



**The Grainger College
of Engineering**

UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN



2019-2020

ANNUAL REPORT • HEALTH CARE ENGINEERING SYSTEMS CENTER

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MESSAGE FROM THE DIRECTOR



In 2014, the Health Care Engineering Systems Center (HCESC) was established as a place where engineering meets medicine in innovative ways, fostering collaboration between engineers and physicians. In 2020, this mission took on a new, special meaning when the COVID-19 pandemic transformed our world. Adaptation, cooperation, and compassion became core values of our center, and we depended on collaboration more than ever.

When it became clear that COVID-19 would have devastating consequences, we launched a special call through the Jump ARCHES endowment to address research needs. Through a rapid review process, we supported 18 key projects that have had a significant impact on the health of our campus such as testing technology and mobile phone software for daily activity tracking. Many projects assisted our greater community, such as the fabrication of PPE and the modeling and prediction of

COVID-19. New devices, such as our UVBot, are promising to bring low-cost, rapid diagnostic systems and sterilization devices to the market. We take immense pride in the ability of Jump ARCHES to bring engineers, clinicians, and social scientists together to tackle these problems in a time of crisis. Read more about this special call and these projects on page 14.

Despite disruptions to our daily workflow, HCESC made consistent progress in pre-pandemic research and regular activities that contribute to the success and prestige of our campus community. Our Jump ARCHES Summer Internship, a ten-week program for University of Illinois students, pivoted to a virtual format and interns successfully conducted meaningful research on their projects (page 12). The Masters in Health Technology program, jointly developed by HCESC and the College of Applied Health Sciences, began accepting applications and welcomed the first cohort of students this past fall (page 20). The Jump Simulation Center conducted over 500 hours of simulation training for students in the Carle Illinois College of Medicine (page 10). These activities, while not all related to COVID-19, will undoubtedly have a tremendous impact on health care in the post-COVID phase, and I applaud our researchers for their continued dedication and passion for their work.

Our world faces unprecedented challenges as we move into the post-COVID phase of mass vaccination and health care delivery. HCESC is eager to assist researchers in finding solutions to these challenges through the Jump ARCHES endowment and collaboration with other departments on our campus. A Jump ARCHES Request for Proposals is already underway, seeking projects that address vaccination and post-COVID health challenges. We are also planning virtual events that bring together experts to address these issues.

HCESC looks forward to serving the campus community and beyond in an even greater capacity this year. Read ahead for an in-depth look at some of our greatest accomplishments this year.

Sincerely,

T. Kesh Kesavadas, Ph.D.
Director, Health Care Engineering Systems Center

ABOUT THE HEALTH CARE ENGINEERING SYSTEMS CENTER AT ILLINOIS

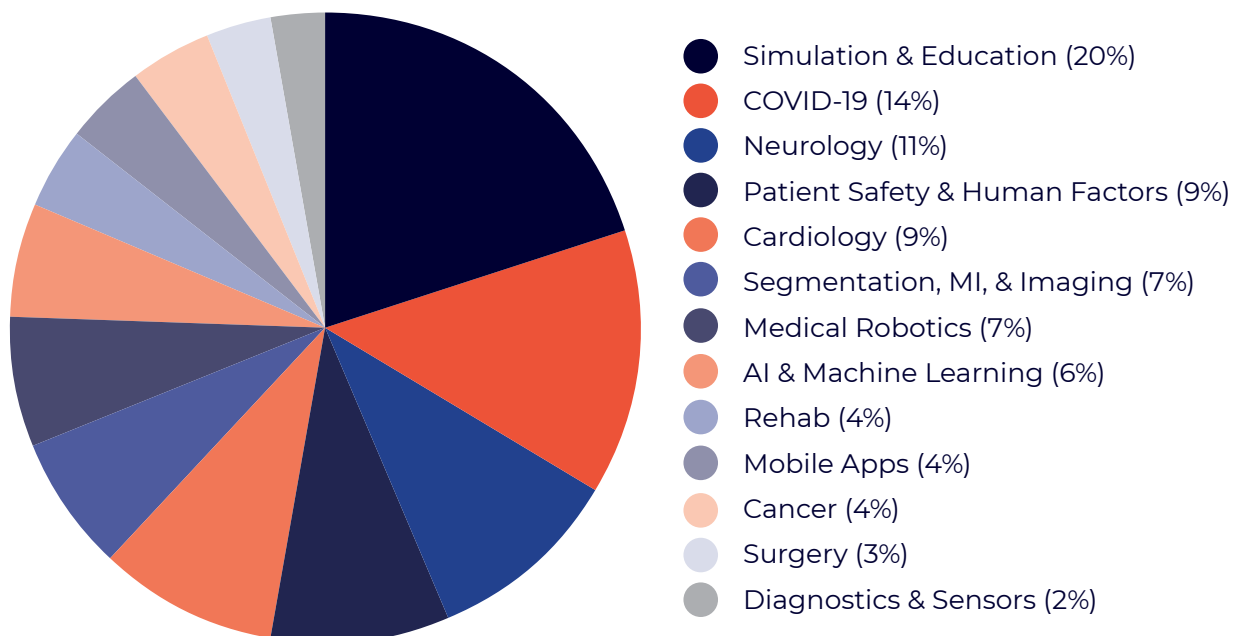
The Health Care Engineering Systems Center (HCESC) at the University of Illinois at Urbana-Champaign was established in 2014 as a research center housed under the Coordinated Science Laboratory in The Grainger College of Engineering. HCESC provides clinical immersion and fosters collaboration between engineers and physicians with expertise in the broad areas of simulation technologies, smart health systems, health data analytics, and medical robotics. The Health Care Engineering Systems Center has grown throughout the past six years as a place where engineering meets medicine in innovative ways, designing and developing collaborative solutions that improve health care outcomes.

“We’re proud to be at the forefront of developing technology that has a direct, tangible impact on the lives and well-being of people in need.”

-T. Kesh Kesavadas
Director, Health Care Engineering Systems Center

HCESC manages the Jump Applied Research for Community Health through Engineering and Simulation endowment (ARCHES) with Jump Trading Simulation and Education Center in Peoria, Illinois to provide funding for researchers working at the intersection of health care and engineering. Read more about Jump ARCHES on page 8.

PROJECT DISTRIBUTION BY AREA



SIMULATION TECHNOLOGY

Virtual Reality and Augmented Reality systems insert the user into immersive situations through screens or goggles to improve education, training, and planning in medicine.

HCESC is creating novel tools and advanced methodologies to help medical professionals, students, and other health workers practice skills in a virtual environment.

ECMO Simulator



The Extracorporeal Membrane Oxygenation Simulator trains users to monitor blood flow when performing ECMO.

Read more about the ECMO Simulator on page X.

SMART HEALTH SYSTEMS

Self-Tracking Kiosk



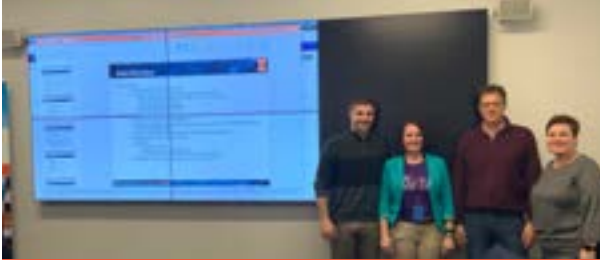
The Self-Tracking Kiosk assists users in evaluating their condition and tracking vitals when entering buildings, exceptionally important in controlling COVID-19.

With the advent of wearable sensors, voice-assisted devices, seamless network data collection, and cloud processing capabilities, health care is becoming smarter than ever before.

HCESC focuses on pioneering solutions specifically focused on the aging population, health monitoring, and personalized patient care.

HEALTH DATA ANALYTICS

Illinois DoA



The Health Data Analytics Initiative is advising the Illinois Department of Aging to predict and help allocate resources for accident prevention and in-home monitoring services for the state's senior population.

The Health Data Analytics Initiative is a central hub connecting clinical investigators with AI and data scientists at Illinois, committed to enabling and driving fundamental medical research and improving health care delivery by designing tailored AI and data retrieval solutions for our partners.

The initiative has received grants from C3.ai Digital Transformation Institute, NSF, and Discovery Partners Institute.

MEDICAL ROBOTICS

Robotic Forearm



This project developed a robotic forearm to simulate abnormal muscle tone due to brain lesions. Different levels of resistance, joint range of motion, and catch angles are selectable to match levels of severity used to characterize a patient clinically.

Advances in robotics and image-guided surgery are improving procedure outcomes by providing the surgeon with precision tools to perform complicated surgeries.

HCESC is developing novel simulators, devices, and algorithms that are assisting in advancing the field.

HUMAN FACTORS

No matter how technological health care becomes, it will always be about the encounter between the patient and the provider.

Research in human factors strives to reduce human errors, increase success of health care procedures, and enhance patient safety and comfort.

VR & Cancer



More than 50% of lung cancer patients experience clinical depression. One study is evaluating the effects of immersing patients into a fictitious lifelike environment to engage in guided meditation.

EDUCATION

MSHT Program



We developed the MS in Health Technology program with the College of Applied Health Sciences to examine public health issues and create innovative technological solutions. Read about the MSHT program on page X.

Incorporating engineering and tech components into medical education results in well-rounded health care providers.

We develop curriculum based around the principles of simulation technology and smart health for universities, continuing education, and certification programs.

A YEAR IN NUMBERS

31
PROJECTS FUNDED
BY JUMP ARCHES

45+
Papers Published

14
Patents Filed

\$1.7 M
Jump ARCHES
Research Dollars
Awarded

2
Start-Ups Founded

5
Virtual Events
Hosted

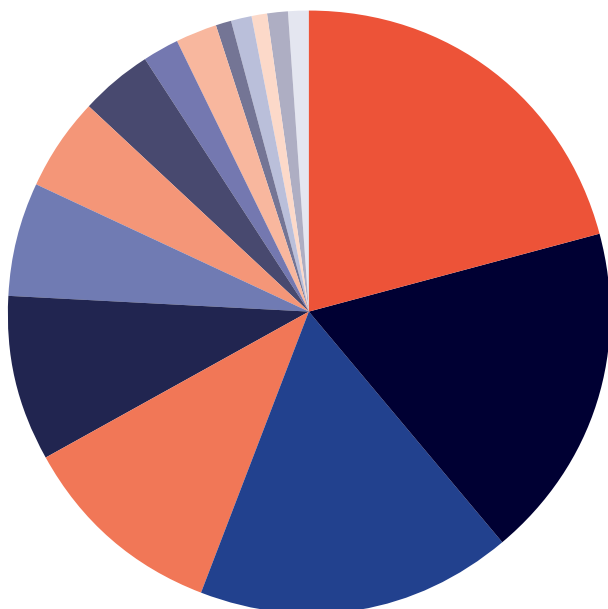
64
Investigators



11 STUDENT INTERNS

5 PH.D. GRADUATES

RESEARCHERS BY DEPARTMENT



- Electrical and Computer Engineering (21%)
- Industrial and Enterprise Systems Engineering (18%)
- Bioengineering (17%)
- Health Care Engineering Systems Center (11%)
- Mechanical Science and Engineering (9%)
- Kinesiology (6%)
- Computer Science (5%)
- Civil Engineering (4%)
- Psychology (2%)
- Chemical and Biomolecular Engineering (2%)
- Nuclear, Plasma, and Radiological Engineering (1%)
- Education Policy, Organization, and Leadership (1%)
- Veterinary Clinical Medicine (1%)
- Mental Health (1%)
- Applied Research Institute (1%)

Jump ARCHES

Jump Applied Research for Community Health through Engineering and Simulation

The Jump ARCHES endowment is the pinnacle of collaboration at HCESC. Jointly managed with Jump Simulation Center in Peoria, IL, the \$112.5 million endowment provides funding for researchers from the University of Illinois Urbana-Champaign, OSF HealthCare, and the University of Illinois College of Medicine Peoria to work together on projects to improve healthcare through engineering and simulation.

Since it was established in 2014, Jump ARCHES has funded over 70 proposals across a wide range of topics. Investigators from many disciplines can apply for funding, the only requirement being that one investigator come from the University of Illinois system and one from OSF HealthCare.

In 2019, the partnership was expanded by an additional \$50 million joint commitment from the DiSomma Family Foundation, the University of Illinois at Urbana-Champaign, and the OSF HealthCare foundation. This expansion has fueled a new generation of joint research projects on mobile sensors, Internet of Things applications, data analytics, and understanding social and behavioral determinants of health.

This past year Jump ARCHES played a vital role in the fight against COVID-19 in Illinois. Jump ARCHES announced an unprecedented special call for proposals in March 2020 to address COVID-19 and other public health crises through smart health, data analytics, AI, and other technologies. A requirement of grant applications was for solutions that could be deployed quickly, within four to six weeks. Jump ARCHES distributed nearly \$800,000 in funding to seventeen research projects, many of which are proving successful and beneficial in COVID-19 research and mitigation.



T. Kesh Kesavadas, Ph.D.

Director, Health Care Engineering Systems Center
Professor, Industrial and Enterprise Systems Engineering
Co-Director, Jump ARCHES



John Vozenilek, M.D., F.A.C.E.P.

Vice President and Chief Medical Officer for Simulation,
Jump Trading Simulation and Education Center
Co-Director, Jump ARCHES

Jump | ARCHES

 THE UNIVERSITY OF ILLINOIS
COLLEGE OF MEDICINE
PEORIA CHICAGO ROCKFORD URBANA

 OSF
HEALTHCARE

JUMP SIMULATION CENTER

Jump Simulation Center is a state-of-the-art educational space focused on using and developing simulation and virtual reality technology to train innovative medical professionals, uniquely equipped to transform the world of health care. Jump Simulation Center provides simulation training needs for the Carle Illinois College of Medicine, the first medical school in the nation created with a focus on the intersection of engineering and medicine. The center was established in 2018 by a generous \$10 million gift from Jump Trading, and serves as a manifestation of the mission of Jump ARCHES - to create new and innovative technology to transform the way health care professionals learn and practice.

The importance of simulation training only grew this year when COVID-19 was declared a pandemic in March. After a month of sheltering in place mandated by the Illinois government, Jump Simulation Center made plans to return safely to a new normal of simulated learning to keep aspiring doctors and nurses in the classroom during a vital time in medicine, where their skills would shortly be needed. With cleaning protocols in place, Plexiglass barriers installed, and room capacities decreased to allow for social distancing, one of the first priorities of the Simulation Center was to teach medical students to properly don and doff personal protective equipment to allow them to return to clerkships in the fall.

Jump Simulation Center was able to provide valuable learning experiences despite the pandemic, one of which being an interactive Diabetic Ketoacidosis simulation. DKA is a complication of diabetes that occurs when the body produces high levels of blood acids, or ketones, due to insufficient production of insulin. It can lead to a diabetic coma or even death. Simulation Center technicians used OBS Studio and B-Line Medical Simcapture to deliver the experience over Zoom. Simulation Center staff and student Lindsey Ades also developed curriculum for Neonatal Respiratory Distress. Using a female simulated patient and a newborn manikin, students were tasked with assessing and treating a premature infant two hours post-birth that developed breathing complications and distress.

576

**INSTRUCTION
HOURS**

40

Unique Simulations

11

Instructors

**LEARN AT JUMP
SIMULATION CENTER!**

View all of our facilities and make an appointment at <https://jumpsimulation.illinois.edu/>.



A UNIQUE FOCUS

The Jump Simulation Center has a unique focus on using and developing virtual reality systems to improve clinical practice.

We recognize that virtual reality, augmented reality, and mixed reality systems are the future of medical education and are proud to be making great strides in developing these systems.

INNOVATION IN ACTION

The Illinois RapidVent is an emergency ventilator that was developed by an interdisciplinary team of Grainger engineers in March 2020 when ventilators were scarce as COVID-19 cases rose.

Extensive testing was done on the RapidVent at Jump Simulation Center. The photo to the right shows Jump Simulation Center manager Shandra Jamison testing the ventilator on a manikin.



PERFECT PRACTICE MAKES PERFECT

First-year Carle Illinois College of Medicine students spent over 400 hours in simulations in 2019 and 2020. These simulations were introductions to the fundamentals of clinical practice, including skills such as performing ultrasounds, catheterizations, suturing, pelvic and prostate exams, and intubations.

JUMP ARCHES SUMMER INTERNSHIP

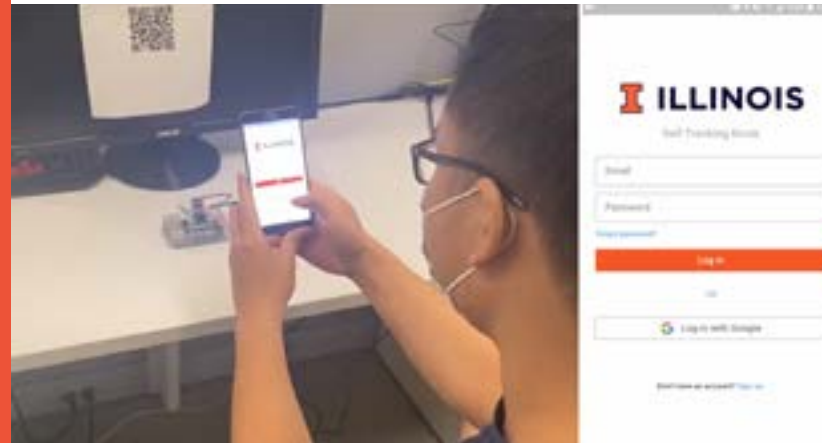
This is a unique, interdisciplinary experience where students apply their knowledge to health care-related technologies in simulation, VR, and health data analytics.

Students receive mentorship from HCESC and OSF HealthCare researchers during this ten week program. This internship provides students with a platform to learn new skills and be proactive problem solvers, preparing them to take on roles in the health care engineering industry.

The experience was even more unique this past summer due to COVID-19, taking on a completely virtual format. HCESC mobilized quickly to adapt projects and schedules to remote work. From all around the globe, interns successfully worked on these seven projects, meeting every Friday over Zoom.

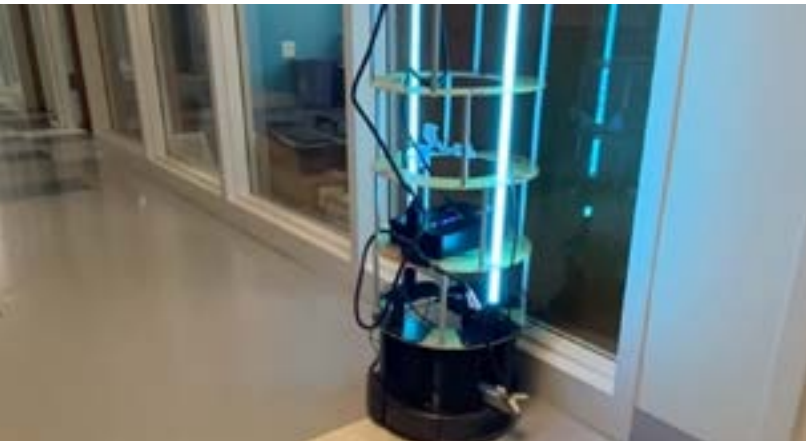
Self-Tracking Kiosk

The Self-Tracking Kiosk is a mobile app to help users evaluate their condition and check for COVID-19 symptoms before entering a building, allowing administrators to better monitor the overall health of the building's occupants.



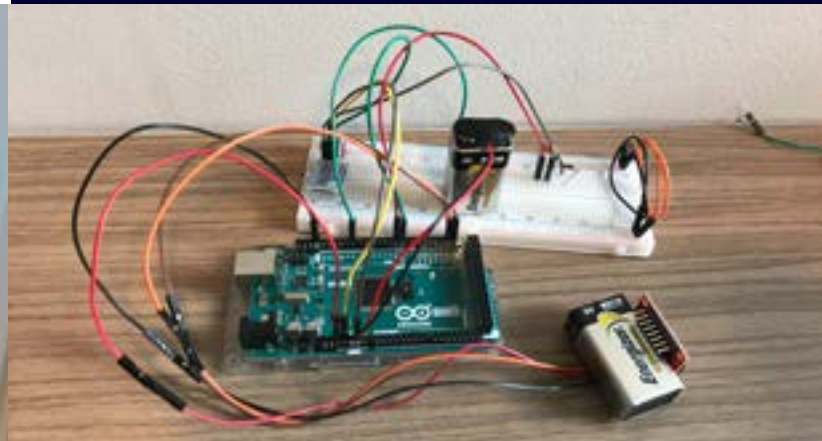
UVBot

The UVBot is a programmable, autonomous robot that uses UV light to disinfect spaces such as offices, schools, and public transportation. It can be made from low-cost materials with its open-source design and software.



iBand

The iBand is a fully functional, low-cost replacement for Myo Armbands used to wirelessly control with hand gestures in research, AR, and other applications.



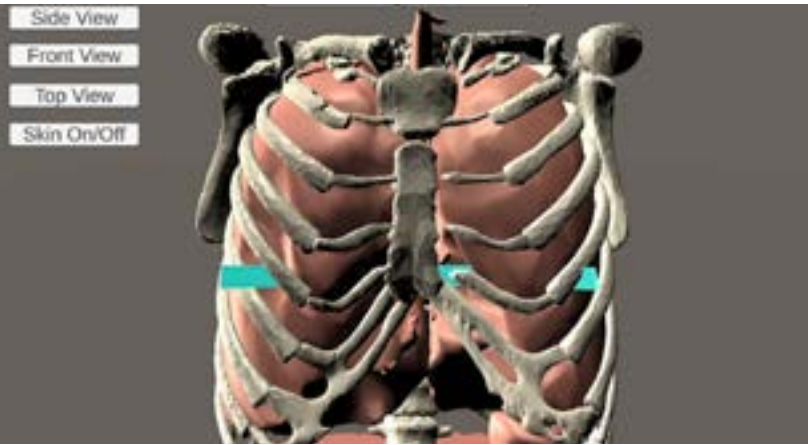
CT VR

The CT VR is an simulated surgical bar placement controlled by the user into a virtual chest for precision surgical planning and case-based skill training. It also allows users to familiarize themselves with procedural knowledge from incision to placing a metal bar.



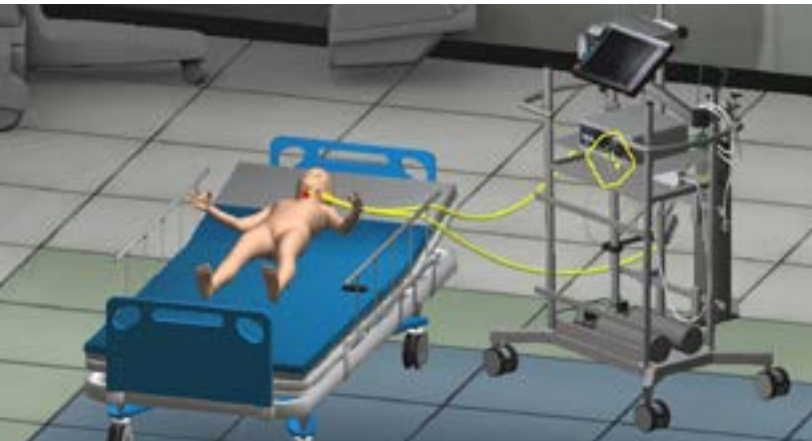
Pectus Excavatum

The Pectus Excavatum VR is a simulation model to train the Nuss procedure, which is a common method to repair Pectus Excavatum through insertion of a stabilizing bar. This project incorporates 3D patient anatomy construction, dynamic surgeon interaction through VR, and predictive risk modeling into the simulation.



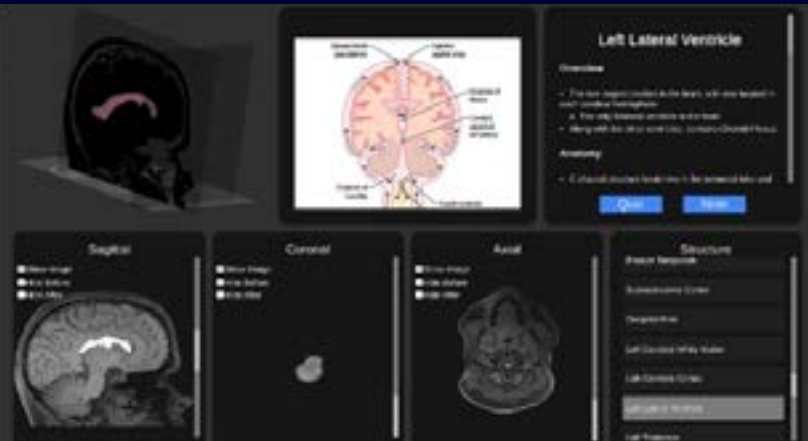
ECMO VR

The ECMO VR is an immersive virtual reality experience where users are taken through the deployment of the extracorporeal membrane oxygenation procedure.



Brain VR

The Brain VR is an app for virtual reality systems, tablets, and computers to allow students to dissect a human brain generated from post-mortem brain slices. It also features educational content on brain structures.



Jump ARCHES & COVID-19

The Jump ARCHES Priority Call for proposals addressing COVID-19, pandemics, and similar public health crises was announced in early March of 2020, shortly after COVID-19 was declared a pandemic by WHO. Research mobilization was immediate: in the brief two weeks that followed, Jump ARCHES was inundated with brilliant proposals from faculty and researchers across the University of Illinois system and OSF HealthCare, all with the same goal of mitigating the pandemic. It was truly unique and special to see such a vast range of proposals, each utilizing the niche skills of their principle investigators, to cover every facet of defeating COVID-19.

“Jump ARCHES has been instrumental in developing tools and processes that have made our campus safer.”

**–Robert J. Jones,
Chancellor, University of Illinois Urbana-Champaign**

In June 2020, Jump ARCHES announced that 17 proposals had been awarded funding totaling to nearly \$800,000 in the areas of personal protective equipment (PPE), artificial intelligence and data analysis, and diagnostics. Proposals ranged from developing simple nasal swab methods to test for COVID-19 to decontaminating N95 masks by creating a plasma in your very own microwave. Researchers worked diligently throughout the summer to deliver promised results and come to new conclusions about COVID-19, many of them assisting in the effort to safely reopen campus for the Fall 2020 semester.

N95 Mask Design & Fabrication

At the beginning of the COVID-19 pandemic, personal protective equipment (PPE) was in short supply for health care workers nationwide, forcing many to reuse disposable respirator masks for weeks.

A proposal led by principal investigator Jeremy Guest, associate professor in the department of civil and environmental engineering, was funded by Jump ARCHES to develop PPE, namely clear N95 respirators, for local health care systems. Clear respirators will also make it easier on those who are deaf or hard of hearing to read the lips of people wearing the masks.

“The goal of this project has been to leverage the collective resources and expertise of the University of Illinois, OSF HealthCare, Carle Foundation Hospital, ShapeMaster, and other local groups to respond to the urgent and sustained need for N95 respirators,” said Guest. “We’ve been working to develop a clear, NIOSH-compliant N95 respirator that, with filter cartridge replacement, can be sanitized and reused for weeks or months.”

The team first developed prototypes in collaboration with ShapeMaster, Inc. in Ogden, IL. The first quantitative fit test was performed at Carle Foundation Hospital in Urbana, where the team found that their N95 respirator mask prototype outperformed disposable N95 masks for fit and sealing properties. The second round of testing took place at OSF Heart of Mary Medical Center in Urbana. Since then, the team has been busy making minor modifications to the design, additional prototype fabrication, and NIOSH filtration testing at a certified laboratory. Once these tasks are successfully completed, they plan on posting the open-source designs online for anyone to manufacture.

Guest’s co-primary investigators included Jared C. Rogers and John F. Kreckman from OSF HealthCare. In addition to affiliates from the University of Illinois, the team worked with Carle Foundation Hospital, Johns Hopkins University, ShapeMaster, Inc., and TEK Mills.

Investigators

Jeremy Guest, University of Illinois
Urbana-Champaign
Jared C. Rogers, OSF HealthCare
John F. Kreckman, OSF HealthCare



Above: Plastic mold for a prototype of the N95 mask fabrication.

Below: Face shield prototype as developed by the Illinois PPE project team.



Rapid SARS-CoV-2 Detection from Nasal Swab Extracts

In August 2020, the University of Illinois announced they would be conducting a hybrid semester of in-person and online learning, with a plan that requires regular COVID-19 testing for students and staff. Creating a test that is painless, easy, and delivers results quickly is no small task, but possible nonetheless. This type of test was necessary in re-opening campus this past fall, an endeavor which brought 50,000 people back to campus.

A proposal led by principal investigator Rashid Bashir, dean of The Grainger College of Engineering, was funded by Jump ARCHES to develop a low-cost COVID-19 test using loop-mediated isothermal amplification to deliver quick results. LAMP is also simpler and more portable as compared to PCR tests, the most common type of test, and could be important in point-of-use testing for a range of applications.

“We have already demonstrated results within one hour of sample acquisition,” said Bashir. “The testing is being performed on patient samples of discarded viral transport media from nasopharyngeal swab tests from OSF HealthCare.”

While their proposed work focused on rapid, point-of-use viral transport media testing from nasopharyngeal swabs, the next phase will focus on saliva samples as acquired. Working with the SHIELD Team from campus, Bashir’s team is currently working on an IRB to acquire further saliva samples from OSF hospitals and other locations. Validation of rapid isothermal LAMP tests for saliva may be used to augment the RT-PCR tests developed for large-scale deployment. A saliva test is already being used as part of the on-campus testing strategy for students, faculty, and staff. This test, developed by U of I professors Paul Hergenrother, Martin Burke, and Tim Fan, promises results within hours and is being used in conjunction with a contact tracing app developed by university researchers called Safer Illinois.

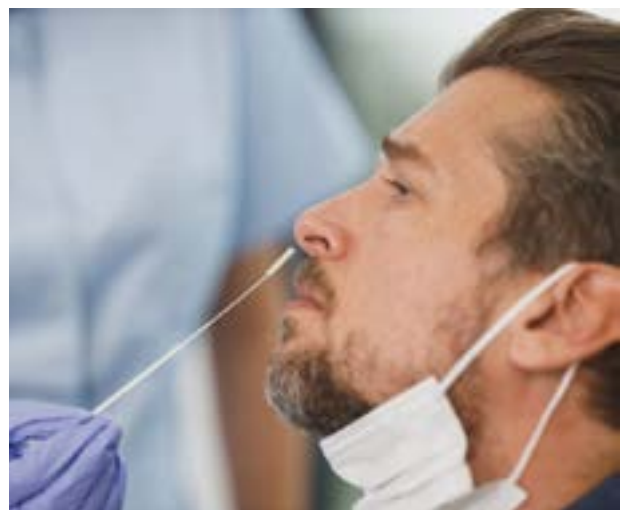
“Testing is extremely important in controlling the spread of COVID-19, which is why we have put a great deal of funding into new strategies and technologies,” said Dr. T. Kesh Kesavadas,

Investigators

Rashid Bashir, University of Illinois
Urbana-Champaign
Enrique Valera - University of Illinois
Urbana-Champaign
Anurup Ganguli - University of Illinois
Urbana-Champaign
Sarah Stewart de Ramirez - OSF
Health Care

Director of the Health Care Engineering Systems Center and Engineer-in-Chief of the Jump ARCHES endowment. “Dean Bashir’s proposal is one of four innovative, point-of-care testing technologies that have been funded by Jump ARCHES this year.”

Bashir’s co-primary investigators included postdoctoral students Anurup Ganguli and Enrique Valera, and Dr. Sarah Stewart de Ramirez of OSF HealthCare. “Without this partnership [with OSF HealthCare], we would not have had the access to the saliva samples necessary to complete our research,” said Bashir.



Mask Decontamination by Plasma in a Microwave Oven

As COVID-19 cases are rebounding across the nation and we prepare for another potential wave, we face another potential shortage of personal protective equipment for health care providers. The question of how to decontaminate N95 respirator masks remains.

Fortunately a team led by David Ruzic, nuclear, plasma, and radiological engineering professor, has proven results of a solution that could be used to decontaminate respirator masks using a microwave oven, funded by the Jump ARCHES endowment.

Professor Ruzic's strategy consisted of creating a plasma inside the microwave oven using common household supplies including a ceramic coffee cup, wire, hydrogen peroxide, and saline solution. The combination of these materials allows for creation of an intense plasma inside the microwave oven, which can decontaminate the mask within approximately 30 seconds.

"This technology could enable hospitals, nursing homes, and first responders to use a microwave oven to decontaminate masks with materials they already have on hand," said Ruzic. "We have shown that 30 seconds of plasma exposure is sufficient to kill viruses and have submitted our findings to the CDC's Journal of Emerging Infectious Diseases. We have also sent treated masks to the CDC for testing and passed their filtration and fit standards, even after three cycles of decontamination."

Professor Ruzic's team included civil and environmental engineering professor Helen Nguyen and Jump Simulation and Education Center engineer Brent Cross. Nguyen's research group specializes in environmental engineering with an emphasis on pathogen transmission and control, and assisted in determining the extent to which the exposure to plasma can inactivate viruses on N95 respirator masks. Civil and environmental engineering professor Vishal Verma's group also assisted with measurement to ensure the treatment did not compromise filtration efficiency of the respirator masks. Ruzic and his team hope that this technology will prove useful as conservation efforts continue for

Investigators

David Ruzic, University of Illinois
Urbana-Champaign
Helen Nguyen, University of Illinois
Urbana-Champaign
Brent Cross, OSF HealthCare



N95 respirator masks. Knowing there is a potential solution could provide peace of mind for medical providers.

"In case of real shortages, we would consider this technique a key tool in keeping our staff and patients safe," said John Kreckman, M.D., Chief Medical Officer of OSF HealthCare Heart of Mary Medical Center in Urbana.

Next steps for Ruzic and his team include introducing the technology to the OSF Peoria campus and waiting for acceptance to the CDC's Journal of Emerging and Infectious Diseases.

See the plasma in action here: <https://www.youtube.com/watch?v=7gm8QBbFGyM>

ALL COVID-19 FUNDED PROJECTS

The COVID-19 Keeping Safe Program

Sanjay Patel, Electrical & Computer Engineering, UIUC
Brent W. Roberts, Center for Social and Behavioral Sciences, UIUC
Roopa Foulger, OSF HealthCare

A Single-Step, 10-minute, Point-of-Care COVID-19 Diagnostic Test Using Activate Cleave & Count (ACC) Technology

Brian Cunningham, Electrical & Computer Engineering, UIUC
Dr. John Farrell, OSF HealthCare/UIC

Converting a Microwave Oven into a Mask Sterilization Unit

David Ruzic, Nuclear, Plasma, & Radiological Engineering, UIUC
Brent Cross, OSF HealthCare

Supply-Driven Hospital Resource Planning and Community Engagement for COVID-19 Treatment

Lavanya Marla, Industrial & Enterprise Systems Engineering, UIUC
Kurt Bloomstead, OSF HealthCare

Development of a Blood Analysis Technology for Artificial Intelligence-assisted, Point-of-Care Decision Making

Rohit Bhargava, Bioengineering, UIUC
James McGee, OSF HealthCare/UICOMP

Testing the Filtration Efficiency of N95 Respirators for Health-Care Employees and Protecting Public Health in Pandemic Flu Emergencies

Vishal Verma, Civil & Environmental Engineering, UIUC
Matthew Bramlet, OSF HealthCare/UICOMP

Data-driven Modeling, Analysis and Simulation of Epidemic Processes: Controlling COVID-19

Carolyn Beck, Industrial & Enterprise Systems Engineering, UIUC
Joseph Kim, UICOMP

Maximizing the Informational Value of PCR-based COVID-19 Tests through Optimal Pooled Community Testing

Hadi Meidani, Civil & Environmental Engineering, UIUC
John Farrell, OSF HealthCare

Healthier Homes: An Assessment of Opportunities to Reduce Risk of Infectious Disease Transmission at Home

Paul Francisco, Applied Research Institute, UIUC
Beth Houser, OSF HealthCare

Rapid SARS-CoV-2 Detection from Nasal Swab Extracts

Rashid Bashir, Bioengineering, UIUC
Sarah Stewart de Ramirez, OSF HealthCare/UICOMP

Rapid, Contactless Vital Signs Collection Using Computer Vision and Consumer Technologies

Ramavarapu Sreenivas, Industrial & Enterprise Systems Engineering, UIUC
Roopa Foulger, OSF HealthCare

Ventilator Duplication Kit

Brad Sutton, Electrical & Computer Engineering, UIUC
Matthew Bramlet, OSF HealthCare/UICOMP

Data Driven Analytics to Predict the Dynamics of the COVID 19 Outbreak and the Impact on Healthcare Providers, Resources, and Communities

Ravi Iyer, Electrical & Computer Engineering, UIUC
William Bond, OSF HealthCare/UICOMP

A Rapid and Affordable Virus Test for Early Warning of a Pandemic

Joseph Irudayaraj, Bioengineering, UIUC
William Bond, OSF HealthCare/UICOMP

Secure Federated Learning for Collaborative Diagnostics

Sanmi Koyejo, Computer Science, UIUC
William Bond, OSF HealthCare/UICOMP

Proposed Plans for the Fabrication of Personal Protective Equipment (PPE) for Local Health Care Systems; N95 Respirator

Jeremy Guest, Civil & Environmental Engineering, UIUC
John Kreckman, OSF HealthCare

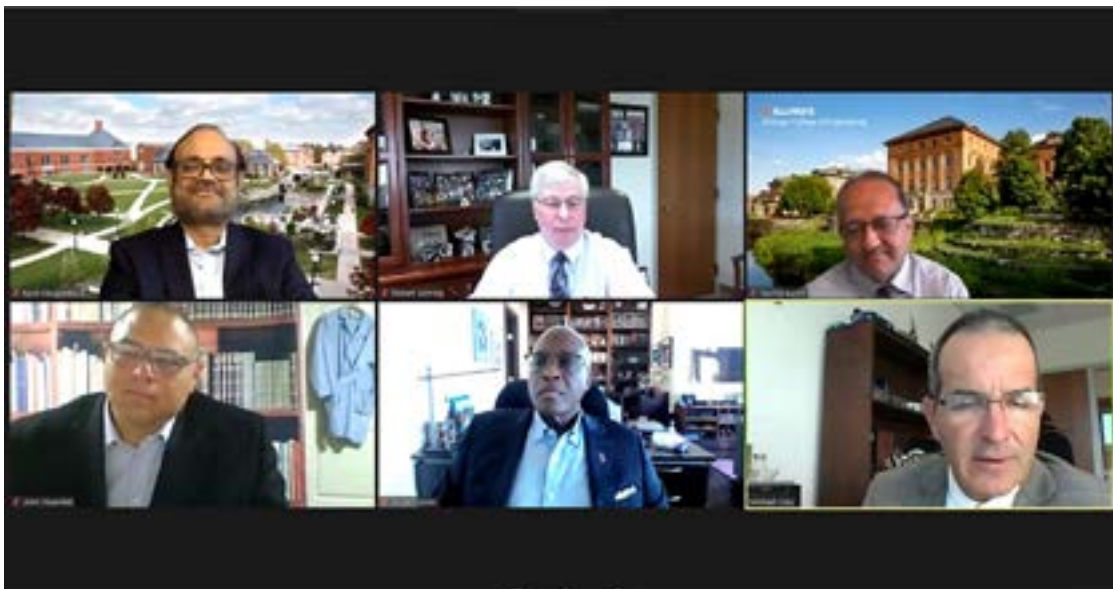
We funded over 30 projects total this year!
View a complete list of all our funded projects on our website here:
www.healtheng.illinois.edu/jump-arches

VIRTUAL EVENTS

Global events transitioned to virtual formats this past year as COVID-19 made it impossible and unsafe to gather in large crowds. While there's nothing quite like an in-person experience, virtual experiences allowed people from across the globe to tune in, participate, and become exposed to research that may not have been possible if they could not make it to the in-person experience.

HCESC's Health Data Analytics Summit, which takes place each spring, was replaced by a COVID-19 Virtual Summit, where we featured speakers from around the college and other state institutions working on COVID-19 mitigation projects, many of which received funding from Jump ARCHES. The Health Care Engineering Systems Symposium, which takes place each fall, was held virtually and featured a selection of researchers discussing both COVID-19 and general health care engineering projects.

HCESC also introduced a COVID-19 Monthly Seminar Series, where we gave all of our Jump ARCHES COVID-19 Priority Call grant recipients a chance to present and share their research. Three installments were held: September's seminar discussed testing technology, November's discussed artificial intelligence and data science, and December's discussed personal protective equipment.



University of Illinois at Urbana-Champaign and OSF HealthCare administration discuss the state of health care engineering research and COVID-19 at the Health Care Engineering Systems Symposium on October 13, 2020.

MSHT PROGRAM

PROJECT SPOTLIGHT

This past fall, The Grainger College of Engineering and the College of Applied Health Sciences welcomed the first cohort of students into the new Master of Science in Health Technology Program with the vision of educating the next generation of applied health technology professionals. The mission of the program is to develop interdisciplinary practitioners through classroom education and experiential learning to have the knowledge, skills, and abilities to advance applied health technology design and implementation. It is aimed at professionals with skills in software application, hardware engineering, human factors, and user-centered design interested in developing wearable devices, assistive robots, and virtual reality to improve the quality of life and care for patients.

The advancement of health technology is vital to improving the health of communities worldwide, especially since the advent of COVID-19. Telehealth and assistive devices are useful to patients who are unable to leave or need care in their homes. Even prior to COVID-19, Health Technology Education Program director Wendy Rogers saw the value in creating a program tailored to professionals interested in this area. In 2017, a team of administration from the College of Applied Health Sciences and The Grainger College of Engineering submitted an Investment for Growth proposal titled Technology for Health and Independence: An Interdisciplinary Educational, Research, and Outreach Program. The proposal described a pressing need for workforce development at the intersection of human factors, engineering, and health technology, along with the potential for this unique professional degree.

The administrative team that submitted the proposal included Rogers, HCESC director T. Kesh Kesavadas, College of Applied Health Sciences dean Cheryl Hanley-Maxwell and Associate Dean for Research Jeff Woods, and The Grainger College of Engineering's dean (at the time) Andreas Cangellaris. The proposal was selected for funding in January of 2018, and Rogers was designated as director and Nicole Holtzclaw-Stone was hired as assistant director. In the two years that followed, the team worked



Students Asif Huq (L) and Gabrielle Choo-Kang (R) completing a prototyping activity for a blood pressure cuff.

diligently to complete the approvals, requirements, and curriculum according to requirements from each department, Illinois Board of Trustees, and Illinois Board of Higher Education. In total, eight new courses were created under the rubric of Health Technology.

The 2020-2021 cohort is made up of six students that reflect the interdisciplinary approach of the program: they have degrees in medical anthropology, computer science, psychology, civil and environmental engineering, and community health. Two students have previous work experience: one in computer science, and another in digital fabrication labs. While the core curriculum concerns software and hardware engineering, human behavior, and human factors methods, each student is able to pick from a variety of elective courses tailored to their interests such as bioinstrumentation, user interface design, or data analytics.

Students are required to complete a capstone project where they work with an external industry, government, or community-based organization to solve practical, real-world problems. These problems range from ethics to device regulation to design thinking, allowing students to utilize their unique skills and interests.

MSHT student Amrutha Kumaran (right) has a B.A. in medical anthropology from Washington University in St. Louis and completed an undergraduate thesis on how physicians counsel patients and implement advanced reproductive health technologies such as in-vitro fertilization. “It’s a little rare to see technology programs acknowledge the need for interdisciplinary training, so I immediately knew that [the MSHT program] would see the value of my B.A. while supporting my interests in data science and product design.” She has enjoyed the Intro to Data Science and Human Factors Methods for Health Technology classes, where students have been working on product evaluation and re-design for blood pressure monitors. Kumaran looks forward to applying knowledge gained from the project to a continuous glucose monitor and other medical devices to better help the user experience in patients with chronic diseases. Kumaran looks forward to taking electives in design and data science, which she believes will as-



sist greatly in her capstone project that she will complete this summer. Kumaran is excited to be a part of the MSHT program: “It’s effective at providing a broad, interdisciplinary training in health technology.”

“We’re proud to provide an educational experience in keeping with the interdisciplinary mission of both HCESC and the College of AHS,” said director T. Kesh Kesavadas. “We look forward to seeing our students influence the development of health tech and quality of patient care in their future professions.”



For more information on the curriculum, tuition costs, and how to apply to the MSHT program, visit <https://ahs.illinois.edu/ht-overview>.

*Above L: Amrutha Kumaran
Above R: Students in class
Left: Students Tia King (L) and Neva Manalil (R) choose items for prototyping activity.*

ECMO SIMULATOR

Extracorporeal membrane oxygenation, also known as ECMO, is an invasive technique that artificially drains blood out, oxygenates it, and pumps it through the body to fuel red blood cells in patients who suffer from insufficient blood oxygenation levels due to acute failure of the heart and/or lungs. It is often used when patients are coding and doctors need to mechanically support their heart and lungs to prevent death. Time is of the essence and stakes are often high when performing this procedure, with little room for error. Many COVID-19 patients are also being given ECMO as a last-resort procedure when ventilators do not provide sufficient oxygen throughout their entire body.

ECMO is usually performed by a cardiothoracic surgeon, trained intensive care specialist, or team of expert surgeons, staff, and nurses, leaving little opportunity for a novice to practice on a real patient. An incision is made in the skin and tubes, or cannulae, are placed into a large vein and/or artery in the chest, neck, or groin. Blood is then pulled through an artificial lung, oxygenated, and cycled back into the body using the ECMO pump.

Dr. Jai Raman, formerly of the University of Chicago & Rush University Medical Center in Chicago, Illinois, and currently of the University of Melbourne in Melbourne, Australia, expressed this concern to T. Kesh Kesavadas, director of the Health Care Engineering Systems Center at the University of Illinois at Urbana-Champaign. "Inserting cannulae into patients that are critically ill can be challenging and fraught with complications due to injury of the vessels," said Dr. Raman. "Simulation platforms for this procedure, where trainees and physicians can practice on a manikin or through virtual reality, would help. This would make access of the vasculature and insertion of the tubes effective, safe, and seamless, ultimately improving patient outcomes and survival." They applied for a grant to study this problem.

After this conversation, the team at HCESC began developing a simulation platform to educate students and clinicians in administering this life-saving procedure. Their ECMO Training Simulator was completed in 2018, in partnership with OSF HealthCare. It is now being used in a research



study conducted by the U.S. Air Force En route Care Research Center.

Dr. Matthew Bramlet, pediatric cardiologist at OSF HealthCare, and Pramod Chembrammel, research scientist at HCESC, teamed up and applied for Jump ARCHES funding to create the ECMO simulator. "As health systems tighten budgets, the number of experienced ECMO providers may decrease which will increase the need for high-fidelity simulators to maintain a higher level of expertise among those performing ECMO." Bramlet and Chembrammel were awarded funding to create the simulator, which consists of a torso manikin and cannulation tubing structure that can be inserted into the femoral or jugular regions of the manikin, connecting to a programmable pump to drive fluid through the tubes.

HCESC simulation engineer Anusha Muralidharan became involved with the project in 2018 working on hardware and sensors. "ECMO requires auto-monitoring of blood flow, pressure, and temperature. It's vital that sensors are able to monitor it correctly," said Muralidharan. This technology helps replicate difficult scenarios in ECMO by interfacing with mathematical models of human physiology, which is what drew research scientist Dr. Inki Kim to this project. "The ability of this simulator to create unlimited cases of pathological scenarios helps optimize learning, realism, and complexity," said Dr. Kim.

After completing a prototype of the simulator, HCESC presented a poster of their new technology at the Military Health System Research Symposium in 2019. They connected with a surgeon from the U.S. Air Force En route Care Research Center, who was intrigued by the technology and was interested in using it to see if it was effective in training military medical personnel. HCESC prepared the technology for institutional use by writing manuals, manufacturing and assembling a new simulator, and packaging materials for delivery. HCESC eagerly awaits reports on usage and outcomes of the technology to further confirm the importance that simulation technology has assumed in training medical professionals.

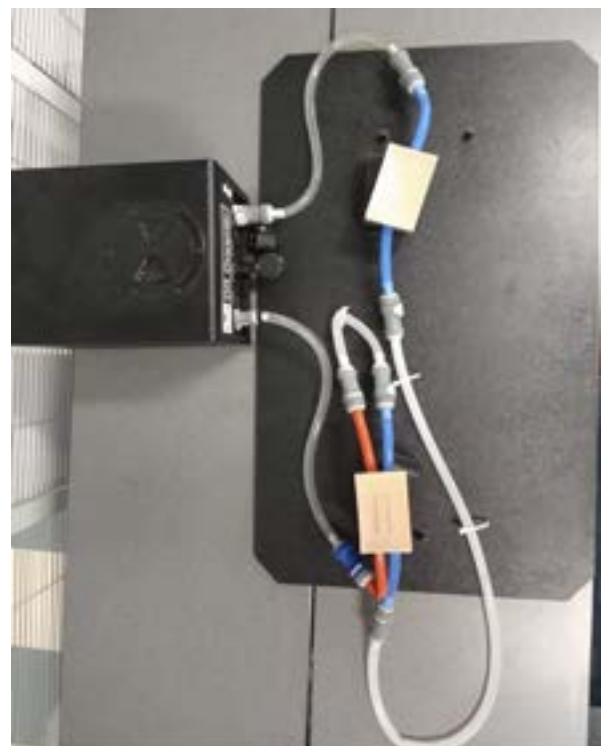
Simulation technology has grown even more important in a time where most learning is taking place over virtual platforms. Unfortunately, this is a time where learning is most important in the medical field due to the high probability of specialized medical personnel becoming infected with COVID-19, leaving others to perform their tasks. “When ECMO is needed, you want the procedure to happen at the patient’s bedside within minutes and be available 24/7,” said Dr. Mark Johnson, director of the Intensive Care Unit at Carle Foundation Hospital in Urbana, Illinois. “To do this, you need an entire team of four to ten people that are trained in performing the procedure.” Johnson cited two local cases of COVID-19 that required the use of ECMO and anticipates more.

ECMO is gaining acceptance in the medical community to salvage and support patients in critical condition, but uniquely to pandemics and seasonal influenza. Dr. Abdul Siddiqui, pulmonologist at Christie Clinic in Champaign, Illinois, cited an “exponential rise” in the use of ECMO across intensive care units in the United States since the H1N1 pandemic in 2009. “ECMO requires substantial resources and frequently carries a high risk of complications and mortality. It involves complex decision-making skills in a timely manner,” said Siddiqui.

Decision-making skills and the ability to perform under pressure are best learned before a medical professional ever sets foot in an operating room or intensive care unit. “These skills can be achieved through simulation,” said Siddiqui.

“Simulations help to understand the intricacies of the ECMO machine and its interaction with the complex physiology of a critically ill patient.” Simulation technologies are rising to fill the gap between the classroom and operating room, to minimize hesitation and increase the confidence of everyone from novices to experienced surgeons in making split-second decisions that could save lives. Simulation can be used to teach specific skills with manikins, virtual reality, or augmented reality scenarios, allowing novices to practice techniques more thoroughly prior to practicing on a simulated or actual patient.

HCESC plans to expand the capabilities of the ECMO simulator in the future by adding a virtual reality component. This would enable the user to situate themselves at a patient’s bedside and fully immerse themselves into a 360-degree experience. A virtual reality component would allow these skills to be trained amid the high-stress environment of an intensive care unit or field hospital. “With the added virtual reality component, this technology would be revolutionary in changing the way medical personnel are trained in performing ECMO,” said Kesavadas. A provisional patent has already been filed.



UVBOT

Ultraviolet light is a form of radiation that can be used for sterilization and disinfection. With schools and offices beginning to meet in-person again despite little change in the rate of COVID-19 infections, easy, low-cost sterilization strategies are necessary to curb the spread of the pandemic. To meet this lofty demand, the Health Care Engineering Systems Center has developed the UVBot: a robot that can be built out of easily accessible objects and programmed to clean spaces using UV light, which kills COVID-19.

In May 2020, HCESC director T. Kesh Kesavadas had an idea to create a low-cost robot that could be used to sterilize common areas such as classrooms, offices, and public transportation. He reached out to Helen Nguyen, professor of civil and environmental engineering and leader of the Illinois PPE team in The Grainger College of Engineering at UIUC. Nguyen, who has an extensive background in sterilization and UV light, saw the value in this idea and proposed to add a UV light to the robot. “From several studies conducted by my lab over the year, we know that commonly used UV irradiation is effective in inactivating or neutralizing SARS-CoV-2, and virus inactivation depends not only on the UV intensive but also the exposure time,” said Nguyen. “To control the exposure time precisely and to prevent humans from exposure to harmful UV light, we need something like a robot.”

While these autonomous robots do exist, they can cost as much as \$50,000. “It’s a difficult position to be in,” said Kesavadas. “Many companies and schools don’t have the funds necessary to purchase a robot that can disinfect spaces, but it needs to happen if people are returning to on-site work or learning. Our robot serves as a low-cost alternative and can be made for under \$1,000.”

Kesavadas and Nguyen decided to move forward on the project and put together an interdisciplinary team of engineers from HCESC, Holonyak Micro & Nanotechnology Lab, Mechanical Engineering, and Veterinary Biosciences: Yao Li, Harris Nisar, Fanxin Wang, Elbashir Araud, and Jump ARCHES summer intern Peter Chien. The result of their teamwork is the UVBot: made from a Roomba robot, UV lamp, and 3D-printed parts, the UVBot



can be controlled by a mobile app over Wi-Fi or Bluetooth and programmed to autonomously clean many different types of spaces. It even has the ability to record and create a library of rooms. Since UV light is dangerous to skin and eyes without protective equipment, this robot is ideal for safe cleaning since it can autonomously plan its path or be controlled remotely on a smartphone. Users would be exposed to neither UV light nor COVID-19.

The team had to navigate creating the robot through the challenges of a pandemic, where remote work and social distancing of utmost importance. Simulation engineer Harris Nisar lead the mechanical design and fabrication of the robot. “I had a great time planning the build. Of course, because of COVID, there were tremendous challenges in getting work done that required tools or facilities such as 3D printers and laser cutters, but we worked through those.”

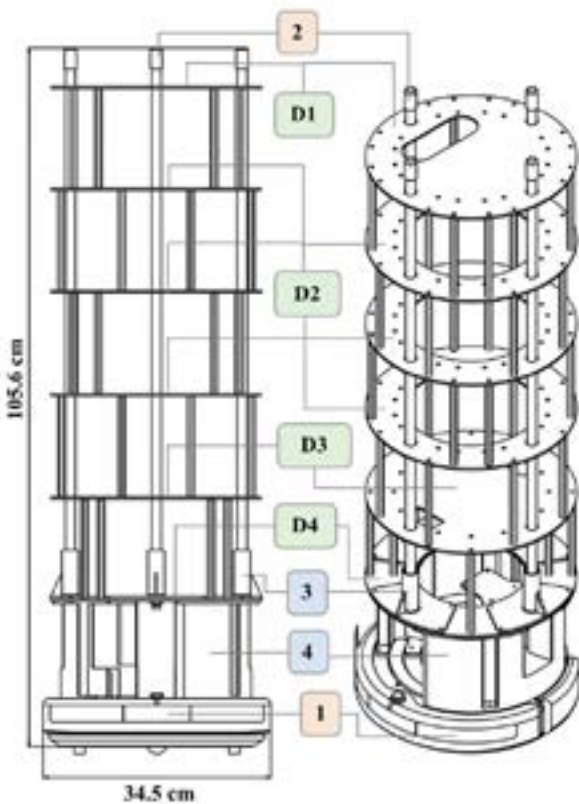
The UVBot promises 99% virus inactivation. The required exposure time and distance for inactivation was systematically tested using an RNA virus similar to COVID-19: Tulane virus.

CUPHD UNIFORM INSPECTION PROGRAM

The team successfully conducted a test inside HCESC facilities to demonstrate the prototype's feasibility as a solution for disinfection. While the UVBot has proven successful, the team is still eager to improve the design with better collision detection, autonomous detection to shut off UV light when a human is detected, and software to support multiple UVBots functioning in the same network.

Kesavadas, Nguyen, and their team were passionate about creating a solution that could be created and implemented by anyone, so they are planning to publish the design, bill of material, software, and environment test data as an open access project on GitHub. Any organization with basic engineering capabilities will be able to download and reproduce the UVBot system. The inventors acknowledge the support of Jump ARCHES.

"It is our hope that schools and organizations feel confident enough in our work to create and utilize the UVBot for themselves," said Kesavadas. "Reopening our country's schools and offices safely is a huge task, and we are proud to be a small part of it."



HCESC's Health Data Analytics Initiative worked with the Champaign-Urbana Public Health District to further develop the Uniform Inspection Program, a strategy to promote consistency and fairness in interpretation and application of the Illinois Food Code and local ordinances among health inspectors when conducting inspections of local establishments.

A major component of the program includes developing a governance dashboard using Big Data analysis methods and Natural Language Processing algorithms to help identify and mitigate variations in health inspection reports and determine evidence-based suggestions to optimize health inspector performance. The unstructured data used to develop these algorithms comes from ten years of existing food inspection reports.

The dashboard will be used to determine whether inspectors assess and educate consistently and coherently against different types of cuisine or food establishments within Champaign-Urbana. It allows for optimization of inspection staffing and report content to advance food safety through code enforcement and education of the establishment's workforce. The dashboard monitors and identifies effective writing styles to acknowledge good performance and to facilitate the transition from a non-compliant to a compliant food establishment by providing logical and easy to apply explanations.

This project is one example how the Health Data Analytics Initiative is helping local institutions and companies to improve their services. This project was made possible in part by a Food Safety Grant from the FDA in December 2019.



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At HCESC, we work with campus-wide, domestic, and international entities to discover new answers to some of the most pressing health care issues.

We pride ourselves in working with the health care industry to achieve better performance through data science, simulation, education, and smart health technologies. Got an idea? Get in touch!