Small Unmanned Aircraft Systems (SUAS) and Manned Traffic near John Wayne Airport (KSNA) Spot Check of the SUAS Facility Map: Towards a New Paradigm for Drone Safety Near Airports

Peter J. Burke [1,2,3]

1   Department of Electrical Engineering and Computer Science, University of California, Irvine, CA 92697, USA; pburke@uci.edu
2   Department of Chemical Engineering and Materials Science, University of California, Irvine, CA 92697, USA
3   Department of Biomedical Engineering, Chemical and Materials Physics, University of California, Irvine, CA 92697, USA

check for updates

Abstract: Using data from an Automatic Dependent Surveillance-Broadcast (ADSB) aggregator, a custom data-mining program was developed to identify all manned aircraft below 500′ AGL within 5 miles of the KSNA airport on six specific days in 2018–2019. The data (a spot check) show that several of the zero-foot grids are well outside of the traffic pattern, with no manned aircraft below 500′ AGL for at least a mile. Detailed maps showing all the traffic on those days are overlaid on the KSNA UAS facility map for comparison. This data-driven safety analysis is outlined as a new paradigm for drone safety near airports, which can be applied worldwide.

Keywords: drone; unmanned aircraft system; air traffic control

1. Introduction

The FAA unmanned aircraft system (UAS) facility maps (UASFM) are used as guidance for FAA airspace approval in controlled airspace for UAS operations [1]. The maps provide altitude limits for each 1 degree × 1 degree (roughly 1 mile × 1 mile) grid in the airspace. Small unmanned aircraft systems (SUAS) flight approval is efficient and usually automatic for requests below that limit; SUAS flights above that limit require special FAA consideration for additional safety and risk mitigation, for example, on the runway or close to the approach path.

The purpose of this report is to compare the altitude limits to manned aircraft traffic data on six specific days in 2018–2019.

During the course of this study, we became convinced that the UASFM should be data driven, and exceptions should be data driven. Our analysis provides a possible paradigm for all SUAS FM decisions, in a way that could be deployed nationwide within the FAA UASFM, and worldwide within the context of drone safety near airports.

The study shows a potential method to increase public safety in manned aviation as well as improve drone access to airspace for possible public safety benefits of unmanned aviation. The National Academy of Engineering has recently stressed that drones can in fact reduce risk in many human endeavors, and that this should be balanced against this increased risk of drone flights, similar to how automobiles increase risk due to accidents but reduce risk in cases where first responders are needed quickly, and overall economic and social gains [2]. Our study paves the way for the FAA to improve its safety procedures and shows there is clear room for improvement in the KSNA case. If scaled countrywide, it could lead to new policy implications that would dramatically improve public safety

of manned aircraft and improve drone access to skies for their important mission. This is consistent with the National Academy of Engineering report [2]. The main take home message is that SAUS FM altitude limits should be based on data-driven analysis, based on quantitative risk analysis, and that this can be done with existing data analysis techniques.

1.1. Database

Public data on manned aircraft location is available from at least four aggregators. The aggregators pull data from various sources, one of which is Automatic Dependent Surveillance-Broadcast (ADSB) out data received by networks of thousands of volunteers around the globe which "feed" ADSB data from local receivers (available for only ~$100 in parts) to the aggregators. For this report, we chose the aggregator "adsbexchange" because 1) they do not filter data, i.e., all reported ADSB aircraft are stored in their database, and 2) they have publicly available data for download on specific days, with a request for donation of ~$3 per day of downloaded data. Additional data from any of the four aggregators is not publicly available and requires additional fees and contracts.

Not all manned aircraft broadcast ADSB data, and not all ADSB broadcasts are guaranteed to be received by the aggregators. Therefore, this report can be considered indicative but not comprehensive.

1.2. Methods

Files containing the entire world's aircraft for each of the six days were downloaded. Each file is approximately 20 GB. Using the Python scripting language, a custom program was written to select only flights below 2000' MSL within approximately 5 miles of KSNA. The data consists of instantaneous lat/lon/alt/etc. information [3], and each aircraft/flight may have a few to a few hundred recorded locations in the database. The lat/lon locations are recorded every minute but the files are intended to also capture the entire timeframe, although we found the data to be spotty in some cases. With this method, each day provided approximately 10,000 lat/lon/alt/etc. data points per day.

The MSL altitude data was converted to AGL using a custom lat/lon to elevation script written in Python programming language (the Google Maps GPS to elevation API is just too slow and expensive). The elevation data was taken from the digital elevation map (DEM) provided by the USGS [4] based on the Global Digital Elevation Model Version 2 created by the Advanced Spaceborne Thermal Mission and Reflection Radiometer (ASTER) with a 30 m resolution, downloaded from the USGS as a GeoTIFF.

Aircraft locations below 500' AGL were saved to a KML format file for inspection in Google Earth. The points were color coded from 0 to 500' AGL (red zero, blue 500'). Aircraft on the ground were labeled as white points. For each day, and for the entire three days in each year, three KML files were created:

- All manned aircraft.
- Fixed wing manned aircraft only.
- Heli manned aircraft only.

The KML files are available upon request from the author.

An open-source repository has been set up in order to provide the detailed methods, and as a service to the scholarly aviation community for future processing. The analysis code, scripts, and detailed instructions are provided in an online repository [5].

1.3. 2018 vs. 2019

The number of flights tracked in 2018 vs. 2019 globally by the aggregator "adsbexchange" was different by about two times, presumably because more volunteers were added to the network during that period. The KSNA overall amount of data showed a similar trend, and thus increased point density in the 2019 vs. 2018 plots is probably not indicative of increased traffic overall.

1.4. Potential for Bias

All of the above processing was done with computer algorithms to avoid bias. The only obvious bias with the overall method is that general aviation is not required to carry ADSB so the data will be biased towards commercial aviation. Therefore, a better method for future work would be to estimate and account for non-ADSB transmitting aircraft.

2. Results

We plot the fixed-wing and manned aircraft on separate plots, separated by year, in order to see if there was a year over year trend (there was not):

- 2018: 1 April, 1 May, 1 June.
- 2019: 1 April, 1 May, 1 June.

The reason the helicopter traffic is plotted separately is that helicopters generally can land anywhere and avoiding by line of sight by SUAS pilots has nothing to do with the distance to the local airport, unless there is a very close helipad, which does not seem to be the case in this study. On the other hand, fixed-wing aircraft near the runway pose the most significant risk for SUAS vs. manned aircraft as they must descend over very specific patterns for landing and ascend in specific patterns for takeoff. The purpose of these studies is to provide a quantitative spot check on actual traffic based on real data.

Fixed-Wing Traffic

The fixed wing traffic is shown in 2018 and 2019 in Figures 1–4 below for all aircraft in the database on those three days below 500' AGL.

Helicopter Traffic

The helicopter traffic is shown in 2018 and 2019 in Figures 5–8 below for all aircraft in the database on those three days below 500' AGL.
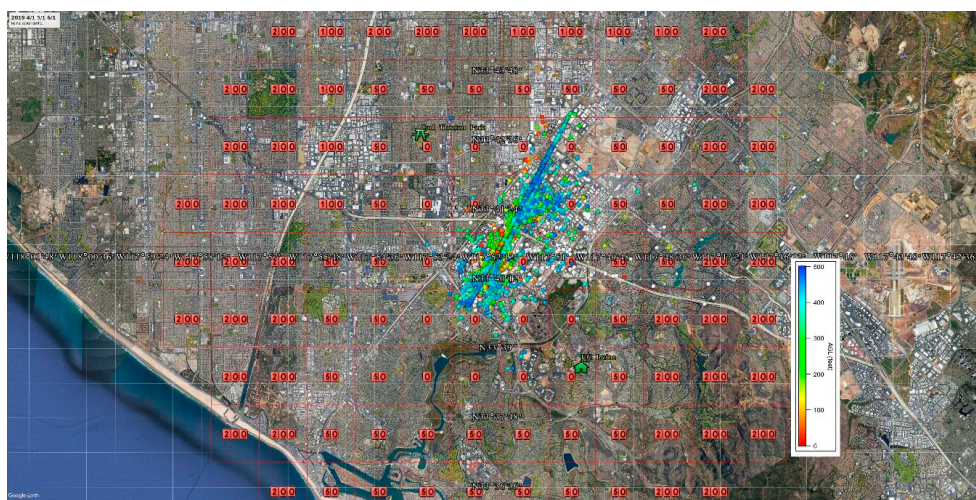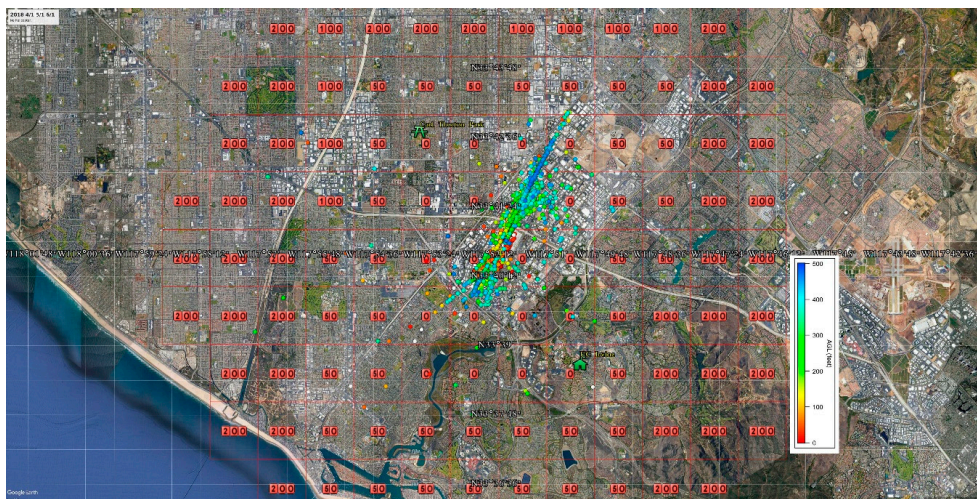

Figure 1. Fixed-wing traffic below 500' AGL near KSNA for 4/1, 5/1, and 6/1/2019. Color code: Red = 0' AGL and Blue = 500' AGL, overlaid with the small unmanned aircraft system (SUAS) facility maps. White is for aircraft with 0 AGL.

Figure 2. Fixed-wing traffic below 500′ AGL near KSNA for 4/1, 5/1, and 6/1/2019. Color code: Red = 0′ AGL and Blue = 500′ AGL, overlaid with the SUAS facility maps. White is for aircraft with 0 AGL.
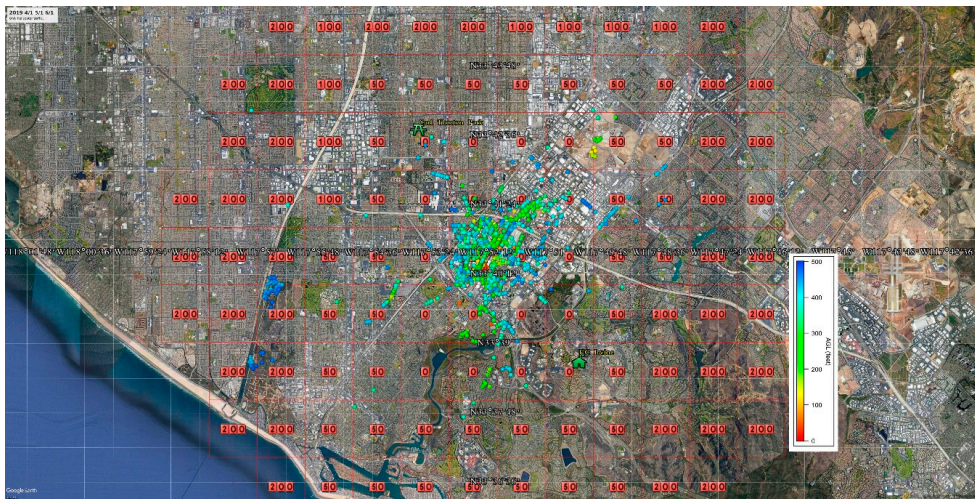

Figure 3. Fixed- wing traffic below 500′ AGL near KSNA for 4/1, 5/1, and 6/1/2018. Color code: Red = 0′ AGL and Blue = 500′ AGL, overlaid with the SUAS facility maps. White is for aircraft with 0 AGL.
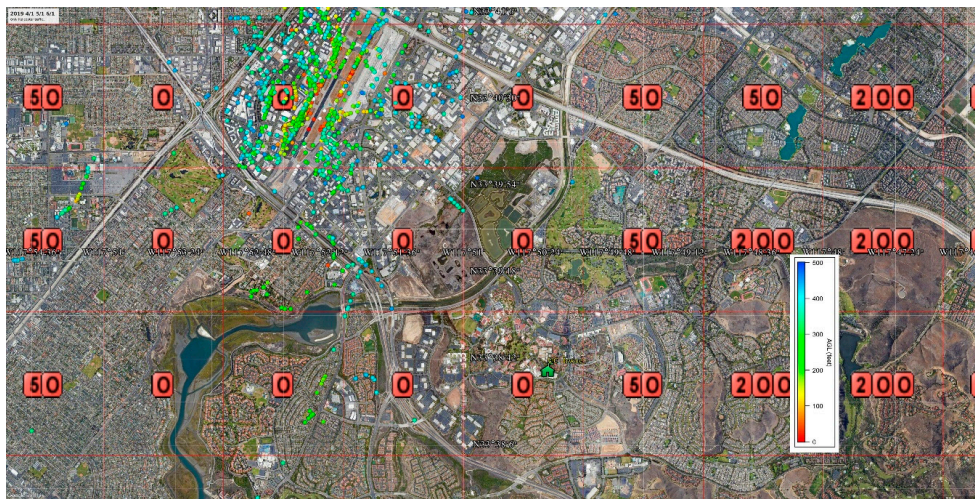

Figure 4. Fixed-wing traffic below 500′ AGL near KSNA for 4/1, 5/1, and 6/1/2018. Color code: Red = 0′ AGL and Blue = 500′ AGL, overlaid with the SUAS facility maps. White is for aircraft with 0 AGL.
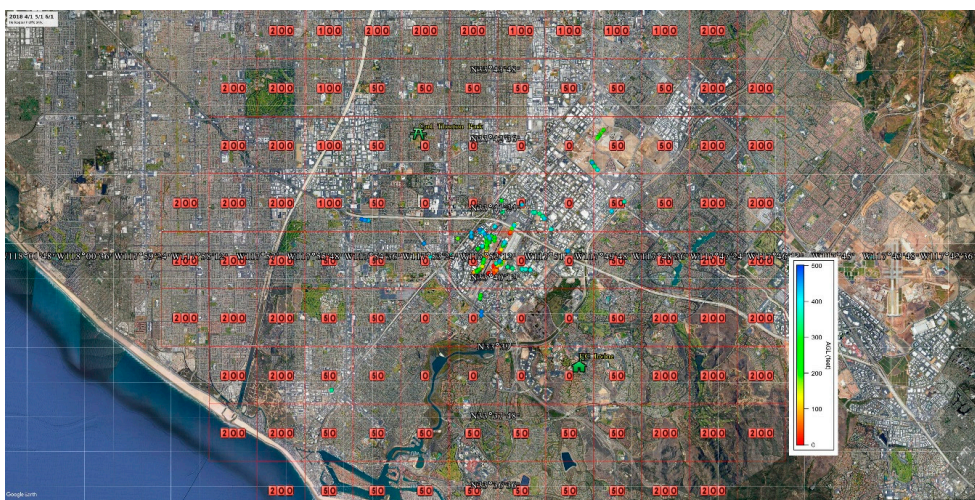
Figure 5. Helicopter-only traffic below 500′ AGL near KSNA for 4/1, 5/1, and 6/1/2019. Color code: Red = 0′ AGL and Blue = 500′ AGL, overlaid with the SUAS facility maps. White is for aircraft with 0 AGL.

Figure 6. Helicopter-only traffic below 500′ AGL near KSNA for 4/1, 5/1, and 6/1/2019. Color code: Red = 0′ AGL and Blue = 500′ AGL, overlaid with the SUAS facility maps. White is for aircraft with 0 AGL.

Figure 7. Helicopter-only traffic below 500′ AGL near KSNA for 4/1, 5/1, and 6/1/2018. Color code: Red = 0′ AGL and Blue = 500′ AGL, overlaid with the SUAS facility maps. White is for aircraft with 0 AGL.

Figure 8. Helicopter-only traffic below 500′ AGL near KSNA for 4/1, 5/1, and 6/1/2019. Color code: Red = 0′ AGL and Blue = 500′ AGL, overlaid with the SUAS facility maps. White is for aircraft with 0 AGL.

3. Discussion

3.1. Altitude/Spacing Criteria

What is a safe distance between SUAS and a manned aircraft? The FAA has not to our knowledge published an altitude/spacing criterion and instead leaves it up to individual towers without standardization between towers. We suggest the following as a conservative criterion, based on the FAA 400′ rule for SUAS in class G airspace and visibility of SUAS pilots flying line of sight:

- 400′ vertical, and
- 1 mile horizontal.

3.2. Altitude/Spacing Criteria: Literature Review

A comprehensive study of the safe distance between large UAS (e.g., military drones) and manned aircraft at high altitudes was published in 2016 [6]. However, there is almost no literature on the safe separation distance between small UAS and manned aircraft at low altitudes. According to a presentation at the June 2019 FAA Drone Symposium [7], there is an unpublished, comprehensive study, the results of which were "published", i.e., resulted in the FAA draft advisory circular WELL CLEAR [8]. That study resulted in a much looser guidance than we proposed (ad hoc) with (apparently) a much more comprehensive analysis, specifically;

- 250′ vertical, or
- 2000′ horizontal.

During the public comment phase of that advisory circular draft, many industry titans commented in support, including the Airline Pilots Organization and many others [9–11]. At present time, the public comment period is closed, and the AC WLCR document is no longer publicly available. In conclusion, the existing scholarly research on this topic is very thin, and supports the approach taken in this paper.

3.3. Additional Criteria

Many factors must come into play in determining where it is safe to fly a SUAS. For example, there may be a large swath that is needed in case of an emergency where manned aircraft do not usually fly. If a large jet loses power on takeoff, it needs the low altitude airspace in front of it reliably clear. Therefore, even flights located a significant distance from the runway, while it may not historically have had manned aircraft, need them as a safety buffer. So, the data in this report is not the only factor.

This may explain some of the zero-foot grids in the regions below the traffic pattern, but does not explain the grids far out of the traffic pattern.

3.4. Zero Grids out of the Traffic Pattern with No Manned Aircraft near Them

Based on this data alone, the following are some of the grids that could be removed from the zero altitude list with no risk to manned aircraft, if the safe distance between manned aircraft and UAVs is 400′ and one mile (Figures 1–8) (excluding grids in the traffic pattern).

Grid at 33.6421366667, −117.841723333 (over UC Irvine, Figure 9, and marked as UC Irvine with a green school icon in the flight pattern figures).

Figure 9. View to the south on takeoff from KSNA RWY 20R. UC Irvine is visible past the open marsh area clearly visible beyond the two black cube-shaped buildings, on the left side of the 73 freeway in the distance. It is unclear how any manned aircraft would be expected to be below 500′ AGL over UC Irvine, since it is so far out of the traffic pattern and over 2 miles out perpendicular to the KSNA runways. The data supports this. Therefore, the zero-foot grid categorization there for SUAS activity is a mystery.

Grid at 33.7085366667, −117.891703333 on the other side of the airport (NW, and marked as Carl Thorton Park with a green picnic bench icon in the flight pattern figures).

If there are additional safety considerations, they are not apparent and have not been provided by the FAA.

3.5. 50′ Grids in and out of the Traffic Pattern

Most of the 50′ AGL grids have no manned aircraft in them. Of the 36 50′ grids, only one has aircraft consistently below 500′ AGL, and it is right in the approach path. The other 35 grids have no manned aircraft in them. Over half of the 35 50′ grids are neighboring grids that also have no

manned aircraft below 500′ AGL. Thus, there is a trend, and it is not isolated to a single grid that was mischaracterized.

3.6. 2018–2019

There is no apparent difference in air traffic in the 2018 vs. 2019 data. This indicates that, whatever the reason the FAA had for changing the KSNA SUAS Facility Maps in early 2019 to make it stricter, it had nothing to do with changes in air traffic patterns.

3.7. Data Quality:

Some of the 0′ grids with very few points grids were inspected by hand. The ad hoc checks show that the singleton points are mostly erroneous. For example, one of the data points is a CRJ at 50 feet (ICAO = A86107) 2.5 miles from the runway, in a perpendicular direction. In another clearly erroneous case, in the 2018 map, it shows a Boeing 717 (ICAO = A996E1) at 200′ AGL at over a mile south of the end of RWY 20R. Another point shows a 737 (ICAO = A6EE47) at 45′ AGL 2 miles SW of RWY 20R. These points are clearly erroneous and therefore trends should be based on multiple points in (or not) in a grid, and not a few outliers. The reason for the outliers is not known at this time. The reader can see potentially erroneous points in the figures as outliers; there are at most a few dozen total. However, to avoid any bias in the data, these points were left in the plots and not manually edited out. In other words, if only a single or a few points appear in one of the grids, they are probably erroneous. For example, a string of points indicates a flight pattern and a circle of points indicates most likely a helicopter circling that particular position.

3.8. Noise Abatement

John Wayne airport has departure procedures to reduce noise; this affects departure paths [12]. The flight paths are shown in Figure 10. After the initial climb-out, the paths over the ocean are beyond the UASFM for this airport. Other information specific to John Wayne Airport (KSNA) is available at [13].
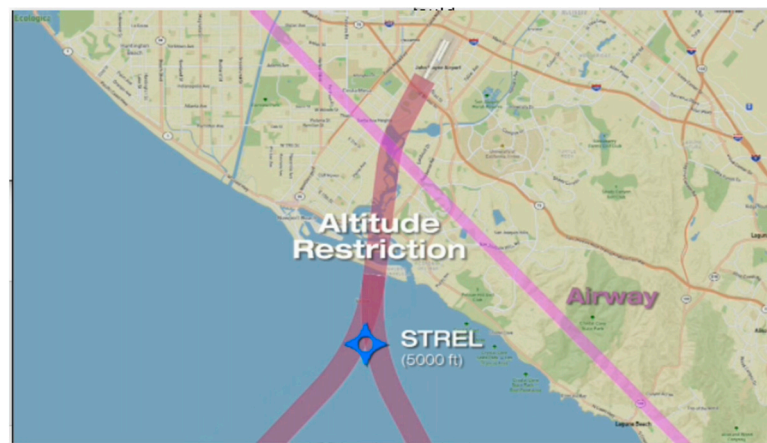
Figure 10. Noise abatement restrictions shown from https://www.faa.gov/tv/?mediaId=1478.

3.9. Historical Altitudes

The FAA does not maintain a public database of the historical progression of the SUAS FM altitudes. Therefore, we filed a freedom of information act request (FOIA) and received the historical altitudes for all airports in the USA from inception of the SUAS FM program in 2017 to mid 2019. In Figure 11, we show the changes to KSNA. As the reader can see for themselves, large swaths of airspace that were previously open to SUAS activities became closed. For example, the southernmost

grid on the east side, which is 6 miles from the airport and out of the traffic pattern, became 100′ and was previously 400′.
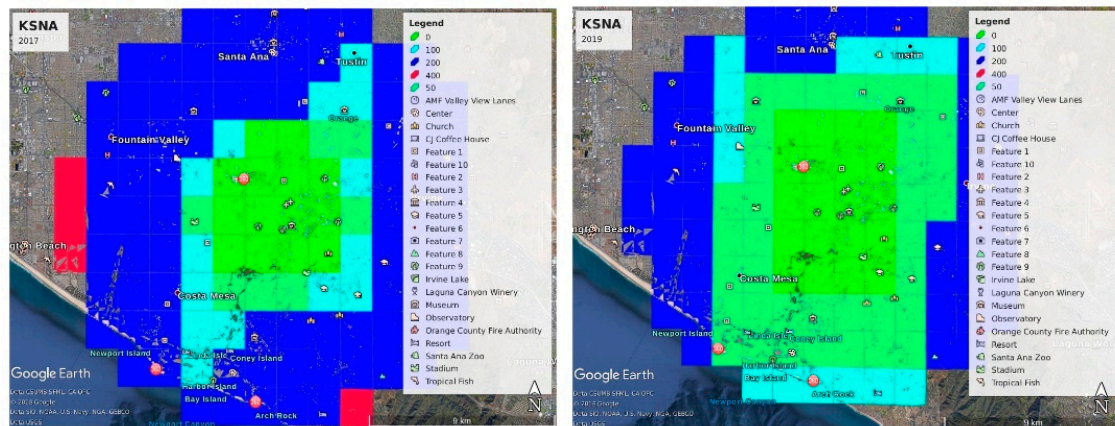

Figure 11. Historical altitude limits at KSNA.

3.10. ADSB and the Future

Since many general aviation aircraft are not outfitted with ADSB (due to the cost), as we mentioned above, non-ADSB aircraft are not captured in this analysis. We suggest two avenues for improvement for this. First, general aviation (GA) aircraft will be required to have ADSB on 1 January 2020. Therefore, using this method in the future should capture more manned aircraft. Second, historical radar records can be mined for all aircraft. To this end, we filed a FOIA request for all radar data for the six specific days analyzed in this manuscript. Data from one of the six days was provided in the format of a .cdr file (actually 12 files totaling 23 GB). The file is binary and cannot be interpreted easily. In a follow-up phone call to the FOIA officer, we were informed that it is a very expensive proposition to interpret .crd radar files, and that typically it is only unpacked in accident cases where additional analysis is worth the additional expense.

3.11. Drone Incidents at KSNA

We filed a FOIA for all reported drone incidents at KSNA to date. There was a total of 34 reports during 3 years. Three of them involved drones flying at or below 400′ AGL (in 2016, 2017, and 2019). These three events were all in the immediate vicinity (within $\frac{1}{4}$ mile) of the airport. Therefore, in the immediate vicinity of the airport there is a clear record and thus need for strict altitude limits. There is no evidence of the need for strict altitude limits at distances a few miles from the airport.

3.12. FAR 77

Federal Regulation 49 CFR Part 77 [14] establishes standards and notification requirements for objects affecting navigable airspace. Therefore, for example, the FAR 77 "imaginary surfaces" which ensure a safe takeoff and landing could be used in addition for setting SUAF FM altitudes. This could be an additional starting point for a more quantitative analysis of SUAS FM altitudes. However, to our knowledge, the lessons learned in FAR 77 have not been applied to drone safety. A Google scholar search for "drone FAR 77" returns zero hits. An advisory circular [15]. which provides guidance to towers in setting SUAS FM altitudes, has no mention of FAR 77.

3.13. FAA Analysis

An FOIA request for records regarding safety analysis of the change in SUAS FM altitudes at KSNA in early 2019 returned no documents. So, it would seem that safety analysis is not being documented within the FAA regarding the setting of SUAS FM. The altitudes are determined behind closed door discussions without much guidance and unclear and inconsistent criteria. The FAA has

released crude guidance to ATC towers (JO 7200.23a [15]), which for example encourages towers to be reasonable and consider tree heights and not set altitude limits below tree heights. The athletic fields at UCI have light posts at 100′ and yet the KSNA limit changed to 50′ in that grid area, in contradiction to the FAA guidance.

We believe this highlights the need for quantitative, objective, data-based analysis of drone safety near airports. The results of such research, which we take the first step in towards in this paper, can result in national and international improvements in safety standards and avoid inconsistent, ad hoc altitude decisions without clear criteria for safety. This in no way should be thought to endorse violations of any regulation. It is more of a discussion of how to ensure the safest regulations possible.

4. Conclusions

4.1. General

This is a spot check and discusses some very important safety issues regarding drones in the vicinity of airports. Although there are many conclusions that can be drawn, this is clearly an evolving research area. The fact that the final word is not out yet on how to safely integrate drones into the national airspace should not prevent a data-driven discussion. This paper is the beginning, not the end, of that discussion, and lays the foundation for some key safety questions that can be asked via a systematic quantitative discussion, rather than an ad hoc case-by-case discussion. Thus, though incomplete, the implications of this paper are, in principle, profound for the future of aviation.

4.2. Local

Based on this data analysis, multiple "zero-foot" and 50′ grids have no manned aircraft traffic with a horizontal spacing of one mile and vertical spacing of 500′ from the ground. Several of the grids are well outside of the traffic pattern and have unclear safety improvements based on the analysis in this report. One of the 50′ grids is clearly in the approach pattern, and it is not clear why that is not a "zero-foot" grid while many other "zero-foot" grids have no traffic for over a mile and are well outside the traffic pattern.

While the data quality is not 100% and not all traffic reports are in the ADSB, the trends indicate this is systematic and not isolated to one particular grid.

4.3. Global

The UASFM are a good first step in drone safety by the FAA. However, our data clearly has shown room for improvement, using this new technique. The method that we have provided in this paper gives a clear path forward towards quantitative analysis and could lead to a new era of drone safety near airports. Although obvious in foresight and in hindsight, data-driven analytics can provide a new paradigm for drone safety around the world.

References

1. FAA. UAS Facility Maps. Available online: https://www.faa.gov/uas/commercial_operators/uas_facility_maps/ (accessed on 30 June 2019).
2. NAE. FAA Should Change Its Safety Risk Assessment Approach for Drones to Effectively Integrate Them into the Nation's Airspace. Available online: http://www8.nationalacademies.org/onpinews/newsitem.aspx?RecordID=25143 (accessed on 9 April 2019).
3. ADSB Exchange. Available online: https://www.adsbexchange.com/datafields/ (accessed on 30 June 2019).

4. USGS. Available online: https://earthexplorer.usgs.gov/ (accessed on 30 June 2019).
5. Burke, P. adsb-plane-mapper. Available online: https://gitlab.com/pjbca/adsb-plane-mapper (accessed on 26 November 2019).
6. Cook, S.P.; Brooks, D.; Cole, R.; Hackenberg, D.; Raska, V. Defining well clear for unmanned aircraft systems. In Proceedings of the AIAA Infotech @ Aerospace, Kissimmee, FL, USA, 5–9 January 2015; pp. 1–20.
7. FAA. FAA UAS Symposium DAA—State of Play. 2019. Available online: https://www.youtube.com/watch?v=D31v5T4-nUo (accessed on 3 June 2019).
8. FAA. *(DRAFT) Well Clear Definition for Small Unmanned Aircraft Systems Operating Beyond Visual Line of Sight draft Advisory Circular, AC 90-WLCLR*; FAA: Washington, DC, USA, 2019.
9. Aircraft Owners and Pilots Association (AOPA). AOPA-ANPRM-Safety-and-Security-Public Comments. 2019. Available online: https://download.aopa.org/advocacy/2019/AOPA-ANPRM-Safety-and-Security.pdf (accessed on 26 November 2019).
10. Small UAV Coalition. Small UAV Coalition Comments on Draft FAA Advisory Circular No. 90-WLCLR. 2019. Available online: http://secureservercdn.net/198.71.233.179/4z7.785.myftpupload.com/wp-content/uploads/2019/04/Small-UAV-Coalition-comments-on-Safe-and-Secure-Operations-ANPRM.pdf (accessed on 26 November 2019).
11. Avionix. Avionix Response to: FAA Advance Notice of Proposed Rulemaking (ANPRM). 2019. Available online: https://uavionix.com/downloads/blog/uAvionix-ANPRM-FAA-2018-1086-Response-v5.pdf (accessed on 26 November 2019).
12. FAA. FAA TV: New Departure Procedures at John Wayne Airport. Available online: https://www.faa.gov/tv/?mediaId=1478 (accessed on 26 November 2019).
13. Pilot Information John Wayne Airport, Orange County (SNA). Available online: https://www.ocair.com/generalaviation/pilotinformation (accessed on 26 November 2019).
14. Register, F. 14 CFR Part 77—Safe, Efficient Use, and Preservation of the Navigable Airspace. Available online: https://www.federalregister.gov/documents/2010/07/21/2010-17767/safe-efficient-use-and-preservation-of-the-navigable-airspace (accessed on 26 November 2019).
15. FAA. *ORDER JO 7200.23A SUBJ: Unmanned Aircraft Systems (UAS)*; FAA: Washington, DC, USA, 2017.