

Heads plus hands
equals wizardry in
Engineering's Product
Realization Lab.

By Sam Scott



MAGIC

IN THE MAKING

Photograph by Tom Lindboe

Director David Beach

It doesn't take a professional's sense of design

to appreciate the device looming behind the desk of Dave Beach, head of Stanford's Product Realization Lab. A childlike glee at peppering people with Nerf balls will do.

The hand-cranked contraption looks vaguely like an old reel-to-reel movie camera, and each quarter, Beach punctuates a lesson in the principles of casting by setting its wheels into a spinning fury, pulling the trigger to unleash a volley of balls out at 40 mph like some good-natured Gatling gun. Beach loves the device for a long list of reasons, not the least of which is that showering students with flying foam turns out to be a pretty good way of getting them intrigued about the ingenuity behind its design and manufacture. "If anybody is beginning to doze off, that will wake them up in a hurry," he says.

The machine—the work of recent TAs Ari Bennett, '15, and Tamara Hasoon, '13, MS '16—represents hundreds of hours of dedication, from conceptualization to prototype testing to the masterful casting of moving parts out of molten aluminum. And the result—however whimsical—epitomizes what Beach has been imparting to Stanford students for four decades: the joy and delight when design, materials, engineering, craftsmanship and aesthetics meld together into what he calls "magic."

The Product Realization Lab, or PRL, as it's mostly known, is the modern name Beach bestowed two decades back on one of the oldest parts of the university—the Stanford Student Shops. A "lab" had a better shot at funding than a shop, Beach jokes.



LAUNCHPAD: Beach (above, in 1974) says he was "terrified" in the early days. Below, the Nerf ball projector by Hasoon and Bennett.



JOHN WALES (TOP); TOM LINDBOE

Even now, the PRL's main location near the heart of campus looks, smells and sounds much like a traditional metal shop. Yes, the PRL has 3-D printers, laser cutters and an injection mold machine. But if you happen to walk into its courtyard as soot-covered students emerge from pouring 2,100-degree molten bronze in the foundry, you might wonder what century you're in.

To Beach, it's less old-school than timeless. The need to make stuff by any means is core to the human condition, right up there with food, shelter and procreation, he says. For many Stanford students, some who barely turned a screw growing up, the feeling of finally making things is abundant happiness and joy.

And in learning the intimate skills needed to do so comes wisdom. The first time he strapped on a helmet to arc weld, Beach says, he was almost drooling at the prospect of commanding 300 amps and a blazing torch before he learned that success required something far more zen.

"It turns out a good welder is more like this: You stop your heart from beating, you stop breathing, you don't think about anything," he says. "Every atom of your body, both spiritually and physically, is concentrating on a little point of energy created by a plasma arc.

"It's a form of concentration and meditation that, when done well, is extreme."

But the PRL's main mission is not nearly so metaphysical. It's a firm belief that the best mechanical engineers and product designers can't just live in a world of theory, computer modeling and computer-assisted design. They need visceral, hands-on knowledge of materials, manufacturing and process. The lab, which encourages students to build from their own designs, isn't trying to produce welders or machinists, but stronger engineers and designers, he says.

"If you don't know how it's going to be made, God help you in terms of converting your vision into physical reality, which is affordable, which is durable, which is used in the way you thought it might be to solve the problem you had in mind," Beach says. "You are a better designer if you also know how it's made."

And in learning how to make things,

Beach says, students gain the confidence to do much more. On the wall outside his office, there's a series of painted phrases that he says spells out the PRL's creed. The last is in red and starts, "I can make anything."

Signo Uddenberg is a believer. As an engineering grad student, he was introduced to Beach and the PRL through Design for Extreme Affordability, an interdisciplinary course in which he worked on a project focused on better ways to manually drill for groundwater in Ethiopia.

He likes to say that it took going to Stanford to learn to weld—his high school had been proudly against teaching "trades," and his undergraduate engineering classes hadn't included any shop work. The PRL experience left him with an abiding belief in the power of moving quickly from concept to prototypes, which then evolve as you go. "Everybody talks about ideas and invention and ideation," says Uddenberg, MS '11. "But the ability to immediately turn it into something is incredibly empowering.

"If you want to test an idea, you shouldn't be stopped by anything. Let's get the material and start building."

Krista Donaldson underwent a conversion too. When she arrived at Stanford as a grad student in applied mechanics in the mid-'90s, she had never been in a machine shop, coming from an education focused on problem sets and theory. Then one day she passed by the PRL and through the windows saw students on lathes, mills and presses. "It was like this 'aha' moment," she says. "This is why I went into engineering."

It was a crucial fork in the road for Donaldson, MS '98, PhD '04. She refocused her studies on product design and was soon falling in love with metalworking during long hours in the lab. She was also getting steeped in PRL tenets that remain vital to her as she leads D-Rev, a nonprofit design firm renowned for its low-cost, high-quality medical devices, such as ReMotion, an \$80 prosthetic knee.

Beach, who is a faculty member in the mechanical engineering department, speaks about design and building with a conviction and energy that make



Changing Lives

Maddy Sides always had strong ideas about how the world should be better. But exactly how to be a force for the change she wanted was much less clear. The idea of, say, getting a PhD, becoming a researcher and writing policy papers just didn't offer the immediacy she craved.

Then she found product development.

She'd got her first whiff of the thrill of making things in a bioengineering class that required simple shop work. That led to her real initiation: Beach's ME203: Design and Manufacturing, the gateway for so many into the Product Realization Lab.

Part of the joy of the class was how much quick, confidence-building progress she made in a range of skills—and how engrossing it was. When Sides first started welding, the experience was so intense she had to remember to breathe.

Her final project was a bar stool, artfully made but not particularly earth-shattering. But she was beginning to grasp a powerful new way of looking at the world—asking how things are made, making connections between a product in one area and a problem in another, knowing how to make ideas real.

"You look at something, and you say, I know how to break that down into bite-sized pieces," she says.

Her senior year she took Design for Extreme Affordability, a hallmark collaboration between the d. school, Business School and PRL, which has a long history of creating life-changing products, such as infant incubators, for a fraction of the traditional cost.

Sides joined a student project working in South Asia to create a low-cost medical device that essentially sucks on wounds like burns and ulcers to promote healing. Negative pressure therapy, as it's called, is typically prohibitively expensive for many people, she says.

Now an incorporated startup called Healyx, where Sides is co-founder and product lead, the company has had a strong reception, she says. Eventually they hope to launch in India and develop numerous therapies. As young grads, her team has been helped immeasurably by their ability to quickly turn around ever-improving, increasingly sophisticated prototypes. This practice of constant evolution is core to PRL training, she says.

"It created my path forward."



A Test Run to Remember

A bike ride from northern Alaska to the tip of Argentina leaves plenty of time for thought. And on desolate days, Sam Hochheimer's thoughts would often return to the many decisions that went into building his bicycle and how he might make them differently with the wisdom of accumulating mileage.

Hochheimer, '13, MS '17, made the rig his senior year in the Product Realization Lab's popular bicycle design class with the epic trek in mind. While classmates welded frames for speed and mobility, Hochheimer chose thick tubes and a long base as he imagined crossing 14,000-foot passes in the Andes saddled with gear.

Bicycle manufacturing at the PRL goes back decades to a student whose son has since passed through the lab. It has become something of a rite of passage in the lab as well as an initiation into the demands and glories of performance design.

"If performance is your goal, physics, God, nature creates beauty in the results," Beach says. "Look at aerospace devices, look at space devices, they're all gorgeous not because the people doing them are sculptors, but because the people doing them understood how to get the maximum performance out of them. And bicycles are in that same category."

It took Hochheimer two years to finish the journey. He rode a bus through the northern desert in Chile to meet a friend in Santiago for Christmas. But otherwise he went unassisted—and unmolested—from the desolate North American West to the sweaty and social tropics and into the majesty of the Andes, camping much of the way.

Most impressive, as far as Hochheimer's PRL work is concerned, was the encounter with a bull. He was climbing a mountain road when he turned a curve to find three farmers screaming about "an angry cow."

Hochheimer dismounted and got off the trail. The farmers' bull picked up the bike and tried to toss it down the hill. But its horns stuck in the spokes and both beast and bike went somersaulting down the embankment. "They were just lying there in a pile," he says. "I thought I might have killed the bull."

Luckily, neither was too worse for wear. Hochheimer's bike had a bent wheel, a bent brake disc and a small ding in the frame. He trued the wheel and was on his way.

He saw many things on the trip—including many other cyclists. One thing he never saw: another rider on a self-made bicycle.

it easy to imagine why his accolades include the Gores Award, the university's highest recognition for teaching. Donaldson says he would do something as simple as bringing a plastic milk jug to class and asking how it was made to get discussions going, as his own wonder for

the process rubbed off on everyone else. "He's magical," she says.

Beach's prospects weren't nearly so bright when he first started work in the shops after getting his master's from Stanford in 1972. Having foundered in his first go at college before working for

years on HP assembly lines, Beach had already taken a circuitous route to get to the Farm. And with a wife and kids at home, he had no business staying to take a job in the student machine shop for a quarter of what the outside world would pay.

"It was such a patently terrible decision," Beach says. "I was drawn to it like a terrible magnet, for sure."

It wasn't just the matter of money to worry about. Beach had been a gifted shop rat as a student. To this day, one of his early projects—a brass and wood re-creation of the device that famously captured the first images of moving objects on Leland Stanford's horse ranch—is held in the permanent collection of Stanford's Cantor Arts Center. But by professional standards, he was a neophyte compared with the journeyman welders and machinists who usually held such jobs on campus.

"I was terrified," Beach says. "My guess was I'd be lucky to last two or three years."

Instead, he flourished. He got his first crack in the classroom teaching a course that he suspects no one wanted after its previous instructor had been denied tenure. It apparently went better than anyone expected.

Still, over the years, he's heard his share of suggestions, implied and explicit, that a shop by any other name is tangential to an elite research university. And he bristles at any suggestion that what the PRL does is less intellectual than what goes on elsewhere at Stanford.

But the PRL is in high demand. Two decades ago, some 250 students used it annually; now, more than 1,000 do, says Craig Milroy, '80, MS '82, the lab's long-time co-director, who oversees daily operations in the main shop. Many of its students go on to top design-focused firms like Tesla, Google and Apple. And it's got a long history as the testing grounds for socially minded ideas focused on improving the world.

"It's like a gathering place for the most curious and physically oriented people to come together, help each other and exchange ideas," says Madeline Sides, '15, a recent PRL course assistant who epitomizes how transformative the lab can be. (See sidebar, page 61.)



SHOP TALK: After 45 years, Beach has no desire to stop: "It keeps getting deeper."

Some of the appeal reflects broader societal interests. The rise of the "maker movement," the popularity of high school robotics and the availability of easy-to-use technologies like 3-D printing have all spiked interest in resources the PRL offers—essentially putting a gleaming white collar on what previously might have seemed like an oily shop world. It's not uncommon for presidents, deans and trustees of other universities to take tours of the PRL looking for ideas to take back to their own schools, Beach says.

Beach has mixed feelings about some of the changes. Downloading a computer file to use the 3-D printer doesn't exactly compare to the poetry of welding or using the forge. But he's come to accept that the technology's low barrier to entry helps bring more people into making things and enables better early-stage prototyping.

The PRL wasn't always held in such esteem. When Jim Adams, MS '59, PhD '62, now professor emeritus of mechanical engineering, arrived in the mid '60s, an increasing emphasis on more abstract and formula-based aspects of mechanical engineering had doomed similar shops. And plans to expand a high-temperature gas dynamics lab—the epitome of the

trend—seemed ready to provide the death-blow at Stanford.

"When I came here, I found out that they were shutting the shop down," Adams says. "To me, it's inconceivable that a mechanical engineer can live without a shop, so I howled and made lots of noise. And the dean said, 'Fix it, then.'"

Hiring Beach proved to be a big part of the solution. At the time, the shop staff members were older technicians, experts in craft but not especially versed in pushing students to see big pictures. They typically provided the class with a uniform set of blueprints to build from. Adams wanted to push the students into building their own designs.

Beach was a compelling choice to make that happen, not just because he had let slip how much he'd missed the shop after graduation. A skilled engineer and craftsman, Beach had also apparently inherited an artistic streak—his father, a museum director, couldn't hit a nail with a hammer but was a talented fine arts painter.

At first, the idea of every student working individually was part of Beach's anxiety. He could reasonably stay ahead of his students if there was a single proj-

ect. But if everyone was going in a separate direction, some on designs requiring machining, others on welding or foundry work, it would be difficult for him to always look like the expert in the room.

Once he got comfortable, though, Beach, later with Milroy, is the one who really launched, honed and expanded the modern-day PRL's emphasis on weaving design and manufacturing, Adams says. Its mission is startlingly obvious at the end of each quarter, when more than 100 PRL students present unique projects at Meet the Makers.

Between his teaching load and administrative duties, Beach doesn't spend as much time as he once did in the shops, though the connection remains strong. "This place is so ingrained into his psyche and his persona, if something happens in the lab, Dave feels a perturbation in the Force," says Milroy.

Forty-six years after taking a job he shouldn't have taken, Beach still feels the thrill. One day, he'll be happy to let go of the administrative demands and politicking of being PRL director. But he's got no desire to stop teaching—or to let go of the magic. "I don't know why, but for me, it keeps getting deeper," he says. ■

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