

2023 YEAR *in* REVIEW

USC *Information Sciences Institute*

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USC Viterbi

SANTA MONICA

VENICE



PLAYA VISTA



LAX



CULVER CITY

Frontiers OF COMPUTING CONQUERS SILICON BEACH

In 1972, USC Information Sciences Institute was established on the Westside of Los Angeles, becoming a tech pioneer in Silicon Beach.

In 2023, USC announced Frontiers of Computing, a \$1B effort focused on three key areas of technology: advancing AI and machine learning software; improving hardware efficiency and scalability; and, in this era of big data, expanding quantum computing. USC will expand its footprint in Silicon Beach, L.A. County's growing tech corridor, with ISI as a key hub in the the area. ■



PHOTOGRAPH BY GREMLIN/ISTOCK

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ANNUAL REPORT

Learn about ISI's scientific postfolio, what our divisions will focus on in 2024, the different programs offered by Viterbi, and hear what the students have to say about their experience as ISI research assistants.



"Transformative projects are propelling us forward"

CRAIG KNOBLOCK
ISI KESTON EXECUTIVE DIRECTOR



At ISI, we are not just observers of change; we are architects of the future, pushing the boundaries of technology to new frontiers. I'd like to reflect on some of the milestones that have not only shaped our journey over the past year, but will impact the future of both ISI and the larger tech landscape.

One of our proudest moments of 2023 was the announcement of the California DREAMS project, a monumental undertaking that has not only propelled us into the forefront of microelectronics but has also provided a clear path forward in defining the future of MOSIS. With DREAMS, we are shaping the next generation of microchips and positioning ISI as a leader in the

ever-evolving landscape of technology.

Similarly, the SPHERE project stands as a testament to our commitment to innovation in cybersecurity and networking – redefining the possibilities in testbed work and paving the way for the development of cutting-edge devices and technologies. SPHERE is poised to revolutionize how we approach technological challenges, ensuring a safer and more connected future.

2023 was a big year for AI worldwide, and that was certainly reflected here at ISI. Adam Russell joined our team as the new AI division director; his wealth of experience and expertise will undoubtedly propel us to new heights. A big AI achievement for the institute was getting

the Center for AI Research in Health up and running. This initiative highlights our commitment to harnessing the power of artificial intelligence for the betterment of society. With a focus on recruiting top talent and fostering groundbreaking research, we are paving the way for groundbreaking advancements in healthcare and beyond.

There are simply too many stand-out projects to mention here, so I do hope you page through this inaugural ISI Year in Review Magazine and see more of the innovative work happening at ISI.

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2023 YEAR IN REVIEW

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Three locations, one *mission*

ISI's mission is to advance society through pioneering research and technological innovation. We cultivate an intellectually vibrant environment where researchers are empowered to imagine bold solutions to complex problems and develop into world-class leaders. Guided by integrity, inclusion and a commitment to excellence, we create unprecedented capabilities that harness information to transform lives. ISI is a place where people can be inspired to realize their potential, an inclusive community where everyone can thrive and feel that they belong.

"ISI researchers are visionary scientists who relentlessly push the envelope of computational capabilities, venturing into uncharted territories of application with a firm belief that creativity is the cornerstone of truly revolutionary scientific achievements," said Ishwar K. Puri, USC Senior Vice President of Research and Innovation.

The Institute's work is characterized by a focus on real-world impact, and our staff gets to work in world-class facilities distributed across three sites. Our headquarters are in a coastal location in Marina Del Rey, California, in a vertical campus across nine floors. Two additional sites are Arlington VA and Boston MA, and personnel are working remotely in several other locations.

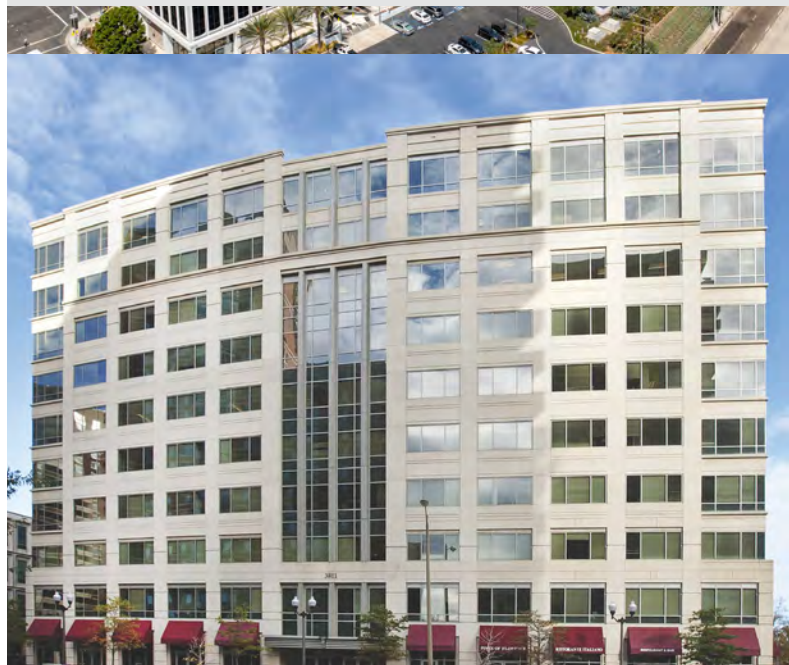
ISI's uniqueness lies in being a very large, university-affiliated research lab, working with a hundred Ph.D. students and junior to well-established researchers and engineers. This allows ISI to manage very large projects with research systems integration and deliverables.

Initially founded by ARPA (now DARPA) to help build the Internet, ISI now focuses on the many challenges facing society today. Our dedicated researchers' mission is to transform lives. And it is our staff, faculty and students that make this possible. ■

OUR MISSION



MARINA DEL REY, CA



ARLINGTON, VA



BOSTON, MA

ISI

MEDIA

The Washington Post

JULY 6, 2023

USC researchers use AI to help translate the Bible into very rare languages

With Ulf Hermjakob, Computer Scientist, and Joel Mathew, Research Engineer

Out of the 7,100 languages that exist, the Bible has been translated into more than 700. Two scientists are looking to new advancements in artificial intelligence to help close the gap. The researchers at the University of Southern California's Information Sciences Institute developed the technology to target "very low-resource languages that are not even in the top 500," said Joel Mathew, a research engineer. They want to work on languages that don't even have a written system, grammar codes, dictionaries or spell-checkers. "We are thinking of languages like Uyghur or Oromo," said Ulf Hermjakob. Oromo is spoken in Ethiopia and northern Kenya.

The Guardian

MARCH 14, 2023

Venmo users on discovering secrets on the app

With Jelena Mirkovic, Principal Scientist

Though users have the option to make their payments private, many forget to. What does this mean for the rest of us? A study conducted by experts at the University of Southern California found that two in five Venmo users publicly reveal "sensitive information" on the app. Another researcher documented a year's worth of public interactions in the lives of strangers on Venmo and found what Vice called "a soap opera". We're all accidentally telling on ourselves.

Spectrum News 1

MARCH 15, 2023

USC research lab developing tech to service satellites in space

With David Barnhart, Director of SERC

Inside a nondescript building in Marina Del Rey, a team of student researchers from the University of Southern California are helping to develop the next generation of space technology. "There's this new field of servicing where we can literally do maintenance repair, upgrade refueling, on platforms that are in spaces which is super cool," said David Barnhart, director of USC's Space Engineering Research Center. He's in charge of the innovation lab and says that's truly the next step in the world of aerospace. Most of the testing is related to what's known as "rendezvous and proximity operations." In other words, getting up close and personal with other objects floating through space that can weigh upwards of two tons.

The Los Angeles Times

APRIL 27, 2023

One billionaire owner, twice the hate: Twitter hate speech surged with Musk, study says

With Keith Burghardt, Computer Scientist

New research shows that (Twitter) underwent another change after Musk took over — it became more hateful. The researchers first developed a "hate lexicon" of 49 racist, antisemitic and homophobic and transphobic terms. Then, they examined the pre- and post-sale postings using an artificial intelligence tool that scanned for the hateful terms and their frequency, weeding out "non-toxic," or non-hateful, uses of the terms. "We first had to create a set of words that we could determine as being hateful," said Burghardt, a computer scientist with the Information Sciences Institute. "Our aim was to find words that were relatively high precision, meaning that if people are using these words, it's unlikely they're being used in a non-hateful manner."

COV

Gizmodo

APRIL 9, 2023

Don't Play Poker With ChatGPT

By Mayank Kejriwal, Computer Scientist

Inspired by the growing body of research in BERTology and related fields like cognitive science, my student Zhisheng Tang and I set out to answer a seemingly simple question about large language models: Are they rational? Although the word rational is often used as a synonym for sane or reasonable in everyday English, it has a specific meaning in the field of decision-making. A decision-making system — whether an individual human or a complex entity like an organization — is rational if, given a set of choices, it chooses to maximize expected gain.

Scientific American

MARCH 31, 2023

How to Tell If a Photo Is an AI-Generated Fake

With Wael Abd-Almageed, Founder of VIMAL, ISI's visual intelligence lab

AI detectors will always be scrambling to keep up with AI image generators. "The battle between AI systems that generate images and AI systems that detect the AI-generated images is going to be an arms race," says Wael Abd-Almageed, a research associate professor of computer science at the University of Southern California. "I don't see any side winning anytime soon." Abd-Almageed says no approach will ever be able to catch every single artificially produced image—but that doesn't mean we should give up. He suggests that social media platforms need to begin confronting AI-generated content on their sites because these companies are better posed to implement detection algorithms than individual users are.

Nature

MAY 24, 2023

Rewriting the quantum-computer blueprint

With Itay Hen, Principal Scientist

Quantum computers can, in theory, perform certain calculations many times faster than conventional digital computers. Not all specialists are convinced that the parity architecture will achieve its desired results, at least when it comes to solving optimization problems. Itay Hen, a numerical physicist at the University of Southern California in Los Angeles, questions whether a quantum computer fitted with the architecture could solve such problems more quickly than would a classical computer — given what he says is the absence of any quantum algorithm that guarantees such an outcome. "Even if we had the perfect quantum computer, we still wouldn't know whether it is better than a laptop," he says.

NPR

OCTOBER 15, 2023

New proteins, better batteries: Scientists are using AI to speed up discoveries

With Yolanda Gil, Senior Director for Strategic Artificial Intelligence and Data Science Initiatives

The U.S. National Academies convened a two-day meeting on the potential for AI to change science. "AI scientists can really be more systematic, more comprehensive and not make errors," says Yolanda Gil, director of AI and data science initiatives at the Information Sciences Institute at USC. Rather than using AI to do all science, she envisions a future in which AI systems plan and execute experiments, in collaboration with their human counterparts. In a world facing increasingly complex technical challenges, "there's not enough humans to do all this work," she says.

The New York Times

APRIL 11, 2023

The R.T.O. Whisperers Have a Plan

With ISI Executive Director Craig Knoblock

When he surveyed his roughly 400 employees and student researchers, Knoblock found that nearly 30 percent of them preferred to work from home — forever. ISI happens to be the very place where in 1981 scientists invented "packet video," the software technology that enables video meetings. Knoblock decided to give up on requiring workers to come into the office three days a week in favor of a more flexible approach. The institute's return-to-office schedule now differs by team. That has been affirming for some workers, who are able to maintain the control over their time that remote work afforded them.

ERAGE

The background is a vibrant, abstract composition. It features a dense field of binary code (0s and 1s) in various shades of blue and green. Overlaid on this are several glowing, curved lines that suggest data flow or digital pathways. The overall effect is one of high-tech, futuristic energy.

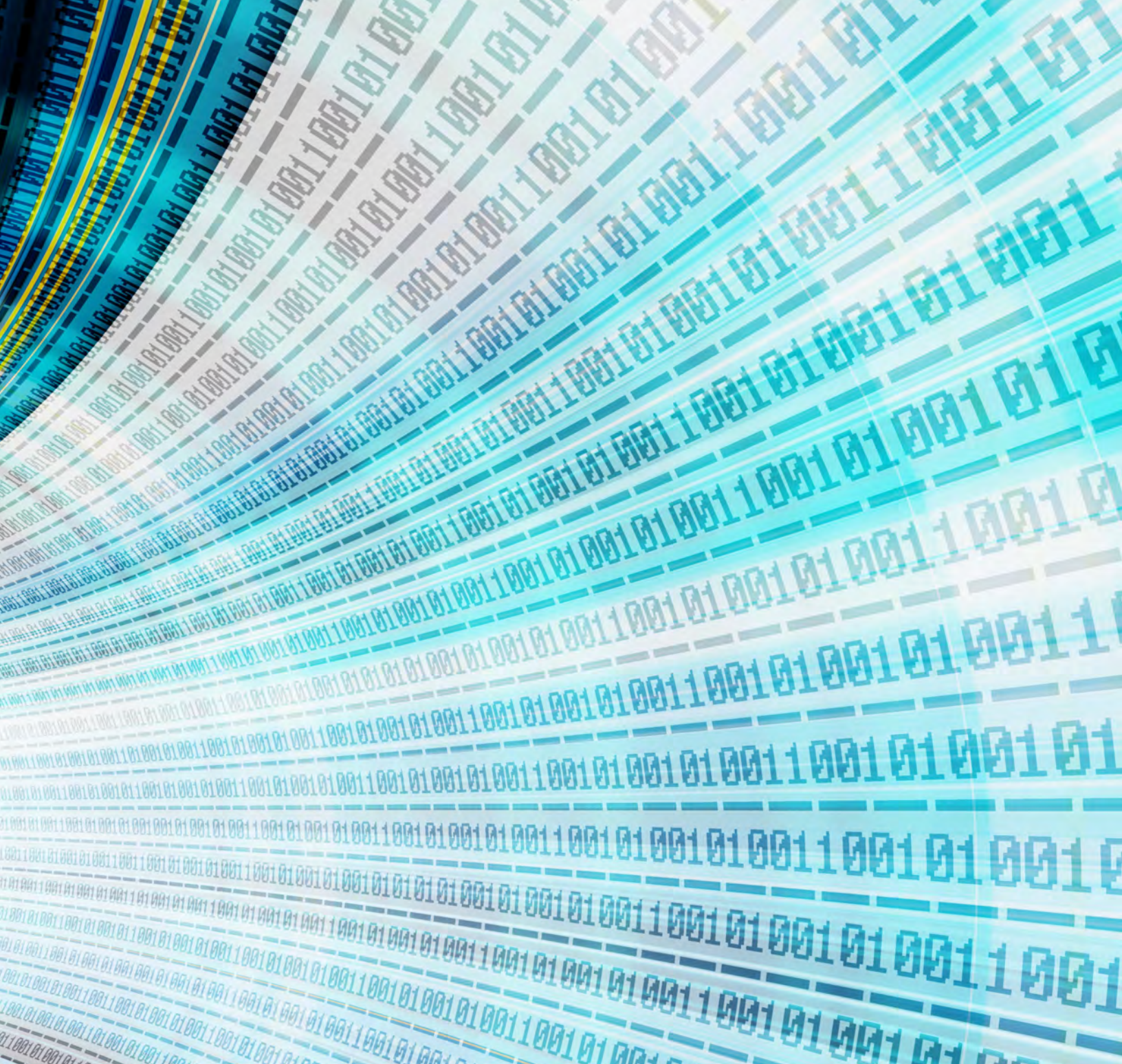
featured RESEARCH

BY YANNIS YORTSOS
DEAN OF THE USC VITERBI
SCHOOL OF ENGINEERING

For five decades, ISI has led exceptional research in computer science and addressed a range of important problems, from fundamental scientific questions to pioneering advanced technological implementations.

Its achievements stand as a testament to the quality and scientific strength of its researchers and scientists, surpassing the aspirations of its founders. We are proud of its

achievements, its expansion to both U.S. coasts and the constant reaching of various milestones. ISI boasts profound expertise in many cutting-edge areas of artificial intelligence, cybersecurity, microelectronics, informatics systems and quantum computing. Its scientists are extending the boundaries of computing, exploring novel applications, driven by exceptional



creativity. As noted by one of our leading researchers, “At ISI, making a difference is about how creative you are. This is what will lead you to doing great things in computer science.”

Today, ISI is leading the Southern California hub for the Microelectronics Commons, spearheading the creation of a next-generation cybersecurity testbed, and developing artificial intelligence tools that are both

ethical and secure, substantially contributing to the burgeoning field of Generative AI. We are filled with joy witnessing ISI's growth and its substantial contributions to the USC Viterbi School of Engineering's recognition as a premier research institution in computer science in general, and advanced computing in particular. ■



THE PROBLEM AI capabilities are drastically outpacing considerations on safety, fairness and ethics	OUR SOLUTION Contributing to the development of responsible AI through research and advocacy	WHAT'S NEXT Engaging in research, policy, and thought leadership to guide AI toward positive futures
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Making AI *safe* and fair

BY STEPHANIE LEE

History suggests that progress in technological safety is often preceded by catastrophe. The Chernobyl nuclear power plant accident, in 1986, led to sweeping international changes in nuclear safety standards. The Challenger space shuttle, that same year, fatally broke apart 73 seconds into its flight, spawning an overhaul of NASA's decision-making processes and safety protocols. A disaster on this scale has not yet been caused by artificial intelligence. But as a technology more powerful and interconnected than systems past, it poses risks unlike any other.

“There are many capabilities in AI that we don’t understand well yet,” said Yolanda Gil, senior director for Strategic Initiatives in Artificial Intelligence and Data Science. “We don't know how to measure them. We don't know how to use them properly.” AI systems may cause unintended harms, have unfair biases, or behave in unpredictable ways. Safety challenges grow as AI becomes more autonomous, complex, and embedded within critical applications. Such speculative scenarios beg the question: what can we do to ensure that our AI systems cause no harm?

BUILDING AI SAFETY FROM THE GROUND UP

This concern lies at the core of an emerging research discipline: AI safety. Its scope is yet to be defined. Some experts believe AI safety should prioritize direct threats to human life or critical resources, such as infrastructure or the environment. Others

interpret AI safety more broadly, taking into account the way AI could risk our social stability, the political process, mental health, and so on. Around the world, scientists, policymakers, and industry leaders are beginning to discuss how to improve safety measures to match capabilities.

“The point is,” said Adam Russell, director of ISI's Artificial Intelligence division, “we have to be proactive now.” He recommends an “all hands on deck” approach where AI safety will require partnerships between academia, industry, and government. This collaboration must also be a global endeavor—even in the face of economic competition and differing national security interests.

In November 2023, one year after the explosive launch of ChatGPT, Russell participated in the inaugural AI Safety Summit in the United Kingdom. “Attendees included representatives from 27 countries, among them U.S. Vice President Kamala Harris and U.K. Prime Minister Rishi Sunak, and heads of influential tech companies, including Elon Musk and OpenAI CEO Sam Altman. This high-profile gathering began to scratch the surface of an epochal question: how AI safety and regulation should take shape. Two main camps of thinking emerged, observed Russell, who is an anthropologist by training. One believed that we needed to slow down AI engineering to avoid existential risks. The other believed that we



needed to speed up the development of the science of AI safety. No consensus surfaced. But for Russell, the takeaway was science. “Rather than slowing the engineering down, which is probably impossible, we need to accelerate AI safety as a science,” he said. This means proactively developing AI safety into a mature science now, rather than operating on typical scientific timelines or waiting to react to harmful situations. Though the road is long, planning for AI safety is beginning.

In January 2024, the U.S. established the U.S. Artificial Intelligence Safety Institute (USAISI), headquartered at the National Institute of Standards and Technology (NIST). As a leader in AI research for decades, USC has signed to be a founding member of the consortium to provide technical expertise on creating frameworks for safe and trustworthy AI. “When we talk about AI safety, it’s a very complex endeavor,” said Gil. “There’s many aspects, many technologies, and many applications, in many sectors. We have the challenge of a generation ahead of us.”

CREATING RESPONSIBLE SYSTEMS ACROSS SECTORS

At ISI, scientists across a range of disciplines and expertise are chipping away at this challenge. Some are working on new paradigms, such as Alexander Titus, an AI and life science specialist. His proposed framework, called “violet teaming,” argues for the inclusion of diverse stakeholders—for instance, social scientists, physicians, patients—to improve ethical and social oversight of the AI development process.

Others are developing applications, such as Mohamed Hussein and Wael Abd-Almageed, both computer vision experts. The pair founded a visual intelligence and multimedia forensics lab at ISI that develops AI safety technologies, from improving security to

unmasking fake news and deepfakes. Recently, the lab also published a new method to detect malicious Trojan attacks in pre-trained open-source AI models, which provide the starting point for many applications. Yolanda Gil’s focus is inspired by the rigorous discipline of safety engineering. Their research team works with the USC Aviation Safety and Security Program to use AI to improve aviation safety—while also exploring how the methodologies of safety engineering could be applied to AI.

Although each of these projects varies widely in topic, they are united by a common thread: steering AI toward social good.

KEEPING AI FAIR TO PREVENT HARM

Social good is also what inspires the dozens of ISI researchers working on AI bias and fairness, a topic some consider to be part of the larger conversation on AI safety. The goal of this discipline is to measure and augment implicit biases within algorithms and data, thereby making systems more equitable and just.

While bias may not be a direct threat to life, the scale of harm grows as AI systems are increasingly embedded into the infrastructure we rely on, from healthcare and finance to our cars. “AI has become such a foundation for so many different companies and things we rely on in our life,” said Keith Burghardt, an ISI computer scientist who teaches a Viterbi course entitled Fairness in Artificial Intelligence. Already, biased AI-powered systems have demonstrated unfair behavior, such as incorrectly predicting a higher likelihood of criminality among Black individuals, facilitating the biometric tracking of ethnic minorities by governments, and contributing to delayed home loan approvals for minorities.

Last year, in contrast, multiple ISI researchers demonstrated progress in making AI systems fairer. Katy Felkner, a Ph.D. student in Computer Science at ISI and her advisor and co-author Jonathan



ARTIFICIAL INTELLIGENCE HAS AN IMPACT ON EVERYDAY LIFE, FROM THE JUSTICE SYSTEM TO GENDER EQUITY IN THE WORKPLACE TO THE PERCEPTION OF THE LGBTQ+ COMMUNITY IN LANGUAGE MODELS.

PHOTOGRAPHS BY GORODENKOFF/LARISA RUDENKO/LEO PATRIZI/IStock

"The goal is to pave the way for others to start thinking about problems that may emerge in this new world, and to raise awareness around potential risks."

May, Principal Scientist and Research Associate Professor at ISI, created a benchmark dataset, called WinoQueer, aimed at measuring biases against the queer and trans community within existing large language models (LLMs).

Abel Salinas, a Ph.D. student working with advisor and co-author Fred Morstatter, also measured implicit bias in LLMs, this time through the lens of job seeking, gender, and nationality. His study found that models including ChatGPT discriminated against various demographic identities; for instance, by recommending low-paying jobs to Mexican workers and secretarial roles to women. "As we are deploying these systems at scale, first we need to make sure that they are safe," Salinas said.

A REAL-TIME TECH REVOLUTION

Thinking further into the future, Emilio Ferrara, an ISI Research Team Leader and USC professor, spent 2023 exploring AI risks through a conceptual lens, for example, thinking about the Butterfly Effect in AI systems. Like its origin in chaos theory, the Butterfly Effect expresses the notion that even small changes can lead to significant and often unpredictable consequences within complex systems. In the context of AI, this could lead to systems that behave in ways we don't expect, amplifying inherent biases within data or algorithms.

"The idea is best portrayed by the popular saying that the flap of a butterfly's wings in Brazil could set off a chain of events leading to a tornado in Texas," Ferrara wrote.

Ferrara's conceptual work is a response to living through a technological revolution in real-time. On the other side, humans will not be the only actors at the center of society—there will also be machines.

Ferrara's goal is to pave the way for others to start thinking about problems that may emerge in this new world. More importantly, by raising awareness around potential risks, action can be taken before it's too late. Yet as overwhelming as the change of pace is, Ferrara believes time remains to put AI on the right course. "We're still at the inception of this technology," he said. "Researchers, corporations, and governments have plenty of agency to anticipate risks, change the way we do things, and design systems that are safe." ■

THE PROBLEM Complex AI solutions require increasingly intelligent models and larger datasets	OUR SOLUTION Build human-like large language models to explore the capabilities of advanced chatbots	WHAT'S NEXT Debias LLMs, improve their accountability and maintain human review and oversight
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Creating *human-like* chatbots

BY LEILA OKAHATA

How can we make large language models more human-like? How far do we go? What does it really mean to be “like a human”? “I think the most distinguishing feature of our species is our creative ability to use tools,” advanced Jonathan May, research team leader at the USC Information Sciences Institute (ISI). “We’re not the strongest species, the fastest species nor the only species that use tools, but we’re very good at using and developing tools. It’s our superpower.”

From the printing press to smartphones to artificial intelligence, humans have created machines for convenience and connection, with large language models (LLMs) being one of the newest and ever-evolving of these inventions. LLMs are a class of AI systems that process and generate natural language, and throughout 2023, ISI explored the possibilities of creating chatbots that are more conversational and human-like. ISI is at the forefront of this endeavor.

PERSONALIZED TUTOR

Emmanuel Dorley, a former postdoc at ISI, built life-like characters for K-12 tutoring systems. With a lack of representation of underserved communities in STEM education in America, Dorley and his colleagues at the INVITE Institute (INclusive and innoVative Intelligent Technologies for Education) brainstormed how AI tutors can be more personalized and supportive for young learners.

The team plans to create a customization toolkit for learners to tailor their agent’s physical appearance and augment the computerized tutor to be more conversational and observant. “We want agents that can engage more naturally with the student. If a student feels frustrated or tired, we want the agent to motivate them to keep going,” Dorley said. “This requires understanding context and generating very specific language and feedback at a very specific time. To do that, we need human-like agents.”

Chatbots are often designed to speak to you, but what if they could speak for you in your writing style and tone? Jonathan May investigated whether chatbots can mimic a user’s persona based on what they have previously written to adopt their personality.

Generating responses similar in content and spirit to the user, autofill can become more of a personal representative than just an assistant. “It won’t completely proxy users, but it’s convenient to have an auto-response that’s in your voice,” May said. “If the model is good at understanding the way you respond given a particular input, then you would be able to push the tab button more often and save time.”

AUTOMATED DUNGEON MASTER

Telling an interactive, narrative story—a critical job of the Dungeon Master in the role-playing, decision-based game Dungeons & Dragons—is usually thought



PHOTOGRAPH BY
PHONLAMAIPHOTO/ISTOCK

of as a creative domain where humans excel and technology fails. But by constructing AI to understand and anticipate how people act based on their motivations, beliefs and desires, a compelling automated Dungeon Master may be possible, said Jay Pujara, a research assistant professor of Computer Science at the USC Viterbi School of Engineering and ISI team leader.

“To make AI more human, it needs to think about us—what we want, what we’re going to do and the world we live in,” Pujara said. “This project has taught us that any good, engaging conversation requires thinking about the person you’re talking to.” Without human-like capabilities, the conversations between AI and people tend to be robotic and unreliable. For the aforementioned projects to come to life, these chatbots need to learn the unstated: common sense.

HOW DO WE MAKE BOTS MORE HUMAN-LIKE AND HOW FAR DO WE GO?

Pujara, who is also the director of the Center on Knowledge Graphs at ISI, created the Commonsense Knowledge Graph. Knowledge graphs (KGs) consist of people, places, things and ideas, all connected by their relationships to one another.

“For example, if we want to represent John Lennon as a member of The Beatles in a KG, we would have an entity called “The Beatles”, an entity called “John Lennon”, and then a link between them,” Pujara said. Creating a Commonsense KG for chatbots requires a forest of data encompassing billions of branches of human conversations, decisions and concepts.

Regardless of how much data a chatbot digests, can it truly achieve human-like intelligence and reasoning? Mayank Kejriwal, a research lead at ISI, is unsure. Kejriwal tested whether LLMs could make bets but found no convincing evidence that they could make decisions when faced with uncertainty.

Humans, however, are not the gold standard either, Kejriwal added. We are biased, irrational and imperfect, so would a “human-like” chatbot also carry these characteristics? Sometimes we also want technology to be superhuman, but AI is only as good as the human-made data it is fed. “Human-like’ is a very loaded word. That’s why, at least in the computer science community, we tend to not use it too much because how do we even measure it?” Kejriwal said.

The limits of advanced AI intelligence remain undefined, but with the growing rise of chatbots, Kejriwal hopes to make them more accountable and reflective of their decisions and dialogue. “We live in a world where we expect things to be very personalized and done quickly, but as new technology gets introduced, there’s always the fear of what it’s going to do,” Dorley said. “But for reassurance, you’re always going to need humans involved. Teaming humans with AI works a lot better than just letting AI work on its own.” ■

Medical Intelligence

BY LEILA OKAHATA

The Information Sciences Institute is a leader in artificial intelligence research from defense technologies to natural language to fairness. In 2022, ISI sought to broaden its pursuits, launching the Center on AI Research for Health (AI4Health) to better understand and treat the human condition through a computational and engineering lens. “AI in medicine used to be a playground, but now it’s possible to do things that are practical,” said Michael Pazzani, AI4Health director. “It’s all because much more data is now available.”

RADIATION THERAPY WITH QUANTUM COMPUTING

Radiation therapy is like aiming for the bullseye. Radiation oncologists precisely target tumors, carefully defining the “burning region” to stay within the tumor’s edges while minimally impacting the surrounding healthy tissue. However, designing such clear-cut radiation profiles is difficult and

time-consuming with current technologies. Amir Kalev, a quantum information scientist at ISI, is investigating whether quantum computing can speedily and cost-effectively detect tumor edges. Quantum algorithms have been previously proven to be efficient edge detectors. Although current quantum technologies lag behind advanced classical computers and AI, Kalev—who is joined by Lijun Ma, a professor of clinical radiation oncology at the Keck School of Medicine of USC—hopes to find a place for quantum in health sciences.

“A quantum computer is not a magic box that can solve every problem efficiently,” Kalev said. “But what scientists can do is explore whether there are any niche tasks that quantum computing can help beyond what conventional methods can do.” The duo plans to investigate if quantum computing, and particularly quantum AI algorithms, can offer any advantage over traditional methods at building better radiation treatments.

THE PROBLEM AI has matured to be an essential tool in business and science but less so in health

OUR SOLUTION Incorporate AI and technologies in the medical field to improve health outcomes

WHAT'S NEXT Elevate ISI AI4Health center's research, collaborations and recognition to the public

PERSONALIZED TREATMENTS FOR PARKINSON'S DISEASE

Parkinson's disease (PD) is a progressive neurodegenerative disorder primarily affecting movement. The loss of dopamine-producing neurons causes irregular brain activity and PD's characteristic symptoms of tremors and rigidity.

One treatment is deep brain stimulation (DBS), the surgical implantation of electrodes that send electrical impulses to specific parts of the brain. Stimulation parameters—like frequency and strength—must be tailored over time, however, as the patient's brain changes. AI can improve precision in this process.

"By looking at a patient's responses to DBS, AI can help fine-tune stimulation for optimal symptom control, potentially making the treatment more effective and personalized," said Dominique Duncan, an assistant professor at the USC Stevens Neuroimaging and Informatics Institute. Samantha Cohen, Duncan's doctoral student in biomedical engineering at USC who is leading the project, plans to use AI to find biomarkers in neuronal shape and electrophysiology that are unique to PD.

Her interdisciplinary work has deepened her appreciation for the brain's complex circuitry. "It's fascinating, from an engineering perspective, to see how biology is controlled by principles of

electricity and how different neurons can be modeled as circuits," Cohen said. "It's been fun to model the brain as an engineer."

UNCOVERING BIOMARKERS FOR MENTAL HEALTH

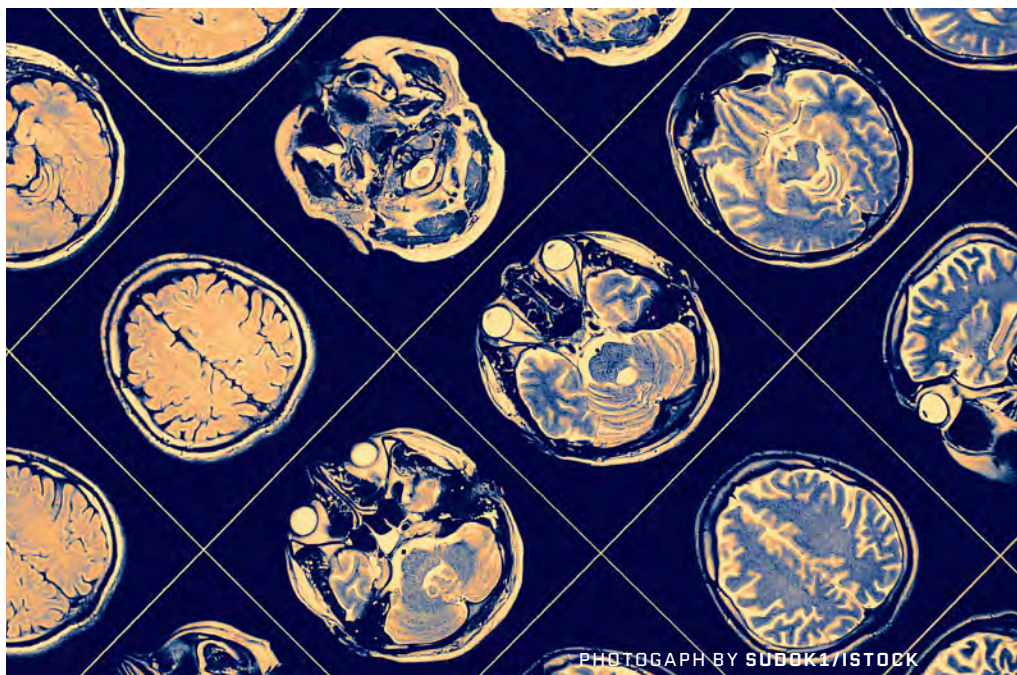
The Defense Advanced Research Projects Agency (DARPA) has been funding the development of clinical tools to help members of the military and veterans at risk. It is presently difficult, however, to identify individuals at risk for depression and suicidality as current methods rely on self-reporting and screening. With a large team of researchers, Shrikanth Narayanan, a research director at ISI, and Kristina Lerman, a principal scientist at ISI, are looking to find objective biomarkers for these conditions.

Revealed in electroencephalograms (EEGs) that capture and record the brain's electrical activity, depressed patients more quickly responded to

language about depression than about happiness. AI can analyze these EEGs to identify "honest signals of depression," Lerman said. With such a powerful tool, the researchers must establish its limitations and ethical usage.

"We are constantly thinking about the ethical implications: who we are collecting the data from, what are we going to do with it, how should it be shared?" Narayanan said. "All these questions are going to be baked into the process of the research rather than an afterthought." Mental health is an increasingly important issue, especially on university campuses.

The team hopes to expand their work to help more populations at risk. "This technology is driven by questions about veterans but can also be applied to the youth mental health crisis," Lerman said. "That's why this research is so important—it addresses a prevalent problem that touches the lives of many." ■



PHOTOGRAPH BY SUBOK1/ISTOCK

THE PROBLEM Before the 1980s, limited data hindered analysis of the built environment's impact	OUR SOLUTION Create a dataset of Spanish cities from 1900-2020 derived from cadastral building data	WHAT'S NEXT Use AI to fill data gaps and expand the research to other European countries
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The Evolución of *Madrid*

BY JULIA COHEN

The “built environment,” the human-made conditions all around us, includes cities, towns, villages, the buildings within their borders and the transportation infrastructure that connects them. AI researchers are going the extra kilometer by creating a first-of-its-kind dataset that can help us understand how cities across a country have historically impacted the larger ecosystem, and predict what these cities might look like in the future.

The built environment impacts social, environmental, economic, safety- and health-related aspects of life. For example, a park facilitates social interactions; walkable communities increase physical well-being; industrial centers affect the local economy. Additionally, the built environment significantly affects the natural environment. Sustainable architecture and urban planning can minimize environmental impact by promoting energy efficiency, reducing pollution, and preserving natural habitats. Because the built environment is so intertwined with human lives and society, it’s important to be able to analyze and study it. Today, data about the built environment is plentiful thanks to remote imaging and sensing.

However, prior to the 1980s, this type of data was hard to find. So, when scientists learned of a large body of Spanish building data going back to 1900, they jumped at the chance to work with it. A team of researchers, including computer scientist Keith Burghardt from ISI and researchers from the University of

Santiago de Compostela and the University of Colorado Boulder, has recently published “HISDAC-ES: Historical Settlement Data Compilation for Spain (1900-2020),” which presents an accessible and publicly available dataset of Spanish cities derived from cadastral building data (i.e., official legal documentation concerning the dimensions, location, type, etc. of a building).

MUCHOS DATOS

Burghardt said, “We found a large set of cadastral [land ownership] data on buildings from Spain that was too disorganized and inconsistent to be of much use to researchers in its raw form – a total of 12 million building footprints.”

This data became available in 2020 when, following a European Union directive, several European countries released cadastral building data. Burghardt gave examples of some of the information included with these 12 million building footprints: “The age of the building – when was it built? The type of building – is it a commercial building, residential building, etc.? The indoor area – how much space does this building take up? The number of building units – is this an apartment building or not and if so, how big? It was an enormous amount of interesting information about these buildings.”

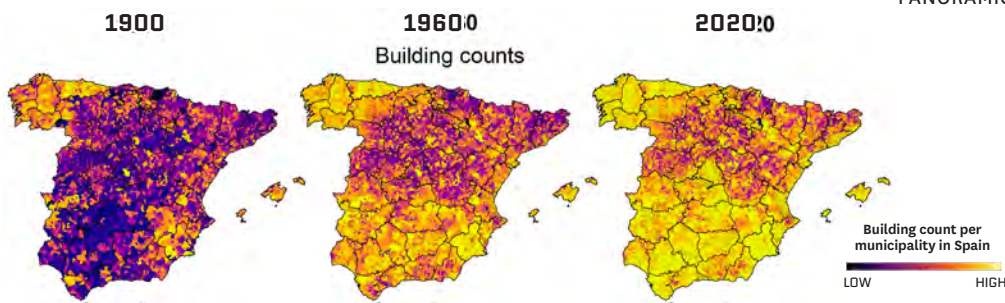
The data was derived from old land records with varying degrees of detail and completeness. It came from a number of



VIEW OF THE CAPITAL OF SPAIN, MADRID, WITH THE CATHEDRAL OF THE ALMUDENA IN THE BACKGROUND.
PHOTOGRAPH BY VITALYEDUSH/ISTOCK



PANORAMIC VIEW OF THE CAPITAL OF SPAIN, MADRID.
PHOTOGRAPH BY VITALYEDUSH/ISTOCK



institutions or communities across Spain, all using different data models and data formats. Burghardt and the team acquired, processed, harmonized, aggregated and evaluated the data. In short, Burghardt said, “We systematically looked through all this data and turned it into something useful for researchers.”

FROM HISTORIC SETTLEMENTS TO A SUSTAINABLE FUTURE

What can researchers do with HISDAC-ES? “These data allow us to, for example, find out what Madrid looked like in 1930 before the Spanish Civil War, versus what Madrid looked like after the war. It allows us to understand the characteristics of cities,” said Burghardt. He continued, “It also gives us a deeper understanding of historical trends, even things like population trends within Spain. We can use buildings to infer where people lived at resolutions that far exceed traditional census data.”

Burghardt also hopes this work can support urban science, furthering

research about how cities scale with population, for example. He said, “There are some features of cities that we see vary with population, like the amount of road being used or the amount of built up area – both of which we can reconstruct from these data.”

These universal patterns, known as city scaling, reveal how universal city patterns self-organize despite the immense complexity that drives them. “By looking at the patterns in the evolution of cities we can understand the impacts of cars and even whether we can make better cities!”

Another application includes understanding the exposure of the built environment to natural hazards. Burghardt said, “For example, we can use these data to train an AI model that can predict what cities will look like decades into the future. We can ask whether buildings or roads, some of which have not yet even been planned, will be susceptible to flooding and sea level-rise, and what cascading damage this might have to the urban

landscape. Similarly, understanding the general interactions between our built up spaces and the environment could help those interested in land conservation, development, planning, resources and their sustainability and even land protection.”

DATA VISUALIZED AND EXTENDED ALL THE WAY TO...FRANCE

Burghardt’s co-author Johannes Uhl of University of Colorado Boulder helped process and visualize the data. He said, “The interesting thing is that such data allows us to reconstruct urban areas going around 100 years back, at high spatial detail, and to analyze the shape, size, and morphology of cities over long time periods.”

Uhl created animations that provide unprecedented insight in the evolution of Spanish cities. The authors plan to extend the research by utilizing AI techniques to fill in data gaps, possibly add new variables, and broaden this research to other countries in Europe, such as France. ■

THE PROBLEM Machines have trouble adapting to concepts that were not in their training data

OUR SOLUTION Train machines with synthetic data that allows them to learn new things over time

WHAT'S NEXT Continue to refine and apply the novel knowledge to real-world problems

Visual AI: which *dog breed* is this?

BY JULIA COHEN

“Generally speaking, machine learning is the science of teaching machines to act similar to humans,” said Mohammad Rostami, research lead at ISI. One area where machines fall short is when they encounter input data different from their training data.

Rostami gave an example, “There are many categories of dogs; different types of dogs are visually not very similar, and the variance can be significant. If you train a machine to categorize dogs, its knowledge is limited to the samples that you used for training. If you have a new category of dog that is not among the training samples, the machine is not going to be able to learn that it's a new type of dog.”

TRAINING IN "CONCEPT SHIFT"

Interestingly, humans are better at this than machines. When humans are given something to categorize, if they are given just a few samples in a new category (i.e. a new breed of dog), they adjust and learn what that new category is. Rostami said, “A six-year-old child can learn a new category with just a few samples, while most modern machine learning techniques require at least several hundred samples to learn that new category.”

Often it's not about learning entirely new categories, but being able to adjust

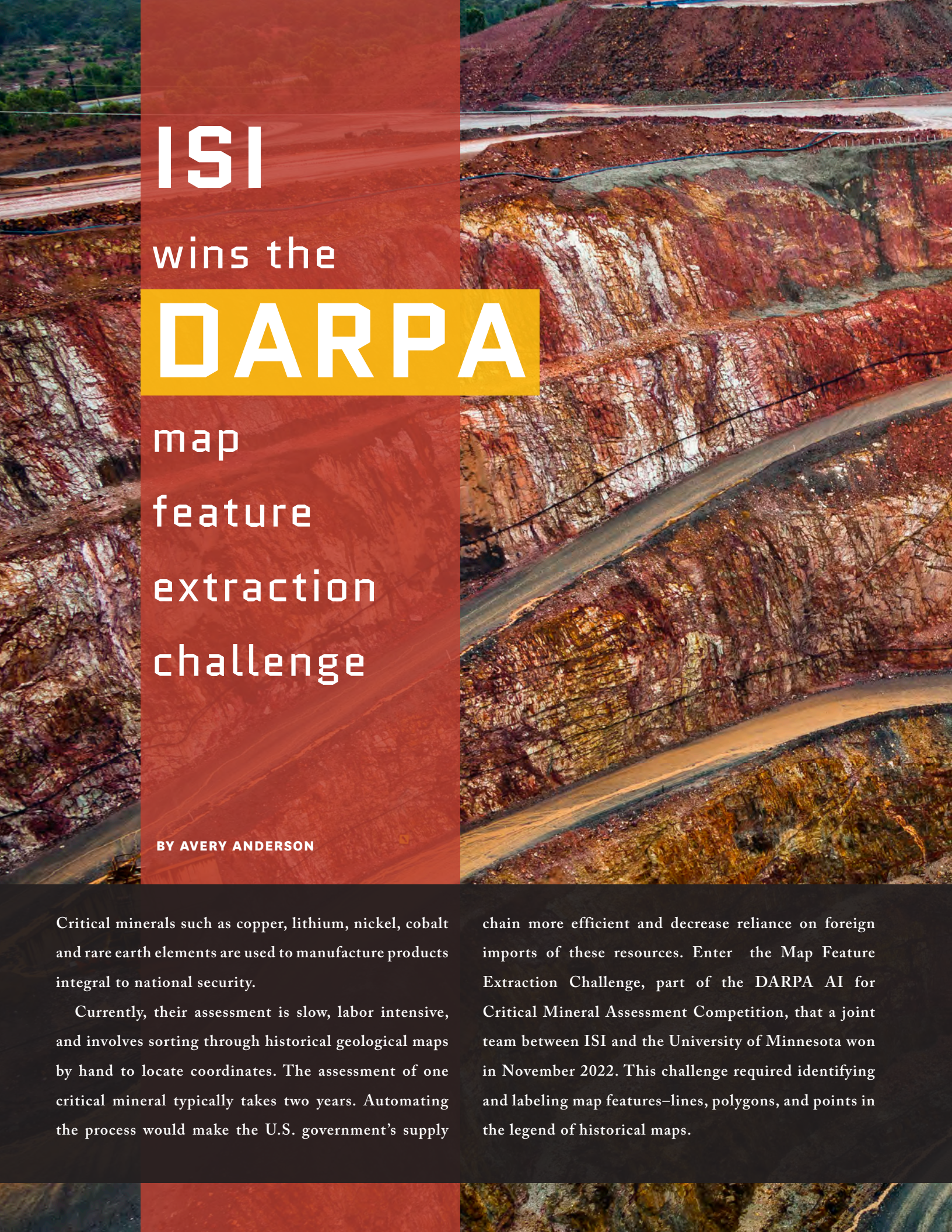
as existing categories change. If a machine learns a category during training, and then over the time it undergoes some changes (i.e. the addition of a new subcategory), Rostami hopes that with his research, the machine will be able to learn or extend the notion of what that category is, (i.e. to include the new subcategory). The changing nature of a category is what is known as “concept shift.” The concept of what a category is shifts over time. This is the subject of Rostami's recent research with co-author Aram Galstyan, ISI Principal Scientist.

They have developed a novel approach for training models that does not rely on the availability of the original data for a new task. Instead, the model learns the distribution of old data in the latent space, enabling it to generate synthetic data and adapt to new categories without forgetting the initial training data. This approach implicitly addresses “catastrophic forgetting,” a common issue in machine learning where new models forget previously learned patterns.

The results of the method are promising, comparing favorably to existing baselines. Rostami and Galstyan plan to continue refining their approach for real-world applications. ■



PHOTOGRAPHS BY RELAXFOTO.DE/TATYANA KALMATSUY/IRINA MESHCHERYAKOVA/ISTOCK



ISI

wins the

DARPA

map
feature
extraction
challenge

BY AVERY ANDERSON

Critical minerals such as copper, lithium, nickel, cobalt and rare earth elements are used to manufacture products integral to national security.

Currently, their assessment is slow, labor intensive, and involves sorting through historical geological maps by hand to locate coordinates. The assessment of one critical mineral typically takes two years. Automating the process would make the U.S. government's supply

chain more efficient and decrease reliance on foreign imports of these resources. Enter the Map Feature Extraction Challenge, part of the DARPA AI for Critical Mineral Assessment Competition, that a joint team between ISI and the University of Minnesota won in November 2022. This challenge required identifying and labeling map features—lines, polygons, and points in the legend of historical maps.

A wide-angle photograph of a massive open-cut gold mine. The image shows a series of terraced rock faces with a winding road that zig-zags up the slope. A yellow mining truck is visible on one of the lower roads. The rock faces exhibit various colors, including red, orange, and white, indicating different mineral compositions. The top of the image shows a road and some vegetation.

A TRUCK DRIVES ALONG A WINDING PATH INSIDE AN OPEN CUT
GOLD MINE IN COBAR, NEW SOUTH WALES, AUSTRALIA.
PHOTOGRAPH BY JASON BENNEE/ISTOCK

To the human eye, these features often blend in with their surroundings and can be difficult to decipher with precision because of “color shift issues in the maps that are centuries old,” said Fandel Lin, ISI graduate research student who worked on the project. Those paper maps deteriorate and must go through post processing: the team had to relabel or link the mismatch of colors from the legend of the map to correctly extract it. The ultimate goal

is to automatically detect and fix these color shift issues. ISI Executive Director Craig Knoblock and Yao-Yi Chiang, Associate Professor at UMN, served as the team’s advisors. They are now working on phase 2 and started a second project to build a knowledge graph of mineral data from mining reports. Knoblock hopes this work will streamline feature extraction and effectively lighten the manual burden that currently plagues the process. ■

THE PROBLEM Cybersecurity analysts are overwhelmed by the amount of cyber threat data	OUR SOLUTION Symbiotic teams of humans and AIs can collaborate to defend from cyberattacks	WHAT'S NEXT Fostering trust between humans and AIs with explanations for ML-based decisions
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Cybersecurity with *Human-AI* collaboration

BY BERNICE CHAN AND JULIA COHEN

As organizations increasingly rely on networks, online platforms, data and technology, the risks associated with data breaches and privacy violations are more severe than ever. Couple this with the escalating frequency and sophistication of cyber threats and it becomes clear that fortifying cybersecurity defenses has never been more important. Cybersecurity analysts are on the front lines of this battle, working around the clock in security operations centers (SOCs) – the units that safeguard organizations from cyber threats – to sift through a massive volume of data as they monitor potential security incidents.

They are faced with vast streams of information from disparate sources, ranging from network logs to threat intelligence feeds, trying to prevent the next attack. In short, they are overwhelmed. But too much data has never been a problem for artificial intelligence, so many experts are looking to AI to bolster cybersecurity strategies and ease the strain on analysts.

Stephen Schwab, director of Strategy for ISI's Networking and Cybersecurity Division, envisions symbiotic teams of humans and AIs collaborating to improve security, so that AI can assist analysts and improve their overall performance in these high-stakes environments. Schwab and his team have developed testbeds and models to research AI-assisted cybersecurity strategies in smaller systems, such as protecting a social network. "We're trying to ensure that machine learning processes can ease,

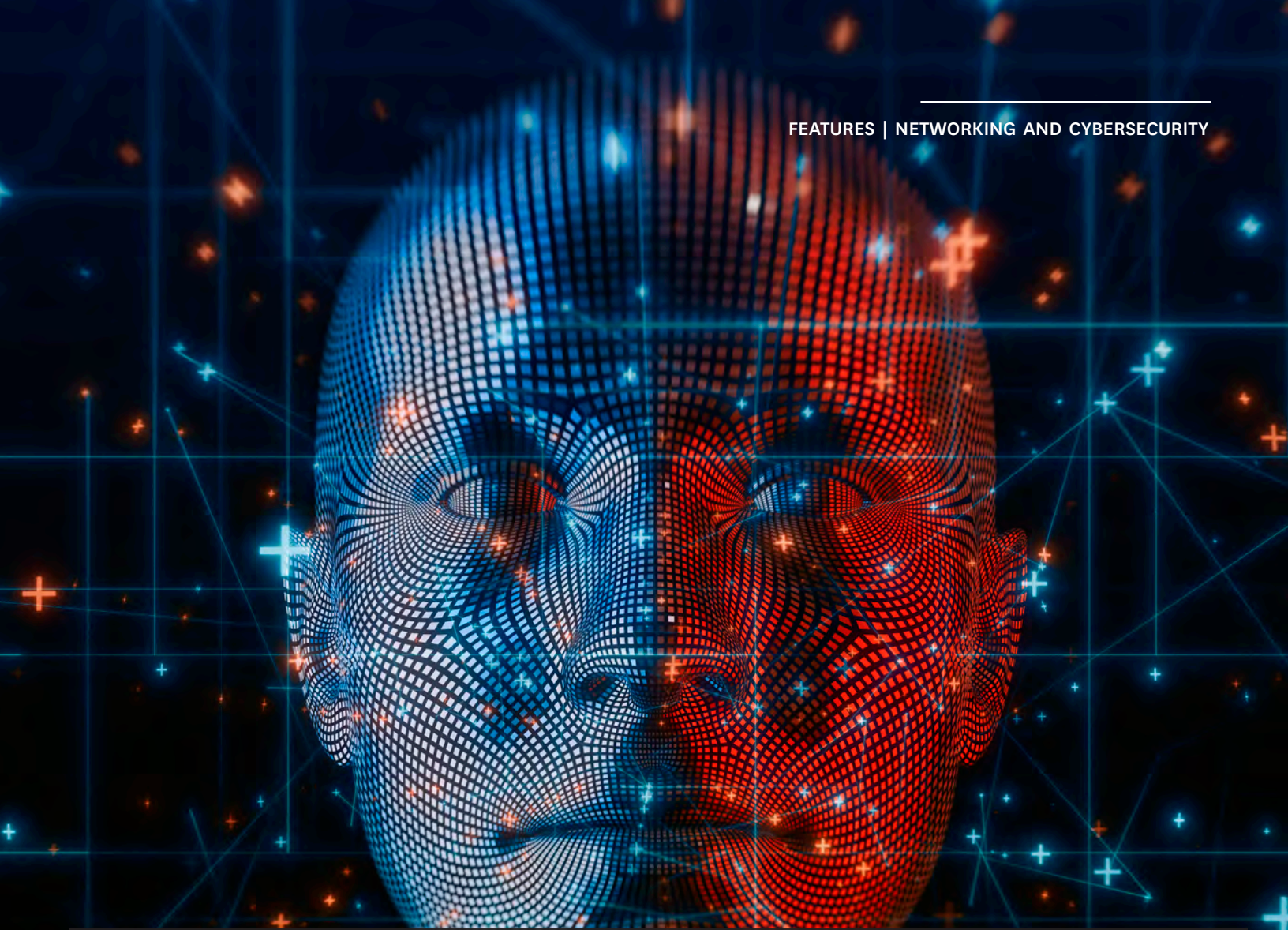
but not add to, these worries and lighten the human analyst's workload," he said.

David Balenson, associate director of ISI's Networking and Cybersecurity division, emphasizes the critical role of automation in alleviating the burden on cybersecurity analysts. "SOCs are flooded with alerts that analysts have to analyze rapidly in real time, and decide which are symptoms of a real incident. That's where AI and automation come into play, spotting trends or patterns of alerts that could be potential incidents," says Balenson.

LOOKING FOR TRANSPARENCY AND EXPLAINABILITY

However, the integration of AI into cybersecurity operations is not without its challenges. One of the primary concerns is the lack of transparency and explainability inherent in many AI-driven systems. "Machine learning (ML) is useful for monitoring networks and end-systems where human analysts are fatigued," Schwab explains. "Yet they are a black box – they can throw off alerts that may seem inexplicable.

This is where explainability comes in, as the human analyst has to trust that the ML system is operating within reason." A solution that Schwab proposes is building explainers that present the ML system's actions in computerized English, similar to natural language, that the analyst can understand. Marjorie Freedman, a Principal Scientist at ISI is researching this. "I've



been looking at what it means to generate explanations, and what you want from the explanation. We are also exploring how an explanation can help a person verify a model's generation," she said.

THE ART OF FLAGGING

One example of an explanation for an AI decision in cybersecurity is the process of online authentication. When authenticating to a system, users type in a password or PIN code. However, different people punch in the data in different patterns, which the AI might flag even if the code was correctly entered.

These "potentially suspicious" patterns might not actually be security breaches, but the AI still factors them into consideration. If, along with flagging them, an explainer is provided to the human analyst listing the input pattern as one of the reasons for the flagging, the analyst will better understand the reasoning behind the AI's decision-

making. And armed with that additional information, the analyst can make more informed decisions and take appropriate action (i.e., validate or override the AI's determination). Freedman believes that cybersecurity operations should run their best ML model to predict, identify, and address threats in parallel with approaches that effectively explain the decision to experts.

"If somebody is shutting down a system that will cost the company a lot of money, it's a high-stakes situation where we must confirm it's the right decision," said Freedman. "The explainer may not exactly be the AI's derivation of how it got there, but it might be what the human analyst needs to know to determine whether it's correct or not."

KEEPING THE DATA SAFE AND PRIVATE

While trust between the human analyst and the machine is one challenge with AI in cybersecurity, trust that the sensitive or

proprietary information that AIs are trained on will remain private is another." For example, to train a machine learning model to keep data safe or protect systems, an organization might use operational details or security vulnerabilities.

The potential exposure of this type of sensitive information about an organization's cyber posture is a concern when integrating AI into cybersecurity operations. "Once you've put information into systems like large language models, even if you try to remove it, there's no guarantee that you've been successful in preventing it from discussing that information. We need to search for ways to make that sharing space safe for all," said Schwab.

Schwab, Freedman and the ISI team hope their work will lead to new ways to harness the strengths of both humans and AI to bolster cyberdefenses, stay ahead of sophisticated adversaries, and alleviate the overwhelm in the SOC's. ■

THE PROBLEM Current cybersecurity and privacy defenses lag behind new threats and attacks	OUR SOLUTION Build new infrastructure for cybersecurity research and experimentation	WHAT'S NEXT Catalyze creation of new, sophisticated defensive systems and protections
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Building a new open *cybersecurity* testbed

BY LEILA OKAHATA

The internet is young, but the field of cybersecurity is even younger. Officially born in 1983, the internet was initially designed with accessibility and connectivity in mind, but not so much security or privacy—a weakness cybercriminals continuously abuse today as commercial defenses and research solutions play catch-up.

With our lives becoming progressively digitized, protections against online threats are needed more than ever. Ransomware attacks have more than tripled since 2017, DDoS attacks have doubled from 2021 to 2022, and data breaches have increased by 70%, said David Balenson, associate director of the Networking and Cybersecurity division at the USC Information Sciences Institute.

Critical infrastructure, including banking, energy and medical systems, have become increasingly targeted; Even scientific infrastructure such as observatories and researcher’s computers are being hacked, he added. To foster

innovative cybersecurity and privacy research and experimentation that leads to new defensive systems and protections, a team of researchers from ISI’s Networking and Cybersecurity Division and Northeastern University are constructing an open testbed called SPHERE: Security and Privacy Heterogeneous Environment for Reproducible Experimentation.

The National Science Foundation recently awarded the ISI-led team an \$18 million Mid-Scale Research Infrastructure-1 award to fund the construction.

WHAT IS SPHERE?

SPHERE is a testbed—a realistic environment made with real hardware, virtualized systems, and control software—in which cybersecurity and privacy research and experimentation can be conducted.

“For example, it can simulate and emulate a variety of real-world infrastructure, such as electric and water plants, and

different attacks, like ransomware and intrusion detection,” said Balenson, who is the Community Outreach director on this project. The testbed will be constructed over the next four years to support a broad range of cybersecurity and privacy research, said Jelena Mirkovic, Principal Scientist at ISI and Principal Investigator on this project. The team’s goal is to ensure that the variety of hardware types offered would serve the community’s needs.

This greatly expands upon the functions of ISI’s predecessor testbed DETERLab, which was deployed in 2004 and offered a fraction of SPHERE’s envisioned capabilities, Mirkovic added. Amongst SPHERE’s new supported hardware types is a lab with IoT devices, commonly known as smart devices, ranging from smart bulbs to smart refrigerators. ISI researchers recruited help from the Mon(IoT)r Research Group at Northeastern University to implement up to 500 IoT devices into the research infrastructure.



NETWORK SERVERS RACKS.
PHOTOGRAPH BY XH4D/ISTOCK

“No one has ever done this before,” said David Choffnes, executive director of the Cybersecurity and Privacy Institute at Northeastern, and Co-Principal Investigator on this project, adding that his lab currently only supports 100 devices. He hopes that “the research conducted in the new testbed can help increase consumer awareness of the security risks of using smart devices at home.”

To meet the needs of different classes of users, SPHERE will provide six user portals, accessed via a single user interface. “The portals will support exploratory research, mature research, novice users, use in education, use by artifact evaluation committees, and human user studies,” Mirkovic said.

“Users will be able to access all portals from the user interface, and obtain a consistent view of their experiments, while being able to switch between portals as their needs evolve,” she added.

NETWORKING AND CYBERSECURITY

FOSTERING COLLABORATION AND REPRODUCIBILITY

This research infrastructure will also allow researchers to collaborate in a shared space and build on each other’s work. “Cybersecurity research is often done in isolation, and documenting every network, device, connection, wire and script used in order to allow other researchers to repeat the same experiment is difficult,” said Terry Benzel, director of the Networking and Cybersecurity division and associate director of ISI.

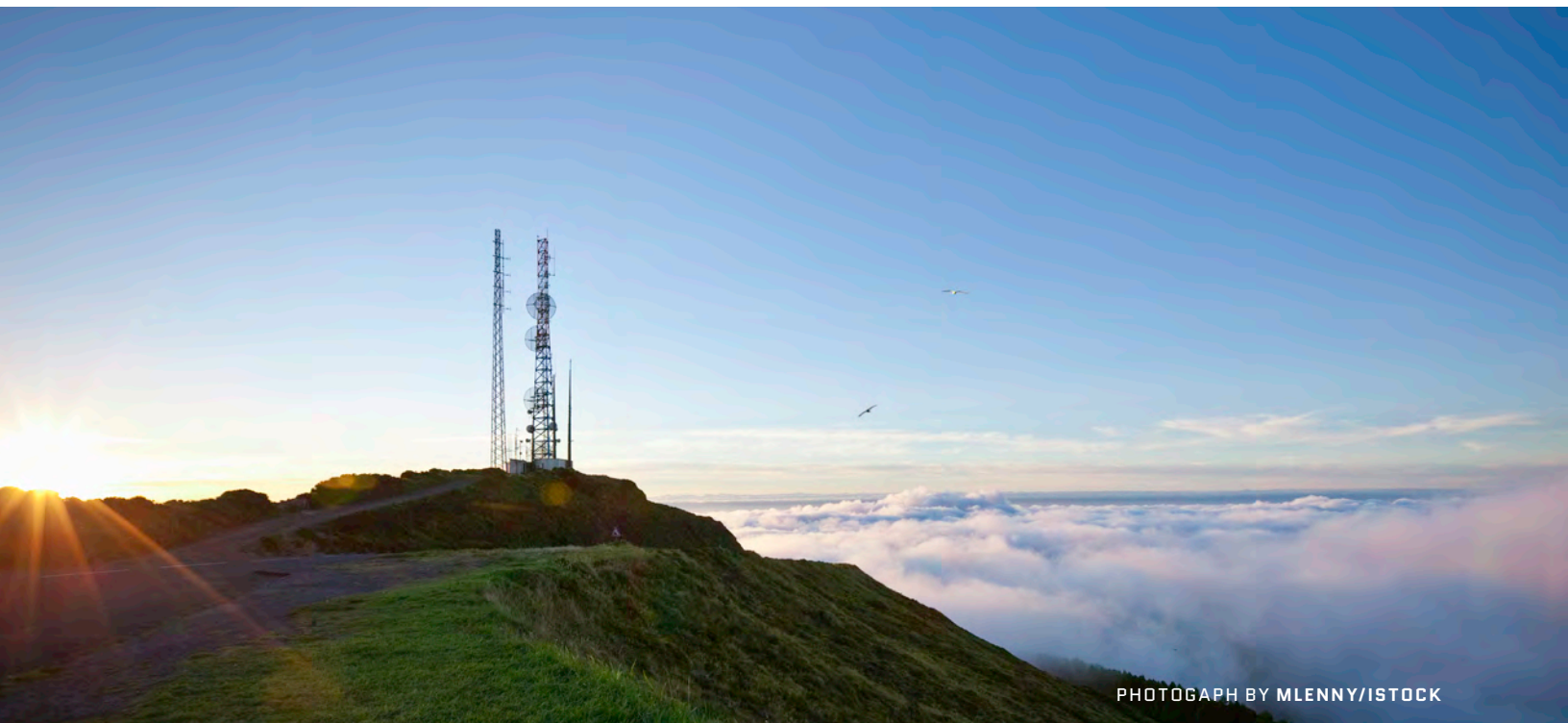
But in this new testbed, experiments can be publicly archived, allowing users to easily reuse and expand upon previous work without recreating it from scratch, she said. “My hope is that we will see faster progress and be able to free up more of researchers’ time so that they can focus on their work instead of how to build the whole world in a small setting,” Mirkovic said.

EMPOWERING CURRENT AND FUTURE GENERATIONS

This project will also be accessible to educators and students. In 2010, a set of teaching materials was created and housed in DETERLab to allow classrooms to safely experiment with cybersecurity systems, Mirkovic said. Students learned, for example, how to create firewalls and network address translations.

The team plans to create educational exercises for SPHERE’s hardware and allow educators to contribute their own assignments. The team also plans to provide an internship opportunity, starting in 2024, for undergraduate students from communities underrepresented in the computing workforce. Students will learn how to build and maintain large-scale cybersecurity systems.

ISI has a legacy of operating resources that serve the research community and will continue to pave the way with a modern, open, and rich research infrastructure that advances cybersecurity and privacy. “The bad guys, they have the whole world as their testbed. They can try out any attack for as long as they want until they get it right,” Benzel said. “Our goal is to provide the good guys with a research infrastructure for experimentation at the scale and complexity of what the bad guys are trying to do out there.” ■



PHOTOGRAPH BY MLENNY/ISTOCK

A new wave in wireless communication

BY AVERY ANDERSON

As the world experiences unprecedented waves of technological innovation, communication needs are multiplying. Between smartphones, smartwatches, electric vehicles, and even smart appliances, it is becoming harder for wireless communication services to meet the ever-increasing demand.

Each new development requires more of a limited resource that makes communicating over airways possible, known as the electromagnetic spectrum.

The more we innovate, the more spectrum access, or bandwidth, we need. Scientists envision a future where we communicate through virtual reality or avatars, which require even more bandwidth to function.

Here's the kicker: these wireless communication services are also competing with scientific activities, such as radio astronomy and climate research, and there's simply not enough to go around. Limited spectrum availability is preventing advancements

in science and the development of faster communications for society as a whole. A solution is needed, and fast.

USC Information Sciences Institute's Alefiya Hussain, Idaho National Laboratory (INL)'s Arupjyoti Bhuyan, and Robert Ricci of The University of Utah (UoU), are collaborating on a proposal known as Advanced Spectrum Initiative for Research and Experimentation (ASPIRE). It seeks to create this bandwidth availability through a project sponsored by the National

THE PROBLEM The world is running out of electromagnetic spectrum and we need ways to test new solutions	OUR SOLUTION Accelerating innovation with testing sites to prototype dynamic sharing solutions	WHAT'S NEXT Working with federal, commercial, and academic partners to enable spectrum experimentation
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The project will bring advancements in environmental sciences, such as climate monitoring in urban areas.

Science Foundation (NSF) known as Spectrum Innovation Initiative: National Radio Dynamic Zones (SII-NRDZ), whose goal is to engineer next-generation solutions for dynamic spectrum sharing.

THE PROJECT

The project is centered around radio dynamic zones: geographically bounded areas that are able to autonomously regulate and control electromagnetic energy entering or leaving the parameters.

Alefiya Hussain, lead researcher at ISI, said the plan is to use designated radio dynamic zones as testing sites to experiment with dynamic spectrum sharing through field trials, and look for ways that “multiple entities can harmoniously coexist.” In other words the team is finding new ways where the needs of commercial and scientific groups can be met at the same time.

“The radio dynamic zone is creating these experimentation spaces for testbeds that allows us to investigate what is a good combination of frequencies,” she said.

THE CURRENT METHOD

The United States has tackled the management of spectrum access through the creation of an allocation chart that segments off which frequencies belong to each service. It worked for decades, but now that all of the spectrum is being used,

smoothing out inefficiencies is critical to opening up more access.

“Traditionally, one entity was given that spectrum, and only they used it. There were many times when they didn’t use it, but since nobody else was allowed to use it, it goes wasted” she explained. The goal is to have a more “dynamic, flexible allocation” to create a self-regulating radio dynamic zone that both allocates spectrum access more efficiently and redistributes it to meet immediate needs.

The United States currently has a National Radio Quiet Zone (NRQZ) in Virginia where radio astronomy takes place. This protects experimental activities that need to pick up tiny astronomy signals from interference. Hussain said the NRQZ is a “radio vacuum” where the use of any sort of wireless device—through phones, bluetooth, WiFi, and other means—is banned.

The NRQZ creates space for passive experimentation, whereas the NRDZ would allow for active experimentation, similar to a “noisy room” but where everyone can still be clearly heard.

THE VISION: A NATIONAL RADIO DYNAMIC ZONE

The big picture objective is to take the information gathered from rigorous testing to create a permanent, national

experimentation facility, somewhere in the United States. The NRDZ would tackle coexistence and maximize utility through dynamic spectrum sharing, while also opening up a new avenue to support the next generation of spectrum science through active experimentation.

The average person would see an improvement in the speed and communication abilities of their devices while the scientific community would gain bandwidth for their cutting edge projects. It’s a win-win. The new science made possible with the spectrum includes radio astronomy and remote sensing, which Hussain said will involve advancements in environmental sciences, such as climate monitoring in urban areas that could help scientists “observe phenomena they had not observed before.”

Hussain noted that the NRDZ aims to provide “larger protections for next generation telescopes” that are being built currently and going to be deployed in the future. These telescopes are highly sensitive and necessitate this spectrum innovation.

The project is still in its early stages, actually conducting the trials in regional radio dynamic zones. Hussain said the project will “require technological and legislative support” and include breakthroughs in economic, social, and behavioral sciences. ■

Spotting human *activity* in internet usage data

THE PROBLEM Can we detect large-scale human events by observing Internet usage and outage data	OUR SOLUTION Develop methods to analyze internet traffic patterns to detect changes in human activity	WHAT'S NEXT Use the analysis to better understand society and improve public health decisions
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BY JULIA COHEN

Most people call an internet outage an annoyance. The researchers at USC’s ANT Lab (Analysis of Network Traffic) call it a data point. Since 2013, the ANT Lab, based out of ISI, has had an ongoing project that actively probes the Internet to detect outages worldwide – currently 5 million networks measured every 11 minutes.

USC Ph.D. student Xiao Song and John Heidemann, principal scientist at ISI and research professor of Computer Science at USC Viterbi School of Engineering, were considering this data when the COVID-19 epidemic started in 2020. They noticed changes in the usage of the ISI network once ISI faculty, staff, and students began to work from home, and wondered if this could be generalized and applied across the entire Internet, to see if they could pick up signals of human activity from internet usage data.

They developed algorithms to clean the existing data, extract underlying trends, and detect changes in activity. They found that they could identify work-from-home orders that were put in place due to the emergence of



COVID-19 in 2020. They could also identify other changes in human activity, such as national holidays and government-mandated curfews.

Song explained, “We looked for significant changes in our human behavior maps and compared those dates to news reports for the same location. For example, around late March 2020, network usage plummeted in Manila, Philippines. The news

timeline confirmed that the change we saw correlated with Manila’s COVID lockdown which began on March 15, 2020.” Using their technique, the team detected activity changes in China in late January 2020.

This correlated with two concurrent events: the Wuhan COVID lockdown and the week-long Spring Festival, a national holiday where people typically do not go into their offices. They also detected network changes in India in both February and March 2020 and found that these correlated with riots in India and the first COVID-related lockdown order, respectively.

These case studies suggest that changes in human behavior can have multiple causes, but their outcome on the Internet is similar. This ability to detect trends in human activity from the Internet data provides a new ability to understand our world.

Heidemann and Song presented their findings in the paper, Inferring Changes in Daily Human Activity from Internet Response, at the Internet Measurement Conference, held in Montreal, Canada in October 2023. ■

SECURING CONNECTED VEHICLES

NETWORKING AND CYBERSECURITY

Internal Components

- Telematics
- Infotainment
- Vehicle gateway
- OBD-II port
- Engine control unit
- Transmission control unit
- Body control unit
- Instrument cluster
- Steering control
- Brake control
- Airbag module
- Safety (wipers, headlights, horn)
- ADAS
- Sensors (camera, radar, lidar, ultrasonic)
- GNSS receiver
- Anti-theft
- TPMS
- Keyless entry
- Bluetooth system
- Wi-Fi hotspot
- Radios
- V2X

Attack Surface of a Connected Vehicle

VEHICLE TO VEHICLE
COMMUNICATION

AIRBAG
CONTROL UNIT

TELEMATICS

ENGINE
CONTROL UNIT

TRANSMISSION
CONTROL UNIT

RADIO

HVAC

OBD-II

KEYLESS ENTRY

ANTI-THEFT

TPMS

BODY CONTROLLER
LOCKS/LIGHTS/ETC.

ANTILOCK
BRAKING SYSTEM

Internal Busses

- Controller Area Network (CAN)
- Low Voltage Differential Signaling (LVDS)
- Local Interconnect Network (LIN)
- Media Oriented Systems Transport (MOST)
- FlexRay
- CAN FD
- Automotive Ethernet

Internal Interfaces

- Software, OSes
- Sensor interfaces
- Hardware interfaces

External Interfaces

- Bluetooth
- Cellular
- Wi-Fi
- Zigbee
- Radio (terrestrial, satellite, RFID, DSRC)

BY MAGALI GRUET

With today's cars becoming "computers on wheels" and increasingly connected, hacking is a real concern. In 2011, a group of researchers demonstrated that once they were able to remotely connect to a vehicle through a cellular connection, they could access all parts of the car.

The reason: those elements are not only designed to talk internally, they are also connected to the world. ISI and its collaborators, the University of Memphis and Colorado State University, are working to enable solutions for securing vehicles against such threats through a 2022 NSF funded project called PIVOT: Platform for Innovative Vehicle Open Telematics. One of the biggest challenges in securing vehicles: the lack of data available to support research.

"Auto manufacturers need to protect their intellectual property, so they are reluctant to share the data, but researchers need high quality, real life data to be successful at defeating the hackers," explained David Balenson, ISI's principal investigator on this project. The solution is to collect this data from cars and trucks already on the road, thanks to volunteers who

agree to participate in this project. The Canadian company, Geotab, is also part of this endeavor. They provide telematic devices and fleet management services for automobiles and trucks all over the globe and are monitoring their customers' vehicles to collect the data. As part of the project, Geotab is providing its telematics devices and data analytics services for use by researchers. Meanwhile, the project is building its own data collection devices as well as developing and maintaining a portal that makes this data and associated tools available and adapted to researchers' needs.

This portal, called the PIVOT Platform, is designed to specifically support research on this topic. ISI spearheads community outreach and engagement to create a robust ecosystem of data providers and consumers. One of the key concerns is privacy: to be the most useful the data collected comprises information about drivers and their driving behaviors. "We learn things like the speed of a vehicle and its origin and destination. We must work to make sure that this data is protected and anonymized but still useful to researchers," adds Balenson. ■

6G

FIFTH GENERATION TECHNOLOGY STANDARD
FOR BROADBAND CELLULAR NETWORKS

AI08 - BRAIN

4th/GEN
host device ID: 2569ch
extended CPUID: e568c10

A communication bridge

THE 16 FOUNDING PARTNERS WILL FURTHER 5G/6G
AND ELECTROMAGNETIC WARFARE (EW) CAPABILITIES.
PHOTOGRAPH BY GEORGIJEVIC/ISTOCK

THE PROBLEM The U.S. needs to move microelectronics innovations in the lab to the fabs

OUR SOLUTION Bring together 16 of Southern California's best academic institutions and industry partners

WHAT'S NEXT Catalyze federally awarded multimillion dollar projects aimed at bridging the gap

California has *microelectronics* DREAMS

BY JONATHAN VAN DYKE

A Los Angeles surgeon maneuvers a scalpel ever so carefully, ready to make a vital incision on a patient in desperate need of urgent care — but the operating table is empty. In fact, these lifesaving measures are taking place halfway across the country — or even the world — as the surgeon watches a video screen and directs robotic arms that mimic their every move with precision. There is no room for error. “Things have to happen right away,” explained USC ISI Associate Director Steve Crago. “You can’t see something happen on a screen and then there’s even half a second of difference between those parallel movements — you’re in surgery.” There can be no lag, or latency from this technology, one that could change the world.

The path to reach this theoretical scenario is in strengthening 5G and then future 6G wireless technology, and the microchips and microdevices that make those leaps possible. To catalyze the necessary environment to reach such lofty goals, the United States Department of Defense (DoD), through the CHIPS and Science Act of 2022, awarded generational investment across the country, including an initial \$27 million for a USC Information Sciences Institute-led consortium called California DREAMS (Defense Ready Electronics and Microdevices Superhub) on Sept. 29, 2023.

Crago has been tapped to be its director. “The idea of this hub is to put funding in place so that the university people working in the lab and the industry people that have the

fabrication facility for production are working closely together, right at the beginning,” he said. “So, when the technology breakthrough makes it past the lab, it’s already been experimented with in a way that was rigorous and harmonious with the fabrication facility, which can then pick that up and run with it. The particular part of these technologies that we are working on is the analog front end. You have sensors that are analog, where data comes in from the real world. And then that can be digitally computed. We are focused on wireless transceivers and arrays, imagers, materials, and processors.”

ADVANCING THE STATE OF THE ART IN MICROELECTRONICS

DREAMS is one of eight regional hubs across the country in the Microelectronics Commons network. Its 16 founding partners will focus on furthering 5G/6G and electromagnetic warfare (EW) capabilities, the future of microelectronics development in the U.S. and the workforce development required to achieve those goals.

“We are delighted that USC will lead a powerful team of universities and industry to advance the state of the art in microelectronics,” USC Viterbi School of Engineering Dean Yannis Yortsos said. “This vital hub will synchronize and further empower the academic prowess of the participating academic and industrial partners. It will also help nurture a



vibrant new environment for microelectronics in Southern California with far-reaching benefits nationwide.”

The DREAMS partner institutions within higher education are Caltech; Morgan State University in Baltimore; North Carolina A&T State University; University of California, Irvine; University of California, Los Angeles; University of California, Riverside; University of California, San Diego; and University of California, Santa Barbara. Among the many companies involved are The Boeing Co., HRL Laboratories, Lockheed Martin, Northrop Grumman, PDF Solutions, Raytheon/RTX and Teledyne Scientific Co.

ADDRESSING A NATIONAL NEED

“It’s an opportunity for Southern California to anchor and address a national need”, said Andrea Belz, Viterbi Vice Dean of Transformative Initiatives and DREAMS director of translational strategy. “And it’s an opportunity for USC to be in a leadership role. Many of our researchers have been working on these technologies for many years and can now step forward and offer their solutions to the nation. The Superhub’s mission is to leverage national investment in world-class universities and transform research into impact.”

Even before the DoD award, Crago and his peers at ISI and across Southern California universities, along with those industry titans, had begun to meet with an eye toward building something significant and collaborative. They were ready to pounce when the federal government announced its strategy.

Why ISI? ISI is the home of MOSIS (Metal Oxide Semiconductor Implementation Service), a leading microchip brokerage service for over 40 years. MOSIS provides the ability for individuals with limited access to rare and expensive equipment

to execute prototypes. DREAMS is catalyzing the revamped organization, known as MOSIS 2.0. Where the original catered to silicon digital chips, the new MOSIS will leverage DREAMS partnerships with DoD-ready fabrication facilities to produce compound semiconductors, which are necessary for the new frontiers of 6G and beyond.

“We are competing in a world with international players, and we want to have the ability to take great ideas and form them into commercial- and defense-relevant microelectronics,” MOSIS 2.0 Director Mike Haney said. “Our goal is to take these partners all across Southern California and make this a single functioning team.”

THINKING ABOUT HOW TO BUILD

At its core, DREAMS will bring together academia and the industry that mass produces its breakthroughs, all while meeting government benchmarks for success. Previously, such synergy between these entities was rare. It was not uncommon to see a student or faculty researcher work diligently on a revolutionary project, only to find out it was not viable as a commercially mass-produced product. The idea was dead in the water, all because the sides didn’t have a conversation ahead of time.

“We want to take the best ideas that have impact, with the DoD or commercial world, and enabling them to be accelerated through the prototyping step. If you don’t do it right it can take years,” Haney said. The connections made from DREAMS can speed up an idea that typically would take a year and see it bear fruit in weeks. “We want students to have a design-to manufacturing-mindset as early as possible. There are examples of really clever, cool ideas built in universities that could never be built in production. We want to enable a culture that thinks about how to build — before we put it forward.”



INAUGURAL SITE VISIT OF THE DREAMS HUB AT NORTHROP GRUMMAN; DREAMS DIRECTOR STEPHEN CRAGO; TESTING ON A SEMICONDUCTOR WAFER.
PHOTOGRAPHS BY NORTHROP GRUMMAN AND JON FISCHER

“Taking the best ideas that have impact, with the DoD or commercial world, and enabling them to be accelerated through the prototyping step.”

MAKING HARDWARE COOL

The other focus of DREAMS is determining who will help build this future. The Semiconductor Industry Association anticipates 115,000 new jobs by 2030, but roughly 67,000 of those are at risk of going unfilled, said Belz, who is spearheading DREAMS’ workforce development plans. “As a nation we have allowed our internal skill sets around hardware development to decay. We have outsourced it,” she added. “We are implementing a philosophy to address each educational stage with specific solutions. It’s a full-spectrum approach to ensuring that we have the needed capabilities in one year, five years and beyond.”

Those stages include K-12, continuing education for high school graduates, college students and graduate students in all stages, including master’s and doctorates. Belz said that the universities can offer facilities to train technicians. Hub partners run nanofabs and cleanrooms where people can learn about chip development techniques.

“We are interested in candidates who are good with their hands but perhaps would not participate in a traditional classroom,” she said. “As a university, we are not used to serving this community as

intently. And yet, the nation requires us to develop this education and recruiting now.”

Making microdevices and hardware cool again — in a world where computer software is king and young students can develop their own apps in days — is of paramount importance moving forward, Crago noted, and will help shift brain power in its direction. Endless possibilities exist for rekindling American excellence in this domain.

The microchips, antennas and sensors that DREAMS will revolutionize will be everywhere: in your car, on the blind spot sensor of your side mirror; in your laptop charger, restoring your battery faster; and in an armored tank or communications satellite, protecting it from electronic jamming interference from a foreign adversary.

And, of course, phones will ultimately operate in a 6G network. ISI will be at the forefront of these transformations. “This is a key win for USC,” ISI Executive Director Craig Knoblock said. “It again demonstrates the university’s long-held status as an innovator in research and education, as well as its ability to collaborate with other institutions and private industry.” ■

THE PROBLEM GPS is easily disrupted and radio signals can be jammed during conflicts	OUR SOLUTION Make quantum sensing tools compact, cheap and accurate for commercial use	WHAT'S NEXT Pitch ideas to the US DoD and develop techniques to enable real-world prototypes
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No GPS, *no problem*

BY BERNICE CHAN

Fundamental physics — let alone quantum physics — might sound complicated to many, but it can actually be applied to solve everyday problems. Imagine navigating to an unfamiliar place. Most people would suggest using GPS, but what if you were stuck in an underground tunnel where radio signals from satellites were not able to penetrate through? That's where quantum sensing tools come in. USC Information Sciences Institute researchers Jonathan Habib and Justin Brown, both from ISI's new Laboratory for Quantum-Limited Information, are working at making sensing instruments like atomic accelerometers smaller and more accurate so they can be used to navigate when GPS is down.

TACKLING THE SIZE CONUNDRUM

Atoms are excellent for making accurate measurements because they are all the same. Atomic measurements made in one laboratory are indistinguishable from those made in another laboratory, as the atoms behave in precisely the same way. One example of how this physics concept can be applied is making a highly accurate navigation system with these atoms. "As an atomic physicist, I work with atoms in a gas and talk to the atoms with lasers," Brown said.

"As atoms have mass, they can be used to measure accelerations, helping us build atom-based sensors like atomic accelerometers." Habib added, "The accelerometers let you know how fast and far you're moving in a given direction. They can be coupled with

gyroscopes, which tell you whether you've changed directions and how far you've turned, to make a complete measurement. These navigation instruments are useful when you don't have access to GPS."

One of the challenges they're facing is how they can engineer this in a thoughtful way. For example, they have to think very carefully about how they can miniaturize atomic accelerometers. These accelerometers have historically operated in big laboratory scale systems, where equipment is heavy and consumes a lot of power. To make the accelerometers suitable for public use, Habib and Brown are investigating how to retain their high precision in a much more compact, power-efficient and attractive medium.

Brown said, "We want to take this out in the field and make it smaller at the same time, but the techniques and supplies that we're drawing from are not very conducive to doing so just yet. I'm thinking about how to talk to the atoms in a different way so that we can get the capabilities to apply it to problems outside the laboratory."

APPLICATIONS IN DEFENSE... AND ADAPTING TO THE REAL WORLD

Not only do quantum sensing devices work in areas that don't have access to GPS, they can also be part of an exciting new avenue: national security applications. "Modern conflicts are



becoming increasingly electronic and less kinetic, as nations vie for information superiority. The radio signal from GPS satellites is easy to disrupt and jam because it is far away.

Thus, in any modern conflict, both sides will attempt to deny each other access to these radio signals," Brown said.

"More traditional navigation instruments like inertial systems are unjammable, as they work by adding up accelerations and rotations to measure

our change in position. So they can replace GPS in times of conflict. However, all the errors made also get added up, so we are interested in using an atom-based measurement to ensure it is more accurate."

Atomic accelerometers are one example of these inertial systems. These

"A lot of these sensors are the size of a washing machine."

systems are present in sensors on aircraft and ships, guiding their movement through airspaces and waters. However, existing mechanical-based sensors can wear out easily due to friction, leading to them being swapped out every year and costing a lot of money.

They are also hard to build because they're small and delicate. The US Department of Defense (DoD) is looking for upgrades in their inertial systems so that these difficulties can be

overcome. The quantum approach based on atoms pursued by Brown and other groups could provide acceleration measurements with no moving parts.

"For example, if a submarine wants to be stealthy and quiet in defense scenarios, keeping track of what it's doing and how it's moved through inertial systems is

pretty much the only game in town. I'm developing ideas on improving these systems for the DoD, so that they can be downsized and more cost-efficient."

SIMPLIFY THE TOOLS

Brown maintains that quantum sensing will be important on many fronts. "Preparing for technical surprise means preparing for when GPS fails – the question isn't if GPS fails," said Brown.

"It's very easy to stop GPS from working, so inertial sensors will always be useful. But it's still vital for us to solve the size issue, because a lot of these sensors still end up at about the size of a washing machine. I could simplify the tool itself, but I still need to make a good measurement."

Achieving this fine balance between simplicity and accuracy is the researchers' main goal, and they hope that their efforts will translate to real-world prototypes someday. ■

THE PROBLEM Modern science is increasingly complex due to big data and multistep pipelines

OUR SOLUTION Create systems that automate and manage data- and compute-intensive research

WHAT'S NEXT Reimagine scientific workflow systems with AI and stronger intelligence

Optimizing data flow



BY LEILA OKAHATA

No one can precisely predict when an earthquake is to happen. Since the 1994 6.7-magnitude Northridge earthquake in Los Angeles County that caused 72 deaths, 9,000 injuries and \$25 billion in damages, Southern California has been anxiously waiting for “The Big One”: a devastating quake predicted to be at least a 7.8 magnitude and 44 times stronger. Seismologists can only say that it may happen within the next 30 years.

EARTHQUAKE CALCULATIONS

Although scientists cannot forecast when and where earthquakes will strike, preparation is key to improving society's resilience to large earthquakes. In particular, the USC-based Statewide California Earthquake Center (SCEC) developed CyberShake, a computational

platform that simulates hundreds of thousands of earthquakes to calculate regional seismic hazard models. Revealing geographical areas in Southern California most at risk for intense shaking, its results have influenced Los Angeles building codes and the design of the earthquake models at the U.S. Geological Survey, the nation's largest earth and geological science mapping agency.

CyberShake studies—and much of modern science, however—are highly data and computing-intensive. With multi-step calculations that feed into numerous interconnected computational tasks executing on local and national supercomputers to simulate 600,000 different earthquakes, CyberShake's scientific workflow is complex. ISI

houses the tools to generate and manage such massive data.

Ewa Deelman, a research professor in computer science and research director at ISI, has continuously designed and updated, since 2000, an automated workflow management system called Pegasus.

OPTIMIZED WORKFLOWS

Pegasus—named after Planning for Execution and Grids (PEG) and Deelman's love for horses—turns research experiments into optimized workflows.

It can be used by scientists in various fields from seismology to physics to bioinformatics because of its abstract design. Deelman likens it to a cooking recipe: “You can use the same recipe in different kitchens. Different users can run the recipe (the workflow) but with their

for scientific *discovery*



PEGASUS CREATES WORKFLOW MANAGEMENT SYSTEMS FOR EARTHQUAKE AND WEATHER PREDICTIONS.

PHOTOGRAPHS BY OZGURDONMAZ/GARYKAVANAGH/REVOLUTION93/MILLERPD/ISTOCK

own cookware (computational resources). When you design things in a broad enough way, they become widely applicable.” In 2016, scientists from the Laser Interferometer Gravitational-Wave Observatory (LIGO) utilized Pegasus to capture gravitational waves in the universe, confirming Albert Einstein’s General Theory of Relativity and earning the 2017 Nobel Prize for physics. During the 16-year collaboration between ISI computer scientists and LIGO members, the software managed thousands of workflows with millions of tasks.

The Collaborative and Adaptive Sensing of the Atmosphere (CASA), an engineering research center dedicated to improving hazardous weather prediction and response, has also ported its pipelines into Pegasus. As severe weather can slow

and compromise local resources and computing capacity, the program sends CASA’s data into cloud infrastructures to ensure continuous workflow.

INSPIRED BY ANIMAL BEHAVIORS

CyberShake has relied on Pegasus for the past 15 years, including its most recent study with its largest set of earthquake simulations yet. Pegasus managed 2.5 petabytes of data and ran 28,120 workflow jobs over 108 days to produce seismic hazard maps in 772,000 node-hours.

“Without Pegasus, there’s no way we’d be able to do this kind of science,” said Scott Callaghan, a computer scientist at SCEC and lead developer on CyberShake. SCEC will be expanding CyberShake to Northern

California, now using the fastest supercomputer in the world, Frontier. Pegasus will continue to remain at their side. “Every time we do one of these studies, we always encounter unexpected challenges. But I’m confident that, with any workflow issues, the Pegasus team will be able to help us work through them so that we can continue getting cutting-edge science done,” Callaghan said.

Deelman is now conducting research and conceptualizing SWARM, another workflow management system inspired by the savvy coordination of group behaviors amongst social animals, like ants. She also plans to enhance Pegasus’ decision-making with artificial intelligence, reimagining how workflow systems will operate in the future. ■

THE PROBLEM The wireless spectrum is becoming increasingly crowded and complex

OUR SOLUTION Design hardware and software out from the minimum viable switchable processing unit

WHAT'S NEXT Build a prototype of the design and test the processing capabilities

Transforming spectrum *processing*



PHOTOGRAPH BY KAR TRISTOCK

BY JULIA COHEN

More devices. Higher Speeds. A never-ending flow of new content to stream and experience with augmented or virtual reality. This is the future we're heading towards. But all of those applications need wireless bandwidth, and the wireless spectrum is becoming increasingly crowded and complex. RF (radio frequency) autonomy is a potential solution; it allows radios to adapt to the wireless environment and use segments of bandwidth that would otherwise go unused.

In 2022, DARPA issued a call for proposals to address spectrum crowding and complexity using RF autonomy. In 2023, \$9M for Phase 1 (with an additional Phase 2 Option of nearly \$10M) was awarded to a team led by Principal Investigator Matthew French, director of the Computational Systems and Technology division at ISI and co-PI John Paul Walters, also of ISI.

Their project, TRACER – Tasklet Reconfigurable Agile spectrum processor – is an innovative solution to the RF challenge. “We came up with a hardware and software

co-design technique centered around the concept of a ‘tasklet,’ the minimum viable processing unit that you could do in both software and hardware,” said French.

“And the idea was to design out from that,” Walters added, “Tasklets can be switched quickly — in tens of nanoseconds — which allows TRACER to adapt the software and hardware at waveform timescales.

TESTING IN A SIMULATED ENVIRONMENT

This adaptivity allows a single TRACER processor to perform the work of many existing traditional processors or FPGAs [field-programmable gate arrays, which are programmable circuits commonly used for these tasks].” Since the start of Phase 1, the TRACER team has been developing a simulation environment.

French explained, “It allows us to model our hypotheses and trade-offs so we can rapidly explore the design space.” They’re ultimately balancing three factors: computational density, switching rate and processor

utilization. Computational density is the speed at which signals are processed per unit area on the device; switching rate is how quickly the processor can switch between tasks; and utilization is a measure of how many of the processors on the chip remain active.

French continued, “These three components play together, and we have to tune them all to address the overall workload that we’re trying to achieve. This is especially important because developing hardware takes a long time, and we don’t want to get locked into a certain decision point only to find out later that it was the wrong point.”

By the end of Phase 1, the team hopes to have a prototype where they can emulate a large subsection of their device, and have software running on an emulator to show the processing capabilities. The TRACER team is comprised of leaders from USC, MIT, NYU and Shared Spectrum Corporation. “Our software team is led by Walters and MIT. ISI is leading the hardware with strong assistance from USC campus and NYU,” said French. ■

THE PROBLEM The Department of Defense is unsure whether it's worth investing in quantum computing

OUR SOLUTION Devise what quantum computers can solve, find out what areas they can help with

WHAT'S NEXT Motivating research efforts in quantum, producing useful software, expanding impact

Is quantum computing really *worth it*?

BY BERNICE CHAN

Quantum computers have often been touted as “magical” devices in science-fiction movies – however, their impact may soon become a reality. ISI's Itay Hen, Research Team Leader, is leading a multi-institutional effort funded by DARPA to figure out how to test the capabilities of quantum computers. With ISI researcher Amir Kalev, USC Dornsife professor Rosa Di Felice and others, he is investigating whether quantum technologies are worth pursuing. “Quantum computers promise many more than standard computers,” explained Hen.

“DARPA wanted to know whether to invest in building large-scale quantum computers, and what society could gain from them.” Our research doesn't just identify problems that quantum could help with, but it also quantify clear benchmarks for testing and determine the required resources. “We need to ensure we develop our efforts where quantum is useful,” he added.

MERGING SCIENCE WITH APPLICATION

Hen gathered multi-disciplinary teams to ensure their contributions were impactful. Subject matter experts devised applicable questions, while quantum computing scientists distilled their computational aspects. Di Felice is one of these experts. She noted, “I identify theories and resources needed to solve the problems we're interested in, and explain why it's more suitable for quantum as opposed to classical computing methods.”

At times, communication was a challenge. “At first, it felt like we were speaking different languages. We quantum information scientists had to explain our thoughts in more grounded language, and not describe things in terms of abstract, algorithmic values,” Hen recalled. “Quantum

computers could help discover new materials with esoteric properties,” said Hen. “They can also solve complicated differential equations, predicting how complex systems, such as the stock market, operate and behave.”

One of their proposed questions is whether quantum computers could help find new superconductors, a high-efficiency material that runs electrical currents without resistance. Normal electrical currents generate a lot of heat and wasted energy, while superconductors are lucrative and run currents without generating heat. As superconductors usually work at low temperatures, the researchers wondered if quantum computers can find some that work at room temperatures, which could become a core component of technological advances. “For example, it's impossible to run a train on superconducting material because things would have to be very cold,” remarked Kalev. “With room-temp superconductors, this would be feasible.”

SOLVING THE YET UNSOLVABLE

So far, the research teams have discovered intriguing techniques to devise problems that no existing computer can solve. If quantum computers prove to be effective at solving these problems, they might transform society for the better. “We needed to formulate questions that we know the answer to, but are impossible for standard computers to solve,” said Hen.

Hen and the others are also planning for a future where quantum's impact continues to grow and spread. Di Felice noted, “Our research motivates other scientists to work harder to create quantum chips. Quantum computing could tap into more industries like health and energy production.” ■

THE PROBLEM We want to collect and manage medical data to empower researchers

OUR SOLUTION Integrate global data, revealing connections to facilitate collaboration

WHAT'S NEXT The scope of research is widening, looking at applications for clinicians

Advancing dental, oral and *craniofacial* research with data

BY JULIA COHEN

Roughly half of all birth defects involve the face and skull, yet scientists remain unclear about why most occur. The way to address tough medical challenges like this one is through data – lots of it. But how to best manage the data, integrate it into meaningful information and create a comprehensive picture that is useful and accessible to researchers is another question. FaceBase offers an answer.

FaceBase is a research resource that provides open access to genetic, molecular and imaging data to the dental, oral and craniofacial (DOC) research community. “Through FaceBase, USC is playing a role in the next generation of dental and craniofacial research,” said Carl Kesselman, FaceBase’s co-Principal Investigator, who is the William H. Keck Professor of Engineering and a Professor in the Daniel J. Epstein Department of

Industrial and Systems Engineering and director of the Informatics Systems Research Division at ISI.

He continued, “We are assembling all of the data, organizing the research community, and providing this service to the National Institute of Dental and Craniofacial Research [NIDCR] and the research community at large.”

THE BASICS OF FACEBASE

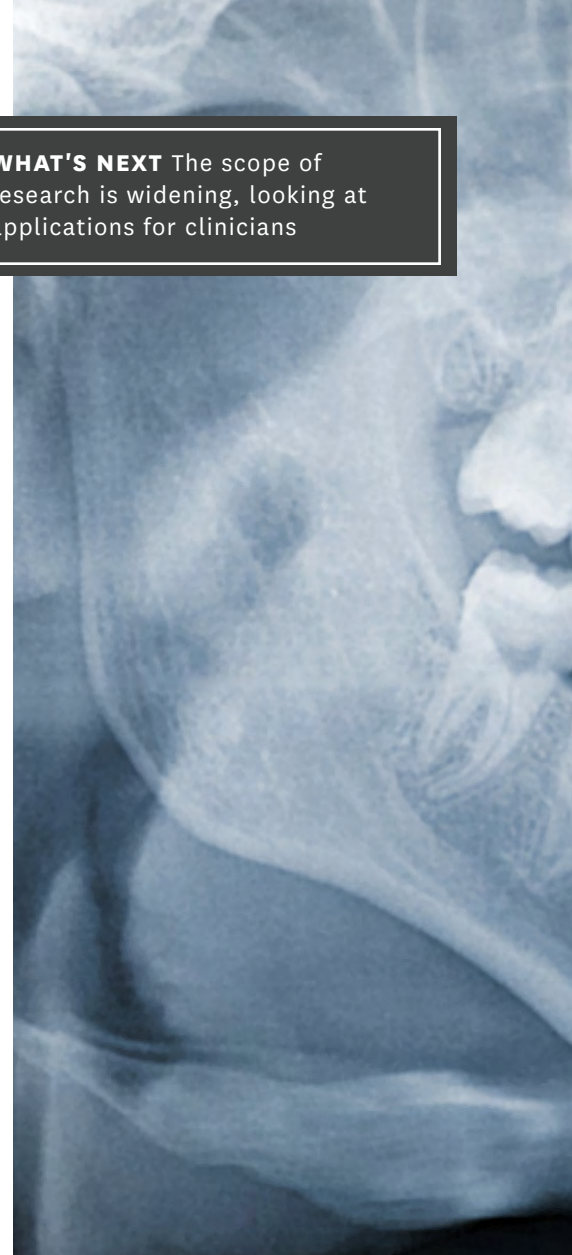
FaceBase is a collaborative NIDCR-funded project that houses comprehensive data in support of advancing research into craniofacial development and malformation. Kesselman leads the team of researchers and staff at ISI who run FaceBase’s coordinating center (i.e., the Hub). The Hub is where large datasets are curated and shared. Researchers in the DOC community can submit their

projects to FaceBase, and datasets from approved projects are added. How does a large database help research?

Rob Schuler, the technical lead for FaceBase and Senior Computer Scientist at ISI, gave examples of how some researchers are using FaceBase data: “to have a larger patient cohort; to compare their own clinical results with research being done on animal models; some of them do analysis and use the large datasets to train neural networks and produce models that can, for example, predict a phenotype based on a patient’s face.” But FaceBase is more than just an ever-growing database.

FACEBASE CONNECTS THE DOTS

One of the missions of the project is to facilitate cooperation and collaboration between the Hub and the craniofacial





USC COMPUTER SCIENTISTS ARE TACKLING DENTAL HEALTH AND BIRTH DEFECTS USING IMAGING DATA.

PHOTOGRAPH BY ADVENTTR/ISTOCK

research community. “There’s a desire to be able to use a data resource like FaceBase to assist researchers in making connections to other people who are possibly working on a similar disease,” said Schuler.

Kesselman said, “We connect the dots. In the absence of something like FaceBase, you have a little piece of data over here and a little piece of data over there, and you can’t figure out how they connect. But we do that. We take all these different aspects and research projects, we integrate them so that they’re more cohesive, and it represents more of the total knowledge of the community rather than isolated silos.”

Kesselman gave examples of two current projects: “We have a large dataset contributed by colleagues looking at the genetic foundations of tooth enamel. And another large set of data from researchers studying oral health in Appalachia.

They’ve looked at social factors, along with all kinds of various health factors associated with oral health.”

WHAT’S NEXT FOR FACEBASE?

Now in its third phase, FaceBase has been opened up to more research from the community at large. In addition to a widening of the scope of research, the FaceBase team is also looking at applications for clinicians, the people who are actually treating and diagnosing patients.

Kesselman said, “We’ve been working with people in the Ostrow Dental School for the last eight years now, applying very sophisticated computer science and research that we’ve developed at ISI. And by applying it in this area we are ultimately making a real impact on dental health and childhood development.” ■

THE PROBLEM Space systems face many threats which affect operational safety and cybersecurity	OUR SOLUTION Target harmful debris with space-qualified tools, build test beds simulating attacks	WHAT'S NEXT 3D perception tools and AI prediction models, software for NASA's space processors
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Solving the *space* dilemma

BY BERNICE CHAN

Space systems are often exposed to operational threats. These threats may be directed towards hardware, such as space debris’ harmful effects to spacecraft. They may also affect software, such as breaches in satellite communication security. USC Information Sciences Institute (ISI) and Space Engineering Research Center (SERC) researchers are devising solutions to these space dilemmas, and they have made valuable progress so far.

REMOVING HARMFUL DEBRIS FROM SPACE

Space debris has been a long-time problem for space operation safety. In 1978, NASA scientist Donald J. Kessler theorized that increasing amounts of space pollution would lead to more collisions between objects in orbit, creating more debris.

To mitigate and remediate the debris issue, the U.S. Space Force launched the Orbital Prime Program, where SERC was a key research partner on several industry teams. SERC Director David Barnhart noted that their REACCH project, a robotic gripper modeled after an octopus, got picked as a topic of interest from a company and USSF and is currently in prototype experimentation. The gripper grabs objects that are not uniform in shape and size, such as pieces of debris. It uses unique Gecko dry adhesive tiles to make the actual contact, like the suction cups on octopus arms.

This project led Barnhart’s team to develop another idea for in-space safety inspections on future spacecraft called STARFISH in October 2021. “While REACCH has solid tentacles that grab debris, we wondered whether we could use the same Gecko adhesive technology for another purpose — to

crawl across a space platform surface to scan for any damages,” Barnhart explained. “So STARFISH was born: a biologically-inspired robot with soft tentacles to crawl along platforms.” Barnhart is working with an industry company to help REACCH become a space-qualified tool. STARFISH got its start with initial seed funding from the Aerospace Corp.

ADVANCING SPACE SERVICING

Space servicing, including inspection, assembly and manufacturing, is a completely new domain in on-orbit operations. SERC is supporting one unique attribute critical to any type of servicing in space by creating CLINGERS, an in-space docking mechanism latching units together with embedded sensors. This cooperatively enables their hosts to connect safely and efficiently. CLINGERS received an award to test onboard the International Space Station (ISS).

These functions become incredibly important while building things in space. “It’s not like on the ground at a construction site where you pull up a truck and you drop all the beams,” Barnhart explained. “In space if you drop the beams, they’re gone.” The project has been successful so far. On November 3, 2023, Barnhart and his student team at SERC uploaded new software to one of the two CLINGERS experimental units on the ISS in preparation for docking tests in the next three months.

“Watching the astronauts working with their experiment was a big step for the USC student team with their first hardware operating in space,” said Barnhart.



SERC STUDENTS WORK ON ROBOTS THAT THEY SEND TO SPACE.
PHOTOGRAPHS BY USC/ISI

COMBATING CYBERATTACKS ON SATELLITE COMMUNICATION

Space systems also face cybersecurity challenges. ISI researchers Alefiya Hussain and Michael Collins are working with NASA JPL to develop Merge test beds simulating inter- and intra-satellite communications. This allows them to explore possible cyberattack scenarios and understand how to design space architectures securely. “There are three components of space security affected by cyber threats: earth to space, space to space, and space to earth,” Hussain explained. “Especially for the earth to space segment, places that can be attacked have increased significantly.”

When Russia invaded Ukraine in February 2022, Viasat Inc’s satellite network was taken over by Russian cyberattacks, disrupting internet access and threatening communications integrity. Hussain remarked that as space becomes increasingly contested and congested, these problems will become more real.

“The number of ground stations with access to satellites grows day by day. We’re trying to prevent these stations from

being exploited by simulating a range of cyberattack scenarios to anticipate loopholes,” said Hussain. “We hope to build a more secure and resilient space system.”

THE NEXT SPACE CHAPTER

Many projects have been initiated. “We’re writing a proposal on 3D perception in space. It fuses augmented reality with real-time video in orbit to represent objects in 3D for space assembly and manufacturing,” said Barnhart. Other projects include artificial intelligence-based prediction models to show satellite function via the SpacePredict platform, which can predict space transport supply chains.

JP Walters, research director at ISI, is developing a new software approach for NASA’s next-generation space processors. This would allow processors to operate through failures and be more robust, preventing possible vulnerabilities during space exploration. ■



The

PEOPLE

of ISI

BY DEREK MIKURIYA

DIRECTOR OF HUMAN RESOURCES

ISI takes great pride in cultivating a team of creative problem solvers, visionary leaders and individuals from diverse backgrounds dedicated to shaping the future of computer sciences. Our people are our greatest asset. We believe in the power of synergy. From the moment we embark on the hiring journey, we focus on building cohesive teams of talented individuals whose varied skills and perspectives intersect harmoniously. But our

commitment to excellence does not end with recruitment.

We empower and recognize our faculty, staff and students, offering professional development opportunities and mentorship programs that further hone the qualities and capabilities of our teams. We believe in continuous improvement, leadership that inspires, and a dedication to supporting each other. The people of ISI never stop learning and evolving.



ISI represents a vibrant kaleidoscope of backgrounds and expertise, and we seek to provide world-class research in safe environments that promote awareness, empathy, and belonging. We are proud to support Diversity, Equity and Inclusion, knowing that a multicultural and multidimensional community sparks ideas, fosters innovation, and drives meaningful change.

From research scientists to administrative staff, from

seasoned professionals to enthusiastic interns, each member is an integral part of a dynamic collective, propelling us forward toward our common goals.

I am proud that we have raised the bar at ISI, not only for cutting-edge technologies and groundbreaking research, but also workplace etiquette and team leadership. Together, we are committed to reshaping the possibilities of information sciences. ■



THE WOMEN OF NETWORKING AND CYBERSECURITY:

TERRY BENZEL, DIVISION DIRECTOR

JELENA MIRKOVIC, RESEARCH FACULTY

MARJORIE FREEDMAN, PRINCIPAL SCIENTIST

GENEVIEVE BARTLETT, LEAD SCIENTIST

ALEFIYA HUSSAIN, PRINCIPAL SCIENTIST

PHOTOGRAPH BY ANGEL ITUA

The *women* researchers of ISI tell their stories

BY MAGALI GRUET

They had similar beginnings: they loved math and got into computer science later on, sometimes by accident, at a time this discipline wasn't trending yet. They hold key roles in artificial intelligence, cybersecurity or cyberinfrastructure. They manage teams and divisions. They advise the Viterbi School of Engineering on research strategy. Yet, for the leading women researchers of ISI, their paths were strewn with obstacles directly related to their gender.

Terry Benzel, ISI's Networking and Cybersecurity division director, abandoned a promising future in abstract algebra because of a "blatantly sexist" advisor in grad school. "There were two women in the class and he would dismiss us and work with the boys; he would give them the best projects and leave us with the crumbs. I started to take computer science classes and decided to pursue a masters in this discipline instead." Today, Benzel is one of the most respected experts in her field, recently named an IEEE fellow, one of the society's highest honors.

Alefiya's Hussain's story is a little less heavy: "I got into computer science as an excuse to not learn a new language in high school," she laughed. Yolanda Gil, senior director for Strategic Initiatives in Artificial Intelligence and Data Science, loved the functionality of AI: "Computer science was a lot like math, but practical, so it was perfect for me. AI in particular. My first AI class blew my mind, and it never stopped doing so. Such an amazing field." Despite their significant contributions, women researchers at ISI represent only

17.6% of the total, a figure in line with the national average of 18% for women in computer science research, according to data from the Computing Research Association.

HISTORICAL DISPARITIES

"At ISI we firmly believe that the contributions of women in research are not just valuable but essential to achieving excellence and innovation", said Craig Knoblock, executive director. "Recognizing the historical underrepresentation of women in our field, we are actively working to increase their presence within the Institute. We are committed to creating an environment where the work of women is celebrated and supported, as we know that their contributions are crucial in driving us toward new frontiers of knowledge and discovery."

At the Viterbi School of Engineering, 48% of the Fall 2023 incoming first year undergraduate students are women - including in computer science. Gender equality drops later on, at the masters and Ph.D. levels. "We had this saying in graduate school that there were more Daves than women," remembered Gil. "Wherever you went, whatever meeting you were in, more people were named Dave than there were women. It's how outrageous the disparity was."

Interestingly, the women ISI researchers who were raised abroad did not seem to face as much imbalance. Jelena Mirkovic studied in Serbia, part of the former Yugoslavia. "I was not aware of any stereotypes growing up, I was not told that women should

THE PEOPLE OF ISI

not get into specific fields. So I chose my studies based on my liking.”

Research Professor Ewa Deelman grew up in Poland and never thought of herself “as a minority by any means, I did not think I was different from men in terms of my abilities.” Alefiya Hussain got her undergraduate degree in India and remembers that 30 to 40% of the class were girls. Mirkovic only noticed the disconnect “when people started talking about it in the United States.” They now share the same reality as their American-born counterparts: as leaders in computer science, being the only woman in the room happens on a daily basis. Deborah Khider has had 5 meetings back-to-back in a day where she was the only woman. For Abigail Horn, this can be an advantage: “As the only woman in a meeting. People remember you.”

Elizabeth Boschee, director of ISI Boston, ran into difficulties when there were two women in the room. “I worked in tandem with Marjorie Freedman and people would always mix us up, even though we look nothing alike. The only commonality is that we’re both women,” she said. Boschee also faced dilemmas reserved to women: “I was concerned that I wouldn’t be taken seriously as a computer scientist just based on the style of how I dressed (think dressy business casual). In my first job, women who dressed nicely were almost exclusively in non-technical roles such as finance or HR, but the researchers wore jeans and t-shirts.”

ATTRACTING MORE WOMEN INTO THE FIELD

And no matter their attire, they have to prove themselves every time they enter a room. Boschee was asked whether a system offered a specific functionality. She said it did. The client was unconvinced and asked her to “double check with the person who built the system.” The system was built by her.

Mirkovic confirms: “There’s this automatic assumption that I don’t know what I’m doing, that I must have done something wrong, and it takes a long time for me to earn the respect I deserve. People talk to me in a way they never would if I were a man.” With this in mind, how do we reverse the trend and give women the place they deserve? It starts by attracting more women into the field. “Women like to go into professions where they can make an impact on society, so we have to highlight that computer science is not only about coding or

“Computer science research offers a flexible schedule, which makes it a very woman-friendly environment.”

playing video games,” explained Deelman. “The career can be much richer than people think and have a direct impact on lives.”

“We need to publicize all the applications of AI that people don’t really think about but are appealing to women: AI can improve health, social sciences, linguistics, justice,” described Gil. Freedman got into AI from the field of linguistics. “I was the ultimate liberal arts undergraduate,” she laughed. She embraced natural language as a tool to pursue her initial passion. “We also need to change the messaging in society that women are not good at math,” adds Deelman. Then women need to be recognized for their contributions.

Kristina Lerman focuses on - among other things - research on gender. The ISI research professor is using AI to demonstrate that women are cited less than men as sources in research papers, which prevents them from being recognized by their peers, and ultimately promoted. To close the gap, she believes that publishers need to get serious about requiring researchers to diversify the references in their papers.

Hussain also insists on having women in management positions. “Women understand the pressure other women face, their needs to balance all aspects of life, such as motherhood. Hybrid work has made it possible for women to



LEFT: EWA DEELMAN, RESEARCH PROFESSOR; ABIGAIL HORN, RESEARCH ASSISTANT PROFESSOR; LIZ BOSCHEE, ISI BOSTON DIRECTOR, ASSOCIATE DIRECTOR OF THE AI DIVISION
RIGHT: DEBORAH KHIDER, LEAD SCIENTIST; YOLANDA GIL, SENIOR DIRECTOR FOR STRATEGIC INITIATIVES IN ARTIFICIAL INTELLIGENCE AND DATA SCIENCE; KRISTINA LERMAN, RESEARCH PROFESSOR

PHOTOGRAPHS BY ANGEL ITUA



continue their careers more than ever,” she adds. ISI is now offering very flexible work arrangements for its staff. Gil believes that this is a game changer. “When you do research in computer science, you are not a doctor who has to see patients with scheduled appointments. You can choose your hours, it is a very woman-friendly environment in that respect.”

MENTORS AND COMMUNITIES

Freedman also points out the importance of mentors of all genders, and how she has been promoted by men who just saw her as an excellent scientist. “I had an incredibly supportive and incredibly mentoring supervisor. If you don’t have that, I would suggest you find a new mentor.”

Benzel, who has hired many women in her division over the years, goes beyond her ISI duties and has founded a community for women in her field. “We created a workshop for women in Ph.D. programs in cybersecurity research and we would hold it

right before the main conference in our field. So the day of the conference they would already know 50 women in attendance, and be comfortable and engage with their peers.” Hussain also believes the change will come from the new generation: “We need to make women researchers more visible and inspire girls to get into computer science at a young age. We want to tell girls, look, this woman did it, so can you... you belong at this table,” she said. “Students on campus are empowered when they see other women pursuing this career and teaching them.”

Genevieve Bartlett was hired by Benzel. She sees “a trend of women getting together and solving problems, but we need buy-in from more than just women. Allyship is incredibly important. Intersectionality – understanding how everyone’s differences can come together for strength – will make it better not just for women, but for everyone.” She advises young girls to “believe in themselves and keep pushing their ideas forward.” ■



CASANDRA RUSTI

PH.D. STUDENT

I was drawn to computer science by its immense impact. Everywhere you look, technology shapes our lives, and I wanted to be part of understanding and contributing to something that drives our world. My passion extends into the ethical components of computer science, particularly AI and machine learning, where my work focuses on measuring and mitigating bias. Despite the challenges, I see significant initiatives aiming to increase women participation in the field. I feel fortunate to be at an institute that nurtures a welcoming and supportive environment for women. A culture of mentorship is vital. It’s about more than just bringing women into the field; it’s about encouraging, supporting, and inspiring them—and all underrepresented individuals—to explore and innovate within computer science. As we push for more gender-balanced representation, progress is being made, but there’s much more to be done. My goal post-graduation is to mentor and inspire the next generation, showing them the vast possibilities within this critical field. It’s not just about addressing gender disparities; it’s about creating a more inclusive, ethical, and fair future in tech.

From ISI researchers

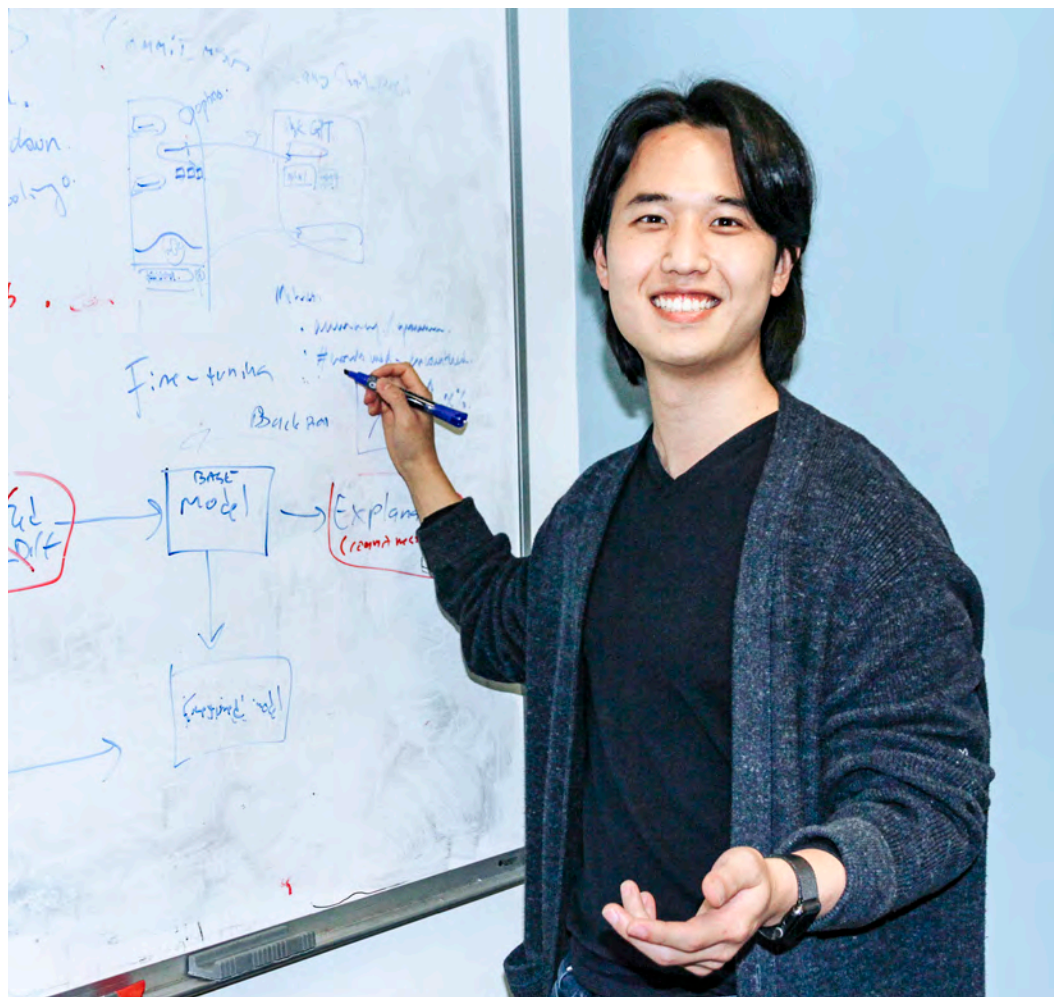
BY BERNICE CHAN

The fruits of scientific research don't only stay on paper, but also produce useful technologies to transform the way things work. Several researchers at USC's Information Sciences Institute have achieved this, founding startups to solve societal issues while facing challenges in the process.

WHAT DOES THE MARKET NEED?

Launching a successful startup doesn't just mean pitching a novel product, it also requires founders to consider consumer needs or pain points. Justin Cho, Ph.D. student at USC ISI, is experiencing this with his startup AutoLang alongside former Hong Kong schoolmates Minhjung Joo and Yongchae Lee.

AutoLang launched on the App Store in June 2023. AutoLang makes language learning personal and practical by teaching how to say things that the learner wants to say through realistic conversations. Instead of gamification metrics, it closely tracks actual fluency. "Even after mastering Chinese lessons on Duolingo, I realized I still could not converse meaningfully," Cho recalled. "I trusted a curriculum without considering how important personalization was."



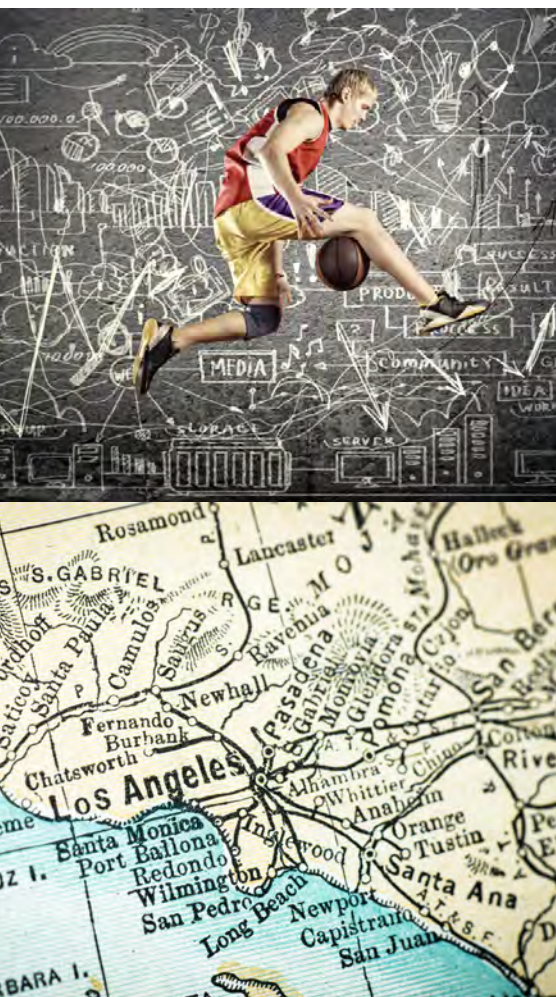
Cho set out to make language learning more engaging, leveraging his previous research on improvisational theater with ISI Professor Jonathan May. He applied the "yes-and" principle stating that agreeing and expanding common ground encourages more grounded communication. Embedding this behavior in AutoLang's chatbot made its conversations more interesting. Cho's experiences at ISI allowed him to learn more than software development.

COMMERCIALIZING RESEARCH FOR SOCIETAL IMPACT, AND GETTING HELP

Presenting his work in front of his peers helped him understand how to repackaging his product for potential consumers, which is no simple feat. "It taught me the value of thinking about target audiences, and iterating until I find a fit with the market," said Cho.

"How do you bridge the gap between research and real-life applications?" is a key question that Craig Knoblock, ISI's

to *startup* founders



PH.D. STUDENT JUSTIN CHO FOUNDED
A STARTUP BASED ON HIS WORK AT ISI.

PHOTOGRAPHS BY
ANGEL ITUA AND ISTOCK

executive director, faced as well. He founded Fetch Technologies, acquired for \$10M in 2011, and Geosemble Technologies, acquired for \$1.5M in 2012. “There’s a common misconception that a technology is a business,” said Knoblock. “But technologies can only make business ideas possible. To build a startup, you have to solve problems.”

For Geosemble, he worked with partner Cyrus Shahabi to develop their GeoXRay technology that takes text information from text documents and automatically links the collected data to physical locations. “By mapping out Culver City near Los Angeles, we discovered that GeoXRay gives people more information about places. For example, after accessing a movie review for a theater, GeoXRay could show a map view of said theater, show you the nearby restaurants and pull up recent articles and reviews of those restaurants.”

GeoXRay provided a compelling tool that allowed an organization to organize their textual data by location to provide a better experience for their users. Yigal Arens, ISI’s senior director for Administrative Affairs, collaborated with Knoblock and Steve Minton on Fetch in 1999, using machine learning techniques to extract and integrate data from web sites.

He shares some words of wisdom: “As researchers, we’re interested in scientific problems. But we don’t necessarily understand market and commercial issues. Having useful technologies isn’t the same as convincing people to pay for them, so we brought in business people.”

SCOUTING MARKETS TO FIND A NICHE

Outsourcing is one way to solve the commercialization dilemma, but there are alternatives. Jeremy Allam and

Marcel Lariviere, USC Viterbi alumni and founders of Exo-Space, took a different approach: networking across the space industry to identify what niches needed to be filled and what products were sought after.

“We went to many meetings, constantly calling companies and universities. Our market research paid off when a potential investor led us to pivot towards building real-time data processing units to quickly identify things on Earth from space,” said Lariviere. “After that, we gained traction faster.” This helped them implement their ideas, such as monitoring and detecting wildfires from space, which was awarded a Phase 2 NASA contract for development. Exo-Space was then acquired in 2023 for \$470K.

A \$200M ACQUISITION

Figuring out a central theme is something that Second Spectrum founders and former ISIs Rajiv Maheswaran and Yu-Han Chang find important as well.

They used camera data and machine learning to analyze and quantify NBA basketball in their 2012 and 2014 studies. They transferred this research to Second Spectrum, building systems to see sports through the eyes of a professional coach by extracting insights from tracking data.

“We discovered that sports was very interested in movement data. One of our key themes was ‘making the invisible visible’, and we’re working on doing it in a fraction of a second, in real time,” Maheswaran explained. Continuing down this trajectory has paid off, as Second Spectrum was acquired in 2021 for \$200M. ■

The *AI/anthropologist*

BY JULIA COHEN

"I believe in thinking hard about good problems," said Adam Russell, who joined ISI as the AI division director on July 10, 2023. ISI was founded in 1972 "to solve the world's most difficult technical problems." Today, the most difficult problems facing computing fields, especially AI, aren't necessarily technical; they range from ethical to existential. This might explain why Russell – a social anthropologist who obtained his D.Phil from the University of Oxford, where he was a Rhodes Scholar – is the right person for the job.

Craig Knoblock, the director of ISI, said of Russell: "We have the opportunity to influence the conversation that's happening about AI. Adam is a terrific person to do that. He is deeply concerned about the issues but optimistic that ISI can play a big role in influencing those discussions and help affect the future in terms of where AI is going."

APPLYING COLLECTIVE INTELLIGENCE TO ARTIFICIAL INTELLIGENCE

And where is AI going? Russell believes the answer to that lies in the collective. In a lot of industries, and certainly in academic areas, there's a focus on individuals and individual genius.

Russell said, "This type of thinking

doesn't give credit to the important feature that ultimately is the success of our species: our ability to coordinate and cooperate. We win in our ability to build social networks and create what some have called a cultural brain."

This is collective intelligence. And it is something he has worked on extensively, most recently at University of Maryland's Applied Research Laboratory for Intelligence and Security (ARLIS), where he helped build its Center for Decision Advantage, focusing on the creation and use of "collective intelligence" capabilities to enable better decision-making processes under deep uncertainty. "We collectively know more than any single individual among us; the really successful organizations in societies understand how to build that and tap that. And increasingly, our collectives are going to involve not just humans, but very smart machines."

The question he asks is: "How do we leverage that and exploit it to the full advantage?" "Hopefully I'll be able to help tap that further, because none of us are smart enough to get us out of these problems that we're facing. Most of our great advances have been made through collectives. And that will be increasingly true going forward. If I can help ISI

continue on this path and make the impact I think it can, it will be because of the collective."

APOCALOPTIMISM ABOUT AI

In Russell's eyes, one impact ISI's AI Division can make will be in keeping AI safe. In fact, he said, "it's our role to be in that mix. AI is clearly one of the more consequential technologies our species will have developed." The term he uses to describe his feelings on it: Apocaloptimism.

"It means, I'm extremely optimistic that there are profound opportunities, but we have to be aware of the risks. It's the right term for me right now, because both extremes are there, and that's what gives me the urgency to be in the discussion." He believes ISI has a role to play in this: "Part of it is to remain technically excellent, but also technically truthful. I think there are going to be new opportunities for ISI to lead the way."

What kinds of opportunities? Russell said, "I'm a big fan of demonstrating things in the world as a way to change what people think is possible. There are opportunities at USC (and beyond) for ISI to provide those demonstrations and help people understand that there are ways to thread this needle."

ADAM RUSSELL TOOK OVER THE AI
DIVISION OF ISI IN JULY 2023.

PHOTOGRAPH BY ANGEL ITUA

HIS VISION *for* AI

It seems obvious to say that - even as we live in a time of unprecedented plenty for many of us - it is also a time marked by massive disruption and increasingly complex problems. What is less obvious is how we - collectively - will rise to the challenge of solving those problems. By any stretch of the imagination, solutions will involve AI in some way, including technical innovation but also intelligent AI policy and regulation. My vision for AI is to make our most positive impacts on problems and policy by also continuing to build our four “Cs”: specifically, our competence - just look at the diversity of technical work of our people, illustrated in even just these few samples of the much broader work that we do; our character - we welcome people with very diverse perspectives but united by a common mission; our connections - both among ISI and USC, but also with other partners, communities, and stakeholders; and our contributions - recognizing that there are many different ways to make real contributions to achieving ISI’s mission, making us collectively more intelligent and wiser.

PLANS FOR THE AI DIVISION

“I’ve been fortunate to have worked with ISI’s AI Division in the past, and I’ve seen what they’re able to do. Technically, they’re incomparable in both the spread and also the depth of talent. I’m excited to take the entrepreneurial spirit that everybody at ISI has and help focus that energy on really important problems.”

As for his goals, Russell said, “I think purpose – knowing why we do what we do, and why it is important – is critical to any organization. A hallmark of success for me would be if people look back at their time in the division as having been impactful, important, and influential in their ‘why’ – as in, why are they in this space?” He laughed about this final goal, and said jokingly, “you know, nothing too ambitious.” ■

ISI Ph.D. student named *Forbes* 30 under 30



JULIE JIANG AT ISI MARINA DEL REY

BY LEILA OKAHATA

The graduating doctoral student in computer science was recognized for her work in amplifying social good on online platforms with her research at ISI.

education but is the first to receive a Ph.D. Math has always been Julie's strongest subject because of its logical reasoning, but she is also fascinated with the incalculable nature of human psychology. "We're simultaneously predictable but also very irrational beings," she said. "It's really

interesting for me to try to encapsulate and understand this paradox."

With her dual interests, Julie uses big data to glean insights into how online platforms can promote positive social behaviors and mitigate harmful ones. In her work she is most proud of, she found sharing one's preferred pronouns on Twitter fosters gender inclusivity: "This simple act of sharing pronouns that some people don't think matters...it matters a lot for promoting inclusivity and initiating a DEI front."

Alongside her research pursuits, Julie

chases self-improvement. With bookmarks saved on admirable scientists, including her ISI advisor Emilio Ferrara, she acknowledges that a great researcher views others not as competition but as growth models. Her colleagues, friends and family are her greatest inspirations. "I don't think any of what I do is just my work. It's a combined effort of people giving me mental support, love and technical guidance," she said.

Ferrara speaks highly of her: "I'm genuinely running out of adjectives to describe the incredible accomplishments that Julie has attained during her doctorate. Her achievements truly speak volumes

about her dedication and I can't wait to see what an amazing journey she'll start once she graduates."

Julie is currently looking

for industry opportunities and plans to transform digital platforms into healthy, diverse and inclusive spaces for all. "I hope to convert some of my research findings into actionable steps," Julie said. "I care about making an impact." ■

**She found sharing
one's preferred
pronouns on
Twitter fosters
gender inclusivity.**

On the morning of November 28, 2023, Julie Jiang woke up to buzzing notifications from loved ones congratulating her as a 2024 Forbes 30 Under 30 in Science. In both joy and disbelief, the LA-based computer social scientist repeatedly refreshed the awardee page, yet her name remained listed. She is both honored and eager to accomplish more. "This is not an endpoint in my career but a starting point," Julie said. She will graduate with a computer science Ph.D. in early 2024, after studying online social behaviors at ISI.

She grew up in both China and Canada, later moving to the U.S. in pursuit of higher education. She is not the only one in her family to complete a graduate

A voice in *public policies*

BY STEPHANIE LEE

In 2024, AI-powered content generation is projected to take a huge leap forward. How could new capabilities, such as fake but realistic-looking video generators, possibly endanger our society? This is the kind of question that legislators might pose to Wael Abd-Almageed, founder of the ISI visual intelligence lab and one of the world's leading experts on deepfake technology.

ADVISING ON BIOTECH

In 2023, Abd-Almageed was working with Homeland Security on deepfake detection strategies. Many other ISIs are actively engaging with public policy. As experts and thought leaders, they are often called in to advise legislators on a number of today's most complex issues at the intersection of policy and technology.

For Alexander Titus, a Principal Scientist in ISI's AI division, the question is biotechnology. With a background in the life sciences, Titus has recently been appointed one of twelve Commissioners on the National Security Commission on Emerging Biotechnology (NSCEB), bringing together members of Congress, academia, and the private sector. "We're people who are tasked with thinking deeply about the US government's collective approach to biotechnology," Titus said.

Taking into account a range of applications, from synthetic biology to new risks such as pandemic agents and

bioweapons, the Commission puts forth policy recommendations aimed at safeguarding against biotech harms, while also leveraging its potential for economic leadership and national security.

Such opportunities to participate in government affairs is as challenging as it is rewarding. "Public service is an important part of a rich personal and professional life," says Andrea Belz, ISI research director. Belz also serves on a federal committee responsible for evaluating the impact of a small business innovation funding program within the DoD. "Studying the impact of these policies in the university setting is another way to perform public service and give back," she said.

For Terry Benzel, ISI's director of the Networking and Cybersecurity division, giving back is at the state level. Benzel serves on the Technical Advisory Committee for the California Department of Transportation's Road Charge Program. This initiative is considering a revolutionary change in how the state collects funds to pay for road repair, replacing the standard gas tax, typically collected at the gas pump, with a per-mile road use fee. It comes in response to the growing number of electric vehicles

in California. But a mileage tracking system will implicate typical network security and privacy issues. This is where Benzel's expertise comes in.

"It gives me a great sense of fulfillment to take my many years of deep research and research management, and put it into the world and society," she said. Only time will tell whether the Road Charge Program, along with Benzel's efforts, will materialize into legislation. "Policy is always a little bit of a dance," she said. But ISI research has certainly helped move the needle before.

ISI'S WORK IN "BOT" LAW

Over the past decade, Emilio Ferrara, ISI Principal Scientist, has spent years studying how social media bots—automated accounts programmed to mimic human behavior online—have contributed to disinformation, misinformation, and political distortion. His work has surfaced misleading bot operations in major political events around the globe, leading him to believe that addressing such threats would require not only technology solutions, but also policy ones.

Ferrara's call was heard. In 2019, California Governor Jerry Brown signed into law Senate Bill 1001, the nation's first "bot" disclosure regulation. Drawing heavily from research and findings from Ferrara's lab, the so-called B.O.T. Act, short for Bolstering Online Transparency, mandated that bots identify as automated accounts before attempting to influence real users' voting or purchasing behavior. "That's one example of how our work contributed to the creation of laws and regulations," said Ferrara. It will not be the last. ■



Excellence in research through diversity

ISI is committed to solving big problems in the world by leveraging differences and ensuring an inclusive environment. Over the past several years, the leadership at ISI has taken steps to show their commitment to diversity, equity and inclusion (DEI), including the formation of the DEI Steering Committee, bringing a DEI consulting firm onboard, creating a DEI position, and more. “Addressing diversity, equity and inclusion throughout ISI is of utmost importance to who we are and our future,” said Terry Benzel, Networking and Cybersecurity division director, who serves as associate director of the DEI Steering Committee.

The following programs have been initiated:

- **Employee Resource Groups** promote inclusivity, authenticity, and belonging.
- **ISI Mentoring Program** aims to improve the ability of all people to succeed.
- **Our Research Engineer Internship Program** provides a pipeline for master’s students and undergrads with an interest in becoming Research Engineers.
- **Stimulating STEM** is a free program designed to spark an interest in STEM among students from marginalized communities who have been historically underrepresented in the industry.
- **Cultural celebrations** to recognize and celebrate diverse identities and underrepresented groups.



BY EMMANUEL DORLEY
ISI POSTDOC

I went into this field because I wanted to find solutions for real life problems that only computer science could solve. Growing up I did not see myself going into this discipline partly because there were not a lot of people who looked like me in this space. It didn’t register that this was a career path that was open to me.

When I was a junior in high school, my teacher recommended a program for students from underrepresented backgrounds. During my senior year, I worked hard to get into a historically Black college or university and was accepted at North Carolina Agricultural and Technical State University. While I was in college, I didn’t notice the lack of Black representation in computer science, I was just

amazed by the technology I was working on.

I saw the disconnect later: this field is not built for people like me because people like me are not working in this field. For example, Siri often does not understand the way I speak, and this made me realize the importance of diversity and having different perspectives in the room when we build those systems.

Computer vision also has a hard time working with certain skin tones. When you ask a bot to draw you someone beautiful, what color will that person be? This is why we need more people like me in computer science, to inspire the youngest to get into this field. Kids of color get into sports because they see athletes who look like them.

We need to do the same for STEM. We also need to fight the fear about AI eliminating low income jobs, and let them see the big picture of how this will benefit them in the long run.



LEFT: OSAZE SHEARS IN THE LAB OF ISI ARLINGTON.
RIGHT: STUDENTS FROM THE STIMULATING STEM PROGRAM VISIT ISI.
PHOTOGRAPHS BY JON FISCHER AND USC/ISI

ALEFIYA HUSSEIN
RESEARCH TEAM LEAD

"ISI has provided a nurturing environment where I am encouraged to explore new directions, make mistakes, and grow. I feel valued for my opinions and unique strengths."

OSAZE SHEARS
SENIOR RESEARCH ENGINEER

"At ISI, I've had the freedom to work on interesting and impactful projects, while collaborating with passionate teams of researchers across the country!"

LINETTE
STIMULATING STEM PARTICIPANT

"Before attending this summer program I was just thinking of getting my bachelor's, but Stimulating STEM has made me want to pursue a master's degree in computer science."



JAMANI KING
DEI SPECIALIST, ISI

"I appreciate the opportunity I have to foster inclusivity at ISI"

Since joining ISI in 2018 I have received nothing but genuine support for my personal and professional goals from my supervisors. I want everyone to feel that at ISI.

In 2022, I suggested to our HR director to create the DEI specialist role. ISI was already going in that direction with a DEI consulting firm, and I had experience running our summer diversity program, Stimulating STEM. ISI's stance on DEI aligns with my personal values and purpose. I've always been passionate about doing meaningful work that makes a positive impact on people's lives. I didn't anticipate I

would be implementing my master's degree in Social Entrepreneurship and Change at the research institute based on information technology.

I appreciate the opportunity I have to foster inclusivity at ISI. My role is important to ISI because this work is crucial to making sure we stick to our commitment and ensure everyone interacting with our organization feels they belong and have a genuine opportunity for success. Lastly, my role can assist in more significant innovation through the work we are doing to diversify our researchers.

The birth *of* ISI Arlington

BY BOB PARKER

ISI's Arlington Office, which celebrated its 25th anniversary in 2022, was a tech innovator from the beginning. Bob Parker recounts its origins.

It was 1997. ISI was an established research center and hub of technological brainpower on the west coast, overlooking the Pacific Ocean. I had just completed an Interagency Personnel Agreement (IPA) at DARPA (Defense Advanced Research Projects Agency), the DoD organization responsible for creating transformational change in support of national security, and was about to return to Marina del Rey. But with historical east coast roots and a desire to raise my family there, I asked a question: could we establish an official east coast presence for ISI?

In 2022 the "Arlington Office" as it is now called – previously known as "ISI-East" – celebrated its 25th anniversary. Located in Arlington, Virginia, near Washington, D.C., it emerged from the consolidation of two existing ISI groups plus a not-yet-formed Advanced Systems Division. ISI-East gradually morphed into a premier research center.



Its proximity to DARPA and other government sponsors positioned the Arlington Office as a hub for applied research, often bridging controlled unclassified work and classified projects, in addition to fundamental research. But before we can talk about what the ISI Arlington Office became, we should understand the focus of the pre-existing component groups and how the Arlington operation changed over time.

IT ALL BEGAN WITH TECH SUPPORT

The earliest east coast ISIers go back to 1989, when DARPA's Computing Systems Technology Office (CSTO) came to ISI with a simple request. DARPA CSTO wanted specialized IT support for their program managers that incorporated the most advanced technology possible. Familiar with the well-established IT support group in the Marina del Rey location, DARPA, ISI's principal sponsor, turned to ISI for help.

In response, ISI hired Dan Pederson to put together a team – John Reed, Larry Bookstaver, Brian Miller, and Ray Mason who was the point of contact in Marina del Rey along with Raymond Bates – and they were initially tasked with providing the office fairly routine day-to-day desktop support. However, this role soon expanded as the computing needs evolved. In 1991, DARPA CSTO initiated plans to relocate to Virginia Square, marking the beginning of “scope creep” for ISI-East.

The IT team suddenly found themselves tasked with ensuring DARPA Program Managers arrived at their new offices equipped with cutting-edge hardware – offices set up with multiple monitor NeXT Cube Color systems complete with in-office printer, document scanners, and a generous (for the time) 1GB of local hard disk storage in addition to what was built into the workstations themselves. A much more advanced setup than the rest of DARPA.

INSPIRED BY THE U.S.S. ENTERPRISE

With the transition to Virginia Square

complete around 1991, the “simple request” became something altogether more complex.

Steven Squires, leading the Computing Systems Technology Office (CSTO) at DARPA and an avid Star Trek fan envisioned a High-Performance Computing Enterprise (HPCE) inspired by the U.S.S. Enterprise. He wanted a futuristic environment in which to showcase DARPA technology based on this series; a presentation space as well as a functional lab that could educate government decision makers and the general public on possibilities and capabilities of the internet.

He called it “the country's access window into the National Information Infrastructure.” It certainly looked the part. Suddenly, the IT support team found themselves at the center of the team that was designing, constructing and provisioning this facility.

“WOULDN'T IT BE NEAT IF...”

The HPCE design was based on the U.S.S. Enterprise control room with similar octagonal design elements, a large projection screen in the front of the room and a raised central seating area where the captain's chair is located.

It would be a configurable laboratory environment that could accommodate the latest DARPA technology, and include an early cave automatic virtual environment (CAVE) which could create a 3D environment in the room with multiple full wall displays. A team was assembled to bring Squires' vision to life.

This included a Hollywood set designer, a construction supervisor, software developers and CAVE specialists. ISI's principal role was provisioning the facility with the latest technology and integrating computers, networking, and AV services within the facility, as well as trying to accommodate Steve Squires' “wouldn't it be neat if” requests.

Hat tip to: Bruce Gibeson, Steve Grinovich, Dave Strout, Richard Ogata, Roger Wuerfel, Michael Kelly, Brian Miller, John Reed, and Dan Pederson

BOB PARKER AT ISI ARLINGTON,
SEPTEMBER 2023.

PHOTOGRAPH BY JON FISCHER

who were all key parts of this “Enterprise” group. Having this impressive facility on site meant a number of DARPA programs wanted their research systems integrated into the environment for demonstration to defense programs. Those were crazy days, as ISI-East found itself at the forefront of showcasing DARPA’s technological prowess in a captivating and futuristic setting.

THE WHITE HOUSE YEARS

The Clinton administration brought a new dimension to ISI-East’s endeavors. Al Gore’s push to bring Internet technology to the White House positioned ISI as a key player and the ISI IT team became frequent White House visitors.

Amidst the White House activities, the team experienced many memorable moments: from Secret Service canines reacting to latent scents in an ISIer’s Jeep left by their dog, to playful interactions with Socks, the White House cat. These episodes added a touch of humor to ISI-East’s impactful contributions to the intersection of technology and government.

Two members of the ISI-East team – John Reed and Brian Miller – installed the technology for a wireless demonstration to PotUS/VPotUS of Multicast backbone (Mbone) video conferencing on the South Lawn of the White House. The demo showcased a world record 4mb Internet connection to the South Lawn using a microwave link. Looking for a location to place the transmitter antenna, Reed was evaluating the rooftop of the Press Club to see if there was a clear line of sight for the microwave link, often called a “clear shot.”

Poor choice of words on his part. John suddenly found himself surrounded by secret service agents! Meanwhile, Miller was on the South Lawn along with folks from Motorola working on the microwave link. He remembers the Motorola team had radios tuned into the Secret Service channels and they picked up some chatter about persons pointing “a long skinny cylindrical object from a nearby rooftop in the direction of where PotUS/VPotUS were going to be in a few hours.”

It all got cleared up and the demonstration went on without a glitch, but it highlights the challenges and excitement of bringing cutting-edge technology to the highest levels of government.

TRANSITION TO A FULL-FLEDGED RESEARCH GROUP

In February 1994, the growing ISI team established an official office at 4350 North Fairfax Drive, Arlington, VA, although they spent most of their time on site at DARPA. Forrest Houston – who is still at the Arlington Office today – joined the group supporting the HPCE. Around this time ISI-East began a gradual transformation into a research group.

In 1995, Allison Mankin was brought onboard from the Naval Research Laboratory in an effort to bolster the research side of

things. Her group worked out of the same building as the ISI IT team, but in different offices. Mankin had been working with ISI researcher Steve Casner and helped create Mbone – which allowed for the streaming of voice and video over the internet to hundreds or thousands of people at once, and was the centerpiece of the demonstrations to PotUS. Her contributions extended beyond Mbone, as she brought a DARPA grant to ISI aimed to build a new testbed, CAIRN, that would provide a wideband ATM backbone and local access at varied speeds.

In 1996, it hosted a community multicast for the IP Next Generation discussion, involving over 500 participants from 40 nations. Additionally, in 1996, Mankin received an NSF grant called TRAIL that enhanced the testbed and was concerned with the scaling and routing designs for IPv6 as it neared operational adoption.

USHERING IN THE NEXT CHAPTER

The transition to a full-fledged research organization was gaining momentum. So, in January 1997, when I returned to ISI from an IPA as deputy director of the DARPA ITO (Information Technology Office), the two groups working out of 4350 North Fairfax Drive combined to

form ISI-East and I became the first director of ISI-East and a deputy director of ISI, steering the institute into a new era. By 1997, changes in DARPA contractor rules meant a shift in ISI’s focus. New rules restricted organizations involved in DARPA support work from competing on research contracts.

ISI chose to withdraw from support work to concentrate on its primary mission of research. As ISI phased out support activities, the IT support group diminished, and Forrest Houston assumed the role of in-house IT support and security officer for ISI-East. January 1997 marked a pivotal moment for ISI-East: I found myself standing in a suite of empty, newly leased offices, wondering how to rapidly build a computing research group from scratch. What I needed was staff and money; that would be the next phase of ISI-East’s evolution. The challenges were significant, but the foundation laid by ISI-East’s early years provided the impetus for the next chapter in the institute’s history.

Today, the primary research areas worked on at the Arlington Office are microelectronics and heterogeneous architectures, cybersecurity and testbeds, and artificial intelligence. A multi-divisional research platform that supports a wide range of research, the Arlington Office continues to shape the intersection of technology and government and remains committed to pushing the boundaries of what is possible in the realm of technology and research. It’s come a long way from that “simple request.” ■

I’d like to acknowledge and thank the contributors to this article who helped piece together this story: Raymond Bates, Larry Bookstaver, Bruce Gibeson, Forrest Houston, Allison Mankin, Brian Miller, John Reed.

**Surrounded by
secret service
agents and canines
while testing at the
White House.**

2023 ANNUAL REPORT

USC *Information Sciences Institute*



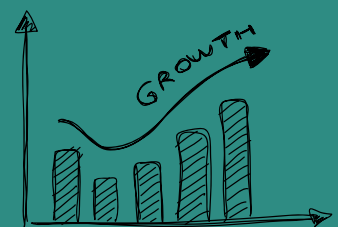
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80 MILLION
IN FUNDING
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PERSPECTIVE

Terry Benzel, MBA, shares
what it takes to be
an ISI leader

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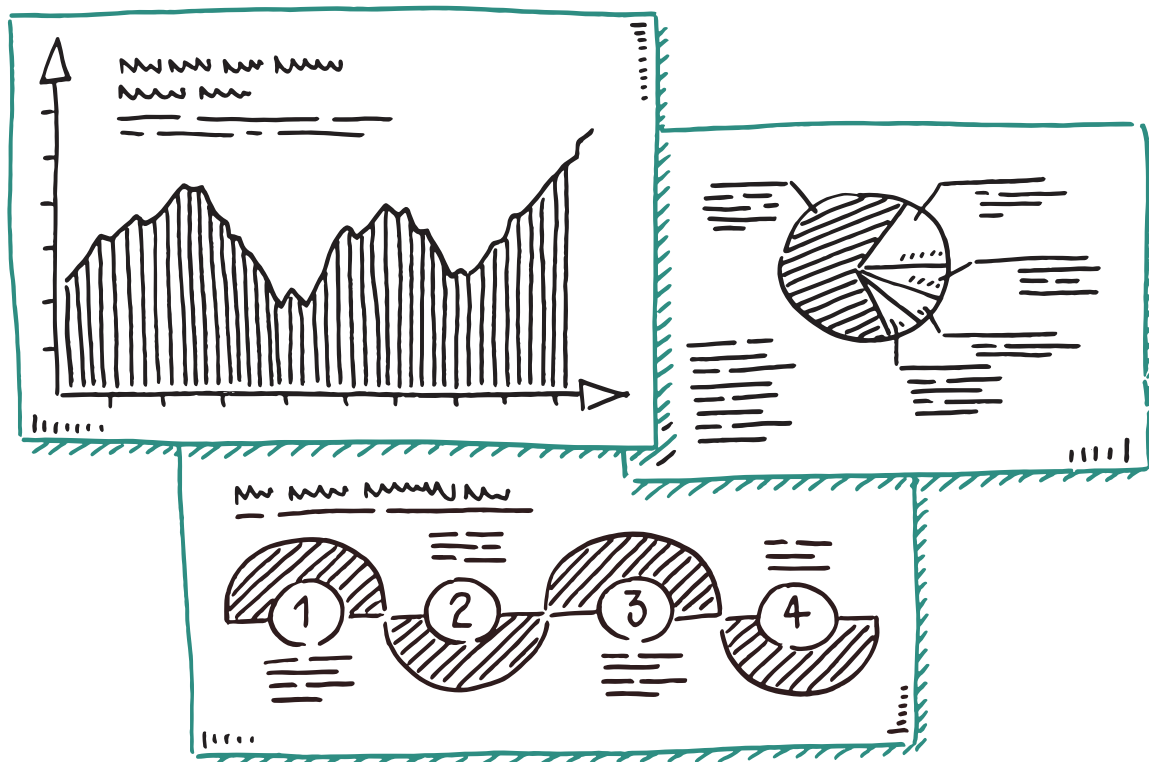
USC Viterbi

WHAT TO EXPECT IN 2024...

We asked our
researchers

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**"Empowering,
collaborating,
and thinking
strategically"**

TERRY BENZEL, MBA
ASSOCIATE DIRECTOR OF ISI



Leadership at ISI is about empowering and encouraging the phenomenal research that happens here, while also navigating the institute through its own exciting growth trajectory. Drawing on my executive MBA in organizational behavior, I bring a unique perspective to the leadership table, one that is deeply rooted in both technical and people-centric aspects.

To me, leadership has three parts: empowering people, working collaboratively as a team, and thinking strategically. Empowering our researchers helps ISI stay ahead in our rapidly evolving landscape. For example, in a recent brainstorming session about addressing growing challenges in networking research, I encouraged the team to redefine the very essence of "networking."

Enabling individuals to think big is paramount for innovation. At the other end of the spectrum from thinking big, there's paperwork – the bureaucratic hurdles faced in research. Part of my role as Networking and Cybersecurity division director is to cut through red tape, allowing our researchers to focus on their work.

Beyond the individual researchers, I also look to empower teams and the institute as a whole through collaboration and strategic thinking. One of the things I love about working at ISI is being around some of the smartest people I've ever encountered, and my job is to ensure they are able to do their best work. Sometimes that means connecting researchers with different areas of expertise, and I've seen it lead to incredibly successful outcomes. But it

can also mean gazing ahead to the future to understand the broader landscape and create an environment where exceptional research can unfold. This type of strategic vision goes beyond internal dynamics. As ISI holds a prominent position in many technical fields, I believe it's important to consider our role as a global leader as we look toward our future.

One of my passions is change leadership, that is, leading an organization through a transition. Right now, ISI is growing substantially and it's crucial – and exciting! – to address the challenges that come with expansion. For those looking to become a leader, my advice to you is: connect with someone in a leadership position that you admire! Ask questions; seek opportunities to join a successful team; be willing to work outside of your research area; jump in and be prepared to do some of the mundane work required for success.

ISI has a mentoring program for new hires, and several workshops led by experienced leaders like Craig and Yigal to instill leadership skills in researchers. We are always looking to provide opportunities for researchers to become leaders.

Leadership at ISI is about much more than being a PI or having multiple grants or contracts. For me, it will always come back to creating an environment that fuels cutting-edge research. As we embrace the challenges of growth, I'm excited about the journey ahead and the incredible impact ISI will continue to have on research and innovation. ■

LEADERSHIP

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Director, The MOSIS Service

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Director, Human Resources

ISI BY THE NUMBERS

STAFF, FACULTY,
AND STUDENTS



4
4
0
+

Postdocs

7

Ph.D. Students

92

Summer Interns

10

Faculty

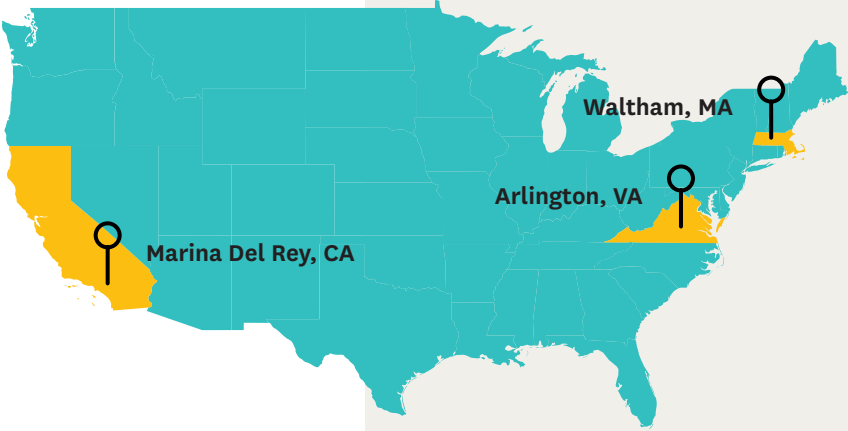
29

STAFF AND FACULTY DEGREES		
Bachelor's		56
Master's		54
MBA		9
Ph.D.		78



- Astronautical engineering
- Biomedical sciences
- Civil and environmental engineering
- Communications
- Computer science
- Electrical and computer engineering
- Physics and astronomy
- Population and public health sciences
- Preventive medicine
- Spatial sciences

ISI LOCATIONS



TOTAL OFFICE SPACE

160,196 SQ FT

QUANTUM COMPUTERS →

ONE

2023
NEW RESEARCH
GRANTS

46



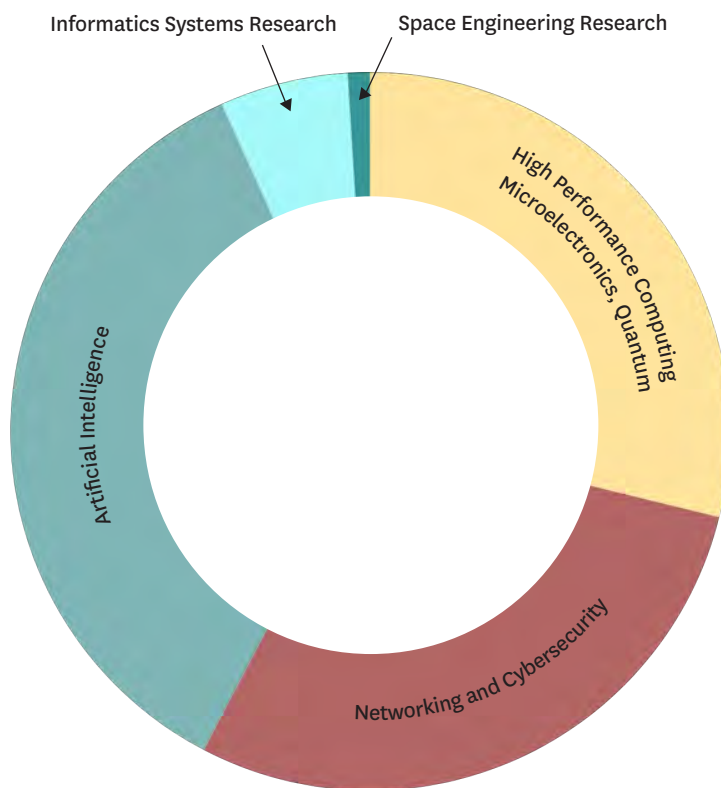
2023
RESEARCH
EXPENDITURES

\$80M



2023
SEMINARS

61



● **Artificial Intelligence**

- Machine learning and data science
- Natural language processing
- Knowledge graphs
- Scientific data analysis and discovery
- Multi-modal understanding
- Common sense and reasoning
- Computational social science
- AI fairness

● **Networking and Cybersecurity**

- Cyber experimentation research, methods, and infrastructure
- Network measurement, analysis, and defenses
- Security for wireless networks
- Cyber-physical systems and autonomy
- Networking consensus algorithms
- Understanding communication for human-focused agents
- Modeling human behavior for cybersecurity

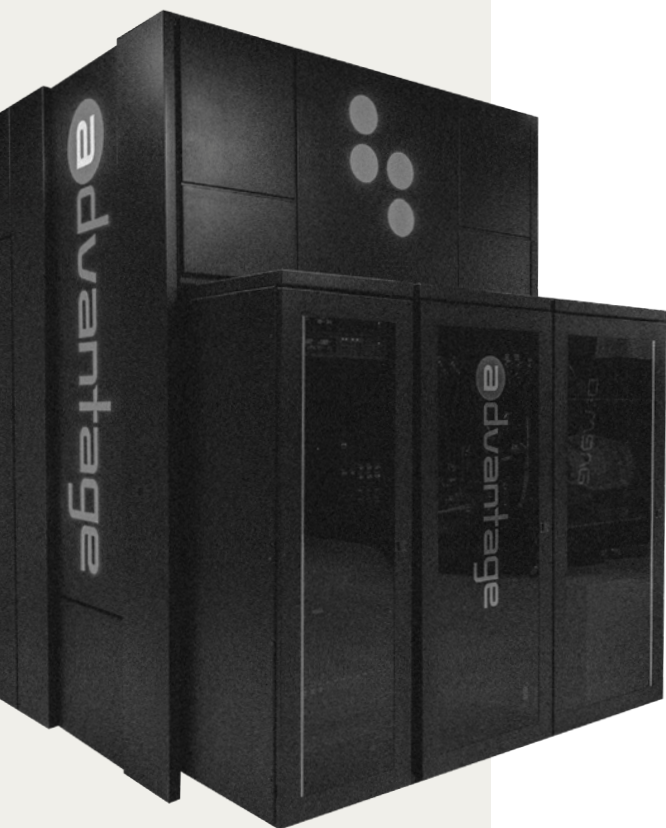
● **Informatics Systems Research**

- Informatics cyberinfstructures
- Medical informatics

● **High Performance Computing, Microelectronics, and Quantum Information Processing**

- Secure, robust, and trusted electronics
- Heterogenous and cloud computing
- High performance computing architectures and software
- Science automation technologies
- Quantum information science
- Materials, devices, circuits, and architectures for advanced microelectronics, photonics, and magnetics; hardware architectures for artificial intelligence and sensors

● **Space Engineering Research**



ISI TIMELINE

1972

- ISI founded by Keith Uncapher
- ARPANET interface

1974

- ARPANET Voice Over IP

1977

- ARPANET Addressing and Request for Comments

1979

- Packet Radio Terminal Concept

1981

- MOSIS Semiconductor Implementation Service

1983

- Internet Domain Name System
- Digital Phone Communications

1985

- Packet Video

1988

- Rhetorical Structure Theory

1992

- Internet Society

1993

- Online Payments

1997

- FASTXchange Spin-off
- ISI Arlington

1998

- ICANN Spin-off

1999

- USC Institute for Creative Technologies Spin-off

1970

1980

1990

2000

- Internet2 Collaboration
- Practical Rhetorical Theory

2003

- DETERLab Cybersecurity Testbed

2008

- Reconfigurable Robots

2009

- SoCal Seismic Hazards Map

2000

2010

- Nano-Satellite

2012

- USC-Lockheed Martin Quantum Computing Center

2014

- Sports Data Analytics

2015

- Human Trafficking Search Tool
- Social Media Bot Detection

2017

- ISI Boston

2019

- MOSIS Alliance with Intel Corporation

2010

2022

- ISI 50th anniversary
- ISI Arlington 25th anniversary

2023

- USC announces Frontiers of Computing
- ISI leads Southern California hub for microelectronics
- SPHERE testbed to replace DETERLab

2020

Artificial *Intelligence*

ADAM RUSSELL

DIVISION DIRECTOR

ELIZABETH BOSCHEE

ASSOCIATE DIVISION DIRECTOR

The Artificial Intelligence Division at ISI is one of the world's largest AI research groups, with over 160 research faculty, staff and graduate students. Most researchers hold graduate degrees in computer science or related disciplines, and many hold research faculty appointments at the Viterbi School of Engineering. The division conducts fundamental and applied research, and – as can be seen from our website - AI researchers actively work across a broad range of technical spaces and disciplines. We believe this diversity of people, technologies and topics is critical for helping us contribute to three areas of growing societal and strategic importance: first, building “superteams” with AI to achieve previously impossible things, whether those are superteams for scientific breakthroughs or superteams for better decision-making. Second, bolstering democracy with AI by building capabilities to make sure that AI ultimately proves to be a positive asset for all of us. Third, being prepared - with AI - by creating capabilities to help society better anticipate, respond to, and ultimately mitigate emerging risks from everything from climate change and potential pandemics to even socio technical risks from AI itself.

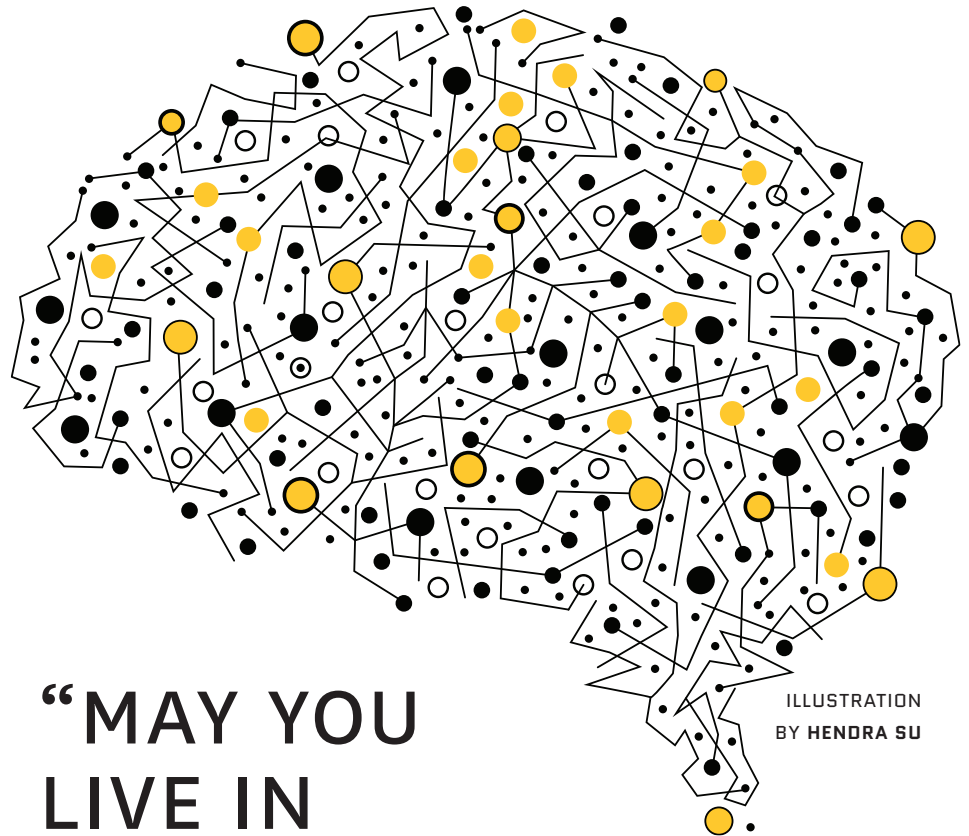


ILLUSTRATION
BY HENDRA SU

“MAY YOU LIVE IN INTERESTING TIMES”

This (apocryphal) Chinese curse nicely captures the world in which we live today, and it's never been more true for an area like AI. Seemingly every week – or even every day – another development that, in less interesting times, might have been seen as game-changing now pops up, almost casually, as a preprint or a news headline or a policy discussion. These are indeed interesting times. Trying to chart a strategy for an AI Division in this environment can feel like a fool's errand, with plans likely to be made obsolete almost as soon as they're created

(even with the help of Generative AI). But strategy is more than planning – strategy serves as a kind of cardinal north for helping us to do the right things, while also helping us do things right, especially in the midst of rapid change.

So it is exactly during these periods of turbulence when strategy is most important – for making sure we can remain focused on supporting ISI's bigger mission while we remain capable of remaining aware of very dynamic technical, funding and policy trends.

A three dimensional strategy for the division: AI Now, AI Next, and AI In The Wild

AID's strategy has been designed as a kind of 3-D lens to help us do just that - focus in and telescope out. This strategy, or what is called our "3(AI)D" strategy, comprises three dimensions.

AI NOW AID researchers and partners will continue to create transformational AI focused on delivering real-world impact today - accelerating scientific discovery, improving healthcare outcomes, analyzing complex data to inform decision making, enhancing our capabilities to forecast what's coming, and more.

AI NEXT Even as we tackle today's problems, we will continue to lay the groundwork for creating the new AI we'll need to address tomorrow's problems. AID will be pioneering new techniques on the frontier of AI research to tackle currently intractable challenges like creating AI that actually reasons, understands us and our world, and can act in ways that are consistent with our most important collective values.

AI IN THE WILD The success of the other dimensions depends, in no small way, on this dimension: creating capabilities that help us understand what AI is doing for, and to us, in order to help us harness

AI as it is deployed into the real world. This dimension is about helping all of us to realize AI's immense promise while mitigating its considerable pitfalls, including challenges of bias, inequality, polarization, and security risks.

These three dimensions are clearly interrelated and interdependent, which is why we think they're the right ones for the moment. These dimensions collectively make up our 3(AI)D lens that allows us to telescope out - to help us decide on the right things to do - but that also allows us to focus in, and ensure we are doing things right.

By combining cutting-edge research across these dimensions, a commitment to trying to solve the most important problems, and engaging with bigger policy discussions on AI, ISI's AI Division will lead the way in promoting AI capabilities that represent the best of human ingenuity and positive impact.

We envision an AI ecosystem that empowers people, uplifts society, and helps build a more just and sustainable future for all - and we look forward to working with each other, our partners, our sponsors, our communities, and - we hope - with you to do just that.

MACHINE LEARNING AND DATA SCIENCE

Developing efficient algorithms to analyze data from various application areas, including biomedical sciences, computational social science, and cybersecurity.

NATURAL LANGUAGE PROCESSING

Low resource machine translation, multilingual representation learning, transfer learning, dialogue, decision-making, question answering, summarization, ontologies, information retrieval, extracting critical information about world events from foreign language sources.

KNOWLEDGE GRAPHS

Using AI and machine learning techniques to construct and exploit large-scale knowledge bases and to induce taxonomies from data.

SCIENTIFIC DATA ANALYSIS AND DISCOVERY

Interactive knowledge capture, intelligent user interfaces, semantic workflows, provenance, large-scale data integration, analysis of biomedical data.

MULTI-MODAL UNDERSTANDING

Image and video understanding for deepfake detection, visual misinformation identification and multimedia analysis, face recognition, biometric anti-spoofing, learning "common sense" knowledge from text, video, images, and audio, learning to automatically discover the structure of complex events from multilingual multimedia data.

COMMON SENSE AND REASONING

Building cognitively inspired computational paradigms for evaluating common sense AI, human-centric dialog agents, game-theoretic simulators.

COMPUTATIONAL SOCIAL SCIENCE

Structure detection and pattern matching in unusually complex systems with hidden information, large-scale contextualized social media analysis, detecting and responding to social engineering attacks.

AI FAIRNESS - detecting and mitigating bias, robustness against adversarial attacks, forecasting, crowdsourcing, identifying cultural values, polarization, and misinformation.

Networking & *Cybersecurity*

TERRY BENZEL

DIVISION DIRECTOR

DAVID BALENSON

ASSOCIATE DIVISION DIRECTOR

The prevalence and interdependence of cybersecurity, networking and social systems informs the research and development agenda of the Networking and Cybersecurity Division. Networking is the backbone of the interconnected world, and cybersecurity is its guardian. The 70+ researchers, faculty, Ph.D. students, and student workers in the division focus on cyber experimentation, network measurement, security for wireless networks, networking consensus algorithms, cyber-physical systems and autonomy, understanding communication for human-focused agents, and modeling human behavior for cybersecurity. "We delve into understanding and analyzing the underlying Internet, innovative approaches to analyzing vulnerabilities and engineered attacks, while applying the theory and practice of distributed computing," says Terry Benzel, division director. "We are leaders in designing, architecting, curating, and operating research infrastructure and data to guide science-based explorations." The division aims to connect and secure our interconnected future.



ILLUSTRATION GENERATED BY DALL-E

CYBER EXPERIMENTATION RESEARCH, METHODS, AND INFRASTRUCTURE

Catalyzing a robust ecosystem of experimental infrastructure, capabilities, and communities by creating models, frameworks, testbeds, tools, and approaches to enhance the science of cyber experimentation. Make the experiments rigorous, reusable, and repeatable.

NETWORK MEASUREMENT, ANALYSIS, AND DEFENSES

Developing novel Internet measurement

techniques, tools, and data; applying formal methods and temporal logic for operational identification of attack dependencies and descriptions of traffic behaviors. Applying machine learning for the classification and quantification of privacy leaks.

SECURITY FOR WIRELESS NETWORKS

Improving the security of wireless networks, including 5G and next-generation mobile networks, through novel network embedding techniques, constraints validation, and protection of

Looking into the Division's Future Research Agenda



In the coming year the division will extend its long history of R&D to explore fundamental questions around redefining networking and cybersecurity, and to expand into new research areas including space, automotive and autonomous vehicle security and privacy, reproducible and democratized research infrastructure, and AI for cybersecurity operations.

NETWORKING is an underlying core to all aspects of research and daily operations across many fields. As information science rapidly accelerates we will explore research challenges in the community ranging from decentralizing the internet, to fully encrypted networking, to formally verifiable networks.

SPACE SYSTEMS are facing an increasing threat landscape focused on all aspects of earth-to-space, space-to-space, and space-to-earth. These threats include jamming, spoofing, and cyberattack. We are engaged with industry, government, and research labs to explore the application of zero-trust architectures, network operating systems for satellites, DevSecOps, hardening of interfaces, and cybersecurity testbeds for space.

SECURING VEHICLES is a critical need. With today's cars becoming increasingly connected and autonomous, hacking is a real concern. A big challenge is the lack of data available to support research. ISI and its collaborators are building data collection devices and developing a

portal to make needed datasets and associated tools available to support the computer science and engineering community pursuing research in automotive and autonomous vehicle security and privacy.

THE SPHERE RESEARCH INFRASTRUCTURE is a newly initiated project to transform and democratize access to cybersecurity and privacy experimental infrastructure. This infrastructure will offer access to a variety of hardware, software, and other resources, connected by user-configurable network substrate, and protected by a set of security policies uniquely aligned with cybersecurity and privacy research needs. We will develop new capabilities for increased reproducibility and replicability while increasing access to a variety of communities and through internships for undergraduate students from communities underrepresented in the computing workforce.

AI TO IMPROVE SECURITY OPERATIONS will explore collaboration between teams of humans and AI to improve operations and intelligence data analysis, including sharing useful information while protecting individual privacy and information confidentiality. We are working to understand the utility of AI in systems and applications. With AI we may finally be at a point where we can develop new operations and analysis technologies to improve the overall performance of human analysts working in stressful environments.

information; applying machine learning to assist identification of applications based on their network traffic. Applying advanced network mapping capabilities.

CYBER-PHYSICAL SYSTEMS AND AUTONOMY

Studying the semantics of cyber-physical systems (e.g., space, energy, medical) to understand how software will interact with higher-level, human-understandable physical models, operate in mission-critical zero-trust environments, and interoperate with legacy systems.

NETWORKING CONSENSUS ALGORITHMS

Researching algorithms for blockchain consensus and smart contracts, federated learning, privacy preserving computations and linkage of data; and their application to financial transactions, medical data records, and 5G/edge compute environments.

UNDERSTANDING COMMUNICATION FOR HUMAN-FOCUSED AGENTS

Enabling better communication between humans and computers through automated comprehension of multimedia data, effective use of operator feedback

for learning, and determining proper representations of objects and actions.

MODELING HUMAN BEHAVIOR FOR CYBERSECURITY

Developing methods for detecting and fingerprinting attack campaigns by leveraging metadata from communication channels and employing novel techniques to redirect attackers. Developing the DASH agent simulation platform to combine observational data with cognitive models of behavior at the scale of millions of individual agents.

Computational Systems & Technology

MATTHEW FRENCH

DIVISION DIRECTOR

The CST division spans electrical engineering, computer science, physics and math to address all aspects of computing systems — from atoms and circuits, to computing architectures and software. The division accommodates recent growth: The California Defense Ready Electronics and Microdevices Superhub (DREAMS) launched and MOSIS joined the division to accelerate innovation transitions. The USC-Lockheed Martin Quantum Computing Center (QCC) continues to pursue quantum computing, communication and sensing research, while the Secure and Robust Electronics Center (SURE) researches assured microelectronics and privacy preserving computation. New forms of computing are being pursued through innovations such as computational physics, in-pixel computing, optical computing, reconfigurable computing, edge computing and 2.5D and 3D heterogeneous integration of application specific hardware. Optimizations target specific domains, such as AI-based signal processing, spaceborne and ground-based data processing and remote sensing systems. These innovations are unleashed through research in system software, compilers, runtime frameworks and science automation technologies.

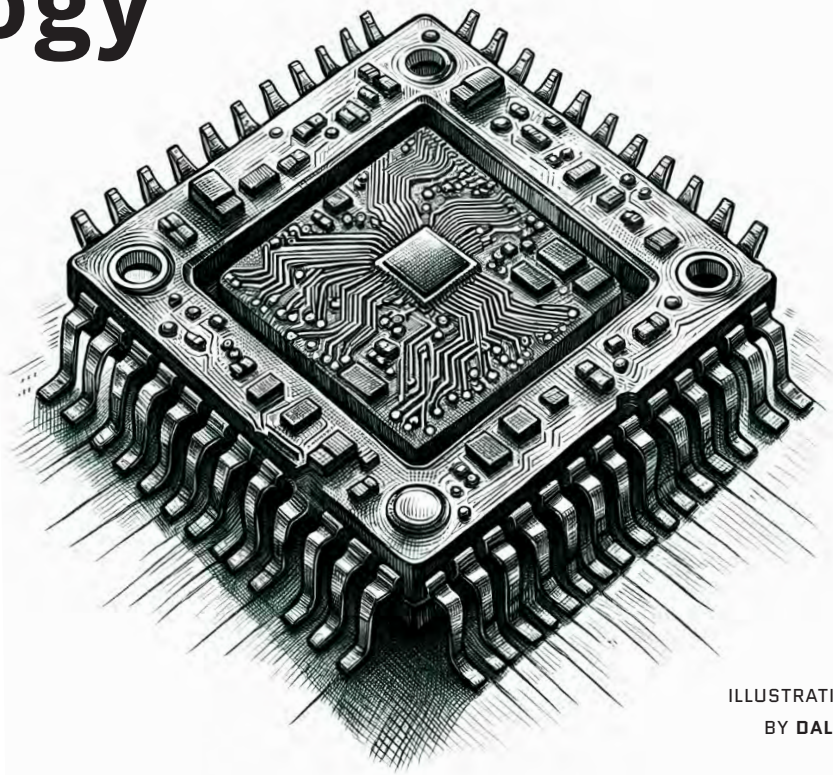


ILLUSTRATION
BY DALL-E

- At ISI Boston's Laboratory for Quantum-Limited Information (QLIlab), researchers explore how to build the most sensitive communications and sensing devices when a signal is imprinted on only a fraction of a photon — the fundamental quantum particle of light.
- The Science Automation Technologies Group (SATG) explores the interplay between automation and management of scientific workflows including resource provisioning and data management. The group leads the design and development of the Pegasus Workflow Management software and conducts research in job scheduling, resource provisioning in distributed systems, workflow performance modeling, provenance capture, and use of edge and cloud platforms for science.
- At the Application Specific Intelligent Computing Lab (ASIC) researchers apply “alternate state variables” such as electrons, photons, phonons and magnetic spins to deliver next-generation hardware fabrics using novel monolithic and heterogeneous device integration for artificial intelligence, smart sensors, smart and secure manufacturing and quantum information.
- The Heterogeneous Systems Group (HSG) spans supercomputing to the computational edge. The group's expertise includes the development of performance-portable compilers and runtime systems, fault tolerance for next-generation space processors and artificial intelligence on resource-constrained devices.

The *MOSIS* Service

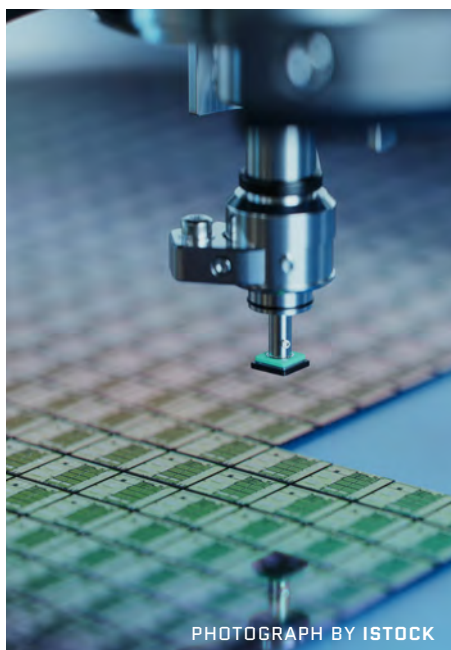
The MOSIS Service offers semiconductor fabrication services to semiconductor integrated circuit (IC) designers at universities, research organizations, defense and aerospace companies and commercial design companies for multiple-project wafer and low-volume dedicated wafer projects.

Since its founding in 1981, MOSIS (Metal Oxide Semiconductor Implementation Service) has processed more than 60,000 IC designs, averaging five chips a week. The service enables IC designers to prototype innovative semiconductor designs within an effective cost structure, offering a range of processes: CMOS FinFET, FD-SOI, Bulk, III-V compound semiconductor, high-voltage BCD, and other specialty processes. MOSIS collaborates with five world-class foundries — TSMC, Intel Foundry Services, Samsung Foundry, WIN Semiconductors, and SkyWater Technology — to offer a range of semiconductor processes from 12nm FinFET to 350nm.

The service supports the design enablement, design support and fabrication sign-off for Intel Foundry Services' 22FFL and 16nm processes for digital, analog and mixed-signal design flows utilizing Intel's Process Design Kit (PDK), IP and EDA tech files.

It collaborates with Intel to establish a customer design support model connecting support capabilities from itself, EDA companies and Intel Foundry Services. In 2023, it supported three riders on four design tapeouts to Intel 16 foundry process for the ATMI Project sponsored by the Air Force Research Laboratory.

MOSIS also started to promote the general workflow to support customer's IC



designs, including at the Microelectronics Reliability and Qualification Workshop and other customer, foundry and collaborator meetings. The workflow supports the IC design flow from the beginning of circuit design to the closure of the project. This support includes problem-solving for PDK, EDA tools, design milestones and tapeout sign-off. The workflow emphasizes the extensive support universities and other organizations receive from MOSIS to

achieve prototype designs successfully with state-of-the-art FinFET processes.

This support model was based on the experiences with the multiple tapeouts to Intel 16 in 2022 and 2023, with the ATMI Project. MOSIS generalized the model and generated the workflow suitable for introduction to customers, foundries and collaborators. MOSIS also continued to work with the Industrial Technology Research Institute (ITRI) in Taiwan to advance the field of microelectronics in research and development, IC design and manufacturing. MOSIS, ITRI and USC ECE explored the semiconductor manufacturing training program at ITRI's fabrication facilities in Taiwan, applicable to semiconductor research projects emphasizing workforce development.

This year it worked with Samsung Foundry, WIN Semiconductors and SkyWater Technology to promote foundry services to customers. MOSIS identified a customer to collaborate on a series of IC designs utilizing a Gallium Nitride (GaN) process offered by WIN Semiconductors, for tapeouts.

In addition to the commercial service, MOSIS staff conduct research in silicon fabrication and Design for Manufacturability (DFM) areas.

**WATCH
OUR MOSIS
VIDEO**



California DREAMS set to leverage regional expertise in radical new partnerships

The California Defense Ready Electronics and Microdevices Superhub (DREAMS) is a culmination of several years of work led by faculty and staff of the Information Sciences Institute's Computational Systems and Technology Division, who will now lead it into 2024 and beyond.

This unique and generational initiative, awarded in September 2023, will tackle the most pressing needs in 5G/6G and electronic warfare (EW) capabilities, microelectronics development in the United States and the workforce development required to achieve those goals.

NEXT GEN SEMICONDUCTORS

California DREAMS is one of eight regional hubs in the Microelectronics Commons network, all funded by the CHIPS and Sciences Act of 2022 and awarded through the U.S. Department of Defense (DoD).

ISI Associate Director Steve Crago was appointed director and MOSIS 2.0 director. Mike Haney will serve as deputy-director. This coalition of research and industry organizations will accelerate the transition of laboratory experiments to fabrication of microelectronics for the DoD in Southern California.

With \$27 million in funding for Year One, 16 base hub partners, over 50 affiliates, and more than 200 of the nation's top radio frequency (RF) researchers and innovators, California DREAMS provides a full scope of rapid prototyping of advanced RF

systems for DoD and commercial use — a main goal of the superhub will be to accelerate the transition from invention to impact.

Because advanced RF systems require a low-volume mix of semiconductor components, California DREAMS includes seven premier university nanofab laboratories and three leading "DoD-volume" fabs, all in Southern California. All are EW and 5G/6G leaders with state-of-the-art research laboratories and compound semiconductor fabs that deliver packaged components into DoD-fielded systems.

Universities and corporate partners will co-create a technology portfolio that meets a wide range of DoD and commercial advanced RF applications. The California DREAMS team of RF and microelectronics technology pioneers are global experts and industry leaders that launched — and now propel — the compound semiconductor industry in GaAs, GaN, InP, InSb, InGaAs, HgCdTe, and other compound semiconductors and related technologies.

The hub includes the premier U.S. compound semiconductor and 2.5D/3D advanced packaging fabs. It will train the next generation of students to support the DoD's EW needs and will implement an experiential program for undergraduate and graduate microelectronics engineers to increase clearable students from 1,000 to 2,000 graduates per year across the U.S. by 2030.

Rebirth: MOSIS 2.0

California DREAMS is anchored by the new MOSIS 2.0, which serves as a storefront and central gateway between users and DREAMS' end-to-end prototyping services, thereby reducing the barriers to innovation. It has architected a secure data and analytics architecture to support electronic design automation (EDA) tools, a manufacturability analytics platform, and connectivity to government and superhub-curated intellectual property (IP). A key aspect of MOSIS 2.0 is its focus on scaling the advanced process and prototyping technologies within the superhub toward eventual transition to high-volume production. This is accomplished by exploiting uniform process control and evaluation methods across the superhub.

California DREAMS provides accelerated prototyping and lab-to-fab transition capabilities for advanced integrated circuit (IC) development across a full range of technology platforms. Customer engagements are tailored to address a wide diversity of fabrication project types – ranging from short turnaround unit process prototyping to full flow IC prototyping to full flow volume IC manufacturing. Projects are enabled by state-of-the-art nanofab and foundry services (covering compound semiconductors and Si within the superhub) with pre-developed processes, pre-negotiated terms, a cloud-based integrated data and analytics architecture, and a dedicated Prototype Integration and Engineering Service (PIES) team.

The PIES team includes engineers from each university and industrial nanofab within the superhub, with expertise in the full range of deposition, etching, lithography, and metrology tools deployed in the superhub for a variety of technology platforms. Each project is shepherded through the nanofab facilities by a PIES engineer who has specific "hands-on" expertise in the nanofab tools and procedures needed for the project and is responsible for designing and executing the project within the superhub. The deployment of California DREAMS' superhub facilities is coordinated via the MOSIS 2.0 service, which coordinates the PIES team to provide the wide diversity of support needed across the spectrum of project types.

Informatics Systems Research

CARL KESSELMAN

DIVISION DIRECTOR

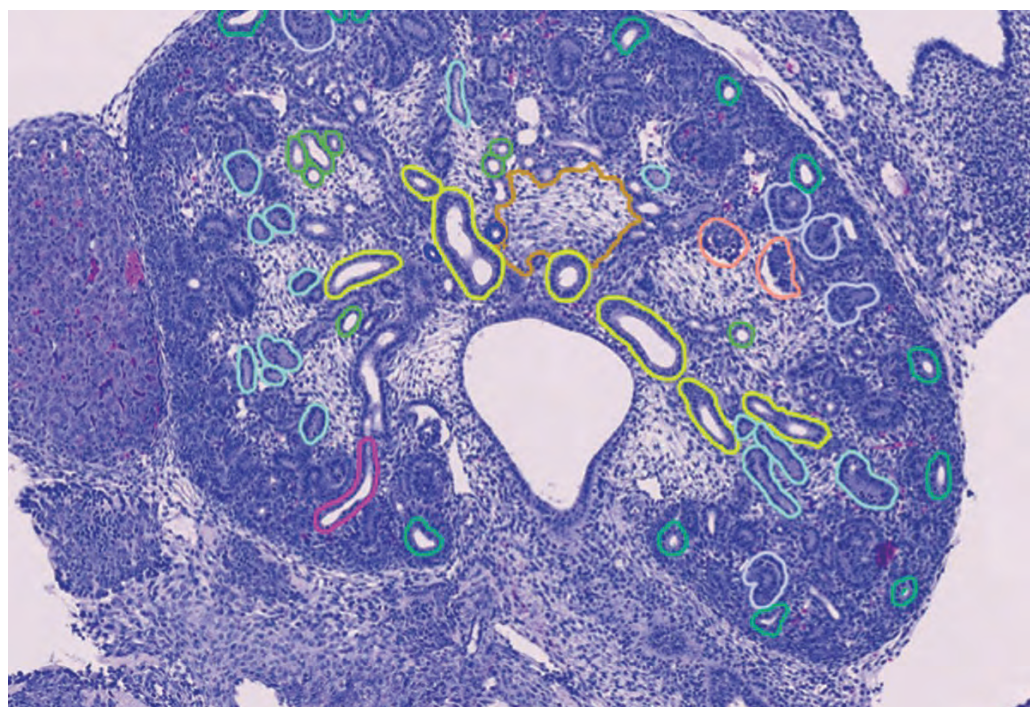
The research agenda of ISI's Informatics Systems Research Division focuses on creating new types of sociotechnical systems that enable and accelerate discovery in domains of high societal impact. The Informatics Systems Research Division takes a holistic, systems-oriented approach, working in areas ranging from basic network service architectures, data management abstractions, computer security, and user-interface design to domain-specific algorithms. The division specializes in highly collaborative, user-driven research in the context of high-impact domain science.

In earlier work, the Informatics Systems Research Division developed grid computing infrastructures to support the creation and operation of “virtual organizations” as a foundation for scientific collaboration and discovery. This work, which focused on understanding methods for sharing computing and storage, played a role in three Nobel prizes:

THE EARTH SYSTEM GRID FEDERATION contributed to the large-scale climate models for the International Panel on Climate Change. 2007 NOBEL PEACE PRIZE

THE DATA ANALYSIS FOR DISCOVERING THE HIGGS BOSON was performed on a global grid infrastructure, the Worldwide LHC Computing Grid. 2013 NOBEL PRIZE IN PHYSICS

THE DISCOVERY OF GRAVITATIONAL WAVES took place using the LIGO Data Grid and the Open Science Grid. 2017 NOBEL PRIZE IN PHYSICS



ANNOTATED MOUSE KIDNEY

COLLABORATIVE PROJECTS

Researchers work with ISI's artificial intelligence, networking, and distributed systems experts and with two of USC's nationally ranked Viterbi School of Engineering departments: Computer Science and the Daniel J. Epstein Department of Industrial and Systems Engineering.

The division participates in collaborative projects with faculty, from basic science to clinical use cases in molecular biology, basic neuroscience, neuroimaging, stem cell research, and craniofacial dysmorphism.

A major current initiative, the first direct study of living synapses in the intact brain, is an interdisciplinary effort with USC's Keck School of Medicine, Dornsife College of Letters, Arts and Sciences, and its Viterbi School of

Engineering. In addition, ISRD plays a central role in four international consortiums as well as one of the eight National Institute of Health funded centers of excellence for Big Data.

The division works with three collaborative centers: FaceBase is a collaborative NIDCR-funded project that houses comprehensive data in support of advancing research into craniofacial development and malformation;

The GenitoUrinary Development Molecular Anatomy Project (GUDMAP) is a consortium of laboratories working to provide tools to facilitate research on the GenitoUrinary (GU) tract; and the (Re)Building a Kidney consortium's goal is to coordinate and support studies that will result in the ability to generate or repair nephrons that can function within the kidney.

Centers & *Labs*



PHOTOGRAPH BY IGNATIEV/ISTOCK

Through collaborations with government agencies, industry partners, and academic colleagues and students, ISI Centers and Labs cover a diverse range of disciplines. Utilizing rigorous design, modeling, and prototyping techniques, our broad capabilities facilitate the development of novel approaches to address issues in the natural and digital world. ISI Centers and Labs are at the forefront of innovation, enabling trailblazing research to advance science, and usher in a more robust and secure technological age.

CENTER ON AI RESEARCH FOR HEALTH

MICHAEL PAZZANI DIRECTOR
JOSE-LUIS AMBITE, YANG CHAI, DAVID CONTI, ABIGAIL HORN, CARL KESSELMAN
CO-DIRECTORS

The center on AI Research for Health was created to nurture collaborations between researchers in AI and those in the health sciences. Focus areas include: Data management, Precision health, Machine learning for health, Telehealth, Knowledge discovery and data analytics. The center sponsored the First Joint Workshop on AI Research for Health, co-hosted by the USC Norris

Comprehensive Cancer Center, to identify and pursue potential avenues at USC for leveraging innovations in AI to impact health and make new discoveries in critical, challenging health problems.

The center received seed funding for four years from a generous donor. ISI matched the first year of funding to award two projects: “Quantum Transfer Learning for Precise Dose Prediction of Stereotactic Radiosurgery and Body Radiotherapy” and “Artificial Intelligence Solutions to Address an Emerging Crisis in Glaucoma Care” (read more p. 88).

Analysis Of Network Traffic: The Ant Lab

JOHN HEIDEMANN FOUNDER

The goal of the Analysis of Network Traffic Lab (ANT Lab) is to improve the Internet by discovering new ways to understand network topology, traffic, security, use, and abuse. ANT was originally founded in 2000. The group's research is led by multiple principal investigators in ISI's Networking and Cybersecurity Division in collaboration with principal investigators from the University of Memphis and Columbia University. The lab carries out Internet measurement with active and passive data collection and big data analysis of network data. ANT has received support from the Department of Homeland Security, the National Science Foundation, DARPA, and from Cisco, Verisign, Northrup Grumman, Amazon, and a Michael Keston Exploratory Research Award.

CI Compass: An NSF Cyberinfrastructure Center of Excellence for Navigating the Major Facilities Data Lifecycle

EWA DEELMAN DIRECTOR

CI Compass provides expertise and active support to cyberinfrastructure practitioners at NSF Major Facilities, such as the Laser Gravitational Wave Observatory (LIGO), the National Ecological Observatory Network (NEON), and the Regional Class Research Vessel (RCRV). These facilities develop and operate unique scientific instruments, data, and computational capabilities for scientists, engineers, students, and the public. CI Compass provides advice, design choices,

and proof of concepts related to the Major Facilities Data Lifecycle. This multi-university collaboration, which includes researchers from Indiana University, RENCi, the University of Notre Dame, Texas Tech, and the University of Utah, contributes knowledge and expertise to enhance the NSF cyberinfrastructure ecosystem.

Center on Knowledge Graphs

JAY PUJARA DIRECTOR

The Center on Knowledge Graphs creates new approaches for amplifying artificial intelligence using structured knowledge. The group combines expertise in artificial intelligence, machine learning, the Semantic Web, natural language processing, databases, information retrieval, geospatial analysis, business, social sciences, and data science. The center has built tools and knowledge graphs to address challenging, real-world problems such as reducing global food insecurity, fighting human trafficking, assessing medical and clinical data, fostering pharmacological discovery, and ensuring scientific reproducibility.

Center for Cyber Defense Technology Experimental Research

TERRY BENZEL CO-DIRECTOR

JELENA MIRKOVIC CO-DIRECTOR

The center focuses on cyber experimentation research, methods, and infrastructure, catalyzing a robust ecosystem of experimental infrastructure, capabilities and communities, for research. Center researchers perform research into models, frameworks, testbeds, tools, and approaches to enhance the science of cyber experimentation and build experiments that are rigorous, reusable, and repeatable. The center

operates DeterLab and associated research infrastructure. The DeterLab Cybersecurity Experimentation Testbed is a public resource serving over 1,000 research teams from 46 countries. Additionally, the DeterLab has been extensively used for cybersecurity education and impacted more than 20,000 students. Numerous publications, master's projects, and Ph.D. theses have resulted from the use of DeterLab, which has been operating since 2004. The Deter testbed now offers three custom testbeds: DCOMP, a specialized distributed computing testbed; Searchlight Testbed, for enterprise control of application QoS at scale; and a Modernized DeterLab.

USC-Lockheed Martin Quantum Computing Center

DANIEL LIDAR SCIENTIFIC & TECHNICAL DIRECTOR

FEDERICO SPEDALIERI OPERATIONAL DIRECTOR

A joint effort of Lockheed Martin Corporation and USC, the Quantum Computing Center (QCC) is housed at ISI. Faculty, researchers, and students perform basic and applied research into noisy, intermediate-scale quantum (NISQ) computing devices and collaborate with researchers around the world. The Quantum Computing Center was the first organization outside D-Wave Systems to house and operate its own D-Wave quantum computer, and it has conducted pioneering research on four different generations of these early NISQ processors. Quantum computing potentially offers orders-of-magnitude gains in speed and memory, as well as greater security, for some computing problems. Applications include "big data" analysis, classification, optimization, and machine learning.

Centers & *Labs*

STEEL: Security Research Lab

JELENA MIRKOVIC DIRECTOR

LUIS GARCIA CO-DIRECTOR

GENEVIEVE BARTLETT CO-DIRECTOR

Founded in 2012, STEEL researchers, Ph.D. students, and master's students conduct cutting-edge research in cybersecurity and testbed experimentation.

The lab focuses on research in network-based cyber attacks, human aspects of cybersecurity, embedded cybersecurity, and binary analysis. STEEL also contributes to improving security through cyber testbed experimentation, including work in making experimentation more rigorous, more accessible, and reliably repeatable.

Science Automation Technologies: SciTech

EWA DEELMAN DIRECTOR

The Science Automation Technologies group (SciTech) conducts research and provides technologies that empower the scientific community to efficiently conduct complex computations on the national, campus, and industrial cyberinfrastructure. By raising the level of abstraction for computation specification (abstract scientific workflow) and by designing workflow management systems, scientists are able to focus on their research

questions rather than the details of the cyberinfrastructure.

The group develops open-source tools that provide the computational foundations enabling scientists to seamlessly run their experiments and analyses in local and distributed resources.

The group concentrates on these research areas:

- Workflow management systems for science
- Machine learning for science
- Enhancing national
- Cyberinfrastructure
- Modeling and simulation of distributed computing systems

Space Engineering Research Center

DAVID BARNHART DIRECTOR

The Space Engineering Research Center (SERC) is dedicated to disruptive space engineering, research, and education for the second-generation workforce—including hands-on training to build, test, and fly spacecraft and satellites. SERC hosts high school, community college, undergrad, graduate, and Ph.D. students from the U.S. and worldwide.

SERC is a longstanding joint venture between ISI and the USC Department of Astronautical Engineering.

SERC seeks to challenge traditional methods of space R&D, manufacturing,

and exploration with approaches that dramatically reduce costs, enable novel capabilities, and support the creation of space-to-space services and interactions.

Secure and Robust Electronics Center

MATTHEW FRENCH DIRECTOR

The Secure and Robust Electronics Center (SURE) focuses on secure, robust hardware R&D to help protect national security, advance industry capabilities and competitiveness, and ensure that citizens can rely on the integrity of their devices. SURE researchers perform applied research to make chips trustworthy, secure, resilient, and reliable.

The center investigates state-of-the-art manufacturing complexities that have compromised critical aspects of chip production. The more powerful integrated circuits become, the more opportunities arise for their integrity to be compromised. SURE researchers also aim to accelerate the scale, pace, and impact of hardware robustness and technology development.

The center's work has been supported by government agencies and by industry partners, including Xilinx Inc, Altera Corporation, Synopsys, and Cadence. Academic collaborators include Stanford, Virginia Tech, Brigham Young University, Arizona State, University of North Carolina, and Georgia Tech Research Institute.



Visual Intelligence and Multimedia Analytics Laboratory

Wael Abd Almageed

FOUNDING DIRECTOR

Mohamed Hussein, Leonidas

Spinoulas CO-DIRECTORS

In the Visual Intelligence and Multimedia Analytics Laboratory (VIMAL), researchers work on visual misinformation identification, face recognition, biometrics, and multimedia forensics. VIMAL's research addresses challenging problems in security, surveillance, and multimedia content analysis, including improving the security of biometric systems, making deep learning algorithms more robust

against adversarial attacks, and identifying deepfake videos and manipulated images. VIMAL's experienced academic and research staff push the boundaries of academic knowledge in areas spanning biometrics, face recognition, optical coherence tomography, speech, image processing, forensics, and multimedia. VIMAL researchers contribute to nationally influential research programs addressing some of today's most pressing challenges in these areas, from improving security to unmasking fake news, and optimizing knowledge extraction.



PHOTOGRAPHS BY ISTOCK

Viterbi *data science* program



ISI researchers were instrumental in working with the USC Computer Science Department leadership to create USC's Data Science Program in the Viterbi School of Engineering. ISI Executive Director Craig Knoblock was a director of the program, and is part of the advisory committee.

Today the program is thriving, and with more than a thousand undergraduate and graduate students, it is one of the largest programs in Viterbi. The interdisciplinary data science degrees are the first of their kind at USC and are designed to introduce non-computer science majors to careers in data science.

- Bachelor of Arts in Data Science
- Undergraduate minor in Foundations of Data Science
- Bachelor of Science in Artificial Intelligence for Business (joint with the USC Marshall School of Business)
- Master of Science in Applied Data Science
- Master of Science in Spatial Data Science (joint with the USC Dornsife College of Letters, Arts, and Sciences)
- Master of Science in Communication Data Science
- Master of Science in Cyber Security Engineering
- Master of Science in Healthcare Data Science
- Master of Science in Communication Data Science (dual degree with Tsinghua University)
- Master of Science in Environmental Data Science (joint with the USC Dornsife College of Letters, Arts, and Sciences)
- Master of Science in Public Policy Data Science (joint with the USC Price School of Public Policy)
- Graduate Certificate in Data Science Foundations
- Graduate Certificate in Applied Data Science
- Progressive Degree Program

LEADERSHIP AND FACULTY

The Viterbi Data Science Program celebrated its 10th year anniversary in 2023. ISI's Yolanda Gil is director of the program; Fred Morstatter is associate director. ISI researchers who lead projects involving large amounts of data teach in the program. They have designed introductory and advanced courses in scalable data systems, machine learning, knowledge graphs, and AI and data ethics. They have also created several first of their kind interdisciplinary programs in data science that are joint with other USC schools, including communication, public policy, law, spatial computing, environmental science, and sports science.

RESEARCH PROFESSORS

Yigal Arens, Carl Kesselman,
Kristina Lerman

RESEARCH ASSOCIATE PROFESSORS

Jose-Luis Ambite, Jelena Mirkovic,
Cliff Neuman

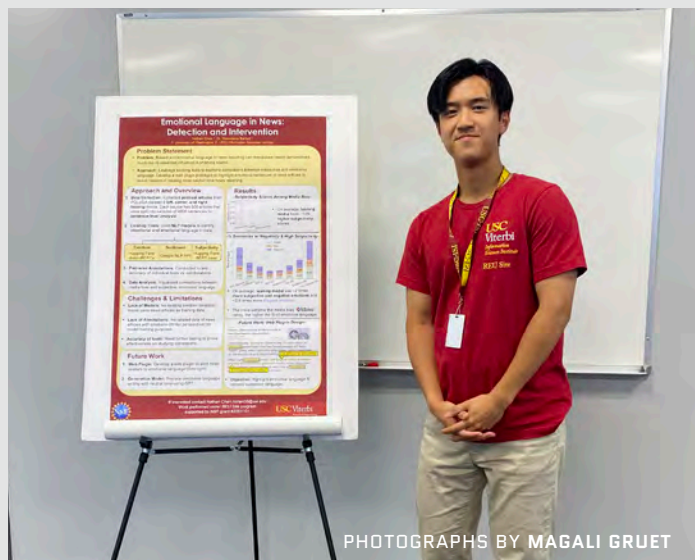
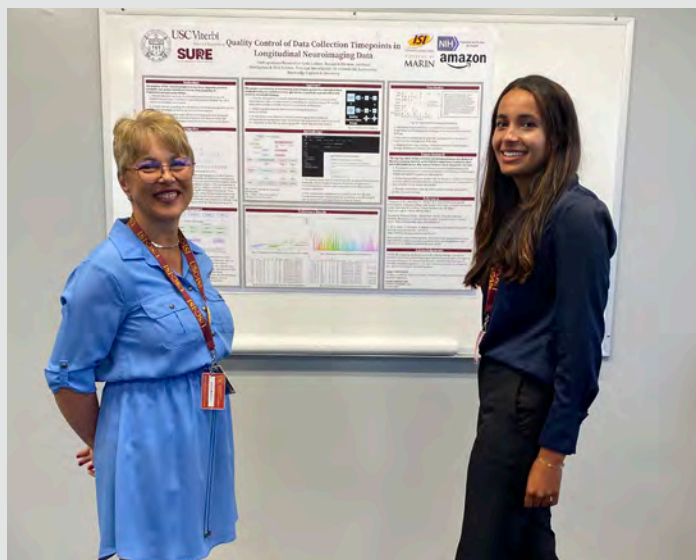
RESEARCH ASSISTANT PROFESSORS

Fred Morstatter, Jay Pujara, Mohammad
Rostami, Satish Thittamaranahalli

PART TIME LECTURERS

Jeremy Abramson, Jim Blythe, Keith
Burghardt, Young Cho, Ulf Hermjakob,
Deborah Khider, Luca Luceri, Gleb
Satyukov, Amandeep Singh, Ke-Thia Yao

Student research *programs*



PHOTOGRAPHS BY MAGALI GRUET

Rising Star MS Internship Program

ISI offers Rising Star Internships to students applying to the Viterbi School of Engineering Master of Science program in computer science, data science, electrical and computer engineering, and related disciplines. The interns collaborate on an ongoing project with a research team—and work directly with an individual mentor throughout the course of the master's degree. Currently, one intern is working with researchers in the Informatics Systems Research Division on data management for the World in a Cell transmedia project with computer scientists, biologists, and film school researchers; another intern is developing an automated shell script parser to perform safe de-obfuscation of malicious shell scripts.

Past interns worked in analyzing malware samples and knowledge graph profiles.

Research Experiences for Undergraduates

The NSF Research Experiences for Undergraduates (REU) program offers an intellectually and socially stimulating paid research experience to undergrads from a broad range of colleges and universities at ISI headquarters in Marina del Rey, CA. In addition to the stipend, students are provided with campus housing at USC and free shuttle service between campus and ISI. Each student concentrates on a specific research project and works closely with ISI research faculty and other ISI researchers.

The broad research theme is *Safe, Usable, Fair, and Reliable Internet*: communication and cybersecurity, scientific experimentation and knowledge capture, and social data science. The program is led by Jelenaw Mirkovic, an ISI cybersecurity researcher and project leader. Over the summer, the undergrads work with ISI

researchers, individually and in teams, and attend seminars and social events. At the conclusion of the program, the students present their research as poster sessions at the ISI REU symposium to their ISI mentors, researchers, and students.

Summer Internship Program

ISI welcomes Ph.D. students, master's degree students, and undergraduates every summer as paid interns to work with senior research leaders and their teams. The internships are available at all three ISI locations, and interns may work on-site or remotely with their ISI mentors and research teams.

Interns work in all ISI research divisions in data science, hardware security, machine learning, natural language processing, quantum information science, and other areas. In addition to research, interns participate in seminars, reading groups, and social activities.

Ph.D. *students*



MOZHDEH GHEINI

AI DIVISION

At ISI, I feel supported and heard by my advisor and colleagues in my endeavors during my Ph.D. I learn the value of brainstorming and making new connections every day. I get to meaningfully contribute to the research problems I care about while honing a wide range of hard and soft skills.



BASILEAL IMANA

NC DIVISION

I chose ISI for its interdisciplinary research opportunities, allowing me to explore projects that bridge my skills and interests. The supportive environment created by my advisers and the robust research infrastructure were crucial to my success as a researcher.



GEORGE PAPADIMITRIOU

CST DIVISION

ISI is a special place where I got to solve real world problems at scale. During my Ph.D. I improved my research and collaboration skills. I provided solutions that leverage workflows and advanced cyberinfrastructure management to increase scientific research productivity.

92 PH.D. STUDENTS SUPERVIZED BY ISI FACULTY IN 2023

The Information Sciences Institute provides a stimulating environment for graduate study and research, joining rigorous academic theory with real world practice. As a Ph.D. student at ISI, you will have the opportunity to work on projects of national and global significance, surrounded by a diverse, engaged, and collaborative community, committed to changing the world through technology.

At ISI, we know that solving tough technical challenges requires solutions that cross disciplines and offer diverse perspectives. That's why our work is informed by a commitment to a multidisciplinary approach, spanning research

areas and departments across USC and beyond, providing our students with exceptional breadth and depth of expertise.

One of the nation's largest and most technologically diverse university-affiliated computer research institutes, ISI's pioneering contributions have helped create some of the most ubiquitous, enduring technology advances of our time.

As part of the University of Southern California (USC), ISI also benefits from the international reputation and valued partnerships of a premier global university. Students learn from and work alongside the foremost minds in computer science and engineering surround-

ed by a diverse community of faculty, researchers, and students at undergraduate, graduate and post-doctoral levels.

ISI Ph.D. advisors hold appointments in multiple departments, including computer science, electrical engineering, industrial systems engineering and Keck Medicine of USC. At ISI, we are thinkers and doers. Our researchers and students thrive in a hands-on, multidisciplinary environment.

Explore new technologies, tackle large real-world projects and build complex systems—our work at ISI bridges theoretical research and prototyping of innovative devices, offering a dynamic, varied and personalized experience.

Ph.D. *graduates*

The proximity of Silicon Beach facilitates Ph.D. graduates' transition into prestigious roles in the tech industry. Our recent graduate students have accepted positions at major research institutions and leading technology companies, including: Amazon, JPL, Google, Facebook, NVIDIA, Yelp, Microsoft, Sandia National Laboratories, and the University of Oxford. ISI encourages students to build professional skills such as problem-solving, research efficiency, strategic thinking and communication which are in high demand in the job market.



NINA MEHRABI

2023 PH.D. IN COMPUTER SCIENCE

I wrote a survey paper on fairness and bias in machine learning. I have received much feedback from the community on how useful the paper was in educating others about these important concepts.



ROBERT SCHULER

2023 PH.D. IN COMPUTER SCIENCE

I worked on the Globus Project that defined the foundations of leading implementation for Grid computing. This led me to do research on data Grid architectures for large-scale biomedical science applications.



HRAYR HARUTYUNYAN

2023 PH.D. IN COMPUTER SCIENCE

With my team we created four clinical prediction benchmarks using data derived from the MIMIC-III database. These tasks covered a range of clinical problems.

**JOIN
US**



80 *million* in funding



CALIFORNIA DREAMS - CALIFORNIA DEFENSE READY ELECTRONICS AND MI- CRODEVICES SUPERHUB

PI: STEPHEN CRAGO

Department of Defense. The California DREAMS project, led by USC, aims to create a national coalition of research and industry organizations with the power to accelerate the development and manufacturing of microelectronics in the United States. It will tackle the most pressing needs in 5G/6G and electromagnetic warfare (EW) capabilities.

TRACER - TASKLET RECONFIGURABLE AGILE SPECTRUM PROCESSOR

PI: MATTHEW FRENCH

DARPA prowess program. TRACER seeks to develop a revolutionary advancement of autonomous RF spectrum signal processing systems to provide the adaptive, highly performant, real-time processing required for spectrum sharing. Laboratory (VIMAL), research.

ARTIFICIAL INTELLIGENCE SOLUTIONS TO ADDRESS AN EMERGING CRISIS IN GLAUCOMA CARE

AI4HEALTH SEED GRANT

PI: CARL KESSELMAN

AI holds the promise of radically transforming glaucoma care. This research lays the foundation to create a scalable data-centric collaboration platform that supports the integration of diverse datasets and the development and validation of a broad range of robust, innovative AI-based glaucoma algorithms for clinical deployment.

QUANTUM TRANSFER LEARNING FOR PRECISE DOSE PREDICTION OF STEREOTACTIC RADIOSURGERY AND BODY RADIOTHERAPY

AI4HEALTH SEED GRANT

PI: AMIR KALEV, LIJUN MA

Stereotactic Radiosurgery (SRS) and Stereotactic Body Radiotherapy (SBRT) are advanced cancer treatments that

precisely deliver high doses of radiation to tumors from multiple angles.

This research is developing a first-of-a-kind quantum ML architecture that can be trained on sparse datasets and make better SRS/SBRT 3D dose distributions compared to traditional (i.e., non-quantum-based) ML models.

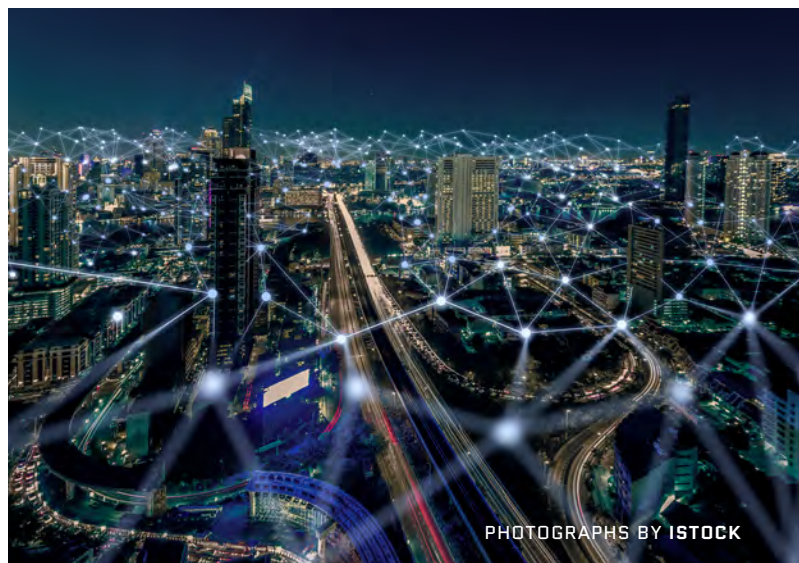
D2K-ATLAS - CENTER AS AN ACCESSIBLE, COMPREHENSIVE DATA PORTFOLIO FOR RENAL AND GENITOURINARY DEVELOPMENT AND DISEASE

PI: CARL KESSELMAN

National Institute of Diabetes and Digestive and Kidney Diseases, Trans-NIH Research Support. As part of a

supplemental fund for the ATLAS-D2K project, which aims to establish a comprehensive data portfolio for renal and genitourinary development and disease, USC explores cloud optimization to increase ATLAS-D2K's availability and efficiency.

In 2023, ISI received 46 new funded research awards, some of which are listed below. Sponsored by the federal government, industry, and philanthropy, the awards range from tens of thousands of dollars to millions. The basic and applied research supported by these awards spans many areas: quantum information science, machine learning, microelectronics, cybersecurity, and more.



**SADIRI - STYLOMETRIC AUTHORSHIP
DISCERNMENT & INTERPRETATION FOR
REALISTIC INPUTS**

PI: ELIZABETH BOSCHÉE

IARPA hiatus program. In collaboration with U. of Michigan, U. of Maryland, and U. of Birmingham, the SADIRI project strives to develop technology for authorship attribution and privacy protection by generating “authorial fingerprint” vectors for documents.

**DOE RESILIENCE, EXPLORING THE POWER
OF DISTRIBUTED INTELLIGENCE FOR RE-
SILIENT SCIENTIFIC WORKFLOWS**

PI: EWA DEELMAN

DOE’s Advanced Scientific Computing Research Program. With the University of North Carolina, Oak Ridge, Lawrence Berkeley and Argonne National Laboratories, the project aims to develop the fundamentals of a computational platform that is fault tolerant, robust to various environmental conditions and adaptive to workloads and resource availability.

**SPHERE - SECURITY AND PRIVACY
HETEROGENEOUS ENVIRONMENT FOR
REPRODUCIBLE EXPERIMENTATION**

PI: JELENA MIRKOVIC

NSF Mid-scale Research Infrastructure-1 program. The SPHERE research infrastructure will offer a novel mix of experimentation capabilities, uniquely tailored to support cybersecurity and privacy research in emerging areas, such as IoT, cyber-physical systems, programmable networks, edge computing, Internet measurement and human-centric cybersecurity and privacy.

**ASPIRE - ADVANCED SPECTRUM INITIA-
TIVE FOR RESEARCH AND EXPERIMENTA-
TION**

PI: ALEFIYA HUSSAIN

NSF Spectrum Innovation Initiative: National Radio Dynamic Zones (SII-NRDZ) program. With Idaho National Laboratory and University of Utah, the ASPIRE project seeks to create increased bandwidth availability through dynamic spectrum sharing.

**PRECOG: MULTIMODAL INTEGRATION OF
NEURAL AND BIOBEHAVIORAL SIGNALS
FOR PREDICTING PRECONSCIOUS
RESPONSE**

PI: SHRI NARAYANAN

DARPA NEAT (Neural Evidence Aggregation Tool) program. In partnership with UCLA, the PRECOG research initiative will use modern technology to identify objective hallmarks of depression and suicidal ideation in order to support clinical screening.

**SPACE SYSTEMS COMMAND MILITARY
COMMUNICATIONS & POSITIONING,
NAVIGATION, AND TIMING DIRECTORATE**

PI: Michael Orosz

Mission Engineering and Integration of Emerging Technologies, US Space Force. The team provided Space Systems Command with mission engineering research expertise to better understand the impacts of Agile/DevSecOps on areas of velocity, security and the use of AI in mission critical capabilities.

Keston *Exploratory* Research Awards

ISI received a generous endowment gift in November 2015 from Los Angeles entrepreneur, philanthropist, and engineer-at-heart Michael Keston and his wife and philanthropic partner, Linda Keston. The Kestons endowed ISI's Keston Executive Director chair. In addition to endowing the director's chair, a portion of the income from the Keston endowment is dedicated each year to sponsoring the Keston Exploratory Research Awards, intended to foster and support exploratory early-stage research not yet funded by outside sponsors. ISI has contributed additional funds to expand the program, creating the ISI Exploratory Research Awards. The Keston and ISI Exploratory Research Awards support research projects that are intellectually intriguing, significant to society, and have the potential to produce results within a year or so. The following describes the work carried out in 2023 under the aegis of the Keston and ISI Exploratory Research Awards program.



MICHAEL KESTON AND HIS WIFE AND PHILANTHROPIC PARTNER, LINDA KESTON

2023 KESTON AWARDS

EARLY DETECTION AND MANAGEMENT OF WOUND INFECTION USING ARRAY MEASUREMENTS AND AI

Mohammad Rostami

A non-invasive colorimetric pH sensor has been developed to measure volatile organic compounds (VOCs) emitted by microorganisms in wounds. To establish the sensor's effectiveness, an AI-based deep learning model is proposed to analyze the sensor's data. Patients can use their smartphones to capture images of the dressing sensor, and AI will predict the wound's condition and potential future infections.

360 EVENT TRACKER

Steven Fincke

Non-English-language American media outlets operate in relative isolation, with less oversight from competitors and public figures to impede

the spread of misinformation and extremism. We address these problems with a new way to aggregate and track information about events of interest, e.g. elections, disease outbreaks, natural disasters, etc. Event Tracker 360 will combine state-of-the-art cross-lingual information retrieval, extraction, and sentiment detection technology to track real-world events.

A.I.-DRIVEN MEAL RECOMMENDATIONS TO MEET SOCIOCULTURAL AND NUTRITIONAL DIETARY NEEDS

Abigail Horn and Keith Burghardt

This work uses large-scale nutrition data and recommender systems to create algorithms to support clinicians in implementing meal prescription interventions that are inclusive of patients with diverse sociocultural backgrounds and food preferences. We are developing a recommendation system algorithm, operationalized through a mobile app.

2023 ISI EXPLORATORY RESEARCH AWARDS

COHERENT AND COMMONSENSICAL AI FOR SOCIAL INFLUENCE - Filip Ilievski and Gale Lucas

WILL FICTION TRUMP FACT? ON THE INEVITABILITY OF IDENTITY INCONSISTENCY IN DEEPPAKE VIDEOS Mahyar Khayatkhoei and Wael Abd-Almageed

DEJA-VU: DESIGN OF JOINT 3D SOLID-STATE MACHINES FOR VARIOUS COGNITIVE USE-CASES Akhilesh Jaiswal, Norbert Fortin, Ajey Jacob

VALUING UTILITY IN THE MEASUREMENT OF INTELLIGENT SYSTEMS - Marjorie Freedman

MULTI-DOCUMENT NEWSWORTHY EVENT MONITORING AND FORECASTING - Muhao Chen, Jonathan May

INTERVENTION TOOLS TO FACILITATE FACTS: FOCUS AND CRITICAL THINKING SKILLS - Genevieve Bartlett

Our list of honors proudly highlights the exceptional achievements of our researchers, who have been recognized with a diverse array of fellowships from leading scientific and academic institutions. This compilation not only celebrates their outstanding contributions to the field of computer science but also underscores the wide-ranging impact and recognition of their work on a global scale.

CARL KESSELMAN

2023 IEEE INTERNET AWARD

2023 IEEE FELLOW

The Institute of Electrical and Electronics Engineers (IEEE) honored Kesselman and his long time collaborator Ian T. Foster with the 2023 IEEE Internet Award for their exceptional contributions to the advancement of Internet technology. Kesselman was also named a 2023 IEEE Fellow in recognition of his “foundational contributions to technologies and applications of global distributed computing.”

TERRY BENZEL

2024 IEEE FELLOW

The Institute of Electrical and Electronics Engineers (IEEE) elevated Benzel to the rank of IEEE Fellow for 2024 in recognition of her “leadership in establishing the field of cybersecurity experimentation.”

SHRIKANTH NARAYANAN

IEEE 2023 CLAUDE SHANNON-HARRY NYQUIST TECHNICAL ACHIEVEMENT AWARD

IEEE 2024 EDWARD J. MCCLUSKEY TECHNICAL ACHIEVEMENT AWARD

The Institute of Electrical and Electronics Engineers (IEEE) Signal Processing Society awarded Narayanan for contributions to spoken language processing technologies and their societal applications; and the IEEE Computer Society awarded him for pioneering contributions to speech, language and multimedia processing and affective computing and their human-centered societal applications.

RICHARD DESWARTE PRIZE IN DIGITAL HISTORY

The Institute of Historical Research (IHR) at the University of London awarded Narayanan for the the best output in digital history published internationally, along with Gábor Mihály Tóth, Tim Hempel, and Krisha Somandepalli for their article ‘Studying Large-Scale Behavioral Differences in Auschwitz-Birkenau with Simulation of Gendered Narratives’. Published in Digital Humanities Quarterly (2022).

ISCA MEDAL FOR SCIENTIFIC ACHIEVEMENT

The International Speech Communication Association (ISCA) awarded the most prestigious award offered by this preeminent organization in the field of human speech communication research at the global level to Narayanan for his “sustained and diverse contributions to speech communication science and technologies and their application to human-centered engineering systems.”

2023 ACM FELLOW

The Association for Computing Machinery has named Narayanan a 2023 Fellow for transformative contributions to computing science and technology, specifically, for his contributions to speech, language, multimedia processing, and affective computing and their human-centered applications.

ROBERT STORY

ROOT SERVER SYSTEM ADVISORY COMMITTEE (RSSAC)

The RSSAC recognized Story for his high level of engagement and outstanding

contributions to the work of RSSAC Caucus in 2023. His contributions to RSSAC001v2 and RSSAC002v5 work parties and his leadership in the Security Incident Reporting work party gained RSSAC’s appreciation.

JAY PUJARA

SWSA 10 YEAR AWARD

Pujara received the 2023 Semantic Web Science Association Ten Year Award for his paper “Knowledge Graph Identification,” which won Best Student Paper in 2013. This award recognizes high-impact papers from the International Semantic Web Conference proceedings a decade earlier.

YOLANDA GIL

COGNITIVE SCIENCE SOCIETY FELLOW

Gil has been recognized for her contributions in cognitive frameworks for scientific discovery, reasoning about complex processes, and AI-mediated collaboration.

2023 ISI FELLOW

Gil has been recognized with ISI’s signal honor, the title of ISI Fellow, for her contributions on knowledge capture and scientific workflows and for promoting the work on AI at ISI to the larger community.

EWA DEELMAN

2023 ISI FELLOW

Deelman has been recognized for her contributions to the automation of scientific computing applications and advancing the role of computation in scientific domains of societal importance.

250 *publications* in 2023

ISI takes immense pride in its extensive portfolio of research publications, a testament to our commitment to advancing the field of computer science. Our researchers have not only made significant contributions to top-tier conferences worldwide but have also authored influential books that further the breadth of knowledge in their respective domains. This curated list showcases the innovative work and thought leadership that define our institute's contribution to the global scientific community.

**THE CHALLENGES OF
BLOCKCHAIN-BASED NAMING
SYSTEMS FOR MALWARE DEFENDERS
2022 APWG Symposium on Electronic
Crime Research (eCrime)**

A. Randall, W. Hardaker, G. M. Voelker, S. Savage, and A. Schulman

The authors study five blockchain naming systems and the challenges and advantages that each present to malware operators and defenders, and conclude that while naming systems present a significant threat, defenders still have viable options for enacting C2 takedowns.

**ARTIFICIAL INTELLIGENCE FOR
INDUSTRIES OF THE FUTURE
Springer**

M. Kejriwal

This book delves into AI's evolving role in industries beyond the big-four tech giants, offering insights into current use-cases and future prospects. It also discusses the regulatory landscape and potential workforce impacts, providing a concise yet comprehensive overview for industry leaders and stakeholders.

**SHOULD CHATGPT BE BIASED? CHALLENGES AND RISKS OF BIASES IN LARGE LANGUAGE MODELS
Published on FirstMonday.Org**

E. Ferrara

This paper looks at the challenges posed by biases in large-scale language models like ChatGPT, exploring their origins and ethical implications. It discusses opportunities to mitigate biases and emphasizes the need for collaborative efforts in developing fair and

responsible AI systems, and catalyzed a number of academic discussions about bias and fairness in the age of ChatGPT and generative AI.

**DEFENDING ROOT DNS SERVERS
AGAINST DDOS USING LAYERED
DEFENSES**

2023 COMSNETS, best paper award

A. S. M. Rizvi, J. Mirkovic, J. Heidemann, W. Hardaker, and R. Story

The authors propose a layered DDoS defense for DNS root nameservers that uses an automated system to quickly select the best defense from a library of defensive filters to effectively reduce traffic to a server under attack.

TEMPORAL KNOWLEDGE GRAPH FORECASTING WITHOUT KNOWLEDGE USING IN-CONTEXT LEARNING

Conference on Empirical Methods in Natural Language Processing

D. Lee, K. Ahrabian, W. Jin, F. Morstatter, and J. Pujara

They show LLMs excel at forecasting future events and relationships, even when the identities of the actors in those events are hidden from the model, suggesting that many forecasts rely more on subtle patterns than world knowledge.

**NONCOMMUTING CONSERVED
CHARGES IN QUANTUM THERMODYNAMICS AND BEYOND
Nature Reviews Physics**

S. Majidy, W. F. Braasch Jr., A. Lasek, T. Upadhyaya, A. Kalev, and N. Yunger Halpern
Quantum thermodynamics is an exciting new area of research which is devoted to

concepts, results and ideas for quantum information theory, quantum many body physics, and thermodynamics. This paper reviews recent advancement in this rising field and identifies key milestones for its advancement.

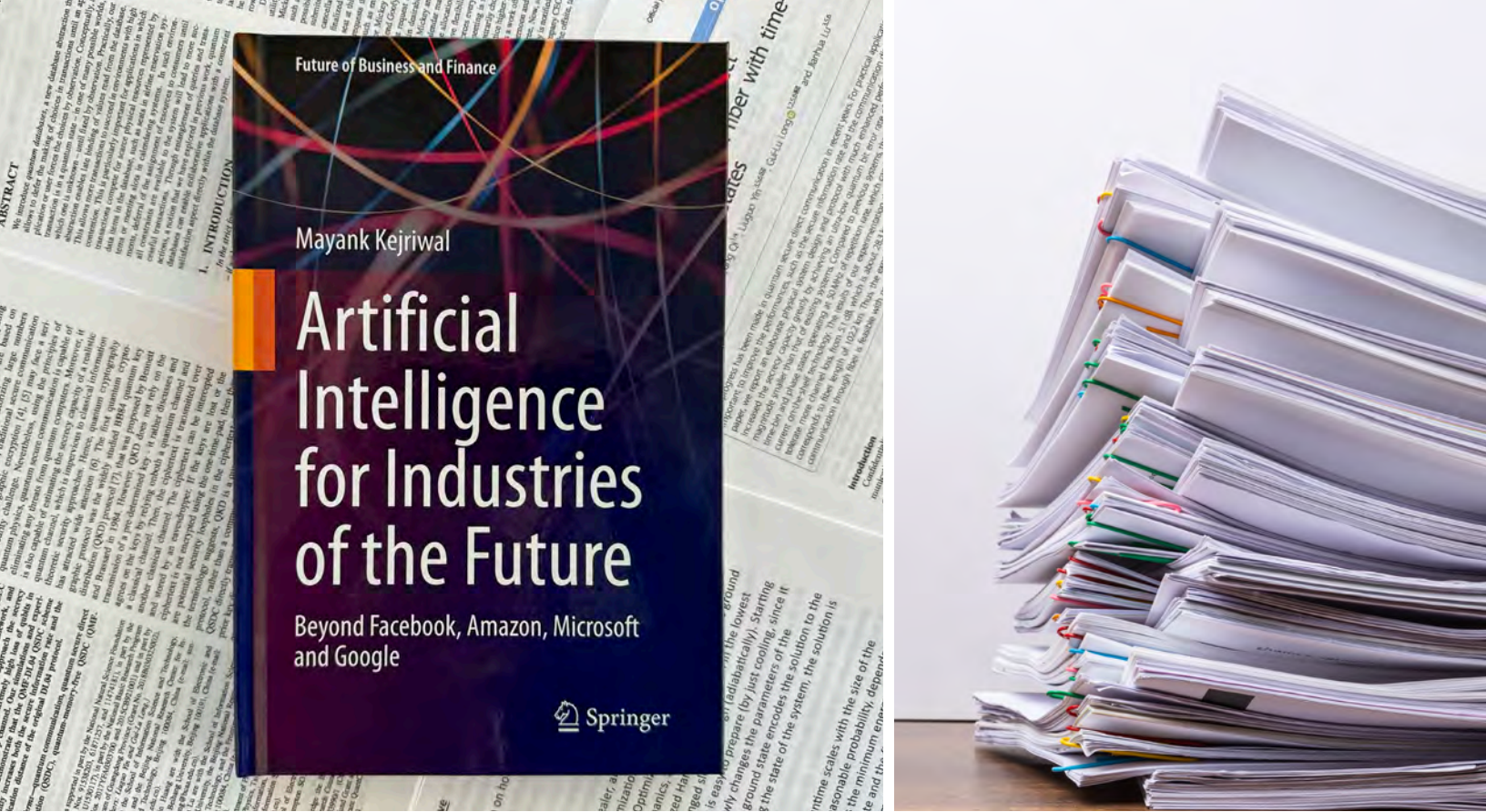
**MINIMIZING DIE FRACTURE IN
THREE-DIMENSIONAL IC ADVANCED
PACKAGING WAFER THINNING PROCESS
BY INSERTING POLYIMIDE PATTERNS
2023 SPIE Advanced Lithography +
Patterning Conference**

L. Chang

The paper demonstrates a new physical design flow to minimize the fracturing of wafers undergoing a thinning process typically performed in three-dimensional integrations.

**MEASURING ONLINE EMOTIONAL REACTIONS TO OFFLINE EVENTS
Presented at ASONAM 2023
conference**

S. Guo, Z. He, A. Rao, E. Jang, Y.e Nan, F. Morstatter, J. Brantingham, K. Lerman
Scientific advancement often relies on new tools to measure physical phenomena, like the microscope or telescope. But we have no similar instruments to measure social phenomena. Social data presents computational/statistical challenges that earlier fields of inquiry had not experienced (e.g., heterogeneity). This paper shows how to solve some of those challenges to observe social systems – in this case online social systems. Without any human input, we can use this “social telescope” to identify important events purely from online data.



MAYANK KEJRIWAL WROTE "ARTIFICIAL INTELLIGENCE FOR INDUSTRIES OF THE FUTURE" PUBLISHED BY SPRINGER.
PHOTOGRAPHS BY MAGALI GRUET AND JARUEK CHAIRAK/ISTOCK

**INFERRING CHANGES IN DAILY HUMAN
ACTIVITY FROM INTERNET RESPONSE**
**2023 Proceedings of the ACM Internet
Measurement Conference**

X. Song, G. Baltra, and J. Heidemann

The paper demonstrates a new physical design flow to minimize the fracturing of wafers undergoing a thinning process typically performed in three-dimensional integrations.

**DETECTION OF LASER LIGHT SCATTERED
FROM AEROSOLS IN A BRIGHT
BACKGROUND USING A BALANCED
COHERENT RECEIVER**
Opt. Continuum

H. Belzer, A. Rittenbach, and J.L. Habif

This paper presents a novel method to detect lasers in the atmosphere, using an adapted quantum sensor developed at ISI. Funded by DARPA, it addresses the critical issue of early detection of lasers, potentially preventing threats like lasers aimed at aircraft to blind pilots.

**BUILDING SPATIO-TEMPORAL KNOWLEDGE GRAPHS FROM VECTORIZED
TOPOGRAPHIC HISTORICAL MAPS**
Semantic Web journal (by IOS Press)

B. Shbita, C. A. Knoblock, W. Duan, Y. Chiang, J. H. Uhl, and S. Leyk

This paper presents a method to convert historical maps into Knowledge Graphs (KGs), allowing researchers to analyze changes in geographic features over time, and providing a standardized framework for storing and linking historical map data, enabling semantic and temporal analysis. By applying this approach to USGS historical topographic maps, the study shows how KGs can help query and visualize temporal changes in railroad networks and wetland areas across different regions.

**POPULATION MOBILITY DATA PROVIDES MEANINGFUL INDICATORS OF FAST
FOOD INTAKE AND DIET-RELATED DISEASES IN DIVERSE POPULATIONS**
Nature Partner Journals Digital Medicine

A. L. Horn, B. M. Bell, B. García Bulle Bueno, M. Bahrami, B. Bozkaya, Y. Cui, J. P. Wilson, A. Pentland, E. Moro & K. de la Haya

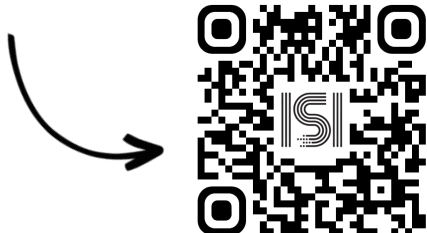
Human mobility data, made up of locations captured by smartphones, provides a new way to observe where people get food; this study shows it's a powerful indicator of population diet and diet-related disease.

**WINOQUEER: A COMMUNITY-IN-THE-LOOP BENCHMARK FOR ANTI-LGBTQ+
BIAS IN LARGE LANGUAGE MODELS**
ACL 2023

V. Felkner, H. H. Chang, E. Jang, and J. May

This work establishes a means for community-grounded bias detection mitigation, defining bias as a tendency to favor real-world attested harmful stereotypes. It shows most LLMs have some homophobic biases and further shows that this bias can be mitigated by exposing these models to data by and about the LGBTQ+ community.

GET THE LIST



What to *expect* in 2024?

We asked our researchers what they believe the hot computer science topics will be in 2024. From Gen AI and the interplay between AI and society, to high agility sensors to cutting-edge text analysis, they anticipate a busy and exciting year.



MAYANK KEJRIWAL
AI DIVISION

2024 will mark a Cambrian explosion for GenAI applications, research, lawsuits, and news, making even 2023 look stale.



MARJORIE FREEDMAN
NC DIVISION

As AI-based applications become more pervasive, I think we'll see more research that focuses on the utility, impact, and security of the underlying models.



ANDREA BELZ
CST DIVISION

For 2024 we are excited to accelerate research in technology trends, using cutting-edge text analysis and our proprietary NASA data.



FRED MORSTATTER
AI DIVISION

Research will focus on the increased interplay between AI and society, with a particular focus on harms that result from irresponsible applications of AI.



GENEVIEVE BARTLETT
NC DIVISION

A big topic will be how AI can be used to prevent the spread of misinformation and proliferation of fraud and scams. As researchers, we need to push hard for transitionable solutions to detect AI boosted attacks and effectively intervene.

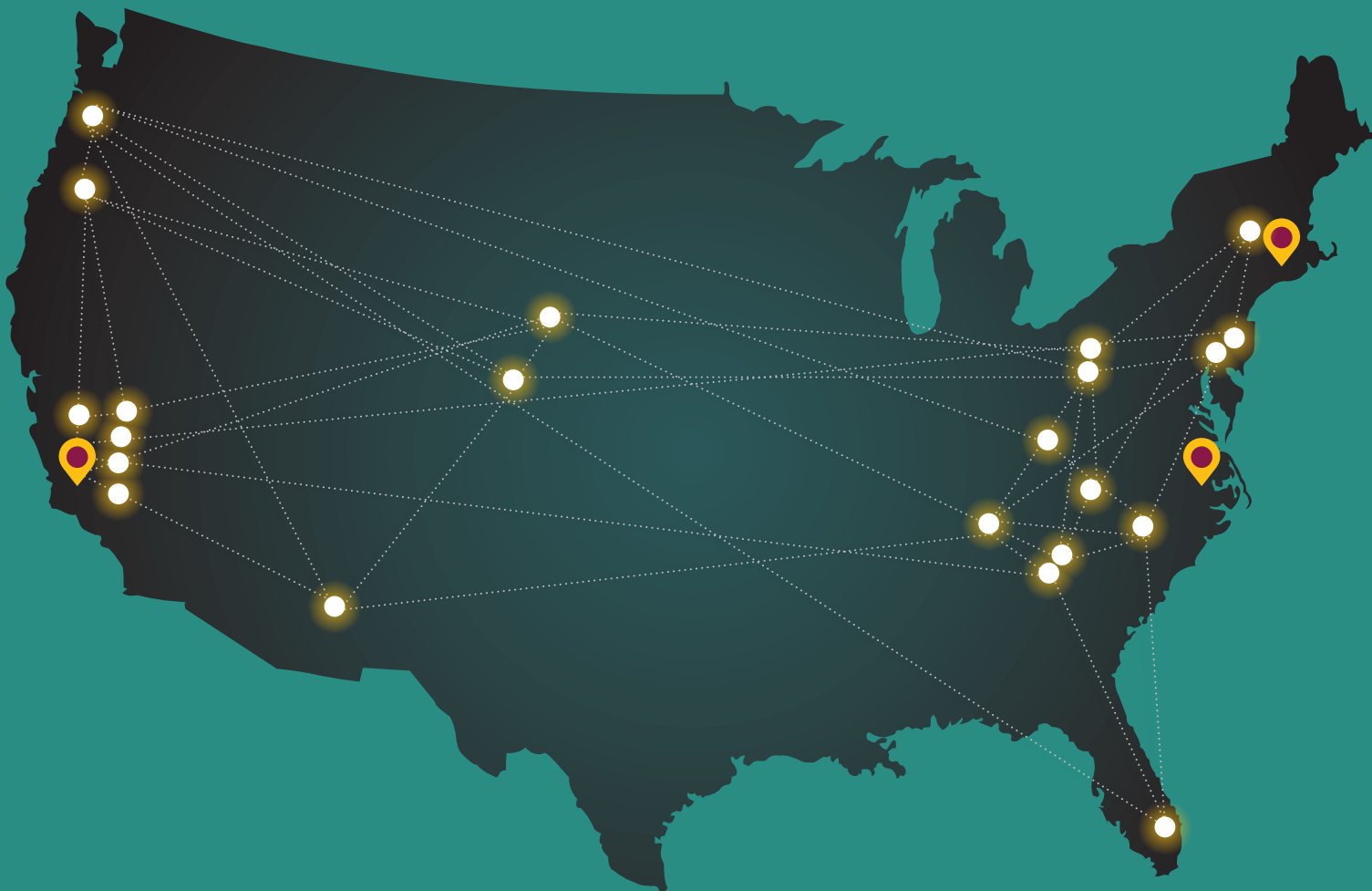


MATTHEW FRENCH
CST DIVISION

We see the confluence of high precision, high agility sensors with intelligent edge processing motivating advances in heterogeneous integration, assurance, and development environments.

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