Department of Nuclear Science and Engineering
Massachusetts Institute of Technology

SPOTLIGHT ON **NSE RESEARCH**

Michael Short spans classroom, forge, reactor

NSE research scientist Michael Short is an exemplar of interdisciplinary knowledge, with two Institute degrees in both nuclear science and engineering and materials science and engineering. “Interdisciplinary work is where the fun stuff is; it’s where you get to work on challenges that many people consider too difficult, or that require a broader perspective,” he says.

But there’s another dimension to Short’s interdisciplinary skill set — extensive hands-on metalworking experience, which amplifies the value of his academic learning and his ability to address challenging problems in fission reactor development.

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"In my freshman year I started Course 22 and took a blacksmithing class. I've stayed with both ever since," says Short, who is also a staff member at the Institute's cross-departmental Uhlig Corrosion Laboratory. "The combination has led me to many advances in the research realm. You can theorize about a part or a model, but if you've held a piece of hot steel in your hands, you'll have better insight into how it will behave. You pick up intuitive knowledge; the combination of that and book knowledge is worth more than the sum of the parts."

For this reason, Short takes his students in class 22.033, Nuclear Systems Design, beyond books and paper. "The students heat-treat metal using the forge in Building 4, and see how an improperly treated piece becomes brittle and breaks apart, while a well-treated one stays tough and strong," he explains. Short has also abandoned laser pointers in class, instead using a different reactor part each week as a visual aid. This gives students a tangible sense of what they're studying and working on — a challenge with nuclear reactors.

Much of Short's research is focused on unwanted deposits that accumulate on fuel cladding during reactor operation. The deposits (known as CRUD, for Chalk River Unidentified Deposits, after the Canadian reactor where they were first observed) can interfere with the reactor's cooling process, ultimately reducing reactor output. Short and his colleagues, including Professors Jacopo Buongiorno and Sidney Yip, are developing a new multi-physics, multi-scale model that will offer insights into CRUD formation at the nano- and meso-scales, revealing the nature of deposition in the reactor vessel's extreme environment.

"There's a heat-transfer reason for why materials drop out of solution from the coolant, but then they have to stick," explains Short. "It's that first process of adsorption that I'm interested in — that first layer of atoms has to stick for a reason, and we have to figure out why. Then we can modify the cladding to make it less susceptible to CRUD deposition, perhaps with ion implantation, gas-ion nitriding, or electro-implantation."

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The NSE researchers are also pursuing an intriguing alternative: learning to grow CRUD that could actually enhance cooling. "We're now able to model the different parameters of CRUD microstructure, and can understand what makes it good or bad in terms of heat transfer," explains Short. "Good CRUD could increase the effective surface area of the fuel rod, which would be great for cooling. If we can't stop it, maybe we can bend it to our will."

Experimentation is an essential complement to modeling, and Short is working with Prof. Mujid Kazimi, director of the Center for Advanced Nuclear Energy Studies, graduate student Ittinop Dumnernchanvanit, and undergraduate Ekaterina Paramonova on a new experimental CRUD growth loop that will duplicate conditions inside pressurized water reactors, where water is brought to 325 degrees C at pressures of 150 atmospheres. Notes Short, "many of our fundamental experiments are being done at room pressure or a bit higher; this gives us a way of seeing what actually happens in more extreme environments."

Short is optimistic that NSE's work will come to fruition in next-generation fission reactors during his working lifetime. "Reactors are one of the most extreme environments we can create on Earth, and are one of our greatest engineering challenges," he says. "If we can do a better job of molding what happens inside the reactor, everything else in the system design process gets simpler — that's why I like the work."

Written by Peter Dunn
Photo by Justin Knight