Arie Kaufman stepped inside the Reality Deck at the Center of Excellence in Wireless and Information Technology at Stony Brook University. Composed of 416 super-high-resolution screens that cover its 11-foot-tall walls, this spacious 30-by-40 foot immersive theater is operated by an 80-graphics-processor cluster that crunches the background data into billions of pixels.
The Reality Deck is one of the latest milestones in Stony Brook’s efforts to advance the convergence of the life sciences with physical sciences, mathematics, big data and engineering.

As the door closed behind him, the lights turned off and the screens lit up with the University’s logo—but not for long. From a console in the middle of the room, Kaufman, chair of the Department of Computer Science at Stony Brook, loaded an image and the walls around him turned the color of burnt orange based on visualizing black swarms. The eerie glow looked like a homogenous smoky canopy, but it was actually an inside view of a human colon. The image is a useful tool for radiologists as they scan the intestine looking for potentially dangerous growths that may turn cancerous.

“See these black curves? These are the hematocostal folds of the colon; they’re completely flat,” Kaufman said, as his hands traced the dark eddies from one rectangular screen to another. He stopped to point out a little bulging spot in a place where it perhaps shouldn’t be. “This round thing looks like it’s protruding a bit. It appears odd. This may be a polyp.”

The Reality Deck is one of the latest milestones in Stony Brook’s efforts to advance the third revolution in medicine—the convergence of the life sciences with physical sciences, mathematics, big data and engineering—aimed at tackling human health issues so complex, they can’t be solved by any individual research discipline. These challenges require joint brainstorming of the best minds from multiple fields and the use of supercomputers and artificial intelligence software capable of analyzing terabytes of data with enormous speed.

It’s only logical that such a convergence is happening. After breakthroughs in molecular biology in the 1970s and human genome project discoveries in the 1990s, physicians gained knowledge in the 1980s and developed a virtual alternative to the physical colonoscopy, which is recommended for early cancer detection in people over 50. The standard procedure, which entails facility, bowel cleansing, isolation and insertion of a camera into the rectum, is so unpleasant that many people skip it despite doctors’ advice.

Medical imaging has been of special interest to Kaufman, a Distinguished Professor, for some time. He had worked in the field since the early 1980s and developed a virtual alternative to the physical colonoscopy, which is recommended for early cancer detection in people over 50. The standard procedure, which entails facility, bowel cleansing, isolation and insertion of a camera into the rectum, is so unpleasant that many people skip it despite doctors’ advice.

On the contrary, Kaufman said, “a virtual colonoscopy is a much more dignified procedure, which requires a less-intensive prep, no anesthesia and only a low-dose CT scan.”

Kaufman’s team is also developing virtual pancreatography technology, which would enable doctors to move into the human pancreas searching for potentially malignant growths.

One of the deadliest diseases known to science, pancreatic cancer kills more than 48,000 Americans per year, according to the American Cancer Society. What’s more, the National Cancer Institute’s Surveillance, Epidemiology and End Results Program estimates that about 35,000 people will be diagnosed with the disease in 2016, but only 7.5 percent will survive past five years.

“The tumors evolve from tiny cysts that grow in the pancreas and by the time they’re detected, it’s typically too late,” Kaufman explained. His procedure would enable radiologists to detect abnormalities they can’t identify with the naked eye.

“When you take a CT scan, it’s either the cysts are too small or not discernible,” he said. But his artificial intelligence algorithm can parse the suspicious formations to assess potential threats. “It’s like an electronic biopsy on the screen,” he added.

Surgery in Silico

In a lab located in the Health Sciences Tower on East Campus, Danny Bluestein, a professor of biomedical engineering and the director of the Biofluids Research Group, is working on optimizing and testing cardiovascular prosthetic devices. He doesn’t use a scalpel for his work; rather, he combines in silico computer simulations with benchtop lab testing.

Bluestein studies how blood flow in three implantable devices reacts to the various flow patterns and mechanical stresses, and uses his research to understand how blood passes through diseased, malfunctioning heart valves.

This enables him to design and optimize devices that surgeons can implant to prevent the heart from failing.

“This is TAVR, a transcatheter aortic valve replacement device,” said Bluestein, holding up a small round piece of metal mesh with three thin polymer leaflets designed to work like the natural heart valves. When a native valve becomes calcified and hardens, its leaflets lose their ability to fully open and close, resulting in life-threatening conditions that may lead to heart failure and the generation of blood clots that may induce strokes. To replace the failing valve with an artificial one, surgeons thread a catheter through the groin all the way to the heart and deploy it over the diseased valve. This is a life-saving solution for patients who may not be able to survive open-heart surgery when heart valve replacement is needed.

These devices require a thoughtful design and tuning to assess that they will function well and last a long time. Built from a polymer, TAVR is a new type of prosthesis that is more durable than the currently available liquid-filled replacements.

Standing next to a VIViro SuperPump, an FDA-approved digitally controlled pump that simulates physiological heart failure, Bluestein explained how TAVR was developed. A team of valves, chambers, valves, endotracheal tubes and wires designed to function like a heart mock-up, the pump serves as a state-of-the-art testing tool for the new prostheses.

“We started with simulations and then moved on to fabricating prototypes, and now we’re conducting a battery of standard tests required by the FDA for each medical device,” said Bluestein, pointing out a location in a pipe where TAVR would be inserted for functionality testing. “Next phase will be animal studies.”

Bluestein also works on optimizing existing and other cardiovascular prostheses, such as ventricular assist devices (VADs), used to treat patients with congestive heart failure, a condition in which the organ cannot pump blood efficiently throughout the body.

“A VAD is a small turbine that looks like a miniature jet engine and spins at an amazing speed of 10,000 rotations per minute,” Bluestein said. “It replaces the functionality of the failing organ, but not in an optimal way— neither in the way our natural anatomy does it.”

Implanting a VAD interferes with blood flow and can lead to clotting, which is why nearly all patients with implants must take anticoagulants. But that is a double-edged sword, as these medications might cause hemorrhaging.

“It’s a very delicate balance,” Bluestein explained. “So optimizing a VAD’s design to minimize clotting is crucial.”

Bluestein’s team runs in silico simulations of how these devices would work post-surgery. By using CT scans and MRIs to reconstruct the anatomy of patients’ hearts, along with computer algorithms that solve complex mathematical equations, the team analyses how VADs would function once implanted.

This is a realistic test of how a patient’s body will respond after the miniaturized turbine starts spinning inside him or her, said Bluestein. The findings are passed to the companies that build cardiovascular devices so that they can fine-tune them to achieve better, more natural blood flow.

Third Revolution in Medicine

The Reality Deck

Top: Danny Bluestein holds a transcatheter aortic valve replacement device, which acts like a natural heart valve.

Bottom: Milutin Stanacevic is working on a device that can notify families when it has been taken.

During testing, the companies that manufacture VADs are required by the FDA to submit a battery of standard tests required by the FDA for each medical device. In this case, this battery includes animal studies, which are critical for ensuring that the device will work as intended in the human body. The animal studies involve implanting the device in animals and monitoring its performance over time. The findings from these studies are then used to improve the design and optimize the device before it is approved for human use.
For people with life-threatening conditions, patients with psychiatric conditions or transplant recipients, it’s imperative that medications be taken at specific times, as skipping even one dose can be dangerous. Yet, despite the preponderance of gadgets that can remind people to take their medications on time, many patients — especially older adults — often forget to do so.

That’s why Stanacevic, an associate professor in the Department of Electrical and Computer Engineering, is developing a pill that can “speak” for itself. When ingested and dissolved inside the digestive tract, it would send a signal using radio-frequency identification technology to notify doctors or caregivers that it had been taken. It’s like texting from the patient’s gut.

The technology behind the pill is akin to that of a supermarket scanner. A reader scans a signal from its antenna to a chip affixed to a product and the chip sends back a response. Stanacevic’s setup is a miniature version. The reader looks like a Band-Aid patch, and the chip is so tiny that it can easily fit on a fingertip. Both devices feature shiny flat metal plates that serve as electrical wiring.

“In real life, this patch would be placed somewhere on the patient’s body and the chip would be inside the pill,” Stanacevic said. “As soon as the pill dissolves, the gastric acid will activate the chip, which will inform the reader that it reached its destination.”

All materials are biocompatible, meaning that they don’t cause adverse effects or stay in the body.

Stanacevic is working on other miniature electronic devices, such as a breathalyzer that can detect certain health issues based on the composition of the gases in a person’s breath. “Patients with asthma have a higher concentration of nitric oxide, so by measuring that gas, you can find out what triggers an attack,” Stanacevic explained. “And by measuring acetone levels, you can monitor people’s metabolic rate and figure out how they’re burning fat and what exercise people’s metabolic rate and figure out how measuring acetone levels, you can monitor concentration of nitric oxide, so by measuring composition of the gases in a person’s breath. You can learn a lot from a person’s breath,” he said. “Wouldn’t it be great if breathing was all you had to do for a diagnosis?”

Big Data to Battle Cancer
In his quiet office above bustling Stony Brook University Hospital, Yusuf Hannun, MD, director of the Stony Brook University Cancer Center, is engrossed in data. His specialty is biochemistry and molecular biology, but nowadays big data is one of his preferred tools. Last year, Hannun’s statistical research led to a paradigm shift in the momentous debate about what causes cells to become cancerous — the random mutations attributed to “bad luck” or external factors like environmental toxins, which mess up cell division. The former means that we can do little to thwart cancer; the latter asserts that proper preventive methods can save lives.

In 2015 Hannun, who is the Joel Strum Professor in Cancer Research, read a paper that contended that cancers are the result of intrinsic causes — essentially an error waiting to happen in cell division, as opposed to extrinsic (environmental) triggers.

He wasn’t convinced. “Any normal cell will introduce one or two mutations each time it divides. That’s how nature works; it’s an unavoidable effect of cells dividing,” he said.

“But many processes can increase that mutation rate: for example, UV light, tobacco smoke and some viruses when they divide in a cell.”

He mobilized a team from the Cancer Center spearheaded by Song Wu, an associate professor in the Department of Applied Mathematics and Statistics, that included Professors Wei Zhu, Applied Mathematics and Statistics, and Scott Powers, Department of Pathology. Together they combined large quantities of cancer data, scrutinizing the information in four different ways. The team looked at mutations (“signatures”) that various cancers leave on patients’ DNA; showed through epidemiological records; assessed how environmental toxins affect cell division; and used computational models to examine how the inner workings of cells affect cancer development. The results overturned the paper’s conclusion.

“One of our results showed that the intrinsic cancer risks were quite low, ranging from 10 to 30 percent, while extrinsic risks were much higher, from 70 to 90 percent,” said Hannun. One of the most revealing findings came from epidemiological data, as Hannun looked up the world map of cancer rates on his desktop computer to demonstrate. “When immigrants move from places with lower cancer incidence to places with higher cancer incidents, they develop it at a similar rate as the residents in their new country,” he said, tracing the map. “Evidently, the exposure to carcinogens has a greater impact on disease development than cell division.”

A decade ago such findings, which are crucial for cancer prevention efforts, would have taken years to prove, but today medical progress is moving at a remarkable pace.

“It used to be that ‘scientists would have to hypothesize, test the idea with data and see if it works,” said CEAS’ Sotiropoulos, “but now supercomputers and artificial intelligence can help us solve problems we couldn’t approach before.”

The convergence of medicine and engineering signifies a new era that requires physicians and engineers to work hand in hand. That’s why Sotiropoulos and Kenneth Kaushansky, MD, MACP, dean of Stony Brook University School of Medicine and associate vice president of health sciences, are setting up “speed dating” workshops between their respective faculties.

Sotiropoulos called this approach “serendipity initiatives,” while Kaushansky dubbed it “productive collisions.” But no matter the name, the idea is to pioneer more groundbreaking research at Stony Brook.

Kaushansky is enthusiastic about the joint collaborations, “We hope that this will be a quantum leap forward in how much time, energy and effort we devote to working together to create a solution to biomedical problems,” he said.

“What it all comes down to is developing “a unique vision that allows us to go beyond research initiatives that are currently funded by federal agencies,” Sotiropoulos said. “We really want to reach across boundaries, break through expectations and define the future.”

Lina Zeldovich writes about science, medicine and technology for magazines like The Atlantic, Popular Mechanics, and O, The Oprah Magazine.

“We can model how cancers develop and assess what therapies may work best,” said Fotis Sotiropoulos, dean of the College of Engineering and Applied Sciences.

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