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Small Unmanned Aircraft System (sUAS) Traffic Analysis (A11L.UAS.91): Initial Annual Report

August 1, 2022

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16. Abstract

As the proliferation of Small Unmanned Aircraft Systems (sUAS) continues within the National Airspace System (NAS), the ability to detect these operations becomes imperative. A 2018 National Academies of Science report described the need for a data-driven approach to inform policy decision-making. The purpose of the current study is to develop a framework to collect and assess sUAS detection data empirically and objectively to conduct sUAS traffic analysis in low-altitude airspace. Through the development of this framework, data can be used to inform the Federal Aviation Administration (FAA) for accurately forecasting sUAS growth, planning additional sUAS integration efforts, completing risk assessments, and measuring compliance rates with existing and proposed regulations. This report presents the activities of the first year of effort on this project. The authors describe the instrumentation, data collection, and analysis procedures to answer the research questions. Using approximately 166 data sensors established at 64 diverse geographical locations across the U.S. provided an extensive dataset to analyze. The findings are presented through six focal task areas such as tool development, the current state of sUAS operations in the NAS, compliance and exceedance rates, near aerodrome sUAS operations, and forecasting industry growth. The results demonstrate clear emergent patterns in the data, such as seasonal and time of day variations. The number of operations based on sUAS types and the activity patterns of these vehicles were also assessed. In addition, the data was used to determine operator compliance with and exceedances of 14 CFR Part 107 regulations.

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Small Unmanned Aircraft Systems (sUAS); National Airspace System (NAS); aerodrome; airport; detection; telemetry; Unmanned Traffic Management (UTM); Urban Air Mobility (UAM); Automatic Dependent Surveillance-Broadcast (ADS-B)

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TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

TABLE OF ACRONYMS

Acronym	**Meaning**
AAM	Advanced Air Mobility
ADS-B	Automatic Dependent Surveillance-Broadcast
AGL	Above Ground Level
AI	Artificial Intelligence
AIRT	Airborne International Response Team
API	Application Programming Interface
ASOS	Automated Surface Observing System
ASSURE	Alliance for System Safety of UAS Through Research Excellence
AWOS	Automated Weather Observing System
AWS	Amazon Web Service
BVLOS	Beyond Visual Line of Sight
C2	Command and Control
CDA	Commercial Drone Alliance
CFR	Code of Federal Regulations
COA	Certificate of Authorization
CT	Civil Twilight
C-UAS	Counter-Unmanned Aircraft Systems
DHS	Department of Homeland Security
EMS	Emergency Medical Services
ESC	Electronic Speed Controller
FAA	Federal Aviation Administration
FIN	Flight Identification Number
GIS	Geographic Information System
GNSS	Global Navigation Satellite System
HIFLD	Homeland Infrastructure Foundation-Level Data
IANA	Internet Assigned Numbers Authority
ICAO	International Civil Aviation Organization
IEM	Iowa Environmental MESONET
IMU	Inertial Measurement Unit
LAANC	Low Altitude Authorization and Notification Capability
METAR	Meteorological Aerodrome Report
MSL	Mean Sea Level
NAS	National Airspace System

NASA	National Aeronautics and Space Administration
NMAC	Near Midair Collision
QGIS	Quantum Geographic Information Systems
RTK	Real-Time Kinematic positioning
SAR	Search and Rescue
SBIR	Small Business Innovation Research
SME	Subject Matter Expert
SR	Sunrise
SS	Sunset
sUAS	Small Unmanned Aircraft System
TFR	Temporary Flight Restriction
UAM	Urban Air Mobility
UAS	Unmanned Aircraft System
UASFM	UAS Facility Map
UCAP	UAS & Counter-UAS Analytics Platform
USAF	United States Air Force
UTM	Unmanned Traffic Management
VLOS	Visual Line of Sight
VTOL	Vertical Takeoff and Landing

UNITS OF MEASUREMENT

Measurement	Acronym	Datum	Type
Feet	ft	MSL or AGL, as indicated	Vertical distance; Lateral Distance
Hour: Minute	hh:mm	UTM or Local, as indicated	Time
Meters	m	N/A	Lateral distance or vertical distance (research team will convert)
Miles per Hour	mph	N/A	Speed
Seconds	s	N/A	Duration
Statute Mile	SM	N/A	Lateral distance
Nautical Mile	NM	N/A	Lateral Distance
Gram	g	N/A	Mass
Pounds	lb	N/A	Weight

EXECUTIVE SUMMARY

This document provides the Initial Annual Report for the Small Unmanned Aircraft System (sUAS) Traffic Analysis (A11L.UAS.91) project. It presents the progress, findings, and preliminary observations on research tasks completed in the first of three years of performance. With the growth of sUAS operations in the National Airspace System (NAS), there is a demonstrated need to identify and report these activities objectively and empirically. The current study aims to establish a framework for addressing this need to conduct sUAS traffic analysis in low-altitude airspace. The collection and analysis of this empirical data is used to inform the Federal Aviation Administration (FAA) in several critical areas: (1) identify, assess, and monitor for sUAS safety hazards; (2) determine the effectiveness of existing sUAS regulations, (3) accurately forecast sUAS traffic levels; and (4) aid in identifying and assessing future aviation risk.

To answer the project's research questions, the researchers established six focal areas to divide the effort functionally. The tasks are: (A) Analysis Tool Development and Literature Review, (B) Current State of sUAS Traffic within the NAS, (C) Compliance and Exceedances of 14 CFR§107 Operational Limitations, (D) Near Aerodrome sUAS Operations and Encounter Risks with Manned Air Traffic, (E) Forecasting Industry Growth and Potential Advance Air Mobility Implications, and (F) Communicating the Findings. Through these different taskings, the team provides clear answers to the research questions posed in this study.

The data for this research was collected via a nationwide deployment of Unmanned Aircraft System (UAS) detection equipment through collaboration with two companies. Working with these partners provides 166 UAS detection sensors deployed across 64 diverse geographical areas. This instrumentation conducts continuous, passive monitoring of detailed operational data such as identification (electronic serial number), location, altitude, speed, and remote pilot's location. Data is collected for sUAS vehicles manufactured by DJI, and their market share is estimated at approximately 76% based on sale volume, indicating the system will detect a high proportion of sUAS operations.

To facilitate the streamlined collection and processing of the data, the project has partnered with Unmanned Systems Robotics Analysis, Inc. (URSA). The team is producing customizable analyses and reports to synthesize the data received from several sources through the use of URSA's UAS & Counter-UAS Analytics Platform (UCAP). This tool leverages modern data science and Artificial Intelligence (AI) capabilities to provide rapid pattern detection, data visualization, and automated reporting capabilities.

The preliminary data has produced several insights into sUAS operations. Through the initial data analysis, the research team assessed operations in several key areas, including sUAS flights by location, airspace use, seasonal variation in operations (including holiday spikes in operations), time of day operations, operations by type of sUAS, maximum sUAS flight altitudes, the proximity of operations near airports, sUAS launch locations, sUAS retirement/abandonment rates, and estimated registration compliance. The research team also assessed a comparison of the empirical data against sighting reports.

In addition, the team assessed and estimated compliance and exceedances of 14 CFR §107, including operations from a moving vehicle, exceedance of daylight operations, beyond line of

sight aircraft operations, operations near and around other aircraft, operations over people/large gatherings, speed and altitude limitations, visibility and cloud clearances, mid-air encounter likelihood, and the effectiveness of the Low Altitude Authorization and Notification Capability (LAANC) system.

The initial annual report provides a detailed analysis of these critical research areas. However, in general, some preliminary findings can be summarized. First, clear patterns emerge in sUAS operations based on seasonal variations and time of day. Second, sUAS operations appear, for the most part, to be compliant with regulations for operations in proximity to airports. Third, sUAS retirement/abandonment rates seem to be high, especially after the first 3-4 months of use. Lastly, in general, the initial findings indicate that most sUAS operations conduct their flights in compliance with 14 CFR §107 regulations. The report discusses these findings in detail, along with the supporting data. While these findings are preliminary, the results inform the FAA about the types of and patterns of operations of sUAS in the NAS. This data informs future decisions, policies, and procedures for integrating unmanned and manned operations.

1 INTRODUCTION & BACKGROUND

1.1 Introduction

This document represents the first annual report for the ASSURE project A11L.UAS.91: sUAS Traffic Analysis. The project aims to provide low-altitude sUAS traffic data captured via sUAS detection technology at locations throughout the United States to advise the FAA on the state of sUAS operations within the NAS. The availability and analysis of this data is anticipated to assist the FAA to: (1) identify, assess, mitigate, and monitor for sUAS safety hazards; (2) determine the effectiveness of existing sUAS regulations; (3) accurately forecast sUAS traffic levels; and (4) aid in identifying and assessing future aviation risk.

To answer the established research project questions, the team functionally divided the effort into the following tasks:

- Task A: Analysis Tool Development & Literature Review
- Task B: Current State of sUAS Traffic within the NAS
- Task C: Compliance and Exceedances of 14 CFR §107 Operational Limitations
- Task D: Near Aerodrome sUAS Operations & Encounter Risks with Manned Air Traffic
- Task E: Forecasting Industry Growth & Potential Advanced Air Mobility (AAM) Implications
- Task F: Communicating Findings

Primary data for the project was acquired from two industry UAS detection service providers, ensuring broad and varied coverage of airspace throughout the United States. The team leveraged cloud storage, software, and digital analytics tools furnished by ASSURE business partner URSA, Inc. to perform data aggregation, analysis, synthesis with other data sources, and visualization. The research team assessed the data and subsequent analysis metrics to provide the FAA with a holistic assessment of the status of sUAS operations within low-altitude airspace within the NAS and provide compelling answers to the posed research questions. In addition to required internal reporting, the research team established relationships with industry standards organizations to brief the findings and recommendations yielded by the project to inform future standards development. This report addresses the project objectives, research approach, assumptions and limitations, findings, analysis, and recommendations.

1.2 Background

In a report assessing risks of UAS integration, the National Academies of Science (2018) highlighted the need for a data-driven approach to inform policy decision-making. According to the report, successful UAS integration into the NAS is contingent on creating a probabilistic risk assessment tool. "Assessing risk is far easier when the risk is well-quantified by relevant empirical data" (National Academy of Science, 2018, p. 41). The collection of such data, however, is not without its challenges. The authors note that UAS operations data is "expensive to collect, scarce, or non-existent, and in some cases, not very reliable" (National Academies of Science, 2018, p. 39).

According to the Government Accountability Office (2018), the “FAA’s ability to perform effective safety oversight is limited by FAA’s lack of reliable data on unsafe use of small UAS” (p. 59). Roggero (2018) states, "Currently, there is no means for any central entity to accurately collect, track, record, report, disseminate, or analyze data regarding how many total UAS flights occur without having a safety incident or terminating in a mishap" (p. 3).

Data gaps were specifically noted for UAS encounter statistics and low-altitude data. Further complicating the collection of low-altitude UAS operations data is the lack of a requirement for transponder equipment or other means of tracking for UAS, since conventional surveillance systems are generally not able to provide adequate detection (Deloitte, 2018, p. 9).

Similarly, the Commercial Drone Alliance (CDA) (2020) emphasized the lack of low-altitude UAS data, stating, ". . . additional effort to properly evaluate the low-level risk that UAS operations present to manned aircraft is necessary" (para. 7). The CDA (2020) argues that the lack of available empirical data makes it difficult to accurately assess low altitude airspace risk prompting the regulatory authorities to take a conservative approach to UAS policy-making. The consumer advocacy group goes on to warn that such an approach may risk the U.S. globally falling behind in implementing low altitude operations (CDA, 2020, para. 8).

The CDA recommends:

> . . . conduct[ing] a sophisticated, national study of the operational risks associated with low-altitude UAS operations below 400 feet [Above Ground Level] AGL. The risk analysis would consider factors such as traffic density, trajectories, weather, population density, terrain, land use and zoning, building heights, and other local factors for the entire United States. . . The federal government could conduct an airspace characterization effort leveraging nationwide radar and other surveillance assets (from FAA, DOD, and other sources) to provide an assessment of the relative risk presented by UAS and AAM operations (CDA, 2020, para 9).

Preliminary Case Study: Dallas-Fort Worth International Airport

The research design of this project is largely based on a regional, preliminary study of sUAS traffic collected near Dallas-Forth Worth International Airport (DFW) from August 22, 2018 to January 31, 2020 (Smith et al., 2022). The research was further extended to August 31, 2021, without agency funding (Wallace, et al., 2022). The purpose of this project was to evaluate UAS user activity in the National Airspace System, as well as conduct an assessment of the accuracy of UAS sighting reports by fusing UAS traffic data collected from UAS detection technology and aviation traffic data. Over the course of the 36-month project, the research team identified 481, 368 sUAS operations from a population of 29,839 DJI platforms (Wallace, et al., 2022). An overview of monthly traffic trends is presented in Figure 1. When relevant, findings from this project are presented in the current report to provide context. Additional information about the DFW project can be found in Smith et al. (2022), Wallace et al. (2022a), and Wallace et al. (2022b).

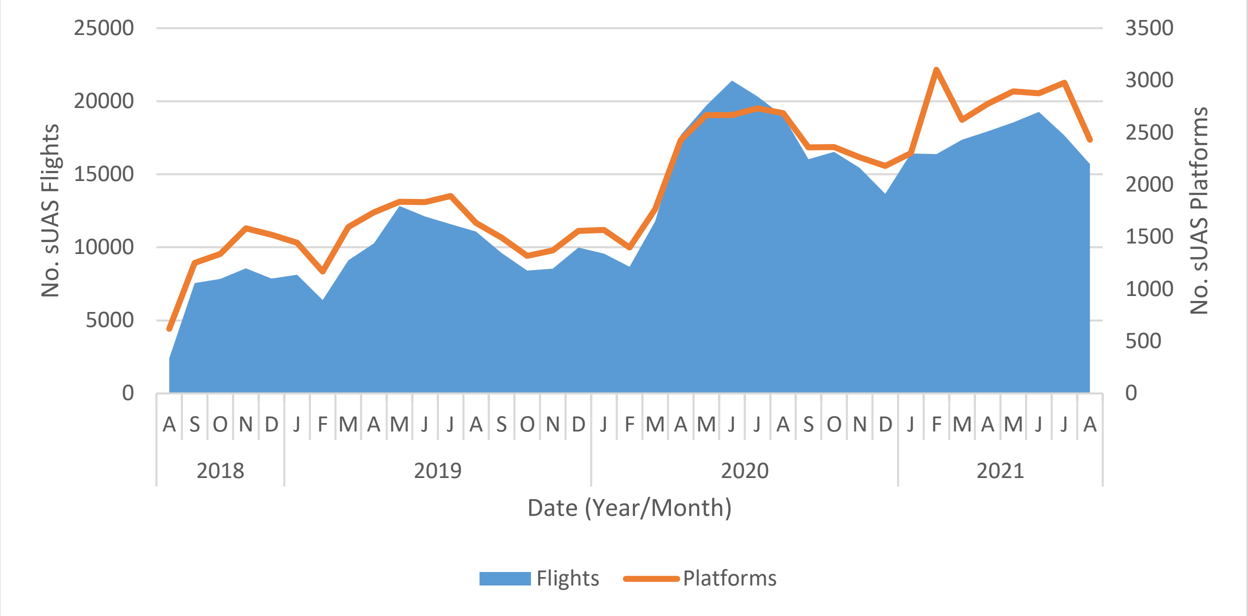


Figure 1. Platforms vs. Flights Captured via UAS Detection Equipment (DFW, Aug 2018-Aug 2022)

1.3 Purpose & Scope

The purpose of this project is to establish a framework for addressing the need to collect empirical data required to conduct sUAS traffic analysis in low-altitude airspace. This framework will support the FAA's efforts in the following activities; accurately forecasting sUAS growth, planning further sUAS airspace integration efforts, conducting risk assessments of proposed sUAS operations, and estimating compliance rates to existing and future regulations. To affect these tasks, the team purchased sUAS detection data from two companies providing sUAS detection services at locations across the United States. Specific emphasis was placed on supporting the following objectives:

- Assessing the effectiveness of existing regulations under 14 CFR §107
- Measuring exceedances to 14 CFR §107 operational limitations
- Assessing the frequency of sUAS encounters with manned aircraft
- Determining the state of sUAS operations and activity in proximity to aerodromes
- Providing findings and recommendations that may inform the development of Unmanned Traffic Management (UTM) requirements and Urban Air Mobility (UAM) route design

Data and analysis of the previous objectives should inform upon the following issues:

- Supporting sUAS forecasting and planning processes
- Furnishing data and analysis that supports sUAS operations risk assessment evaluations
- Inform the development of future sUAS regulation and policy-making
- Create analysis benchmarks and methodologies for assessing future Remote Identification (RID) data

It is anticipated that the analytical methods developed during this project will provide a framework for evaluating future Remote Identification data. According to the FAA (2022f), UAS operators must adhere to Remote Identification requirements by September 16, 2023.

1.4 Instruments & Data Analysis Resources

The research team made use of the following resources to accomplish project objectives:

1.4.1 UAS Detection Equipment

This project employed radio frequency sensors capable of real-time detection and tracking of DJI-manufactured sUAS by monitoring datalink communications exchanged between the operator and unmanned aircraft (DJI, 2021; 911 Security, 2021). These sensors provide for continuous, passive monitoring of detailed operations data, including sUAS: identification (electronic serial number), location, altitude, speed, and remote pilot's location (DJI, 2021; 911 Security 2020). The sensors sample sUAS datalink information at a rate of 1 Hz at ranges out extending to 50 km. These devices recognize one of four DJI-proprietary communications protocols, including Lightbridge, OcuSync, OcuSync 2, and Wifi. DJI (2018) outlines the communications protocols used in DJI's portfolio of sUAS platforms. The UAS detection devices are limited to only detecting sUAS manufactured by DJI. According to a report released by market consulting company Asia Perspective (2021), DJI's U.S. market share is estimated to be approximately 76%, based on sales volume.

1.4.2 UAS Detection Data Description

The UAS detection sensors used in this project collected the following data:

- **Detection Time:** Date Time Group for detection (sampling rate 1 Hz)
- **Sensor ID:** 14-digit alphanumeric ID of detection sensor
- **Drone Type:** sUAS Model, including "null" or "unknown" entries
- **Drone ID:** 14-digit unique alphanumeric electronic serial number of the sUAS controller
- **Flight ID:** 32-digit alphanumeric ID of a continuous sUAS flight; a single sUAS flight *may* be inadvertently split into multiple flight IDs in the event continuous reception of datalink communications is lost. This is most commonly caused by flight near terrain or manmade structure that obstructs electronic line of sight between the aerial vehicle and UAS detection sensor.
- **Latitude/Longitude:** Instantaneous sUAS location, reported to 14-decimals; accuracy subject to standard GPS error(s)
- **Speed:** Instantaneous speed (m/s) of the sUAS
- **Altitude:** Instantaneous altitude (m) of the sUAS above launch location
- **Home Latitude/Longitude:** Origin location of the aerial vehicle at time of launch; accuracy subject to GPS error(s)
- **Pilot Latitude/ Longitude:** Instantaneous location of sUAS controller (contingent on controller enabled GPS-enabled capability); accuracy subject to GPS error(s)

While the dataset includes unique Drone IDs, the research team did not have access to any data that would have enabled correlation to personally-identifying information. All data resulting from individual Drone IDs was reported in aggregate. Some individual case studies were extracted from the dataset, however, Drone ID information was stripped from these examples to protect data from possible reconstruction or correlation to personally-identifying information (PII).

1.4.3 Data Partners, Sensor Deployment, and Sampling Locations

This project leverages the participation of two companies that employ UAS detection equipment and provide UAS detection services. These companies provide UAS detection services to both public and private entities such as airports, prisons, stadiums, law enforcement departments, critical infrastructure owners, and other stakeholders interested in maintaining situational awareness for safety or security purposes. These data providers furnished sUAS detection data collected throughout their network of sUAS detection sensors. UAS detection data was collected starting July 1, 2021 and is projected to last until June 30, 2024. One hundred sixty-six UAS detection sensors deployed in 64 diverse geographical locations throughout the U.S. provided data for this initial report. An overview of data sampling locations is presented in

Table 1. For additional context, sampling locations are presented relative to §44807 [Hobbyist] registrations (Figure 3); 14 CFR §107 registrations (Figure 4); and, active Remote Pilot certificates (Figure 5).

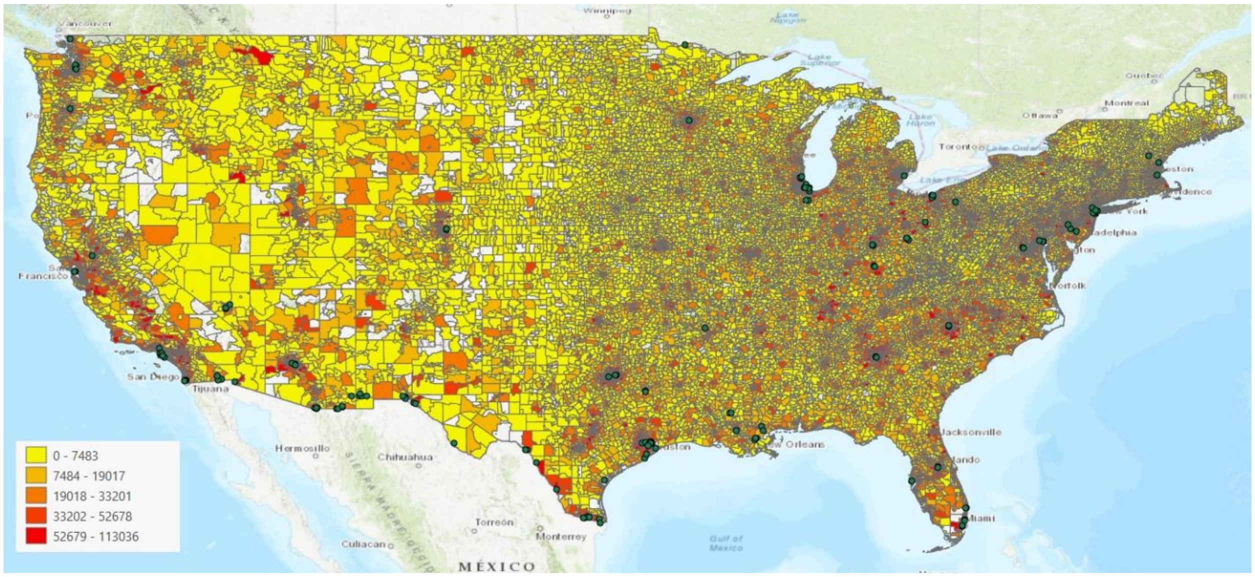


Figure 2. UAS Activity Data Sampling Locations & 49 U.S.C. §44807 UAS Registrations

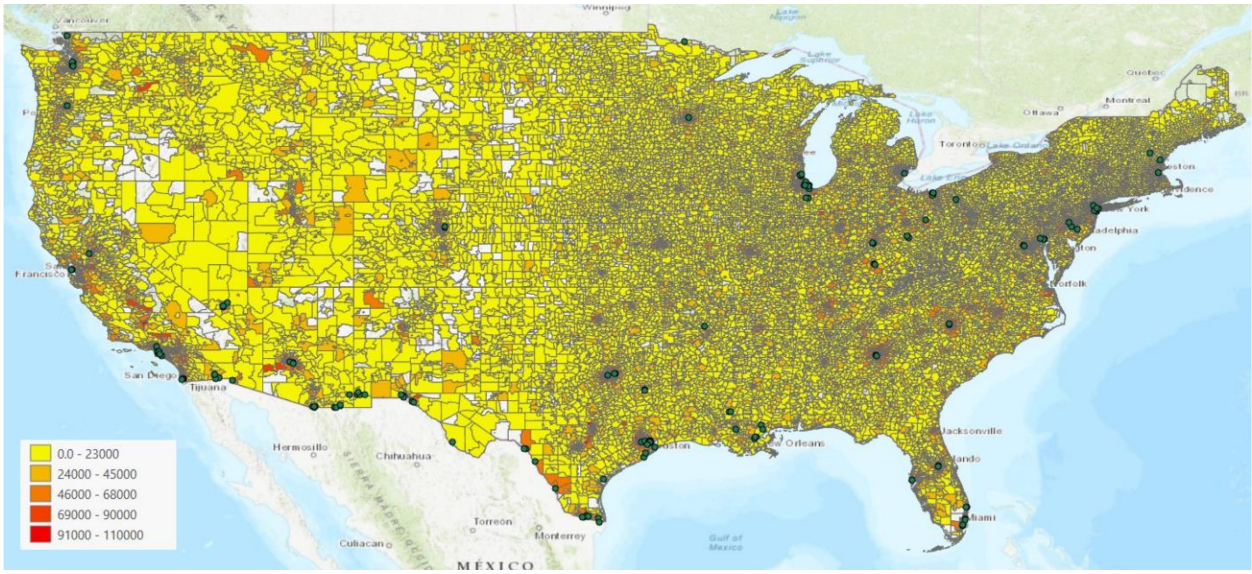


Figure 3. UAS Activity Data Sampling Locations & 14 C.F.R. §107 UAS Registrations

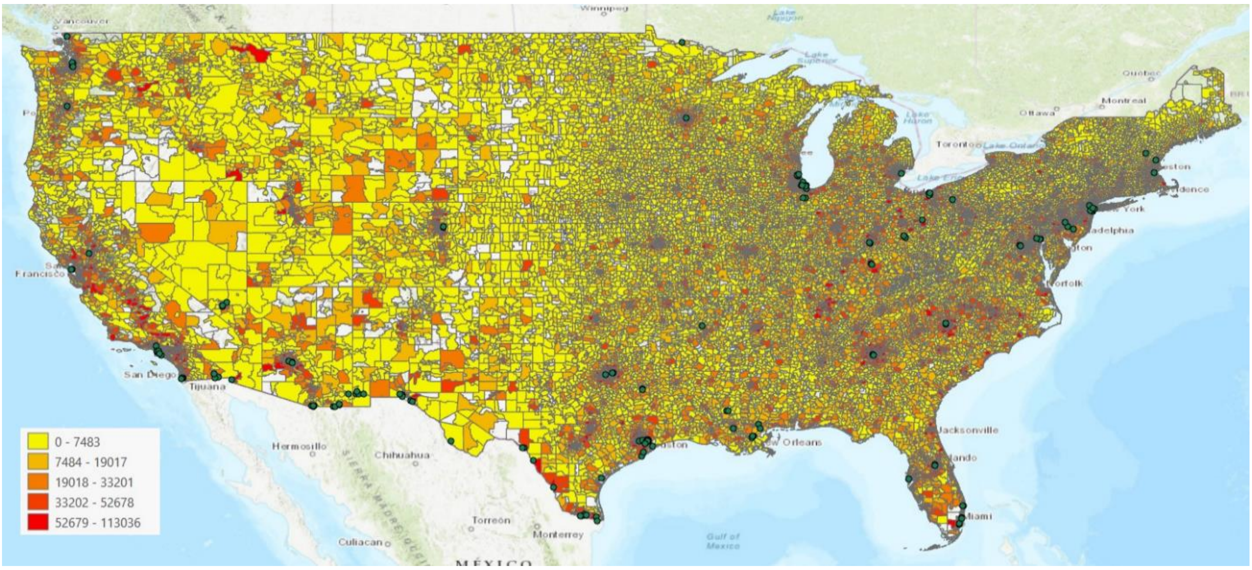


Figure 4. UAS Activity Data Sampling Locations & Remote Pilot Certificate Issuances

Table 1. UAS Detection Sampling Locations by State.

AZ	Douglas	FL	Orlando	MS	Woodville	TX	Bullard
AZ	Naco	FL	Tampa	NC	Charlotte	TX	Corpus Christi
AZ	Nogales	FL	West Palm Beach	NH	Concord	TX	Dallas
AZ	Phoenix	GA	Atlanta	NM	Playas	TX	Del Rio
AZ	Yuma	IL	Chicago	NV	Las Vegas	TX	Eagle Pass
CA	Burbank	IL	Kankakee	NY	Brooklyn	TX	El Paso
CA	Calexico	IL	Waukegan	NY	New York	TX	Freeport
CA	Long Beach	KY	Lexington	NY	Staten Island	TX	Houston
CA	Los Angeles	LA	Baton Rouge	OH	Chillicothe	TX	Laredo
CA	Sacramento	LA	New Orleans	OH	Cincinnati	TX	McAllen
CA	San Diego	LA	Slidell	OH	Cleveland	TX	Presidio
CA	San Francisco	MA	Boston	OH	Springfield	TX	Texas City
CO	Denver	MD	Baltimore	OH	Youngstown	WA	Ferndale
DC	Washington	MI	Detroit	OR	Portland	WA	Lynden
FL	Fort Lauderdale	MN	International Falls	PA	Philadelphia	WA	SeaTac
FL	Miami	MN	Minneapolis	TX	Brownsville	WA	Seattle

1.4.4 Unmanned Robotics Systems Analysis

An external company was subcontracted to streamline creation of a database, integrate diverse data sources, and create analytics tools at the direction of the research team.

1.4.4.1 Organization

URSA (https://ursainc.com/) is an ASSURE Center of Excellence Certified Partner and project sub-awardee. URSA is a leading UAS and Counter-UAS (C-UAS) data analytics company. URSA has supported U.S. Air Force (USAF) C-UAS integration efforts through Small Business Innovation Research (SBIR) grants, Customs & Border Protection (CBP) and the FAA through UAS forensics contracts, and is involved with a C-UAS test and evaluation exercise for the Bureau of Prisons as the system of record for all C-UAS and UAS telemetry data. URSA's platform enables operators, law enforcement, and regulators to investigate UAS behavior and activity by bringing together a wide variety of data sources into a single, flexible platform.

1.4.4.2 UAS & Counter-UAS Analytics Platform (UCAP)

URSA's customizable UCAP platform provides scalable, vendor-agnostic data analytics capable of processing multi-source telemetry and Geographical Information Systems (GIS) data. The system operates on an integrated web-based platform supported by the powerful Amazon Web Services (AWS) framework for performing both generalized assessment and detailed case-level data analysis. Leveraging modern data science and AI capabilities, the platform provides rapid pattern detection, data visualization, and automated reporting capabilities.

1.4.5 Additional Datasets

The research team integrated sUAS detection data with a diverse array of additional datasets to answer the posed research questions. The following datasets were used in this project:

1.4.5.1 OpenSky Network

Started in 2012 as a collaborative, multinational research project between Armasuisse, the University of Kaiserslautern, and the University of Oxford, the OpenSky Network (https://opensky-network.org/) is a non-profit organization with the mission of "improving the security, reliability, and efficiency of the air space usage by providing open access of real-world air traffic control data to the public" (OpenSky Network, n.d., "About Us"). This access is supported by a robust infrastructure network comprised of more than 4,100 peer-sharing Automatic Dependent Surveillance-Broadcast (ADS-B) and Mode-S sensors deployed in more than 190 countries worldwide (OpenSkyNetwork, n.d.). The network provides access to historical and real-time traffic data supporting non-profit air traffic research efforts (OpenSky Network, n.d.). A heat map of coverage within the U.S. is provided in Figure 5.

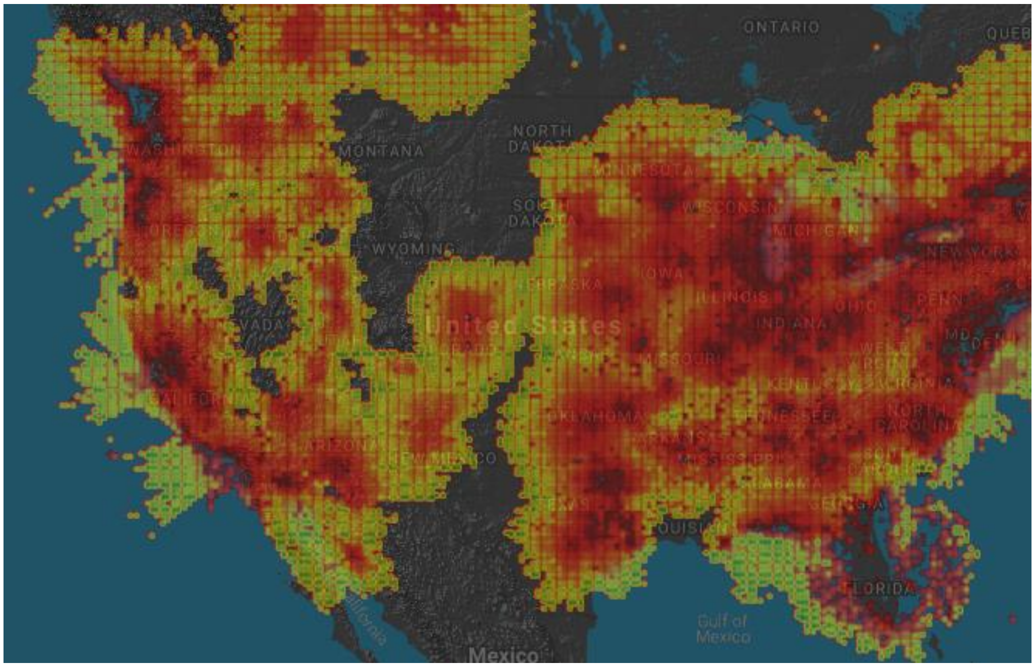


Figure 5. OpenSky Network Coverage.

Note: Darker-coloration represents areas with improved low-altitude coverage.

1.4.5.2 DroneResponders Public Safety UAS Program Map & Dashboard

The Airborne International Response Team (AIRT) is the parent company that manages a non-profit program called the DroneResponders Public Safety UAS Alliance (https://www.droneresponders.org/). This is a non-profit program designed to unite emergency response stakeholders who use UAS to facilitate the exchange of information, training, and best practices to improve the use of UAS in public safety (AIRT, 2021). Through a partnership between Esri (n.d.), an international GIS and geodatabase supplier, and NASA Ames Research Institute, DroneResponders has created "a comprehensive directory of public safety and emergency services drone programs" (DroneResponders, n.d., p. 1). The DroneResponders Public Safety UAS Map and Dashboard provide detailed geolocation and program information for more than 950 registered UAS public safety agencies worldwide, shown in Figure 6. One critical data element collected by the DroneResponders database is an overview of each registered agency's sUAS fleet composition. This information will aid the research team in locating public safety agencies within each sample area that utilize DJI-manufactured sUAS that are capable of being detected with the UAS detection technology utilized in this project.

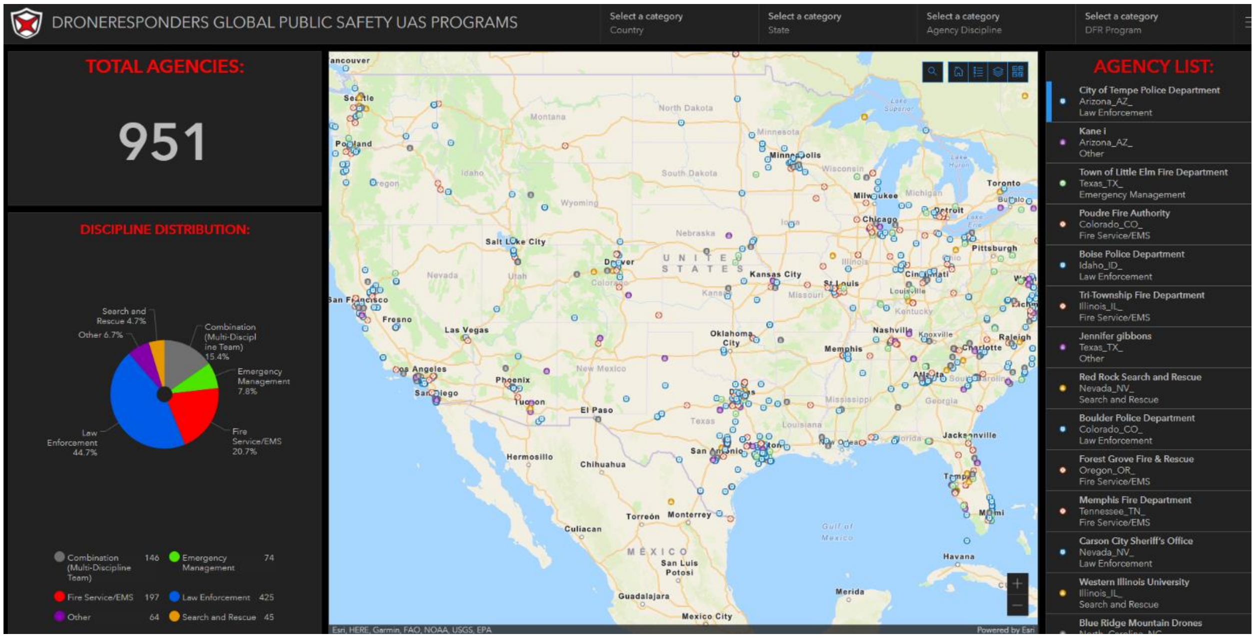


Figure 6. DroneResponders Public Safety UAS Program Map & Dashboard.

1.4.5.3 Iowa State University Environmental MESONET (IEM)

The Iowa State University Environmental MESONET (https://mesonet.agron.iastate.edu/) maintains archival data for aviation weather observation stations worldwide (Iowa State University, 2021). Observations are collected from either Automated Weather Observing Systems (AWOS) or the more sophisticated Automated Surface Observing Systems (ASOS). According to the Flight Safety Foundation (2018):

> AWOS systems generally collect ceiling, sky condition, visibility, temperature, dew point, altimeter setting and wind speed, gusts, and direction. ASOS can additionally provide the type and intensity of precipitation (rain, snow, freezing rain), and obstructions to visibility such as fog and haze. (p. 1).

This dataset will be paired to proximate sUAS telemetry data to identify instances in which sUAS flights exceed regulatory authority for operation in adverse weather or visibility conditions.

1.4.5.4 Department of Homeland Security (DHS) Homeland Infrastructure Foundation-Level Data (HIFLD)

Established datasets in 2002 to improve geospatial information sharing and support. The HIFLD datasets (https://hifld-geoplatform.opendata.arcgis.com/) were designed to enable better data visualization and analysis of national infrastructure (DHS, n.d.). The HIFLD database contains 496 individual GIS datasets, containing a wide variety of information across the 16 sectors of national critical infrastructure. Access to specific datasets varies based on the sensitivity of the data, user need, and security credentialing. Some of these datasets were used to evaluate the potential risk posed by sUAS in support of tasks D.8-D.9.

1.4.5.5 FAA Aeronautical Data Delivery Service

"The Aeronautical Data Delivery Service (https://adds-faa.opendata.arcgis.com/) is an FAA-enabled web service that makes data available in CSV, JSON, KML, and Shapefile formats to meet the needs of developers and other stakeholders" (FAA, 2018, p. 1). The database contains

47 individual datasets containing a wide variety of aeronautical information, including: National Defense Temporary Flight Restriction (TFR) areas, aeronautical obstacles, stadiums, airports, airspace boundaries, and related data. Elements of these datasets were used in support of tasks B.1 and D.8.

1.4.5.6 FAA UAS Facility Maps (UASFM) Datasets

"UAS Facility Maps show the maximum altitudes around airports where the FAA may authorize part 107 operations without additional safety analysis" (FAA, 2021d, p. 1). The vertical and lateral boundaries of the established FAA UAS Facility Maps can inform operators about the viability of airspace authorization requests or waivers for flights conducted within controlled airspace areas (FAA, 2021d). These datasets also contain Prohibited Areas, National Security UAS Flight Restrictions, and location information for Recreational Flyer Fixed Sites (FAA, 2021d). These datasets will be used in support of tasks B.1, and D.3-D.5. UAS Facility Map data is available from the Federal Aviation Administration website for geographical information systems: https://faa.maps.arcgis.com/apps/webappviewer/index.html?id=9c2e4406710048e19806ebf6a06754ad

1.4.5.7 FAA GLARE Analysis Tool

The FAA uses the Geographic Low Altitude Risk Estimation (GLARE) GIS visualization tool (https://www.youtube.com/watch?v=TJlNPozpLLg) to evaluate sUAS risk and waiver applications. The tool allows overlays of multiple layers of GIS data, including airspace classes, recreational fixed flyer sites, annual airport operations counts, airport types; heliport locations, population densities, sUAS/aircraft registration densities, sUAS sightings locations, athletic fields, and critical infrastructure locations (FAA, 2022b). At least some of the data is derived from the DHS-HIFLD database. Access to this dataset was used to support the completion of multiple task sets, including D.7 and D.8.

1.4.5.8 FAA sUAS Registration Database

14 CFR §48 requires operators of sUAS to have a completed registration in the sUAS Registration Database (https://faadronezone-access.faa.gov/#/) and mark their sUAS with the provided registration number. The research team utilized registration information to complete Task B.2.

1.4.5.9 FAA Low Altitude Authorization & Notification Capability (LAANC) UAS Data Exchange

FAA LAANC is a collaborative approach to managing low-altitude airspace data and serves as a critical capability for furnishing sUAS operators with access to airspace near airports in controlled airspace. The UAS Data Exchange (https://www.faa.gov/uas/getting_started/laanc), which manages this process, integrates request and airspace authorization information exchanged between UAS Service Suppliers and the FAA (FAA, 2022e). The research team used this data to support analysis of Tasks D.3 and D.5.

1.4.5.10 FAA UAS Sightings Report Database

The FAA UAS sightings database is derived from reports of hazardous UAS activity provided by pilots, law enforcement personnel, and others (FAA, 2022g). This dataset includes the location, time, and narrative description of UAS encounters and other suspect UAS activity. Information about UAS sightings reports can be obtained online at the following URL: https://www.faa.gov/uas/resources/public_records/uas_sightings_report

1.4.5.11 U.S. Navy Astronomical Almanac

Location-specific sunrise, sunset, and civil twilight times were derived from the U.S. Naval Observatory data and accessed via PyEhpem (https://rhodesmill.org/pyephem/index.html), a python-based source code for celestial positions (Rhodes, 2020).

1.4.5.12 Internet Assigned Numbers Authority (IANA)

Time Zone information was obtained using a public-domain zone database derived from IANA (https://www.iana.org/time-zones). The agency provides global coordination for coding and technical standards for internet applications (IANA, 2020).

1.4.5.13 Open Elevation

Open Elevation (https://www.open-elevation.com/) is a publicly-available, free source of geographical elevation data provided by Application Programming Interface (API) (Lourenço, n.d.). Open Elevation provides comparable data to the Google Elevation API (Lourenço, n.d.).

1.4.5.14 OpenStreetMap

Open Street Map (https://wiki.osmfoundation.org/wiki/Main_Page) is a community-built, open-source geographical map of the world (OpenStreetMap Foundation, 2021). Maps are produced and validated using local knowledge, aerial imagery, and GPS devices (OpenStreetMap Foundation, 2021).

1.5 Teaming & Organization

This project is supported through a collaboration of experts from Embry-Riddle Aeronautical University (12), Kansas State University (5), and the National Institute for Aviation Research at Wichita State University (4). The team also includes a number of graduate and Ph.D. students in supporting roles. Specific team member roles and responsibilities are overviewed in Figure 7.

The project leverages the unique skillsets of 21 subject matters experts from multiple fields and institutions. To best meet the project's multiple objectives within the prescribed timeframe, team members are organized by functionality, according to six keys tasks associated with the project: (1) UAS Detection / GIS Data Collection & Support; (2) sUAS Activity Monitoring; (3) Aircraft Traffic & Encounters; (4) Analysis & Policy; (5) Analysis Tool Development; and (6) External Liaison and Communication.

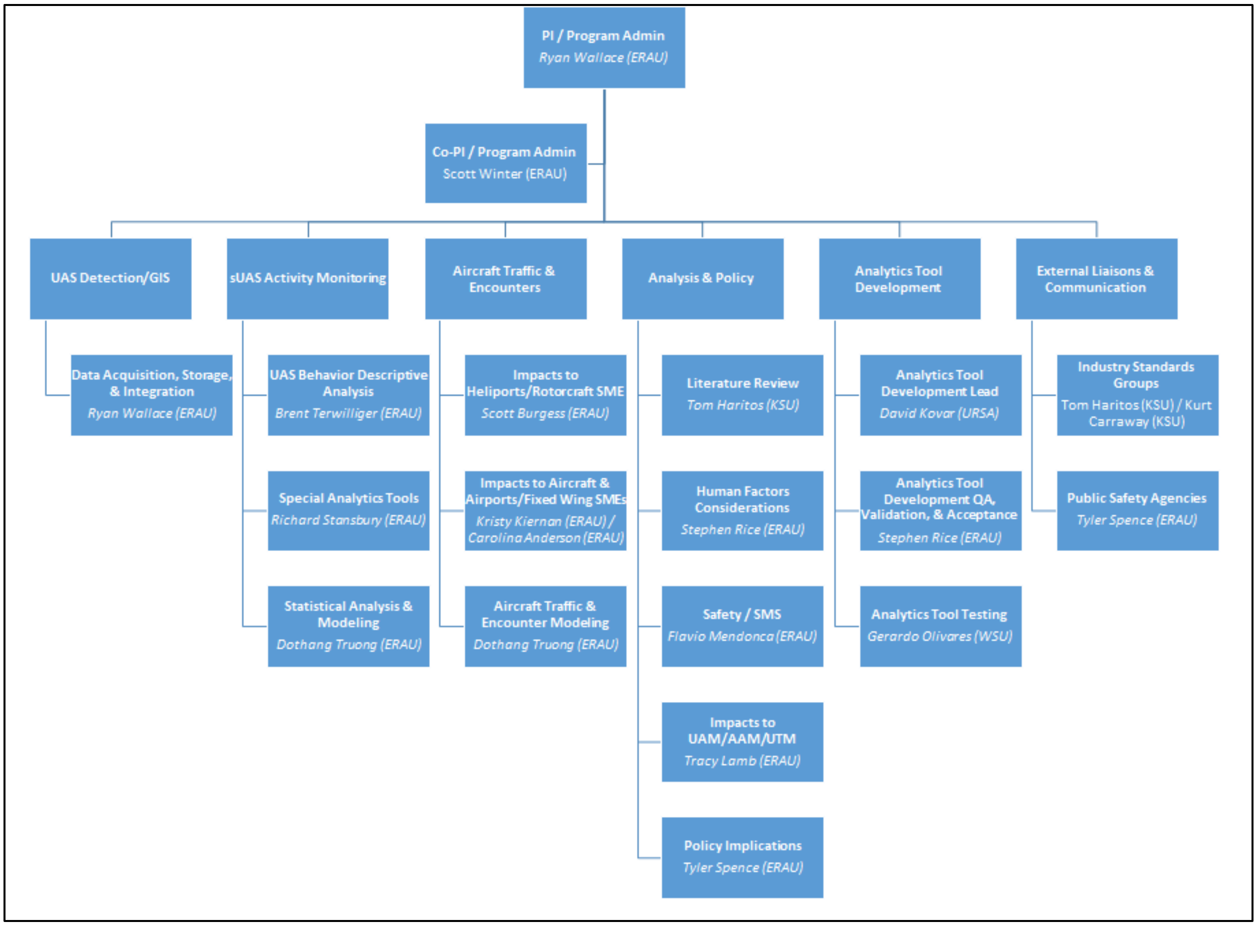


Figure 7. Project Team Organization & Task Responsibilities.

1.6 Assumptions & Limitations

The research team acknowledges the following assumptions and limitations apply to this project:

- The UAS detection sensor only detects platforms within electronic line of sight. The range of stationary sensor units is reported to be up to 50 km. Platforms outside that range or operating in a manner that does not provide line of sight to the sensor are unlikely to be detected.
- Some DJI platforms do not support sensor platform identification. These platform types will be reported as either "null" or "unknown."
- It has been reported that UAS operators can suspend data transmission from their sUAS effectively shielding it from detection from the UAS detection sensor suite with specialized software (Skove, 2022). While the research team acknowledges this technological limitation, there is little evidence to suggest widespread operator use of this technology.
- A study by Department 13 (2017) highlighted cybersecurity concerns with the UAS detection sensor technology, suggesting the system is vulnerable to hacking and potential ID spoofing. In a response to Department 13's report, DJI suggested that most operators will comply with very few bad actors taking efforts to circumvent the drone's identification systems (Kesteloo, 2017). The research team also acknowledges this limitation, and agrees

with the manufacturer's presumption that few operators are likely to exploit this vulnerability.

- Analysis of air traffic data utilizes ADS-B information. Although most aircraft are equipped with ADS-B, as required by 14 CFR §91.225 and §91.227, some aircraft are not required to utilize ADS-B. Generally, ADS-B is required for operation in Class A (not applicable to this study), Class B, Class C, above 10,000 ft Mean Sea Level (MSL) in Class E, and within 30 NM of specified Mode C Veils (FAA, 2020a). This may result in some aircraft—particularly those not equipped with ADS-B or Mode-S capability and operating in Class G airspace—not being included in study results.
- The authors are unable to assess which operational ruleset sUAS operations are being conducted under: 14 CFR §107 (Commercial), 49 U.S.C. §44809 (Recreational / Hobbyist), 49 U.S.C. §40102(a)(41) and §40125 (Public Aircraft) or under a Certificate of Authorization (COA). It is also not possible to determine if an operator under 14 CFR §107 is operating under the authority of a waiver or airspace authorization.
- This study collected data from more than 64 diverse sample locations. These areas may not necessarily be representative of operating areas across the nation. Certain areas may be influenced by lurking variables, which may include seasonality, weather, state operating restrictions, limited access to airspace or flight areas, or other factors beyond the scope of the study. Readers should be cautious before generalizing localized findings.
- The UAS detection sensor only detects DJI-manufactured sUAS platforms. It is estimated that true sUAS activity reported in each sampling area is likely to be up to 24% higher than reported (based on DJI market share).
- This study defined 64 individual data capture areas designed to segregate and compare data within different geographical locations. A small number of these data capture areas have geographical overlap, which may cause limited duplicate counting for some analytics. Values subject to this limitation are annotated with an asterisk (*).

1.6.1 UAS Platforms Detected

The following represent descriptive details of examined sUAS model categories (series, platform, or product line) featured throughout this research. Understanding such contextual details of the sUAS models featured in this study is anticipated to help to explain factors contributing towards the presented observations, results, and implications. Table 2 provides additional sUAS specifications.

A3 – This group is not a specific sUAS platform, it represents a series of DJI-manufactured flight controllers including the A3 (186g) and the A3 Pro (386g). Both designs feature three Inertial Measurement Units (IMU)s, three Global Navigation Satellite Systems (GNSS), embedded algorithms (including those for attitude determination, multiple sensor data sampling and integration, and Electronic Speed Control [ESC]); and three receivers. The platform is primarily configured for use on the Matrice 600 Pro.

Agras – Released in November 2020 as a sUAS solution to agricultural and other spraying applications, the DJI Agras T10 and larger T30 models represent a significant design shift towards specialized missions. The hexacopter design features fixed motor arms extending from the main fuselage, which simultaneously support the spraying apparatus. The 30-liter application tank is cradled in the central core of the fuselage (likely to improve weight and balance and controllability characteristics), and rests on two braced, fixed-strut landing skids. Equipped for Real Time Kinematics (RTK), the device is prepared for precision navigation and can reportedly cover up to 40 acres per hour. The T30 platform variant weighs in at 26,400g (58.2 lbs), flies relatively slowly at 15.7 mph, and has an endurance of 20.5 minutes.

DJI Mini 2 – Released in November 2020, the DJI Mini 2 Series improves upon the capabilities of the Mavic Mini with higher video quality, longer flight time, and other features packed into an extremely small, light platform. The fuselage of the quadrotor follows the Mavic Mini design trend, with foldable motor arms that can easily fit into the palm of a hand. Improvements were made to the controller, flight stability, and other elements. Like its predecessor, the platform weighs less than 249g (<.55 lbs), can fly faster—up to 35.8 mph—and has a flight endurance of 31 minutes.

First Person View (FPV) – Released in January 2021, the DJI First Person View (FPV) model is a quadrotor designed for speed and drone racing. The model integrates with DJI's immersive FPV Goggles and can be flown with either a two-stick configuration remote controller or a single handheld Motion Controller. The 795g (1.75 lb) unmanned aircraft (UA) can reach speeds up to 100 mph and has a battery endurance of nearly 20 minutes.

Inspire 1 – The Inspire 1 Series drones include the original Inspire 1 released in November 2014 and newer Inspire 1 2.0 model released in November 2015. This quadrotor UA features a ventral-mounted gimbaled electro-optical camera and retractable landing struts that double as the support structure for the motor assembly. The UA weighs approximately 3060g (6.74 lbs) fully configured and can reach up to 49 mph. Battery endurance provides for approximately 18 minutes of flight time.

Inspire 2 – The Inspire 2 Series was released in November 2016 and exhibits similar design configuration as the Inspire 1 series. The Inspire 2 UA contains the same retractable struts as the Inspire 1, which enables lifting the motors above the fuselage during flight. The Inspire 2 is configurable with two batteries, rather than the single battery configuration for Inspire 1 models, increasing the flight endurance to approximately 27 minutes. The UA weighs approximately 3440g (7.58 lbs) and is capable of speeds approaching 58 mph.

Matrice 100 (M100) – Released in June of 2015, the Matrice 100 drone is a quadrotor design configured on an open, lattice core, with mountable forward-facing, gimbaled sensor options. The Matrice 100 has configurable motor arms, enabling a slight upward angle of the propulsion mounting. The platform is designed for broad customization and payload configurations. Built primarily for commercial operators, the platform weighs approximately 2400g (5.29 lbs) and can fly at 49 mph. The platform is capable of up to 40 minutes of flight time, with dual batteries.

Matrice 200 (M200) – The Matrice 200 series includes both the original 200-series released in February 2017 and 200 version 2.0 models released in February 2019. The Matrice 200 employs a quadrotor design with fixed motor arms attached to a central fuselage, and fixed ventral landing struts. The platform is capable of carrying multiple gimbaled sensor payloads. Sensor data is integrated into the controller configuration, enabling multiple, simultaneous feeds. The platform comes standard with two anti-collision beacons for night operation. The platform weighs in at 4,690g (10.34 lbs) and can fly at speeds up to 50.3 mph, with a reported endurance of up to 38 minutes.

Matrice 300 (M300) – The Matrice 300 series was released in May of 2020 and employs a similar design to the Matrice 200 platform, with the fuselage seemingly flipped upside down. The platform contains fixed, quadrotor arms and landing struts with downward-facing foldable props and forward gimbaled sensor mounting bracket. The platform enables customizable payloads, with multiple sensor configurations. The M300 comes fully-equipped with RTK positioning, enabling improves survey accuracy. Without a payload, the M300's endurance can reach up to 55 minutes. The UA weighs 6300g (13.89 lbs) and can fly at speeds up to 51.4 mph.

Matrice 600 (M600) – The Matrice 600 Series includes the base model released in April 2016 and the improved Matrice 600 Pro, released in November of the same year. The Matrice 600 series platforms were designed for professional aerial photography and other commercial and industrial applications. Built on a central fuselage with retractable landing struts and extended motor arms, the hexacopter UA can carry up to 5500g of payload (12.1 lbs). Platform endurance can reach up to 40 minutes without a payload, and 18 minutes completed loaded. The platform weighs 9600g (21.16 lbs) and can fly at speeds approaching 40.3 mph.

Mavic 2 Enterprise – The Mavic 2 Enterprise series includes the Mavic 2 Pro, Zoom, Enterprise, and Enterprise Dual variants released between August and October 2018. An updated model from the very popular original Mavic Pro design, the platform leverages a similar quadrotor fuselage design, with foldable motor arms and props, and forward-mounted sensor gimbal. The Enterprise Dual variant sports both an electro-optical camera and thermal imagery capability. The platform is equipped with a dorsal auxiliary port, enabling customized configuration of mission equipment which can be controlled from the remote, including strobe light, spotlight, speakers, or other swappable device. The variants weigh between 899g-905g (1.98-1.99 lbs) and can fly at speeds up to 44.7 mph. Maximum endurance of the platform is reported to be 31 minutes.

Mavic 3 – The newest November 2021 release in the popular Mavic Series, which includes Standard and Cine variants. Both quadrotor variants are largely comparable with the Cine variant containing additional onboard memory storage for video projects. The drone is compatible with the RC Pro controller, which enables support of third-party applications. The platform comes equipped with two cameras, one with a highly-capable telephoto lens for high-resolution imagery and videos. The drone weighs between 895g-899g (1.97-1.98 lbs) depending on the variant. It has an endurance of 46 minutes and can fly at speeds up to 42.5 mph.

Mavic Air – Released in January of 2018, the Mavic Air series has a smaller quadrotor profile than the popular Mavic platform, but maintains a similar design, with opposed, foldable motor arms which double as landing struts, and forward-facing, tilting sensor shrouded by the fuselage. The Mavic Air Series is considered by some to be an upgrade of the Spark. The platform can be controlled by remote, smartphone, or even using hand gestures. The platform weighs just 430g (.95 lbs) and flies at speeds approaching 42.5 mph. Maximum flight time for the platform is 21 minutes.

Mavic Air 2 – Released in April 2020 as the updated version of the original Mavic Air, the new model is both heavier and more robust than its original release version. The quadrotor features a design that closely replicates the original Mavic. Characteristic features include folding motor legs and a gimbaled forward-facing camera, but without the sensor shroud found in the previous model. The platform weighs in at 570g (1.26 lbs) and sustains the same speed of 42.5 mph as its predecessor, and has an improved endurance of 34 minutes.

Mavic Mini – The Mavic Mini Series released in October 2019 was DJIs improved foray into the small, lightweight drone market. Considered a drastic improvement over the Spark, the Mavic Mini is smaller, cheaper, and nearly as capable as larger products. The quadrotor's design is nearly identical as the Mavic Air 2, but with a smaller footprint and reduced camera resolution. The platform weighs just 249g (<.55 lbs), exempting it from the FAA's registration requirements. The platform has an endurance of 30 minutes and flies at speeds over 29 mph.

Mavic Pro – Released in September 2016, the Mavic Pro revolutionized the industry. The sleek, compact, folded quadrotor design deviated significantly from previous product lines. The platform features a gimbaled camera slung below an extended ventral fuselage, with added sensor protection offered by a plastic gimbal cover. The platform weighs in at 743g (1.64 lbs) and can fly at speeds up to 40 mph. The maximum flight time of the platform is 27 minutes.

Phantom 3 (P3) – The Phantom 3 Series released starting in April 2015, and includes the Standard, Professional, and Advanced models. The entry-level quadrotor reflects DJI's early design parameters with short, fixed motor arms that integrate into a central fuselage, with fixed landing struts and a central ventral-hung, gimbaled electro-optical camera. The platform weighs in at 1216g (2.68 lbs) and can fly at speeds up to 35.8 mph, with an endurance of 25 minutes.

Phantom 4 (P4) – Released in March of 2016, the Phantom 4 improves upon the Phantom 3, with several upgrades. The platform sports the same basic design as the Phantom 3, with a sleeker fuselage and additional safety features, such as obstacle avoidance. Additional camera features such as Active Track, which enables the UAS to automatically follow a moving subject in the camera frame, rounds out the new capabilities. An RTK variant is available for high-precision operations, which adds 11g to the base platform weight. The platform is slightly heavier than its predecessor at 1380g (3.04 lbs), has a slightly improved endurance of 28 minutes of flight time, and can fly at speeds up to 35.8 mph.

Spark – The Spark Series released in May 2017, represents DJI's initial push to package the features of the larger, popular quadrotor drones like the Mavic Pro in a smaller size. The Spark has a boxier design than other DJI products, with fixed motor arms extending from the dorsal fuselage and a shrouded, tilting, forward-faced camera. Unlike most other DJI products, there are no landing struts—the platform is designed to land on the belly of the fuselage. The platform only weighs 300g (.66 lbs) and can fly at 31 mph. Flight endurance is relatively short, with a maximum reported flight time of only 16 minutes.

Unknown – Sometimes the UAS detection sensor is unable to identify the platform type for an UA. In most cases, these findings are reported as "unknown." In other cases, the research team articulated how unknown platform types were analyzed and reported.

Table 2. sUAS Specifications

Platform	Released (Mo/Yr)	Available	Weight (g)	Size (mm)	Price*	Endurance (min)	Max Speed (mph)	1 Arc-Min (ft)
Agras (T16)	November-20	Y	18500	N/A	$21,499	18	22.4	N/A
Mini 2	November-20	Y	249	203	$449	31	35.8	2289.6
FPV	January-21	Y	795	312	$999	20	100	2842.2
Inspire 1	November-14	N	3060	581	$1,999	18	49	6552.9
Inspire 2	November-16	Y	3440	605	$3,299	27	58	6823.6
Matrice 100	June-15	N	2400	650	$3,299	40	49	7331.2
Matrice 200	February-17	N	4690	887	$5,999	38	50.3	9992.9
Matrice 300	May-20	Y	6300	810	$13,700	55	51.4	9135.7
Matrice 600	April-16	N	9600	1668	$4,599	40	40.3	18812.9
Mavic 2 Enterprise	October-18	Y	905	322	$1,999	31	44.7	3631.7
Mavic 3	November-21	Y	899	448	$2,049	46	42.5	5052.9
Mavic Air	January-18	N	430	213	$799	21	42.5	2402.4
Mavic Air 2	April-20	Y	570	253	$799	34	42.5	2853.5
Mavic Mini	November-19	N	249	202	$399	30	29	2278.3
Mavic Pro	September-16	N	743	335	$749	27	40	3778.4
Phantom 3	April-15	N	1216	350	$799	25	35.8	3947.5
Phantom 4	March-16	N	1380	350	$1,500	28	35.8	3947.5
Spark	May-17	N	300	170	$499	16	31	1917.4

Note: specifications and pricing derived from available online sources.

Every platform identified in this list may not appear in each respective sUAS operational model research task; a specific group will only be specified when detected and identified in the associated data for that task. Any new DJI models released by the company and captured in subsequent collection efforts will be added to the data analysis, tables, charts, and conclusions. Further details and subsequent conclusions regarding models will be presented in future iterations of this report, as additional data, contextual observations, and analysis results become available.

1.6.2 Addressing Data Assumptions: Data Filtering, Cleaning, & Validation

One challenge encountered when using the UAS detection sensor is the potential for the device to miscount or mischaracterize segments of sUAS flights in which it does not maintain continuous, uninterrupted tracking. In the event the UAS detection sensor loses the sUAS datalink Command and Control (C2) signal (such as the UA flying behind an obstacle) or otherwise losing electronic line of sight, the device will log the operation as multiple flights. Additionally, sUAS flying under conditions that would inhibit good sensor detection of the C2 signal (such as those flying at the extent of the sensor's range) may only log a small number of telemetry points for the flight. Finally, the UAS detection sensor detects sUAS activity upon activation of the datalink between the controller and UA—even if the UA is not in flight. This can result in some UAS flight detections that do not present an aerial hazard.

A series of data filtering, cleaning, and validation methods were used to address the aforementioned limitations and ensure the project uses the most valid data. These data cleaning procedures were used at the discretion of the research team and annotated in the report when applied. This discretion enables each subject matter expert (SME) to assess the data before and after correcting for the potential validity threat. In some cases, it was important to *retain* spurious flight detections, ground activity, or incomplete data (such as when performing sUAS population counts). In other cases, such as assessing sUAS encounters with aircraft, it is more important to ensure higher data accuracy and validity.

1.6.2.1 Data Treatment Prior to Loading into URSA's UCAP System

Prior to loading data into UCAP system for analysis, the URSA team performed several preliminary procedures designed to ensure data validity:

- Eliminate data duplication from overlapping detection dates received from UAS detection data providers.
- Align data with altitude datum (AGL/MSL)
- Add universal coordinated time (UTC/Zulu) for temporal data, as required.

1.6.2.2 Data Treatment After Loading into URSA's UCAP System

The research team employed one or more methods to correct UAS detection data validity issues, including:

- Removing data points with illegal latitude or longitude values
- Removing data points with null latitude/longitude or Drone ID values
- Removing single data point flight detections from analyzed UAS detection data
- Removing sUAS ground activity or tracks that do not become airborne
- Track melding or connecting data points from a single sUAS operation that yield separated flights IDs that occur within a similar timeframe (pending implementation)
- Employ bounding box to limit analytics to only those contained within the continental United States. Bounding box for initial analysis includes flights within approximately 20 SM of the U.S. border (including territorial waters and parts of the Exclusive Economic Zone). Fidelity of bounding boxes can increase to 5 meter accuracy, however, this analysis requires increased server processing time.

1.7 Year One Progress Overview

This report articulates progress, findings, and preliminary observations on research tasks completed in the initial year of the three-year performance period. Reported data is based on sUAS detection sampling that took place between July 1, 2021 and January 31, 2022. Table 3 provides an overview of task progress with appropriate caveats. Observed trends or patterns, as well as inferences and conclusions, are subject to change based on a multitude of influencing factors, including potential changes in regulations, laws, sUAS availability, and financial or economic conditions. The intent of sharing early observations, including any potential identification and discussion of implications, is to establish a contextual baseline for future comparison.

Table 3. Summary of Year One Progress by Research Task.

Research Tasks					
Task: Description		**Task#**	**Title**	**Status**	**Notes**
A	**Analysis Tool Dev & Literature Review**	A.1	Analysis Tool Development	Complete	Refining Analysis Tool Reliability
		A.2	Literature Review	Complete	N/A
B	**Current State of sUAS Traffic within the National Airspace System**	B.1	Current sUAS traffic attributes	Preliminary Results Available	N/A
		B.2	Estimated registration rates	Preliminary Results Available	N/A
		B.3	Where sUAS fly	Data Collected	Adapting NLC Database data for integration
		B.4	Retirement & abandonment	Data Collection In Progress	At least 12-24 months of data required for validity
		B.5	Public safety use of sUAS	Sample Established	Preparing Solcitation for Agency Participation
		B.6	sUAS population < .55lbs	Preliminary Results Available	N/A
		B.7	Impacts of using ADS-B	Data Collected	Adapting methodology from D.1 to address RQ
C	**Compliance and Exceedances of 14 CFR 107 Operational Limitations**	C.1	Exceedances for vehicle ops	Preliminary Results Available	N/A
		C.2	Exceedances for daylight ops	Preliminary Results Available	N/A
		C.3	Exceedances for VLOS	Preliminary Results Available	N/A
		C.4	Exceedances near aircraft	Preliminary Results Available	N/A
		C.5	Exceedances over humans	Data Collected	Determining appropriate integration of pop. density datasets
		C.6	Exceedances for ops limits	Preliminary Results Available	N/A
D	**Near Aerodrome sUAS Operations & Encounter Risks with Manned Air Traffic**	D.1	Likelihood of encountering UAS	Preliminary Results Available	N/A
		D.2	Likelihood of aircraft encounter	Preliminary Results Available	N/A
		D.3	Effectiveness of 400 ft / LAANC	Data Collected	Addressing database filtering issue to limit dataset
		D.4	Aircraft penetrating UASFM	Data Collected	Addressing database filtering issue to limit dataset
		D.5	sUAS exceeding UASFM	Preliminary Results Available	N/A
		D.6	Hotspots for sUAS encounters	Preliminary Results Available	N/A
		D.7	Hotspots predictive for sightings	Preliminary Results Available	N/A
		D.8	sUAS flight in no-fly zones	Data Collection In Progress	Refining spatial & temporal NFZ integration
		D.9	sUAS near critical infrastructure	Preliminary Results Available	N/A
		D.10	Rates of BVLOS flight	Preliminary Results Available	N/A
E	**Forecasting Industry Growth & Potential Advanced Air Mobility Implications**	E.1	Impacts to AAM/UAM	Partial Preliminary Results Available	N/A
		E.2	Improving UTM safety	Partial Preliminary Results Available	N/A
		E.3	Impact of air routes	Deferred pending further data collection	N/A
		E.4	Conveying abnormal traffic	Deferred pending further data collection	N/A
F	**Communicating Findings**	F.1	Task deliverables & reporting	Projected On-Time	N/A
		F.2	Standards groups liaison	In progress	N/A

2 METHODOLOGY, PRELIMINARY FINDINGS & DISCUSSION

Initial reporting of project tasks are organized according to the approved Research Task Plan:

- Task A: Analysis Tool Development & Literature Review
- Task B: Current State of sUAS Traffic within the NAS
- Task C: Compliance and Exceedances of 14 CFR §107 Operational Limitations
- Task D: Near Aerodrome sUAS Operations & Encounter Risks with Manned Air Traffic
- Task E: Forecasting Industry Growth & Potential AAM Implications
- Task F: Communicating Findings

The following sections follow the categorization of related tasking to address the investigated topic. Where appropriate, tasking has been further subdivided, along logical divides, as sub-tasks and subsections (e.g., *Task B.1.#*) to contextually present and discuss the material. Each subsection features a descriptive overview of the sub-task; discussion of findings, as related to the captured data and accompanying figures; and notable concluding remarks relating to the interpretation or implications of the findings.

2.1 Task A: Analysis Tool Development

Due to the extent of data generated from the sampling locations across the U.S., it was not possible to analyze the sUAS detection data using conventional tabular means, such as Microsoft Excel or related software. Excel is limited to datasets with fewer than 1,048,576 rows. The research team's initial collection of sUAS detection data, generated during a nearly three-year period near Dallas-Fort Worth International (DFW) Airport (August 2018-2021), produced more than 3.8 million lines of data. This data processing is further complicated when ADS-B data was added to the analysis. Even when filtered to exclude ADS-B tracks to those at low altitudes and within a limited range to the DFW airport, the size of data files *for one day* generally exceeded 150 MB.

With the large number of sampling locations in this project, a cloud-based computing approach was required to store, process, and analyze the extent of produced data. This approach was warranted for the following reasons:

- Distribution and management of data to multiple, simultaneous users
- Enabled simultaneous analytics tool development and user interface, with limited interruption during version updates
- Volume of data exceeded capacity of desktop solutions (past year data storage exceeded 800 GB for ADS-B data alone)
- Need for access to multiple, simultaneous data sources increased processing requirements

URSA's UAS and C-UAS Analytics Platform was used to store, format, integrate, database, process, analyze, display, and filter the various datasets to streamline the analysis process for the research team. The Analysis tool development process is led by the URSA team, who programed and integrated the various analysis processes into the UCAP analysis tool under the research team's guidance and direction. URSA was furnished with specific technical requirements designed to support the objectives and deliverables proposed in this research task plan. A research liaison oversaw URSA's UCAP development process, to coordinate and advise on behalf of the Principal Investigator regarding:

- User Interface / User Experience
- Sourcing external data inputs
- Data integration & validation
- Information displays & visualizations
- Methodological approach for various analytical processes
- Available analytics tools, statistics, & outputs
- Data filters
- Data cleaning & validation processes
- User preferences
- Features
- Other related issues

The liaison and Principal Investigator evaluated functionality and validity of completed analytics toolsets. The preponderance of the UCAP development process was completed prior to July 1, 2022, with additional refining expected throughout the remainder of the grant's performance period.

2.2 Task B: Current State of sUAS Traffic within the NAS

The objective of this task is to provide a descriptive analysis of sUAS traffic trends from sample detection data. An emphasis will be placed on quantifying operational trends.

2.2.1 Task B.1: What are current sUAS traffic attributes over urban areas (i.e., number of operations, flight altitudes, durations, classes of airspaces, & proximity to airports)?

The objective of this task is to provide a descriptive analysis of sUAS traffic attributes.

Findings: The research team conducted sampling from July 1, 2021 through January 31, 2022. During the sampling period, the research team detected 470,902 sUAS flights from among a population of 116,915 sUAS platforms using the 166 UAS detection sensors at 64 separate sampling locations around the United States. Figure 8 highlights sampled areas of sUAS activity with observed prominent use concentrated in Chicago [IL] (*n*=31,061 sUAS flights), McAllen [TX] (*n*=28,117 flights), and Philadelphia [PA] (*n*=27,727 flights). The distribution of flights for the remaining sampling locations can be seen in Figure 9 and Table 4. Cumulative, active sUAS registrations for 14 CFR Part 107 and 49 USC 44807 operations were calculated for each sample area by assessing zip codes that fell inside the detection range of each sample area and extracting registration values from the sUAS registration database by zip code. Registration data was provided for context to enable assessment of detected sUAS activity against known UAS registration information. A detection rate for each location was also calculated by dividing the number of flight detections by the sampled days, with these three same locations continuing to indicate the highest detection rates; Chicago (144.47 detected flights per day), McAllen (133.38 detected flights per day), and Philadelphia (128.96 detected flights per day) as shown in Figure 10.

Comparing the daily detection rate of these three high use areas to their respective estimated resident populations (derived from U.S. Census Bureau, 2021), provides the means to calculate a ratio indicative of the number of metro population members (residents) to each detected flight. There are notable population differences between the two larger metropolitan areas featuring more than 1.5M residents (Chicago, IL: 2,696,555 and Philadelphia, PA: 1,576,251) and the smaller, less urban area (McAllen, TX: 143,920 residents). Despite the distinct difference in observable population, McAllen, TX features a much higher proportion of daily operations (i.e., *population use ratio*) than the other two much larger metro regions, given the size of the resident population (McAllen, TX: one flight per 1,079.02 residents or 1:1,079.02 ratio; Philadelphia, PA: 1:12,222.79 ratio; and Chicago, IL: 1:18,658.23 ratio). Chicago would need a 17.04 fold increase in daily operations to equal the same ratio at McAllen, TX, while Philadelphia would require a 11.16 increase in use, based on their respective populations. Calculating the population use ratio for the entire data set results in the identification of three locations where use is notably high, given the respective population: 1) Brownsville, TX (18.32 daily detection rate: 9,661 population; 1:527.40 ratio), 2) Texas City, TX (87.88 daily detection rate: 54,247 population; 1:617.28 ratio), and 3) Freeport, TX (10.21 daily detection rate: 10,594 population; 1:1,037.26 ratio). Alternatively, the areas with the lowest use ratio (in descending order) were New York, NY (34.96 daily detection rate: 8,467,513 population; 1:242,191.30 ratio), Sacramento, CA (3.56 daily detection rate: 525,041 population; 1:147,532.18 ratio), and Los Angeles, CA (41.66 daily detection rate: 3,849,297 population).

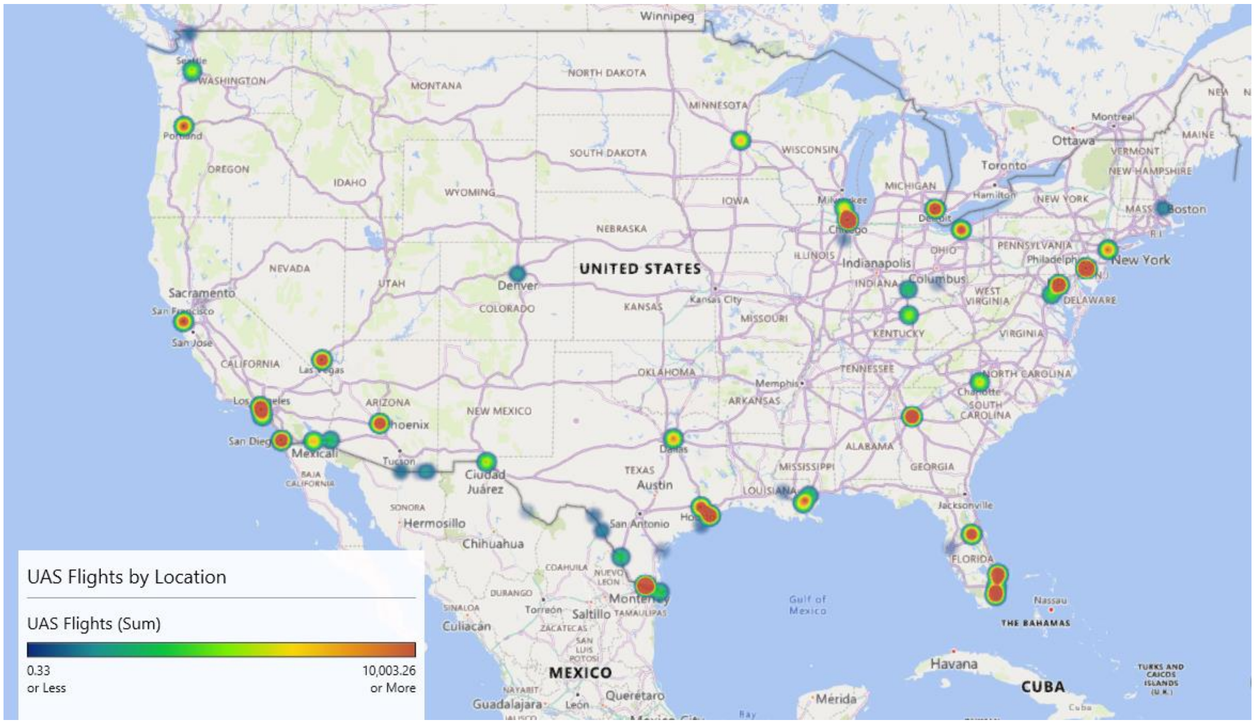


Figure 8. Map of Drone Flights by Location (Jul 2021-Jan 2022)(*N*=470,902).

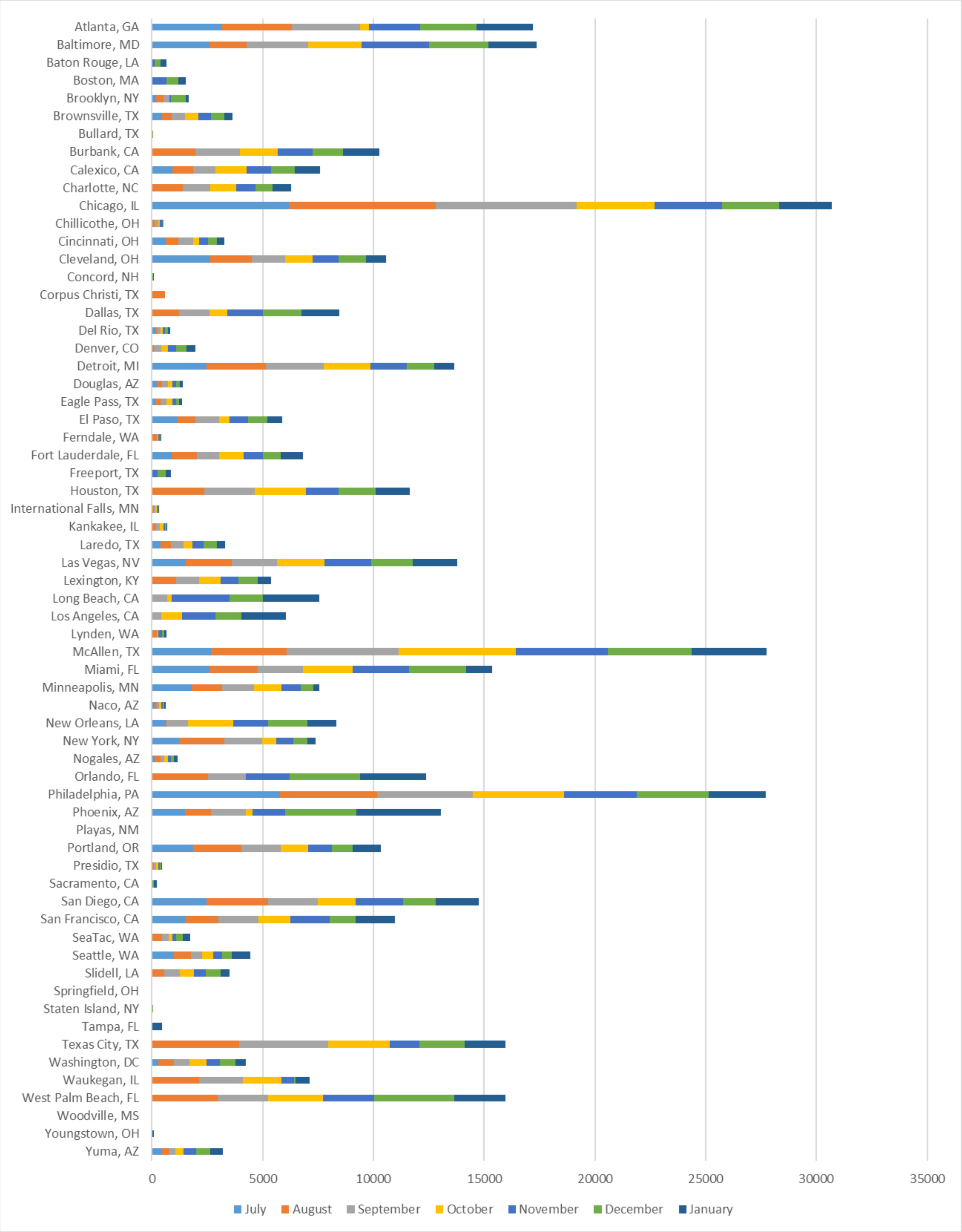


Figure 9. Drone Flights by Month by Location (*N*=422,380).

Table 4. Drone Flights by Location (N=422,380).

	Total		**Daily**						**UAS Registrations**	
Location	**Days**	**Flights**	**Min**	**Max**	**Mean**	**Median**	**SD**	**Rate**	**§107**	**§44807**
Atlanta, GA	186	17213	1	215	92.05	93	35.09	92.54301	5373	7483
Baltimore, MD	215	17380	1	395	80.46	76.5	43.22	80.83721	2986	4235
Baton Rouge, LA	84	650	1	21	7.74	7	4.68	7.738095	646	777
Boston, MA	87	1540	1	64	17.70	16	10.64	17.70115	2823	4509
Brooklyn, NY	173	1660	1	61	9.60	6	10.10	9.595376	1390	2624
Brownsville, TX	198	3627	1	56	18.32	18	8.76	18.31818	219	277
Bullard, TX	22	34	1	3	1.50	1	0.66	1.545455	191	232
Burbank, CA	184	10618	2	98	55.83	56.5	16.46	57.70652	4682	5699
Calexico, CA	211	7600	2	76	36.02	34	12.91	36.01896	89	135
Charlotte, NC	185	6486	5	77	34.04	33	15.42	35.05946	2530	3640
Chicago, IL	215	31061	4	584	142.22	134	83.22	144.4698	4460	8315
Chillicothe, OH	107	569	1	26	4.93	4	4.31	5.317757	247	426
Cincinnati, OH	212	3287	1	70	15.50	14	9.77	15.50472	1607	2642
Cleveland, OH	215	10573	3	513	48.95	44.5	42.06	49.17674	1677	2971
Concord, NH	48	97	1	6	2.02	2	1.15	2.020833	456	835
Corpus Christi, TX	28	580	1	60	20.71	19.5	12.32	20.71429	522	644
Dallas, TX	176	8688	6	108	48.07	45	20.35	49.36364	5033	8344
Del Rio, TX	182	838	1	21	4.60	4	3.20	4.604396	16	43
Denver, CO	147	1978	1	44	13.46	13	6.25	13.45578	5447	7467
Detroit, MI	215	13815	3	175	63.53	58	36.83	64.25581	2058	4372
Douglas, AZ	207	1402	1	34	6.74	6	4.67	6.772947	13	24
Eagle Pass, TX	198	1375	1	29	6.91	7	4.26	6.944444	18	22
El Paso, TX	203	5895	1	122	28.90	28	13.53	29.03941	473	671
Ferndale, WA	91	398	1	25	4.37	2	4.90	4.373626	547	855
Fort Lauderdale, FL	203	6822	1	109	33.61	33	15.67	33.60591	2763	4430
Freeport, TX	89	909	1	26	9.80	9	5.56	10.21348	131	241
Houston, TX	185	11999	7	141	62.86	63	27.32	64.85946	5253	7978
International Falls, MN	128	303	1	10	2.37	2	1.66	2.367188	5	9
Kankakee, IL	163	733	1	15	4.36	3	3.01	4.496933	134	270
Laredo, TX	215	3297	2	55	15.33	14	7.28	15.33488	99	146
Las Vegas, NV	215	13987	7	212	63.83	64	21.04	65.05581	2274	3646
Lexington, KY	184	5615	2	65	29.27	30	13.61	30.5163	756	936
Long Beach, CA	140	7560	1	142	54.00	46	37.64	54	646	1119
Los Angeles, CA	145	6041	1	114	41.65	45	24.80	41.66207	3307	4572
Lynden, WA	110	666	1	26	6.05	4.5	5.50	6.054545	374	523
McAllen, TX	214	28117	8	289	129.61	122.5	55.14	131.3879	417	478
Miami, FL	202	15359	2	184	75.66	73	28.29	76.03465	1840	3102
Minneapolis, MN	210	7568	1	107	36.04	34	23.12	36.0381	2946	4195
Naco, AZ	175	617	1	13	3.51	3	2.64	3.525714	34	64

New Orleans, LA	191	8344	1	226	43.62	47	30.43	43.68586	684	801
New York, NY	211	7377	2	124	34.96	27	27.24	34.96209	3421	4873
Nogales, AZ	186	1159	1	27	6.23	6	4.09	6.231183	14	31
Orlando, FL	146	12515	6	246	84.86	89	43.73	85.71918	3324	5311
Philadelphia, PA	215	27726	9	697	128.36	121	65.83	128.9581	4617	6900
Phoenix, AZ	189	13053	3	344	68.70	55	49.45	69.06349	4507	7970
Playas, NM	1	1	1	1	1.00	1	0.00	1	14	27
Portland, OR	214	10354	4	106	48.38	52	23.72	48.38318	3252	5302
Presidio, TX	159	458	1	21	2.88	2	2.54	2.880503	2	9
Sacramento, CA	68	242	1	10	3.56	3	2.19	3.558824	1443	2002
San Diego, CA	215	14755	2	158	68.31	68.5	24.39	68.62791	3627	5787
San Francisco, CA	212	10975	1	161	51.53	51	22.46	51.76887	4961	5066
SeaTac, WA	168	1744	1	40	10.37	9.5	7.07	10.38095	1128	2081
Seattle, WA	213	4805	1	63	20.83	19	13.75	22.55869	1212	1749
Slidell, LA	186	3659	1	59	18.91	18	10.13	19.67204	384	491
Springfield, OH	1	4	4	4	4.00	4	0.00	4	182	296
Staten Island, NY	10	31	1	5	2.60	2	1.62	3.1	491	1184
Tampa, FL	11	468	3	70	42.55	48	19.67	42.54545	3791	5688
Texas City, TX	185	16258	4	298	86.27	82	49.90	87.88108	1191	1803
Washington, DC	215	4301	2	62	19.60	17	11.66	20.00465	6809	9279
Waukegan, IL	137	7450	2	125	51.99	52	28.41	54.37956	1943	3717
West Palm Beach, FL	186	16437	1	256	85.78	86	37.45	88.37097	1776	2593
Woodville, MS	5	6	1	2	1.20	1	0.40	1.2	26	38
Youngstown, OH	34	83	1	7	2.44	2	1.46	2.441176	433	1051
Yuma, AZ	214	3218	1	47	15.04	13	7.28	15.03738	179	270

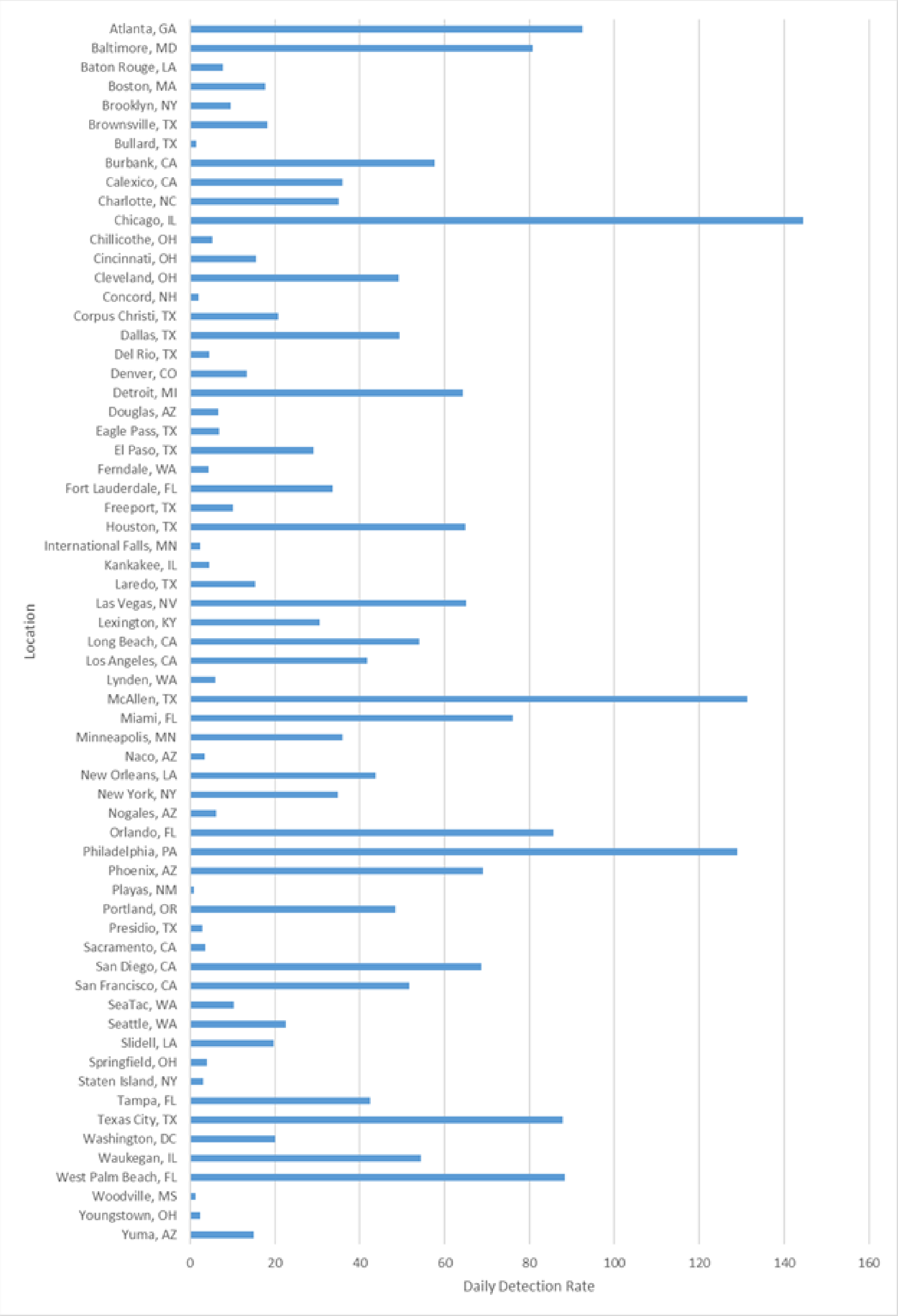


Figure 10. Average Daily Detection Rate by Location.

Conclusions: Examination of further data, in combination with additional investigation of potential influencing factors, as well as the findings and details in the following sections, may provide further insight, evidence, or details to address the following: 1) Why some locations, especially those with a low resident population, have relatively high utilization rates; 2) Who is using sUAS in such areas; 3) What further factors should be examined to understand how/why use is higher in the noted municipalities, compared to other locations with high resident populations values, such as Los Angeles (41.66 daily detection rate: 3,849,297 population; 1:92,393.32 ratio); New York (34.96 daily detection rate: 8,467,513 population; 1:242,191.30 ratio), and San Diego (68.63 daily detection rate: 1,381,611 resident population; 1:20,131.91 ratio); 4) If there is a discernible connection with peak utilization of UASFM grids for these areas (per Task B.1.1 *Airspace Use findings*) and a higher population use ratio; and 5) Any observable/ discernible relationships between use and registration rate (Task B.2 *What are estimated registration rates for sUAS?*). Further details and subsequent conclusions regarding airspace use will be presented in future iterations of this report, as additional data, contextual observations, and analysis results become available.

Future Research Recommendations: For future related research efforts it may be beneficial to conduct additional data collection, analysis, and investigation of topics, attributes, and research questions highlighted here and in the subsections that follow. Future iterations of this report may include additional recommendations concerning the collection, isolation, or further investigation of relevant details, based upon observation, analysis, or inferences drawn from contextual examination of materials. Such recommendations are intended to support the definition and development of future related research efforts that are beyond the scope of this project.

The following subsections represent investigated characteristics associated with current sUAS traffic over urban areas, including airspace use, number of operations, operational model distribution and use, flight timing, active vs inactive populations, flight altitudes, flight durations, and proximity to airports. The coverage of each attribute features a contextual introduction, discussion of findings, presentation of related figures and tables, and concluding remarks identifying applicable trends, implications, and other important details.

2.2.1.1 Task B.1.1 Airspace Use

The research team compared sUAS operating location and telemetry of each sUAS flight to evaluate airspace use. This tabulation represented the calculated number of *airspace touches*, with entries into separate classes of airspace counted only once per flight. The material is organized and presented in terms of uncontrolled (Class G) and controlled (Class B, C, D, and [Surface] Class E) airspace use; it does not specifically identify or classify operations that may have occurred within include Class A, special use, or other airspace areas (e.g., military training routes, those areas encompassed in a temporary flight restriction or national security area).

Findings: Class G airspace represented the most extensive use observed, accounting for 70% of all airspace uses. Other airspace used included (in descending order of observed use): Class B (14%), Class D (10%), Class C (6%) and Surface Class E (<1%) as shown in Figure 11. Individual airport airspace utilization metrics can be seen in Figure 12.

The research team did not have access to LAANC approval data. To estimate LAANC utilization, sUAS flights telemetries were assessed in a similar manner as airspace touches. A count was logged each time a sUAS flight entered a new UAS Facility Map grid. Flight altitudes were compared to each grid ceiling to assess if the entry was compliant with altitude limitations. Total utilization of UASFM grids within the sample area culminated in 358,826, with 71.2% of flights occurring below UASFM grid ceilings and 28.8% occurring above UASFM maximum ceilings, shown in Figure 13. The preponderance of UASFM utilization occurred in 400-foot grids, accounting for 43.6% of all UASFM uses. Exceedance rates tended to increase at low ceiling levels, peaking in 0-foot grids with a 49.2% exceedance rate. It is important to note that operators *can* receive permission to operate above UASFM ceilings by initially filing an automated LAANC airspace approval request and coordinating with air traffic control to receive a manual LAANC approval for operation above the respective grid ceiling. Peak utilization of UASFM grids within the sample set was found at Miami International Airport [MIA] (*n*=19,821), McAllen International Airport [MFE] (*n*=19,044), McCarran International Airport [LAS] (*n*=17,188) and Philadelphia International Airport [PHL] (*n*=16,040) as shown in Figure 14.

The data indicates controlled airspace use, in terms of the number of detected sUAS flights. For Class B, there were a total of 79,106 airspace touches, representing 13.94% of the total. The average number of UAS flights detected for this class was 1,521.27; the top three use locations were: Miami, FL (11,720 airspace touches; 2.07% of total flight detections); Las Vegas, NV (10,895; 1.92%); and Philadelphia, PA (8,596; 1.52%). For Class C, there were a total of 30,776 airspace touches, representing 5.42% of the total. The average number of flight detections for this class was 591.85; the top three use locations were: Burbank, CA (8,158; 1.44%); West Palm Beach, FL (7,668; 1.35%); and Fort Lauderdale, FL (6,029; 1.06%). For Class D, there were a total of 57,897 airspace touches, representing 10.21% of the total. The average number of flight detections for this class was 1,113.40; the top three use locations were: McAllen, TX (9,473; 1.67%); Calexico, CA (6,115; 1.08%); and Detroit, MI (5,536; .98%). Finally, for Class E, there were a total of 2,070 airspace touches, representing .36% of the total. The average number of flight detections for this class was 39.81; the top three use locations were: Laredo, TX (1,320; .23%); Texas City, TX (392; .07%); and International Falls, MN (238; .04%).

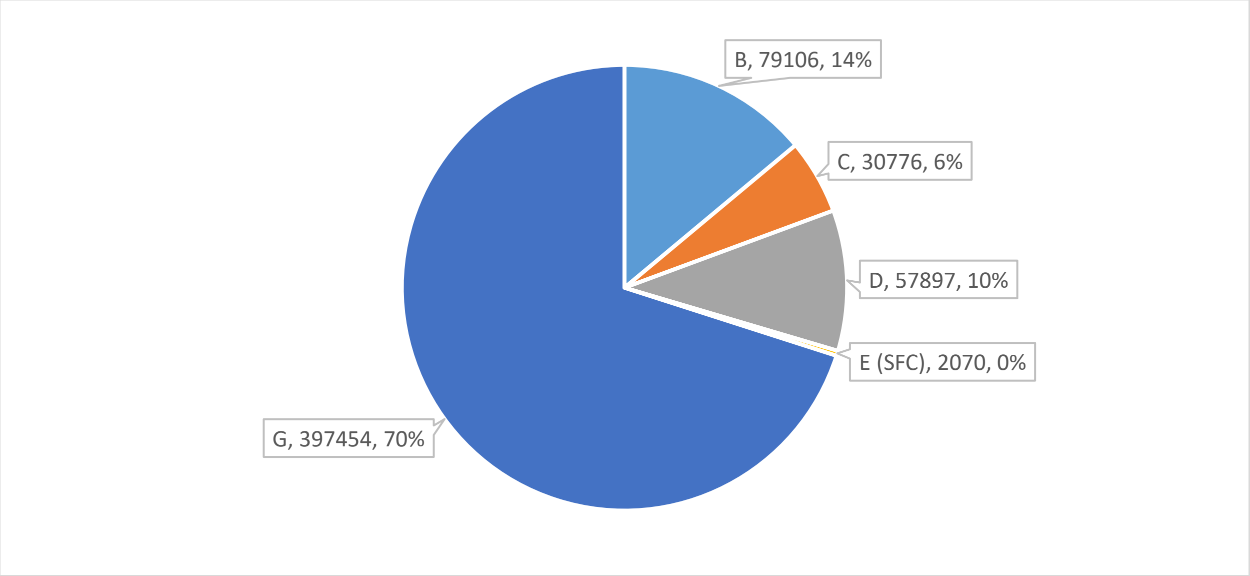


Figure 11. Airspace Touches by Class (*N*=567,303).

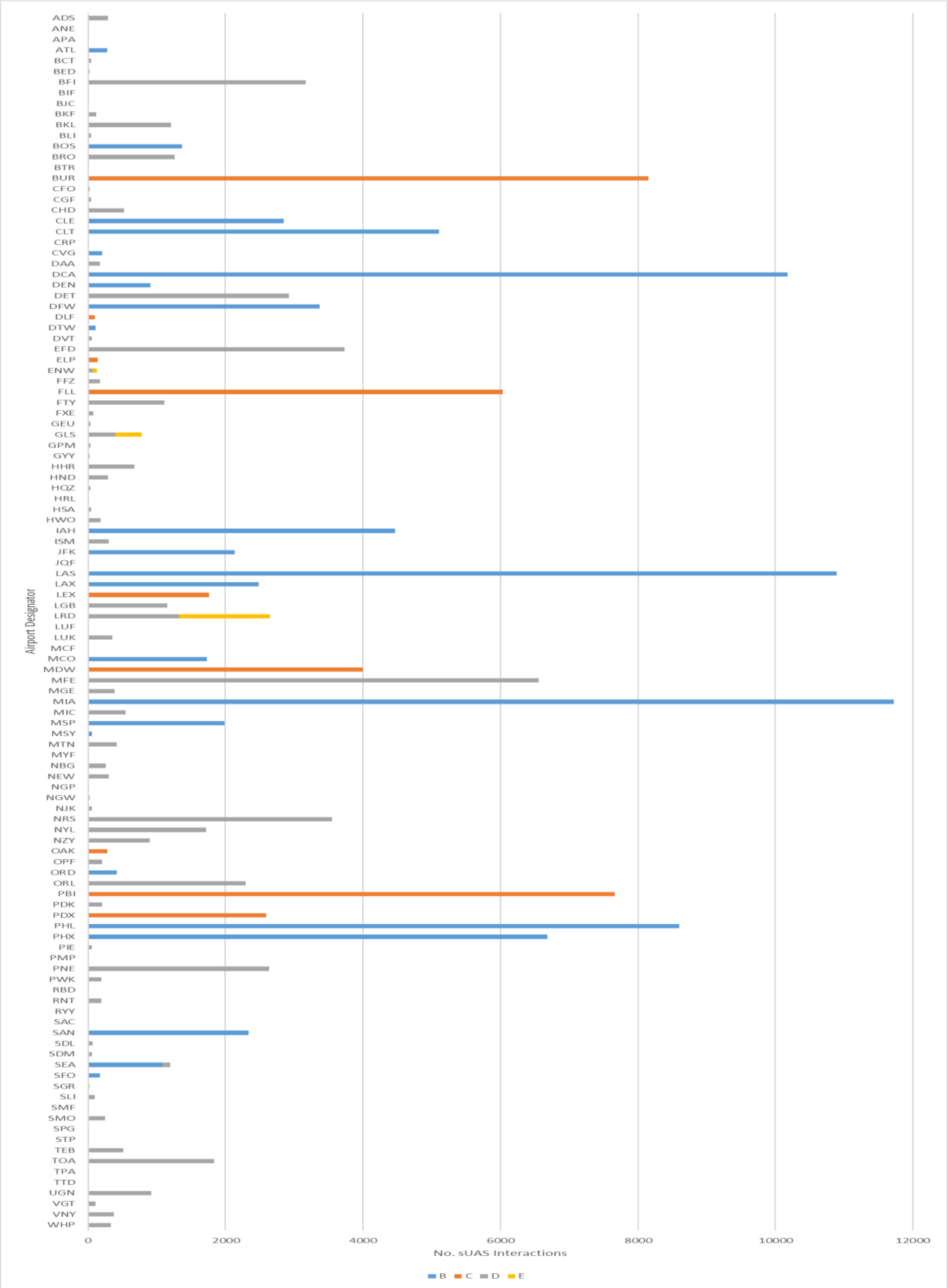


Figure 12. Distribution of sUAS Activity within Classes of Airspace by Airport Designator (Excludes Class G, E)(*N*=156,822).

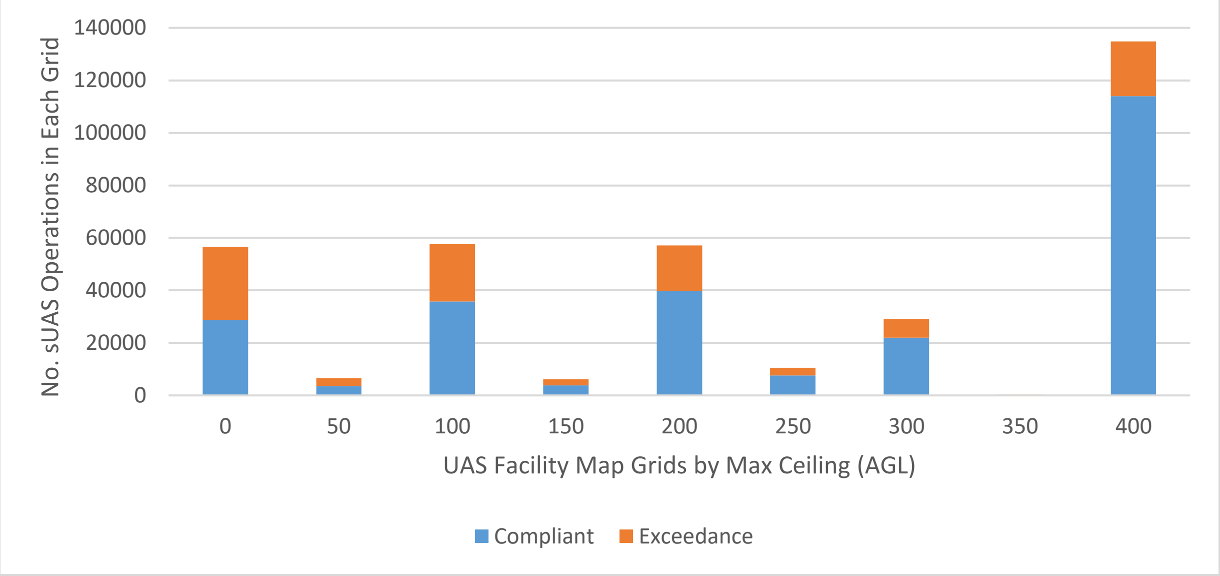


Figure 13. Cumulative UAS Facility Map Activity by Grid Maximum Altitude (*N*=358,826).

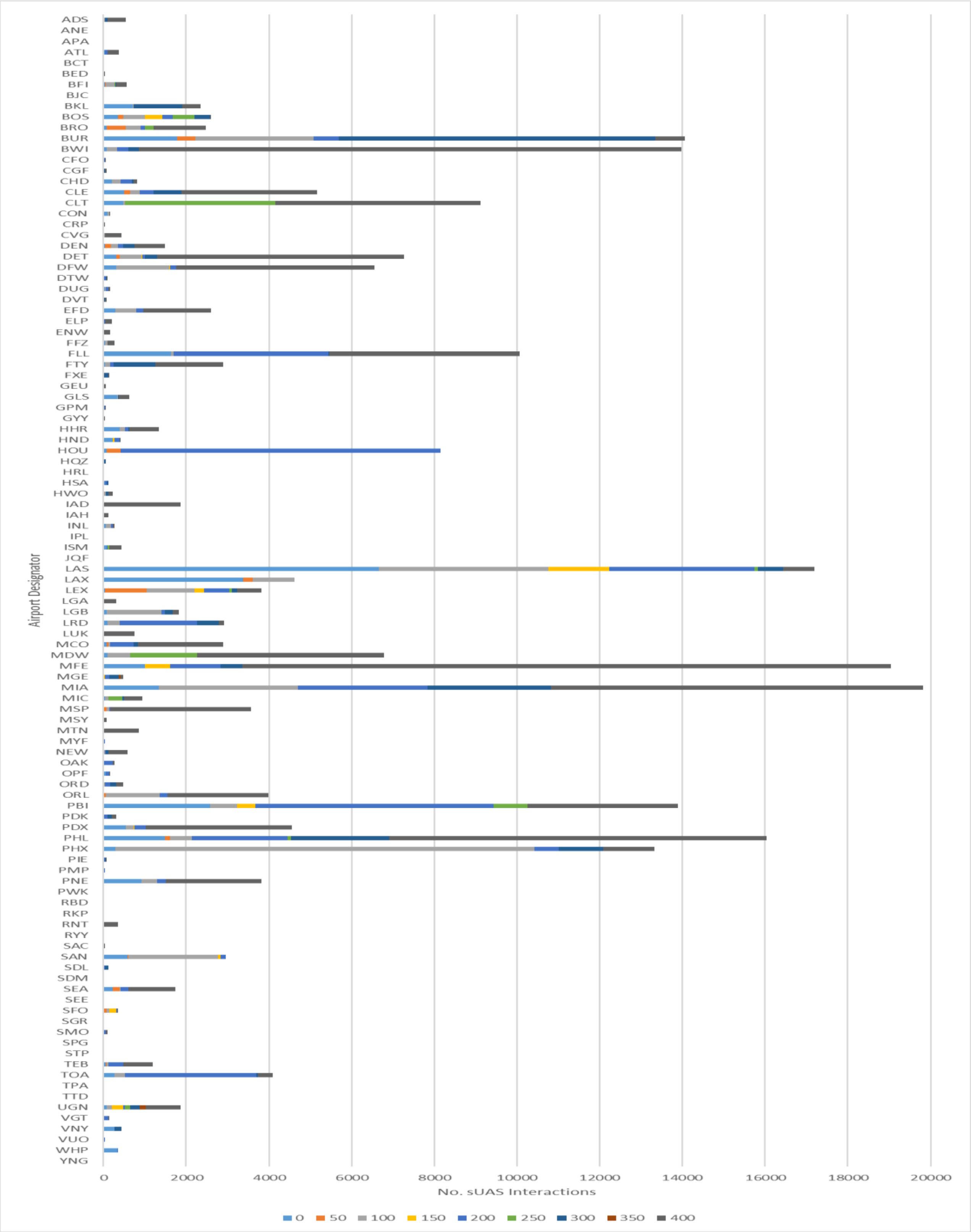


Figure 14. UAS Facility Map Activity by Airport Designator and Grid Maximum Altitude (N=255,531).

Conclusions: The total number of observed UAS flights occurring in Class G (uncontrolled) airspace equaled 393,545 (30.1%), while those in controlled airspace were 169,849 (29.9% of observed flights); any observed operations in controlled airspace may have been conducted under an approved waiver and airspace authorization.

The FAA (2022a), reports that as of 2022 LAANC covers 732 airports and there have been more than 1 million LAANC airspace requests submitted through the UAS Data Exchange. The disposition of these requests include 545,074 Part 107 requests that were automatically approved; 352,775 49 CFR §44809 [Recreational] requests that were automatically approved; and, 102,837 that were submitted for further coordination. According to FAA (2022a) airspace waiver or authorization submission data: 16.7% (*n* = 26,471) are requested for Class B airspace; 18.0% are requested for Class C airspace; 54.3% (*n* = 86,238) are requested for Class D airspace; and, 11.0% (*n* =17,529) are requested for Class E airspace.

Additional analysis, including comparing the sampled data against known population values, may yield additional insight to help inform future recommendations, as well as subsequent analysis for this and other sUAS traffic attributes. To date, the sampled data represents less than 20% of the total planned sampling period (seven of 36-months). Further details and subsequent conclusions regarding airspace use will be presented in future iterations of this report, as additional data, contextual observations, and analysis results become available.

Future Research Recommendations: For future related research efforts it may be beneficial to compare and contrast observed airspace touches to filed and approved LAANC authorizations (if available to investigator). Such comparisons may support identification of permissible use versus potential violation. Future versions of this report may include additional recommendations concerning the collection, isolation, or further investigation of relevant details, based upon observation, analysis, or inferences drawn from contextual examination of materials. Such recommendations are intended to support the definition and development of future related research efforts that are beyond the scope of this project.

2.2.1.2 Task B.1.2 Number of Operations

A cumulative census of national sUAS activity from all sampled locations is included, with descriptive statistics. A census of all sUAS activity, presented for each sample area, is also included. Traffic counts are based on the UAS detection equipment's Flight Identification Number (FIN). A FIN is recorded each time a new flight operation is detected. A single sUAS flight may be re-issued a FIN in the event a sUAS loses line of sight with the UAS detection sensor. This may result in a small number of flight duplications being recorded by the sensor, which the research team considers to be an acceptable limitation for this study. The number of operations will be furnished on a daily basis for each sample location (see appendix). The research team will highlight days of the year in which flight activity was abnormally high. *Abnormally high flight activity* was defined as any day that exceeded the mean daily flight activity for the respective month plus one standard deviation. An online calendar program called WinCalendar was used to identify nationally-significant holidays or dates of interest (Sapro Systems, 2022).

Findings: As previously indicated, a total of 470,902 sUAS flights were recorded from among a sUAS population of 116,915. Figure 15 highlights daily sUAS flight detections throughout the sampling period. Clear daily peaks and troughs are visible in the resultant data depiction shown in Figure 15. Descriptive statistics for cumulative monthly sUAS activity are provided in Figure 16 and Table 5. Both mean and median values indicate an almost 20% higher monthly flight activity for August and September, compared to remainder of the sampling period. It is unclear to the research team why national sUAS flight activity in July was diminished, compared to earlier observed trends. This finding does not align with previous studies conducted at DFW, which clearly shows flight activity peaking in the mid-summer months of June and July, shown in Figure 17. Nationwide flight activity in October through January continues to show relative consistency.

An assessment of high activity days was conducted by identifying outlying activity levels that were above at least one standard deviation of the mean for each calendar month. These results closely align with regional findings conducted at DFW, which indicate certain holidays yielded higher sUAS flight activity. Most prominent in the dataset, was July 4 (Independence Day) with 4,905 sUAS flights, which was nearly five standard deviations from the monthly mean. Other abnormally high activity days included December 31 (New Year's Eve; *SD*=3.3), Oct 2 (no known holiday; *SD*=2.9), November 6 (end of daylight savings time; *SD*=2.9), and December 25 (Christmas Day; *SD*=2.5). Additional results are presented in Table 6.

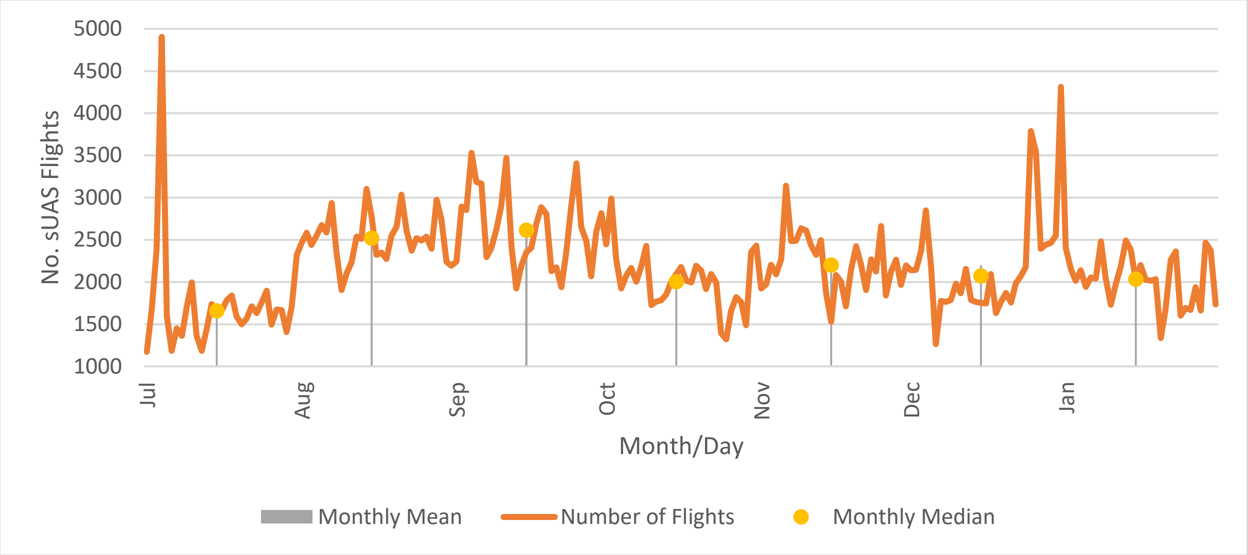


Figure 15. UAS Activity by Day (Nationwide)(*N*=470,902).

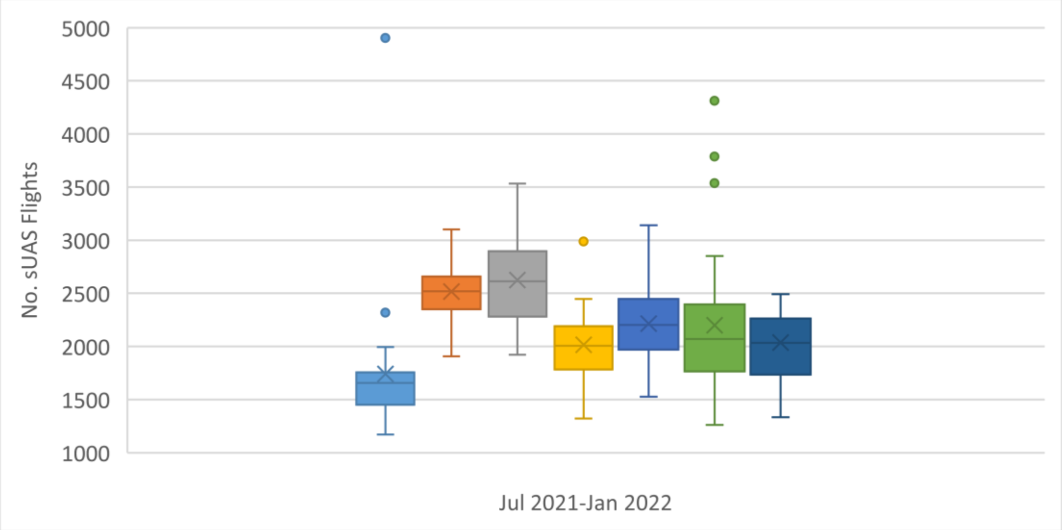


Figure 16. sUAS Flight Activity by Month (Quartiles)(N=470,902).

Table 5. sUAS Flight Activity by Month (N=470,902).

	Jul	Aug	Sep	Oct	Nov	Dec	Jan
Mean	1741	2516	2626	2015	2213	2199	2036
SD	638.2662	265.3235	434.6477	332.0706	322.1881	641.6235	290.1355
Max	4905	3101	3533	2988	3141	4312	2492
Q3	1747.5	2633.5	2891.25	2183.5	2432	2383	2231.5
Median (Q2)	1657	2520	2612.5	2005	2202	2071	2033
Q1	1473	2352.5	2309.5	1801.5	1981.25	1769.5	1836.5
Min	1172	1906	1922	1321	1528	1262	1335

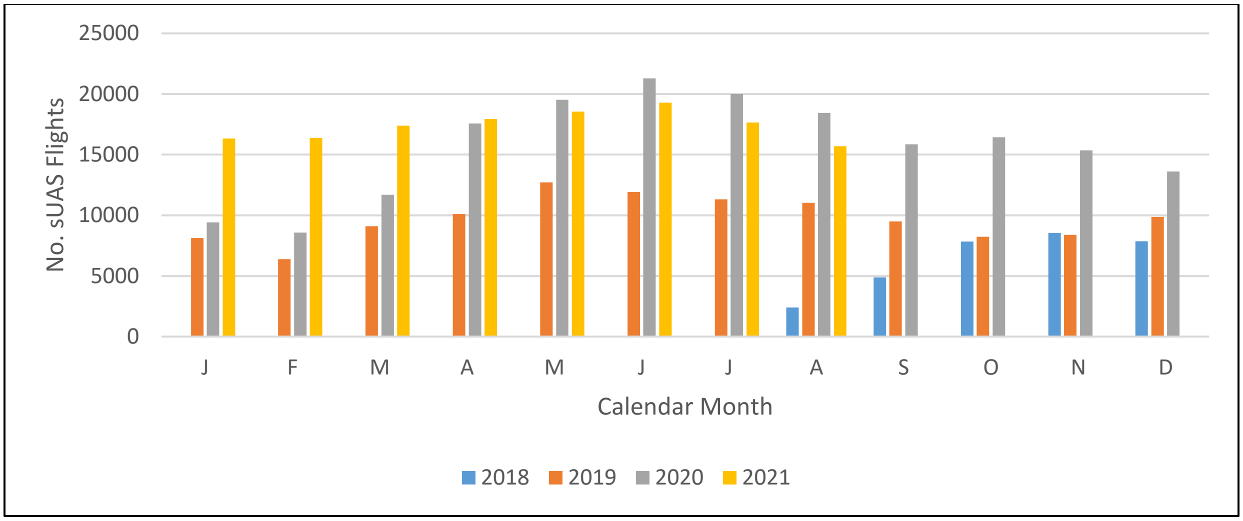


Figure 17. sUAS Flight Activity by Month at DFW Airport (Aug 2018-Aug 2021)(N=475,257).

Table 6. Abnormally High sUAS Activity (N=470,902).

Date	Total Flights	No. SD > Mean	Day of Week	Holiday
3-Jul-21	2393	1.020910899	Saturday	Day before Independence Day
4-Jul-21	4905	4.956572954	Sunday	Independence Day
7-Aug-21	2935	1.578839745	Saturday	
14-Aug-21	3101	2.204491165	Saturday	
21-Aug-21	3034	1.951969206	Saturday	
28-Aug-21	2975	1.729599124	Saturday	
4-Sep-21	3533	2.08720762	Saturday	Labor Day Weekend
5-Sep-21	3188	1.293461336	Sunday	Labor Day Weekend
6-Sep-21	3167	1.245146345	Monday	Labor Day
11-Sep-21	3470	1.942262646	Saturday	Patriot Day (Sep 11)
25-Sep-21	3407	1.797317673	Saturday	
1-Oct-21	2446	1.297236766	Friday	
2-Oct-21	2988	2.929419794	Saturday	Mahatma Ghandi's Birthday
9-Oct-21	2427	1.240020018	Saturday	
30-Oct-21	2357	1.029221472	Saturday	Day before Halloween
31-Oct-21	2432	1.255077057	Sunday	Halloween
6-Nov-21	3141	2.879580701	Saturday	End of Daylight Savings
9-Nov-21	2637	1.315277169	Tuesday	
10-Nov-21	2609	1.228371418	Wednesday	
25-Nov-21	2662	1.392871591	Thursday	Thanksgiving
4-Dec-21	2850	1.014814762	Saturday	
25-Dec-21	3788	2.476731216	Saturday	Christmas Day
26-Dec-21	3538	2.087094635	Sunday	Day after Christmas Day
31-Dec-21	4312	3.293409492	Friday	New Years Eve
1-Jan-22	2404	1.26881746	Saturday	New Years Day
8-Jan-22	2481	1.534210667	Saturday	
13-Jan-22	2492	1.572123982	Thursday	
14-Jan-22	2388	1.21367082	Friday	
23-Jan-22	2365	1.134397524	Sunday	
29-Jan-22	2467	1.485957357	Saturday	
30-Jan-22	2375	1.168864174	Sunday	

Note: Abnormally high activity assessed as outlier values exceeding 1 SD from the mean.

Conclusions: Due to the short duration of the initial sampling, the research team is unable to draw any firm conclusions about seasonality impacts on sUAS activity at this time. Further details and subsequent conclusions regarding sUAS activity, based on seasonality and annual trends, will be presented in future iterations of this report, as additional data, contextual observations, and analysis results become available.

Seasonal influence on sUAS operations and associated attributes is also being investigated in Task B.1.4 Time of Operations; Task B.1.5 Active vs. Inactive sUAS Population; and Task C.2 What are exceedance rates for Daylight Operation [14 CFR §107.29]?). The observations, findings, and conclusions associated with these research efforts may offer additional insight to this task, specifically factors that may influence the number of operations, such as seasonal dawn/dusk and changes due to geographic location (e.g., latitudinal positioning).

Future Research Recommendations: For future related research efforts it may be beneficial to isolate and examine operational trends associated with specific geographic regions in consideration of the potential effects of environmental factors (e.g., seasonal precipitation, temperature, visibility changes, and available light levels). Investigation of such details may support identification of further trends and lead to an increased understanding of factors contributing to annual, monthly, and daily operational use totals. Future versions of this report may include additional recommendations concerning the collection, isolation, or further investigation of relevant details, based upon observation, analysis, or inferences drawn from contextual examination of materials. Such recommendations are intended to support the definition and development of future related research efforts that are beyond the scope of this project.

2.2.1.3 Task B.1.3 Distribution of sUAS Flights by Model Over Time

An assessment of different DJI models flown over the sample period was conducted. Models were categorized into like classifications to simplify analysis and interpretation. Every flight assigned a unique FIN is counted as an operation under its respective model category. For monthly platform utilization, unique platforms operated in separate months are counted separately (i.e., a unique platform operated in both the months of June and July is counted under its respective platform category in both months).

Findings: An analysis of the sUAS model population from detection data revealed the following categorical composition, in order from largest to smallest population segments as shown in Figure 18: Mavic Mini 2 (*n*=36,254, 31.0% of the sample population); Mavic Air 2 (*n*=19,999, 17.1%); Mavic 2 (*n*=16,673, 14.3%); Other (*n*=12,718 10.9%); Mavic Mini (*n*=12,562, 10.7%); FPV (*n*=5,501, 4.7%); Air 2S (*n*=4,860, 4.2%); Mavic Pro (*n*=4,120, 3.5%); Mavic Air 2S (*n*=2,306, 2.0%); and unknown (*n*=1,922, 1.6%). The data indicates that the current population is primarily made up of more modern DJI platforms, with far fewer legacy system (such as the Phantom or Inspire) product lines. Collectively, commercial-grade (i.e., “prosumer”) DJI platforms (e.g., Matrice-series) collectively made up less than .1% of the population.

Monthly platform utilization information can be seen in Figure 19. Monthly platform use showed an uptick in August and September, plateauing in the remainder of the sampling period. The research team noted an approximate 5% drop in the monthly platform utilization of the Mavic 2 Enterprise platforms in the final two months of the sampling period. Release of the Mavic 3 in November 2021 shows strong initial utilization, which may displace utilization from legacy platforms. The Mavic Mini 2 shows additional growth, with a similar downtrend in use of the

Mavic Mini series. This is potentially indicative that consumers are upgrading their legacy Mavic Mini platform for the newer model Mini 2 (i.e., abandonment in favor of a more recent design). Mavic Air models also show recent diminishing platform activity, but without the accompanying increase in platform activity for the newer Mavic Air 2 model. The FPV drone shows a nearly 50% growth in platform use, but still represents a relatively small proportion of the overall detected sUAS population (5% of total population) as seen in see Figure 20. Monthly flight activity seems to closely reflect the pattern of unique monthly platform use, shown in Figure 21. The proportionality of the number of flights by model category is also closely aligned with the monthly platform utilization as shown in Figure 22.

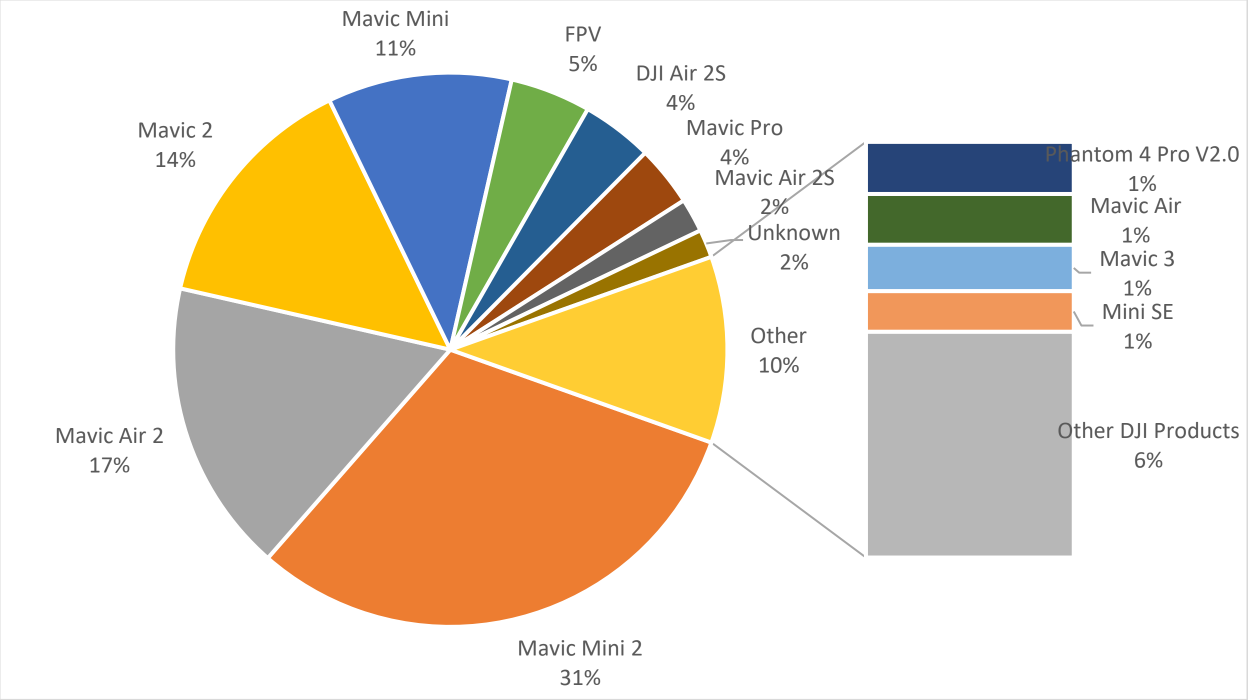
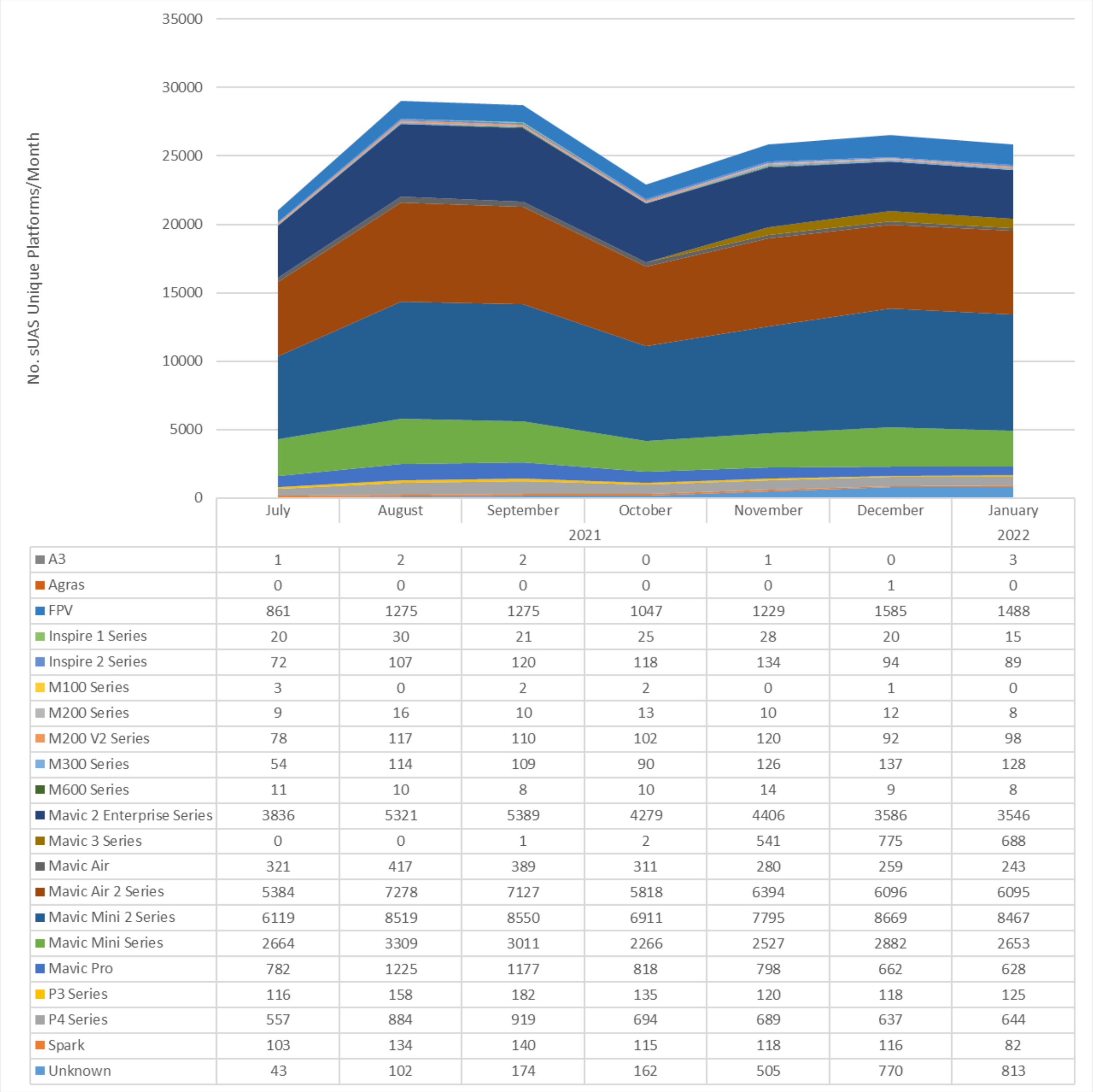
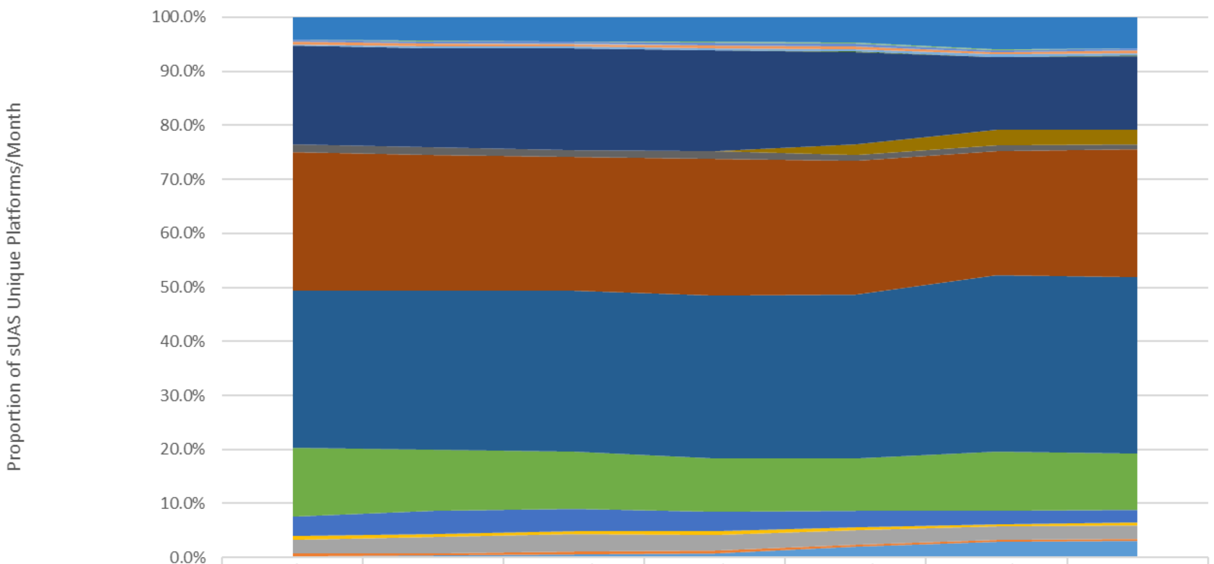


Figure 18. UAS Population by sUAS Type (*N*=116,915).



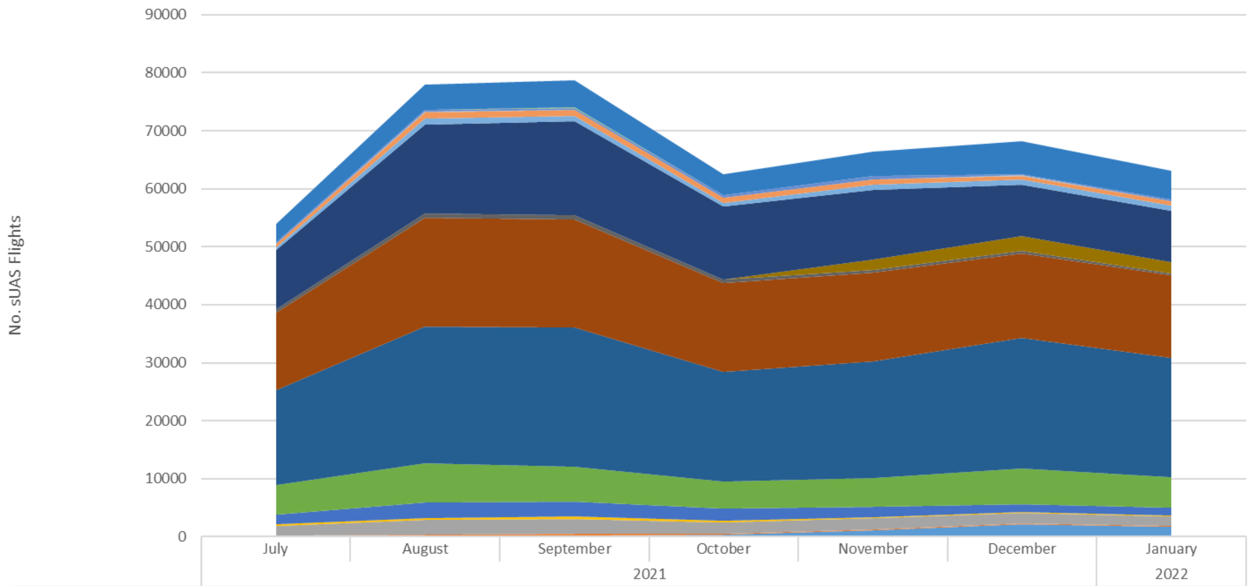
	July	August	September	October	November	December	January
■ A3	1	2	2	0	1	0	3
■ Agras	0	0	0	0	0	1	0
■ FPV	861	1275	1275	1047	1229	1585	1488
■ Inspire 1 Series	20	30	21	25	28	20	15
■ Inspire 2 Series	72	107	120	118	134	94	89
■ M100 Series	3	0	2	2	0	1	0
■ M200 Series	9	16	10	13	10	12	8
■ M200 V2 Series	78	117	110	102	120	92	98
■ M300 Series	54	114	109	90	126	137	128
■ M600 Series	11	10	8	10	14	9	8
■ Mavic 2 Enterprise Series	3836	5321	5389	4279	4406	3586	3546
■ Mavic 3 Series	0	0	1	2	541	775	688
■ Mavic Air	321	417	389	311	280	259	243
■ Mavic Air 2 Series	5384	7278	7127	5818	6394	6096	6095
■ Mavic Mini 2 Series	6119	8519	8550	6911	7795	8669	8467
■ Mavic Mini Series	2664	3309	3011	2266	2527	2882	2653
■ Mavic Pro	782	1225	1177	818	798	662	628
■ P3 Series	116	158	182	135	120	118	125
■ P4 Series	557	884	919	694	689	637	644
■ Spark	103	134	140	115	118	116	82
■ Unknown	43	102	174	162	505	770	813

Figure 19. Number of Unique sUAS Serial Numbers per Month by sUAS Model Category (*N*=116,915).



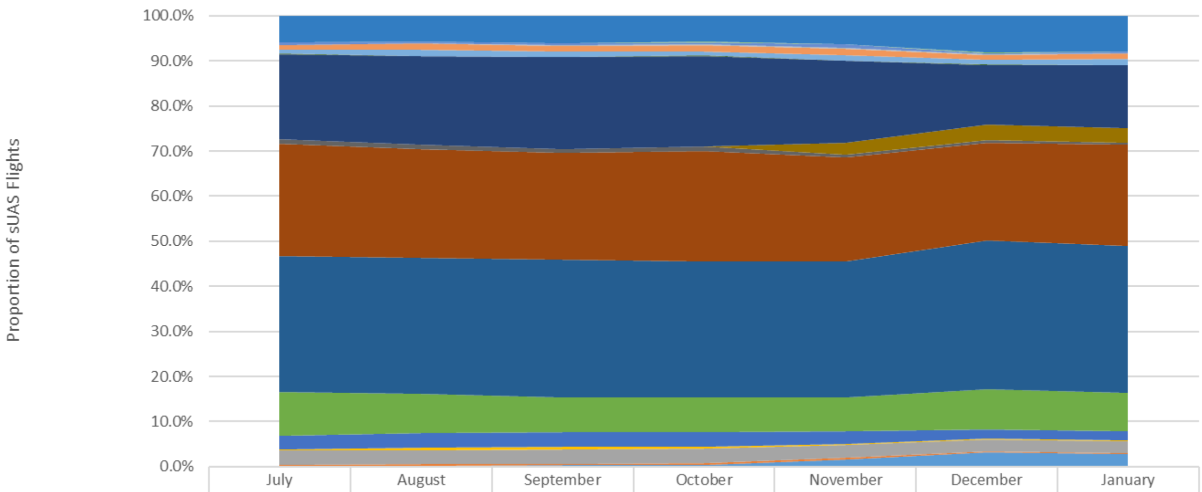
	July	August	September	October	November	December	January
	2021						2022
■ A3	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
■ Agras	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
■ FPV	4.1%	4.4%	4.4%	4.6%	4.8%	6.0%	5.8%
■ Inspire 1 Series	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
■ Inspire 2 Series	0.3%	0.4%	0.4%	0.5%	0.5%	0.4%	0.3%
■ M100 Series	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
■ M200 Series	0.0%	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%
■ M200 V2 Series	0.4%	0.4%	0.4%	0.4%	0.5%	0.3%	0.4%
■ M300 Series	0.3%	0.4%	0.4%	0.4%	0.5%	0.5%	0.5%
■ M600 Series	0.1%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%
■ Mavic 2 Enterprise Series	18.2%	18.3%	18.8%	18.7%	17.1%	13.5%	13.7%
■ Mavic 3 Series	0.0%	0.0%	0.0%	0.0%	2.1%	2.9%	2.7%
■ Mavic Air	1.5%	1.4%	1.4%	1.4%	1.1%	1.0%	0.9%
■ Mavic Air 2 Series	25.6%	25.1%	24.8%	25.4%	24.7%	23.0%	23.6%
■ Mavic Mini 2 Series	29.1%	29.4%	29.8%	30.2%	30.2%	32.7%	32.8%
■ Mavic Mini Series	12.7%	11.4%	10.5%	9.9%	9.8%	10.9%	10.3%
■ Mavic Pro	3.7%	4.2%	4.1%	3.6%	3.1%	2.5%	2.4%
■ P3 Series	0.6%	0.5%	0.6%	0.6%	0.5%	0.4%	0.5%
■ P4 Series	2.6%	3.0%	3.2%	3.0%	2.7%	2.4%	2.5%
■ Spark	0.5%	0.5%	0.5%	0.5%	0.5%	0.4%	0.3%
■ Unknown	0.2%	0.4%	0.6%	0.7%	2.0%	2.9%	3.1%

Figure 20. Proportion of Unique sUAS Serial Numbers per Month by sUAS Model Category (*N*=116,915).



	July	August	September	October	November	December	January
	2021						2022
■ A3	7	3	5	0	1	0	18
■ Agras	0	0	0	0	0	1	0
■ FPV	3170	4373	4764	3579	4166	5603	4984
■ Inspire 1 Series	39	62	53	64	65	47	26
■ Inspire 2 Series	247	292	379	335	557	230	230
■ M100 Series	11	0	3	2	0	1	0
■ M200 Series	26	35	23	59	60	25	25
■ M200 V2 Series	609	1176	1045	853	890	675	756
■ M300 Series	442	977	861	623	848	820	900
■ M600 Series	27	21	10	20	42	42	22
■ Mavic 2 Enterprise Series	10168	15335	16230	12613	12013	8941	8815
■ Mavic 3 Series	0	0	3	4	1742	2437	1996
■ Mavic Air	569	735	644	556	461	425	317
■ Mavic Air 2 Series	13434	18781	18628	15335	15278	14660	14133
■ Mavic Mini 2 Series	16326	23617	24101	18877	20137	22521	20621
■ Mavic Mini Series	5175	6705	6018	4743	4980	6069	5295
■ Mavic Pro	1639	2639	2570	2066	1760	1365	1248
■ P3 Series	193	370	382	277	233	226	219
■ P4 Series	1684	2498	2578	2004	1878	1783	1650
■ Spark	162	237	226	178	212	176	112
■ Unknown	55	143	251	284	1074	2118	1745

Figure 21. Number of sUAS Flights by Model Category Over Time (*N*=470,902).



	July	August	September	October	November	December	January
■ A3	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
■ Agras	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
■ FPV	5.9%	5.6%	6.0%	5.7%	6.3%	8.2%	7.9%
■ Inspire 1 Series	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.0%
■ Inspire 2 Series	0.5%	0.4%	0.5%	0.5%	0.8%	0.3%	0.4%
■ M100 Series	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
■ M200 Series	0.0%	0.0%	0.0%	0.1%	0.1%	0.0%	0.0%
■ M200 V2 Series	1.1%	1.5%	1.3%	1.4%	1.3%	1.0%	1.2%
■ M300 Series	0.8%	1.3%	1.1%	1.0%	1.3%	1.2%	1.4%
■ M600 Series	0.1%	0.0%	0.0%	0.0%	0.1%	0.1%	0.0%
■ Mavic 2 Enterprise Series	18.8%	19.7%	20.6%	20.2%	18.1%	13.1%	14.0%
■ Mavic 3 Series	0.0%	0.0%	0.0%	0.0%	2.6%	3.6%	3.2%
■ Mavic Air	1.1%	0.9%	0.8%	0.9%	0.7%	0.6%	0.5%
■ Mavic Air 2 Series	24.9%	24.1%	23.6%	24.5%	23.0%	21.5%	22.4%
■ Mavic Mini 2 Series	30.2%	30.3%	30.6%	30.2%	30.3%	33.0%	32.7%
■ Mavic Mini Series	9.6%	8.6%	7.6%	7.6%	7.5%	8.9%	8.4%
■ Mavic Pro	3.0%	3.4%	3.3%	3.3%	2.7%	2.0%	2.0%
■ P3 Series	0.4%	0.5%	0.5%	0.4%	0.4%	0.3%	0.3%
■ P4 Series	3.1%	3.2%	3.3%	3.2%	2.8%	2.6%	2.6%
■ Spark	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.2%
■ Unknown	0.1%	0.2%	0.3%	0.5%	1.6%	3.1%	2.8%

Figure 22. Proportion of sUAS Flights by Model Category (*N*=470,902).

Table 7. Correlation Between Unique Monthly Platforms & Total sUAS Flights (N=470,902).

Model Category	***r***	**Unique Monthly Platforms**	**Flights**	**Intensity**
A3		9	34	3.778
Agras		1	1	1.000
FPV		8760	30639	3.498
Inspire 1 Series		159	356	2.239
Inspire 2 Series		734	2270	3.093
M100 Series		8	17	2.125
M200 Series		78	253	3.244
M200 V2 Series		717	6004	8.374
M300 Series		758	5471	7.218
M600 Series		70	184	2.629
Mavic 2 Enterprise		30363	84115	2.770
Mavic 3 Series		2007	6182	3.080
Mavic Air		2220	3707	1.670
Mavic Air 2 Series		44192	110249	2.495
Mavic Mini 2 Series		55030	146200	2.657
Mavic Mini Series		19312	38985	2.019
Mavic Pro		6090	13287	2.182
P3 Series		954	1900	1.992
P4 Series		5024	14075	2.802
Spark		808	1303	1.613
Unknown		2569	5670	2.207
TOTAL (Cumulative)	**0.994**	**179863**	**470902**	**2.618**

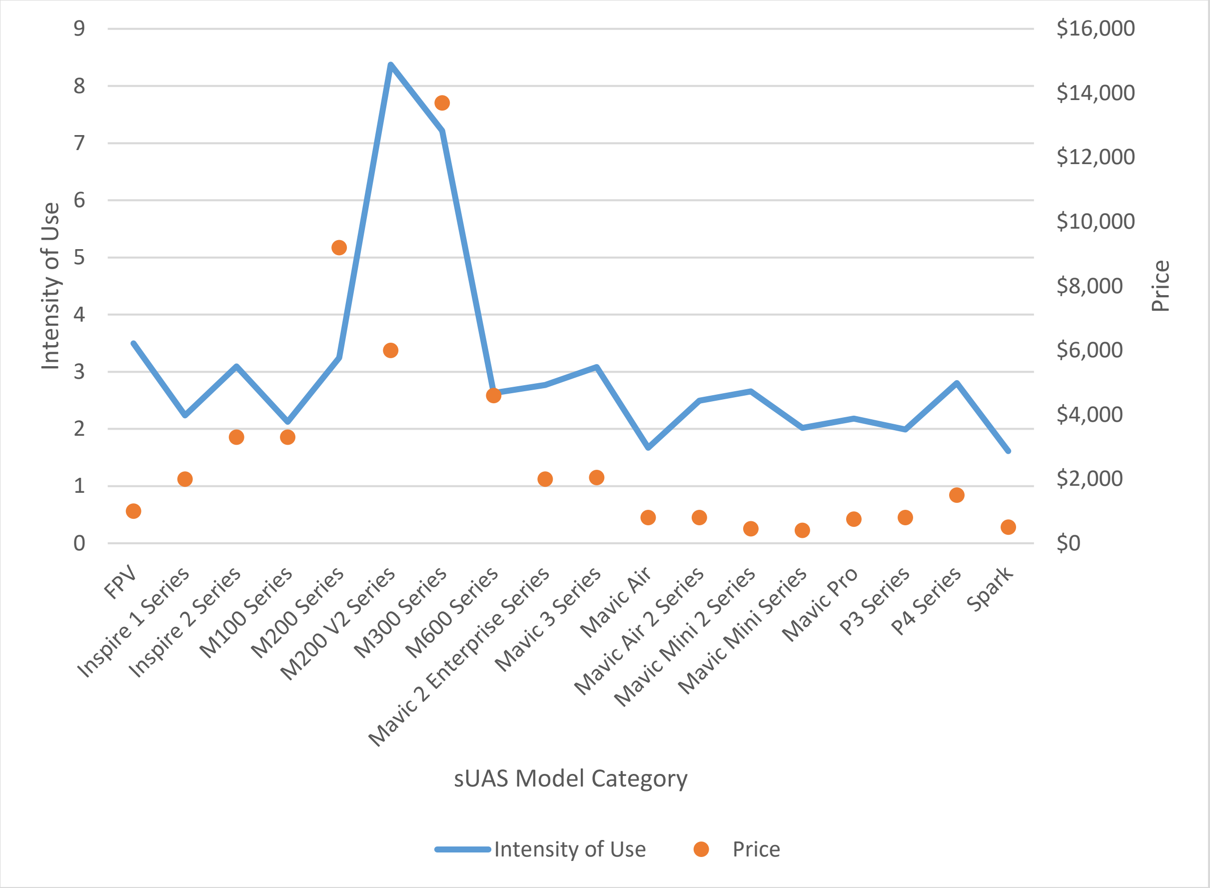


Figure 23. Intensity of Use to Price (N=470,902)

Conclusions: Initial indications suggest there is a relationship between the number of model platforms and the number of flights performed each month as shown in

Table 7. A Pearson's Correlation was performed on the monthly platform utilization data and monthly flights by platform, revealing a very strong correlation *r*(147) = .99. Additional analysis on this relationship will be conducted as additional data becomes available.

There are also several notable observations connected to consumer behavior that may help inform future trending analysis. First, users appear to be replacing their legacy Mavic Mini platforms for the newer model Mini 2, which potentially represents abandonment in favor of an upgrade to a more recent design. Alternatively, Mavic Air models also show recent diminishing platform activity, but without the accompanying increase in platform activity for the newer Mavic Air 2 model. The recently introduced FPV platform shows a nearly 50% growth in platform use, but still represents a relatively small proportion of the overall detected sUAS population (5%) shown in Figure 19. The observed monthly flight activity seems to closely reflect the pattern of unique monthly platform use, as shown in Figure 21 with the proportionality of the number of flights by model category also closely aligning with monthly platform utilization, shown in Figure 19. Further details and subsequent conclusions regarding model use over time will be presented in future iterations of this report, as additional data, contextual observations, and analysis results become available.

Additional sections also featuring research of model classification include Task B.1.5 *Active vs. Inactive Population;* Task B.1.7 *Flight Durations;* Task B.3 *Where do sUAS fly and at what altitudes are they flying at?;* Task B.4 *Can rough estimates be made regarding sUAS retirement/abandonment rates?;* Task B.6 *What percentage of the detected sUAS population weighs less than 0.55 lbs and is not required to be registered?;* Task C.1 *What are exceedance rates for Operations from a moving vehicle [14 CFR §107.25]?;* and Task C.3 *What are exceedance rates for Visual Line of Sight Aircraft Operations [14 CFR §107.31]?).*

Future Research Recommendations: For future related research efforts the further investigation of associated users (e.g., public safety, aerial filming, and other categorical applications) and communities may help to identify how such models are being used within the NAS, including potential limitations and risks, to support future evaluation and consideration of operational use requests or waivers. Future versions of this report may include additional recommendations concerning the collection, isolation, or further investigation of relevant details, based upon observation, analysis, or inferences drawn from contextual examination of materials. Such recommendations are intended to support the definition and development of future related research efforts that are beyond the scope of this project.

2.2.1.4 Task B.1.4 Time of Operations

An aggregation of detected sUAS flight times was presented by day of week and local time of detection. A line graph is presented indicating the total number of flights during each day of the week and hour of the day. A heat chart indicates days and hours of aggregated peak flight activity, based on the proportion of sUAS activity relative to the cumulative total.

Findings: sUAS flight activity was noted to increase towards the end of the week, peaking midday on weekend days Friday, Saturday, and Sunday, as shown in Figure 24 and Table 8. Generally, flight activity on each day increased over the early morning until cresting during the late morning to early afternoon hours. This pattern was similar on weekend days, with slightly higher flight activity, as shown in Figure 25. Table 9 shows proportional flight activity during each day of the week and hour of the day (local time). From the initial data capture and analysis, the effects of longer-term seasonal influences, such as an increase in the availability of daylight (post-winter solstice), are not clear. However, as the data sampling is increased, seasonal effects and subsequent trends are anticipated to become more readily observable.

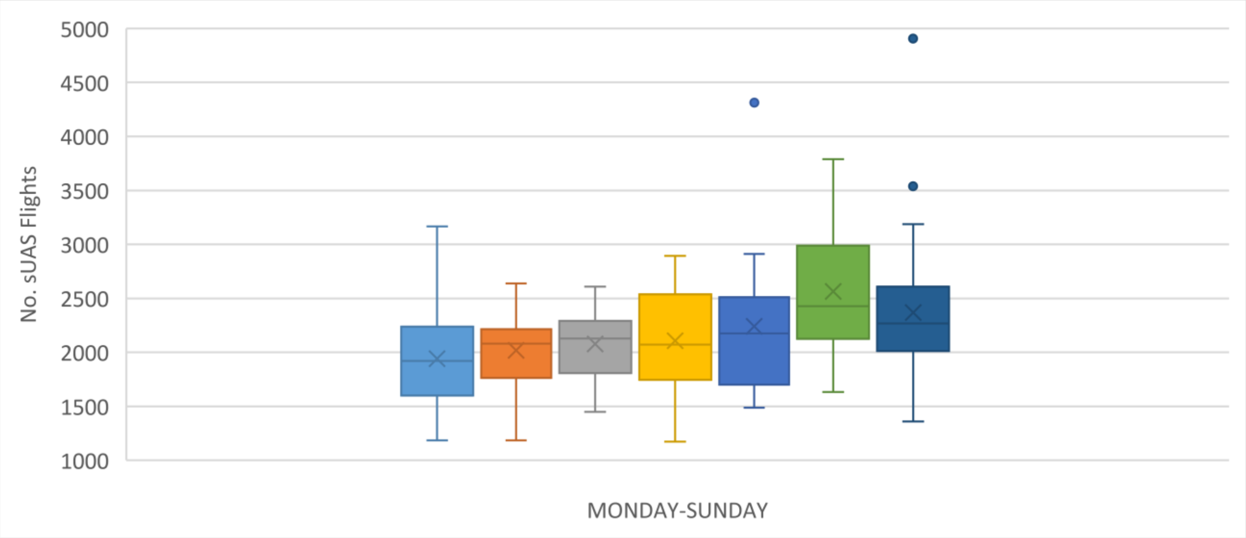


Figure 24. UAS Activity by Day of Week (N=470,902).

Table 8. Cumulative & Proportional sUAS Activity by Day of Week (*N*=470,902).

Day of Week	Total Flights	Proportion
Monday	60219	12.8%
Tuesday	60566	12.9%
Wednesday	62344	13.2%
Thursday	65350	13.9%
Friday	69482	14.8%
Saturday	79488	16.9%
Sunday	73453	15.6%

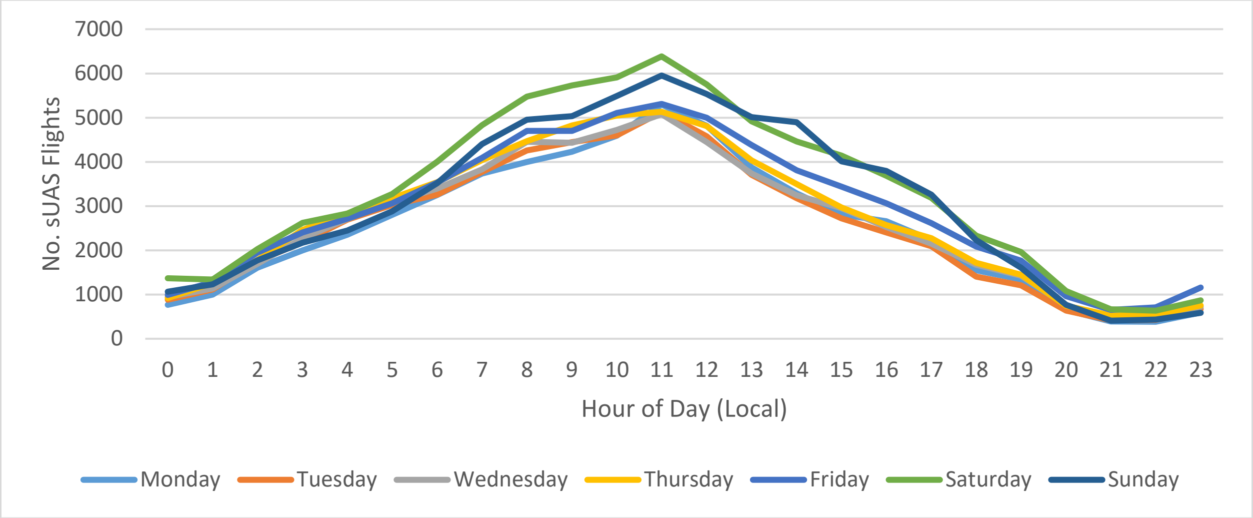


Figure 25. sUAS Activity by Day of Week and Hour of Day (N=470,957).

Table 9. Heat Chart of sUAS Flight Activity by Day of Week and Hour of Day (Local Time)(N=470,957; includes data from June 31, 2021).

Hour (L)	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**	***n***
0	0.2%	0.2%	0.2%	0.2%	0.2%	0.3%	0.2%	6935
1	0.2%	0.2%	0.2%	0.3%	0.3%	0.3%	0.3%	8359
2	0.3%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	12579
3	0.4%	0.5%	0.5%	0.5%	0.5%	0.6%	0.5%	16120
4	0.5%	0.6%	0.6%	0.6%	0.6%	0.6%	0.5%	18574
5	0.6%	0.6%	0.7%	0.7%	0.6%	0.7%	0.6%	21303
6	0.7%	0.7%	0.7%	0.8%	0.8%	0.9%	0.7%	24509
7	0.8%	0.8%	0.8%	0.9%	0.9%	1.0%	0.9%	28703
8	0.8%	0.9%	0.9%	0.9%	1.0%	1.2%	1.1%	32308
9	0.9%	0.9%	0.9%	1.0%	1.0%	1.2%	1.1%	33392
10	1.0%	1.0%	1.0%	1.1%	1.1%	1.3%	1.2%	35465
11	1.1%	1.1%	1.1%	1.1%	1.1%	1.4%	1.3%	38283
12	1.0%	1.0%	0.9%	1.0%	1.1%	1.2%	1.2%	34930
13	0.8%	0.8%	0.8%	0.9%	0.9%	1.0%	1.1%	29654
14	0.7%	0.7%	0.7%	0.7%	0.8%	0.9%	1.0%	26372
15	0.6%	0.6%	0.6%	0.6%	0.7%	0.9%	0.9%	23046
16	0.6%	0.5%	0.5%	0.5%	0.7%	0.8%	0.8%	20712
17	0.5%	0.4%	0.5%	0.5%	0.6%	0.7%	0.7%	17811
18	0.3%	0.3%	0.4%	0.4%	0.4%	0.5%	0.5%	12990
19	0.3%	0.3%	0.3%	0.3%	0.4%	0.4%	0.3%	10761
20	0.1%	0.1%	0.2%	0.2%	0.2%	0.2%	0.2%	5601
21	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	3538
22	0.1%	0.1%	0.1%	0.1%	0.2%	0.1%	0.1%	3653
23	0.1%	0.1%	0.2%	0.2%	0.2%	0.2%	0.1%	5359

Conclusions: Examination and interpretation of the current data related to this task resulted in limited observations and findings, due to the limited timeframe of this initial data collection segment. Further details and subsequent conclusions regarding sUAS operational timing will be presented in future iterations of this report, as additional data, contextual observations, and analysis results become available. Seasonal influence on sUAS operations and associated attributes is also being investigated in Task B.1.2 *Number of Operations*; Task B.1.5 *Active vs. Inactive sUAS Population*; and Task C.2 *What are exceedance rates for Daylight Operation [14 CFR §107.29]?* The observations, findings, and conclusions associated with these research efforts may offer additional insight to this task, specifically factors that may influence time of operations and model categorization.

Future Research Recommendations: For future related research efforts it may be beneficial to investigate the feasibility of differentiating the following: civil/public (14 CFR §107) versus recreational use; implementation by businesses/organizations (i.e., full time) versus supplemental/part time work use; and time of year/ seasonality (winter, spring, summer, and fall; or in/out of daylight savings), in relation to local dawn, midday, dusk, and night. Future versions of this report may include additional recommendations concerning the collection, isolation, or further investigation of relevant details, based upon observation, analysis, or inferences drawn from contextual examination of materials. Such recommendations are intended to support the definition and development of future related research efforts that are beyond the scope of this project.

2.2.1.5 Task B.1.5 Active vs. Inactive sUAS Population

The research team tabulated sUAS models (as assessed by individual unique serial number) that remain in active service over a period of 90 days. Models were tracked using their assigned electronic serial number and categorized into like classifications, consolidating sub-models of the same type. A platform was determined to be "active" if used within the previous 90 days, as of January 31, 2022.

Findings: The active sUAS platform population remained relatively high during the sampling period, with 51.4% of platforms (*n*=60,144) active within the 90 days preceding the end of the sampling period (January 31, 2022), shown in Figure 26. There did not appear to be significant disproportionality within the dataset, indicating that activity versus inactivity was fairly consistent across platform types. The most notable reduction in activity (inactivity) was associated with the Mavic Mini 2 series (16,861 cases of inactivity; 46.63% of the series; 14.53% of the total population); second-most was with the Mavic Air 2 series (13,295; 48.28% of the series; 11.46% of the total population); and the third-most reduction was associated with the Mavic 2 Enterprise series (8,895; 51.42% of the series; 7,67% of the total population). These notable reductions were most likely due to greater overall rates of adoption within the user segment, as each also represented the top three most active platforms, in the same sequential order (19,297 [Mavic Mini 2]; 14,240 [Mavic Air 2]; and 8,405 [Mavic 2 Enterprise]). Calculating the percentage inactive within a given series results in identification of 10 platform series that feature an inactivity rate of 50% or more(in descending order): 1) M100 (1:7 active to inactive ratio; 87.50% inactivity rate); 2) Mavic Pro (879:1,354; 60.64%); 3) Mavic Air (170:259; 60.37%); 4) P3 (301:451; 59.97%); 5) Spark (91:128; 58.45%); 6) Inspire 1 (23:30; 56.60%); 7) M200 (23:28; 54.90%); 8) Mavic Mini (6,574:7,347; 52.78%); 9) P4 (1,469:1,606; 52.23%); and 10) Mavic 2 Enterprise (1,681:1,779; 51.42%).

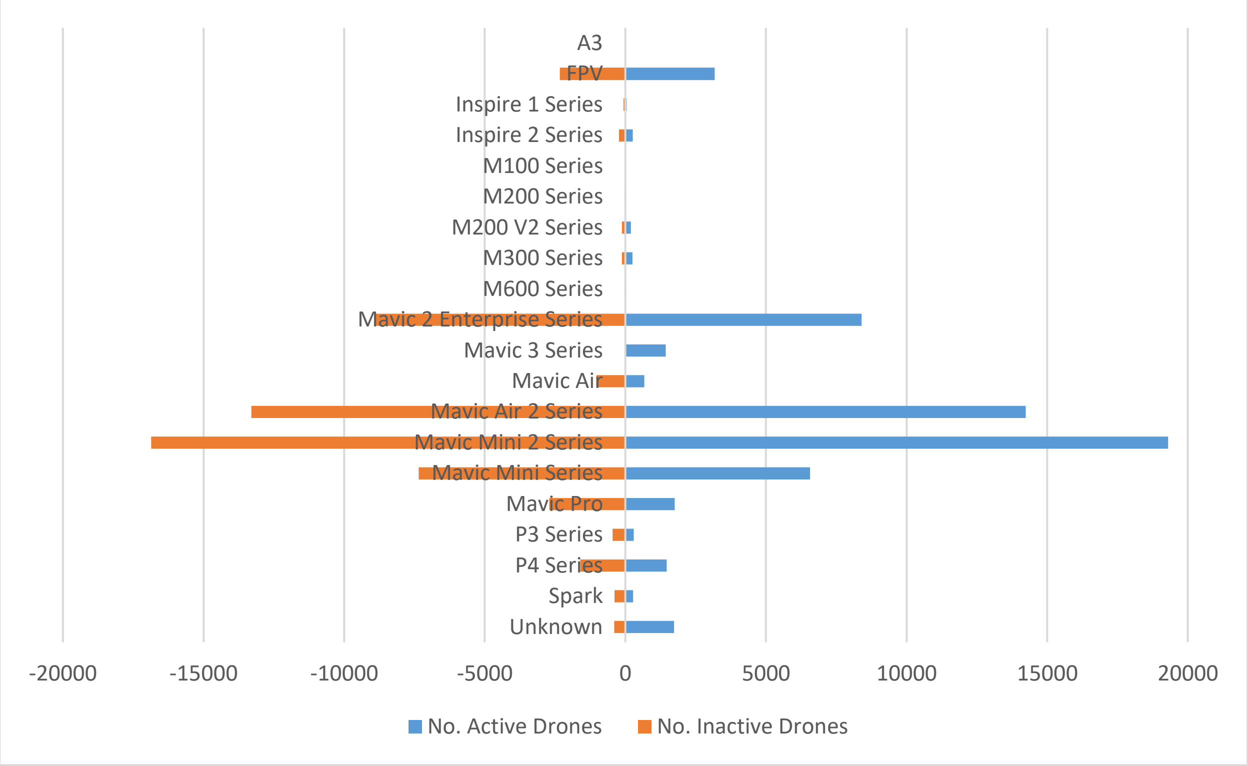


Figure 26. Distribution of Active vs. Inactive sUAS Population (*N*=116,043).

Note: Reflects proportion of active vs. inactive sUAS population. Total active platforms were 60,144 (51.4%), inactive platforms numbered 55,899 (47.8%) with 872 platforms (.7%) removed from the complete dataset.

Conclusions: The research team highlights that the utility of this data is fairly limited without further data collection. During the second annual report, the criteria for inactivity will be increased from 90-days to six months (180-days), which should provide a more accurate assessment. The data from subsequent investigation should help the research team to potentially ascertain whether inactivity is due to seasonal influence or platform abandonment. Further details and subsequent conclusions regarding the examination of the active versus inactive population will be presented in future iterations of this report, as additional data, contextual observations, and analysis results become available.

Seasonal influence on sUAS operations and associated attributes is also being investigated in Task B.1.2 *Number of Operations*; Task B.1.4 *Time of Operations*; and Task C.2 *What are exceedance rates for Daylight Operation [14 CFR §107.29]?*). Additional sections also featuring research of model classification include Task B.1.3 *Distribution of sUAS Flights by Model Over Time*; Task B.1.5 *Active vs. Inactive sUAS Population*; Task B.1.7 *Flight Durations*; Task B.3 *Where do sUAS fly and at what altitudes are they flying at?*; Task B.4 *Can rough estimates be made regarding sUAS retirement/abandonment rates?*; Task B.6 *What percentage of the detected sUAS population weighs less than 0.55 lbs and is not required to be registered?*; Task C.1 *What are exceedance rates for Operations from a Moving Vehicle [14 CFR §107.25*]?; and Task C.3 *What are exceedance rates for Visual Line of Sight Aircraft Operations [14 CFR §107.31]?*).

The observations, findings, and conclusions associated with these research efforts may offer additional insight to this task, specifically factors that may influence activity.

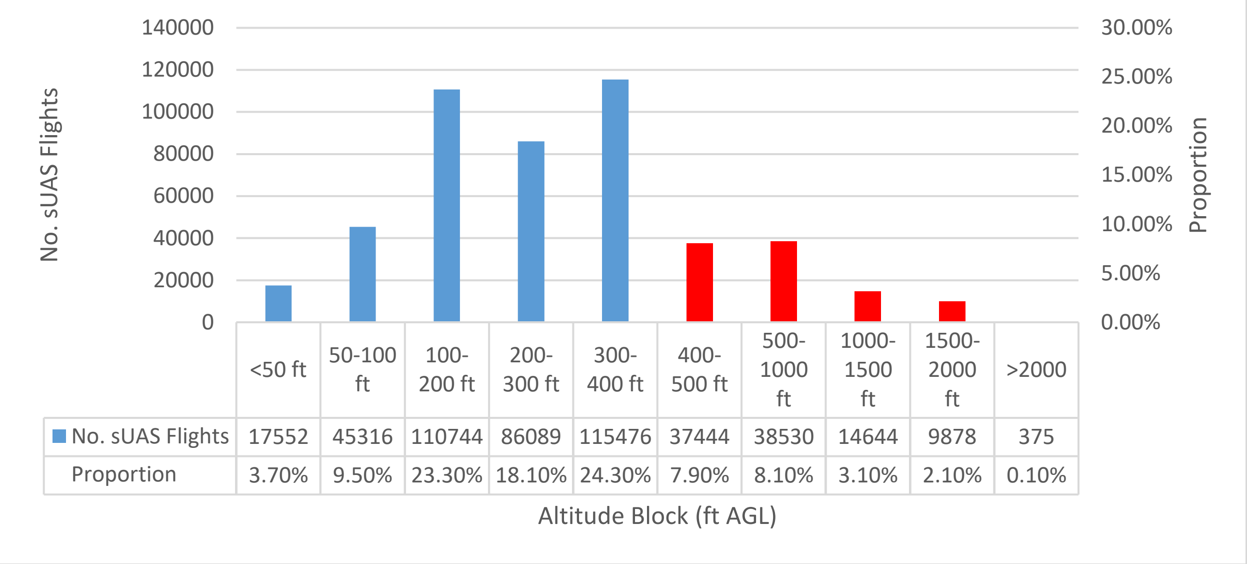
Future Research Recommendations: Future versions of this report may include additional recommendations regarding investigation of the active versus inactive sUAS user population, based upon observation, analysis, or inferences drawn from contextual examination of materials. Such recommendations are intended to support the definition and development of future related research efforts that are beyond the scope of this project.

2.2.1.6 Task B.1.6 Flight Altitudes

An aggregation of maximum sUAS flight altitudes as reported by the sUAS detection equipment will be presented. Altitude is reported in feet above launch location, which should reasonably reflect AGL altitudes, provided surrounding terrain does not exhibit significant elevation differences.

Findings: The research team is working to address an inconsistency in this dataset, as the total number of flights sampled for this metric exceeded the total number of flights available by 1.0% (*n*=5,146). It is notable that some of the contributed data from the data service providers come from overseas sources, which are filtered from analytics metrics. The research team believes that this metric may not be filtering properly. In spite of this error, the research team believes this data to be reasonably valid due to the large sample size.

Approximately 78.9% of flights in the sample set were found to be operating below 400 feet, shown in Figure 27. High utilization rates were noted for the 300-400 foot altitude levels (24.3%) and 100-200 foot levels (23.3%). Flight activity above 400 feet is somewhat concerning, as 21.3% of flights appear to be operating at altitudes that are not generally permitted under 14 CFR §107.51 and 49 USC §44809. It is notable that the only a small fraction of the flights are operated above 2,000 feet. The research team believes that the substantial reduction in flights above 2,000 feet are largely due to DJI's user protection features that restricts flight above 500 meters (1,640 feet).



	<50 ft	50-100 ft	100-200 ft	200-300 ft	300-400 ft	400-500 ft	500-1000 ft	1000-1500 ft	1500-2000 ft	>2000
■ No. sUAS Flights	17552	45316	110744	86089	115476	37444	38530	14644	9878	375
Proportion	3.70%	9.50%	23.30%	18.10%	24.30%	7.90%	8.10%	3.10%	2.10%	0.10%

Figure 27. Cumulative Distribution/Proportion of sUAS Flight Altitudes (*N*=476,048*).

Conclusions: Observed exceedances may have been approved for operation under the LAANC system or a waiver (§107.51).

It is possible that some detected altitude exceedances were conducted in accordance with FAA waiver criteria articulated in 14 CFR §107.205. According to the FAA, the agency received 4,007 requests to deviate from altitude limitations. Of those requests, 500 (12.5%) were withdrawn by the submitter before disposition, 3,215 (80.2%) were disapproved, 75 (1.9%) are pending agency review, and 217 (5.4%) were approved.

It is also possible that some altitude variation may be due to variability within the environment, such as terrain slope rising away from the launch point with the sUAS maintaining a fixed altitude above the increasing slope, while still within acceptable visual line of site distance to the operator. Further details and subsequent conclusions regarding sUAS flight altitudes will be presented in future iterations of this report, as additional data, contextual observations, and analysis results become available.

Future Research Recommendations: For future related research efforts it may be beneficial to investigate Time of Year, Time of Day, location of observed exceedances, and specific model types to determine if there are any discernible connections or patterns. Future versions of this report may include additional recommendations concerning the collection, isolation, or further investigation of relevant details, based upon observation, analysis, or inferences drawn from contextual examination of materials. Such recommendations are intended to support the definition and development of future related research efforts that are beyond the scope of this project.

2.2.1.7 Task B.1.7 Flight Durations

A mean of sUAS flight durations (seconds) for each sUAS model is calculated, with flight durations determined by evaluating the time differential between the initial detection and final detection of a sUAS the same assigned FIN.

Findings: The research team evaluated detection data to assess the distribution of flight durations. More than 56.6% of platforms flew for a period of less than five-minutes, 20.2% of platforms flew between five and 10 minutes, and 23.2% of platforms flew for greater than 10-minutes. The distribution of flight durations and means are presented in Figure 28. Table 10 features *power availabl*e values, presented in seconds (s), and as advertised by the manufacturer. The individual *percent power used* values were calculated by dividing each reported mean *duration* value, as observed in Figure 28, by the manufacturer advertised *max flight time* values. The subsequent *percent power remaining* was calculated by subtracting the *percent power used* from 100-percent. The mean *duration* values for each model type were also compared to manufacturer advertised maximum flight time (i.e., operational endurance) to calculate percentage values for power used and remaining, as well as accompanying descriptive statistics. The average operational flight time available across model types is 1,763.33 seconds (29.39 minutes), with platforms using approximately 23.90% of their available power, leaving 76.10% in reserve. The lowest observed calculated value for *percent power remaining* was 63.24% (Inspire 2 series), leaving a notable percent of power remaining for emergency use. The examination of the captured data and the calculated values, shown in Figure 28 and Table 10, supports the observations that smaller platforms generally tended to fly shorter duration flights, for example those series weighing 300g or less (Spark [217 seconds; 3.62 mins], Mavic Mini [302 seconds; 5.03 mins], and Mavic Mini 2 [377 seconds; 6.29 mins]) flew an average of 298 seconds (4.97 mins). Larger platforms, such as the Matrice (M100 [3,600 g], M200 [3,800 g], M200 v2 [4,690 g], M300 [6,300 g], M600 [9,960 g]) and Inspire series (v.1 [3,060 g] and v.2 [4,250 g]), have exhibited longer flight durations of greater than 495 seconds (8.25 minutes).

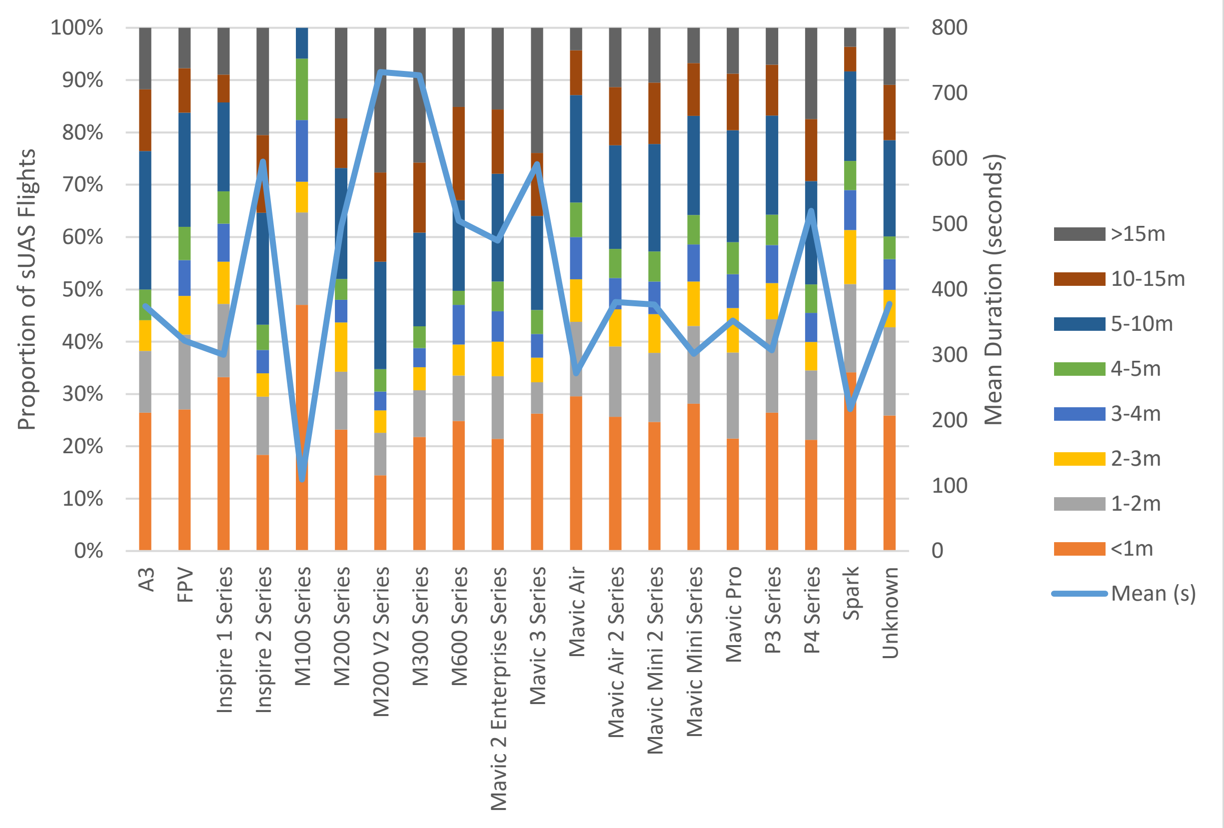


Figure 28. Distribution of sUAS Flight Durations by Model Category (N=476,047*).

Note: Chart utilizes an abbreviated list of sUAS models, consolidating sub-models of the same type.

Table 10. sUAS Models Power Usage (N=476,047*).

Drone Group	**Max Flight Time (s)**	**Percent Power Used**	**Percent Power Remaining**
A3	NA	NA	NA
FPV	1200	26.79%	73.21%
Inspire 1 Series	1080	27.80%	72.20%
Inspire 2 Series	1620	36.76%	63.24%
M100 Series	1320	8.28%	91.72%
M200 Series	1620	30.65%	69.35%
M200 V2 Series	2160	33.91%	66.09%
M300 Series	3300	22.04%	77.96%
M600 Series	2100	24.04%	75.96%
Mavic 2 Enterprise Series	1860	25.52%	74.48%
Mavic 3 Series	2760	21.43%	78.57%
Mavic Air	1260	21.56%	78.44%
Mavic Air 2 Series	2040	18.67%	81.33%
Mavic Mini 2 Series	1860	20.25%	79.75%
Mavic Mini Series	1800	16.75%	83.25%
Mavic Pro	1620	21.74%	78.26%
P3 Series	1500	20.45%	79.55%
P4 Series	1680	30.96%	69.04%
Spark	960	22.60%	77.40%
Unknown	NA	NA	NA
Mean	1763.33	23.90%	76.10%
Median	1620	21.89%	76.68%
Mode	1620	NA	NA
Min	960	8.28%	63.24%
Max	3300	36.76%	91.72%

Note: Given that the DJI *A3* (Pro Flight Controller) does not represent a specific platform and the elements within the *Unknown* category cannot be determined, associated power usage values could not be calculated for either of these categories (reported as NA).

Conclusions: Further details and subsequent conclusions regarding flight durations will be presented in future iterations of this report, as additional data, contextual observations, and analysis results become available. Additional sections also featuring research of model classification include Task B.1.3 *Distribution of sUAS Flights by Model Over Time*; Task B.1.5 *Active vs. Inactive sUAS Population*; Task B.3 *Where do sUAS fly and at what altitudes are they flying* *at?*; Task B.4 *Can rough estimates be made regarding sUAS retirement/abandonment rates?*; Task B.6 *What percentage of the detected sUAS population weighs less than 0.55 lbs and is not required to be registered?*; Task C.1 *What are exceedance rates for Operations from a Moving Vehicle [14 CFR §107.25*]?; and Task C.3 *What are exceedance rates for Visual Line of Sight Aircraft Operations [14 CFR §107.31]?*).

Future Research Recommendations: Future versions of this report may include additional recommendations regarding the investigation of sUAS operational flight durations, based upon observation, analysis, or inferences drawn from contextual examination of materials. Such recommendations are intended to support the definition and development of future related research efforts that are beyond the scope of this project.

2.2.1.8 Task B.1.8 Proximity to Airports

The research team evaluated sUAS operations location (based on homepoint) to determine its proximity to nearby aerodromes, including airports, heliports, ultralight facilities, seaplane bases, balloon facilities, and glider ports. The analysis included all facilities within 5 SM of each sUAS operation.

Findings: A total of 1,577 aerodromes were included in the sample, as shown in Figure 29. Figure 30 shows the number of operations near heliports vastly outnumbered all other aerodrome types, likely due to the larger number of heliports within the sampling areas. Only a small number of operations were found to occur within .5 SM from each aerodrome type. Only 28,601 sUAS operations came within ½ SM of a heliport, which represents approximately 1.6% of the total sample. Figure 31 shows the proportionality of sUAS operations within proximity to aerodromes within each distance bucket.

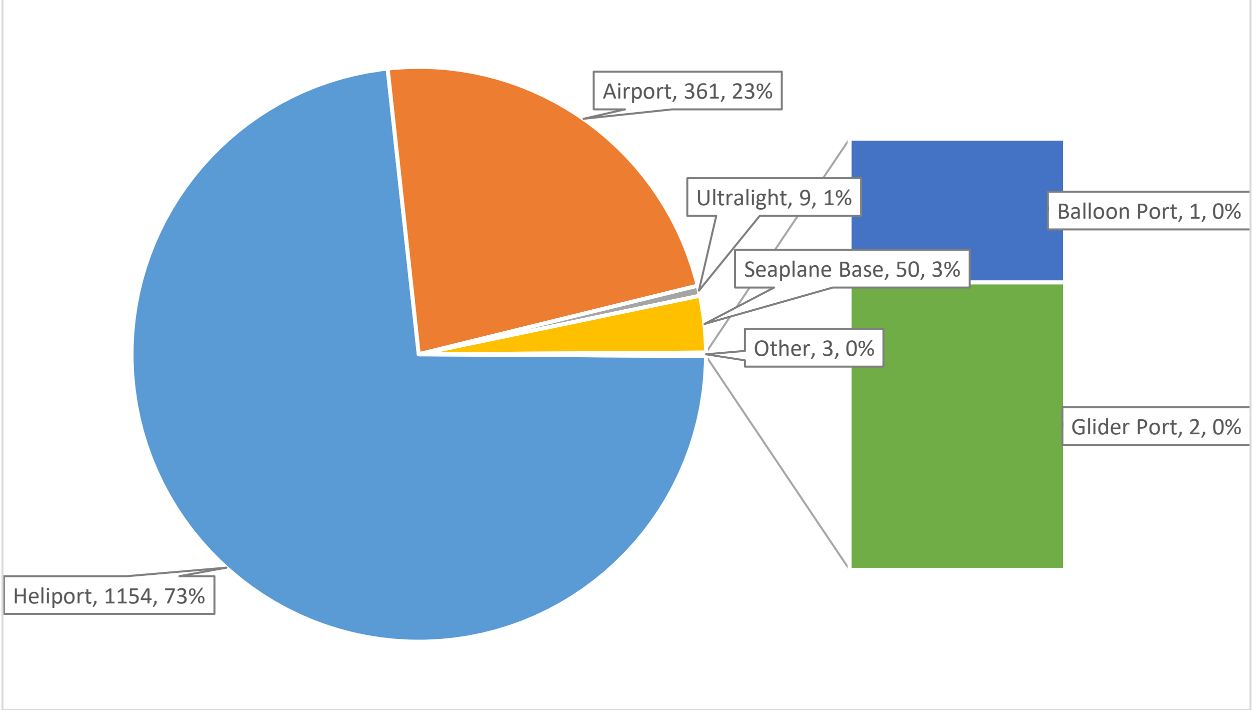


Figure 29. Distribution of Aerodrome Types in Sample Areas (*n*=1,577).

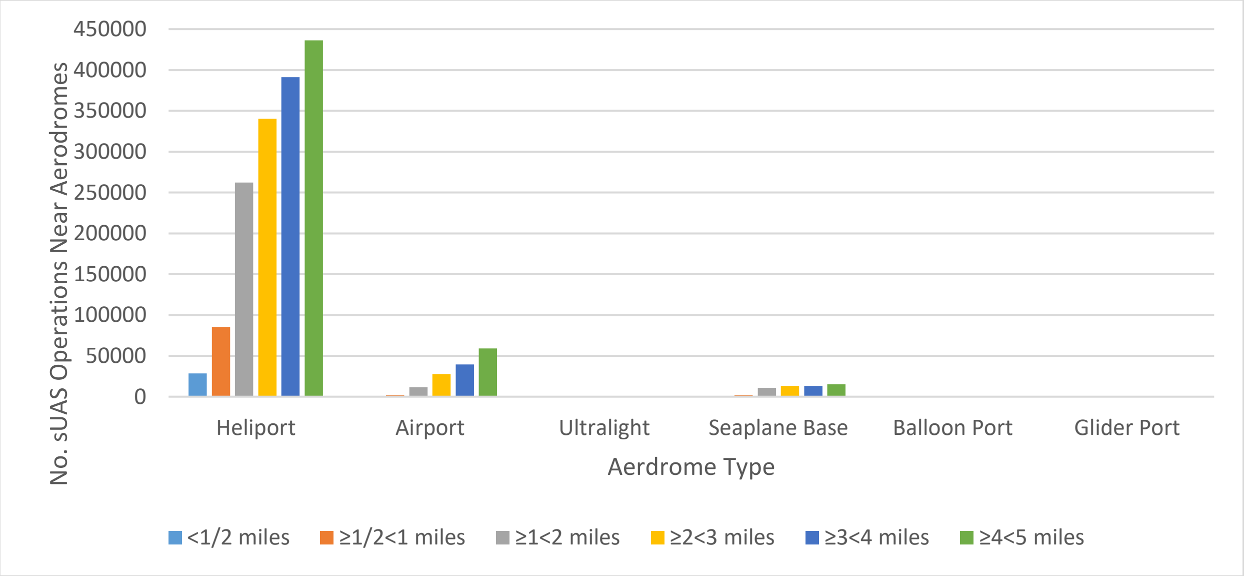


Figure 30. Distribution of sUAS Activity within Proximity to Aerodromes by Type (*n*=1,577).

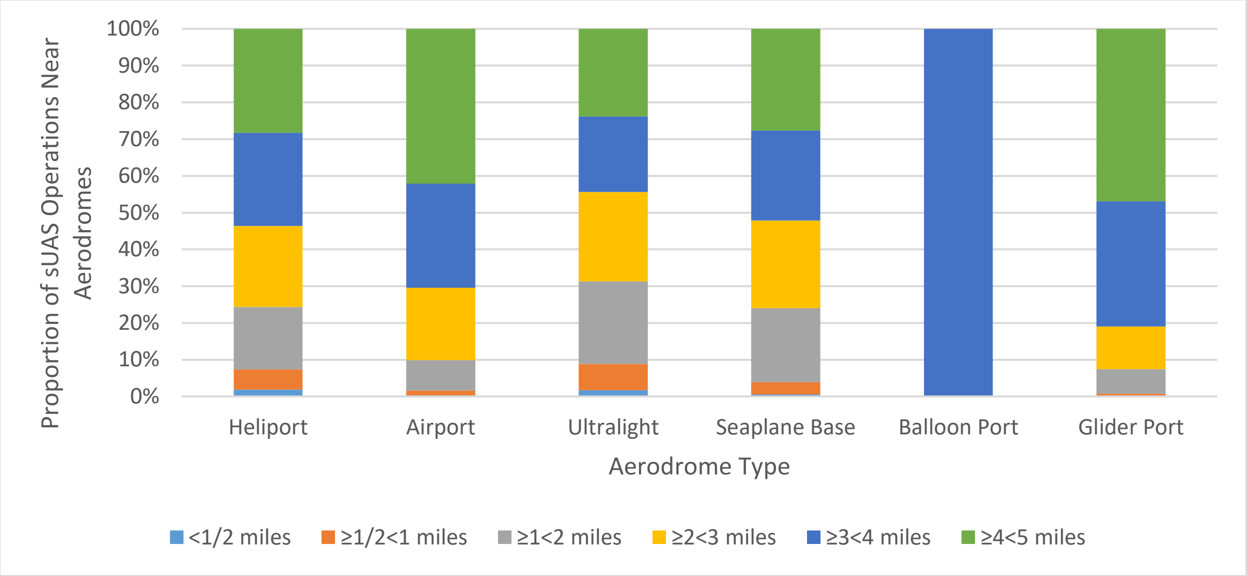


Figure 31. Proportion of sUAS Activity within Proximity to Aerodromes by Type (*n*=1,577).

Conclusions: Further details and subsequent conclusions regarding airport proximity will be presented in future iterations of this report, as additional data, contextual observations, and analysis results become available. Given the high number of observations near heliports, it can be assumed that findings and conclusions associated with this task will share common connections, influencing factors, and other contextual elements with the Task E.1.3 (*Proximal VTOL Facility Impacts*) investigation, which features examination of heliport specific data to serve as analog to "vertiports."

Future Research Recommendations: Future versions of this report may include additional recommendations concerning the investigation of sUAS airport proximity, based upon observation, analysis, or inferences drawn from contextual examination of materials. Such recommendations are intended to support the definition and development of future related research efforts that are beyond the scope of this project.

2.2.2 Task B.2: What are estimated registration rates for sUAS?

The UAS detection equipment collects data relating to sUAS launch locations, also known as the "homepoint." A primary operating area (zip code region) was determined for each detected sUAS by: 1) The preponderance of homepoints detected within a single zip code region; 2) The zip code region in which the initial homepoint was detected; or, 3) The zip code region in which the initial flight was detected. A census of sUAS platforms was reported for each zip code region. The FAA provided the research team with a current database of aggregated sUAS registrations by zip code. The research team evaluated the number of sUAS platforms detected within each zip code region relative to the FAA's registration data. It is important to note that not all sUAS are required to be registered. According to the FAA (2022c), "All drones must be registered, except those that weigh 0.55 pounds of less (less than 250 grams) and are flown exclusively under the Exception for Recreational Flyers [hobbyist use]. It is also notable that drones flown exclusively under the provisions of 49 U.S.C. §44809 are permitted to have multiple sUAS registered under a single registration number issued to the operator—this is differentiated from sUAS registered for commercial (14 CFR §107) use, in which each individual sUAS platform is issued a unique registration number. The National Academy of Public Administration (2020) estimates that the true number of drones operated under 49 U.S.C. §44809 can be accurately estimated by adjusting the number operator registrations by an additional 40%.

Findings: Figure 32 shows a national heat map showing the ratio of sUAS flight detections from sUAS detection equipment relative to the number of sUAS registrations in each area. Since there is a large potential for data skewing in areas of inadequate detection coverage, the research team confined the analysis to the top 30 platform zip code detection locations. Not surprisingly, large urban areas exhibited the highest rates, suggesting that larger numbers of platform detections of individual, serialized sUAS platforms were detected when compared to the number of registrations in that particular area. Table 11 shows the relative number of detected platforms, number of 14 CFR §107 registrations, hobbyist registrations, and remote pilots in each zip code area. The research team believes the most accurate values are represented when the number of platform detections, registrations, and remote pilot values are high, such as that reflected by zip code 77573 (League City, TX). Similarly, the value of unique platform detections per remote pilot is relatively low—4.12—indicating that four unique platforms were detected for each 14 CFR §107-certificated remote pilot in the area. Another reasonable example is zip code 92101 (San Diego, CA), with a relatively high value of registrations and remote pilots. In this area, the platform detection-to-registration rate is 2.18, a slightly higher value than that detected in League City, TX. In San Diego, the ratio of unique platform detections to remote pilots is 8.43—nearly double that of League, Texas. These higher values *may* indicate San Diego has a slightly lower registration compliance rate.

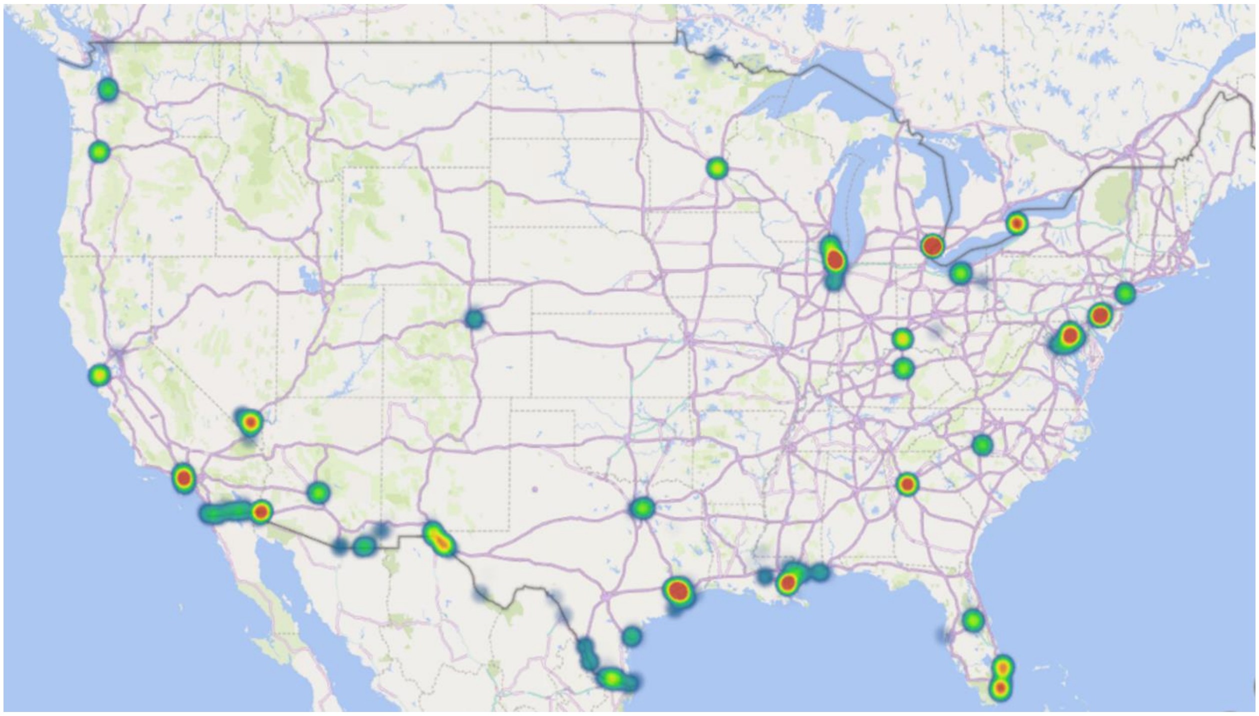


Figure 32. sUAS Detections to Registration Ratio by Location (*N*= 82,081 [Part 107]; 124,738 [§44809])

Table 11. Top 30 sUAS Platform Detection Locations with sUAS Registrations and Remote Pilot Certificates. (*N*= 82,081 [Part 107]; 124,738 [§44809])

Zip Code	Detected Platforms	Part 107	Hobby	Adjusted Hobbyist**	Platforms / Registration Rate	RP	Platforms to RP Rate	City, State
60605	1530	49	77	108	9.757653	21	72.85714	Chicago, IL
90068	1269	59	75	105	7.737805	31	40.93548	Los Angeles, CA
48207	1218	12	22	31	28.45794	10	121.8	Detroit, MI
30318	1184	59	82	115	6.812428	64	18.5	Atlanta, GA
48226	1060	27	11	15	25	6	176.6667	Detroit, MI
85281	950	143	110	154	3.198653	66	14.39394	Tempe, AZ
11201	870	90	96	134	3.877005	29	30	Brooklyn, NY
28202	865	50	33	46	8.991684	33	26.21212	Charlotte, NC
89109	807	25	33	46	11.33427	7	115.2857	Las Vegas, NV
33480	785	9	22	31	19.72362	6	130.8333	Palm Beach, FL
89103	764	22	42	59	9.455446	13	58.76923	Las Vegas, NV
90731	745	45	77	108	4.875654	30	24.83333	San Pedro, CA
70130	737	23	24	34	13.0212	14	52.64286	New Orleans, LA
30313	726	14	18	25	18.52041	2	363	Atlanta, GA
60616	700	45	88	123	4.161712	21	33.33333	Chicago, IL
77573	676	153	204	286	1.541268	164	4.121951	League City, TX
89118	649	58	44	62	5.426421	19	34.15789	Las Vegas, NV
33019	613	26	49	69	6.479915	29	21.13793	Hollywood, FL
77571	601	42	76	106	4.049865	17	35.35294	La Porte, TX
32819	599	104	77	108	2.82814	37	16.18919	Orlando, FL
30309	590	77	90	126	2.906404	64	9.21875	Atlanta, GA
60608	586	42	68	95	4.271137	25	23.44	Chicago, IL
60657	583	53	109	153	2.835603	40	14.575	Chicago, IL
48201	579	6	19	27	17.76074	3	193	Detroit, MI
79912	560	85	108	151	2.370872	89	6.292135	El Paso, TX
92101	548	145	106	148	1.867757	65	8.430769	San Diego, CA
60613	539	81	100	140	2.438914	39	13.82051	Chicago, IL
33130	531	49	92	129	2.986502	27	19.66667	Miami, FL
94107	531	84	116	162	2.155032	28	18.96429	San Francisco, CA
33401	530	71	58	81	3.48226	35	15.14286	West Palm Beach, FL

**Note: Adjusted Hobbyist provides an estimated number of platforms operated by registered hobbyists based on recommendations from the National Academy of Public Administration (2020).

Conclusions: Additional data is required before the research team is prepared to draw conclusions. Further details and subsequent conclusions regarding estimated registration rates will be presented in future iterations of this report, as additional data, contextual observations, and analysis results become available.

Future Research Recommendations: For future related research efforts it may be beneficial to compare calculated registration rates to Task B.1 location data, as well as resident population values (i.e., population density) to determine if there is an observable relationship between use and registration. Future versions of this report may include additional recommendations concerning estimating registration rates, based upon observation, analysis, or inferences drawn from contextual examination of materials. Such recommendations are intended to support the definition and development of future related research efforts that are beyond the scope of this project.

2.2.3 Task B.3: Where do sUAS fly and at what altitudes are they flying at?

The research team planned to assess and aggregate the launch (origination) locations of sUAS activity using homepoint data to correlate with the relevant land use category in the 2015 U.S. land use survey. However, detailed land use data is not available for all sampling areas. The development of this task was originally designed based on sUAS detection data derived from Dallas-Fort Worth International Airport. Detailed land use data was available from the Regional Data Center's North Central Texas Council of Government's (NCTCOG) 2015 Land Use GIS database, which categorized 33 types of land use within the region (NCTCOG, 2018). In the absence of this dataset, the research team is using the National Land Cover (NLC) Database (U.S. Geological Survey, 2018). While not as detailed as the NCTCOG's land use data, the NLC dataset categorizes land use on a national scale into one of eight land cover categories (U.S. Geological Survey, 2018).

Server access to this query the NLC dataset is problematic due to recurrent connectivity drops. The research team is working to download the complete dataset for the selected sample areas to complete this task. Further reporting on this task will be deferred to a future annual report while the team solves these technical problems.

Findings: For this initial report, the research team leveraged data from the DFW study, conducted from August 2018-August 2021. This study evaluated operations from 29,839 platforms over the 36-month sampling period. Nearly 80.5% of flights (*n*=387,432) conducted in proximity to the DFW contained origination (homepoint) location data. Based on sUAS detection data, the following areas were most commonly used as launch locations: single-family homes (27.9%), parks/recreation areas (14.2%), commercial spaces (12.1%), vacant lots (12.0%), mutli-family homes (6.6%) and education facilities (5.9%). The aforementioned categories accounted for 78.8% of sUAS flights. Additional details on origination location can be observed in Figure 33.

The research team suspects that large proportion of these flights represent hobbyist/recreational sUAS operators launching platforms from their homes. Under this assumption, the research team isolated flights originating from single-family homes to identify the distribution of sUAS platforms used and number of flights performed. It is believed that this method will more accurately identify flight characteristics of hobbyist/recreational operators. Results are presented in Figure 34 and Table 12. The initial findings appear to support a researcher hypothesis that hobbyist and recreational operators show a preference towards smaller, more capable sUAS platforms (e.g., DJI Mavic family of products); this notion is further supported by observations and findings made in support of Task B.6 (*What percentage of the detected sUAS population weighs less than 0.55 lbs and is not required to be registered?*) where further market consolidation appears to be trending towards adoption and use of smaller, lighter platforms.

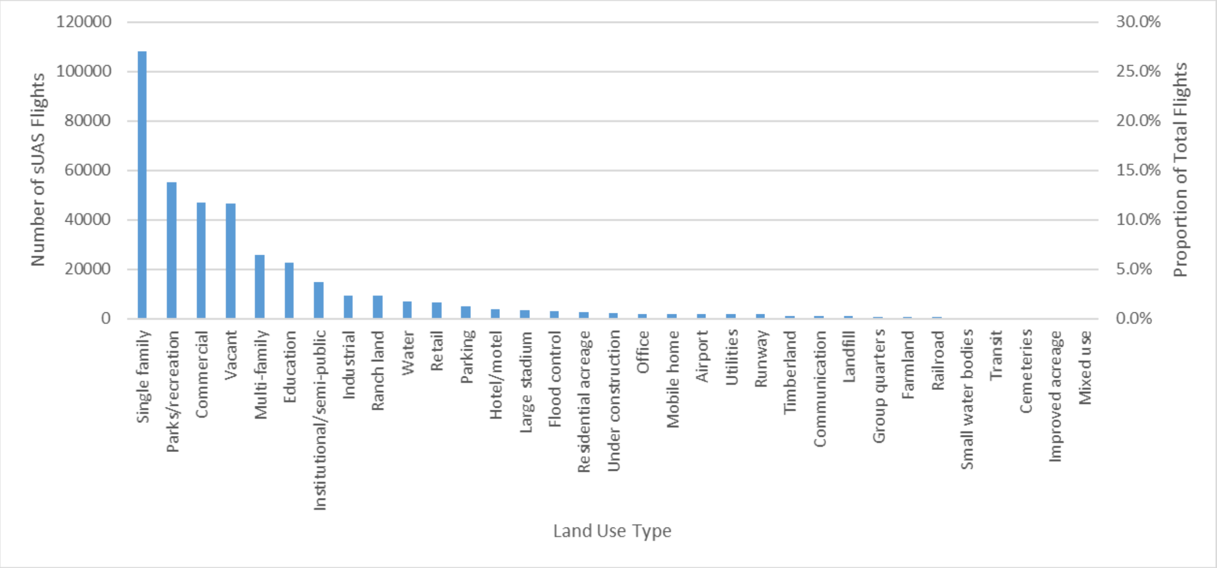


Figure 33. Land Use Types of sUAS Launch Locations around DFW Airport (August 2018-August 2021)(*N*=130,572).

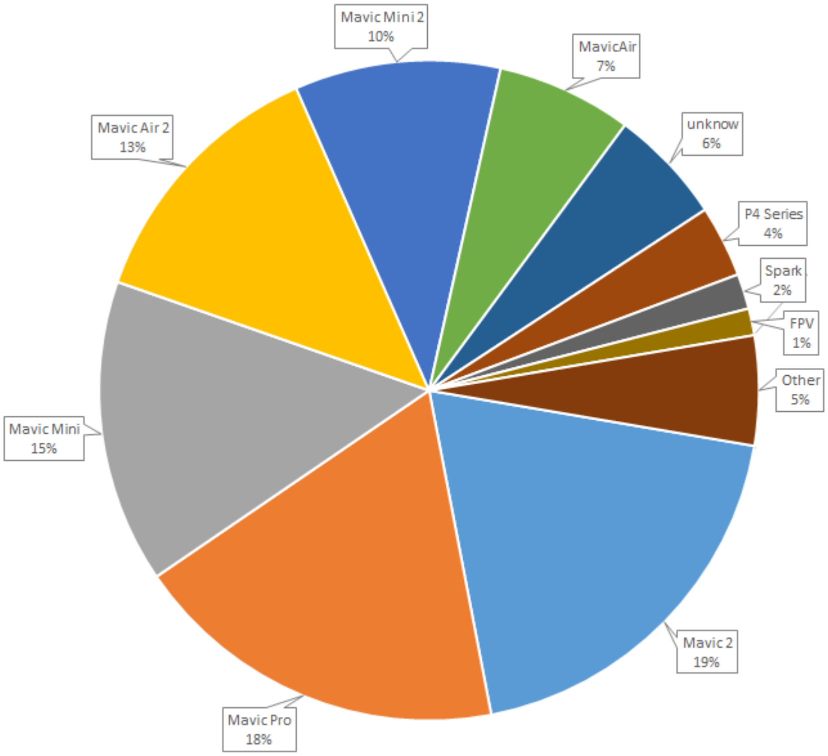


Figure 34. Distribution of Suspected Hobbyist/Recreational Platforms, DFW Airport (August 2018-August 2021)(N=10,919 [platforms]; 108,153 [flights]).

Table 12. Table of Suspected Hobbyist/Recreational Platforms, DFW Airport (August 2018-August 2021)(N=10,919 [platforms]; 108,153 [flights]).

Drone Type	**Platforms**	**Flights**	**Proportion-Platforms**	**Proportion-Flights**	**Flights / Platform**
Mavic 2	2107	28915	19.3%	26.7%	13.7
Mavic Pro	2019	18853	18.5%	17.4%	9.3
Mavic Mini	1623	11551	14.9%	10.7%	7.1
Mavic Air 2	1427	19680	13.1%	18.2%	13.8
Mavic Mini 2	1101	9864	10.1%	9.1%	9.0
MavicAir	725	4757	6.6%	4.4%	6.6
unknow	617	5274	5.7%	4.9%	8.5
P4 Series	383	2063	3.5%	1.9%	5.4
Spark	188	691	1.7%	0.6%	3.7
FPV	143	2123	1.3%	2.0%	14.8
P4P	109	613	1.0%	0.6%	5.6
P4P 2.0	95	1036	0.9%	1.0%	10.9
Mavic Air 2 S	80	585	0.7%	0.5%	7.3
P3 Series	65	204	0.6%	0.2%	3.1
Inspire 1	48	127	0.4%	0.1%	2.6
null	48	509	0.4%	0.5%	10.6
Mavic 2 Ent.	34	202	0.3%	0.2%	5.9
P3P	29	75	0.3%	0.1%	2.6
P4	21	236	0.2%	0.2%	11.2
Inspire 2	17	140	0.2%	0.1%	8.2
M200 V2	8	208	0.1%	0.2%	26.0
P4RTK	6	83	0.1%	0.1%	13.8
M300 RTK	5	138	0.0%	0.1%	27.6
P4 RTK	5	38	0.0%	0.0%	7.6
M100	4	36	0.0%	0.0%	9.0
Mavic 2 Ent. Adv.	4	47	0.0%	0.0%	11.8
M200	3	26	0.0%	0.0%	8.7
P3S	2	6	0.0%	0.0%	3.0
P4A	2	43	0.0%	0.0%	21.5
M600 Pro	1	28	0.0%	0.0%	28.0
M600	0	2	0.0%	0.0%	

Conclusions: Further details and subsequent conclusions regarding location-specific sUAS operational details will be presented in future iterations of this report, as additional data, contextual observations, and analysis results become available. Additional sections also featuring research of model classification include Task B.1.3 *Distribution of sUAS Flights by Model Over Time*; Task B.1.5 *Active vs. Inactive sUAS Population*; Task B.1.7 *Flight Durations*; Task B.4 *Can rough estimates be made regarding sUAS retirement/abandonment rates?*; Task B.6 *What percentage of the detected sUAS population weighs less than 0.55 lbs and is not required to be registered?*; Task C.1 *What are exceedance rates for Operations from a Moving Vehicle [14 CFR §107.25*]?; and Task C.3 *What are exceedance rates for Visual Line of Sight Aircraft Operations [14 CFR §107.31]?*).

Future Research Recommendations: For future related research efforts it may be beneficial to investigate if there are any potential relationships among adoption and use to cost, weight, and system capability and complexity to determine if there are any discernible connections or patterns. Future versions of this report may include additional recommendations concerning the investigation of location-specific sUAS operational details, based upon observation, analysis, or inferences drawn from contextual examination of materials. Such recommendations are intended to support the definition and development of future related research efforts that are beyond the scope of this project.

2.2.4 Task B.4: Can rough estimates be made regarding sUAS retirement/abandonment rates?

The UAS detection equipment has the ability to detect individual sUAS platforms by electronic serial number (SN). By tracking these individual sUAS serial numbers over time, the research team can aggregate utilization data and provide reasonable estimates for sUAS platform lifespan. Since sUAS platforms can be purchased over time, the research team will calculate each serial number's number of months of active utilization. A sUAS will be considered active from the calendar month of initial detection to the calendar month it was last detected. For example, if a specific SN of a sUAS was detected in January 2020 and later detected in October 2020, this would equate to 10 months of utilization, regardless of how many flights the platform performed in that timeframe. The research team will present the proportion of sUAS by the models still in active use over the collection timeframe. Note that utilization rates of newer sUAS platforms may be artificially skewed lower due to a lack of product longevity.

Findings: The team has secured initial data for this analysis, however, the research team cautions the use of these initial findings, as the reliability of this assessment will increase as further data is integrated. Initial data collection yielded approximately 32-weeks of usability data. Similar to findings collected during the previously described DFW study, the research team observed a significant decline in the utilization of platforms after the first several weeks (13% decrease from weeks 1-5; Figure 35). Higher utilization rates were observed for Matrice-series platforms (M100/200/300/600) and Mavic Enterprise 2 series platforms (Figure 36). This higher utilization is suspected to be associated with commercial activity, rather than hobbyist/recreational use.

Figure 35. Mean / Median of sUAS Retirement / Abandonment Rates (Preliminary)(*N*=116,908; Excludes A3 model).

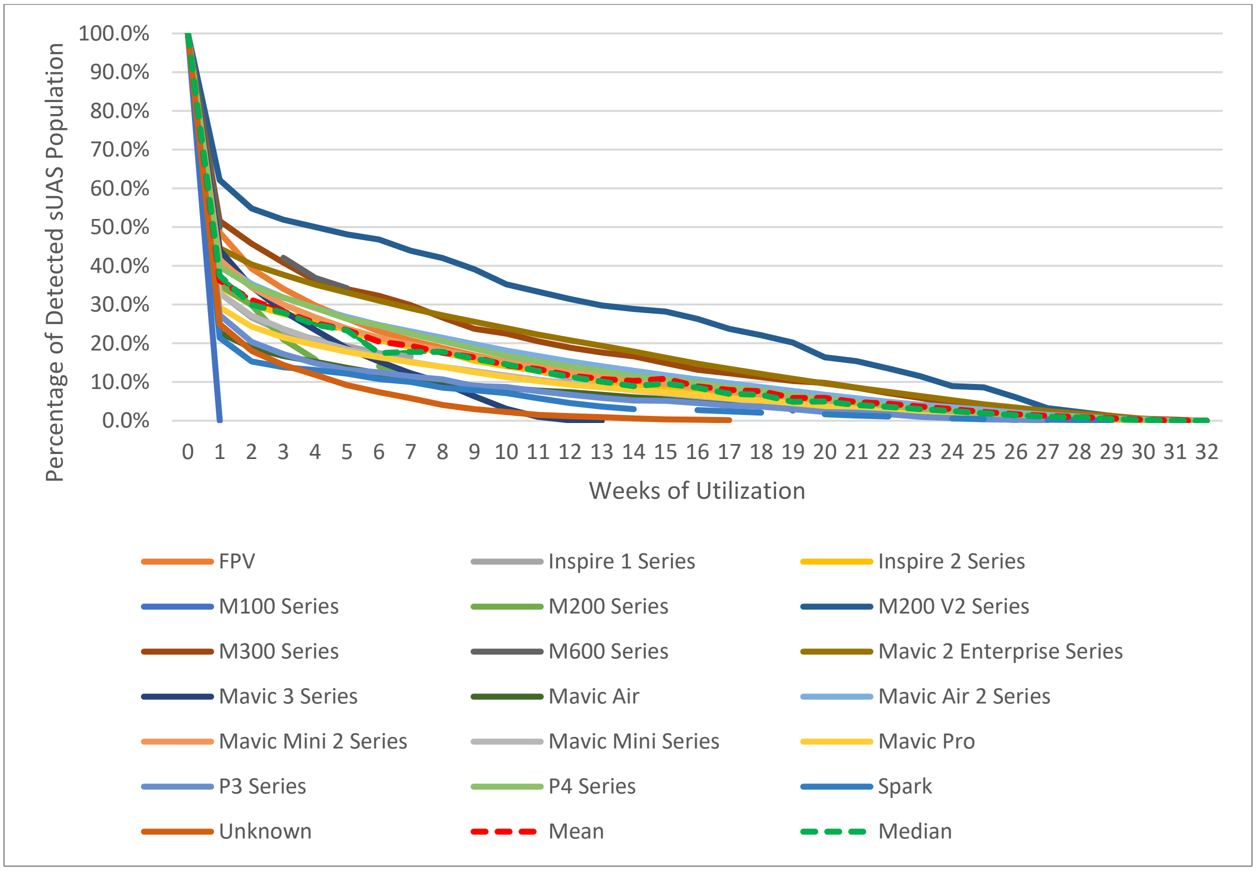


Figure 36. Proportion of sUAS Retirement / Abandonment Rates by Model Group (Preliminary) (N=116,908; Excludes A3 model).

Conclusions: Further details and subsequent conclusions regarding platform retirement or abandonment will be presented in future iterations of this report, as additional data, contextual observations, and analysis results become available. Additional sections also featuring research of model classification include Task B.1.3 *Distribution of sUAS Flights by Model Over Time*; Task B.1.5 *Active vs. Inactive sUAS Population*; Task B.1.7 *Flight Durations*; Task B.3 *Where do sUAS fly and at what altitudes are they flying at?*; Task B.6 *What percentage of the detected sUAS population weighs less than 0.55 lbs and is not required to be registered?*; Task C.1 *What are exceedance rates for Operations from a Moving Vehicle [14 CFR §107.25*]?; and Task C.3 *What are exceedance rates for Visual Line of Sight Aircraft Operations [14 CFR §107.31]?*).

Future Research Recommendations: Future versions of this report may include additional recommendations concerning investigation of platform retirement or abandonment, based upon observation, analysis, or inferences drawn from contextual examination of materials. Such recommendations are intended to support the definition and development of future related research efforts that are beyond the scope of this project.

2.2.5 *Task B.5: Can public agency (eg. Police, fire, government) use of sUAS be estimated?*

The research team established a collaboration with DroneResponders to support this task. Using the DroneResponders Public Safety UAS Database, the research team determined all public safety agencies that fall within sUAS detection capture areas. Successful completion of this task requires applicable public safety agencies to "opt-in" to the study and submit information to the research team. An email will be sent to each respective department in collaboration with DroneResponders requesting their participation. Instructions will be provided to identify the unique electronic serial number for each sUAS in their fleet, found in the controller's DJI Go4 Application. Upon receipt of the culminated list of serial numbers for the public safety sUAS, the research team will enter the serial numbers into URSA's UCAP platform filter, thereby isolating public safety operations activities from the remainder of the dataset. Traffic attributes of public safety sUAS will be reported in a similar fashion as identified in Tasks B.1 and B.3. Findings from this task will be reported in a subsequent annual report.

Findings: The research team liaised with DroneResponders to identify public safety agencies within the sampling areas that utilize DJI sUAS. A total of 143 public safety agencies met the established criteria. The possible sample includes 63 law enforcement agencies, 29 Fire/Emergency Medical Service (EMS) organizations, 26 multi-disciplinary public safety departments, 14 emergency management divisions, 4 Search and Rescue (SAR) entities, and 7 other organizations (see Figure 37). The geographical distribution of these agencies are presented in Figure 38. The will team enlist voluntary participation to collect sUAS detection data from sUAS platforms operated by these agencies to answer the posed research question. Additionally, this data is limited to those organizations willing to share their involvement (i.e., opt-in), it does not represent an all inclusive list of sUAS flown for government purposes as “public aircraft” in accordance with 49 U.S.C. § 40102(a)(41) and §40125.

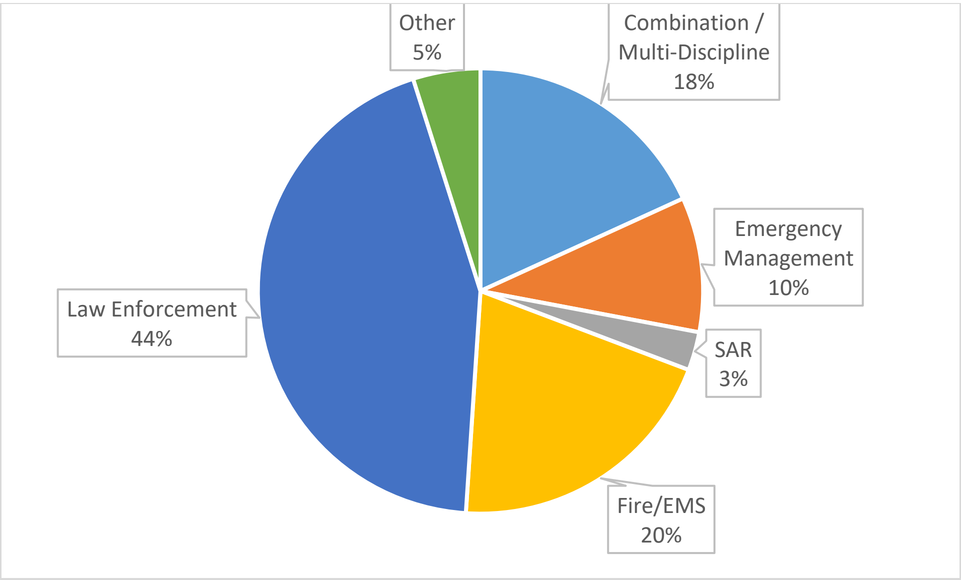


Figure 37. Public Safety Agencies Operating DJI sUAS Fleet within sUAS Detection Capture Areas by Agency Type (*n*=143).

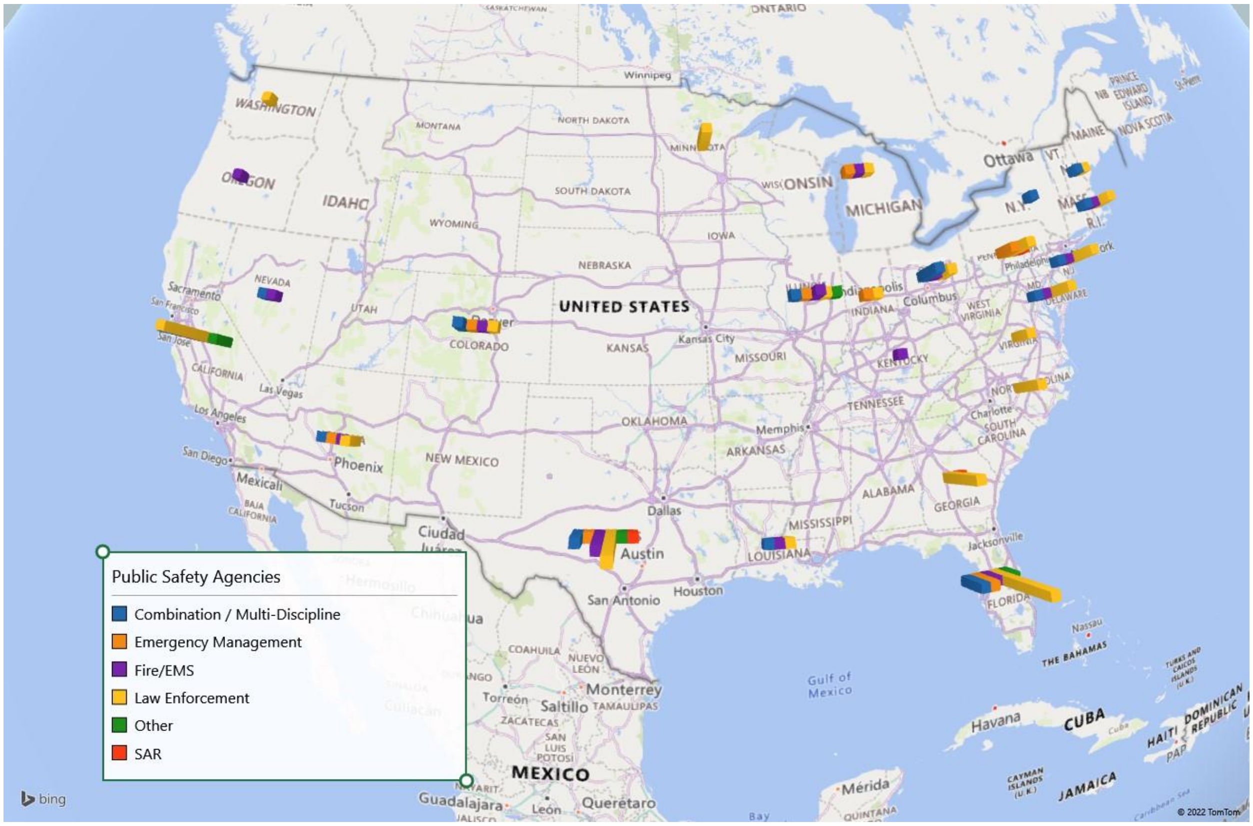


Figure 38. Map of Public Safety Agencies Operating DJI sUAS Fleet within sUAS Detection Capture Areas by Type (*n*=143).

Conclusions: Further details and subsequent conclusions regarding public agency use will be presented in future iterations of this report, as additional data, contextual observations, and analysis results become available. Additional sections also featuring research of model classification include Task B.1.3 *Distribution of sUAS Flights by Model Over Time*; Task B.1.5 *Active vs. Inactive sUAS Population*; Task B.1.7 *Flight Durations*; Task B.3 *Where do sUAS fly and at what altitudes are they flying at?*; Task B.4 *Can rough estimates be made regarding sUAS retirement/abandonment rates?*; Task C.1 *What are exceedance rates for Operations from a Moving Vehicle [14 CFR §107.25*]?; and Task C.3 *What are exceedance rates for Visual Line of Sight Aircraft Operations [14 CFR §107.31]?*).

Future Research Recommendations: For future related research efforts it may be beneficial to further examine how other operational factors, such as State/local regulations, organizational/departmental policies, best practices promoted by industry/ professional/ advocacy groups, as well as environmental considerations and public perception, influence or affect public agency adoption, use, and sustainment of sUAS technologies within their respective agencies and fields. Future versions of this report may include additional recommendations concerning the investigation of public agency use based upon observation, analysis, or inferences drawn from contextual examination of materials. Such recommendations are intended to support the definition and development of future related research efforts that are beyond the scope of this project.

2.2.6 Task B.6: What percentage of the detected sUAS population weighs less than 0.55 lbs and is not required to be registered?

The research team will provide a proportional breakdown of all sUAS detected by model, along with their respective weights in pie graph format. Weight information was derived from reported sUAS weight values reported in DJI platform specifications published on the manufacturer's website and model user manuals.

Findings: A total of 114,736 sUAS platforms contained information enabling the research team to assess the platform weight. Nearly 44% of all detected platforms were found to be less than .55 lbs (250g; see Figure 39). More than 24% of platforms weighed more than 1.5 lbs, but less than 2.0 lbs; and 18% weighed more than 2.0 lbs, but less than 4.0 lbs. Only 1,438 (1.3%) of detected platforms weighed more than 4.0 lbs. The Matrice 600 and Matrice 600 Pro, the largest platforms currently manufactured by DJI, both weigh approximately 9,960g (~21.96 lbs).

The research team further observed the distribution of platforms by weight over time in monthly intervals (see Table 13). During the seven-month sampling period, it was observed that the proportion of platforms weighing more than 1.5 lbs, but less than 2.0 lbs, decreased, as did the category of platforms weighing more than 2.0 lbs, but less than 4.0 lbs. In the same timeframe the proportion of platforms weighing less than .55 lbs increased. This trend may indicate further market consolidation in smaller, lighter platforms; however, until further data can be collected and analyzed it will be unclear whether this is due to seasonal influence or it represents an emerging trend.

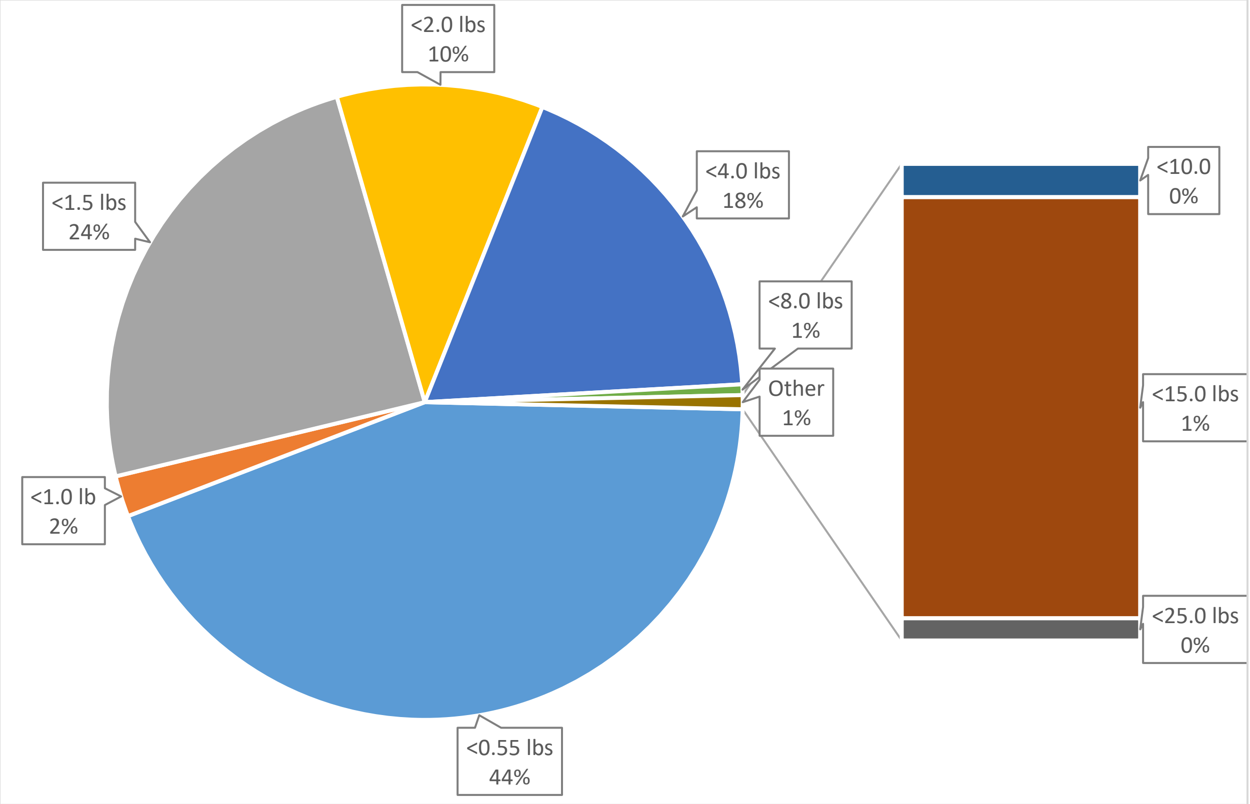


Figure 39. UAS Population by sUAS Platform Weight (*N*=114,736).

Note: Derived from 114,736 data points that included sUAS model information (2,179 data points removed).

Table 13. Month to Month Comparison of sUAS Popualtion Distribution by Weight Category (N=114,736).

	July	**August**	**September**	**October**	**November**	**December**	**January**
≥ 25 lbs	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
< 25.0 lbs	0.1%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%
< 15.0 lbs	0.6%	0.8%	0.8%	0.8%	1.4%	0.9%	0.9%
< 10.0	0.0%	0.1%	0.0%	0.1%	0.1%	0.0%	0.0%
< 8.0 lbs	0.5%	0.5%	0.5%	0.6%	0.9%	0.4%	0.4%
< 4.0 lbs	25.2%	26.1%	26.7%	25.9%	36.2%	21.8%	21.8%
< 2.0 lbs	4.1%	4.4%	4.4%	4.6%	6.8%	6.0%	5.8%
< 1.5 lbs	25.6%	25.1%	24.8%	25.4%	35.3%	23.0%	23.6%
< 1.0 lb	2.0%	1.9%	1.8%	1.9%	2.2%	1.4%	1.3%
< 0.55 lbs	42.0%	41.1%	40.9%	40.7%	17.2%	46.5%	46.2%

Conclusions: Further details and subsequent conclusions regarding unregistered platforms weighing less than .55 lbs will be presented in future iterations of this report, as additional data, contextual observations, and analysis results become available.

Future Research Recommendations: Future versions of this report may include additional recommendations concerning estimating the number of unregistered platforms weighing less than .55lbs, based upon observation, analysis, or inferences drawn from contextual examination of materials. Such recommendations are intended to support the definition and development of future related research efforts that are beyond the scope of this project.

2.2.7 Task B.7: What are the potential impacts of implementing ADS-B (Out) for sUAS?

This task will be executed in a manner very similar to Subtasks C.1-C.2. A temporal and spatial analysis will be conducted to identify instances in which detected sUAS come within a proximity of 2.5 SM (slant range) from a manned aircraft, based on fusing ADS-B data with sUAS detection data. Data will be presented in heatmap format with 2.5 SM influence range, based on the sUAS launch location (homepoint). Additionally, the plot of the distribution of the closest points of approach will be provided.

Findings: Data collection for this task is still underway. Preliminary findings are not available for reporting at this time. Updates on this task will be provided in a subsequent annual report.

Conclusions: Further details and subsequent conclusions regarding implementation of ADS-B (Out) will be presented in future iterations of this report, as additional data, contextual observations, and analysis results become available.

Future Research Recommendations: Future versions of this report may include additional recommendations concerning the use of ADS-B (Out), based upon observation, analysis, or inferences drawn from contextual examination of materials. Such recommendations are intended to support the definition and development of future related research efforts that are beyond the scope of this project.

2.3 Task C: Compliance and Exceedances of 14 CFR §107 Operational Limitations (Performers)

The primary objective of this task is to provide an overview regarding the exceedance rates of various elements of 14 CFR, including §107 and §48. The remainder of this section breaks down Task C into a series of subtasks.

2.3.1 Task C.1: What are exceedance rates for Operations from a Moving Vehicle (14 CFR §107.25)?

One of the data points collected by the detection system includes the sUAS controller's location. Unlike the sUAS homepoint, which is generally static, the controller location is updated via GPS sensor information derived from the attached iOS device (iPhone or iPad) running the DJI Go 4 Application. The UAS detection equipment will report updated controller location information at each 1 Hz data sampling interval. The controller location was available for approximately 54% of data points based on historically-collected data from DFW. The research team will identify case studies in which operator displacement takes place.

Findings: Approximately .2% (*n* = 1,000) of flights indicated that the remote pilot exhibited significant movement. These flights were carried out by 615 unique platforms, which represents just over .5% of the total detected sUAS population (*N* = 116,043). Most pilot movement (81.7%) fell within 1 SM of the origination location, shown in Figure 40. Nearly 13% fell within 2 SM of the origination location. The remaining 5.5% of flights were in excess of 2 SM. A small number of remote pilots (*n*=10) moved in excess of 5 SM. It is unlikely that a remote pilot would displace at these distances without the aid of a vehicle or other form of conveyance, suggesting possible exceedances to 14 CFR §107.25, Operation from a moving vehicle or aircraft.

Most platforms used in this fashion were newer, Mavic-series models, including the Mavic Mini 2, Mavic Air 2, and Mavic 2, which made up 75.3% of remote pilot movement cases, shown in Figure 41. The large number of pilot movement cases in McAllen, TX, and Texas City, TX, may indicate that remote pilots are more likely to operate their sUAS from a vehicle in less dense urban areas, shown in Figure 42.

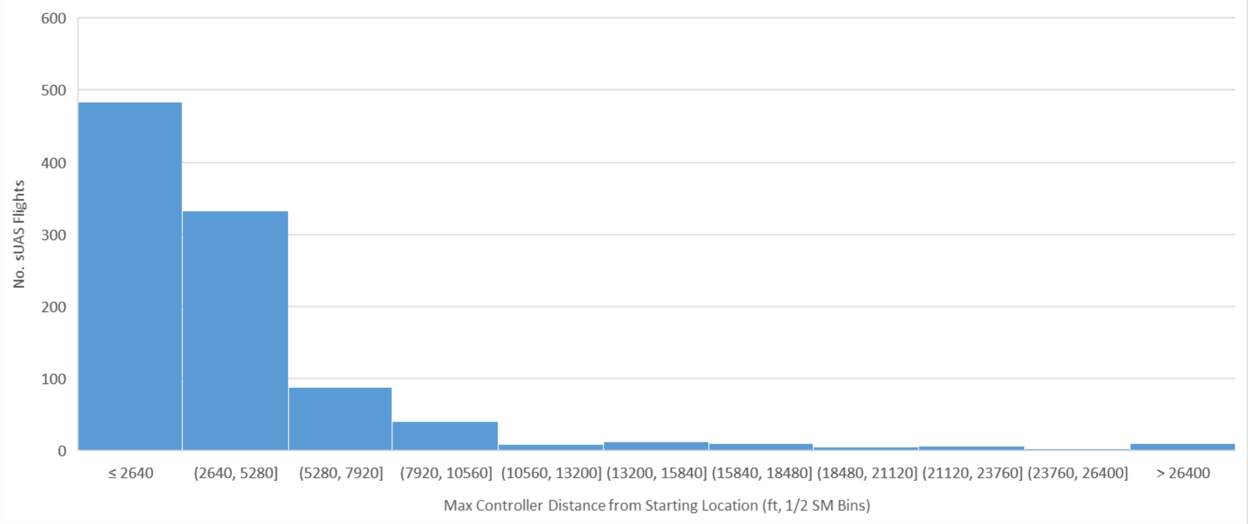


Figure 40. Distribution of Max Controller Distances from Starting Location (*n*=1,000).

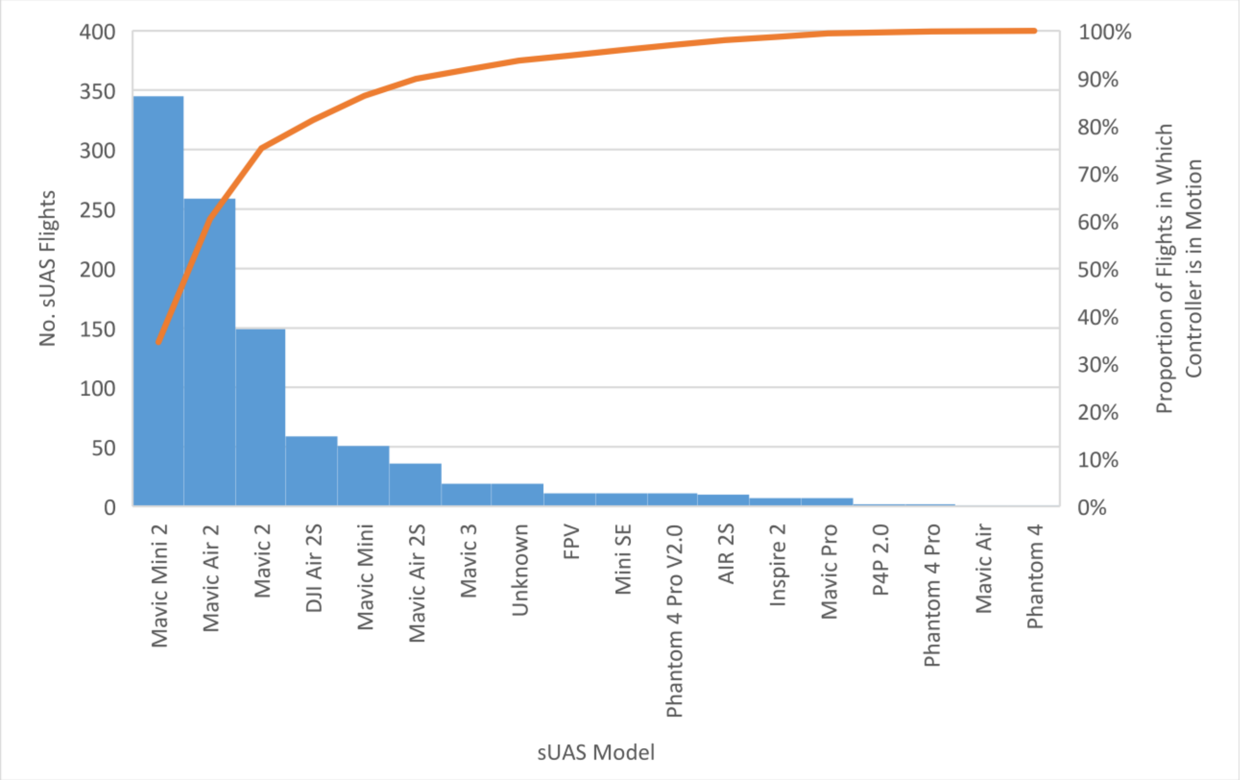


Figure 41. Distribution of Flights in Which Controller is in Motion by sUAS Model (*n*=1,000).

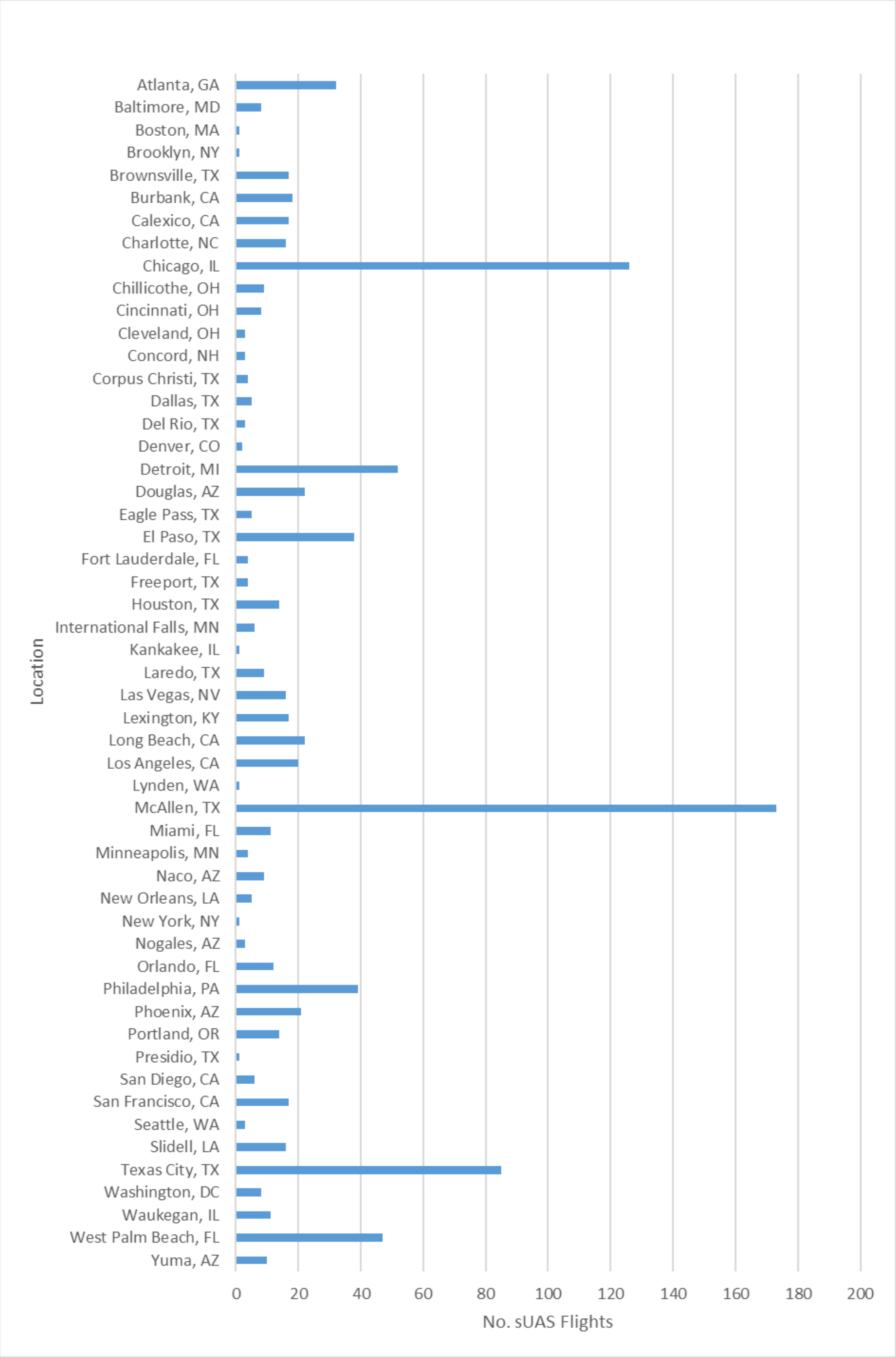


Figure 42. Distribution of Flights in Which Controller is in Motion by Location (*n*=1,000).

Conclusions: It is possible that some operations conducted from a moving vehicle were approved by the FAA in accordance with waiver criteria articulated in 14 CFR §107.205(a). According to the FAA, the agency received 2,416 requests to conduct operations from a moving vehicle. Of those requests, 186 (7.7%) were withdrawn by the submitter before disposition, 2,148 (88.9%) were disapproved, 34 (1.4%) are pending agency review, and 48 (2.0%) were approved.

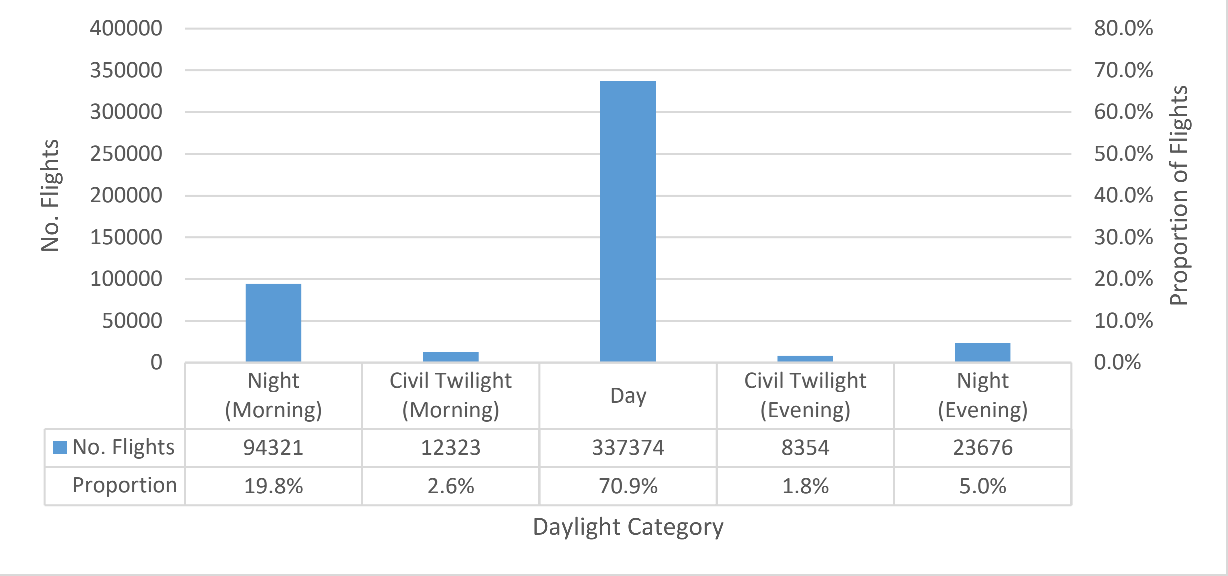
Further details and subsequent conclusions regarding moving vehicle operation exceedance rates will be presented in future iterations of this report, as additional data, contextual observations, and analysis results become available. Additional sections also featuring research of model classification include Task B.1.3 *Distribution of sUAS Flights by Model Over Time*; Task B.1.5 *Active vs. Inactive sUAS Population*; Task B.1.7 *Flight Durations*; Task B.3 *Where do sUAS fly and at what altitudes are they flying at?*; Task B.4 *Can rough estimates be made regarding sUAS retirement/abandonment rates?*; Task B.6 *What percentage of the detected sUAS population weighs less than 0.55 lbs and is not required to be registered?*; and Task C.3 *What are exceedance rates for Visual Line of Sight Aircraft Operations [14 CFR §107.31]?*).

Future Research Recommendations: Future versions of this report may include additional recommendations concerning investigation of moving vehicle operation exceedance rates, based upon observation, analysis, or inferences drawn from contextual examination of materials. Such recommendations are intended to support the definition and development of future related research efforts that are beyond the scope of this project.

2.3.2 Task C.2: What are exceedance rates for Daylight Operation (14 CFR §107.29)?

The research team will compare the detection time (local) for each flight against known sunrise (SR), sunset (SS), and civil twilight (CT) information for each detection area. Flight Activity will be separated into five categories, including: Morning (12:00am-CT); Morning CT (CT-SR); Daylight (SR-SS); Evening CT (SS-CT); and Night (CT-11:59pm). Both cumulative and proportional operations data will be presented to show trending.

Findings: An evaluation of flight times showed that the majority of operations (70.9%) were conducted during daylight hours, with 24.8% of flights conducted at nighttime, and 4.3% conducted during both periods of Civil Twilight. The data indicated that nearly four times as many nighttime operations occurred between midnight and morning Civil Twilight than occurred during the period from evening Civil Twilight and midnight. This finding is further reflected in Figure 43 and Table 9.



	Night (Morning)	Civil Twilight (Morning)	Day	Civil Twilight (Evening)	Night (Evening)
No. Flights	94321	12323	337374	8354	23676
Proportion	19.8%	2.6%	70.9%	1.8%	5.0%

Figure 43. Distribution of sUAS Flights by Daylight Category (N=476,048*).

Conclusions: It is possible that some detected daylight operational exceedances were conducted in accordance with FAA waiver criteria articulated in 14 CFR §107.205. According to the FAA, the agency received 14,562 requests to conduct night operations. Of those requests, 2,046 (14.1%) were withdrawn by the submitter before disposition, 8,787 (60.3%) were disapproved, and 3,729 (25.6%) were approved. On April 21, 2021, the FAA updated rules under 14 CFR §107.29, permitting routine sUAS operations at night, provided that: “(1) the remote pilot in command complete an updated initial knowledge test or online recurrent training, and (2) the sUAS is equipped with anti-collision lighting visible for at least 3 SM that has a flash rate sufficient to avoid a collision” (FAA, 2022d, p. 1). Since all data was collected *after* the FAA rule change for routine night operations, applicability and interpretation of data should remain consistent throughout the study.

Further details and subsequent conclusions regarding daily operation exceedance rates will be presented in future iterations of this report, as additional data, contextual observations, and analysis results become available. Seasonal influence on sUAS operations and associated attributes is also being investigated in Task B.1.2 Number of Operations; Task B.1.4 Time of Operations; and Task B.1.5 Active vs. Inactive sUAS Population). The observations, findings, and conclusions associated with these research efforts may offer additional insight to this task, specifically factors that may influence daily operation exceedance rates.

Future Research Recommendations: Future versions of this report may include additional recommendations concerning investigation of daily operation exceedance rates, based upon observation, analysis, or inferences drawn from contextual examination of materials. Such recommendations are intended to support the definition and development of future related research efforts that are beyond the scope of this project.

2.3.3 Task C.3: What are exceedance rates for Visual Line of Sight Aircraft Operations (14 CFR §107.31)?

By analyzing the sUAS telemetry data, the research team will assess the furthest point of flight from the sUAS launch location (homepoint). An assessment will be made of each sUAS model to determine its maximum visible range. The research team will determine the lateral visual footprint of the sUAS using manufacturer-reported technical specifications and use trigonometry to reverse calculate the range at an angle of 1 arc-minute, the minimum visual angle for an average person to reliably detect an object (Greening, 1976; Woo, 2017). A scatterplot and stacked bar chart will provide amplifying information regarding the distribution of sUAS flight distances relative to visual line of sight criteria.

Findings: Detection data was analyzed to determine the distribution of maximum line of sight distances (slant range) from each sUAS flight origination point (homepoint) to the UA at its furthest detected range along the telemetry. More than 83.6% (*n*=393,740) of flights contained adequate data to calculate Visual Line of Sight (VLOS) distance. Nearly 86.9% of sampled flights were conducted within a line of sight range of less than .5 SM from the launch location, shown in Figure 44.

The size of each sUAS platform type was evaluated and used to tabulate the range in which the platform would encompass one arc-minute of visual footprint (see Table 14). The maximum line of sight distance for each flight was compared against the detected sUAS model, and categorized into five visual categories: <1 Arc-Minute (Object unlikely to be seen); 1-10 Arc-Minutes (Object at human critical visual angle/maximum human visual performance); 10-15 Arc-Minutes (Object detectable, but not necessarily recognizable), 15-30 Arc-Minutes (Object recognizable 30-40% of the time); and >30 Arc-Minutes (Object recognizable 50-100% of the time). Results are presented in Figure 45.

A majority of sampled sUAS flights (57.0%) resulted in a visual range that would have been at minimally visible to the operator (see Figure 45). More than 11.0% of sampled flights were conducted at distances resulting in less than one arc-minute of visual angle, making them unlikely to be seen by an operator with normal visual acuity. The Mavic Mini 2, Mavic Air 2, Mavic 2 Enterprise, and FPV sUAS models comprise the majority (89.9%) of flights conducted with visibility of less than one arc-minute, as shown in Figure 46.

Figure 47 provides a scatterplot of all flights conducted at visual angles of less than one arc-minute by platform type. Figure 48 displays a subset of Figure 47, with a lateral limit of 5 SM laterally and 2,000 feet vertically. The multitude of sUAS flown at visual angles of less than one arc-minute are flown within 3 SM laterally, and 1,600 feet vertically of the origination point. It is notable that the vertical limitation is likely influenced by DJI's embedded programming, which limits sUAS altitude to not more than 500 meters (~1,640 feet) above the homepoint.

The research team suspects that some sUAS operators may be exceeding FAA rules for maintaining visual line of sight with their UAs by relying upon datalink video and C2 data to maintain situational awareness on the sUAS flight operation.

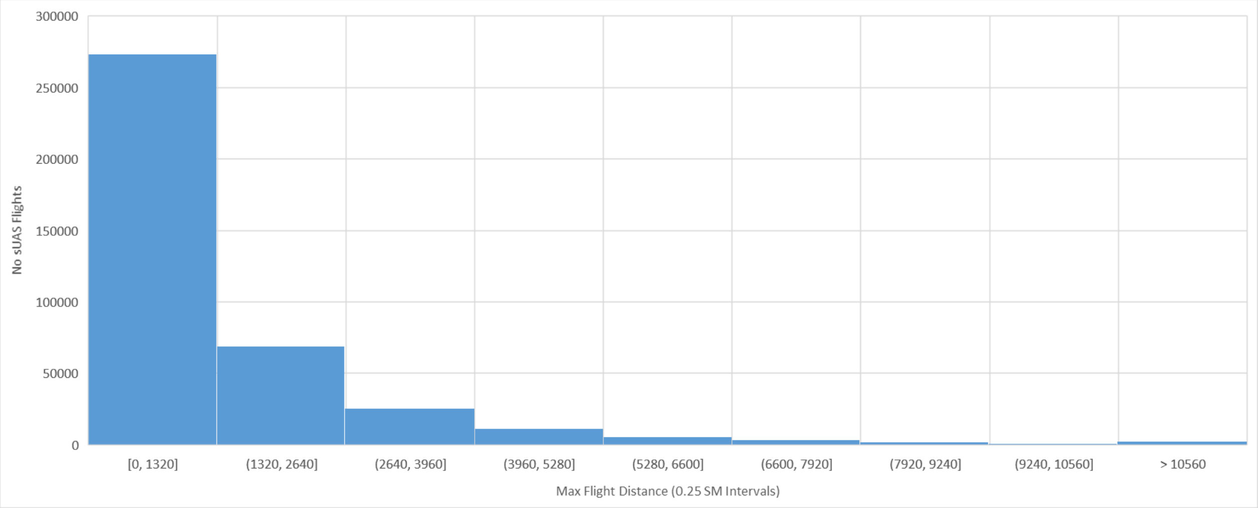


Figure 44. Histogram of Maximum Flight Distances (*N*=393,740).

Table 14. Beyond Visual Line of Sight Values

Platform	**Size (mm)**	**1 arc-min (ft)**	**10 arc-min (ft)**	**15 arc-min (ft)**	**30 arc-min (ft)**
Mini 2	203	2289.6	229.0	152.6	76.3
FPV	312	2842.2	284.2	189.5	94.7
Inspire 1	581	6552.9	655.3	436.9	218.4
Inspire 2	605	6823.6	682.4	454.9	227.5
Matrice 100	650	7331.2	733.1	488.7	244.4
Matrice 200	887	9992.9	999.3	666.2	333.1
Matrice 300	810	9135.7	913.6	609.0	304.5
Matrice 600	1668	18812.9	1881.3	1254.2	627.1
Mavic 2 Ent.	322	3631.7	363.2	242.1	121.1
Mavic 3	448	5053.0	505.3	336.9	168.4
Mavic Air	213	2402.4	240.2	160.2	80.1
Mavic Air 2	253	2853.5	285.4	190.2	95.1
Mavic Mini	202	2278.3	227.8	151.9	75.9
Mavic Pro	335	3778.4	377.8	251.9	125.9
Phantom 3	350	3947.5	394.8	263.2	131.6
Phantom 4	350	3947.5	394.8	263.2	131.6
Spark	170	1917.4	191.7	127.8	63.9

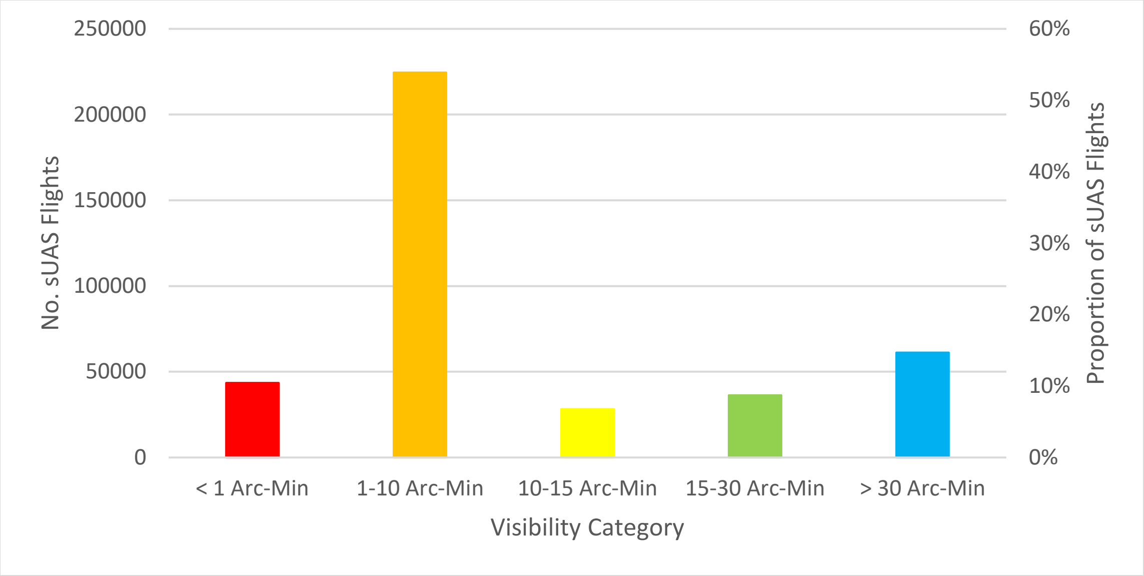


Figure 45. Distribution of sUAS Visibility Categories (*N*=393,740).

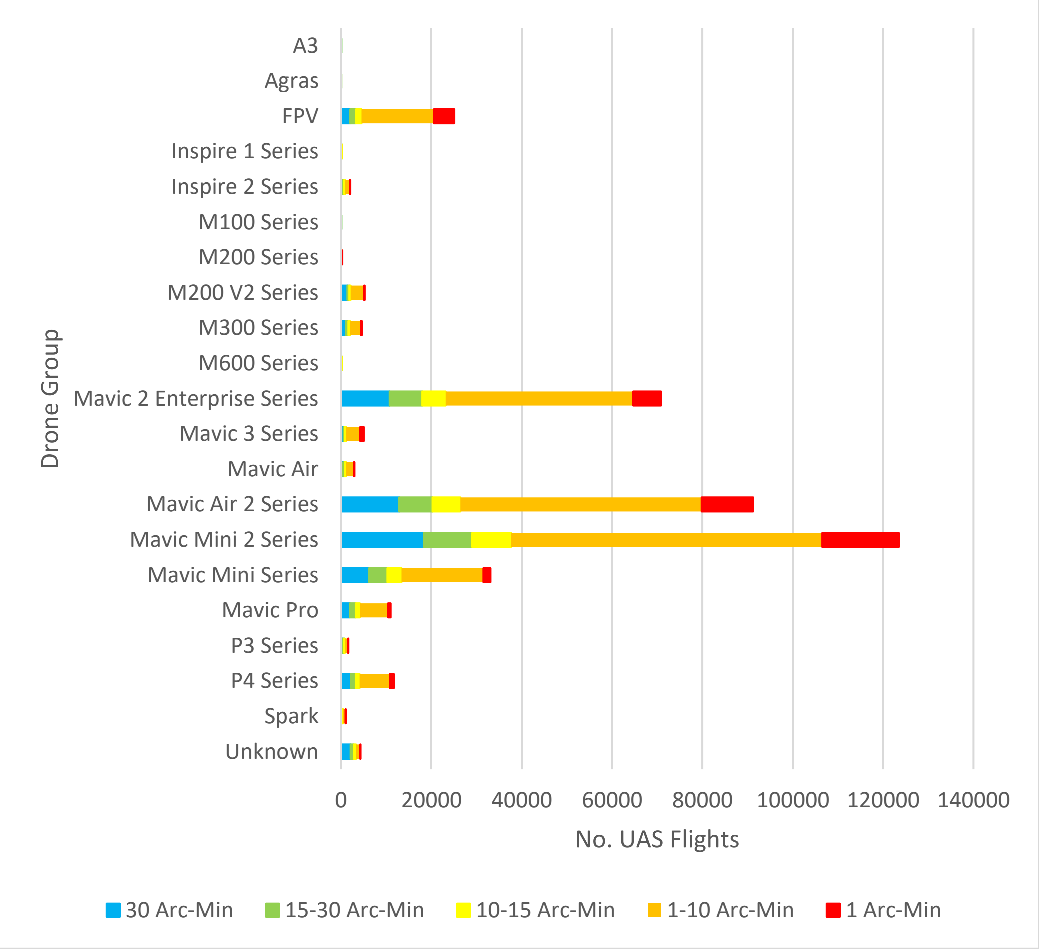


Figure 46. Distribution of sUAS Flights by Visibility Category and sUAS Platform Type (*N*=393,740).

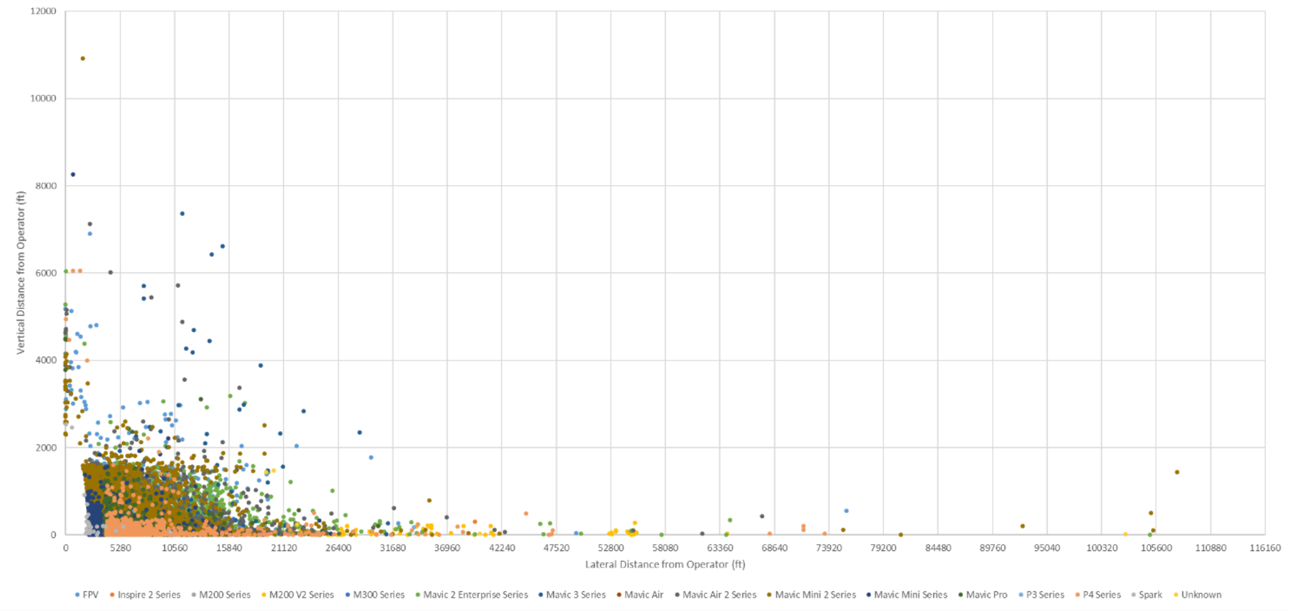


Figure 47. sUAS Beyond Visual Line of Sight (BVLOS) Flights by Platform Type (*n*=43,459).

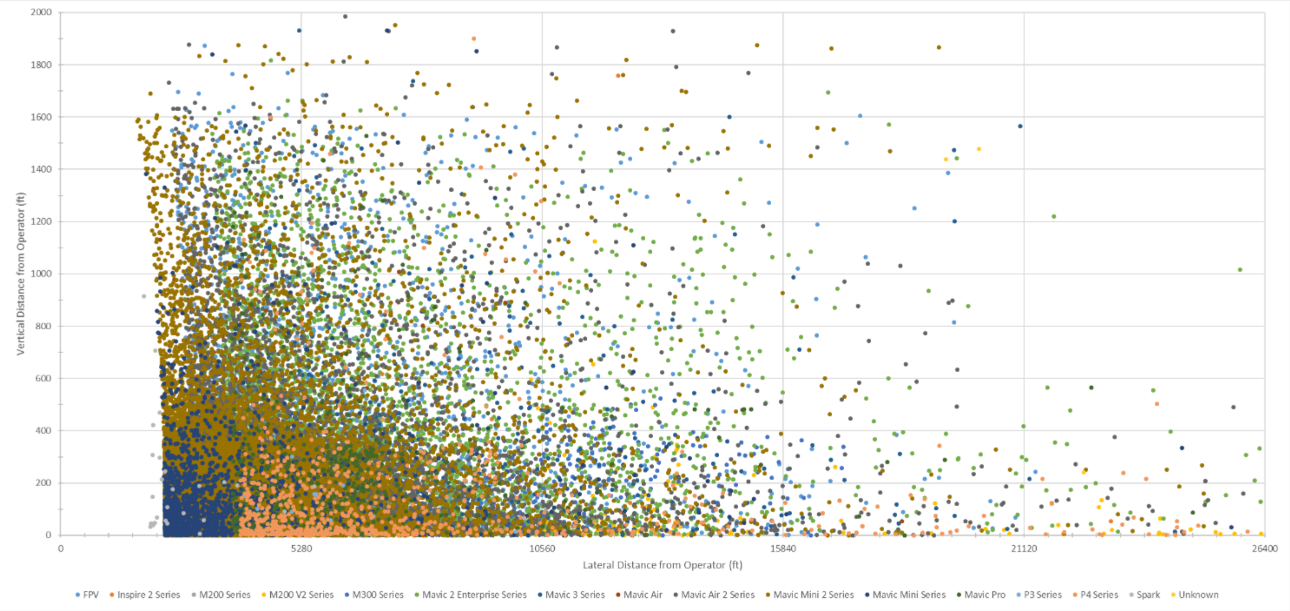


Figure 48. sUAS BVLOS Flights by Platform Type (<2,000 ft Vertical, <5 SM Horizontal)(*n*=43,459).

Conclusions: It is possible that some detected visual line of sight exceedances were conducted in accordance with FAA waiver criteria articulated in 14 CFR §107.205(c). According to the FAA, the agency received 4,977 requests to conduct beyond line of sight operations. Of those requests, 499 (10.0%) were withdrawn by the submitter before disposition, 4,157 (83.5%) were disapproved, 64 (1.3%) are pending agency review, and 257 (5.2%) were approved.

Further details and subsequent conclusions regarding VLOS aircraft operation exceedance rates will be presented in future iterations of this report, as additional data, contextual observations, and analysis results become available. Additional sections also featuring research of model classification include Task B.1.3 *Distribution of sUAS Flights by Model Over Time*; Task B.1.5 *Active vs. Inactive sUAS Population*; Task B.1.7 *Flight Durations*; Task B.3 *Where do sUAS fly and at what altitudes are they flying at?*; Task B.4 *Can rough estimates be made regarding sUAS retirement/abandonment rates?*; Task B.6 *What percentage of the detected sUAS population weighs less than 0.55 lbs and is not required to be registered?*; and Task C.1 *What are exceedance rates for Operations from a Moving Vehicle [14 CFR §107.25*]?.

Future Research Recommendations: Future versions of this report may include additional recommendations concerning investigation of VLOS aircraft operation exceedance rates, based upon observation, analysis, or inferences drawn from contextual examination of materials. Such recommendations are intended to support the definition and development of future related research efforts that are beyond the scope of this project.

2.3.4 Task C.4: What are exceedance rates for Operation Near Aircraft (14 CFR §107.37)?

The research team will evaluate the sUAS detection and ADS-B datasets for instances in which sUAS came within proximity of a manned aircraft. The FAA (n.d.b) defines a Near Midair Collision (NMAC) as:

> . . . an incident associated with the operation of an aircraft in which the possibility of a collision occurs as a result of a proximity of less than 500 feet to another aircraft, or a report is received from a pilot or flight crew member stating that a collision hazard existed between two of more aircraft. (p. 1)

The research team will report the number of incidents in which sUAS came within 500 feet of a manned aircraft. The research team will provide a cumulative distribution plot of the closest points of approach for all sUAS-aircraft encounters.

Findings: The research team sampled 10 locations within the dataset for aircraft-sUAS encounters (see Task D.2 for additional information). A total of 237 encounters between aircraft and sUAS were identified within a criterion of 4,000 feet (horizontal), 500 feet (vertical), and 2-seconds (temporal). One of these encounters (.4%) occurred within a horizontal distance of 500 feet and a vertical distance of 100 feet—a breach of adequate separation between the aircraft and sUAS. No collisions between aircraft and sUAS platforms were detected.

Figure 49 shows the distribution of distances of encounters, based on pre-established lateral and vertical buckets. The number of encounters that fall within each encounter bucket diminishes rapidly, as the lateral and vertical confines are constrained. Figure 50 shows the lateral and vertical (absolute value) separation of each encounter at the closest point of approach (CPA). Note the single point in the bottom left portion of the graph, which showed a lateral separation of 462 feet and a vertical separation of 29 feet.

To better understand these encounters, the research team assessed the aircraft heading and plotted the sUAS position at the CPA to determine its relative visual angle and range to the flight deck, shown in Figure 51. Encounters that exceed 30-60 degrees left or right of the aircraft heading are highly unlikely to be spotted by flight deck personnel. Moreover, the research team further assessed each sUAS model type, based on sUAS detection information, and calculated the visual angle that the footprint of the model would have produced at the CPA. Any model that produced a visual angle of less than 1 arc-minute was assessed as unlikely to be seen by the flight crew—these encounters are plotted in orange. Finally, the data was also plotted in the vertical axis to provide an overview of the lateral *and* vertical visual angles produced at the CPA, shown in Figure 52. It is highly unlikely that sUAS encounters at lateral angles of greater than 30-60 degrees, or at vertical angles of greater or less than 20 degrees would be seen by the flight crew.

Using International Civil Aviation Organization (ICAO) ICAO24 codes collected from ADS-B data, the research team validated aircraft information using an ICAO Calculator (Avionics Tools, n.d.) to convert the hex address to the respective N-number. N-number information was then queried in the FAA Aircraft Registration Database to validate the aircraft type (FAA, n.d.a). The research team identified 124 fixed-wing jets, 53 fixed-wing piston aircraft, and 51 helicopters involved in sUAS encounters (see Figure 53). Nine aircraft were of foreign registration and could not be identified.

To provide further contextual information for encounters, the research team assessed the closest point of approach of each sUAS and corrected the reported altitude (typically altitude above homepoint) for elevation at the CPA point to provide true AGL. In most cases, this adjustment was just a few feet. Results are presented in Figure 54. Results indicated that in 73.5% of encounters, the sUAS was at an altitude of less than 400 feet AGL.

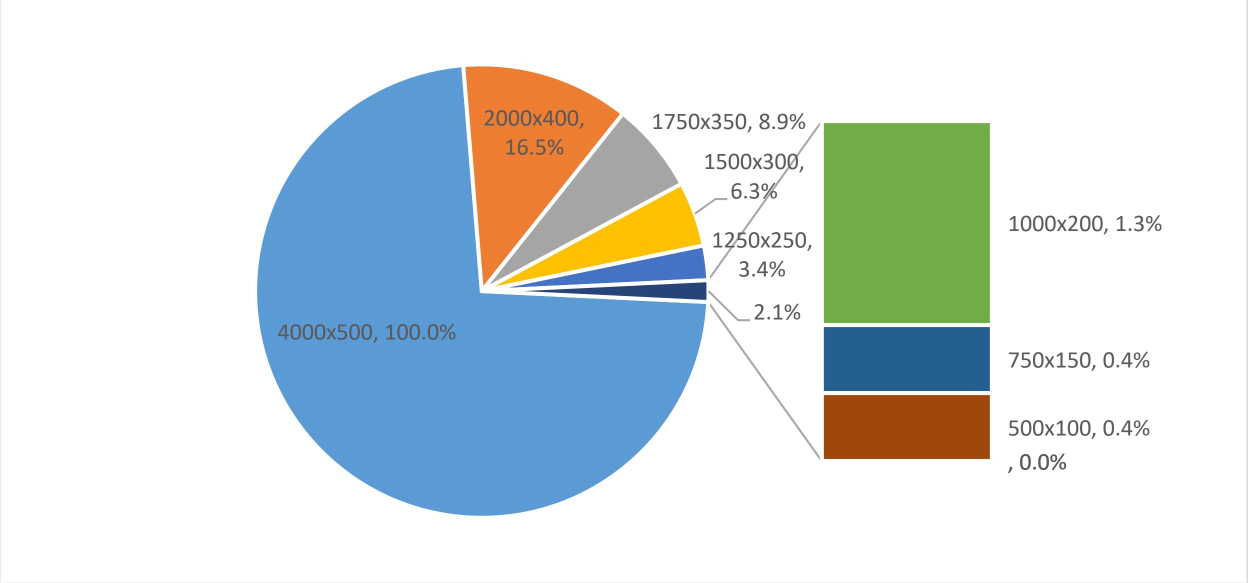


Figure 49. Preliminary Aircraft-sUAS Encounter Distance Distributions (*n*=325).

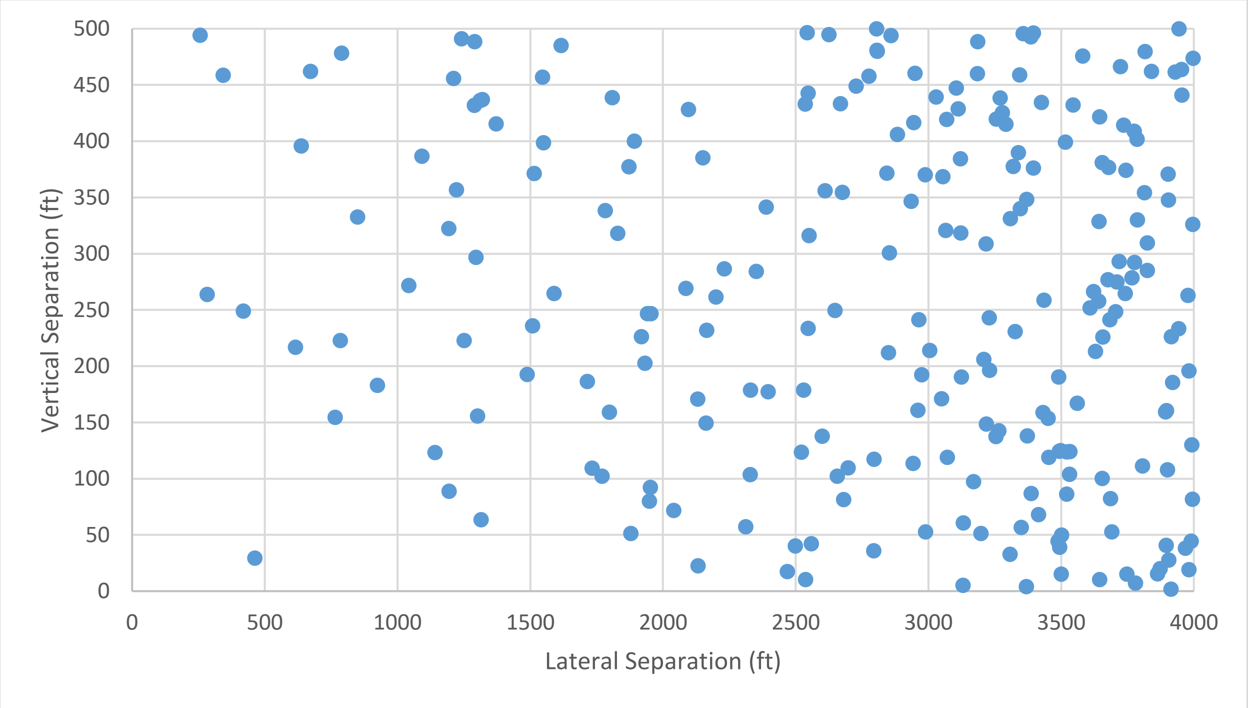


Figure 50. Aircraft-sUAS Encounters Separation Distances (*n*=325, 10 areas, 4,000' lat/500' vert/2s, Jul 2021-Jan 2022).

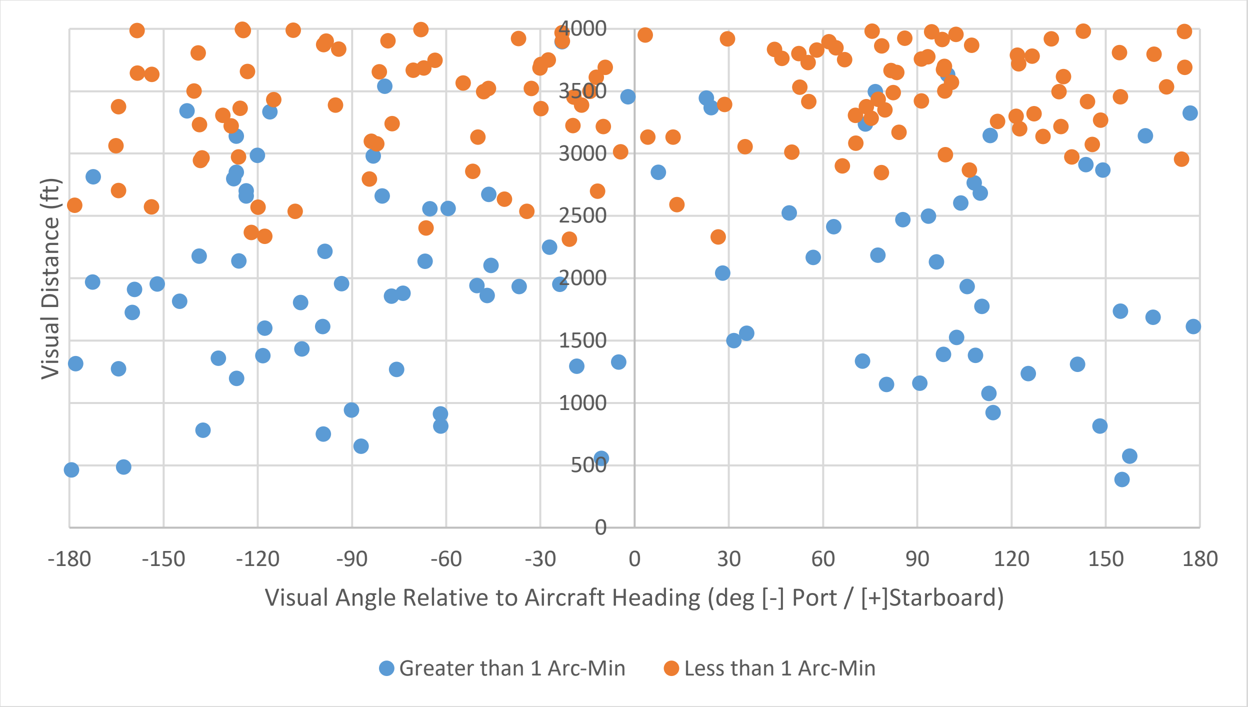


Figure 51. Relative Aircraft-sUAS Encounter Visual Angle, Range, and Estimated Visibility of sUAS.

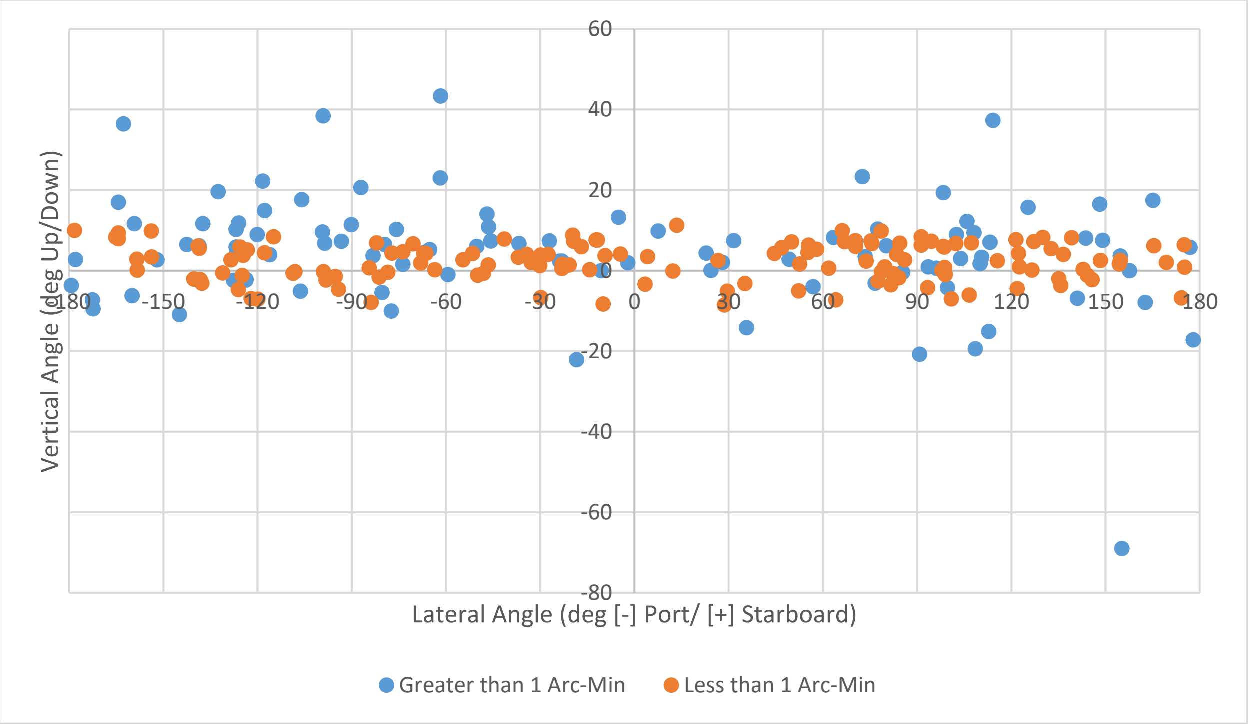


Figure 52. Relative Aircraft-sUAS Encounter Lateral & Vertical Visual Angles and Estimated Visibility of sUAS.

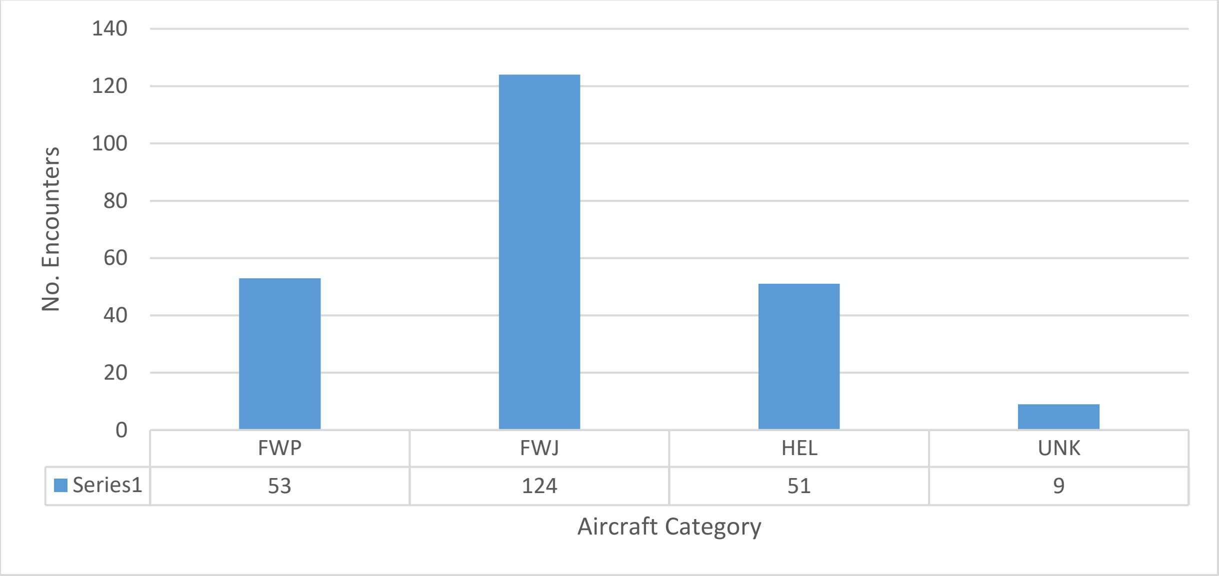


Figure 53. Aircraft-sUAS Encounters by Aircraft Category (*n*=237).

Note: Aircraft Categories include Fixed-Wing, Piston (FWP); Fixed-Wing, Jet (FWJ); Helicopter (HEL), and Unknown (UNK).

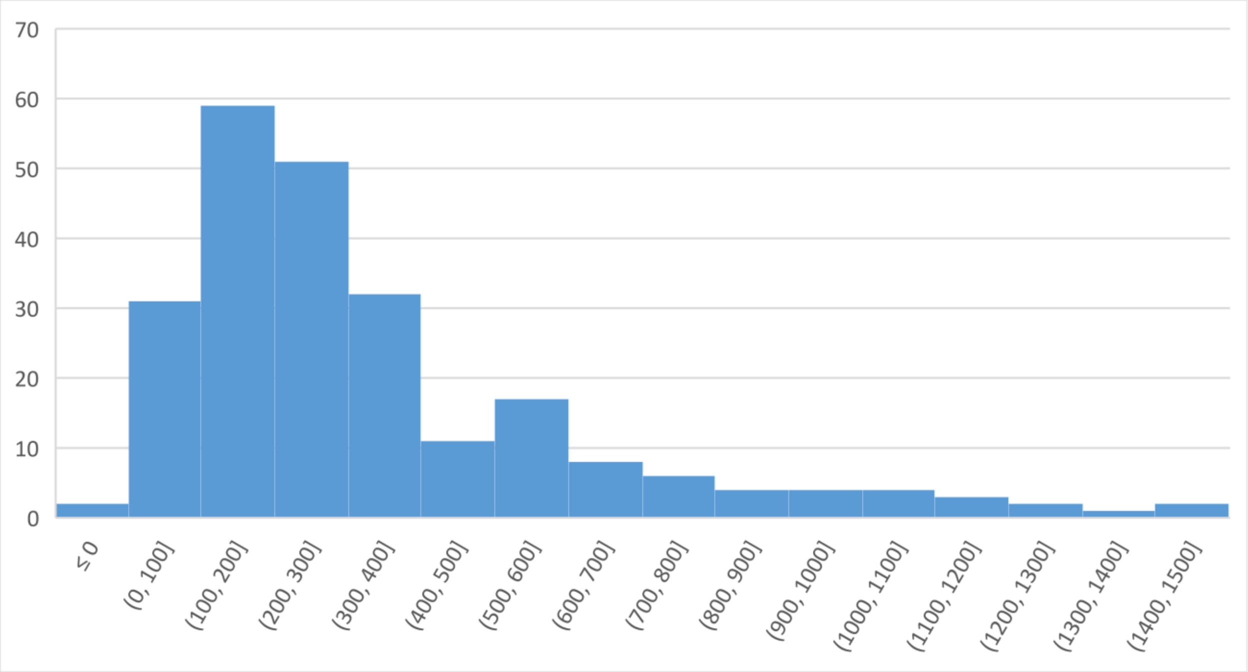


Figure 54. Distribution of Aircraft-sUAS Encounters sUAS Altitudes at Closest Point of Approach Corrected for AGL.

Discussion: The research team carefully considered encounter data and assessed several considerations as to why such encounters were occurring:

UAS Considerations

14 CFR §91.113 requires all aircraft operators to maintain vigilance so as to see and avoid other aircraft and obstacles to maintain safety of flight. 14 CFR §91.113 also establishes right-of-way rules for maintaining well clear of other aircraft. Studies have shown, however, that visually acquiring sUAS from manned aircraft cockpits is difficult (Wallace et al, 2019).

Low Altitude Authorization and Notification Capability

The LAANC system was established as a collaboration between the FAA and the sUAS industry to support sUAS integration into controlled airspace. It serves the purpose of permitting licensed remote pilots access to approved altitudes in controlled airspace. This capability enables awareness for remote pilots as to where they are allowed to operate for the times and locations reserved in the LAANC system. Air Traffic Services (ATS) are also able to retain that same visibility to where drones may operate in their airspace. Unfortunately, LAANC data is not directly available to manned aviation, and they must rely on ATS to provide that feedback. Right of way rules still apply when a remote pilot secures a LAANC authorization no matter what altitude was approved through the system.

In Joint Order 7210.3 (FAA, 2021c) Section 9, there is a requirement for further coordination by ATC when a LAANC request is above an altitude limit from the facility map, shown in Figure 55. This generates a manual approval process as opposed to automatic if the request is below the posted altitude. Mitigations are determined by air traffic control whether acceptable or not and if approved, it is then up to ATC to communicate to manned traffic. Further, the policy states “the ATM or designee will periodically review LAANC to maintain situational awareness of sUAS activity in their airspace” (FAA, 2021c, p. 12-9-5(d)) An ATC tower can determine approved LAANC authorizations in their airspace if they log-in to their portal (laanc-atc.gaa.gov and use their secure access) which they are directed to do (periodically), or if they manually approved a request that was above posted LAANC altitudes, which is a prescribed process.

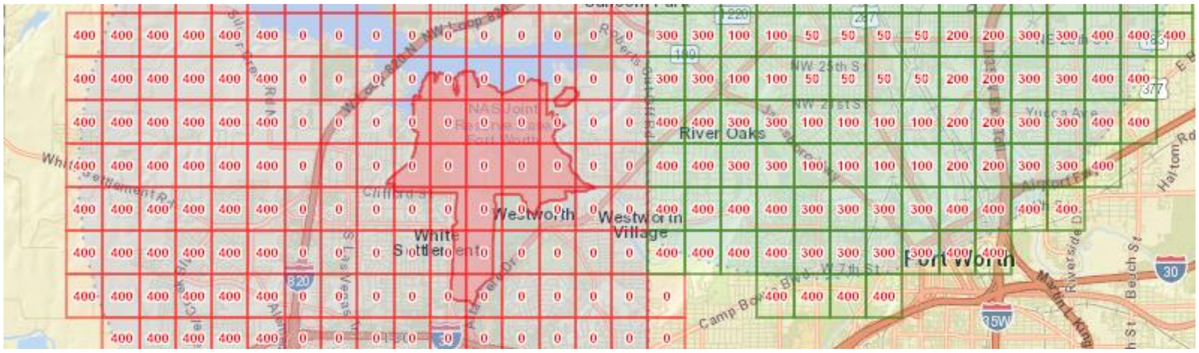


Figure 55. Low Altitude Authorization and Notification Capability UASFM Grid near Fort Worth, Texas.

Note. Red indicates military facility, green indicates civil facility. The altitudes showing each block indicate the maximum altitude allowed in that sector.

There are a number of assumptions in the policy. Interestingly, “When a UA operation has been approved, the affected facilities will receive an email that will include the responsible person’s contact information, location, altitude, time and date of UA operation” (FAA, 2021c, p.

12-10-3(i)). With this in mind, there does not appear to be a policy that directs communicating UAS operations within a portion of their controlled airspace. Air traffic control is directed to use their best judgement about communicating to manned traffic as to the proximity of a potential encounter.

Fixed-Wing Considerations

Fixed-wing operations include commercial, military, and general aviation operations. Commercial operations generally involve predictable operations between commercial service airports, with minimal time spent at low-level, and low-level operations confined to the airport terminal area. Commercial aircraft almost all fly in airspace in which ADS-B out is required. Hence, almost all commercial traffic is captured with ADS-B tracking, and any aircraft or UAS equipped with ADS-B in will be able to detect commercial aircraft.

Military operations include a much wider variety of flight profiles. Fixed-wing military operations may include point-to-point operations similar to commercial aircraft, or may include low level visual and instrument training, aerobatics, aerial refueling, or formation flying. Military operations can occur at almost any altitude or airspeed, although operations including low level flight or maneuvering generally occur within designated airspace, such as military training routes, alert areas, Military Operating Areas (MOAs), or restricted areas. Except for restricted areas, these designated airspace areas are open to other manned or unmanned traffic who may or may not be communicating with air traffic control, and may or may not be equipped with ADS-B.

General aviation encompasses essentially any other crewed aircraft operations that are not commercial or military. General aviation includes, but is not limited to:

- Business aviation
- Agricultural operations
- Air ambulance
- Search and rescue
- Flight training
- Banner towing
- Sightseeing
- Aerial firefighting
- Skydiving
- Recreation

General aviation aircraft may or may not be equipped with ADS-B out, depending upon the airspace in which they operate or whether they have an exemption. Business aircraft operations generally follow the same flight profiles as commercial aircraft, though from a wider variety of airports, including airports in Class E or G airspace. Business aircraft can range in size and speed from small four-seat aircraft operating below 10,000 feet and 200 knots to larger jet aircraft that routinely operate above Flight Level (FL) 400 and .8 Mach. While low level business operations are generally confined to the airport terminal environment, other general aviation operations can occur at low level in areas not near an airport.

Fixed wing aircraft are most vulnerable at low speeds and low altitudes, including departure and arrival, for several reasons: low speed limits aircraft maneuverability; low altitude also limits aircraft maneuverability; departure and arrival are typically busy times in the cockpit, with attention divided between numerous tasks. In terms of physical vulnerability, sensors, leading edge surfaces, and propulsion systems such as propeller arcs and fan blades are vulnerable to foreign object damage.

Visual vs. Electronic Scanning

The advent of ADS-B and portable electronic devices has transformed the way fixed-wing pilots approach the requirement to see and avoid. At very low cost, a general aviation pilot can now have electronic situation awareness of other ADS-B equipped traffic that previously was the province of only TCAS-equipped commercial aircraft. With a tablet, an app, and a portable receiver, general aviation pilots can know the callsign, heading, and altitude of any nearby transmitting aircraft. Looking out the window may now actually be a far less safe and effective way to identify what traffic may become a conflict, though looking out the window remains the best way to avoid a conflict once the location of the other aircraft is known in general terms. The functional implication of this change is that while pilots always divided their attention between inside the cockpit (flight instruments) and outside the cockpit (traffic and clouds), their attention is now generally divided a third way to electronic devices that show traffic. This is not necessarily less safe, as the electronic devices may actually provide better situation awareness regarding ADS-B traffic than looking out the window, but it is a factor that must be considered when factoring in how much time an average fixed wing pilot spends scanning out the window. While most sUAS will soon be required to transmit Remote ID information, there is no requirement for crewed aircraft to receive these signals. Further, sUAS are not permitted to transmit ADS-B signals. Therefore, pilots who have become accustomed to relying on electronic conspicuity as a part of their traffic awareness do not have that advantage when it comes to spotting sUAS.

Rotary-Wing Considerations

The versatility of the helicopter allows them to land wherever there is room to safely approach and touchdown horizontally, or vertically. This may occur in urban, suburban, or rural locations and away from (off-site) a published aviation facility (airport or vertiport). In many cases, there is no public declaration required prior to landing at off-site locations. Flight safety in these cases then becomes the sole responsibility of the crewmembers on board. Hazards include natural or manmade obstacles that may or may not be completely attached to the ground (birds, wires, bridges, manned and UA). The helicopter specific narrative in the sections below is an attempt to apply context to the data found in Table 15.

Traditional flight profiles for helicopter operators will vary but are generally going to fly at low levels (1000 feet AGL and below) at certain times depending on a number of factors. 14 CFR §91.119(d) directs aircrews to determine their level of safety when they plan on operating below §91.119(b)(c) altitudes unless on a prescribed flight route/altitude. Agriculture flights under 14 CFR §137.49, are allowed below 500’ AGL even over congested areas, though only when involved in dispensing operations. Most critically, helicopter pilots must have the awareness of many factors (natural and manmade) when considering which altitude to fly at to maintain both obstacle avoidance and auto-rotational performance.

Flight Training. Training aircraft will generally stay at traffic pattern altitudes (1000’ AGL and above) unless purposefully training at low levels, and this normally occurs in specific (sometimes via NOTAM), and generally more rural locations. In recent years, the helicopter industry has promoted helicopter flights to remain above 2000 feet AGL for both noise abatement and flight safety in the event of an engine failure in order to identify a landing spot to maneuver and land safely in an auto-rotative state. Class D airports are predominant locations for helicopter flight training.

Public Safety Aviation. Flights that remain below 1000 feet AGL may include some type of public safety operators (law enforcement, helicopter air ambulance [HAA], and firefighting). Law enforcement may require lower altitudes during certain mission sets due (SWAT, pursuit) to visual acquisition needs. HAA operations when not operating from published facilities (airports, vertiports, or hospital helipads), often land on streets, highways, next to roads, or paved areas such as parking lots; wherever there is a safe location to land near the scene of an emergency exists will be a potential landing zone. Firefighting helicopters will mostly remain at low levels while conducting operations depending on the location of the fires and other assets involved. The conditions present also dictate altitudes to be flown as environmental (density altitudes, visibility) and performance (MTOW) conditions will limit maneuverability. PSA aircraft fly in controlled and uncontrolled airspaces somewhat equally.

Commercial Operations. There are a number of variables that will keep a commercial helicopter below 1000 feet AGL in a congested environment (built-up areas). These may be affiliated with construction, inspections, newsgathering, infrastructure servicing, etc. In more rural locations, precision agriculture, animal management, infrastructure inspections/servicing, etc. are normal types of operations. Transitional flight (between takeoffs and landings) profiles in more rural locations may or may not include flight above 1000 feet AGL. While this observation is true of most operations, some operations, like Helicopter Emergency Medical Services (HEMS), may operate and much lower altitudes.

Table 15. Typical Helicopter Mission Profile Flight Altitudes.

Mission Set	Enroute	On-Site
Construction	IAW § 91.119	Generally Shielded
Inspections	IAW § 91.119	Generally Shielded
Newsgathering	IAW § 91.119	Generally flying straight and level or enter a circuit at an altitude that enables transmission to station
Infrastructure Servicing	IAW § 91.119	Generally Shielded
Law Enforcement Pursuit	IAW § 91.119	Vertical volume (>500' up to enroute)
Law Enforcement SWAT	IAW § 91.119	Pinpoint landings with steep approaches and takeoffs
Air Ambulance	IAW § 91.119	Pinpoint landings with steeper approaches and takeoffs
Firefighting	IAW § 91.119	NOTAM'd vertical volume with possible corridors
Precision Agriculture (Spraying/Pollination)	IAW § 137.49	<100'
Precision Agriculture (Animal Mustering)	IAW § 137.49	<100'
Precision Agriculture (Animal Survey)	IAW § 137.49	Sensor dependent. Higher altitudes preferred

Notes. These profiles are generally aligned with flight doctrine used in each mission set. Weather, terrain, airspace factors and obstacles can modify these profile configurations. Transitions between enroute and mission site flight profiles may place unmanned and manned platforms in potential conflict. See notes above regarding enroute considerations.

Takeoff/landing Configurations. The helicopter is most vulnerable in takeoff and landing situations. Takeoffs are sometimes the most dangerous conditions as performance limitations reside with the biggest power limits due to power-to-thrust ratios hampered by weight at initial takeoff (fuel and cargo).

Tail Rotor/Main Rotor. Impacts of UAS with helicopter main rotors have been non-catastrophic in most recent examples, however, these collisions were with sizeable rotors containing significant inertia. Tail rotors are another subject, however, and are more susceptible to significant damage due to their size and performance characteristics. The most vulnerable times are during takeoff and landing profiles.

Contributing Factors. The following conditions or flight profiles will affect helicopter vulnerability as a layered factor to low-level operations.

Visibility (haze/fog/precipitation). reaction times are reduced, instigating reaction to a rapid encounter and could cause loss of control and subsequent contact with a manmade/natural object, or loss of orientation, leading to a loss of controlled flight.

Masking. Low-level hovering or slow flight may place a helicopter behind a natural/manmade obstacle (masked) and a sudden reaction on encountering a drone could cause loss of control and/or subsequent contact with a manmade/natural object.

Light conditions (sunlight). sun glare during flight at low and slow conditions can mask observation of a UAS encounter. This may cause a sudden loss of control and/or subsequent contact with a manmade/natural object.

Defensive Capabilities

Visual Acquisition. Aviation doctrine (FAA-H-8083-21A and FAA-H-8083-25B) address pilot visual techniques for scans during low-level flights. Aircrew will scan more aggressively at low levels where there are more threats, as opposed to straight and level flight at a higher altitude. It must be noted that a helicopter crew flying at any altitude is always identifying emergency landing locations for an auto-rotative flight profile. In these cases, the pilot flying is dividing attention off the nose of the aircraft, glancing down for landing zones, and to the instrument panel. In that scan, distances within 4000' may or may not enable acquiring a drone in flight.

Depending on the availability of somewhat safe, unencumbered, linear or vertical landing areas, aircrew will have this additional, necessary, and continuous distraction. In an enroute segment of the flight, the aircrew will fly at higher altitudes, and a scan might be narrower than at lower/slower profiles. At lower altitudes and slower airspeeds, aircrew would realistically be scanning for birds, drones, trees, poles, towers, wires, and other protruding natural or manmade objects.

Depending on a number of factors, aircrew in descent to landing will begin a broader scan, and transitions in and out of the aircraft become more rapid as performance issues require more attention than at altitude. As landing sites can also be within an area confined by natural and manmade objects, aircrews are trained to circle the landing site as a safety reconnaissance observation and are at these times primarily focused on the landing area and around the area. At slower airspeeds, helicopter pilots may successfully acquire a drone below them; however, if the drone is not moving in their field of view, it is much harder to acquire.

Aircrew Coordination. In situations where there are at least two rated or trained aircrew in front, and/or one or more aft, the crew traditionally coordinates conditions where eyes are outside the aircraft or required by duties to be inside the aircraft. This coordination helps solidify times where the aircraft is most vulnerable and has the most crew attention possible. This is typically at takeoff, landing, and low and slow situations. Aircrew would typically be assigned sectors outside the aircraft. The fewer the available crew, the more challenging the ability to acquire other threats becomes.

Systems. Sensor systems on helicopters capable of detecting birds or drones are not well developed, widely available, nor affordable in their current state.

Conclusions: The research team is not prepared to make preliminary conclusions regarding this task at this time. Further details and subsequent conclusions regarding operation near aircraft exceedance rates will be presented in future iterations of this report, as additional data, contextual observations, and analysis results become available.

Future Research Recommendations: Future versions of this report may include additional recommendations concerning investigation of operation near aircraft exceedance rates, based upon observation, analysis, or inferences drawn from contextual examination of materials.

Such recommendations are intended to support the definition and development of future related research efforts that are beyond the scope of this project.

2.3.5 Task C.5: What are exceedance rates for Operation Over Human Beings (14 CFR §107.39)?

Leveraging static population density data, the research team will attempt to codify the potential risk posed by sUAS operations over human beings. While population density does not provide a direct measurement of exceedance criteria for this research question, there is very little dynamic data available. The research team will provide a census of sUAS activity within various population density categories, based on available GIS census data.

Additionally, the research team will attempt to codify flights that present a *likely potential* to involve flight over unprotected (i.e., not in a vehicle or structure) human beings, based on operating location derived from Task A.3. Specific areas of interest include stadiums, parks or recreation areas, and parking lots. Other areas of interest may be explored based on further FAA guidance.

In January 2021, the Federal Aviation Administration released new rulemaking regarding sUAS flight over people. Codified in 14 C.F.R. §107.39 and 14 C.F.R. §107, Subpart D, the rule states (FAA, 2020b):

- **14 C.F.R.** §**107.39:** No one may operate a sUAS over a human being unless (1) the human being is directly participating in the operation of the sUAS; (2) the human being is located under a covered structure or inside a stationary vehicle that can provide reasonable protection from a falling sUAS; or (3) the operation meet the requirements of at least one of the operation categories specified in subpart D of this part [Operation Over Human Beings].
- **14 CFR 107, Subpart D, Operation Over Human Beings.** The rule establishes four new categories of small unmanned aircraft for routine operations over people: Category 1, Category 2, Category 3, and Category 4. The rule also allows for routine operations over moving vehicles.
  - **Category 1:** eligible small unmanned aircraft must weigh less than 0.55, including everything on board or otherwise attached, and contain no exposed rotating parts that would lacerate human skin. No FAA-accepted Means of Compliance (MOC) or Declaration of Compliance (DOC) required. Remote pilots are prohibited from operating a small unmanned aircraft as a Category 1 operation in sustained flight over open-air assemblies unless the operation meets the requirements for standard remote identification or remote identification broadcast modules established in the Remote ID Final Rule.
  - **Category 2:** eligible small unmanned aircraft must not cause injury to a human being that is equivalent to or greater than the severity of injury caused by a transfer of 11 foot-pounds of kinetic energy upon impact from a rigid object, does not contain any exposed rotating parts that could lacerate human skin upon impact with a human being, and does not contain any safety defects. Requires FAA-accepted means of compliance and FAA-accepted declaration of compliance. Remote pilots

are prohibited from operating a small unmanned aircraft as a Category 2 operation in sustained flight over open-air assemblies unless the operation meets the requirements for standard remote identification or remote identification broadcast modules established in the Remote ID Final Rule.

- **Category 3:** eligible small unmanned aircraft must not cause injury to a human being that is equivalent to or greater than the severity of injury caused by a transfer of 25 foot-pounds of kinetic energy upon impact from a rigid object, does not contain any exposed rotating parts that could lacerate human skin upon impact with a human being, and does not contain any safety defects. Requires FAA-accepted means of compliance and FAA-accepted declaration of compliance. Must not operate the small unmanned aircraft over open-air assemblies of human beings. May only operate the small unmanned aircraft above any human being if operation meets one of the following conditions: (1) The operation is within or over a closed- or restricted-access site and all human beings located within the closed- or restricted-access site must be on notice that a small unmanned aircraft may fly over them, or (2) The small unmanned aircraft does not maintain sustained flight over any human being unless that human being is directly participating in the operation of the small unmanned aircraft; or located under a covered structure or inside a stationary vehicle that can provide reasonable protection from a falling small unmanned aircraft.
- **Category 4:** eligible small unmanned aircraft must have an airworthiness certificate issued under Part 21 of FAA regulations. Must be operated in accordance with the operating limitations specified in the approved Flight Manual or as otherwise specified by the Administrator. The operating limitations must not prohibit operations over human beings. Must have maintenance, preventive maintenance, alterations, or inspections performed in accordance with specific requirements in the final rule.

Findings: Data collection for this task is still underway. Preliminary findings are not available for reporting at this time. Updates on this task will be provided in a subsequent annual report.

Conclusions: Further details and subsequent conclusions regarding operation over human beings exceedance rates will be presented in future iterations of this report, as additional data, contextual observations, and analysis results become available. The resident population values examined in connection with Task B.1 (*What are current sUAS traffic attributes over urban areas?*) will be used to corroborate population density and may, subsequently, offer additional insight and findings to help with the investigation and analysis of this task.

Future Research Recommendations: Future versions of this report may include additional recommendations concerning investigation of operation over human beings exceedance rates, based upon observation, analysis, or inferences drawn from contextual examination of materials. Such recommendations are intended to support the definition and development of future related research efforts that are beyond the scope of this project.

2.3.6 Task C.6: What are exceedance rates for Operating Limitations for sUAS (14 CFR §107.51)?

The objective of this research task is to evaluate for potential exceedances of sUAS operating limitations associated with 14 CFR §107.51 operational flight restrictions, including: speed, altitude, and visibility/cloud clearance limits.

2.3.6.1 Task C.6.1 Speed Limitations

The research team will determine the maximum instantaneous sUAS speed (mph) for each flight and create a stacked bar chart showing the flight count distribution by the model, as shown in Figure 56. Distribution of sUAS Speed by Model Category.. Additionally, cumulative distribution of maximum instantaneous speeds will be generated for all models.

Findings: Only 28.8% (*n*=135,819) flights contained adequate data to conduct speed sampling. The bulk of sUAS (29.0%) were flown at less than 5 mph, as shown in Figure 56. More than 24.9% of sUAS flights were conducted at speeds between 20-30 mph. More than 97.1% of sUAS flights are conducted at less than 50 mph. Nearly 95% of all sUAS flights detected at speeds above 50 mph were flown by the FPV platform. Only .002% (*n*=3) of all sampled flights—all FPV platforms—were flown at speeds in excess of 100 mph, an exceedance of 14 CFR §107.51(a).

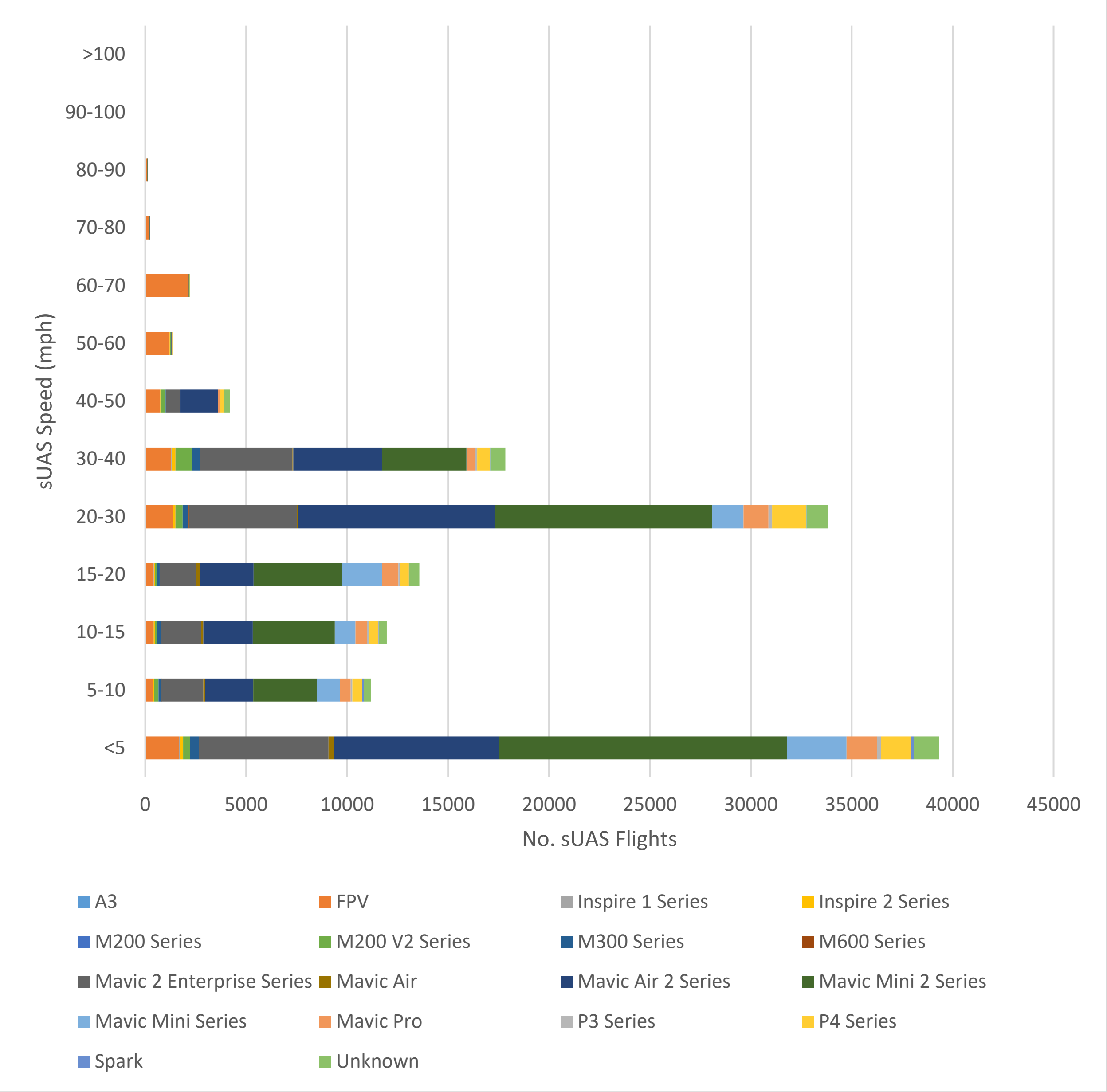


Figure 56. Distribution of sUAS Speed by Model Category.

Conclusions: Further details and subsequent conclusions regarding sUAS speed limitations exceedance rates will be presented in future iterations of this report, as additional data, contextual observations, and analysis results become available.

Future Research Recommendations: Future versions of this report may include additional recommendations concerning investigation of sUAS speed limitations exceedance rates, based upon observation, analysis, or inferences drawn from contextual examination of materials. Such recommendations are intended to support the definition and development of future related research efforts that are beyond the scope of this project.

2.3.6.2 Task C.6.2 Altitude Limitations

sUAS operating altitudes exceeding 400 ft AGL will be reported in Task A.1. This task will focus specifically on evaluating sUAS operations taking place around structures or buildings, as defined in 14 CFR §107.51(b)(1) and (2).

> Many counties or municipalities maintain offices that collect and manage geospatial information. This data is commonly used for assessing floodplains, zoning, emergency resources, critical infrastructure, and related purposes. The research team will request GIS shapefiles or other available data that contains building or structure elevation information. One anticipated challenge for assessing this subtask is the lack of available GIS data containing required elevation information to needed successfully accomplish this task. In the event building elevation data is not available, the research team proposes to utilize available HIFLD GIS tower data, which generally includes tower height information. Specific applicable HIFLD datasets include Cellular Towers, Land Mobile Broadcast Towers, AM Transmission Towers; FM Transmission Towers, Paging Transmission Towers, Land-Mobile Commercial Transmission Towers, and Microwave Service Towers. The research team will assess detected sUAS activity within 400-foot lateral proximity of the respective towers and assess sUAS altitude to determine the number of operations that exceed 400-feet above the maximum tower elevation.

Findings: Data collection for this task is still underway. Preliminary findings are not available for reporting at this time. Updates on this task will be provided in a subsequent annual report.

Conclusions: Further details and subsequent conclusions regarding sUAS altitude limitations exceedance rates will be presented in future iterations of this report, as additional data, contextual observations, and analysis results become available.

Future Research Recommendations: Future versions of this report may include additional recommendations concerning investigation of sUAS altitude limitations exceedance rates, based upon observation, analysis, or inferences drawn from contextual examination of materials. Such recommendations are intended to support the definition and development of future related research efforts that are beyond the scope of this project.

2.3.6.3 Task C.6.3 Visibility & Cloud Clearance

Using the historical ASOS aviation weather information derived from the Iowa State University Environmental MESONET, the research team will assess the following: (1) When sUAS have been operated during timeframes in which visibility was reported at less than 3 SM (14 CFR §107.51(c) exceedance) or (2) When a cloud ceiling is 500 feet or less (14 CFR §107.51(d)(1) exceedance).

Findings: The research team assessed sUAS flight operations that were conducted within 5 miles of an ASOS or AWOS reporting station. Evaluated flights were further limited to those flights that occurred within 5 minutes of a published Meteorological Aerodrome Report (METAR) report. A total of 4,696 flights met criteria for station proximity and temporal limitations to include in the sample. The research team assessed when flights were conducted in reported visibility conditions of less than 3 SM, or when a cloud ceiling (5/8 or greater cloud coverage / Broken or

Overcast) was reported at 500 feet or less. The research identified 38 (.8%) cloud ceiling exceedances, 94 visibility exceedances (2.0%), and 49 (1.0%) exceedances of both ceiling and visibility limits as seen in Figure 57. The mean and median of ceiling and visibility exceedances were found to occur in the morning between 7:00am – 9:00am (local time) as shown in Table 16. The preponderance of visibility exceedances (49.7%, *n*=71) occurred when visual conditions were reported at between 1¾ – 3 miles of visibility as shown in Figure 58.

The majority of cloud clearance exceedances (83.9%, *n*=73) occurred during overcast conditions, with the number of exceedances decreasing with lower reported ceilings, shown in Figure 59. To better understand sUAS operator behavior in varying cloud cover conditions, the research team assessed the sample data for cloud coverage conditions during sUAS flights that did not exceed ceiling limitations, which included 40.2% (*n*=1,888) of the sample data points as seen in Figure 60. The distribution of sUAS flights which did not exceed ceiling regulatory limits is presented in Figure 61. Overall, the vast majority of those flights (29.2%, *n*=551) were carried out with cloud coverage at or above 5,000 feet.

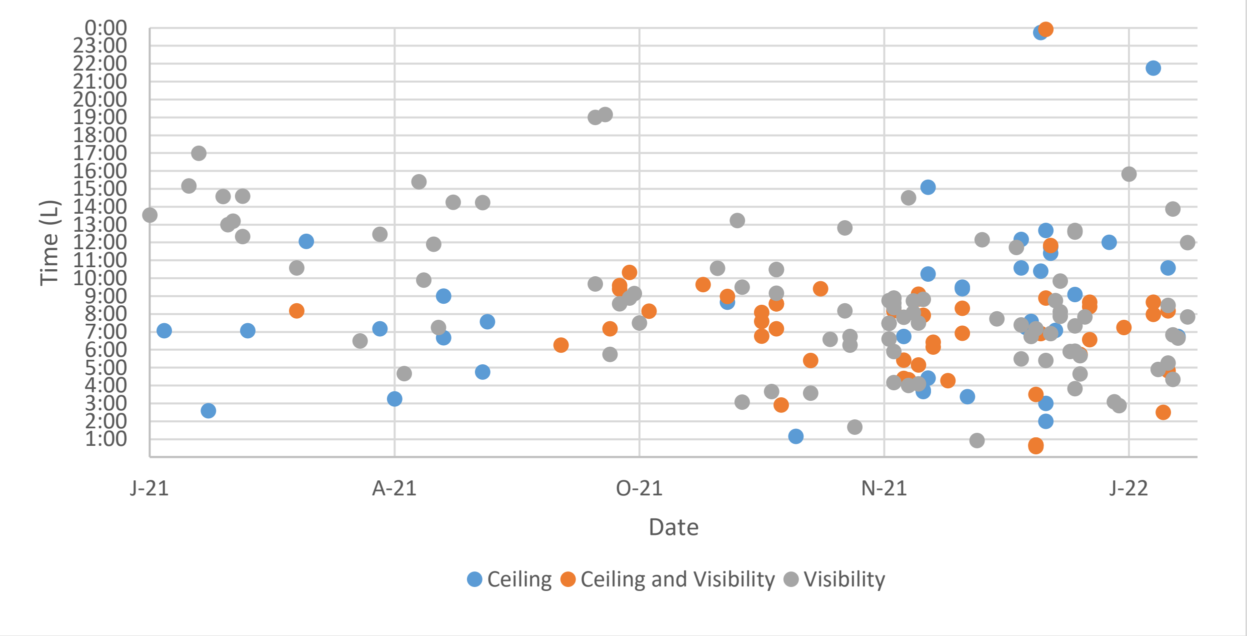


Figure 57. Weather Exceedances by Date, Time & Type (Jul 2021-Jan 2022).

Note: 4,696 flights met criteria for evaluation (within 5 miles of reporting weather station; operation within 5m of published weather report); violations occur when flying in visibility of less than 3 SM or when cloud (ceiling) clearance was less than 500 feet. Ceiling exceedances (38)(.8%); Both ceiling & vis exceedances (49)(1.0%); Visibility exceedances (94)(2.0%).

Table 16. Descriptive Statistics of Ceiling & Visibility Exceedance Times.

	Ceiling	**Visibility**	**Ceiling & Visibility**
Mean	8:29	8:47	7:12
Median	7:34	8:08	7:35

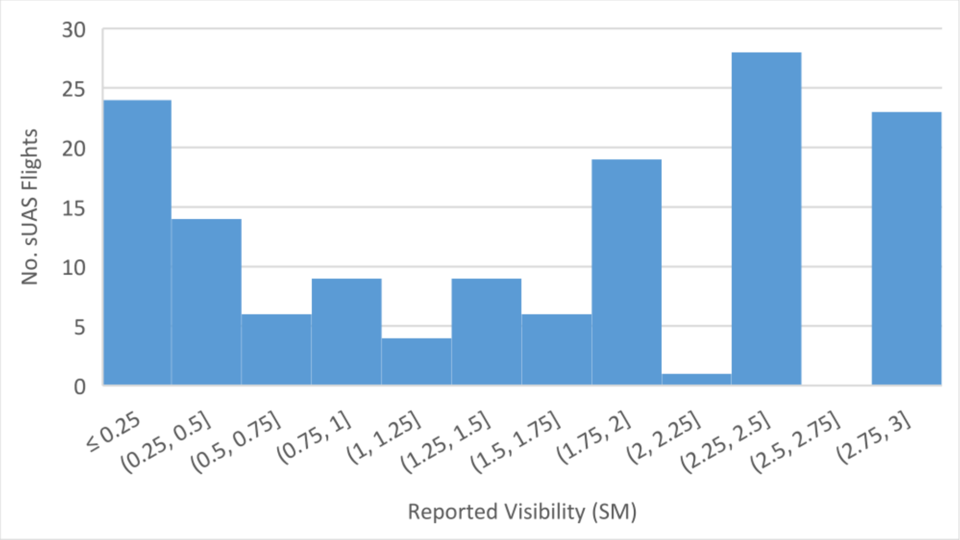


Figure 58. Histogram of sUAS Visibility Exceedances.

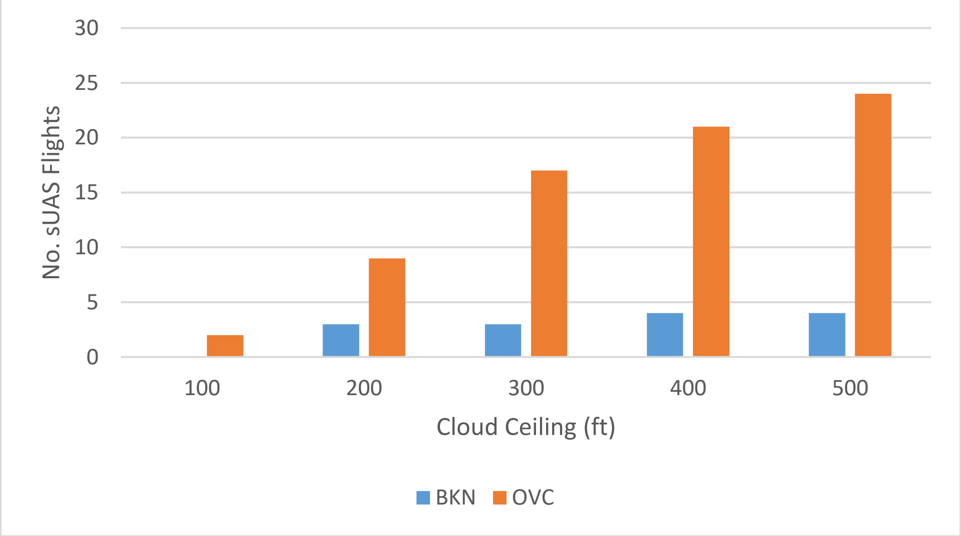


Figure 59. Bar Graph of Cloud Clearance Exceedances by Ceiling Type.

Note: Cloud ceilings indicated by Broken [BKN], 5/8 to 7/8 cloud cover; and Overcast [OVC], 8/8 cloud cover.

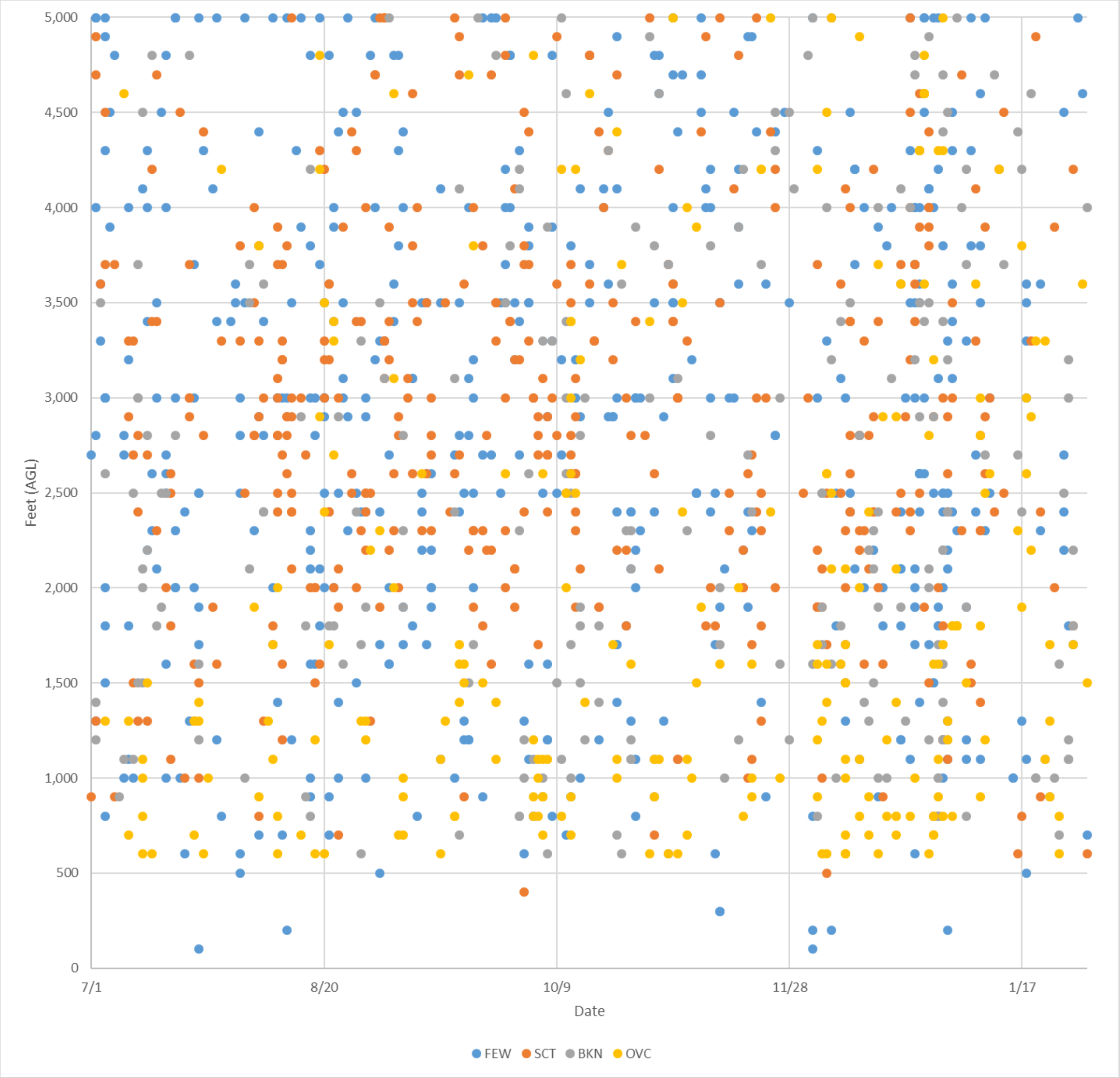


Figure 60. Cloud Ceilings During Compliant sUAS Operations.

Note: Cloud ceilings indicated by Few [FEW], 1/8 to 2/8 cover; Scattered [SCT], 3/8 to 4/8 cover; Broken [BKN], 5/8 to 7/8 cover; and Overcast [OVC], 8/8 cover.

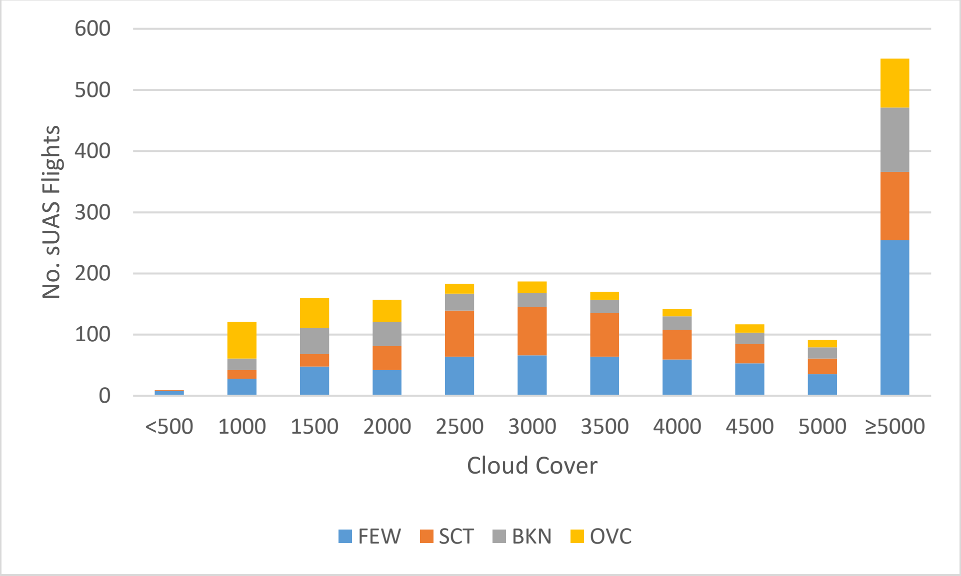


Figure 61. Distribution of Cloud Coverage of sUAS Flights (Excluding Exceedances).

Conclusions: Further details and subsequent conclusions regarding sUAS visibility and cloud clearance limitations exceedance rates will be presented in future iterations of this report, as additional data, contextual observations, and analysis results become available.

Future Research Recommendations: Future versions of this report may include additional recommendations concerning investigation of sUAS visibility and cloud clearance limitations exceedance rates, based upon observation, analysis, or inferences drawn from contextual examination of materials. Such recommendations are intended to support the definition and development of future related research efforts that are beyond the scope of this project.

2.4 Task D: Near Aerodrome sUAS Operations & Encounter Risks with Manned Air Traffic (Performers)

The purpose of this task is to highlight potential risks to aviation operations as a result of sUAS flight around aerodromes and near manned air traffic. This section will also identify potential security challenges posed by sUAS operating in no-fly zones and critical infrastructure.

2.4.1 Task D.1: What is the likelihood of encountering another sUAS during a flight?

The research team performed a spatial and temporal (time) analysis of all sUAS flights within each sampling area to determine occurrences of sUAS operated in simultaneous proximity to each other. According to DJI, the OcuSync 2.0 transmission protocol has a maximum transmission distance of 10,000m (~6.2 SM), with other transmission protocols having lessor transmission ranges of 7,000m (~4.3 SM), 4000m (~2.5 SM), and 2,000m (~1.2 SM). The research team will report the number of sUAS simultaneously operating within 4,000 feet horizontally, 500 feet vertically, and within a temporal space of 60 seconds. Using the various encounter distances, the research team will report an encounter curve based on the respective likelihoods of sUAS encountering other sUAS during flight. The answer to this research question should inform upon both the likelihood of sUAS encounters and assess the potential for datalink transmission interference from nearby sUAS operations.

Findings: The analysis tool calculated Euclidean distance between sUAS flight telemetry from 37 sample areas within the dataset. Those flights that measured within the specified distance criteria were then tested to ensure they fell within the established temporal range. A total of 1,696 drone-drone encounters were discovered within the dataset that fell within the established distance and time criteria (4,000 feet laterally, 500 feet vertically, 60-second temporal separation). Closest point of approach data is provided in Figure 62. Generally, drone-drone encounters tended to demonstrate positive skewness, indicating more drone encounters occurred within the vertical space. This condition may indicate that operators are conducting flights within confined lateral areas, such as a park or other public space. Unlike aircraft-sUAS encounters, drone-drone encounters tended to occur at much closer distances, with almost 77% of the sample (*n*=1,302) coming within a distance of 500 feet horizontally and 100 feet vertically (60s temporal). Additional data is presented in Figure 63.

Initial analysis shows a relatively strong correlation between the number of flights within a particular sample area and the resulting number of encounters, $r(36) = .82$, $p = <.001$. A linear regression was performed to predict the number of encounters from the number of flights within each sample area, $F(1,35) = 73.3$, $p = <.001$, $R^2 = .677$, $R^2_{adjusted} = .668$. The regression coefficient ($B = .008$, 95% CI [.006, .010]) indicated that an increase in one sUAS flight corresponded, on average, to an increase in the number of encounters by .008, shown in Figure 64.

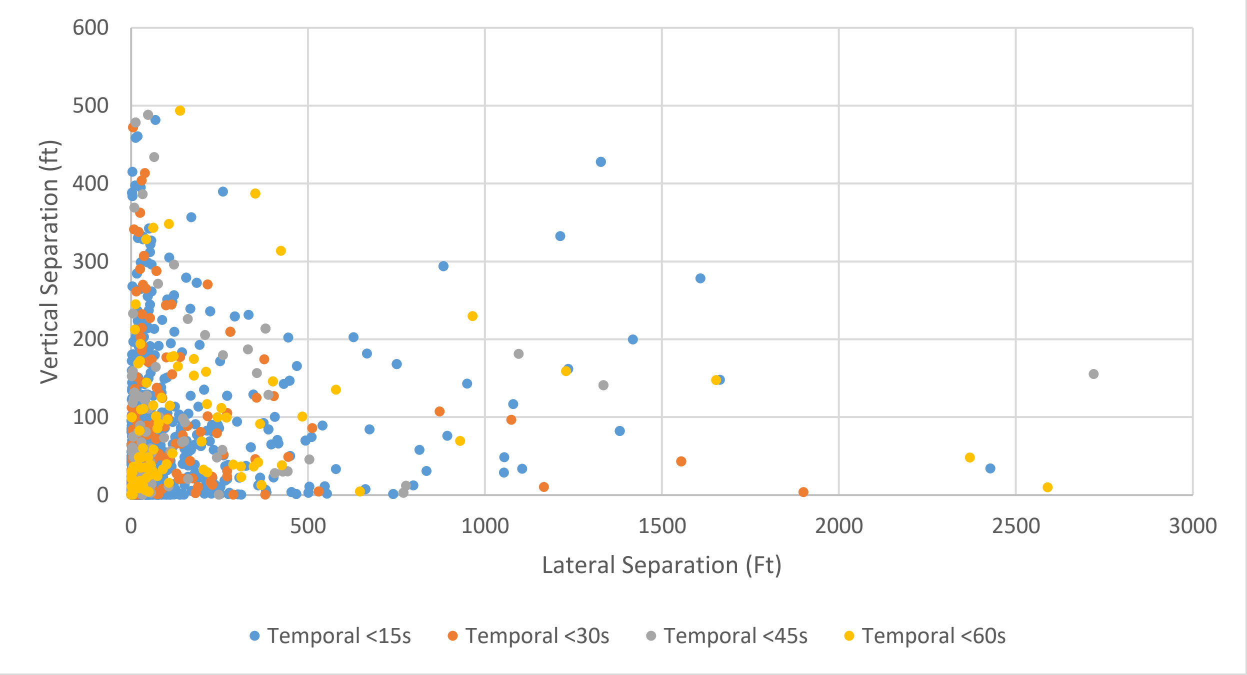
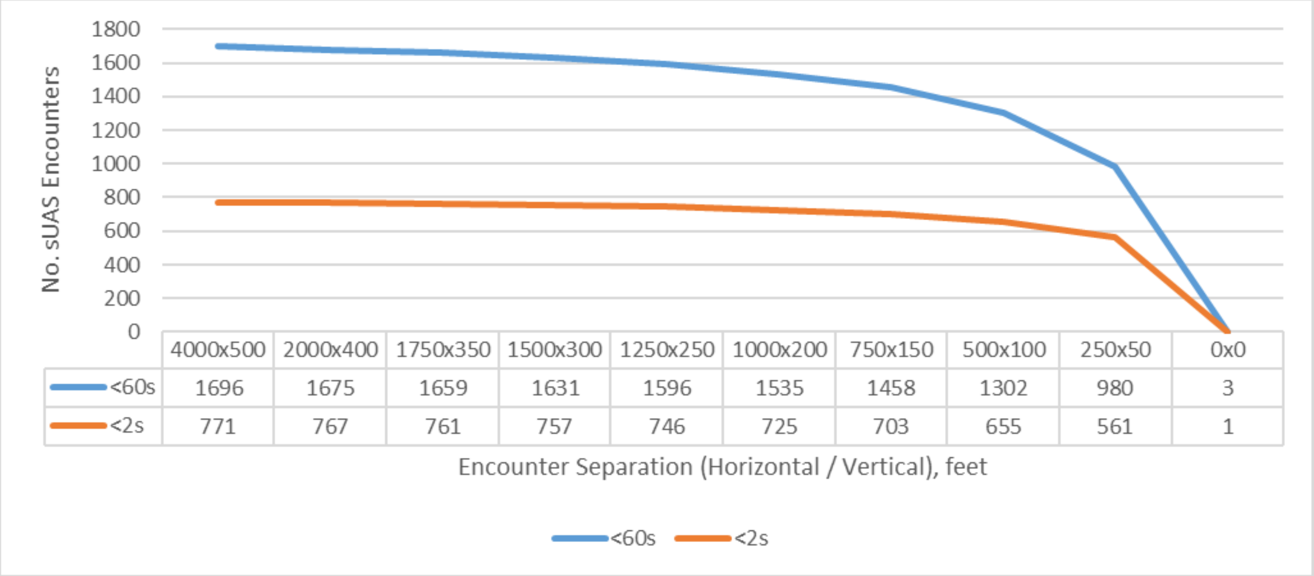


Figure 62. Drone-Drone Encounter Separation Distances (4,000 ft Horizontal/500 ft Vertical, 60s Temporal).



	4000x500	2000x400	1750x350	1500x300	1250x250	1000x200	750x150	500x100	250x50	0x0
<60s	1696	1675	1659	1631	1596	1535	1458	1302	980	3
<2s	771	767	761	757	746	725	703	655	561	1

Figure 63. Distribution of Drone-Drone Encounters (n=1,696, 37 sampling areas).

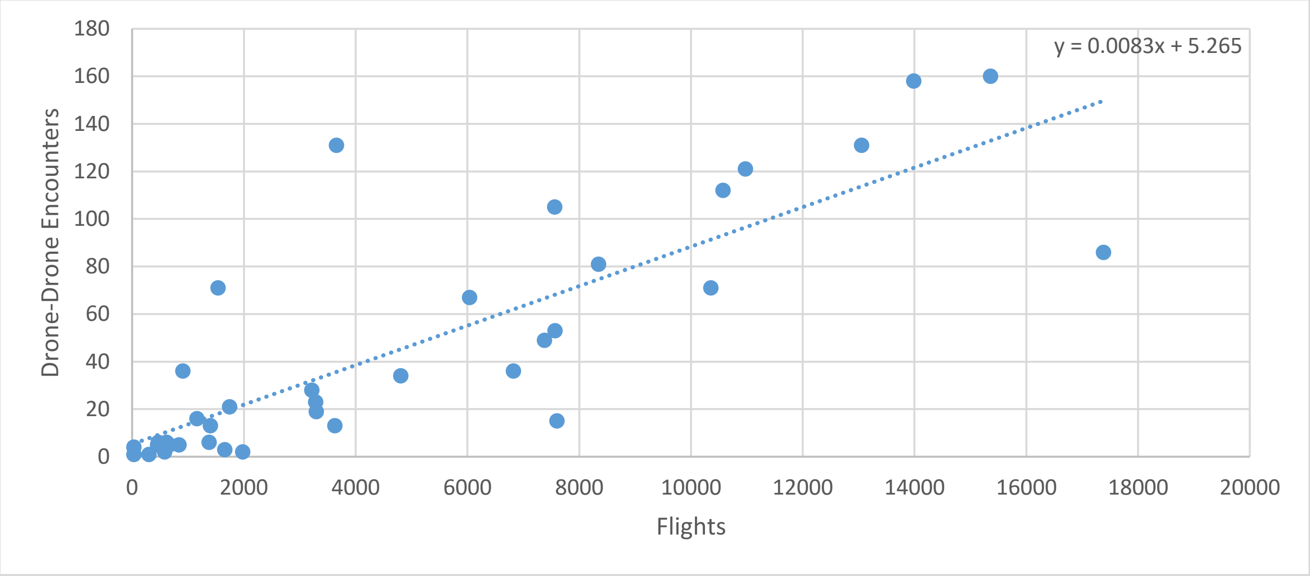


Figure 64. Number of Flights in Each Sample Area Relative to Number of Drone-Drone Encounters.

Conclusions: Further details and subsequent conclusions regarding sUAS operational encounter potential will be presented in future iterations of this report, as additional data, contextual observations, and analysis results become available.

Future Research Recommendations: Future versions of this report may include additional recommendations concerning investigation of sUAS operational encounter potential, based upon observation, analysis, or inferences drawn from contextual examination of materials. Such recommendations are intended to support the definition and development of future related research efforts that are beyond the scope of this project.

2.4.2 Task D.2: What is the likelihood of a low altitude manned aircraft encountering a sUAS during a flight?

Leveraging a similar approach to Tasks C.4 and D.1, the research team will analyze the sUAS detection and ADS-B datasets for near encounters based on several different distance/altitude settings. Analysis distances will begin at 4,000 feet horizontally / 500 feet vertically. This procedure will generate a likelihood of encounter curve, based on the closest points of approach. An execution error resulted in the temporal analysis being conducted using 60 seconds of separation rather than 2 seconds, as used in Task C.4. Future analysis will implement a consistent temporal separation value.

Findings: Encounter results were analyzed from Task C.4. A total of 10 locations were sampled, yielding a total of 237 encounters [within 4,000 feet horizontally, 500 feet vertically, 2s temporal separation] as shown in Table 17. Although it is generally not appropriate to conduct statistical analysis, with only 10 samples, however, the research team wanted to evaluate possible relationships between the number of encounters and other factors, such as the number of recorded aircraft flights, UAS flights, and UAS population within each sample area to see if any patterns began to emerge as seen in Figure 65. The resulting x-y scatterplot did not yield any discernable relationship patterns. A subsequent Pearson Correlation test of the variables all yielded low correlation coefficients.

An encounter curve was produced to show the relativistic drop in the number encounters, based on confining the encounter criteria as shown in Figure 66. While Figure 66 shows the cumulative distribution of aircraft-sUAS encounters, Figure 67 further divides the encounters into their respective sampling areas.

Table 17. Table of Aircraft-sUAS Encounters by Location.

Location	**Encounters**	**AC Flights**	**UAS Flights**	**UAS Population**	**Sample Days**
BatonRouge, LA	4	93	650	175	66
Boston, MA	153	194131	1540	679	179
Brooklyn, NY	76	595438	1660	785	179
Brownsville, TX	33	11244	3627	942	109
Chillicothe, OH	8	35433	527	152	179
Concorde, NH	12	47254	97	41	179
Ferndale, WA	13	90166	398	196	179
Kankakee, IL	2	129102	710	191	179
Sacramento, CA	11	104432	242	137	179
Yuma, AZ	13	6911	3218	729	179

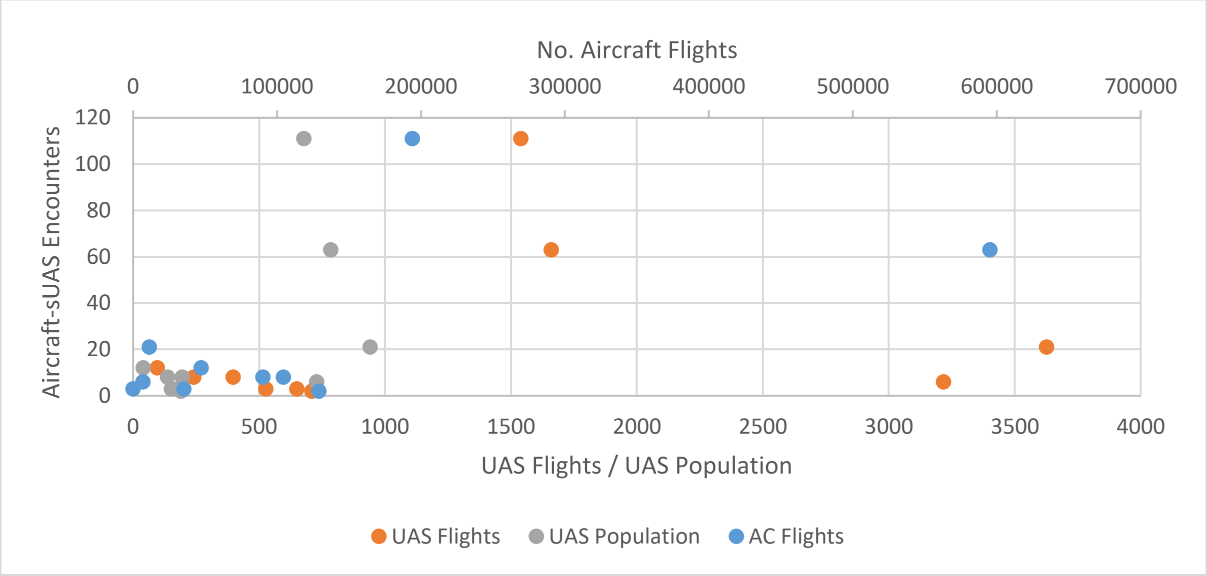


Figure 65. X-Y Scatterplot of Aircraft Encounter Variables.

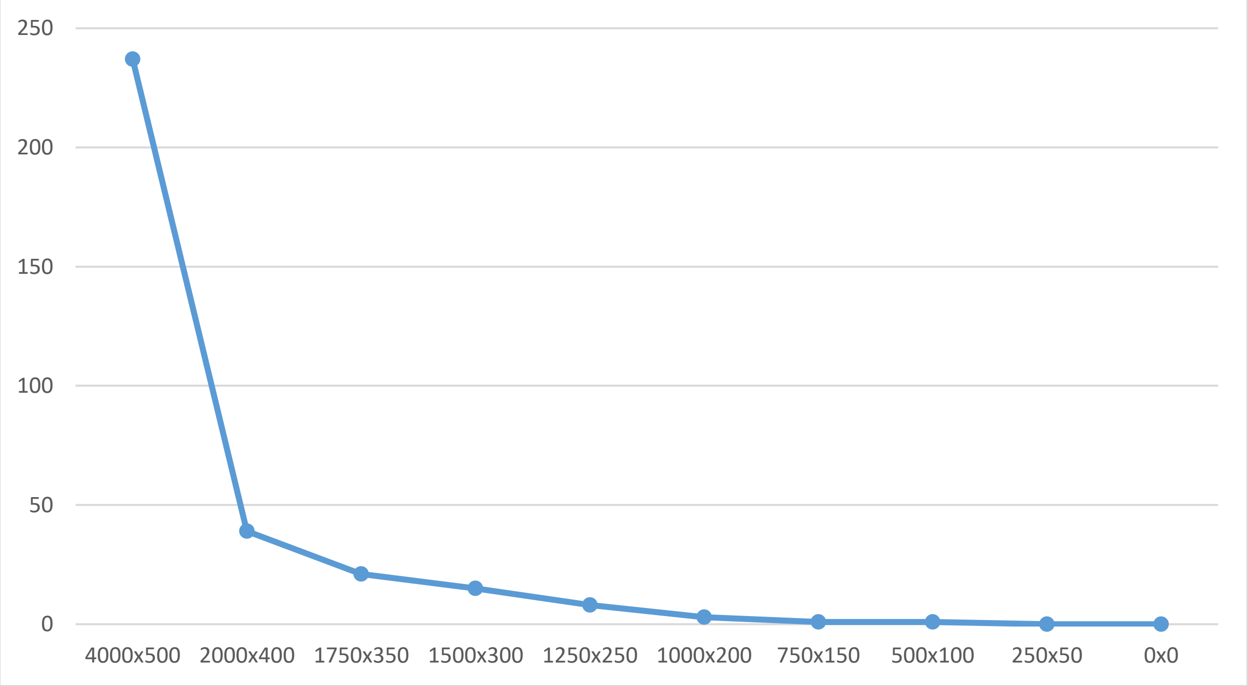
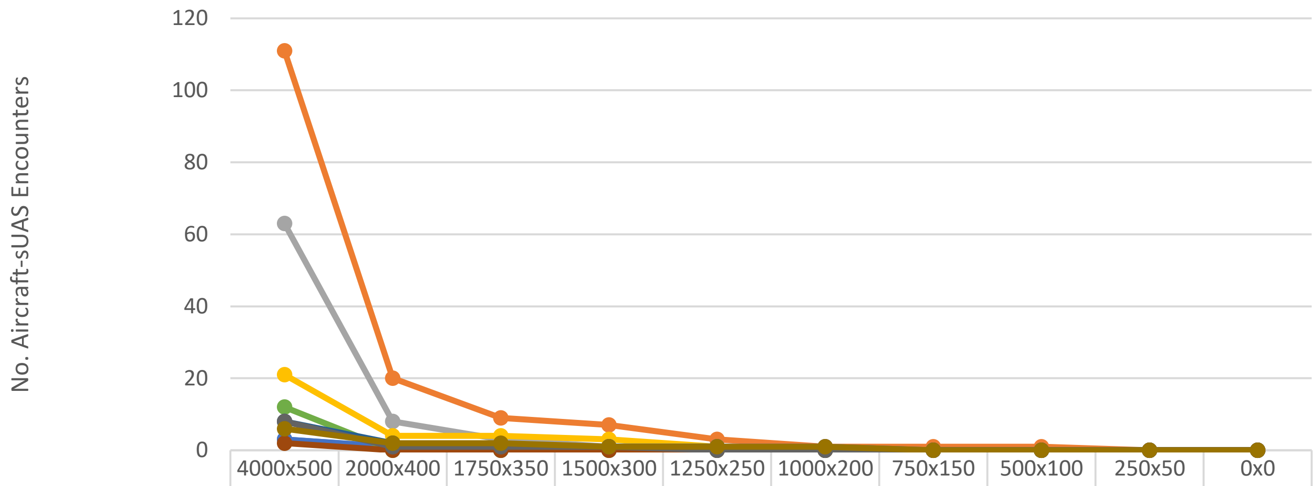


Figure 66. Distribution of Aircraft-sUAS Encounters (*n*=325, 10 areas, 4,000’ lat/500’ vert/2s, Jul 2021-Jan 2022.



	4000x500	2000x400	1750x350	1500x300	1250x250	1000x200	750x150	500x100	250x50	0x0
BatonRougeLA	3	1	0	0	0	0	0	0	0	0
BostonMA	111	20	9	7	3	1	1	1	0	0
BrooklynNY	63	8	3	1	1	0	0	0	0	0
BrownsvilleTX	21	4	4	3	1	0	0	0	0	0
ChillicotheOH	3	1	1	1	1	1	0	0	0	0
ConcordeNH	12	0	0	0	0	0	0	0	0	0
FerndaleWA	8	2	1	1	1	0	0	0	0	0
KankakeeIL	2	0	0	0	0	0	0	0	0	0
SacramentoCA	8	1	1	1	0	0	0	0	0	0
YumaAZ	6	2	2	1	1	1	0	0	0	0

Figure 67. Distribution of Aircraft-sUAS Encounters by Location (Jul '21-Jan '22)(*n*=325).

Discussion: This section aims to analyze the data of paired encounters (sUAS to manned-aircraft) over specific locations across the U.S. An encounter was based on single sUAS and manned-aircraft readings. Once the vertical and horizontal separations between them were less or equal to 500 and 4000 ft., respectively, the encounter was recorded. The provided data has information regarding the geographical locations of the aircraft and the sUAS, along with the aircraft call sign, aircraft *ICAO24* code, drone type, horizontal separation, and vertical separation.

The gathered data was filtered to identify each encounter by a *Drone Serial Number* and a unique Aircraft *ICAO24* code. Figure 68 shows the daily number of encounters from August 2021 to the end of January 2022. The highest count of encounters occurred in November and December 2021, whereas the lowest was in September and October 2021.

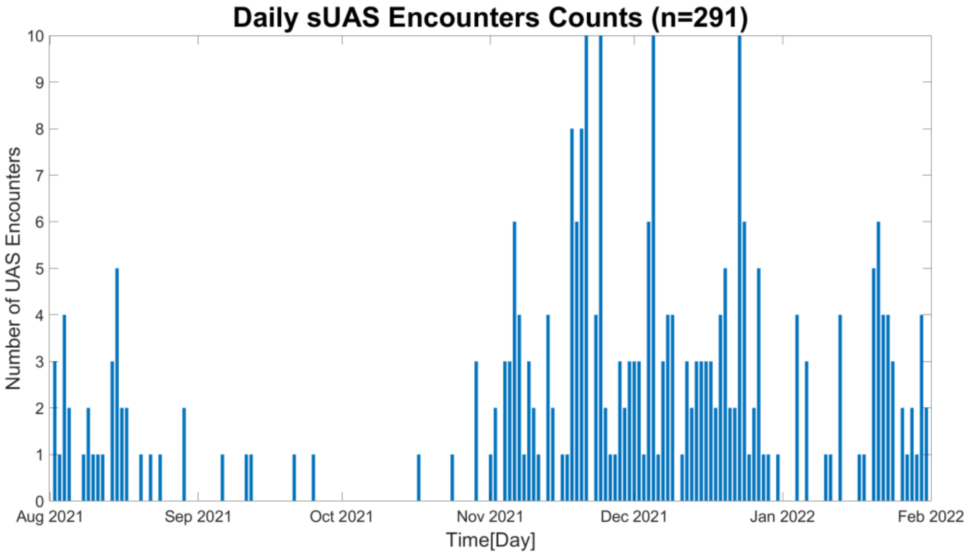


Figure 68. Daily sUAS Encounters Counts.

This section presents an analysis of the separation distance between the sUAS and the manned aircraft encounters (up to 60s temporal separation). Figure 69 shows a scatter plot of the vertical and horizontal missed distances for four sUAS weight classes. The noticeable trend is the predominance of sUAS with weights ranging from 0 to 2 lbs. Moreover, only 4 encounters penetrated the 500x100 ft. (loss of separation) volume. Figure 70 illustrates a probability of volume violation given an encounter, which can be described through a cubic regression. For this analysis, an encounter is defined as any sUAS activity within 4,000 ft. horizontally and 500 feet vertically from a manned aircraft.

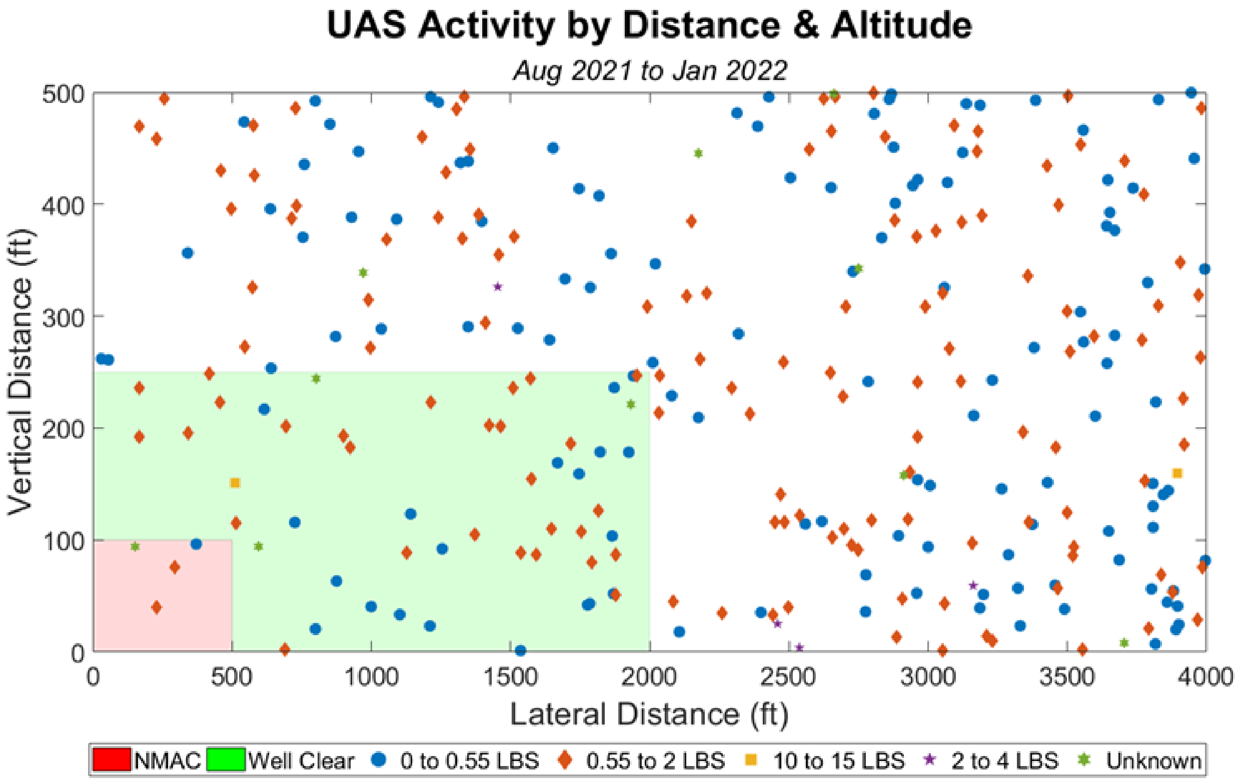


Figure 69. UAS Activity by Distance & Altitude.

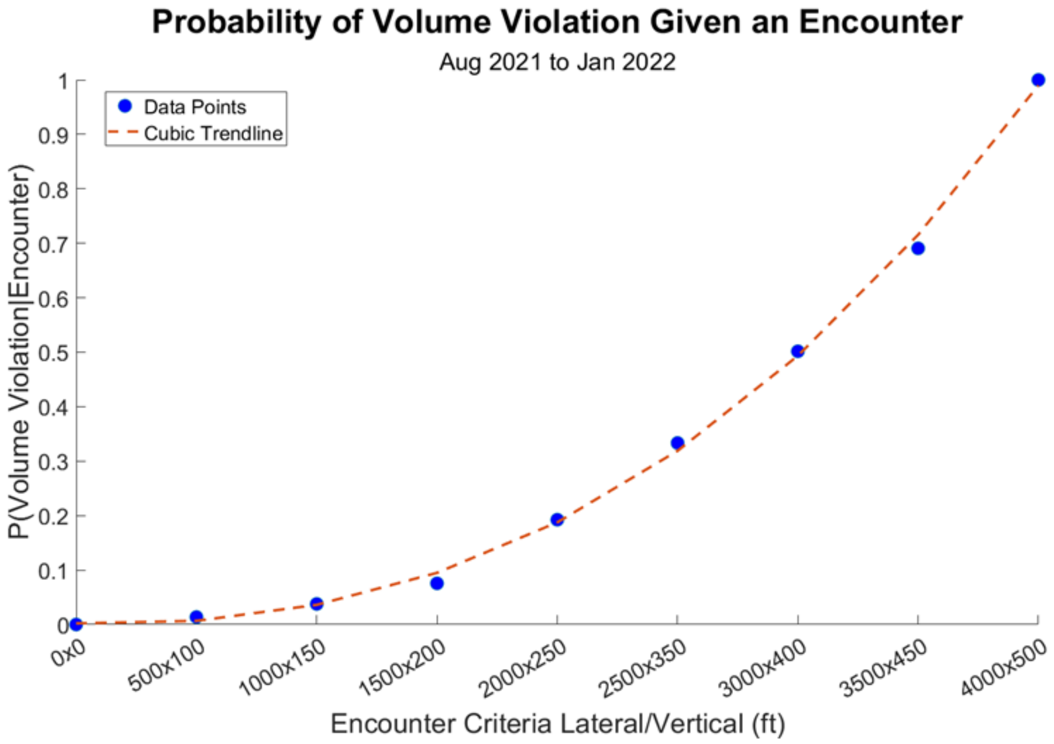


Figure 70. Probability of Volume Violation given an Encounter from August 2021 to January 2022.

The analysis in this section aims to identify the correlation of aircraft and sUAS encounters to the presence of landmarks. The geographical locations of each encounter, for each city, are plotted to observe any particular behavior or trends within the data. Figure 71 shows two locations, Boston, MA, and Concorde, NH, in which an airport can be identified within a 10 miles radius.

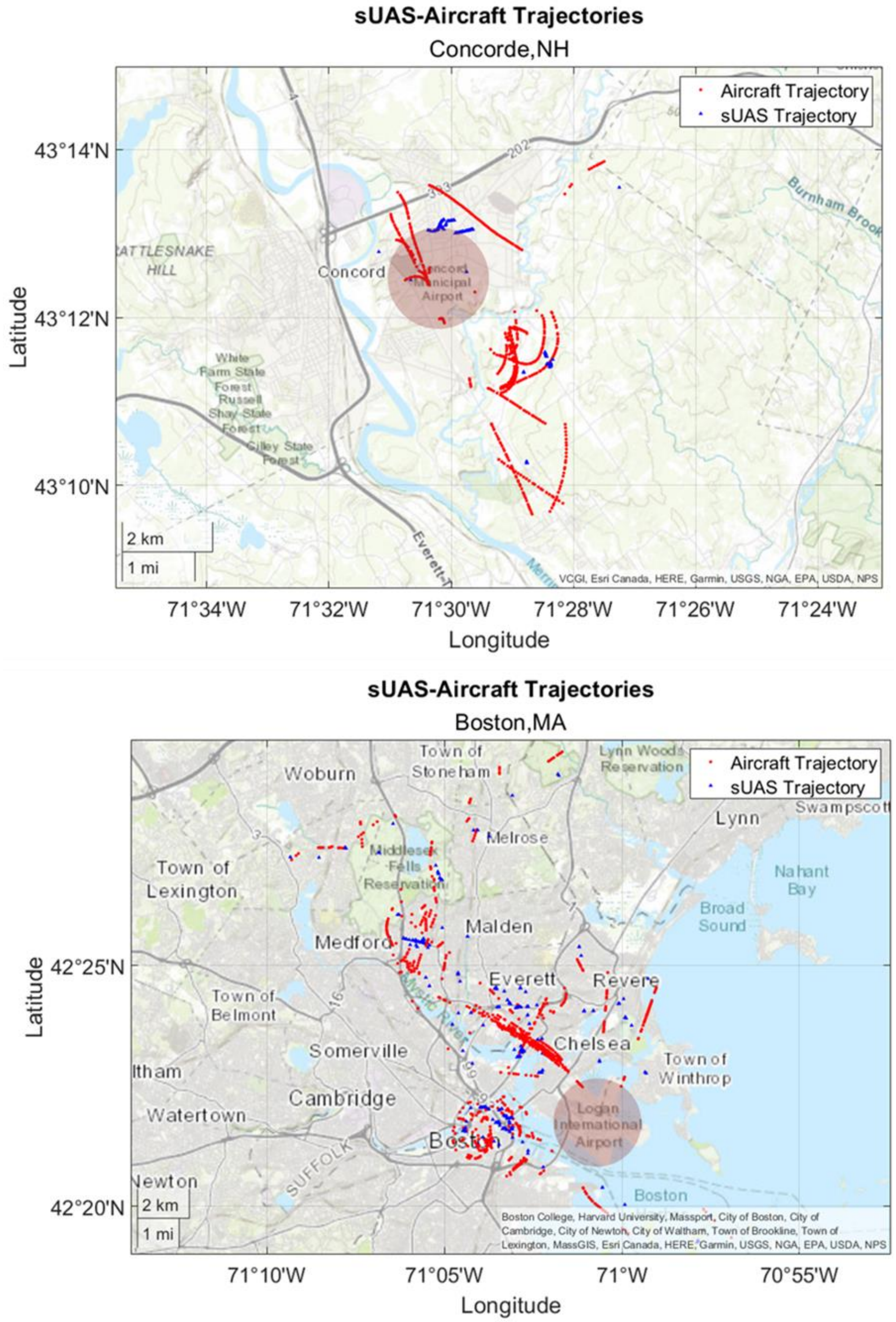


Figure 71. Geographical Overview of Encounters over Boston, MA and Concorde, NH.

When combining all locations, there is usually a higher number of encounters whenever an airport is within a 5-10 miles radius of the geometric center of all encounters in a city. It is also observed that trajectories of the manned aircraft in these locations represent an airport pattern, either a landing approach or a take-off route out of the airport. Locations such as Boston or Brooklyn, where the downtown area is close to an airport, also show a high number of operations.

The geographic locations of airports in each of the studied cities were gathered to determine if the airport distance to an encounter relationship exists. Figure 72 provides a count graph showing the number of encounters within 0-5 miles and >5 miles. Boston, Brownsville, and Concorde have a high number of encounters within a 5-mile radius from an airport.

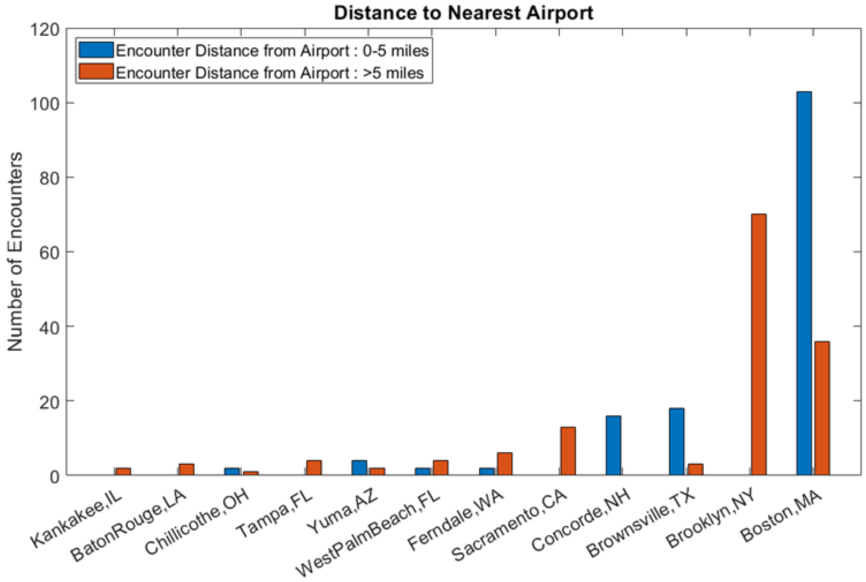


Figure 72. Distance Distribution to Nearest Airport.

Figure 73 and Figure 74 show the relationship between airport class and airport operations to the number of encounters. Even though there is a general trend, the data points show large scatter behavior, and concrete conclusions cannot be made at this time. More information such as sensor location, numbers of sensors installed in a particular area, and irregularities in the number of UAS operations per day would be needed to relate airport information to the number of encounters during this period.

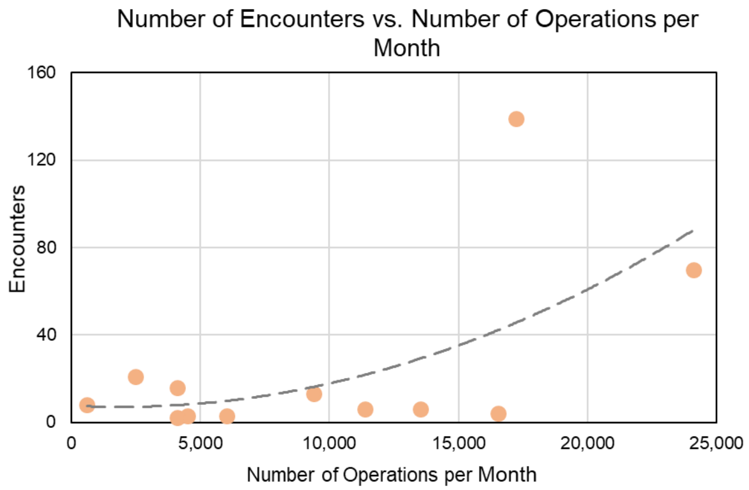


Figure 73. Relationship of the Airport Average Number of Operations per Month to Number of Encounters.

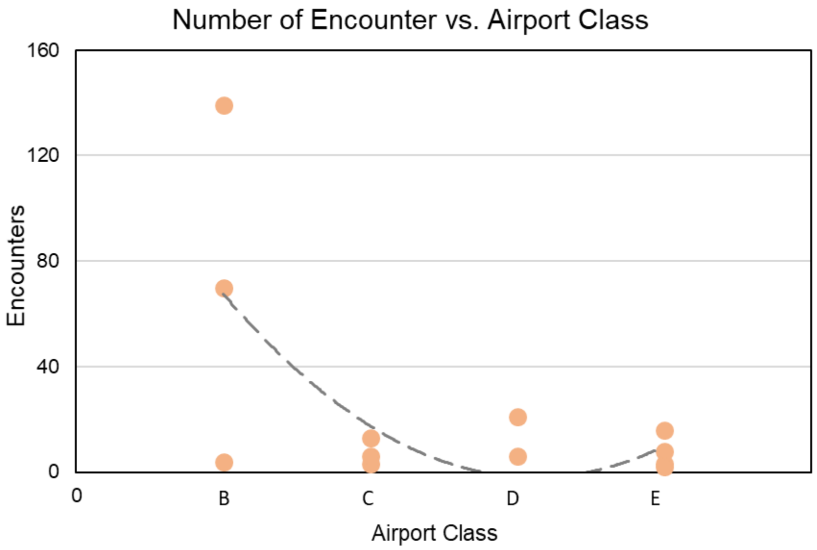


Figure 74. Relationship of Airport Airspace Class to Number of Encounters.

Figure 75 highlights the counts for four types of aircraft in the encounters for each city. For Boston and Brooklyn, the cities with the highest sUAS-aircraft encounters, commercial transport aircraft were the most common, followed by rotorcraft. Even though this trend did not repeat in other cities in this dataset, it indicates that in locations where these types of aircraft operate, the risk of an sUAS-aircraft encounter increases.

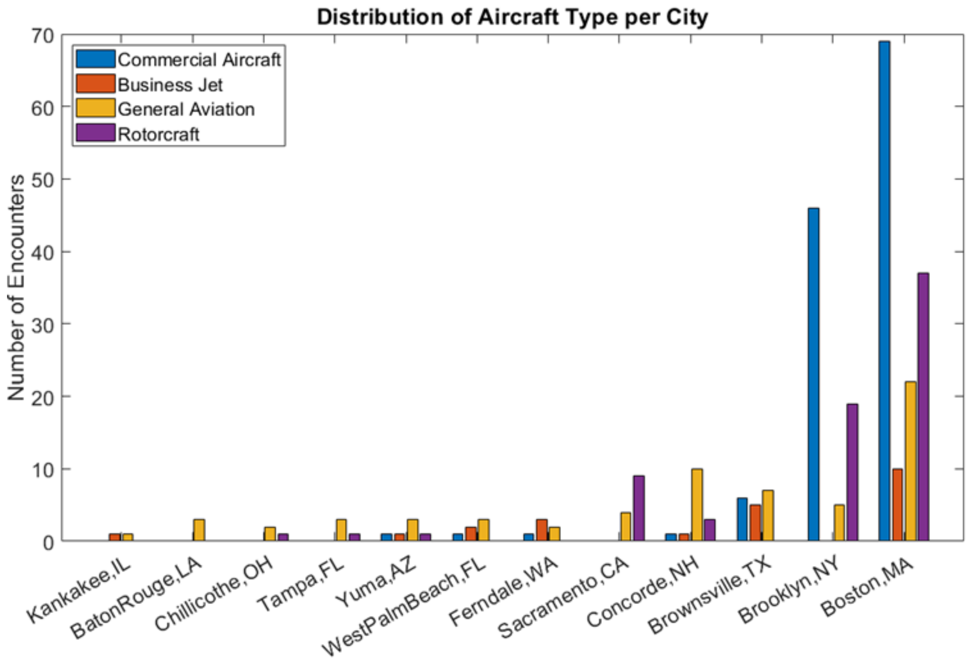


Figure 75. Aircraft Type Count per City.

Findings: Based on the results of all the analyses, there are several key findings. Most of the detected encounters are located within a 10-mile radius distance from an airport. Therefore, an encounter was produced when the manned aircraft was executing maneuvers related to airport operations. There seems to be no indication that an aircraft maneuvers away from the sUAS. Additionally, the cities with a lower number of encounters are related to lower population density. This, however, needs further investigation.

Conclusions: Further details and subsequent conclusions regarding the potential for low altitude manned aircraft and sUAS encounters will be presented in future iterations of this report, as additional data, contextual observations, and analysis results become available.

Future Research Recommendations: To provide more insight and more reasonable explanations regarding the widespread data distribution, these future studies are recommended:

a) The effect of population density on encounter detection.

b) The impact of the number of sensors located in a particular area on the number of encounters detected.

c) The result of different terrain on the altitude of the sensor location possibly results in a high encounter detection.

d) Study of sensor locations in each city.

e) Study of famous landmarks within a 5-10 mile radius of the encounter locations to determine the reason for increased sUAS operations.

Future versions of this report may include additional recommendations concerning investigation of the potential for low altitude manned aircraft and sUAS encounters, based upon observation, analysis, or inferences drawn from contextual examination of materials. Such recommendations are intended to support the definition and development of future related research efforts that are beyond the scope of this project.

2.4.3 Task D.3: How well are the 400-foot maximum altitude (14 CFR §107.51) rule and Low Altitude Authorization & Notification Capability (LAANC) altitudes (i.e. via UAS Facilities Map [UASFM]) working for segregating sUAS operations from General Aviation (GA) aircraft and helicopters?

A scatterplot will be presented that contextually displays the LAANC grid and minimum altitude of any aircraft penetrating below the established UAS Facility Map maximum altitudes in each respective sampling areas. This plot will be similar to that depicted in Task D.5.

Findings: Data collection for this task is still underway. Preliminary findings are not available for reporting at this time. Updates on this task will be provided in a subsequent annual report.

Conclusions: Further details and subsequent conclusions regarding established GA and sUAS operational segregation mechanisms will be presented in future iterations of this report, as additional data, contextual observations, and analysis results become available.

Future Research Recommendations: Future versions of this report may include additional recommendations concerning investigation of established General Aviation and sUAS operational segregation mechanisms, based upon observation, analysis, or inferences drawn from contextual examination of materials. Such recommendations are intended to support the definition and development of future related research efforts that are beyond the scope of this project.

2.4.4 Task D.4: How many manned aircraft dip below UAS Facility Map altitudes when flying inside/outside terminal airspace?

The research team will assess manned aircraft telemetry for any segments that dip below the maximum UAS Facility Map / LAANC grid areas for each applicable airport within the sampling areas. The research team will provide a census of this type of event and a graphical depiction for each LAANC area, with overlays of flight segments that dipped within the LAANC grid system.

Findings: Data collection for this task is still underway. Preliminary findings are not available for reporting at this time. Updates on this task will be provided in a subsequent annual report.

Conclusions: Further details and subsequent conclusions regarding manned aircraft terminal airspace altitudes (below) will be presented in future iterations of this report, as additional data, contextual observations, and analysis results become available.

Future Research Recommendations: Future versions of this report may include additional recommendations concerning investigation of manned aircraft terminal airspace altitudes, based upon observation, analysis, or inferences drawn from contextual examination of materials. Such recommendations are intended to support the definition and development of future related research efforts that are beyond the scope of this project.

2.4.5 Task D.5: How many sUAS fly above UAS Facility Map altitudes when flying inside terminal airspace?

The research team will assess how many sUAS fly above the maximum UAS facility map altitudes.

Findings: The research team detected 358,826 instances of sUAS activity within UAS Facility Map areas. In 28.8% (*n*=103,295) of instances, the sUAS was above the maximum altitude designated by the UAS Facility Map. A distribution of exceedances by UAS Facility Map maximum altitude is provided in

Figure 76. The distribution of UAS Facility Map exceedances at individual airports is provided in Figure 77. Additional analysis of UAS Facility Map utilization and exceedances is provided in Task B.1.1.

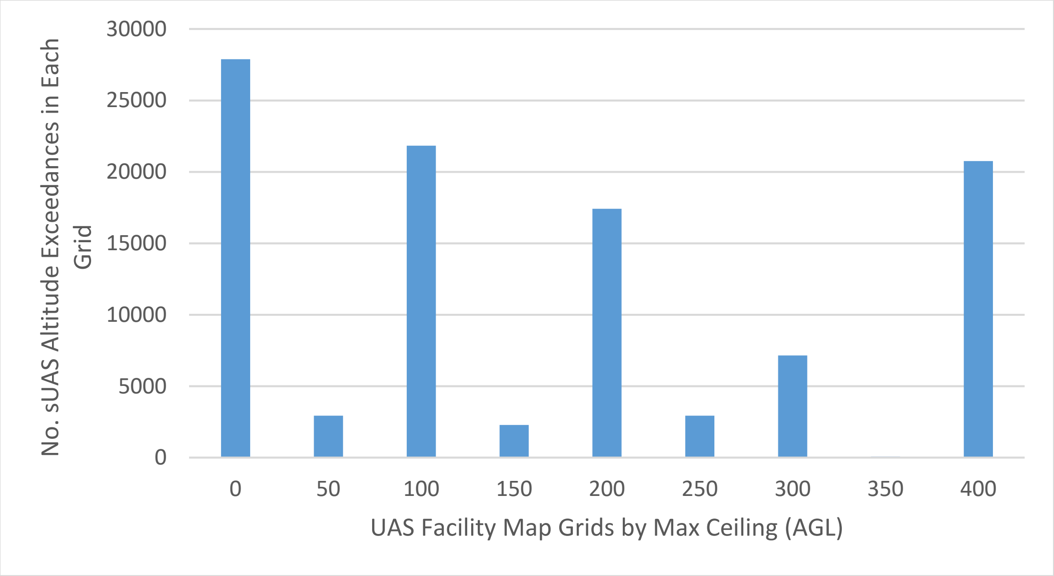


Figure 76. Distribution of UAS Facility Map Exceedances by UAS Facility Map Grid Maximum Altitude.

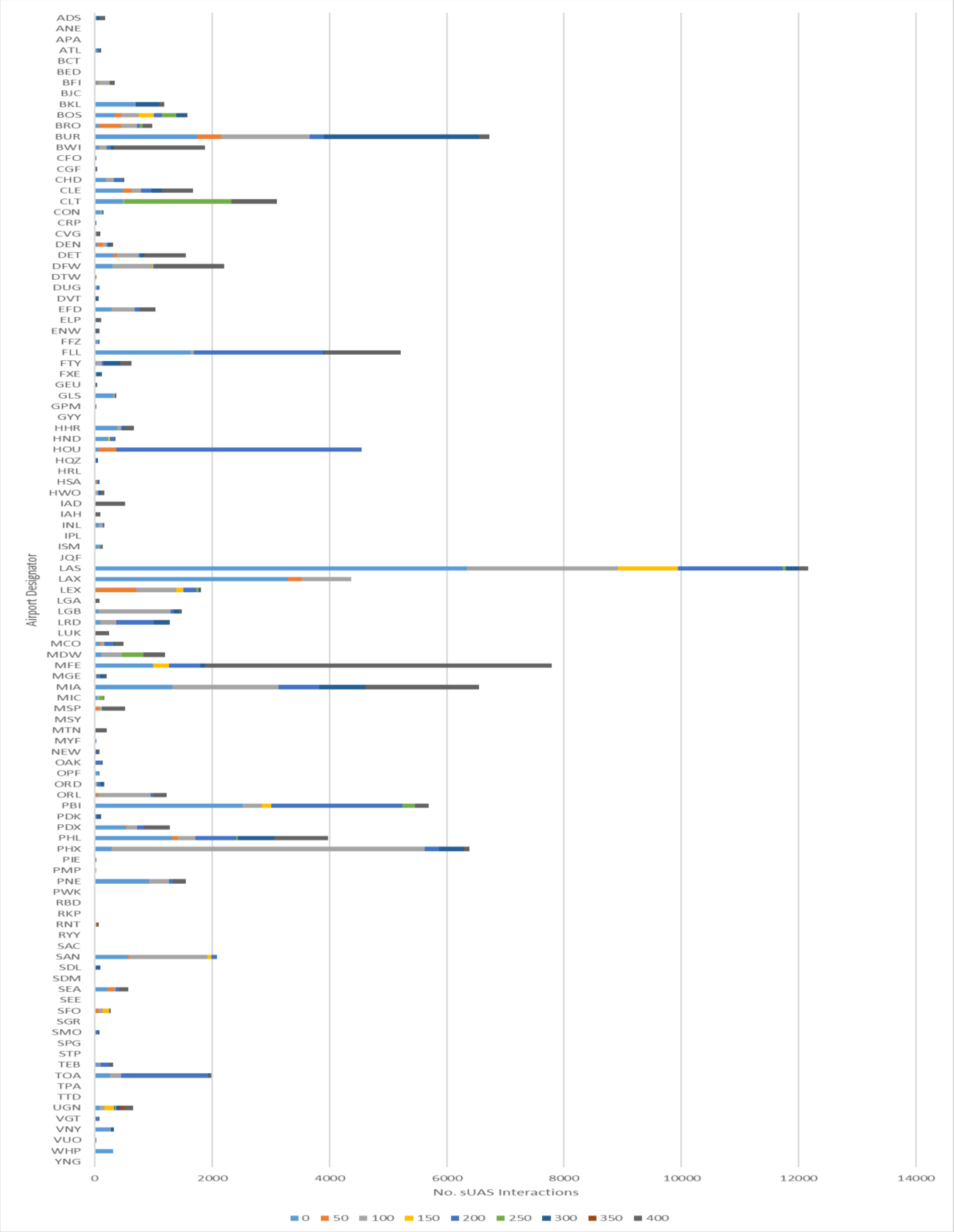


Figure 77. UAS Facility Map Altitude Exceedances by Airport Designator and Grid Maximum Altitude.

Conclusions: Further details and subsequent conclusions regarding manned aircraft terminal airspace altitudes will be presented in future iterations of this report, as additional data, contextual observations, and analysis results become available.

Future Research Recommendations: Future versions of this report may include additional recommendations concerning investigation of manned aircraft terminal airspace altitudes, based upon observation, analysis, or inferences drawn from contextual examination of materials. Such recommendations are intended to support the definition and development of future related research efforts that are beyond the scope of this project.

2.4.6 Task D.6: Can "hotspots" be identified that indicate vulnerability to sUAS encounters?

The research team evaluated sUAS activity locations to determine if these areas were predictive of sUAS sightings. Sighting location data was obtained from the FAA. The research team utilized QGIS to plot and assess geographical information for this analysis.

Findings: The research team identified several case studies that support general findings. Figure 78 shows the area surrounding Boston-Logan International Airport. Strong sUAS activity is seen in the Everett, MA area along the approach path to Runway 15R. Sightings reports do not appear to correlate with areas of elevated sUAS activity. In some areas, such as Miami International Airport as seen in Figure 79, sighting reports appear to exhibit a linear behavior, roughly aligned, but offset from airport runway orientations. Again, these sighting reports do not seem to align with elevated sUAS activity locations, which are noted along the coastline. Similarly, elevated sUAS activity in downtown Seattle, WA concentrated near the Space Needle, does not appear to correlate with sighting reports observed further to the south as seen in Figure 80. Finally, sUAS flight activity concentrated near the Port of San Francisco and Oakland waterfront areas do not appear to correspond to the sightings report locations shown in Figure 81. It is believed that slight delays in aircraft crew reporting of sighting information may contribute to location estimation errors. The research team will continue to evaluate this issue, as more data becomes available.

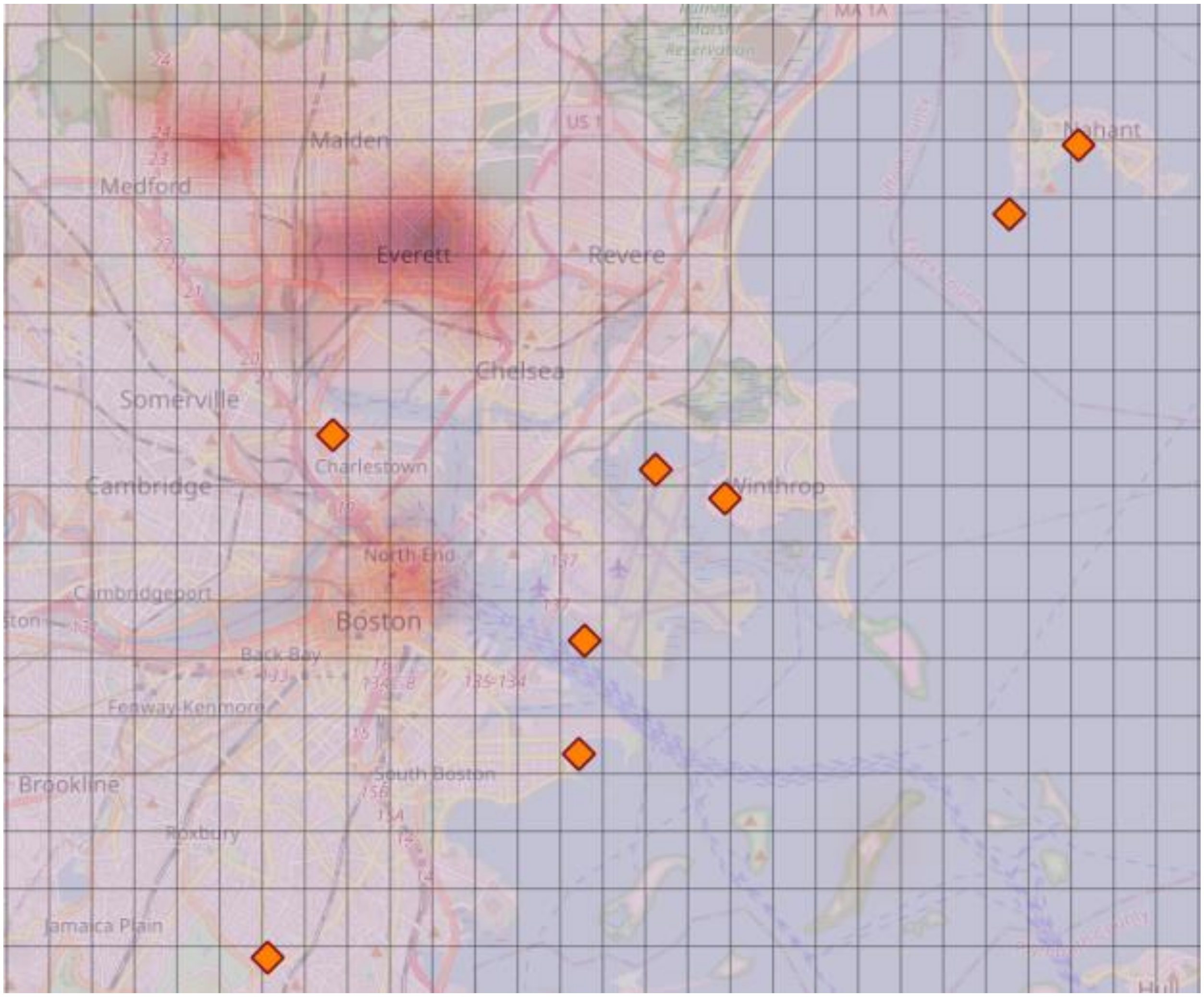


Figure 78. UAS Detection Hotspots with Estimated UAS Sighting Report Locations, Boston, MA (Jul 2021-Jan 2022).

Note: Heat map indicates areas of high sUAS flight activity within UAS facility map area. Orange diamond symbology represents estimated locations of UAS sighting reports, as provided by the FAA.

Figure 79. UAS Detection Hotspots with Estimated UAS Sighting Report Locations, Miami, FL (Jul 2021-Jan 2022).

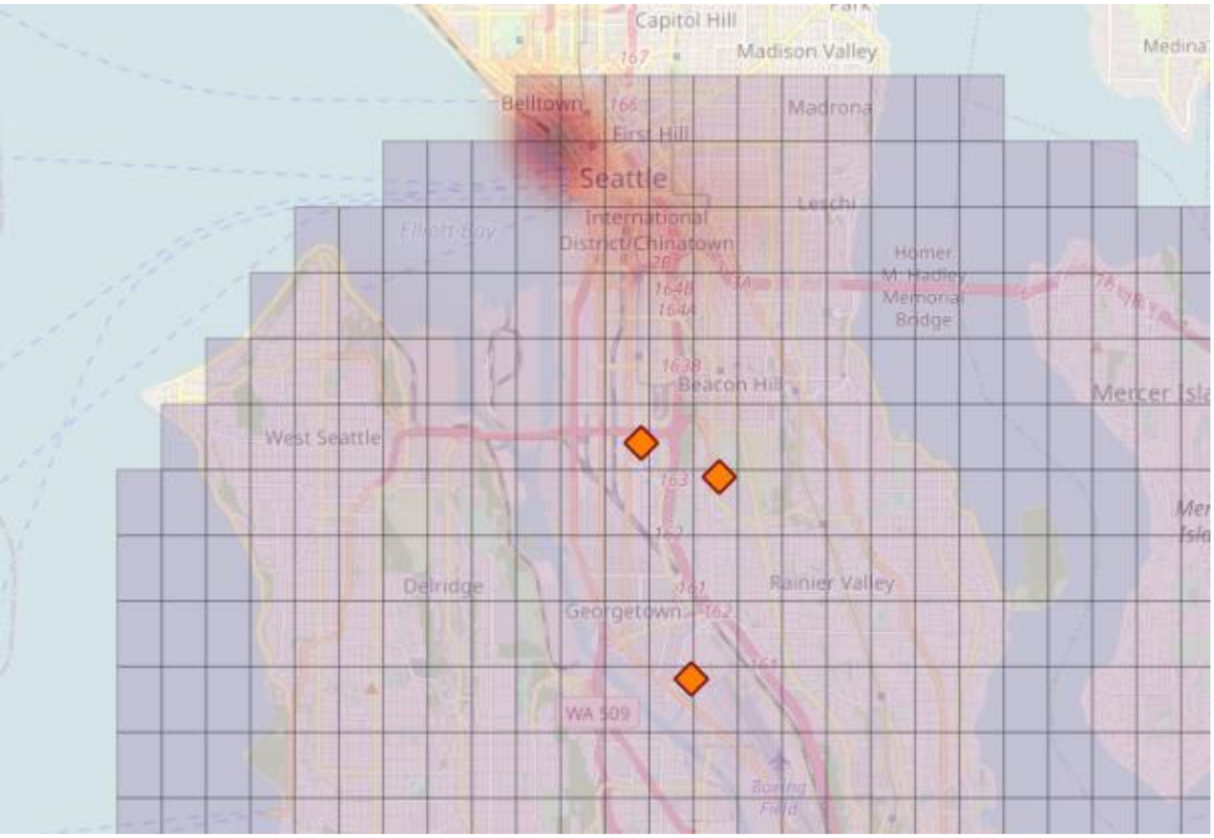


Figure 80. UAS Detection Hotspots with Estimated UAS Sighting Report Locations, Seattle, WA (Jul 2021-Jan 2022).

Figure 81. UAS Detection Hotspots with Estimated UAS Sighting Report Locations, San Francisco, CA (Jul 2021-Jan 2022).

2.4.7 *Task D.7: Are sUAS hotspot locations predictive of UAS sighting report locations?*

Using the location data generated in Task D.6, the research team will plot the locations of detected encounters on a map, and add sighting report locations as an overlay for contextual comparison. This task will require the FAA to provide sighting report location GIS data, obtained from the FAA GLARE analysis toolset.

Findings: Integrating confirmed aircraft-sUAS encounters (as identified from fusing sUAS detection telemetry with historical ADS-B data), provided a much clearer picture of encounter risk. For example, the research team was able to identify several patterns of encounters that seem to align along a clear axis of travel, such as that observed in New York City as seen in Figure 82. One can clearly observe a string of sUAS encounters along a linear axis over Prospect Park and proceeding along a northeastern trajectory. Most encounters occurred with fixed-wing jet aircraft, with a small number of helicopter encounters also noted. This analysis filtered sUAS activity heat map information to only areas within the UAS Facility Map grid, so the research team was unable to correlate these encounters to sUAS activity data.

A similar, linear pattern of encounters was noted near Boston-Logan International Airport as seen in Figure 83. A sizable portion of these encounters occurred within direct proximity to areas of elevated sUAS activity. Most encounters appeared to align with approach path to Runway 15R when aircraft were overflying residential areas around Everett. A number of helicopter encounters also occurred near the downtown area, corresponding to elevated sUAS activity in that area. Encounters were also noted near an area of elevated sUAS activity in a residential neighborhood southwest of Malden.

Aircraft-sUAS encounters also appeared to align with areas of elevated sUAS activity near the downtown waterfront and adjacent residential districts in Sacramento, CA as seen in Figure 84. In this area, encounters were occurring more than five miles away from nearby airports.

It is notable that in most cases, areas of elevated sUAS activity did not align with reported UAS sightings location data. Areas of elevated sUAS activity, however, did correlate to locations of aircraft-sUAS encounters, as determined by sUAS detection and ADS-B data. These observations throw into question the validity and usefulness of reported sightings data. The research team will conduct further analysis as additional encounter data becomes available.

Figure 82. UAS Detection Hotspots with Estimated UAS Sighting Report Locations & Aircraft-UAS Encounters, New York City, NY (Jul 2021-Jan 2022).

Note: Heat map indicates areas of high sUAS flight activity within UAS facility map area. Orange diamond symbology represents estimated locations of UAS sighting reports, as provided by the FAA. Circle symbology indicates individual flight encounters with sUAS, as determined by UAS detection data and ADS-B telemetry information. A flight encounter was defined as any aircraft that encountered a sUAS within 4,000 feet horizontally, 500 feet vertically, and within a temporal space of 2 seconds. The color of the circles indicates the category of aircraft involved in the encounter with Fixed-Wing Jets depicted in Gray; Fixed-Wing Piston depicted in Orange, and Helicopters depicted in Green.

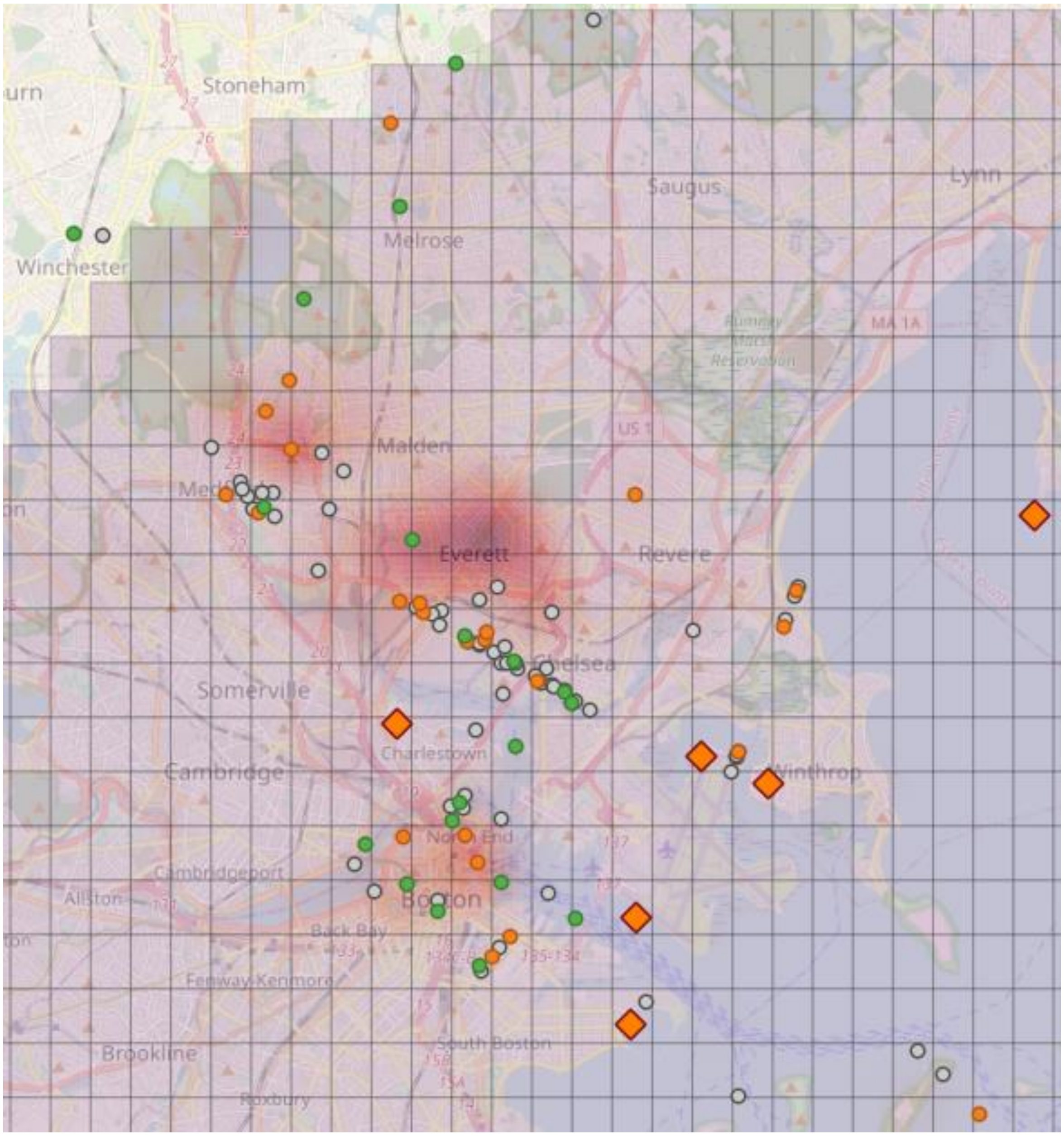


Figure 83. UAS Detection Hotspots with Estimated UAS Sighting Report Locations & Aircraft-UAS Encounters, Boston, MA (Jul 2021-Jan 2022).

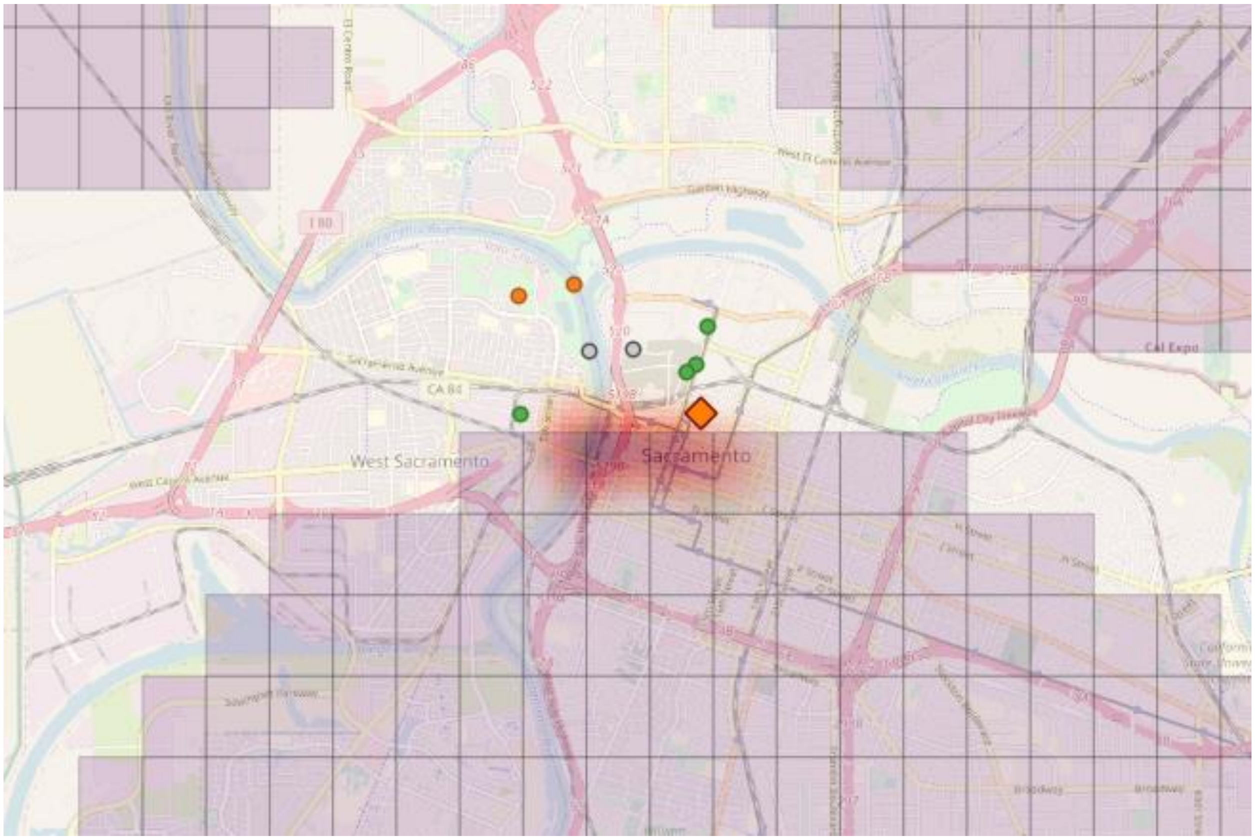


Figure 84. UAS Detection Hotspots with Estimated UAS Sighting Report Locations & Aircraft-UAS Encounters, Sacramento, CA (Jul 2021-Jan 2022).

Conclusions: Further details and subsequent conclusions regarding vulnerable sUAS encounter hotspots will be presented in future iterations of this report, as additional data, contextual observations, and analysis results become available.

Future Research Recommendations: Future versions of this report may include additional recommendations concerning investigation of vulnerable sUAS encounter hotspots, based upon observation, analysis, or inferences drawn from contextual examination of materials. Such recommendations are intended to support the definition and development of future related research efforts that are beyond the scope of this project.

2.4.8 Task D.8: How many sUAS are flying inside no-fly zones?

According to the FAA (2019), sUAS are not permitted to fly within Prohibited Areas, Restricted Areas, or Temporary Flight Restricted Areas. The research team will integrate data from the FAA's Aeronautical Data Delivery Service, including the following GIS datasets: Special Use Airspace Map and Temporary Flight Restriction List. Alternatively, similar GIS datasets available from the FAA's GLARE Analysis Tool may be utilized. The research team will provide a graphical display of sUAS telemetry for all sUAS activity within the three designated types of no-fly zones within the sampling areas. Additionally, a bar graph depicting the number of flight violations into each of the respective no-fly zones types will be provided.

Findings: Data collection for this task is still underway. Preliminary findings are not available for reporting at this time. Updates on this task will be provided in a subsequent annual report.

Conclusions: Further details and subsequent conclusions regarding sUAS operations in no-fly zones will be presented in future iterations of this report, as additional data, contextual observations, and analysis results become available.

Future Research Recommendations: Future versions of this report may include additional recommendations concerning investigation of sUAS operations in no-fly zones, based upon observation, analysis, or inferences drawn from contextual examination of materials. Such recommendations are intended to support the definition and development of future related research efforts that are beyond the scope of this project.

2.4.9 Task D.9: How many sUAS are flying near critical infrastructure?

Completion of this task will involve integrating selected elements of the DHS HIFLD datasets. The FAA will provide guidance upon specific critical infrastructure for evaluation. The research team suggests the following items *should* be considered for assessment, based on FAA (2021d) guidance restricting sUAS operations: prisons and correctional facilities, military bases designated as Department of Defense facilities, selected national landmarks, designated critical infrastructure such as nuclear power plants. The research team will report the number of incidents of sUAS operations coming within proximity to critical infrastructure areas. Additionally, the research team will highlight unique case studies of risks presented by these flights, as appropriate.

Findings: Preliminary assessment of sUAS operations near critical infrastructure was conducted by assessing sUAS flights near correctional institutions. At least 78 sUAS flights were detected near correctional facilities, in which the sUAS telemetry showed an overflight or penetration into the airspace overhead a correctional facility structure. A distribution of sUAS incursions are provided in Figure 85 according to correctional facility type.

The data seemed to indicate that most sUAS incursions over correctional facilities were unintentional rather than deliberate. When observing the telemetry of selected case studies, one can clearly see that incursion duration was limited. Moreover, sUAS telemetry did not indicate evidence of loitering or surveillance activity as seen in Figure 86 and Figure 87. What is somewhat concerning is that telemetry of several flights did not indicate that geofencing had prevented these incursions. According to DJI (2022),

> DJI's GEO System delineates where it is safe to fly, where flight may raise concerns, and where flight is restricted. GEO zones that prohibit flight are implemented around locations such as airports, power plants, and prisons. They are also implemented temporarily around major stadium events, forest fires, or other emergency situations. Certain GEO zones don't prohibit flight, but do trigger warnings that inform users of potential risks. By default, GEO limits flights into or taking off within zones that raise safety or security concerns. If a flight within one of these locations has been authorized, GEO allows users with verified DJI accounts to temporarily unlock or self-authorize their flights. This unlock function is not available for sensitive national-security locations. The GEO system is advisory only. Each user is responsible for checking official sources and determining what laws or

> regulations might apply to his or her flight. In some instances, DJI has selected widely-recommended general parameters without making any determination of whether this guidance matches regulations that may apply specifically to [the operator]. (p. 1)

DJI's geofencing system implements several types of zones designed to inform the user of potential flight hazards, enhance user accountability (by requiring the user to login with an authenticated account), or in the cases of the most sensitive or hazardous locations, restrict or prohibit user flight. Users can request unlocking access for areas that restrict or prohibit UAS flight, by submitting a request with authorization documentation to DJI (DJI, 2022). According to DJI (2022), the following geofencing zones are implemented into their product line:

- **Restricted Zones**: users are prompted with a warning and flight is prevented. Users with authorization to fly within a restricted zone can request online unlocking from DJI.
- **Altitude Zones**: users receive warnings in the DJI application and flight altitude is limited.
- **Authorization Zones**: users are prompted with a warning and flight is limited by default. Authorization zones can be unlocked by authorized users using a DJI verified account.
- **Warning Zones**: users will be prompted with a warning message.
- **Enhanced Warning Zones**: users are prompted to unlock the zone in the same manner as an Authorization zone, however, a verified account is not required
- **Regulatory Restricted Zones**: flights within special areas are prohibited due to local regulations and policies
- **Recommended Flight**: suggests recommended areas for flight

Unfortunately, the research team is unable to assess if these sUAS flights were granted authorization to fly in these areas and received geozone unlock permissions from DJI or otherwise found methods of circumventing geozone protections.

It is notable that some correctional facilities are co-located with other public safety agency facilities. The research team believes that at least some of these overflights represent sUAS flights conducted by public safety personnel conducting practice flights. Additionally, some sUAS operations conducted near correctional facilities appeared to indicate sUAS were used in support of legitimate activities, including inspection of solar paneling, mapping and surveying, and other related functions. Since the research team does not currently possess identifying information for any public safety agency sUAS platforms, it is currently not possible to assess the validity of this assumption.

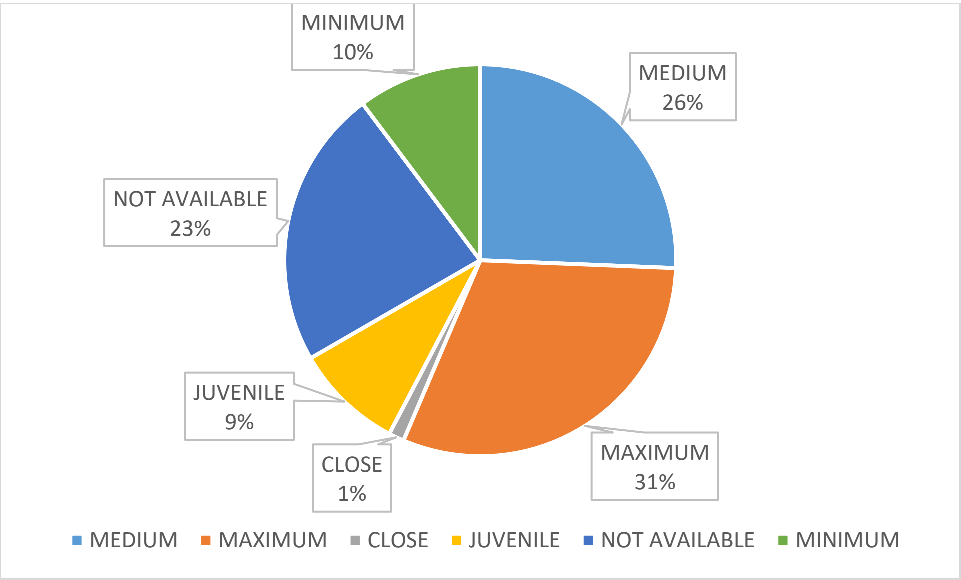


Figure 85. Sample Correctional Facility Incursions with sUAS by Type.

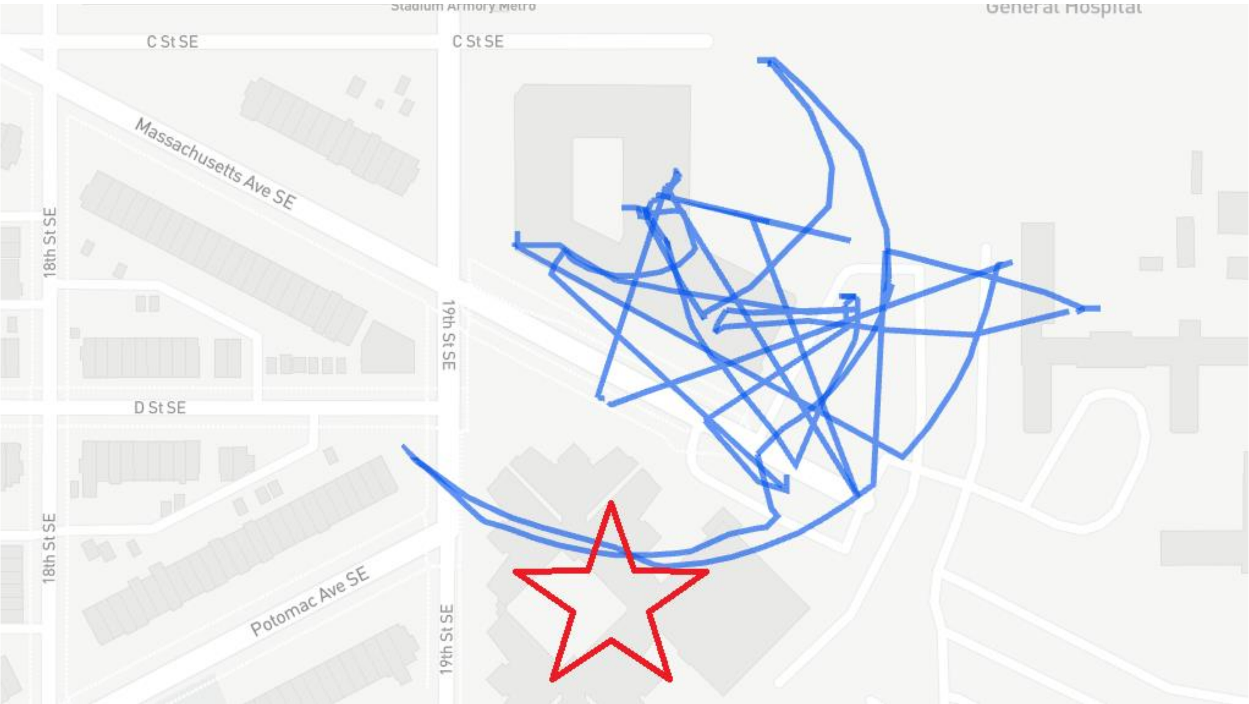


Figure 86. Sample Correctional Facility Incursions, Washington, D.C., Phantom 4-Series, August 2021.

Note: Blue lines indicate sUAS flight path, based on sUAS detection data. Red star indicates location of correctional facility.

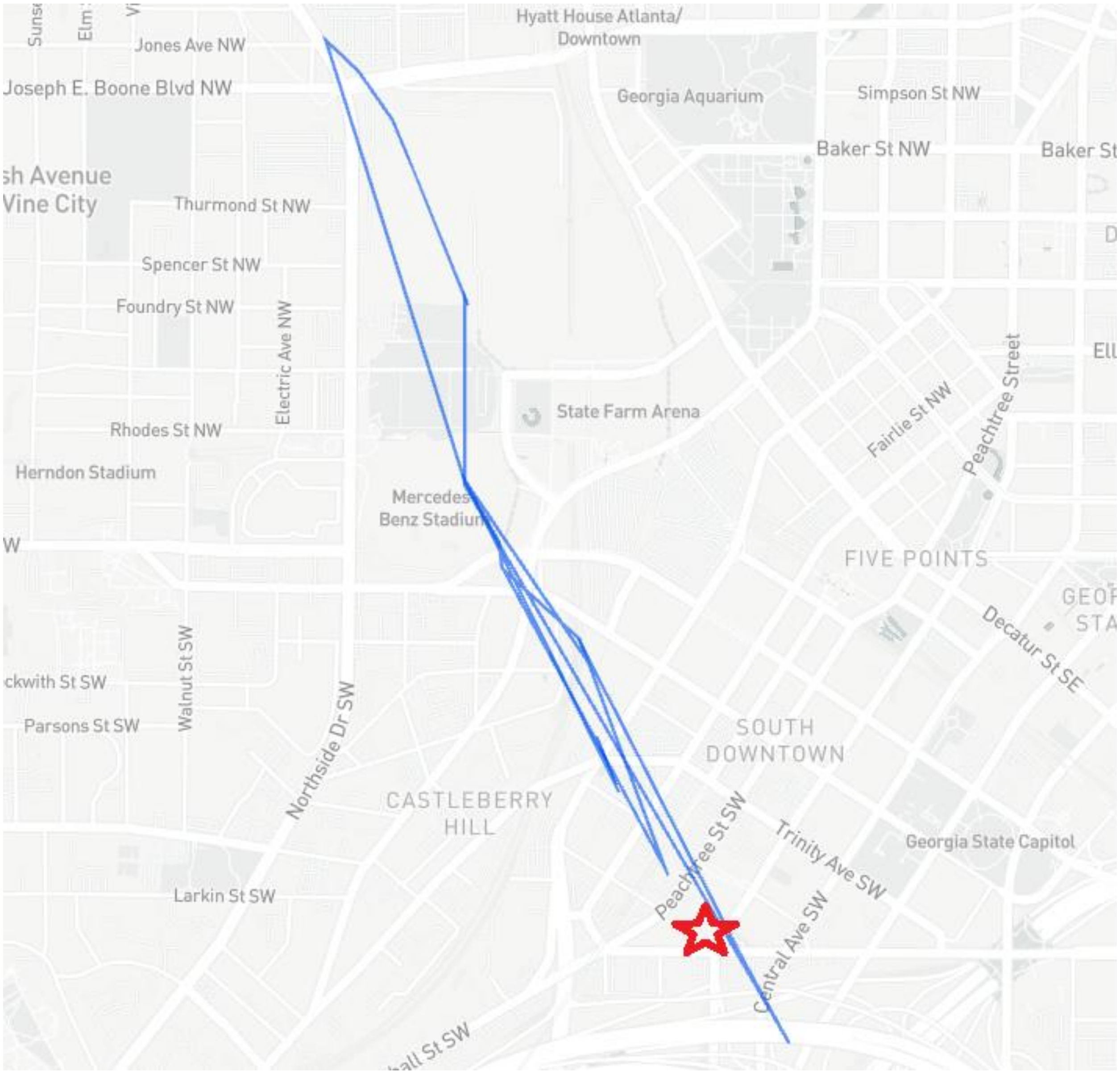


Figure 87. Sample Correctional Facility Incursions, Atlanta, GA, Inspire 2-Series, August 2021.

Note: Blue lines indicate sUAS flight path, based on sUAS detection data. Red star indicates location of correctional facility.

Conclusions: Further details and subsequent conclusions regarding sUAS operations in close proximity to critical infrastructure will be presented in future iterations of this report, as additional data, contextual observations, and analysis results become available.

Future Research Recommendations: Future versions of this report may include additional recommendations concerning investigation of sUAS operations in close proximity to critical infrastructure, based upon observation, analysis, or inferences drawn from contextual examination of materials. Such recommendations are intended to support the definition and development of future related research efforts that are beyond the scope of this project.

2.4.10 Task D.10: How art are remote pilots flying their drones (rates of BVLOS flight)?

This task will be accomplished in a similar manner and using the same criterion as described in Task C.3. The research team will provide a graphical map displaying sUAS which meet BVLOS criteria. The research team will provide a census of sUAS operations conducted BVLOS. Additionally, a scatterplot of sUAS flights conducted BVLOS, based on the maximum distance flown from the launch location (homepoint).

Answers to this research question are largely addressed in Task C.3.

2.5 Task E: Forecasting Industry Growth & Potential Advanced Air Mobility Implications (Performers)

The intent of this task is to leverage data gathered throughout the course of this project to inform upon industry growth, development, and further sUAS integration efforts.

2.5.1 Task E.1: What are the likely impacts of Urban Air Mobility (UAM) / Advanced Air Mobility (AAM)? / Task

The research team believes the following UAM / UTM operational and safety issues can be informed by the findings from this project.

The following subsections represent investigated characteristics associated with UAM/AAM impacts due to sUAS activity, including altitudes supporting traffic deconfliction, notable geographic locations and features, impacts to Vertical Takeoff and Landing (VTOL) facilities, boundaries of operational influence, and the timing of diminished activity.

2.5.1.1 Task E.1.1 Traffic Deconfliction Altitudes

The intent of this task is to examine ideal working altitudes that provide maximum deconfliction from both manned aircraft and sUAS traffic.

Findings: Data collection for this task is still underway. Preliminary findings are not available for reporting at this time. Updates on this task will be provided in a subsequent annual report.

Conclusions: Further details and subsequent conclusions regarding traffic deconfliction between sUAS and manned aircraft will be presented in future iterations of this report, as additional data, contextual observations, and analysis results become available.

Future Research Recommendations: Future versions of this report may include additional recommendations concerning investigation of traffic deconfliction, based upon observation, analysis, or inferences drawn from contextual examination of materials. Such recommendations are intended to support the definition and development of future related research efforts that are beyond the scope of this project.

2.5.1.2 Task E.1.2 Notable Geographic Locations and Features

The intent of this task is to investigate geographical locations or characteristics in which UAM /AAM are likely to be adversely impacted by either air traffic or sUAS operations density.

Findings: Data collection for this task is still underway. Preliminary findings are not available for reporting at this time. Updates on this task will be provided in a subsequent annual report.

Conclusions: Further details and subsequent conclusions regarding sUAS operational locations and features will be presented in future iterations of this report, as additional data, contextual observations, and analysis results become available.

Future Research Recommendations: Future versions of this report may include additional recommendations concerning investigation of sUAS operational locations and features, based upon observation, analysis, or inferences drawn from contextual examination of materials. Such recommendations are intended to support the definition and development of future related research efforts that are beyond the scope of this project.

2.5.1.3 Task E.1.3 Proximal VTOL Facility Impacts

The intent of this task is to examine the level of sUAS activity in proximity to heliports, which are anticipated to exhibit similar characteristics to vertiports.

Findings: The research team asserts that the answer to this research question is provided in Task B.1.8.

Conclusions: Further details and subsequent conclusions regarding sUAS activity in close proximity to heliports will be presented in future iterations of this report, as additional data, contextual observations, and analysis results become available.

Future Research Recommendations: Future versions of this report may include additional recommendations concerning investigation of sUAS activity in close proximity to heliports, based upon observation, analysis, or inferences drawn from contextual examination of materials. Such recommendations are intended to support the definition and development of future related research efforts that are beyond the scope of this project.

2.5.1.4 Task E.1.4 Operational Influence Bounding

The intent of this task is to examine and identify the average radius of influence of sUAS activity.

Findings: Initial data is available in Table 18. Preliminary findings are not available for reporting at this time. Updates on this task will be provided in a subsequent annual report.

Conclusions: Further details and subsequent conclusions regarding the average radius of operational influence will be presented in future iterations of this report, as additional data, contextual observations, and analysis results become available.

Future Research Recommendations: Future versions of this report may include additional recommendations concerning investigation of the average radius of operational influence, based upon observation, analysis, or inferences drawn from contextual examination of materials. Such recommendations are intended to support the definition and development of future related research efforts that are beyond the scope of this project.

Table 18. Lateral & Vertical sUAS Flight Footprint Distribution (ft).

Lateral Dist.	**<528**	**<1056**	**<1584**	**<2112**	**<2640**	**<3168**	**<3696**	**<4224**	**<4752**	**<5280**	**≥5280**
	46.9%	17.2%	11.0%	7.3%	4.8%	3.2%	2.3%	1.6%	1.2%	0.9%	3.6%
Vertical Dist.	**<50**	**<100**	**<150**	**<200**	**<250**	**<300**	**<350**	**<400**	**<450**	**<500**	**≥500**
	45.2%	16.8%	10.5%	7.2%	5.1%	3.7%	2.7%	1.6%	1.0%	0.8%	5.1%

*Note: Lateral and vertical distribution information sorted by platform type are included in the Appendix.

2.5.1.5 Task E.1.5 Diminished sUAS Activity Timing

The intent of this task is to investigate times of diminished sUAS activity, as applies primarily toward AAM package delivery operations.

Findings: Data collection for this task is still underway. Preliminary findings are not available for reporting at this time. Updates on this task will be provided in a subsequent annual report.

Conclusions: Further details and subsequent conclusions regarding times of diminished sUAS activity will be presented in future iterations of this report, as additional data, contextual observations, and analysis results become available.

Future Research Recommendations: Future versions of this report may include additional recommendations concerning investigation of timing of diminished sUAS activity, based upon observation, analysis, or inferences drawn from contextual examination of materials. Such recommendations are intended to support the definition and development of future related research efforts that are beyond the scope of this project.

2.5.2 E.2: How can sUAS detection data be leveraged to improve safety and efficiency in Unmanned Traffic Management (UTM)?

The purpose of this task is to evaluate any data, findings, or conclusions from tasks performed in this project that can enhance safety or efficiency for unmanned traffic management within the low-altitude NAS.

Findings: Data collection for this task is still underway. Preliminary findings are not available for reporting at this time. Updates on this task will be provided in a subsequent annual report.

Conclusions: Further details and subsequent conclusions regarding leveraged UTM safety and efficiency improvements will be presented in future iterations of this report, as additional data, contextual observations, and analysis results become available.

Future Research Recommendations: Future versions of this report may include additional recommendations concerning investigation of leveraged UTM safety and efficiency improvements, based upon observation, analysis, or inferences drawn from contextual examination of materials. Such recommendations are intended to support the definition and development of future related research efforts that are beyond the scope of this project.

2.5.3 Task E.3: How do air routes impact sUAS activity?

The research team intends to deter addressing the methodology for this task until the second annual reporting period. It is currently unknown if there will be any AAM/UAM activity within any of the proposed capture areas. Deferring this task provides the research team additional time to explore collaborations or alternative sources of data to address this research question.

Findings: Data collection for this task is still underway. Preliminary findings are not available for reporting at this time. Updates on this task will be provided in a subsequent annual report.

Conclusions: Further details and subsequent conclusions regarding air route impact on sUAS activity will be presented in future iterations of this report, as additional data, contextual observations, and analysis results become available.

Future Research Recommendations: Future versions of this report may include additional recommendations concerning investigation of air route impact on sUAS activity, based upon observation, analysis, or inferences drawn from contextual examination of materials. Such recommendations are intended to support the definition and development of future related research efforts that are beyond the scope of this project.

2.5.4 Task E.4: How can "abnormal sUAS traffic" conditions (i.e. volume and proximity) be conveyed to air traffic control (ATC), general aviation, helicopter, and manned aircraft pilots?

The research team proposes that this research question be deferred until the second annual reporting period. This will provide an opportunity for the research team to present the full extent of *normal* sUAS traffic and collaboratively consider appropriate criteria for the identification of *abnormal* sUAS traffic conditions necessary to answer this research question.

Findings: Data collection for this task is still underway. Preliminary findings are not available for reporting at this time. Updates on this task will be provided in a subsequent annual report.

Conclusions: Further details and subsequent conclusions regarding methods to effectively convey abnormal sUAS operational details to affected aviation communities will be presented in future iterations of this report, as additional data, contextual observations, and analysis results become available.

Future Research Recommendations: Future versions of this report may include additional recommendations concerning investigation of methods to effectively convey abnormal sUAS operational details to affected aviation communities, based upon observation, analysis, or inferences drawn from contextual examination of materials. Such recommendations are intended to support the definition and development of future related research efforts that are beyond the scope of this project.

3 CONCLUSIONS

This document provided the Initial Annual Report for the sUAS Traffic Analysis (A11L.UAS.91) project. It presented the progress, findings, and preliminary observations from the research tasks completed in this first-year effort. The findings offer value in providing empirical and objective data on sUAS detection through data collected from a network of 166 sensors spread across 64 diverse geographical areas.

The study reports on several critical areas, namely to (1) identify, assess, and monitor for sUAS safety hazards; (2) determine the effectiveness of existing sUAS regulations; (3) accurately forecast sUAS traffic levels; and (4) aid in identifying and assessing future aviation risk. Through the establishment of six research task areas, the research team is providing answers to the research questions under investigation.

Data collection was completed through a streamlined process in collaboration with URSA. From this platform, customizable analyses and reports were produced that synthesize data received from several sources. This tool offered AI capabilities to detect rapid pattern detection, data visualization, and automated reporting capabilities.

The preliminary findings offer insights into sUAS operations in the NAS. Several noticeable patterns have emerged in the data analysis such as sUAS flights by location, airspace use, seasonal variation in operations (including holiday spikes in operations), time of day operations, operations by type of sUAS, maximum sUAS flight altitudes, the proximity of operations near airports, sUAS launch locations, sUAS retirement/abandonment rates, and estimated registration compliance.

The team also assessed estimated compliance and exceedances of 14 CFR §107. The researchers examined issues such as operations from a moving vehicle, exceedance of daylight operations, BVLOS operations, operations near and around other aircraft, operations over people/large gatherings, speed and altitude limitations, visibility and cloud clearances, mid-air encounter likelihood, and the effectiveness of the LAANC system. These data offer insights into the behavioral patterns and tendencies of sUAS operations, which can be used to inform decisions, policies, and procedures related to their actions.

In the remaining two years of the research project, the team will focus on collecting further data to generate conclusions for deferred research tasks, as well as validate existing research findings and conclusions. Special emphasis will be placed on identifying operational trends that can inform upon the identification and mitigation of potential hazards in the NAS, support forecasting efforts, and enable data-driven policymaking.

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5 APPENDIX

Table A2

Distribution of sUAS Flights by Location & Daylight Category (based on 422,380 flights)

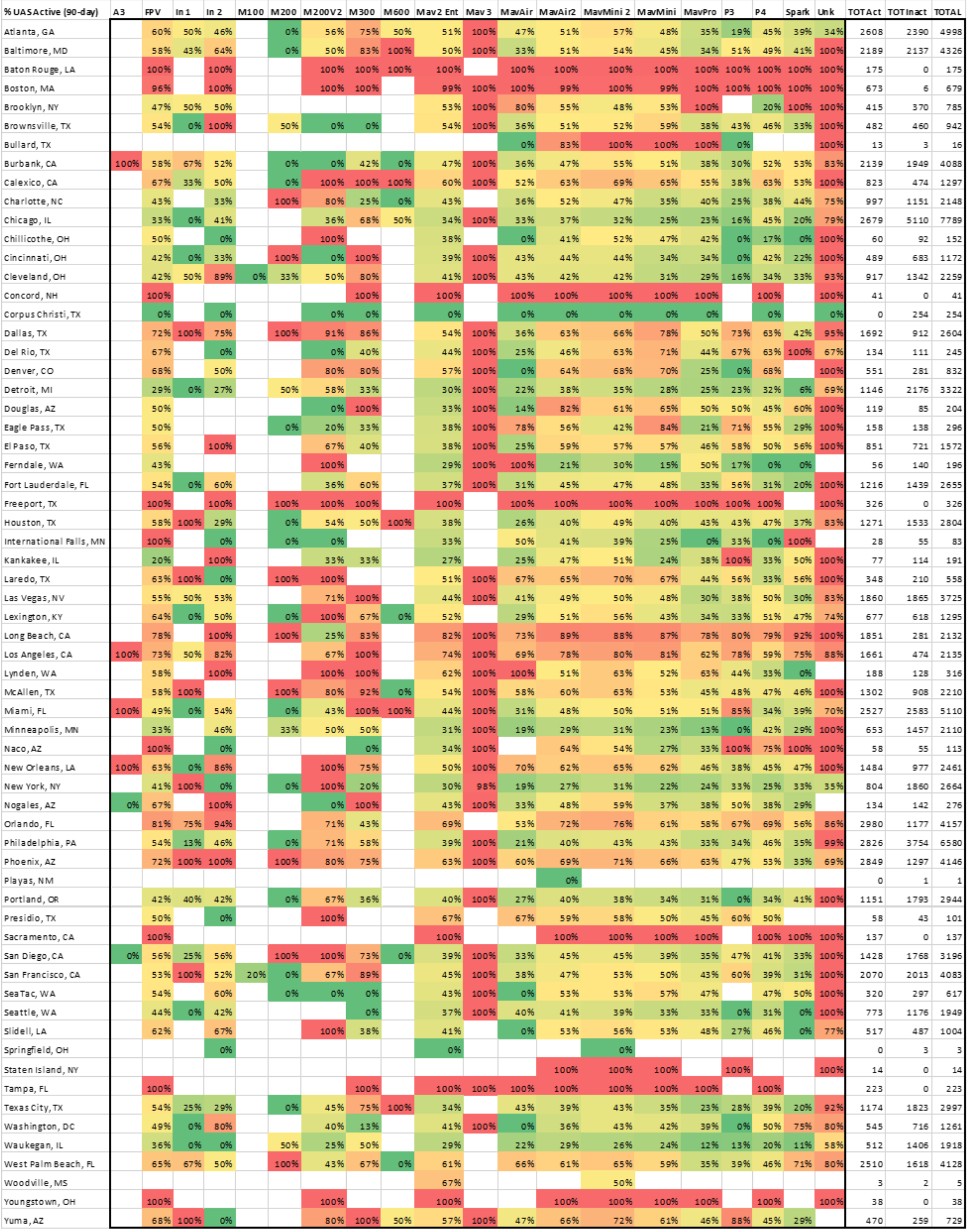
Location	Night (Morn)	CT (Morn)	Daytime	CT (Eve)	Night (Eve)
Atlanta, GA	27.3%	2.7%	67.6%	0.4%	2.0%
Baltimore, MD	17.0%	3.1%	76.8%	0.6%	2.4%
Baton Rouge, LA	1.2%	0.8%	73.8%	5.2%	18.9%
Boston, MA	23.1%	3.6%	66.4%	1.0%	6.0%
Brooklyn, NY	13.4%	2.2%	71.0%	3.2%	10.2%
Brownsville, TX	27.3%	2.7%	67.8%	0.4%	1.8%
Bullard, TX	0.0%	0.0%	70.6%	17.6%	11.8%
Burbank, CA	3.9%	0.8%	80.1%	5.6%	9.6%
Calexico, CA	33.0%	3.1%	60.1%	0.4%	3.4%
Charlotte, NC	3.0%	1.6%	79.5%	5.7%	10.2%
Chicago, IL	17.3%	2.8%	72.8%	2.1%	5.1%
Chillicothe, OH	1.8%	0.4%	84.9%	3.9%	9.1%
Cincinnati, OH	18.7%	4.0%	75.3%	0.5%	1.6%
Cleveland, OH	11.7%	2.7%	82.9%	0.7%	2.0%
Concord, NH	2.1%	3.1%	82.5%	6.2%	6.2%
Corpus Christi, TX	1.7%	0.9%	88.4%	5.2%	3.8%
Dallas, TX	11.3%	1.3%	73.3%	4.8%	9.3%
Del Rio, TX	28.2%	2.6%	68.1%	0.6%	0.5%
Denver, CO	40.4%	4.6%	50.0%	0.5%	4.6%
Detroit, MI	13.8%	2.9%	78.5%	1.1%	3.6%
Douglas, AZ	31.5%	2.9%	61.5%	0.6%	3.6%
Eagle Pass, TX	28.2%	3.3%	66.3%	1.1%	1.1%
El Paso, TX	32.8%	3.4%	62.2%	0.2%	1.4%
Ferndale, WA	34.2%	5.5%	56.5%	0.5%	3.3%
Fort Lauderdale, FL	19.0%	2.9%	75.1%	0.5%	2.6%
Freeport, TX	1.1%	0.7%	87.5%	5.3%	5.5%

Houston, TX	3.4%	0.7%	80.6%	4.1%	11.2%
International Falls, MN	17.8%	4.0%	70.3%	1.0%	6.9%
Kankakee, IL	1.4%	0.8%	81.7%	6.1%	10.0%
Laredo, TX	24.4%	3.0%	68.2%	1.0%	3.3%
Las Vegas, NV	23.6%	2.6%	62.0%	1.9%	9.9%
Lexington, KY	2.4%	1.2%	83.4%	6.3%	6.8%
Long Beach, CA	36.1%	4.1%	52.1%	0.7%	7.0%
Los Angeles, CA	37.1%	3.3%	53.5%	0.9%	5.2%
Lynden, WA	48.9%	6.0%	42.2%	0.3%	2.6%
McAllen, TX	29.1%	2.7%	63.8%	0.5%	3.8%
Miami, FL	16.9%	2.9%	76.6%	0.6%	3.0%
Minneapolis, MN	23.0%	4.0%	71.3%	0.5%	1.2%
Naco, AZ	37.8%	4.2%	51.7%	0.3%	6.0%
New Orleans, LA	29.3%	3.4%	64.0%	0.7%	2.6%
New York, NY	19.6%	2.6%	73.4%	0.5%	3.9%
Nogales, AZ	34.1%	2.5%	59.5%	0.2%	3.7%
Orlando, FL	3.2%	0.9%	80.2%	5.1%	10.5%
Philadelphia, PA	26.2%	3.2%	67.7%	0.3%	2.6%
Phoenix, AZ	37.1%	3.2%	55.8%	0.2%	3.6%
Playas, NM	0.0%	0.0%	100.0%	0.0%	0.0%
Portland, OR	36.8%	3.9%	54.9%	0.2%	4.1%
Presidio, TX	33.0%	2.0%	62.7%	0.7%	1.7%
Sacramento, CA	2.5%	0.8%	80.6%	5.4%	10.7%
San Diego, CA	35.7%	3.2%	56.8%	0.3%	3.9%
San Francisco, CA	34.3%	4.0%	56.5%	0.3%	4.8%
SeaTac, WA	38.9%	6.5%	51.7%	0.3%	2.6%
Seattle, WA	30.5%	4.6%	59.4%	0.4%	5.1%
Slidell, LA	1.5%	0.5%	85.1%	4.7%	8.2%
Springfield, OH	0.0%	0.0%	100.0%	0.0%	0.0%
Staten Island, NY	0.0%	0.0%	96.8%	0.0%	3.2%
Tampa, FL	21.8%	1.7%	75.0%	0.0%	1.5%

Texas City, TX	2.2%	1.0%	83.6%	5.1%	8.2%
Washington, DC	12.1%	2.0%	79.7%	2.2%	4.0%
Waukegan, IL	0.6%	0.4%	88.0%	5.6%	5.3%
West Palm Beach, FL	1.6%	0.9%	85.3%	4.4%	7.8%
Woodville, MS	0.0%	0.0%	83.3%	0.0%	16.7%
Youngstown, OH	0.0%	1.2%	90.4%	2.4%	6.0%
Yuma, AZ	35.5%	2.9%	58.1%	0.2%	3.4%

Table A3

Ratio of Active vs. Inactive sUAS Platforms (56,470 active/55,317 inactive platforms, 90 days)



% UAS Active (90-day)	A3	FPV	In 1	In 2	M100	M200	M200V2	M300	M600	Mav2 Ent	Mav 3	MavAir	MavAir2	MavMini 2	MavMini	MavPro	P3	P4	Spark	Unk	TOT Act	TOT Inact	TOTAL
Atlanta, GA		60%	50%	46%		0%	56%	75%	50%	51%	100%	47%	51%	57%	48%	35%	19%	45%	39%	34%	2608	2390	4998
Baltimore, MD		58%	43%	64%		0%	50%	83%	100%	50%	100%	33%	51%	54%	45%	34%	51%	49%	41%	100%	2189	2137	4326
Baton Rouge, LA		100%		100%			100%	100%	100%	100%		100%	100%	100%	100%	100%	100%	100%	100%	100%	175	0	175
Boston, MA		96%		100%			100%	100%		99%	100%	100%	99%	100%	99%	100%	100%	100%	100%	100%	673	6	679
Brooklyn, NY		47%	50%	50%						53%	100%	80%	55%	48%	53%	100%		20%	100%	100%	415	370	785
Brownsville, TX		54%	0%	100%		50%	0%	0%		54%	100%	36%	51%	52%	59%	38%	43%	46%	33%	100%	482	460	942
Bullard, TX												0%	83%	100%	100%	100%	0%			100%	13	3	16
Burbank, CA	100%	58%	67%	52%		0%	0%	42%	0%	47%	100%	36%	47%	55%	51%	38%	30%	52%	53%	83%	2139	1949	4088
Calexico, CA		67%	33%	50%		0%	100%	100%	100%	60%	100%	52%	63%	69%	65%	55%	38%	63%	53%	100%	823	474	1297
Charlotte, NC		43%		33%		100%	80%	25%	0%	43%		36%	52%	47%	35%	40%	25%	38%	44%	75%	997	1151	2148
Chicago, IL		33%	0%	41%			36%	68%	50%	34%	100%	33%	37%	32%	25%	23%	16%	45%	20%	79%	2679	5110	7789
Chillicothe, OH		50%		0%			100%			38%		0%	41%	52%	47%	42%	0%	17%	0%	100%	60	92	152
Cincinnati, OH		42%	0%	33%		100%	0%	100%		39%	100%	43%	44%	44%	34%	34%	0%	42%	22%	100%	489	683	1172
Cleveland, OH		42%	50%	89%	0%	33%	50%	80%		41%	100%	43%	42%	42%	31%	29%	16%	34%	33%	93%	917	1342	2259
Concord, NH		100%						100%		100%		100%	100%	100%	100%	100%		100%		100%	41	0	41
Corpus Christi, TX		0%		0%			0%	0%		0%		0%	0%	0%	0%	0%		0%		0%	0	254	254
Dallas, TX		72%	100%	75%		100%	91%	86%		54%	100%	36%	63%	66%	78%	50%	73%	63%	42%	95%	1692	912	2604
Del Rio, TX		67%		0%			0%	40%		44%	100%	25%	46%	63%	71%	44%	67%	63%	100%	67%	134	111	245
Denver, CO		68%		50%			80%	80%		57%	100%	0%	64%	68%	70%	25%	0%	68%		100%	551	281	832
Detroit, MI		29%	0%	27%		50%	58%	33%		30%	100%	22%	38%	35%	28%	25%	23%	32%	6%	69%	1146	2176	3322
Douglas, AZ		50%					0%	100%		33%	100%	14%	82%	61%	65%	50%	50%	45%	60%	100%	119	85	204
Eagle Pass, TX		50%				0%	20%	33%		38%	100%	78%	56%	42%	84%	21%	71%	55%	29%	100%	158	138	296
El Paso, TX		56%		100%			67%	40%		38%	100%	25%	59%	57%	57%	46%	58%	50%	56%	100%	851	721	1572
Ferndale, WA		43%					100%			29%	100%	100%	21%	30%	15%	50%	17%	0%	0%		56	140	196
Fort Lauderdale, FL		54%	0%	60%			36%	60%		37%	100%	31%	45%	47%	48%	33%	56%	31%	20%	100%	1216	1439	2655
Freeport, TX		100%		100%		100%	100%	100%		100%		100%	100%	100%	100%	100%	100%	100%		100%	326	0	326
Houston, TX		58%	100%	29%		0%	54%	50%	100%	38%		26%	40%	49%	40%	43%	43%	47%	37%	83%	1271	1533	2804
International Falls, MN		100%		0%		0%	0%			33%		50%	41%	39%	25%	0%	33%	0%	100%		28	55	83
Kankakee, IL		20%		100%			33%	33%		27%		25%	47%	51%	24%	38%	100%	33%	50%	100%	77	114	191
Laredo, TX		63%	100%	0%		100%	100%			51%	100%	67%	65%	70%	67%	44%	56%	33%	56%	100%	348	210	558
Las Vegas, NV		55%	50%	53%			71%	100%		44%	100%	41%	49%	50%	48%	30%	38%	50%	30%	83%	1860	1865	3725
Lexington, KY		64%	0%	50%		0%	100%	67%	0%	52%		29%	51%	56%	43%	34%	33%	51%	47%	74%	677	618	1295
Long Beach, CA		78%		100%		100%	25%	83%		82%	100%	73%	89%	88%	87%	78%	80%	79%	92%	100%	1851	281	2132
Los Angeles, CA	100%	73%	50%	82%			67%	100%		74%	100%	69%	78%	80%	81%	62%	78%	59%	75%	88%	1661	474	2135
Lynden, WA		58%		100%			100%	100%		62%	100%	100%	51%	63%	52%	63%	44%	33%	0%		188	128	316
McAllen, TX		58%	100%			100%	80%	92%	0%	54%	100%	58%	60%	63%	53%	45%	48%	47%	46%	100%	1302	908	2210
Miami, FL	100%	49%	0%	54%		0%	43%	100%	100%	44%	100%	31%	48%	50%	51%	51%	85%	34%	39%	70%	2527	2583	5110
Minneapolis, MN		33%		46%		33%	50%	50%		31%	100%	19%	29%	31%	23%	13%	0%	42%	29%	100%	653	1457	2110
Naco, AZ		100%		0%				0%		34%	100%		64%	54%	27%	33%	100%	75%	100%	100%	58	55	113
New Orleans, LA	100%	63%	0%	86%			100%	75%		50%	100%	70%	62%	65%	62%	46%	38%	45%	47%	100%	1484	977	2461
New York, NY		41%	100%	0%		0%	100%	20%		30%	98%	19%	27%	31%	22%	24%	33%	25%	33%	35%	804	1860	2664
Nogales, AZ	0%	67%		100%			0%	100%		43%	100%	33%	48%	59%	37%	38%	50%	38%	29%		134	142	276
Orlando, FL		81%	75%	94%			71%	43%		69%		53%	72%	76%	61%	58%	67%	69%	56%	86%	2980	1177	4157
Philadelphia, PA		54%	13%	46%		0%	71%	58%		39%	100%	21%	40%	43%	43%	33%	34%	46%	35%	99%	2826	3754	6580
Phoenix, AZ		72%	100%	100%		100%	80%	75%		63%	100%	60%	69%	71%	66%	63%	47%	53%	33%	69%	2849	1297	4146
Playas, NM													0%								0	1	1
Portland, OR		42%	40%	42%		0%	67%	36%		40%	100%	27%	40%	38%	34%	31%	0%	34%	41%	100%	1151	1793	2944
Presidio, TX		50%		0%			100%			67%		67%	59%	58%	50%	45%	60%	50%			58	43	101
Sacramento, CA		100%								100%			100%	100%	100%	100%		100%	100%	100%	137	0	137
San Diego, CA	0%	56%	25%	56%		100%	100%	73%	0%	39%	100%	33%	45%	45%	39%	35%	47%	41%	33%	100%	1428	1768	3196
San Francisco, CA		53%	100%	52%	20%	0%	67%	89%		45%	100%	38%	47%	53%	50%	43%	60%	39%	31%	100%	2070	2013	4083
SeaTac, WA		54%		60%		0%	0%	0%		43%	100%	0%	53%	53%	57%	47%		47%	50%	100%	320	297	617
Seattle, WA		44%	0%	42%				0%		37%	100%	40%	41%	39%	33%	33%	0%	31%	0%	100%	773	1176	1949
Slidell, LA		62%		67%			100%	38%		41%		0%	53%	56%	53%	48%	27%	46%	0%	77%	517	487	1004
Springfield, OH				0%						0%				0%							0	3	3
Staten Island, NY													100%	100%	100%		100%			100%	14	0	14
Tampa, FL		100%						100%		100%	100%	100%	100%	100%	100%	100%		100%			223	0	223
Texas City, TX		54%	25%	29%		0%	45%	75%	100%	34%		43%	39%	43%	35%	23%	28%	39%	20%	92%	1174	1823	2997
Washington, DC		49%	0%	80%			40%	13%		41%	100%	0%	36%	43%	42%	39%	0%	50%	75%	80%	545	716	1261
Waukegan, IL		36%	0%	0%		50%	25%	50%		29%		22%	29%	26%	24%	12%	13%	20%	11%	58%	512	1406	1918
West Palm Beach, FL		65%	67%	50%		100%	43%	67%	0%	61%		66%	61%	65%	59%	35%	39%	46%	71%	80%	2510	1618	4128
Woodville, MS										67%				50%							3	2	5
Youngstown, OH		100%					100%			100%			100%	100%	100%	100%		100%		100%	38	0	38
Yuma, AZ		68%	100%	0%			80%	100%	50%	57%	100%	47%	66%	72%	61%	46%	88%	45%	29%		470	259	729

Table A4

Distribution of sUAS Flight Altitudes by Location (based on 422,380 flights)

Location	<50'	50-100'	100-200'	200-300'	300-400'	400-500'	500-1000'	1000-1500'	1500-2000'	>2000'
Atlanta, GA	3.0%	5.7%	18.6%	17.7%	27.5%	13.4%	9.8%	3.2%	1.0%	0.0%
Baltimore, MD	0.8%	4.7%	20.1%	22.0%	35.0%	7.4%	6.6%	1.8%	1.2%	0.4%
Baton Rouge, LA	0.0%	0.2%	3.5%	9.8%	33.4%	14.2%	21.5%	8.8%	8.6%	0.0%
Boston, MA	3.3%	8.3%	29.7%	14.8%	20.8%	8.2%	9.4%	3.0%	1.2%	1.3%
Brooklyn, NY	5.0%	11.7%	24.7%	18.4%	22.8%	7.3%	6.5%	2.3%	1.3%	0.0%
Brownsville, TX	1.3%	6.0%	19.7%	19.7%	29.6%	9.5%	9.5%	2.6%	2.2%	0.0%
Bullard, TX	0.0%	5.9%	11.8%	17.6%	17.6%	11.8%	11.8%	0.0%	23.5%	0.0%
Burbank, CA	7.2%	14.9%	27.2%	16.4%	18.0%	6.9%	6.3%	1.9%	1.2%	0.0%
Calexico, CA	2.5%	11.4%	29.4%	18.7%	19.2%	6.2%	8.7%	2.0%	1.9%	0.0%
Charlotte, NC	3.8%	6.9%	20.1%	20.9%	28.6%	6.9%	9.4%	2.5%	0.7%	0.0%
Chicago, IL	3.4%	10.1%	24.8%	18.2%	23.7%	10.2%	6.3%	2.1%	1.2%	0.1%
Chillicothe, OH	4.2%	3.9%	16.0%	15.8%	34.3%	8.6%	9.5%	4.7%	3.0%	0.0%
Cincinnati, OH	3.8%	6.7%	17.4%	16.6%	33.2%	8.8%	10.0%	2.5%	1.1%	0.0%
Cleveland, OH	1.3%	2.9%	16.5%	26.1%	31.4%	9.8%	7.3%	2.4%	2.1%	0.2%
Concord, NH	9.3%	2.1%	13.4%	19.6%	32.0%	6.2%	4.1%	9.3%	4.1%	0.0%
Corpus Christi, TX	2.4%	5.5%	16.6%	27.6%	29.7%	8.8%	6.7%	1.9%	0.9%	0.0%
Dallas, TX	1.3%	6.6%	17.7%	18.5%	29.9%	9.9%	10.4%	3.1%	2.6%	0.0%
Del Rio, TX	3.1%	8.9%	22.8%	20.3%	20.4%	6.7%	13.5%	3.5%	0.8%	0.0%
Denver, CO	6.6%	19.5%	37.1%	14.7%	14.5%	3.5%	2.6%	1.0%	0.6%	0.0%
Detroit, MI	2.0%	7.2%	23.1%	19.4%	26.2%	8.2%	9.9%	2.4%	1.3%	0.3%
Douglas, AZ	8.7%	22.0%	21.8%	13.6%	15.2%	7.2%	7.3%	1.8%	2.4%	0.0%
Eagle Pass, TX	3.3%	10.5%	23.2%	17.7%	23.6%	5.3%	10.8%	2.6%	3.0%	0.0%
El Paso, TX	5.0%	9.0%	16.2%	15.1%	29.6%	10.0%	9.8%	3.4%	1.8%	0.0%
Ferndale, WA	1.8%	4.8%	13.8%	18.6%	24.9%	8.3%	18.1%	6.8%	3.0%	0.0%
Fort Lauderdale, FL	1.3%	4.6%	17.5%	18.2%	28.5%	8.8%	12.4%	4.2%	4.3%	0.2%
Freeport, TX	4.0%	7.5%	21.1%	23.7%	29.5%	5.7%	5.8%	2.1%	0.7%	0.0%
Houston, TX	3.1%	10.4%	21.1%	17.6%	23.4%	9.2%	8.3%	3.9%	3.1%	0.0%
International Falls, MN	2.3%	3.6%	26.4%	18.2%	21.5%	11.2%	8.9%	3.0%	5.0%	0.0%
Kankakee, IL	2.6%	10.8%	19.6%	18.3%	31.9%	6.0%	7.4%	2.2%	1.2%	0.0%
Laredo, TX	2.5%	11.9%	27.6%	16.0%	18.5%	6.1%	8.6%	4.8%	4.0%	0.0%
Las Vegas, NV	10.3%	10.0%	23.4%	15.7%	21.7%	8.2%	7.2%	2.1%	1.6%	0.0%

Lexington, KY	3.6%	13.2%	31.4%	17.2%	22.9%	6.1%	3.7%	1.0%	0.9%	0.1%
Long Beach, CA	4.2%	10.1%	27.3%	19.3%	24.0%	6.8%	5.5%	1.5%	1.2%	0.0%
Los Angeles, CA	3.7%	9.6%	30.5%	20.3%	19.3%	6.0%	5.1%	2.6%	2.5%	0.3%
Lynden, WA	2.7%	4.8%	12.0%	17.1%	24.0%	8.4%	18.2%	7.2%	5.6%	0.0%
McAllen, TX	0.7%	4.5%	15.8%	13.3%	19.3%	6.9%	17.2%	14.2%	8.1%	0.0%
Miami, FL	4.8%	15.3%	29.5%	16.7%	18.3%	6.5%	6.8%	1.3%	0.7%	0.0%
Minneapolis, MN	8.2%	14.2%	25.9%	18.0%	22.6%	9.2%	1.5%	0.3%	0.1%	0.0%
Naco, AZ	6.0%	5.7%	9.7%	9.6%	13.1%	4.7%	42.5%	4.2%	4.5%	0.0%
New Orleans, LA	7.1%	21.2%	25.5%	14.5%	18.1%	5.4%	5.7%	1.4%	1.0%	0.0%
New York, NY	6.5%	7.8%	17.6%	14.2%	21.5%	11.8%	12.6%	5.5%	2.4%	0.1%
Nogales, AZ	9.4%	13.6%	23.0%	18.6%	21.0%	4.9%	6.1%	1.9%	1.4%	0.0%
Orlando, FL	1.0%	7.8%	33.9%	22.9%	23.1%	5.1%	4.0%	1.1%	1.0%	0.2%
Philadelphia, PA	2.6%	8.7%	27.6%	21.7%	25.2%	6.2%	6.0%	1.4%	0.7%	0.0%
Phoenix, AZ	6.9%	18.4%	29.2%	15.0%	17.0%	4.5%	5.0%	2.0%	1.9%	0.0%
Playas, NM	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%
Portland, OR	6.1%	9.5%	21.9%	18.7%	25.1%	9.1%	6.1%	2.1%	1.2%	0.2%
Presidio, TX	10.7%	19.4%	23.1%	16.2%	13.8%	3.9%	9.4%	3.1%	0.4%	0.0%
Sacramento, CA	2.9%	2.5%	12.0%	14.9%	46.7%	8.7%	10.7%	0.8%	0.8%	0.0%
San Diego, CA	6.7%	8.3%	19.9%	18.1%	30.4%	8.6%	5.7%	1.4%	0.9%	0.0%
San Francisco, CA	7.0%	8.1%	15.3%	15.8%	24.4%	9.5%	12.6%	4.9%	2.4%	0.0%
SeaTac, WA	1.8%	4.6%	27.5%	18.9%	26.9%	7.4%	7.0%	2.6%	3.3%	0.1%
Seattle, WA	5.7%	8.1%	18.2%	15.9%	24.5%	12.2%	11.7%	2.4%	1.4%	0.0%
Slidell, LA	0.2%	1.1%	16.8%	21.4%	31.6%	8.4%	11.5%	4.4%	4.5%	0.0%
Springfield, OH	0.0%	25.0%	25.0%	0.0%	50.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Staten Island, NY	22.6%	9.7%	12.9%	9.7%	22.6%	3.2%	12.9%	3.2%	3.2%	0.0%
Tampa, FL	7.1%	12.0%	36.5%	16.7%	19.2%	4.1%	3.6%	0.2%	0.6%	0.0%
Texas City, TX	2.1%	14.6%	26.2%	16.1%	21.0%	5.6%	7.9%	3.3%	3.2%	0.0%
Washington, DC	2.3%	4.8%	20.8%	20.5%	31.9%	7.3%	7.7%	2.3%	2.0%	0.5%
Waukegan, IL	0.6%	4.2%	20.0%	20.3%	33.9%	7.8%	7.9%	2.6%	2.7%	0.0%
West Palm Beach, FL	3.2%	21.1%	32.2%	17.3%	16.9%	4.2%	3.5%	0.8%	0.7%	0.0%
Woodville, MS	0.0%	0.0%	0.0%	16.7%	66.7%	0.0%	16.7%	0.0%	0.0%	0.0%
Youngstown, OH	2.4%	1.2%	1.2%	16.9%	34.9%	22.9%	6.0%	4.8%	9.6%	0.0%
Yuma, AZ	7.3%	19.7%	31.1%	15.6%	17.2%	4.0%	3.7%	0.6%	0.8%	0.0%

Table A5

Distribution of Flights by Visibility Category & sUAS Type

	Lateral		Vertical		Visibility Category					
Drone Group	**Mean**	**Median**	**Mean**	**Median**	**30 Arc-Min**	**15-30 Arc-Min**	**10-15 Arc-Min**	**1-10 Arc-Min**	**1 Arc-Min**	**TOTAL**
A3	2305.4	1024.8	291.4	199.14	5	10	1	11	0	27
Agras	1410.5	1410.5	40.4	40.35	0	1	0	0	0	1
FPV	1691.2	1052.6	197.4	82.35	2078	1267	1182	15978	4569	25074
Inspire 1 Series	870.7	375.5	92.2	28.21	102	54	23	127	0	306
Inspire 2 Series	1220.3	788.9	139.3	70.87	415	269	213	1104	24	2025
M100 Series	628.4	131.1	23.6	10.17	4	2	3	5	0	14
M200 Series	1498.0	700.2	78.1	34.13	77	28	17	87	6	215
M200 V2 Series	3384.5	1720.4	103.2	38.71	1375	427	350	2919	194	5265
M300 Series	2455.2	1183.0	83.4	44.94	1057	537	392	2397	234	4617
M600 Series	1563.0	1087.4	97.7	23.78	44	48	28	42	0	162
Mavic 2 Enterprise Series	1373.0	728.2	137.3	61.67	10737	7280	5107	41553	6155	70832
Mavic 3 Series	2336.9	1451.7	192.0	95.14	547	302	264	3137	802	5052
Mavic Air	661.1	330.6	105.9	50.19	484	340	313	1686	156	2979
Mavic Air 2 Series	1281.6	686.1	133.5	62.01	12861	7383	6204	53359	11408	91215
Mavic Mini 2 Series	1050.8	488.2	140.5	65.61	18330	10722	8542	68925	16948	123467
Mavic Mini Series	609.5	289.9	90.8	45.61	6219	4048	3101	18159	1516	33043
Mavic Pro	1037.6	522.8	128.9	59.39	1981	1259	939	6238	578	10995
P3 Series	599.6	277.8	91.4	39.37	441	264	166	695	15	1581
P4 Series	1428.3	711.9	91.8	38.38	2154	1129	826	6716	820	11645
Spark	366.7	172.1	95.2	44.29	194	170	98	509	29	1000
Unknown	1385.0	605.2	113.6	52.5	2092	761	478	889	5	4225

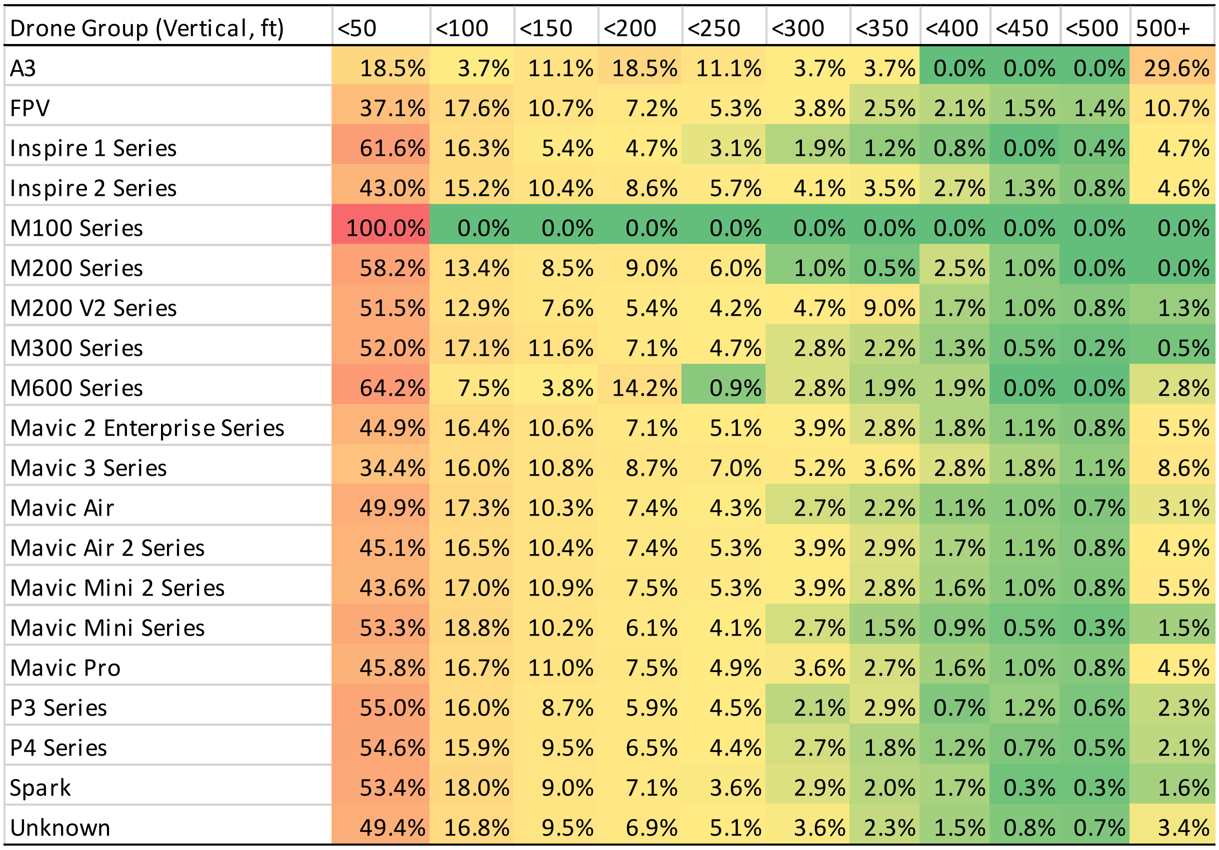
Table A6

Lateral sUAS Flight Footprint Distribution by Drone Type in Feet (n=351,980)

Drone Group (Lateral, ft)	<528	<1056	<1584	<2112	<2640	<3168	<3696	<4224	<4752	<5280	5280+
A3	25.9%	25.9%	7.4%	0.0%	3.7%	3.7%	0.0%	0.0%	11.1%	7.4%	14.8%
FPV	31.1%	17.7%	12.8%	10.1%	7.4%	5.3%	3.8%	2.7%	1.8%	1.3%	6.0%
Inspire 1 Series	57.8%	14.3%	8.9%	7.8%	3.1%	2.3%	1.6%	0.4%	1.2%	2.3%	0.4%
Inspire 2 Series	38.6%	20.9%	15.8%	8.4%	5.2%	3.7%	2.1%	1.2%	1.5%	0.6%	2.1%
M100 Series	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
M200 Series	42.8%	14.4%	8.5%	12.9%	9.0%	2.5%	1.5%	1.5%	0.0%	0.5%	6.5%
M200 V2 Series	32.6%	10.6%	6.7%	4.9%	4.2%	4.1%	2.9%	2.8%	3.6%	4.1%	23.5%
M300 Series	30.6%	14.7%	10.4%	7.2%	5.6%	3.5%	2.2%	2.6%	2.5%	2.7%	18.2%
M600 Series	34.9%	21.7%	14.2%	12.3%	2.8%	3.8%	0.9%	4.7%	0.9%	0.9%	2.8%
Mavic 2 Enterprise Series	41.9%	18.4%	12.2%	8.1%	5.3%	3.4%	2.4%	1.8%	1.3%	1.0%	4.1%
Mavic 3 Series	24.6%	15.4%	11.2%	9.7%	7.8%	6.5%	4.9%	3.4%	2.8%	2.1%	11.6%
Mavic Air	62.2%	19.3%	8.7%	3.7%	1.4%	1.4%	0.9%	0.6%	0.6%	0.6%	0.7%
Mavic Air 2 Series	44.0%	17.5%	11.6%	7.8%	5.3%	3.7%	2.6%	1.8%	1.3%	0.9%	3.4%
Mavic Mini 2 Series	51.7%	16.1%	10.2%	6.9%	4.5%	3.0%	2.1%	1.4%	1.0%	0.7%	2.4%
Mavic Mini Series	64.8%	17.5%	8.7%	4.0%	1.9%	1.1%	0.6%	0.4%	0.3%	0.2%	0.5%
Mavic Pro	50.4%	19.7%	10.9%	6.2%	3.4%	2.3%	1.7%	0.9%	0.8%	0.6%	3.2%
P3 Series	67.4%	17.8%	6.9%	3.7%	1.5%	1.0%	0.7%	0.4%	0.1%	0.1%	0.6%
P4 Series	43.8%	19.3%	12.4%	8.7%	5.0%	3.1%	1.9%	1.2%	0.9%	0.7%	3.0%
Spark	81.2%	10.2%	4.3%	2.6%	0.8%	0.5%	0.1%	0.1%	0.0%	0.1%	0.1%
Unknown	46.7%	16.7%	11.4%	7.0%	4.6%	2.6%	2.3%	1.6%	1.0%	1.0%	5.1%

Table A7

Vertical sUAS Flight Footprint Distribution by Drone Type in Feet (n=351,980)



Drone Group (Vertical, ft)	<50	<100	<150	<200	<250	<300	<350	<400	<450	<500	500+
A3	18.5%	3.7%	11.1%	18.5%	11.1%	3.7%	3.7%	0.0%	0.0%	0.0%	29.6%
FPV	37.1%	17.6%	10.7%	7.2%	5.3%	3.8%	2.5%	2.1%	1.5%	1.4%	10.7%
Inspire 1 Series	61.6%	16.3%	5.4%	4.7%	3.1%	1.9%	1.2%	0.8%	0.0%	0.4%	4.7%
Inspire 2 Series	43.0%	15.2%	10.4%	8.6%	5.7%	4.1%	3.5%	2.7%	1.3%	0.8%	4.6%
M100 Series	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
M200 Series	58.2%	13.4%	8.5%	9.0%	6.0%	1.0%	0.5%	2.5%	1.0%	0.0%	0.0%
M200 V2 Series	51.5%	12.9%	7.6%	5.4%	4.2%	4.7%	9.0%	1.7%	1.0%	0.8%	1.3%
M300 Series	52.0%	17.1%	11.6%	7.1%	4.7%	2.8%	2.2%	1.3%	0.5%	0.2%	0.5%
M600 Series	64.2%	7.5%	3.8%	14.2%	0.9%	2.8%	1.9%	1.9%	0.0%	0.0%	2.8%
Mavic 2 Enterprise Series	44.9%	16.4%	10.6%	7.1%	5.1%	3.9%	2.8%	1.8%	1.1%	0.8%	5.5%
Mavic 3 Series	34.4%	16.0%	10.8%	8.7%	7.0%	5.2%	3.6%	2.8%	1.8%	1.1%	8.6%
Mavic Air	49.9%	17.3%	10.3%	7.4%	4.3%	2.7%	2.2%	1.1%	1.0%	0.7%	3.1%
Mavic Air 2 Series	45.1%	16.5%	10.4%	7.4%	5.3%	3.9%	2.9%	1.7%	1.1%	0.8%	4.9%
Mavic Mini 2 Series	43.6%	17.0%	10.9%	7.5%	5.3%	3.9%	2.8%	1.6%	1.0%	0.8%	5.5%
Mavic Mini Series	53.3%	18.8%	10.2%	6.1%	4.1%	2.7%	1.5%	0.9%	0.5%	0.3%	1.5%
Mavic Pro	45.8%	16.7%	11.0%	7.5%	4.9%	3.6%	2.7%	1.6%	1.0%	0.8%	4.5%
P3 Series	55.0%	16.0%	8.7%	5.9%	4.5%	2.1%	2.9%	0.7%	1.2%	0.6%	2.3%
P4 Series	54.6%	15.9%	9.5%	6.5%	4.4%	2.7%	1.8%	1.2%	0.7%	0.5%	2.1%
Spark	53.4%	18.0%	9.0%	7.1%	3.6%	2.9%	2.0%	1.7%	0.3%	0.3%	1.6%
Unknown	49.4%	16.8%	9.5%	6.9%	5.1%	3.6%	2.3%	1.5%	0.8%	0.7%	3.4%

Table A8

Public Safety Agencies Operating DJI sUAS Fleet within sUAS Detection Capture Areas

State	City	Agency
AZ	Glendale	Glendora Fire Department
AZ	Glendale	Glendale Police Department
AZ	Phoenix	Amp-Aero Technologies
AZ	Sun City West	Arizona Fire & Medical Authority
AZ	Tempe	City of Tempe Police Department
CA	Beverly Hills	Beverly Hills Police Department
CA	Chula Vista	Chula Vista Police Department
CA	Los Angeles	Los Angeles City Fire Department
CA	Los Angeles	Los Angeles Park Rangers
CA	Los Angeles	Matterhorn
CA	Los Angeles	Los Angeles Fire Department
CA	Moraga	Moraga Orinda Fire District
CA	National City	National City Police Department
CA	Oakland	Alameda County Sheriff’s Office
CA	Pasadena	Phase 5 Environmental
CA	Redondo Beach	Flying Lion, Inc.
CA	Sacramento	Sacramento County Sheriff's Office
CA	Sacramento	Sacramento Metropolitan Fire District
CA	Sacramento	Sacramento Police Department
CA	San Diego	BEAD Global
CA	San Diego	Birds Eye Aerial Drones, LLC
CA	San Diego	San Diego State University
CA	Sausalito	Southern Marin Fire Protection District
CA	Torrance	Torrance Police Department
CA	West Sacramento	West Sacramento Police Department
CO	Aurora	Adams & Arapahoe Counties ARES
CO	Centennial	CO Division of Homeland Security and Emergency Management
CO	Frederick	Frederick Police Department
CO	Lakewood	Colorado Department of Public Safety
CO	Lakewood	West Metro Fire Rescue
DE	Dover	Delray Beach Police Department

FL	Boca Raton	City of Boca Raton Police Department
FL	Coral Springs	City of Coral Springs
FL	Davenport	Photo Video Connection
FL	Doral	Miami-Dade Fire Rescue
FL	Fort Lauderdale	CERT
FL	Jupiter	Jupiter Police Department
FL	Kissimmee	Osceola County Office of Emergency Management
FL	Largo	City of Largo
FL	Largo	Largo Fire Rescue
FL	Miami Beach	Airborne International Response Team (AIRT)
FL	Miami Beach	Miami Beach Police Department
FL	Miramar	City of Miramar Police Department
FL	New Port Richey	Pasco County Sheriff's Office
FL	Orlando	Orange County Sheriff's Office
FL	Orlando	Orlando Arson / Bomb Squad
FL	Sanford	Sentinel Sky
FL	West Palm Beach	City of WPB
FL	West Palm Beach	Palm Beach County Sheriff's Office
GA	Atlanta	Alpha Team K9 SAR
GA	Atlanta	Georgia Tech Police Department
GA	Brookhaven	Brookhaven Police Department
GA	College Park	South Fulton Police
GA	College Park	South Fulton Police Department
GA	Johns Creek	Johns Creek Police Department
IL	Aurora	Scully Staffing Solutions
IL	Chicago Ridge	Chicago Ridge EMA
IL	Glenview	Glenview Fire Department
IL	Lynwood	Lynwood Fire
IL	Romeoville	Romeoville Fire Department
IL	Willow Springs	Willow Springs Police Department
IN	Munster	Munster Police Department
IN	Sellersburg	Clark County Sheriff’s Office Search and Rescue
KY	Hebron	Hebron Fire Protection District
LA	Benton	Boston Fire Department

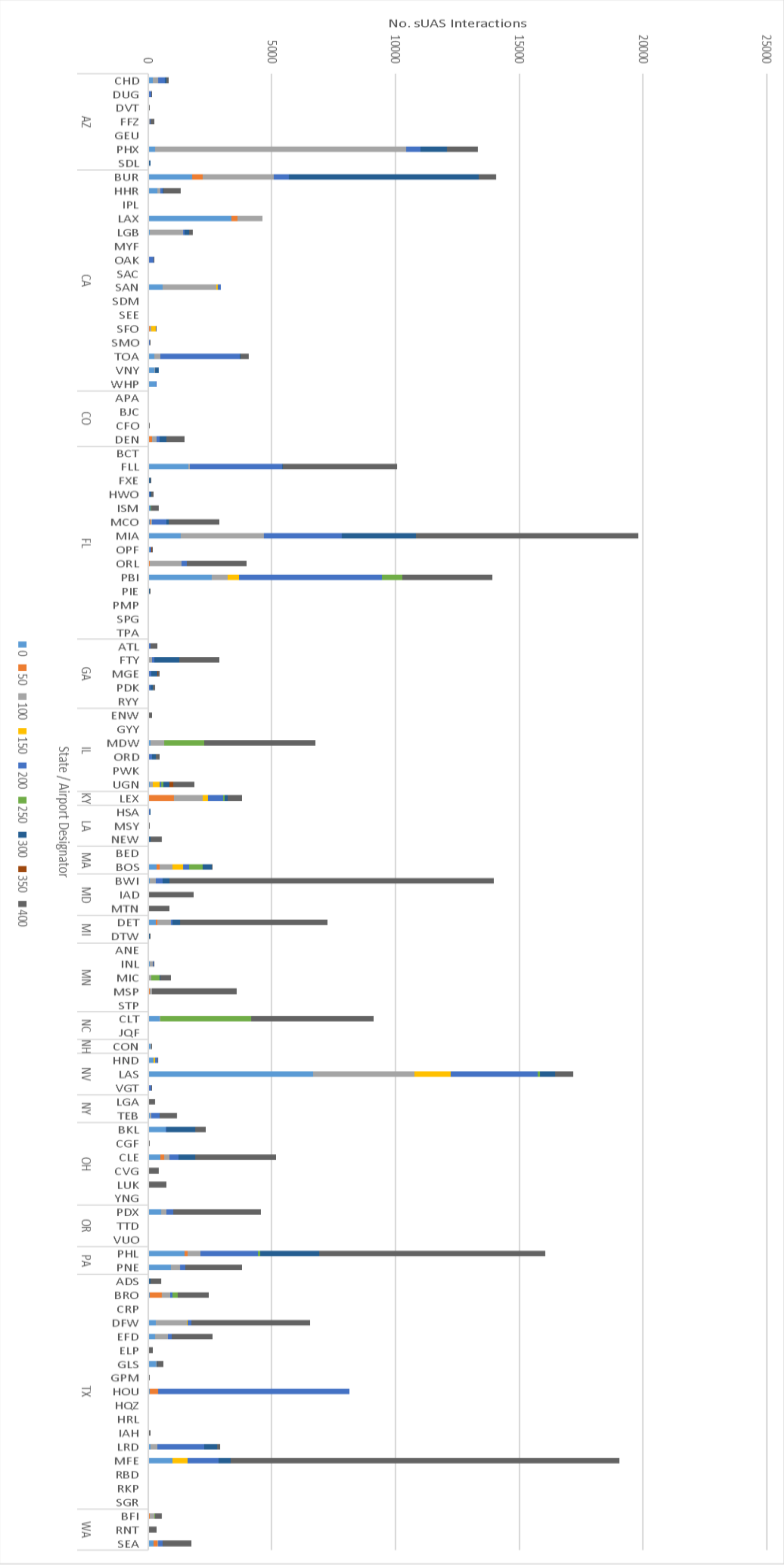
LA	Mandeville	St. Tammany Fire District #4
LA	Slidell	Slidell Police Department
MA	Boston	MassDOT Aeronautics Division
MA	Burlington	Burlington PD
MA	Burlington	Burlington Police Department
MA	Lynn	Lynn Fire Department
MD	Baltimore	BWI Airport Fire Rescue
MD	Bowie	SMC Tactical Communications
MD	Ellicott City	Howard County Police Department
MD	La Plata	Charlotte Fire Department
MD	Sykesville	MD Department of Public Safety & Correctional Services
MI	Detroit	Tredyffrin Township Police Department
MI	Livonia	Western Wayne County HMRT
MI	West Bloomfield	West Bloomfield Police Department
MN	Alexandria	Douglas County Sheriff's Office
MN	Edina	Edina Police Department
MN	Plymouth	Plymouth Police Department
NC	Charlotte	Charlotte-Mecklenburg PD
NC	Charlotte	Charlotte-Mecklenburg Police Department
NC	Huntersville	Huntersville Police Department
NH	Hillsboro	Hillsboro NH Police
NH	Weare	Blue View Drone Services, LLC
NJ	Cinnaminson	Cinnaminson Fire Department
NJ	Fort Lee	Fort Lee Police Department
NJ	Hoboken	Hoboken Police Dept
NJ	Linden	Linden Police Department
NJ	North Bergen	North Bergen Police Department
NV	Henderson	Henderson Fire Department
NV	Las Vegas	City of Las Vegas
NY	New York	FDNY
OH	Aurora	Aurora Police Department
OH	Blue Ash	Blue Ash Police and Fire Departments
OH	Cleveland	Cuyahoga Community College
OH	Holland	Springfield Twp. Fire Department

OH	Willoughby	Lake County Public Safety UAS
OH	Woodlawn	Woodlawn Fire Dept
OR	Tigard	Tualatin Valley Fire & Rescue
PA	Bensalem	Bensalem Township Police
PA	Oaks	Township of Upper Providence
PA	Phoenixville	Friendship Diving Rescue Unit, Station 77
PA	Phoenixville	Upper Providence Township Police Department
PA	West Chester	Chester County Hazmat
PA	West Chester	West Chester Borough Police
TX	Allen	City of Allen Police Department
TX	Alvin	Alvin Fire Department
TX	Arlington	North Central Texas Emergency Communications District (NCT9-1-1)
TX	Bayou Vista	Bayou Vista Vol. Fire Department
TX	Bellaire	Bellaire Police Department
TX	Corpus Christi	Corpus Christi Fire Department
TX	Cypress	The Response Group
TX	Dallas	Southern Methodist University
TX	Deer Park	DeKalb County Fire Rescue
TX	Deer Park	Shell Deer Park
TX	Desoto	Desoto Police Department
TX	DFW Airport	DFW Airport DPS
TX	Duncanville	Duncanville Police Department
TX	El Paso	Del Valle Disaster Response CERT Team
TX	Euless	Euless Police Department
TX	Frisco	Frisco Police Department
TX	Grapevine	Grapevine Fire Department
TX	Houston	AirScape Drone Solutions
TX	Houston	FAASTeam (FAA Safety Team)
TX	Houston	Harris County Fire Marshal's Office
TX	Houston	Memorial Villages Police Department
TX	Irving	Irving Texas PD
TX	Laredo	Fly High Elite
TX	Lewisville	City of Lewisville Fire and Police
TX	Pearland	Pearland Police Department

TX	Plano	Plano Police Department
TX	Richardson	Richardson Fire Department
TX	Sachse	Sachse Fire Rescue
TX	Seguin	Seminole County Fire Department
TX	The Colony	The Colony PD
TX	Webster	Webster Police Department
TX	Wylie	Wylie Fire Rescue
VA	Fairfax	George Mason University Police
VA	Fairfax	Fairfax County Police
WA	Pacific	Palm Beach County Fire Rescue

Figure A1

UAS Facility Map Utilization by State and Airport Designator



UAS Detection Hotspots within Selected UAS Facility Maps

Figure A2. Phoenix, AZ

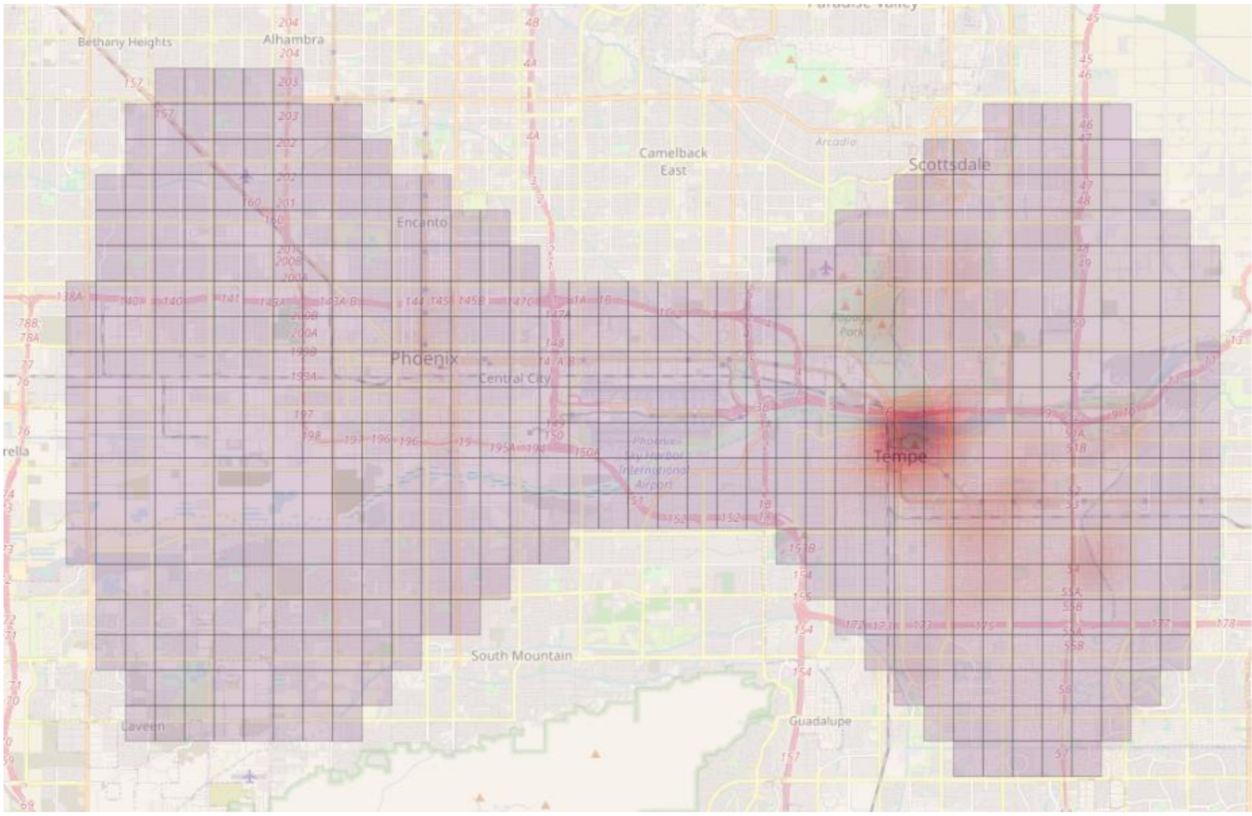


Figure A3. Burbank, CA

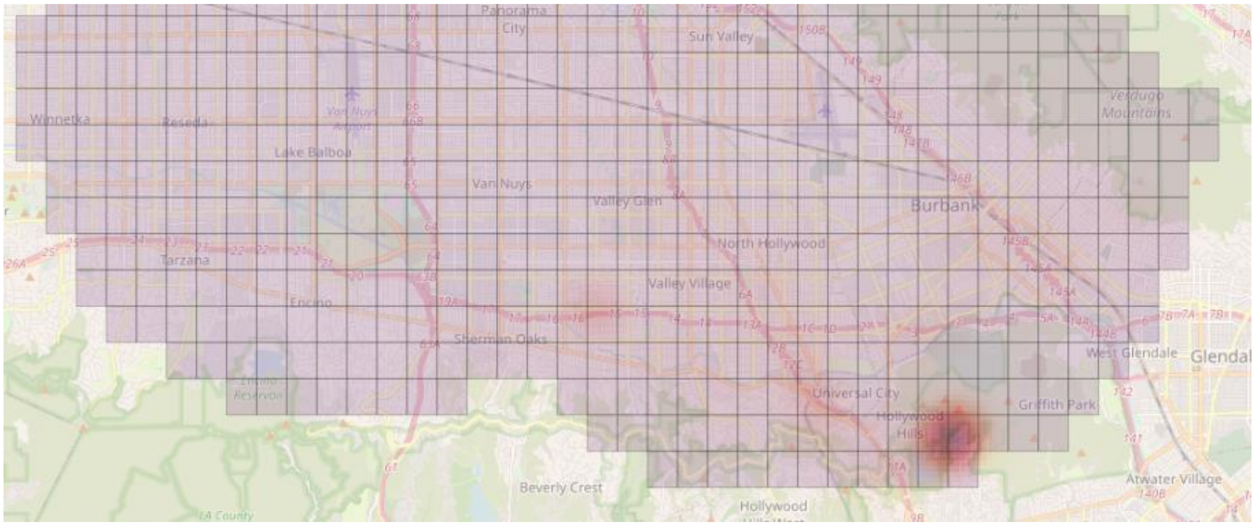


Figure A4. Long Beach, CA

Figure A5. Los Angeles, CA

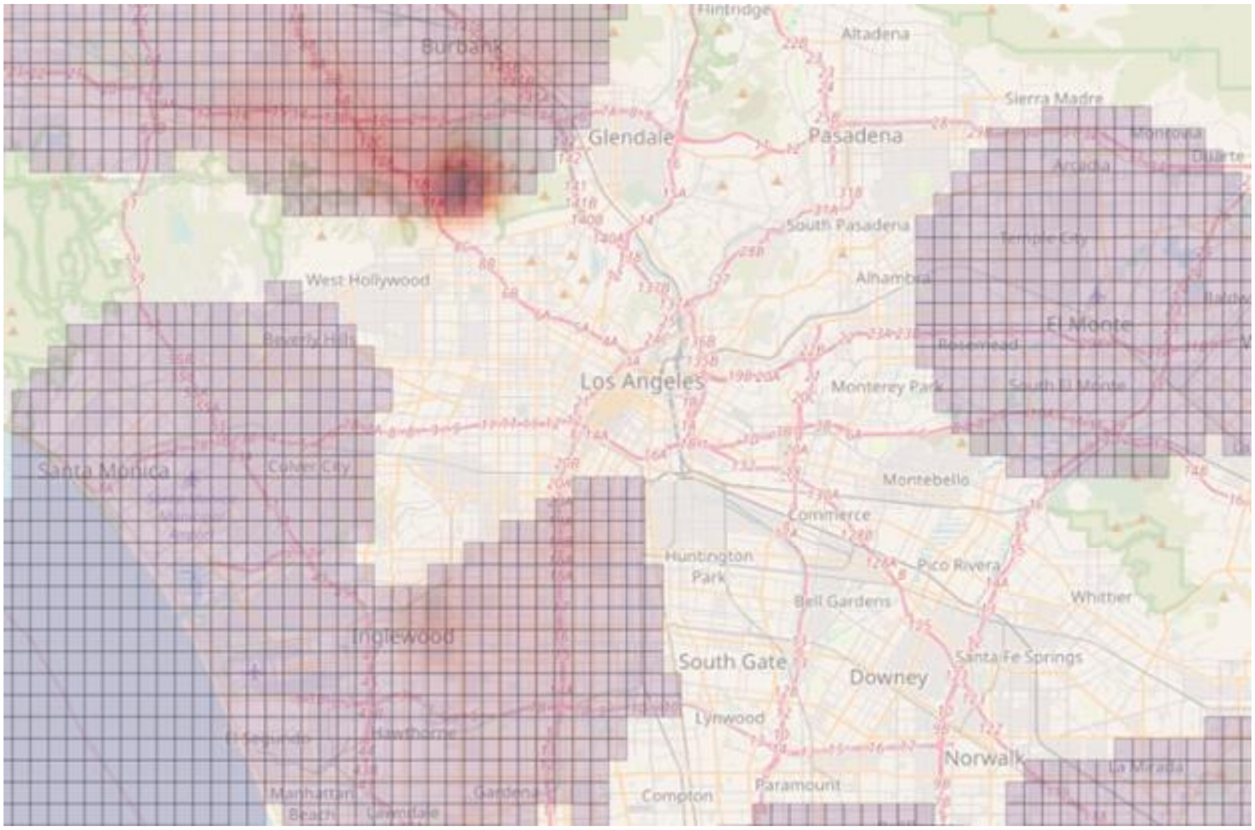


Figure A6. San Diego, CA

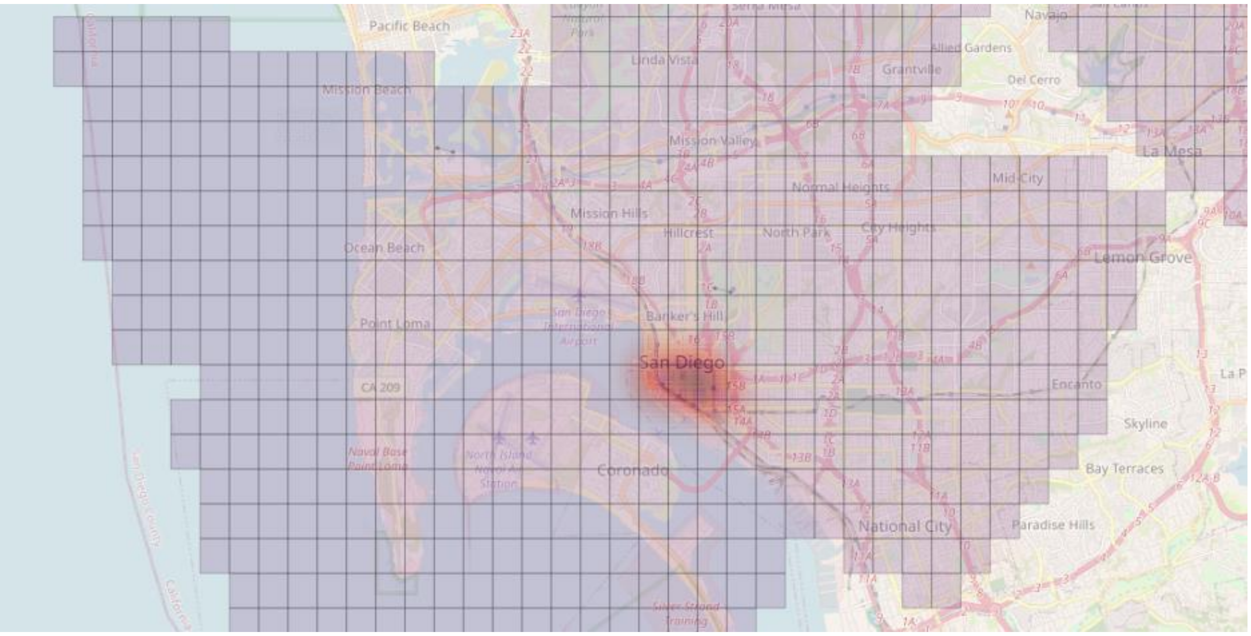


Figure A7. Denver, CO

Figure A8. Washington, D.C.

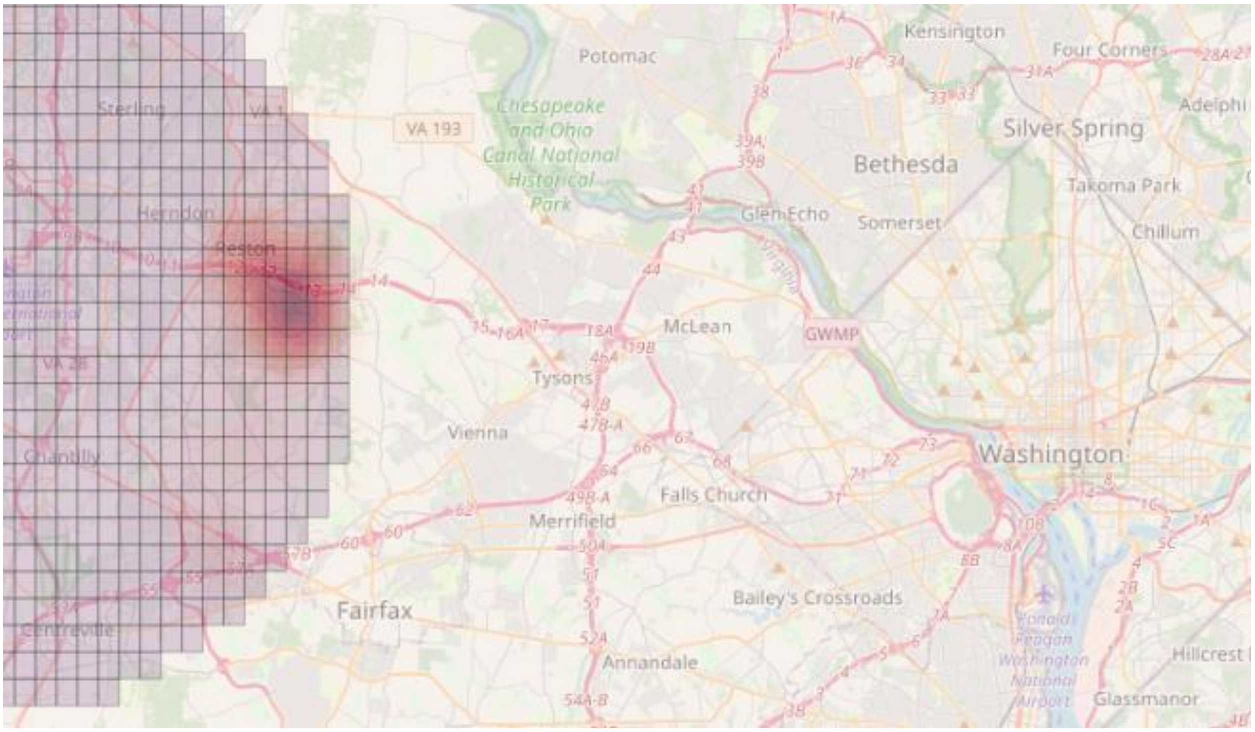


Figure A9. Fort Lauderdale, FL

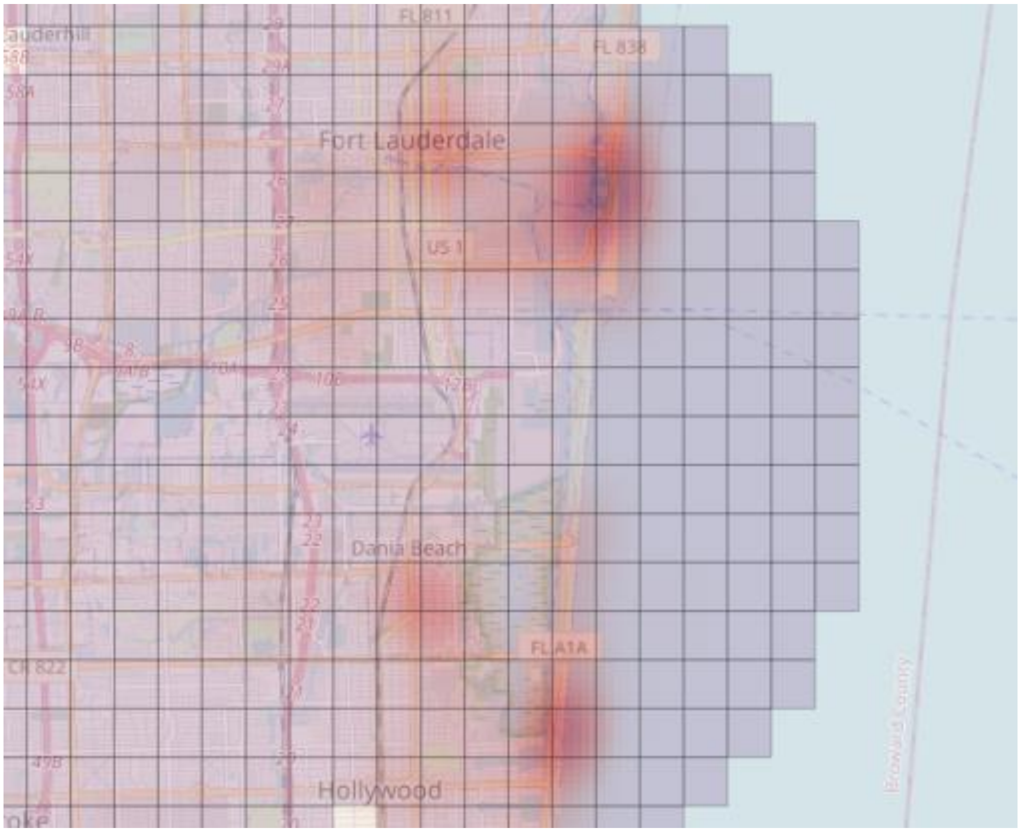


Figure A10. Orlando, FL

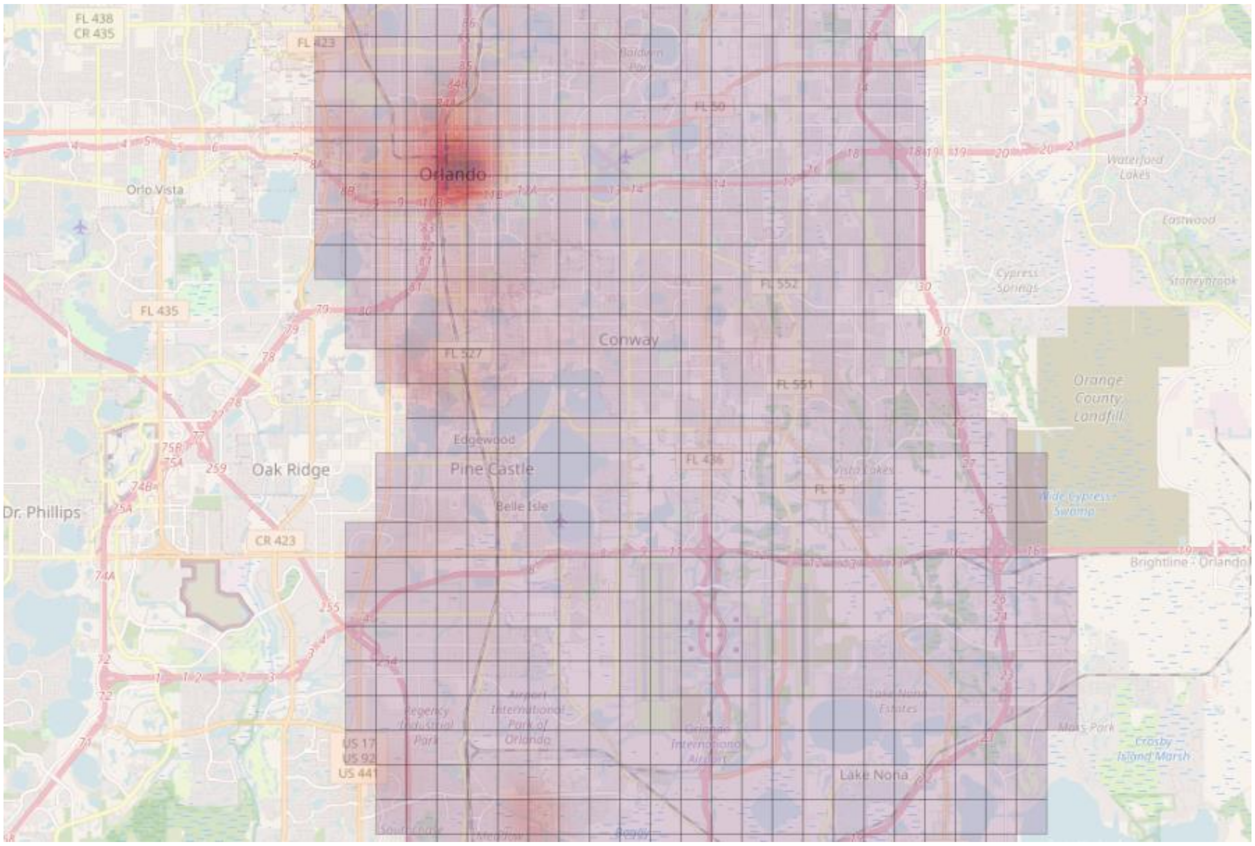


Figure A11. Tampa, FL

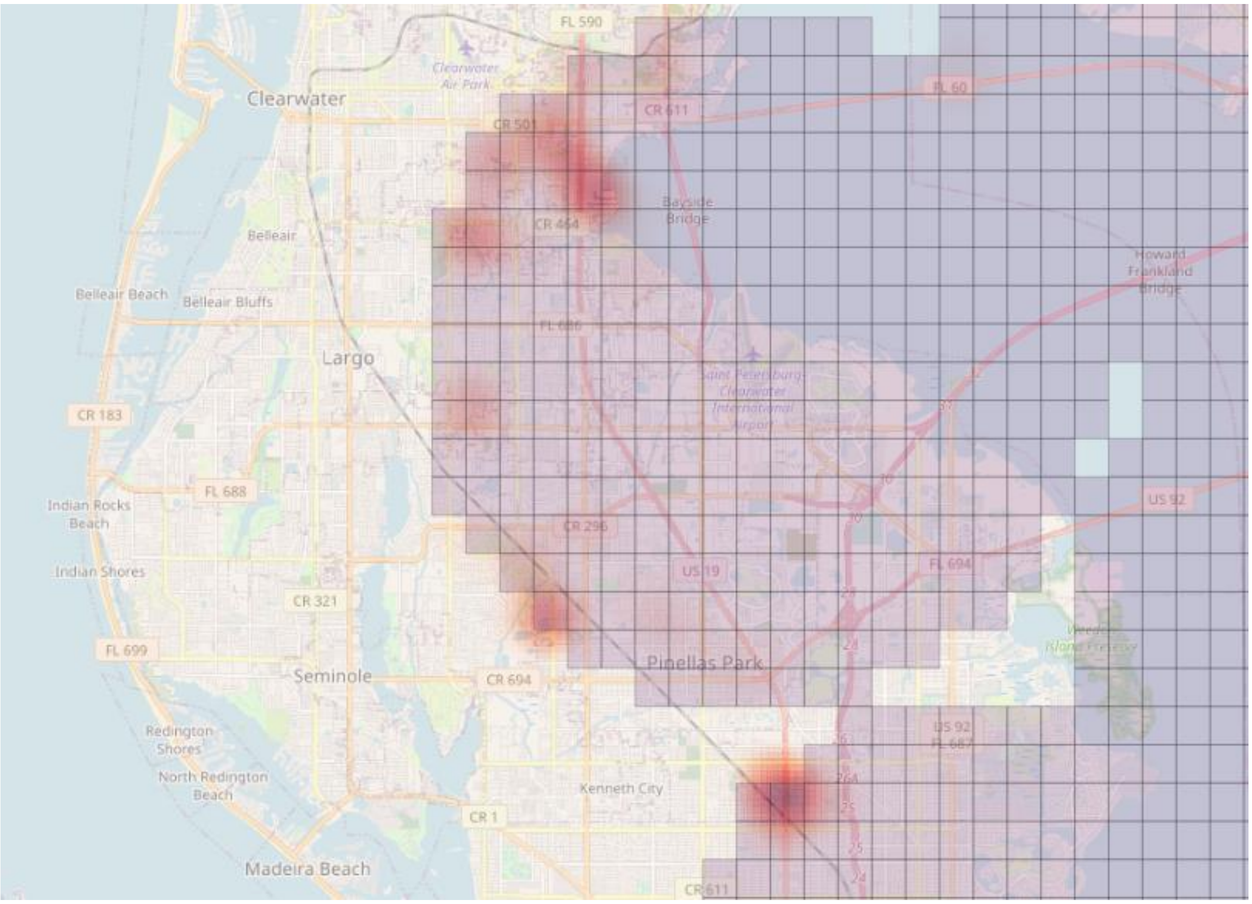


Figure A12. West Palm Beach, FL

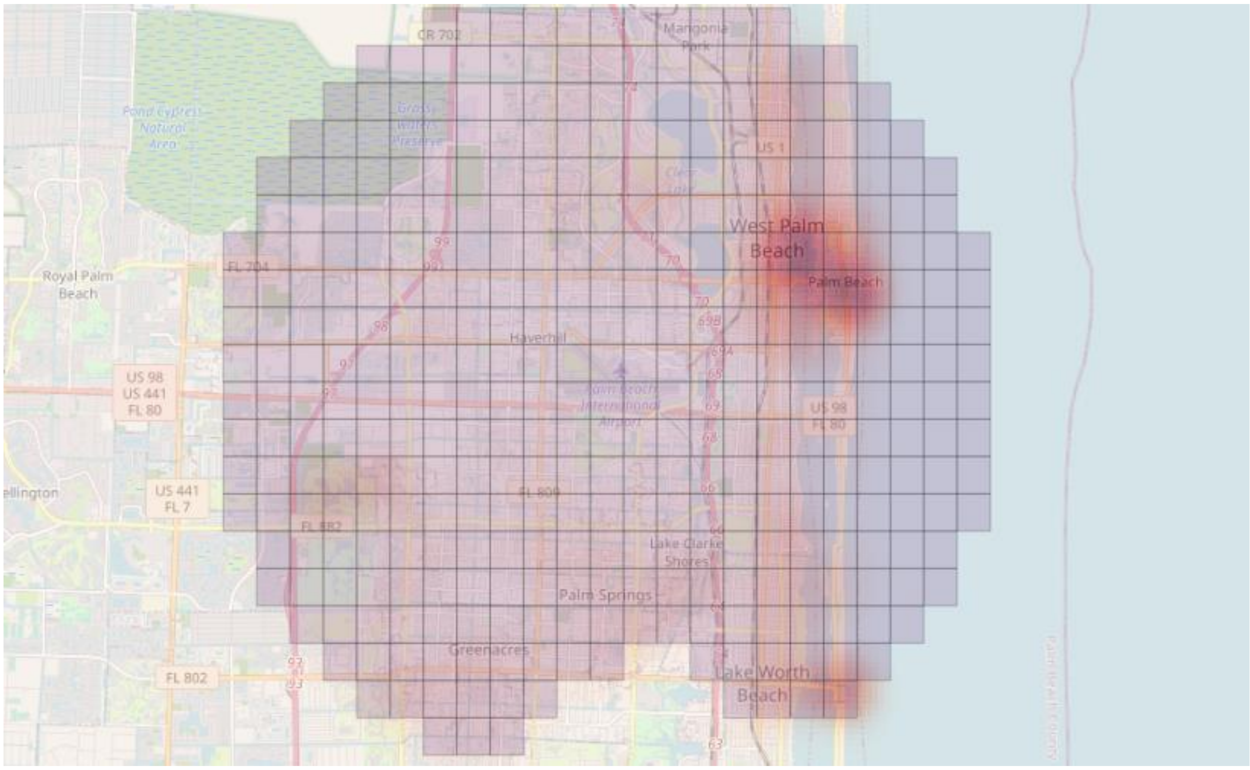


Figure A13. Atlanta, GA

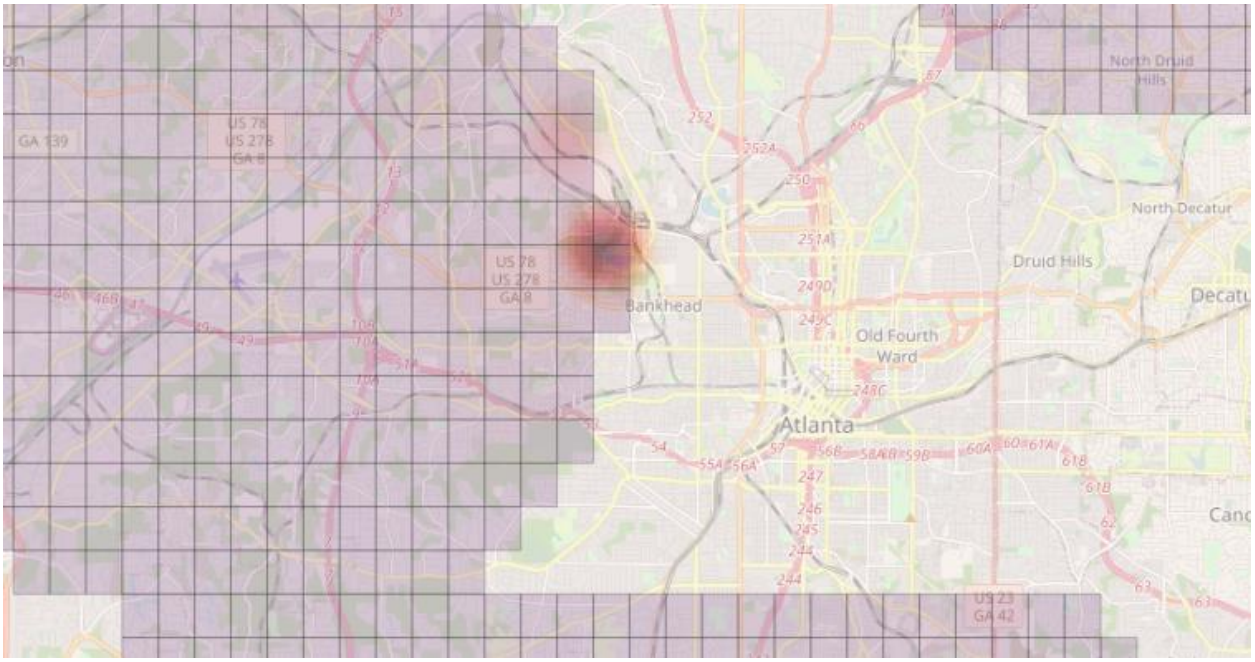


Figure A14. Chicago, IL

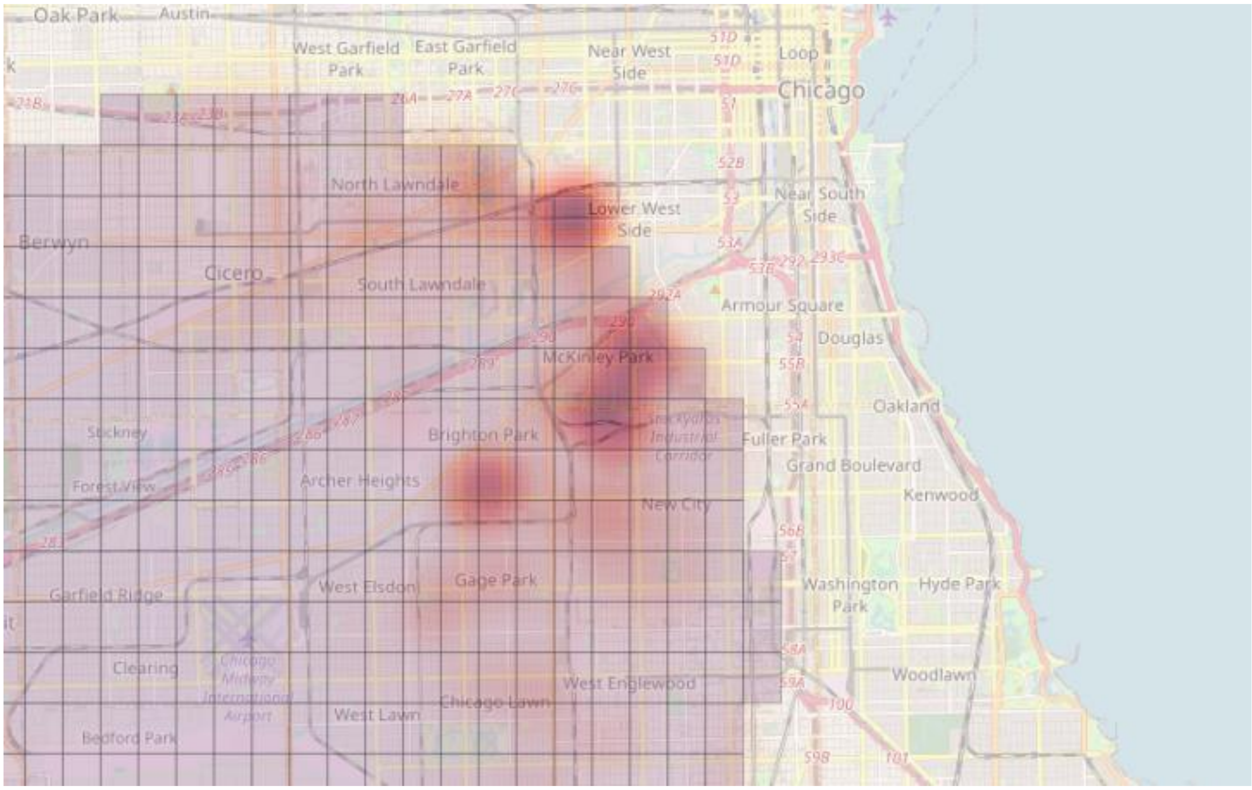


Figure A15. Lexington, KY

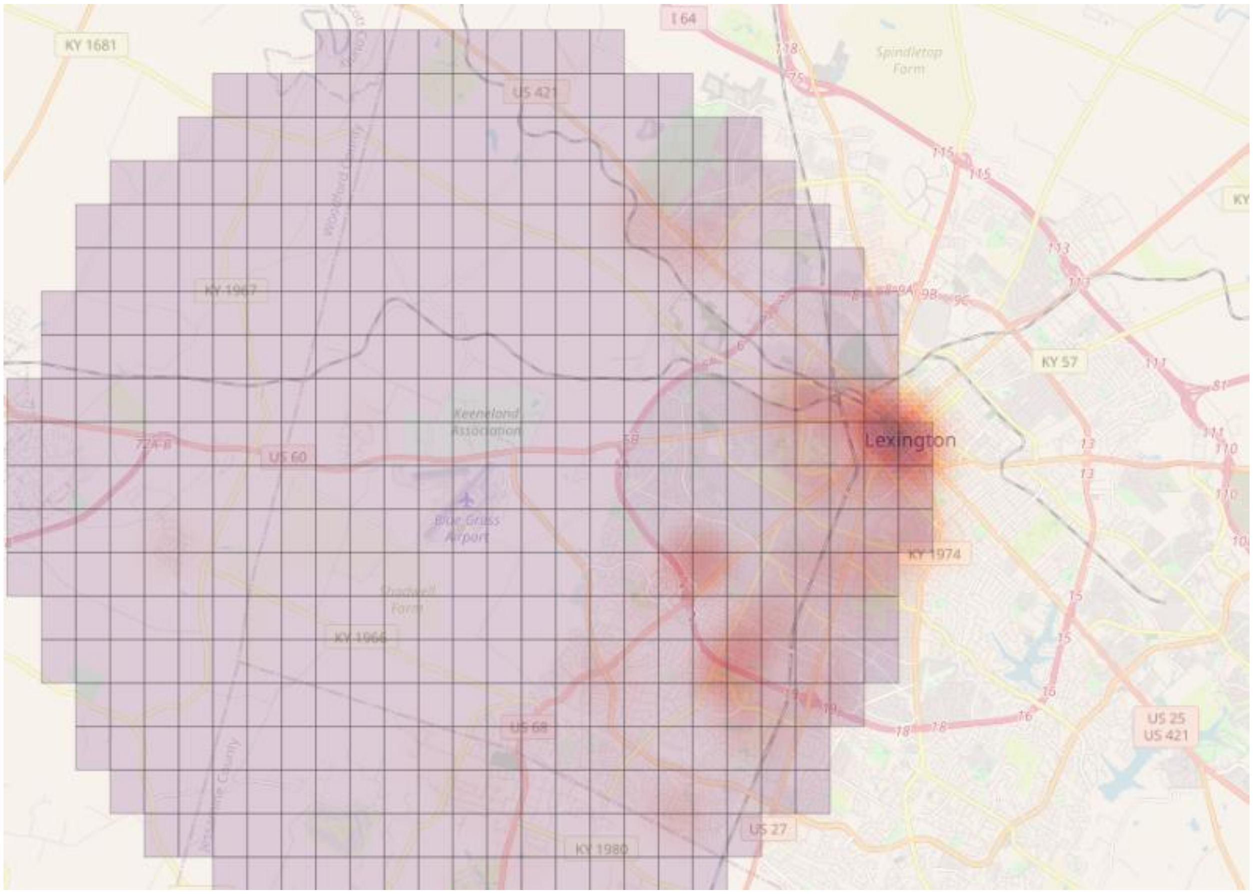


Figure A16. Baton Rouge, LA

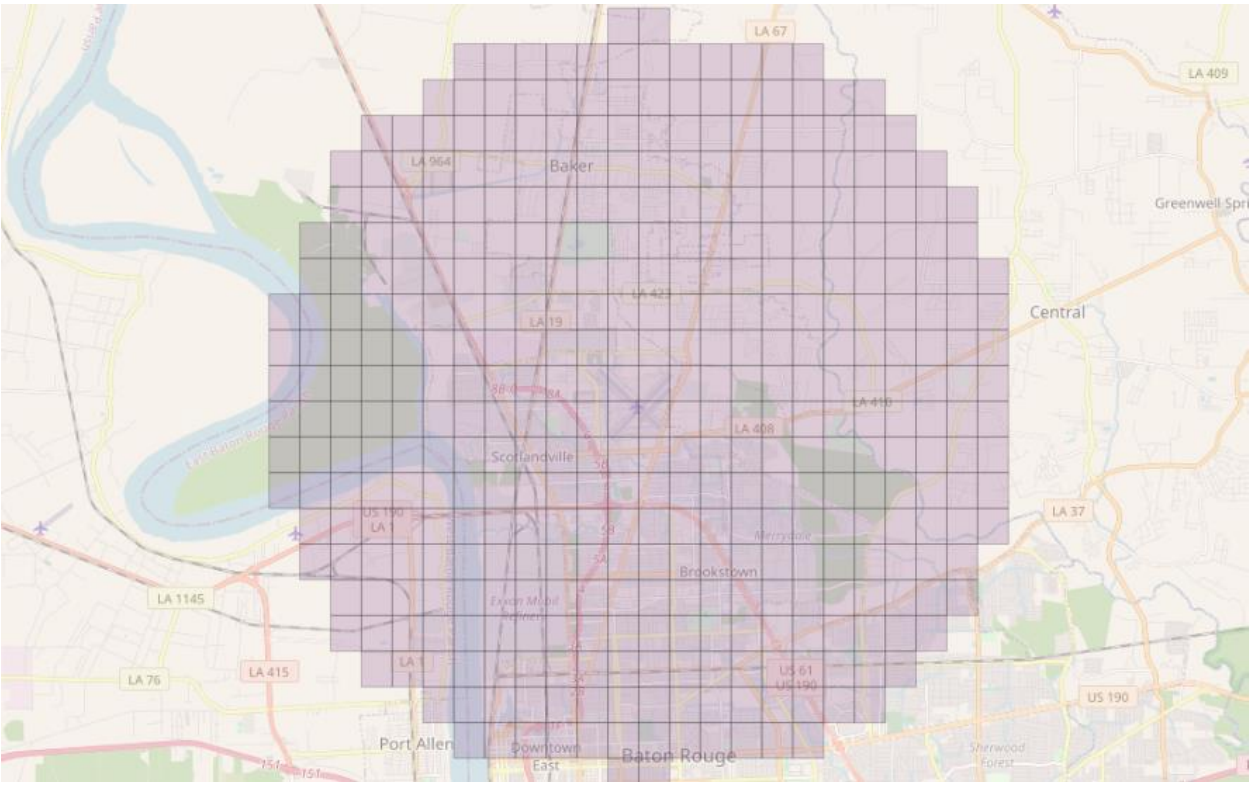


Figure A17. New Orleans, LA

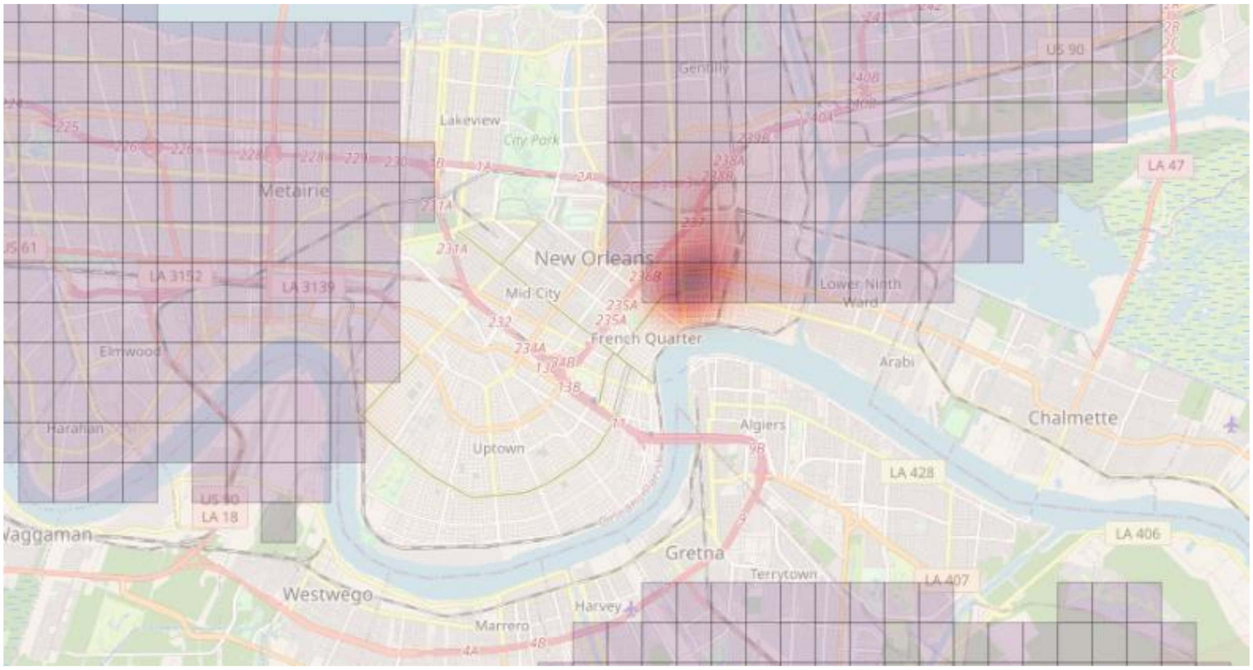


Figure A18. Baltimore, MD

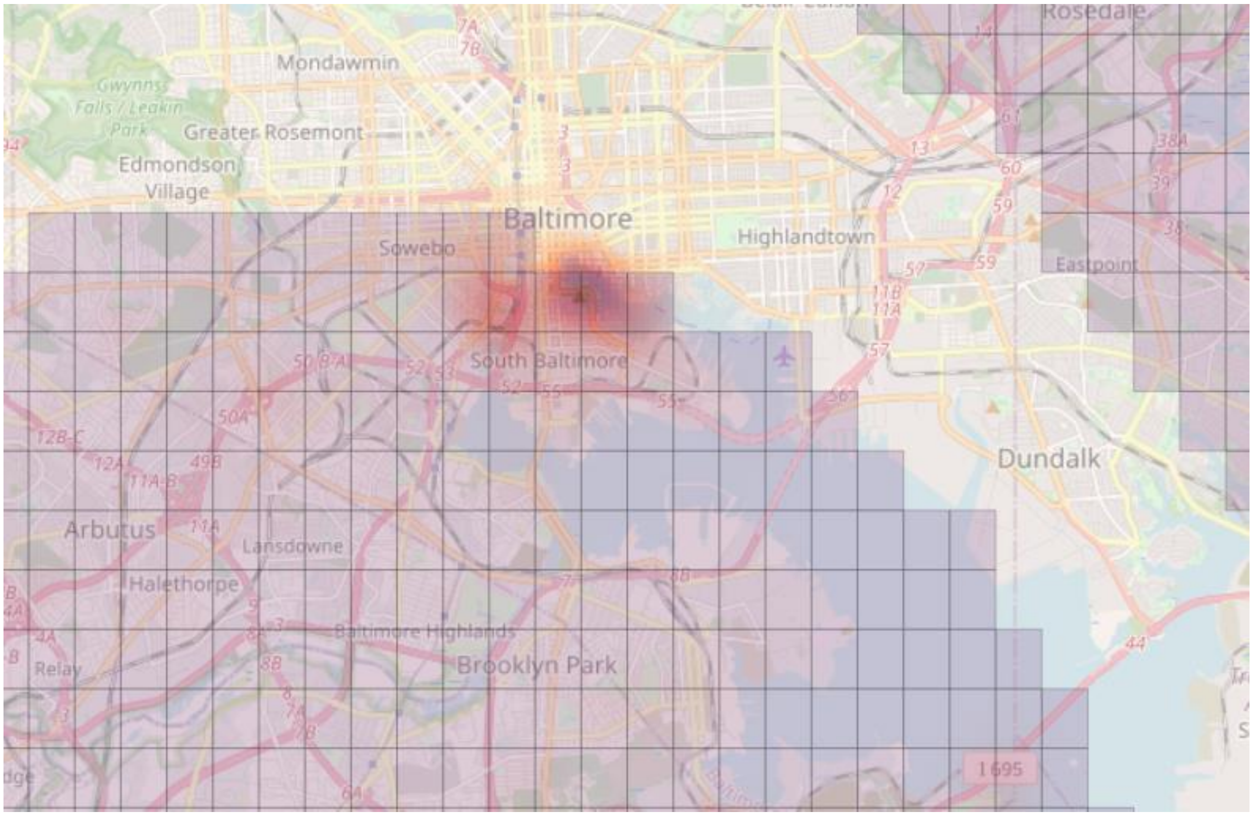


Figure A19. Detroit, MI

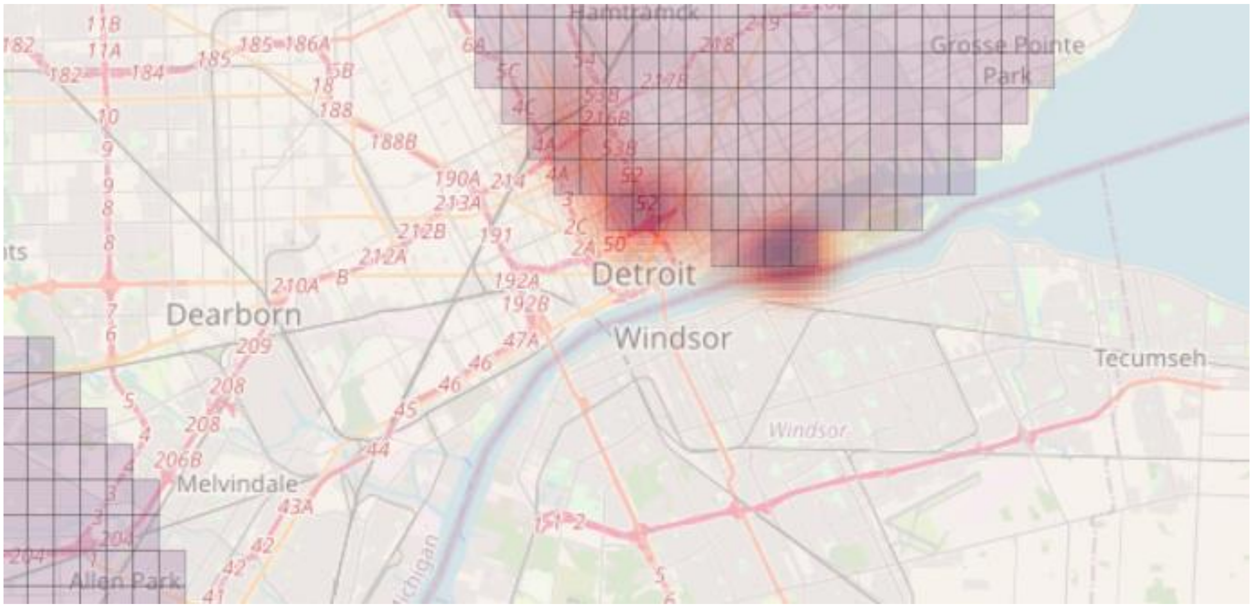


Figure A20. Minneapolis, MN

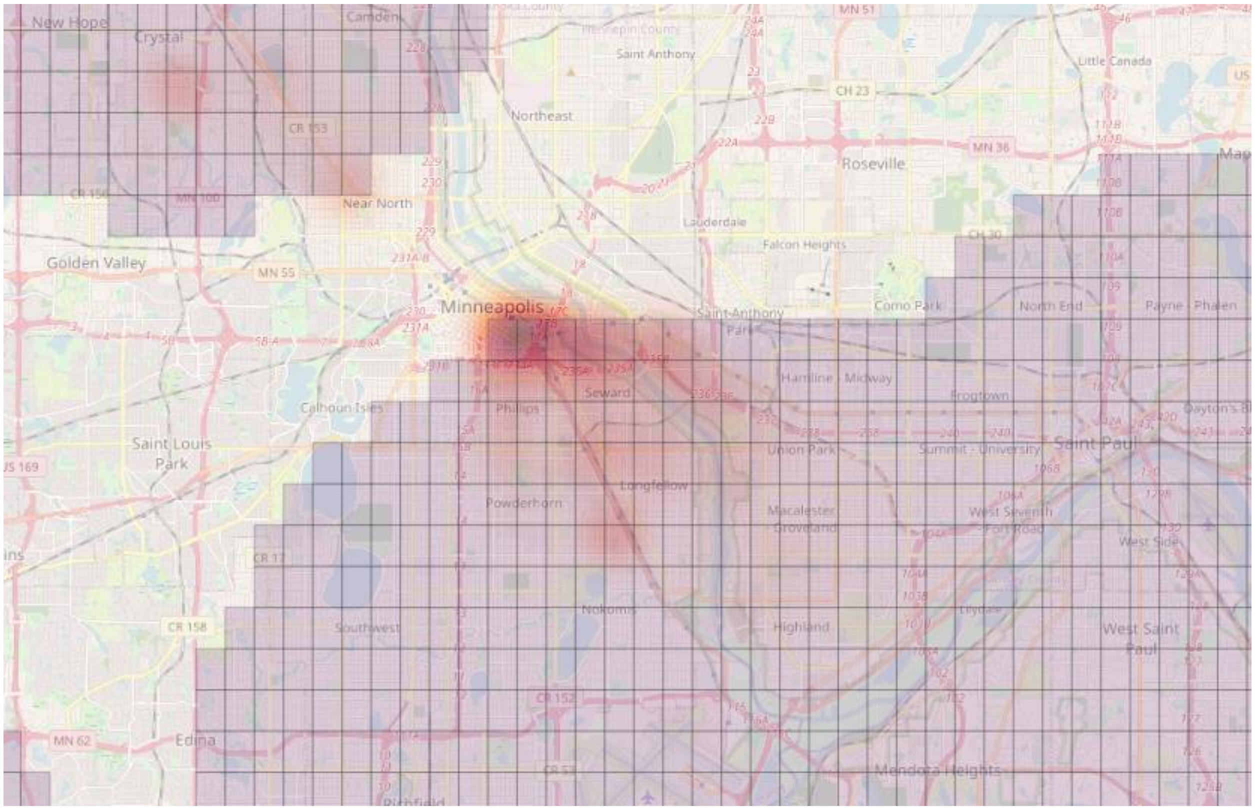


Figure A21. Charlotte, NC

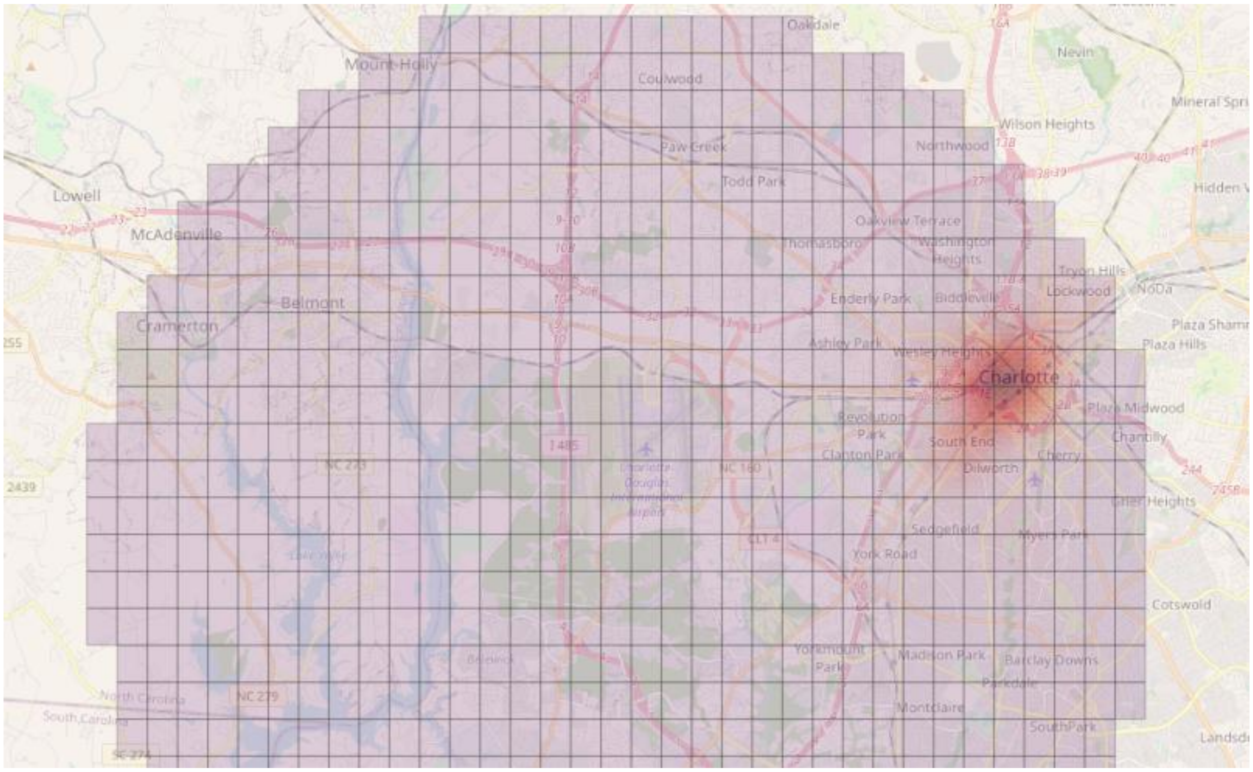


Figure A22. Las Vegas, NV

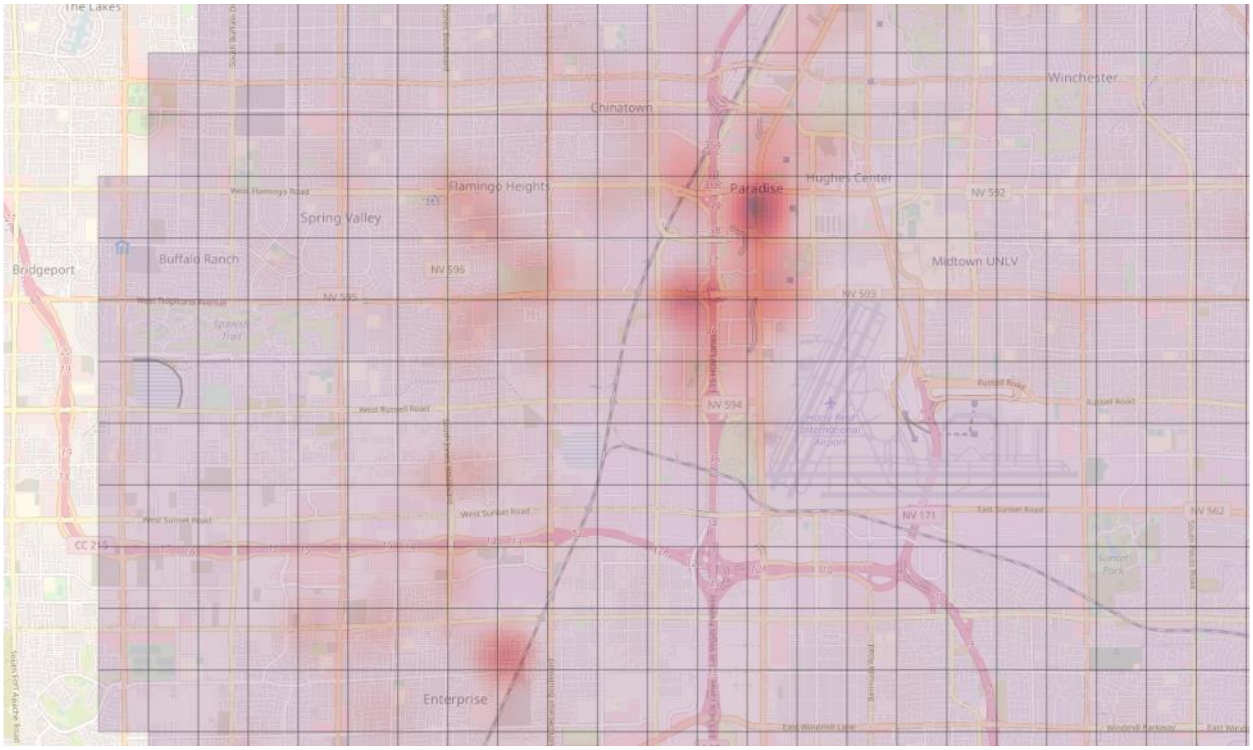


Figure A23. Brooklyn, NY

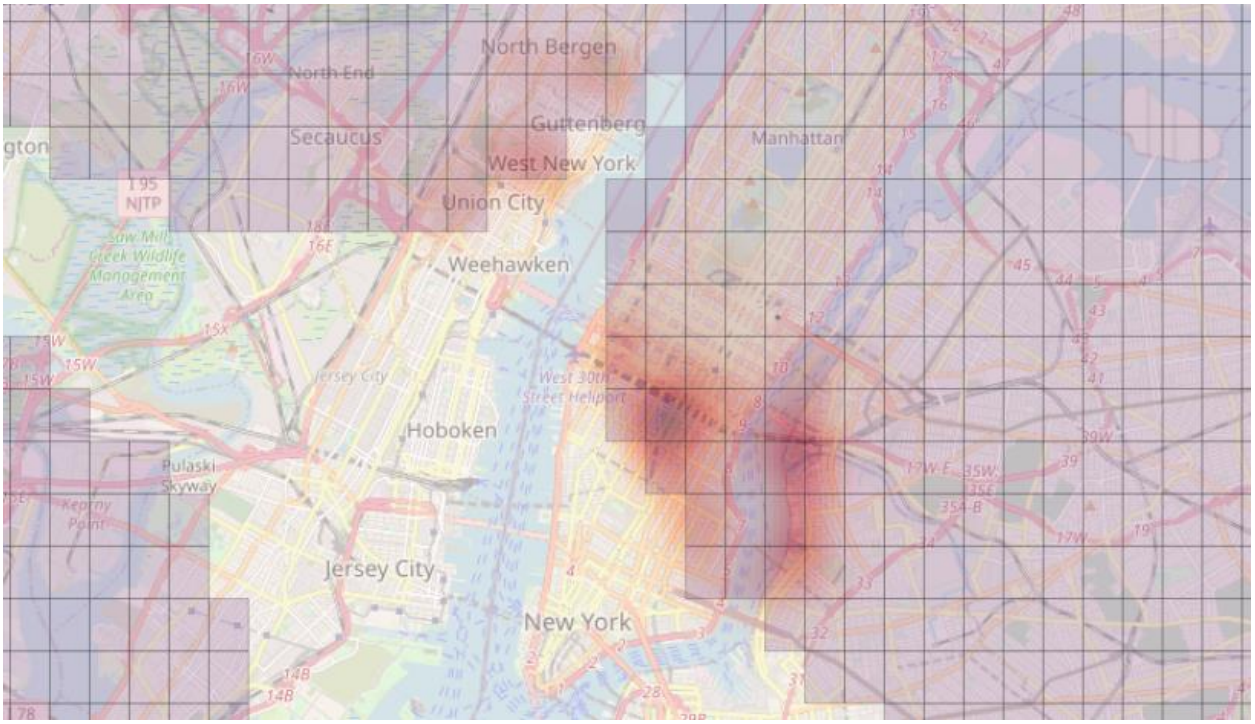


Figure A24. Staten Island, NY

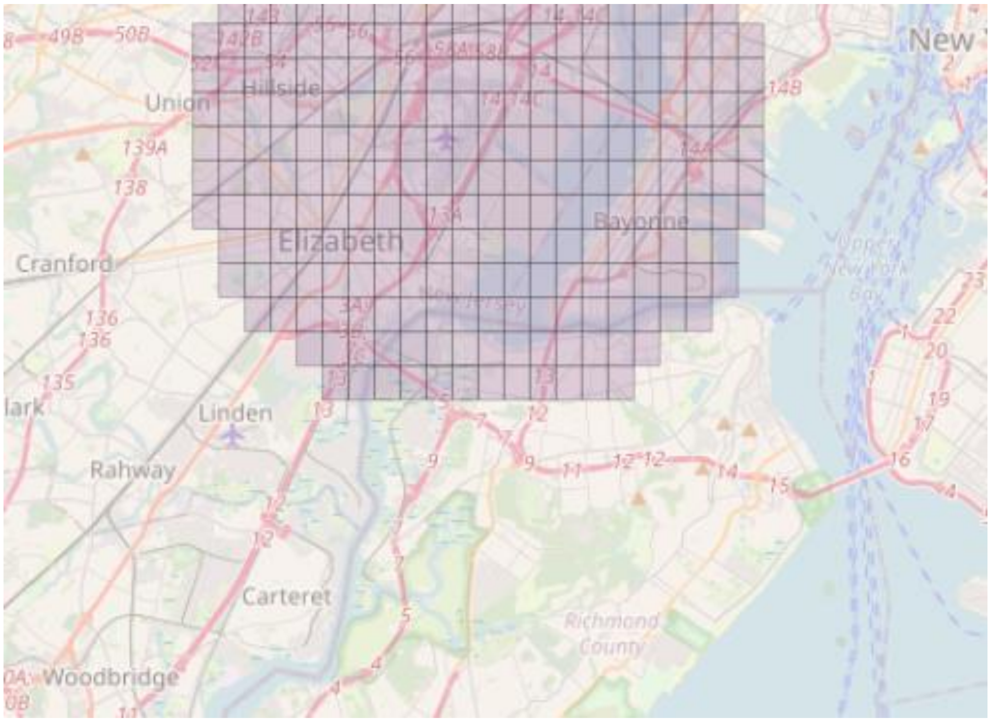


Figure A25. Cincinnati, OH

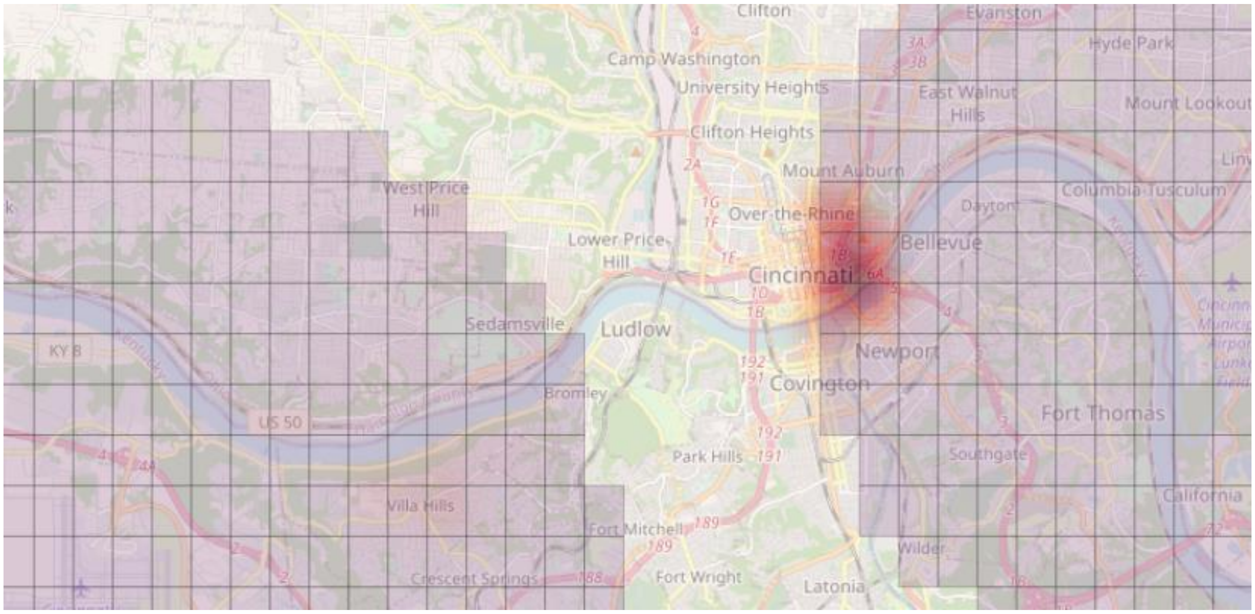


Figure A26. Cleveland, OH

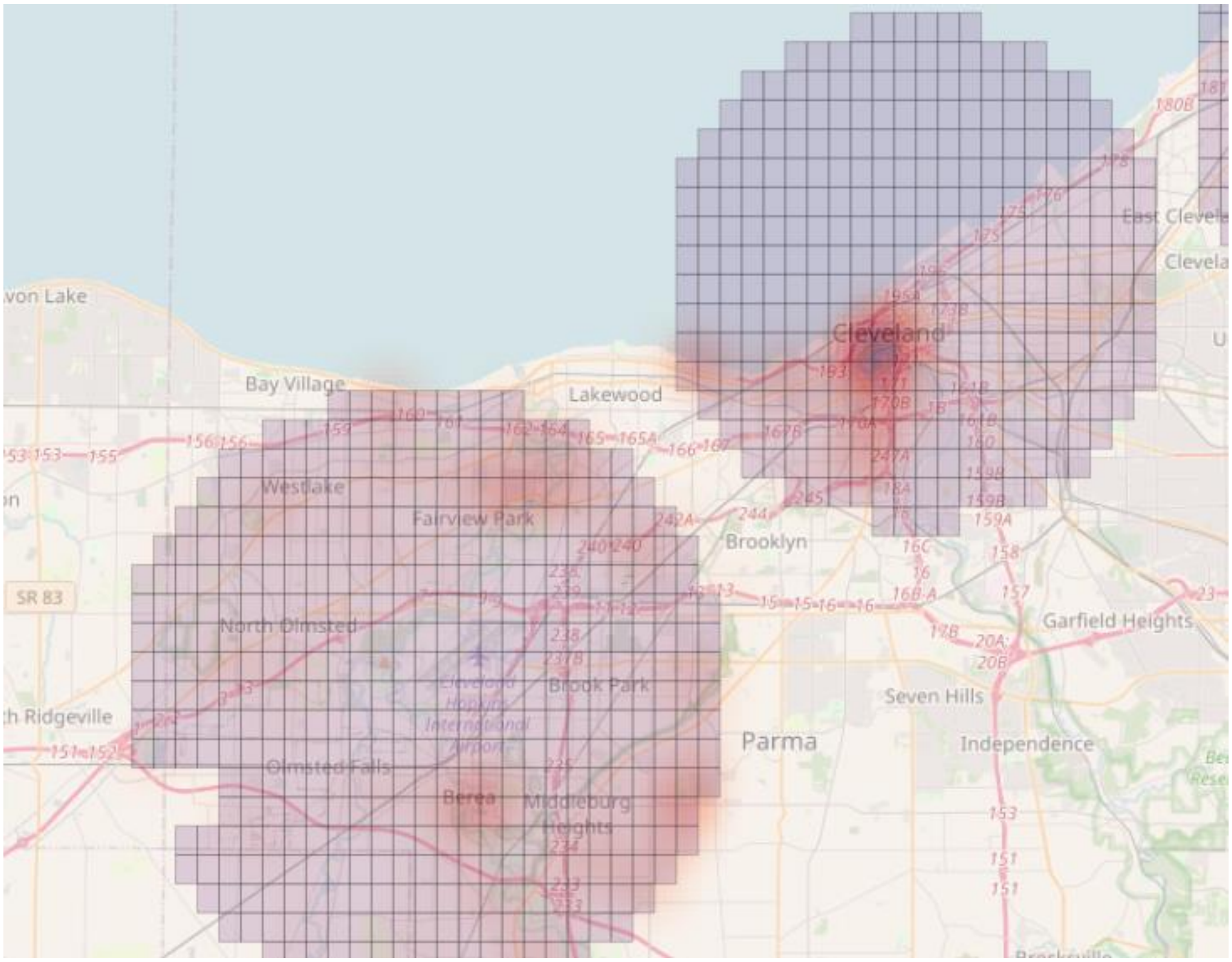


Figure A27. Portland, OR

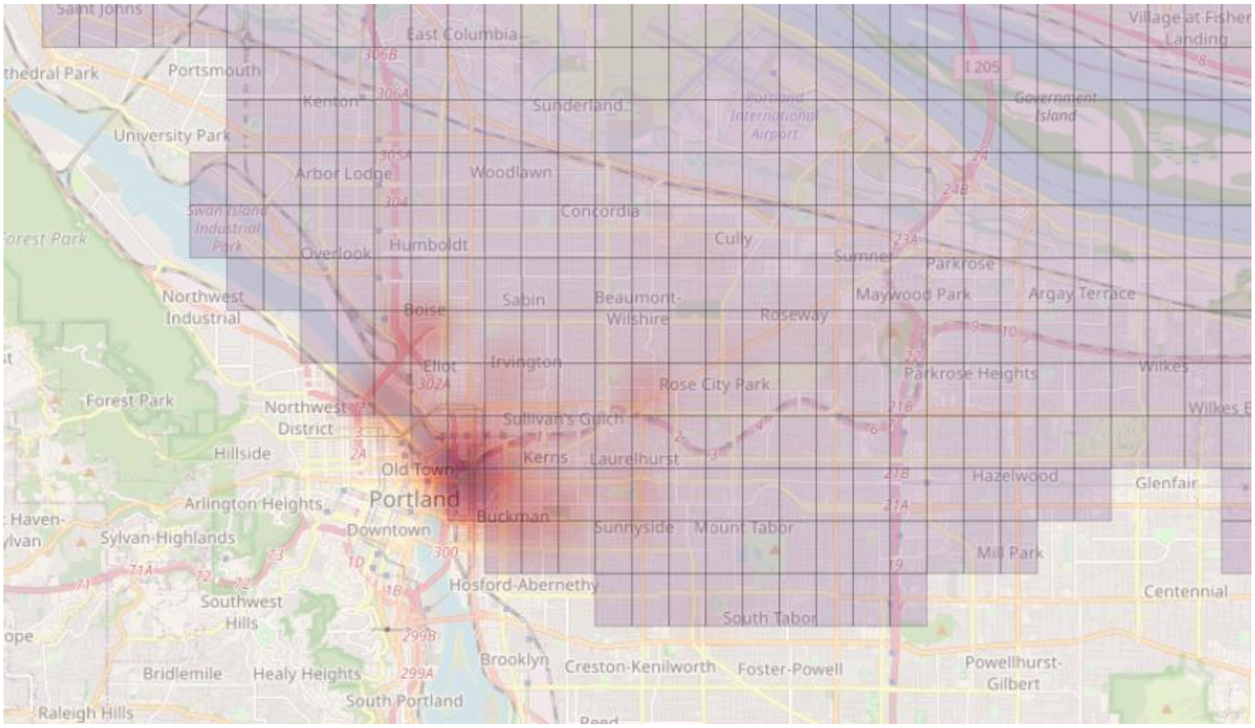


Figure A28. Philadelphia, PA

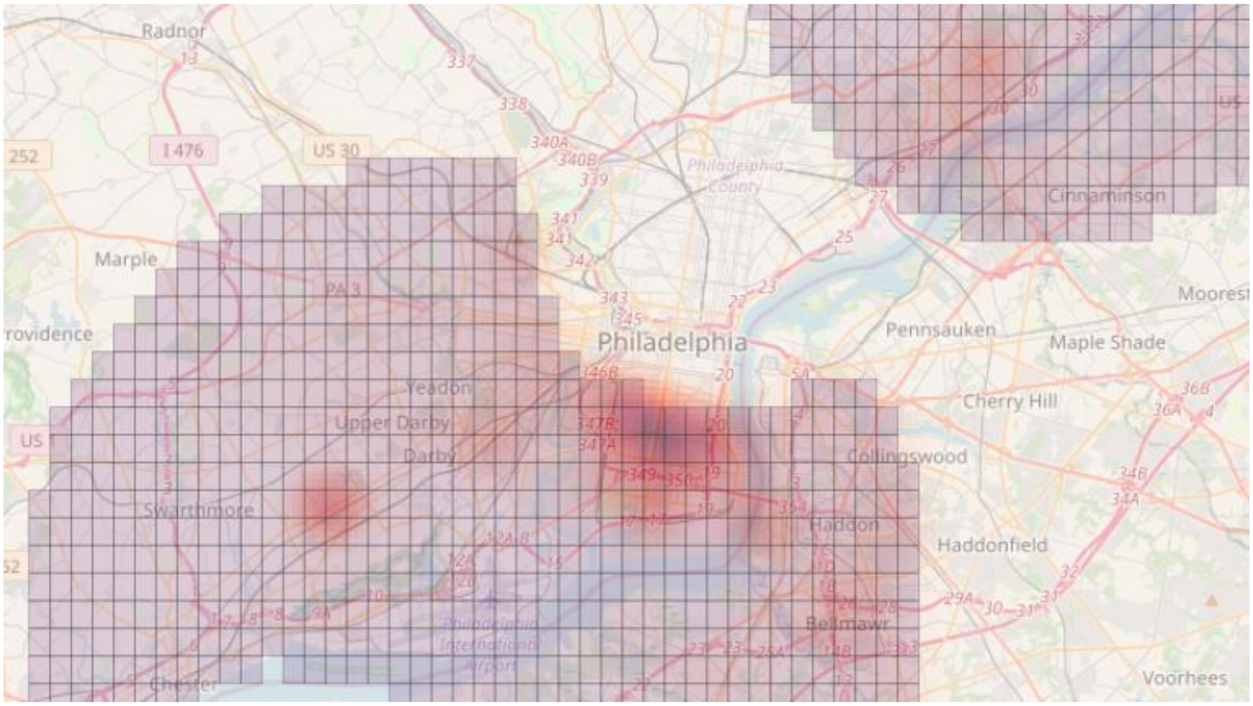


Figure A29. Corpus Christi, TX

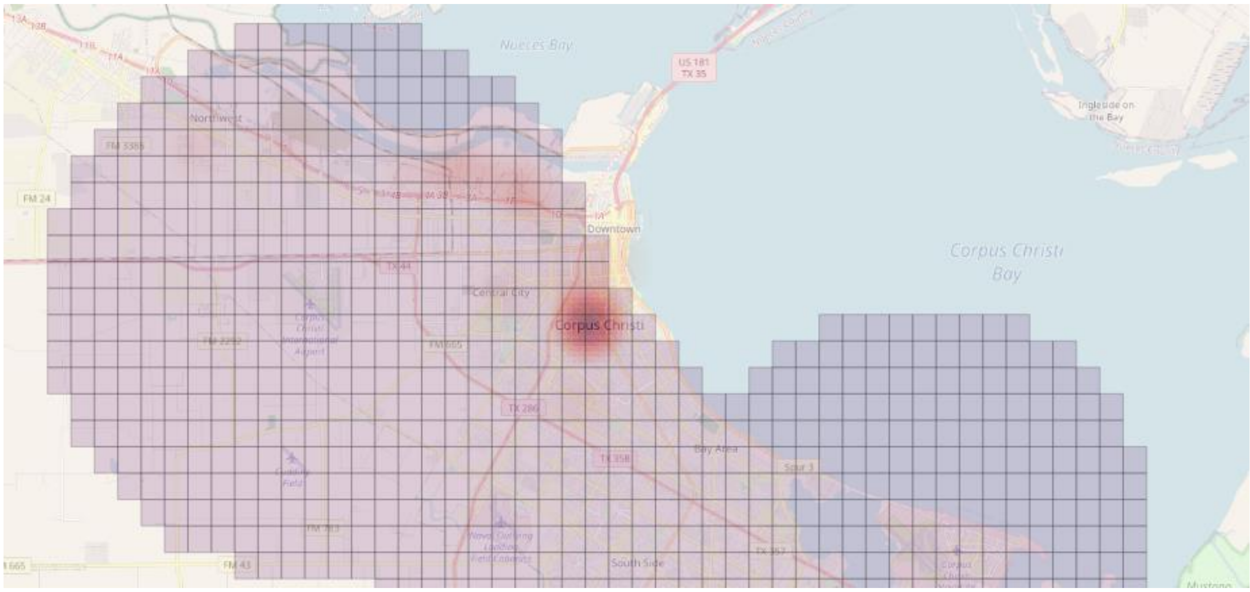


Figure A30. Dallas, TX

Figure A31. El Paso, TX

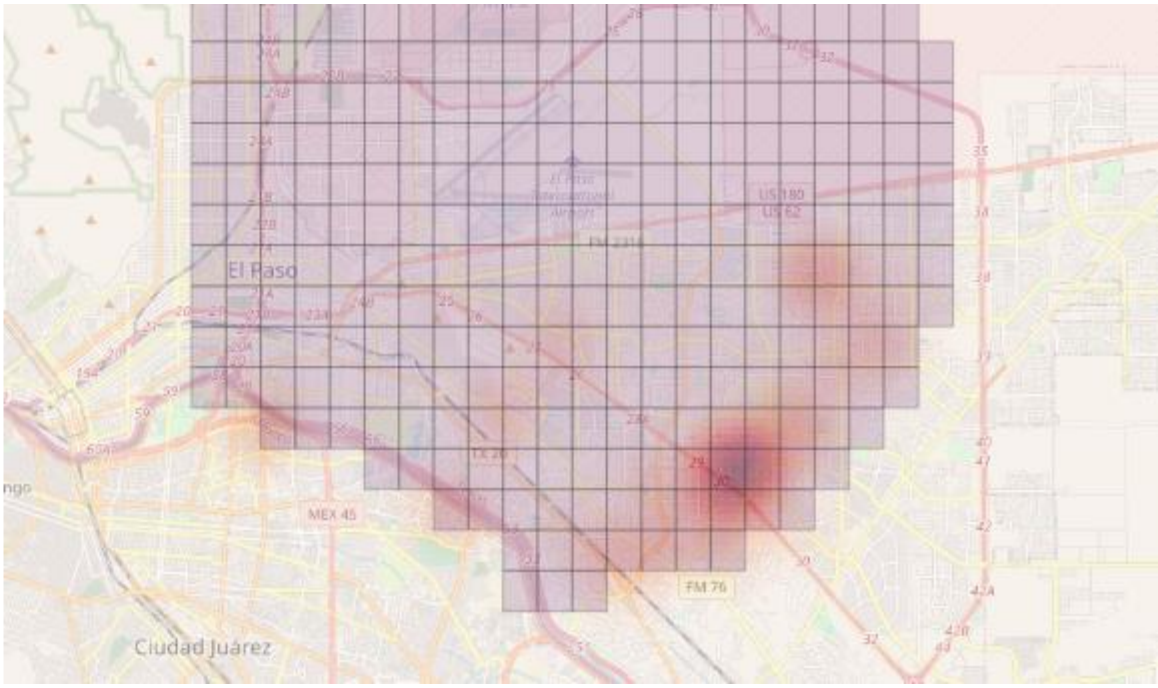


Figure A32. Houston, TX