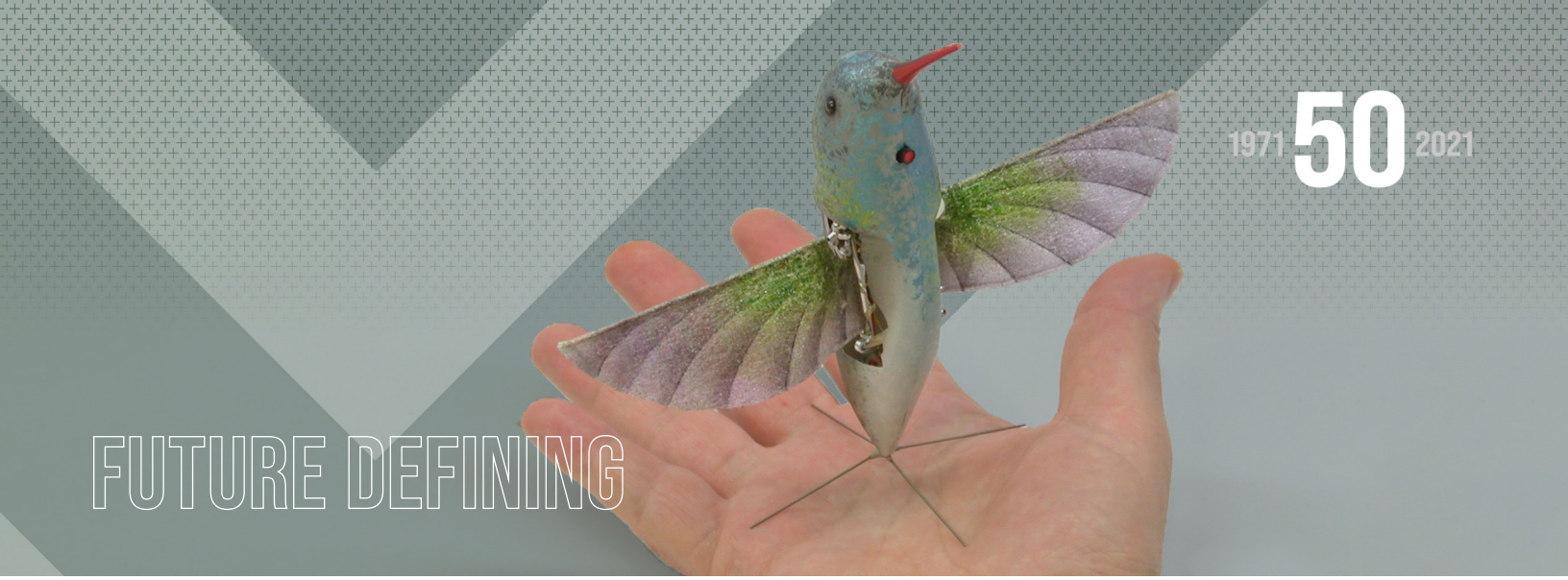

Look, Up in the Sky...It's a Bird...It's a Plane... It's a...Nano Hummingbird

A micro air vehicle that exceeded expectations

By Aimee Wiederhold, Content Marketing

The Nano Hummingbird proved to be a first-of-its-kind innovation. The micro air vehicle was the first flapping-wing nano unmanned air vehicle (UAV) with tri-axis control, which enabled it to hover and fly sideways, backward and forward, as well as rotate clockwise and counterclockwise – all by remote control.

Designed and developed by AeroVironment's MacCready Works Advanced Solutions team, the Nano Hummingbird was a unique project that satisfied a specific customer requirement. That requirement called for a remote-controlled aerial vehicle that was tiny, but highly maneuverable, with an embedded camera so pilots could navigate it into buildings using only a live video stream. And it had to be modeled after an actual bird!

The Defense Advanced Research Projects Agency (DARPA) announced the Nano Air Vehicle program in 2005. Not long after the announcement, the Nano Hummingbird went into development in 2006 and made its memorable debut in 2011.

DARPA chose AeroVironment for the initiative, not once, but twice. Initially, AeroVironment was chosen based on previous successful DARPA-funded micro air vehicle projects, such as the Black Widow and Microbat, as well as the quality of the company's proposal. Later, AeroVironment was selected to move forward with development based on its successful prototype concept.

The DARPA nano air vehicle requirements were challenging. Physically, the vehicle could be no larger than 7.5 cm (2.95 in) in any dimension, and the gross takeoff weight (GTOW) had to be 10 g (0.35 oz) or less while carrying a 2 g (0.07 oz) payload. For comparison, a standard U.S. penny weighs between 2.5 g (0.08 oz) and 3.11 g (0.1 oz) and a standard U.S. nickel weighs 5 g (0.17 oz). Notional mission performance requirements included a range greater than 1,000 m, the ability to hover in place for 60 seconds or more, slow and fast forward speeds of 0.5 and 5-10 m/s, close quarter navigation and controlled payload drop capability. In addition, the vehicle was to be tele-operated from a ground control station, but not required to operate fully autonomously. While not strictly required, minimal visual and acoustic signatures, as well as stealth by biological mimicry were highly desired. All of these requirements were to be achieved without thrusters and propellers.

The Nano Hummingbird differs from other ornithopters in its ability to control attitude in roll, pitch, and yaw during hover through the actuation of the same flapping wings it uses for propulsion. Other hovering ornithopters have used large tail surfaces to deflect the wake of the main wings. By providing propulsion and control with its wings alone, the Nano Hummingbird moves one step closer to nature's flyers, which commonly demonstrate the ability to hover without large tails or large tail deflections.

Close-up of the Nano Hummingbird in flight 2011.

Knowing that the wings would handle the majority of the workload, it is no wonder the team designed and tested more than 300 wing prototypes. It was not just about the look and function of the wings, but also their sound. Acoustics always play a significant role when drones are considered. If the aircraft is designed for surveillance, stealth cannot be achieved if it is too loud. The soft, structured wings of a real hummingbird dampen its sound. However, the hummingbird drone leans more towards large Asian beetles on the sound scale because of its rigid structure and the vibrations that flight generates throughout the vehicle.

For such a small "bird," it created a huge impact in the UAV world. The micro ornithopter drew the attention of Popular Mechanics, TIME magazine, and numerous news outlets.

The Nano Hummingbird captured the cover of TIME magazine's The Invention Issue – being named one of the top 50 inventions of 2011. It also took best in the field of robotics for Popular Mechanics Breakthrough Awards 2011 and was featured live at the event.

Matt Keennon, project manager and principal researcher, shared his view of the Nano Hummingbird task.

"I think it was inspirational – particularly to young engineers, students, and kids that are interested in robotics and science. The hummingbird really captured people's imaginations because it was the first of its kind. It flew so impressively and looked so realistic. I think that's why it landed on the cover of TIME."

He also shared that should there be another opportunity of this type, he would definitely take on a next generation hummingbird project with a focus on improving the wing flapping mechanism.

"Improved wing performance means quieter efficiency and improved video imaging," he said. "The small scale platform naturally leads to shaking, which makes it difficult to produce high-quality video during flight."

When asked if he could change the type of animal to model another micro air vehicle after, Keennon said, "A hummingbird would again be a great choice – a sparrow or swift bird would be great as well. For a very small animal, a dragonfly would be the ultimate micro UAV."

AeroVironment's success with the Nano Hummingbird project went beyond meeting the DARPA program requirements. The technological success with this program echoes in more recent efforts such as a MacCready Works Advanced Solutions project that models artificial intelligence after insect brain functionality. Keennon shared that the project's incredible technology left a lasting impression, especially with Dr. Bob Balaram at NASA Jet Propulsion Laboratory (JPL). Dr. Balaram previously stated that the Nano Hummingbird contributed to the decision to select AeroVironment as a key contributor on the Mars Helicopter project.

The tiny air vehicle embodies the iconic spirit that makes AeroVironment a pioneer and leader in unmanned systems. Perhaps in AeroVironment's next 50 years, more opportunities will emerge to further explore the niche of nano air vehicles and bio-mimicry.

Keennon is a 25-year AeroVironment veteran, model aircraft enthusiast and experienced flyer. He is currently positioned as a principal electrical engineer for the Rapid R&D group.

Karl Klingebiel, AeroVironment GNC (guidance, navigation and control) engineer, also played a critical role throughout the Nano Hummingbird project. He joined AeroVironment straight out of school because of his interest in the Nano Hummingbird work. Klingebiel learned mechanical engineering and design, and CNC machining just for this project. As the project grew, he moved on to software, controls, and electrical engineering including PCBA design. He also took the lead on wind tunnel testing, bench testing, and flight engineering. He was often one of the faces that represented the Nano Hummingbird project.

Nano Hummingbird flies between the hands of actress Sigourney Weaver and AeroVironment's Matt Keennon at the Popular Mechanics Breakthrough Awards October 2011. AeroVironment's Karl Klingebiel (far left) is also pictured.

Photo Credit: Popular Mechanics

AeroVironment's Matt Keennon (l) discusses the Nano Hummingbird's features with film director James Cameron at the Popular Mechanics Breakthrough Awards October 2011.

Photo Credit: Popular Mechanics