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SYSTEMSOLUTIONS

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Securing computer hardware

ISR expertise is improving the security of integrated circuit chips

Also: ISR's multidisciplinary pandemic research contributions

ISR hardware security expertise, partnerships key to winning four contracts

Cybersecurity threats are far more than people clicking links in the wrong email. Attacks can be directed against the very integrated circuit (IC) chips that run every computer—from top-secret super computers, to laptops, to Internet of Things devices like "smart" TVs and thermostats. Today, a well-placed cyberattack on IC chips can potentially impact billions of devices.

There are tremendous opportunities for hardware security experts to develop tools, methods and solutions that can be put into wide use to increase security of IC chips as they are designed and manufactured.

The University of Maryland, and ISR in particular, has a great deal of faculty expertise and well established federal and industry partnerships in this area. This combination has enabled ISR faculty to win a number of large hardware security contracts in the past year. Our expertise includes the following areas.

Design obfuscation

Because of the high cost of maintaining a semiconductor facility and the evolving complexity of modern system designs, design companies increasingly outsource their chip designs to offshore foundries. However, this trend has led to severe security vulnerability issues associated with intellectual property (IP) piracy, reverse engineering, counterfeiting, and overproduction of hardware designs. Such IC supply chain attacks lead to losses in magnitudes of billions of dollars per year.

To counter these threats, ISR Director and Professor **Ankur Srivastava** (ECE/ISR) and his research group are working on circuit obfuscation techniques that can prevent a circuit design from being pirated by an untrusted foundry. They have developed:

- "Anti-SAT," a provably secure circuit block that counters SAT formulation-based attacks;
- Delay locking and stripped-functionality delay locking techniques to enhance the security of designs against all known attacks on logic locking;
- Architecture-level obfuscation schemes for securing CPU, GPU, and memory subsystems; and
- A strong obfuscation driven chip design flow based on 2.5D ICs that can effectively obfuscate the functionality as well as layout of designs and mitigate potential attacks.

Side-channel attacks

Side-channel attacks (SCAs) pose a major threat to various cryptographic primitives, protocols, and devices. Even when the robustness of a cryptosystem has been established under rigorous mathematical analysis, an adversary can exploit the unintentional leakage of information from the physical implementation of the cipher to reveal the secret key.

SCAs can be broadly classified into two categories: active and passive side-channel analysis. In active SCAs, an adversary tampers with the proper functioning of a device, e.g., by introducing faults that induce errors in computations. In passive SCAs, the external behavior of cryptographic implementation is monitored without disturbing any operation of the underlying algorithm.

There can be various sources of passive side-channel leakages of a device, such as power consumption, timing variation, and electromagnetic emanation. A side-channel adversary tries to find out the correlation between the observable side-channel information and the secret key dependent internal state of the cryptographic implementation.

Professor Srivastava's group has investigated the vulnerabilities of both conventional cryptosystems and emerging technology-based cryptosystems to such SCAs. Professor **Gang Qu's** (ECE/ISR) research group has performed extensive security analysis of systems against SCA attacks including demonstrating the use of dynamic voltage and frequency scaling mechanisms to mount fault injection attacks on Intel software guard extensions (SGX).

Hardware trojans

IC designers increasingly are outsourcing fabrication to foundries and incorporating third-party intellectual property cores into their designs. This practice leads to security problems including hardware trojans (HTs), malicious circuitry incorporated within modern ICs that can potentially steal sensitive information and/or render the chip useless. HTs can change IC functionality, reduce IC reliability, leak valuable information from the IC, and even cause denial of service. Detecting the presence of HTs is very important, and a number of different detection approaches have been proposed.

Professor Srivastava's group has developed a host of techniques for detecting and mitigating HTs. Some of these techniques rely on post silicon reverse engineering based approaches. Others use runtime measurements of signals such as temperature to detect anomalies stemming from HT activity. The research group is also developing systematic trojan insertion algorithms to model a sophisticated attacker who has the knowledge of state-of-the-art HT detection algorithms.

Security and privacy issues in machine learning

In recent years, deep neural networks (DNN), a type of machine learning (ML) model, have been used extensively for artificial intelligence-related tasks. The current trend in the supply chain of DNNs has also caused security concerns: due to the high hardware and data requirement to train state-of-the-art DNN models, DNN developers increasingly tend to just decide the structure of the DNN and use the computation resources (sometimes even data) provided by a machine-learning-as-a-service (MLaaS) provider to train the DNN. When the developer receives the trained DNN model from the MLaaS provider, he or she publishes the DNN and end users can download and run it on their own device.

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Professor Srivastava's group has considered two security and privacy concerns in this process, namely the integrity of the DNN model trained by an MLaaS provider and the privacy of the DNN model when being run on an end user's device. Specifically, their work has demonstrated that the MLaaS provider can embed malicious functionality, a.k.a. neural trojans, in the trained DNN model. They also have proposed countermeasures. The group has demonstrated how an end user can reverse engineer a DNN model from side-channel information and developed defense techniques.

Professors Srivastava and Qu began working on the following hardware security projects in the past year.

DARPA AISS semiconductor security project

The University of Maryland is receiving $4.96 million in funding as part of a multi-team Defense Advanced Research Projects Agency (DARPA) project, Automated Implementation of Secure Silicon (AISS). AISS aims to make scalable on-chip security pervasive by developing a design tool and intellectual property ecosystem—including tool vendors, chip developers, IP licensers, and the open source community—capable of automating the process of adding security into integrated circuits, ultimately making scalable on-chip security ubiquitous.

UMD's portion of this massive project is led by the Applied Research Laboratory for Intelligence and Security (ARLIS), includes researchers in ISR, ECE, the Fraunhofer USA Center for Experimental Software Engineering, and a group from New York University. They will try to break through the security and discover key attributes of the IC chip being protected.

Warren Savage, a visiting researcher at ARLIS, is the principal investigator for this Independent Verification and Validation (IV&V) aspect.

Professors Ankur Srivastava and Gang Qu will exploit hardware trojan and side channel attacks. Srivastava will validate obfuscation techniques and assess the AISS design flow's resilience against the insertion of hardware trojans into chip designs and the interoperability of third-party obfuscation/locking technology with AISS design tools.

Qu's group will use side channel attacks such as power, timing, electromagnetic leakage, cache and scan chains to try to break through the AISS security engine to reveal secret keys.

The Fraunhofer USA CESE team, led by its Executive Director and ISR-affiliated Professor **Adam Porter** (CS/UMIACS), will address supply chain concerns.

Learn more: *go.umd.edu/aiss1220.*

DoD 'SHIP' hardware security project

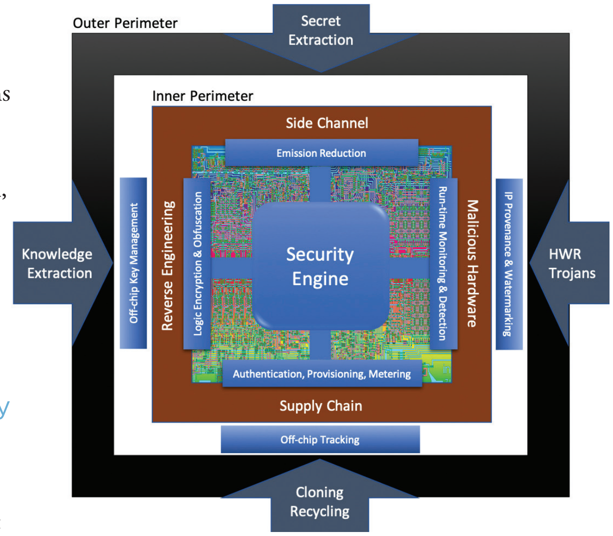
Ankur Srivastava and Gang Qu are subcontractors in the "State-of-the-Art Heterogeneous Integrated Packaging (SHIP) Prototype Project" funded by the Department of Defense (DoD) and led by Intel Corp. Srivastava is the principal investigator and Qu is the co-PI for a three-year, $700K subcontract, "Red Team, Chiplet IP Protection and Countermeasures."

They will investigate multiple attack methodologies that could be used against prototype SHIP IC chiplets. The attacks include those framed in strong theoretical foundations such as SAT, appSAT and bounded model checking, and those that rely on simulation and analysis. The researchers will explore FSM & combinational locking as well as watermarking.

Learn more: *go.umd.edu/ship321.*

DARPA 'SAHARA' hardware security project

Ankur Srivastava is part of the large "Structured Array Hardware for Automatically Realized Applications (SAHARA)" program funded by DARPA and led by Intel Corp. The program is developing obfuscation technologies for structured Application Specific Integrated Circuit (eASIC) chips. Srivastava is the principal investigator for a three-year, $700K "Red Team" subcontract that will stress test the security of these chips through rigorous verification, validation and development of new attack methodologies. Srivastava's team will develop strategies for attacking the integrated eASIC design flow that incorporates Logic Locking and One Time Programmable (OTP) Look-Up Table (LUT) configuration,



AISS IMAGE COURTESY DARPA

Obfuscation, and Network on Chip (NoC) router table configuration.

Learn more: *go.umd.edu/sahara321.*

AFRL delay locking technology project

Ankur Srivastava is part of the Air Force Research Laboratory (AFRL) "Locked Electronics for Assured Design" (LEAD) program led by Northrop Grumman Corp. He is the principal investigator for "Delay Locking ASIC IP Blocks to Protect Functionality," a two-year, $200K subcontract.

Logic locking is a technique that has been proposed to thwart IC counterfeiting and overproduction by an untrusted foundry. The security of logic locking has been threatened by the new "SAT" attack, which can effectively decipher the correct key of most logic locking techniques. In 2017, Srivastava and Yang Xie proposed a technique called delay locking to enhance the security of existing logic locking techniques.

In this new project, Srivastava's team will employ rigorous mathematical techniques to quantitatively assess the performance of the time delay obfuscation technique in protecting ASIC chips. They also will evaluate the probability of reverse-engineering the key from the netlist, as well as the effectiveness of the method to prevent unauthorized use of the digital circuit. This analysis will lead to the development of associated tools and ultimately, new silicon tapeout with delay locking technology.

Learn more: *go.umd.edu/dl321.*

'GANRED' attack wins ACM Cloud Computing Security Workshop Best Paper Award for Srivastava, Liu

"GANRED: GAN-based Reverse Engineering of DNNs via Cache Side-Channel" won the Best Paper Award at the 2020 ACM Cloud Computing Security Workshop, held in conjunction with the ACM Conference on Computer and Communications Security. The paper was written by ISR Director and Professor **Ankur Srivastava** and alumnus **Yuntao Liu** (ECE Ph.D. 2020). Liu, Srivastava's former Ph.D. student, is now his postdoctoral researcher.

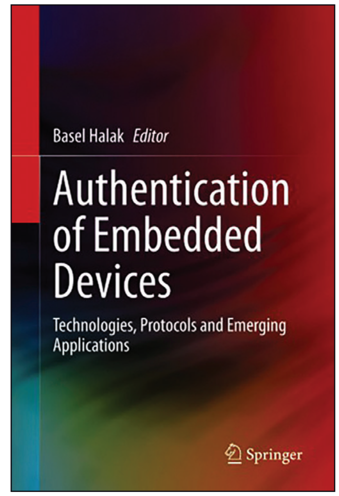
As deep neural networks (DNN) have become an important type of intellectual property, DNN stealing attacks have emerged and many attack surfaces have been exploited. Cache timing side-channel attacks do not need physical probing or direct interaction with the victim to estimate the DNN model.

Existing cache side-channel-based DNN attacks rely on analyzing the binary code of the DNN library that must be shared between the attacker and the victim in main memory. However, in reality, the DNN library code is often inaccessible because the code is proprietary, or memory sharing has been disabled by the operating system.

Srivastava and Liu's paper proposes GANRED, an attack based on the generative adversarial nets (GAN) framework which utilizes cache timing side-channel information to accurately recover the structure of DNNs without memory sharing or code access.

GANRED does not need DNN library code analysis or a shared main memory segment between victim and attacker. It can locate the exact structure of the victim model, unlike existing attacks which only narrow down the structure search space. This new attack requires only minimal resources and efficiently scales to deeper DNNs, exhibiting only linear growth in the number of layers in the victim DNN.

Gang Qu, alumni contribute two chapters to authenticating embedded devices book



Professor **Gang Qu** (ECE/ISR) and his former students **Xi Chen** (ECE Ph.D. 2018) and **Md Tanvir Arafin** (ECE Ph.D. 2018) have contributed two chapters to the new Springer book, *Authentication of Embedded Devices: Technologies, Protocols and Emerging Applications*. The book is edited by Basel Halak, director of the embedded systems and Internet of Things program at the University of Southampton in England.

This book provides comprehensive coverage of state-of-the-art integrated circuit authentication techniques, including technologies, protocols and emerging applications.

In the chapter, "Integrated Circuit Digital Fingerprinting-Based Authentication," Qu and Chen review the general requirements and the available schemes to create digital fingerprints for IP protection, discuss the challenges of applying these methods for device authentication in IoT applications, and explain how to overcome these difficulties. They consider that embedded devices are designed by reusing IP cores with reconfigurable scan network (RSN) as the standard testing facility and elaborate how to generate unique IC identifications (IDs) based on different configurations for the RSN. These circuit IDs can be used as IC fingerprints to solve the device identification and authentication problems. This IC fingerprinting method complies with IEEE standards and has a high practical value.

In the chapter, "Hardware-Based Authentication Applications," Qu and Arafin address how the widespread employment of the Internet of Things (IoT) results in authentication becoming a central concern in the security of resource constraint internet-connected systems. Interconnected elements of IoT devices typically contain sensors, actuators, relays, and processing and control equipment that are designed with a limited budget on power, cost, and area. Incorporating security protocols can be challenging. The authors discuss hardware-oriented security applications for the authentication of users, devices and data. These applications illustrate the use of physical properties of computing hardware such as main memory, computing units, and clocks for authentication applications in low power on IoT devices and systems.

Srivastava, Northrop Grumman develop new IC security method

ISR Director and Professor **Ankur Srivastava** has long partnered with Northrop Grumman on computer hardware security research. A new security method for integrated circuits that accurately and rapidly detects and locates hardware Trojans has been developed jointly by his research group and Northrop Grumman. This technology, which is being implemented in real systems built by Northrop Grumman, could be a game changer in guaranteeing security.

The new method is featured in the article "Detecting Imported Hardware Trojans," written by Tracy Staedter for Northrop Grumman.

"With semiconductor chips made overseas, U.S. military technology faces high risks," Staedter writes. "Strong Trojan detection techniques reduce these security issues. These new integrated circuit security methods allow the government to contract with untrusted foundries with expertise in producing high-performance integrated circuits."

The technology involves placing specially-designed logic circuits called Linear Hybrid Cellular Automata in state-of-the-art silicon being developed by Northrop Grumman. In computer simulations, the new method detected all inserted hardware Trojans, including some that were undetected using other techniques.

Learn more. Read about this new technology and the partnership between Srivastava and Northrop Grumman on the Northrop Grumman website. Access it at *go.umd.edu/ngtro221*.

Brain and Behavior Initiative is now a UMD institute

The Brain and Behavior Initiative has officially become the Brain and Behavior Institute, and is now headed by a founding director, Professor **Elizabeth Quinlan** (Biology).

Growing out of a workshop organized by then-ISR Director **Reza Ghodssi** (ECE/ISR) in 2014, the initiative has fostered interdisciplinary interactions in neuroscience across disciplines, particularly in the physical and life sciences. The initiative's seed grant program has yielded a 900% return on seed grant investments, through 15 awards from private organizations and government funding, including the National Institutes of Health BRAIN Initiative, National Institute of Mental Health, National Science Foundation, and Air Force Office of Scientific Research.

As an institute, BBI will continue to strengthen collaborations among neuroscientists, engineers, computer scientists, mathematicians, physical scientists, cognitive scientists and humanities scholars. It will play a vital role in the university's neuroscience ecosystem, and foster interactions with collaborators at other institutions, including the University of Maryland Baltimore.

Little-understood poststroke cognitive issues verified

Poststroke acute dysexecutive syndrome (PSADES) is a cognitive dysfunction that people commonly experience after even minor strokes. The condition becomes evident soon after the stroke occurs, and while it correlates to having dead tissue lesion(s) in the brain left behind by the stroke, it does not seem to be related to their location. Fortunately, PSADES gradually improves in the months after recovery. But what has been going on inside the brain during this time?

Although stroke patients have reported these cognitive difficulties to their doctors for a long time, until now, the evidence of this problem has mostly been anecdotal. A new study by University of Maryland, Johns Hopkins University and New York University researchers for the first time provides measurable physical evidence of diminished neural processing within the brain after a stroke. It suggests that PSADES is the result of a global connectivity dysfunction. "Poststroke acute dysexecutive syndrome, a disorder resulting from minor stroke due to disruption of network dynamics," has been published in the *Proceedings of the National Academy of Sciences of the United States of America*.

SHUTTERSTOCK IMAGE

The paper was written by Professor **Jonathan Simon** (ECE/ISR/Biology), his former postdoctoral researcher **Christian Brodbeck**, and ECE Ph.D. student **Joshua Kulasingham**; the Johns Hopkins School of Medicine's Associate Professor Elisabeth Marsh, Professor Rafael Llinas and Dania Mallick, all of the Department of Neurology; and NYU Grossman School of Medicine Research Professor Rodolfo Llinas. Marsh is the lead author.

New algorithms for estimating latent dynamics of biological processes

Estimating latent dynamics underlying biological processes is a central problem in computational biology. State-space models with Gaussian statistics are widely used for estimation of these dynamics and have been successfully utilized in analyzing biological data. Gaussian statistics, however, fail to capture several key features of the dynamics of biological processes such as abrupt state changes and exogenous processes that affect the states in a structured way. Although Gaussian mixture process noise models have been considered as an alternative, data-driven inference of their parameters is not well established.

In "Dynamic estimation of auditory temporal response functions via state-space models with Gaussian mixture process noise," published in *PLOS Computational Biology*, six ISR researchers developed efficient algorithms for inferring the parameters of a general class of Gaussian mixture process noise models from noisy and limited observations, and used them to extract neural dynamics that underlie auditory processing from magnetoencephalography data in a cocktail party setting.

The paper was written by **Sina Miran** (EE Ph.D. 2019); his advisor, Associate Professor **Behtash Babadi** (ECE/ISR); **Alessandro Presacco** (NACS Ph.D. 2016); his advisor, Professor **Jonathan Simon** (ECE/ISR/Biology); Professor **Michael Fu** (BMGT/ISR) and Professor **Steve Marcus** (ECE/ISR).

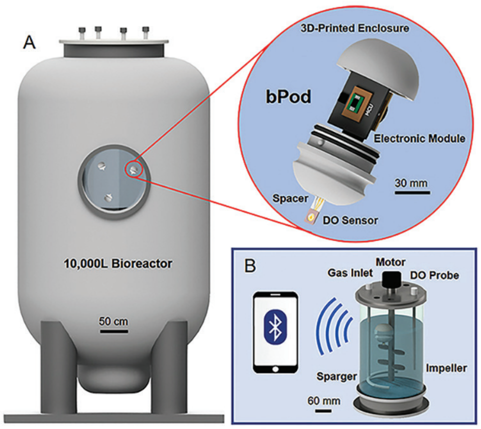
Espy-Wilson, Ghodssi, Abshire 'AIM-HI' to address health challenges

The $1.8 million AIM-HI (AI + Medicine for High Impact) program to target major health care challenges brings together experts in medicine and artificial intelligence at UMD and the University of Maryland Baltimore (UMB). Two projects are led by ISR faculty.

Professor **Carol Espy-Wilson** (ECE/ISR) is part of a project leading a shift in machine learning for mental health. It treats the dominant paradigm of individual-level classification or regression not as an end in itself, but rather as providing necessary components in a broader framework. Co-PIs include Philip Resnik (Linguistics/UMIACS/BBI), John Dickerson (CS/UMIACS), and UMB's Deanna Kelly.

Professor **Pamela Abshire** (ECE/ISR), Professor **Reza Ghodssi** (ECE/ISR), and Associate Professor **Behtash Babadi** (ECE/ISR) are involved in a project that will search for novel, localized biomarkers associated with gastrointestinal pain through mass spectrometry imaging as well as proteomic, lipidomic and RNA sequence analysis; miniaturized, multiplexed biochemical sensors to measure localized biomarkers; and machine learning. They are joined by UMB's Robert Ernst, Richard Traub, and Alison Scott.

'Smart marble' sensors for monitoring pharmaceutical bioreactors



Before COVID-19, few in the general public were aware of the role of bioprocessing reactors in the pharmaceutical industry. These large, fully-automated machines rapidly mass produce a wide variety of mammalian and bacterial cell cultures for vaccines, biologic drugs and antibiotics. The processes within these reactors must be closely monitored for uniformity so that the cultures they produce will be effective and of high quality.

Since 2017, and with funding from the National Science Foundation and the Advanced Mammalian Biomanufacturing Innovation Center (AMBIC), a team of faculty and students from ISR, the Fischell Department of Engineering and the Robert E. Fischell Institute for Biomedical Devices has been developing "smart marbles." These neutrally buoyant sensors can wirelessly transmit readings from inside a bioprocessing reactor. Also known as bPods (bio-processing online devices), they offer the promise of real-time, *in situ* monitoring of cell culturing parameters such as dissolved oxygen.

Existing commercial monitoring solutions, such as inline instrumental probes, are limited to single-point measurements that are then used as an averaged value for the entire bioreactor. This technology cannot capture the distribution of process parameters throughout the bioreactor. It is unable to detect the presence of gradients or heterogeneity in physical parameters (i.e. temperature/pH) and the concentration of compounds of interest (i.e. glucose/oxygen) throughout the bioreactor. A bPod sensor could permeate and travel through bioreactor flows, continuously recording variations in key parameters. It would provide high-precision bioprocess monitoring that could help to achieve a more uniform and effective product.

In 2020, the advancement of this technology was documented in papers published in *Sensors and Actuators B: Chemical* and the *Journal of Microelectromechanical Systems.* The first bPod prototype in 2018 was the size of a baseball. Since then, the Maryland researchers have been refining and reducing the bPod to golf ball size. They also have been upgrading its capabilities.

"The bPod is an embedded sensing system that demonstrates hybrid fabrication and packaging technologies," says Professor **Reza Ghodssi** (ECE/ISR). "It makes use of 3-D printing, customized microsensors sensors, and low-power electronics to enable *in situ* measurements and real-time data extraction in environments where this was not previously possible."

"The 26 world-leading biopharmaceutical companies that are part of AMBIC are aggressively pursuing advanced and innovative analytical technologies to streamline manufacturing processes," says Professor **William Bentley** (BIOE/Fischell Institute). "Our bPod 'smart marbles' platform is being viewed as a potential game-changer."

The platform represents significant progress towards scalable *in situ* applications ultimately targeting bioreactor heterogeneity. While the sensor is not available for use in current COVID-19 vaccine production, it holds promise for improving the production efficiency and quality of future vaccines, biologics and antibiotics.

A NOTE TO OUR READERS

It goes without saying that we have been living through extraordinary times during the COVID-19 pandemic. This lingering disaster has exposed not only the cracks in human societies, but also the limitations of the systems on which we rely. Yet, the pandemic has also revealed the importance of many areas of research in which ISR faculty and students are involved, much of which flies under the radar in more normal times. It also has opened up new avenues of inquiry for our work. Here we present a few stories of ISR's valuable contributions to society in these consequential days.

Study finds fewer pandemic cases and deaths in rule-abiding cultures

The United States' poor record in controlling the spread of COVID-19 could be partially due to its "loose" culture, according to Professor **Michele Gelfand** (Psychology), Professor **Dana Nau** (CS/ISR) and their colleagues.

The work published in *The Lancet Planetary Health* showed that in the first months of the pandemic, "looser" nations—with relaxed social norms and fewer rules and restrictions—had five times more cases and more than eight times more deaths from COVID-19 than "tighter" countries.

Gelfand has pioneered tightness-looseness theory, which holds that "tight" cultures with stricter social norms are less tolerant and have harsher disciplinary measures, while more creative and open "loose" societies have weaker norms and a higher tolerance for violations. She notes that throughout history, tight cultures have generally faced more ecological and human-made threats than loose ones.

In fall 2020, the researchers examined data from 57 countries and found looser nations like the U.S., Brazil and Spain experienced significantly more COVID-19 cases and deaths by October than tighter countries like South Korea, Taiwan and Singapore. Nau developed game-theoretic computer simulations that showed similar results.

"This is the first time we have been able to examine how countries around the world respond to a simultaneous collective threat," Gelfand said. "We found that, perhaps because they are more willing to follow rules, tight cultures are better equipped to deal with a global pandemic than loose cultures."

"Our rule-breaking spirit in the U.S. is great for creativity and innovation, but it's not well-matched to dealing with a collective threat," she says.

Gelfand says the research suggests that in loose cultures, interventions will be needed to strengthen acceptance of public health restrictions like physical distancing and wearing face masks.

"We need more 'cultural ambidexterity'—the ability to tighten and loosen based on how much danger we're actually facing."

—Thanks to Sara Gavin, UMD College of Behavioral and Social Sciences, for this story.

MATTHEW P. D'AGOSTINO, M.A., PHOTOGRAPHER, OFFICE OF COMMUNICATIONS AND PUBLIC AFFAIRS, UNIVERSITY OF MARYLAND, BALTIMORE.

UMMS COVID-19 VACCINATION CLINIC AT THE UNIVERSITY OF MARYLAND BALTIMORE SMC CAMPUS CENTER

Herrmann: vaccination clinic design, higher ed risk management

Professor **Jeffrey Herrmann** (ME/ISR) has been working as a subject matter expert with the University of Maryland Medical System (UMMS) as it brings COVID-19 vaccination clinics into service. Herrmann, who has extensive public health clinic predictive modeling expertise, has been helping UMMS plan clinic layout and operations.

The operations research specialist is building on what he learned developing mass dispensing and vaccination clinic models a decade ago with the U.S. Centers for Disease Control and Prevention (CDC); the National Association of County and City Health Officials (NACCHO), and public health officials from the Montgomery County, Md., government.

Large teams of people are needed to figure out the issues involved in "getting shots into arms." Herrmann is using his skills to build predictive mathematical models for decision making and put them in user-friendly Excel spreadsheet tools that will aid teams in their planning.

Herrmann says those on the front lines are so busy dealing with everything the situation is throwing at them that they don't have the bandwidth to do things like modeling to help them make the best decisions. "Because I'm not on the line as they are, and because I have expertise in building models to predict the future based on data and reasonable assumptions, I can help support them."

"UMMS has done a great job, even given all the uncertainties," Herrmann says. "There are so many challenges in standing up an unprecedented operation like this in such a short period of time. It is satisfying to know I can help people today because of the things I learned in my research."

Herrmann is also in the midst of work with two colleagues in the School of Public Health, Professor Donald Milton and Professor Hongjie Liu, on a NSF EAGER grant, "Protecting University Communities from COVID-19 with Model-Based Risk Management."

Higher education institutions—like every other segment of society—have been forced to make critical decisions about how and when to reopen that could have significant health and financial implications. And because of the unprecedented nature of the pandemic, these decisions are being made with limited information, constrained resources and no reliable road map.

To fill in the gaps about how to keep people safe in a university setting, this research team is developing modeling tools that can help colleges and universities keep students effectively and safely progressing toward their degrees in the context of the disease patterns and practices in the surrounding community.

Learn more. Get access to Herrmann's clinic modeling tools and learn more about his work at *go.umd.edu/jwhtools121*.

Wu, Milton improving telemedicine

One of the first side effects of the pandemic was the sudden switch to telemedicine for routine appointments by doctors' offices and their patients.

And as part of its pandemic response, the National Science Foundation offered funding for pandemic-related research solutions through Rapid Response Research (RAPID) grants.

ISR-affiliated Professor **Min Wu** (ECE/UMIACS) is the principal investigator and Professor **Donald Milton** (Applied Environmental Health, School of Public Health) is the co-PI on a RAPID project that is improving telemedicine capabilities. The project considers how video-based physiological sensing technologies can aid in contactless remote triage and rehabilitation during pandemics. The researchers are devising methods to track, visualize and archive health indicators such as respiration rate, heart rate, and blood oxygen saturation levels just from the information available in typical telemedicine videos taken by low-cost, consumer-grade cameras,

Wu and Milton's video data collection techniques could become part of improved telemedicine systems that would offer enhanced tools for health care professionals to perform remote triage and rehabilitation. These tools would be valuable not only in future pandemics, but also in routine telemedicine care in rural communities around the world.

Markov chain predictive model aids medical decisionmakers

Modeling research by Professor **Michael Fu** (BMGT/ISR) and academic colleagues in China helped decisionmakers there better forecast the spread of the COVID-19 pandemic. The model they developed was adopted by the Shanghai assistance medical team in Wuhan's Jinyintan Hospital, the first hospital in the world that took COVID-19 patients. Forecasts from the model were used to prepare medical staff, intensive care unit beds, ventilators, and other critical care medical resources, as well as to support real-time medical management decisions.

Recent funding to ISR faculty

FAA extends funding for NEXTOR III aviation operations research consortium

In summer 2020, the National Center of Excellence for Aviation Operations Research (NEXTOR) received renewed funding at a crucial time for air travel.

NEXTOR is a University of Maryland-led, Federal Aviation Administration (FAA)-funded research consortium that addresses aviation operations issues on behalf of the federal government, the airline industry and the flying public. In announcing a new seven-year contract for "NEXTOR III," the FAA expressed its confidence in the value of the eight-university group's research for a second time. The new extension has an expenditure cap of $24 million.

The announcement came at a time of critical upheavals in air travel due to the COVID-19 pandemic. Shortly after its funding was extended, NEXTOR hosted a series of seminars that explored the effects of the pandemic on the aviation industry. The seminars can be viewed at nextor.org.

NEXTOR was established in 1996, led by the University of Maryland and Professor **Michael Ball** (BMGT/ISR). Ball and Professor **David Lovell** (CEE/ISR) will lead the NEXTOR III consortium. In addition to Maryland, other consortium member universities are George Mason University; the Massachusetts Institute of Technology; the University of California, Berkeley; the Virginia Polytechnic Institute and State University; the Georgia Institute of Technology; the Ohio State University; and Purdue University.

The consortium's basic research, modeling and investment analysis addresses the needs of the National Airspace System (NAS) on a wide range of aviation operational problems, while promoting increased dialogue between the FAA and the airline industry. NEXTOR's broad research program encompasses air traffic management and control; safety data analysis; aviation economics and policy; human factors; communication, data collection and distribution; and system performance evaluation and assessment measures.

NEXTOR's decision support tools, operational and system concepts, and policymaking tools have had a substantial impact on aviation practice. Its research results have been incorporated into FAA systems and have led to improved NAS performance.

"I'm proud of the research contributions the consortium has made," Ball said recently. "In a certain sense, it's like we have become a research arm of the FAA."

Raghavan is PI for illicit drug trafficking network project

Professor **S. Raghu Raghavan** (BMGT/ISR) is the principal investigator for a five-year National Science Foundation collaborative research award worth nearly $1M ($743,806 to UMD), "Discovery, Analysis, and Disruption of Illicit Narcotic Supply Networks."

As transnational drug cartels continue to grow, their trafficking networks have become more complex and fragmented. This project takes a multidisciplinary, scientific approach to build better insight and optimization of U.S. counter-narcotics efforts. The research will support the disruption strategies of anti-narcotics and other law enforcement agencies.

Raghavan and his colleagues Margret Bjarnadottir (BMGT), John Dickerson (CS), Greg Midgette (Criminology and Criminal Justice) and Marcus Boyd (START) will analyze the dynamics of narcotic supply networks and how interdiction strategies disrupt them. Their approach will encompass operations research, computer science, criminology, public policy, geography, and economics. Network analysis of temporal and spatial cocaine price data will be used to infer illicit supply chain network structures and flow. Artificial intelligence and learning models will be applied to the empirical data to extract network behavior in response to interdiction activities, while game theoretic models will blend combinatorial optimization and agent-based simulation to evaluate the outcomes of various interdiction strategies.

The research results will be integrated into a network optimization model to explain the structure of illicit drug supply chains and provide evidence to support successful disruption strategies.

Fu, Marcus team for AFOSR simulation optimization project

Professor **Michael Fu** (BMGT/ISR) is the principal investigator and Professor **Steve Marcus** (ECE/ISR) is the co-PI for a three-year, $871,982 Air Force Office of Scientific Research project, "Simulation Optimization: New Approaches to Gradient-Based Search and Maximum Likelihood Estimation."

Simulation optimization aims to guide planning and decision making under uncertainty in complex dynamic settings. It is useful in tasks such as unmanned aerial vehicle path planning, supply chain management, risk management, and various neuroscience applications.

This research project will address two overlapping simulation optimization settings. In the first, simulation is required to estimate performance of a complex underlying system where direct gradient estimates are available, such as simulation models of large queueing networks. The goals of this research are to develop new computationally efficient algorithms with provable convergence guarantees and to provide practical guidelines for how best to combine gradient estimates with performance estimates. Applications include path planning for unmanned aerial vehicles, as well as practical problems arising in supply chain management and risk management/mitigation.

The second setting addresses maximum likelihood estimation problems for estimating underlying system input parameters, where the likelihood function is not available explicitly or is very likely to be non-convex, requiring simulation-based global optimization algorithms. An example of the former would be large queueing networks where only a simulation model is available. Many problems falling into the latter situation arise naturally in statistical applications, such as those in neuroscience.

Maryland engineers receive $10M to transform shellfish farming

A multidisciplinary team led by Professor **Miao Yu** (ME/ISR) has received a $10 million grant from the United States Department of Agriculture's National Institute of Food and Agriculture to accelerate sustainable shellfish aquaculture in the United States.

The research will develop novel technologies and a sustainable management framework to help farmers tap the economic potential and environmental benefits of shellfish aquaculture. The research team has expertise in sensing and imaging, robotics and artificial intelligence, automation for agriculture and seafood, aquaculture extension economics, shellfish biology, and software development

"Aquaculture of shellfish such as oysters, mussels, and scallops provides a sustainable, environmentally beneficial source of high-protein food, as well a way to grow the economy in rural coastal areas," said Yu. "Up to this point, we haven't really explored this industry's potential because it still relies on antiquated technologies—in some cases, tools that go back hundreds of years."

"By developing and incorporating advanced technologies into shellfish farming, including underwater drone monitoring and smart harvesting, we can bring about a major boost in production," Yu said.

Professor **Yiannis Aloimonos** (CS/UMIACS) and Professor **Nikhil Chopra** (ME) are ISR-affiliated faculty on the grant.

The team also includes collaborators from the Clark School; the College of Agriculture and Natural Resources; the College of Computer, Mathematical, and Natural Sciences; and the Fraunhofer USA Center for Experimental Software Engineering. The team also includes the University of Maryland Center for Environmental Science, the University of Maryland Eastern Shore, Louisiana State University, the Pacific Shellfish Institute and Virginia Tech.

Current practices and technologies used in shellfish farming have many shortcomings. For example, harvesting of bottom-culture shellfish relies on dredging, in which machinery drags a net across the bottom of an ocean, bay, or other body of water to scrape up and collect buried shellfish. The process is highly imprecise and can be ecologically catastrophic. It damages reefs, which are important habitats for oysters and other aquatic species.

By synthesizing recent advances in the fields of robotics, agricultural automation, computer vision, sensing and imaging, and artificial intelligence, the team will develop new, smart technologies and a management framework to help enhance productivity and profitability for both farmers and coastal economies while better protecting fragile aquatic ecosystems.

Babadi research to reveal computational principles for the brain's sensory processing and behavior

New research by Associate Professor **Behtash Babadi** (ECE/ISR) will develop methodologies to infer network-level characteristics of ensemble neuronal activity from two-photon imaging data, and will apply these methods to large-scale recordings. These methodologies will help reveal the computational principles that underlie sensory processing and behavior.

Babadi is the principal investigator for a three year, $360K National Science Foundation grant, "Robust Network-Level Inference from Neuronal Data Underlying Behavior."

Within the brain, individual neurons are drastically variable and unreliable. Yet, when these same neurons act together in a network, they enable robust brain function and precise behavioral outcomes. How is this possible? The answer may help to improve prosthetics for people with paraplegia and make possible reconfigurable neuromorphic devices.

The advent of large-scale neural recording technologies, such as two-photon calcium imaging, has enabled scientists and engineers to study the activity of large populations of neurons. It is now possible to decipher how neurons collectively encode and distill information from the external world to elicit robust behavior. However, to make full use of this data, computationally efficient and mathematically principled techniques for robust network-level inference are needed.

In the research, Babadi will develop a robust framework for joint inference of the intrinsic and stimulus-driven correlations of neuronal activity and design a functional taxonomy to characterize the relevance of neuronal activity to sensory processing and behavioral outcomes. He also will construct an estimation framework for capturing the dynamics and functional relevance of higher-order synchronous neuronal activity.

This project addresses several challenges faced by existing methodologies. These include biased network characterization incurred by two-stage analysis pipelines, intermixing the contributions of exogenous and endogenous processes to collective neuronal activity, and studying sensory processing and behavioral elicitation as disjoint problems. By employing two-photon calcium imaging data from mice and zebrafish, the modeling and estimation framework will be used to investigate several fundamental problems in systems neuroscience, such as tonotopic diversity in the auditory cortex, interaction of sensory processing and decision-making, and visuo-motor coordination.

The project will provide signal processing solutions that can be used in neural control and neuromorphic systems such as neural prosthetics used by people with paraplegia. In addition, understanding how the brain performs rapid reconfigurations could help researchers design reconfigurable neuromorphic devices.

Fermüller is PI for 'NeuroPacNet'

Artificial intelligence (AI) is becoming ubiquitous in modern life. But AI systems based on the current paradigm of data-driven approaches and machine learning technology require large amounts of energy for all the computing and sensing, which causes pollution and other environmental problems. There are also well-known privacy issues.

Alternatively, an understanding of how biological brains work could lead to AI systems modeled on neurological principles. Such systems would likely use low-power hardware and software solutions and could lead to new applications for society, such as computing on cell phones, neuro-based prostheses, intelligent hearing aids, and smart sensory systems that include predictive capabilities, such as wearables, thermostats, security systems and irrigation and safety systems.

Further advances—on the scale of a grand scientific challenge—are needed to advance this concept, including developing common computational tools and principled experimental approaches.

ISR-affiliated Associate Research Scientist **Cornelia Fermüller** (UMIACS) is the principal investigator for a four-year, $1.75M National Science Foundation award: "NeuroPacNet —Accelerating Research on Neuromorphic Perception, Action, and Cognition." The four-year project will develop a "network of networks" to link international researchers developing a new neuromorphic AI paradigm.

Co-PIs are Professor **Shihab Shamma** (ECE/ISR), Associate Professor **Behtash Babadi** (ECE/ISR), and two long-time collaborators at Johns Hopkins University, Professor Ralph Etienne-Cummings and Professor Andreas Andreou.

NeuroPacNet will connect international experts in neuromorphic engineering with computational neuroscientists, roboticists, control theorists, and perception researchers from seven global networks. It will advance computational research that integrates perception, action, and cognition.

Researchers will develop new methods and approaches for intelligent system design that will lead to building adaptable systems for robustly processing signals in real time. The network will help experts coordinate across research areas and develop new approaches for sensorimotor control, motor learning, event-based computations, and learning in spiking neural networks.

MEI^2 leads U.S. side of $18.4M U.S.-Israel Energy Center focused on energy storage

The University of Maryland's Maryland Energy Innovation Institute (MEI^2) is leading the U.S. side of a $18.4M, five-year program awarded by the U.S.-Israel Energy Center to promote energy security and economic development through innovative technology research and development.

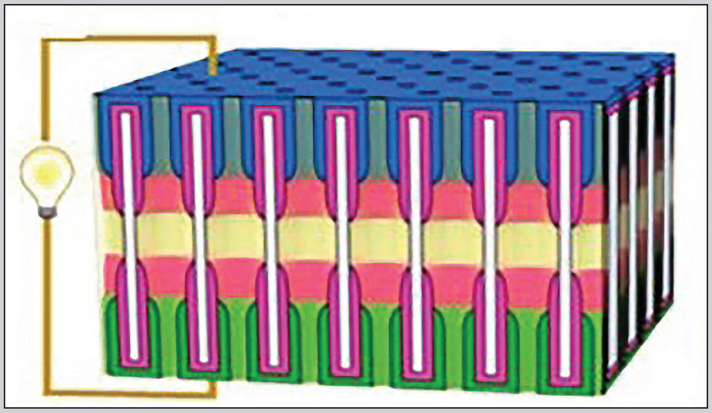
The center is sponsored by the U.S. Department of Energy and the Israel Ministry of Energy. MEI^2 participants include Professor **Gary Rubloff** (MSE/ISR), Eric Wachsman, Sang Bok Lee and Paul Albertus.

The researchers will investigate solid-state batteries that use either lithium or sodium metal as the anode material; these batteries offer a performance breakthrough of more than 30 percent over current Lithium-ion batteries as well as a lower cost from increasing energy density and using less expensive materials. They also will be safer, using electrolyte materials with improved intrinsic thermal stability, and offer the ability to be used in aerospace, transportation and stationary storage. The researchers will work on advanced coatings, cell components, cells, and materials informatics software, for both Na and Li metal batteries.

Rubloff: Thin films for solid-state batteries

Solid-state batteries are made with nonflammable, solid electrolytes such as ceramics or polymers, which offer high energy and power density and strong cycling ability, while eliminating the risk of battery-related fire in mobile devices and electric automobiles.

Professor **Gary Rubloff** (MSE/ISR) is a longtime expert in thin film patterning, an electronics manufacturing process that enables, among many other things, nanopore batteries.



A NANOPORE BATTERY ARRAY

Now Rubloff is the principal investigator for a three-year, $2.25M Department of Energy project, "Thin Film Platforms to Advance Scientific Frontiers in Solid State Energy Storage." The research will illuminate the fundamental role of electrochemistry at the nanoscale in determining the power and energy performance of electrical energy storage devices.

Co-PIs on the project include Paul Albertus (ChBE), Sang Bok Lee (Chem/Biochem) and A. Alec Talin (Sandia National Lab). The work will focus on precision 3D battery designs fabricated by thin-film techniques that have driven the microelectronics and related industries for decades. This approach is quite different from how batteries currently are manufactured.

These techniques will make possible 3D structures capable of providing new measurements and insights currently inaccessible in conventional batteries. Some will address what architectural shapes and dimensions are favorable not only for power and energy, but also for stability during charge/discharge cycling. Others are aimed at determining properties of important interfaces buried underneath layers of battery materials and identifying what happens when a battery is charging or discharging.

"Precision 3D battery architectures, controlled at the nanoscale, provide a profound opportunity to take battery science to a new level," Rubloff said. "We believe the resulting insights will benefit today's technology and offer alternative pathways to how batteries are designed and manufactured."

The research builds on previous work by the DoE's $27.2M Nanostructures for Electrical Energy Storage Energy Frontier Research Center (2009–2020), of which Rubloff was director.

Srivastava wins NSF funding for integrated circuit fabrication security

ISR Director and Professor **Ankur Srivastava** (ECE/ISR) is the principal investigator for a three-year, $500K National Science Foundation Secure and Trusted Cyberspace award, "A High Level Synthesis Approach to Logic Obfuscation."

Use of untrusted foundries for integrated circuit (IC) fabrication has raised piracy and overproduction concerns. Logic/design locking (also known as logic obfuscation) can secure design details from an untrusted fabrication facility by incorporating a locking key that hides the circuit's functional and structural information.

Dr. Srivastava's project will develop a system-level methodology to design locked digital circuits that are rendered useless if the attacker uses any incorrect key and are resilient to state-of-the art attacks such as a satisfiability attack (SAT).

The project will develop several high-level design optimization techniques to open new possibilities of locking design details at the system level. The main optimization goal is corruption of an application for any incorrect key. The techniques are designed to automatically inform gate level locking constructions to achieve resiliency against SAT attacks. First, a few error-critical inputs will be identified at the application level. Then, the architecture will be synthesized using appropriate system-level decisions to render the circuit dysfunctional for a wrong input key.

The project repository will be maintained well beyond the duration of the project and for as long as necessary subject to university archiving guidelines. It will be accessible at srivastava.umd.edu.

Porter studying team cognition and AI solutions for intelligence analysts

ISR-affiliated Professor **Adam Porter** (CS/UMIACS), the executive director of the Fraunhofer USA Center for Experimental Software Engineering, is the co-PI on a project to study team cognition and artificial intelligence (AI) solutions to aid intelligence analysts in deriving actionable and accurate intelligence information.

Research Professor Susannah Paletz (College of Information Studies) is the principal investigator for "Human-Agent Teaming on Intelligence Tasks," a three-year, $616,700 grant funded by the Army Research Office. Paletz is an affiliate of the UMD Applied Research Laboratory for Intelligence and Security (ARLIS).

AI has the potential to support intelligence analysts in reviewing potentially hundreds of thousands of source documents, pulling out key findings, and assembling them into actionable intelligence. AI also can aid in the flow of information and projects among members of the intelligence team, improving the efficiency and accuracy of their work.

"AI-driven technology has sometimes been touted as a replacement for human intelligence," said Porter. "In practice, however, AI doesn't always work, or gives limited or biased answers. Human oversight is still required, and it's therefore critical that we deeply understand how humans and AI can work best together."

The project will focus on how interactive AI agents, such as chatbots, either mitigate or exacerbate communication and coordination problems such as inaccuracy blindness and overlooking potentially relevant information that can occur with shift handovers of intelligence work. It also will examine how humans could deal with blind spots, biases, or inaccuracies.

The researchers will develop an experimental infrastructure to help test team cognition challenges within the work completed by intelligence analysts. This work consists of task-relevant input materials, such as mission descriptions and source documents, activity recording tools, experimental monitoring capabilities, and AI supports for human analysts, such as chatbots offering advice on a particular task.

This project will substantially increase insight into the strengths and weaknesses of AI technology to support intelligence tasks. It will help shed light on how and when human analysts can safely place their trust in AI technology, and how they can proactively identify problems in AI-generated input.

Amazon investment funds initiatives in diversity, robotics research and education

The Clark School and Amazon have partnered for the Amazon Lab126 Robotics and Diversity Initiative, a mutually beneficial, strategic collaboration to advance diversity and robotics research and education. It is the first Amazon/University of Maryland investment to provide fellowships aimed at increasing diversity, and the university's first collaboration specifically with Amazon Lab126.

Amazon invested $100,000 in the initiative for academic year 2020-2021. This includes funding for two Ph.D. fellowships in robotics, for the Clark School's Center for Minorities in Science and Engineering, for the expansion of a capstone course in autonomous robotics, and for the University of Maryland's chapters of the Black Engineers Society and the Society of Professional Hispanic Engineers.

The Ph.D. fellowships are a first for the Maryland Robotics Center housed within ISR. "Amazon Lab126 has shown a tremendous commitment to supporting diversity through this partnership," says the center's director **Derek Paley** (AE/ISR). "These fellowships will give deserving Ph.D. students the resources they need to conduct state-of-the-art robotics research while completing their degrees."

Led by ISR-affiliated Professor **Dinesh Manocha** (ECE/UMIACS/CS), the fellowships will support research in automatic robotic navigation, including mobile robotics, robot motion planning, computer vision, pedestrian tracking, and machine learning.

Estefany Carrillo and **Sara Honarvar** are the first fellowship recipients. Carrillo is a third-year Aerospace Engineering Ph.D. student with research interests in dynamics and control for robotics systems. She is advised by Assistant Professor **Huan Xu** (AE/ISR). Honarvar is a second-year Mechanical Engineering Ph.D. student who conducts research in the Collaborative Controls and Robotics Laboratory. She is advised by Assistant Professor Yancy Diaz-Mercado (ME).

"As one of the few female Hispanic students pursuing an Electrical Engineering degree as an undergraduate and then a doctoral degree in Aerospace Engineering, I was well aware of the importance of someone like me succeeding," Carrillo says. "I truly believe that increasing participation of people from diverse backgrounds in STEM fields can lead to innovative ideas that approach problems from different perspectives."

ISR faculty news

Academic society fellows and major awards

Professor **Gang Qu** (ECE/ISR) has been elected a Fellow of the Institute of Electrical and Electronics Engineers "for contributions to hardware intellectual property protection and security."

Former ISR director and ISR/ECE-affiliated Professor **William Regli** (CS), the director of the Applied Research Laboratory for Intelligence and Security, has been named a Fellow of the American Association for the Advancement of Science. Regli was elected for "work at the interface between science and government, primarily at the Defense Advanced Research Projects Agency."

Distinguished University Professor **John Baras** (ECE/ISR) has been named a Fellow of American Institute of Aeronautics and Astronautics "for fundamental and high impact contributions to Internet over satellite technology, cybersecurity, automatic control, model-based systems engineering, and for academic leadership."

Professor **Sennur Ulukus** (ECE/ISR) has received the Distinguished Technical Achievement Recognition Award of the IEEE Communications Society Technical Committee on Green Communications and Computing, for "outstanding technical leadership and achievement in green wireless communications and networking."

ISR-affiliated Professor **Dinesh Manocha** (ECE/CS) received the Solid Modeling Association's 2020 Pierre Bézier Award in recognition of his technically significant and lasting contributions in solid, geometric and physical modeling and their applications.

Professor **Alireza Khaligh** (ECE/ISR) is one of the recipients of the 6th Nagamori Awards, one of the most prestigious international awards in the power electronics and electric machines field.

The *Journal of Time Series Analysis* gave ISR-affiliated Professor **Benjamin Kedem** (Math) the status of JTSA Distinguished Author, based on the research articles he has contributed to the 40 volumes of the journal.

NSF CAREER Award

ISR-affiliated Assistant Professor **Mark Fuge** (ME) was awarded an NSF Faculty Early Career Development (CAREER) Award for "Learning Design Representations: The Effect of Differential Geometric Manifolds on the Inference of Design Structure." It will enable Fuge to expand his research at the intersection of engineering design and machine learning, enabling computers to learn how to design complex systems like new aircraft or vehicles.

Keynote speaker

ISR-affiliated **Warren Savage**, a visiting researcher with UMD's Applied Research Laboratory for Intelligence and Security, delivered a keynote presentation, "Design for Security: The Next Frontier of Smart Silicon," at DesignCon 2020. The DesignCon conference addresses engineering design challenges in the electronics industry. Savage advocated for a new skill he calls "design for security" to create highly secure devices.

Book

A new book on soft robotics, edited by Maryland Robotics Center Director and Professor **Derek Paley** (AE/ISR) and Professor **Norman Wereley**, Department of Aerospace Engineering chair, has been published by Springer. *Bioinspired Sensing, Actuation, and Control in Underwater Soft Robotic Systems* looks at state-of-the-art research in this emerging field, with a focus on bioinspired soft robotics for underwater applications.

Patents

ISR-affiliated Professor **Min Wu** (ECE/UMIACS) and her former student **Chau-Wai Wong** (EE Ph.D. 2017) are the inventors on U.S. Patent 10,726,256. "Counterfeit Detection Scheme Using Paper Surfaces and Mobile Cameras" uses the microscopic roughness of paper's surface captured by mobile cameras to authenticate merchandise packaging and valuable documents such as tickets and ID.

Professor **Alireza Khaligh** (ECE/ISR) and his former students **Yichao Tang** (EE Ph.D. 2015) and **Chuan Shi** (EE Ph.D. 2018) were awarded U.S. Patent 10,562,404 for "Integrated onboard chargers for plug-in vehicles." The invention is an onboard charger for both single-phase and three-phase charging of a battery in plug-in electric vehicles (PEVs).

New ISR affiliate faculty

Associate Professor **Dana Dachman-Soled** (ECE) is ISR's newest affiliate faculty member. Dachman-Soled's research interests are in cryptography, including security against physical attacks, post-quantum cryptography, secure multiparty computation, and black-box complexity. She received an NSF CAREER award in 2015.

Promotions

Behtash Babadi (ECE/ISR) has been promoted to the rank of associate professor with tenure. Babadi has broad research interests in statistical and adaptive signal processing, neural signal processing, systems neuroscience. He works with a broad range of ISR faculty members in projects across a variety of domains.

ISR-affiliated faculty member **Nikhil Chopra** (ME), has been promoted to full professor. Chopra has been associated with ISR since 2007. Chopra's work is motivated by applications in networked control of robotic systems and mixed human-robot teams.

Appointment

Professor **David Lovell** (CEE/ISR) has been appointed the director of Gemstone, a multidisciplinary research-focused undergraduate honors program at the University of Maryland.

Gemstone was founded in 1996 by William Destler, past dean of the A. James Clark School of Engineering, and was originally administered through ISR.

The program is open to students in all disciplines. As freshmen, students form teams of 10–15 members to research solutions for major societal problems. A team thesis is presented in their senior year to a panel representing academia, industry, and government. Students who complete the program receive a Gemstone Citation along with their diploma.

University of Maryland awards

ISR-affiliated Professors **Dinesh Manocha** and **Bill Fagan** were named Distinguished University Professors in 2020. This is the highest honor bestowed on tenured faculty members at the University of Maryland. It recognizes their excellence in teaching; their significant contributions, both domestically and internationally, to their field of expertise; and the distinction they have brought to the university. Other ISR Distinguished University Professors include John Baras (ECE/ISR), Gary Rubloff (MSE/ISR), Tony Ephremides (ECE/ISR) and Ben Shneiderman (CS/UMIACS).

Professor **Pamela Abshire** (ECE/ISR) has been named a University of Maryland ADVANCE Professor. These faculty serve as mentors and knowledge brokers for faculty within their college, providing strategic advice on grants and research submissions, workload, work-life policies, developing professional networks and preparing materials for tenure and promotion.

At ISR's 2020 awards ceremony, Professor **Gang Qu** (ECE/ISR) won the ISR Outstanding Faculty Award. He was nominated by Professor Sennur Ulukus and Professor John Baras. Qu focuses on cybersecurity, hardware security and trust. His work is fundamental for a systems approach to security and trust and for the important development of composable and compositional security.

Three deserving graduate students were each given the 2020 George Harhalakis Outstanding Systems Engineering Graduate Student Award. **Abhishek Chakraborty** was nominated by his advisor, ISR Director Ankur Srivastava. He has investigated and contributed to multiple aspects of hardware security, including logic obfuscation, side-channel analysis, security of emerging technologies, and neural network model IP protection. His contribution to the field is diverse and substantial.

Akshay Singh was nominated by his advisor, Professor Alireza Khaligh. His research spans several areas of power electronics and energy systems including modeling, simulation, design, and development of power electronic interfaces for transportation electrification, particularly more electric aircrafts.

Michael D'Antonio was nominated by his advisor, Professor Alireza Khaligh. His Ph.D. research project is focused on the design of a low-cost and highly reliable microinverter for residential solar applications. His interdisciplinary work necessitates thermal, mechanical, and reliability perspectives to be considered in all electrical design decisions.

In memoriam

Lynn Preston

On Oct. 26, 2020, ISR lost a longtime friend when **Lynn Preston**, the retired leader of the National Science Foundation Engineering Research Center (ERC) program, died after a lengthy illness.

"Lynn was there at the start of the ERC program and has been a great encouragement to ISR throughout our history," said ISR Director Ankur Srivastava. "We were tremendously saddened to hear of her passing."

LYNN PRESTON WITH JOHN BARAS IN 2015 AT ISR'S 30TH ANNIVERSARY CELEBRATION.

ISR was one of the "original six" ERCs chartered in 1985. Founded as the Systems Research Center at both the University of Maryland and Harvard University, Professor John Baras (ECE/ISR) was its first director.

"The premature passing of Lynn Preston filled me with sadness and at the same time with so many wonderful memories of her friendship, leadership and pioneering vision," Baras said.

Preston and longtime ERC Program communications contractor Court Lewis had recently completed a history of the NSF ERC program titled *Agents of Change: NSF's Engineering Research Centers,* which can be read online at *erc-history.erc-assoc.org.*

Radhakisan Baheti

Dr. Radhakisan Baheti, a program director in the Electrical, Communications, and Cyber Systems Division of the Engineering Directorate at the National Science Foundation since 1989, passed away March 9, 2021. Through his funding work at NSF, Kishan, as he was known, became an important advocate for electrical engineering and control, robotics, cyber-physical systems, and nanotechnology. He was a positive influence on the careers of researchers in these areas across the country.

"Our community has lost a true friend and a strong and effective supporter," said former ISR Director Eyad Abed (ECE). "I worked closely with him while serving as a rotator at NSF, and witnessed his devotion not only to supporting quality research, but also to the many individuals he touched through his work. Seeing the successes of his grantees was a source of happiness for him. He seemed to derive added motivation with every piece of positive news. He was rightly proud of his work and the work of NSF, and he was proud of us, his partners in the path of advancing knowledge. May he rest in peace."

David Elliott

ISR's longtime colleague **Dr. David L. Elliott** passed away on July 2, 2020. He is survived by his wife Pauline Tang. Elliott was a Professor Emeritus of Mathematical Systems at Washington University in St. Louis. Starting in 1992 and until his death, Elliott held a senior visiting faculty appointment with ISR, where he continued to conduct research on bilinear systems and interacted with ISR faculty and students.

During his affiliation with ISR, Elliott wrote the book *Bilinear Control Systems—Matrices in Action*, published by Springer in 2009. Previously, he had written *Neural Systems for Control* with Omid Omidvar.

Professor Tony Ephremides (ECE/ISR) writes: "David Elliott belonged to a class of scientists that are nowadays sorely missed. He was truly devoted to his Science and to his Profession as a researcher and Teacher (with a capital T). He was gentle, interesting, pleasant, reliable, humorous, inspiring. In short, he was a true gentleman."

Alumni news

Academic society fellows and awards

Rajiv Laroia (EE Ph.D. 1992) was inducted into the National Academy of Engineering in February "for contributions to adaptive multiuser orthogonal frequency division multiplexing for cellular voice and data systems."

In 2020 Laroia won the IEEE Alexander Graham Bell Medal, "for contributions to cellular wireless data systems." Laroia was advised by Nariman Farvardin, currently president of Stevens Institute of Technology.

Stefano Coraluppi (EE Ph.D. 1997) has been elected a Fellow of IEEE "for contributions to multi-sensor, multi-target tracking." Coraluppi was advised by Professor Steve Marcus (ECE/ISR). Coraluppi's career has focused primarily on technology development for United States and NATO defense and intelligence systems. He is a chief scientist at Systems & Technology Research in Massachusetts.

Himanshu Tyagi (EE Ph.D. 2013) has received the prestigious 2020 Indian National Science Academy Medal for Young Scientists. Tyagi is an assistant professor in the ECE Department at the Indian Institute of Science in Bangalore. At Maryland, he was advised by Professor Prakash Narayan (ECE/ISR). The award is the highest recognition of promise, creativity and excellence in a young scientist, and is made annually to those distinguished by their research work carried out in India.

Jing Yang (EE Ph.D. 2010) has been honored with two IEEE Communications Society awards: the "Networking Networking Women" Stars in Computer Networking and Communications Award, and the Women in Communications Engineering's Early Achievement Award. The Penn State faculty member was advised by Professor Sennur Ulukus (ECE/ISR). Her work involves understanding fundamental limits of wireless networking systems and designing efficient scheduling, resource allocation and learning algorithms for system performance optimization.

In 2020, **Donald E. K. Martin** (Statistics Ph.D. 1990) was a Black History Month honoree of the Network of Minorities in Mathematical Sciences. Martin is an associate professor in the Department of Statistics at North Carolina State University. His research involves computing distributions of patterns in Markovian sequences through an auxiliary Markov chain. Martin earned his B.S. in Mathematics, and M.S. and Ph.D. in Mathematical Statistics at the University of Maryland, advised by ISR-affiliated Professor Benjamin Kedem (Math).

New positions

Former postdoctoral researcher and assistant research scientist **Chrysa Papagianni** has been appointed as an assistant professor in the MultiScale Networked Systems group of the University of Amsterdam. She will be working in secure programmable networks. Since leaving Maryland, Papagianni has continued her collaboration with Professor John Baras (ECE/ISR) and the Maryland Center for Hybrid Networks (HyNet) on integrated satellite-terrestrial networks and UAV-aided multi-hop wireless networks.

Dipankar Maity (EE Ph.D. 2018) has joined the electrical and computer engineering faculty of the University of North Carolina Charlotte as a tenure-track assistant professor. At Maryland, Maity was advised by Professor John Baras (ECE/ISR). As a student, Maity was honored with the Clark School of Engineering Distinguished Graduate Fellowship and the UMD Graduate School's Outstanding Graduate Assistant Award.

Zhenyu Lin (EE Ph.D. 2020) is working at Google as a software development engineer on the Google Assistant team. His work involves helping Google Assistant provide useful information when users ask for recommendations. At Maryland, Lin was advised by Professor John Baras (ECE/ISR).

Promotions and awards

Michigan State University has named **Xiaobo Tan** (EE Ph.D. 2002) as the Richard M. Hong Endowed Chair in Electrical Engineering. Tan was advised by Professor John Baras (ECE/ISR) and Professor P. S. Krishnaprasad (ECE/ISR). Tan will use his chair to further MSU's robotics program.

Sean Andersson (EE Ph.D. 2003) has been promoted to full professor in the Department of Mechanical Engineering and the Division of Systems Engineering at Boston University. His research centers on systems and control theory, focusing on two very different research areas: robotics, and nanobioscience and nanotechnology. Andersson was advised by Professor P. S. Krishnaprasad (ECE/ISR).

Ravi Tandon (EE Ph.D. 2010) has been promoted to associate professor with tenure at the University of Arizona. He has been on the electrical and computer engineering faculty since 2015. At Maryland, Tandon was advised by Professor Sennur Ulukus (ECE/ISR). Tandon received an NSF CAREER Award in 2017 for information theory and coding.

Achievements

Hyun Jung (EE Ph.D. 2016), a bioinformatics analyst at the Frederick National Laboratory for Cancer Research's Imaging and Visualization Group, claimed a top spot in a computing and artificial intelligence challenge. In "Multi-Organ Nuclei Segmentation and Classification 2020," Jung and his teammates Yanling Liu and G. Tom Brown took third place overall and were the top group in the "industry" category. The challenge required entrants to develop a computer-based method for segmenting and identifying four types of cells in stained histopathology slides of tissues from human organs. At Maryland, Jung was advised by Professor Reza Ghodssi (ECE/ISR).

Two alumni have collaborated on an article published in *Proceedings of the Royal Society A*. **Kevin Galloway** (EE Ph.D. 2011) and **Biswadip Dey** (EE Ph.D. 2015) co-wrote the paper, "Beacon-referenced pursuit for collective motion in three dimensions." They introduce a decentralized control mechanism to guide steering control of autonomous agents maneuvering among multiple moving and stationary entities in a three-dimensional environment. Both were students of Professor P. S. Krishnaprasad (ECE/ISR). Galloway also was promoted to associate professor with tenure at the United States Naval Academy in 2020.

Student news

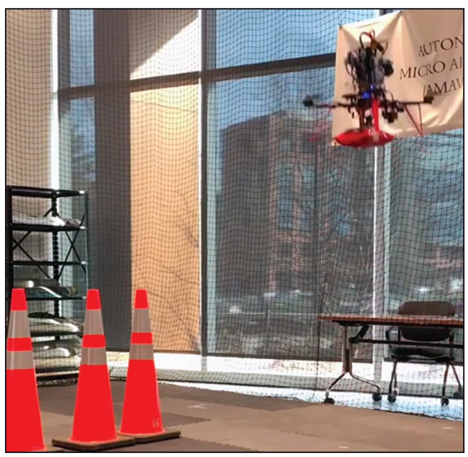
Statistics Ph.D. student **Gustavo Varela-Alvarenga**, who recently completed a National Science Foundation Mathematical Sciences Graduate Internship, is featured in a profile article on the website of the Oak Ridge Institute for Science and Education. Varela-Alvarenga is advised by ISR-affiliated Professor Benjamin Kedem (Math). In summer 2019, Varela-Alvarenga spent 10 weeks at the Pacific Northwest National Laboratory in Richland, Wash., researching methods to simulate new compositions of alloys that would allow them to withstand the necessary changes for use in fossil fuel energy systems.

ECE Ph.D. student **Baturalp Buyukates** won second place in the best student paper contest at the 2020 Asilomar Conference on Signals, Systems and Computers. Buyukates won for his paper, "Timely Updates in Distributed Computation Systems with Stragglers." Buyukates is advised by Professor Sennur Ulukus (ECE/ISR). The paper considers a status update system in which the update packets need to be processed to extract the embedded useful information. Buyukates shows that an asymptotically MM-MDS coded scheme outperforms other schemes. The paper also characterizes age-optimal codes.

Bioengineering Ph.D. student **Ashley Chapin** won the University of Maryland Three-Minute Thesis competition and went on to represent Maryland in the international finals. Chapin's video, "Demystifying the Gut-Brain Axis," reflects her dissertation work, "Serotonin Sensor Technology Integration into In Vitro and In Vivo Systems as Research and Clinical Tools to Address the Gut Brain Axis." Chapin is advised by Professor Reza Ghodssi (ECE/ISR). The competition challenges graduate students to communicate the significance of their projects to a non-specialist audience in just three minutes.

Each year, the Clark School presents the **Dean's Doctoral Student Research Awards** to distinguished graduate student researchers, helping propel their careers and demonstrating the value of high-quality engineering research. In 2020, second place went to ECE Ph.D. student Proloy Das for "Bayesian Modeling and Estimation Frameworks for Neuro-Imaging Data Analysis." Das is advised by Associate Professor Behtash Babadi (ECE/ISR).

Third place went to ECE Ph.D. student Shenli Zou, for his project, "A Gallium Nitride Integrated Onboard Charger." Zou is advised by Professor Alireza Khaligh (ECE/ISR).



A UMD STUDENT TEAM VIDEO SUBMITTED TO THE VERTICAL FLIGHT SOCIETY'S ANNUAL MAV STUDENT CHALLENGE.

Clark School student teams took first and second place in the 8th Annual Micro Air Vehicle Student Challenge, sponsored by the Vertical Flight Society. The teams repeated their 2019 successes, when they placed at the top of the competition in Philadelphia.

This electric-powered, vertical takeoff and landing (VTOL) micro air vehicle (MAV) competition encourages student interest in autonomous/unmanned aircraft technology as well as small air vehicle design and fabrication. The 2020 challenge was for the MAV to pick up, transport and drop off sandbag payloads for an imagined flooding event.

Normally, the competition takes place at the Vertical Flight Society's Annual Forum in May. However, because of the pandemic, this year's student contest was conducted remotely via videos sent in by the teams.

The first-place winning team, "Autonomous Sand Emergency Transport," was advised by Distinguished University Professor Inderjit Chopra, the director of the Alfred Gessow Rotorcraft Center.

In second place was the "Autonomous Micro Air Vehicle" team, advised by director of the Maryland Robotics Center and Professor Derek Paley (AE/ISR) and Postdoctoral Researcher Artur Wolek.

Learn more. View the winning videos at *youtu.be/GZLUbTSWPI8* and *youtu.be/kbU-DcmW9P4.*

Sara Pohland (EE B.S. 2020) spent the 2020 summer as a technical intern for Northrop Grumman before moving to the west coast to start graduate studies at University of California, Berkeley as an NSF Graduate Research Fellow.

Pohland spent her final three semesters at Maryland working in the Intelligent Servosystems Laboratory with Professor P. S. Krishnaprasad (ECE/ISR). She conducted research on human robot interaction and safety in reinforcement learning and is continuing this research in her Ph.D. work.

She graduated with a 4.0 GPA and was part of the Gemstone honors program, where she developed a haptic feedback system for robotic surgery. She also served as a teaching assistant and steering committee member for Gemstone courses.

Pohland also was a part of ECE's peer mentor leadership team and both the undergraduate and general academic affairs committees. In 2019 she was awarded the Clark School's Dinah Berman Memorial Award. She spent the summer of 2019 in an NSF Research Experiences for Undergraduates program at UC Berkeley.

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Hazard mitigation software moves UAVs closer to National Airspace System integration

Most of us have heard that "sometime soon" companies will be using unmanned aerial vehicles (UAVs) for package delivery. The integration of UAVs into the National Airspace System (NAS) has been touted for some time; however, a number of practical problems need to be solved before this can happen. Chief among these is improving the safety of UAVs.

UAVs can collide with other aircraft, or crash into the ground, structures or, in the worst-case scenario, people. These are very real hazards. UAVs can have accident rates as high as 32 accidents per 100,000 flight hours—32 times higher than small aircraft, and 3,200 times higher than large airliners.

Additional UAV safety measures are needed, including new technologies that allow for safer flight control and response to anomalies during flight. Software for autonomous control should allow the UAV to detect and avoid potential hazards, as well as respond to critical failures midflight without input from a human operator.

Assistant Professor **Huan Xu** (AE/ISR), alumnus **Andrew Poissant** (MSSE 2018), and Assistant Research Scientist Lina Castano (AE) have developed a software module for UAV hazard mitigation that guards against ground impact in highly populated areas. Their paper, "Mitigation of Ground Impact Hazard for Safe Unmanned Aerial Vehicle Operations," was published in the December 2020 issue of the *AIAA Journal of Aerospace Information Systems*.

The researchers dealt with both propulsion and actuator faults. Their ground impact and hazard mitigation (GIHM) software considers engine and control surface failure flight modes, generates feasible ground impact footprints based on glide equations, and selects the safest ground impact sites based on a high-resolution LandScanUSA population dataset. The software also can control the UAV's descent to a selected site.

If the UAV experiences a fault that will cause it to crash, GIHM locates a crash point within an estimated reachable ground area that minimizes expected casualties. The software's success rates are higher when there are low population areas that the UAV can resort to when it experiences a fault.

Integrating the new GIHM with standard UAV flight software can reduce maximum casualty expectations by 97 percent compared to flight software alone. Its use will help to bring UAVs closer to being safe enough for integration into the NAS.