STEVENS
INSTITUTE of TECHNOLOGY
THE INNOVATION UNIVERSITY®

IMPACT

The research newsletter of Stevens Institute of Technology Fall 2021

Powering the Pivot to Sustainable Energy

Stevens innovates the next wind, solar, wave and battery power advances

As the U.S. works to develop sweeping new infrastructure to support cleaner, lower-emissions, renewable energy — including electric vehicle fleets, improved batteries, new wind power facilities and smarter smart grids — Stevens is closely involved.

"We have worked on sustainability issues for decades," notes Muhammad Hajj, director of Stevens' Davidson Lab.

Wind power, green transport

The Departments of Interior, Energy and Commerce recently set a goal to produce 30 gigawatts (GW) of offshore wind energy by 2030, removing nearly 80 million metric tons of carbon dioxide emissions annually in the process. The target moves to 110 GW by 2050.

Stevens faculty are contributing in key areas.

Recent NSF CAREER award recipient Weina Meng develops novel seawater-resistant, high-performance materials that can be cast underwater. Mechanical engineering researchers analyze wind turbine motions, forces and stresses to improve design and prevent mechanical failures.

Stevens nanotechnologists including Chang-Hwan Choi develop surfaces specially engineered to prevent aircraft wings from icing — work directly applicable to wind-power systems — while geomechanics experts work to optimally site sea-based facilities by mapping and analyzing the ocean floor.

Greener transportation is another priority, including a goal of converting federal vehicle fleets to zero-emission. More efficient, sustainable and larger-capacity batteries will be critical to that effort.

Stevens energetic materials scientist Jae Chul Kim develops alternatives to lithium-ion batteries, testing lithium metal anodes, all-solid electrolytes and sodium and potassium storage cathodes. Materials expert Pinar Akcora studies ionic nanoparticles with energy applications. Another group is developing thin, lightweight hydrogen fuel cells that may power drones and other light vehicles up to 10 times longer than conventional batteries.

Biofuels, solar panels, smart grids

Biofuels, solar cells and wave power are also areas of focus and expertise.

Stevens' Center for Environmental Systems develops systems to cultivate microalgae in wastewater streams, producing algal oils that can power light vehicles and small facilities. The Department of Defense is a long-time collaborator in the work, which is currently in medium-scale pilot testing.

Vice Provost for Research and Innovation Dilhan Kalyon collaborates with New York University to develop alternatives to silicon-based photovoltaic panels, innovating conjugated polymer-based gels that may be more energy-efficient, scalable and cost-effective than conventional materials. Additional Stevens research teams work to enhance the efficiency of thin-film solar cells and develop ocean wave-power technologies in partnership with the U.S. Department of Energy.

Energy demand must also be more intelligently managed in order to prevent and control power outages. Lei Wu, a leading Stevens energy systems expert, designs AI methods to optimize power grids.

"We can't rebuild the grid," concludes Wu. "But we can redesign and optimize the tools that control and operate it to develop a greener, more efficient system that can withstand and rebound from weather extremes."

INSIDE HIGHLIGHTS:

stevens.edu/research

UNDERGRADUATE INNOVATION

New Tech to Diagnose Brain Injuries in the Field

Student team leverages AI to process, analyze reflexes

When diagnosing a potential brain injury, every second counts. An estimated 1.5 million Americans sustain traumatic brain injuries every year, and more than 5 million live with permanent disabilities resulting from such an injury.

To address this challenge, a Stevens undergraduate team has developed technology to make quicker, more accurate judgments about the severity of sudden head injuries by analyzing autonomic reflexes in the human eye.

Zamin Akmal, Nicole Chresomales, Amanda Delorme and Sophie Makepeace conducted the research under the mentorship of professor Vikki Hazelwood and Capt. William Shepherd, a former NASA astronaut and visiting senior research scientist.

One medical indicator of mild traumatic brain injury is a change in the eye's normal pupillary contraction reflex to bright light. Normally this reaction takes place immediately, within as little as milliseconds. When a brain injury occurs, however, reflex response time decreases measurably.

Drawing on this insight, the Stevens team developed new algorithms capable of analyzing changes in the reflex.

The algorithm processes color video data of patients' pupils as they are exposed to light, converting video frames to grayscale and black-and-white imagery and calculating changes in pupil size over time to predict whether a brain injury may have occurred.

A beta version of the system operates on ATAK (Android Team Awareness Kit) devices such as smartphones and tablets utilized by U.S. military personnel in training and combat, first responders, coaches and athletes. Research on the system will continue at Stevens, say Hazelwood and Shepherd.

The team presented the work virtually at the 47th Annual Northeast Bioengineering Conference earlier this year.

Analyzing Social Media in Natural Disasters

Stevens-Carnegie Mellon project mines data to inform emergency response

A Stevens research team is analyzing social media chatter to help decision-makers plan for and mitigate the impacts of future severe weather events.

The work, led by systems professor Jose Ramirez-Marquez and Carnegie Mellon University information systems professor Gabriela Gongora-Svartzman, analyzed more than 6 million Twitter posts made before, during and after three major 2017 hurricanes: Harvey (which made landfall in Texas), Irma (Florida) and Maria (Puerto Rico).

Ramirez-Marquez and Gongora-Svartzman used text-processing and graph network-analysis methods to understand the relationships among nine distinct categories of Twitter users during those natural disasters.

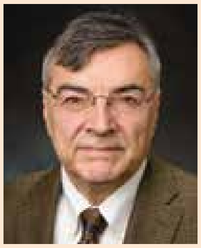
The researchers created metrics to calibrate information dissemination, including the intensity of messages and communications around the hurricanes. Their analysis demonstrated communication peaks shortly before or after a hurricane's landfall — but that subsequent social cohesion varied considerably.

After Hurricane Maria struck, for instance, significant conversations between and among citizens, responders and others continued for more than one week, indicating that post-disaster management strategies were being enacted, rescues were occurring and rebuilding efforts were beginning.

However, studies of the two other hurricanes showed that intense communications did not persist in those cases, indicating potential breakdowns in cohesion and resilience.

The research was reported in the journal *Risk Analysis* in September.

How a 'Clustering' Approach to Research and Technology Development and Commercialization Drives Innovation Forward



The research enterprise of Stevens has grown considerably during the last two years, with research awards accelerating from a mean of $35.9 million per year in the period between 2016 and 2019 to $46 million in 2020 and $50.6 million in 2021. Revenues from the licensing of Stevens-developed technologies have seen a more modest increase.

What will it take to keep increasing the volume of research awards and generate a corresponding impact on Ph.D. students and publications, while more robustly increasing revenues derived from the commercialization of technologies and IP? We all know laboratory space is finite, new research equipment and its maintenance are expensive, and recruiting star Ph.D. students is a constant challenge. Time devoted to technology development and commercialization takes time away from active research. And the administrative burdens of research increase with each additional project undertaken.

The success of Stevens' recently adopted clustering approach is already being reflected in an increase in research awards.

To address these challenges, we at Stevens have begun promoting a clustering approach to both research and technology commercialization. Faculty members are encouraged to form research clusters by joining forces to share space, equipment, supervisory responsibilities and costs such as personnel, proposal creation, and the hiring and training of safety officers and technicians. Clusters also help faculty increase reach when recruiting top Ph.D. candidates by pooling efforts to travel to feeder schools and nations, identify talent and otherwise collaborate.

We have implemented important changes to the timing and structure of many of Stevens' research projects, as well.

I believe it is fair to say technology development and commercialization are rarely primary considerations in most university research, which is typically driven by the familiar cycles of proposal submission, awards, reports, publications and theses. Capturing IP is rarely considered until the conclusion of university projects. However, invention disclosures created at the last minute are frequently compromised: students graduate, equipment is re-tasked — and market opportunities identified during the patenting phase often cannot be fully realized.

To prevent this from happening, we interweave technology development and commercialization into research from the very beginning of each project. We ask Stevens researchers to identify societal needs, and the ways in which proposed new technologies can be of assistance to address them, at the beginning of the proposal stage.

An entrepreneur-in-residence is also often included in a cluster to provide information on market needs and opportunities, and a lawyer specializing in the research area (when available) provides timely advice on patentability and the state and scope of patenting and licensing activities in the specific area.

Finally, we have found that an investment ecosystem to support and nurture technologies developed by clusters is also essential, for example when funding prototype development. Early-stage investments are important to consider and seek out when first forming these clusters.

We all know how success breeds more success. The success of Stevens' recently adopted clustering approach is already being reflected in an increase in research awards. This model has set us on a path that will continue strengthening our research enterprise, and also continue leading to the generation of important new technologies that address the pressing societal challenges of our time.

Dilhan M. Kalyon
Vice Provost for Research and Innovation

$7 MILLION TO QUANTUM INVESTIGATIONS TEAM

As part of an omnibus award, the U.S. Department of Defense's U.S. Army Combat Capabilities Development Command (DEVCOM) has granted Stevens $7 million for a sweeping multi-investigator project that will explore novel quantum technologies and applications of artificial intelligence (AI).

Ten faculty members from the university's AI and quantum research clusters will participate in the work, which will comprise seven complementary projects. The team will include primary investigator Yuping Huang and professors Rupak Chatterjee, Jason Corso, Victor Lawrence, Souran Manoochehri, Xiaofeng Qian, Chunlei Qu, EH Yang, Ting Yu and Michael Zabarankin.

Record-Breaking Research Support

Upward trend: 97% funding increase in 10 years

Stevens has set a new university high-water mark for research funding. FY21 awards to Stevens surpassed $50 million for the first time, continuing a decade-long uptrend during which research funding has increased by 97%. Noteworthy awards acquired during the fiscal year included more than $9 million from the Department of Defense; a $3.1 million grant from a private partner; and robust continued NSF, NIH and DARPA support in areas including biomedical science, quantum technology and AI.

"This new data point once again reinforces how Stevens' research is on the rise," said Dilhan Kalyon, Vice Provost for Research and Innovation.

Mission: Safe Landing Sites on Venus

In June 2021, NASA announced two new missions to explore the atmosphere and surface of Venus, scheduled to launch between 2028 and 2030.

One of those spacecraft will orbit, while the other will make scientific measurements before crash-landing. Stevens professor Jason Rabinovitch is working to ensure future missions can touch down, landing safely and intact.

Combining data, image processing

Venus is notoriously difficult to land upon: its atmosphere is composed of intensely hot toxic gases, under high pressure, at temperatures that can melt lead. The landscape is also marked with complex valleys, mountains and volcanoes.

Working with NASA and Caltech's Jet Propulsion Laboratory (JPL), Rabinovitch develops methods to analyze data gathered from exploratory missions and zero in on the most likely safe landing sites.

With JPL scientist K.M. Stack, Rabinovitch examines panoramic images compiled by earlier missions. Applying image processing and statistical techniques, the researchers analyze rock distribution and size and other physical features. They also processed radar images of the surface previously gathered by Magellan, an orbiting NASA satellite that surveyed Venus from 1990 through 1994.

Combining those analyses with the best currently available surface geological maps of the planet, the duo has identified approximately 180 sites with the highest probabilities for a successful landing. They will continue narrowing choices as NASA and other space agencies ramp up mission planning for future Venus missions.

The ongoing research is reported in the planetary science journal *Icarus* (Vol. 363, 114429).

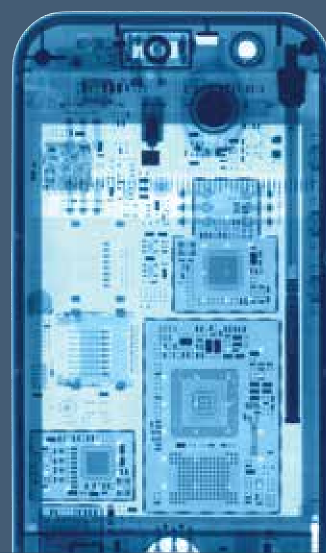
DEVICE SECURITY PROJECT WINS DARPA SUPPORT

Software vulnerabilities in smartphone and other device systems are increasingly being exploited to install ransomware and other malicious processes, often via a single text or email.

Stevens researcher Georgios Portokalidis is working to make securing devices more practical by developing systems that leverage modern hardware to efficiently prevent compromises — and produce alerts at potential intrusions.

His project, "Effective Software Monitoring Leveraging Hardware Debugging Extensions," has been awarded nearly $500,000 in support by the Defense Advanced Research Projects Agency (DARPA) through a prestigious Young Investigator Award.

Portokalidis will work to create improved monitors and other processes that improve software inspection without unnecessarily impeding computing, device, network or server performance. He will leverage and enhance debugging features (such as execution tracing and data logging) engineered into modern ARM-style computer processors that enable transparency into software processes and flaws in real time. He will also leverage parallel-processing techniques.



The work could lead to novel, specialized processors dedicated to ensuring the security of devices' operational processors, says Portokalidis. The project will extend for two years, with a DARPA option to supply $480,000 in additional funding at that time.

INNOVATION APPLIED

U.S. Patents, NSF Support for Skin Cancer Imaging

Stevens professor Negar Tavassolian has been awarded two U.S. patents and National Science Foundation support for research toward a handheld device that promises to accurately inspect potential skin cancers.

The world's most common cancer, skin cancer causes 50 deaths daily in the U.S. alone; nearly 10,000 more Americans are diagnosed with some form each day.

With former doctoral student Amir Mirbeik, Tavassolian received an NSF Small Business Technology Transfer grant to further develop ongoing work in technologies that enable earlier diagnoses and more precise treatments.

The system highlights contrasts between tumors and healthy skin tissue in 3D with highly detailed views, using millimeter-wave imaging similar to that used in airport body scanners. The pair created novel algorithmic methods to process and improve imaging resolution by extending its bandwidth.

In tests, images produced enhance the underlying shape and profile of suspicious tissues, helping clinicians identify proper areas for biopsy and defining excision areas more closely. A prototype is now being studied for accuracy and usability at a New Jersey medical center.

Additional iterations of the technology could detect tooth decay, monitor wound healing or measure blood glucose, notes Tavassolian.

NEWS & NOTES

Abhishek Sharma received $1.55 million from the **National Institutes of Health** (NIH) for a five-year investigation, "Novel Acylborons and Alpha-hydroxy Borons to Enable Modular, Regio- and Stereocontrolled Synthesis of Bioactive Molecules and Protein Conjugates."

Philip Orton published research in ***Nature Communications*** [12, No. 2720] determining that Hurricane Sandy's devastating effects on the metropolitan New York region were exacerbated by human-driven climate change and sea-level rise, accounting for an estimated $8.5 billion of the 2012 storm's estimated total damages of more than $60 billion. The study team included researchers from **Princeton University**, **Rutgers University** and the **U.S. Army Corps of Engineers**.

Samantha Kleinberg received $1.1 million in renewed support from **NIH** to continue her project, "BIG DATA: Causal Inference in Large-Scale Time Series," exploring the use of enhanced intensive-care unit (ICU) data analysis and AI to assist in stronger decision-making in medical environments.

Hady Salloum received a $500,000 **Department of Homeland Security** award to address cybersecurity with the U.S. Coast Guard.

Philip Odonkor placed third in **Princeton University's** Empower Pitch Competition, part of Princeton's annual Empower conference celebrating Black academic entrepreneurship. Odonkor's proposed Grid Discovery technology enables city planners and developers to efficiently identify suitable microgrid locations.

Athula Attygalle received the 2021 Arnold Berliner Award for his ***Science of Nature*** [107, No. 26] article "Biosynthetic origin of benzoquinones in the explosive discharge of the bombardier beetle *Brachinus elongatulus*."

Yuping Huang received approximately $570,000 from the **Office of Naval Research** for his project "Nonlinear-Optical Pseudo Atoms on Chip." The work seeks to develop strong photon-photon interaction as a foundation for room-temperature quantum computing, using single photons.

Ying Wu co-authored "Is Currency Risk Priced in Global Equity Markets?" in the *Review of Finance* with **Cornell University** economist George Andrew Karolyi and also co-authored "The Sound of Silence: What Do We Know When Insiders Do Not Trade?" in *Management Science* with Cornell professors David Ng and George Gao and **California State University, Chico** professor Qingzhong Ma.

Yong Zhang received NIH support for his project "Molecular Mechanisms of Metal-Mediated Biological Functions for NO, O_2 and HNO." He also received **NSF** support for the project "CAS: Mechanistic Investigation of Heme-based Catalysts for Sustainable Carbene Transfer Reactions."

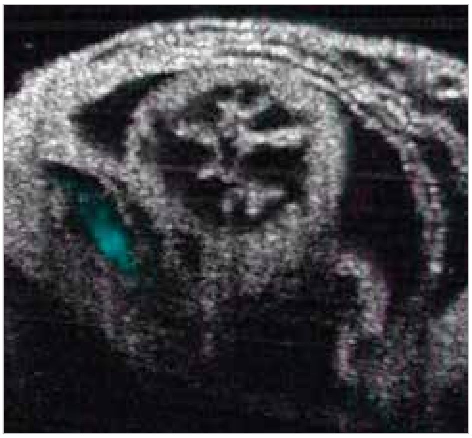
Pinar Akcora and **Patricia Muisener** received $375,000 from **NSF** for their project "REU/RET Site: Interdisciplinary Research Experience in Sustainable Energy and Bioengineering." Akcora also received a separate NSF award of $424,000 for her project "Directed Ionic Transport in Poly(Ionic Liquid)-Grafted Nanoparticles in Polarizable Media."

Shining Light on Biological Processes

NIH commits $2.3M to imaging developmental biology, cancer research

Biomedical engineering professor Shang Wang's laboratory has received a $1.9 million Maximizing Investigators' Research Award (MIRA) from the National Institute of General Medical Sciences. The program will establish a novel multi-contrast, high-resolution dynamic imaging platform to provide deeper insights into the process of biological development.

Wang's team will develop the new imaging platform based on optical coherence tomography (OCT) — a noninvasive modality that utilizes light to create sequences of thinly sliced images for 3D visualizations at microscale resolution, of millimeter-level depth and at a range of time scales. With Baylor College of Medicine investigator Irina Larina, he recently demonstrated an OCT-based, 4D functional imaging approach to assess how the mammalian valveless embryonic heart pumps blood, a long-standing question in early cardiac development. The work appeared in the *Journal of Biomedical Optics* [*25*(8), 086001].



The duo previously reported on OCT-based dynamic imaging used to view eggs and embryos in motion through the mammalian oviduct for the first time in *Cell Reports* (*36*, 109382).

With Stevens researcher Marcin Iwanicki and Fox Chase Cancer Center investigator Denise Connolly, Wang is also developing imaging methods to study ovarian cancer metastasis. The National Cancer Institute recently supported the trio's collaborative project "High-resolution dynamic imaging of ovarian cancer metastasis post chemotherapy" with an award of approximately $420,000.

ABOUT STEVENS

Stevens Institute of Technology is a premier, private research university situated in Hoboken, New Jersey, overlooking the Manhattan skyline. Since our founding in 1870, technological innovation has always been the hallmark and legacy of Stevens' education and research. A range of academic and research programming spanning business, computing, engineering, the arts and other fields actively advances the frontiers of science and leverages technology to confront our most pressing global challenges. Stevens is home to two national research centers of excellence as well as interdisciplinary research programs in artificial intelligence and cybersecurity; data science and information systems; complex systems and networks; financial systems and technologies; biomedical engineering, healthcare and life sciences; and resilience and sustainability. Stevens is currently in the process of executing a 10-year strategic plan, *The Future. Ours to Create.*, which is growing and transforming the university, further extending the Stevens legacy to create a forward-looking, far-reaching institution with global impact.

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Stevens Launches First NSF Fintech Science Center

Industry-university partnership, NSF's first with a business school, to address critical challenges and develop new research and tech for digital financial age

Stevens has launched the first-ever National Science Foundation industry-university research center devoted specifically to financial technology and science.

The university is partnering with Rensselaer Polytechnic Institute in the creation and launch of the Center for Research toward Advancing Financial Technologies (CRAFT).

"This is a crucial opportunity for industry and academia to work together to define the most pressing challenges and find solutions that will have a real and lasting impact on the economy," said Gregory Prastacos, dean of Stevens' School of Business.

As lead institution for the new center, Stevens brings unique expertise to the table in fintech, including two game-changing financial laboratories and thought leadership in risk engineering; portfolio management; equities analysis and forecasting; high-frequency trading modeling, simulation and regulation; cybersecurity; quantum science; and other relevant areas.

"The NSF's investment in CRAFT demonstrates the critical need for collaborative fintech research and policy initiatives to guide the industry," noted Stevens business professor Steve Yang, who will serve as center director and co-lead investigator with Stevens financial laboratory director George Calhoun and RPI finance professor Aparna Gupta.

"Stevens' close proximity to New York City, its leading financial analytics labs and its long expertise in technology and business, coupled with our strong relationships with the financial industry, position us well for this new effort."

Research phase begins in early 2022; memberships available

CRAFT will begin formal operations, including creation of an Industry Advisory Board, in early 2022, when collaborative research projects in a range of topics will also begin.

The center's university and industry members will work together to explore, develop and commercialize financial technologies in key areas such as enhanced cybersecurity, quantum computing, cryptocurrencies, high-frequency automated markets, applications of machine learning and AI to finance and novel applications of the blockchain, and other distributed-ledger technologies.

CRAFT will also leverage student research to serve as both a training ground and career pipeline for financial-industry workforce development.

Contributing members, said Yang, will obtain full licensed access to all research outcomes, publications, technology and IP developed at the center on a non-exclusive, royalty-free basis, and will receive both voting shares and contribution matches from the NSF.