Airborne Shape Shifters

By Steve Douglass

Sightings

A hawk hovers on a thermal, eyeing the desert below looking, for prey. With incredibly sharp vision he spots a tiny field mouse foraging for food in the thick grass. Fixed on his target the hawk tucks his wings in tight and dives at lightning speed. Just before he strikes, the wings come forward drastically slowing the hawk so it will not overshoot his meal, allowing him to deploy his razor-sharp talons to make the kill.

At an aeronautical engineering think-tank, scientists dissect a video of the hawk's attack in super-slow motion. Frame by frame they study the hawk's hunting prowess in an attempt to reverse engineer nature's incredible feat of bioengineering . Other flying creatures are studied as well, hummingbirds, condors, dragonflies and bats. Taking structural cues from nature and incorporating them into aeronautical engineering is called biomimetrics and may lead to the next great leap in aviation technology.

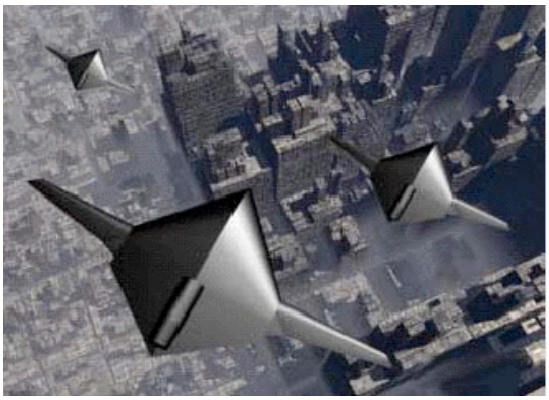
During the early days of manned flight, engineers also looked to nature as the template for creating flying machines. Although there were some early attempts to build machines with wings that flapped it soon became clear that trying to duplicate nature's way of flying just wouldn't work. Instead ,a brute-force type of engineering was needed which meant whirring propellers forcing air over stiff wings with flight controls consisting of bulky levers, wires, pulleys and actuators. Although not near as versatile birds these wood and metal contraptions (not much more than motorized box-kites) did usher in an era of manned flight which began with the Wright Brothers and led to the incredible B-2 Stealth bomber.

Now look at the Pentagon's inventory or war planes. You'll find many of them named after the birds they supposedly emulate. There's the F-22 Raptor and the F-117 Nighthawk. How about the V-22 Osprey or the AV-8B Harrier? Although these prime examples of complex military technology may seem to exceed nature in some regards, they are still products of the brute-force school of engineering and lack the amazing versatility and adaptability of natures solutions.

For decades, Pentagon planners have strived to create military aircraft are as versatile as a hawk. They imagine a precision bomber that can become a super-agile-fighter or supersonic intelligence gatherer ,at the flick of the switch. In the pursuit of a true mission-adaptive multi-role aircraft they have experimented with mechanically swept wings, such as those on the B-1B bomber and F-14 Tomcat, directed-vectored-thrust, such as on the F-22 or as in the V-22 Osprey they have combined wings and rotors to create a high-lift and moderately fast aircraft that can also hover. But not one of these aircraft embodies all the flight characteristics needed for a true multi-mission instantly re-configurable warplane.

Now technologists at the Defense Advanced Research Projects Agency (DARPA, at NASA's Langley

Research Center, as well as at universities across the nation , are looking to nature to solve this aeronautical engineering conundrum.



When a hawk unthinkingly changes the configuration of his wings to dive, hover or lift he is in technological terms "morphing" his wing from one shape to another. Morphing may be the key to building a military aircraft that can do any mission imagined by warplanners, be it precise pinpoint bombing, high -speed reconnaissance or long duration over the target loitering.

In a DARPA's 30-month study the chief goal is to morph an area of an aircraft's wing by 50% with a 20-deg, change in wing sweep. Other goals include shape changing engine inlets that could be modified to optimize air flow at different speeds or creating morphing control surfaces that could eliminate the need for mechanical controls which are heavy, bulky and non stealthy. Existing stealth aircraft such as the F-117 and B-2 bomber use conventional flaps for control that can spoil their low radar signature. A shape-morphing aircraft might be able to create virtual rudders that can be morphed back into the best non radar reflecting shape.

In the short-term, DARPA is focusing on creating morphing wings. In the long-term they hope to create a 40-ft wingspan spyplane that can physically change it's shape from a small delta shape (for speed) into a longer less-swept winged craft for loitering or dropping precision bombs. The initial 30-month project will focus on developing several wing designs for wind-tunnel testing. Eventually DARPA hopes to build a prototype that would include shape-changing structures beyond the wing such as morphing engine inlets for all speed regimes and a fuselage contracts in size as fuel is depleted which will in turn decrease It's radar signature. The study is supported by the Air Force Research Laboratory and NASA, which in 2001 began their
"21st Century Aerospace Vehicle project which includes a look into morphing technology. According to DARPA program director, Dr. Ephrahim Garcia, " The ability to morph would heavily influence system performance characteristics, such as: turning radius, endurance, payload, and maximum velocity, among others. The goal of the Morphing Aircraft Structures Program is to create and advance enabling technologies and ultimately design, build, and demonstrate a seamless, aerodynamically efficient, aerial vehicle capable of radical shape change."

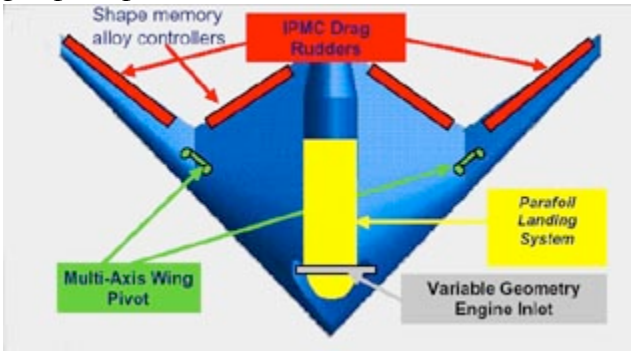
Ongoing research into biomimetrics may soon provide the insight needed for engineering wings that can flex and change shape. Scientists at research institutions and NASA are studying the structures of plants and animals for insight into creating materials, fluid mechanics, controls, power, sensors, and even self-repairing systems, all things that nature seems to create so easily. A hawk changes the flight aspect of his wings through nerve inputs to muscles, which in turn move tendons and flexible bones that provide the stiffness and shape of the wings. Plants create incredibly flexible and strong materials that if replicated could lead to aircraft structures of with incredible morphing capabilities.

University of Illinois researchers are attempting to create composite materials that automatically heal themselves when cracks develop. Microcapsules containing binary-polymerized healing agents (working much like epoxy resins) that harden when combined and exposed to air could be imbedded

in a wing's skin. When a crack or hole appears the capsules break, mix and harden repairing the damage instantly.

Many types of off-the-shelf materials are also being studied. Chief among them are memory composites that can have their shape altered by electrothermic input and piezoelectrics which expand and contract(like muscles) with the application of electronic current. Success is dependent on whether current morphing materials are strong and stiff enough to handle the aerodynamic forces that combat aircraft are subject to.

Recently the School of Aeronautics and Astronautics Purdue University West Lafayette, Indiana completed a study concerning Aeroelastic Tailoring or finding the right stuff to create an efficient morphing aircraft. Their research report included a proposal to build a morphing UCAV called The Sentinel. The Sentinel is a stealthy unmanned aircraft that could be aeroelastically reconfigured in-flight to be either a slow loitering spy aircraft or high speed precision bomber.



The Sentinel would be carried aloft by a mother-ship aircraft and released in a glide from 60,000 feet. At 40,000 feet the engines would start up and the wings morphed-outward to form a long and slender cruciform planform perfect for loitering over the target area. Once an enemy target was detected and selected, the wings would be morphed back into a highly swept configuration for a high speed dash at the target at an altitude of only a thousand feet above ground level. After dropping it's ordinance the Sentinel would return to high altitude and fly to friendly territory where it would deploy a parafoil and gently land to be recovered and reused by friendly forces.

But just how pie-in-the sky is morphimg? Air Force and NASA estimates imagine fleets of morphing aircraft by the year 2020 which may sound like the far flung future but is less than 18 years away.

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