Honeywell Aerospace is working on fly-by-wire control technology for eVTOL aircraft being developed for urban air mobility applications.

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SOLVING THE AVIONICS PIECE OF THE UAM PUZZLE

Urban Air Mobility (UAM) has become a buzzword in the mainstream transportation industry with high-profile companies such as Uber, Bell and Sikorsky jumping into the fray. Behind the scenes, many component manufacturers are diligently working to solve the problems that naysayers contend will keep UAM from becoming reality for decades, at least at a scale that Uber imagines.

SOLVING THE AVIONICS PIECE OF THE UAM PUZZLE

Aircraft designed to operate in dense urban environments, and some cases autonomously (i.e. no pilot on board), are making new demands of those who develop the avionics responsible for key flight safety functions. New approaches to detect and avoid (DAA) capability are called for, along with autonomous navigation, command and control beyond visual line of sight (BVLOS) and new levels of data transmission are all called for from a fast-emerging sector of aviation that is in a hurry to succeed.

Overall, what's happening in cockpit technology is every bit as important as what's happening with advances in battery and motor technology that are driving the higher-profile race to achieve all-electric power. And so, this is where a big part of research and development for the urban air mobility (UAM) sector needs to go. It is by no means clear that some start-up pioneers grasp the sophistication that is required to let these aircraft fulfil their potential, and the level of redundancy to ensure that they do this safely.

Some of the answers to these challenges lie in software advances and, in this respect, it is no surprise that some of the best and brightest from Silicon Valley's stellar IT sector believe they have what it takes to drive the key breakthroughs. But aircraft are more than just computers with wings and rotors and so the task of integrating advanced software and digital systems requires a holistic aeronautical approach.

IT'S A BIRD, IT'S A PLANE… IT'S SOMETHING TO DETECT AND AVOID

Advances in DAA technology hold an important piece of the puzzle especially as the UAM industry entertains ideas of autonomous operations. Current radar technology for small and commercial unmanned aerial systems (UAS) is often not granular enough or not of sufficient range to provide the information needed to avoid collisions with objects such as birds, wires, or even a bundle of helium balloons in an urban environment. But as new radars with increasing range and granularity are already being developed for the what is being defined as the sUAS market, advances in DAA the hope is that technology will be available by the time the market is ready.

NASA used the Ikhana unmanned aircraft to test detect and avoid capability to allow autonomous aircraft to operate in the U.S. National Airspace System outside Class A and special use airspace. In this 2017 test flight, a King Air aircraft operated by Honeywell deliberately intruded on the Ikhana's airspace to prove that on-board systems would alert its ground-based pilots and allow the unmanned aircraft to maintain a safe separation distance.

"If [UAM] was just [entailed] airplanes [detecting] airplanes flying at 5,000 feet, then current ADS-B [automatic dependent surveillance-broadcast], TCAS [terrain collision avoidance systems], and weather radar technology would all be sufficient," said Michael Ingram, vice president of Cockpit Systems for Honeywell, which is one of several leading avionics manufacturers looking to meet the needs of these new generation aircraft. "But now we're talking about flying in urban areas, low to the ground, in vehicles that are inherently smaller in mass where there is greater probability of having contact with a bird or high wind zipping around a building. We need to be able to detect these things and still provide a safe operation."

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Ingram says that higher frequency/shorter range radars are being developed that will be able to detect birds and, "even a helium balloon going by." A relatively new radar system involving light imaging, detection and ranging (commonly known as LiDAR) is also being used to help prototype UAM vehicles navigate around urban obstacles.

LIDAR equipment uses pulsed ultraviolet, visible or near infrared light to measure distances to a target, building a digital 3-D representation of the target for mapping and navigation. Some autonomous automobiles such as Google's Waymo are already using LIDAR technology for vehicle control and navigation. Airborne laser swath mapping (ALSM) and laser altimetry are other laser-based technologies being explored for use in UAM vehicles.

Cameras can also be used for DAA and navigation. In the automobile market, Tesla founder Elon Musk was recently quoted by various sources as saying that using LiDAR for autonomous cars was "freaking stupid" due to its cost and complexity, and that, "once you solve vision, [LiDAR] is worthless."

However, the fact is that what is somewhat simplistically referred to as "vision" is far from being completely solved in the commercial airborne market yet. With military and sUAS applications, combinations of cameras and sensors of wavelengths have been used, and the same could be done for UAM aircraft, albeit with not insignificant cost of marrying up aircraft speed and radar range.

"Cameras can be continually looking at the ground to calculate safe landing zones," Ingram told **FutureFlight**. "For instance, determining between an empty parking lot that could serve as an emergency landing zone at night, but during business hours it's filled with cars and is not a good landing zone. It's really challenging to the engineers to be able to use the data that's available and calculate specific new ways to do things."

EO/IR sensors use electro-optical and infrared wavelengths to provide imaging in day or night conditions,

< Electro-optic/infrared sensors like those developed by FLIR Systems for its Aeryon Skyranger surveillance aircraft is one option now being considered for aircraft being developed for urban air mobility applications.

often generating gigapixels of data every second. Currently used in military applications for imaging and targeting applications, the UAM market is researching using EO/IR sensors for DAA operations.

Also making the leap from military to commercial UAS applications are acoustic DAA systems. Cypress, California-based Scientific Applications and Research Associations (SARA) Inc. has developed an acoustic sensor that can detect "non-cooperative" targets (meaning that they are not broadcasting their location via ADS-B or transponder) within a 5 nautical mile (nmi) radius. A 2018 report by the U.S. Federal Aviation Administration's Pathfinder Phase Two identifies SARA's Passive Acoustic Non-Cooperative Collision Avoidance System (PANCAS) as the only sensor technology available that provides a 360-degree field of regard, is small and light enough to be used on a sUAS, and has a large enough detection range to allow the vehicle to maneuver.

Generally small radar systems offer no more than a 120-degree field of regard, and multiple radar systems that provide a 360-degree field of regard to at least a 3 nmi range have not yet proved to be feasible in terms of size and weight restrictions for sUAS. However, these restraints may not be as restrictive for a larger passenger UAM aircraft.

THE SURVEILLANCE PIECE

Another factor to DAA in the UAM arena is avoiding other UAM traffic. While it's likely that UAM vehicles will be required to adhere to the same ADS-B requirements as other aircraft in the national airspace, the numbers and routes for the UAM traffic will differ from traditional aviation traffic. Regulators and manufacturers are discussing creating dedicated airspace corridors for UAM traffic, and vehicles will need to detect and avoid other piloted or autonomous vehicles within those corridors.

"We live in an air traffic management infrastructure, which means the aircraft is talking to someone on the ground, usually ATC [air traffic control], and that will initially continue with UAM," said Ingram. "But there's a huge amount of discussion and rulemaking that's happening around autonomous traffic management or unmanned traffic management [UTM]. The industry is talking about creating these corridors. The ATM (air traffic management) will stay out of these UTM 'tubes' and vehicles within these tube corridors will have to self-separate and regulate themselves."

Ingram says the UTM corridors would likely be from one to three nautical miles wide and eventually allow point to point navigation from "vertiports" on the outskirts of urban areas to downtown centers.

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To help UAM and other aircraft detect and avoid each other, regulatory and industry researchers are working on the next generation of TCAS-type solutions—called Airborne Collision Avoidance System (ACAS)—and how to use these in the UAS/UAM environment. ACAS will not pick up small organic obstacles such as birds, as it is meant to detect and avoid airspace objects such as other aircraft and drones using ADS-B and TCAS-like technologies.

ACAS is one piece of the overall DAA architecture, which will also include the aforementioned small radars, EO/IR systems, and acoustic systems. But it is one of the key pieces of technology to the FAA allowing BVLOS operations for future autonomous UAM vehicles.

THE PATHFINDER PLAN

The FAA's Pathfinder research program describes four core pieces of technology for drones to safely fly BVLOS: UAS tracking (transmitting live trajectory information), real-time manned aircraft data feed, detect and avoid system, and a display that provides tracking and DAA information to the pilot in command. While these four will likely not be the only four pieces required for passenger UAM vehicles to be allowed BVLOS operations, they will likely be included in standards currently being written by the regulators.

While the ACAS standards are still being written, tests of the technology are already underway. In October 2018, the Northeast UAS Airspace Integration Research Alliance (NUAIR) conducted a successful demonstration of ACAS-sXu, a version of ACAS developed for small UAS or drones, at Griffiss Airport in Rome, New York.

As a smaller, more-compact version of the ACAS X systems being developed for passenger and cargo aircraft, the ACAS-sXu used information from airborne and ground-based sensors to provide "detect and avoid" capabilities. Ten entities, including the FAA, GE Aviation, the Massachusetts Institute of Technology, Forem Technologies, and the John Hopkins University Applied Physics Lab were involved in the test.

According to a statement issued by NUAIR in November 2018, the ACAS tests showed that the system could be

Swiss-based Daedalean is working on an artificial intelligence-based autopilot system using cameras to allow the flight control system to "see" everything that a pilot would see from the cockpit.

"run as an airborne system, as well as a cloud-based system inside of the unmanned aircraft systems traffic management (UTM) architecture, with similar detect and avoid abilities."

"Through this successful demonstration, these partners have helped the unmanned systems industry reach another milestone," said Marke Gibson, [then] NUAIR chief executive officer, in the statement. "These collaborative efforts support the research and development critical to the safe integration of unmanned systems in the national airspace. Together we are advancing the industry as a whole and furthering this region's position as a national leader for UTM technologies."

Meanwhile, on the other side of the Atlantic, Estonia and Finland are already carving out airspace specifically designated for drones, at least on a trial basis. The Gulf of Finland unmanned airspace (or U-space) is part of a European sky air traffic management research program designed to provide secure airspace access to drones and other unmanned vehicles. The U-space was open from June through August 2019 to allow demonstrations of urban drone fleet operations with police intervention in various parts of Estonia and Finland. Operations included manned and unmanned aircraft flying in shared airspace, forestry inspections, power line inspection, maritime search and rescue, drone parcel delivery, and a flight by Volocopter electric vertical takeoff and landing aircraft in controlled airspace at Helsinki International Airport.

AUTONOMOUS NAVIGATION, COMMAND AND CONTROL

In a wide-open sky, GPS works well as a global navigation solution. But for an autonomous passenger-carrying UAM environment, relying solely on a GPS-based solution can be risky due to signal jamming, GPS-denied environments, and equipment failures. Regulators tend to avoid single points of failure in passenger-carrying vehicles, so there will need to be back up systems to GPS navigation, especially as vehicles become more autonomous.

"UAMs are going to be flying 1,000 to 2,000 feet above the tallest structure, so GPS navigation typically won't be a problem even in urban areas," said Christian Ramsey, president of uAvionix, a Montana-based manufacturer of ADS-B, communications, navigation, and surveillance equipment for general aviation and UAS since 2015. "Backups are still going to be required so GPS isn't a single-point of failure, but that's mainly for autonomous operations because if you have a pilot in the loop, which you will for years or decades before these vehicles will be allowed to go fully autonomous, the pilot would be able to navigate using more traditional methods."

Technologies using the same camera and sensors as for DAA can be used for navigation backups to GPS. Some sUAS continually take photos or video of ground infrastructure during their flight, collect the data in a database, and then use that data as reference for navigating back to their starting positions. For UAMs regularly flying over the same corridors, the terrain and urban feature data could be saved in synthetic vision databases and pre-programmed into the vehicle for navigation as a backup to the GPS.

Inertial sensors, such as those currently used on military air transport vehicles are one option, although a fairly expensive one.

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Part of the navigation puzzle is command and control of the passenger-carrying UAM, especially when discussing the autonomous option. "The question becomes whether a general aviation autopilot going to be sufficient for UAM, and I think not," said Ramsey. "[The industry] must figure out a more complex autopilot type of system to navigate for urban air mobility, developed to the same design assurance standards as existing autopilots carrying people on board."

Ramsey also stressed that since most UAM vehicles are VTOL or eVOTL designs, the size, weight, and power consumption of any avionics on board will be even more critical than for traditional helicopters or other aircraft.

"More weight results in less flight time or payload capacity before needing to be recharged," said Ramsey. "Everything we've done to miniaturize [components] for unmanned systems is directly applicable to the UAM market, whereas some of our competitors who have built larger systems for general aviation and up are not necessarily optimized for low size, weight, and power. We think they have a little catching up to do in terms of meeting the power consumption requirements of these eVTOL aircraft."

DATA AND SYSTEM SECURITY

As manufacturers work toward autonomous vehicles, the role of the pilot will be less about deflecting control surfaces and more about managing systems and the data that these systems generate. Already a commercial aircraft can generate terabytes of data in a single flight, between predictive maintenance data from airframe and engine sensors to recording flight control inputs and position tracking. Often this data is stored onboard and then offloaded when the aircraft is on the ground.

For UAM vehicles using cameras, radars and other sensing technology for either autonomous flight or remote pilot operations, the data generated may require greater onboard processing capability or data streaming bandwidth not currently available to the commercial market. Fortunately, a host of new communications technologies are being developed that should be available by the time UAM vehicles are ready. Ingram says that one of the crucial enabling technologies when it comes to communication will be the 5G cellular network currently being implemented in major cities worldwide that could deliver speeds up to 20Gbps.

"We're talking about orders of magnitude more data and faster data speeds than we have today with 4G," said Ingram. "5G will not only enable us to get data on and off the airplane, but also be able to sequence ourselves and communicate from vehicle to vehicle and from vehicle to ground."

Ingram says 5G implementation is still facing "a number of big challenges" but estimates that 5G will be available about the same time as UAM aircraft begin operating in the mid 2020s. With this in mind, some eVTOL aircraft developers have been forging alliances with 5G telecommunications groups such as AT&T in the U.S. and Vodafone in Europe.

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Other high-speed communications solutions include new low Earth orbit satellite networks designed to provide high-speed Internet access around the globe. One example is SpaceX's proposed 12,000 satellite Starlink constellation, which received U.S. Federal Communications Commission approval in November 2018 contingent on launching at least 6,000 satellites by 2024.

But with data transmission comes security risks. "Security is a huge issue that we all have to tackle," said Ramsey. "Some of the technologies out there like blockchain, and how we implement that level of encryption and security, is part of the conversation when it comes to communication."

PUTTING IT ALL TOGETHER

Avionics manufacturers are working with several UAM aircraft developers, although, in quite a few cases, with a high degree of secrecy about the extent of these partnerships. Ramsey said uAvionix is "working with a UAM developer but cannot say who," and Garmin declined to talk to **FutureFlight** for this article, although Ed De Reyes, CEO of Sabrewing, discussed the collaboration between Garmin and California State University Channel Islands for navigation systems on his semi-autonomous cargo craft currently undergoing FAR Part 23 certification.

"California State University Channel Islands is building the sensor interface computer to allow the aircraft to maneuver autonomously around air and ground targets," De Reyes said. "The university is teaming with Garmin using a GWS 70 radar as an anti-collision radar spotting targets out to 50 nm; if [a target] gets within 8 nm, the aircraft will autonomously move around that target and send a notification back to the operator. The ground system is also made by Garmin."

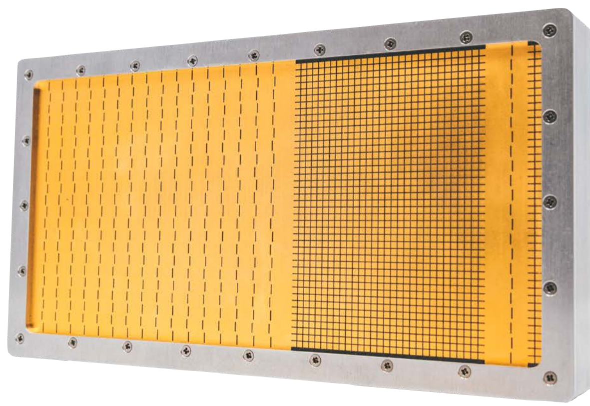
De Reyes also listed the myriad other avionics units required to make the Sabrewing semi-autonomous craft work in the current airspace including Cobham satellite communication equipment, FLIR camera-based system, Iris Automation artificial intelligence computer, Total Engineering LiDAR, and uAvionix ADS-B. The cargo craft will also contain a Euroavionics triple redundant autopilot system, with each autopilot "backed by an IMU (inertial measurement unit) and each IMU is backed by a GPS input."

"We're mandated by FAA to have a pilot still follow the progress of the aircraft from the ground," said De Reyes, "But there are no stick or throttle controls. It's a semi-autonomous system. When the pilot wants to take off, he pushes a keyboard button. The aircraft executes a takeoff and follows the flight plan already fed into the triple-redundant autopilot system."

Honeywell's partnerships include Israel-based start-up Eviation Aircraft, which is developing an all-electric 9-place fixed wing commuter aircraft called Alice to meet FAR Part 23 standards and scheduled to conduct first flights later this year; and also Pipistrel, a Slovenia-based electric aircraft pioneer now working on two eVTOL models. On January 24, 2019, Honeywell and Pipistrel announced the signing of a memorandum of understanding to explore and develop solutions for eVOTL aircraft.

Several leading avionics manufacturers are working behind the scenes with developers of eVTOL aircraft but most of these are reluctant to state publicly which programs they have established formal partnerships with or when and how their technology may be adopted.

"Honeywell's expertise in integrated avionics and flight control systems, systems integration, certification, and manufacturing, combined with our capabilities in designing and developing advanced light aircraft, makes us the perfect pairing to advance the urban air mobility market," said Ivo Boscarol, founder and president of Pipistrel in the joint press release about the partnership. "Pipistrel was chosen to be one of Uber's vehicle development partners [in 2017] for its urban mobility solution, and our VTOL air vehicle features next generation propulsion technology for achieving embedded lift. We have the concept that unlocks a cost-attractive electric VTOL opportunity by addressing efficiency and noise hurdles in vehicle lift, hover and cruise stages of flight."



< Honeywell is offering its Intuvue RDR-84 radar for urban air mobility aircraft. The system offers 360-degree awareness viatmultiple compact, software-based phased array sensors.

"We're working very closely with Pipistrel," said Ingram. "We're talking about architectures, flight controls, avionics, some of the environmental control systems, actuation, and propulsion. So, we're very much engaged with them and their vehicle. They're one of the top five on the Uber list of OEMs with the highest probability of building vehicles [for the ride-sharing group's planned air taxi services]."

PILOT OR NO PILOT

While the overall aim of UAM is toward autonomous flight, UAM vehicles will likely start out with fully certificated pilots. Over time the pilot position may evolve into a combined systems operator and flight attendant as regulatory bodies and the general public increase their confidence in UAM. The vehicle operator would likely have some type of lower-level flight certificate showing a familiarity with the vehicle systems and would be able to land in emergency situations. The operator may serve as a sort of flight attendant as their normal job, checking passengers in, making sure safety belts are secured, and keeping passengers calm during an emergency.

Flying in urban conditions low to the ground, there isn't going to be a lot of time for someone to react in an emergency, especially someone who isn't a pilot or familiar with the systems. So, the vehicle will need to be ultra-reliable and the systems easily operated by either a remote pilot or the flight attendant on board before autonomous flight will be allowed.

Even when the avionics and other systems are fully capable of autonomous flight without a pilot on board, it may take several decades before trust in UAMs will increase to the point that passengers are willing to strap into a pilotless vehicle. "Obviously aircraft have been flying on autopilot and flight controls for decades, so it's more of a passenger perception that is the big roadblock to autonomous flight," said Ingram. "When will passengers feel comfortable not having a pilot up front?"