Clifford Johnson, the U.K.-born theoretical physicist who grew up on on the Caribbean island of Montserrat, is comfortable leaping worlds.

A professor of physics and astronomy at the USC Dornsife College of Letters, Arts and Sciences, Johnson came to prominence by developing theoretical tools to describe the basic fabric of nature. He works mainly on superstring theory, quantum gravity, gauge theory and M-theory, studying objects such as black holes and Dirichlet membranes (dynamical extended objects in quantum gravity that can move, wiggle, and wrap around things), using math and physics.

But he's also one of the few physicists with movie credits to his name. Many of Hollywood's biggest sci-fi movies and TV shows — think *Avengers: Infinity War* and *Endgame* and *Star Trek: Discovery*, to name a few — are grounded in elements of real science thanks to Johnson. He helped convince Marvel to explore the meaning of Thor's hammer having been forged in the "heart of a dying star." He also advised on the time travel scenarios that became the central plot of *Avengers: Endgame*. In 2017, he wrote and illustrated *The Dialogues*, a nonfiction graphic novel meant to be a modern-day Socratic dialogue about the science of the universe for non-scientists.

We interrupted Johnson in between solving the mysteries of the universe and his next big Hollywood project to talk to us about black holes, parallel universes and how a glass of beer could explain multiverse theory.

How do you describe your work?

Whenever I'm asked this, I often use the word "origins" — everything that we have seen so far about our universe and what everything is made of. In the last few years, I've focused on aspects of black holes, which in some ways contain some of the biggest clues to these origin questions. Black holes and quantum physics — putting them together in what's called quantum gravity — is my main line of investigation these days.

How does the multiverse play into this?

That origin question is what often knocks on the door of things like the multiverse, because if you're trying to describe this universe and you come up with a class of theories, like string theory — which I also work on to describe model universes — oftentimes, out of those same equations come alternate universes. And you ask yourself: Is there just the one that's correct? Or maybe they're all correct? That's one of the ways people arrive at the multiverse idea, with equations that essentially tell you that you have choices.

What are some of the current ideas about the multiverse?

The term "multiverse" is very loosely used in public and even among some physicists. There are several distinct things that can lead you to the idea of multiple universes, and they're not necessarily connected. I guess the only way to describe it is to tell you some of the different options.

The most famous one is due to people thinking about quantum physics, people like David Deutsch (who pioneered the field of quantum computation) and also Hugh Everett (who first proposed the many-worlds interpretation of quantum physics). Everett was trying to understand the fact that quantum physics tells you that, fundamentally, you seem to have choices in the outcome of an experiment. Not the familiar randomness of tossing coins, but built-in, you have all these different quantum outcomes. Each of these in turn has a certain probability, but when you do a measurement, you measure only one of the outcomes. So you get to ask the question: If I chose one, what happened to all the others? For a long time, people were worried about this fundamentally probabilistic nature of our universe that emerged with quantum physics. People like Everett were thinking that maybe those choices do happen but in a different universe. It isn't just that the universe is making these probabilistic choices — both choices were chosen, but you only live in the one where that particular choice was made. Every time there's a quantum choice, for every microscopic system, for every molecule, there's a huge number of universes in this quantum multiverse. I certainly can't disprove that because the basic idea is such that these universes then don't have anything to do with each other.

But my take on that is that it seems to be an incredibly uneconomical solution to an interpretation problem, namely the interpretation of quantum physics. To have it fit within our classical notions of how physics should be, you must invent an infinite number of these universes that you can't interact with. That sounds to me like we're putting something on nature that nature doesn't do. Perhaps that's a question best left to the philosophers.

A separate multiverse idea seems to be forced on you by the physics, as we understand it so far. This has to do with the dynamic question as we start thinking about cosmology. We know now from observation that the best explanation we have for how our universe came to be involves not just the Big Bang, but also what's called a period of inflation, where the universe is born out of a rapid expansion. You start out with a tiny patch of primordial space-time and that gets exponentially large for a fractionally small amount of time. It keeps doubling and doubling and doubling, if you like, in size until it gets up to the macroscopic scale that we live in today. After that period of inflation, you get the usual sort of Big Bang–type physics, where the universe expands over the 13.8 billion years. So, in the first few fractions of a second, there's this inflationary period that's essential to describing how the universe looks today. The problem with inflationary theory is that there's no reason why it just happened to that one patch of primordial space-time.

Also, we can't explain what turns on and off the inflationary period, so what would we learn that would be consequential to our reality?

Right. Picture a glass of beer and watch what happens as I pour beer into your glass. Some mechanism gives rise to bubbles forming, and it's cool. You could focus on one bubble and start describing its physics. But why are you focusing on just that one bubble when there are thousands of bubbles forming all the time and doing different things? You know they're all bubbles, and you have your theory of bubbles, but you can't predict where the other one will form and what it will do. So you must deal with the fact that if you have a mechanism that creates that one bubble, it can create many more bubbles of slightly different types in your beer glass. That's the multiverse. Once you've written all the equations down and you feel good about it and it's describing all these cool things about our universe you go, 'But what's wrong with all these other choices?" This could keep happening. More universes could be generated. That's the fundamental cosmological origin of the multiverse idea.

> It isn't just that the universe is making these probabilistic choices — both choices were chosen, but you only live in the one where that particular choice was made.

Now, if we were to stop right here it might not be so interesting. But the point is that this may have observational consequences. What happens if these bubbles interact with each other? These different universes might leave signatures of the existence of the others in some sort of thing that we could measure, maybe by looking in the sky at the right thing. Something about how galaxies are distributed, something about how the different periods of the universe, the first stars, the first light, may depend upon whether it's interacting with other universes.

You can imagine universes that are slightly different — even a tiny amount of difference perhaps in the laws of physics for that universe. The makeup of fundamental particles that make everything up might be slightly different. It might be that the rules are the same but the ingredients are slightly different so you could end up with a slightly different universe. Or it could be that the ingredients are the same but the rules are slightly different.

Let's talk about your work as a science advisor on films. What films have you worked on?

I've worked on several Marvel movies, and for me, it's fascinating to think about other ways our universe could be. Another way people arrive at the multiverse idea is through time travel as it shows up in the *Avengers: Infinity War* and *Endgame* movies. People resolve the paradox of going back into the past and changing things such that when you go back, you're no longer in the universe you began with, you're in a new universe — the multiverse. This idea of multiple universes is beginning to show up a lot more in the *Loki* series. Actually, these multiverse ideas started entering the Marvel Cinematic Universe with the second season of the *Agent Carter* TV series, for which I was the science advisor. Later, you started seeing them show up in *Doctor Strange*.

> You can imagine universes that are slightly different — even a tiny amount of difference perhaps in the laws of physics for that universe.

What elements of the Marvel Cinematic Universe do you help shape?

Primarily, I talk to writers and directors about plot elements and terminology. I also sometimes help the visual effects artists formulate their vocabulary of the visuals, in addition to advising the filmmakers about the different scientists they might have on screen and putting words in their mouths. I also help them with the look of things, if they're interested. What a setting might look like, whether it be the chalkboard that a scientist is writing on, or the look of the wormhole in *Thor: Ragnarok*. They don't always take my advice, but I give it if they ask.

There are the rules of the film, but then there are the laws of physics. Do you often find yourself in the middle of a story that contradicts the physics?

My job is to understand their story goals, not to help them make a physics documentary.

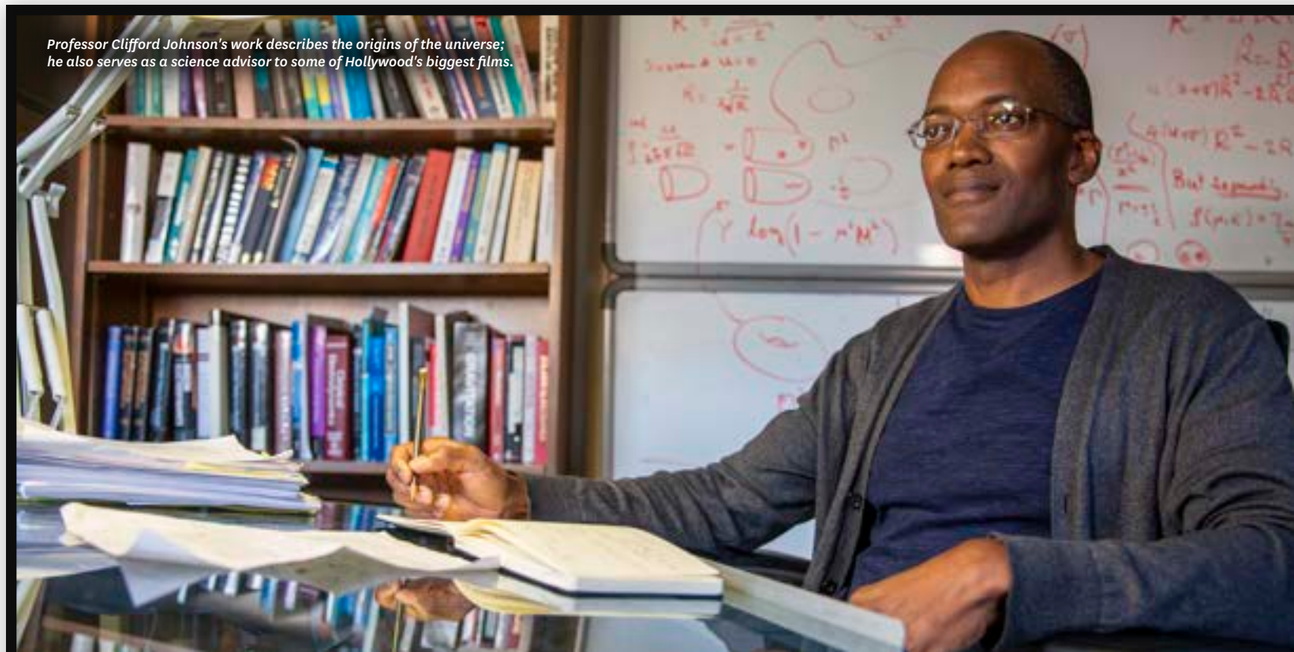
I ask the filmmakers, "What are you trying to achieve here?" Sometimes that can help them improve the science of the story and use science that is more directly connected to the real science. I can see this fun thing they're doing here with a bit of science, but here's this other bit of science that they don't know about that's much more fun and connects to the real world that they can use instead. Oftentimes, that results in more story ideas, and even characters, that they hadn't originally thought of because they hadn't talked to a scientist. For me, that's when it works best.

How do you reconcile the scientist with the science advisor on a Marvel movie?

I see my role as someone who invites more people to play in this awesome space called science. I think there's too much of this belief that it takes a very narrow kind of person to do science. Or people saying, "I don't have the right kind of brain for it." I think that's nonsense. If we think of ourselves as some sort of educated literate citizen out there in the world, we ought to be able to dabble in lots of things and one of those things should be science. It's all part of what makes human culture so rich.

I also encourage filmmakers to broaden who is a scientist on screen. I don't want people to think it's only Tony Stark or Bruce Banner. Let's also have women and people of color, all kinds of people being the primary scientists, solving problems by use of reason, not just hitting stuff and blowing stuff up.

On the other hand, the science community must embrace the power of storytelling because, frankly, as a society we spend a lot of our time entertaining ourselves with the moving image. It's where our eyeballs are. So, if I'm smart and I'm trying to get people excited about some ideas, I should go to where their eyeballs are, right? People won't suddenly go and pick up a physics book. So why not bring the physics to where they're already looking?



Professor Clifford Johnson's work describes the origins of the universe; he also serves as a science advisor to some of Hollywood's biggest films.

PHOTOGRAPHY: MIKE GLIER

USC Viterbi
School of Engineering

University of Southern California
Los Angeles, CA 90089-1451

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THE SEARCH BEGINS ON PAGE 13