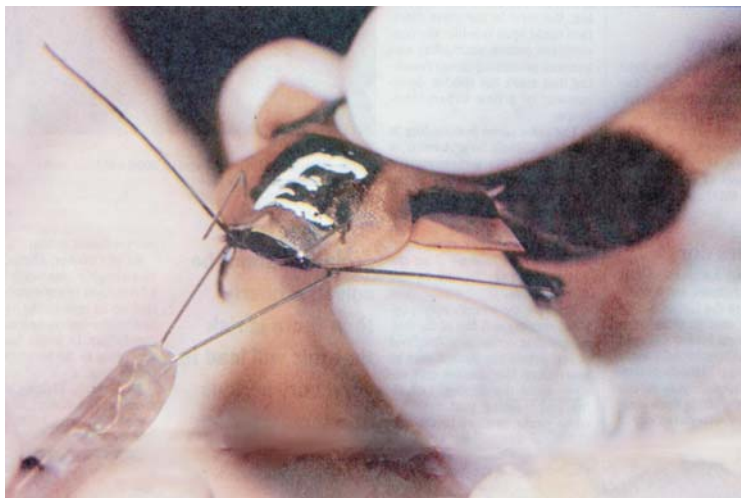
ROACH-INSPIRED TECHNOLOGY

"We could be saving lives, all because of a cockroach."
Troy Prince, *Orbital vice president of technology*



A Case Western Reserve University student examines a cockroack attached to a tether. Researchers have created a computer model of the bug's nervous system.

Brian E. Albrecht
Plain Dealer Reporter

Anyone who ever tried stomping a cockroach knows that the bug is often quicker than the foot.

That's because the little critters are neurologically hard-wired for escape.

They're equipped with sensors capable of detecting the slightest disturbance in the surrounding air and ground vibrations of less than one-millionth of a millimeter.

A roach's nervous system can transmit that sensory warning in 50/1,000ths of a second directly to its legs, while instantly analyzing its surroundings and reflexively choosing the right way to move.

It doesn't think, it just moves. Cut off its head and a cockroach will still try to elude a perceived threat.

Now imagine if you took that same ability and applied it to an aircraft collision-avoidance system that could make flying a plane into a skyscraper or mountain almost impossible.

Or, if you turned that escape reflex around to create a missile interceptor targeting program.

Engineers at Orbital Research Inc. in Highland Heights have done just that, capitalizing on cockroach research conducted at Case Western Reserve University for the past 25 years.

"Even if you couldn't see an obstacle or tried to intentionally run into a building, the plane would be able to sense it and automatically make an evasive maneuver," said Fred Lisy, Orbital chief operating officer. "It's the same as a cockroach facing that I have a foot coming down on me, what do I do to get away?'"

Converting cockroach capability into cockpit reality basically involved creating a computer model of the bug's nervous system based on years of laborious study - "nerve-poking work" as one scientist described it - at CWRU and elsewhere.

Roy Ritzmann, CWRU biology professor, said cockroaches were chosen for the study because much was already known about their nervous system, and because they're easier to work with than vertebrates.

The cockroach's escape response is also an enviable bit of natural engineering. "It has to be fast and it has to be robust, because if it fails, it's cat food," Ritzmann said. (Though researchers did wonder whether they were working with "escape-response losers" because their test roaches had, in fact, been captured for study.)

Tracing neurons

In a CWRU lab where hundreds of the six-legged test subjects are kept (appropriately enough) in a garbage can, Ritzmann described the process of using electrodes to trace each of the hundreds of neurons involved in a roach's escape response as something like working out the wiring diagram of a radio.

Once that diagram was established, creating a computer program based on the same neural elements fell to Randall Beer, a professor of electrical engineering and computer science. Beer said he modeled the biology based on the patterns of response that enable a roach to react differently to various situations.

Case Western Reserve University Professor Roger Quinn, with "Ajax", a fifth-generation mechanical robot based on the study of the cockroach.

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That computer model was then applied by Roger Quinn, a professor of mechanical and aerospace engineering, to a collision-avoidance system tested in a small radio-controlled car.

The car was fitted with ultrasonic sensors, and when it approached an obstacle, the cockroach-inspired escape-response circuit would take control to avoid a crash. The car could slow down, speed up, turn right or left.

Self preservation

There was no way to predict how it would respond, which Quinn said was a plus. "As it turns out, one way a cockroach avoids being eaten is that it's not only fast, it's also unpredictable," he said.

Quinn currently is applying another cockroach attribute, locomotion, to creation of mechanical muscles and legs that could be used in robotics exploration or search and rescue vehicles.

He said further work with the collision-avoidance program will enable it to mimic a cockroach's ability to monitor its surroundings, and continuously update its escape response according to changing conditions.

But he noted that even in its current form, the collision-avoidance system could work well with the sort of unmanned vehicles popular with the military.

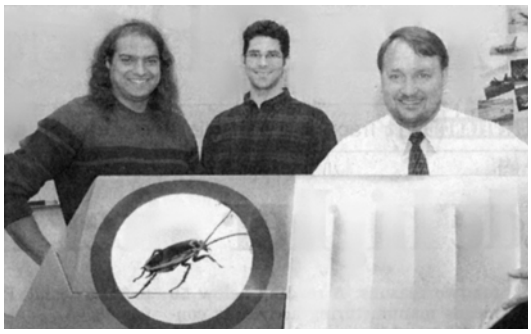
One of Quinn's students, Ravi Vaidyanathan, brought the idea to Orbital Research when he was hired as an engineer by the firm in 1998.

The concept of a control system that Orbital calls "BioAvert" (for Biologically Inspired Autonomous Vehicle Escape Reflex Tactic) is one of several research projects at the company.

Model fliers

The 20-employee firm specializes in development of micro-sensors and advanced controls for potential use in everything from braille computers and autonomous cargo-handling systems, to guiding just about anything that flies (including artillery shells and missiles).

Working with a $500,000 Small Business Innovation grant from the U.S. Air Force, Orbital developedroach-based their collision-avoidance system and tested it with radio-controlled airplanes - crashing three and discovering that engineers aren't necessarily the best pilots.



The "roach boys" from Orbital Research in Highland Heights are, from left, Ravi Vaidyanathan, senior controls engineer; Charles Williams, mechanical engineer, and Frederick J. Lisy, senior vice president and chief operating officer.

"We severely underestimated what it took to fly one of those things," said Orbital engineer Charles Williams. (The firm eventually hired a veteran radio-control hobbyist for the flight trials.)

Averting a crash

The good news was that the collision-avoidance system overcame human error; taking control of the plane as it approached a computer-simulated obstacle in the sky, and making evasive maneuvers to avert an imaginary crash.

The results were even better when the avoidance program was switched around, becoming "Bioseek," so that instead of avoiding an obstacle, the airplane targeted it. In one test, the aircraft passed close to the simulated target, then looped back to hit it.

"We had no idea it was going to do that," Vaidyanathan said. "We can't predict how it goes after a target, which is good. If it can't be predicted, it can't be countered."

In computer simulations, Vaidyanathan said he even created targets that made moves that were physically impossible in the real world. Bioseek still hit them.

The next step in research for both systems is to go beyond computer models and small radio-controlled planes to larger, unmanned test vehicles.

Computer guidance

Orbital hopes to interest the military in use of Bioseek for interceptor missiles. Company officials said the collision-avoidance program could be integrated into the computer guidance systems of military or commercial aircraft without need for extensive new hardware.

Detection of an obstacle or target could be accomplished with GPS satellite tracking data or short-range radar systems, or both.

"It gives you another backup, and reacts much faster than the pilot," said Troy Prince, vice president of technology. "We could be saving lives, all because of a cockroach."

Researchers have gained a greater appreciation for a bug generally regarded as something to be stomped and squished.

Quinn, of CWRU, said he's taken a whole new look at cockroaches since the research began.

Complicated bug

"More than a dozen years ago, I used to think insects were fairly simple, and it wouldn't be a big deal to get circuits from them," he said. "Now I have a greater respect for all living creatures in terms of the fact that it's not that simple just understanding one cell, and there are 10,000 or more neural cells involved in the [cockroach's] locomotion system alone.

"There's nothing simple about these creatures at all."

Vaidyanathan, at Orbital, also had to tip his hat to Mother Nature's cockroach engineering.

"The sensory integration is phenomenal," he said. "A good engineer shouldn't repeat a design that already works, and this is a design that has been out there working stunningly well for millions of years."

However, there are limits. Respect cockroaches as an engineer, sure, but as Vaidyanathan noted, "I still stomp on them in my apartment."

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