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I, Robot

Meet BLEEX, the first functional human exoskeleton, which pairs human brains and mechanized brawn.

BY KARA PLATONI

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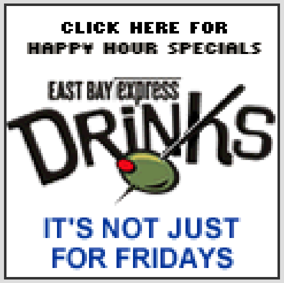
Courtesy Berkeley Robotics and Human Engineering Laboratory

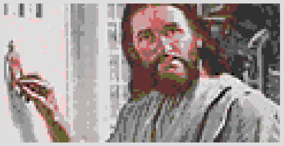
BLEEX looks like a backpack with leg braces.

Imagine there's a massive Bay Area earthquake. Buildings sway and then give; injured people are stuck on the top floors of one. Members of a rescue crew prepare to go in, hastily strapping on the tools of their trade: Helmets? Check. Backpack full of medical supplies? Check. Robotic legs? Check.

Sound far-fetched? Not so fast. Engineers have dreamed for decades of wearable human exoskeletons designed to give people extraordinary strength. Researchers around the world have struggled with a deceptively complex problem: how to design a mobile machine strong enough to help people lift heavy loads, yet lightweight and agile enough to walk smoothly in concert with them. The challenge has been to develop a robotic exoskeleton that can increase the strength of its human wearer without getting in his way, slowing him down, or squashing him flat.

General Electric was the first big firm to attempt the task. In the mid-1960s, it designed a behemoth called the HardiMan, which was envisioned as a suit of "mechanical muscles" that would enable its operator to lift up to 1,500





pounds. HardiMan was hardly lithe. It looked like a pair of girders strapped to its operator's waist, forearms, and feet, topped by two clawlike hands. GE ultimately had to admit that it wasn't yet possible to make a machine small enough for a person to safely wear. In fact, HardiMan was so gigantic and fearsome-looking that although the company's engineers did test one of its arms, they never turned on the whole suit for fear that if it unexpectedly convulsed, it might rip apart the person inside.

For the next several decades, exoskeletons rarely made it past the drawing board. Much of the scientific interest came from within the biomedical community, which began to explore their potential to help paralyzed people walk again. Most notably, last year a Japanese company succeeded in creating HAL-3, the Hybrid Assistive Leg, a set of motorized leg braces with a backpack power source designed to help the elderly and disabled walk normally.

But if the world of mechanical engineering has largely failed to produce working exoskeletons, 20th-century pop culture was churning them out at a fantastic rate. *Starship Troopers*, Robert Heinlein's 1959 novel about war between humans and aliens, is widely acknowledged as the exoskeleton's literary debut. In the book, futuristic infantry soldiers wear "powered armor" that allows them to effortlessly jump over buildings and shoot arcs of fire in their wake. Heinlein's troopers were outfitted in helmeted full-body suits so bulky they gave soldiers the appearance of a "hydrocephalic gorilla." They served as full life-support systems complete with air and water supply, as well as a helmet-mounted visual display that the soldiers manipulated by pressing their chins on a control plate, and a communications system they activated by biting down on sensors inside their mouths. "That is the beauty of a powered suit: you don't have to think about it," the author presciently imagined. "You don't have to drive it, fly it, conn it, operate it; you just wear it and

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it takes orders directly from your muscles and does for you what your muscles are trying to do. This leaves you with your whole mind free to handle your weapons and notice what is going on around you ... which is *supremely* important to an infantryman who wants to die in bed."

Another popular early version of the exoskeleton came from Stan Lee's 1960s comic *Iron Man*, in which a war-wounded inventor, held in a prison camp, builds himself a metal suit of armor in order to protect his shrapnel-pierced body, and then goes on to battle Communist villains. Over the next few decades, movie and television writers created a host of characters that were part man and part machine: *Robocop*, *The Terminator*, *The Six Million Dollar Man*, and Dr. Miles Hawkins, the wheelchair-bound exoskeleton-wearing hero from *M.A.N.T.I.S.*, to name just a few. Japanese *anime* gave viewers another set of hybrid heroes, as well as hugely successful series such as *Robotech* and *Gundam* which introduced American viewers to the related genre of *mecha*, giant human-shaped robots. More recently, video games such as *Halo* have made exoskeleton-like body armor de rigueur accessories for the first-person shooter set.

Perhaps the most memorable fictional depiction of an exoskeleton occurred during the climactic moment of James Cameron's sci-fi thriller *Aliens*. Hero Ellen Ripley strapped herself into a bright-yellow forklift-like exoskeleton and used it to smack around a drooling, hissing insectoid alien. Her use of the exoskeleton essentially leveled the playing field: Where the alien had claws, Ripley had massive robotic pincer arms; where the alien had a protective outer carapace, Ripley now had her own metal shell. Moral of the story: It takes a bug to fight a bug.

All of these fantasies have contributed to the popular notion that exoskeletons are inherently violent. After all, Americans have been fed a steady diet of pop culture that has portrayed exoskeletons as imposing battle machines. It's a perception that UC Berkeley mechanical engineering professor Homayoon Kazerooni eagerly seeks to dispel. Kazerooni and his team of Berkeley grad students recently unveiled their contribution to the field of exoskeleton research: the Berkeley Lower Extremity Exoskeleton, or BLEEX. From the outside, BLEEX appears far more *sci* than *fi*. It resembles a set of metallic leg braces topped by a large hiking backpack, at the base of which is a small plastic box containing the exoskeleton's computer. The pilot stands neatly inside it, looking for all the world like someone about to go camping someplace very, very steep.

BLEEX cannot leap tall buildings, or even jump at all. It does not wield mechanized pincers or flamethrowers, or as yet even arms. Its exterior cannot repel weaponry of any type, although its interior features some intensely complicated feats of engineering. Yet thanks to the vast quantities of robot-based entertainment that most of us have ingested, Kazerooni and his colleagues keep having to answer questions about whether BLEEX is a violent contraption bent on global domination. "I get a lot of 'So, you're building the next Terminator that's going to take over the world,'" says Cal graduate student Andrew Chu, who has worked on BLEEX for the last four years. "People are worried that we're working on some super-military killing machine."

After all, BLEEX *is* funded solely by the Defense Advanced Research Projects Agency, the offshoot of the Department of Defense that bankrolls cutting-edge military technology research. Just as sci-fi fans have long envisioned the day when smart but squishy humans could wrap themselves in the metallic embrace of a robot, so too has the Department of Defense, with its desire to make soldiers stronger and more technologically enhanced than ever. When BLEEX was formally introduced to the scientific and military world last month at a DARPA symposium in Anaheim, the Department of Defense hailed it as a boon to modern soldiers, who must carry heavy loads of rations, emergency supplies, batteries, and weapons on their backs. Conference attendees bombarded the Berkeley team with questions about how to make the machine faster, stealthier, and more powerful.

Perhaps it's unsurprising that among the first public responses to BLEEX were some qualms about the advent of mechanically amplified soldiers. When news of its invention broke on the tech Web site **Slashdot.org**, some writers voiced satiric if misinformed reservations about how the government might one day use the new technology. "Bush wants his soldiers to carry back the oil a barrel at a time," groused one poster. "If you protect soldiers from small arms, you only add incentive for everyone else to make larger arms," worried another. "You can see the obvious cycle." Someone else referred to the "FEAR OF GOD it would put into the soldiers when they see a 40-story-tall metal killing machine running at 100km/hr towards them." A more enthusiastic poster wrote, "I, for one, welcome our robotically enabled masters!" Someone else crowed: "Imagine a soldier that could roll over a 70-ton tank. It would be like having an army of He-men. We could rule the world."

Talk of this type easily gets under Kazerooni's skin. He is insistent that his motivation is not a military one. Where his government funders may see supersoldiers, Kazerooni says he sees firefighters, rescue crews, UPS workers, factory and warehouse employees, and other people who lift heavy burdens every day. The exoskeleton will make their work easier, prevent back injuries, and maybe even help people with degenerative muscle disorders walk again, he says. "I am committed to make machines that are useful for workers, for people who do hard physical jobs," he says. Kazerooni never tires of pointing out that the "exo" is merely a helpful machine, not something designed to blast through your doorway or kick over your car.

Like his students, the professor is a pretty tough critic of Hollywood's ideas about exoskeletons. "Some of these machines that are actually made in movies violate the very first laws of physics," he says with a laugh. To make the machines look exciting, he notes, prop designers have produced exoskeletons so enormous and top-heavy that if they were built in real life, they would tip over or be extraordinarily clumsy. They're so inefficiently designed that, in a real battle, you'd be better off if the enemy troops were wearing them, he says. And although he says it would have been technologically possible for his team to design a somewhat larger-than-life machine and still make it work, at a certain point it would have become a vehicle, rather than a wearable device, which defies the whole point of the human-augmentation project. Smaller is better, he says, even if the results are less cinematic.

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eastbayexpress.com | originally published: April 14, 2004

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