Unmanned Vehicles Mimic Insects

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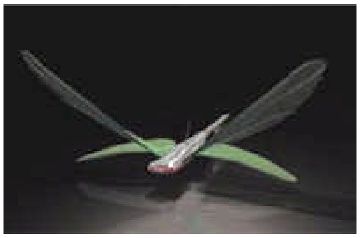

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Gaggles of mechanical grasshoppers, flies, bees and spiders -- each a relatively dumb creature -- can be networked into very smart networks to conduct intelligence, surveillance and reconnaissance.

In the last decade, remote sensors arrays have been changing from somewhat obvious, hard-to-mask, mechanical objects to autonomous, self-propelled, insect-like devices that can climb walls or jump up stairs and then lie dormant until motion, noise or vibrations trigger their activation.

The grandchildren and great-grandchildren of "WolfPack" -- a coffee-can size, air-dropped network of ground sensors -- include fast-moving spiders, high-jumping grasshoppers, bees with detachable surveillance payloads and sensor-equipped dragonflies.

Development of BAE Systems' WolfPack worked out the dynamics of connecting a series of low-cost, not-so-smart sensors to create a very smart network. That network could, for example, monitor and analyze nearby communications and map the information flow. It then could trigger electronic jamming or even the injection of a data stream of algorithms that captures low-power traffic, attacks communications protocol stacks and otherwise manipulates a foe's flow of information. A second-generation WolfPack added a propulsion system to manipulate the modules and recharge the batteries.

"Advanced communications can move intelligence, surveillance and reconnaissance (ISR) around the battlefield in real time," says Lt. Gen. Dave Deptula, the U.S. Air Force's Deputy Chief of Staff for ISR. "These ISR sensors now are transformed into the nodes of a truly global, net-centric weapons system."

But autonomy, networking and flight are no longer enough. The introduction of camouflage, deception, autonomous processing and advanced robotic microsystems are being used to design the much more sophisticated offspring of WolfPack. The research is supported by a series of company-led Micro Autonomous Systems and Technology (MAST) and Collaborative Technology Alliance initiatives.

Mechanical bug development, which also draws on biology, animal psychology and designs from nature, is part of an Army research lab-funded, five-year, $37-million development program that was won by BAE Systems, says Aaron Penkacik, chief technology officer for the company's electronics and integrated systems. A group of small businesses, subcontractors and universities provide specialized materials, technology and research. The military is already anticipating how to absorb the new data sources.

Researchers elsewhere are studying the efficiencies of biological designs with an eye to operating devices with as little as one-thousandth of the energy they now consume. For example, a whale uses no more than 12 volts to push 1,000 liters of blood through more than 100 mi. of veins and arteries with a single pulse of its heart, according to a recent report. The University of Maryland is using the hearing mechanism of flies -- a pair of mechanically-coupled ears -- to create miniature acoustic receivers for an "artificial fly" micro-UAV that can navigate into otherwise inaccessible locations. The surfaces of plants and animals are being examined for both naturally occurring friction-free and adhesive qualities.

"We're trying to expand our capability by integrating traditional ISR with the new technologies," Deptula says. "In five years, I'd like the term 'nontraditional ISR' to go away. If it's ISR, it doesn't matter what platform it comes from."

What the articulated critters, operating in groups, will eventually look like will be determined by ongoing system-level trades. The spiders, grasshoppers, bees and dragonflies may give way to something else. Regardless of the final biological shape, MAST products will have some similarities to WolfPack. For example, electronic order of battle-type missions -- including signals and communications intelligence-gathering (sigint) and analyses -- will be MAST capabilities. But each element will be much smaller and somewhat less capable than in WolfPack.

Research goals include: introducing insect swarming behavior -- communicating and working for a group purpose -- into the battlespace; capturing biologically inspired mobility associated with insects and birds; and adapting university research on very small, biologically inspired robots.

"Think about the way a hummingbird flies," Penkacik says. "The aerodynamics are very different than on aircraft or even small UAVs. Wingtip vortices become what you're worried about instead of standard pressure differentials and lift indices of a wing. So the question is, can we emulate biological-mechanical functions in building some of these small robots?" A team from Harvard has built and demonstrated a mechanical dragonfly.

"How do we now take something like that dragonfly and put a payload on it that has some military significance?" Penkacik asks and then answers. "It could be a small sigint package, an imaging sensor, a chemical or biological agent detector, acoustic device or magnetometers."

A second group developed a mechanical grasshopper. "They demonstrated how far it could go in a single jump -- it's pretty amazing," he says. "We're also taking a look at how crawling insects climb a wall and if there's a way to mechanically simulate the surface of [a spider's] legs so we can produce the adhesion to the wall that you get in nature. Those things are understood."

Researchers here are examining these very complicated features with systems analyses and trade studies models to determine what a swarm of these creatures would look like and how it would operate. A mission that is fed into the simulation is to penetrate an urban building that is down the street and around the corner.

"You want to monitor activity someplace, because you think bomb fabrication is going on," Penkacik explains. "What would the swarm look like that you deploy to provide surveillance for a week? It would involve a flying robot with an imager that would perch on a building across the street. It would probably be in a sleep mode until an acoustic or seismic sensor on a crawling robot [inside the target building] detects a vehicle arriving. Through the ad hoc network, the sensors will wake up and begin the surveillance mission. You can track the activity and introduce additional robots into the swarm."

Decentralized data fusion is being examined as a way to build even more intelligence into the swarm. If each robot provided a separate data stream, it would overwhelm the operators' BlackBerry-size control devices. The effort to convert the mass of surveillance data into a refined stream of useful knowledge through distributed processing is being worked through BAE Systems Australia at the University of Sydney.

"Everybody does a little piece of processing and you may have larger algorithms executed by multiple micro-scale processors," Penkacik says. "It's analogous to using home computers to help solve enormously complex mathematical problems rather than buying a Cray [high-speed computer]."

But that also means additional system trades. How much processing is done by the robots and how much can be done by the swarm operators' hand-held communications devices? That equation dictates the bandwidth needed to push the data to the intelligence analysts and operational users.

"What if countermeasures and things you need to do the jamming were already [at the target]? We've got to start thinking about how to be a node in a network. The things you need aren't on the [aircraft], they're somewhere else. It could be something you shoot, air drop or that walks into the area of interest," says an EW specialist.

"We're administering a $40-million program for the Army that is developing micro-mechanical robots. You make robots imitate biological objects of that size and it gives you new ways to deliver payloads," says Karl Brommer of BAE's innovation center for EW. "I've got a thumb-sized Ipod Nano with two gigabytes of memory, digital signal processor, power amplifier and you can't break it -- all for $40. We can do things analogous to that in the EW world. We're trying to ride that trend of cheap commercial technology like engineered materials that are LEDs imprinted into a polymer or painted on with computers and have power built in. It can be printed by the roll and you just tape it [to the delivery device of choice]."

The MAST effort is also looking at the use of even smaller-scale nanotechnologies such as miniature radios with very-low power consumption. These are important for the robot bugs and insects, as are wings with solar cells and legs that function as antennas.

Electronics offer an associated set of issues including significant processing in small packages, mission-specific electronics and control circuitry for moving objects, and they all need to be integrated into small robots.

"The system-on-a-chip world, which integrates RF, power and digital electronics, is going to be very important to us," Penkacik says. "We're already seeing applications in EW and communications which have common building blocks. The company investment is to build the customized pieces that allow them to be applied to various applications such as local oscillators, digital RF memory jammers, filters and architecture."

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