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Scientists develop diving suits for cyborg cockroach swarms – and it could enable them to explore Mars

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By [WILLIAM HUNTER, SENIOR SCIENCE & TECHNOLOGY REPORTER](#)

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Once again proving that mad scientists aren't just a Hollywood invention, researchers have built diving suits for their cyborg cockroach swarms.

The tiny 3D-printed suits will allow insects remotely controlled with electrical implants to survive without oxygen for up to three hours.

Scientists sent these robo-bugs crawling underwater and through tunnels filled with suffocating CO2 with no ill effects.

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In the future, their suits could even be adapted to survive the harsh conditions of space and enable creepy crawlies to explore the surface of [Mars](#).

For now, however, scientists say that cyborg insects could be an invaluable team during search and rescue operations.

While that sounds far-fetched, 10 augmented roaches were used to help search for survivors as part of Operation Lionheart following the 2025 Myanmar [earthquake](#).

Equipped with their own little oxygen tanks, the researchers say that these robot bugs will be able to delve into even more inaccessible locations.

Lead researcher Professor Hirotaka Sato, of Nanyang Technological University in Singapore, says: 'By expanding the operating parameters of our cyborg insects to include underwater travel, we believe they can enhance search-and-rescue efforts.'



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Researchers at Nanyang Technological University in Singapore have created miniature diving suits to allow cyborg cockroaches to explore underwater ruins

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While their search and rescue aims are already ambitious, the researchers want to prepare their cyborgs to explore even more dangerous environments.

Professor Sato told the **New Scientist**:
'The ultimate goal is to [take this technology to] space.

'It's kind of one step, one big step, towards space suits for cyborg insects. Exploration over the Mars surface, for example.'

While robots are often seen as the future of space exploration, cyborgs are far more energy efficient, cheaper to make, and can survive for longer without power.

However, space agencies are likely to object to using living organisms over fears that they might contaminate alien planets with biological materials.

That could lead to a 'false positive' in later searches for signs of life, something that is a major ambition for Mars exploration.

The research team now plan to test the diving suits in the sorts of environments cockroaches might encounter out in space.

That includes very low or high temperatures, airless vacuums, and intense radiation exposure.



Do you think it is ethical to turn insects into cyborgs for search and rescue missions?

- ✔ Yes, if could help save humans
- ✔ No, it's cruel
- ✔ I'm not sure yet

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The cyborg cockroaches (pictured) have tiny electrodes implanted in their bodies that allow scientists to remotely steer them through small electrical signals

In 2021, Professor Sato and his co-researchers first demonstrated that they could transform Madagascar hissing cockroaches into tiny cyborgs by fitting them with electric backpacks.

These allowed the cockroaches to be remotely controlled by applying an electrical current to sensory organs known as cerci.

When current is applied to the left or right cerci, the roach rotates in that direction, allowing scientists to steer their cyborg creations with a surprising level of accuracy.

Later, in 2024, Professor Sato developed the concept further by driving a swarm of 20 cyborg insects that coordinated to avoid obstacles and each other.

Although it might sound mad, hijacking an insect is actually a pretty sensible solution for a search and rescue operation.

The electronic components are only telling the cockroach where to go, while the insect's own muscles do all the heavy lifting.

That means cyborgs use very little power compared to robots of a similar size, allowing them to work for longer without refuelling while carrying a smaller battery.

Cockroaches are also incredibly tough, come with their own fuel supply, and have reflexes that let them move over rough terrain and dodge obstacles far better than any robot.

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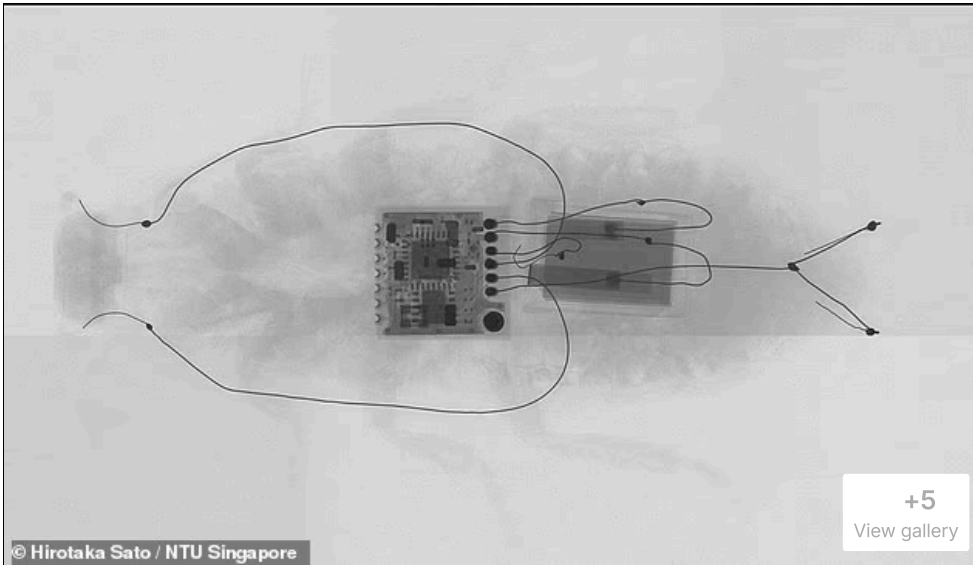
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The cyborgs are controlled by applying an electrical current to sensory organs known as cerci. When current is applied to the left or right cerci, the roach rotates in that direction

The only problem is that, unlike robots, cyborgs are still powered by the insect's own respiratory system and can't operate in areas without oxygen.

Cockroaches, like many other insects, don't breathe through their lungs, but rather through tiny holes called spiracles.

If these get blocked by water or gases like CO₂, the cyborgs soon collapse and stop responding to commands.

'This is important because real disaster sites can be challenging after heavy rain or flooding, blocking access routes in the rubble, drains and narrow gaps,' says Professor Sato.

The solution, naturally, was to build tiny diving suits for the army of swarming cyborg cockroaches.

Professor Sato says: 'Our new insect diving suit works like the oxygen tank used by human divers.'

Where this differentiates from diving tanks used by humans is that the cockroach doesn't have a pressurised tank of air.

Instead, the researchers used a small amount of dilute hydrogen peroxide and a sponge coated with a catalyst, which constantly produces a steady supply of oxygen.

How do you make a cyborg cockroach?

A cyborg is simply any biological organism that has been augmented with technology.

To turn cockroaches into cyborgs, scientists implant tiny electrodes into their carapaces.

These electrodes carry a small electrical signal to appendages called cerci.

Normally, these would be used to detect vibrations or wind directions, but the electrical current allows scientists to 'steer' the cockroach.

The insect itself is still doing all the walking and working out how to navigate the terrain; the only difference is that its direction can now be controlled.



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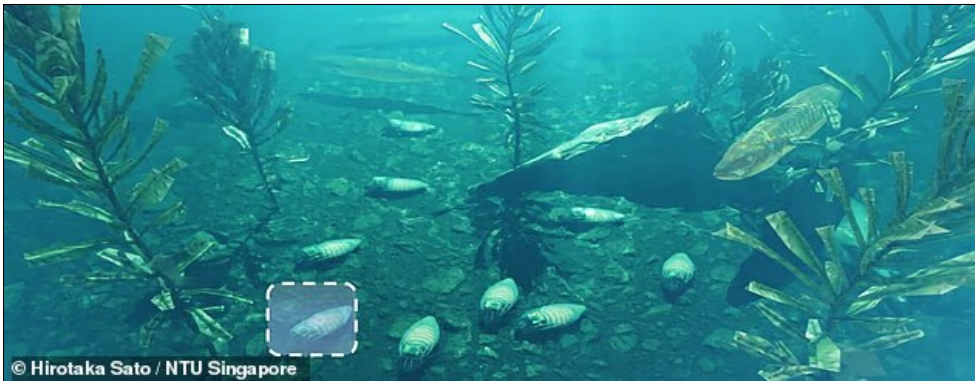




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The diving suit protects the insect's breathing holes and contains a small oxygen generator that provides them with up to three hours of air



© Hirotaka Sato / NTU Singapore

For now, the cockroaches are intended for use in underwater search and rescue operations, but they could have a role exploring distant planets in the future

Also, because the flexible shell would get in the way of the bug's legs, the suit uses four small tubes to carry air to the spiracles on its thorax.

Co-author Professor Shinjiro Umezumi, of Waseda University, says: 'The key engineering challenge was to build a system that was small, light and flexible enough for the insect to wear while still producing enough oxygen for long-duration underwater movement.'

'This allows the insect to retain its natural mobility while being protected from an environment that it cannot normally survive in.'

Fitted with their new suits, the cyborgs were able to walk underwater for up to three hours at a time at a depth up to 50 centimetres and make their way through tunnels filled with CO₂.

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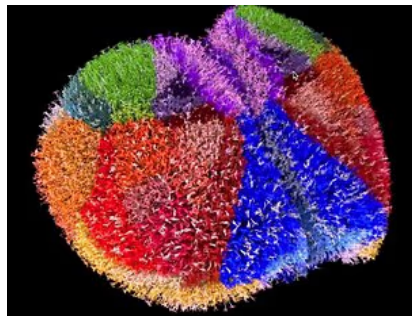
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Remarkably, being underwater barely slowed the land-dwelling insects down, dropping the suit-wearing cyborgs' speed from 87.5 millimetres per second to 78.4 millimetres per second.

And the roaches showed no adverse reactions to having explored such unnatural environments, with all five insects that were monitored after wearing the suits still healthy three days later.

This could allow swarms of robot cockroaches to make their way through rubble, collapsed buildings, and flooded areas after natural disasters.

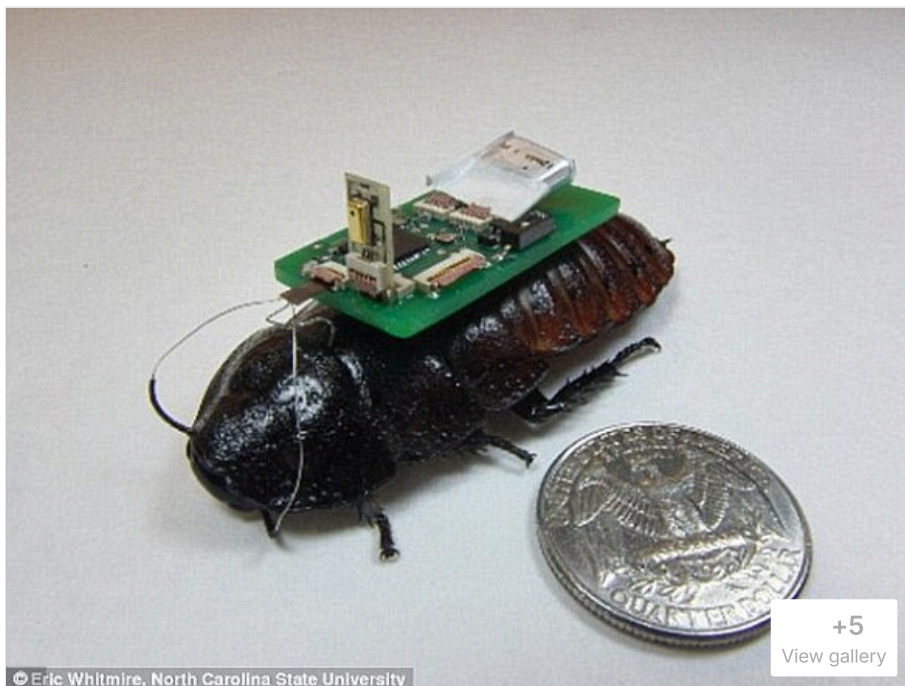


HOW COULD CYBORG COCKROACHES HELP IN DISASTER ZONES?

In November 2014, researchers at North Carolina State University fitted cockroaches with electrical backpacks complete with tiny microphones capable of detecting faint sounds.

The idea is that cyborg cockroaches, or 'biobots', could enter crumpled buildings hit by earthquakes, for example, and help emergency workers find survivors.

'In a collapsed building, sound is the best way to find survivors,' said Alper Bozkurt, an assistant professor of electrical and computer engineering at North Carolina State University.



© Eric Whitmire, North Carolina State University

North Carolina State University researchers have developed technology that allows cockroaches (pictured) to pick up sounds with small microphones and seek out the source of the sound. They could be used in emergency situations to detect survivors

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'The goal is to use the biobots with high-resolution microphones to differentiate between sounds that matter - like people calling for help - from sounds that don't matter - like a leaking pipe.

'Once we've identified sounds that matter, we can use the biobots equipped with microphone arrays to zero-in on where those sounds are coming from.'

The 'backpacks' control the robo-roach's movements because they are wired to the insect's cerci - sensory organs that cockroaches usually use to feel if their abdomens brush against something.

By electrically stimulating the cerci, cockroaches can be prompted to move in a certain direction.

In fact, they have been programmed to seek out sound.

One type of 'backpack' is equipped with an array of three directional microphones to detect the direction of the sound and steer the biobot in the right direction towards it.

Another type is fitted with a single microphone to capture sound from any direction, which can be wirelessly transmitted, perhaps in the future to emergency workers.

They 'worked well' in lab tests and the experts have developed technology that can be used as an 'invisible fence' to keep the biobots in a certain area such as a disaster area, the researchers announced at the IEEE Sensors 2014 conference in Valencia, Spain.



Mars

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