# THE INCREDIBLE

## (BLIND, PARAPLEGIC, AND UNSTOPPABLE)

# BIONIC MAN

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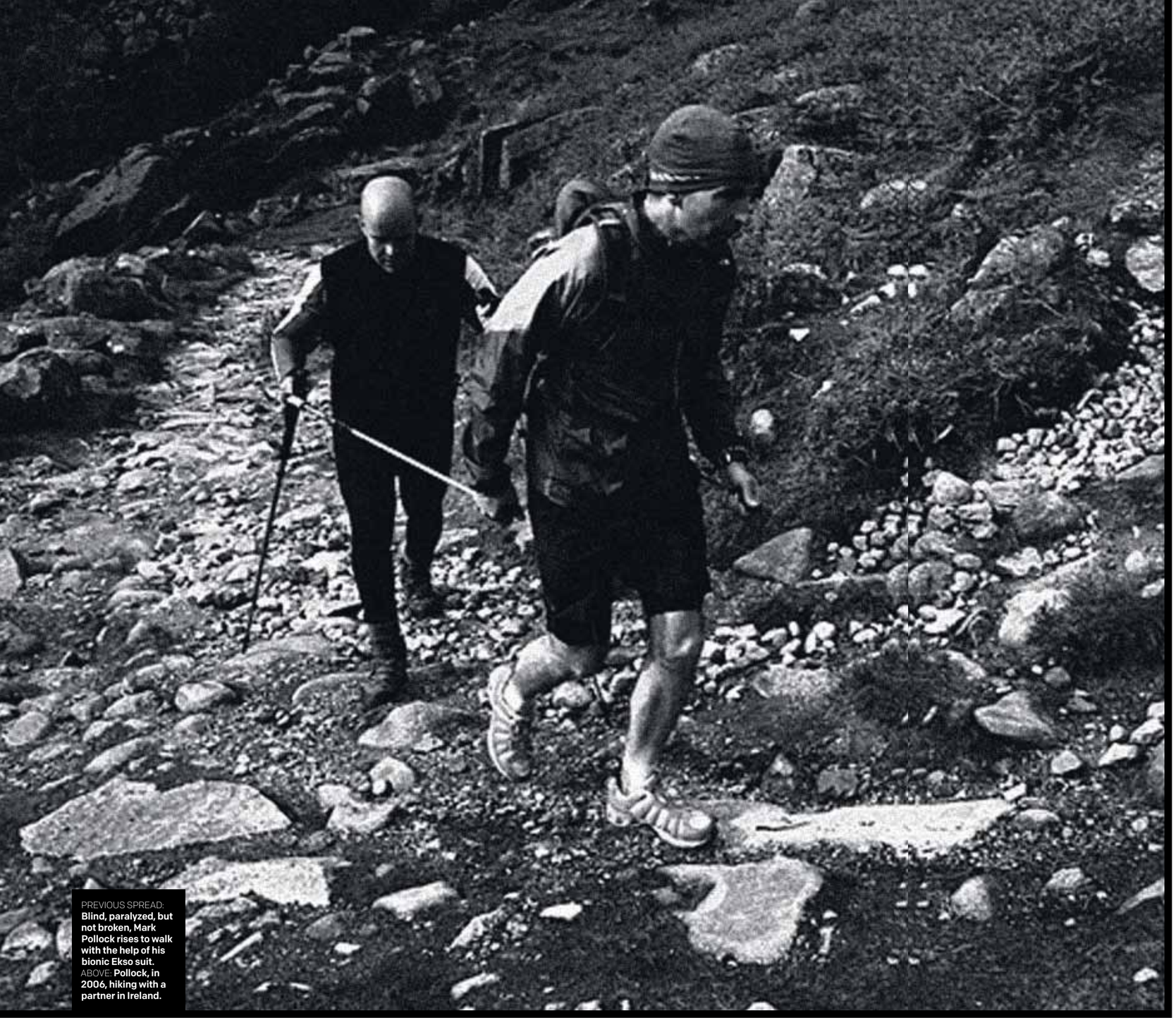

PREVIOUS SPREAD: **Blind, paralyzed, but not broken, Mark Pollock rises to walk with the help of his bionic Ekso suit.** ABOVE: **Pollock, in 2006, hiking with a partner in Ireland.**

PHOTO CREDIT HERE

# MARK POLLOCK

stands up—a little unsteadily at first, like a guy recovering from a long night. He exhales, centering himself, the crutch in each hand providing a modicum of support. He's in great shape—six feet tall, barrel-chested, muscles bulging through a tight shirt. His head is shaved, and the overhead lights in the gym at Trinity College in Dublin, Ireland—a home away from home where he works out two or three hours a day, six or seven days a week—are reflecting off his polished cranium. He's handsome, the kind of guy who can pull it off.

The goal today is 2,200 steps. Pollock exchanges a few words with his lead trainer, Simon O'Donnell. They speak a well-worn shorthand, evidence of a friendship born of intense experiences, like the time they raced to the South Pole together. That was back in early 2009, ten years after Pollock went blind, and one and a half before the fall that left him paralyzed from the waist down. Now Pollock puts one of the crutches out in front of him, tapping it on the ground. He takes a step forward, and as he does, the thin backpack strapped to his torso emits a gentle chirp.

To know Mark Pollock well, to really understand him, you have to divine something about the relationship between man and machine. Watching Pollock walk, it's obvious that he's achieved a certain synchronicity with the mechanical. Though he can't move his legs on his own, he stands and takes steps with the aid of an unobtrusive bionic exoskeleton—a robotic suit worn over his clothes. The backpack, lashed to his torso by what looks like a weight lifter's belt, connects to a slick tubular assembly that runs down the outside of each leg. These braces keep Pollock upright, bending dynamically to mimic his natural gait as they propel him forward.

Pollock actuates each step with the crutches, reaching forward and lightly placing one and then the other on the ground. When he's found a good rhythm, the chirps come about a second apart. The only other sound is a gentle electric whir from the exoskeleton's four motors. Pollock has been called Iron Man and a real-life Steve Austin—the comparisons don't stretch the imagination.

But even before the pair of events that threatened his independence, before he became the most ambitious user on the planet of a new class of technology that may soon let paraplegics walk again—a technology being developed in an old Ford assembly plant 5,000 miles away in Richmond, California—Pollock had formed a bond with the devices around him. They've never defined him, the machines. It's just that through them, he's always found the purest ways to express himself.

The engineers developing the technology that's enabling Pollock to walk again share a similar connection with machines. Last spring I visited Ekso Bionics, the Richmond-based company that's bringing bionic exoskeletons out of the realm of science fiction. About 45 people—engineers, programmers, assembly workers, physical therapists, and office staff—work in the company's 44,000-square-foot headquarters overlooking Richmond's Inner Harbor. The company's signature Ekso suits hang from tethers around the high-ceilinged factory space, waiting to be worked on. A pair of spindly legs attached to a backpack that contains rechargeable batteries, each suit looks eerily like a new model from Cyberdyne Systems—Terminator Lite.

Employees call this area Base Camp, and it's

where physical therapists can learn how to work with patients who will be using the device. It's also where a number of those patients—most having suffered spinal cord injuries or strokes—take their initial rehabilitative steps. Pollock logged his first uncertain strides in 2012 in the company's old headquarters in Berkeley, the first time that a blind person had used the suit. The experience of seeing someone with paralysis stand and walk again is always cause for celebration at Ekso Bionics, and the premises are imbued with an infectious atmosphere of hope. Even the bathrooms teasingly hint at the company's aspirations—stick figures in bionic suits complement the usual emblems on the door placards.

Nate Harding and Russ Angold, cofounders of Ekso Bionics, are not what one might call spec-sheet engineers, operating in the realm of the conceptual and academic. Rather, they are proud gearheads, and their tinkerer's approach has helped them advance bionic exoskeleton technology far beyond what was previously possible.

Around that time, Angold was finishing up an undergrad degree in agricultural engineering at Cal Poly, San Luis Obispo. For a senior project, he and some friends built a competition pull tractor powered by a 12-cylinder Allison aircraft engine, the kind used in early fighter planes. Angold needed a job after graduation, but he wasn't wild about his prospects. Bay Area recruiters tend to overlook nuts-and-bolts engineers in favor of students who work well at a computer. Angold didn't even look like an engineer—he has the same bulldog face and thick biceps as his brother, a former Navy SEAL.

When he finally got a call back for an interview, he knew that he had to make it count, so he invited the interviewer—who turned out to be Harding—to campus. "Holy shit," Harding said when Angold unveiled his plane-engine pull tractor, "I can't believe you built this thing as a class project." That's how Ekso's future CEO and chief technology officer met—not in a lab or an office, but drooling over a piece of souped-up farm equipment.


INDOMITABLE: **Since going blind at 22, Pollock has accomplished more than most sighted people will in a lifetime. From left, a partial survey of his triumphs: Trekking to the South Pole, running the Everest Marathon, paddling in the Irish Sea Kayak Challenge, rappelling in Austria, surviving the Round Ireland Yacht Race, competing in Ironman Switzerland, completing the Gobi March, and, post-paralysis, hand-peddling a bike in Norway.**

Harding, the company's chief executive officer, is tall, with black-framed glasses, dark hair, and a guileless smile. He cut his engineering teeth as a kid in a suburb of Houston. "I drank a lot of beer and worked on a lot of bikes," he recalls with a soft Texas twang, "and by high school it was cars." Because no one in his neighborhood of carpetbagging oil families spent much time turning a wrench, he put in free labor at a machine shop that built racing engines.

After getting a crash course in robotics at Carnegie Mellon University, Harding landed in the UC Berkeley graduate school lab of Professor Homayoon Kazerooni, a pioneer in the field of wearable robotics technology. This was the early '90s, and prototypes for bionic suits were a far cry from the nimble, slip-on devices of Marvel Comics fantasy. "They were these gigantic gorilla things that seemed pretty scary just to get into," Harding remembers. With the technology still a long way from maturity, Harding decided to leave academia. He got a job with an East Bay company and started designing and building specialized industrial machinery.

It all started with a rowing scull. Mark Pollock, a skinny 11-year-old from a suburb of Belfast, Northern Ireland, was strolling down the hall during the second week of middle school, scanning the booths set up by ambassadors from the school's clubs. Behind one booth, a long object sat perched in a wooden cradle. It was an aquatic bullet, all sex and shellac, from which all nonessential boatness had been stripped. It stopped Pollock in his tracks.

This was the late '80s, and the Troubles were raging in Northern Ireland. For Pollock, middle-class and ostensibly Protestant, the conflict played just offstage, a disquieting hum behind more pressing matters like girls and grades. His eyes were a bigger problem, the retinas prone to peeling off his eyeballs like cruddy wallpaper. Back when he was five years old, one of his retinas had detached, rendering him completely blind in his right eye. He had never been able to play football or rugby with his mates, though that was all he longed to do.

Pollock planted himself in front of the rowing booth, and eventually the coach told him to come by after school. The swimming pool was short, just long enough to take a couple of strokes with the oars, but Pollock shot across the surface, unzipping the water beneath him. "The oars felt like they were an extension of my body," he remembers. "The boat was a part of me."

From that moment, Pollock devoted himself to rowing. By the spring of 1998, when he walked out of the gym at Trinity College one day at age 22, his formerly sunken chest had ballooned outward. He was six feet tall and all muscle, an elite university rower in line for the Irish national team. It was the kind of day he loved—dry and crisp, the light so intense that it seemed to soften everything to a glow. But the blurred edges of his vision were a warning of impending disaster. When he realized that something was wrong, he rushed to the hospital and underwent surgery to pump gas into his "good" left eye, pressing the retina back into place.

Pollock awoke from surgery on April 10, 1998. The date gave him reason to be optimistic: Political factions in Northern Ireland had just signed the Good Friday Agreement, the greatest hope yet for lasting peace. He found that when he put his head down, the gas pushed his retina against the inside back wall of his eyeball and he could see. He stared at the floor, memorizing patterns in the laminate, hopeful that he would soon be back on his boat. But gradually the trick stopped working. He was going completely blind.

"I went into a consulting room," Pollock recalls, "and the doctor said that he had tried all he could. Doctors don't say you'll never see again; they just say they can do no more. I was leaving the hospital with no more options." The hulking college senior held on to his mother's elbow as they returned to the waiting room. That's when the impact of the news swept over him. "I got across the room and doubled over. I was walking out of the hospital with no sight, and that was the way it was going to be. I was crying, my mom was crying. A nurse got me a seat. I sat there and gathered my thoughts and strength. Then we left the hospital."

Pollock returned to his mother's house. He couldn't finish school right away—he had no idea how to survive on his own in this new reality—and he felt an overwhelming sense of loss and a fear of being left behind. "People were graduating and going off to world championships in rowing, going off to travel around the world and work on yachts over the summer, to start new jobs and get on with their lives. I was sitting in the bedroom I had grown up in, unable to leave the house or look after myself."

Pollock's mother dedicated herself to finding help for her son. She brought in government service workers to teach him how to use a white stick to navigate his surroundings. She bought a talking watch, which let him distinguish between night and day. She didn't coddle him, and she encouraged him not to feel sorry for himself. Progress was slow and grueling, but hope began to return.

"The big change came when I found out I could get in a computer course and learn to use a computer that talks to you," Pollock says. "I figured if I could write a letter on a computer, I'd have a chance of getting a job. I didn't consider rowing an option, or studying. I just wanted to get a job to earn money to go to the next stage of life like all my friends."

Pollock threw himself into learning the talking computer. He arranged to make up his remaining schoolwork and finish his degree, and he was matched with a seeing-eye dog. Armed with his new skills, he moved back to Dublin, where he took a job coordinating events for an agrifood company and started a master's program in business. In 2001, at age 25, he began training with an old rowing buddy from Trinity College. Together they launched a campaign to compete the following year in the Commonwealth Rowing Championships, a quadrennial event that features competitors from 10 countries and territories in the British Commonwealth. There is no blind category—Pollock competed with and against able-bodied athletes—but he made the Northern Ireland crew, which took silver in the eight-man race.

Achieving success in a boat made Pollock wonder what else he could accomplish. In 2003, on a dare, he tried the Gobi

## HOW TO MAKE A PARALYZED MAN WALK

It looks like something out of a military catalog—DARPA does SkyMall—but the titanium and aluminum Ekso suit has more peaceful applications. Powered by a lightweight battery that burns wattage only when the limbs are in motion, the robotic exoskeleton mimics a user's gait with uncanny ease. Once the cost—over $100,000 per unit—comes down in the next few years, the Ekso could replace older therapeutic tools like reciprocating gait orthosis, which allows paraplegics to take laborious steps by heaving their torso from side to side. By contrast, the Ekso does all of the heavy lifting.

March—an insane six-stage footrace across one of the most inhospitable stretches of desert in the world. He finished the event, holding on to his teammate's elbow for seven days. The challenge was invigorating, and soon he was casting about for new adventures. He completed the UVU North Pole Marathon, tripping over the undulating arctic ice so much that 60-year-old Sir Ranulph Fiennes, the world's most famous living explorer, kicked his ass by almost two hours. "I'm always going to beat you on this type of terrain," the arctic adventurer consoled him. Pollock had better luck in Ironman Zurich, and then the 48.7-kilometer Dead Sea Ultra Marathon, where he and his teammate finished in the top 30. In 2009, Pollock went land sailing in Argentina, screaming across the dry earth in a wind-powered buggy. In 2010, he raced a two-man yacht around Ireland, braving howling gales a hundred miles off the coast. The onboard electronics failed, leaving the vessel's navigation system as blind as its crewman, but the boat loved the weather—it communicated to Pollock, pulsing through the cleated rigging. During moments like those, in touch with his equipment and confident in his abilities, he felt most alive.

Whenever he could, Pollock used his athletic endeavors to raise money for charities: Sightsavers International, Irish Guide Dogs for the Blind, the Royal National Institute for the Blind. He made money by giving motivational talks at conferences and corporate gatherings. In 2009, he finished the Amundsen Omega 3 South Pole Race, his most daring challenge yet. Over 22 days, he and two teammates skied 1,000 kilometers across the largest ice cap in the world while hauling their own sleds. Pollock faced temperatures as low as minus 58 degrees and elevations as high as 9,000 feet on his way to becoming the first blind man to reach the geographic South Pole. The irony of this feat was that it hardly mattered that Pollock was blind. When it's life-threateningly cold, with whiteout snow swirling around you from above and below, the gift of sight is vestigial. You have to trust your equipment—the skis, the ropes pulling your sled.

It had been more than a decade since Pollock had lost his sight, years during which he had braved the harshest conditions on earth, built a name for himself as an adventure athlete, and raised tens of thousands of dollars for organizations doing outstanding work. Then, in the summer of 2010, tragedy struck for the second time. Pollock was in England to support friends racing in the Henley Royal Regatta. "I was staying with a friend. I had been out during the day and had gone back to the house. The next thing I remember is being in intensive care."

Pollock had fallen 25 feet from an open window. No one saw it happen, and he has no memory of the event. Friends were nearby at the time, and they rushed to the garden where he'd landed, terrified by what they saw.

Nate Harding's old mentor at UC Berkeley, Professor Kazerooni, had been working for years to build a practical robotic exoskeleton. The stumbling block had always been the power supply. The first untethered exoskeleton out of the Berkeley Robotics & Human Engineering Laboratory at UC Berkeley was called BLEEX. A YouTube video of the device in action shows a dazed test subject schlubbing around a sheet-draped room with a gigantic gas-powered lawnmower engine strapped to his back. He's keeping it together admirably, but he doesn't look comfortable.

BLEEX was a major breakthrough for Kazerooni—a wearable robotic device that could carry its own power—but the gas engine was bulky and too noisy for most applications. Kazerooni needed fresh ideas, so he began hiring consultants to work alongside his students. One of the people he called was Harding, who had been in the corporate world for about a decade. Kazerooni wanted his former pupil to find a way to make the power supply silent. "You needed a petroleum-type fuel because nothing else would have the energy density," Harding recalls. "After I looked into it for a few months, I said, 'That's crazy. I don't know what to tell you, but you can't do it.'"

In 2004, Harding called the most talented engineer he'd ever worked with: Angold, whom he'd hired out of Cal Poly four years earlier to work at an industrial equipment company called Berkeley Process Control. "It was like Disneyland for engineers," Angold recalls. Harding had quickly realized that Angold had a rare intuition, a phenomenal ability to see problems in ways that others couldn't. The younger man joined Kazerooni and Harding in the lab at Berkeley, and before long he had reframed the question they had been trying to answer.

Early on, the target market for exoskeleton technology was the military, which has an obvious interest in extending normal human capabilities. Troops humping equipment over long distances might use a bionic suit to carry heavier loads, and futurists have long conjectured about the tactical applications of robot-assisted manpower. DARPA was funding Kazerooni's research, which explains why the test schlub in the video is wearing camouflage. But when Angold played the same video for his brother, the former Navy SEAL, he was met with laughter. "He was like, 'No way are we ever going to use gas-powered engines,'" Angold recalls. "He told me they were too big and too heavy for the military. It was a nonstarter."

Angold pushed the team in a new direction. "All exoskeletons and a lot of robots to that point used a ton of power even when they weren't moving," he says. "They're standing there consuming 2,000 watts. They're fantastically expensive heaters at that point." With the exoskeleton requiring power just to keep itself upright, a petroleum engine was the only viable option—batteries would die too quickly. But humans are much more efficient than BLEEX was engineered to be—when we stand still, we don't expend much energy at all. So the team started looking at prosthesis technology, especially at unpowered artificial limbs. Says Angold: "It was like, 'Well, wait a minute. How are these people walking on unpowered knees while we feel we have to power all these degrees of freedom?'"

The team's new goal was to build an exoskeleton that could support its own weight passively, without using any power. No single technological breakthrough led to their eventual success, but once they were asking the right question, the engineering goals suddenly became much more achievable. By eliminating power consumption except in cases of real work—taking a step, say—the team soon managed to drastically diminish the amount of power needed to operate prototypes. They replaced the petroleum engine with lighter rechargeable batteries and a solar panel, and soon they had a slimmed-down device that was whisper quiet and weighed about 30 pounds.

Kazerooni, Harding, and Angold formed a company in 2005 and introduced their new exoskeleton the same year. Still vying for military contracts, they named it the ExoHiker. "That made a lot of waves," Harding says, "because essentially it took the state of the art from 5,000 watts to 5 watts." The ExoHiker fit in a case that was about the size of an average end table.

Still, it would take an eye-opening accident and some outside intervention to get the team thinking about applying the technology to cases of spinal cord injury. In 2004, not long after Harding and Angold started working on exoskeletons, Angold's brother broke his neck. The former SEAL eventually regained full mobility—"He can do, like, a million pull-ups," Angold says—but the accident brought home to the team the devastating nature of spinal cord injuries. Two years later, a doctor sent the team a video of a patient trying to walk in a reciprocating gait orthosis, a contraption that allows paraplegics to take steps by heaving their torso from side to side. "We watched the video," says Angold, "and the guy literally makes it 10 yards down the hallway, and he's just exhausted. The doctor told us that that was the state of the art to help these guys walk again. And we were like, 'Oh shit, we can do better than that.'"

When Pollock woke up in intensive care, he had a fractured skull and his brain was bleeding in three places. His chest had filled with blood, and scans showed a possible weakening of the aorta. Several of his ribs were broken, and he had a probable spinal cord injury. He couldn't remember what had happened. He was awake, that was all he knew, and in excruciating pain—and he couldn't feel anything below his navel. The indications were grim, but it would be over a month before he would know whether he would regain the ability to walk.

When he was stable, Pollock was moved to the spinal unit at Stoke Mandeville Hospital in England, where his back was sliced open and two of his vertebrae were bridged with metalwork. Like the eye doctors, the physicians there never definitively stated the worst—that he would never walk again. They simply said that there was nothing more they could do. During this uncertain time, between vomiting and struggling to take full breaths, Pollock managed to write a few blog entries.

"Since [my last surgery]," he wrote on August 18, 2010, "I have endured days of demoralizing pain, vomiting, an unidentified infection, endless drugs, blood transfusions, and fluid running into me through needles in my wrists. When my wrists ran out of available veins, they used my ankles. I was in some dark places in my head; I am not sure if I have ever experienced as tough a week as last week."

Pollock spent the next six months in agonizing recovery. "I was blind, paralyzed, and broken," he says. "Physically blind, physically paralyzed, but mentally broken." A year and a half earlier, he'd been standing at the geographic South Pole, savoring his greatest physical triumph. A documentary about his trip—called *Blind Man Walking*—happened to air while he was in the hospital. To Pollock, it already felt like a different life.

Hope is subtle, though; it plants seeds. Pollock's fiancée, Simone George, stayed by his side, lifting his spirits and helping him to look ahead to what she assured him would be brighter days. Friends gave him magazine articles about the latest treatments for spinal cord injury and about emerging technologies that were helping people with paralysis thrive. He read about a company in New Zealand called Rex Bionics, and then about an Israeli company called ReWalk. In November of 2010, *Time* named the latest exoskeleton from Ekso Bionics one of the 50 best inventions of the year.

Pollock started reaching out to the companies in 2011, but it was slow going. Interest in exoskeletons was sky-high by then, and demonstrations were difficult to arrange. He finally got a chance to visit Ekso Bionics' East Bay headquarters in January 2012. "I was really worried that my original disability, my blindness, was going to feature in my attempts to deal with my new disability," he says. It's challenging for paraplegics to know where their legs are in space without seeing them, and no one was sure how capably Pollock would manage in the Ekso suit. In California, he was tested and measured by physiotherapists, counseled, and then strapped into the device. From a seated position, he clasped a walker and listened to instructions. There was a countdown; Pollock shifted his weight forward—and then he stood up, grinning from ear to ear.

"How much taller does it make me?" he asked.

"I'm six-one, and I feel like I'm looking up to you," the physical therapist answered.

In hopes of buying an Ekso suit, Pollock started working the phones as soon as he returned home to Ireland. The Ekso suit currently costs around $110,000, though the company hopes to slash that figure by more than half in the next few years. At present, demand is still low enough that many of the parts used in the device are machined to order. As the customer base grows and demand increases, Harding expects those same parts to be made using less expensive techniques like casting or forging. Harding compares the Ekso to a high-end motorcycle: If you just build one, it's hugely expensive, but when you make lots of them, you get efficiencies of scale.

About 40 Ekso suits are currently being used in rehabilitation clinics in North America, Europe, and South Africa. At present, the suit is being offered as a therapeutic device for reducing secondary complications associated with sitting in a wheelchair all day. Recently it has been made available as a tool for teaching patients how to walk again after debilitating strokes and incomplete spinal cord injuries. It is not yet for sale as a mobility device, primarily because the company is taking a cautious approach. As with any new medical technology, the drawback of rushing to market without strict guidelines lies in the potential for unforeseen risks. The gurus at Ekso Bionics want to be sure that their suit is optimized for real people to take into the real world before offering it as a complement to or a replacement for a wheelchair.

The good news is that this is projected to happen sooner rather than later. "You're going to see somebody get onto an airplane and sit down in coach, and you're not going to really know if they're paralyzed or not," says Harding, envisioning a future that he believes is less than five years out. "It's all going to look very easy all of a sudden."

Mark Pollock is helping to make that possible. In October 2012, he became the first individual in the world to own an Ekso—that number has now climbed to six. Harding and Angold believe that the former elite rower is logging more time—up to several hours a day—and distance in his device than anyone else using a bionic exoskeleton. Every step that Pollock takes is logged and sent electronically to Ekso Bionics' headquarters. His goal for last February, which marked one full year in the suit, was 2,200 steps in one hour. He managed 2,196 and was hugely disappointed. Now, a year later, he's obliterated that old mark—his personal best currently stands at 3,207 steps.

By pushing the suit to its absolute limits, Pollock is helping to root out unforeseen problems. When he burned through one of the hip motors on his device, engineers at Ekso Bionics redesigned the motor, and the company replaced the faulty part throughout the entire fleet. He is also helping the company understand the effects of the suit on the human body, sending in regular medical reports and detailed entries from a personal diary. The data are part of an ongoing study to track factors like neuropathic pain and bowel and bladder function among users of the device, crucial issues for people living with paralysis.

Pollock's journey as a paralyzed man is only just beginning, but already he's being recognized as an important voice in the community. Soon after his injury, friends and family started the Mark Pollock Trust to help relieve the enormous financial burden of his recovery. Pollock is using the trust as a platform to connect disparate groups working on spinal cord injuries—in particular, to bring technologists like Harding and Angold, who are helping people live with paralysis, together with the scientists who are striving to eradicate it.

A lifelong athlete, Pollock has a keen interest in exercise therapy as a possible way forward for spinal cord injury sufferers. His trust sponsors high-profile running events to raise money for research and to promote awareness about the ongoing drive to get people out of wheelchairs. This past summer, he and his fiancée joined the board of the Christopher & Dana Reeve Foundation, where they are helping support a major project exploring how epidural stimulation may combat secondary problems of paralysis, like loss of bladder, bowel, and sexual function.

For the man who pushed his body to the limits of endurance, who has competed in some of the harshest environments on earth, this latest chapter in his life represents perhaps the greatest challenge yet. "With the adventure racing, even in all those extreme places, it was always clear that I was an athlete competing in a structured event," Pollock says. "I feel like I'm more of an explorer now than I ever was at the South Pole. The Shackletons, the Scotts, and the Amundsens were exploring the frontiers of the physical landscape a hundred years ago. I feel now that I'm exploring the frontiers of recovery from spinal cord injury." ❐