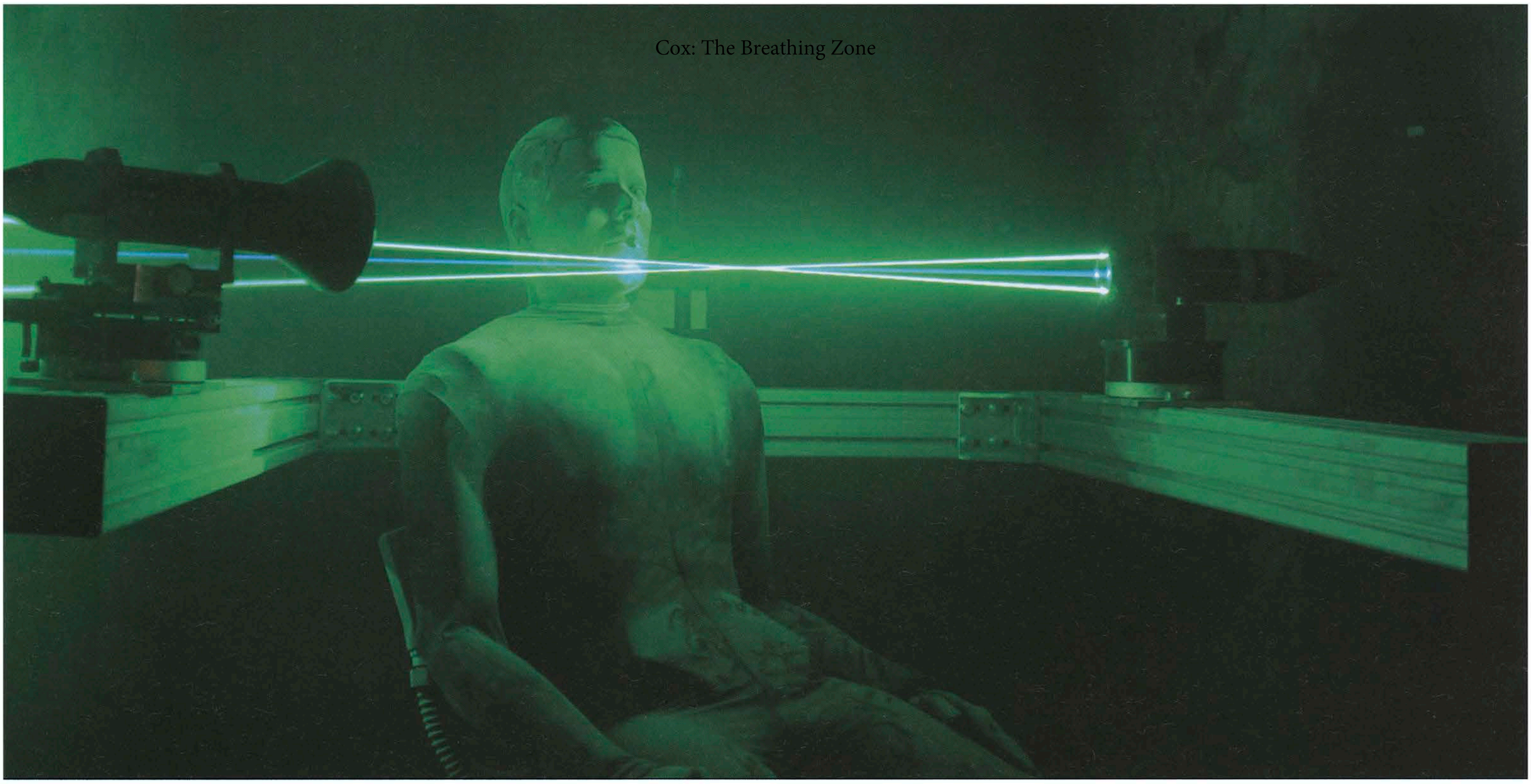
Photo by David Marr/Photo illustration by Laurie Cronin

Entering the Breathing ZONE

BY JAY COX

At the Indoor Flow Laboratory, a team of engineers stirs up "dust" with a mannequin to gain insights on enhancing the quality and safety of indoor air

AS FAR AS OFFICE COWORKERS GO, THIS GUY IS TAME. He doesn't sneeze all over the place, make wild gestures that trigger paper-pile landslides on his desk, or spill coffee on his keyboard. He sits quietly in his cubicle, occasionally moving slowly back and forth in a chair, his feet nearly grazing the ventilation duct in front of him. And every breath he takes is closely monitored by a team of engineers carrying out a carefully designed, indoor air-quality experiment that tracks how particles flow through a room and enter a person's breathing zone. "The big picture is we want to study the effectiveness of the thermal plume—the layer of warm air that surrounds a person's body—as a pump, if you will, for bringing nasty things from down around our feet up into the breathing zone," says Professor Mark Glauser of the Department of Mechanical and Aerospace Engineering at the L.C. Smith College of Engineering and Computer Science (LCS). »



Once particles are introduced into the Indoor Flow Laboratory, researchers use an optical-based technique known as laser Doppler anemometry to collect information on particle velocity, concentration, and flux.

Welcome to the experimental world of the New York State STAR Center for Environmental Quality Systems (EQS Center), the academic research arm of the Syracuse Center of Excellence in Environmental and Energy Systems, a federation of more than 140 upstate New York firms and institutions devoted to advancing research, and developing and marketing innovative technologies. Through collaborative research efforts, the EQS Center seeks to enhance human health and performance and create energy efficient systems by improving the quality of urban ecosystems and built environments. "At the center of our research are people working and studying in spaces," says EQS Center director H. Ezzat Khalifa, NYSTAR Distinguished Professor at LCS. "Studies indicate that people's performances, whether in learning or productivity, are affected by their environments. The challenge for us is how to allow people to customize their environments and monitor them while they're sitting in offices connected to other offices. There is an array of nested environments, starting with the individual and working outward, from the office to the suite to the building to the urban setting to the larger environment."

The thermal plume experiment is connected to several EQS Center research projects funded by the U.S. Environmental Protection Agency. They focus on what Khalifa calls the "personal micro-environment"—the immediate area around a person, including the flow of air, contaminants, and particles. As Khalifa points out, we all have a "personal dust cloud," a manifestation of our own motion and body heat. The cloud swirls around each of us like the one that travels with Charlie Brown's pal, Pig-Pen. In this particular experiment, the cubicle-confined coworker is actually a thermal breathing mannequin, one of several developed by LCS scientists for use in indoor air-quality research. One, for instance, can sweat. "We don't use mannequins like the ones you see at Saks Fifth Avenue," Khalifa says. "They are tools for us—some are simple and some are very sophisticated." This "office" mannequin is your standard med school model equipped with breathing and heating systems. As part of the experiment, the mannequin is warmed to 92 degrees Fahrenheit—roughly our skin temperature—to create the plume, or thermal buoyancy, allowing researchers to gather data and study the plume's interaction with the flow of particles introduced through the ventilation duct. Glauser and his team of graduate-student researchers designed the experiment as a foundation they can build upon for different levels of information. If need be, they can make the mannequin cough or sneeze, or introduce other factors affecting airflow and particle movement. "We wanted a balance between fundamental and realistic," says researcher Ian Spitzer G'07, a graduate of the master's program in mechanical and aerospace engineering. "We could add clothes, computers, desks—all kinds of stuff. But to study the fundamental things, we needed to keep it fairly simple."

After injecting a specified amount of particles through the duct, they monitor particle levels in the mannequin's breathing zone as it goes through the breathing cycle. This may seem like a relatively simple task, but consider some of the variables in play: air flowing through the duct; the mannequin's thermal plume, positioning, movement, and breathing cycle; and the mixture of all this with the movement of incoming air and

Photo by David Marr

particles. "What we have here is the interaction of a lot of different, fundamental flows," says researcher David Marr G'07, who earned a Ph.D. in mechanical and aerospace engineering. "It takes a long time to determine what is due to what."

The team's primary objective is building a database of information on particle velocity, concentration, and flux (amount of particles that flows through a unit area per unit time). They share the data with three groups of computational fluid dynamics (CFD) scientists associated with the EQS Center, headed by Professor Goodarz Ahmadi of Clarkson, Professor Lance Collins of Cornell, and Professor Thong Dang of LCS. "With the proper amount of data, our [CFD] colleagues can create simulations on their computers," says Glauser, associate director for research at the EQS Center. "Once they've calibrated their codes to match our data, they have some level of confidence in expanding the simulations to more general sets of problems. They'll essentially be able to predict more exotic and intense motions."

By investigating different scenarios through simulations, scientists will better understand how their information can be applied to a variety of situations, from enhancing comfort in indoor work environments to reducing the spread of viruses in hospitals to—at the extreme level—combating acts of bioterrorism. "There is a whole range of things that this research impacts," Glauser says.

Enter the Indoor Flow Lab

Glauser began work on the mannequin project with colleagues and a team of student researchers five years ago. As part of the setup work, Marr developed the mannequin's heating system with the assistance of LCS research design engineer Jim Smith, who designed and built the system's electrical box. Before experimenting with the mannequin, the team created the Indoor Flow Lab in a Skytop research building on South Campus. The lab, built by Marr, has an outer room that is 12 feet wide, 16 feet long, and 10 feet high, and an inner chamber, where the mannequin works, that is 8 feet by 8 feet by 6 feet. "We're introducing particles and want to know where in the room they're going to go," Glauser says. "Remember, in an indoor environment, people are sources of particles. We're kicking stuff up and we've got plumes doing interesting things, so how does that affect what we're actually breathing?"

The particles they use aren't your ordinary specks of dust. They are industrially produced, spherical in shape, and roughly 1 to 10 microns in size. "We picked them because the instrumentation we use works best with spherical particles and you can buy them by the bag," Spitzer says. "They're really cheap."

Once the chamber was constructed, Marr mapped out the aerodynamics of the space. Using aerosolized olive oil, he tracked the flow of oil droplets from the floor duct through the chamber—both with and without the mannequin—and collected velocity measurements using an optical-based technique known as particle image velocimetry. Spitzer's work focused on obtaining measurements at specific points within the flow area. After introducing the experimental particles, he employed another optical-based method, laser Doppler anemometry, to measure particle velocity, concentration, and flux. They also had the mannequin scanned into a computer as a three-dimensional image to assist CFD researchers with their simulations. Once everything was in place, on went the fan that runs the ductwork, into the room went the particles, and there the mannequin sat, either still or swiveling up to 30 degrees in each direction in front of the duct. From start to finish, the experiment could take up to 80 hours to run. "There are so many systems that all have to be working right at the same time," Spitzer says. "It can be challenging."

From Sonic Speed to Sputtering

Interestingly enough, a room away from the flow lab, Glauser has a transonic jet lab. His background is in aircraft aerodynamics and turbulent flows, and he is used to dealing with speeds in the Mach range. His jet propulsion system kicks out a plume at the rate of Mach .85 (about 280 meters per second), while the particles in the flow lab puff out of the duct at a velocity of approximately 0.2 meters per second. Talk about cooling your jets. But Glauser says techniques used by aerospace scientists translate well for indoor-air experimentation. "There is a lot of signal processing and time series analysis involved in understanding where we are at the time we're taking measurements," he says. "So we brought a lot of those tools to bear on this problem."

In the coming months, Glauser and his team will plumb the plume issue more deeply by introducing a second mannequin into the mix. Glauser is working with LCS graduate student Srikar Kaligotla to explore the interaction of breathing zones with two thermal breathing mannequins seated at a table. For Glauser and his research team, it's the next step in refining experimental methods as they pursue an understanding of the movement of indoor pollutants and contaminants and their impact on health. "We can look at all sorts of scenarios," Glauser says. "The idea is to get as much information as we can to do quality simulations. We're probing and trying to understand what's happening. And as engineers, we want to go to the next step. We want to take these physical insights and start creating products that make things better for people."