ALTISCOPE

Metrics for Near-Miss Events: Understanding Airprox, NMAC and "Inadequate Separation"

There is no publicly available global metric for comparing air traffic safety events in which two aircraft engage in a near-miss incident. Three separate and overlapping terms exist, and different air navigation service providers (ANSPs) may report and classify those events in separate ways.

Understanding the current metrics is important, as there is a propensity to compare near-miss rates in projected future high-density UAV environments to current rates observed globally. Indeed, these rates are interesting reference points when viewed alongside simulated UAV loss-of-separation and collision data. But applying the current rates as benchmarks for future UAV traffic densities - which could be between ten and 100 times higher than today's most congested airspace - would result in thousands more such events each year, which would almost certainly result in a much larger number of actual mid-air collisions as well. So while these metrics may provide an appropriate starting point for evaluating UAV near-miss severity and risk, developing an appropriate benchmark rate will require further research and awareness of local regulatory expectations.

We evaluated three metrics used by regulators today. It isn't currently possible to make direct comparisons between all of the metrics with publicly available data because near-miss events are reported and categorized in different ways. All three are qualitative, even if specific proximity information is available from radar or surveillance replay data. Therefore these metrics can't, in their present form, be used to derive separation minima or "well-clear" standards that would indicate a safe required distance between two UAVs or between a UAV and a manned aircraft.

Based on the following review of current reporting metrics and severity classifications, **we recommend that going forward, the UAS industry use the ICAO Airprox A+B metric as a starting point** to develop a new, quantitative metric appropriate to high-density UAV operations.

Airprox (Air Proximity Hazard)

ICAO defines an Airprox as an event in which either a pilot or a controller feels there was an increased risk of collision between two aircraft.[1] The aircraft involved don't need to be

[1] ICAO Doc 4444, Procedures for Air Navigation Services: Air Traffic Management. Sixteenth Edition, 2016.

talking to air traffic controllers to report an Airprox encounter. For example, an Airprox could be between two aircraft in the traffic pattern at an uncontrolled airport. Airprox events also encompass encounters between a manned aircraft and a UAV, balloon or remote-controlled hobby aircraft.

Airprox reports are categorized by severity, after the fact, using a qualitative process and whatever information is available from controllers and pilots.[2] This may include radar and audio replays, as well as written voluntary safety reporting program (VSRP) entries. The nature of the process means that there is no specific distance between aircraft at which an Airprox is automatically counted–relative trajectories and whether either aircraft received timely traffic advisories from air traffic control are also considered in assigning categories.

Each regulator is responsible for establishing its own Airprox investigation procedures, but most countries do not publish their findings. In the UK, for example, a panel of 14 people with aviation and air traffic experience review each report with assistance from subject-matter experts.[3] The UK Airprox Board issues monthly reports detailing each event reviewed, as well as annual summary statistics and trends. Each Airprox, under ICAO guidance, receives one of the following four classifications:

- **A - Risk of collision.** The risk classification of an aircraft proximity in which serious risk of collision has existed.
- **B - Safety not assured.** The risk classification of an aircraft proximity in which the safety of the aircraft may have been compromised.
- **C - No risk of collision.** The risk classification of an aircraft proximity in which no risk of collision has existed.
- **D - Risk not determined.** The risk classification of an aircraft proximity in which insufficient information was available to determine the risk involved, or inconclusive or conflicting evidence precluded such determination.[4]

Airprox events that are categorized as A or B are considered “risk bearing,” while the Category C and D events are considered to have no or unknown actual risk of collision, respectively.

Airprox can be methodically applied to an event review using defined investigatory procedures and qualitative risk barrier scoring methods[5] to place events into one of the four severity categories. The investigation and ranking process means that ultimately, not all Airprox filings are counted equally. Indeed, the UK adds a fifth category (“E”) for non-risk

[2] AIRPROX (Aircraft Proximity), SKYbrary. September 2017.
[3] UK Airprox Board (UKAB) Factsheet. May 2016.
[4] UK Airprox Board. “Causal factors and risk ratings.” Accessed January 4, 2018.
[5] Airprox Barrier Assessment Guide, July 2017.

events that meet reporting criteria but are found to be properly separated, normal operations.[6]

The UK Airprox Board further categorizes events based on whether they involved general aviation, military or commercial aircraft. Starting with its 2016 report, the UK segregates Airprox events involving UAVs, since they now constitute about one third of all Airprox events.[7] The table below includes Airprox A and B events between all aircraft types, including general aviation, military, commercial and UAVs.

	UK CAA			
	Number of events	**Total Flight Hours**	**Rate/flight hour**	**Rate/1M flight hours**
2015 Airprox A+B	107	2,671,000	*4.01E-05*	***40.06***
2016 Airprox A+B	123	2,709,000	*4.54E-05*	***45.40***

NMAC (Near Mid-Air Collision)

The FAA, by contrast, counts NMACs as those events in which the proximity between aircraft was less than 500 feet, and the pilot making the report considered there to be a collision hazard. Each event is then reviewed against specific criteria to determine severity, and assigned one of five category labels. Based on published definitions, a Critical NMAC is equivalent to a Category A Airprox, and a Probable NMAC is equivalent to a Category B Airprox.[8] We conducted searches of the FAA's public NMAC database to determine the number of Critical and Probable NMAC events recorded in the table below. The combined totals of those two categories are labeled "NMAC A+B." These events include all aircraft types, including general aviation, military, commercial and UAV NMACs.

	US FAA			
	Number of events	**Total Flight Hours**	**Rate/flight hour**	**Rate/1M flight hours**
2015 NMAC A+B	124	39,262,747	*3.16E-06*	***3.16***
2016 NMAC A+B	230	39,607,747	*5.81E-06*	***5.81***

In 2016, the FAA reported 304 NMAC events overall, double the number from the previous year, and largely a result of an increasing number of UAV-aircraft encounters.[9] Of those events, 230 were considered to be Critical or Probable, and therefore counted in the above

[6] UK Airprox Board Airprox Findings on Cause and Risk, June 2016.
[7] Analysis of Airprox in UK Airspace. Report Number 32. ISSN 1479-2729
[8] FAA Order 8900.1 Change 552, Flight Standards Information Management System. Volume 7, Chapter 4. September 27, 2017.
[9] Administrator's Fact Book. Federal Aviation Administration. December 2017.

table. Under the FAA's criteria, NMACs are almost always generated by pilot reports. A severe loss of separation may also trigger an NMAC, but only if one of the pilots involved reports it as such. The FAA does not publish information on how many losses of separation are also counted as NMACs.

The FAA's NMAC rates for Critical and Probable events are an order of magnitude lower than the UK's equivalent Airprox rates. There are several possible reasons to explain this difference, including overall NMAC under-reporting in the United States (some pilots, for example, may decide not to formally report an NMAC, even if they question an operation as being too close for comfort). While the United States sees a large number of total flights, those operations are spread across tens of millions of square miles and more than 5,000 public-use airports. While the UK's total flight hours are lower, its terminal areas are more concentrated and aircraft use just 300 public airports. Therefore, it's also possible that there are simply fewer areas where NMACs are likely to occur in the U.S. than in the UK.

Inadequate Separation and Separation Minima Infringements (SMI)

EUROCONTROL maps its event severity categories to comparable ICAO categories, so it is easier to draw some comparisons.[10] In the case of separation minima infringements (equivalent to losses of separation), those instances marked as Serious or Major Incidents in EUROCONTROL terminology correspond to Airprox Category A and B, respectively. However, EUROCONTROL states that not all Serious and Major SMIs are investigated as Airprox events.

In addition, EUROCONTROL began publicly reporting the number of inadequate separation events that occurred in 2015.[11] These are situations "in which aircraft were perceived to pass too close to each other for pilots to ensure safe separation," but in which a specific separation standard did not exist.[12] For example, there is no separation standard between two VFR aircraft in Class E airspace. Just as with an Airprox or an NMAC, the pilot need not be in communication with air traffic controllers to report an instance of inadequate separation. As with the NMAC and Airprox numbers above, EUROCONTROL's numbers below include all types of aircraft, including UAV encounters in the case of inadequate separation reports.

Only about 11 percent of the inadequate separation events in the table below are Category A or B occurrences. We cannot make a precise comparison between event rates in FAA and EUROCONTROL airspace with available data. However, the most serious NMACs in the United States and inadequate separation events in Europe occur at the same order of magnitude in both regions.

[10] Mapping Between The Eurocontrol Severity Classification Scheme & The Icao Airprox Severity Scheme. November 2002.
[11] Safety Regulation Commission. EUROCONTROL Annual Safety Report 2016.
[12] Reporting and Assessment of Safety Occurrences in ATM. December 2009.

	EUROCONTROL			
	Number of events	**Total Flight Hours**	**Rate/flight hour**	**Rate/1M flight hours**
2015 SMI A+B	241	15,565,912	*1.55E-05*	***15.48***
2015 Inad. Sep. A+B	120	15,565,912	*7.71E-06*	***7.71***

Conclusions

Airprox A+B is the most useful metric to use in comparing near-miss events in a simulated environment with the real-world because of the way it systematically evaluates and categorizes event severity. But current rates of near-misses, regardless of the metric, may result in an undesirably high number of mid-air collisions if extrapolated to the much higher volumes and densities of urban air mobility traffic expected in the coming years. Much more research is required to determine whether current rates would translate to acceptable benchmarks for future safe operations — and even whether current metrics would be sufficient in defining such a benchmark.

Among metrics being used today, Altiscope believes that Airprox A+B provides the best starting point for evaluating the safety of UAS operations. It may only be sufficient to a point, and we expect that there will be a need to develop a new, quantitative metric that can be applied globally when evaluating proximity events between UAVs. Such a metric would have added value to industry and regulators when defining specific separation minima between vehicles or "well-clear" distances. And it would be useful in assessing airspace capacity, throughput and efficiency. In a future UAV environment, this framework would enable reporting by fleet managers or even automated reporting from vehicles themselves based on quantitative proximity or closure rate measures.

A move by the UAS industry to adopt Airprox metrics would allow for simpler comparisons of safety event rates around the world. This is an important step toward harmonizing operations and adopting best practices, regardless of one's geographic location.

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