

PART OF THE CROWD

THESE ENGINEERS DESIGN FOR AN INCLUSIVE WORLD

BY GAVIN JENKINS

ABOVE: Children play at Morgan's Inspiration Island using PneuChairs, which were designed and built at Pitt's Human Engineering Research Laboratories.

Photo by Robin Jerstad

Brandon Daveler twisted the throttle on his Yamaha and hit a jump at full speed. It was the first American Motorcyclist Association race of the 2005 season, and Daveler, a 15-year-old thrill seeker who enjoyed working on engines, was confident he could win the District 5 title. But his life changed in midair.

Daveler flipped over the handlebars and landed on his head. Lying on the dirt track at the Greene County Fairgrounds in southwestern Pennsylvania, he heard the announcer yell, "Red flag! Red flag!" indicating that the race had stopped. The paramedics rushed to Daveler. He felt as though he were still sitting on the bike—like his arms were still holding the handlebars. But they were at his side on the dirt. After a life flight to a Morgantown, W.Va., hospital, he learned he'd suffered a fracture to his fourth and fifth cervical vertebrae and had quadriplegia. After months of rehabilitation, he regained movement in his arms but not in his wrists or hands.

An only child, Daveler relished his independence. He preferred racing to basketball because there weren't teammates. The accident's aftermath was shocking: The boy who repaired his bike alone at his home in Uniontown, Pa., had to ask people to scratch his head. When he returned to the ninth grade the following autumn, Laurel Highlands High School bought him a laptop and hired an aide to assist him. But the friends who came to his house to ride his dirt bike slowly stopped coming.

The physical and social exclusion was hard to accept then, and it remains a challenge today. "You're always adjusting," says Daveler, now a 28-year-old PhD student in the University of Pittsburgh's rehabilitation science program. "I don't think [adjusting to life in a wheelchair] ever ends."

Pitt's Rory Cooper believes the next generation of engineers will make life a lot easier for people with disabilities. His vision is to create a world where people with disabilities are included in all aspects of society, without physical or social barriers. And he is mentoring Daveler and others he expects will lead the way.

Pitt has been at the forefront of assistive technology since 1994, when Cooper founded the Human Engineering Research Laboratories (HERL). In association with the U.S. Department of Veterans Affairs, HERL is a joint effort of the University of Pittsburgh School of Health and Rehabilitation Sciences and the School of Medicine, and it thrives as an interdisciplinary operation where computer, mechanical, and bio- engineers collaborate with physicians and occupational and physical therapists. Pitt associate professor of physical medicine and rehabilitation Brad Dicianno (MD '01, Fel '05) is its medical director.

Cooper, the FISA & Paralyzed Veterans of America Professor and Distinguished Professor of Rehabilitation Science and Technology, is also a professor of physical medicine and rehabilitation, of orthopaedic surgery, and of bioengineering. He credits his generation with raising the bar for wheelchair users from simply living healthy lives to participating more fully in society. "Now we're in the crowd," he says. "The next step is to be part of the crowd."

Cooper has played a significant role in this progress.

While earning his PhD at the University of California at Santa Barbara, he collaborated with a group of designers to create one of the first racing wheelchairs. He was the first engineer to use a solid frame to replace a traditional folding frame, and he was one of the first to introduce a three-wheeled chair. He invented the SmartWheel, a feedback mechanism tracking the force and movements on push rims. The SmartWheel creates automated reports for doctors to optimize wheelchair setup and cater push styles to reduce repetitive stress and the risk of carpal tunnel and rotator cuff injuries.

Inspired by the data the SmartWheel obtained, Cooper moved the axle forward on his racing chair, which some have argued is the most revolutionary advance in manual wheelchair design history. He was the first to put fenders over the wheels on a racing chair to prevent the tires from bruising arms. Wheelchair racers often overcompensated for the crown on roads and crashed, but Cooper fixed that issue when he designed a crown-compensation mechanism to keep the chair rolling straight.

At HERL, Cooper oversees dozens of full-time employees in a 40,000-square-foot facility in Pittsburgh's Bakery Square. Google is a neighbor. Cooper, a veteran who has a disability, hires many veterans, several of whom have a disability, as well.

Along one wall in Cooper's office is a wood and wicker wheelchair from the early 1900s; in the corner, stands a foldable, steel Everest and Jennings wheelchair from the World War II era. The latter is similar to the wheelchair Cooper was given after his own cycling accident in 1980. When Cooper sees the chairs, he says he thinks about how far human engineering has progressed.

Cooper says the biggest change in wheelchair design over his career is that the focus is now on the person, not the chair. "The change happened when the consumers got involved [in engineering]," he says.

The engineer doesn't know which of HERL's 70 current projects excites him the most. "It's like picking your favorite child," he says. A couple of notable projects include a robotic bed that folds and then shifts like a conveyer belt to move people in and out of a wheelchair and a cueing kitchen that helps people with disabilities prepare meals safely with portable and sensing technology. HERL is also developing a few robotic arms: the Personal Mobility and



Jonathan Duvall (left) and Brandon Daveler (right) are graduate student researchers at HERL.

Photo by John Altdorfer

Manipulation Appliance (PerMMA) incorporates two robotic arms to help with everyday tasks, and StrongArm, which is mounted on a wheelchair, lifts users, transfers them, and then folds behind the backrest. And a team that includes Pitt Med physical medicine and rehabilitation assistant professors Robert Gaunt and Jennifer Collinger (both PhD engineers) and professor Michael Boninger, HERL's senior associate medical director, have been developing a brain-computer interface. The technology allows a user to move a robotic arm just by thinking about it. The user can even sense when the robotic arm is touching something. That project, based on science done by Distinguished Professor of Neurobiology Andrew Schwartz, has generated a lot of buzz.

Not surprisingly, considering Cooper's resumé, HERL is developing a couple of promising new wheelchairs:

With six wheels, MEBot (Mobility Enhancement Robotic Wheelchair) climbs curbs, and in 2017, it won the Blackwood Design Award for best new concept.

The PneuChair is likewise making waves—it's a waterproof, motorized chair propelled by compressed air, and it won Pitt's Kuzneski Innovation Cup. In the spring of 2017, Morgan's Wonderland, a 25-acre theme park in San Antonio, opened a companion water park named Morgan's Inspiration Island. The fully accessible park uses PneuChairs from HERL. (See Follow-up on p. 34.)

A graduate student researcher at HERL, Daveler was the lead mechanical design engineer on PneuChair and MEBot. Daveler didn't travel to Texas with Cooper to see the PneuChair in action at the park, but he saw videos of children playing in the water in the chairs.

"It's rewarding to see the reactions of people when they see the devices in action," Daveler says. "But it really hit home" with the videos.

Daveler says the independent streak that led him into racing now fuels his desire to help other power chair users live self-sufficiently.

It's similar to what drives his boss: "It's really about making a difference in people's lives," Cooper says.

Along with others of his generation, Cooper made it easier for Daveler to return to school following his accident, to be "in the crowd."

On July 23, 1980, Cooper suffered a severe spinal cord injury while stationed in Germany. He was a U.S. Army sergeant pedaling a bicycle along Berliner Strasse in the town of Worms, heading to see his future wife, Rosemarie Emans. A bus forced him into oncoming traffic, and he was hit by a truck.

Months after the accident, Cooper returned to his home state and enrolled at California Polytechnic State University, San Luis Obispo. The Americans with Disabilities Act was a decade from becoming law. Public buildings weren't required to have ramps or elevators. Cooper often had to be carried up stairs to labs, where the tables were too high for him;

in classrooms, he turned desk chairs backward and hunched over them to take notes. Cooper and his friends who faced similar challenges were frustrated with technology dating from the Truman administration. They were inspired to research wheelchair designs, saying, *Nobody's going to change it unless we change it ourselves.*

So that's what they did. Twenty patents granted or pending later, Cooper's contributions have gained notice. His office shelves are decorated with an array of pictures, plaques, and awards. Among his many honors: the Secretary of Defense Meritorious Civilian Service Medal and the American Association for the Advancement of Science Mentor Award.

In 2016 alone, he was recognized nine times with national and international honors. Last year, Partnership for Public Service gave him the Samuel J. Heyman Service to America Medal, also known as a "Sammie." And Cooper was just named a fellow of the American Association for the Advancement of Science.

Cooper is an avid marathoner. In 1988, he won a bronze medal in the Paralympic Games in Seoul. Since 1983 he has won a gold every year in the National Veterans Wheelchair Games. The medalist's visage has been featured on a Cheerios box. In his daily life, Cooper uses an 18-pound titanium wheelchair that he helped design. It looks like a racing wheelchair.

Daveler says he was mesmerized the first time he entered Cooper's office. He looks up to Cooper and is inspired by his achievements. Jonathan Duvall feels the same way.

On Feb. 13, 2007, Jonathan Duvall, a 21-year-old Pitt undergrad from Salem, Ohio, was sledding. A blizzard had pummeled the city, and a walkway created a natural jump. Duvall flew off it on an inner tube and landed on his head.

Duvall's friends gathered around as they waited for paramedics to arrive. Looking up at them, Duvall was shocked and scared. He had heard his neck crack, and he couldn't move.

"Kick my legs," he said.

Duvall assured his friends that he wanted to know whether he could feel it. So, they kicked, and when he felt their boots land, he hoped it was a good sign. But it wasn't. He'd broken his fourth cervical vertebra and developed quadriplegia.

And four months later, after he had dropped out of Pitt and moved in with his sister in Ohio, Duvall wasn't depressed or angry. He was bored.

He wasn't mapping out his life like his friends were. He was watching television, and that was about it. But then he broke his leg during physical therapy and returned to Pitt to see John Horton, an MD assistant professor of physical medicine and rehabilitation. Horton had been working alongside Rory Cooper since 1998, and he asked Duvall if he had returned to college yet.

"I was like, *I can go back to school?*" Duvall says.

Like Brandon Daveler, Duvall is now a graduate student researcher at HERL and is earning a PhD in rehabilitation science. The two have become good friends. They each volunteer as peer mentors to other wheelchair users. Duvall founded Pitt's Students for Disability Advocacy group and was its first president. Daveler is its current president. They have discussed starting a consulting firm together.

Cooper says, "What makes [Duvall and Daveler] really stand out in this field is their personal insight and their persistence to learn and incorporate new advances and concepts."

Jonathan Duvall was part of a team that developed a pathway measurement tool: a three-wheeled device that collects data on sidewalk length, width, roughness, and tripping hazards. After winning first place and $20,000 at the 2014 Randall Family Big Idea Competition, hosted by Pitt's Innovation Institute, the engineers launched their own company, Pathway Accessibility Solutions, or pathVu.

Duvall's interest in urban landscapes began shortly after his accident. Several months after he had returned to Ohio, he visited Pittsburgh to see his friends. His fraternity was hosting a party at a house on Semple Street in South Oakland. It was a warm day, and Duvall was hanging out on the sidewalk when one of his pals invited him inside. The house sat on a hill, and to get inside, Duvall needed to scale two flights of concrete stairs. With a sarcastic smirk, Duvall asked how he was supposed to get up there.

"Pledges!" the friend yelled.

The fraternity's pledges carried Duvall up the stairs and into the house. (They made a second trip for his wheelchair.) Later, they carried him back down. Reminiscing about that night, Duvall calls it neat. But the event also drove home issues of inaccessibility. He says this barrier can play with your mind.

"If I was trying to get into a place, I felt like everyone was thinking, *Why is he making us go through this hassle holding doors?*" he says.

Pittsburgh is a particularly difficult city for people with disabilities to call home. Many apartments are in houses that are around a hundred years old and inaccessible, and new rental units, like the ones in Bakery Living, across the street from HERL, tend to be expensive.

More than 2 million Americans use a wheelchair for daily tasks, according to the CDC. However, the U.S. Department of Housing and Urban Development determined in 2011 that while a third of housing may be modifiable for wheelchair users, only .15 percent of U.S. homes were accessible to them.

Future iterations of MEBot could help. The robotic chair, now on its second version, can climb an 8-inch-high curb in 30 to 40 seconds. MEBot's first version took a few minutes to do this.

One recent December morning, Jorge Candiotti, a postdoc and MEBot's lead software and electrical engineer, demonstrated MEBot scaling a curb in the lab. Candiotti pressed a lever, and MEBot rose. Daveler explained that the point of the height increase was to make turning on light switches and talking to people at eye level easier.

MEBot runs on six wheels—two large center driving wheels that reposition to the front, middle, and rear of the frame and four smaller caster wheels (two in the front and two in the back) that are controlled with compressed air and move up and down freely. This design served as Daveler's master's thesis, and it has brought HERL closer to creating an indoor-



Rory Cooper, sitting in a wheelchair that he helped design, outside HERL's 40,000 square-foot facility in Bakery Square. He says that the most significant changes happen when consumers get involved in engineering.

Photo by John Altdorfer

outdoor chair that can handle various terrains.

Using the power controls, Candiotti rolled the chair in front of a curb-like platform. He pressed a lever, and the chair rose using compressed air.

"He's elevating the chair to get the front wheels up onto the curb," Daveler said. "And now, what will happen is he'll move the entire frame forward onto the curb."

The frame slid forward, and the rear caster wheels lifted off the ground. MEBot was on the curb. Even with Daveler's narration, the demonstration took less than a minute. The increased speed was a major improvement over MEBot's first version.

But, in 2013, when Daveler and Candiotti showed the simulation to Cooper, he challenged them to go further, to design it to scale a staircase. Daveler says it was an example of "Dr. Cooper being Dr. Cooper."

The MEBot team spent the next four months changing designs and running simulations. But they couldn't come up with a way for MEBot to climb stairs without making major redesigns. It needed to be much longer, but that would have made it less maneuverable indoors, and the project's goal was to create a power chair that overcame obstacles both inside and out. Daveler concluded it wasn't safe for the 440-pound power chair to climb stairs.

He calls the day he accepted this and admitted it to Cooper one of his hardest times on the project.

The MEBot team is now switching the chair's power system from pneumatics to hydraulics. But Daveler might not be at HERL when the next iteration is complete. He plans to start a company around pneumatic-powered mobility devices when he graduates next year. After Jonathan Duvall finishes his PhD this spring, he'd like to continue at HERL and join the faculty.

When Daveler leaves HERL, he will miss working in a lab where projects are designed, built, and tested in the same building.

And, he notes, "There aren't many universities that allow its students to go from having an idea to commercializing it."

He'll also miss working for Cooper, a mentor who has become his friend.

"Everything that he's done, and his passion to help people with disabilities and veterans, it's really inspiring."

Cooper says HERL's success wouldn't be possible without help from Pitt, UPMC, and the VA. And he wants to follow in the footsteps of the former two by growing globally. HERL already collaborates with labs in Japan and Germany; later this year, Cooper will begin to mentor graduate student researchers with disabilities from the United Kingdom and Germany.

"What we've done with Jonathan and Brandon, we're going to do that worldwide," Cooper says. ■



ROBIN JERSTAD

Morgan's Inspiration Island in San Antonio

"LIKE WAKING UP ONE DAY AND BEING ABLE TO FLY"

ACCESS TO FUN



COURTESY PRISCILLA HANEY

Sammi Haney

Gordon Hartman needed a wheelchair that could get wet. He was building Morgan's Inspiration Island, the world's first fully accessible water park, in San Antonio.

But, as Hartman told the *New York Times* for a December video, "That didn't exist."

Hartman reached out to Rory Cooper, director of Pitt's Human Engineering Research Laboratories (HERL) and Distinguished Professor of Rehabilitation Science and Technology, who has multiple Pitt appointments, including professor of orthopaedic surgery. It just so happened that HERL was developing PneuChair, a motorized wheelchair that uses high-pressure air as an energy source. Unlike traditional power chairs, which depend on heavy batteries and electronics, PneuChair is waterproof—a perfect fit for Morgan's Inspiration Island.

HERL loaned one PneuChair to the San Antonio park last year; the park purchased three more, and it expects to have six more by the time it opens this spring.

Brandon Daveler, a graduate student researcher at HERL, was the lead mechanical design engineer on the PneuChair project. (See p. 29 for more on Daveler, Cooper, and HERL.) Daveler is also a power-chair user. He told the *Times* that being able to play at a water park would change the lives of children with disabilities: "It would be like somebody waking up one day and being able to fly. You're free. You can do it, like any other person who can go to a water park."

The *Times* story and video chronicles 8-year-old Sammi Haney as she visits Morgan's Inspiration Island for the first time. Haney has osteogenesis imperfecta, or brittle bone disease, and uses a power wheelchair. She was born with 19 fractures and breaks a bone multiple times a year.

As the Haney family arrives at the park in the video, Sammi says, "This is going to be awesome!" and zips ahead of everyone. Soon after, she's dousing herself and spraying her older brother with a water cannon.

Cooper says he received 300 e-mails the day after the *Times* story came out. People were interested in using PneuChair in therapy pools, at beaches, and in rivers for fishing.

Cooper founded HERL in 1994 with the goal of helping to create a more inclusive world. And that includes access to fun. "It does affect your quality of life if you're excluded from these summertime activities," Cooper says.

"Seeing the smiles on those kids' faces when they got to go to the water park for the first time and actually do things on their own was such a reward."

As the *Times* video closes, a happy Sammi Haney sings, *I can swim in the water. I can swim in the air.* —*Gavin Jenkins*