



Sense and avoid - re-visited

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Abstract

In the aviation world, two main elements exist to avoid mid-air collisions; sense-and-avoid, and the aircraft being where it should be, i.e. flight planning. In a perfect world all aircraft would have flight plans (validated to ensure non-interference with other aircraft) and follow them as expected. A UAV only has its flight plan, so for an autonomous UAV a great deal of time and effort goes into ensuring this flight plan is good, and that the UAV is capable of following it.

Some traditional aircraft developers (and regulators) concentrate on the airborne aspects, without necessarily recognising the importance of the ground element issues. For a UAV, as for a manned aircraft, the "pilot" must keep situational awareness (to mitigate against the unexpected intruder) - but for a UAV, this pilot is on the ground.

Recent experience has led Praxis to conclude that whilst UAV pilots might not be in the air, they can still maintain sufficient situational awareness to implement a large part of a sense-and-avoid capability. The onboard systems and the air traffic provider report the aircraft's situation to the (on-ground) pilot. This places requirements on ground systems in both planning and operational phases. It also places dependencies on external agencies, such as airspace surveillance providers. Any potential move to ATC commands being data, not verbal, plays into the hands of the UAV system that always follows ATC requests. Does this remove (or reduce) the need for sense-and-avoid?

1 Introduction

In an ideal world, a UAV always follows its flight plan. This, coupled with the fact that the flight plan is correct, should be sufficient to ensure that the UAV avoids terrain (including obstacles) and other UAVs (assuming co-ordinated planning) and that it stays where it should be.

Given that flight planning is clearly key to avoiding collision, its integrity is paramount, especially where it is preferred over other methods more usually available with manned aircraft.

A longer-term additional requirement to enable VFR flights in non-segregated airspace is for the UAV to remain in VMC. This is not discussed here – instead, we discuss realising shorter-term aims for a “sense-and-avoid” capability.

2 What do the standards say?

Because of this reliance on the integrity of flight planning, one would think that aviation standards were explicit in their requirements for it, but this appears not to be the case. While the standards include much guidance and advice from the regulators on airborne UAS elements, any UAS has many ground-based components. The guidance contained in these standards is more limited for ground-based elements, a point noted by the UAV Task Force final report [1].

However, flight planning is a ground-based element – and we have already seen that flight planning is key to sense-and-avoid!

There is of course the aspect of maintaining VMC also – less of an issue for UAVs of course, but definitely an issue for other manned aircraft in their vicinity.

3 The problem

The rules of the air [2] state:

“Irrespective of whether a flight is being made with air traffic control clearance, it is the duty of the “pilot”, to take all possible measures to ensure that his aircraft does not collide with other aircraft”.

So even with “perfect” flight planning and execution, the need for sense-and-avoid is not removed. It is not enough to just always follow our plan – we cannot assume “we are in the right”. Incursion into our route must be catered for.

In practice, we can mitigate incursions by a number of means:

- defining UAV airspace – this, of all mitigations, must surely be key. It cannot (for the incursion reasons discussed above) be relied upon in ignorance of all else, but is one of the main ways



in which UAVs can be kept separate from other aircraft in the air.

- restrictions to segregate other traffic

With these mitigations in place, two issues then arise:

- Our UAV straying from its airspace
- Other aircraft “straying into our airspace”

Whilst preventing our UAV from exiting its airspace is controllable within our own system, preventing (or even being aware of) other aircraft coming into ours is not internally controlled. It can however be mitigated by radar coverage and communications (principally to inform the UAV operator of the impending incursion allowing them to take the required action(s)).

4 Situational Awareness

Traditionally, manned aviation has had limited awareness of the environment in which they are flying. Consider a pilot’s viewpoint from the front of an airliner – they have forward and sideways vision, limited vision up and down and no rearward vision at all.

Compare the operator of a single UAV, who from their seat in the ground control station has a 360° plan view of the aircraft in its surroundings, along with a predicted view of its future route shown on a graphical map display. On this display can be overlaid airspace boundaries, with geographic hazards highlighted for terrain avoidance. Which scenario gives the aircraft “pilot” better situational awareness?

In the case of the UAV operator, there is also the potential for even greater situational awareness – the ATC air picture could be provided as a map overlay on the UAV operator display. This is certainly the case in at least one UAS currently in use. Does this remove the need for sense-and-avoid?

5 See-and-avoid “lapse”

The following example shows that even in manned aviation, where see-and-avoid is not only possible but also routinely practiced, lapses (sadly often fatal) occur:

“Pilots of two electronic news gathering helicopters that collided in July 2007 while reporting a real-time

police chase ... failed to use “see and avoid” measures required by visual flight rules, the US NTSB has ruled. Contributing to the [fatal] accident ... were job duties that required the pilots to perform ... visual tracking duties.” [1]

6 Not a level playing-field

Societal perception appears still to be the biggest driver for UAV requirements. The general aviation requirements for software, where the resultant accident is Catastrophic, is limited to level C [4], yet the CAA are (at least anecdotally) indicating that a UAV of comparable size and weight to that of GA needs to have software compliant to level A.

And yet it is apparent that even manned aircraft do not always meet the requirements placed upon them – the rate at which general aviation mid-air collisions occur is in the order of ~ 1e-6 per flying hour.

7 So what for sense-and-avoid?

It is clear that a practicable solution for sense-and-avoid is not yet available. But that should not lead the UAS community to “sit on their hands” and wait for one to appear. This paper has shown that there are other things that can be done – now. These include:

- Maximising planning integrity – and that of the UAV to follow its flight plan
- Providing a surveillance/de-confliction service for the UAV
- Using the arguably wider situational awareness that the UAV operator currently has
- Realising the potential for extra situational awareness from giving further information to the UAV operator

In conjunction with these, robust mitigation for failures can also be implemented:

- Preparing for and dealing with loss of communications from the ground to the UAV
- Having contingency for engine failure (autonomous action backed up by operator action e.g. to warn other air users)



References

- 1 JAA/EUROCONTROL WORKGROUP NPA 16 Appendix, section 7.3 "UAV system elements to be included in Type Certification Basis"
- 2 AvP67, "MoD DPA Flying Orders to Contractors"
- 3 Source: Flight International, 02/02/09
- 4 AC23.1309-1C