



## INSPIRED by the biology of a bee and the insect's hive behavior ...

we aim to push advances in miniature robotics and the design of compact high-energy power sources; spur innovations in ultra-low-power computing and electronic "smart" sensors; and refine coordination algorithms to manage multiple, independent machines.

## Practical Applications

Coordinated agile robotic insects can be used for a variety of purposes including:

- autonomously pollinating a field of crops;
- search and rescue (e.g., in the aftermath of a natural disaster);
- hazardous environment exploration;
- military surveillance;
- high resolution weather and climate mapping; and
- traffic monitoring.

These are the ubiquitous applications typically invoked in the development of autonomous robots. However, in mimicking the physical and behavioral robustness of insect groups by coordinating large numbers of small, agile robots, we will be able to accomplish such tasks faster, more reliably, and more efficiently.

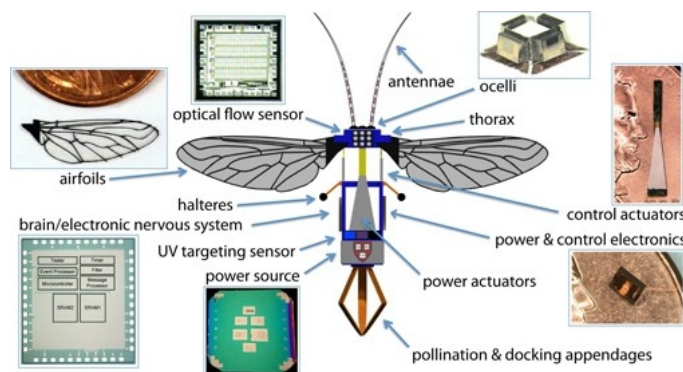
## Vision and Aims

The collaborators envision that the Nature-inspired research could lead to a greater understanding of how to artificially mimic the collective behavior and "intelligence" of a bee colony; foster novel methods for designing and building an electronic surrogate nervous system able to deftly sense and adapt to changing environments; and advance work on the construction of small-scale flying mechanical devices.

More broadly, the scientists anticipate the devices will open up a wide range of discoveries and practical innovations, advancing fields ranging from entomology and developmental biology to amorphous computing and electrical engineering.

Through a relationship with the Museum of Science, Boston, the team will also create an interactive exhibit to teach and inspire future scientists and engineers.

## Body, Brain, and Colony



From flies to fish to lobsters, small insects and animals have long been ideal models for roboticists and computer scientists. Bees, for example, possess unmatched elegance in flight, zipping from flower to flower with ease and hovering stably with heavy payloads.

### Body

By leveraging existing breakthroughs from Professor Wood's Microrobotics Lab, which conducted the first successful flight of a life-sized robotic fly in 2007, the team will explore ways to emulate such aerobatic feats in their proposed devices. In addition, achieving autonomous flight will require compact high-energy power sources and associated electronics, integrated seamlessly into the 'body' of the machine.

### Brain

One of the most complicated areas of exploration the scientists will undertake will be the creation of a suite of artificial "smart" sensors, akin to a bee's eyes and antennae. Professor Wei explains that the ultimate aim is to design dynamic hardware and software that serves as the device's 'brain,' controlling and monitoring flight, sensing objects such as fellow devices and other objects, and coordinating simple decision-making.

### Colony

Finally, to mimic the sophisticated behavior of a real colony of insects will involve the development of sophisticated coordination algorithms, communications methods (i.e., the ability for individual machines to 'talk' to one another and the hive), and global-to-local programming tools to simulate the ways groups of real bees rely upon one another to scout, forage, and plan.

## The Team

The **investigators**, primarily based at **Harvard's School of Engineering and Applied Sciences**, will coordinate efforts with faculty from the Department of Organismic and Evolutionary Biology in the Faculty of Arts and Sciences at Harvard and Northeastern University's Department of Biology.

In addition, Centeye, a microelectronics firm in Washington, D.C., specializing in vision chip and visual sensor technology, will contribute technical knowledge.

A number of the collaborators are core faculty members of the newly created **Wyss Institute for Biologically Inspired Engineering**. As the work fits particularly well with Wyss's mission of "creating new materials and devices using Nature's design principles," the Institute, along with SEAS, will play a critical role in supporting the research, providing laboratory space and in-kind financial support.

## Funding

Harvard is one of three lead institutions receiving the latest round of awards under the NSF's Expeditions in Computing program.

The program, established last year by the Directorate for Computer and Information Science and Engineering (CISE), provides the CISE research and education community with the opportunity to pursue ambitious, fundamental research agendas that promise to define the future of computing and information and render great benefit to society. Funded at levels up to \$2,000,000 per year for five years, Expeditions represent some of the largest single investments currently made by the directorate.

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## Videos

### **Boston Museum of Science/NECN**

Check out the **videocast** about our research!

### **Background on Micro Air Vehicles**

An **excellent introduction** to how the military is using micro air vehicle technology for surveillance and other battlefield applications.

### **Insect-Inspired Robots in Action**

**Overview by BAE Systems** (who has sponsored research by PI Robert Wood) on some of the future, practical possibilities for insect-inspired robots.

## In the Media

*Popular Science* **explains how linked, collaborative micro air vehicles** could improve agriculture and find disaster victims.

## The RoboBees Project and Colony Collapse Disorder (CCD)

One potential application of micro-robotic "insects" might someday be to artificially pollinate crops. However, we do not see robotic pollination as a wise or viable long-term solution to Colony Collapse Disorder. If robots were used for pollination—and we are at least 20 years away from that possibility—it would only be as a stop-gap measure while a solution to CCD is implemented to restore natural pollinators. External funding for the RoboBees project is provided entirely by the National Science Foundation. **Read more**

## Blog

### **Read the blog**

This is the blog for the project. The blog will be used as an informal forum for disseminating research results, discussing relevant projects and papers, and raising different points of view.

Check out the **link** and read about the 3 Expeditions in Computing projects awarded by the NSF this year.



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