

Air to Air Sense and Avoid on UAS

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UNSY 605: Unmanned Systems Sensing, Perception, and Processing

2017

Web version: <https://ryanblakeney.com/papers/air-to-air-sense-and-avoid.html>

Abstract

Every day in the National Airspace System (NAS), Unmanned Aircraft Systems (UAS) fly among civilian and commercial air traffic. These UAS are not fully equipped to handle flying among other aircraft because the pilots operating them cannot use a see and avoid method for clearing other aircraft. The FAA currently uses large bubbles around UAS to maintain a large separation from manned aircraft operating nearby. By introducing a system for UAS that is like the widely used Traffic Collision Avoidance System (TCAS), the FAA and other users in the NAS would likely become more comfortable operating among UAS. I am proposing a collision avoidance system that would sense and avoid automatically and immediately alert the UAS operator and either take control or recommend immediate action to resolve the conflict. This would improve the outlook of the future of Military and Civilian UAS in the NAS and eventually global operations.

Keywords: unmanned systems, UAS, NAS, commercial, airspace

Summary

Large Military and Civilian UAS operations in the NAS are heavily regulated. They are currently requiring UAS to operate in special use airspace or they are keeping manned aircraft far away to keep the aircraft well clear of each other. “This concern is also shared by other NAS stakeholders. The Aircraft Owners and Pilots Association (AOPA) has repeatedly stated that UAS (even small ones) should be governed by the same rules that apply to manned aircraft. AOPA is also against the use of restricted airspace to segregate UAS operations, since pilots would need to circumnavigate that airspace raising their expenses” (Dalamagkidis et al, 2011)

I believe it would be in the best interest of all NAS users to institute a TCAS type system on these UAS that would automatically avoid other aircraft. According to MIT Lincoln labs, there is a system being created called the Airborne Collision Avoidance System X. “Unlike TCAS II’s rule-based logic, ACAS X’s logic employs probabilistic models to represent various sources of uncertainty (e.g., pilot nonresponse, surveillance errors, etc.) and computer optimization to consider safety and operational objectives as defined by system experts and operational users.” (MIT, 2015) A system like this that can integrate into the current TCAS system that is already utilized by all commercial aircraft could greatly reduce hesitation on the use of UAS around manned aircraft.

Learning outcomes from this type of system would include requirements of the ability to autonomously avoid other aircraft with or without pilot input. I would like to understand the limitations involved with operating near aircraft that may not have a TCAS system installed such as a General Aviation (GA) aircraft. These types of objectives are what stand in the way of a safer and efficient NAS.

Problem Statement

With the current state of aviation in the NAS, UAS are still seen as a liability among manned traffic. A policy that is currently being used by the FAA states “Approvals for UAS operations require the proponent to provide the UAS with a method that provides an equivalent level of safety comparable to see-and-avoid requirements for manned aircraft. Methods to consider include, but are not limited to, radar observations, forward- or side-looking cameras, electronic detection systems, visual observation from one or more ground sites, monitoring by patrol or chase aircraft, or a combination thereof.” (FAA, 2015) These types of requirements show that the FAA is still very concerned about the safety of manned aircraft that have pilots who can actively look outside for other aircraft.

There are some work arounds for these types of requirements and that is special use airspace. For global operations, there is usage of the Notice to Airmen (NOTAM) system to restrict areas or to let other aircrew know that there are UAS operating in certain areas. “Despite these problems, many countries have established preliminary operational guidelines that allow limited operations in their respective NAS. For safety reasons, UAS flight is currently segregated from the rest of the air traffic, mainly with the use of NOTAMS.” (Dalamatidis et al, 2011) The use of airspace to keep UAS away from manned traffic is a nuisance for the UAS pilots and the manned pilots involved because they must fly around each other. NOTAMS for UAS operations can also pop up out of nowhere as they are not posted until UAS operations are happening. This causes problems for commercial aircraft and limits the UAS’s ability to move outside of the designated special use airspace. A system that can autonomously avoid other traffic could change the current perception on UAS and how they operate in the NAS.

Significance of Issue

The FAA is still working on regulations for the NAS regarding UAS. They currently require a Certificate of Authorization or Waiver (COA) to operate UAS among manned traffic in the NAS. “The Federal Aviation Administration (FAA) has established a process enabling public agencies to request a Certificate of Authorization or Waiver (COA) to operate UAS in the NAS. The COA process is resource intensive and lengthy; additionally, COAs are restrictive and often lack the flexibility to meet the needs of the entire mission. For UAS to integrate seamlessly in the NAS, major technical and regulatory challenges must be resolved.” (Consiglio, 2012) This process can tie the hands of even the military when these COAs are not correctly or expeditiously approved. With these requirements, both manned and unmanned aircraft must steer clear of each other due to an airspace assignment from the COA. These types of issues can cause problems for UAS in that they cannot leave their assigned airspace. This causes issues for manned aircraft because they must avoid the special airspace and burn more fuel and take more time to go around them.

TCAS

The Traffic Collision Avoidance System is a device installed on the actual aircraft. It is used to help separate aircraft from each other when Air Traffic Control (ATC) has failed to keep them separated or if the aircraft in question are outside of radar coverage and they do not see each other. “TCAS is a family of airborne devices that function independently of the ground-based air traffic control (ATC) system, and provide collision avoidance protection for a broad spectrum of aircraft types. All TCAS systems provide some degree of collision threat alerting, and a traffic display.” (FAA, 2011) These systems fall into the Sense and Avoid (SAA) category and act as a back up to the pilots flying the aircraft. This is significant because it shows that pilots are not always going to catch the other traffic that may be flying in their area. The TCAS system saved my life one day over Afghanistan. Our C-130 came face to face with an unmanned aircraft and the TCAS system told me to descend. My reaction to this warning helped me avoid crashing into another aircraft and saved our lives.

Airborne Collision Avoidance System X

The Airborne Collision Avoidance System X is “A next-generation onboard safety system that uses a new approach to collision avoidance logic reduces midair collision risk and extends collision avoidance protection to new aircraft classes.” (MIT, 2015) This system detects other aircraft from mounted sensors on your own aircraft. It then estimates the relative position and velocity. This system is different from TCAS in that it doesn’t use standard rule based logic to determine if other traffic is a threat. It uses real time modelling to determine if the aircraft are a threat to each other. This system is significant because advances in technology and computational power have allowed it to think in real-time. This type of power allowed it to be used on an unmanned aircraft for testing. “In 2014, the FAA completed an initial ACAS Xu flight test in conjunction with the National Aeronautics and Space Administration and General Atomics. This test represented the first time that a coordinated automatic response was employed by a UAS to resolve collision avoidance conflicts.” (MIT, 2015) This type of system will change the world of aviation by giving UAS the ability to fly near manned aircraft without fear of midair collisions.

Sense and Avoid

“The purpose of a sense and avoid (S&A) function is to act in the place of a human pilot to detect and resolve certain hazards to safe flight. These hazards consist of other traffic or objects presenting a risk of collision. Air traffic encompasses aircraft, gliders, balloons and even other unmanned aircraft system (UAS). Other hazards include terrain and obstacles (e.g., buildings, towers, power lines).” (Angelov, 2012) The ability for UAS to sense and avoid other aircraft is paramount for its success to fly alongside other aircraft. Currently UAS are kept separated by using COAs and special use airspace. If we can use SAA, we would be able to lower the distance required by the systems. The SAA systems can usually see other aircraft when the pilots cannot. “The ‘see and avoid’ process can be difficult in some conditions of poor visibility, confusing backgrounds or high workload. The premise that UAS S&A need only be as good as human see and avoid is looked upon unfavorably by airspace regulators.” (Angelov, 2012) Airspace regulators, or the FAA, do not currently believe that SAA is a valid tool for separating aircraft. This creates the requirement for an automated system that when it sense another aircraft, it autonomously moves the aircraft to a safe position by itself.

Ground Based SAA. A ground base SAA system would be in constant contact with the UAS. This system will monitor the UAS’s position while simultaneously looking for other aircraft that may be near the primary UAS. If the ground based system detects a threat, it will then make the decision on the ground on the best way to maneuver the aircraft. This would be the least desirable by still effect method for this type of separation of aircraft due to the constant link with the ground station. This would also require the aircraft to stay within whatever footprint the ground station has for coverage.

Airborne Based SAA. An airborne based SAA system would be separate from the ground station. This would allow the aircraft to detect its own targets, declare them a threat, and select the maneuver that is most desirable to avoid the threat. This is the best choice in selecting a SAA system. This allows the aircraft to fly autonomously anywhere the operator wants to go without having any limitations due to performance limitations in the ground station. This also doesn’t require a constantly link with the ground station to keep a safe distance from other aircraft.

Ground & Airborne SAA. The ground and airborne SAA system would have a combination of the two systems. The aircraft or the ground station could detect any potential threats around the UAS. This data would then be transferred through a communications link to the ground station where the threat will be determined if it is a problem or not. If the ground station determines that the threat will be an issue, it determines what action it wants the aircraft to take to avoid the threat. This would then be sent back to the aircraft over the link and the aircraft would respond with that maneuver. This is not as desirable as the airborne SAA, however most modern UAS are flying with a constant connection to the ground station. This makes the Ground and Airborne SAA a viable option.

Airborne Sensing

Airborne sensing technology that would be required for SAA is already available today. Examples of these systems are the ADS-b, electro-optical cameras, LIDAR, Onboard radar, Ground Based Radar, and Acoustic. For the case of sensing other aircraft, this technology exists. When we consider the possibility that the threat aircraft may not be carrying a collision avoidance system like GA aircraft, we can use onboard systems to detect them. An example of this type of system is “A Pitot-static tube linked to a Micro-Electro-Mechanical Systems (MEMS) pressure sensor allowed the airspeed to be determined, providing the relative speed of the UAV to a stationary obstacle to be determined. Knowledge of the radar parameters and the vehicle speed allow the presence of obstacles in each of the four quadrants to be determined. The use of Doppler beam sharpening allows readings that correspond to obstacles which do not pose a threat to the vehicle’s current trajectory to be discarded.” (Viquerat et al., 2008) This type of system shows that if we have aircraft flying around without transponders or collision avoidance system, we can detect that and react to their presence.

Ground Based Sensing

Ground based sensing would require a ground based radar that is constantly monitoring the UAS that are flying. This already exist if you consider the ATC coverage over North America. By using this data and data from the Next Gen system, the aircraft can see other aircraft flying around that may or may not have a transponder or collision avoidance system. “The cost of a radar is likely suitable only for governmental use; private UAS operators would need to arrange access to the surveillance data.” (Angelov, 2012) This type of system would require more resources than an airborne system and this would likely drive the use of an airborne system instead.

Collision Avoidance & Self-Separation

Collision avoidance is the primary goal of these systems. The resolution of a threat to the aircraft must be defined and executed for the goal to be accomplished. “The usual choice for the collision avoidance function would equate to the ‘critical near-midair collision’ definition [4] of a truncated cylinder ± 100 ft. in height and 500 ft. in radius.” (Angelov, 2012) By having a standard definition, we can then start to determine how the aircraft will separate itself from the threat aircraft. Since the collision avoidance may take place between a manned and unmanned aircraft, it would be ideal if the system is designed to use the right of way rules in place for manned aircraft. This would make the UAS predictable as it maneuvers.

One consideration for this type of system is, who has the authority to perform the avoidance maneuver. When the UAS is being flown by a pilot, there must be a decision on if the aircraft will do what the pilot wants to do or what the aircraft wants to do regarding self-separation. The aircraft must then be maneuvered to a safe position away from the threat.

Alternative Actions

Alternative ways to accommodate UAS in the NAS are not plentiful. The most promising way to ensure the safety of all aircraft, is to keep the aircraft separated. A possible alternative would be separate highways in the sky for the different systems. This would get tricky due to the growth of commercial UAS use. The commercial users and the military will undoubtedly want to use their aircraft in airspace that may be different from the assigned highways. This will also be an issue due to the current growth of commercial UAS. “The commercial, non-hobbyist UAS fleet is forecast to grow from 42,000 at the end of 2016 to about 442,000 aircraft by 2021, with an upside possibility of as many as 1.6 million UAS in use by 2021. Pilots of these UAS vehicles are expected to increase from 20,000 at the end of 2016 to a range of 10 to 20 times as many by 2021.” (UAS Vision, 2017) This leads us back to our current position

of assigning special use airspace to the UAS while they operate with distance between them and the manned aircraft. Another alternative would be ADS-B. This system is being implemented by the Next Gen ATC system and all commercial aircraft and most civilian will require this system.

Recommendation

For MACA on UAS, the answer is clear. Equipping the aircraft with onboard systems that can detect other aircraft can improve their ability to SAA. By showing the FAA and the world that UAS are capable of safe operations, it is highly probable that the current limitations on UAS operations in the NAS will be lifted and they will be allowed to operate among manned aircraft. These systems are still in their infancy; however, the technology exists for these systems to be utilized. I recommend that Large UAS take advantage of these systems to allow them more freedom and capabilities when flying in the NAS.

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