POWERED BY GovTech

Singapore: NTU Develops Flexible Diving Suit for Cyborg Cockroaches

Digital Government • 1 July, 2026

Researchers from Nanyang Technological University Singapore (NTU Singapore) and Waseda University have developed a flexible underwater "diving suit" that allows cyborg cockroaches to survive and move in underwater and low-oxygen environments for up to three hours. The research, published in Nature Communications, could support future search-and-rescue operations in flooded or obstructed disaster zones where conventional robots face mobility challenges.

The development builds on Singapore's wider investment in robotics and applied artificial intelligence, including initiatives such as the robotics and physical AI testbed in Punggol Digital District. Researchers said the amphibious cyborg insects may eventually assist in infrastructure inspection and emergency response in confined or hazardous spaces.

Extending the operational range of cyborg insects

Cyborg insects are living insects fitted with lightweight electronic controllers that guide movement. Unlike miniature robots powered entirely by onboard motors and batteries, the insects use their own muscles for locomotion, reducing energy demands.

However, their dependence on natural respiration has limited their use in submerged or oxygen-poor environments. Cockroaches breathe through spiracles connected to an internal tracheal system, which cannot extract oxygen from water.

To address this limitation, the research team designed a soft, flexible suit equipped with an oxygen-generation system. Laboratory tests used plastic tubes simulating flooded tunnels and carbon dioxide-rich low-oxygen environments. Researchers found that insects fitted with the suit remained active underwater for as long as three hours.

> "Our new insect diving suit works like the oxygen tank used by human divers. It generates oxygen and delivers it directly to the insect's breathing holes, allowing the cyborg cockroach to survive and move in underwater or low-oxygen environments. "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. By expanding the operating parameters of our cyborg insects to include underwater travel, we believe that they can enhance search and rescue efforts." – **Hirotaka Sato, School of Mechanical and Aerospace Engineering, NTU Singapore**

How the underwater system operates

The underwater suit combines three core components: an oxygen-generation tank, a flexible waterproof shell and four silicone oxygen-supply tubes. Together, the system creates a sealed mechanism that channels oxygen directly to the insect's spiracles while preventing water ingress.

The oxygen tank was produced using 3D printing with PMMA-type resin, a transparent plastic-like material. Inside the tank, researchers placed a sponge coated with manganese dioxide, which acts as a catalyst. Diluted hydrogen peroxide was then injected into the chamber and sealed using ultraviolet adhesive.

When activated, the manganese dioxide gradually decomposes the hydrogen peroxide and releases oxygen. This oxygen flows through silicone tubes connected to the cockroach's thoracic spiracles, enabling underwater respiration without impairing movement.

> "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. "Our approach combines a soft waterproof shell with a simple yet reliable chemical oxygen generator. This allows the insect to retain its natural mobility while being protected from an environment that it cannot normally survive in." – **Shinjiro Umezu, School of Creative Science and Engineering, Waseda University**

Potential applications in emergency response and infrastructure inspection

The researchers tested the suit using Madagascar hissing cockroaches, a species commonly selected for cyborg insect studies because of its durability, size and wingless body structure. The addition of the underwater system effectively transforms the insects from land-based platforms into amphibious systems capable of operating across wet and dry environments.

The work extends more than a decade of research at NTU Singapore into cyborg insect applications across land, sea and air. According to the university, these systems have already been deployed in operational settings, including search-and-rescue activities linked to Operation Lionheart following the 7.7 magnitude earthquake in Myanmar on 28 March 2025.

Researchers are now working to improve the durability of the diving suit and integrate additional sensors and navigation capabilities for field deployment. The project aligns with broader national efforts to advance applied robotics, digital systems and AI-enabled technologies, including programmes supporting real-world AI deployment and research infrastructure such as Singapore's ASPIRE 2B supercomputer initiative.

Beyond disaster response, the technology may support inspection of flooded drains, tunnels, pipes and other confined infrastructure environments that remain difficult for conventional robotic systems to access. Researchers also suggested that the concept could be adapted for other terrestrial insects, including beetles and locusts, which share similar respiratory structures.

The study was supported by Singapore's Ministry of Education and Waseda University's Top Global University Project. Researchers stated that all insects were treated in accordance with research guidelines and were not harmed during the experiments.

This article is created with the assistance of OpenGov AI.

Channel: **Digital Government**

Share:

Latest News in Digital Government: