Managing Unmanned

Projections for growth in civil unmanned aircraft operations boost NASA plan to create low-altitude airspace system

Graham Warwick Washington

Today's air traffic management system was born of necessity, out of a deadly mid-air collision over the Grand Canyon in 1956. Now visionaries who foresee low altitudes buzzing with small unmanned aircraft do not want to wait until people are hurt before bringing some order to this uncontrolled airspace.

Unmanned package-delivery aircraft, such as the vehicle-based HorseFly (above and inset) under development by the University of Cincinnati and electric vehicle maker AMP Trucks, are expected to be heavy users of low-altitude airspace.

UNIVERSITY OF CINCINNATI PHOTOS

NASA is crafting an unmanned aerial system (UAS) air traffic management (UTM) program to enable safe and efficient use of airspace close to the ground for civil UAS operations ranging from aerial photography and package delivery to precision agriculture and infrastructure monitoring. Long term, the system could enable low-altitude operations by personal air vehicles and autonomous air taxis.

UTM will not remove today's ban on civil UAS, but once FAA regulations are in place, it will enable users to understand where they can fly and when, who else will be using the airspace, whom to tell if flight plans change and what to do if something goes wrong. The goal is to allow initial low-altitude operations within five years and scaled-up, fully autonomous operations in 10-15 years.

"If we do not have a system in place for UAS at low altitude, we will have to respect the history of air traffic management" and risk relearning the lessons of the Grand Canyon collision, says Parimal Kopardekar, UTM principal investigator and manager of NASA's project to develop concepts and technology for the FAA's NextGen program to modernize the national airspace system (NAS).

"Not enough attention is being paid to integration in low altitude, particularly Class G airspace," he says. This is uncontrolled airspace, typically below 1,000 ft. above ground level and outside the national airspace system managed by FAA air traffic control. "Self-driving cars do not eliminate the need for roads and signs," Kopardekar says. "We need to be ahead of the game and create a system for low-altitude airspace."

Once developed, UTM could be operated by the FAA or other certified service provider—such as state or local authorities—similar to toll roads today. "Or they could privatize it, as long as regulations and certification standards are met," he says.

UTM is part of a larger NASA plan to bring autonomy to civil aviation. The National Research Council (NRC) has just completed a NASA-commissioned report outlining a research agenda for increasing autonomy (see page 28). Low-altitude airspace could provide room to try out concepts. "This could unfold in a way that allows us to bring autonomy to airspace operations," Kopardekar says.

Conceived through an internal process that encourages researchers to develop new ideas, UTM quickly attracted enough external interest to catch the attention of NASA headquarters. "We got a lot of feedback from the external community that this was an experiment worth trying," says Kopardekar. The NASA Advisory Council (NAC) supported the idea and NRC's autonomy study team was briefed on the concept. "Everyone thought it is definitely worth a try," he says.

"It's a perfect NASA idea—what if we create a separate air traffic system for things that fly in what the FAA does not consider navigable airspace?" says John Langford, president of UAS maker Aurora Flight Sciences and a NAC member. "The NAS is well-tuned and is not a laboratory to test new ideas. This is a way to create a lab within the NAS, a separate architecture for the little stuff where we can cut the Gordian knot and experiment with modern technologies, then propagate them into the bigger NAS."

An industry day in February attracted 150 participants from UAS and ATM manufacturers, universities and laboratories, government agencies and FAA test sites, application experts and insurance companies. "There seems to be a lot of interest in NASA taking the lead in bringing the community together to test concepts and demonstrate operations," Kopardekar says.

Industry "supports the goals of the effort, which would encourage commercial use of such systems while safeguarding the national airspace system," says the Association for Unmanned Vehicle Systems International, adding that "developing such a system will require partnerships between government, industry and academia."

The initial UTM concept is to provide UAS users with a cloud-based interface to enter the planned trajectory for a low-altitude operation and see if the airspace is open or closed and if there is bad weather or congestion, so they can decide if it is worth flying. "In the beginning, it would be procedural in nature," he says, but UTM will evolve to be increasingly dynamic and agile.

The system will provide information on airspace activity, weather conditions, terrain and obstacles to avoid, and any areas that are "geo-fenced" to reduce the impact on other low-altitude operations or to respect community noise or privacy concerns. Predicting severe weather, particularly high winds, is a key function, as many small quadcopters will fly backwards in anything more than moderate winds, he says. Predicting and managing airspace congestion to ensure safety is another key capability. "That will come pretty soon—the large operators are ready to move."

To this basic service will be added the ability to detect conflicts between planned trajectories and suggest conflict-free pathways to users. The system will also provide information to general-aviation operators such as emergency medical helicopters to alert them to low-altitude airspace where there is high UAS activity.

"The system will serve as an information source enabling all operators to plan and execute missions within constraints," says Kopardekar. NASA's goal is a single system architecture that can manage multiple customers with diverse mission needs and profiles, flying UAS that range from portable to persistent. UTM will authenticate users to avoid unauthorized use of airspace.

Under a 5-6-year program to begin in fiscal 2015, NASA plans to evolve the near-term system over four builds about 18 months apart. Build UTM1 will provide information that affects UAS trajectories, including "rules of the road" for procedural separation of aircraft based on altitude. This will enable users to generate, file and adjust a trajectory and check it for obstacle avoidance, airspace congestion and forecasted weather. The UTM airspace manager will be able to set up rules for geo-fencing, blocking and delegating airspace for single UAS or fleets.

Build UTM2 will enable the system to make dynamic adjustments to airspace availability and manage contingencies such as loss of the command-and-control communications link to a UAS or a vehicle failure. UTM2 will be able to predict when airspace demand and capacity are getting out of balance and adjust UAS scheduling when the expected demand is high.

UTM3 will add autonomy to manage separation and predict and avoid conflicts between different classes of UAS using capabilities in the vehicle or on the ground. With this build, the system will be able to actively monitor whether vehicles conform to their trajectories inside geo-fenced areas. UTM3 will add the web interface providing access to all other operators, such as helicopters and general aviation aircraft.

The final build, UTM4, will focus on contingency management and particularly large-scale circumstances that require all vehicles to land immediately, such as hackers taking control of a UAS. "The system would call out 'Everybody land' to identify who is the rogue UAS," says Kopardekar. "There are arguments about whether we need that level of capability, but I feel our 9/11 experience shows we need large-scale contingency management to maintain safety and security."

NASA plans to develop UTM through partnerships with stakeholders including UAS manufacturers and retailers as well as companies that can provide needed technologies such as cellphone-based data links and low-altitude radars. "We will do joint tests of each build, the number and heterogeneity of vehicles increasing with each event," he says. "The first will have a few vehicles, all doing the same thing. . . . Then we will add more vehicles and more diverse missions, different platforms with different capabilities, all in the same airspace."

"Toward the end of 2015 we will put out a request for information to seek partners for the tests," says Kopardekar. "We are looking at a very aggressive partnership model. We want to run like a start-up company, with groups tightly working together to understand the scenarios and develop an architecture rapidly," he says. "We are trying to be more agile, to build a little, test a little."

R&D focus areas include the "last/first 50-feet issue" of safely landing and taking off autonomously without hitting animals, people or obstacles; noise analysis to determine nuisance levels as low-altitude operations increase; onboard collision avoidance that works in all conditions with cooperative and non-cooperative, manned and unmanned aircraft; back-up separation management, both onboard and offboard; dynamically changing trajectories; and fully autonomous airspace capacity management. "We need more sensors sending a lot of data," says Kopardekar.

"When fully mature, the system will be based on the principles of autonomicity, or self-management," he says. These principles include self-configuration between normal and safe modes; self-optimization of airspace to maintain efficiency; self-help in degraded conditions; and self-protection. "Humans will still do the goal setting, but it will be management by exception," he says.

Enabling Autonomy

Nondeterministic systems will be key to unmanned operations in civil airspace

Graham Warwick Washington

BOEING

Boeing's experimental Phantom Eye is on the technology path from automated to autonomous unmanned aircraft.

As unmanned systems evolve rapidly from remote piloting through automated flying to autonomous decision-making, civil aviation will not escape unscathed. Beyond unmanned aircraft, the technology is expected to find its way into aircraft cockpits and air traffic control centers to increase efficiency and safety.

Ensuring safe and reliable behavior by systems that can adapt to their environment is the barrier to increasing autonomy in civil aviation, says a report by the U.S. National Research Council (NRC), commissioned by NASA's Aeronautics Research Mission Directorate The report identifies key barriers and provides a national research agenda for enabling the introduction of autonomy into civil aviation.

"[Increasingly autonomous] systems have the potential to improve safety and reliability, reduce costs and enable new missions," states the report. But deploying such systems "is not without risk," and failure to implement them "in a careful and deliberate manner" could have the opposite effect, it warns.

The critical challenge is being able to assure that adaptive and nondeterministic systems, which can modify their behavior in response to the external environment, are safe and reliable. Key barriers to meeting that challenge, the report says, include the lack of accepted design and test practices for decision-making by advanced autonomous systems and existing validation and verification (V&V) and certification processes that are insufficient to engender trust in those systems.

Nondeterministic systems can make decisions in real time to improve performance, but do not always respond the same way to identical inputs, the report notes. Current certification criteria and processes and V&V methods can only cope with deterministic systems.

"Autonomy is growing with computing power, and bringing with it a host of new issues," says Mike Francis, chief of advanced programs at United Technologies Research Center. One is the impact on air traffic management, which is today physics-based, when machines can make their own decisions, he says.

Today certifying software is based on "testing inputs and outputs with a pass/fail mentality," he says. "We drill through every line of code to ensure it performs as promised. A deterministic outcome is assumed. But a different kind of software is coming that learns from the past and changes its behavior, . . . for physical functions [and] mission-level decisions. Today's certification approach will not work at all. Certification needs to be more like that for pilots and crew, which is less purely objective."

The report identifies eight high-level research projects, involving NASA and other government agencies, to address the barriers to increased autonomy. The top four focus on the behavior of adaptive/nondeterministic systems; operation without continuous human oversight; modeling and simulation; and validation, verification and certification.

Research into characterizing and limiting the behavior of advanced systems would include developing performance criteria (such as stability, robustness and resilience) and methods beyond input-output testing; and determining the roles humans play in limiting that behavior.

Research into human oversight would include looking at requirements for supervision as a function of the missions, capabilities and limitations of autonomous aircraft; and developing systems that respond safely to failures, mitigate high-risk situations, and detect and avoid threats without oversight.

Modeling and simulation research should encompass its use within advanced autonomous systems; for coaching adaptive systems and human operators during training; to assess safety and cybersecurity; to increase trust and confidence in systems, and to assist in accident investigations.

Recognizing that the level of aviation safety within national airspace is built on FAA requirements for formal verification, validation and certification, the NRC recommends research to define requirements for intelligent software and systems; improve test fidelity; define new design requirements; and propose new certification standards.

Credibility Crunch

Group readies "last, best chance" to show NextGen relevance

John Croft Washington

A government and industry team charged with bringing more credibility to the FAA's next-generation air transportation (NextGen) system will guide the rollout of specific FAA projects over the next three years in an effort to demonstrate progress.

"This may be our last, best chance for some near-term benefit from NextGen. A big stumble here may jeopardize industry confidence," says Bill Ayer, chairman of RTCA's NextGen Advisory Committee (NAC), which launched the NextGen Integration Working Group (NIWG) in February. That group is charged with recommending to the FAA the highest impact, near-term projects related to performance-based navigation (PBN), surface operations, closely spaced parallel runways and controller-pilot datalink communications. Ayer says the goal is to "deliver measurable benefits by certain dates, and thereby increase the community's confidence in NextGen."

The push comes amid ongoing concerns by lawmakers, government watchdogs and airlines that the FAA has not adequately defined or demonstrated NextGen's capacity and efficiency-enhancing capabilities and benefits, despite spending billions in the 10 years since the program started. NextGen is expected to crest $40 billion when the final system is in place in 2025, with airlines paying a portion through avionics and training costs.

Multiple audits have suggested that the agency can regain stakeholder confidence by accelerating elements of NextGen in which airlines can participate in the near-term largely by using the avionics already purchased, thus making a business case for additional investment.

The NIWG teams are taking "deep dives" into the four capabilities to identify what is necessary for the FAA to get a jump start on deployment, accelerating or modifying existing plans that may not have had the same emphasis. The group will deliver an integrated implementation plan to the NAC in October, after which, Ayer says, the NAC is "working to determine appropriate follow-up mechanisms or formats to hold the industry and the FAA accountable for the commitment being made, track progress and identify [and resolve] problems early."

The NIWG datacomm team, which includes six airlines, plans to accelerate the deployment of controller-pilot datalink capability for departure clearances (DCL) at 56 airports. Longer-term plans call for datalink communications in 20 air route traffic control