BY DAVID ROBERTS
PHOTOGRAPHS BY NIGEL PARRY/CPI

.reinventing the human machine

Thirty years ago, MIT scientist **Hugh Herr** lost his lower legs in a climbing accident. But he also found the purpose of his life: to use technology to make disability disappear. This year, after the Boston Marathon bombings, his mission took on a new urgency.

Hugh Herr *at his MIT lab with a robotic device that maps body dimensions for fitting prosthetics.*

On April 15 of this year, Hugh Herr's work gained a sudden new importance. "I was in Spain," he recalls, "hiking on the Camino de Santiago. I first heard reports from students of mine who were trapped in the MIT Media Lab. Bombings, carjackings, shootings—at first I didn't think it was real. Then I felt hopeless, powerless. I was so far away." ¶ Perhaps as much as anyone in the world, Herr knew what the victims of the Boston Marathon bombings would be going through, and even more important, how they could be helped. ¶ When he returned to Cambridge, Herr didn't immediately try to contact those who'd lost limbs. "It takes time," he says, "for a victim and their family to reach out. And there were so many celebrities coming forth, I took a backseat at first."

Soon, however, he began doing public speaking engagements about the benefits technology could bring to accident victims. Attending one event was 33-year-old Adrianne Haslet, a professional ballroom dancer from Boston who'd lost her left leg below the knee in the marathon bombing. That setback was as terrible for Haslet as Herr's own tragedy had been 31 years before.

"I remember her towering smile as she sat in the audience with her parents," recalls Herr. After the talk, Haslet shyly approached the stage and introduced herself. A few days later, she visited him at MIT, where he showed her a high-tech artificial leg he'd invented. Battery and microprocessor-controlled, it's the most advanced prosthetic device in the world. Haslet put it on.

"I started jogging around the office like a little kid," she says. "I was yelling, 'I can't believe I can do this!' But then Hugh said, 'Let's go outside. I want you to walk down a hill.' I didn't think I could do it. But he took me by the hand, and we started walking. After the first few steps, I grabbed Hugh and hugged him.

"When I put on the prosthesis, for the first time I could feel my foot move," Haslet adds. "It was pretty emotional. Now Hugh's become my good friend. He's so warmhearted and humble, it's easy to forget that he's an amazing inventor. What I admire most about him is that he doesn't settle for anything. He knows that things can get better, and that everybody deserves that.

"Now I know I'll dance again."

HUGH HERR HAS COME A LONG way from the 17-year-old kid I first met 30 years ago at his home in Lancaster, PA. At the time he was crafting his own artificial legs out of rubber, metal, plastic, and wood in a local machine shop.

He was doing what he could to come back from a terrible ordeal, one that had nearly killed him and a friend.

Only a few months before, despite his youth, Herr had emerged as one of the best rock climbers in the United States, putting up new routes at the Shawangunks (aka "the Gunks") near New Paltz, NY. With no plans to go to college and no notion of a future career, the teenager lived for climbing.

On Jan. 22, 1982, Herr and his friend Jeff Batzer drove up to New Hampshire for an ice climb in Huntington Ravine, on Mount Washington. The next day, after an uneventful ascent of Odell's Gully, the boys headed for the summit. Engulfed in a whiteout blizzard, the pair got disoriented. Instead of descending the easy Central Gully, they accidentally ventured into a remote chasm called the Great Gulf, sending them down the wrong side of the mountain.

Utterly lost and without snowshoes, the two floundered on through deep snow for three more days. After three wretched bivouacs in the unrelenting storm, both climbers were on the verge of death from hypothermia and frostbite and had given up all hope of surviving. They prayed. They talked about death. Finally, Herr said to Batzer, "I think this is it," and Batzer replied, "I think so, too."

But suddenly they heard a noise, and saw a woman only 10 feet away. She was an Appalachian Mountain Club rescuer. "It was like a vision," Herr recalls. The woman asked if the pair were "the guys from Odell's Gully. "We spilled out a 'yes,'" Herr says. "She gave us some raisins and a sweater." Soon they were helicoptered out.

After more than a week of morphine-hazed agony in a hospital in Littleton, NH, Herr was transferred to Philadelphia's Penn Presbyterian Medical Center, where both legs were amputated six inches below the knees. Batzer underwent amputation of one leg, one foot, and the thumb and fingers of one hand. The outcome seemed to spell not only a terrible loss for Herr, but also the end of his climbing career.

Yet only five months after his amputations, to the astonishment of his peers, he was back at the Gunks, where, with the help of prosthetics, he was leading 5.11 pitches (the number rating reflecting the difficulty of a climb)—not far below the level he'd attained before Mount Washington.

In the following months, he upped his standard to 5.12. And then, with climbing partners Lynn Hill and Russ Clune, he put up Vandals, the first 5.13 climb established on the East Coast. Not only was Herr climbing with artificial legs—he'd also manufactured a variety of wooden "feet" to attach to the prostheses. Depending on the moves required for a given route, he could also insert "blocks" to change his height from 5'7" to more than 7'. His friends at the Gunks nicknamed him "the Mechanical Boy"—a moniker he relished.

The profile of Herr I wrote for *Outside* magazine, titled "The Mechanical Boy Comes Back," heralded the most amazing recovery of an athlete from a state of irreversible disability I'd ever heard of. In person, I found Herr shy and likable. But I had my doubts. He seemed to be floating on what alcoholics call the "pink cloud"—the illusory euphoria that the first few weeks of sobriety can induce. Herr was claiming that his artificial feet actually gave him an advantage over "normal" climbers. With all the wisdom of his 17 years, he was making grandiose pronouncements: "In the future, with technology, people will be less afraid of something. They'll just come back and be better, stronger, faster. They have everything artificial now except the brain."

Was the kid, I wondered, simply in denial about his loss? To counter his upbeat flights, I quoted his grieving father: "I don't think Hugh has a day without intense pain," he told me. "You have to remember, he can climb a whole lot better than he can walk. That's a lot of crap, that it's an advantage not to have feet."

TODAY, IN HIS OFFICE AT MIT'S MEDIA LAB, HUGH HERR rolls up the cuffs of his blue jeans. Instead of human flesh, I see a pair of gleaming silver-and-black metal devices that connect the stumps of his

Grooming by Michele McGrath/Anchor Artists.

"What I admire most about Hugh is that he doesn't settle for anything. He knows that things can get better, and that everybody deserves that."

knees to the running shoes he wears on his artificial feet. They look like features a cyborg would flaunt in some apocalyptic sci-fi movie.

"Is that the computer?" I ask, pointing at the square black box mounted on the back of one of Herr's prostheses.

"No," he answers. "That's the battery. The computers—there are three of them—are built into the metal structure itself. Each of them is the size of your fingernail. Smaller than your fingernail."

"Wow," I mutter involuntarily.

At age 49, Herr is an MIT faculty member with the tongue-twisting title of associate professor of media arts and sciences and health sciences and technology. He's the director of the 35-person Biomechatronics research group. His life's work is designing prostheses for maimed athletes, and using technology to expand the possibilities of the human body—skills at which he's arguably the world's leading practitioner.

The complex metal apparatus that Herr rolled up his jeans to show me, and which Adrianne Haslet now wears, is called the BiOM. Invented by Herr and developed by the Biomechatronics group under his leadership, the BiOM, commercially available since 2010, differs from all other artificial legs in that it "emulates lost muscle function," he explains. "Other prostheses use the person's remaining muscles to supply the energy to move the legs," but the BiOM "transports the human body. It's like a car. The other prostheses are like bicycles."

The BiOM is also the first prosthesis to normalize walking speed, walking metabolic energy, and the stress walking puts on the body, Herr says. "In other words, if you measure the walking of two people with the same height, weight, and age, one with a normal human leg and one wearing a BiOM, there's no statistical difference. To me, the most exciting benefit is that we've mitigated leg stress believed to be causal of osteoarthritis that severely afflicted amputees using conventional prostheses." When you see Herr walk, you can't tell he's wearing artificial limbs. In fact, he can tap-dance with them, as he did at the end of a TEDMed talk in 2010.

It's not coincidental that in the years since his accident, Herr's career has soared in a trajectory he couldn't have dreamed of when all that mattered to him was climbing. The teenager who never planned to go to college got his B.A. in physics from Millersville, a small university near his Lancaster home. From there, he headed to MIT, where he earned a masters in mechanical engineering, then to Harvard for a Ph.D. in biophysics. He's now tenured at MIT. The Mechanical Boy has become a grown-up biomechanical genius.

Herr goes on to explain how the BiOM ankle-foot system works. "The sensors built into the foot detect the force you need when you take a step. They send the appropriate information to the computers. Then the computers tell the motor—which is also built into the structure—how much energy to supply. The battery is the source of the energy."

Of course, it's far more complicated than that. "The ankle is the most important joint in the human body, and the Achilles tendon is its spring," he explains. "We replicate it with a mechanical spring. The human body contains many, many springs, like strong elastic bands. Tendons and ligaments are springs. Even bones and muscles. We build in all kinds of other springs, to control the heel pad, the arch, and so on."

For all his seriousness, Herr smiles as he confesses, "It's all somewhat mysterious, even to me." But then he continues, "There's such an amazing complexity going on between the machine, the human body, and the environment. We discovered that interaction only by studying how the human body works, then 'stealing from nature.'" His lab has shot hundreds of hours of video to generate complex computer models of the human stride in action.

IT'S INSPIRING TO SEE THE results, with real people in the real world. But the passion that drives this workaholic scientist is fueled by something else. It's guilt, which Herr has transformed into a debt he feels he owes to the world. The guilt has its roots in the tragedy that happened those three decades ago.

During the massive search for Herr and his friend, a rescuer named Albert Dow was killed in an avalanche on a steep slope not far from the top of Odell's Gully. Herr has never gotten over that death, for which he feels directly responsible. The simple mistake he and Batzer made in an instant, when they went the wrong way in the midst of the whiteout gale, ultimately cost a man his life. As he says today, "I thought it would be an insult to the memory of Albert Dow to pity myself and to stay in a wheelchair. Out of this came an enormous will to walk again, to climb again."

The prostheses his doctors fitted him with—state of the art in 1982—seemed woefully crude to the budding mechanic. "I thought," Herr recalls, " 'Really? That's it?' " And so, he adds, "I very quickly dedicated my life to making artificial body parts better and better, to the point where they're actually bionic."

He admits that guilt about Albert Dow is still a major motivating force. "Not really on a conscious level anymore," he explains. "It's not a daily thought. But it's an underlying driver."

Herr's intensity verges on the legendary. Rodger Kram, a professor at the University of Colorado in Boulder and Herr's close friend and colleague in biomechanics, offers a keen insight: "Hugh lacks the ability to be superficial. He really has no concept of or patience for small talk. Let's say that I arrive at an airport and meet him. He knows that he's supposed to ask me how my flight was. But the second thing out of his mouth is, 'I've got this amazing idea that's going to revolutionize...' Then he'll talk about it really fast, and I'll struggle to understand what he's saying. But I try hard to keep up because it's probably really important. It's not that I'm stupid. It's just that Hugh will tell me about things that are truly far out there. I think he finds words to be an awkward way of sharing what he sees inside his own head."

If even Herr's own explanation of how the BiOM works remains cryptic, take a look at the YouTube videos of BiOM users. As LisaMarie Mallette, of Pierrepont, NY, walks up and down an inclined ramp, she suddenly raises her palms upward and shouts, "Oh, my God! It's as if I had a real leg!" Steve Martin, from Phoenix, jogs skillfully up a rocky desert trail strewn with scree. As he comes to a stop, he starts giggling with sheer joy.

No Barriers Boston, a fund launched by Herr and others, is a spin-off of No Barriers USA, an organization for which Herr was a board member for several years. One of its goals, according to executive director David Shurna, is to help people who've suffered devastating physical trauma reshape their lives to overcome adversity. Its program Soldiers to Summits enlists disabled vets to climb serious peaks (such as Cotopaxi,in Ecuador) with the help of guides. Another project in the works is an overland trek partway to the South Pole.

At No Barriers' biennial Summit Conference in Telluride in August 2013, Herr was a featured speaker. Says Shurna, "Hugh is humble and soft-spoken, but his talk was completely inspirational. Many in the audience told me that his message—that through technology, we can eventu-

Vintage photo courtesy of James Balog

Left: *Hugh Herr, at age 18 in 1983, shows off the artificial feet he built to continue climbing after his near-fatal mountaineering accident.*
Below: *Herr at his biomechanics lab at MIT in September 2013.*

ally live in a world without disability—profoundly affected them."

Herr's idea of no disability is not a rhetorical one. As he sees it, over time his bionic legs, rather than aging, will actually improve due to hardware and software upgrades. That's something not available to "normal" people, he says. Eventually, with the right technology, people with disabilities will seem as normal as those who wear glasses.

"What I get from Hugh is the belief—so central to No Barriers—that it will take a shifting mindset, not just a shifting skills set, to change the world," says Shurna.

Herr has done much more than invent the BiOM. He holds more than 30 patents for all kinds of other biomechanical devices, including something called the Rheo Knee. And he's been widely celebrated for his work. *Time* magazine twice saluted him, in 2004 and 2007, for making one of the top-10 inventions of the year. He's won the Spirit of da Vinci Award (2008) and the 13th Heinz Award for Technology, the Economy, and Employment (2007). And way back in 1989, he was inducted into the Sports Hall of Fame.

One of his biggest achievements came in 2008, after a milestone ruling by the governing body of international athletics, the IAAF. It banned Oscar Pistorius—who's now facing trial for the death of his girlfriend in South Africa—from the Olympics. The IAAF argued that Pistorius' carbon-fiber "cheetah" prostheses gave him an unfair advantage over other runners. The IAAF hired a German research team to test its finding, which the team certified.

Pistorius' New York law firm got in touch with Herr, who, with Kram, agreed to reevaluate the biomechanical tests the Germans had run. The physics involved are complex, but according to Kram, "The German team asked the wrong question and used inadequate tools to answer it. They did so under pressure from the IAAF." Kram and Herr's retesting, since verified by other experts, persuaded the IAAF to relent. Pistorius was cleared to run in the 2008 Olympics (though he later failed to qualify).

Whatever Pistorius' present personal fiasco signifies, Herr looks on the 2008 case proudly. For him, the controversy was more than a question of science. "The IAAF was saying, 'We can't let Oscar run or it will destroy the purity of the sport.' It's the same kind of argument that's been used in the past against women and blacks."

Herr's colleagues at the Media Lab know best how he works, and are unstinting in their admiration. Says Sony Corporation career professor Neri Oxman, "What Hugh has is grace under pressure. When rock climbing, he's able to clearly envision the single path of ascent that makes for the most effective climb, while in reality there are close to infinite paths to be taken. This is also true of his work and his way of being in the world."

Nicholas Negroponte, co-founder of the MIT Media Lab, who hired Herr in 2004, wryly observes, "A conversation with Hugh is as much about what he doesn't say. Minor issues aren't discussed. Big ones are. You cannot imagine how refreshing this is in an environment, the academic one, where people argue strenuously because they have too little to lose or gain."

Adds Oxman, "His integrity is the quality I admire the most. He's a man of few words and fearless actions, with childlike curiosity. T.S. Eliot once said that only those who risk going too far can possibly find how far one can go. Hugh is amongst these rare searchers."

ALTHOUGH HERR ADMITS TO BEING A WORKAHOLIC, HE tries to balance his life away from the MIT Media Lab. He and author Patricia Ellis Herr, who has a masters in anthropology from Harvard,

are the parents of two young girls, Alex and Sage. At the age of 9, Alex became the youngest person—male or female—to reach in winter the summits of all 48 New Hampshire peaks higher than 4,000 feet. Her mother wrote a beguiling memoir about that quest, titled *Up: A Mother and Daughter's Peakbagging Adventure*.

Surprisingly, Herr's career as a climber had nothing to do with Alex's mission. It was only after she was well into her campaign among "the 4,000ers"—and after her parents began to worry about the dangers of the Presidential Range in January—that Herr sat his daughters down and told them the story of how he'd lost his legs. The girls had simply assumed that Papa was different, a father with metal legs instead of ones made of flesh and bone. They often enjoyed helping him put on his prostheses in the morning.

The girls were horrified by the story ("Did it hurt, Papa? Were you cold?"). But Alex went right on challenging the rime-covered peaks, often with Sage as her partner. Their drive, no doubt, owes something to their genes.

With his focus and modesty, Herr is often perceived as unemotional, all science, no nonsense. He's aware of that, and it bothers him. "Actually, I'm very emotional," he says. "I just don't express what's inside. My students tend to be afraid of me, and I wish they weren't."

"Why are they afraid of you?" I ask.

He laughs. "Because I'm stoic to a fault. I suspect it's coupled with my intensity, and that makes them nervous."

This reflection launches a kind of apologia for the way Herr operates. "To be creative," he says, "you have to believe in something that doesn't yet exist. The act of creation is human-like, not machine-like. You have to have faith in what most of the world says is impossible. That's very emotional, even spiritual.

"I'm very calm under pressure," he goes on. "I think good leaders have to convey the impression that they're under control in very stressful circumstances. When you're facing death, or a deadline, and you have to rip your chest open to get your ideas out into the world, you can't panic. You have to stay calm."

Herr stops for a moment, then adds, "Great ideas come from meditation. I don't get my ideas when I'm speaking or attending conferences. I get them sitting in a chair, in a quiet place. Alone. And I have to be very well rested.

"Idea people are overflowing with emotions. That's where ideas come from."

NO MATTER WHAT, HUGH HERR remains an extraordinary example of a person turning a tragedy into not only personal accomplishment, but also a career devoted to improving the lives of others. At the end of our meeting in the Media Lab, I say, "The accident at 17 was obviously the turning point of your life. In some ways, are you glad it happened?"

Herr pauses, deep in thought, his hands steepled.

"I'd do anything to go back and erase what happened to Albert Dow," he says. "But if I couldn't, and a fairy offered me one wish, I wouldn't wish for normal legs. I'm completely happy with my bionic limbs. I think my body is far more interesting than a normal body." ■

For more info on No Barriers Boston, visit nobarriers.fundraise.com/nobarriersboston