(Probably) see and (possibly) avoid

By Stanislaw Drozdowski, EUROCONTROL and Harry Hutchinson, QinetiQ, UK

The *see-and-avoid* principle is as old as aviation and is rather straightforward: the pilot conducts a continuous visual scan of the surrounding airspace in order to detect hazards (principally other traffic) that might constitute a threat to his own aircraft. If a threat is detected, the pilot will then undertake an avoidance manoeuvre. This principle is applied successfully countless times every day, not only by pilots operating under VFR (Visual Flight Rules) but also when separation is provided by air traffic control.

See & Avoid

ICAO Annex 2 lays out 'The Rules of the Air', contained within which is the requirement that "An aircraft shall not be operated in such proximity to other aircraft as to create a collision hazard", and the statement that "It is important that vigilance for the purpose of detecting potential collisions be exercised on board an aircraft, regardless of the type of flight or the class of airspace in which the aircraft is operating…". The exercise of this vigilance, and the execution of any manoeuvres required for the purpose of avoiding hazards, is generally referred to as the 'See & Avoid principle'.

In this article we discuss the probabilities of the visual acquisition of other traffic and of successful avoiding action. The discussion is illustrated by a recent near mid-air collision[1] in UK airspace during which neither see nor avoid worked: the five crew members of a large military transport aircraft were alerted to the presence of a small single-engine aircraft but failed to see it; the pilot of the small aircraft saw the military aircraft but his avoiding manoeuvre did not prevent close proximity of the aircraft.

The terms "see" and "avoid" are habitually mentioned together. The implication is that the former leads inevitably to the latter: that a threat once seen will be successfully avoided, but this is not necessarily the case. "Visually acquiring" a threat does not guarantee that the threat can be avoided. For example: the threat may be seen too late for any successful avoiding action to be taken; an adverse manoeuvre by the threat may hinder the avoiding action; or a misperception of the relative position and motion of the threat may result in an ineffective avoidance manoeuvre.

Experience and anecdotal evidence suggest that the see-and-avoid principle usually works successfully in the case of slow moving and low-flying aircraft, but that its application becomes more challenging in the case of faster and/or smaller aircraft. Due to their speed and size, these aircraft are difficult to see and visual acquisition may occur too late to allow for any successful avoidance manoeuvre.

The chance of visual acquisition (and therefore the chance of a successful avoidance manoeuvre) increases if the pilot is aware of the presence of the potential threat. This awareness may come from traffic information provided by ATC or from observing other aircraft on a cockpit traffic display such as those provided by TCAS equipment.

A recent study conducted by QinetiQ for EUROCONTROL quantified the chance of visual acquisition, by implementing a simple mathematical model. The model takes account of the geometry of the encounter (the aircraft speeds and the angle of approach of the threat), the size of the aircraft, the visibility conditions, and whether the pilot has been alerted to the presence of the threat. The probability of visual acquisition was calculated for numerous and diverse illustrative encounter scenarios and readers who are interested in the detailed results are invited to consult the study report[2]. The study was conducted in a specific context (viz. the introduction of very light jets), but its finding are universally applicable.

TCAS

The Traffic Alert and Collision Avoidance System (TCAS) comprises airborne avionics that detects and tracks nearby aircraft through their SSR transponders. The relative position of these aircraft is displayed on a cockpit display of traffic.

- **TCAS I is a basic form of TCAS that provides Traffic Advisories (TAs) alerting the pilot to aircraft that may constitute a threat to his own aircraft. TCAS I is not mandated in Europe.**
- **TCAS II is a more capable system that in addition to TAs provides Resolution Advisories (RAs) telling the pilot how to regulate of modify his vertical speed in order to reduce the risk of collision with the conflicting traffic. In encounters between two TCAS II aircraft the sense of the RAs is coordinated. TCAS II is mandated for medium and large aircraft in Europe.**

The study concluded that the TAs generated by TCAS I can undoubtedly aid visual acquisition, being most effective against large and slow moving threats. However, in head-on encounters against smaller threats (GA and light jets), or fast moving threats (military jets), visual acquisition is particularly ineffective: the small size and high closing speed of the threat mean that there is virtually no prospect of timely visual acquisition, even when aided by a traffic display. Furthermore, the effect of reduced visibility markedly decreases the prospect of timely visual acquisition in all encounter geometries (even when the visibility is above the threshold for VFR).

Paradoxically, the increased chance of visual acquisition afforded by TCAS I equipment can have a potentially adverse effect in some encounters. If the threat is TCAS II equipped there is a significant chance that an avoidance manoeuvre based on visual acquisition will be initiated at about the same time as an avoidance manoeuvre in response to an RA by the threat. In these circumstances there is no guarantee that the two avoidance manoeuvres will be compatible and they may hinder each other, thus failing to resolve the risk of collision (if both aircraft were TCAS II equipped then the vertical sense of the RAs generated in the two aircraft would be coordinated so that the aircraft execute compatible avoidance manoeuvres).

See-and-avoid is effective in the majority of cases. Because of that its inherent limitations are often forgotten. Any failure of see-and-avoid where it is the sole means of collision avoidance may have very serious consequences. While probability calculations provide mathematical insight into the efficacy of see-and-avoid, the analysis of an incident in the UK serves as an illustration of its limitations.

Stanislaw Drozdowski

is an ATM Expert at EUROCONTROL HQ in Brussels, working in the area of ground and airborne safety nets. Previously, he worked as a system engineer with Northrop Grumman and as an Air Traffic Controller in Poland and New Zealand.

Harry Hutchinson

is an ACAS expert at QinetiQ in Great Malvern. Harry trained as a physicist at the University of Bristol and moved to RSRE (which has since become part of QinetiQ) to work on semiconductor physics, before moving into the field of ATM research.

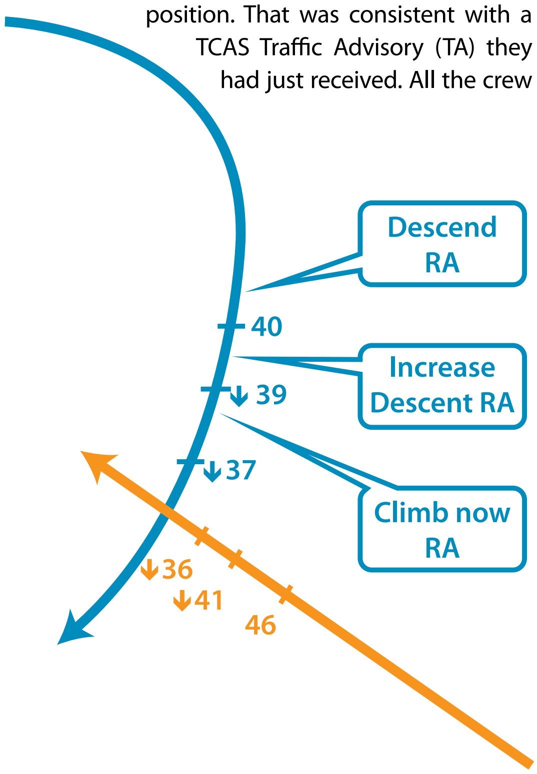
1- Near mid-air collision is defined in TCAS Technical Standards as an encounter in which the horizontal separation between two aircraft is less than 500 feet (0.08 NM) and the vertical separation is less than 100 feet. It is not defined operationally by ICAO.
2- The results of the Illustrative Probabilities of Visual Acquisition study are available from: www.eurocontrol.int/msa/gallery/content/public/documents/AVAL_Illustrative.pdf

(Probably) see and (possibly) avoid (cont'd)

The incident occurred during daylight in good weather conditions (scattered clouds, visibility 20 km) in Class G airspace. The events that led to the incident and the role of ATC are not described here, as they are not relevant for the topic of the article.

The aircraft involved were a single-engine Glasair RG flying under VFR and a large military transport aircraft, a C17 Globemaster III, on an IFR flight. The Glasair pilot was flying solo cross-country. His aircraft was equipped with a Mode S transponder but no TCAS. The C17 crew consisted of 5 people and the aircraft was equipped with TCAS II. The aircraft was painted in grey and had its high intensity strobe lights switched on.

The C17 was in a holding pattern at FL40, turning onto heading 220° at 230 kts, awaiting an approach clearance. The crew was advised by ATC of traffic 500 feet above in their 10–11 o'clock position. That was consistent with a TCAS Traffic Advisory (TA) they had just received. All the crew



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members started to search for the traffic. They were able to focus their visual scan to the relevant area by observing the target on the TCAS traffic display and having the benefit of ATC traffic information. Still, none of the 5 crew members saw the Glasair. Some 10 seconds after the TA, when the separation reduced to 2.2 NM and 500 feet a sequence of RAs was issued by TCAS II to the C17 crew: first "Descend", which strengthened to "Increase Descent" 7 seconds later, reversing after 2 seconds to "Climb now". At this point the separation was 1.2 NM and 200 feet.

The Glasair maintained FL45, flying heading 307° at 170 kts when the pilot saw a conflicting aircraft for the first time. It was at his "one-thirty" position at a distance of 1–2 NM, crossing from right to left. He could not judge the exact distance as he did not know the type (and the size) of the other aircraft. The Glasair pilot assessed that the conflicting aircraft was in level flight at the same altitude. Being fully aware of Rules of the Air, he knew that it was his responsibility to keep clear of the other aircraft and he thought he had enough time to do so. He decided to descend, rather than turn, as he wanted to keep the other aircraft in sight. As he approached the C17 it started to descend in response to a TCAS RA and the Glasair was forced to increase his descent to high speed dive (over 3000 feet/min.) in an attempt to maintain separation.

During the RA manoeuvres the C17 crew continued their effort to acquire the traffic visually. It was only during the climb in the response to the "Climb now" RA that they saw the Glasair passing directly beneath them.

The subsequent investigation conducted by the UK Airprox Board[3] established that the separation between the aircraft at Closest Point of Approach was 26 feet vertically and 0.05 NM (92 metres) horizontally. To put these numbers in perspective: the height of a C17 is 55 feet and the wingspan is 52 metres.

In conclusion, the exercise of the see-and-avoid principle is part of good airmanship and should be conducted whatever the type of flight or equipage of the aircraft. The probability of acquiring the threat visually and performing a successful avoidance manoeuvre is influenced by the geometry of the encounter, visual conditions, and the size of the threat. Ironically, increased probability of visual acquisition of a threat brings with it an increase in the probability that the two aircraft will potentially perform incompatible avoidance manoeuvres (especially true if one of them is following a TCAS RA). If both aircraft are TCAS II equipped then the RAs are coordinated to ensure that manoeuvres are compatible. Model based studies and incidents such as the one discussed here highlight inherent limitations of see-and-avoid in certain circumstances, even when the pilot is alerted to the presence of other traffic and an avoidance manoeuvre is performed.

3- UK AIRPROX Report No 2009-044, available as pages 43-48 at: www.airproxboard.org.uk/docs/423/UKAB2009-09AssessedAirprox.pdf