They're Robots? Those Beasts!

By SCOTT KIRSNER

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NAHANT, Mass.

JOSEPH AYERS was crouched over a laptop in a cool cinder block shed barely big enough to house a ride-on lawn mower, watching a boxy-shelled black lobster through a rectangular acrylic window.

Dr. Ayers's shed is adjacent to a fiberglass saltwater tank that looks like a big above-ground swimming pool, and through the window, he observed as the seven-pound lobster clambered across the sandy bottom and struggled to surmount small rocks.

"He's pitched backwards onto his tail, and his front legs aren't really touching the ground," said Dr. Ayers, a professor of biology at Northeastern University in Boston, sounding vexed.

A few minutes later, Dr. Ayers noticed a screw missing from one of the trio of legs extending from the right side of the lobster's abdomen. Were this lobster not made of industrial-strength plastic, metal alloys and a nickel metal hydride battery, Dr. Ayers - the author of several lobster cookbooks, including "Dr. Ayers Cooks With Cognac" - seemed frustrated enough to drop the robotic lobster into a boiling pot of water and serve it up for dinner.

Dr. Ayers was at his university's Marine Science Center on the peninsula of Nahant, which pokes out into Massachusetts Bay. He was trying to get his robotic lobster ready for a demonstration in late September for the military branch that funds his work, the Office of Naval Research. By then, he hopes to have the lobster using its two claws as bump sensors.

"When it walks into a rock," he explained, "it'll be able to decide whether to go over it or around it, depending on the size of the rock."

Dr. Ayers is one of a handful of robotics researchers who regard animals as their muses. Their field is often referred to as biomimetics, and the researchers who are developing robotic lobsters, flies, dogs, fish, snakes, geckos and cockroaches believe that machines inspired by biology will be able to operate in places where today's generation of robots can't go.

"Animals have adapted to any niche where we'd ever want to operate a robot," Dr. Ayers said. His RoboLobster, for instance, is being designed to hunt for mines that float in shallow waters or are buried beneath beaches, a harsh environment where live lobsters have no trouble maintaining sure footing.

Another researcher, Howie Choset of Carnegie Mellon University, has been testing sinuous segmented robots based on snakes and elephant trunks that may be the perfect machines to search for survivors inside the rubble of structures destroyed by explosions or natural disasters.

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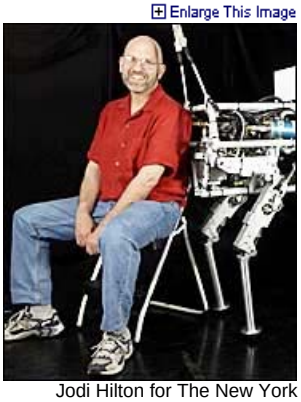

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Marc Raibert with a running quadruped.

SNAKE
snakerobot.com
Carnegie Mellon University's snake robot.

COCKROACH
rhex.net
RHex, a six-legged robot inspired by the cockroach.

GECKO
berkeley.edu/news/media/releases/2002/09/rfull/robots.html
Mecho-Gecko, developed by iRobot Corporation and the University of California, Berkeley.

LOBSTER
www.neurotechnology.neu.edu
Northeastern University's robot lobster (click on any link under Online Animations of Biomimetic Systems).

FLY
berkeley.edu/news/media/releases/99legacy/6-15-1999pix.html
Robotic fly project at the University of California, Berkeley.

FISH
web.mit.edu/towtank/www/media.html #pike
M.I.T.'s robotic fish, RoboPike and RoboTuna.

But replicating biology isn't a breeze, and some think that despite the well-publicized introduction of Sony's toy dog, Aibo, in 1999, useful biomimetic robots may still be many years off.

"What has been a surprise to me is how hard it has been to make progress," said Shankar Sastry, a professor at the University of California who has been helping to design robotic flies, fish and the wall-climbing gecko.

Another challenge is the sporadic nature of project financing, which predominantly originates with government agencies like the National Science Foundation, NASA and the Defense Advanced Research Projects Agency, better known as Darpa.

"I hate to gripe, but funding is hard to get these days," said Dr. Choset, designer of snakebots that can slither up stairways or down drainage pipes.

The military has been interested in animal-like robots at least since 1968, when General Electric built a gasoline-powered walking machine for the Army that resembled an elephant. But the machine required a human operator, and it was difficult to control.

At the time, some saw the work as frivolous, according to Paul Muench, a research scientist at the Army's Tank-Automotive and Armaments Command in Warren, Mich., a group known as Tacom. "Somebody wrote to a senator and asked why we were working on that while we were in Vietnam," Mr. Muench said. "The program got squashed."

But now, Tacom has allocated just over $1 million to conduct more research into walking robots. One is a robotic "mule" that would serve as a diesel generator, providing power to mobile units. It is being designed by a pair of former Disney employees who were responsible for building a nine-foot dinosaur robot named Lucky that sometimes roams the Disney theme parks.

Another Tacom mule would carry equipment for soldiers, enabling them to march longer distances. A robotic dog, being developed for Tacom by a Cincinnati company called Yobotics, might someday serve as a soldier's best friend. "Imagine you have a sniper hiding behind a wall," Mr. Muench said. "You want to send something out, something sacrificial to draw fire, or to look around corners where you don't want to look."

Of course, "they're going to be awfully expensive to use as a sacrificial lamb, no doubt about it," Mr. Muench said. "You don't want it to be destroyed. The only justification will be if they save lives."

Researchers working on the robotic menagerie aren't thinking only about military uses, although they try to paint dramatic wartime and homeland defense scenarios to attract funds. Robotic whales could one day swim alongside real whales, beaming back data and images to marine biologists studying migration patterns, or to students in a classroom.

"Instead of reading about the ocean, you can be in the ocean," said Robert Full, a professor of integrative biology at the University of California.

Others say that advances in legged robots could eventually lead to more realistic and utilitarian prosthetic limbs for amputees. At Carnegie Mellon, Dr. Choset thinks that his

Jodi Hilton for The New York Times; Jeff Swensen for The New York Times

ANIMAL WORLD Joseph Ayers, top, holding a biomimetic lobster he developed at Northeastern; Anthony Kolb of Carnegie Mellon, below, with a trunk-shaped robot.

Jeff Swenson for The New York Times

IT'S A ZOO - Howie Choset with a robot inspired by the elephant's trunk.

reptilian robots could one day be used to inspect underground fuel tanks or, on a smaller scale, to perform medical tests and surgery inside the human body.

"One goal of ours is to be able to do surgical procedures in a minimally invasive fashion," Dr. Choset said. This summer he performed a preliminary test, inserting a snake robot with a diameter of less than an inch into the abdomen of a live pig.

But today, few robots used by the military, consumers or businesses resemble animals. One reason is that wheels and tank treads, rather than legs, are a much more efficient means of locomotion, said Helen Greiner, the president of iRobot Corporation, a Massachusetts-based maker of robots. Early on, the company worked with NASA to build insectlike robots, which the space agency was considering for planetary exploration. But the mechanical bugs remained earthbound, and the robots that NASA sent to Mars instead resembled all-terrain vehicles.

"Where the rubber meets the road, wheels are very efficient," Ms. Greiner said. Her company's robotic vacuum cleaner rolls along on a set of tiny wheels, and looks less like an aardvark than an oversize hockey puck. "We're putting on the market the most effective solution today," she said. "That's not to say in the future we won't see legged robots."

Researchers say that an important advance will be artificial muscle, a synthetic substance that can contract and relax when electricity is applied, just like organic muscle. "Muscles are spectacular springs, shock absorbers, struts, brakes, and motors, all rolled up into a thin little tissue," Dr. Full said.

The RoboLobster has delicate, wiry artificial muscles that move its legs, made of a nickel-titanium alloy called nitinol that contracts when electricity is applied. And earlier this year, a start-up company called Artificial Muscle was spun out of SRI International, a Silicon Valley research group, to commercialize a new kind of musclelike polymer.

But biomimetics researchers aren't waiting around for the ultimate artificial muscle. They're looking for any insights they can find into how animals do things that the current class of robots can't.

Dr. Full has been studying the tiny hairs at the ends of a gecko's toes that allow the lizard to grab onto smooth surfaces, scale walls and hang from ceilings. "We brush their toes and the hairs fall off, and we put them under electron microscopes," he said. "We don't yet understand how they self-clean, and how come they don't mat, or stick together. We're going to figure that out."

Marc Raibert, the president of Boston Dynamics, a private company based in Cambridge, Mass., watches videos of mountain goats scampering up steep, rocky terrain. "That's inspiring," he said. "What's going on in the goat's foot is very interesting - how it gets traction on very steep surfaces."

Dr. Raibert's company is working on several biomimetic projects, and he's relying on Harvard biologists, who dissect goats' feet, for a better understanding of how a robot might achieve similar poise.

Boston Dynamics has been working on a climbing robot that may use Dr. Full's geckolike substance for adhesion, and also a six-legged robot that has springy legs similar to a roach's. But the company's primary project right now is a running quadruped called BigDog, under contract from Darpa.

Hanging from a steel I-beam in the company's offices, BigDog is slightly larger than a Great Dane, with a gleaming metal skeleton and rubber clublike feet that look as though they were drawn by Dr. Seuss. It has no head yet - NASA's Jet Propulsion Lab is still working on the vision system - but there is a small radiator where the chest would be, to cool the oil that runs through BigDog's hydraulic system.

"We don't slavishly imitate what evolution has created," Dr. Raibert said. "My dream is for any part of the robot to look like a machine, and when it moves, you go, 'Wow, it's an animal.' "

RoboLobster already fits the bill, at least partially. As it moves across the sandy bottom of Dr. Ayers's tank, it ambles forward and sideways like a true crustacean. Where it falls

short, though, is in its ability to wiggle out of jams. Dr. Ayers hopes to program that behavior soon.

Despite the difficulties with RoboLobster's recent outing, which was one of the first trial runs using a newly designed battery pack, Dr. Ayers was enthusiastic as he guided RoboLobster around the tank with computer commands. "We ought to put an odometer on this thing," he said. "We're really logging some miles here."

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