Surveillance Relies on Unmanned Flying Vehicles

Flight, payload technologies in pilotless MAVs drive their capabilities

Randy Frank, Contributing Editor -- Design News, June 15, 2009

Micro Air Vehicles or MAVs have proven themselves in military situations and are now poised for consideration in domestic applications. Going beyond MAVs, the U.S. Dept. of Defense Advanced Research Projects Agency (DARPA) is pursuing the next generation of even smaller craft dubbed Nano Air Vehicles (NAVs). Creating ever smaller, pilotless and even autonomous flying vehicles requires a shopping list of sophisticated technologies. Continued improvement of existing technologies or technology breakthroughs are among the issues confronting developers of these crafts.

Surprisingly, many of the same systems found on the largest airplanes are also found on some of the smallest, including the infamous black box. The interaction among the flight systems is even more critical in the smaller aircraft adding to the complexity of the design problem.

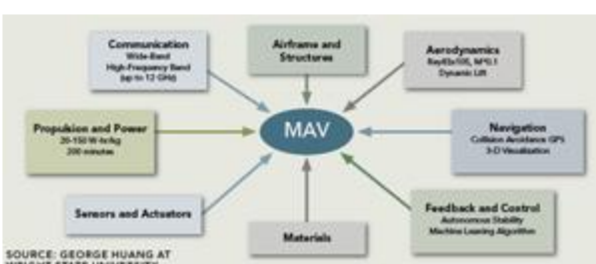
"We are really looking at a very interdisciplinary type of activity, especially the control theory is completely redefined," says George Huang, Ph.D., a professor and chair of the Dept. of Mechanical and Materials Engineering in the College of Engineering and Computer Science at Wright State University, Dayton, OH. Huang and other university researchers are striving to take MAVs to an even smaller scale. In partnership with Wright Patterson Air Force Base, Huang is working to solve the flight problems of lightweight MAVs, which weigh only grams. A few manufacturers have solved these issues on larger MAVs currently used by the U.S. Air Force, Navy, Army and other defense organizations in a variety of missions.

Fixed-Wing MAVs

AeroVironment Inc., a California company that develops unmanned aircraft systems, shrunk its highly successful 4-lb Raven Unmanned Air Vehicle (UAV) to a 1-lb MAV called the WASP III. "It had to be small and to be packaged in a very, very small area and volume such that it could be carried into the field by the operators who have to carry not just a UAV system, but also all the other things that they need to do their job," says Gabriel Torres, project manager and technical lead for the development of AeroVironment's WASP Project.

The propulsion system for the WASP III is heavily optimized for efficiency enabling it to carry a rather heavy infrared (IR) night vision camera (approximately 2-lb payload) for 45 minutes. "You can increase the endurance of an airplane by doing two things, decreasing its weight or increasing its efficiency," says Torres. "Obviously, when you have a fixed payload that you have to carry, you can't do much about the first one."

As a result, the engineering development involved an extensive amount of testing and optimization of the propulsion and battery systems for the electrically powered airplane. "The battery is the latest technology in lithium polymer cells," says Torres. The propulsion system and propeller are optimized for performance, while generating a minimum amount of heat.



One design issue AeroVironment engineers confronted was field serviceability. "For all of our systems, and WASP is no exception, we make a very careful, deliberate decision in the design process to make sure that the system is completely repairable in the field for the things that are going to be possibly damaged," says Torres. "We have parts in every one of our airplanes that are considered frangible - they're meant to break to relieve stress so that the expensive parts don't break."

For the fixed wing WASP III, the plastic propeller provides stress relief and may break to prevent damage to the engine. AeroVironment engineers developed an innovative method to quickly replace a propeller in less than five seconds, without using tools. "A custom-designed hub for the propeller allows you take it in and out very, very quickly," says Torres.

Ducted Fan MAVs

Vertical Take-Off and Landing (VTOL) aircraft using a ducted fan design avoid the propeller problem of a fixed-wing airplane but, at this point, is a much heavier aircraft. A ducted fan system draws air into the duct creating a region of low pressure around the duct that causes aerodynamic lift. DARPA has ducted fan data dating back to at least the 1950s, but a viable vehicle eluded reality until this decade. "The ducted fan system itself is just a completely unstable system, so it takes a very sophisticated flight control system and very fast processing rates to close the loop on those flight controls to keep it stable enough to employ a sensor," says Vaughn Fulton, senior unmanned aerial systems program manager, Honeywell's Defense and Space Electronics Systems.

For Honeywell's T-Hawk MAV, the solution employs its microelectromechanical systems (MEMS) technology. "Micro but very capable flight mission computers and inertial sensors together in a very small package," says Fulton. "Prior to that, the ducted fan vehicles had trouble because the size of the mission computers necessary to run these very complex flight controls was 20, 30 pounds worth of avionics and LRUs (line replaceable units)," he says.

In addition, Honeywell leveraged its design capability in engines, the nacelles that go around engines and the airflow associated with the turbojet engine components to improve a ducted fan aircraft performance. "We drove a several fold magnitude increase in the efficiency of a ducted fan system," says Fulton.

Cameras are another system area Honeywell engineers address in the development process. Initially, the cameras chosen for the MAV did not provide acceptable situational awareness. "We changed the field of view to match better the experimentation at the infantry level, how they want to employ the vehicle, at what range they were employing it, what altitude, their standoff ranges," says Fulton. "All of that drove additional specifications on the camera."

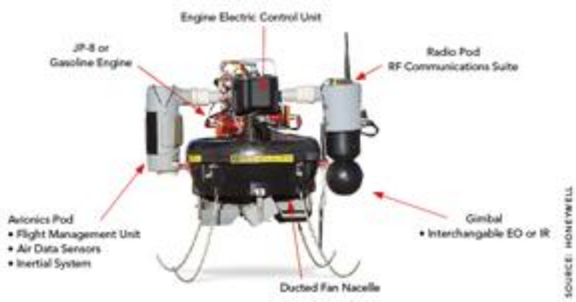
VTOL with a Twist

Aurora Flight Sciences initiated its GoldenEye 50 program as a technology validation aircraft. The project allowed Aurora to investigate various system and subsystems details of a ducted fan VTOL aircraft with two movable wings.

"The key figure of merit, the thing that you are interested in, is the ability to lift payload and fuel," says Tom Clancy, chief technical officer and vice-president of engineering, Aurora Flight Sciences. A rather complex set of trade-offs involve the duct sizing associated with the thrust loading of the lift fan and the power to weight of the engine.

Networking plays an important role in GoldenEye 50's control. Aurora Flight Sciences uses a network architecture for communications both inside and outside of the MAV.

Because of the networked architecture, the one operator and one aircraft with a point to point link between them of a typical radio-controlled UAV changes dramatically. Clancy explains, "It's a whole different paradigm, where you have multiple users doing different things and information being exchanged with different nodes of the UAV system all seemingly simultaneously."



Coping with the Environment

Working under non-laboratory conditions brings even greater challenges to MAVs. Weather not only impacts the flight of a MAV, it can destroy the communications. Radio communications can be disabled by lightning or electrostatic discharge (ESD) similar to any other RF system. In the case of an unmanned radio-controlled MAV, the loss of communication means lack of control and certainly the loss of transmitted data. To protect the radio components in guided missiles and other critical RF equipment, the military is turning to a surge protection scheme initially developed for amateur radio applications.

"A lightning strike is one thing, but actually the electrostatic discharge from a cloud-to-cloud event also can generate a 3,000 to 5,000V short duration pulse that is coupled into antennas," says Don Tyrrell, president of Alpha Delta Communications, a company that designs and manufactures surge suppressors, including the Model TT3G50 ARC-PLUG module.

Instead of a traditional LC suppression design, Alpha Delta Communications' solution is a constant impedance microwave-type thru line with a replaceable gas tube ARC-PLUG cartridge that bypasses high voltages to ground. The Defense Logistics Agency (DLA) qualified 50Ω surge suppressor (Cage Code 389A5) has been protecting ground receiving antennas for Raytheon in the Patriot missile program and recently added UAVs to its list of applications.

The need for suppression demonstrates one of many subtle design aspects that can be overlooked and forgotten in a sophisticated design project such as a MAV.