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

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16. Abstract

This report summarizes the ASSURE A11L.UAS.91: Small Unmanned Aircraft Systems (sUAS) Traffic Analysis, which assessed low-altitude sUAS activity in the National Airspace System (NAS) using Remote Identification (ID) sensors deployed near U.S. airports and aviation hubs. Objectives included identifying safety hazards, evaluating sUAS regulations, forecasting traffic, and informing aviation risk assessments. Data collection faced limitations due to Remote ID range and restricted access to large hub airports. Partnering with Remote ID vendors, the team analyzed trends showing operational exceedances, traffic peaks during holidays, and DJI's market dominance. Key issues include flights exceeding the 400-foot ceiling, operations near aerodromes and residential areas, and short flight durations limiting intervention opportunities. Most flights occur in daylight and calm weather, though nighttime operations may increase with expanding commercial use. The removal of DJI geofencing raises further safety and security concerns regarding incursions into protected airspace. Recommendations focus on enhancing Remote ID effectiveness, expanding data collection, and improving airspace risk assessments. Operational improvements include heliport plotting on charts, broadcasting sUAS alerts to manned aircraft, updating FAA guidance, and expanding FAA WINGS training. These actions aim to support data-driven decision-making to improve safety and scalable integration of sUAS into the NAS.

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UNITS OF MEASUREMENT

Measurement	Acronym	Datum	Type
Feet	ft	MSL or AGL, as indicated	Vertical distance
Hour: Minute	hh:mm	UTM or Local (L), 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

TABLE OF ACRONYMS

Acronym	Meaning
AAM	Advanced Air Mobility
ADS-B	Automatic Dependent Surveillance-Broadcast
AGL	Above Ground Level
API	Application Programming Interface
ARP	Airport Reference Point
ASSURE	Alliance for System Safety of UAS through Research Excellence
ASOS	Automated Surface Observing Systems
ASTM	American Society for Testing and Materials International
ATC	Air Traffic Control
AWOS	Automated Weather Observing Systems
BVLOS	Beyond Visual Line of Sight
CDA	Commercial Drone Alliance
CFR	Code of Federal Regulations
COA	Certificate of Authorization
C-UAS	Counter-Unmanned Aircraft System
DHS	Department of Homeland Security
FAA	Federal Aviation Administration
FRIA	FAA-Recognized Identification Area
GIS	Geographic Information System
GLARE	Geographic Low Altitude Risk Estimation
HAE	Height Above Ellipsoid
HIFLD	Homeland Infrastructure Foundation-Level Data
ID	Identification
IP	Ingress Protection
LAANC	Low Altitude Authorization and Notification Capability
LTE	Long-Term Evolution (Wireless Communication Standard)
MSL	Mean Sea Level
N/A	Not Applicable
NAS	National Airspace System
NOTAM	Notice to Airmen
OEM	Original Equipment Manufacturer
ORNL	Oak Ridge National Laboratory
PI	Principal Investigator
RID	Remote Identification
RSSI	Received Signal Strength Indicator
sUAS	Small Unmanned Aircraft System
TFR	Temporary Flight Restriction
UAM	Urban Air Mobility
UAS	Unmanned Aircraft System
UASFM	UAS Facility Map
UAS ID	UAS Identification and Tracking
URSA	Unmanned Robotics Systems Analysis
UTM	Unmanned Traffic Management
VOR	Very High Frequency Omnidirectional Range

EXECUTIVE SUMMARY

This report presents the consolidated findings of the ASSURE A11L.UAS.91: Small Unmanned Aircraft Systems (sUAS) Traffic Analysis. This project aimed to provide objective insight into low altitude traffic in the National Airspace System (NAS) using empirical data. Fixed, Remote Identification (ID) sensors were placed at selected locations throughout the United States to capture sUAS activity and telemetry data. The primary objectives of this project were 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 project research questions, this report is divided into the following functional sections:

- Data Collection and Analysis Methodology
- Current State of sUAS Traffic within the National Airspace System
- Compliance and Exceedances of 14 Code of Federal Regulations (CFR) 107 Operational Limitations
- Near Aerodrome sUAS Operations and National Airspace System Risk Analysis
- Forecasting Industry Growth and Potential Advanced Air Mobility Implications

The research team partnered with Pierce Aerospace, Inc, an industry Remote Identification detection service provider to support data collection efforts. Pierce Aerospace furnished the Remote ID collection technology, and conducted device installation, support, and routine data extraction. Sampling locations were purposefully selected proximate to airports and other aviation activity. Remote ID technology range limitations, limited the research team from collecting datasets at highly-desired, large hub airport locations due to airfield access restrictions and legal approval hurdles.

The research team also leveraged cloud storage, software, and digital analysis tools furnished by Unmanned Robotics Systems Analysis (URSA), Inc. to support data aggregation, analysis, synthesis, and visualization. The research team leveraged the aforementioned industry resources to compile a comprehensive assessment of sUAS operations within the low-altitude airspace of the NAS and address the project objectives and research questions.

The study highlights several key challenges and risks associated with sUAS operations. Remote ID detection is limited to a range of about 10 miles or less, making it challenging for large-scale airspace surveillance. As of mid-April 2025, Remote ID adoption was reported as 207,665 of the total 415,095 Part 107 registrations (*n*=50.03%), with 81.26% Standard Remote ID equipage and 18.74% Remote ID Broadcast Modules (FAA Aviation Policy & Plans [APO], personal communication, April 18, 2025). Similarly, the FAA recorded 139,166 recreational registrations with Remote ID equipage out of 456,169 total recreational registrations (*n*=30.51%), comprised of 76.18% Standard Remote ID equipage and 23.82% Remote ID Broadcast Modules (FAA Aviation Policy & Plans [APO], personal communication, April 18, 2025). Additionally, the absence of a consolidated remote ID sUAS detection network hinders the enforcement of operator accountability and real-time airspace risk assessment. The discrepancy between Low Altitude Authorization and Notification Capability (LAANC) approvals and detected sUAS operations highlights a disproportionate number of flights are being carried out under certificates of authorization or airspace authorizations, or may also suggest that some flights in controlled airspace may be carried out without authorization. Notably, sUAS traffic spikes around holidays, suggesting significant recreational use, while non-recreational (Part 107) operations continue to expand, particularly as new integration measures emerge. Data also indicates a preference for smaller, newer platforms, with DJI models dominating the market.

Operational trends reveal several areas of concern, including altitude exceedance issues, with some flights surpassing the 400-foot regulatory ceiling and posing potential risks to manned aviation. Many operations are concentrated in residential neighborhoods, increasing the likelihood of encounters with manned aircraft in those areas. Short flight durations, typically under 35 minutes, present transient risks but also limit opportunities for intervention. Furthermore, sUAS activity is notably higher near aerodromes and heliports, with some flights exceeding altitude limits, posing potential safety hazards to low-flying aircraft. Most flights occur in calm weather and daylight hours, while current nighttime operations remain minimal, but could increase with the expansion of commercial applications, such as package delivery. The recent removal of DJI geofencing raises additional safety and security concerns, potentially increasing incursions into controlled airspace and over protected facilities and infrastructure.

The recommendations focus on improving the safe and efficient integration of sUAS into the NAS by addressing key gaps in policy, technology, and operational guidance. Research efforts should expand to better understand remote ID effectiveness, including its range, signal interference, and coverage limitations. Additionally, the study emphasizes the need for broader data collection efforts to improve statistical reliability and better inform national airspace risk assessment. These efforts are slated for inclusion in the follow-on ASSURE A83 project, which aims to further refine drone traffic analysis.

Suggested operational improvements include enhanced situational awareness through heliport plotting on sectional charts, broadcasting sUAS traffic alerts to manned aircraft, and updating Federal Aviation Administration (FAA) guidance on collision avoidance and conspicuity. Further, expanding training opportunities for UAS operators via the FAA WINGS program and consolidating critical flight reference materials into a singular, centralized online hub will streamline access to essential operational resources. Collectively, these recommendations support data-driven decision-making and proactive risk mitigation strategies, fostering a safer and more scalable framework for UAS integration into the NAS.

1 INTRODUCTION AND BACKGROUND

In a report assessing risks of Unmanned Aircraft System (UAS) integration, the National Academies of Sciences (2018) highlighted the need for a data-driven approach to inform policy decision-making. According to the report, successful UAS integration into the National Airspace System (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). However, collecting such data presents notable challenges. The authors noted 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). According to Roggero (2018), "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 noted explicitly for UAS encounter statistics and low-altitude data. Complicating the low-altitude UAS operations data collection is the lack of a requirement for transponder equipment or other means of tracking for UAS, since conventional surveillance systems generally cannot 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 empirical data hinders accurate assessment of low altitude airspace risk, prompting the regulatory authorities to adopt a conservative approach to UAS policy-making. The consumer advocacy group warns that such an approach may risk the U.S. falling behind in implementing low altitude operations globally (CDA, 2020, para. 8).

> The Commercial Drone Alliance recommends:
>
> . . . conducting a sophisticated, national study of the operational risks associated with low-altitude UAS operations below 400 feet 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 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)

1.1 Purpose and Scope

This project aimed to establish a framework for addressing the need to collect empirical data required to conduct sUAS traffic analysis in low-altitude airspace. This framework was designed to support the FAA's efforts in the following activities: 1) accurately forecasting sUAS growth; 2) planning further sUAS airspace integration efforts; 3) conducting risk assessments of proposed sUAS operations; 4) estimating compliance with existing regulations; and 5) informing the development of future regulations and policies.

The research team acquired historical sUAS activity and telemetry data from sensors operated by Pierce Aerospace, Inc., a sUAS Remote Identification company. The data was assessed, using various analytical processes and methods to achieve the following outcomes:

- Assess the effectiveness of existing regulations under 14 CFR 107
- Measure exceedances to Part 107 operational limitations

- Determine the state of sUAS operations and activity in proximity to aerodromes
- Assess the risk of potential sUAS encounters or collisions with aircraft operating within the NAS
- Provide findings and recommendations that may inform the development of Unmanned Traffic Management (UTM) requirements and Urban Air Mobility (UAM) route design

The resultant data and findings of this study inform upon the following agency objectives:

- Support sUAS forecasting and planning processes
- Furnish 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 Remote Identification data

1.2 Background

1.2.1 Background of Remote Identification Technology

Remote ID enables a UAS in flight to provide identification and location information that other parties can receive (UAS Remote Identification, 2023). In simplified terms, Remote ID functions as a digital "license plate" that identifies the UAS, its location, and where its control station is located. Its primary function is to allow the public and authorities to monitor airspace activity, identify UAS, and take appropriate actions against unlawful activities.

At the end of 2020, the FAA released two landmark rules that will be integral to unlocking the enormous potential of UAS: Remote Identification of Unmanned Aircraft (Remote ID Rule 1) and Operation of Small Unmanned Aircraft Systems Over People (OOP Rule 2) (Trock and Matthews, 2021). These rules require UAS operators to meet specific identification requirements. All UAS pilots required to register their aircraft must comply with these new regulations. Operators can maintain compliance by choosing one of three technology options: purchasing a UAS with remote ID technology installed by the manufacturer ("Standard Remote ID"), retrofitting a remote ID module ("broadcast module") to their current UAS, or operating without remote ID equipment within a pre-approved airspace called a FAA-Recognized Identification Area (FRIA) (see Figure 1).

Figure 1. Three Means of Compliance for Remote Identification.

1.2.2 Remote ID Function

Remote ID functions as a digital license plate, providing real-time identification and location data for UAS. UAS broadcasting a Remote ID signal must include the following elements in the broadcast message (UAS Remote Identification, 2023):

- A unique identifier for the UAS.

- The UAS's latitude, longitude, geometric altitude, and velocity.
- An indication of the latitude, longitude, and geometric altitude of the control station (standard) or take-off location (broadcast module).
- A time mark.
- Emergency status (Standard Remote ID UAS only).

Remote ID signals are typically broadcast via Wi-Fi or Bluetooth and can be received by compatible personal wireless devices. While most wireless devices within range of the UAS will be able to detect the signal, correlating the serial number or session ID with the registration database will be limited to the FAA and can be made available to authorized law enforcement and national security personnel upon request (UAS Remote Identification, 2023).

Additionally, there are several rules manufacturers must follow to ensure their product complies with the new rules. While the minimum performance requirements for compliance are listed in the final publication (Remote Identification of Unmanned Aircraft, 2021), how they are achieved are left unspecified, allowing for various means and design processes. The rule further amends 14 CFR Parts 91 and 107 to prohibit using Automatic Dependent Surveillance-Broadcast (ADS-B) Out or Air Traffic Control (ATC) Transponders on UAS unless otherwise authorized. ADS-B is allowed only if flying under a flight plan and in two-way radio communication with ATC. This type of transponder authorization will likely be used for more extensive UAS operating within controlled airspace. This means that ADS-B is not considered an acceptable means of compliance with Remote ID requirements but may be an additional requirement for Advanced Air Mobility (AAM) vehicles operating under certain conditions.

1.2.3 Remote ID Capability

Remote ID can be implemented via two primary methods: network-based and broadcast-based (Belwafi et al., 2022). The network-based method would have required UAS to transmit Remote ID data over the internet to a third-party service provider. After significant public pushback, the FAA eliminated the requirement for network-based remote identification due to technical and implementation challenges (Remote Identification of Unmanned Aircraft, 2021). Only broadcast-based technologies are required by the final ruling (Remote Identification of Unmanned Aircraft, n.d.). The broadcast-based method transmits identification data locally via one-way communication over a Bluetooth or Wi-Fi signals, independent of internet connectivity. A local server equipped with a handheld device can receive the Remote ID in real time using the proposed communication links. These remote ID mechanisms aim to detect, identify, track, and manage UAS operating within urban airspace.

1.2.4 Strengths of Remote ID

Implementing Remote ID technology offers significant strengths and benefits in enhancing the safety, security, and effective integration of UAS into the NAS. These strengths make Remote ID a critical component in ensuring the safe and responsible operation of UAS while safeguarding the airspace for all users.

First and foremost, Remote ID enables a real-time identification and tracking of UAS in flight. By providing accurate and up-to-date identification and location information, Remote ID empowers authorities and the public to monitor and understand the activities of UAS operating within the airspace. This capability enables prompt detection of unauthorized or potentially malicious UAS operations, enabling swift and appropriate responses to mitigate potential threats or risks.

Moreover, Remote ID is vital in enforcing regulations and ensuring compliance with existing and future UAS regulations. With Remote ID technology, authorities can verify the identity and compliance status of UAS, helping deter unlawful activities and promoting adherence to operational limitations and safety protocols. Monitoring and enforcing compliance through Remote ID helps maintain the integrity of the airspace and promotes responsible UAS operations.

In addition, Remote ID supports effective integration of UAS into the NAS by providing valuable data for accurate forecasting of sUAS growth. By collecting comprehensive and reliable information on sUAS traffic patterns and trends, Remote ID facilitates informed decision-making and planning for the safe and efficient integration of UAS into airspace. This data-driven approach would allow the FAA to anticipate and address potential challenges and capacity issues, optimizing airspace utilization.

Finally, Remote ID technology contributes to risk assessments for proposed UAS operations. By having access to identification and location information, authorities can evaluate and analyze the potential risks associated with specific drone operations, particularly those near critical infrastructure, populated areas, near an airport, or other sensitive locations. This capability enables identifying and mitigating potential safety hazards, enhancing overall situation awareness and risk management within the airspace.

1.2.5 Delayed Implementation of Remote ID Rules

On January 15, 2021, the Remote Identification of Unmanned Aircraft final rule (Remote Identification of Unmanned Aircraft, 2021) was published to the Federal Register, and codified in federal aviation regulations under 14 CFR §89. The new rule mandated implementing and using Remote identification equipment while operating applicable unmanned aircraft systems effective September 16, 2023. In a subsequent policy directive issued on September 12, 2023—just days before mandatory Remote ID compliance—the FAA announced a deferral of enforcement for the Remote Identification rule (Enforcement Policy Regarding Operator Compliance Deadline for Remote Identification of Unmanned Aircraft, 2023). Clarifying the agency's position, the announced deferral acknowledged that the FAA had received a high volume of FRIA applications that had not been processed before the rule's implementation date. Moreover, the agency noted concerns regarding the limited availability of Remote ID broadcast modules. As a result, the agency exercised its enforcement discretion, effectively deferring non-compliance with the Remote Identification rule for a six-month period, which ended on March 16, 2024.

The implications of this policy remain unclear; however, the agency's decision to defer enforcement may likely result in further operator delays in implementing Remote ID equipment without tangible consequences.

1.2.6 Capabilities and Limitations of Remote ID

The implementation and maintenance costs of Remote ID systems are significant considerations. Developing and maintaining the necessary infrastructure, such as dedicated servers and network connectivity, may impose financial burdens on regulatory bodies, industry stakeholders, and drone operators. The costs associated with hardware, software, data storage, and ongoing maintenance may vary depending on the scale and scope of the Remote ID implementation.

When recommending Remote ID requirements, the UAS Identification and Tracking Aviation Rulemaking Committee (UAS ID ARC)—the committee responsible for recommending Remote Identification rulemaking policy to the FAA—did not reach consensus on final recommendations to the FAA (UAS ID ARC, 2017). One central point of contention was determining the requirements for Remote ID broadcast disposition. The ARC determined two methods of broadcasting RID information: 1) Direct (local) broadcast; and 2) Network broadcast. *Direct broadcast* means Remote ID data is transmitted locally and can be received by any device within range, without requiring a specified recipient. This implementation requires no additional infrastructure to function. The key disadvantage of this approach is that absent Remote ID receivers in the area, Remote ID transmissions are not received, recorded, or utilized. The alternative approach involves *network publishing* of Remote ID data. Remote ID information is transmitted to an internet-based database or service provider via cellular, satellite, or other data communications network. This approach would enable improved collection, analysis, and utilization of Remote ID data over the direct broadcast solution. In the final implementation of Remote ID rules codified in 14 CFR Part 89, the FAA elected to pursue the direct broadcast solution (FAA, 2021c).

Another notable challenge from the adopted Remote ID implementation is the relatively limited reception range of sUAS Remote ID transmissions. Pierce Aerospace estimates that Remote ID reception range varies from approximately 3 NM in urban/suburban areas to 7 NM in rural settings; however, reception is subject to many factors including weather, terrain, interference, and other factors (A. Pierce, personal communication, April 24, 2025). While several technologies were considered for adoption by the UAS ID ARC, the agency implemented a low-power, direct radio frequency approach. In responding to Notice of Proposed Rulemaking comments, the agency clarified their position on the subject, stating:

> The FAA agrees with the commenters who proposed that broadcast remote identification is sufficient to provide the required remote identification message elements to support typical unmanned aircraft operations and satisfy security requirements. Broadcast remote identification does not rely on Internet availability, and is a secure method that is less susceptible to widespread failure caused by malicious actors or systems outages. Broadcast remote identification is also an independent, less expensive, and less complex method of providing the required remote identification message elements. The FAA has determined that a requirement for unmanned aircraft to broadcast remote identification information will provide the FAA, law enforcement, the general public, and other parts of the aviation community with real-time information about unmanned aircraft operations in any area where broadcast signals can be received. The broadcast will permit detection of unmanned aircraft. It will permit law enforcement and the general public that receives the broadcasted message elements to have information about the unmanned aircraft location and about the control station or takeoff location. Personal wireless devices capable of receiving 47 CFR part 15 frequencies, such as smart phones, tablets, or other commercially available devices, will be able to receive broadcast remote identification information directly without reliance on an Internet connection. (FAA, 2021c, p. 75)

The agency further acknowledged the potential range limitations of low-power radio frequency transmissions, stating, “The FAA notes that the broadcast range of Remote Identification information will have a finite limit based on signal strength limitations for unlicensed devices” (FAA, 2021c, p. 121). The FAA (2021c) would further state, “The FAA acknowledges that the use of part 15 devices for Remote identification broadcasts may result in reduced distance and reliability as compared to solutions leveraging licensed spectrum” (p. 146). The use of low-power radio frequency transmissions to transmit Remote ID messages within an unlicensed spectrum will likely be subject to performance limitations—particularly interference and range reception.

To enable Remote ID compliance for existing UAS or homebuilt platforms, the FAA instituted a policy that allows an operator to retrofit their UAS with a Remote ID *broadcast module*—a small, attachable, self-contained transmitter that broadcasts required Remote ID elements from takeoff to shutdown (FAA, 2021c). The potential limitation of this device is that while it identifies the operator, it does not enable the identification of the UAS platform in use without additional amplifying information. Moreover, the broadcast module could be swapped across multiple owned platforms, making it more difficult to measure operational patterns adequately. The researchers acknowledge that these limitations do not adversely affect regulatory compliance. Still, some restrictions apply specifically to the ability to discern applicable information to answer the research questions posed in this study.

Table 1 lists the minimum performance specifications required to maintain compliance with the Remote ID ruling. There may also be limitations regarding signal range and coverage in broadcast-based Remote ID systems. The effective transmission and reception of Remote ID signals via Bluetooth or Wi-Fi technology are subject to the limitations of these communication protocols, such as signal strength, interference, and range. In certain situations, such as dense urban environments or areas with significant electromagnetic interference, the broadcast-based Remote ID signals may face challenges in reaching receivers or experience signal degradation. This presents challenges, as the technology must be robust and not susceptible to interference, while maintaining the required minimum performance specifications.

Table 1. Remote ID Performance Requirements (14 CFR §89.310).

Message Element	Requirement
UAS Latitude / Longitude Accuracy	100 ft
UAS Altitude Accuracy	150 ft
Control Station Latitude / Longitude Accuracy	100 ft (Standard Remote ID)
Control Station Altitude Accuracy	15 ft (Standard Remote ID)
Takeoff Location Latitude / Longitude Accuracy	100 ft (Broadcast Modules)
Takeoff Location Elevation Accuracy	150 ft (Broadcast Modules)
Message Update Rate	1 Hz
Message Latency	1 sec (max)

Remote Identification is advantaged by several characteristics, including a relatively high message refresh rate. An anecdotal review of collected Remote ID message frequency reveals that some Remote ID manufacturers have implemented designs that vastly exceed the minimum message update rate—sometimes as much as 16 Hz. While this approach may aid in improved temporal fidelity for individual platforms, it also has notable drawbacks, including the potential for data saturation and complicated analysis. Higher than required message update rates require analysts to filter and process vast quantities of data, while offering only negligible benefit in reception, fidelity, and accuracy.

Another notable challenge of Remote Identification technology is the inability to differentiate between different flights or sorties—singular missions or operations--performed by the same platform in a short period. Sortie counts are an essential measure of platform activity that aids analysts and policymakers in identifying the operational frequency, tempo, and risk exposure of a UAS operation.

Additionally, ensuring interoperability and compatibility between Remote ID systems and platforms remains challenging. As the UAS industry continues to evolve and new technologies emerge, the need for seamless integration and data sharing between different Remote ID systems become crucial. This involves addressing technical aspects and establishing standardized protocols and data formats to enable cross-platform compatibility and interoperability among Remote ID solutions from various manufacturers and service providers. Achieving comprehensive interoperability among diverse remote ID systems requires ongoing efforts to develop and implement standardized solutions that promote effective data exchange in the evolving UAS landscape.

1.2.7 UAS Remote ID Data Description

This project utilized Remote ID sensors capable of detecting and tracking sUAS in real-time. These sensors were deployed in the context of new FAA regulations, effective September 16, 2023, which require all UAS operators to register their drones and comply with Remote ID standards outlined in 14 CFR §89 and portions of 14 CFR §107. As such, the sensor data is instrumental in evaluating operator compliance and system-level adoption trends. These sensors provide for continuous, passive monitoring of detailed operations data, including UAS location, altitude, speed, control station location, control station altitude, takeoff location, and other details.

The Remote Identification detection sensors used in this project collect the data presented in Table 2.

Table 2. Remote Identification Data Elements.

• Identification (ID) • Mode • Timestamp • Origin Address • Origin Point Latitude • Origin Point Longitude • Origin Point Heading • Origin Point Speed • Origin Point Altitude Mean Sea Level (MSL) Geodetic • Origin Point Altitude Barometric Meters • Origin Point Altitude Height Above Ellipsoid (HAE) • Operational Status • Point Latitude • Point Longitude • Point Heading • Point Speed • Point Altitude MSL Geodetic • Point Altitude MSL Barometric	• Point Altitude HAE • Remote ID Details Remote ID Compliant • Remote ID Details Takeoff Location Latitude • Remote ID Details Takeoff Location Longitude • Remote ID Details Takeoff Location Heading • Remote ID Details Takeoff Location Speed • Remote ID Details Takeoff Location Altitude MSL Geodetic • Remote ID Details Takeoff Location Altitude MSL Barometric • Remote ID Details Takeoff Location Altitude HAE • Remote ID Radio Bluetooth Received Signal Strength Indicator (RSSI) • Remote ID Radio Wi-Fi RSSI • Remote ID Radio Estimated Receive Interval • Database Only Human Notes

Data collection standards conform to American Society for Testing Materials (ASTM) F3411-22, Standard Specifications for Remote ID and Tracking (ASTM International, 2022).

2 DATA COLLECTION AND ANALYSIS METHODOLOGY

This section outlines the data collection approach, analysis methodology, and related processes and procedures for conducting the sUAS traffic analysis.

2.1 Instruments and Data Analysis Resources

Pierce Aerospace, Remote ID Data Partner

To acquire necessary data, the research team partnered with a Remote Identification provider called Pierce Aerospace (Pierce Aerospace, 2025). Pierce Aerospace has developed Remote ID solutions since 2017 and is funded by the U.S. Air Force, the State of Indiana, and Techstars. The company provides a myriad of Remote ID solutions, including commercial and government Remote ID beacon sets, as well as the company's proprietary Remote ID Receiver. Pierce Aerospace is located in Fishers, Indiana.

The research team subcontracted Pierce Aerospace to deploy Remote ID sensors to selected, prioritized locations. Pierce Aerospace constructed, deployed, and operated all sensor platforms in each sampling location chosen (see Figure 2). The Remote ID devices were equipped with mobile hotspots using Long-Term Evolution (LTE) cellular connectivity, enabling real-time transmission of Remote ID data to Pierce Aerospace's data server. The company regularly delivered data batches to the research team through project completion.

Figure 2. Pierce Aerospace Remote ID Receiver.

Remote ID Deployment and Sampling Locations

UAS Remote ID data were collected between October 1, 2023, and September 30, 2024, from approximately sensors deployed at geographically diverse locations throughout the U.S, selected to capture variation in airport proximity, population density, and regional air traffic characteristics.

Unmanned Robotics Systems Analysis (URSA)

Organization

URSA 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 C-UAS integration efforts through Small Business Innovation Research grants, Customs and Border Protection 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 combining various data sources into a flexible platform (URSA, 2020).

Airspace Awareness Platform

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

2.2 Additional Datasets

Iowa State University Environmental MESONET

The Iowa State University Environmental MESONET provides archival data from aviation weather observation stations worldwide, including Automated Weather Observing Systems (AWOS) and

Automated Surface Observing Systems (ASOS) (Iowa State University, 2021). According to the Flight Safety Foundation (2018):

> AWOS systems generally collect ceiling, sky condition, visibility, temperature, dew point, altimeter setting, 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 was paired to proximate sUAS telemetry data to identify instances where sUAS flights exceed regulatory authority for operation in adverse weather or visibility conditions.

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 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 national critical infrastructure sectors. 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 around critical infrastructure.

Federal Aviation Administration Aeronautical Data Delivery Service
"The Aeronautical Data Delivery Service 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 multiple tasks related to data contextualization and risk assessment within the NAS.

Federal Aviation Administration Geospatial Data & UAS Facility Maps 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 were used in support of LAANC analysis and risk assessment tasks. UAS Facility Map data is available from the Federal Aviation Administration website for geographical information systems:

Federal Aviation Administration GLARE Analysis Tool
The FAA uses the Geographic Low Altitude Risk Estimation (GLARE) GIS visualization tool 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 sighting 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.

Federal Aviation Administration sUAS Registration Database
Title 14 CFR §48 requires operators of sUAS to have a completed registration in the sUAS Registration Database and mark their sUAS with the provided registration number (FAA, n.d.b). Beginning on September 16, 2023, sUAS operators must update their registration with the serial number of their sUAS (for Standard Remote ID) or serial number of the Remote ID broadcast module (for those with an attached

Remote ID Broadcast Module). The research team utilized registration information to assess sUAS population and forecasting.

FAA Low Altitude Authorization and Notification Capability (LAANC) UAS Data Exchange
FAA LAANC is a collaborative approach to managing low-altitude airspace data. It is a critical capability for furnishing sUAS operators with access to airspace near airports in controlled airspace. The UAS Data Exchange (FAA, 2024d), which manages this process, integrates request and airspace authorization information between UAS Service Suppliers and the FAA (FAA, 2024d). The research team used this data to support analysis of LAANC authorizations and aid in contextualizing airspace hot spots.

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, 2025b. This dataset includes the location, time, and narrative description of UAS encounters and other suspect UAS activity. This dataset was used to assess potential risk areas in the NAS, as well as evaluate if sUAS traffic density could be correlated to elevated risk metrics.

UAS Navy Astronomical Almanac
Location-specific sunrise, sunset, and civil twilight times were derived from the U.S. Naval Observatory data and accessed via PyEphem, a Python-based source code for celestial positions (Rhodes, 2020). This dataset supported evaluation of sUAS operation times, to assess if operations were conducted during daylight, civil twilight, or nighttime, in each respective sample location.

Internet Assigned Numbers Authority (IANA)
Time Zone information was obtained using a public-domain zone database derived from IANA. The agency provides global coordination for coding and technical standards for internet applications (IANA, 2020). This dataset ensured standardization and translation of timing information.

Open Elevation
Open Elevation is a publicly available, free source of geographical elevation data provided by an Application Programming Interface (API) (Lourenço, n.d.). It offers comparable data to the Google Elevation API (Lourenço, n.d.). This dataset provided baseline elevation information for several analysis elements.

Open Street Map
Open Street Map 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 Global Positioning System (GPS) devices (OpenStreetMap Foundation, 2021). This database supported mapping applications to visually contextualize geographic information.

2.3 Teaming and Organization

This project was supported by collaboration with experts from Embry-Riddle Aeronautical University, Kansas State University, and the National Institute for Aviation Research at Wichita State University. The team also includes several graduate and Ph.D. students in supporting roles.

2.4 Assumptions and Limitations

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

- Remote ID detection sensors only provide detection and tracking for sUAS platforms equipped with either an operable embedded or attached Remote ID beacon that meets specifications of ASTM F3411-22, Standard Specifications for Remote ID and Tracking (ASTM International, 2022). Drones not equipped with Remote ID or beacons that do not meet the ASTM F3411-22 standard were not detected.

- Remote ID detection sensors only detect platforms within electronic line of sight. The range of Remote ID detection sensors can be affected by various factors, including sensor elevation, terrain, obstructions, and antenna configuration. While the research team will coordinate to deploy multiple Remote ID sensors in each sampling location, the team cannot estimate the effective coverage area or detection range. Additionally, signals used by Remote ID beacons, such as Wi-Fi and Bluetooth, are relatively weak, and have limited penetration power. Obstacles that interfere with the electronic line of sight between the sUAS and Remote ID sensors will likely prevent detection.
- Platform or model identification relies on accurate sUAS registration submitted to DroneZone.
- Some data values, such as Above Ground Level (AGL) altitudes are presumed, based on an assumption that sUAS are launched at ground level. In other cases, these values may be derived based on ellipsoidal height.
- 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 impossible to determine if an operator under 14 CFR §107 is operating under the authority of a waiver or airspace authorization.
- While the study plans to collect data from multiple sample locations, these areas may not necessarily represent 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 these localized findings.

2.5 Addressing Data Assumptions: Data Filtering, Cleaning, and Validation

One challenge encountered when using Remote ID data is the potential for the device to miscount or mischaracterize segments of sUAS flights in which it does not maintain continuous, uninterrupted tracking. Additionally, sUAS flying under conditions that would inhibit good detection of the Remote ID beacon signal (such as those flying at the extent of the Remote ID detection sensor's range) may only log a small number of telemetry points. Finally, Remote ID detects sUAS activity upon initial activation—even if the aerial vehicle is not in flight. This can result in some Remote ID detections that do not present an aerial hazard.

Data filtering, cleaning, and validation methods have been proposed to address the aforementioned limitations and ensure the project uses the most valid data. These procedures are designed to be implemented at the discretion of the research team. This discretion enables each subject matter expert to assess the data before and after correcting it for potential validity threats. In some cases, retaining spurious detections, ground activity, or incomplete data (such as when performing sUAS population counts) may be important. In other cases, ensuring higher data accuracy and validity is more important.

2.5.1.1 Data Treatment Prior to Loading into URSA's Airspace Awareness Platform

Prior to loading data into the URSA Airspace Awareness Platform for analysis, the URSA team performed several preliminary procedures designed to ensure data validity:

- Eliminate data duplication from overlapping Remote ID sensors, as appropriate
- Ensure data aligns to appropriate standards for datum and formatting requirements

The research team will employ one or more methods to correct Remote ID data validity issues, including:

- Removing data points with invalid latitude or longitude values
- Removing data points with null latitude/longitude or Remote ID Serial Number values
- Removing single data point flight detections from analyzed Remote ID data
- Removing sUAS ground activity or tracks that do not become airborne

3 METHODOLOGY AND RESEARCH TASKS

This section provides a breakdown of the research tasks planned to address the research questions for the project. The following research tasks were performed:

- Task A: Analysis Tool Adaptation
- Task B: Current State of sUAS Traffic within the National Airspace System
- Task C: Compliance and Exceedances of 14 CFR 107 Operational Limitations
- Task D: Near Aerodrome sUAS Operations and Encounter Risks with Manned Air Traffic
- Task E: Forecasting Industry Growth and Potential Advanced Air Mobility Implications
- Task F: Communicating Findings

3.1 Task A: Analysis Tool Adaptation

The primary objectives of this task include adapting the capabilities of URSA's existing Airspace Awareness analytics platform to store, format, integrate, database, process, analyze, display, and filter the Remote ID datasets. While this platform has been used in previous UAS detection studies, analytics methods must be adapted to Remote ID data, which has slightly different formatting and structure than prior datasets.

3.1.1 Analysis Tool Adaptation

Due to the extent of Remote ID data generated from the proposed locations across the U.S., it is impossible to analyze detection data using conventional tabular means, such as Microsoft Excel or related software. Microsoft Excel, for example, is limited to datasets with fewer than 1,048,576 rows. One collection site near Dallas-Fort Worth International Airport generated over 3.8 million detection records across nearly three years of data. Cloud-based computing was required to store, process, and analyze the full scope of data produced.

URSA's *Airspace Awareness* analytics platform was selected 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 Adaptation process was led by David Kovar and the URSA team, who directed the programming, integration, and adaptation of Remote ID data and previously developed analysis processes into the *Airspace Awareness* platform. URSA was provided with specific technical requirements to support the objectives and deliverables outlined in the research task plan.

In parallel, the Principal Investigator (PI) was responsible for securing data access to the aforementioned Remote ID data and ancillary GIS data used in the project. The PI coordinated data access/licensing agreements, negotiated pricing, and completed all necessary purchase processes in accordance with grant requirements and established procurement procedures. Once data sources were secured, the PI transferred data access to URSA for integration into the Airspace Awareness analytics tool.

3.2 Task B: Current State of sUAS Traffic within the National Airspace System

This task presents descriptive analysis of sUAS traffic trends from sample data. The research team used Remote ID detection data to quantify key operational trends. Due to airport access issues and limited Remote ID sensor resources, convenience sampling was used throughout the study. Readers should be cautious about making broad population generalizations or inferences from the collected data. Sampling was carried out from November 2023 through November 2024. The team deployed seven Remote ID sensors at five locations throughout the U.S., including: 1) Indianapolis, IN (2 sensors); 2) Daytona Beach, FL (1 sensor); 3) Fishers, IN (2 sensors); 4) Columbus, IN (1 sensor); and 5) Terre Haute, IN (1 sensor). More precise sensor location data was available to the research team for analysis but cannot be reported publicly due to security and privacy reasons.

3.2.1 Remote Identification Detection

This assessment examined the distribution of sUAS detections obtained from deployed Remote Identification sensors to assess the normal detection range. Understanding Remote ID detection range can improve future deployment and monitoring performance of Remote Identification sensors.

One of the key limitations of Remote Identification is its limited detection range. Remote ID signals generally utilize either Wi-Fi or Bluetooth. This was a well-known limitation of using these signal sets and was identified by several commenters in the Remote ID Notice of Proposed Rulemaking (NPRM) public comment process (Remote Identification of Unmanned Aircraft, 2021). The FAA acknowledged these limitations, stating, “The FAA notes that the broadcast range of remote identification information will have a finite limit based on signal strength limitations for unlicensed devices” (Remote Identification of Unmanned Aircraft, 2021, p. 4421). Figure 3 shows the cumulative distribution of detection ranges of all Remote ID signals detected during the project, with their respective detection range from the sensor. Data shows that approximately 11.5% of all Remote ID data was recorded within .1 mile; 14.9% from .1-.2 miles; 11.4% from .2-.3 miles; 8.7% from .3-.4 miles; and 6.5% from .4-.5 miles. Cumulatively, two-thirds of all Remote ID messages were received within 1 mile of the receiver. Reception drops off precipitously thereafter, with each additional mile accounting for an approximately 5% ratio of the data. More than 99.5% of the data was recorded at distances of less than 10 miles.

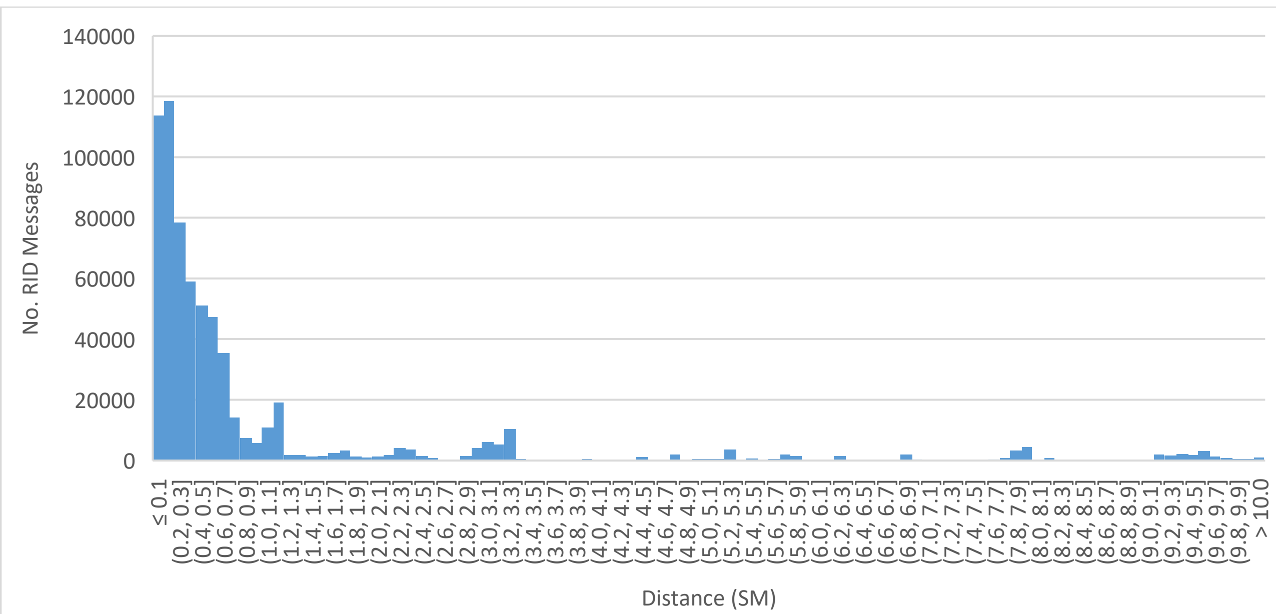


Figure 3. Cumulative Sensor Detections by Range (SM).

The research team concluded that Remote ID transmissions may be ineffective at extended ranges. The research team noted that these findings are based on captured, real-world data using proprietary Remote ID detection systems outfitted with off-the-shelf, omni-directional antenna arrays. No testing was performed to assess Remote ID sensor performance or evaluate whether a known UAS operating at a known distance could be detected. The research team further acknowledges that Remote ID detection was carried out in field conditions, and signal reception may be subject to other influencing factors, such as line of sight issues (terrain, obstructions), signal interference/noise, and related factors not assessed in this research project.

The research team cautions that interpretation of these findings should be taken with some context:

- Remote ID technology is still in its infancy, with opportunities for technical capability evolution for both transmission and receiver technology.
- Remote ID technology has limitations that in many cases are comparable to other forms of UAS detection. For example, radar technology also has significant range limitations in detecting UAS, primarily due to their small size (and accompanying radar cross section), low altitude, and slow speed. It is important to note that *all* UAS detection technologies have one or more limitations that curtails their effectiveness.
- There are currently no performance requirements for Remote ID that apply to transmission range or power output under 14 CFR §89. The research team anecdotally noted that there are fairly wide variances in OEM implementation of Remote ID, which may impact the ability of UAS to be detected by any radio frequency system. Preliminary observation of Remote ID implementation suggests there are technical avenues for enhancing performance, such as enhancing transmission power output, that retain the FAA's intent and general FCC framework for Remote ID.
- The research team is not aware of any formal assessments or audits of Remote ID capability or performance to determine performance gaps and identify potential areas for technical improvement.

It is anticipated that further analysis of Remote ID effectiveness will be included in the follow-on ASSURE A83, Drone Traffic Analysis study.

3.2.2 Current Traffic Attributes

This assessment aimed to identify and codify key attributes of sUAS traffic trends, based on data collected from the Remote ID sampling locations.

The research team assessed operations using two separate metrics—number of platforms and flights. The number of platforms represents the distinct sUAS Remote ID serial numbers detected for each metric. The second metric used was flights (sometimes called sorties), which traditionally represents operations from takeoff to landing. Unlike some other UAS detection technology, Remote Identification does not differentiate between individual UAS flights. To determine normalized sortie duration, the research team referenced UAS operator surveys conducted in support of the 20-Year Aerospace Forecast. According to the UAS operator survey published in the FAA (2024c) 2024-2044 Aerospace Forecast, recreational operators reported a mean flight duration of 14 minutes and median flight duration of 10 minutes; and non-recreational operators reported average flight times between 20-30 minutes, with median flight times of approximately 20 minutes. When determining a sortie counting strategy, the research team sought to minimize duplicate counting of similar operations. To address this issue, the research team determined that flight detections occurring at least 20 minutes apart were counted as separate operational sorties. This accounts for short operational interruptions in detection, such as an operator landing to change a battery, without artificially inflating the operations counts.

The research team assessed recurring activity in calendar month intervals, with the number of individual platforms counted independently, each month (see Figure 4). During the sampling period, the research team detected 3,216 separate platforms, which conducted more than 6,311 separate flights. The cumulative number of platforms at all sample locations varied from a low of 24 platforms in December 2023 to a high of 436 in August 2024. Similarly, the number of flights varied from a low of 24 in December 2023 to a peak of 961 in May 2024. While several additional factors impacted these values for individual sampling, such as initial sensor deployment, sensor uptime, and related factors, the data shows a seasonality effect, with more platform flights and operations taking place during the summer months.

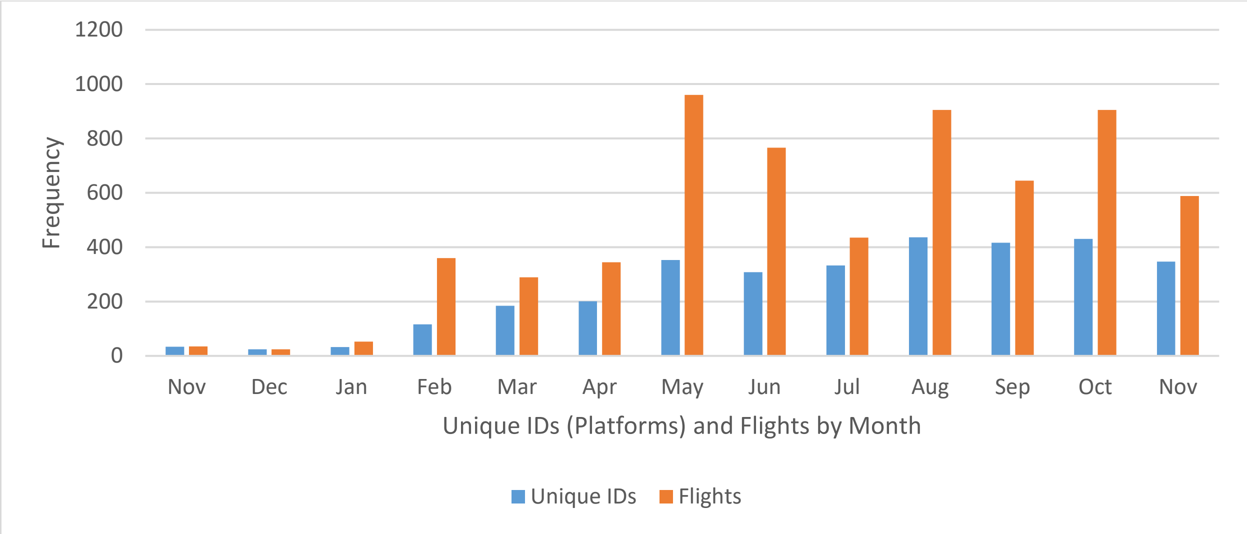


Figure 4. sUAS Unique IDs (Platforms) vs. Flights.

Across the sampling period, the platforms performed a mean of 1.96 flights per platform, per month. To evaluate the variance of flights over time, the research team also assessed the ratio of flights conducted each month relative to the number of detected platforms. Ratios varied from a low of 1.0 in December 2023 to a maximum of 3.1 in February 2024 (see Figure 5). Generally, ratios increased by nearly 0.5 flights per month in the summer months and diminished slightly into the colder winter months. Based on the ratio of flight operations relative to the number of platforms, the research team believes the preponderance of detected flights likely represents recreational operations. These values align with the recreational median flight frequency values collected in the FAA (2024c) UAS operator survey.

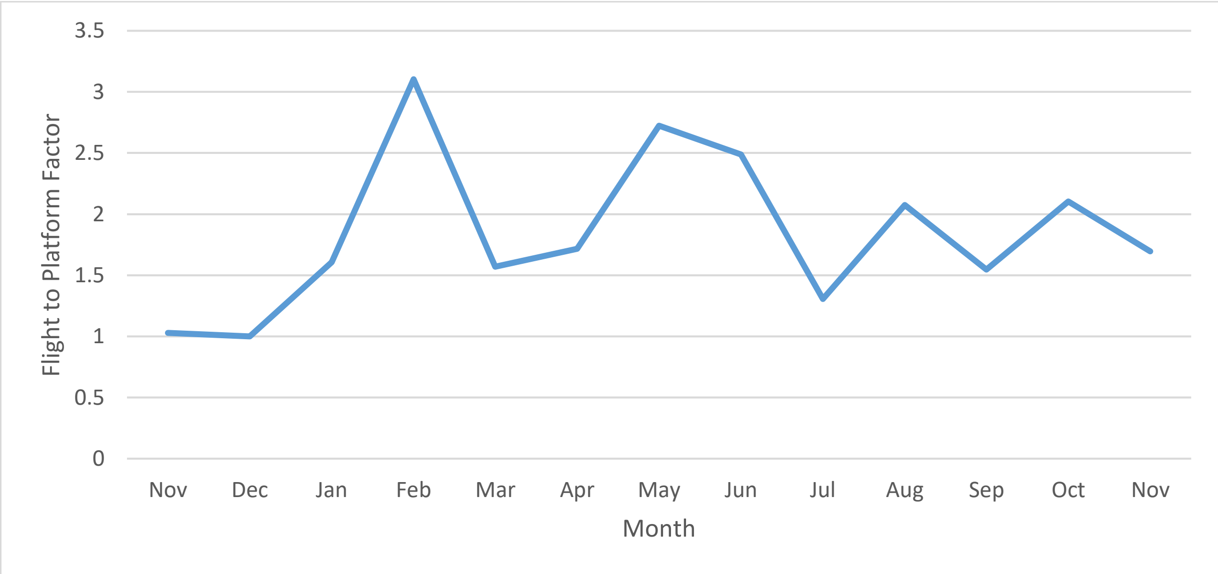


Figure 5. Running Flights/Platforms Ratio by Calendar Month.

A detailed breakdown of platform detections by location is presented in Figure 6. To illustrate platform occurrence trends and more accurately represent actual activity, the chart adjusted the counting methodology to identify only the initial occurrence of platform serial numbers, removing subsequent monthly counts and avoiding duplicative counting. This accounts for the reduction in platform sampling. There was generally wide variability of platform detections each month.

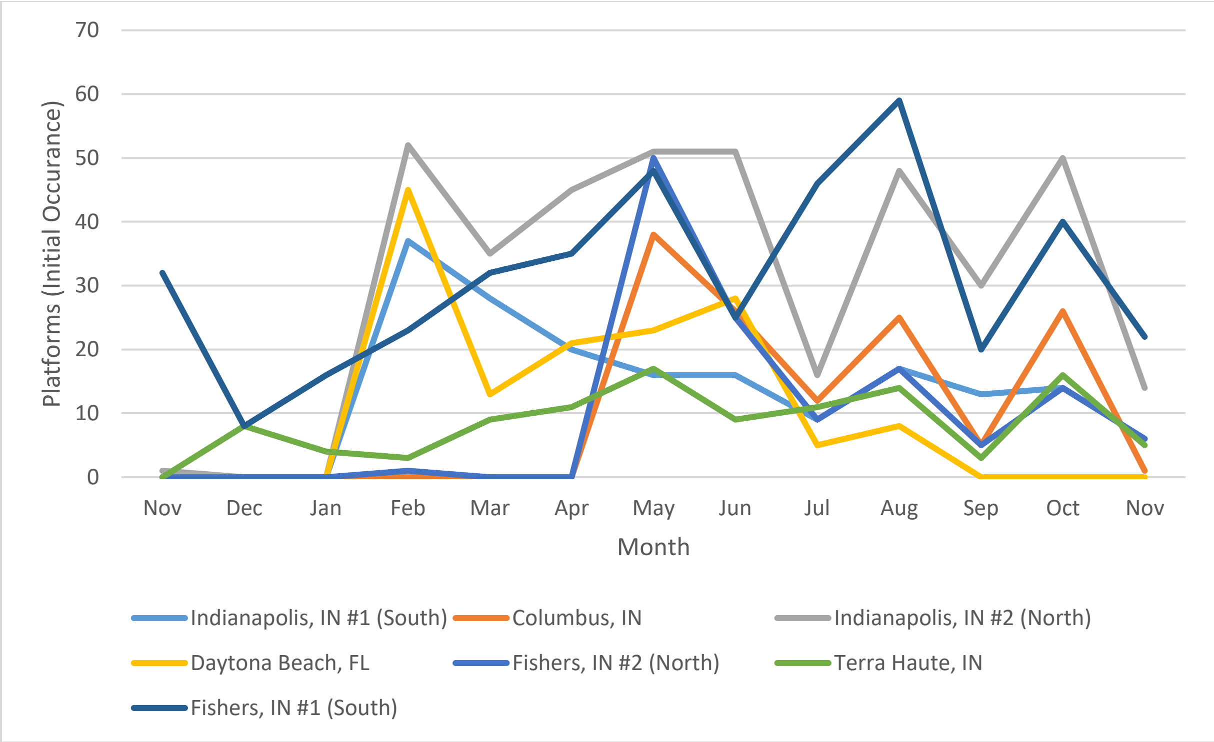


Figure 6. Platform Trends by Location, Initial Occurrence (*n*=1,488, Nov 2023-Nov 2024).

The research team evaluated publicly available UAS registration data to provide further context to platform data. The team assessed Remote ID sensor locations and determined proximate zip code and correlated registration data. Results are presented in Table 3, with amplifying data and descriptive statistics.

Table 3. Sampling Locations, Detection Data Descriptive Statistics, and UAS Registration Data.

Sensor Name	Sample Days	Min	Max	*m*	*M*	*SD*	Platforms	Flts	Zip	§44809	§107
Columbus, IN	211	0	11	3.01	1	2.13	148	636	47203	49	14
Daytona Beach, FL	195	0	13	1.72	1	1.95	145	335	32114	50	788
Fishers, IN #1 (South)	394	0	18	3.80	3	3.79	467	1499	46038	76	71
Fishers, IN #2 (North)	316	0	50	1.96	0	4.45	212	618	46202	21	135
Indianapolis, IN #1 (South)	296	0	25	1.95	1	2.55	262	578	46204	13	85
Indianapolis, IN #2 (North)	367	0	27	3.69	3	4.12	504	1356	46204	13	85
Terre Haute, IN	356	0	13	1.06	1	1.46	120	376	47803	0	15

Data from Table 3 was synthesized and presented graphically in Figure 7 for ease of comparison. Except Fishers, IN, and Columbus, IN, 14 CFR §107 registrations vastly outnumbered recreational (49 USC §44809) registrations in the zip code areas corresponding to the sensor locations. This was particularly true at the Daytona Beach, FL, location. The research team believes that values for Daytona Beach are likely not representative, as they likely reflect a large concentration of remote pilot-certificated students attending Embry-Riddle Aeronautical University, who may not be actively flying sUAS. Local campus flight restrictions may also influence this. There appears to be a much higher ratio of platforms and flights to registrants in the Terre Haute sampling area. This is likely to reflect individuals flying outside their registration area. The research team did not have an accurate means of assessing this effect in greater detail. Another notable observation was that the ratio of flights appears to increase with the proportion of §44809 registrants (see data spikes in Columbus and Fishers #1), however, this observation was not consistent in the Indianapolis #2 and Terre Haute sampling areas.

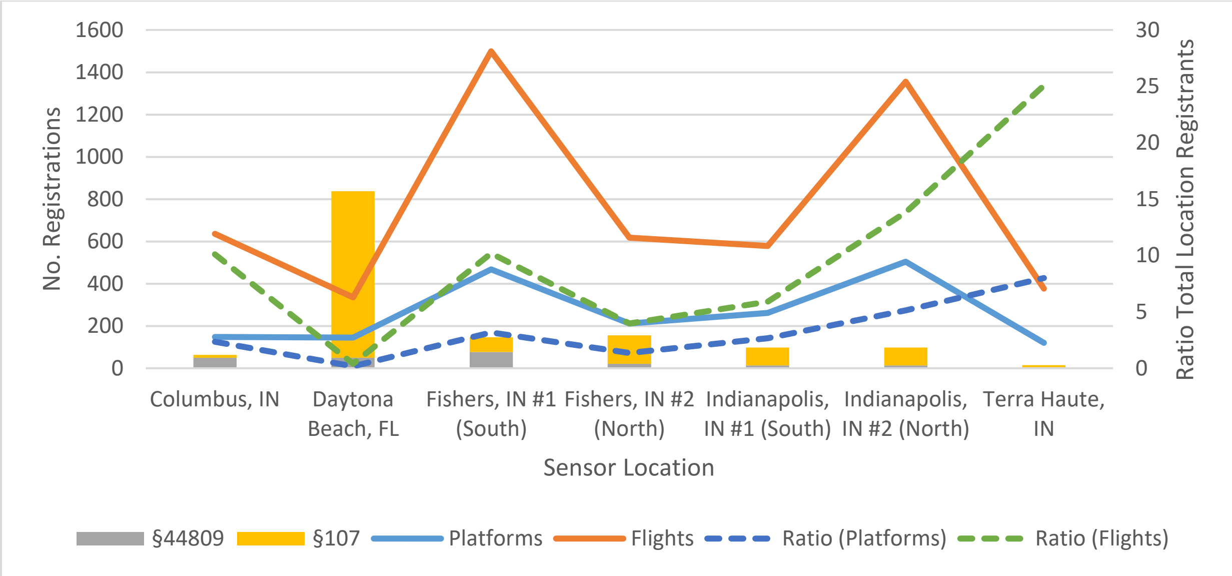


Figure 7. Comparison of Platforms, Flights, and Registrations by Sensor Location.

The research team also analyzed platform, flight, and registration data against location population data, acquired by zip code tabulation area from reported P1 values [total population] of the U.S. Census (2020) (see Figure 8). The research team performed a correlation analysis across multiple dataset factors to explore possible relationships. Results are presented in Table 4. Generally, correlations showed relatively weak relationships across most variables, except for recreational (§44809) registrations, which showed a strong correlation (r = .85) to P1 population. This seems to indicate that recreational flyers may be more representative of the overall population. However, this study's low sample size requires further confirmation of this observation in a more extensive and comprehensive evaluation.

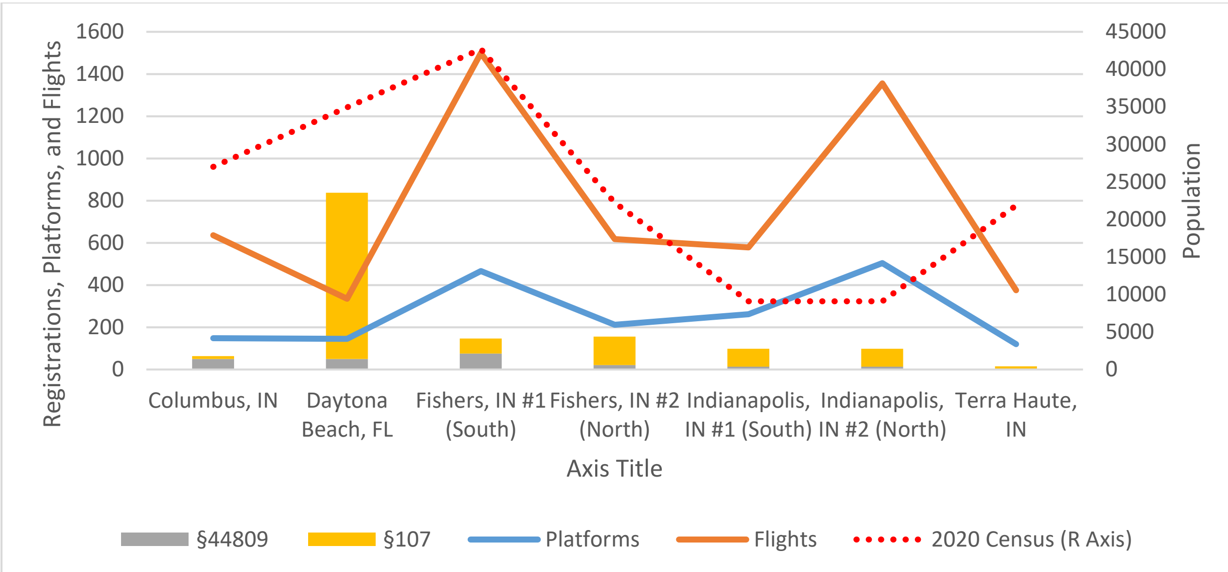


Figure 8. Comparisons of Platforms, Flights, and Registrations by Location to Census Population (P1).

Table 4. Correlation of Platforms, Flights, and Registrations by Location to Census Population (P1).

Factor	**Correlation (*r*)**
Platforms-P1	-0.08
Flights-P1	0.11
§44809-P1	0.85
§107-P1	0.36
Total Registrations-P1	0.43

A detailed breakdown of flight activity by sensor location is presented in Figure 9. The seasonal effect seems more readily apparent in this dataset, with elevated activity in the summer and diminished activity in the winter months.

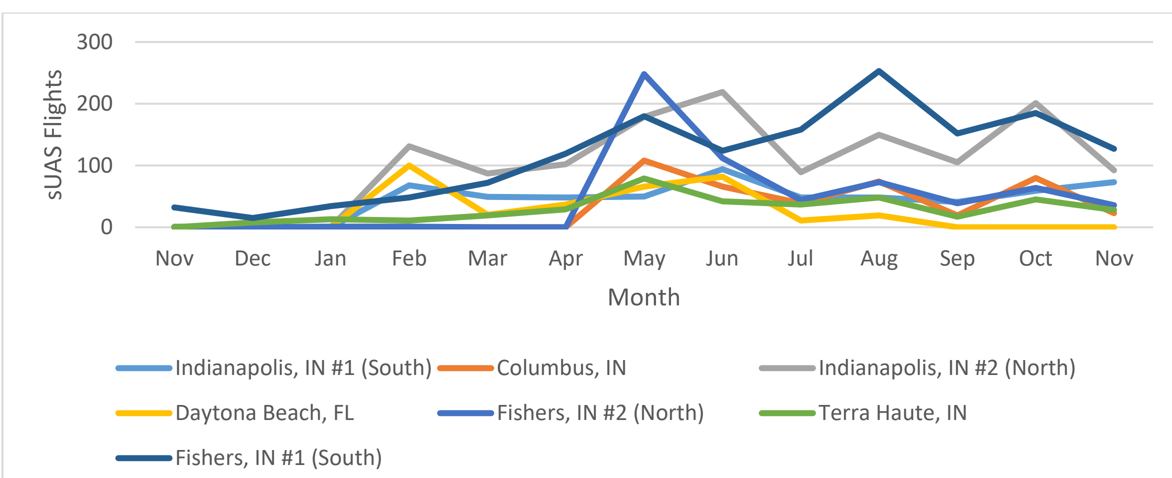


Figure 9. Flight Trends by Location (*n*=5,171, Nov 2023-Nov 2024).

The research team analyzed UAS activity by individual sample day to assess activity trends (see Figure 10).

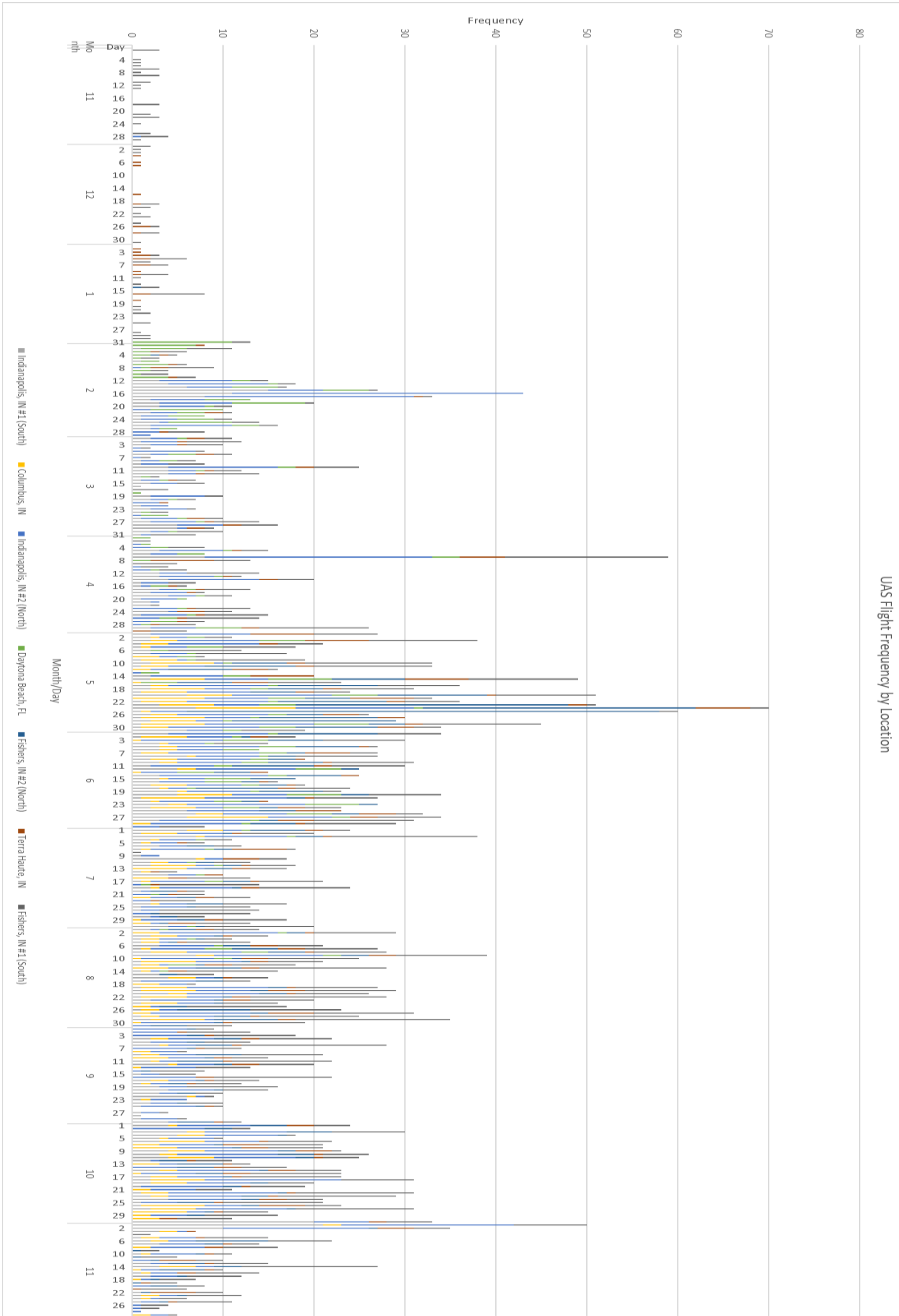


Figure 10. Daily sUAS Flight Frequency Trends by Location.

A boxplot of daily flights at each sampling location is provided in Figure 11.

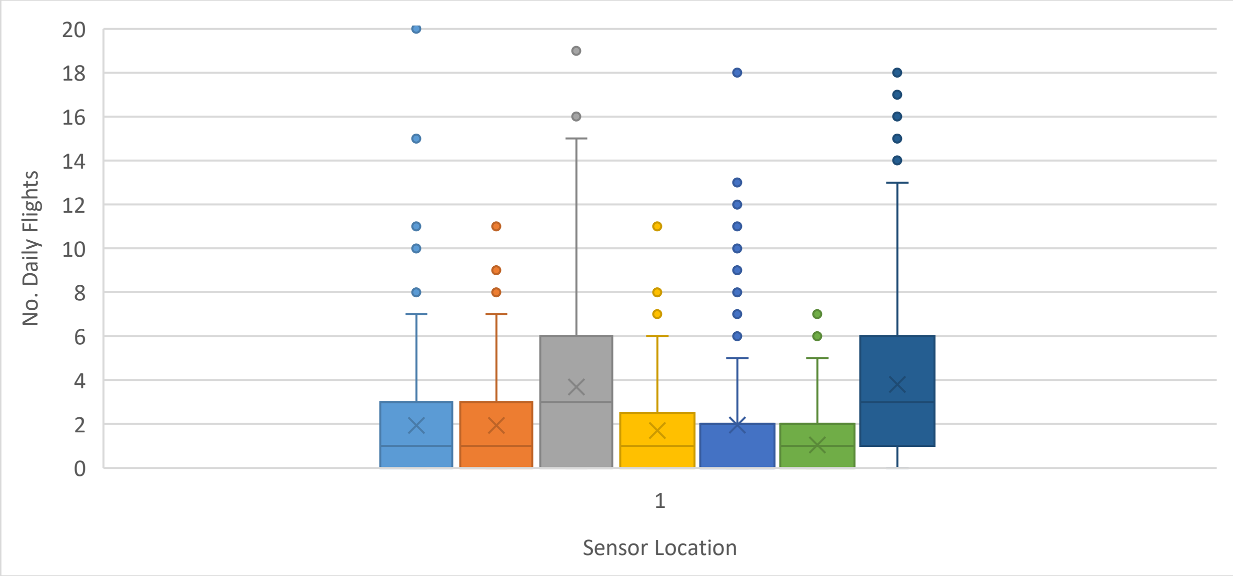


Figure 11. Boxplot of Daily Flights by Sample Location.

Note: Five outliers truncated above 20 to improve data display and interpretation. The max daily outlier value was n = 50 for Sensor #5 (Fishers #2). Presentation order and locations correspond to list in Table 3.

Standard deviation of daily flight detection values varied between 1.46 (Terre Haute) to a high of 4.45 (Fishers #2). The research team calculated high frequency flight days across all sampling locations. Dates with the highest flight frequencies are presented in Table 5.

Table 5. High Frequency Flight Dates by Sampling Location.

Date	Max	Sensor	Notes
5/26/24	50	Fishers #2	SU; Memorial Day Weekend
2/17/24	32	Indianapolis #2	SA; President's Day Weekend
5/24/24	30	Fishers #2	FR proceeding Memorial Day
5/25/24	30	Fishers #2	SA; Memorial Day Weekend
4/8/24	25	Indianapolis #2	MO
2/18/24	23	Indianapolis #2	SU; President's Day Weekend
11/2/24	21	Indianapolis #1	SA
11/1/24	20	Indianapolis #1	FR
5/29/24	18	Fishers #2	WE
8/30/24	17	Fishers #1	FR
7/4/24	16	Fishers #1	TH; Independence Day
9/7/24	16	Fishers #1	SA
11/3/24	16	Indianapolis #2	SU
2/16/24	15	Indianapolis #1	FR
8/23/24	15	Fishers #1	FR
10/19/24	15	Indianapolis #2	SA
11/15/24	15	Fishers #1	FR
5/11/24	14	Fishers #1	SA; Mother's Day Weekend
8/14/24	14	Fishers #1	WE

Note: Weekdays are coded using the first two letters in the notes column.

Assessment of high-frequency flight dates indicated elevated flight activity occurring during holiday weekends and some non-holiday weekends. The researchers acknowledged that there may be local factors influencing high-activity flight dates that were not evaluated. The research team recommended that the FAA consider adding questions related to holiday flying activity to the annual sUAS Activity Survey.

Moreover, the distribution of detected platforms—as determined from correlating Remote ID serial numbers with Remote ID declaration of compliance numbers (FAA, n.d.c)—more closely represents a large proportion of plat
forms used for recreational rather than non-recreational (commercial) purposes. The research team inferred that the majority of flights conducted during holiday periods is carried out by recreational/hobbyist operators.

3.2.3 sUAS Manufacturers, Models, and Trends

The purpose of this evaluation was to assess the distribution of sUAS models currently being flown within the NAS. Understanding model distribution can inform upon the platform weight, equipage, capabilities, and potential air and ground risk.

During the study, the research team detected a total of 2,524 platforms that contained a remote ID serial number. Of these, 2,192 platforms (*n* = 86.8%) could be correlated to an FAA Remote ID Declaration of Compliance, which was used to determine sUAS manufacturer and model. The research team detected 41 separate sUAS models from ten manufacturers (see Table 6).

DJI platforms accounted for 86.3% of all detected models, indicating brand dominance. This was followed by unknown models, representing 13.2% of the dataset. The research team believes most unknown models represent broadcast modules, as these serial numbers were often excluded from the FAA's Remote ID Declaration of Compliance database (FAA, n.d.c). The data suggest dominance of DJI platforms within the U.S. market appears to continue to increase.

Table 6. Detected sUAS Types by Manufacturer.

Manufacturer	Frequency	Proportion
Anzu	1	0.0%
Autel	3	0.1%
BRINC	1	0.0%
DJI	2,178	86.3%
DroneBeacon	1	0.0%
Holy Stone	3	0.1%
Ruko	2	0.1%
Skydio	1	0.0%
Spektrum	1	0.0%
Wingtra	1	0.0%
Unknown	332	13.2%
TOTAL	2,524	100.0%

Figure 12 shows the distribution of all detected sUAS models. The most dominant platforms (excluding broadcast modules) were the DJI Mini 4 Pro (22.4%), DJI Air 3 (11.8%), DJI Air 2S (9.6%), DJI Mavic 3 (7.2%), and DJI Mini 3 Pro (5.4%). All other individual platforms made up 5% or less of the detected dataset. An analysis of platforms by weight will be presented in a subsequent section of the report. To enabled improved comparison of detected platforms, a chart of basic specifications is provided in Table 6.

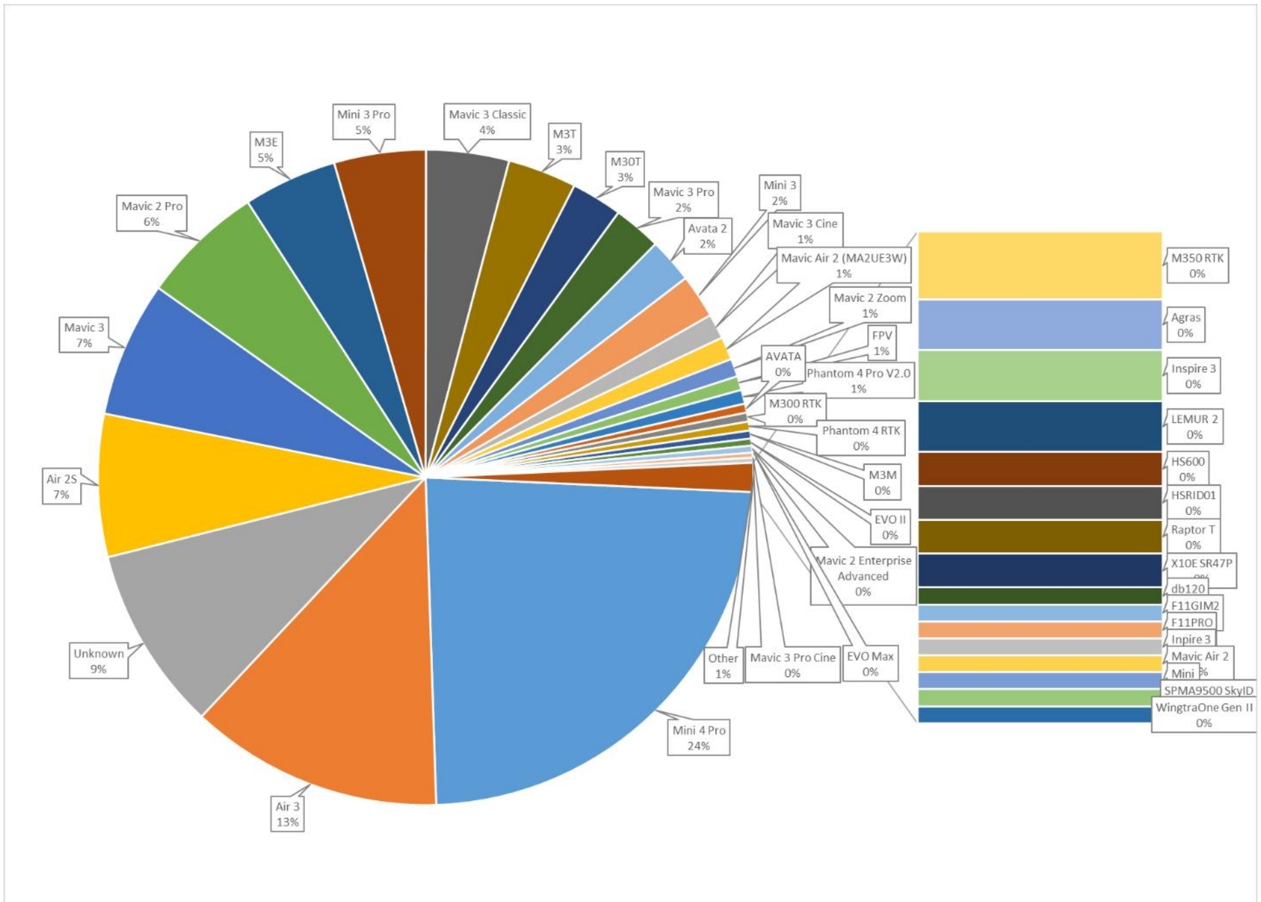


Figure 12. sUAS Models Detected.

Table 7. sUAS Model Specifications.

Drone Model	Release Date (Mo/Yr)	Available	Weight (g)	Price ($)	Endurance (min)	Max Speed (mph)
Agras (T50)	April-24	No	5,200	N/A	N/A	N/A
Air 3	June-23	Yes	720	$1,099.00	46	46.9
Avata	August-22	Yes	410	$499.00	18	60.3
Avata 2	April-24	Yes	377	$489.00	23	60.3
EVO II	January-20	Yes	1150	$4,799.00	40	45
Evo Max 4T	January-23	Yes	1645	$8,999.00	42	51.4
F11 GIM2	N/A	Yes	560	$480.00	28	22.3
F11 Pro	October-19	Yes	520	$379.00	30	19
HS600	November-21	Yes	541	$459.00	28	N/A
FPV	March-21	No	795	$699.00	20	87
Inspire 3	April-23	Yes	3,995	$16,499.00	28	58.4
Lemur 2	March-23	No	1,496	N/A	20	48
M300 RTK	May-20	Yes	6,300	$15,497.00	55	51.4
M30T	March-24	Yes	3,780	$10,881.00	41	51.4
M350 RTK	May-23	Yes	6,470	$13,403.00	55	51.4
M3M	November-22	No	951	$4,618.00	43	46.9
M3T	September-22	Yes	920	$5,899.00	45	46.9
Mavic 2 Enterprise Advanced	December-20	Yes	909	$6,500.00	31	44.7
Mavic 2 Pro	August-18	Yes	907	$1,799.00	31	44.7
Mavic 2 Zoom	August-18	Yes	905	$1,349.00	31	44.7
Mavic 3	November-21	Yes	895	$2,049.00	46	46.9
Mavic 3 Cine	November-21	Yes	899	$4,999.00	46	46.9
Mavic 3 Classic	November-22	Yes	895	$1,179.00	40	46.9
Mavic 3 Pro Cine	April-23	Yes	963	$4,799.00	43	46.9
Mavic Air 2	April-20	Yes	570	$559.00	34	42.5
Mavic Air 2S	April-21	Yes	595	$999.00	31	42.5
Mavic Mini	October-19	Yes	249	$299.00	30	29.1
Mini 3	December-22	Yes	248	$339.00	51	35.7
Mini 3 Pro	May-22	Yes	290	$669.00	47	35.7
Mini 4 Pro	September-23	Yes	249	$759.00	45	35.7
Phantom 4 Pro V.2	May-18	Yes	1375	$1,999.00	30	45
Raptor T	April-24	Yes	920	$8,099.00	45	46.9
Skydio X10	September-23	No	2,140	N/A	40	45
WingtraOne Gen 2	August-21	No	3991?	N/A	59	35.8

The research team evaluated UAS models detected over time at monthly intervals. Results are presented in Figure 13. Seasonality effects likely account for the substantial rise in operations over the summer months and accompanying diminishment towards the winter months. On initial evaluation, model distribution appears reasonably stable, with no significant industry disruption.

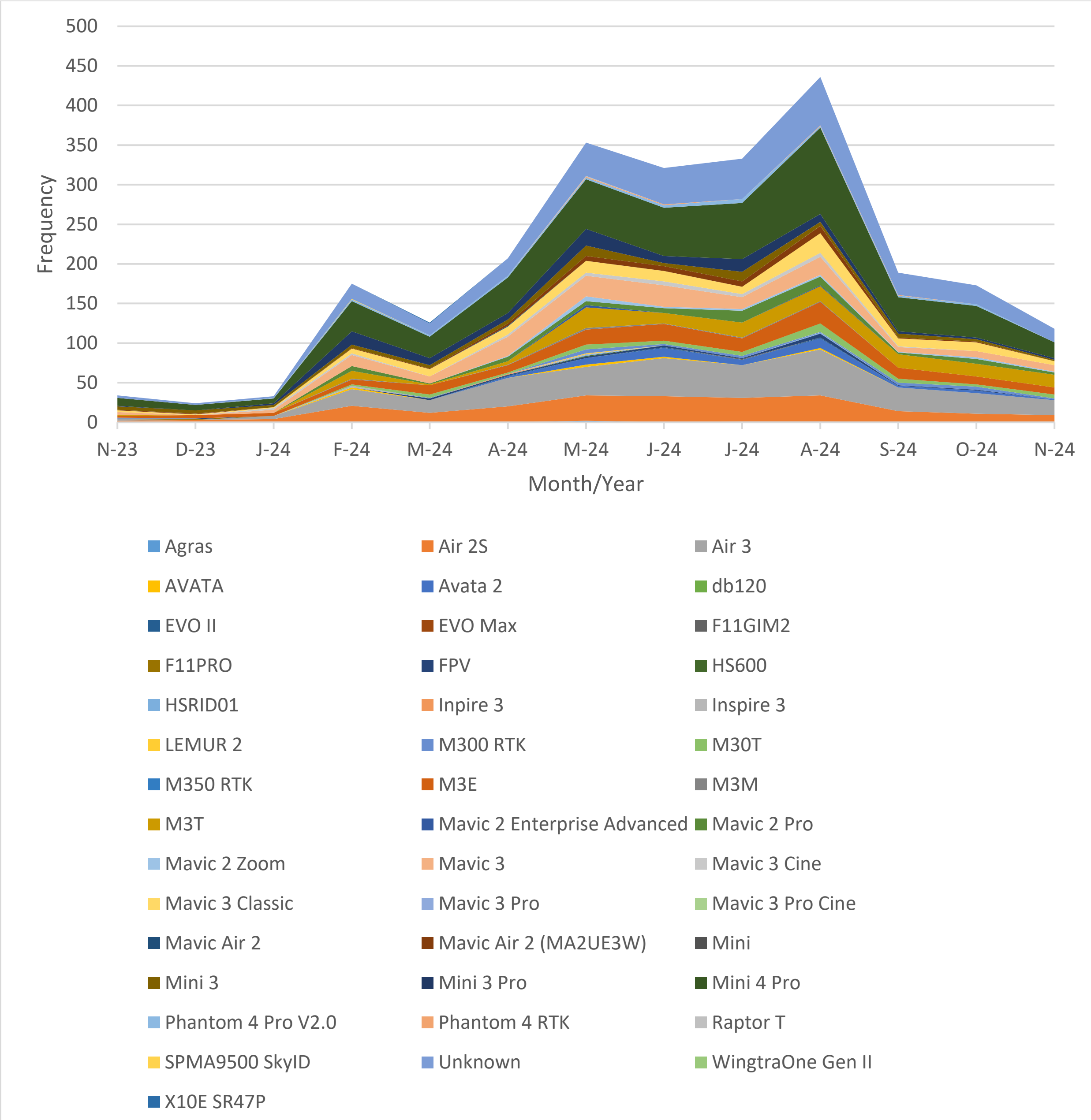


Figure 13. Distribution of Models by Monthly Activity (*n*=3,235).

To better understand model utilization and accompanying operations trends, the research team analyzed model use proportionally to evaluate model distribution changes over time. Results are presented in Figure 14. At the onset of the sampling period, the DJI Mini 4 Pro represented nearly 30% of monthly platforms, diminishing over the next 12 months to less than 20% of monthly activity. With the Mini 4 Pro's recent release in September 2023 (retail $1,099), this trend makes sense, as the sampling timeframe likely just missed the ramp up in utilization from this newly released platform. Meanwhile, the DJI Air 3 (released in October 2024; $1,099 retail cost) and DJI M3T (released September 2022; $5,498 retail cost) have steadily gained monthly usage, approaching nearly 15% of monthly platform activity. Activity from unknown platforms also increased over the previous year, rising from less than 10% of platforms to almost 15%. The research team believes this increase is primarily due to increased Remote ID compliance—most likely broadcast modules for older platforms. Meanwhile, several platforms have also been dropping in monthly activity, such as the older 2021 DJI Air 2S model (retail price $899). The DJI M3E has also been slowly falling in utilization (released in September 2022; retail cost $3,788) to just over 5%. The remainder of the platforms detected represent less than 5% of monthly activity.

It is difficult to say at this point if monthly Remote ID implementation or equipage has reached saturation, however, heavy variability in the data leads the research team to suspect that it is likely not the case. Moreover, the research team further believes that platform distribution and DJI's continued dominance may be overrepresented within the dataset due to early Standard Remote ID adoption, integration, and manufacturing.

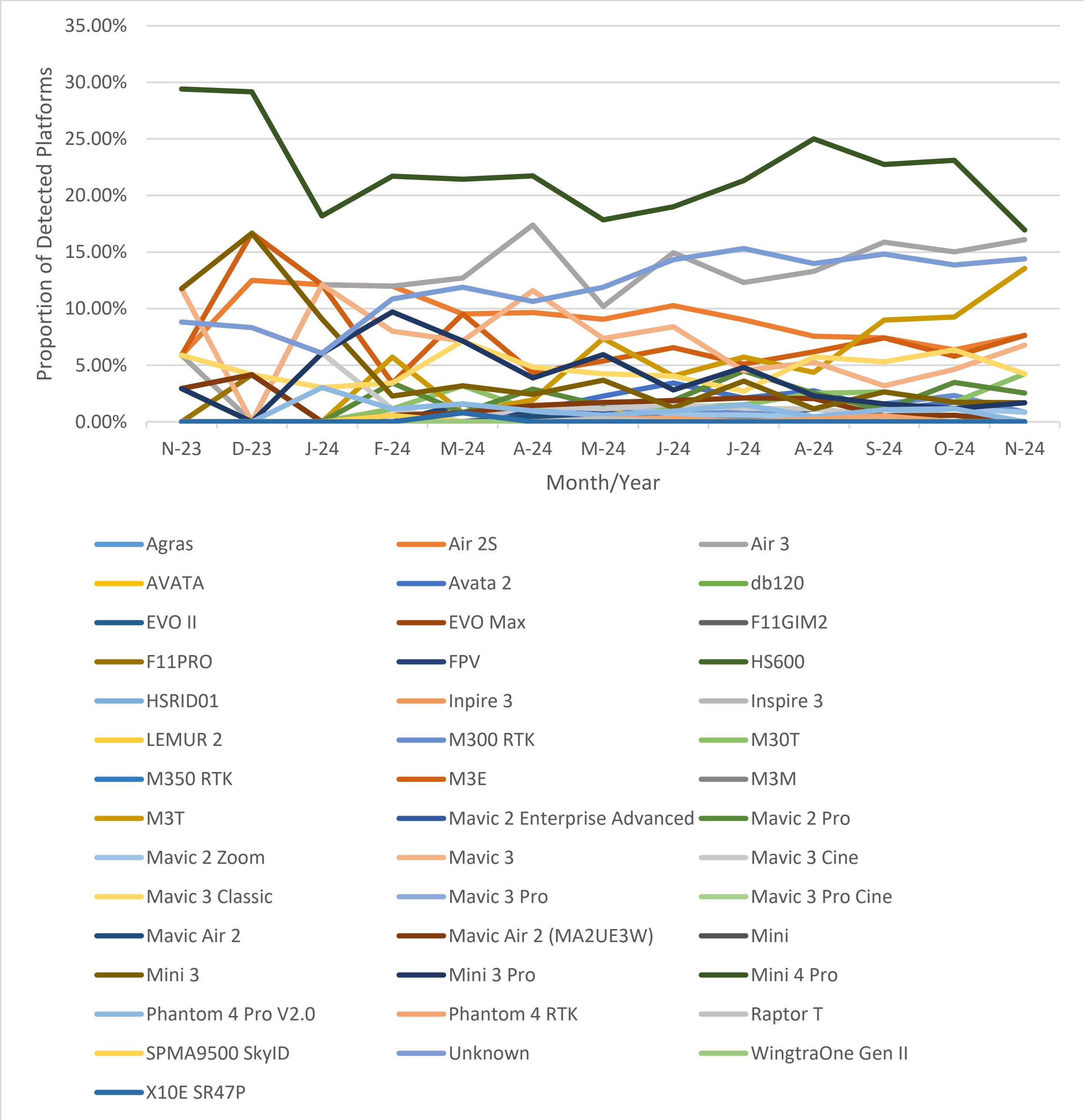


Figure 14. Proportional Distribution of Monthly sUAS Activity by Model.

The research team consolidated the Figure 14 model data to reflect the frequency of drone platform use by individual manufacturers. Results are presented in Figure 15. Perhaps not surprisingly, DJI comes out on top, leading operational utilization by several orders of magnitude, compared to its competitors.

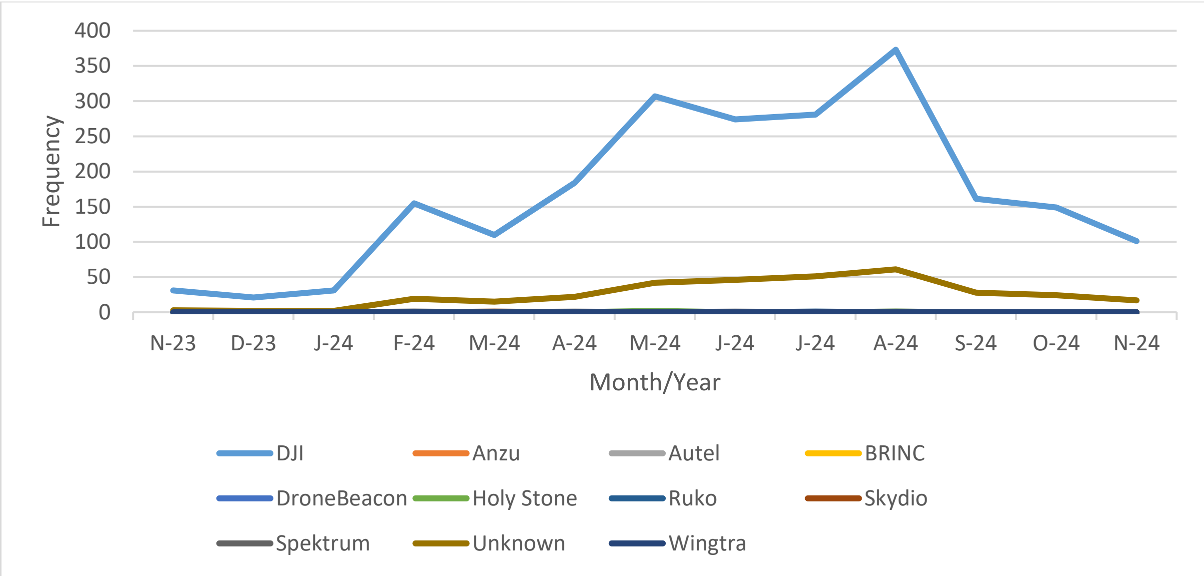


Figure 15. Manufacturer Activity by Month.

Although DJI continues to dominate, based on utilization metrics, a proportional analysis of monthly utilization by manufacturer, shows a slow, but measurable declination in DJI use, dropping from a peak monthly utilization rate of 93.9% in January 2024 to 85.6% by the end of 2024 (see Figure 16). While no single manufacturer is seen as the clear beneficiary, it seems that collectively non-DJI manufacturers may be showing limited success in slowly and steadily chipping away at DJI's commanding market position.

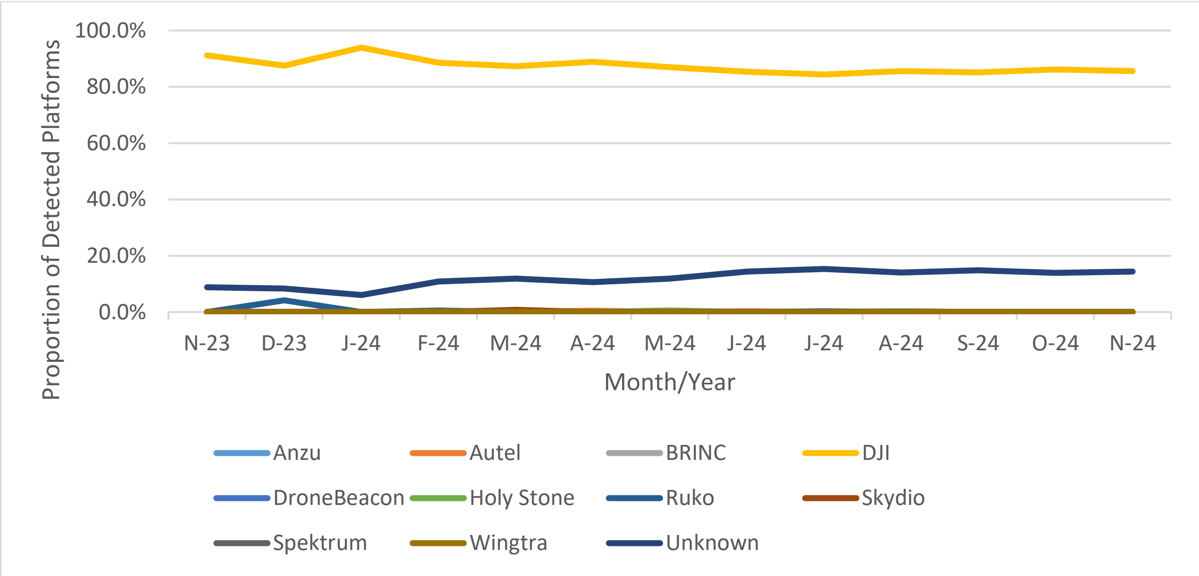


Figure 16. Proportional Distribution of Monthly Activity by Manufacturer.

3.2.4 Temporal Traffic Activity

The purpose of this assessment was to evaluate sUAS operations based on various temporal factors, including time of day and day of week to identify disproportionate operational patterns.

Most detected sUAS platforms were only operated during a single calendar month (*n* = 90.0%). The research team assessed monthly activity distribution by platform Remote ID serial number from among the 1,406 platforms in the dataset.

The research team assessed flight activity using various temporal metrics to understand better when sUAS operations occurred. The research team first assessed weekday flight activity to determine if sUAS operations were evenly distributed. Sampling included 56 Mondays, Tuesdays, and Sundays; and, 57 Wednesdays, Thursdays, Fridays, and Saturdays. Raw values are presented in Figure 17. Figure 18 plots average values, based on the number of weekdays in each calendar month.

Table 8 shows the total number of historical weekdays every month. A boxplot of cumulative average values is presented in Figure 19.

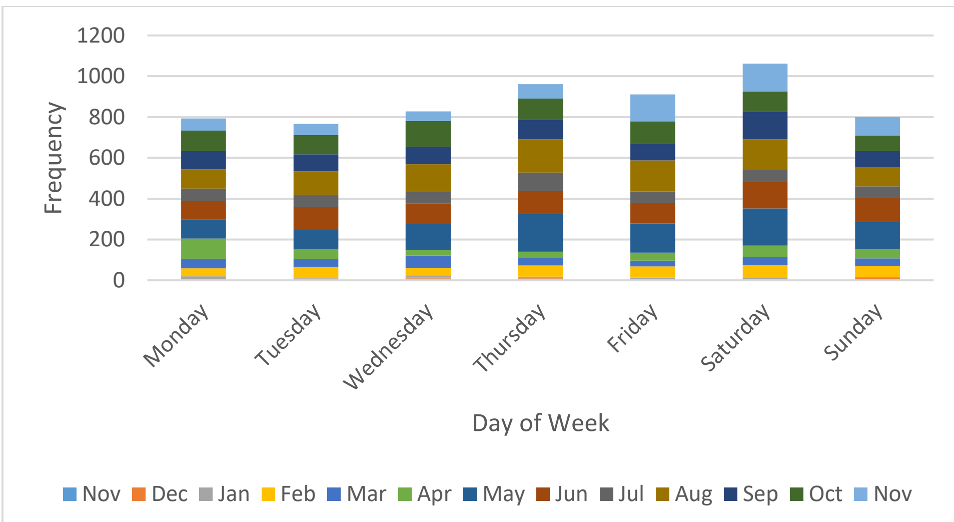


Figure 17. sUAS Flight Activity by Day of Week (Cumulative).

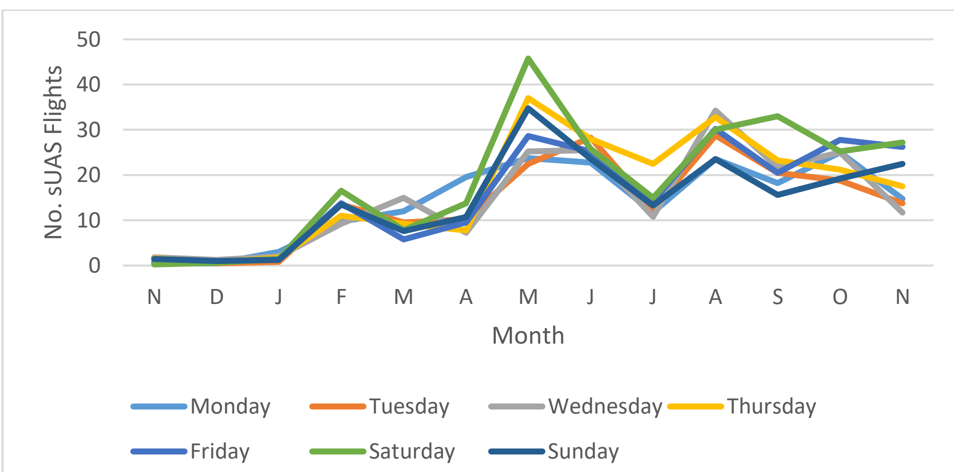


Figure 18. Average Monthly sUAS Flight Activity by Day of Week (Corrected for No. Weekdays).

Table 8. Number of Monthly Weekdays During Sampling Period.

Day of Week	N	D	J	F	M	A	M	J	J	A	S	O	N
Monday	4	4	5	4	4	5	4	4	5	4	5	4	4
Tuesday	4	4	5	4	4	5	4	4	5	4	4	5	4
Wednesday	5	4	5	4	4	4	5	4	5	4	4	5	4
Thursday	5	4	4	5	4	4	5	4	4	5	4	5	4
Friday	4	5	4	4	5	4	5	4	4	5	4	4	5
Saturday	4	5	4	4	5	4	4	5	4	5	4	4	5
Sunday	4	5	4	4	5	4	4	5	4	4	5	4	4

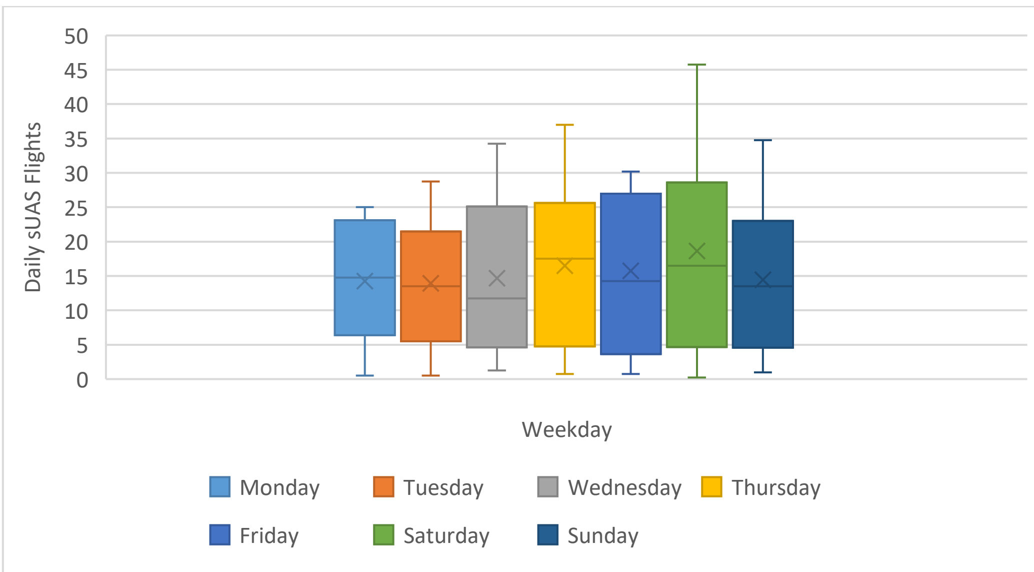
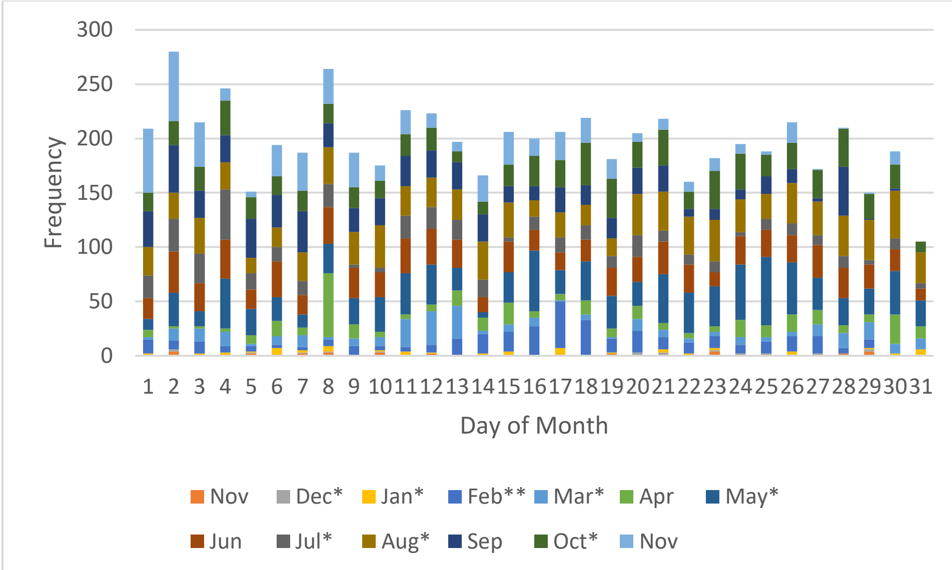


Figure 19. Boxplot of Average Monthly sUAS Flight Activity by Weekday.

Results show that more sUAS operations were carried out on Thursdays and Saturdays. This data partially reflects prior studies, which showed elevated activity on weekends. The research team believes that higher levels of weekend activity generally indicate recreational activity. It was unclear why activity was elevated on Thursdays.

A similar analysis was carried out to assess the day of month. Results are presented in Figure 20. There appear to be some data spikes in the early portion of the month, although some may be influenced by specific months (such as elevated April 8 activity). Since not all months have an equivalent number of days, there is an anticipated drop at 31.



Note: *Indicates month with 31 days; **Feb 2024 was a leap year with 29 days
Figure 20. sUAS Flight Activity by Day of Month.

The research team further analyzed the local time of operations and corrected for local time. Cumulative findings are presented in Figure 21. Results reflect prior studies indicating that the preponderance of sUAS flight activity occurs during daylight hours. All sampling locations were in the Eastern Time Zone. Flight operations tended to increase in the morning, generally peaked midday, and diminished into the evening hours of darkness. While there were some operations at nighttime, these were typically few in number. Higher proportions of early morning activity were observed to be carried out during the summertime months (see Figure 22).

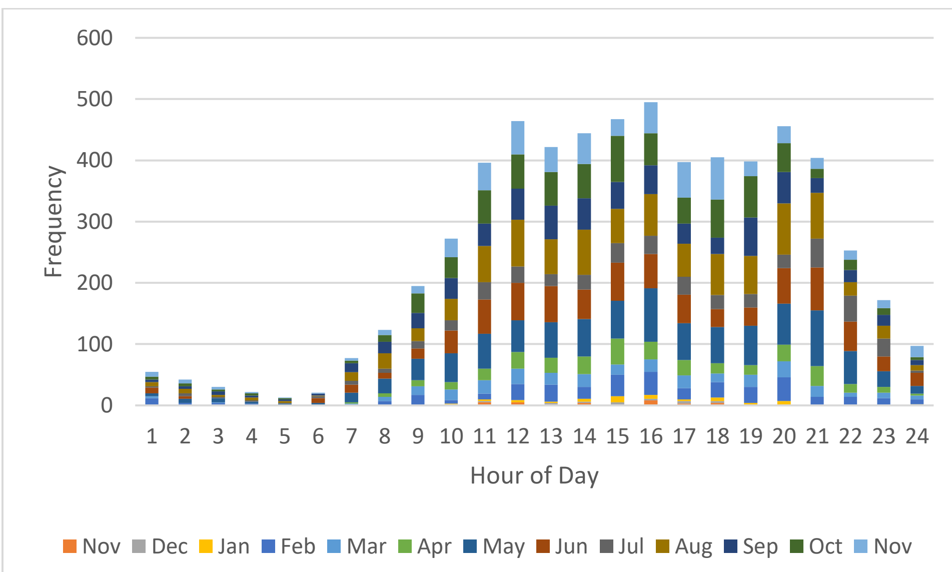


Figure 21. sUAS Flight Activity by Hour of Day (Cumulative).

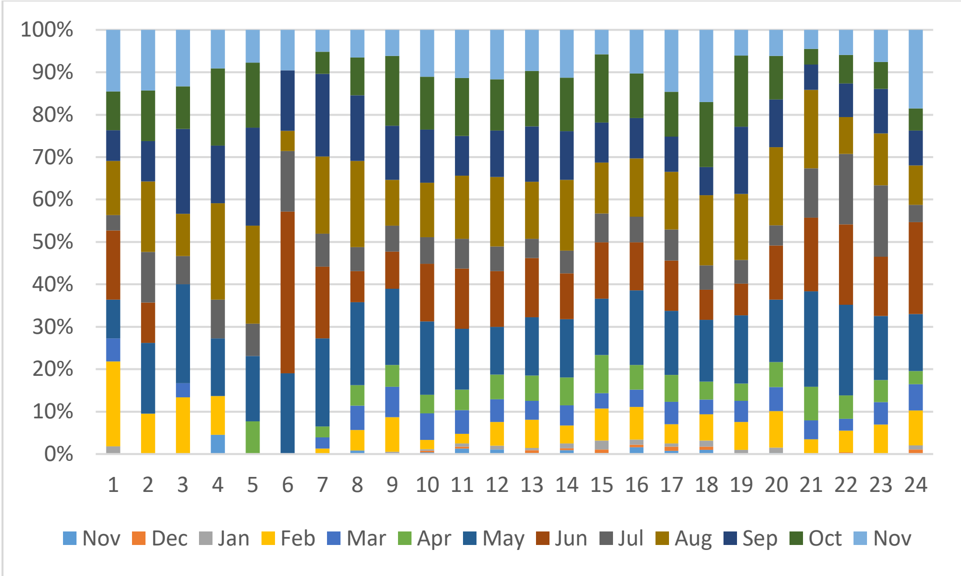


Figure 22. sUAS Flight Activity by Hour of Day (Proportional).

The research team assessed flight times to determine the distribution of flight durations. Results are presented in Figure 23. The research team assessed the dataset, filtering flights that did not contain time information. The final analysis sampled a total of 4,351 flights. At least 38.3% (n = 1,666) of flights lasted less than 5 minutes, representing the dataset's largest segment. Nearly 90% of flights recorded durations of less than 35 minutes. Flight durations between 1-2 hours represented 2.6% of the dataset, with flight durations over 2 hours comprising nearly half that number—1.2%.

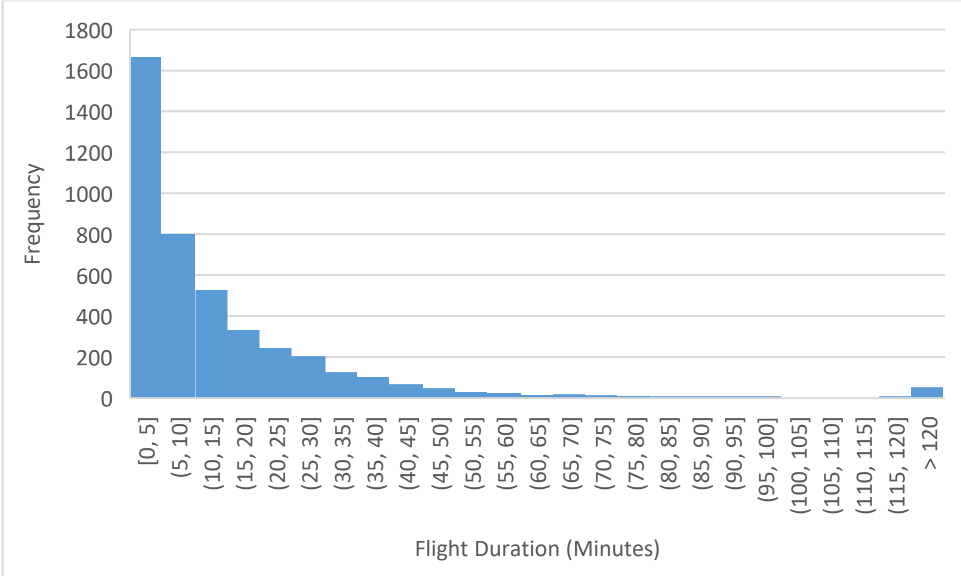


Figure 23. Flight Duration Frequency (n = 4,351).

To better understand the flight duration variability, the research team assessed flight durations based on individual sUAS models to see if the data was consistent (see Figure 24). The research team suspected that flight duration may be heavily influenced by the type of mission or activity performed. To illustrate, there is a clear difference in the flight duration between the DJI Mini 3, Mini 3 Pro, and Mini 4 Pro platforms—all of which show relatively short flight durations vs. the Mavic 3 Enterprise (M3E), Mavic 3 Enterprise-Thermal (M3T). The DJI Mini 3, Mini 3 Pro, and Mini 4 platforms are all lightweight (less than 250g) platforms generally popular among hobbyists, whereas the M3E and M3T platforms—primarily due to their cost—are almost exclusively acquired for commercial purposes. The research team cautions interpretation of model flight durations for platforms with low sampling.

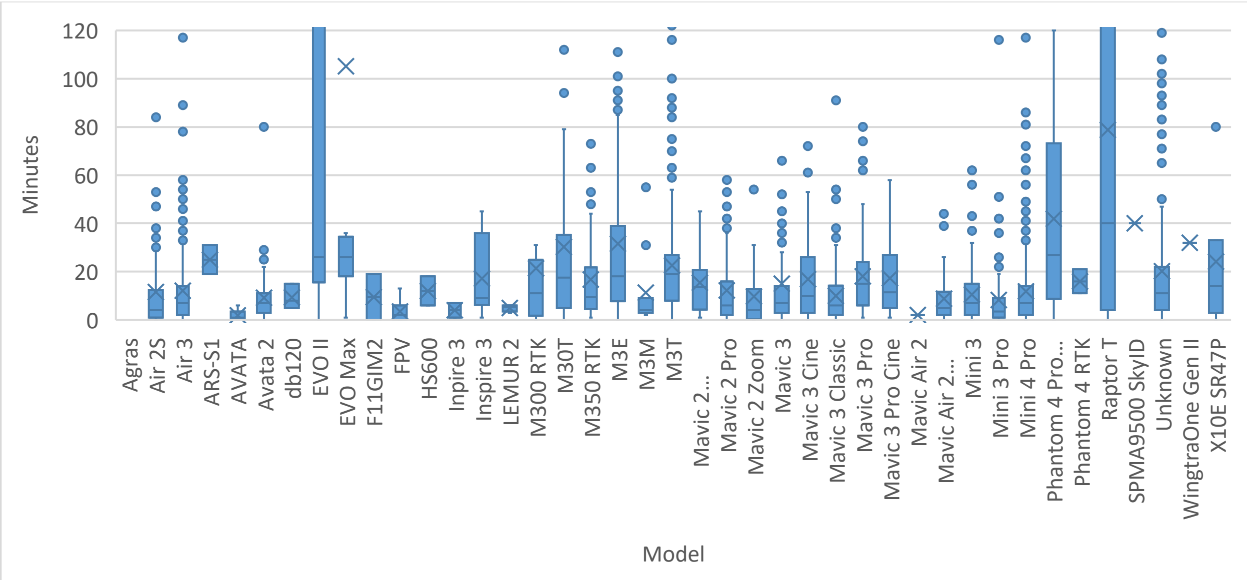
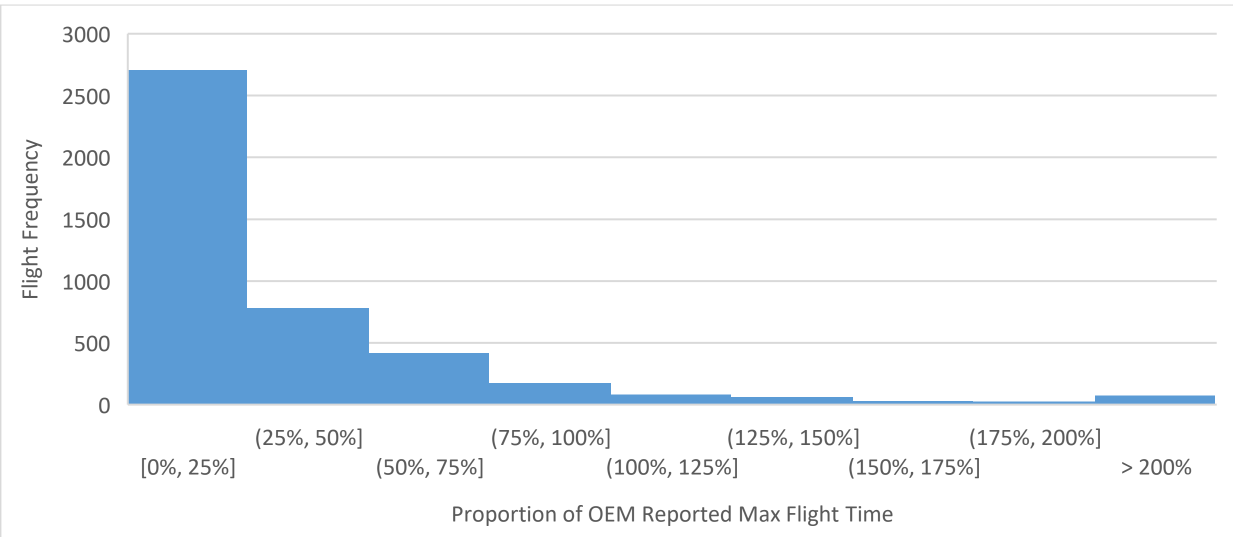


Figure 24. Flight Duration by Model (*n*=4,351).

To provide further context, the research team compared flight durations against the Original Equipment Manufacturer (OEM) reported max flight durations (see Figure 25). This assessment provides a relativistic comparison of the use distribution relative to the battery life ratio expended for each flight. One can also consider this as the proportionality of utilization relative to the battery life, enabling a more consistent comparison between platforms of variable battery capacity. The research team further notes that duration factors exceeding 1.0 likely suggest that one or more battery swaps had been performed during the respective flights.



Note: 1,960 data points removed due to invalid values (zero flight duration/durations exceeding 12 hours)

Figure 25. Proportion of OEM Reported Max Flight Duration (*n*=4,351).

Similarly to flight duration, the research team assessed each distribution by platform type, as well (see Figure 26). The EVO II and some flights of the Inspire 3, Phantom 4, and Raptor T platforms had a higher distribution of suspected battery swaps—platforms exceeding the OEM max flight duration ratio of 1.0. It is initially unclear why these particular platforms showed higher duration factors, as the research team could not determine a platform or operational commonality that would explain this finding.

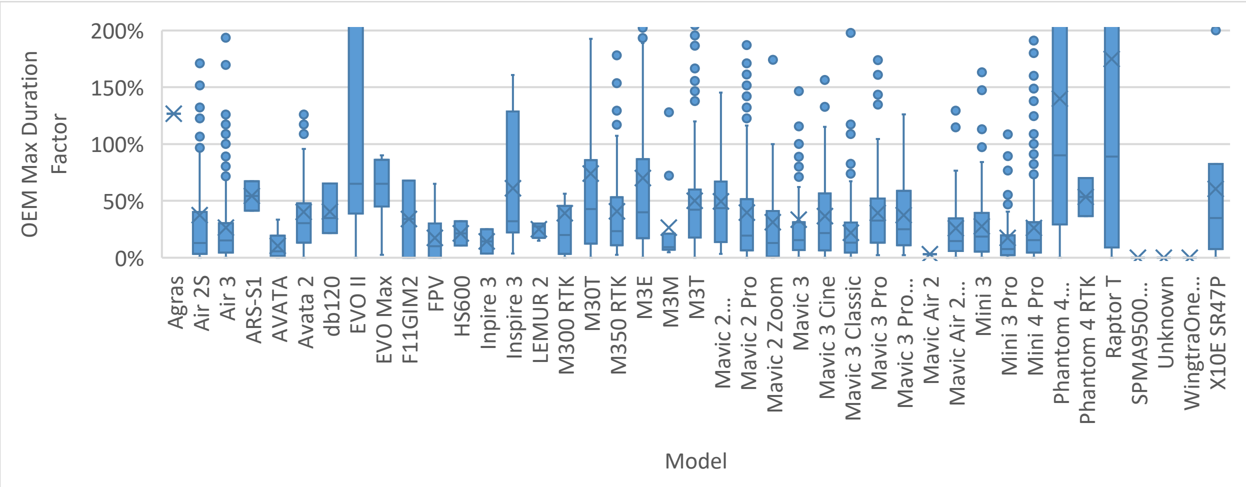


Figure 26. Flight Duration by Model as a Proportion of OEM Reported Max (*n*=4,351).

The research team assessed the operational ranges and altitudes at which sUAS were operated relative to the operator. A scatterplot of findings is presented in Figure 27, with lateral range limited to 1.0 NM. Some initial findings are evident in the scatterplot. First, it is readily apparent that most flights (*n*=77.5%) do not generally exceed 400 feet above ground level (AGL), based on FAA operational rules [14 CFR §107.51(b) and 49 USC § 44809(a)(6)]. Additionally, it is observed that flights operating above 400 feet AGL do not exceed 1,640 ft (approx. 500m), a default maximum altitude threshold set by DJI in their DJI Go4 Application. The authors note that software exists online to turn off altitude protections established by the manufacturer (Drone-Hacks Wiki, n.d.). Further, the following paragraphs present a detailed analysis of altitude and distance findings.

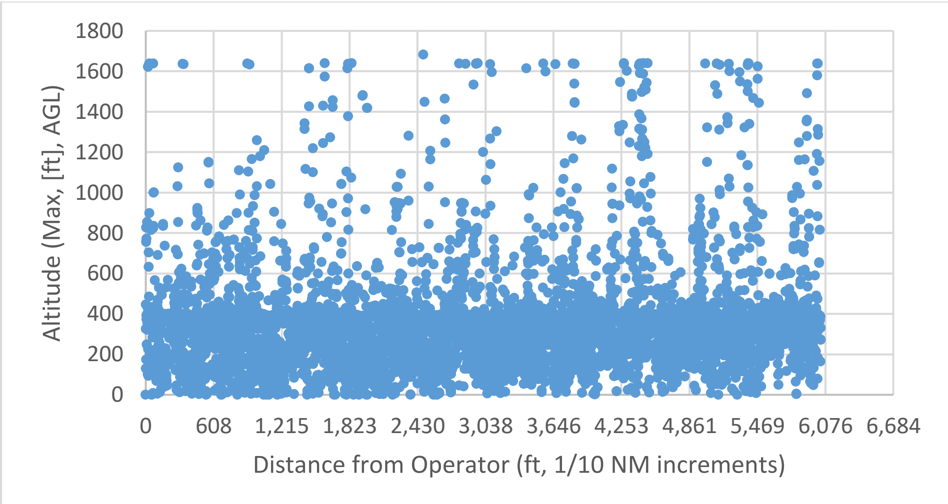


Figure 27. Scatterplot of Max Altitude (AGL) of sUAS Flights and Distance (NM) from Operator.

The research team first assessed the distribution of maximum flight distances flown during each flight (see Figure 28). On average, operators flew to a maximum lateral distance of 1,482 feet (less than .25 NM), with a median of 619 feet (about .10 NM). While some flights occurred at much further ranges, they represented a tiny proportion of the dataset. Generally, about 49.6% of flights recorded maximum flight distances of less than .1 NM (*n* = 2,992); 18.4% recorded max distances between .1-<.2 NM (*n* = 1,113); and 10.8% of flights recorded max distances between 0.2-<0.3 NM (*n*=652). Only 3.0% of flights (*n* = 180) recorded maximum flight distances over 1.0 NM.

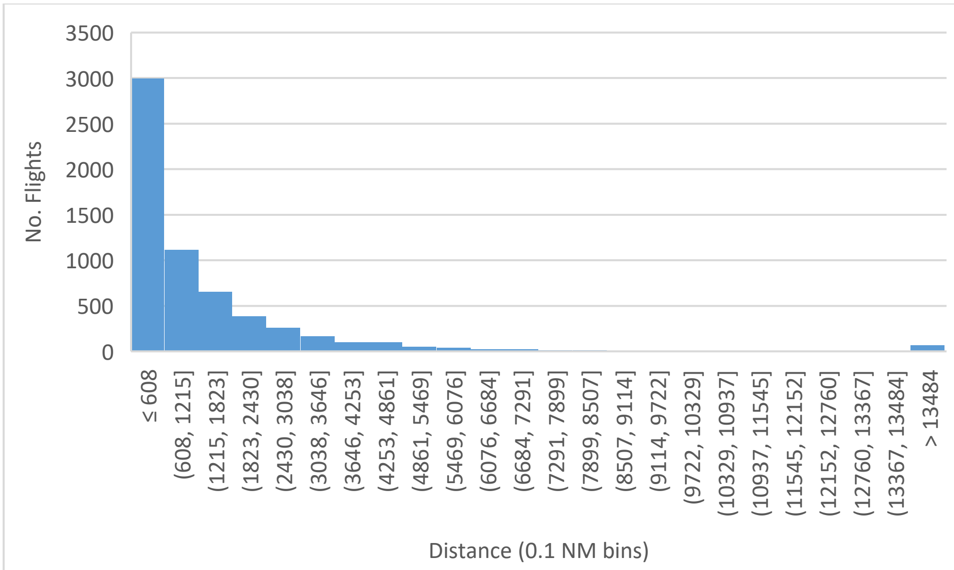


Figure 28. Distribution of Max Lateral Distance by Flight (*n*=6,037).

The research team further assessed instantaneous operator distance from the aerial vehicle (see Figure 29). This assessment shows a cumulative distribution of all Remote ID messages, based on their instantaneous distance from the operator. Whereas the previous graphics displayed the maximum range and altitude *per flight*, this analysis evaluated the range distribution of *each moment* of all operational flights. This approach provides a better contextual understanding of the extent of time spent at various ranges, rather than just the maximum range. This assessment is based on the distances at which sUAS are most commonly flown relative to the operator. Most Remote ID messages (*n* = 44.9%) indicated sUAS were flown within—1 NM of the operator. A smaller proportion of operations occurred between 0.1-0.2 NM (*n* = 15.1%); and 24.1% of operations occurred from 0.2 to 0.3 NM. Cumulatively, only 16.0% of flight operations occurred at distances over .3 NM from the operator, based on collected Remote ID data. Only .4% of sUAS operations occurred at distances over 1.0 NM.

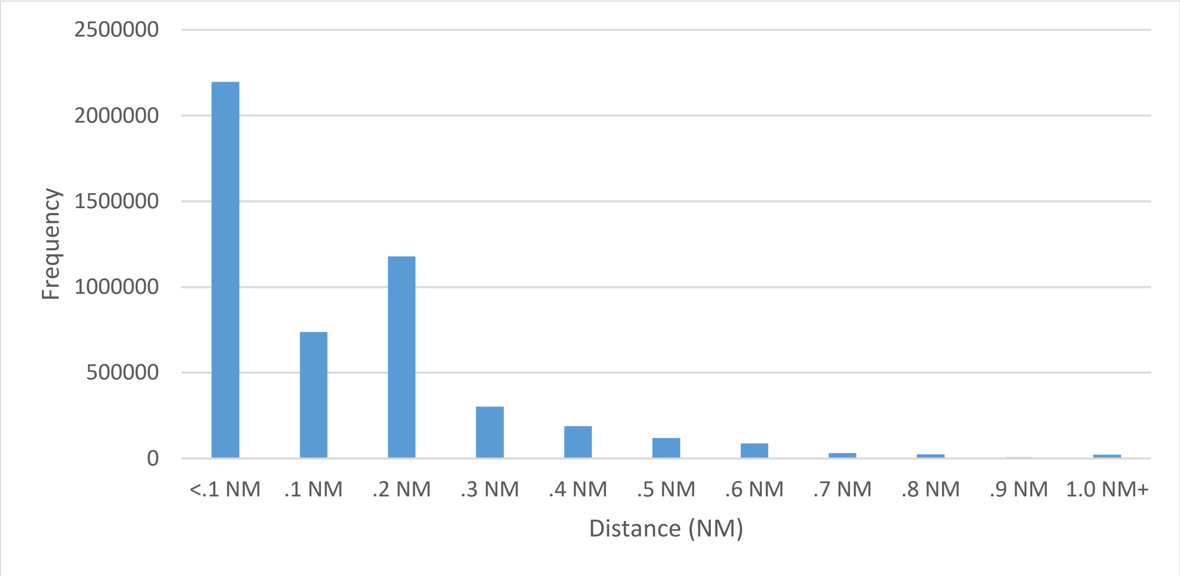


Figure 29. Instantaneous Operator Distance (NM) (*n* = 4,895,512).

The research team also assessed instantaneous altitude of sUAS flights (see Figure 30). The advantage of evaluating instantaneous altitude rather than maximum altitude on a per-flight basis is that the result provides a more effective means of assessing cumulative exposure. The preponderance of altitude utilization occurred at 400 feet AGLt, with about half as much utilization at 350 feet or less. Altitude use between 400 ft and 500 ft AGL represented approximately 3.9% of the dataset, with flight above 500 ft AGL representing 9.9%. This suggests that sUAS operations may present an elevated risk to manned aircraft, by operating at altitudes typically used by manned aviation approximately 10% of the time.

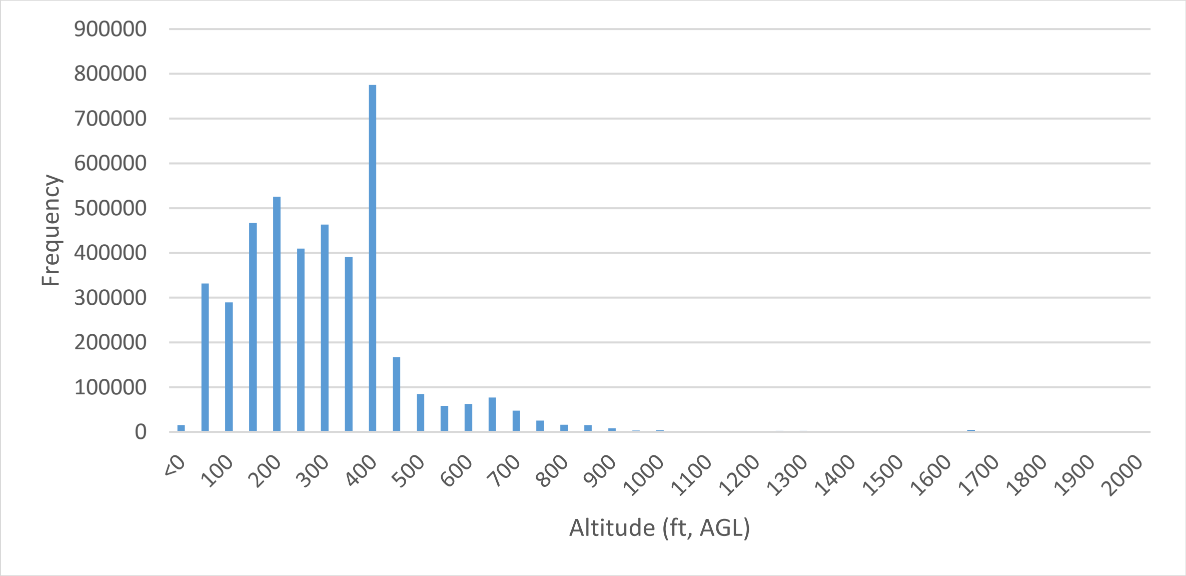


Figure 30. Instantaneous Altitude Utilization (*n* = 4,255,512).

To further assess altitude utilization by sUAS, the research team also evaluated the maximum altitude use of sUAS by individual flight operation (see Figure 31). A total of 6,037 sUAS flights contained altitude information and were included in the analysis. Like the instantaneous altitude analysis, the preponderance of maximum flight altitudes occurred at the 400 ft AGL level. At least 573 (*n* = 9.4%) flights were conducted at altitudes between 400-500 ft AGL. At least 781 flights (*n* = 12.9%) were performed at 500 ft or above altitudes. When taken in context with the instantaneous altitude data, it appears that a slightly more significant proportion of flights have operated at altitudes exceeding 400 feet AGL, however, the proportion of time or exposure at these altitudes remains relatively low.

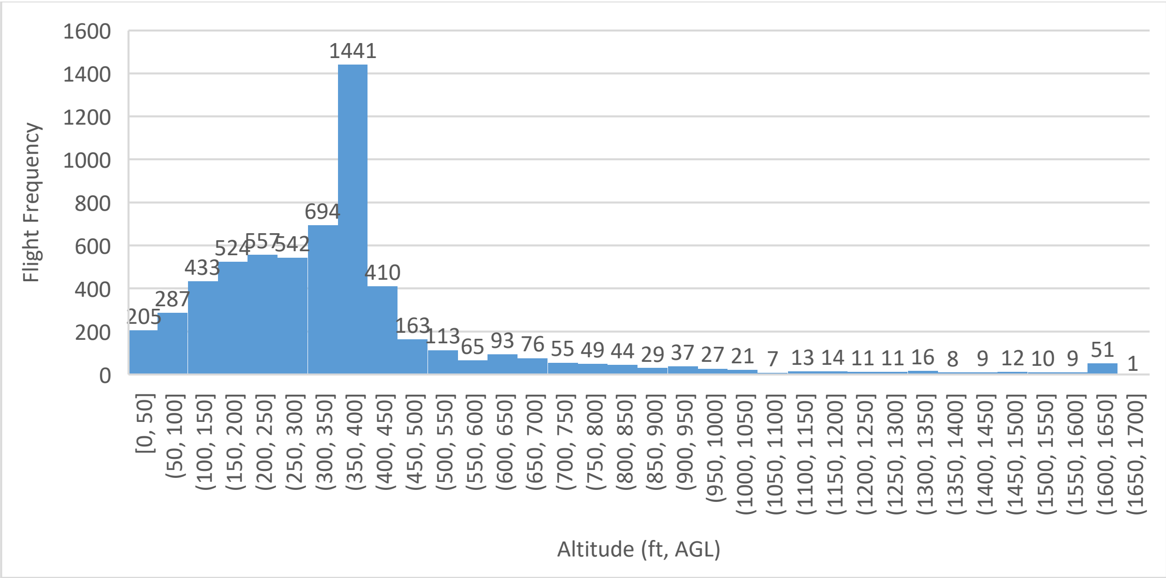
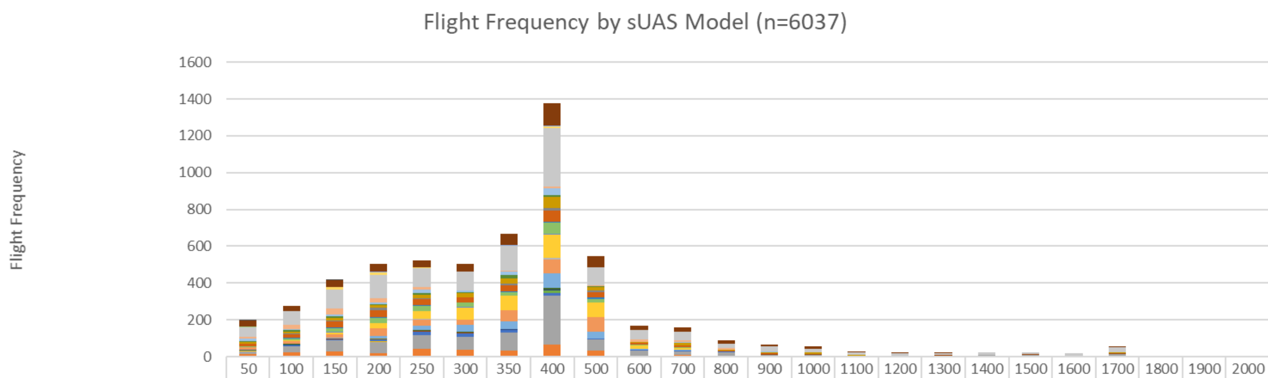


Figure 31. Distribution of Max Flight Altitude by Flight (*n* = 6,037).

The research team further assessed these flights to determine whether specific sUAS models were disproportionately operated at higher altitudes. Results are presented in Figure 32. A total of 6,037 sUAS flights contained altitude and serial number information, enabling the research team to derive model identity. Three platforms showed disproportionately higher overall use at altitudes of 500 ft and above: the Mavic 2 Pro, Mini 3 Pro, and Mavic 3. Similarly, some platforms such as the Mavic 3 (Thermal) (M3T) and Mavic 3 Enterprise (M3E) showed disproportionately lower use at altitudes of 500 feet and above. These platforms are presumed that the M3T and M3E platforms tend to represent commercial flight operations, primarily due to their unique sensor capabilities and higher acquisition cost. These trends suggest that flights above 500 ft AGL are more likely to represent recreational than commercial operations. The research team acknowledges that it is impossible to confirm this finding definitively since there is no valid methodology currently available for determining sUAS operational purpose from Remote ID information.



	50	100	150	200	250	300	350	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000
X10E SR47P	6	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unknown	33	29	34	39	34	43	62	118	59	21	25	16	8	18	5	5	1	0	0	0	2	0	0	0
SPMA9500 SkyID	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Raptor T	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phantom 4 RTK	0	0	0	2	0	0	2	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phantom 4 Pro V2.0	0	1	13	13	4	2	2	9	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Mini 4 Pro	55	75	103	130	107	100	136	317	98	52	46	24	28	17	14	14	12	10	6	12	26	0	0	0
Mini 3 Pro	7	21	36	22	11	4	5	12	4	11	8	8	2	0	0	0	0	0	0	0	0	0	0	0
Mini 3	12	6	8	7	20	9	16	35	3	2	8	4	4	0	0	1	0	2	0	0	1	0	0	0
Mavic Air 2 (MA2UE3W)	7	8	9	6	7	1	18	8	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mavic Air 2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mavic 3 Classic	7	10	13	14	21	22	31	64	19	4	12	1	2	7	1	0	0	0	1	0	4	0	0	0
Mavic 3 Cine	2	6	4	16	5	3	6	14	6	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0
Mavic 3	14	19	34	35	32	26	33	60	32	8	7	5	5	3	0	0	0	0	0	0	0	0	0	0
Mavic 2 Zoom	0	2	5	4	7	0	4	4	6	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0
Mavic 2 Pro	5	12	18	31	26	26	19	61	20	5	6	3	1	1	0	0	0	0	1	1	1	0	0	0
Mavic 2 Enterprise Advanced	0	1	7	0	0	2	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
M3T	0	1	6	25	44	66	80	129	79	18	6	0	0	0	0	0	0	0	0	0	0	0	0	0
M3M	0	0	3	1	1	2	1	9	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
M3E	14	16	18	44	36	27	61	74	80	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0
M30T	0	1	3	12	23	38	42	81	33	4	4	0	1	0	0	0	0	0	0	0	0	0	0	0
M300 RTK	1	2	2	0	5	5	1	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Inspire 3	1	0	0	1	0	0	2	5	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Inpire 3	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HS600	0	1	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FPV	0	3	1	1	3	3	0	0	1	1	0	0	1	1	0	1	2	0	2	0	1	0	0	0
F11GIM2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EVO II	0	0	0	1	0	0	1	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Avata 2	3	7	7	9	17	19	15	14	6	2	3	2	0	0	1	0	0	0	0	0	2	0	0	0
AVATA	4	1	1	2	2	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Air 3	13	31	57	62	72	72	98	264	61	29	22	20	9	9	4	2	5	7	8	4	14	0	0	0
Air 2S	11	23	30	19	44	35	32	65	32	5	7	4	2	2	1	0	1	2	3	1	0	0	0	0
Agras	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Altitude (ft, AGL)

Figure 32. Flight Frequency by sUAS Model (*n* = 6,037).

3.2.4.1 Operations Near Structures

The purpose of this assessment was to examine the extent of sUAS operations carried out near known structures as well as evaluate the maximum altitude of such operations relative to the structure's peak height.

The research team sampled instances of sUAS operations carried out near structures in the Fishers, Indiana sampling location. A total of 88 occurrences of flight near structures were identified. A plot of the findings is presented in Figure 33.

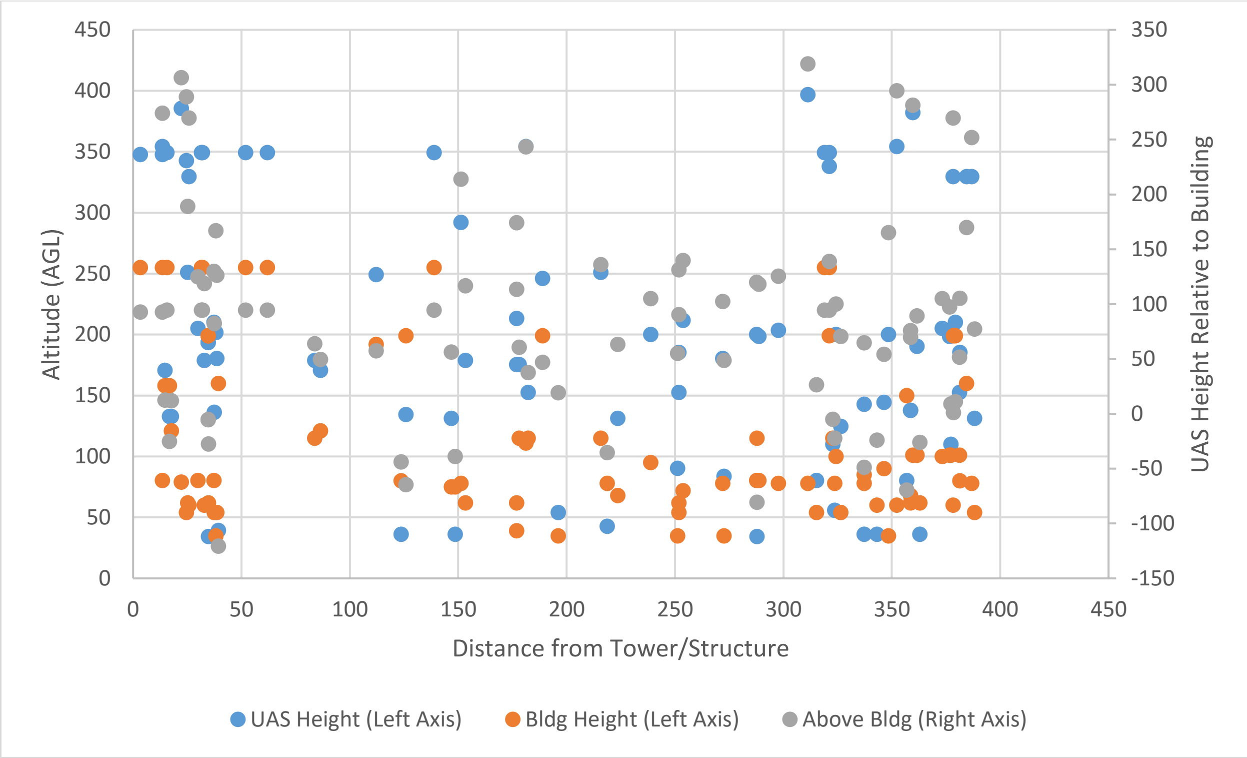


Figure 33. UAS Flight within 400 ft of Towers/Structures (Fishers, IN-South, *n* = 88).

Of the sUAS flown in a 400-foot lateral proximity to structures, none of the sampled flights exceeded an altitude of more than 400-feet above the relevant structure's uppermost limit. A distribution of sUAS maximum heights relative to structure height is provided in Figure 34. The majority of sUAS operations flown above structures were conducted between 50-100 feet above the structure's uppermost limit.

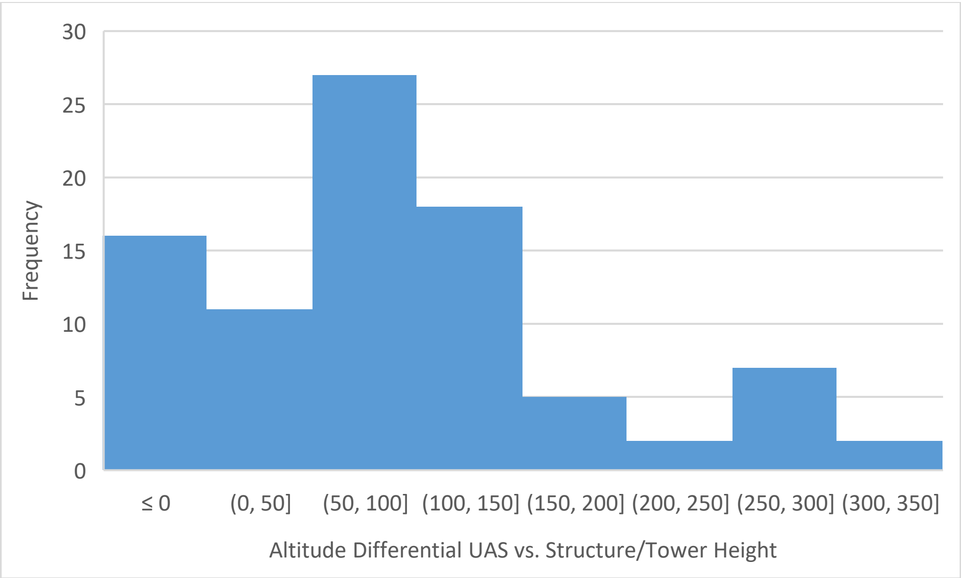


Figure 34. Distribution of UAS Flight Altitudes Relative to Building/Structure Height (Fishers, IN-South, *n* = 88).

3.2.5 Traffic Activity by Location

The purpose of this assessment was to codify and evaluate sUAS operations in the context of various airspace, locations, and related information. Case studies of potential hazards or unique operational behaviors or trends were identified and assessed accordingly.

3.2.5.1 Terre Haute (HUF)

Terre Haute Regional Airport (HUF) is located within Class D airspace extending up to 3,100 feet, with a Surface Class E extension to the northeast (see Figure 35). The airfield is situated near two additional general aviation airfields to the northwest and east. Additionally, an Aerobatic Practice Area is located just southeast of the airfield. According to FAA (n.d.a), Terre Haute Regional Airport supported 68,334 operations in 2024.

In 2023, the city of Terre Haute reported a population of 58,502 and is known for its history, culture, and higher educational institutions. The city is home to Indiana State University Rose-Hulman Institute of Technology, and Ivy Tech Community College of Indiana. The area is also home to U.S. Penitentiary Terre Haute, located approximately 5 miles west-southwest of the airfield.

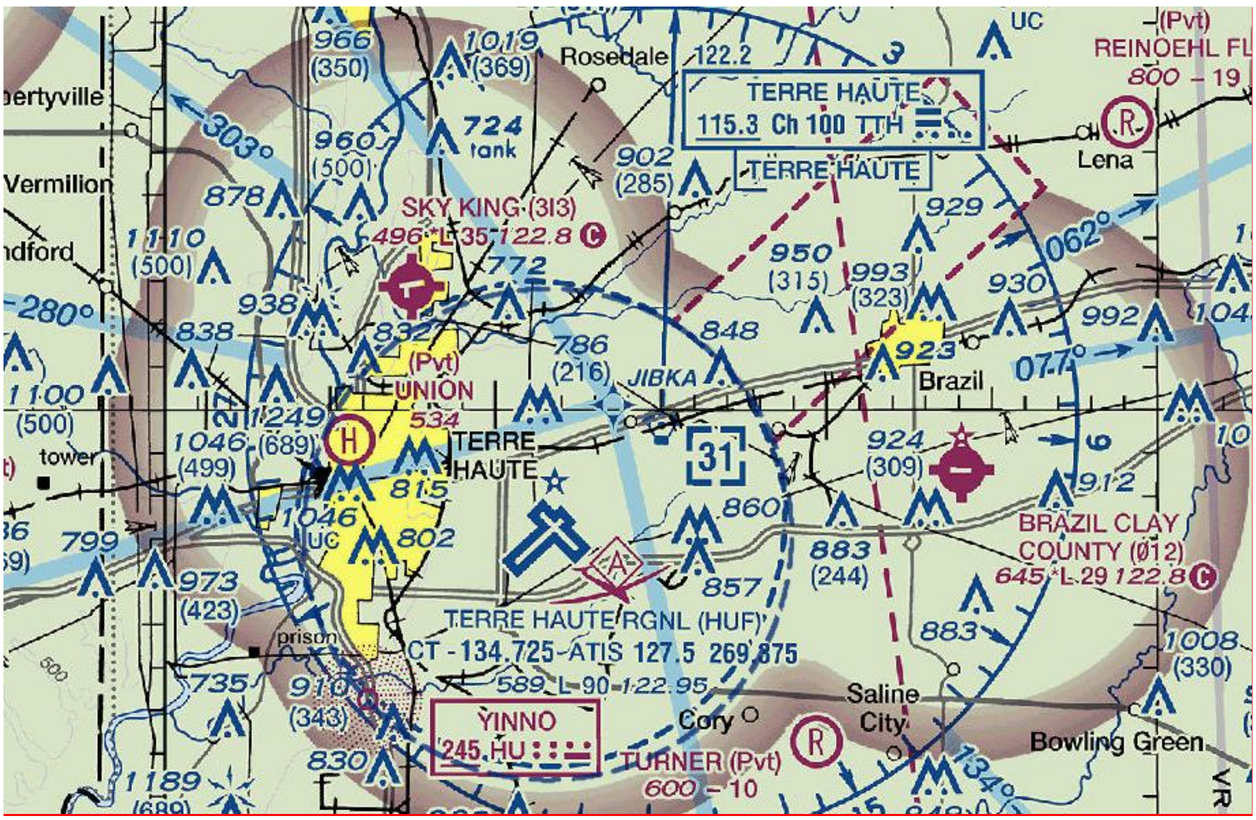


Figure 35. Terre Haute Regional Airport (HUF) and Surrounding Airspace.

Concentrated sUAS activity was noted approximately 2,500 feet southwest of the Runway 5 threshold near an industrial material storage site (see Figure 36). The research team believes this activity represents a volumetric analysis of materials like sand or aggregate. Additional light activity was noted in a shopping center parking lot to the north, which likely represents recreational activity. The other significant concentration of sUAS activity is overhead, at a construction site for a local casino and resort project. In this case, sUAS will likely be used for construction monitoring or surveying purposes.

Figure 36. sUAS Activity in Proximity to HUF Airfield Runway 5.

3.2.5.2 Daytona Beach (DAB)

Daytona Beach Airport lies in Class C airspace, extending up to 4,000 feet, within the core, with a shelf at 1,200 feet AGL (see Figure 37). As of 2023, Daytona Beach has a reported population of 82,485. The area is a popular tourist destination for its beaches and speedway, home to the iconic Daytona 500 annual race. The airport is also home to Embry-Riddle Aeronautical University, one of the largest aviation training universities in the world. According to the FAA (n.d.a), the airport supported 304,160 operations in 2024.

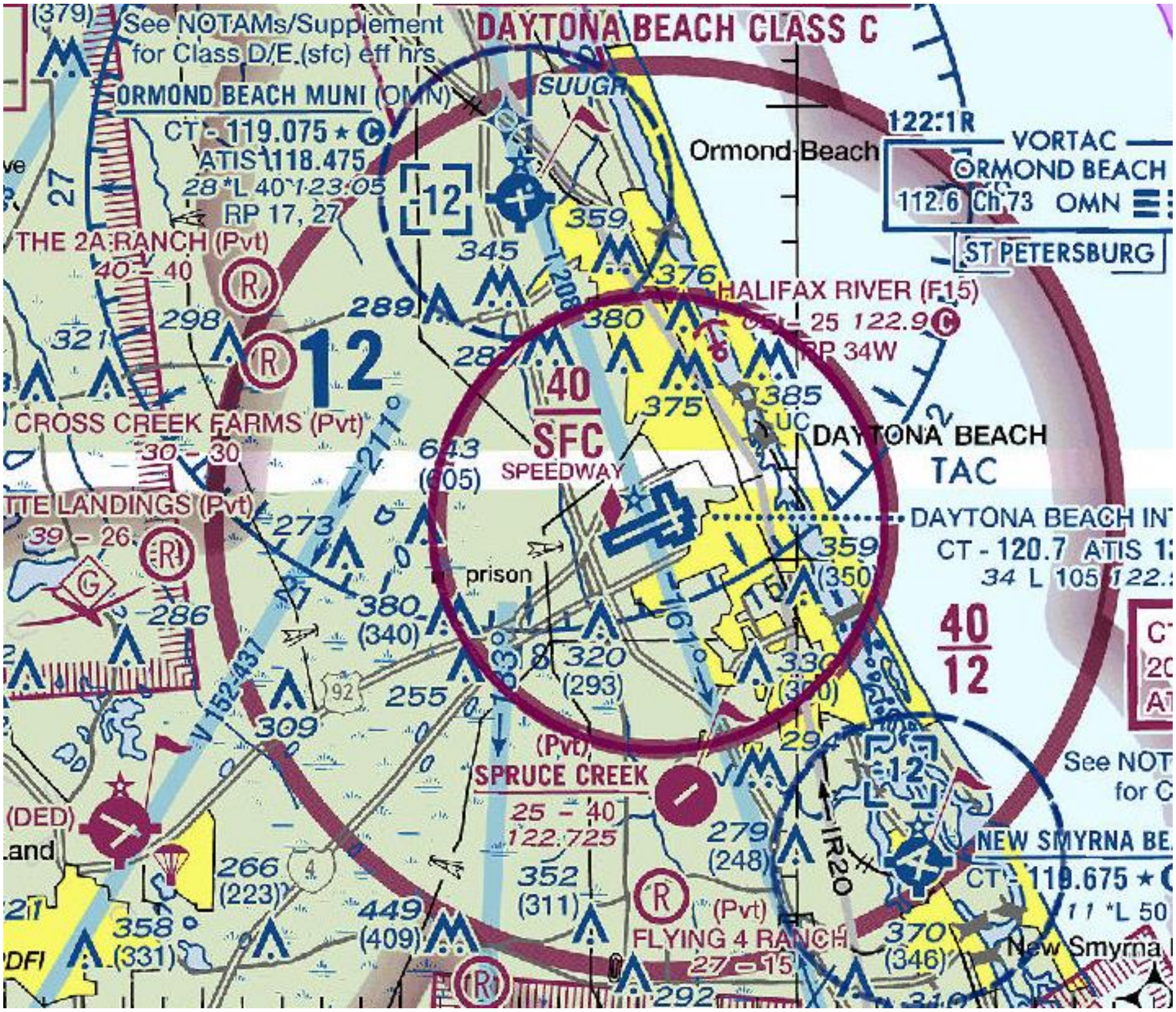
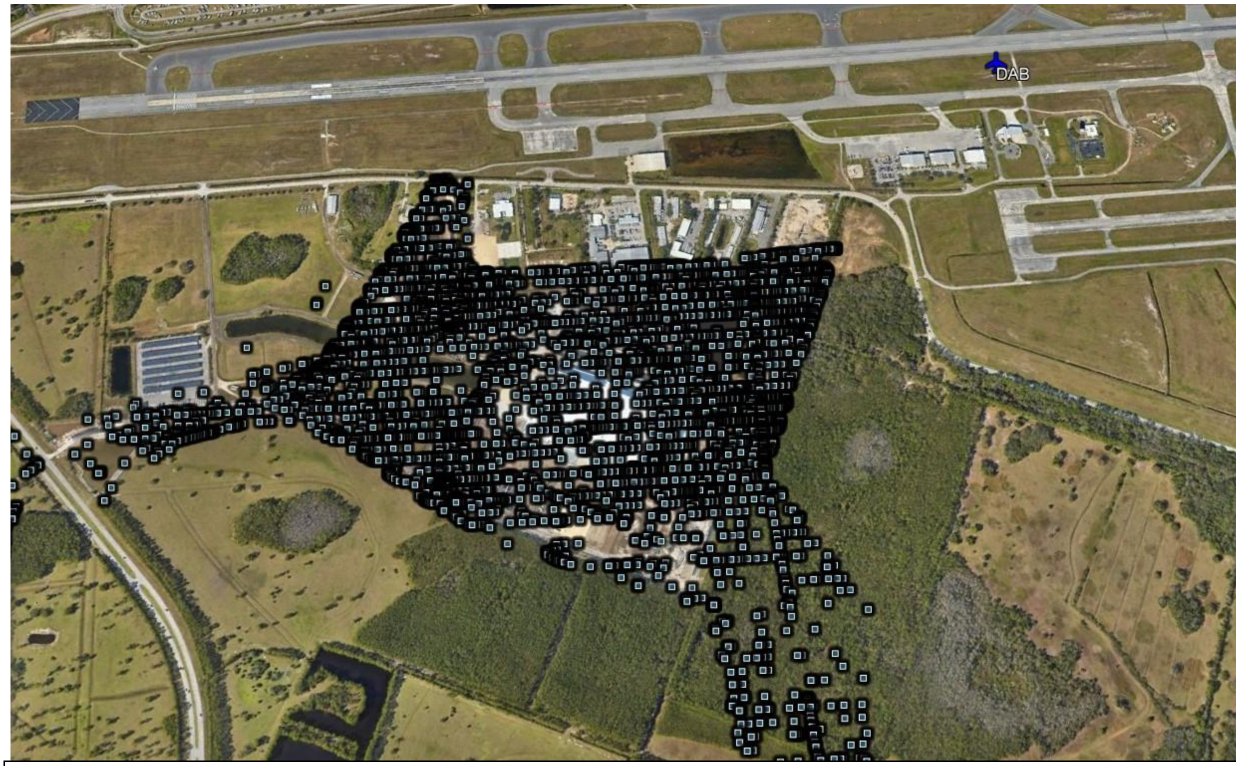


Figure 37. Daytona Beach International Airport (DAB) and Surrounding Airspace.

The Daytona Beach, FL, area noted several distinct, ongoing operations. First, a sUAS was routinely used for surveying construction of a local Amazon distribution facility immediately south of the airfield (see Figure 38). This activity was likely conducted under either a waiver or airspace authorization, and a Notice to Airmen (NOTAM) was filed. Flight operations appeared well-confined within a trapezoidal area, likely defined by the FAA airspace authorization. While some activity appears to be aligned within the approach path of the southern east-west running runway, the operation appears well offset from causing any potential traffic interference unless aircraft approach pathing is well below standard.



DAB NOTAM:!DAB 01/073 DAB AIRSPACE UAS WI AN AREA DEFINED AS 0.25NM RADIUS OF 291007N0810354W (.48NM SSW DAB) SFC 200FT AGL DLY SR SS 2401191302 2412312237

Figure 38. sUAS Operations Adjacent to DAB Airfield (Amazon Fulfillment Center Construction Surveying).

The second area of elevated sUAS activity was identified near Embry-Riddle Aeronautical University, located on the east side of the airfield (see Figure 39). Activity was generally concentrated within the athletic fields along the periphery of the university property, and near several centralized structures inside the university proper. While some activity also appears overhead the roadway bisecting the campus, these operations appear limited. It is noted that the university maintains several FAA-issued waivers and airspace authorizations permitting operations in areas adjacent to the airfield. Additional activity on local high school property is reported north of the university (adjacent to the northern baseball field). Again, operations appear well-confined, and well-separated from nearby approach paths.

Figure 39. Collegiate and Secondary Education and Training sUAS Traffic East of DAB Airfield.

Of more significant concern was activity identified north of the high school near heliport 29FL, a local medical center (see Figure 40). Drone activity was noted in the adjacent area, as well as the defined landing pad overhead. With the unpredictability of emergency helicopter operations and the low altitude and unpredictable flight pathing of the nearby drone, this detected activity represents a potentially unmitigated threat. The relatively inconsistent flight path led the research team to suspect that the operation was likely recreational, as potential commercial mission applications were not distinguishable from the telemetry set.

Figure 40. UAS Operations Northeast of DAB in Proximity of Hospital Heliport (29FL).

The last notable location within the Daytona Beach area was the area near the Daytona Flea and Farmer's Market, an area on the extreme west of the city (see Figure 41). A local helicopter tour business conducts regular flights from a makeshift landing area south of the Farmer's Market buildings and open parking lot (see arrow, Figure 41). On December 30, 2023, local police reported a drone colliding with an R-44 helicopter conducting aerial tours. The collision occurred at approximately 180-200 feet AGL. The drone operator allegedly recorded video supporting a local construction company. Following the crash, "the helicopter returned to the airport and landed safely" (Frigerio, 2024). At the time of the collision, the helicopter was carrying three passengers. Approximately $60,000 in damage was incurred on the helicopter's main blade.

During the study sampling period for the Daytona Beach area (approx. February-August 2024), no sUAS activity was noted near the Farmer's Market. All sUAS activity in the area was recorded east of the north-south running interstate highway.

Figure 41. UAS Activity in Proximity to Daytona Flea and Farmer's Market (Informal Heliport for Sightseeing Helicopter Tours).

3.2.5.3 Columbus (BAK)

Columbus Municipal Airport (BAK) is ensconced within Class D airspace, extending from the surface to 3,200 feet (see Figure 42). West of the airfield lies Restricted Airspace (R-4301/2) and Racer Military Operations Area supporting military flight operations originating out of Himsel Army Airfield (HBE) of the Indiana National Guard. In 2023, Columbus had a reported population of 51,522. Columbus is known for its architecture, public art, and small-town appeal. The area is also home to Atterbury-Bakalar Air Museum. According to the FAA (n.d.a), BAK airport supported 59,238 operations in 2024.

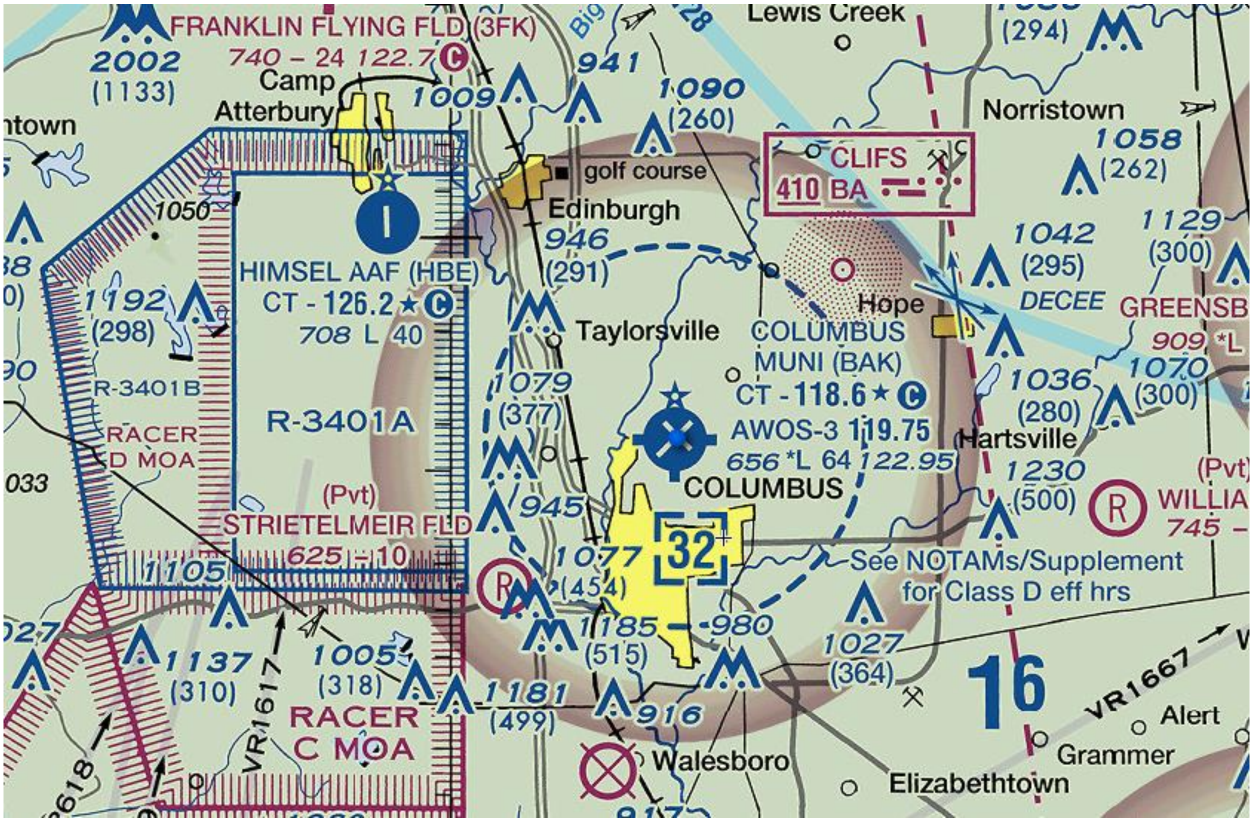


Figure 42. Columbus Municipal Airport (BAK) and Surrounding Airspace.

The research team noted several areas of sUAS activity in proximity to Columbus Airport (see Figure 43), primarily to the south, and west, and to a lesser extent in rural areas north of the airfield.

To the west, concentrated activity was noted near a local aggregate/sand company, likely performing surveying or volumetric analysis of stockpiled gravel or other resources. Several concentrations of activity are located to the south of the airfield and include: flights over a local soccer club, possibly documenting athletic events; various flights over the town’s commercial sector; large amounts of activity with the remainder of activity overflying residential neighborhoods, believed to be primarily recreational flights.

Figure 43. sUAS Operations Near BAK Airport, Runways 5 and 32 (Southern Quadrant).

One flight was noted directly on the airfield immediately south of the primary Runway 5-23 (see Figure 44). The exact purpose of this flight was not immediately apparent; however, the duration of the flight appeared limited to just a few minutes.

Figure 44. sUAS Operations on BAK Airfield.

Activity to the north of the airfield is believed to support agricultural operations, however, the extent of some of the telemetry patterns makes it difficult to determine the application being performed (see Figure 45). The activity in the southern portion of the rural sector appears to be some form of linear analysis or activity. One flight follows the course of a small waterway. Based on the orientation and field routing, the research team suspects sUAS use may be used in one case to evaluate rotary irrigation systems. Activity to the east shows more concentrated activity confined within a field, which may suggest remote sensing, spraying, or other related activity. Further assessment will be necessary to identify the type of platform in use. Additional activity to the east shows centralized flight over a residential area, followed by a semi-circular, peripheral pattern, which the research team believes to be some form of aerial photography or videography. The final concentration of activity in the central portion of the image includes multi-directional linear patterns originating from a nearby farmhouse. The flight bisects two nearby farm fields diagonally, with the spokes east-west lateral segments that seem to conform with plowing patterns. The research team was unclear as to the purpose or function of this flight.

Figure 45. Rural sUAS Operations North of BAK Airport.

Additional flight activity was noted in the central portion of Columbus near a hospital heliport (see Figure 46). Significant flight activity was recorded in straight-line segments along various vectors. The organization and lack of directional variability suggest that these flights may be purposeful, however, the research team could not discern any recognizable pattern or locational context that would reveal their application. The research team expressed concern over the proximity of these flights to the hospital heliport, which, like other emergency heliport locations, may be subject to unannounced, unpredictable flight schedules. The nearby concentrated, low-altitude activity level may present potential flight hazards or interference with emergency heliport patient transport operations.

Figure 46. sUAS Activity in Proximity to Hospital Heliport South of BAK (27IN).

It appears that at least some of this activity was originating from the parking lot of several box stores to the north (see Figure 47). The more haphazard telemetry pathing and curvilinear turns seem more reflective of recreational activity; however, these presumptions are not conclusive.

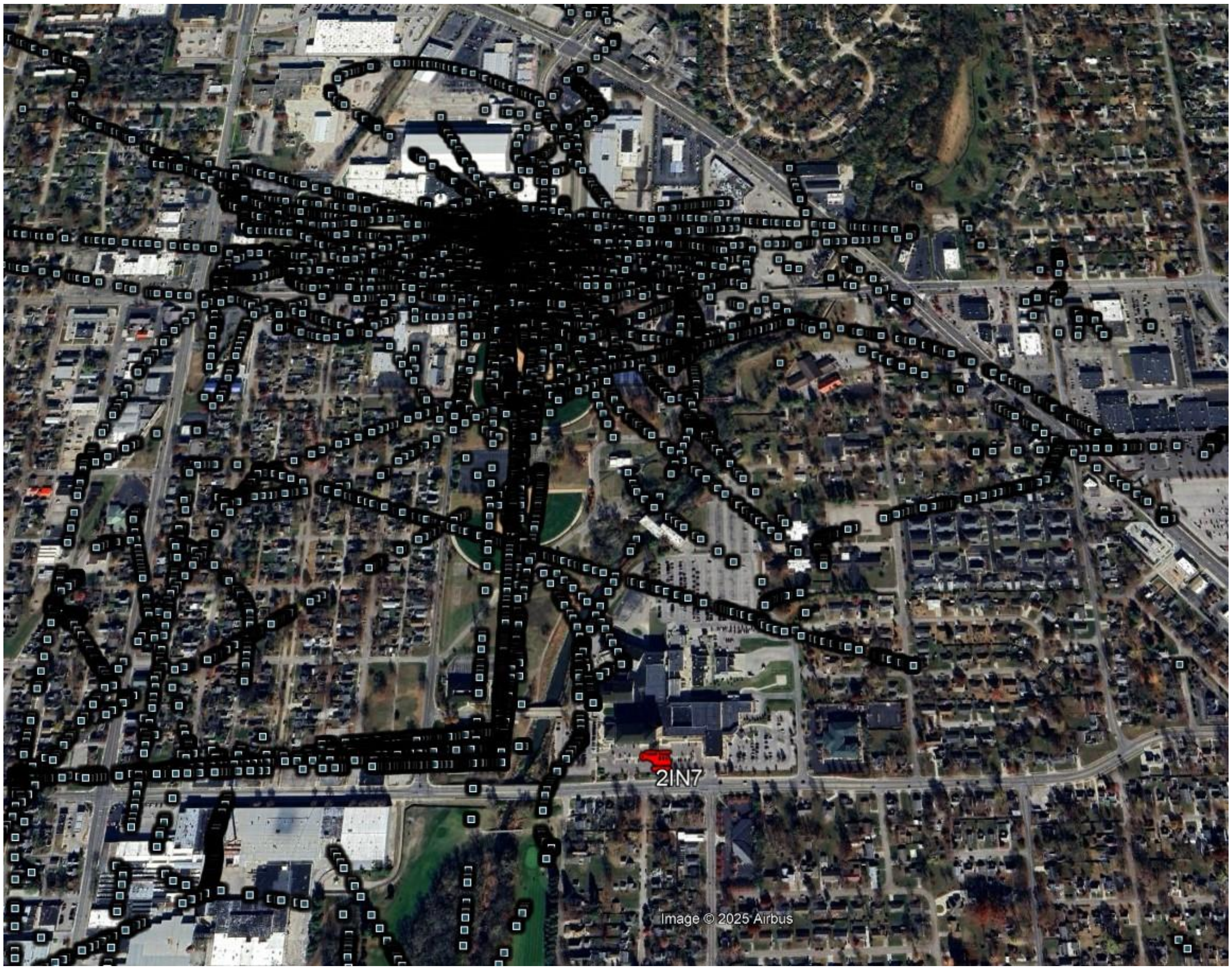


Figure 47. sUAS Activity in Shopping Center Parking Lot North of Hospital Heliport (27IN).

3.2.5.4 Indianapolis, IN

Since downtown Indianapolis was not near significant aeronautical activity, the area was not the focus of a detailed analysis effort. However, the research team did note one unique event that warranted reporting. In sUAS data timestamped February 15, 2024, at 23.37 (UTC), the research team identified a collision between a sUAS operating at 200.5 barometric meters (approx. 658 ft AGL) and the 811-ft Salesforce Tower Building in downtown Indianapolis. Telemetry of the incident derived from Remote ID data is provided in Figure 48. Based on the Remote ID serial number, the sUAS was identified as a DJI Mini 3, an approximately 249g sUAS. It is unknown if the sUAS caused any appreciable damage to the building.

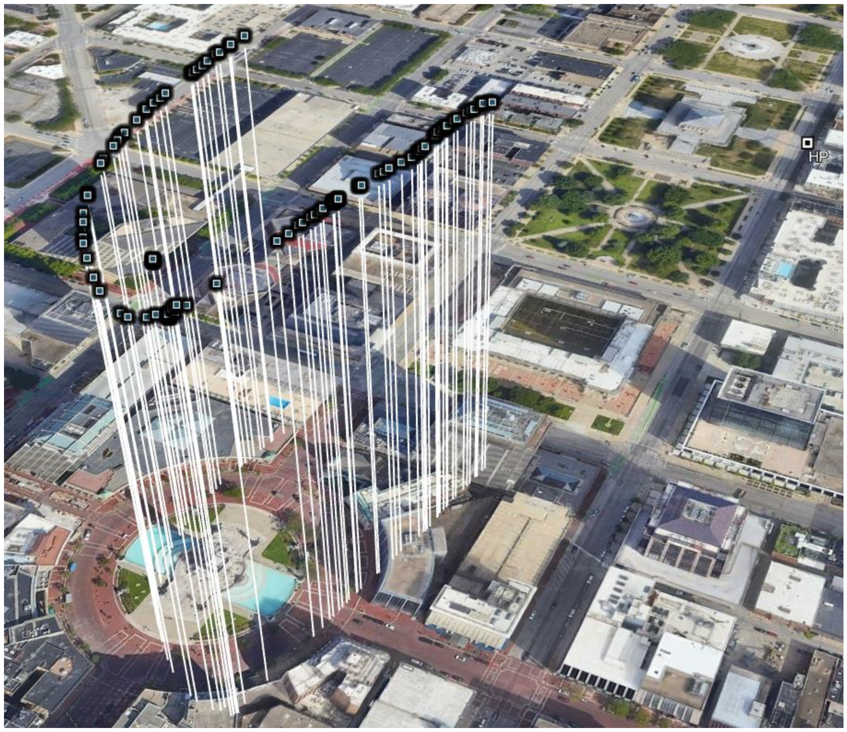


Figure 48. Flight Telemetry of sUAS Collision with Salesforce Tower Building, Indianapolis, IN.

The sUAS was recorded falling from 658 feet to the ground in 8.3 sec, with vertical speed accelerating to 29.5 m/s (approx. 66 mph). During the event, the Remote Identification signal was in an emergency status mode, which activated approximately one minute and 13 seconds into the flight. The research team assessed that the sUAS was attempting to return to the home point or operator location, approximately two blocks north-northeast of the structure. As shown in Figure 49, GPS updates were lost following the initial impact, however, barometric altitude readings continued until ground impact. The research team believes this incident likely represented an automated return to home, although the cause could not be identified from the remote ID data.

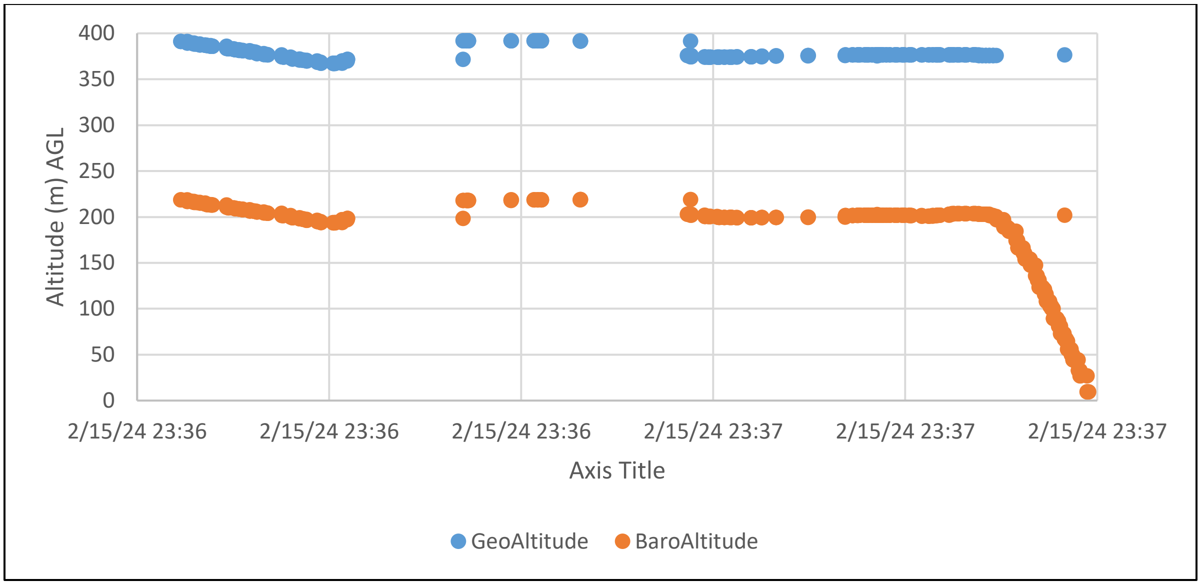


Figure 49. Altitude Telemetry from sUAS Collision with Salesforce Tower, Indianapolis, IN.

3.2.6 Lateral and Vertical Footprint of Detected sUAS Operations

The purpose of this assessment was to determine the average operational footprint of sUAS operations, to identify the potential range and altitude of influence of sUAS flight operations.

Leveraging more than 4.2M Remote ID data points, the research team constructed a profile showing the distribution footprint of detected Remote ID signals at various ranges and altitudes relative to the operator (see Table 9). Lateral distance was measured in nautical miles, and altitude in feet (AGL). Presented groups are exclusive. The proportion of detected Remote ID messages is reported for each interval, from the listed minimum distance and altitude up to but excluding the level of the following reported interval. As an example, the proportion of Remote ID messages in the zero distance and zero altitude level should be interpreted as 13.52% of the cumulative Remote ID dataset was confined within a distance from 0 NM up to but excluding 0.1 NM and at an altitude of 0 ft AGL up to but excluding 100 ft AGL. Results are highlighted using a heat map color gradient, with green colors indicating higher values and red values indicating lower values. Evaluating footprint data based on Remote ID messages rather than on a per-flight basis provides a more effective measure of exposure since the complete detected flight profile can be assessed. However, this approach has limitations. Message-based analysis may underrepresent fast-moving aircraft that transit quickly through altitude or distance intervals, particularly if sampling rates are low or irregular. Additionally, gaps in telemetry reception due to signal interference, terrain obstructions, or receiver limitations may result in incomplete flight profiles.

Most sUAS activity (n = 49.9%) was conducted within 0.1 NM from the operator at altitudes of less than 400 feet AGL. Approximately 13.9% of activity was carried out at altitudes above 400 ft AGL, with 7.8% carried out above 500 ft AGL, which presents a potentially elevated risk of interference with manned aviation operations. Only 0.5% of sUAS activity was noted at ranges exceeding 1.0 NM. This relatively positive finding may temper evidence of excessive flight distances, suggesting that the overall exposure of such activity is limited.

Table 9. Lateral (NM) and Vertical (ft AGL) Footprint of Detected sUAS Operations

Distance (x) / Altitude (y)	0	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000
0	13.52%	15.01%	11.12%	10.26%	1.80%	0.64%	0.54%	0.27%	0.08%	0.05%	0.04%	0.02%	0.03%	0.01%	0.04%	0.02%	0.01%	0.00%	0.00%	0.00%	0.00%
0.1	0.74%	4.54%	4.56%	5.24%	1.23%	0.56%	0.24%	0.06%	0.06%	0.01%	0.01%	0.01%	0.02%	0.01%	0.00%	0.02%	0.04%	0.00%	0.00%	0.00%	0.00%
0.2	0.35%	1.97%	2.29%	3.98%	1.20%	0.42%	0.24%	0.10%	0.18%	0.02%	0.00%	0.01%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
0.3	0.09%	0.95%	1.25%	3.19%	0.57%	0.28%	0.55%	0.10%	0.07%	0.04%	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%	0.02%	0.00%	0.00%	0.00%	0.00%
0.4	0.04%	0.42%	0.68%	2.13%	0.58%	0.25%	0.19%	0.12%	0.03%	0.01%	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
0.5	0.02%	0.16%	0.25%	1.37%	0.24%	0.32%	0.32%	0.10%	0.02%	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%
0.6	0.01%	0.12%	0.15%	0.57%	0.13%	0.26%	0.45%	0.22%	0.08%	0.03%	0.02%	0.00%	0.01%	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%
0.7	0.01%	0.05%	0.09%	0.28%	0.08%	0.04%	0.10%	0.01%	0.03%	0.01%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
0.8	0.00%	0.04%	0.04%	0.15%	0.04%	0.05%	0.24%	0.01%	0.00%	0.00%	0.00%	0.00%	0.02%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
0.9	0.00%	0.02%	0.03%	0.08%	0.01%	0.00%	0.01%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1	0.01%	0.02%	0.03%	0.06%	0.01%	0.00%	0.02%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1.1	0.00%	0.01%	0.04%	0.02%	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1.2	0.00%	0.01%	0.01%	0.01%	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1.3	0.00%	0.00%	0.01%	0.10%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1.4	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1.5	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1.6	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1.7	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1.8	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1.9	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2	0.00%	0.03%	0.01%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

To provide further context to the data, distributions of both distance (Figure 50) and altitude (Figure 51) are provided.

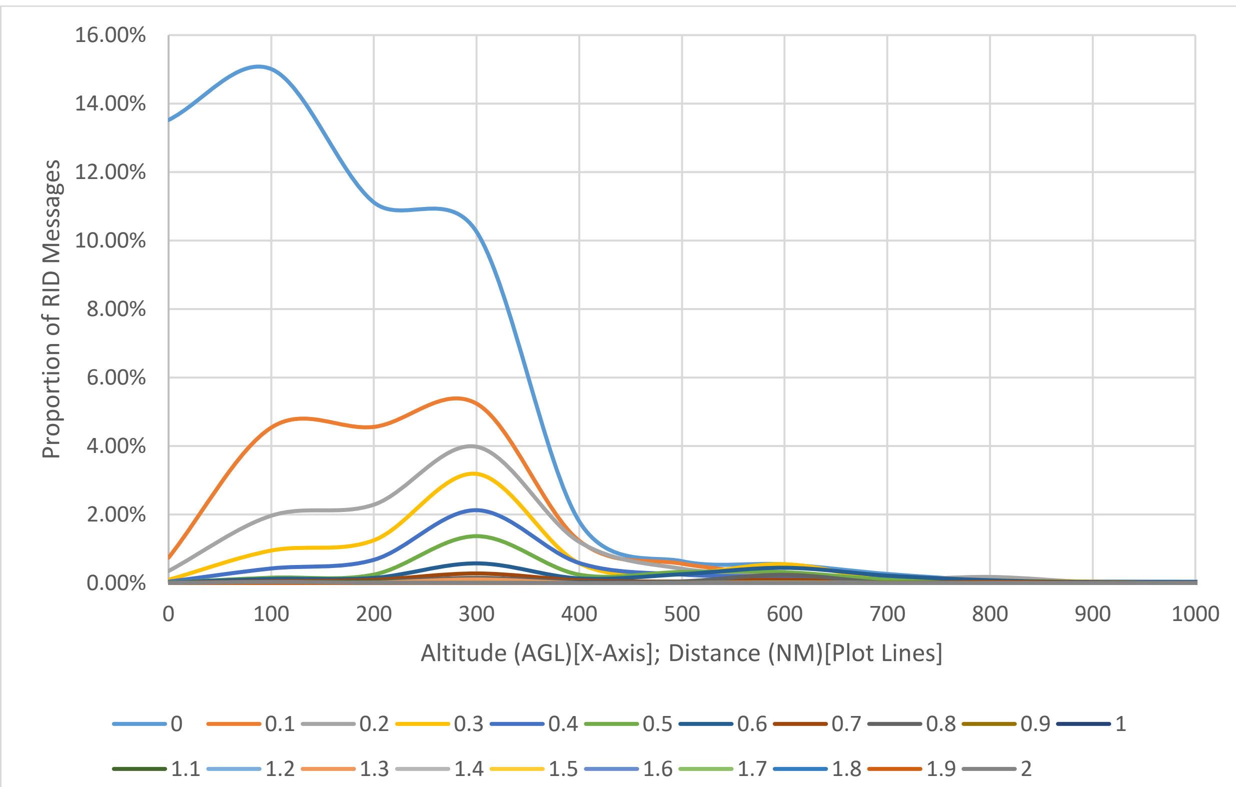


Figure 50. sUAS Operations Footprint by Distance (NM) and Altitude (AGL).

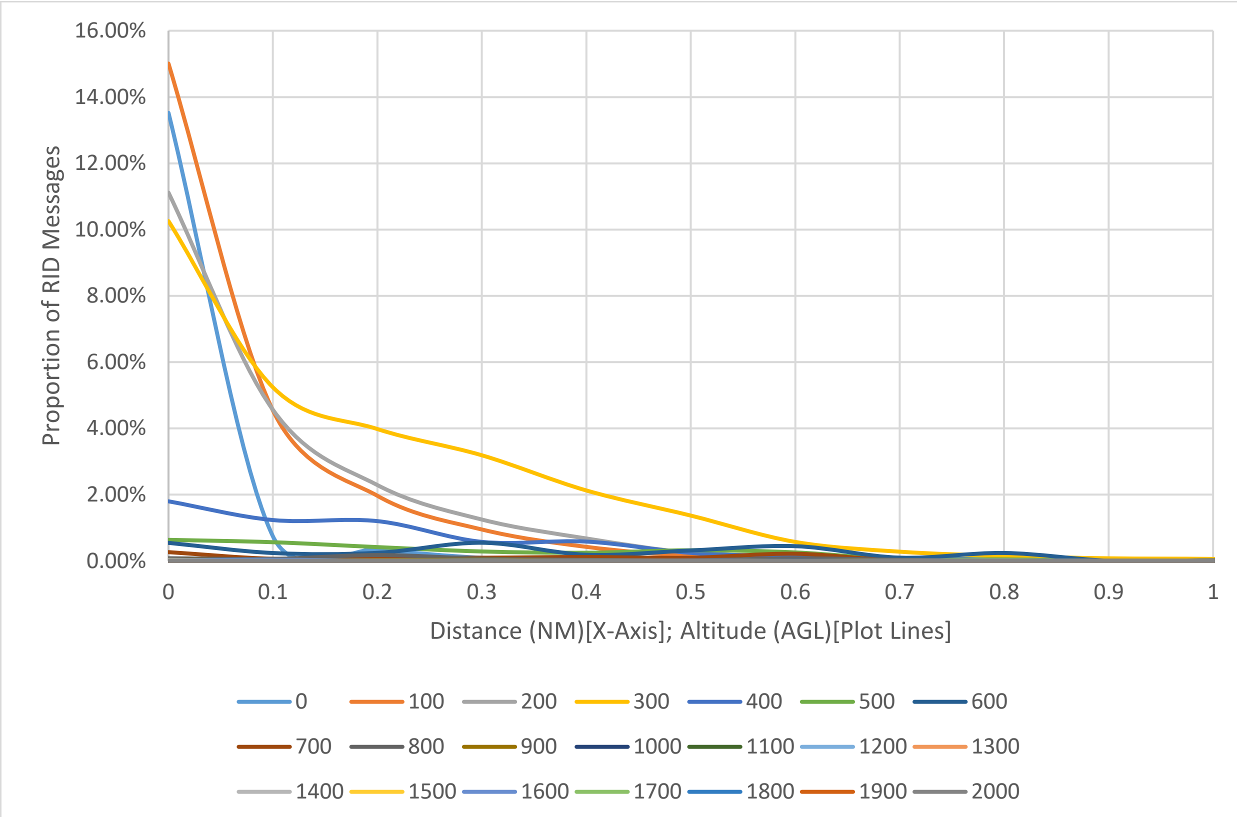


Figure 51. sUAS Operations Footprint by Altitude (AGL) and Distance (NM).

A similar profile was constructed to show the distribution of Remote ID messages across the day of the week and local time of day (see Table 10). A heat map-style color gradient was used to aid in result interpretation. Generally, sUAS flight operations were noted at higher levels starting around 9 a.m. local time and extending until 9 p.m. local time. Elevated activity in the early morning weekend hours was noted compared to weekday activity. Activity levels appeared to peak on Saturdays in the early afternoon, extending into the evening.

Table 10. Table of Remote ID Messages by Weekday and Time (Local).

Hour (L)	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	n
0	0.01%	0.02%	0.00%	0.17%	0.09%	0.20%	0.22%	29953
1	0.03%	0.03%	0.02%	0.10%	0.26%	0.68%	0.28%	59638
2	0.00%	0.00%	0.02%	0.02%	0.63%	0.26%	0.19%	48165
3	0.01%	0.00%	0.00%	0.01%	0.05%	0.44%	0.19%	30188
4	0.00%	0.00%	0.02%	0.00%	0.00%	0.05%	0.03%	4405
5	0.00%	0.31%	0.13%	0.28%	0.02%	0.19%	0.07%	42578
6	0.13%	0.16%	0.12%	0.77%	0.05%	0.33%	0.36%	82085
7	0.18%	0.28%	0.14%	0.24%	0.35%	0.44%	0.62%	95535
8	0.28%	0.22%	0.83%	0.45%	0.22%	0.56%	0.51%	130920
9	0.30%	0.82%	0.45%	1.08%	0.83%	0.37%	0.80%	197641
10	0.53%	0.75%	0.96%	1.08%	1.00%	0.58%	0.60%	234199
11	1.04%	0.86%	1.44%	1.52%	0.80%	0.92%	0.51%	301624
12	1.00%	0.68%	1.13%	1.38%	0.54%	0.98%	0.66%	271062
13	1.08%	0.95%	0.92%	1.15%	1.06%	0.87%	0.63%	283847
14	1.39%	1.12%	1.00%	0.74%	0.76%	1.27%	1.04%	311581
15	1.51%	0.60%	0.94%	0.81%	0.89%	2.02%	0.56%	311387
16	0.56%	0.37%	0.86%	0.64%	1.05%	1.42%	0.49%	229264
17	0.77%	0.50%	0.57%	0.42%	0.83%	1.68%	0.79%	236267
18	0.80%	0.91%	0.39%	1.07%	0.89%	1.44%	0.73%	264452
19	0.82%	1.07%	0.71%	0.99%	0.66%	1.05%	1.40%	285377
20	1.05%	0.71%	0.65%	0.49%	0.99%	1.13%	1.38%	271923
21	0.87%	0.66%	1.15%	0.67%	1.06%	1.31%	0.39%	259561
22	1.05%	0.08%	0.34%	0.78%	0.23%	1.44%	0.39%	183783
23	0.07%	0.06%	0.12%	0.35%	0.34%	0.97%	0.21%	90077

3.2.7 Proximity of sUAS Traffic to Aerodromes

The purpose of this evaluation was to determine the proximity of sUAS operations to nearby aerodromes to assess potential collision risk or interference hazards to manned aviation operations.

The research team analyzed the proximity of sUAS operations relative to aerodromes within each sampling area. A total of 43 aerodromes were analyzed, including three public heliports, 33 private heliports, five public airports, one private airport, and one public seaplane base. A total of 5,171 sUAS flights contained geospatial information, enabling distance information calculation. Distance was calculated using a Haversine formula, based on the horizontal distance between the reported sUAS aerial vehicle location coordinates and the airport reference point (ARP). Notably, the ARP is generally centralized on the airfield, so the distance between a sUAS flight and the nearest airport hazard area, such as a runway, may be closer than reported. A cumulative boxplot of results by aerodrome code is presented in Figure 52. A boxplot of sUAS distances by aerodrome type is provided in Figure 53.

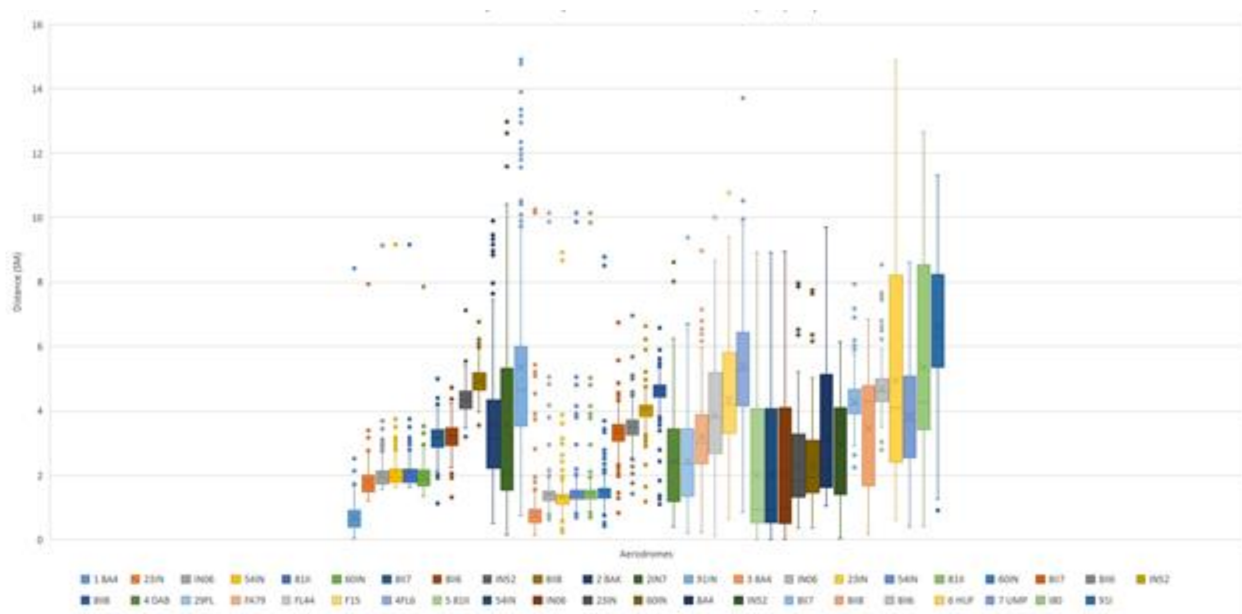


Figure 52. sUAS Operations by Distance from Aerodromes (*n*=5,171).

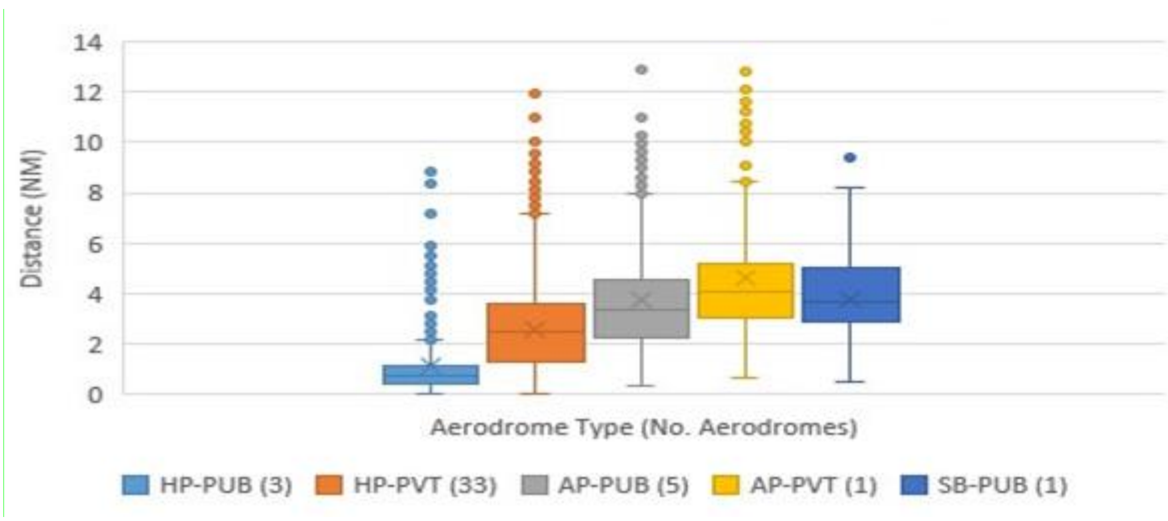


Figure 53. Boxplot of sUAS Flight Distances to Nearest Aerodrome by Type.

Aerodromes were organized by sensor area, aerodrome type, and aerodrome code to improve the interpretation of results. A distribution of sUAS flights detected in each region was presented using a stacked bar graph (see Figure 54). A proportional comparison of sUAS proximity to aerodromes is provided in Figure 55 to enable standardized comparison. The research team acknowledges that distance distributions may be influenced by placement of the Remote ID sensors. The research team noted that sUAS flights of less than 0.5 NM were encountered exclusively at heliport locations. This may be due to several factors. First, there are a significantly greater number of heliports when compared to other aerodrome types in operation in the NAS. Secondly, the relatively small footprint of heliport locations makes them easy to disperse across communities. This factor makes them harder to recognize among urban sprawl than other aerodrome types, such as airports or seaplane bases, with a much larger and more prominent footprint. Finally, existing planning resources, such as Sectional Charts, do not depict the locations of heliports, making it even more difficult for remote pilots to recognize their sUAS operations may inadvertently impinge on heliport activities.

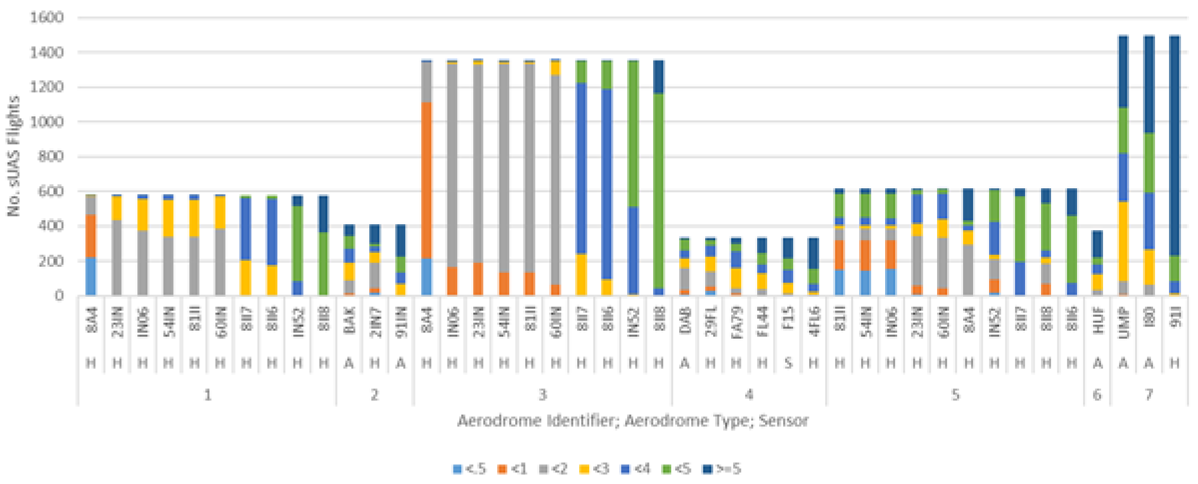


Figure 54. sUAS Proximity to Aerodromes (NM), Cumulative Flight Count.

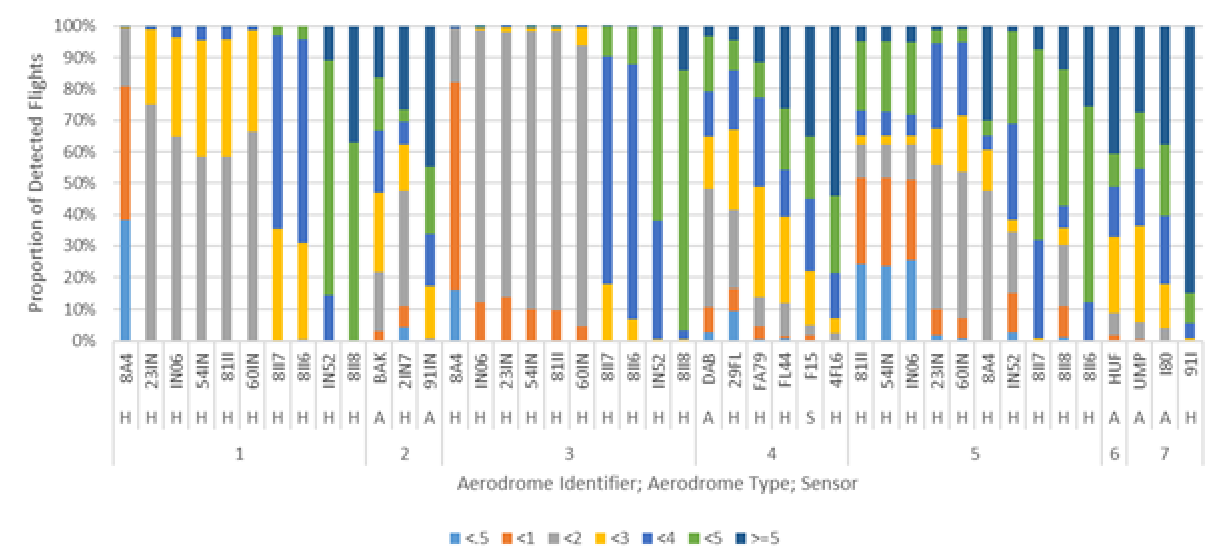


Figure 55. sUAS Proximity to Aerodromes (NM), Proportional.

3.2.8 Estimated Registration Rates

The purpose of this analysis is to provide a forecasting estimation for the sUAS fleet size, for both recreational/hobbyist (49 USC §44809) and non-recreational (commercial, 14 CFR §107) operations.

A summary of the currently projected FAA forecast values for sUAS is contained in Table 11.

Table 11. FAA sUAS Fleet Forecast.

Historical	Recreational (44809)			Commercial (107)		
	Low	Base	High	Low	Base	High
2023	557.3	1776.8	1776.8	361	842	842
Forecast						
2024	555.7	1826.4	1830.8	369	951	960
2025	583.2	1847	1867.4	371	1032	1050
2026	609.2	1867.3	1891.3	372	1083	1113
2027	621.3	1878.7	1907.5	373	1110	1152
2028	628.8	1883	1920.8	374	1122	1176

*Thousands of units

Note: Derived from FAA (2024c)

The research team evaluated historical nationwide LAANC data provided by the FAA for possible operational and growth trends (see Figure 56). Additionally, the research team added ancillary contextual data, including part 107 (remote pilot) certificates, and historical sUAS registration data. Seasonality effects are clearly visible throughout the dataset, with elevated activity in traditional summer months and diminished activity in winter. To mute seasonality impacts, the research team integrated a 12-month, rolling average to show lagging operational trends. As evidenced in Figure 56, commercial LAANC operational activity has increased within the past year, with accompanying, steady Part 107 remote pilot certificate growth. Although these trends are not fully reflected in the Part 107 sUAS registration data beyond December 2022, the research team believes this may be due to modifications in the agency's methodology for counting and reporting registrations, as similar data inconsistencies were noted in the 44809 registrations during the same time period.

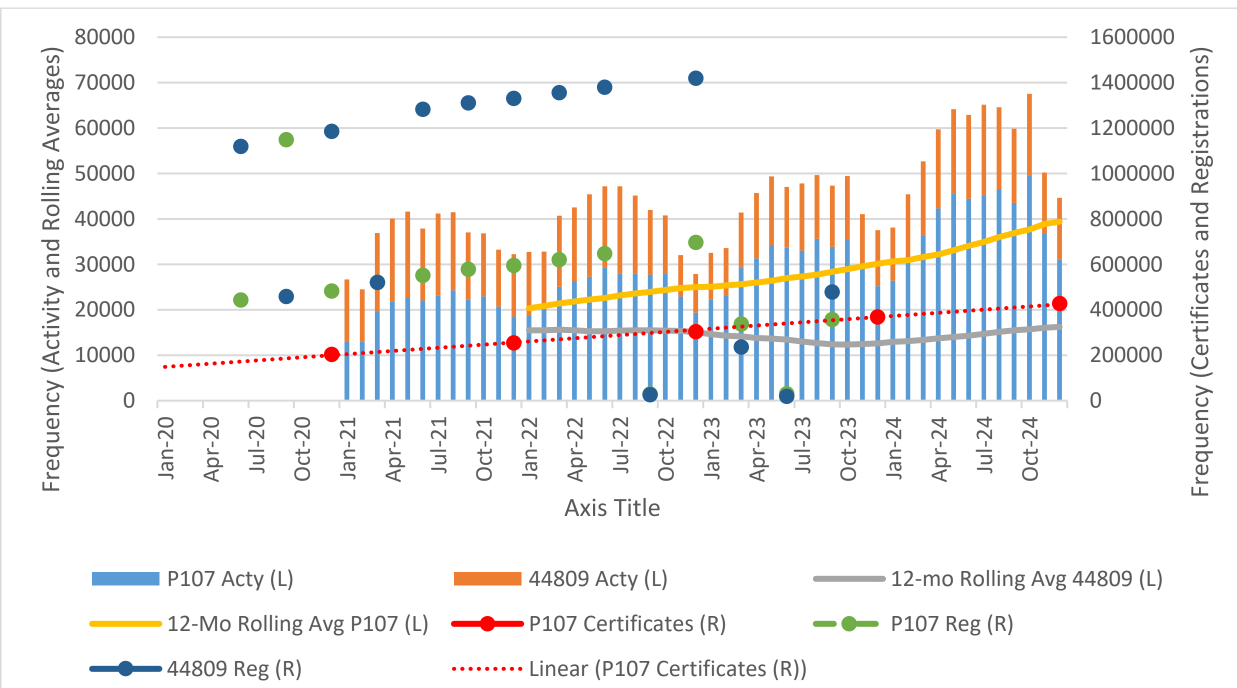


Figure 56. Cumulative LAANC Activity, Part 107/Part 44809 Registrations, and Part 107 Certificates.

The research team agrees with the FAA's assessment that recreational registration will remain relatively flat or experience low percentage growth. As evidenced by the long-term projections, the agency likely assesses that the recreational fleet is approaching saturation, with plateauing growth thereafter.

Conversely, the continued, relatively consistent addition of certificated remote pilots, coupled with a measured 2024 increase in Part 107 LAANC operations, seems to suggest growth potential in commercial sUAS activity, which may extend beyond 2025. The research team further anticipates a potential spike in commercial growth once the FAA releases permanent beyond visual line of sight (BVLOS) regulations. The research team also cautions that the aforementioned indicators may not fully capture the extent of operations taking place within the NAS, potentially resulting in under-sampling or under-representation of certain populations. For example, LAANC activity does not account for operations carried out under Part 91 COA, airspace authorizations, activity at fixed recreational sites, or FRIA locations. The evaluation of Remote ID concentrations and their divergence from LAANC utilization data suggest recurrent, routine operations are likely being under-counted.

Moreover, when taking into account Remote ID data, it is difficult for the research team to fully moderate the apparent sUAS growth trends to account for Remote ID adoption and registration. The research team suggests caution in interpreting apparent growth trending seen in the Remote ID data, it is unknown what portion should be attributable to initial Remote ID adoption, platform replacement, and related factors. Based on Remote ID platform census data, however, it seems apparent that most operators continue to favor new sUAS that come equipped with Standard Remote ID. Based on this assertion, it is highly likely that Remote ID registrations continue to lag truth data, based on observations made through Remote ID sensor detections. To further assess if registration data *also* lags, it is recommended to determine if model registrations mirror model detection data.

3.2.9 Operating Locations

The purpose of this analysis was to determine the origination location of sUAS flights to better understand operator behavior and determine potential risk areas that may be exposed to disproportionate levels of sUAS activity.

The research team compared pilot locations, or where absent, launch locations, to ascertain the origination point of flights in the Indianapolis area. Leveraging data from the Indianapolis and Marion County (n.d.) GIS Mapping Applications, the research team fused UAS origination locations with land use applications associated with geographical area zoning. The research correlated 5,154 UAS Remote ID data points to perform the assessment. The land use/zoning dataset used during the analysis contained 30 different land-use categories, including industrial, commercial, residential, government, agriculture, utilities, recreational, hydrology infrastructure, medical, and transportation spaces. The complete list of categories and results of the analysis are presented in Figure 57.

The top categories of UAS activity were found to be low-density residential areas (16.8%), agricultural locations (11.5%), "other" special use spaces (9.3%), community commercial spaces (8.3%), and two classifications of medium-density residential areas (collectively 14.0%). The remainder of the 24 categories comprise just over 40% of UAS activity. .

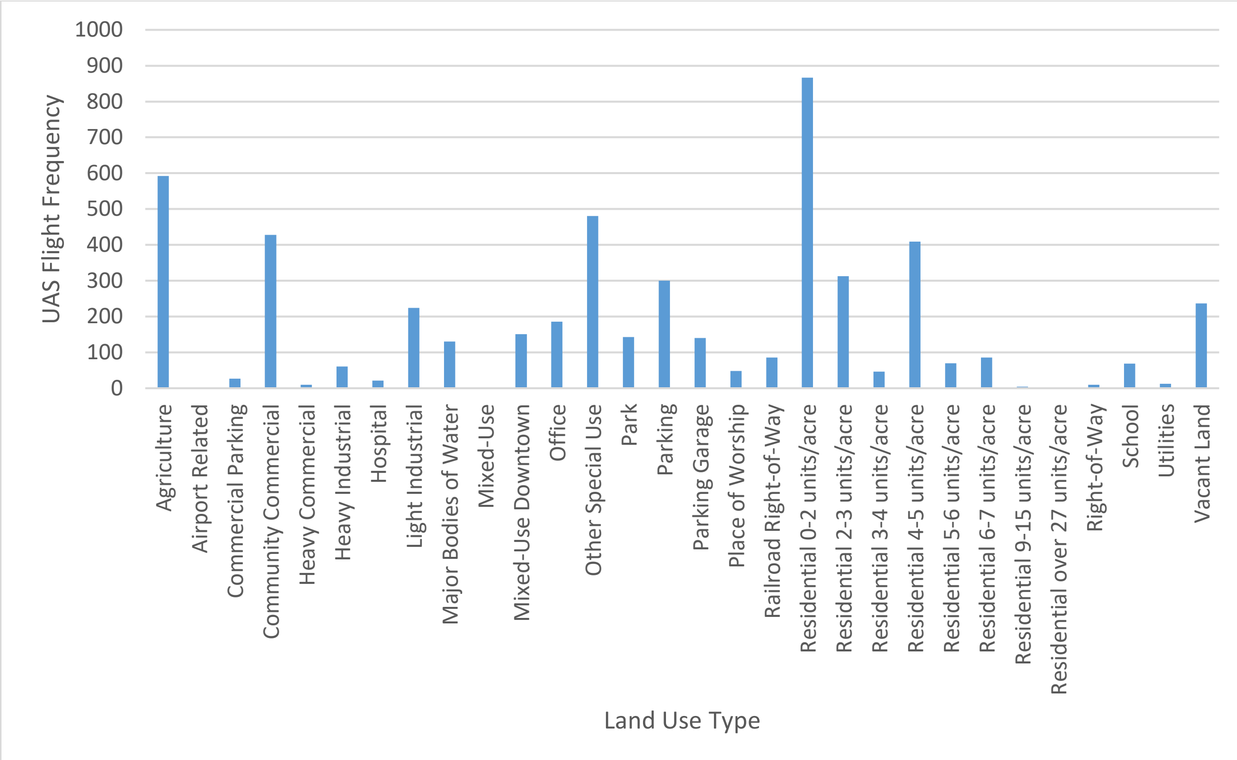


Figure 57. sUAS Launch Locations by Land Use.

These findings are generally similar to data collected by Wallace et al. (2024) from Dallas-Fort Worth International Airport (see Figure 58). Differences in land use classifications prevent a direct comparison, however, general similarities can be seen in both assessments. Single-family residential spaces or low-to-medium density residential neighborhoods continue to be the leading category of UAS origination. This finding suggests primarily recreational operations. Other data presented throughout this report point to elevated activity in the late afternoon/early evenings, weekends, and holidays.

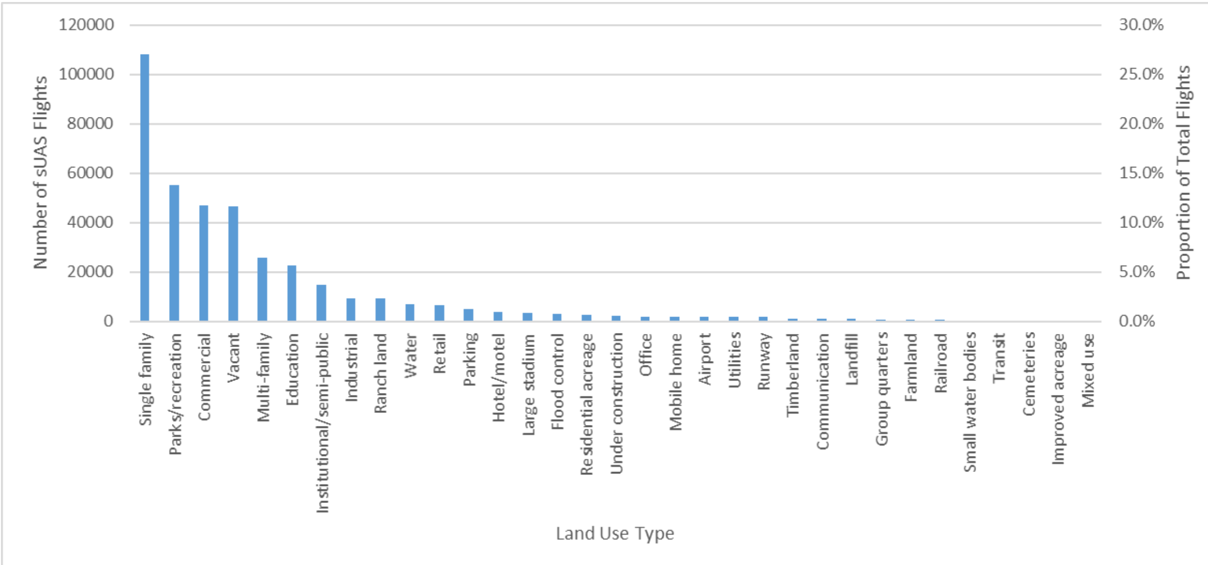


Figure 58. sUAS Operator Locations by Land Use (Proximate to Dallas-Fort Worth International Airport [DFW]).

UAS flight origination from residential neighborhoods presents a unique challenge for aviation safety for several reasons; foremost, is that crewed aviation operators are unlikely to recognize the overflight of residential spaces as presenting an elevated collision risk with UAS platforms. This may warrant additional education or safety alerting to notify crewed aircraft NAS users so they can better understand the nature and origin of UAS hazards. Conversely, this finding may also present a silver lining, as many locations—particularly those in larger, urban areas and near major airports—have procedures or approach and departure paths that avoid residential neighborhoods for noise abatement purposes. These procedures may help to segregate crewed aircraft operations from hazards posed by UAS operators flying over residential areas.

3.2.10 sUAS Utilization, Retirement, and Abandonment Rates

The purpose of this assessment was to determine the longevity of sUAS utilization to assess normal sUAS lifespans of operation and use patterns.

The research team evaluated sUAS utilization patterns to assess repeated use of platforms to interpolate usage cessation, which suggests operator platform retirement, abandonment, or replacement. Cumulative results are presented in Figure 59. Results suggested platforms are generally operated for a small proportion of time—generally within one calendar month—with limited reutilization thereafter. Although the sampling period of the current study was relatively limited, it was anticipated to see more recurrent platform activity. This seems to reflect findings from prior studies that indicated sUAS have relatively short platform lifespans (Wallace et al., 2024). While it is possible that other factors may be influencing this data (such as operators conducting operations in locations outside the study's sensor coverage areas), the data trend is indicative that recurrent platform use *may* be limited.

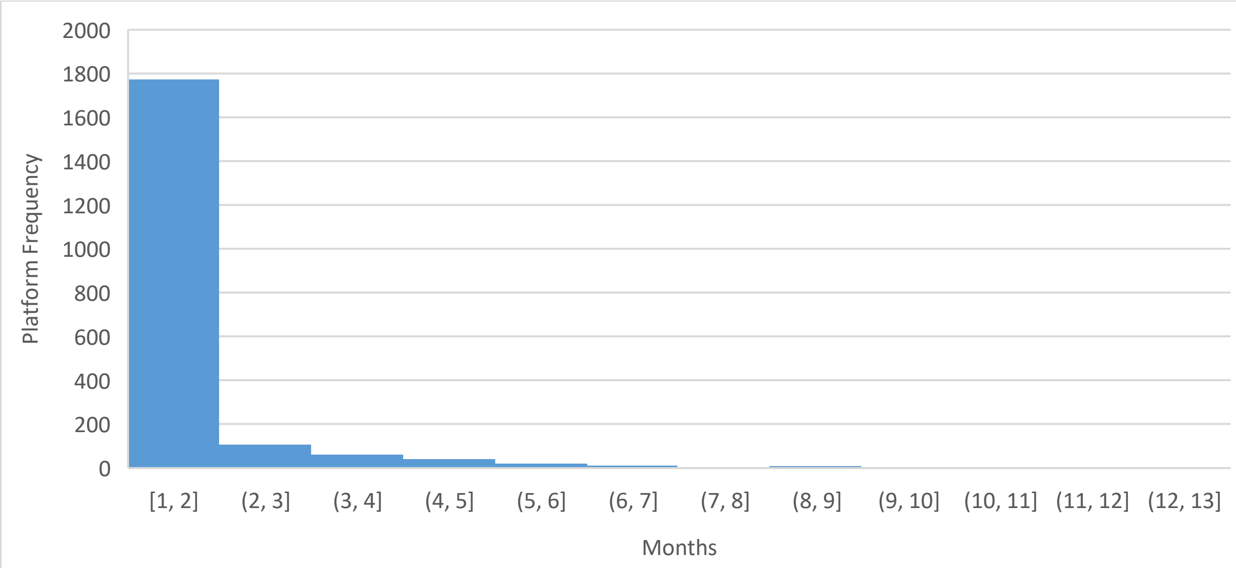


Figure 59. sUAS Platform Activity by Remote ID Serial Number, Months (n=3,235).

A boxplot of activity months is provided by platform type for all sUAS models operated for more than one calendar month (see Figure 60). These findings were somewhat unexpected. In prior studies, higher utilization patterns could be correlated to platforms that could clearly be tied to commercial activity (e.g., Matrice 600, Matrice 210, RTK models, etc.). However, this trend did not appear to be reflected in the dataset. The top three sUAS platforms with elevated utilization rates included the DJI Mavic 3 Enterprise, DJI Phantom 4 Pro 2.0, and Mavic 2 Pro.

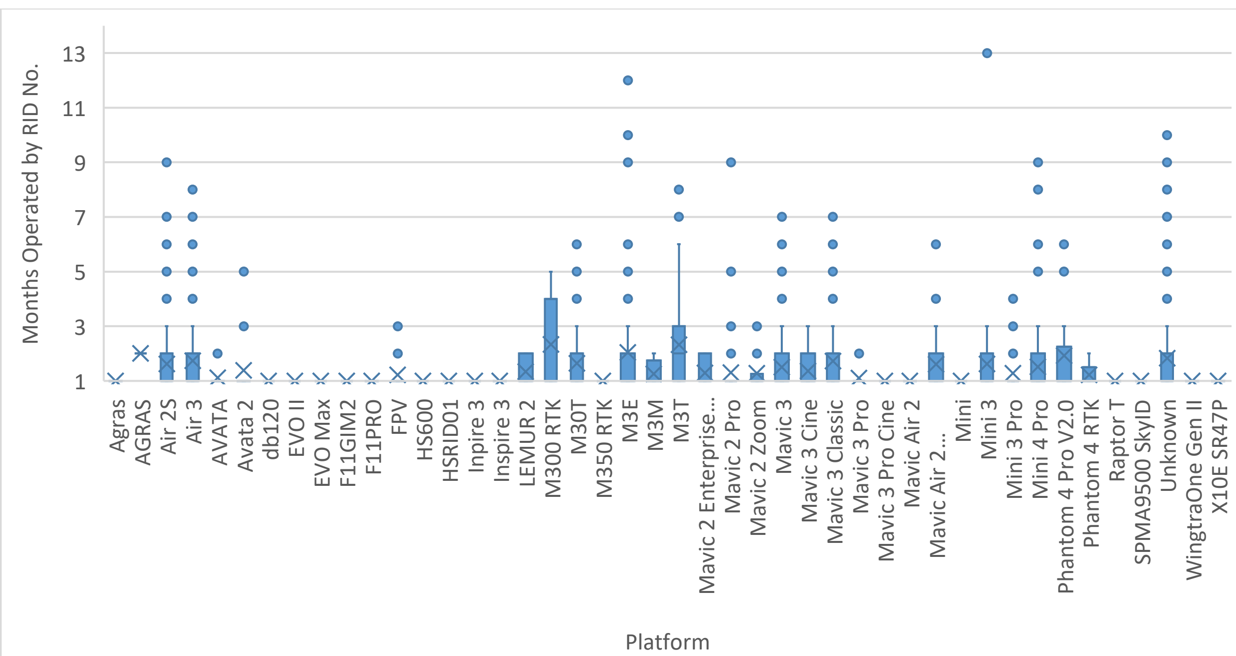


Figure 60. sUAS Platforms Operated over One Calendar Month.

3.2.11 Public Agency Use of sUAS
The purpose of this assessment was to determine the extent of public safety use of sUAS.

During the study, the research team could not secure identifying sUAS Remote ID information for public safety agencies in the sample areas, making identifying public safety missions exceedingly tricky. This task was further complicated by the selected sampling locations, which were generally unsuitable for detecting these types of operations.

There are, however, other evolving means for identifying sUAS operational activity. One of the ongoing challenges with Remote ID detection is that it is not currently possible to determine from Remote ID data alone how an operator is complying with FAA regulations, nor is it possible to definitively identify the purpose or mission application of sUAS flights. Research is advancing to predict flight activity using telemetry information, generally coupled with artificial intelligence and machine learning tools to assess telemetry patterns. This technology compares detected sUAS telemetry against known use cases by applying supervised or unsupervised machine learning training methods to identify pattern similarities and determine probability models for classification. For example, the raster telemetry pattern seen in Figure 61 (Left), likely represents a surveying or mapping application, while the image in Figure 61 (Right) suggests 3-dimensional modeling or photogrammetry (Wallace et al., 2024).

Figure 61. Sample Telemetry Patterns and Operational Applications.

The research team will attempt to address the objectives of this task more thoroughly in the follow-on research project, ASSURE A83, Drone Traffic Analysis study.

3.2.12 sUAS Platforms by Weight Classification

The purpose of this assessment was to determine the distribution of sUAS in operation by weight. The weight of a sUAS plays a large role in the potential damage that can be inflicted by the platform in either an aerial collision with an aircraft or a ground collision with a structure or person. Understanding the distribution of platforms in use can inform upon the potential damage risk to NAS stakeholders and injury potential to persons on the ground.

While monthly activity by manufacturer and platform helps assess market share, additional contextual information can be derived by correlating monthly sUAS activity to each platform's size or weight. Figure 62 shows the relativistic sUAS activity trends based on 12 different weight classes of sUAS platforms. Figure 63, shows the overall frequency of platforms in each weight class and the proportionality of platforms across the various weight classes. An evaluation of this data reveals several interesting findings.

First, there is a clear rising trend in activity from tiny platforms—those weighing less than .55 lbs (250g). This is followed by platforms weighing 2.0 lbs, 2.5 lbs, and 1.5 lbs, respectively. The operational frequency of heavy platforms is negligible within the dataset. This seems to indicate that consumers favor the operation of low-weight platforms. This finding generally reflects prior studies, however, the trend toward smaller, lighter platforms appears to be becoming more prominent.

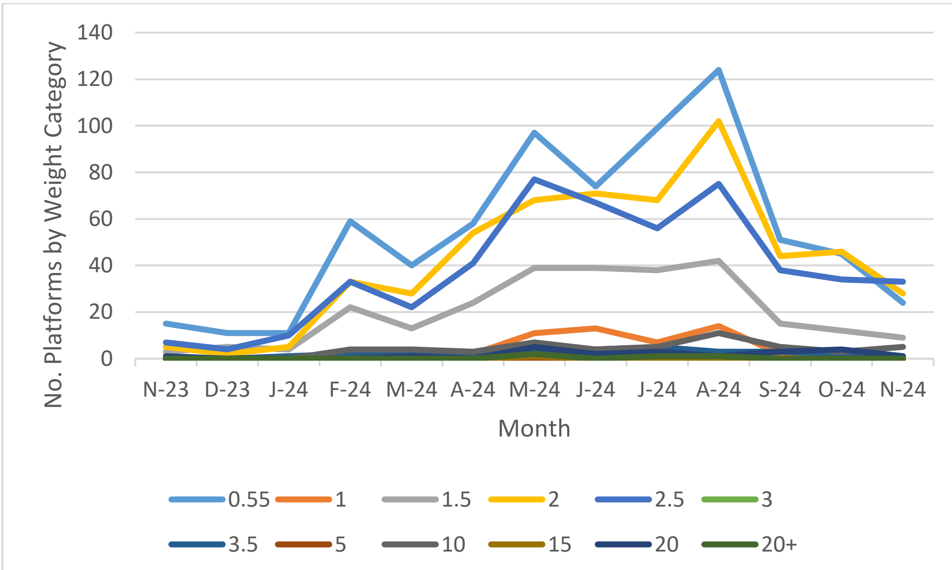


Figure 62. sUAS Monthly Platform Activity by Weight Classification (*n*=2,187).

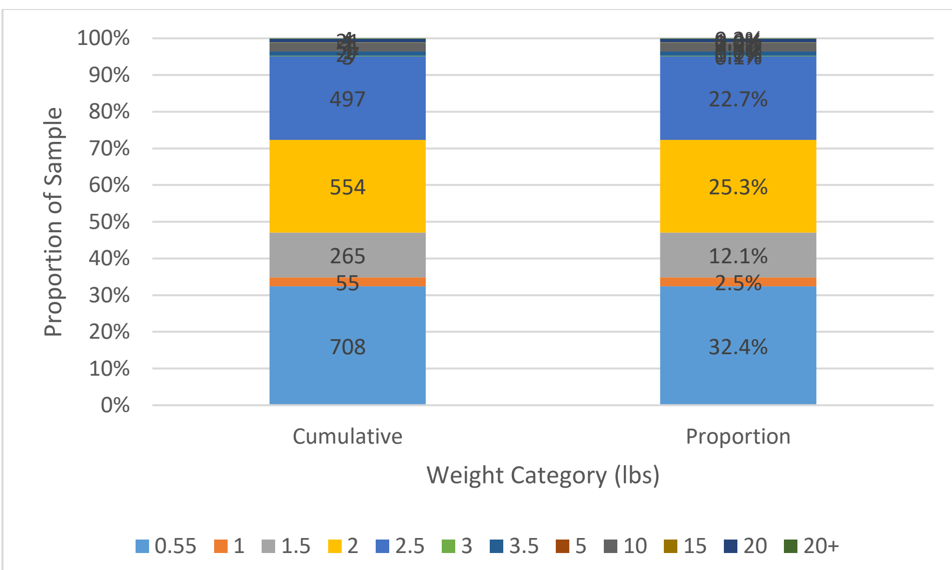


Figure 63. Cumulative Detected sUAS Platform Distribution by Weight Category.

3.2.13 Potential Impacts of Implementing ADS-B (Out) for sUAS

The purpose of this task is to ultimately determine the extent of concentrated operations, primarily for sUAS (but potentially including manned aircraft as well), and to assess the potential implications for signal interference should ADS-B be implemented as a Remote ID solution.

ADS-B has been previously suggested as one of several possible solutions to address the challenges associated with sUAS detection, identification, and tracking (UAS Identification and Tracking [UAS ID] Aviation Rulemaking Committee [ARC], 2017). However, during the UAS ID ARC's (2017) deliberations, it was assessed that possible interference of sUAS ADS-B signals could disrupt or overwhelm manned aviation ADS-B signals, potentially compromising safety. The UAS ID ARC (2017) would ultimately recommend options for low-power direct broadcast or network publishing solutions. Follow-on FAA rulemaking would ultimately implement a local direct broadcast, although not using ADS-B as the underlying technology (FAA, 2021c). This final rule would become codified in 14 CFR 89, Remote Identification of Unmanned Aircraft (2021).

The research team collected sUAS flight density information to codify the extent of simultaneous operations. The largest extent of simultaneous sUAS flight operations occurred in the Indianapolis and Fishers sample areas. Figure 64 shows the collection of individual flights carried out in Indianapolis over the sampling period within a 5 NM radius.

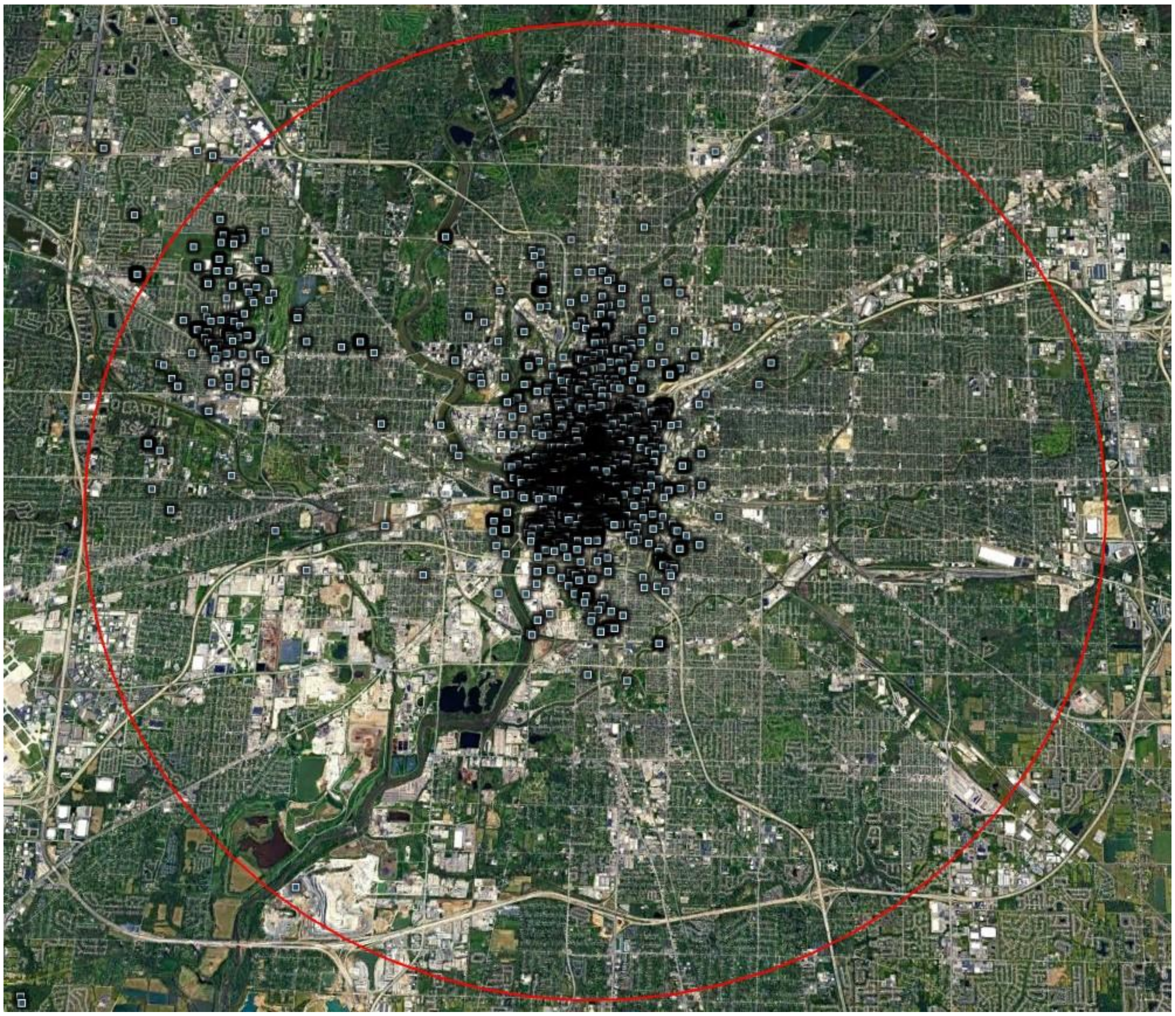


Figure 64. Remote ID Flight Originations, Indianapolis, IN, 5 NM Range Circle.

Figure 65 shows the average and maximum number of flight operations in both sample areas, based on local, hourly segments. Fishers saw a maximum of up to nine simultaneous flight operations within two separate periods in the mid afternoon and late evening. Indianapolis, also saw a maximum of nine simultaneous flight operations, also in the mid-afternoon, and slightly fewer simultaneous flights in the late evening.

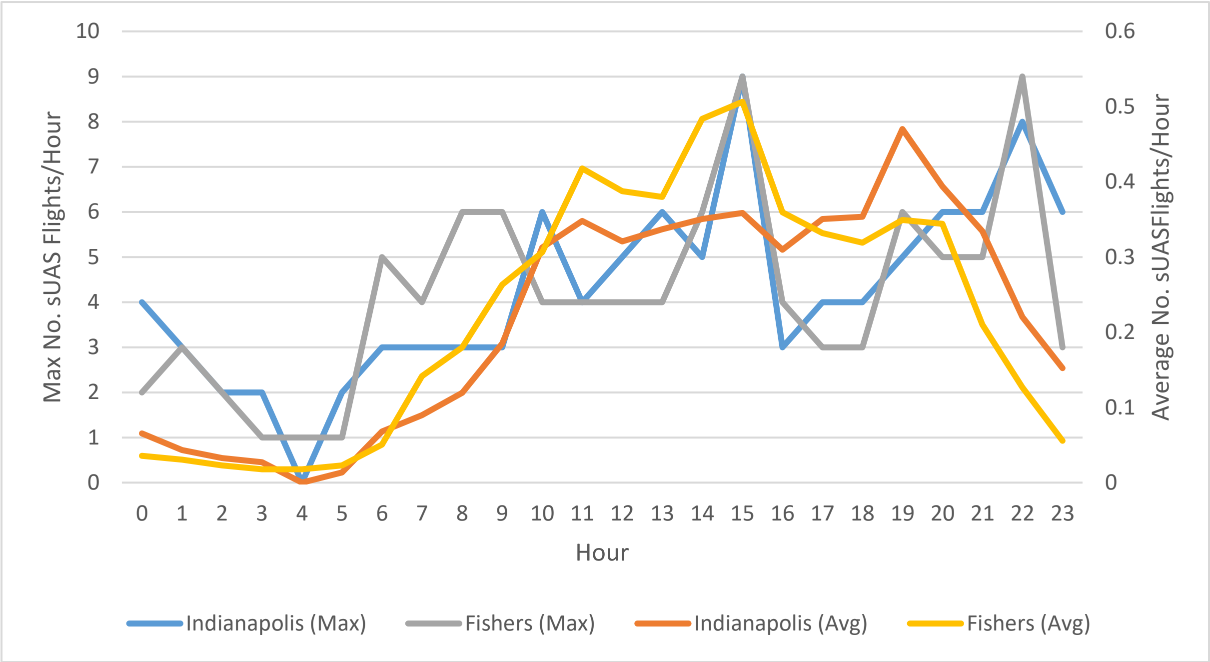


Figure 65. Distribution of sUAS Flights/Hour (Indianapolis and Fishers Sample Areas).

To contextualize these values, the research team selected the busiest U.S. airport by number of annual operations in 2024, determined to be Hartsfield-Jackson Atlanta International Airport (ATL). In 2024, ATL handled a total of 796,224 operations, with approximately 98.1% (*n* = 781,216) air carrier operations (FAA, n.d.a). Based on 8,760 total hours in a calendar year, this equates to an average of nearly 91 flights per hour—well above the measured simultaneous sUAS threshold at either of the sample areas. Moreover, the actual number of operations could likely be higher, since the research team was unable to account for traffic variability during ATL peak operations hours.

The exact capacity of the ADS-B is ill-defined; however, several source documents inform upon this issue. Sources assessed the potential growth and performance implications of operating ADS-B in congested airspace (ADS-B Aviation Rulemaking Committee [ARC], 2008). The report assessed that exceeding 45,000 transmitters within a given airspace could result in interference or message degradation or loss (ADS-B ARC, 2008). A study by Tabassum and Semke (2018) addressed the risk of ADS-B congestion and accompanying message data loss, known as *dropout:*

> "Over the past several years, airspace has become congested with the increasing number of flights. The introduction of unmanned aircraft systems (UAS) into the National Airspace System (NAS) has further increased congestion, especially below the transition altitude where most general aviation aircraft fly." (p. 2)

The Tabassum and Semke (2018) study identified that up to 32.49% of ADS-B messages encountered dropout problems when the ADS-B update rate was greater than 3 seconds. Beyond the provided material, documentation regarding specific ADS-B system capacity thresholds is relatively limited. Aircraft positional latency is generally required to be less than 0.6 seconds, whereas overall latency must be less than 2.0 seconds (FAA, 2015).

Based on a three-year study of sUAS activity at a major, Core 30 airport researchers identified 481,368 flights from a combined 29,839 sUAS platforms (Wallace et al., 2024). Even this large number of sUAS operations only aggregates to approximately 18 sUAS flights per hour—much lower than Core 30 manned aircraft operations numbers. Moreover, sUAS are less likely to inject interference, as they generally operate at low altitudes, subjecting any ground-based ADS-B monitoring to implications of terrain and obstacle masking, further lowering potential interference at substantial range.

Based on the preponderance of the data, operations activity, and informative literature on the subject, sUAS are unlikely to cause significant interference, if using ADS-B (Out). Potential interference or ADS-B signal degradation is only likely to be experienced in particularly traffic-dense airspace at or in the immediate vicinity of our nation's busiest airports.

3.3 Task C: Compliance and Exceedances of 14 CFR 107 Operational Limitations

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

3.3.1 sUAS Operation During Daylight, Civil Twilight, and Nighttime

The purpose of this assessment was to evaluate when sUAS operations take place, relative to local daylight, civil twilight, and nighttime conditions.

The research team selected two sample areas to conduct daylight analysis, which included the Indianapolis and Daytona Beach areas. These areas were chosen due to the large availability of flights for sampling. Collectively, the research analyzed 4,795 data points. Sampling timeframe was primarily based on data availability from deployed sensors. Astronomical data for sunrise, sunset, and civil twilight times were derived from Time and Date (2025). Findings are presented in Figure 66 and Figure 67. Data for both locations were strikingly similar. Data collected at Indianapolis showed more than 80% of flights occurred during daylight hours, with approximately 10.8% occurring at nighttime [local civil twilight to midnight], and 3.5% occurring during morning hours [midnight to morning civil twilight]. Flights during civil twilight hours represented only 5.3% of the dataset, with 4.3% occurring in the evening and just over 1.0% occurring in the morning. Data collected from Daytona Beach was similar, with 86.0% of flights occurring during daylight hours, 8.7% occurring at nighttime, 1.5% during the morning, .2% occurring during morning civil twilight, and 3.6% during evening civil twilight.

The consistency of the data distributions gives the research team confidence in predicting that daylight operations likely represent 75-85% of operations in most locations, with nighttime operations comprising 5-15% of operations, and morning operations estimated at less than 5%. Operations during morning civil twilight were generally de minimis, with nighttime civil twilight operations likely comprising 3-5%.

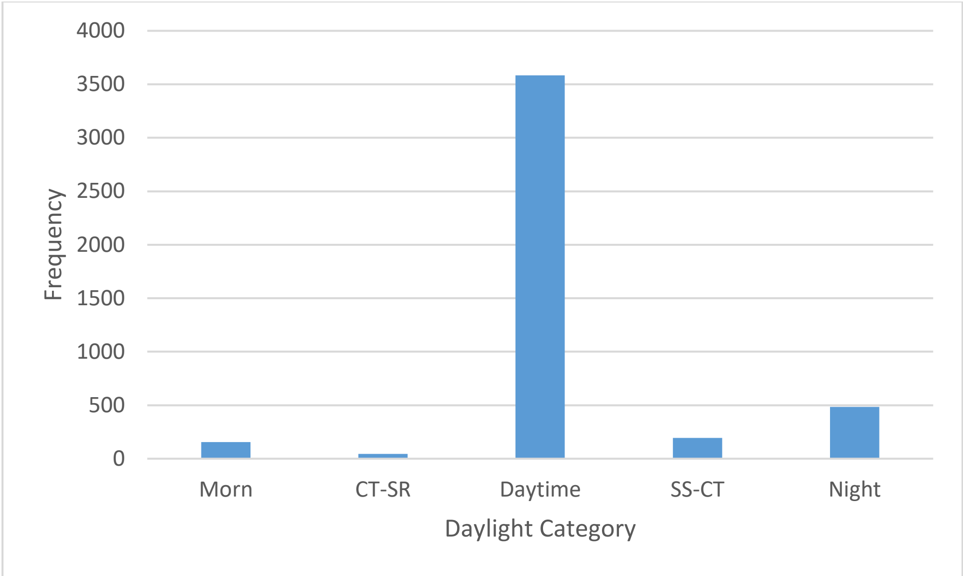


Figure 66. sUAS Flights by Daylight Category (Indianapolis, IN, *n* = 4,460, Nov 2023-Nov 2024,).

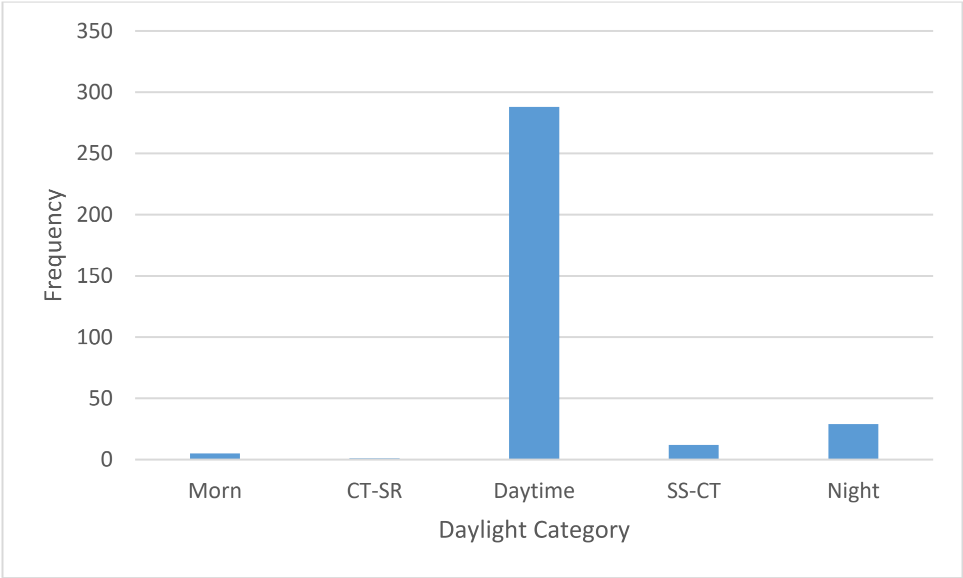


Figure 67. sUAS Flights by Daylight Category (Daytona Beach, FL, *n* = 335, Feb 2024-Aug 2024,).

3.3.2 Flight Over Human Beings and Populated Areas

The purpose of this evaluation was to estimate the extent of sUAS operations being carried out over human beings not protected by a structure or shelter.

The research team assessed the launch locations of each detected flight to assess the density of proximate human activity. The research team used Oak Ridge National Laboratory's LandScan USA 2021 dataset as a metric for human activity (Weber et al., 2022). "The LandScan Program was initiated at Oak Ridge National Laboratory (ORNL) in 1997 to address the need for improved estimates of population for consequence assessment" (ORNL, 2025, p. 1). The LandScan USA 2021 fuses population census data, demographics, socioeconomic information, infrastructure, and other related information (ORNL, 2025).

The dataset provides a spatial resolution of 3 arc-seconds (90m x 90m), and a temporal resolution of about 12 hours (ORNL, 2025). For this assessment, the research team defaulted to using daytime data.

The composite results of the analysis are presented in Figure 68, with detailed geospatial assessments following. Results indicated that most flights were flown in areas with less human activity. Approximately 25.4% of flights originated from locations assessed to have no human activity. Approximately 31.6% of flights originated from locations with human activity values of less than 10 people per 90m x 90m area (approx. 1,230 persons per km^2). Only 8.9% (n = 462) of flights occurred in the highest-density human activity areas of 251-30,000 persons per $8{,}100m^2$ area (approximately 30,873 to 3,690,000 persons per km^2).

The research team notes that LandScan human activity values may not represent more urbanized locations, as the number of densely populated areas in the sample dataset was limited. Moreover, the research team acknowledges that flights can easily transition between human activity areas. However, the research team did not assess flight telemetry for this assessment.

Figure 68. sUAS Operator Locations by LandScan Value (Daytime).

Flight activity in the Columbus, Indiana area was evenly distributed, with a slight elevation over roadways and other transportation mediums. Dense population pockets were located in the downtown area to the southwest, with several flights noted in the area (see Figure 69).

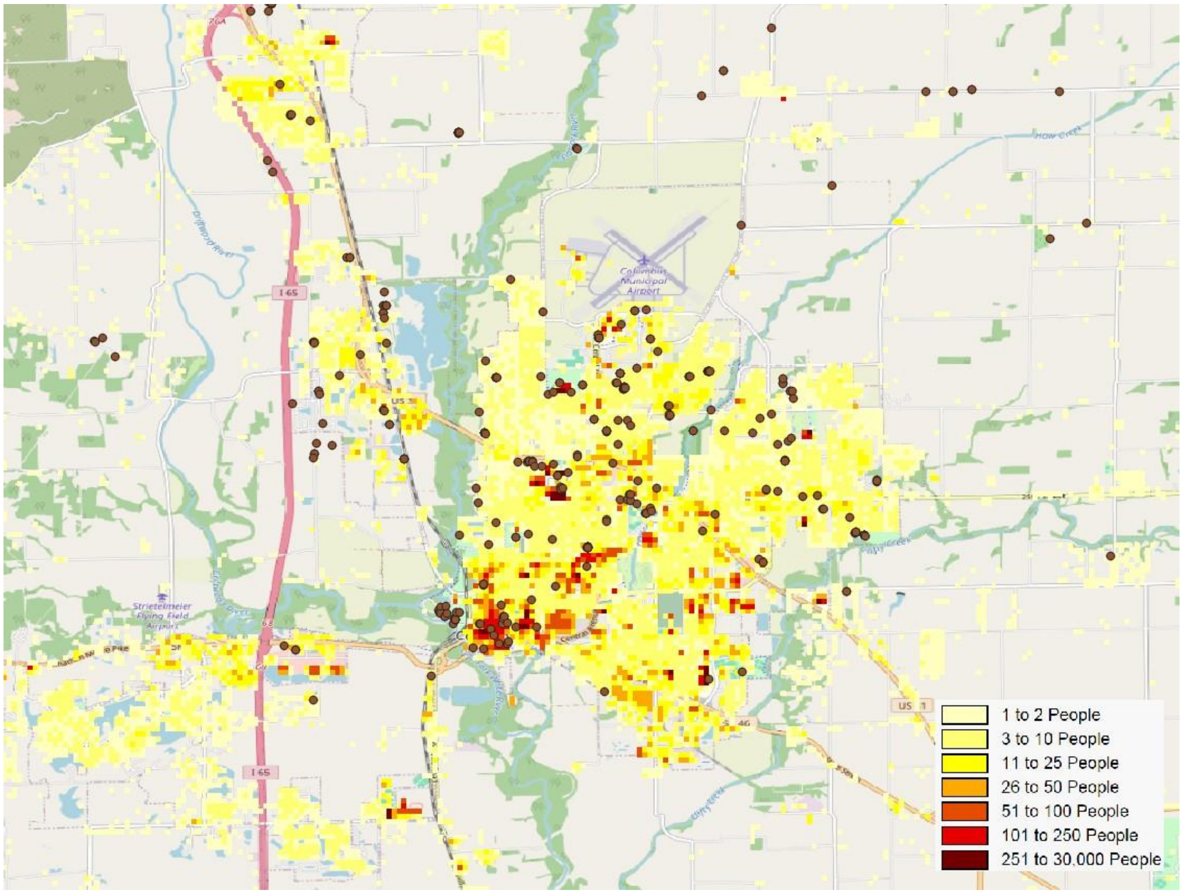


Figure 69. sUAS Operator Locations Overlaid with LandScan USA, Columbus, IN, 90m x 90m Resolution, Daytime.

Flight activity in the Daytona Beach, Florida area was heavily concentrated along the main east-west roadway adjacent to DAB airport and along the coastline near the Halifax River and ocean beach (see Figure 70). With the exception of some beach-side areas, these flights correspond to higher-population-activity areas.

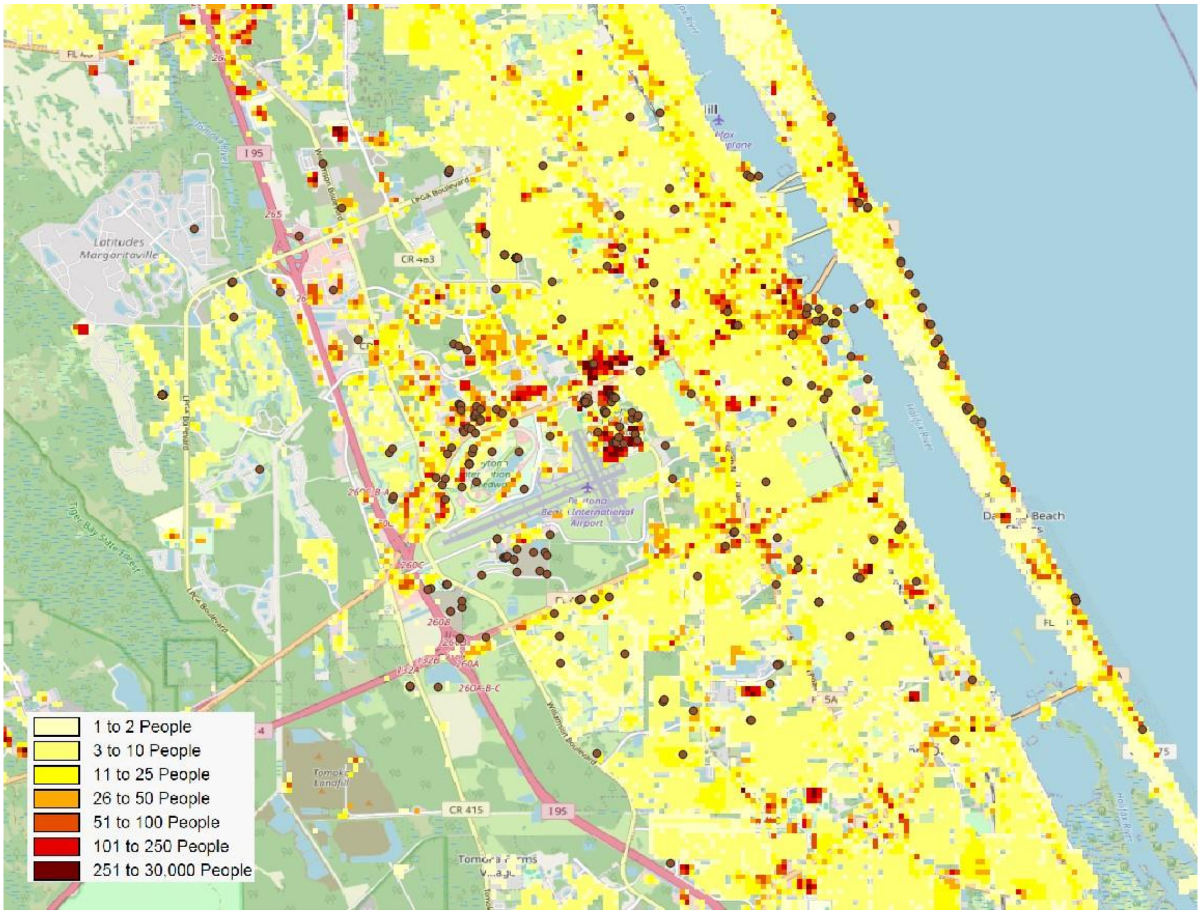


Figure 70. sUAS Operator Locations Overlaid with LandScan USA, Daytona Beach, FL, 90m x 90m Resolution, Daytime.

Similar to Columbus, Indiana, flight activity in the Fishers, Indiana, area appeared to concentrate around roadways and thoroughfare areas, which generally corresponds to higher human activity areas (see Figure 71). Flight origins in this sample area appear to extend somewhat further from roadways than in other regions, although the reason for this variability is not immediately apparent.

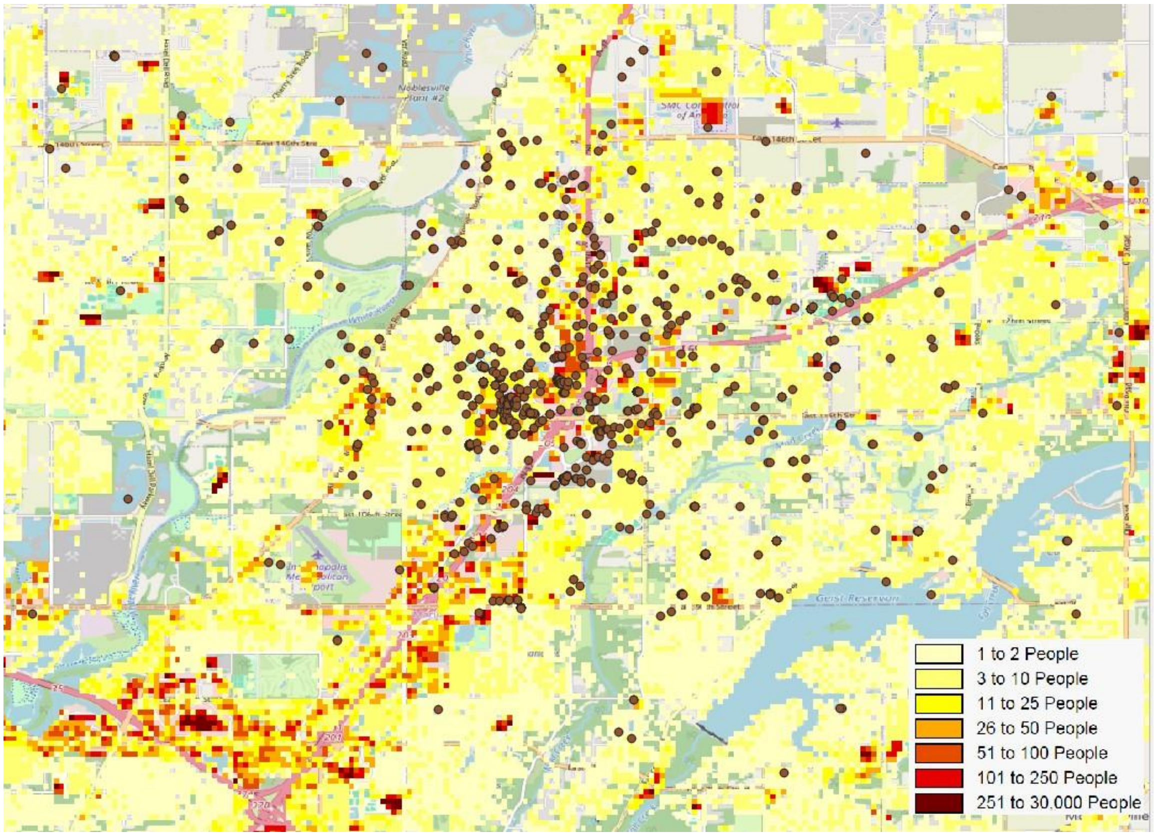


Figure 71. sUAS Operator Locations Overlaid with LandScan USA, Fishers, IN, 90m x 90m Resolution, Daytime.

Unlike other sampling areas, flight activity in downtown Indianapolis, Indiana, was heavily concentrated in the most densely populated areas but did not necessarily correlate to significant highways or roadways (see Figure 72).

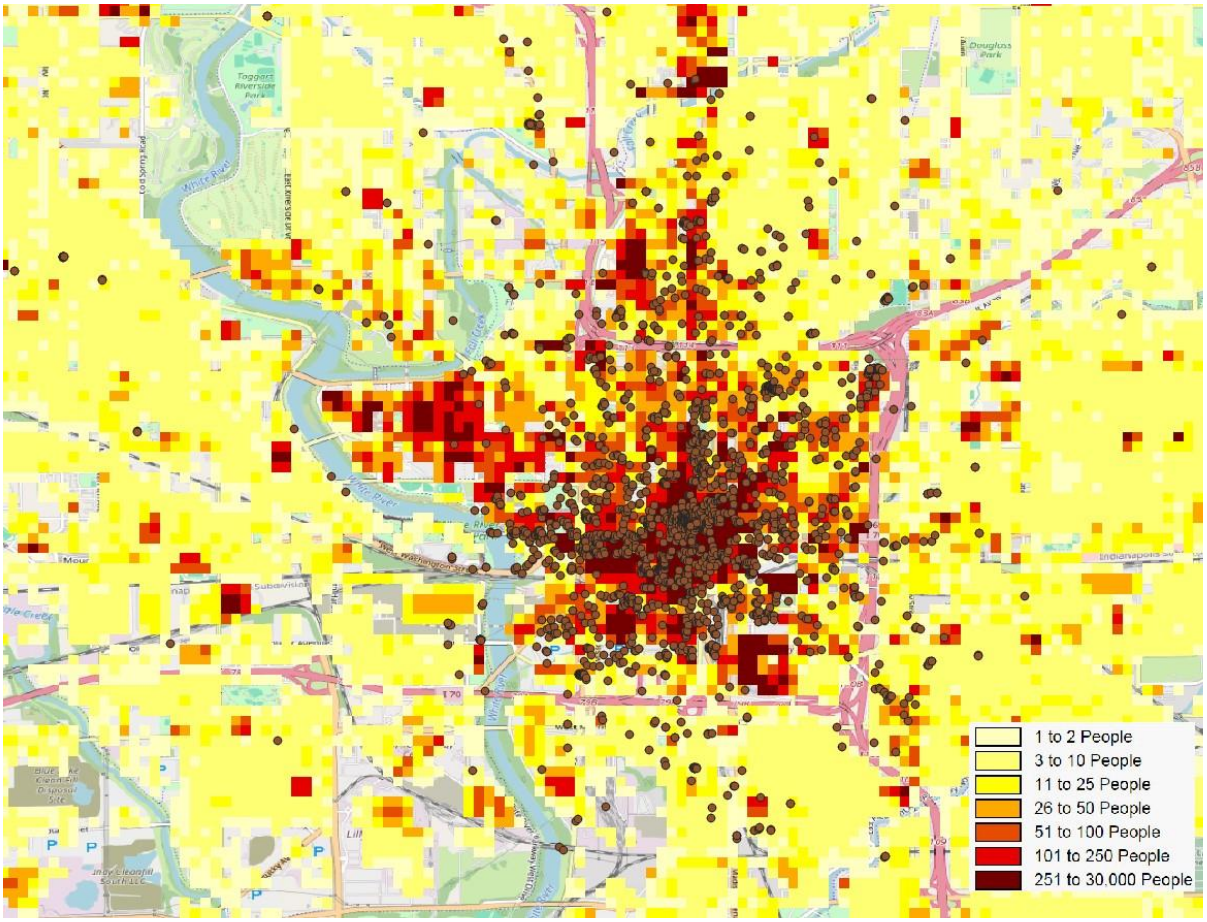


Figure 72. sUAS Operator Locations Overlaid with LandScan USA, Indianapolis, IN, 90m x 90m Resolution, Daytime.

Flight activity in the Terre Haute, Indiana sampling area did not appear to follow the same pattern as other sampled locations (see Figure 73). Unlike other areas where flight activity appeared to concentrate around areas of higher human activity, flight activity in the Terre Haute sampling area seemed to avoid these areas almost entirely. It is not altogether clear why this discrepancy occurred. The research team acknowledges that sensor coverage and obstructions in this area may have prevented effective detection over the western portion of the sampling area. Flight activity in this area could still be generally correlated to major roadways.

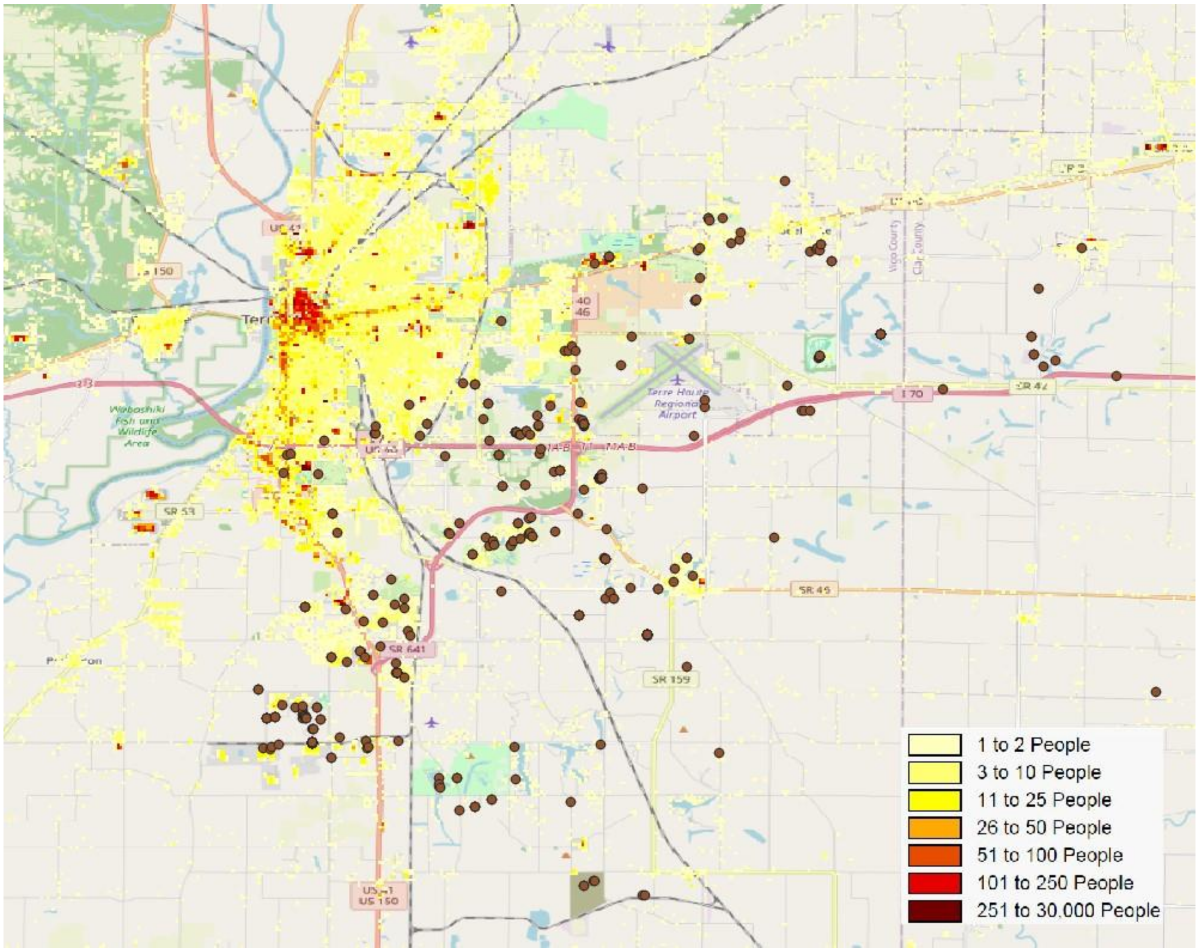


Figure 73. sUAS Operator Locations Overlaid with LandScan USA, Terre Haute, IN, 90m x 90m Resolution, Daytime.

These findings suggest that sUAS activity tends to concentrate around major roadways and areas of elevated human activity. While ORNL (2025) LandScan has typically been used as a metric for assessing UAS risk to persons on the ground, it may also be helpful as a proxy for estimating sUAS activity concentrations. Additionally, sUAS activity proximate to roadways and other major thoroughfares should also be explored in future studies.

3.3.3 sUAS Operating Limitations

The primary purpose of this research is to examine sUAS operational activity to baseline operational factors and assess potential regulatory exceedances that could potentially impact the safety of the NAS.

3.3.3.1 sUAS Speed

The purpose of this assessment was to determine the distribution of sUAS lateral and vertical speed. Understanding sUAS operational speeds can provide a baseline to assess potential sUAS kinetic risk to manned aircraft and persons on the ground. Additionally, sUAS speeds can also inform metrics used to assess manned aircraft encounters and collision risks in the NAS.

The research team sampled and assessed more than 4.6 million Remote ID messages to evaluate instantaneous UAS speed. This approach is more accurate than prior methods, which only evaluated maximum flight speeds. This approach captures a more precise distribution of UAS flight speeds while highlighting elevated speeds or exceedances. Results are presented in Figure 74.

The largest speed category for UAS operations was static or hovering maneuvers, representing 21.7% of the dataset. Relatively equal distributions flew at 10 mph (13.9%) and 5 mph (13.9%). Flight categories between 15-30 mph varied between 10.5% and 11.6%. Flight above 30 mph comprised only 2.2% of the dataset, with continuously diminishing operations occurring at speeds exceeding 65 mph. No platforms exceeded the maximum 14 CFR §107.51(a) regulatory speed restrictions for sUAS operations (100 mph/87 kts, groundspeed).

These findings are logical when contextualized to the distribution of detected UAS platforms. The vast majority of platforms representing DJI products are generally limited to 30 mph or less in P-mode and between 40-50 mph in Sport-mode. Since most of these UAS are used as camera platforms, it makes sense that remote pilots would limit operational speed to ensure compelling image or video capture. Moreover, data sampling contained only a tiny number of racing-style UAS platforms, such as DJI FPV (~1% of the dataset), capable of speeds up to 87.2 mph. Other platforms, such as the AVATA and AVATA 2, can have speeds exceeding 60 mph in manual mode; however, these platforms collectively comprise only about 2% of the dataset. Sampling locations did not include recreational flying areas, which are likely to host faster, racing-style platforms. In regions near recreational flying sites, the average and top speed distribution is expected to be higher.

For generalization purposes, the research team suggests that the preponderance of sUAS operations occur at speeds less than 30 mph. This finding is valuable, as this estimate can be used to predict the closure rate and physics of potential damage by providing a rational threshold for estimating a maximum UAS speed during aircraft encounters or midair collisions.

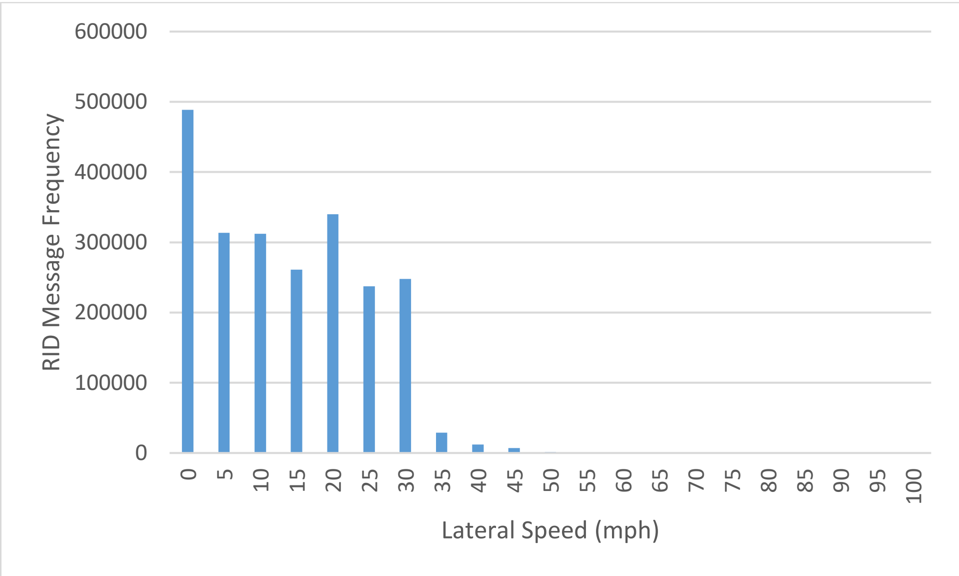


Figure 74. Instantaneous sUAS Lateral Speed (mph, n = 4,640,071).

The research team also evaluated platform instantaneous vertical speed to gain additional perspective on sUAS operational practices related to aerial vehicle speed. The research team believes this assessment to be even more applicable than lateral speed, as midair collisions between manned and unmanned platforms are less likely to be the result of an in-motion sUAS platform striking an aircraft, but rather a static or vertically-maneuvering, unseen sUAS being hit by a manned aircraft. This was the case in the accident between a police DJI Matrice M210 that was hit by a Cessna 172N aircraft on final approach to Toronto/Buttonville Municipal Airport (CYKZ), Ontario, on August 10, 2021 (Transportation Safety Board of Canada, 2023). During the incident, the sUAS was operating 400 feet AGL:

> …remained stationary while the police members close to the RPA pilot were able to watch the operation unfold on the TV display. The RPA *was in a stationary hover for more than 2 minutes* when 1301 a collision occurred with the Censsa, which was on final approach for Runway 15 [at CYKZ]. (p. 7).

Prior flight testing research by Wallace et al. (2019) showed that pilots encountered difficulty spotting static sUAS targets, with participants only achieving a 13.6% detection rate—the lowest of all tested conditions.

The research team used the same dataset as the one used to evaluate instantaneous lateral speed, with a total sample of more than 4.6 million data points. The results of the vertical speed assessment are presented in Figure 75. A more detailed assessment of vertical speed by sUAS model is presented in Figure 76. Although the graph is difficult to discern individual platforms, clear patterns emerge, with the majority of platforms operating at vertical speeds of +/-2,000 fpm, and lateral speeds of less than 50 mph.

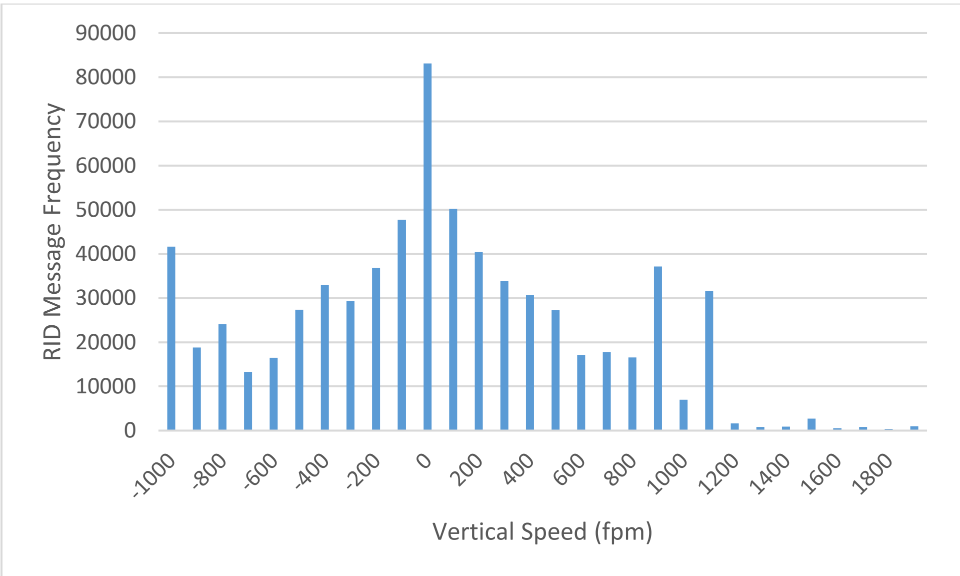


Figure 75. Instantaneous sUAS Vertical Speed (fpm, *n* = 4,640,071).

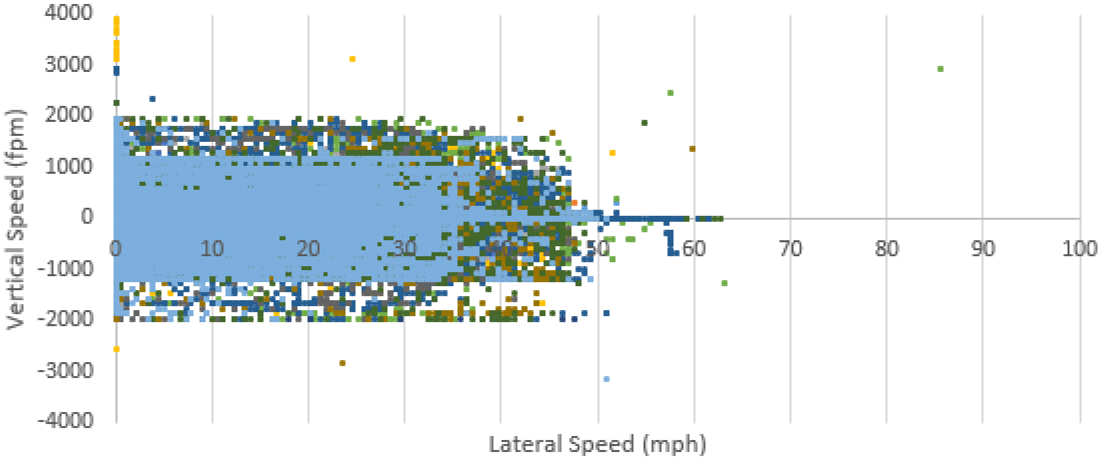


Figure 76. Plot of Instantaneous Lateral (mph) and Vertical (fpm) Speed by Platform Type.

3.3.3.2 Weather Conditions, Visibility and Cloud Clearances

The purpose of this examination was to evaluate sUAS operations in the context of environmental and weather factors. This assessment can aid in determining the extent of conditions in which sUAS operators fly, aid in assessing exceedances from regulatory guidance, and assess potential weather risks to sUAS operations.

The research team assessed factors derived from AWOS and ASOS sensors in proximity to sUAS flight activity to evaluate: 1) conditions in which sUAS were flown; 2) determine possible exceedances of regulatory weather restrictions; and 3) evaluate potential implications to sUAS safety, such as exceedances of manufacturer-specified operational restrictions. For this analysis, the research team assessed reported visibility, cloud ceiling, precipitation, temperature, wind speed, and wind gust speed. The research team cautions that while AWOS and ASOS data provide valid and reliable weather data, weather conditions at sUAS flight locations may deviate from reported conditions. Additionally, the research team acknowledges that weather conditions may either improve or degrade over time; however, a temporal assessment of changing weather conditions was beyond the scope of this study. This analysis assessed weather data based on the initial flight detection, correlated to the most recently available AWOS/ASOS issued report. The degree of variability of weather conditions will likely increase with increased distance from the AWOS/ASOS sensor.

To provide a high-level context of findings, the research team plotted visibility and cloud ceiling conditions for two of the sampling areas in Figure 77 and Figure 78. Using regulatory restrictions for visibility and cloud ceilings articulated in 14 CFR 107.51(c) and (d), the research team plotted sUAS flights detected in each area, and overlaid cloud ceiling and weather conditions that would have restricted sUAS flight operations. Sunrise, sunset, and civil twilight times were overlaid for further context. Finally, the research team plotted dates and times UAS were spotted and reported to the FAA's UAS Sightings Report Database.

Notably, different locations have varying levels of adverse weather conditions, which is readily apparent between Figure 77 and Figure 78. Generally, the sUAS activity level appears diminished during adverse visibility and cloud ceiling conditions. It is unknown if this behavior results from operator regulatory compliance or a response to the undesirability of flying during adverse weather or visibility conditions.

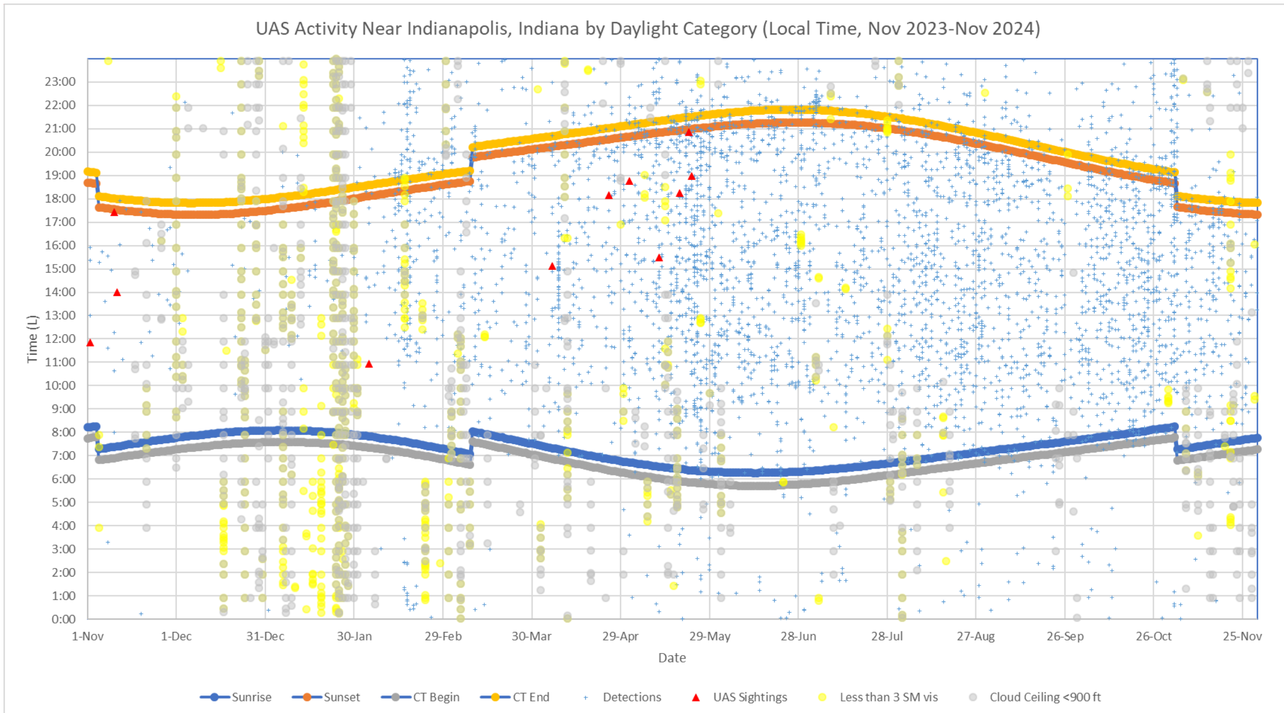


Figure 77. Visibility and Cloud Clearance Exceedance [14 CFR 107.51(c) and (d)(1)] by Date and Time (IND).

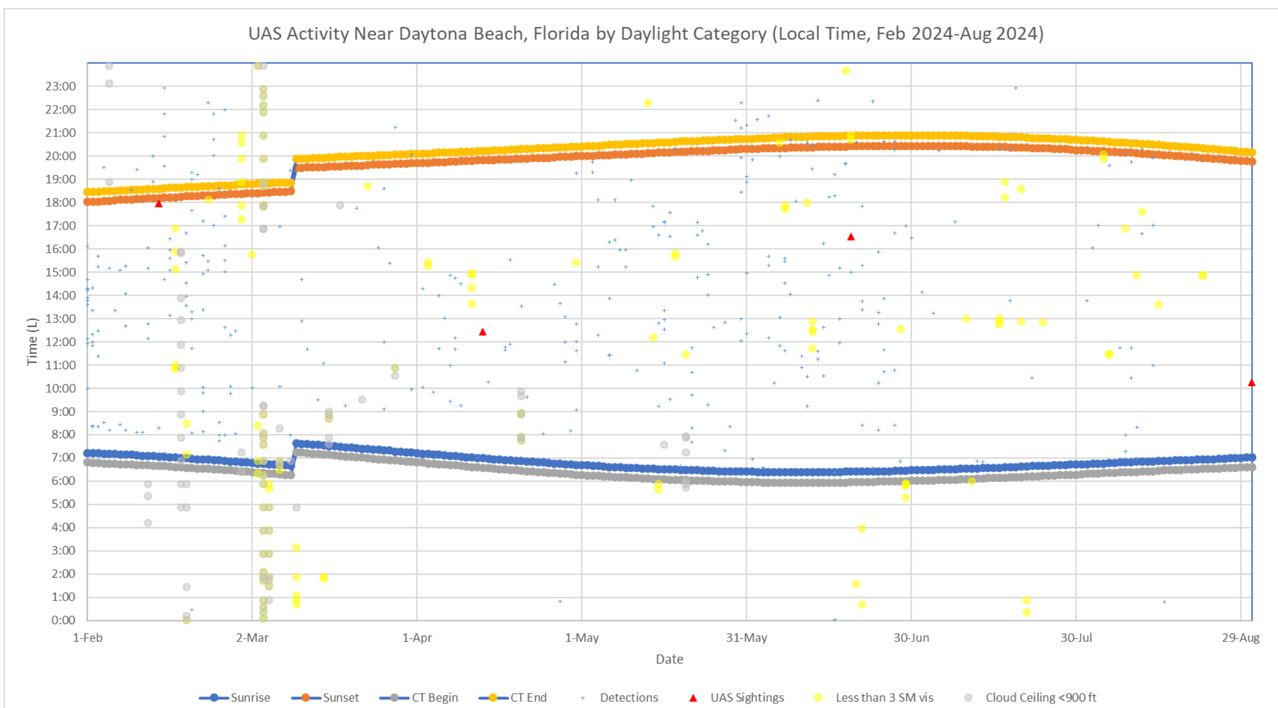


Figure 78. Visibility and Cloud Clearance Exceedance [14 CFR 107.51(c) and (d)(1)] by Date and Time (DAB).

The research team sampled weather information from 5,171 sUAS flights. More than 90.8% of flights (*n* = 4,697) were conducted with reported visibility of 10 or more statute miles. Visibility data was unavailable for less than 0.1% (*n* = 4) flights. Flights conducted in visibility conditions of less than 10 SM are presented in Figure 79. Only 0.7% of flights (*n* = 35) were conducted in visibility conditions less than 3 SM.

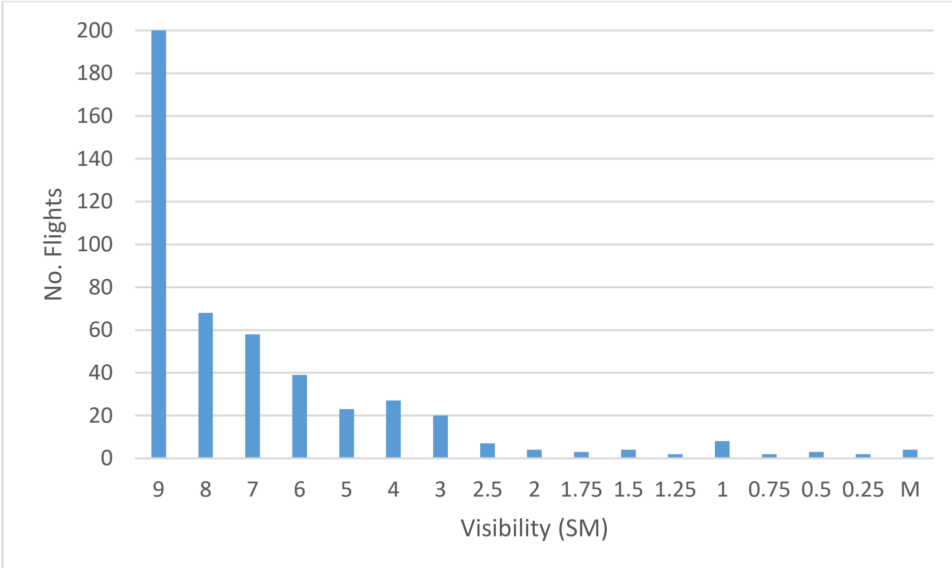


Figure 79. sUAS Flight by Visibility (<10 SM).

Note: Missing data denoted by "M" category (*n* =4).

The research team assessed the reported sky conditions at the onset of each flight. Sky conditions generally include an assessment of cloud coverage and altitudes. Cloud coverage is reported based on the proportion of the sky obscured by clouds. Benchmarks for cloud coverage reporting are contained in Table 12.

Table 12. Sky Condition Reporting Requirements.

Terminology	METAR Abbreviation	Sky Coverage
Clear	CLR	0 / 8
Few	FEW	1-2 / 8
Scattered	SCT	3-4 / 8
Broken	BKN	5-7 / 8
Overcast	OVC	8 / 8
Vertical Visibility	VV	8/ 8 (with sky obscuration)

At least 5,167 sUAS flights (*n*=99.9%) contained sky condition reports. A majority of sUAS flights were carried out in Clear [CLR] skies (*n* = 31.4%), with Few clouds [FEW] (*n*=32.6%), or in Scattered conditions [SCT] (*n* = 17.5%). Ceilings of greater than 5/8 sky coverage were present in 960 sUAS flights (*n* = 18.6%), with 12.6% of flights carried out in Broken [BKN] conditions, 6.0% of flights in Overcast [OVC] conditions, and less than 0.1% of flights containing Vertical Visibility [VV] obscuration reports. Figure 80 highlights reported ceiling conditions and altitude distributions during detected sUAS flights.

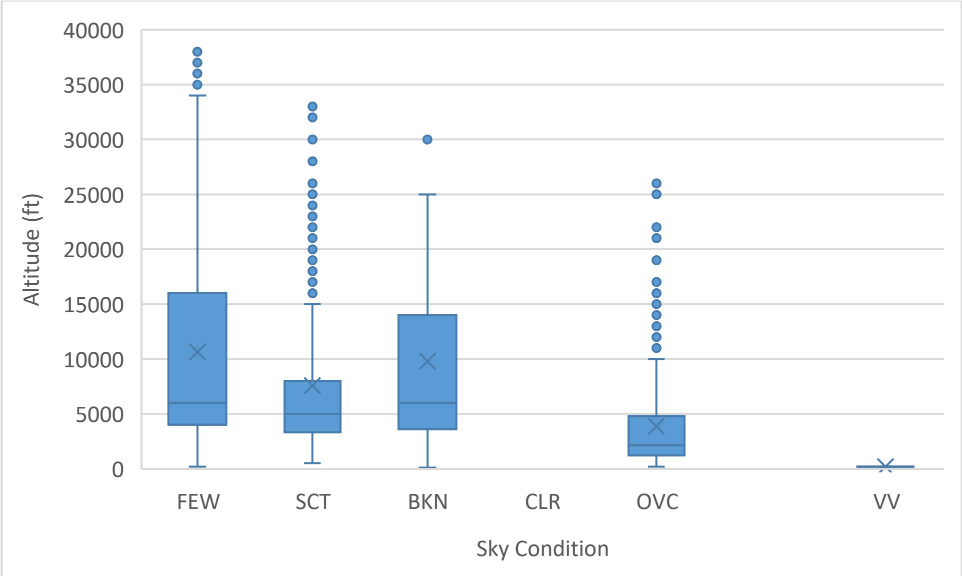


Figure 80. Flight Operations by Sky Condition.

Figure 81 Overviews the distribution of altitudes for sUAS flights in which a ceiling condition (i.e. BKN, OVC, or VV) was reported with an altitude of less than or equal to 900 ft. Ceilings of less than 900 ft would necessitate restricting maximum sUAS flight altitudes to comply with 14 CFR §107.51(d)(1), which requires sUAS to maintain a minimum distance of 500 ft below clouds. Ceilings were reported for a total of 1,826 flights (*n* = 35.3%). Sixty-two reports (*n* = 1.2% of all flights; *n* = 3.4% of flights with a reported ceiling) were identified for cases where a ceiling was reported at an altitude of 900 feet or less. Only 22 flights (*n* = 0.4% of all flights; *n* = 1.2% of flights with a reported ceiling) were conducted with a reported ceiling of 500 feet or less. Under these conditions, it would be tough to maintain compliance with the 500-ft 14 CFR §107.51(d)(1) vertical clearance requirements from clouds, as the maximum operational flight altitude would be essentially ground level.

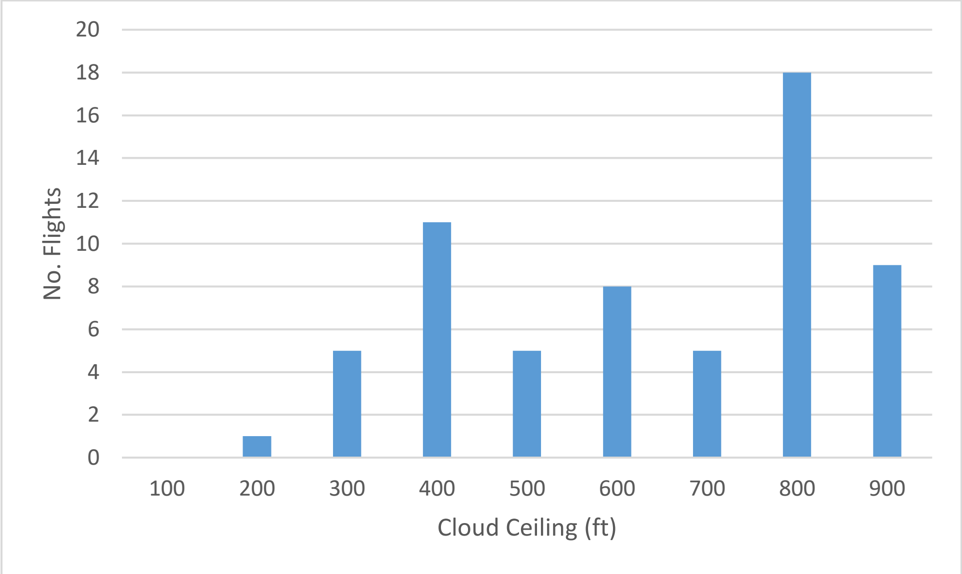


Figure 81. Flight Frequency by Ceiling Maximum.

The research team also assessed routine aerodrome weather report (METAR) weather condition codes that were in effect at the onset of each flight. One hundred thirty-two flights (*n* = 2.6%) were conducted during weather codes. A total of 146 weather codes were identified during the analysis, with some UAS flights subject to more than one weather code. Summary findings are presented in Figure 82. Flights during visibility-obscuring conditions, such as haze (HZ), were most prominent, affecting 67 flights (n=1.3% of flights), followed by 45 flights (*n* = 0.9%) conducted during mist (BR) conditions. A total of 17 flights (*n* = 0.3%) were conducted during reported thunderstorm (TS) conditions, and a further nine flights (*n* = 0.2%) were conducted with thunderstorms in the vicinity (VCTS).

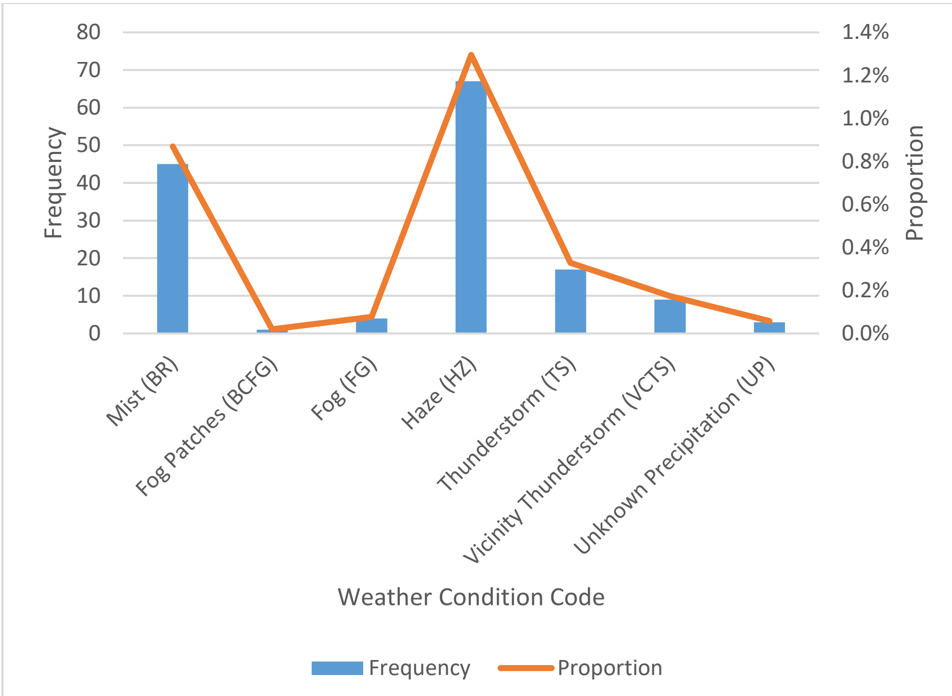


Figure 82. Frequency of sUAS Flight During Selected Weather Condition Codes (*n* = 5,171 flights).

The research team further assessed flight activity during periods of reported precipitation (see Figure 83). Precipitation levels are reported in millimeters per hour (mm/hr). Precipitation can adversely affect sUAS's electrical systems. In 2020, the Air Accident Investigation Branch of the United Kingdom issued a warning to users of the DJI Matrice 200-series sUAS, indicating that 16 prior accidents had been reported over 18 months due to ingress of moisture into aerial vehicle electrical components (Thompson, 2020). Precipitation rates are also relevant to reported manufacturer Ingress Protection (IP) ratings, which prescribe maximum limits for water, dust, and related contaminants. Precipitation was reported during 50 sUAS flights (*n* = 1.0%). Precipitation of 1mm comprised 34 sUAS flights (*n* = 0.7%), loosely equating to IPX1 rating. Precipitation over 1mm/hr extending up to 3mm/hr comprised 12 flights (*n* = 0.2%), which approximates requirements for the IPX2 rating. A total of four flights (*n* = <0.1%) reported hourly precipitation rates over 3mm.

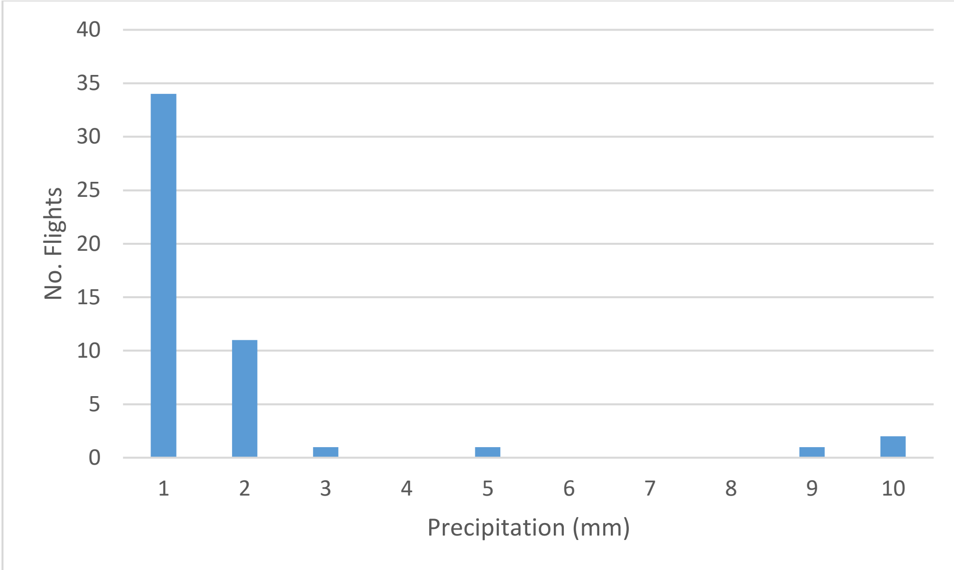


Figure 83. Flights During Various Precipitation Levels (mm).

Temperatures were analyzed during each flight to evaluate potential operational implications, based on manufacturer-prescribed limitations (see Figure 84). For example, the Mavic 3, a popular DJI-manufactured sUAS platform has an operating temperature range of 10°C-40°C (approximately 14°F-104°F). Temperature information was available for only two sUAS flights (*n* = <0.1%). Ambient air temperatures recorded during sUAS flights ranged from a low of -2.0°F to a high of 95.0°F. The preponderance of flights were conducted at temperatures between 70°F-75°F. Temperatures are highly influenced by sampling location, season, and local weather factors. Five flights (*n* = 0.1%) were conducted during the sampling period at temperatures less than 14°F. The research team notes that operational temperature limitations vary by *both* manufacturer and model. The prior example is provided merely for contextual purposes.

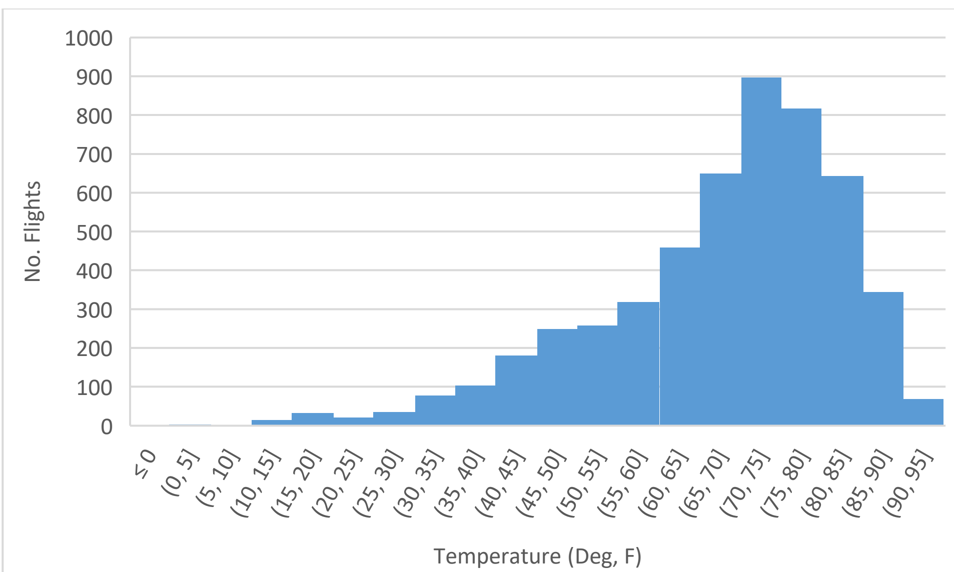


Figure 84. Distribution of sUAS Flights by Temperature (F).

The research team also assessed sustained and gusting wind speeds during sUAS flights. Manufacturers often report maximum wind resistance specifications, identifying the maximum wind speed at which the sUAS can maintain stable flight. Operating at speeds over these prescribed limits can result in flight instability or loss of controllability. Wind resistance limitations vary by manufacturer and sUAS model and are generally reported in the manufacturer specifications or operating manual. For example, the DJI Mini 2 and Mini 3 Pro have reported maximum wind resistance levels of 10.7 m/s (24 mph). Conversely, the DJI Inspire 3—a larger, more powerful sUAS—has a maximum wind resistance of 14 m/s (31.3 mph).

Sustained wind information was available for all but seven sUAS flights (*n* = 0.1%). Gust information is only reported when sustained wind speed exceeds 10 kts (approximately 11.5 mph). Wind gust information was reported during 527 flights (*n* = 10.2%). Summary results for sustained winds are presented in Figure 85 and results for gusting winds are presented in Figure 86. At least 597 flights (*n* = 11.5%) were conducted during calm winds (0 kts/0 mph). The preponderance of sUAS flights (*n* = 3,612, 70%) were performed at wind speeds of less than 10 mph (approx. nine kts).

For contextual purposes, at least eight sUAS flights (*n* = 0.2%) were conducted with sustained winds over 24 mph (approximately 21 kts). No flights were conducted in suffered winds greater than 31.3 mph (approximately 27 kts). At least 195 flights (*n* = 3.8%) were performed with gusts over 24 mph; of those flights, at least 24 (*n* = 0.5%) were conducted with more than 31.3 mph gusts.

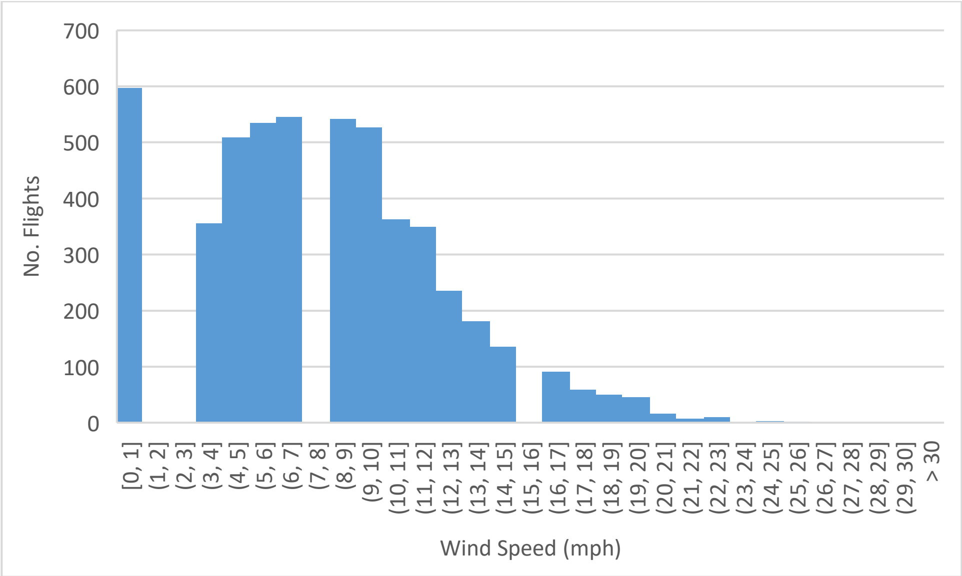


Figure 85. Distribution of sUAS Flights by Sustained Wind Speed (mph).

Note: Distribution gaps due to knots to mph conversion.

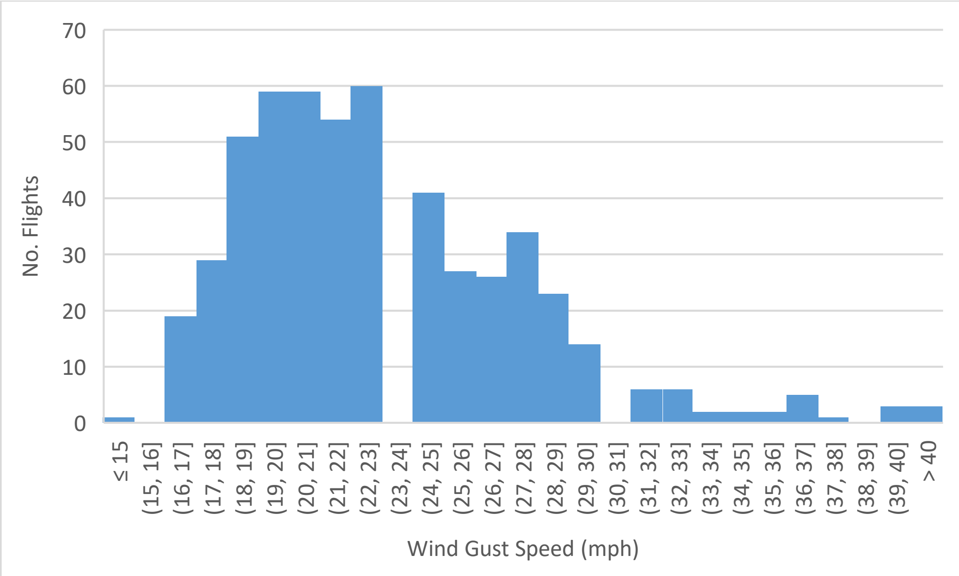


Figure 86. Distribution of sUAS Flights by Wind Gust Speed (mph).

Note: Distribution gaps due to knots to mph conversion.

Figure 87 presents the relationship between reported sustained wind speeds and gusting wind speeds for flights across the dataset. Generally, gusting winds are nearly perfectly correlated with sustained wind speeds at approximately 10 mph more than reported sustained wind speeds.

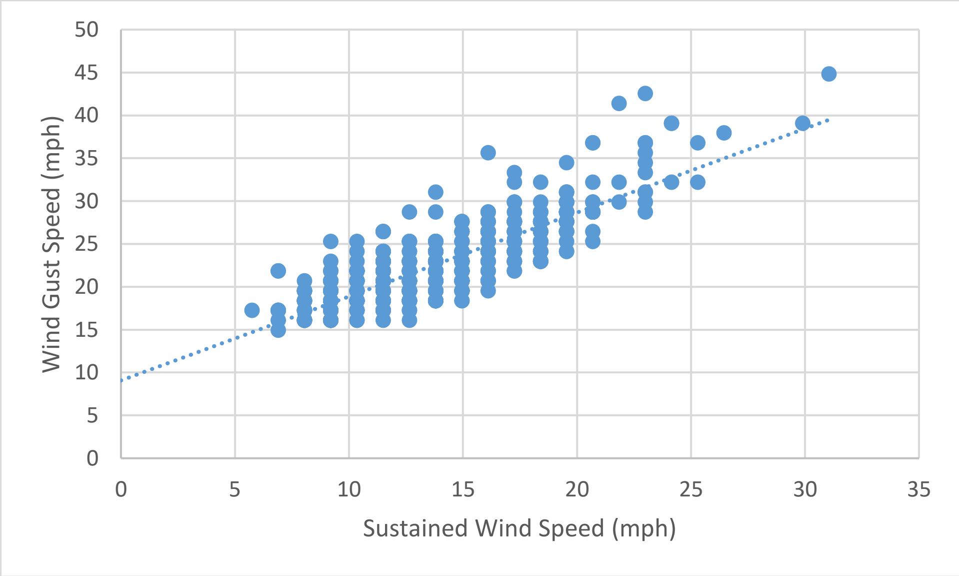


Figure 87. Relationship Between sUAS Flights in Sustained Wind and Gusty Conditions.

3.4 Task D: Near Aerodrome sUAS Operations and Encounter Risks with Manned Air Traffic

This task aimed to highlight potential risks to aviation operations caused by sUAS flights around aerodromes and near manned air traffic. This assessment also identified potential security challenges posed by sUAS operating in no-fly zones and critical infrastructure.

3.4.1 Low Altitude Authorization and Notification Capability (LAANC) Data

The purpose of this assessment was to determine the extent and trends associated with sUAS LAANC approvals in controlled airspace. These trends were then compared against collected Remote Identification data to evaluate alignment or determine identified disparities.

The Low Altitude Authorization and Notification Capability, more commonly known by its acronym LAANC, is another metric that might inform airspace activity—particularly in controlled airspace areas (FAA, 2024d). LAANC provides automated airspace authorizations by allowing remote pilots to submit UAS flight requests electronically. The system checks airspace requests against several data sources, including UAS Facility Maps maximum altitudes, special use airspace data, airspace classification, TFRs, and NOTAMs (FAA, 2024d). According to the FAA (2024, 2024d), LAANC is enabled at more than 726 airports across the U.S. In 2023, LAANC provided 496,914 automated approvals, which accounted for nearly 68.7% of Part 107 operations and 31.3% of 49 U.S.C. §44809 (recreational) operations. Over 90% of LAANC requests receive automated approval, and approximately 8.8% of requests undergo additional coordination. The LAANC system yielded a cumulative 540,674 authorizations for airspace approval in 2023.

For the current project, three sampled airports were included in the LAANC system, including Columbus Municipal Airport (BAK), Daytona Beach International Airport (DAB), and Terre Haute Regional Airport (HUF). Air traffic management specialists determine the configuration and altitude limitations imposed within each facility map. Grids measure approximately 30” in (latitude) length and 30” (longitude) width, with varied altitude limits generally at 50- or 100-foot intervals, usually decreasing in proximity to the airfield. BAK includes 310 individual UAS Facility Map grids, DAB has 405, and HUF has 580.

During the sampling period (November 2023-November 2024), the three airports collectively issued 4,464 LAANC approvals, including 282 at BAK, 3,344 at DAB, and 838 at HUF. Of the total 4,464 issued LAANC approvals, 4,422 (*n* = 99.06%) were automated approvals, and 42 (*n* = 0.94%) were approved following additional coordination. The distribution of LAANC approvals for each airport by approval type is provided in Figure 88. Approval details and descriptive statistics for LAANC approvals at each airport are contained in Table 13.

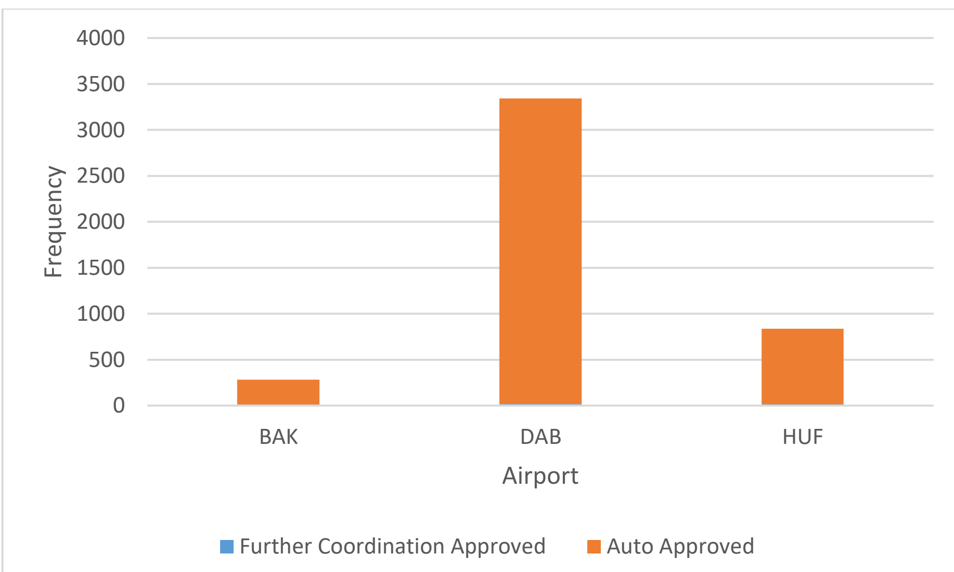


Figure 88. LAANC Approvals by Type.

Table 13. LAANC Approval Statistics by Airport and Regulation Type.

Airport	BAK		DAB		HUF	
Time	BAK (107)	BAK (44809)	DAB (107)	DAB (44809)	HUF (107)	HUF (44809)
N (2023)	6	5	164	41	30	5
D	5	2	125	57	25	8
J (2024)	4	8	161	90	26	14
F	3	5	185	100	48	10
M	2	2	177	132	22	16
A	10	12	225	119	87	41
M	28	5	201	75	70	15
J	36	14	154	93	37	13
J	12	21	149	66	55	19
A	21	11	135	73	56	13
S	17	10	142	77	99	18
O	13	10	268	94	63	11
N	7	13	163	78	32	5
Min	2	2	125	41	22	5
Max	36	21	268	132	99	41
Range	34	19	143	91	77	36
Mean	12.6	9.1	173	84.2	50	14.54
Median	10	10	163	78	48	13
SD	10.4	5.4	39.4	24.5	24.6	9.1

The variability of LAANC data over time at each of the respective airports is relatively limited when compared to Remote ID detection data (see Figure 89 and Figure 90). It is not easy to discern seasonality variability, as was seen in the Remote ID data. The research team believes that the primary driver of this difference stems from the disproportionate level of Part 107 (commercial) operations represented by LAANC approvals. The research team suspects that recreational (44809) operations are more accurately reflected in Remote ID detection data. The research team asserts that Part 107 operations—particularly those conducted for commercial purposes—are more likely to reflect routine, recurrent operations at lesser levels of variability than recreational operators. If this observation is accurate, it may indicate a compliance deviation in recreational operators obtaining airspace approvals under the LAANC system.

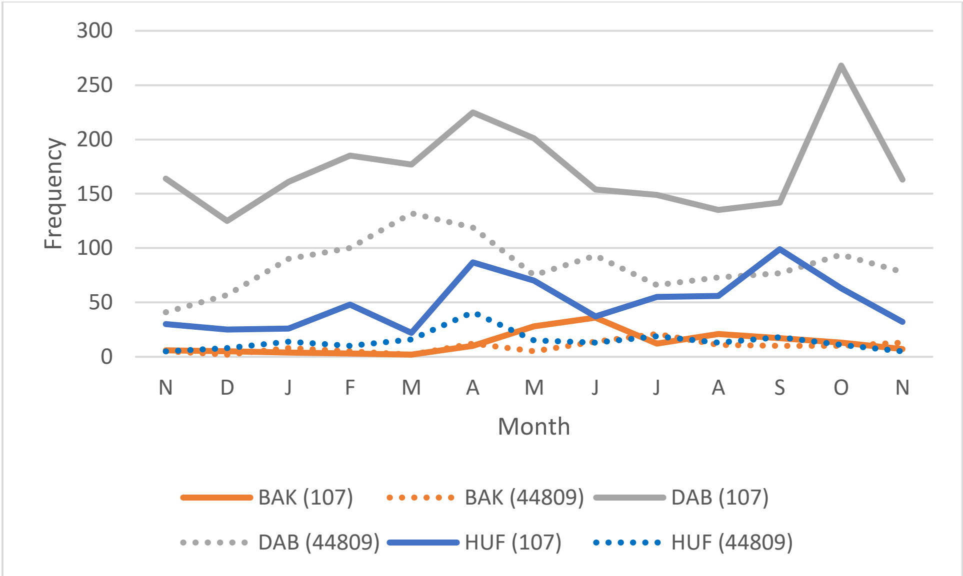


Figure 89. LAANC Approvals by Airport and Regulation.

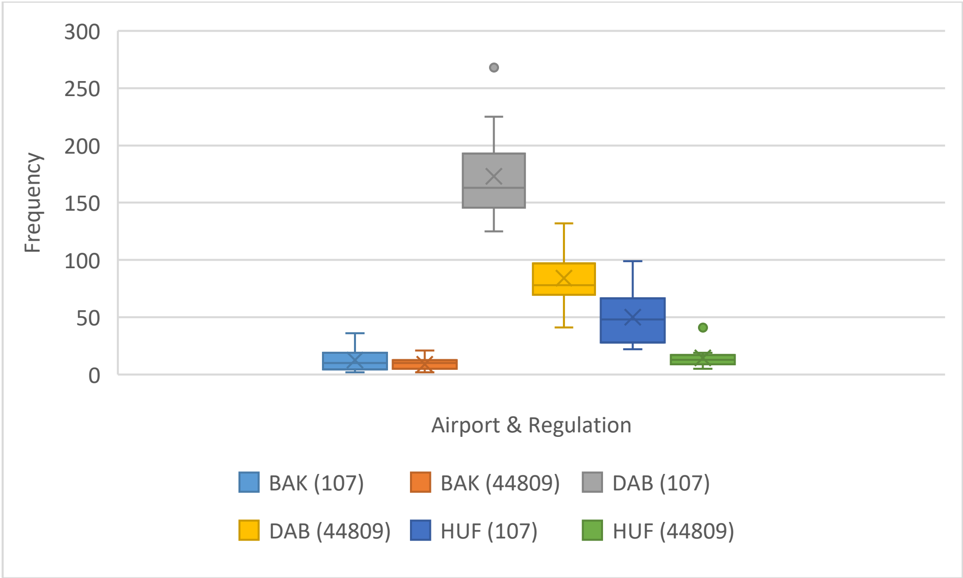


Figure 90. Boxplot of LAANC Approvals by Airport and Regulation.

Several unique observations are available by evaluating geospatial data of LAANC approvals at each respective airport.

Figure 91 Provides a visual heat map of LAANC approval activity at BAK. In this case, the preponderance of approval activity is concentrated at the periphery of the BAK UAS Facility Map, in the southern commercial district adjacent to connecting thoroughfares.

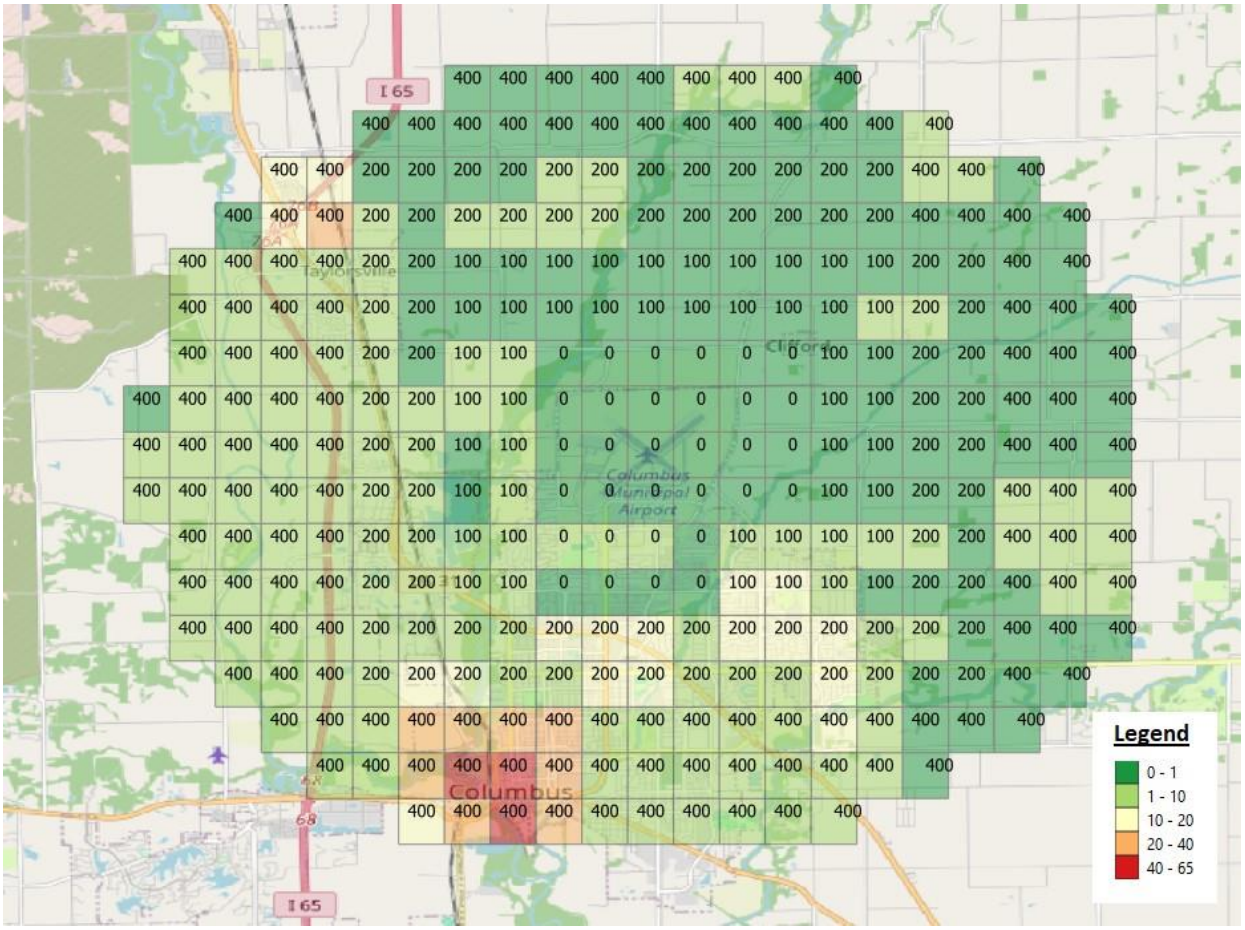


Figure 91. Heatmap of sUAS LAANC Authorizations by Grid at Columbus Airfield (BAK).

Note: Heat mapping Indicates number of LAANC authorizations during sampling period. Numeric value in each grid cell indicates maximum UAS Facility Map altitude (AGL).

Similarly reflected in the Remote Identification data, LAANC approvals primarily occur during daylight hours (See Figure 92). Virtually no activity occurs in the hours leading up to sunrise, with activity rising during the midday hours, and diminishing steadily towards the mid-evening. Part 107 operations are slightly more concentrated in the mornings, with more extensive recreational operations occurring in the late afternoon and continuing into the evening.

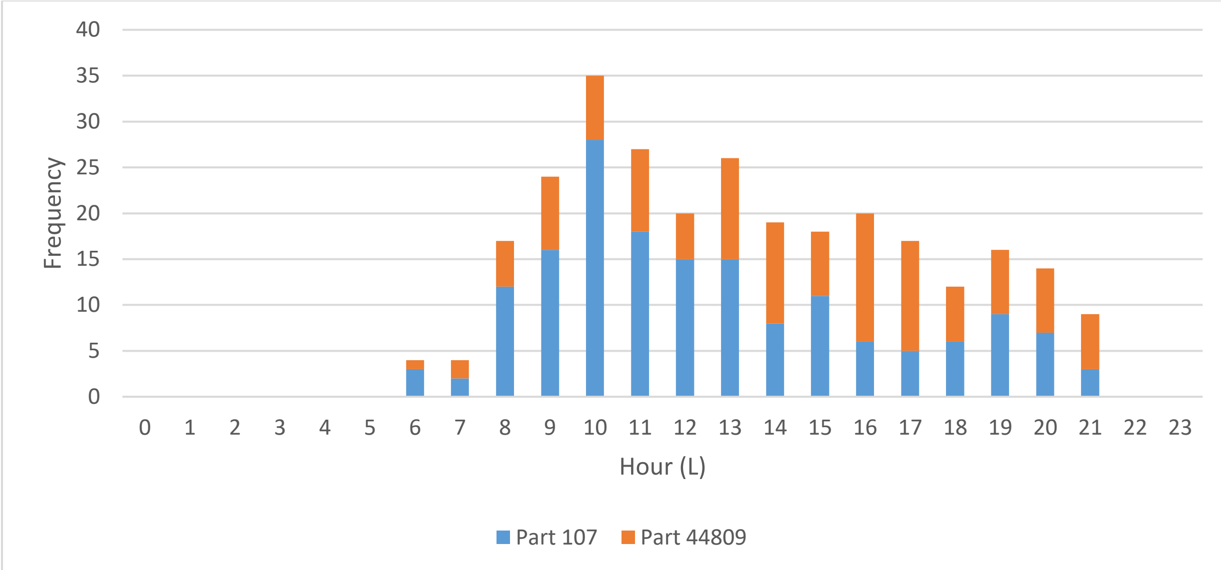


Figure 92. Distribution of LAANC Authorization Start Times (BAK) by Regulation.

Most LAANC approvals at BAK request between two and five UAS Facility Map (UASFM) grids (see Figure 93). While some operations request significantly more airspace, these represent only a tiny proportion of LAANC activity. For airspace areas exceeding five grids, approvals are disproportionately represented by recreational operations, and exclusively for those approvals exceeding 20 grids. The research team does not entirely understand this trend. One possible explanation is that these recreational flights represent fixed-wing operations that require a larger airspace footprint for maneuvering.

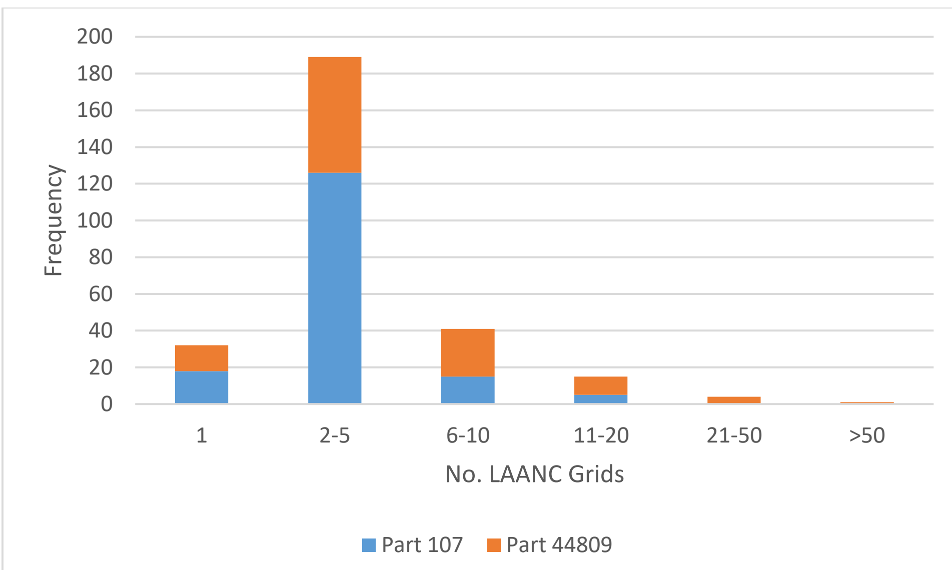


Figure 93. Number of Grids Requested by Regulation (BAK).

Requested LAANC altitudes are reasonably evenly distributed between commercial and recreational operations across most altitude blocks, with a slightly higher representation of Part 107 operators within the highest (300-400 ft) altitude segments (see Figure 94).

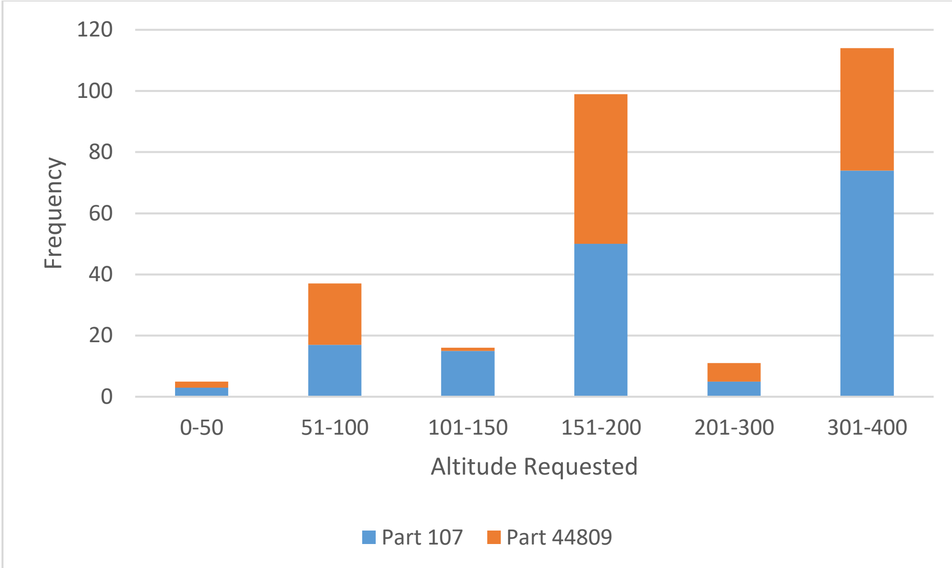


Figure 94. LAANC Grid Altitude Requests by Regulation (BAK).

Most LAANC approvals at BAK are relatively short, with 45.0% (*n*=127) lasting less than one hour and 32.3% (*n*=91), lasting between one and two hours in duration (see Figure 95). Collectively 22.7% of approvals (*n*=64) represent longer-duration flights, up to 12 hours.

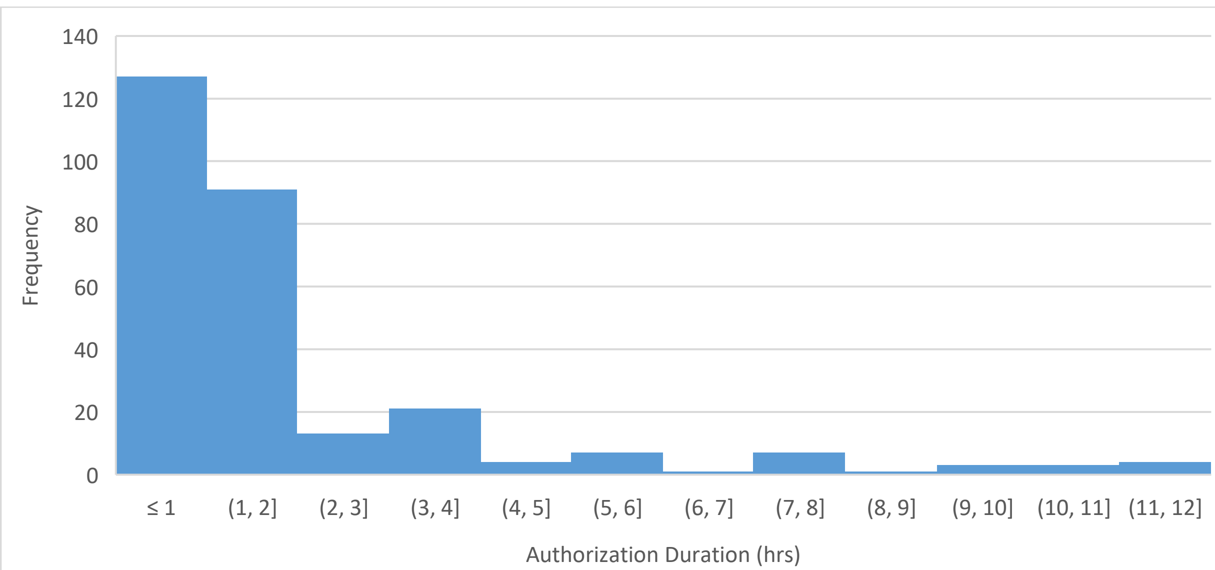


Figure 95. Distribution of BAK LAANC Authorization Duration (hrs).

To further illustrate LAANC grid utilization, the research team plotted all LAANC approvals to compare the total number of LAANC grids requested and the cumulative duration of time requested (see Figure 96). Flights that requested larger numbers of grids were generally short—usually just a few hours. Conversely, flights that requested fewer grids had wider variability, with some lasting as long as 12 hours.

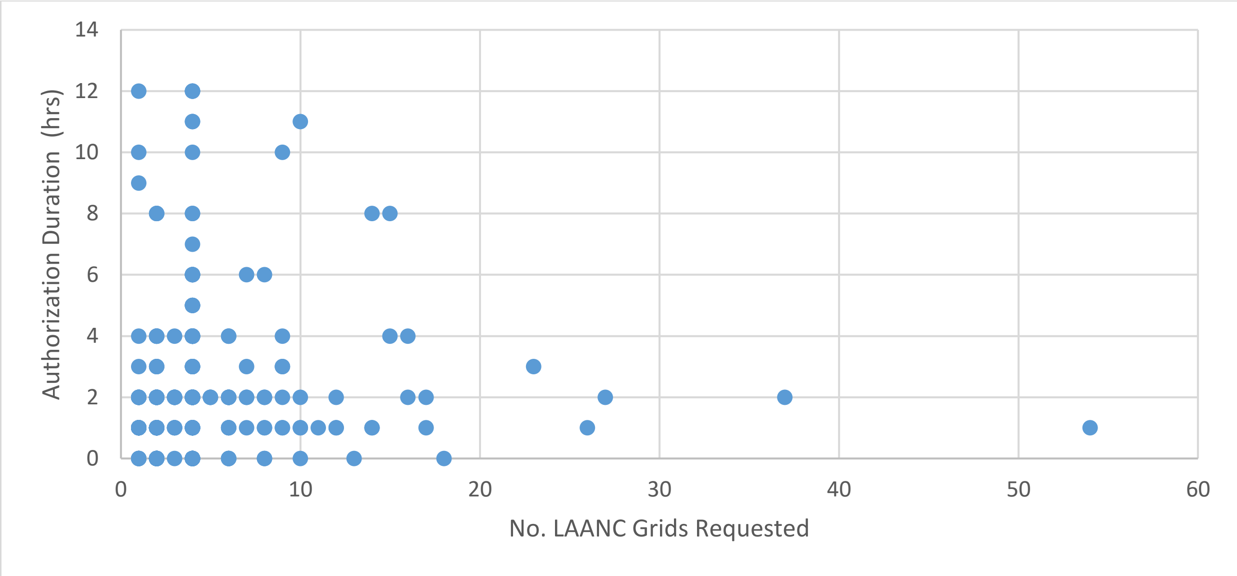


Figure 96. Scatterplot of BAK Requested LAANC Grids to Authorization Duration.

Figure 97 shows a heat map of LAANC authorization activity at DAB. While remote ID data collection did not extend throughout the entire data collection period (Nov 2023-Nov 2024), this analysis includes LAANC authorization data for the whole sampling period to enable effective comparison with the other sample locations. Elevated LAANC authorization activity is noted along the periphery of the UASFM grid to the northeast, along the ocean beachfront, and to a lesser extent on the inter-coastal Halifax River areas. Both of these areas are popular tourist destinations. Medium activity is noted in other places, generally corresponding to the urbanized portions of the UASFM grid map.

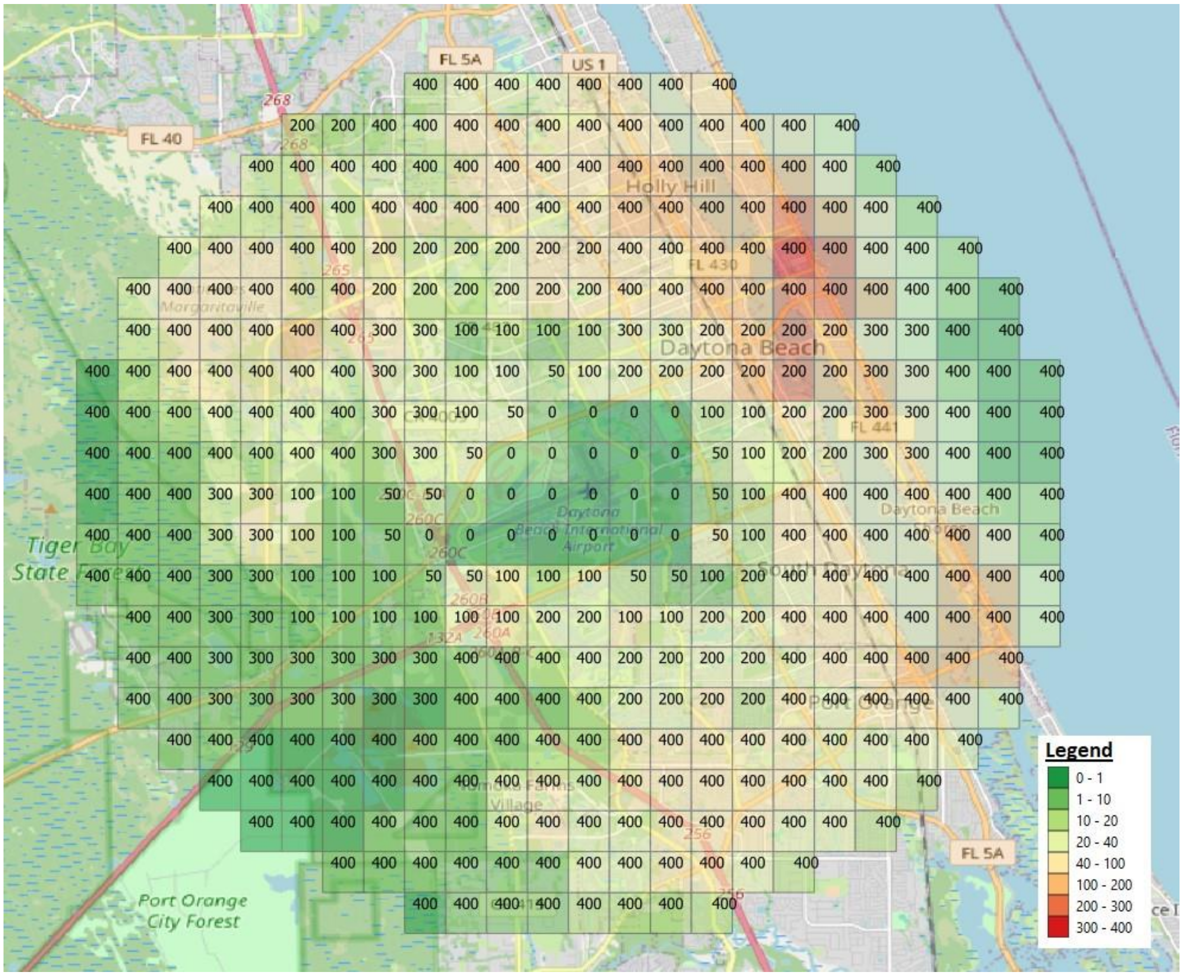


Figure 97. Heat Map of sUAS LAANC Authorizations by Grid at Daytona Beach Airfield (DAB).

Note: Heat mapping Indicates number of LAANC authorizations during sampling period. Numeric value in each grid cell indicates maximum UAS Facility Map altitude (AGL).

Like BAK, LAANC activity at DAB occurs primarily during daylight hours (see Figure 98). Activity is noted shortly after sunrise, peaking in the morning hours, and steadily diminishing mid-afternoon to evening. DAB LAANC activity is disproportionately represented by higher levels of Part 107 authorizations.

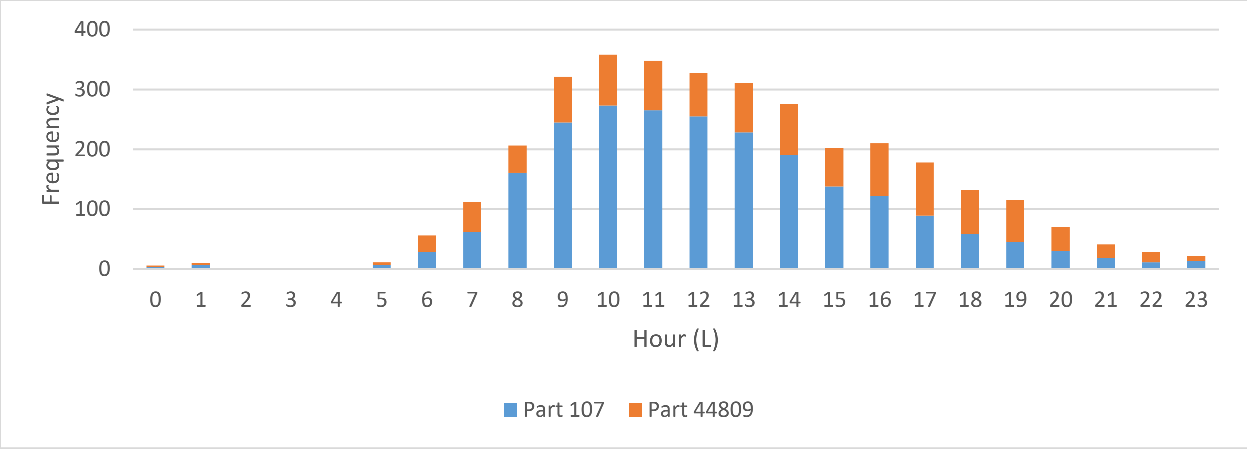


Figure 98. Distribution of LAANC Authorization Start Times (DAB) by Regulation.

Similar to BAK, most LAANC authorizations include approvals for between two and five grids (see Figure 99). Small numbers of activity requests and higher numbers of grids are generally limited.

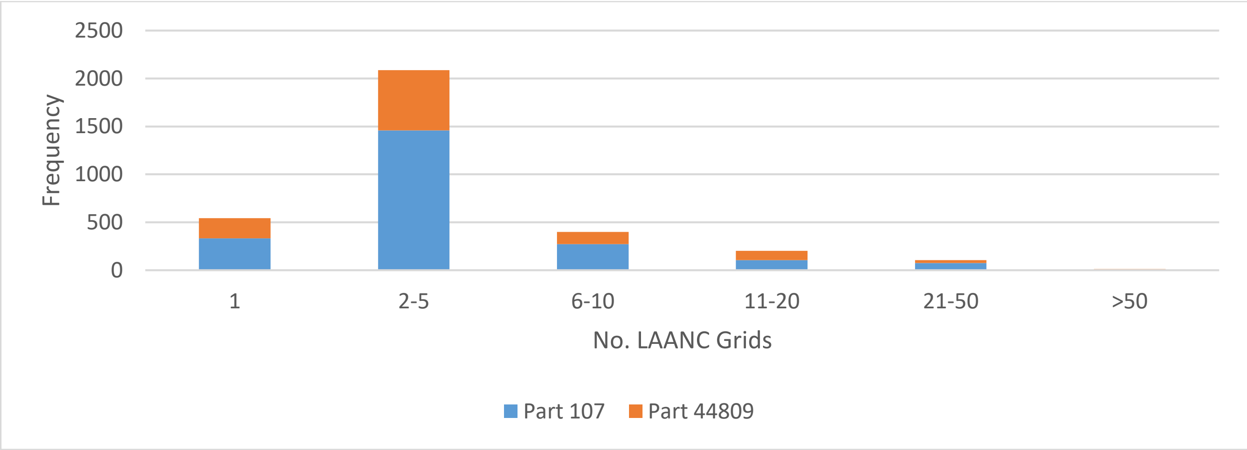


Figure 99. Number of Grids Requested by Regulation (DAB).

The distribution of LAANC authorization altitudes is largely similar to BAK, with the highest number of authorizations applying to 300-400 ft grids (see Figure 100). The research team believes this trend is due to the higher number of 400-ft UASFM grids within each UASFM area. This finding may also indicate a trending elevated level of demand for operations at the periphery of airport areas. The research team believes some of this activity may be location-specific (i.e. operations conducted at designated locations supporting a particular mission set). However, it is suspected that some sUAS activity may not require a specific location and authorizations are requested in areas that do not have a significant altitude restriction (i.e. 400-ft UASFM grid areas).

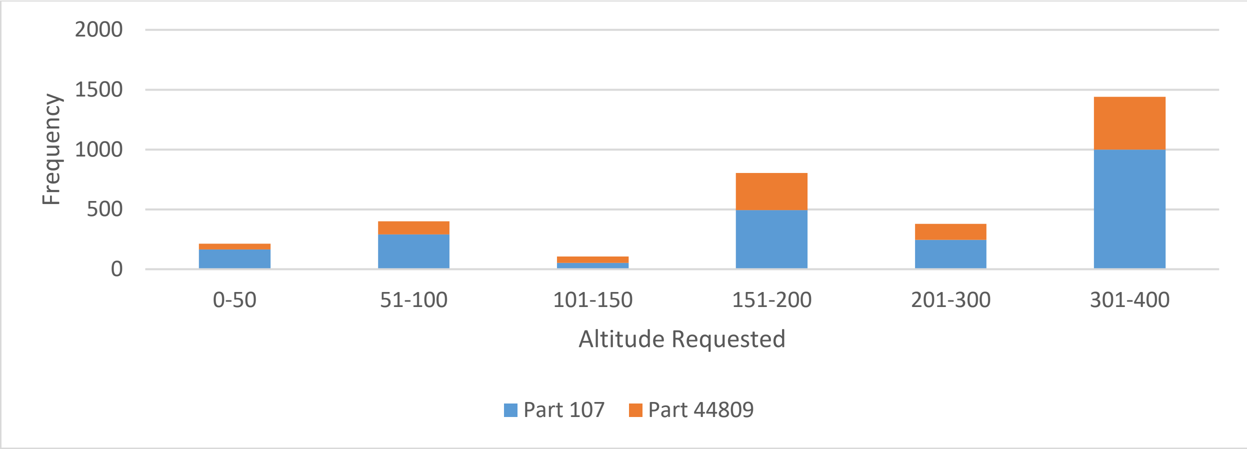


Figure 100. LAANC Grid Altitude Requests by Regulation (DAB).

Like BAK data, the majority of LAANC authorizations were granted for periods of less than two hours (see Figure 101). Although some authorizations lasted much longer, these were generally few in number.

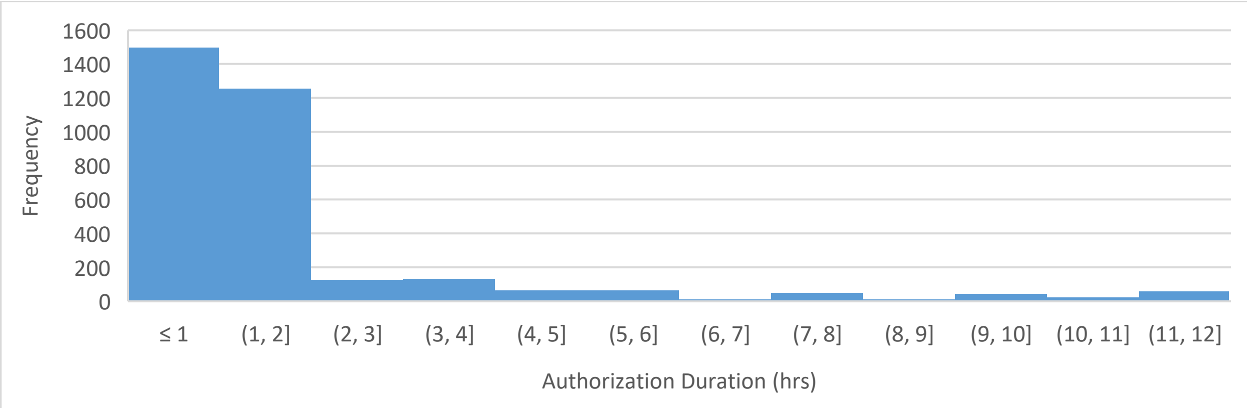


Figure 101. Distribution of DAB LAANC Authorization Duration (hrs).

When comparing the number of requested LAANC grids to authorization duration, it was noted there were several requests for a large number of LAANC grids (more than 70) for a moderate duration of approximately seven or fewer hours (see Figure 102). The research team is inquisitive about what operations would require such a large area. The research team highly suspects that these areas represent fixed-wing operations, as it would be doubtful that multi-rotor sUAS operations would require such a large operational footprint.

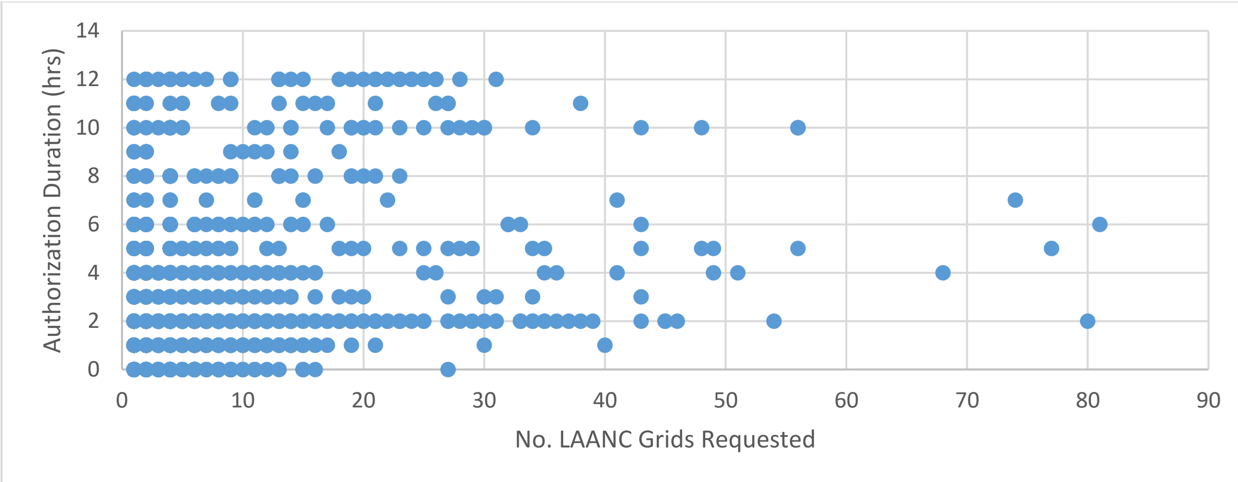


Figure 102. Scatterplot of DAB Requested LAANC Grids to Authorization Duration (hrs).

Analysis of LAANC authorizations in the Terre Haute area in proximity to HUF airport indicates elevated activity in the west periphery of the airfield UASFM area (see Figure 103). This area corresponds to the central commercial district near Indiana State University. Moderate activity was noted immediately west of the airfield, which primarily comprises residential neighborhoods.

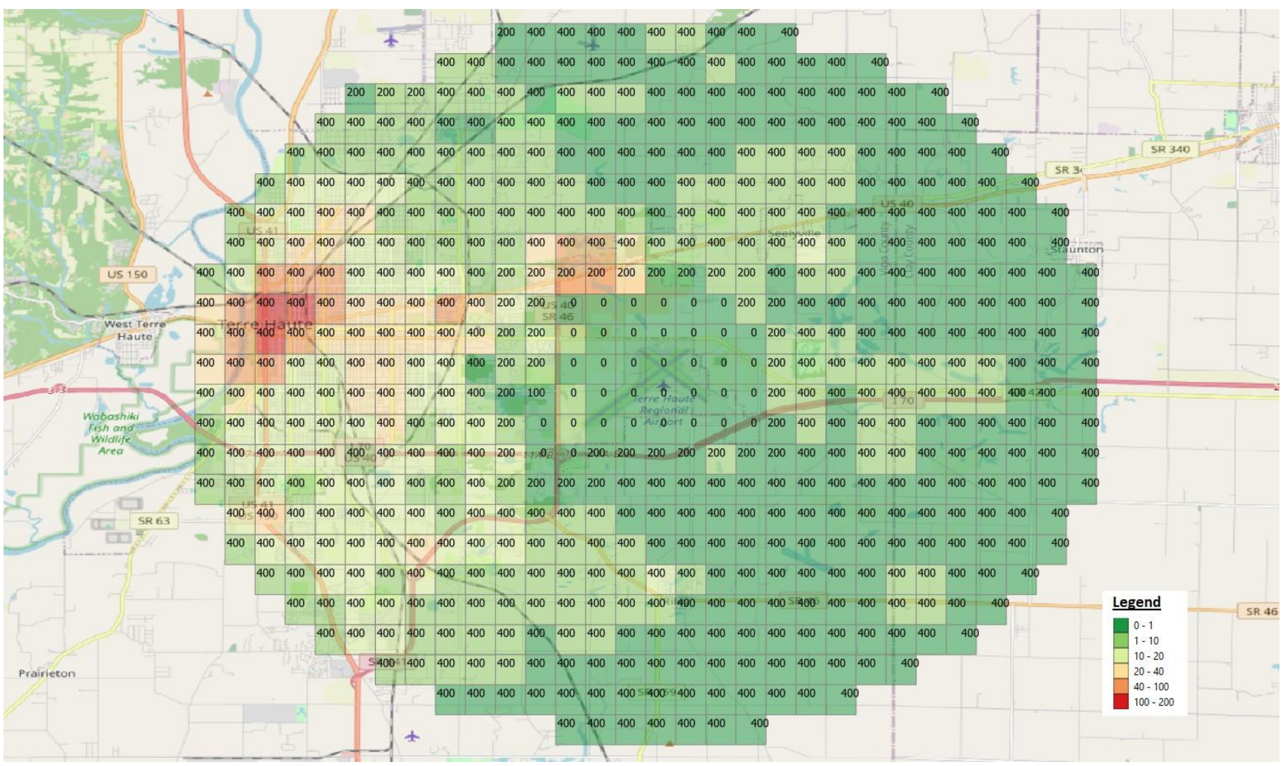


Figure 103. Heat Map of UAS LAANC Authorizations by Grid at Terre Haute Airfield (HUF).

Note: Heat mapping Indicates number of LAANC authorizations during sampling period. Numeric value in each grid cell indicates maximum UAS Facility Map altitude (AGL).

Like both BAK and DAB, HUF authorization times generally aligned with daylight hours (see Figure 104).

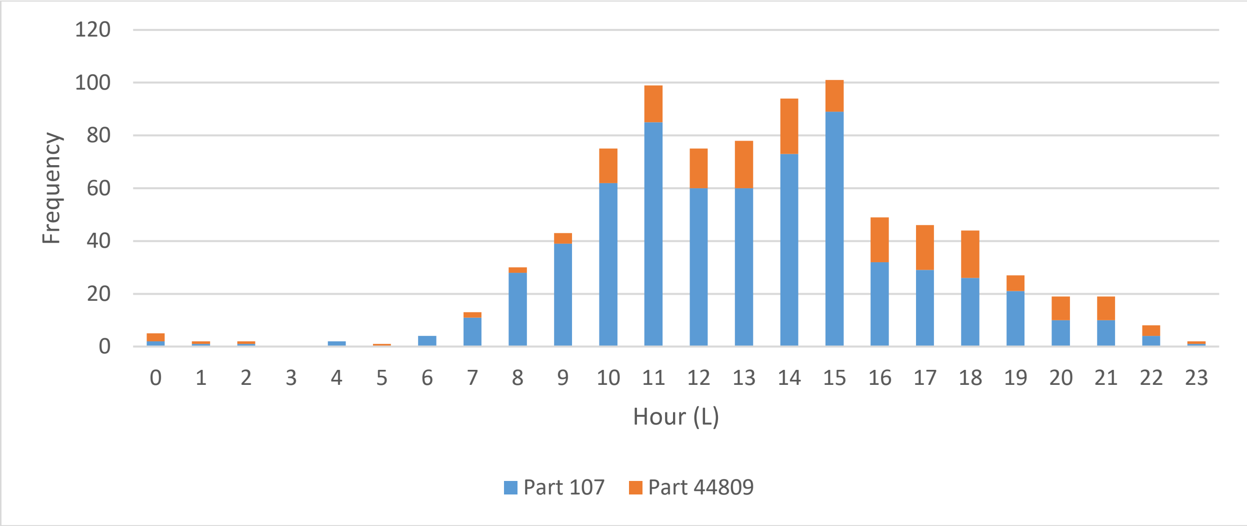


Figure 104. Distribution of LAANC Authorization Start Times (HUF) by Regulation.

Similarly, the preponderance of requested grids at HUF was between 2-5 (see Figure 105).

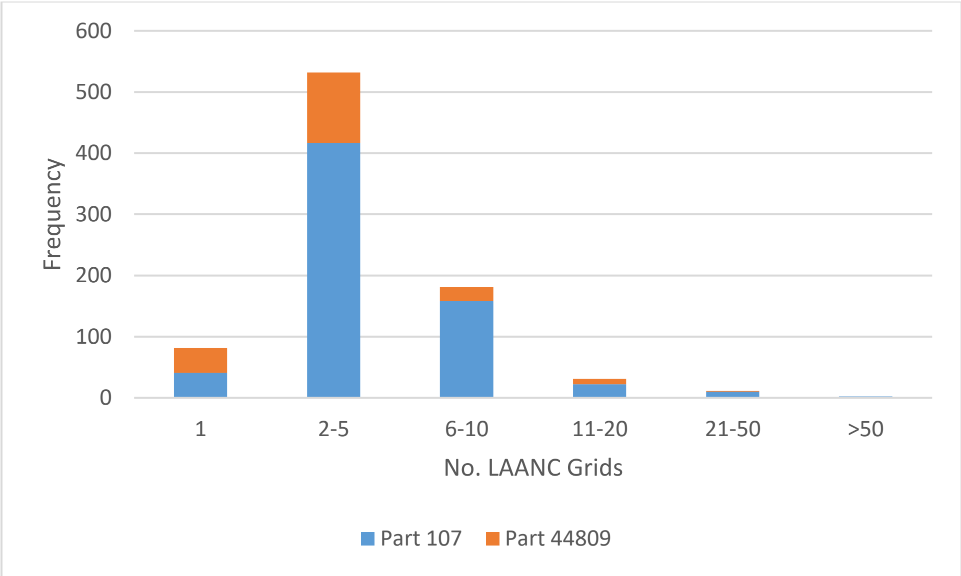


Figure 105. Number of Grids Requested by Regulation (HUF).

Although proportions differ slightly, the majority of requested altitudes for HUF were for 300-400 feet AGL, and to a lesser extent, 150-200 feet AGL (see Figure 106).

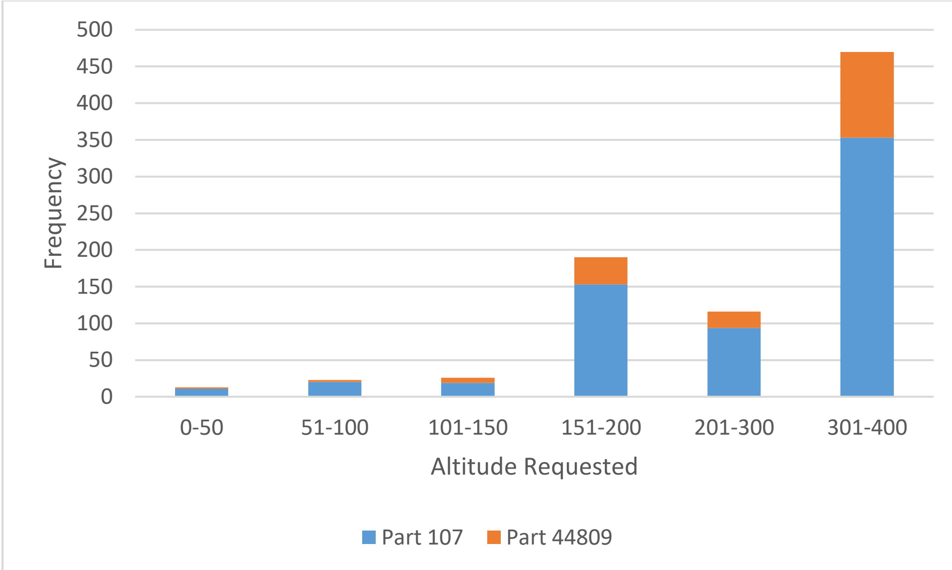


Figure 106. LAANC Grid Altitude Requests by Regulation (HUF).

LAANC authorizations at HUF were slightly longer than either DAB or BAK, with the preponderance of authorizations approved for between one and two hours (see Figure 107).

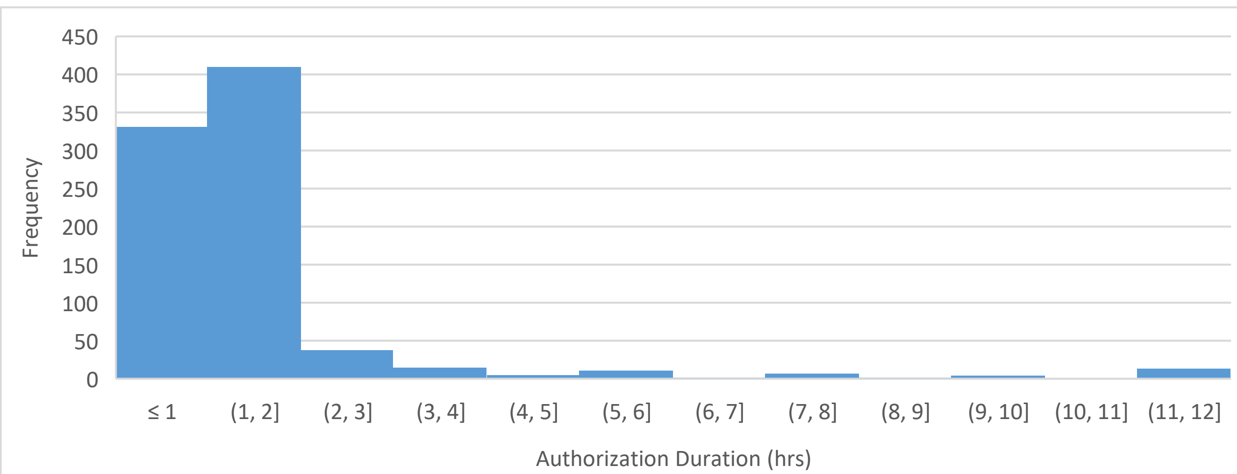


Figure 107. Distribution of HUF LAANC Authorization Duration (hrs).

The distribution of requested grids at HUF and authorization was reasonably in line with BAK (see Figure 108). The research team noted three notable outliers—one approval for 125 grids for a duration of 12 hours; a second for 68 grids for 1 hour; and an approval for 40 grids for a period of 6 hours. When compared to Remote ID telemetry patterns for all sample locations (See Figure 109, Figure 110, and Figure 111), the researchers did not note any flight telemetry that *actually used* the full extent of the requested grids. The researchers note it is possible that approved flights were not transmitting Remote Identification, or that Remote Identification signals were not received due to extreme signal range, obstructions, terrain masking, or other related reasons.

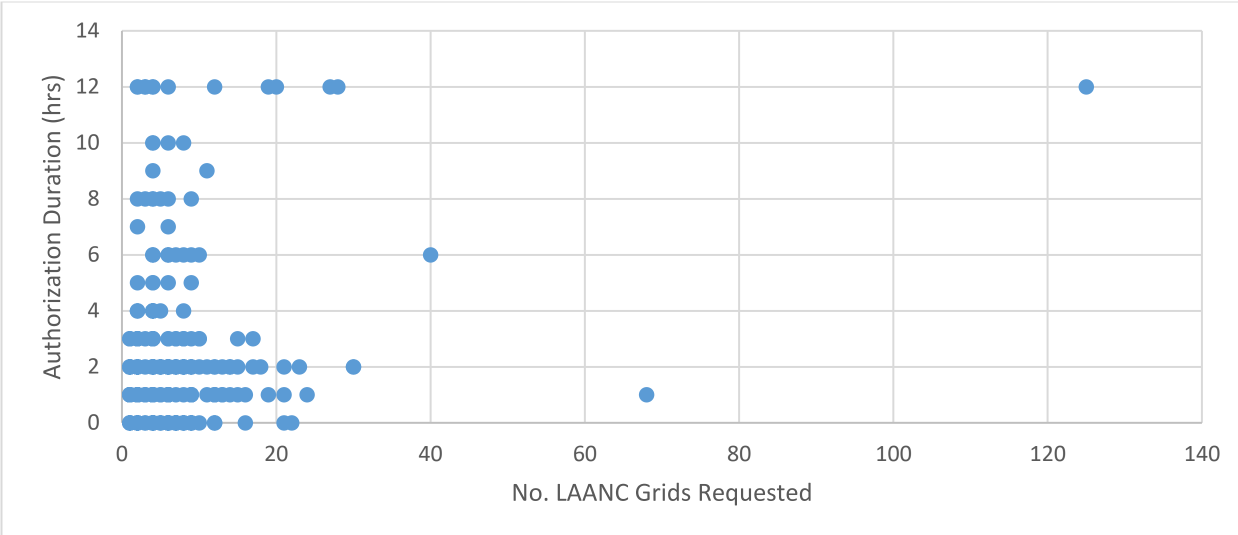


Figure 108. Scatterplot of HUF Requested LAANC Grids to Authorization Duration (hrs).

While research team provided a description of activity concentrations for each sample location in a previous section, this section includes telemetry plots with accompanying UAS Facility Map grids and accompanying maximum altitudes for contextual purposes (see Figure 109, Figure 110, and Figure 111).

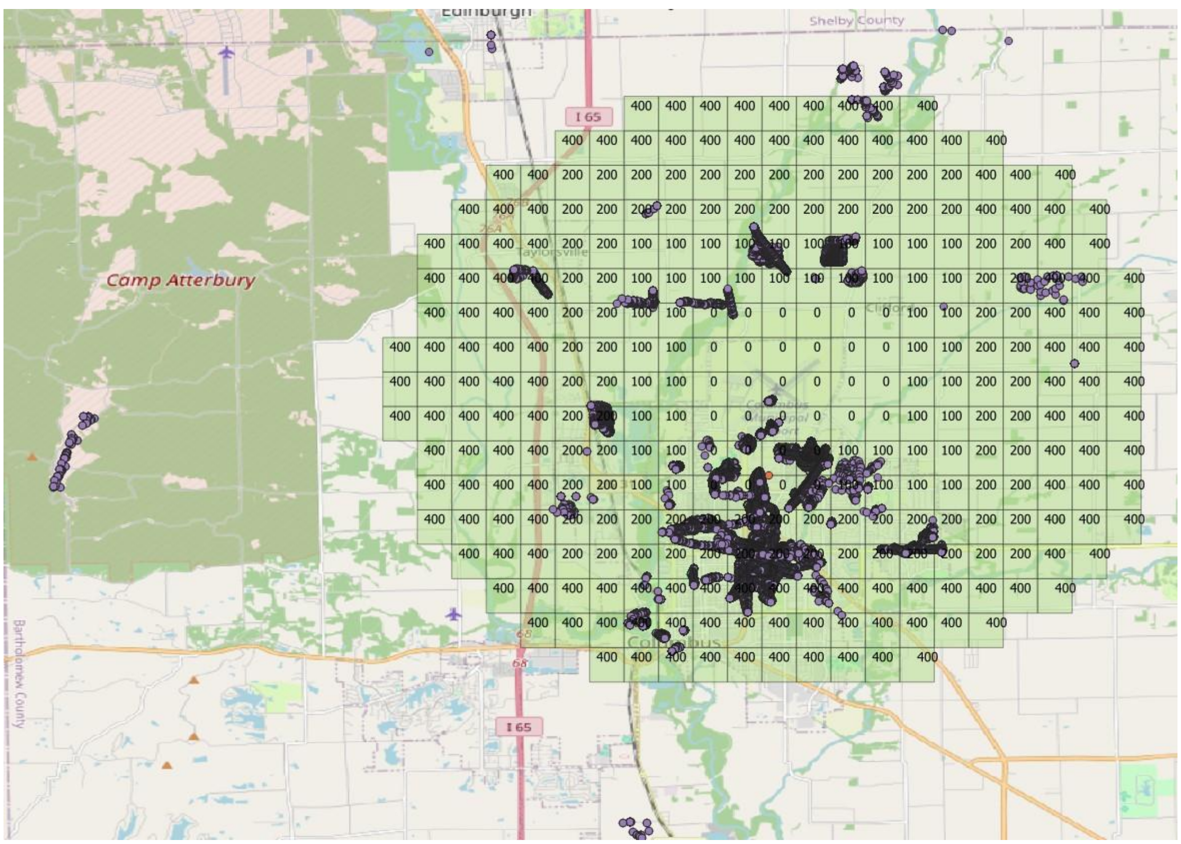


Figure 109. sUAS Detections within UAS Facility Map Grids in Proximity to Columbus (BAK).

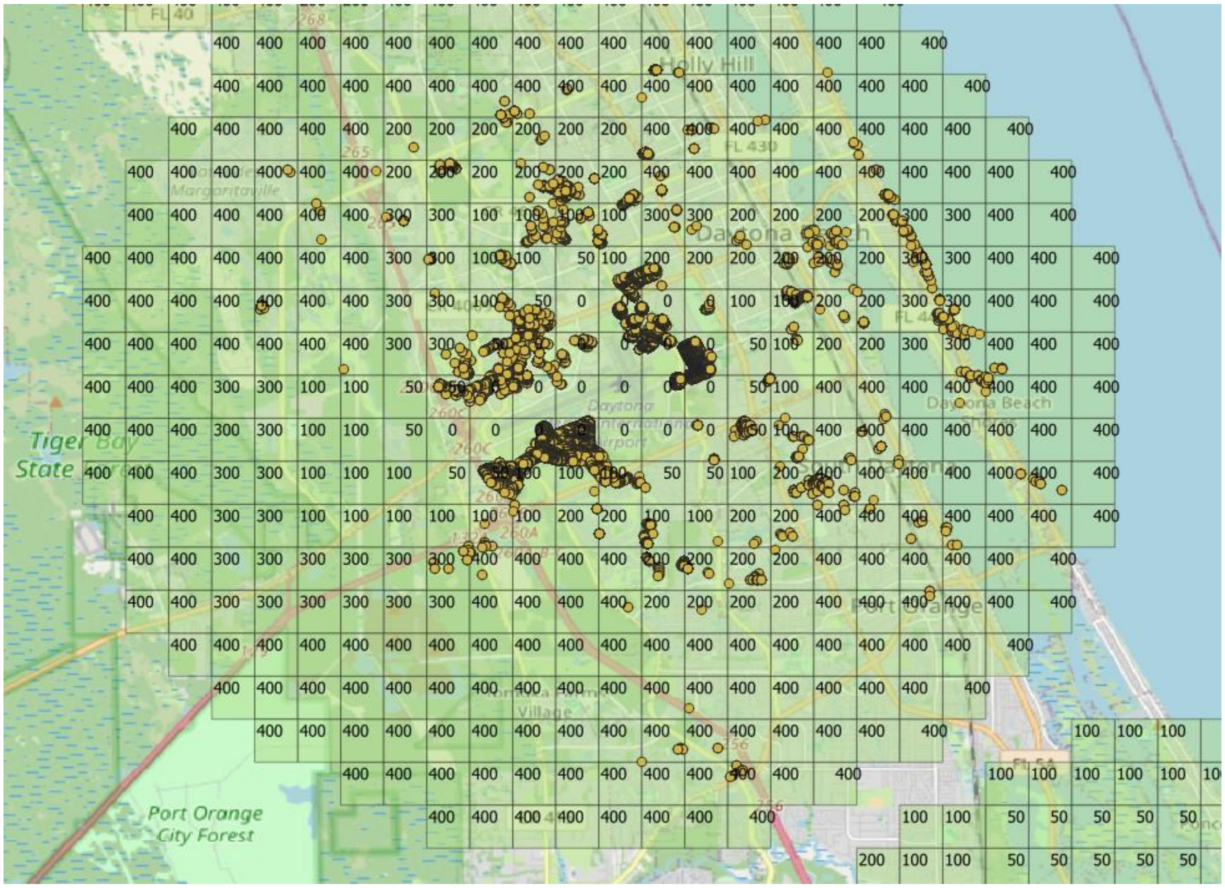


Figure 110. sUAS Detections within UAS Facility Map Grids in Proximity to Daytona Beach (DAB).

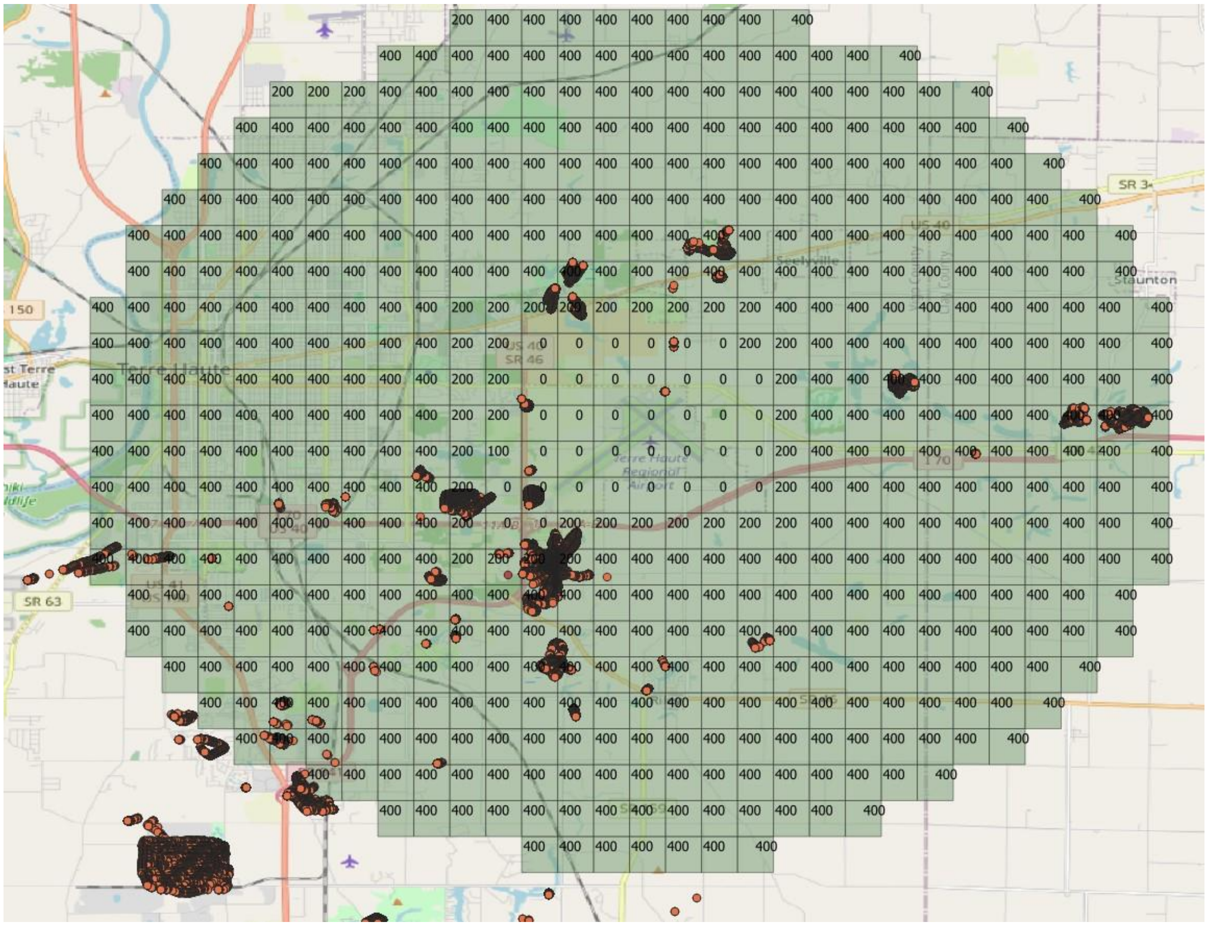


Figure 111. sUAS Detections within UAS Facility Map Grids in Proximity to Terre Haute (HUF).

3.4.2 sUAS Exceedances of UAS Facility Map Grid Altitudes

The purpose of this assessment was to evaluate the extent of sUAS operations flying above the maximum sUAS facility map altitudes. Generally determined by air traffic control specialists and airspace managers for each respective airport, UAS Facility Map altitudes are established to ensure sUAS operations can be conducted safely in controlled airspace without causing interference or presenting a collision or safety risk to manned aviation operations.

The research team correlated sUAS operations detected with Remote ID in each sample area with UASFM grids. This enabled the research team to further assess detected sUAS altitudes against maximum UASFM grid altitudes. Altitudes were both assessed on a per-flight basis, as well as individual Remote ID message basis. More detected Remote ID messages at elevated altitudes equates to more time a sUAS is active at those altitudes. Therefore, evaluating sUAS based on individual Remote ID messages provides a more effective means for assessing potential NAS and manned aircraft collision risk exposure. Finally, the research team assessed the time and UASFM grids where detected flights were conducted to determine if a LAANC approval was active for the relevant locations.

The research team was able to correlate 409 flights in the Columbus (BAK) as being operated inside the UASFM area. Figure 112 shows the distribution of maximum altitudes (AGL) for each of these correlated flights.

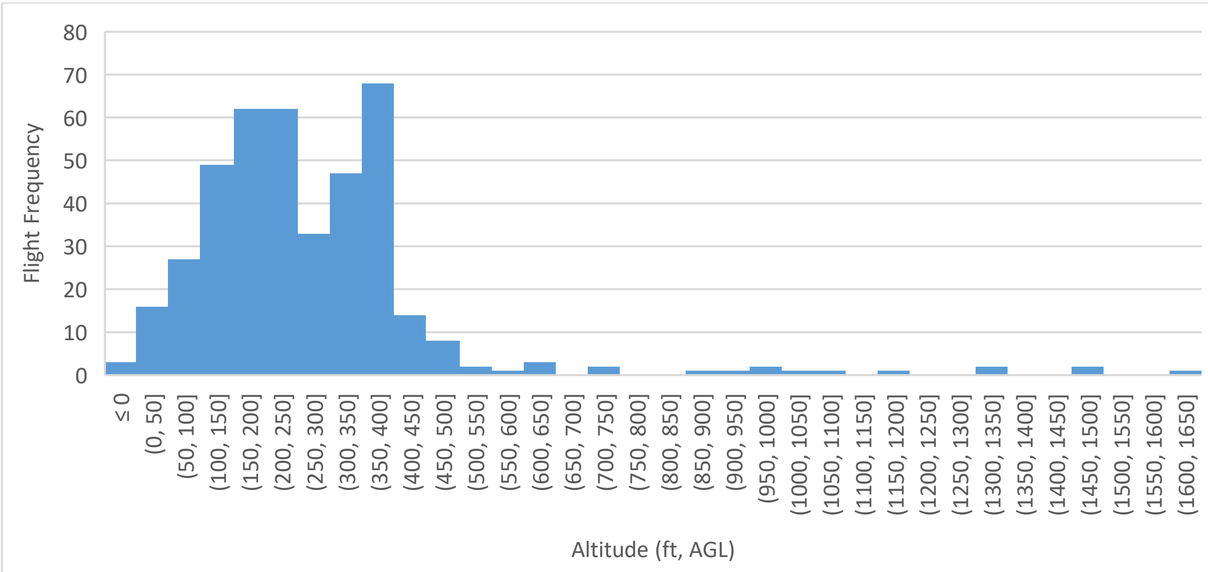


Figure 112. Distribution of Maximum Altitudes (AGL) for sUAS Flights in BAK UASFM Grids.

Figure 113 is a scatterplot of the difference between the ceiling of the correlated grid in which the sUAS was operating, relative to the maximum altitude detection of the sUAS. Values on the X-axis are individual sUAS flights, whereas values on the Y-axis represent the altitude above (+) or below (-) the UASFM grid maximum. For BAK, 218 (*n*=53.3%) flights had positive values, meaning that they were flown *above* the UASFM grid maximum. At BAK, 190 flights (*n*=46.5%) had negative values (flown below grid limits) and one flight had a zero-value (flown at grid limit).

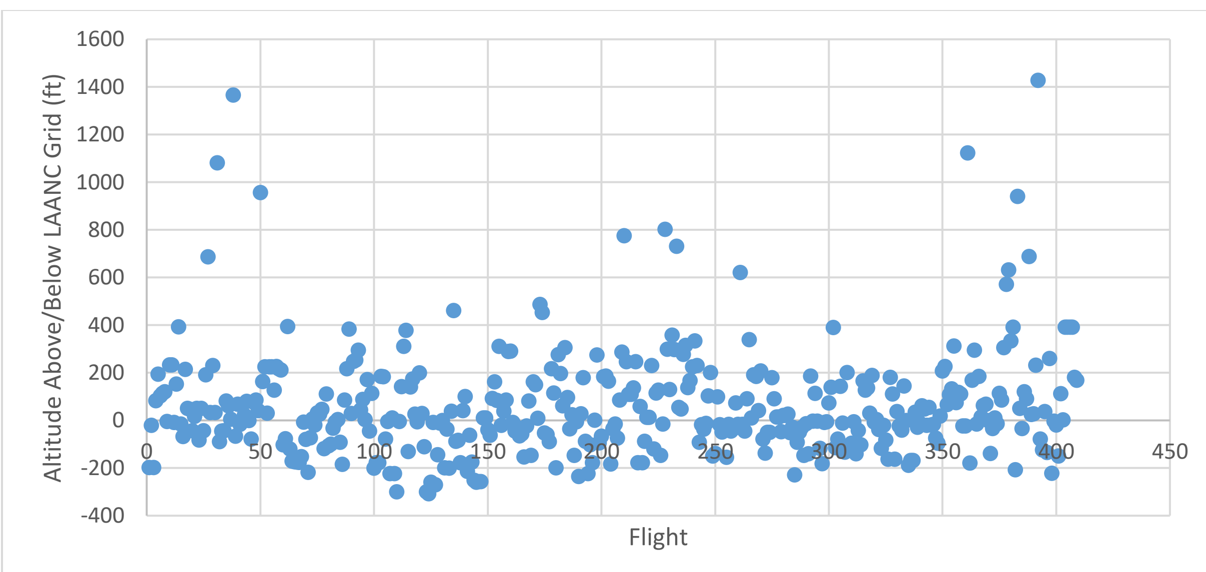


Figure 113. Scatterplot of sUAS Detected Altitude vs. LAANC Grid Max (BAK).

Figure 114 shows the distribution frequency of flights operating at altitudes below (-) or above (+) the UASFM grid limits. Distribution bars marked in green show the frequency of sUAS flights operating in adherence to UASFM limits.

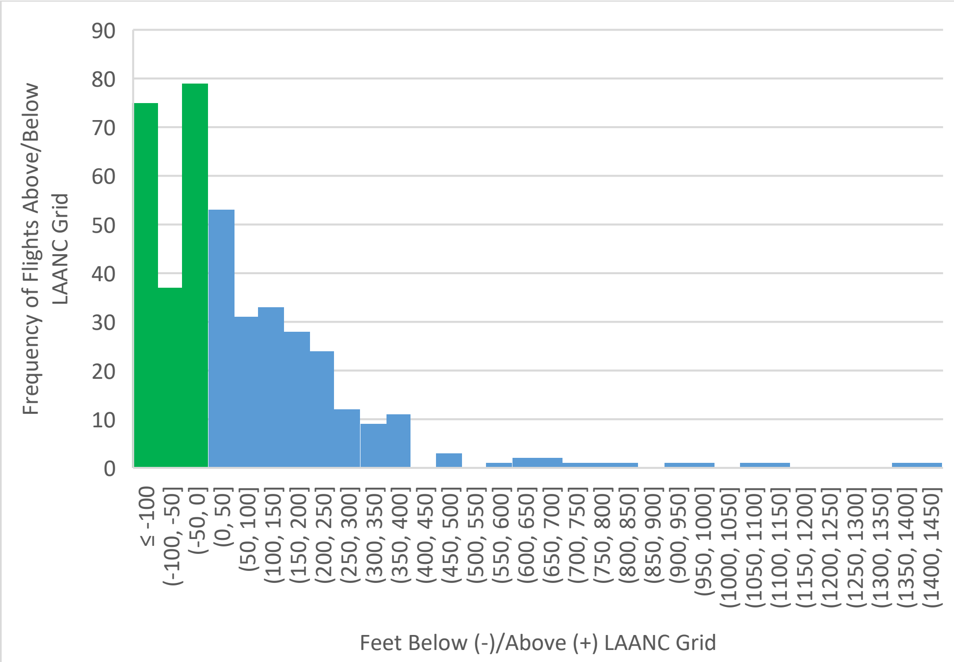


Figure 114. Distribution of Detected Altitude vs. LAANC Grid Max (BAK).

Figure 115 shows the distribution of Remote ID messages above (+) or below (-) the respective UASFM grid maximum altitude. The research team collected 149,439 Remote ID messages from flights conducted inside the BAK UASFM grid. When evaluating BAK Remote ID messages, 106,991 (*n*=71.6%) were recorded above the UASFM grid maximum; 1,555 (n=1.0%) messages were reported at the grid maximum; and 40,892 were reported below the grid maximum (*n*=27.4%).

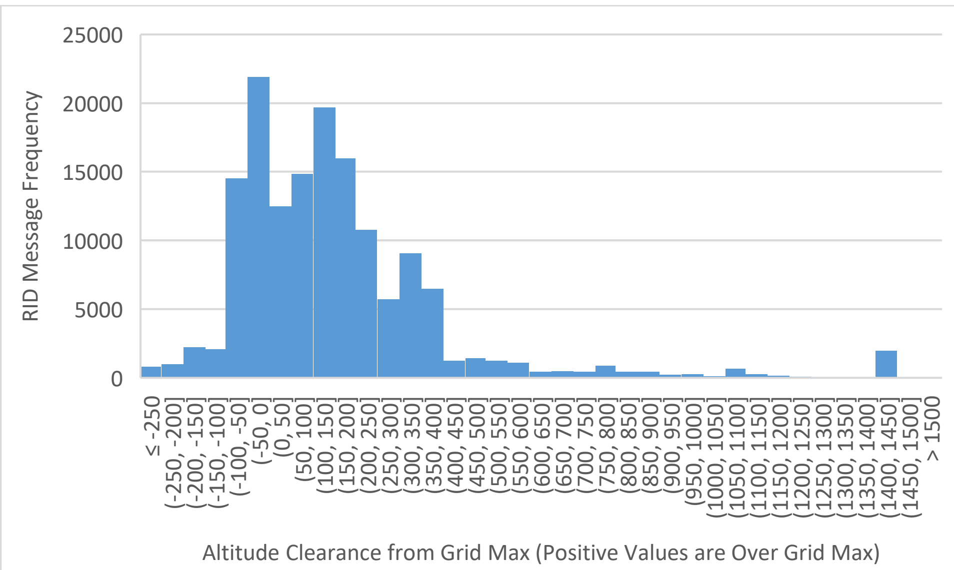


Figure 115. Distribution of Remote ID Message Altitudes vs. LAANC Grid Max (BAK).

Figure 116 shows the variability of BAK Remote ID message frequency, based on various UAS Facility Map grid maximums.

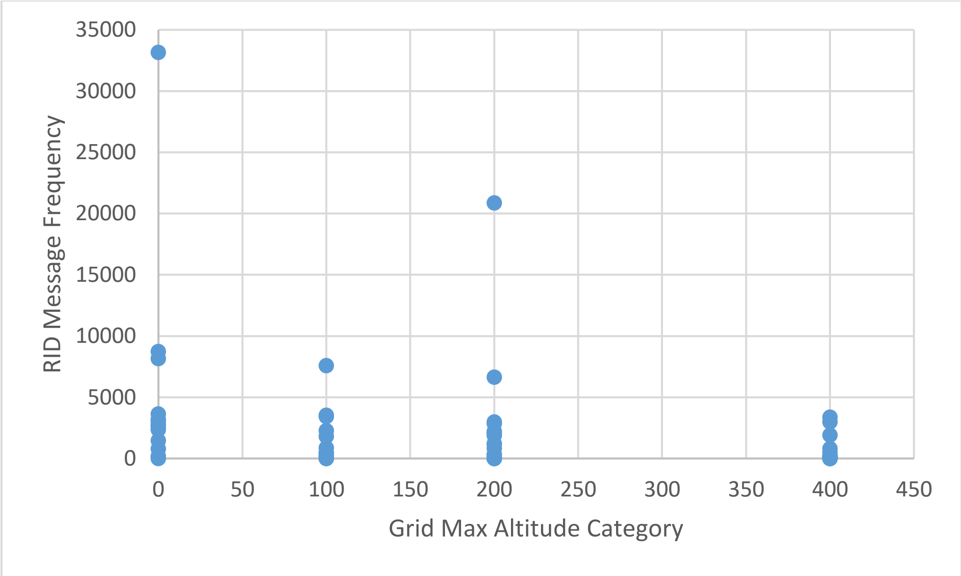


Figure 116. UAS Facility Map Grid Utilization by Remote ID Message Count and Max Grid Altitude (BAK).

Finally, the research team attempted to correlate flights detected with Remote ID against LAANC approvals, based on time and grid location. For BAK, 33 (n = 19%) of the total 409 flights were able to be correlated against a LAANC approval, whereas 333 (n = 82%) were unable to be correlated to a LAANC approval (see Figure 117).

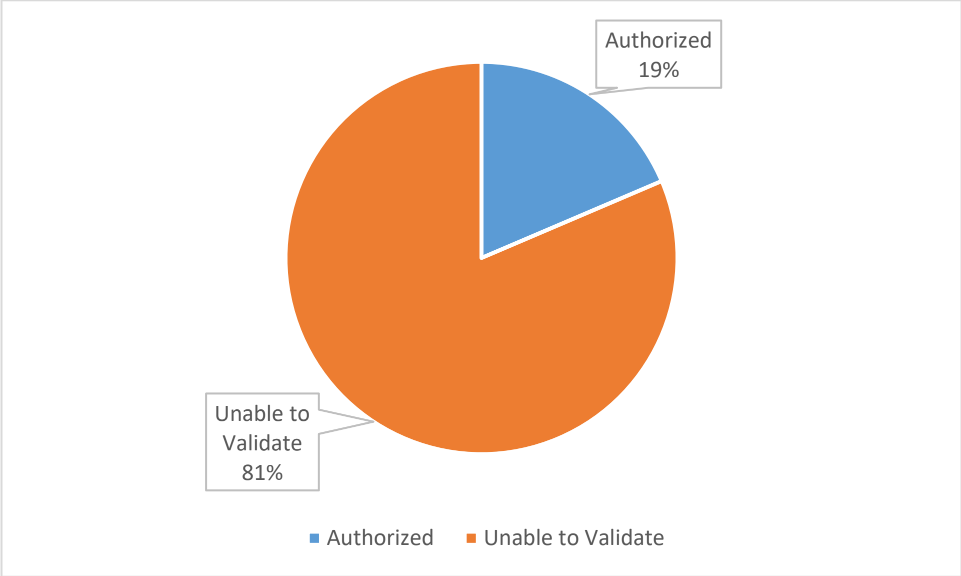


Figure 117. sUAS Flights During Authorized Time and Location (BAK).

The research team was able to correlate 335 flights in the Daytona Beach (DAB) area as being operated inside the UASFM area. Figure 118 shows the distribution of maximum altitudes (AGL) for each of these correlated flights.

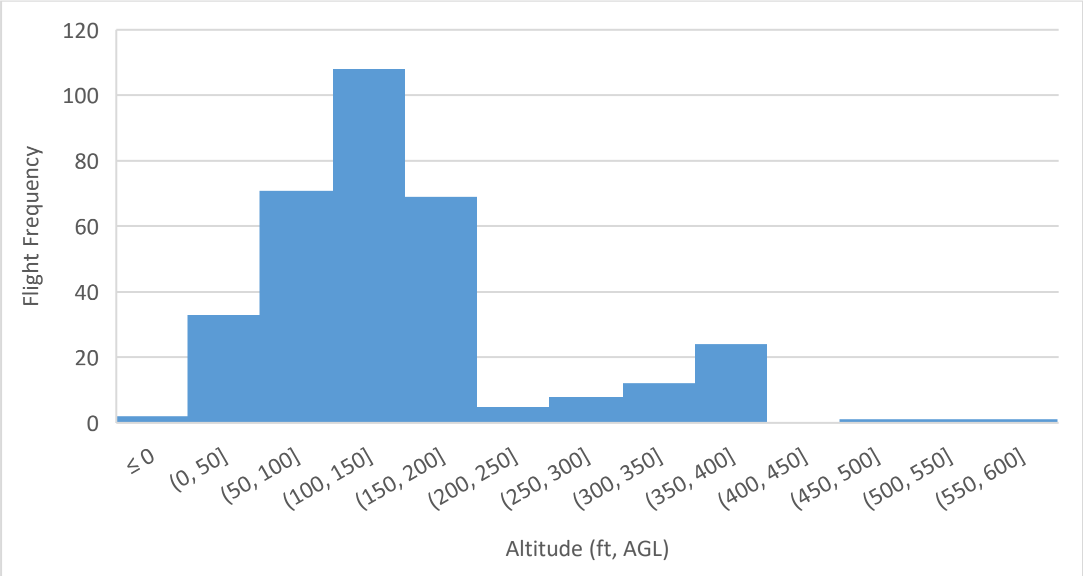


Figure 118. Distribution of Maximum Altitudes (AGL) for sUAS Flights in DAB UASFM Grids.

Figure 119 presents the difference between the ceiling of the correlated grid in which the sUAS was operating, relative to the maximum altitude detection of the sUAS. Values on the X-axis are individual sUAS flights, with positive values being above the UASFM grid maximum and negative values below. For DAB, 161 (n = 48.1%) flights had positive values, meaning that they were flown *above* the UASFM grid maximum. At DAB, 174 flights (n = 51.9%) had negative values (flown below grid limits) and no flights had a zero-value (flown at grid limit).

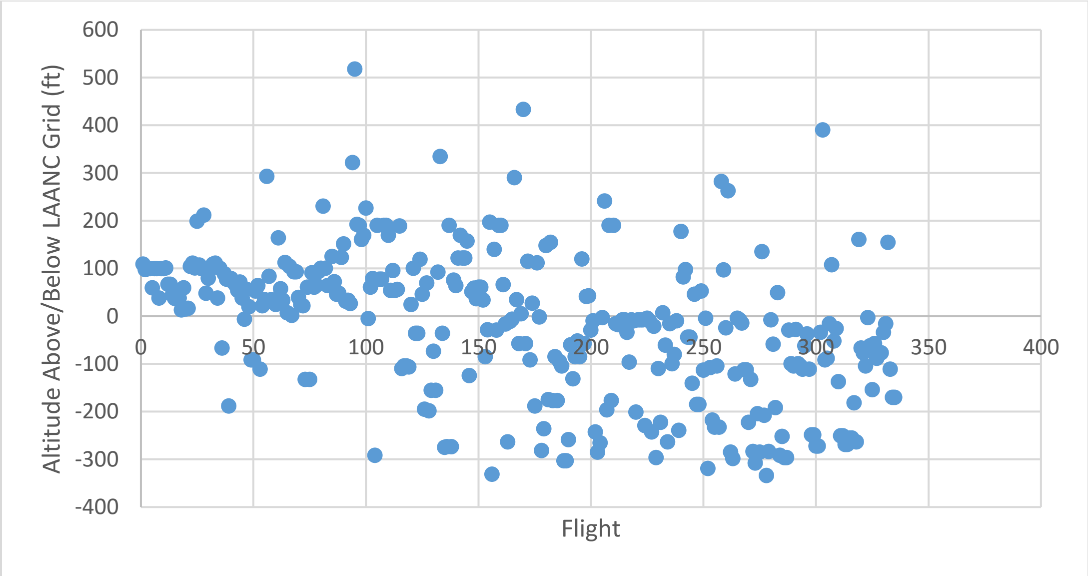


Figure 119. Scatterplot of sUAS Detected Altitude vs. LAANC Grid Max (DAB).

Figure 120 shows the distribution frequency of flights operating at altitudes below (-) or above (+) the UASFM grid limits. Distribution bars marked in green show the frequency of sUAS flights operating in adherence to UASFM limits.

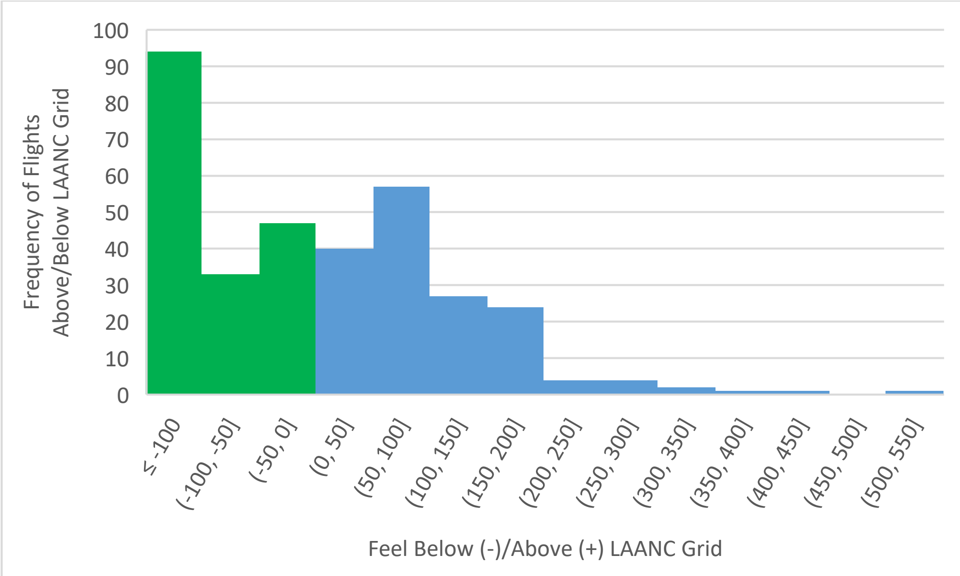


Figure 120. Distribution of Detected Altitude vs. LAANC Grid Max (DAB).

Figure 121 shows the distribution of Remote ID messages above (+) or below (-) the respective UASFM grid maximum altitude. The research team collected 54,437 Remote ID messages from flights conducted inside the DAB UASFM grid. When evaluating DAB Remote ID messages, 48,229 (n = 88.6%) were recorded above the UASFM grid maximum; 264 (n = 0.5%) messages were reported at the grid maximum; and 5,944 were reported below the grid maximum (n = 10.9%).

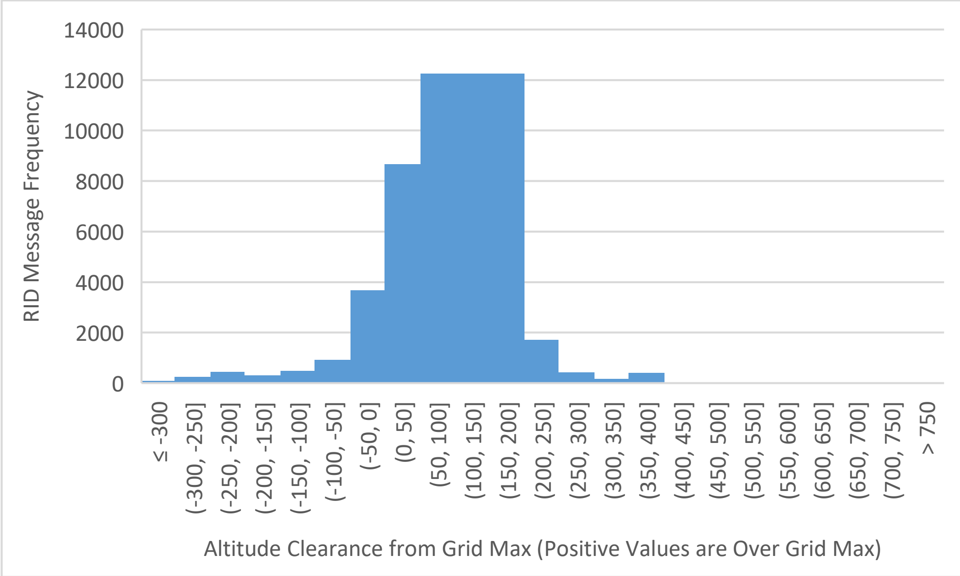


Figure 121. Distribution of Remote ID Message Altitudes vs. LAANC Grid Max (DAB).

Figure 122 shows the variability of DAB Remote ID message frequency, based on various UAS Facility Map grid maximums.

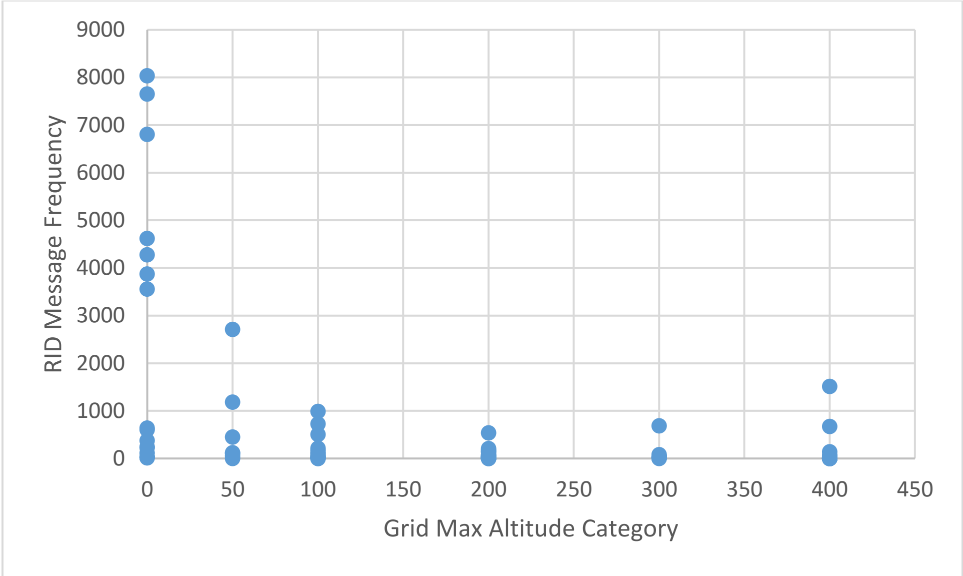


Figure 122. UAS Facility Map Grid Utilization by Remote ID Message Count and Max Grid Altitude (DAB).

Finally, the research team attempted to correlate flights detected with Remote ID against LAANC approvals, based on time and grid location. For DAB, 179 (*n* = 53%) of the total 335 flights were able to be correlated against a LAANC approval, whereas 47% (*n* = 156) were unable to be correlated to a LAANC approval (see Figure 123).

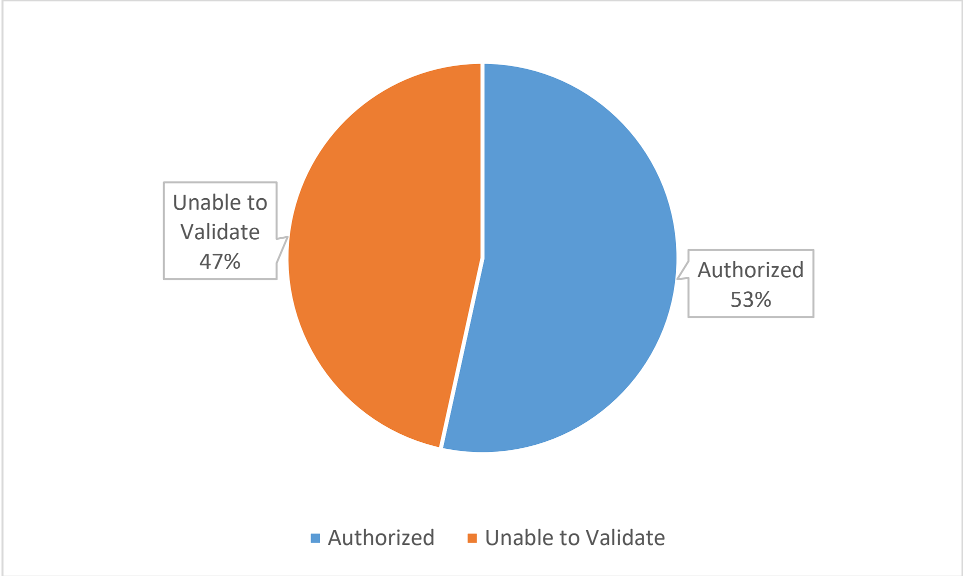


Figure 123. sUAS Flights During Authorized Time and Location (DAB).

The research team was able to correlate 376 flights in the Terre Haute (HUF) area as being operated inside the UASFM area. Figure 124 shows the distribution of maximum altitudes (AGL) for each of these correlated flights.

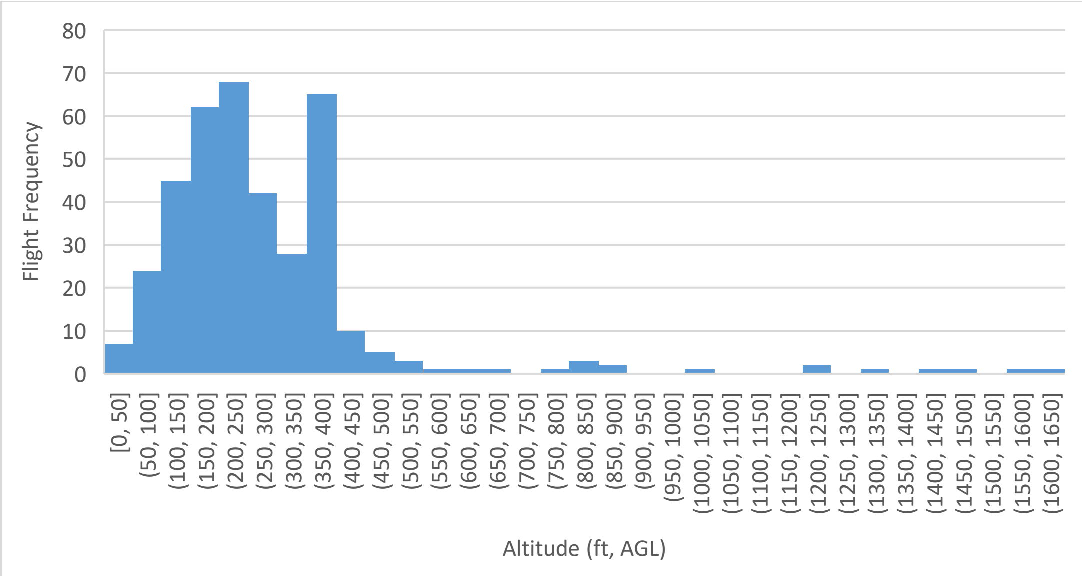


Figure 124. Distribution of Maximum Altitudes (AGL) for sUAS Flights in HUF UASFM Grids.

Figure 125 presents the difference between the ceiling of the correlated grid in which the sUAS was operating, relative to the maximum altitude detection of the sUAS. Values on the X-axis are individual sUAS flights, with positive values being above the UASFM grid maximum and negative values below. For HUF, 99 (n = 26.3%) flights had positive values, meaning that they were flown *above* the UASFM grid maximum. At HUF, 275 flights (n = 73.1%) had negative values (flown below grid limits) and two flights had a zero-value (flown at grid limit).

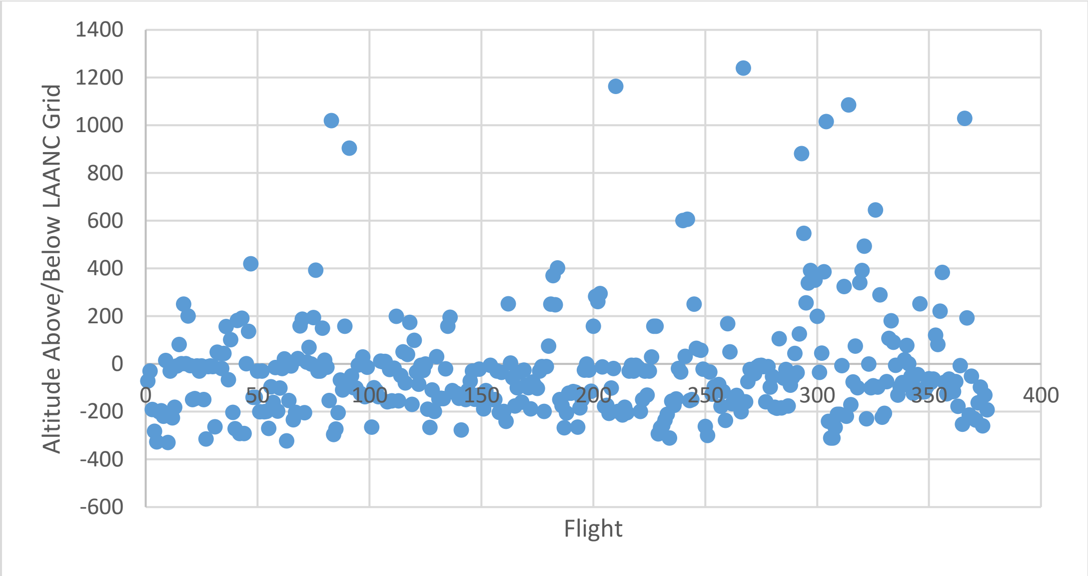


Figure 125. Scatterplot of sUAS Detected Altitude vs. LAANC Grid Max (HUF).

Figure 126 shows the distribution frequency of flights operating at altitudes below (-) or above (+) the UASFM grid limits. Distribution bars marked in green show the frequency of sUAS flights operating in adherence to UASFM limits.

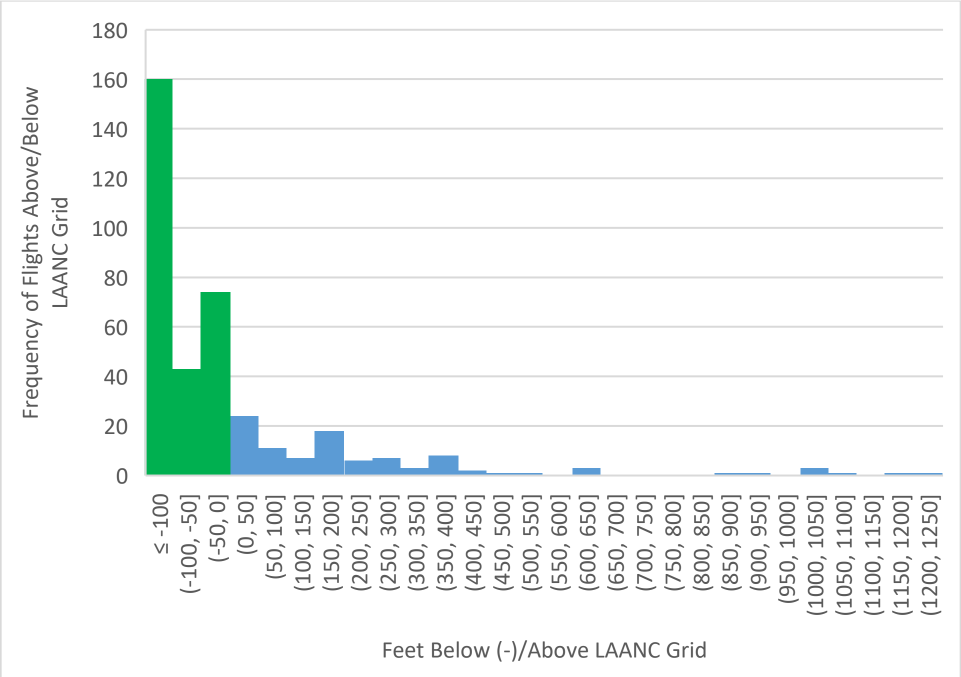


Figure 126. Distribution of Detected Altitude vs. LAANC Grid Max (HUF).

Figure 127 shows the distribution of Remote ID messages above (+) or below (-) the respective UASFM grid maximum altitude. The research team collected 125,523 Remote ID messages from flights conducted inside the HUF UASFM grid. When evaluating HUF Remote ID messages, 47,911 (*n* = 38.2%) were recorded above the UASFM grid maximum; 5,838 (*n* = 4.7%) messages were reported at the grid maximum; and 71,773 were reported below the grid maximum (*n* = 57.2%).

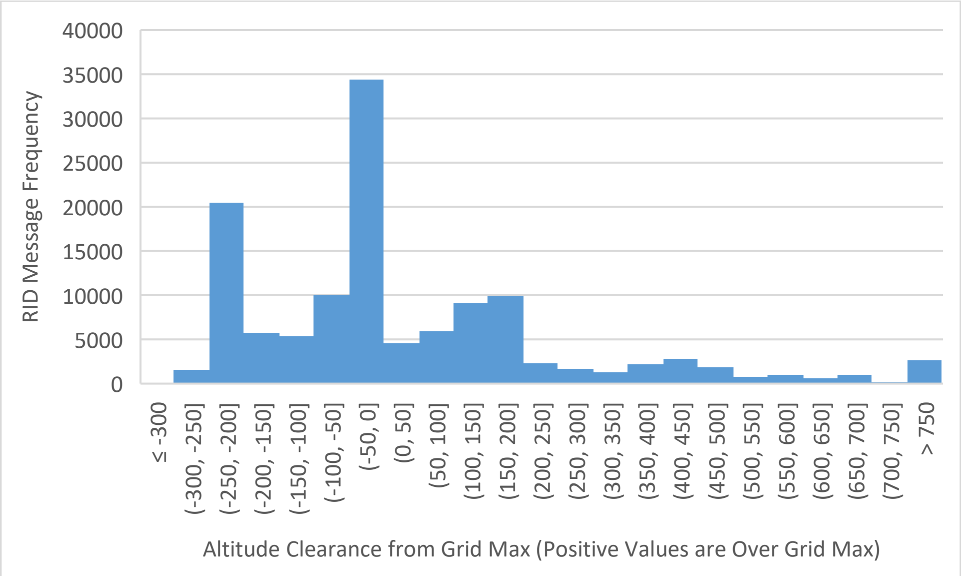


Figure 127. Distribution of Remote ID Message Altitudes vs. LAANC Grid Max (HUF).

Figure 128 shows the variability of HUF Remote ID message frequency, based on various UAS Facility Map grid maximums.

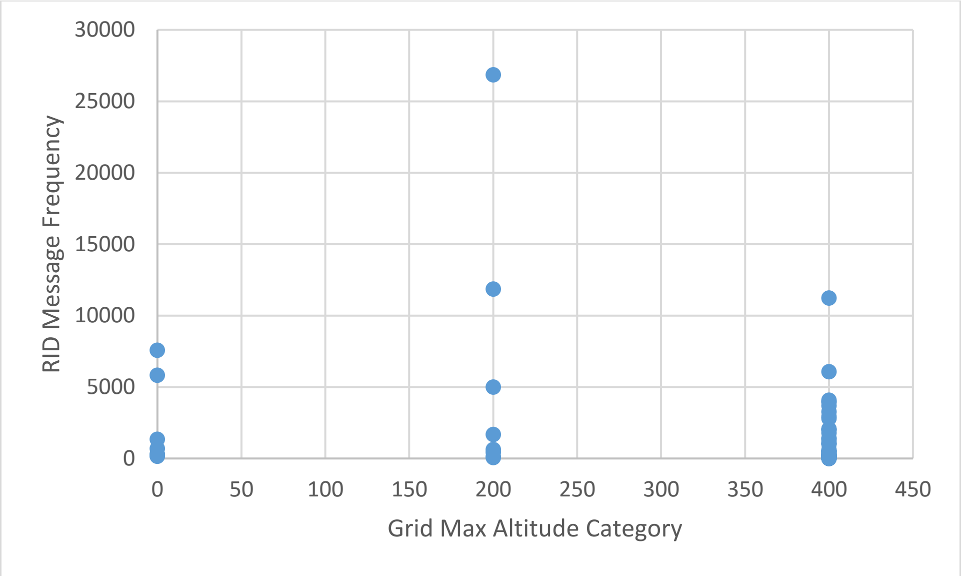


Figure 128. UAS Facility Map Grid Utilization by Remote ID Message Count and Max Grid Altitude (HUF).

Finally, the research team attempted to correlate flights detected with Remote ID against LAANC approvals, based on time and grid location. For HUF, 121 (*n* = 32%) of the total 376 flights were able to be correlated against a LAANC approval, whereas 68% (*n* = 255) were unable to be correlated to a LAANC approval (see Figure 129).

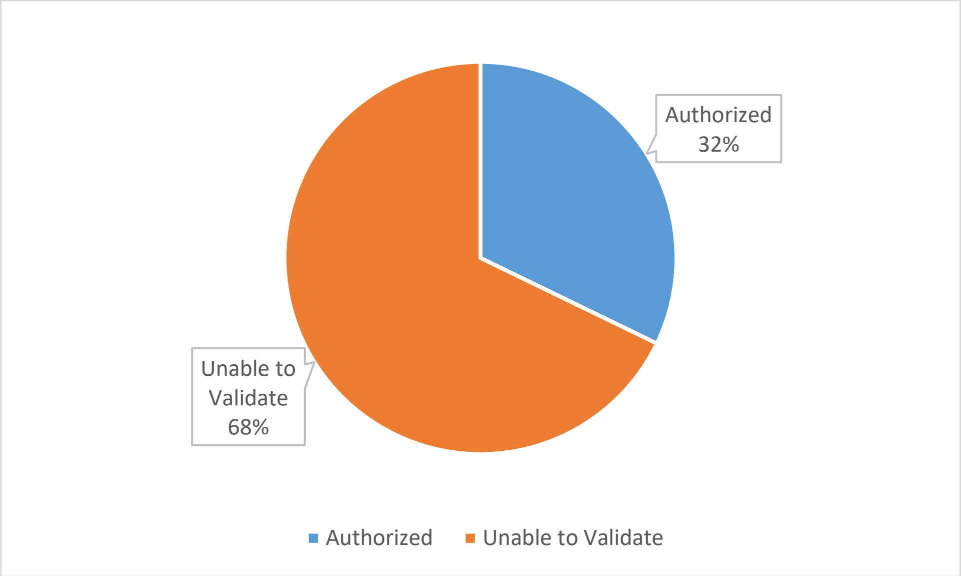


Figure 129. sUAS Flights During Authorized Time and Location (HUF).

Findings from all three sample locations suggest that a high proportion of sUAS flights are being conducted above the maximum UAS Facility Map grid altitudes. Moreover, a large percentage of detected sUAS operations cannot be correlated to a LAANC authorization, suggesting that detected operations may be: 1) operating under a different regulatory authority (such as a certificate of authorization or airspace approval); or, 2) exceeding regulatory approval requirements.

3.4.3 sUAS Activity Concentrations

The purpose of this assessment is to identify sUAS activity concentrations in each sample area and determine potential hotspots that may present safety issues to manned aircraft operations.

The research team leveraged collected Remote Identification data to plot heat maps of activity in each respective sample area. Results for Columbus (BAK) are plotted in Figure 130; Daytona Beach in Figure 131; and Terre Haute (HUF) in Figure 132. The research team noted that the plotted hot spot locations did not correlate to the heat maps depicting LAANC approvals at each of the sample locations in Figure 91 (BAK), Figure 97 (DAB), and Figure 103 (HUF).

It is notable that detected Remote ID data suggests that sUAS flights are concentrated nearer to airport locations, whereas LAANC approval data indicates approvals tend to be concentrated at UASFM peripheral areas. The discrepancy in this data suggests that a large proportion of flight operations may not be accounted for under LAANC approval authority. This may indicate that flights carried out under certificates of authorization or airspace approvals may account for a significant proportion of overall Remote ID detections. Alternatively, this finding could also indicate that UAS operations flying in proximity to aerodromes are not requesting LAANC approval to operate and may be operating without authorization. Further study and data collection is necessary to evaluate this phenomenon.

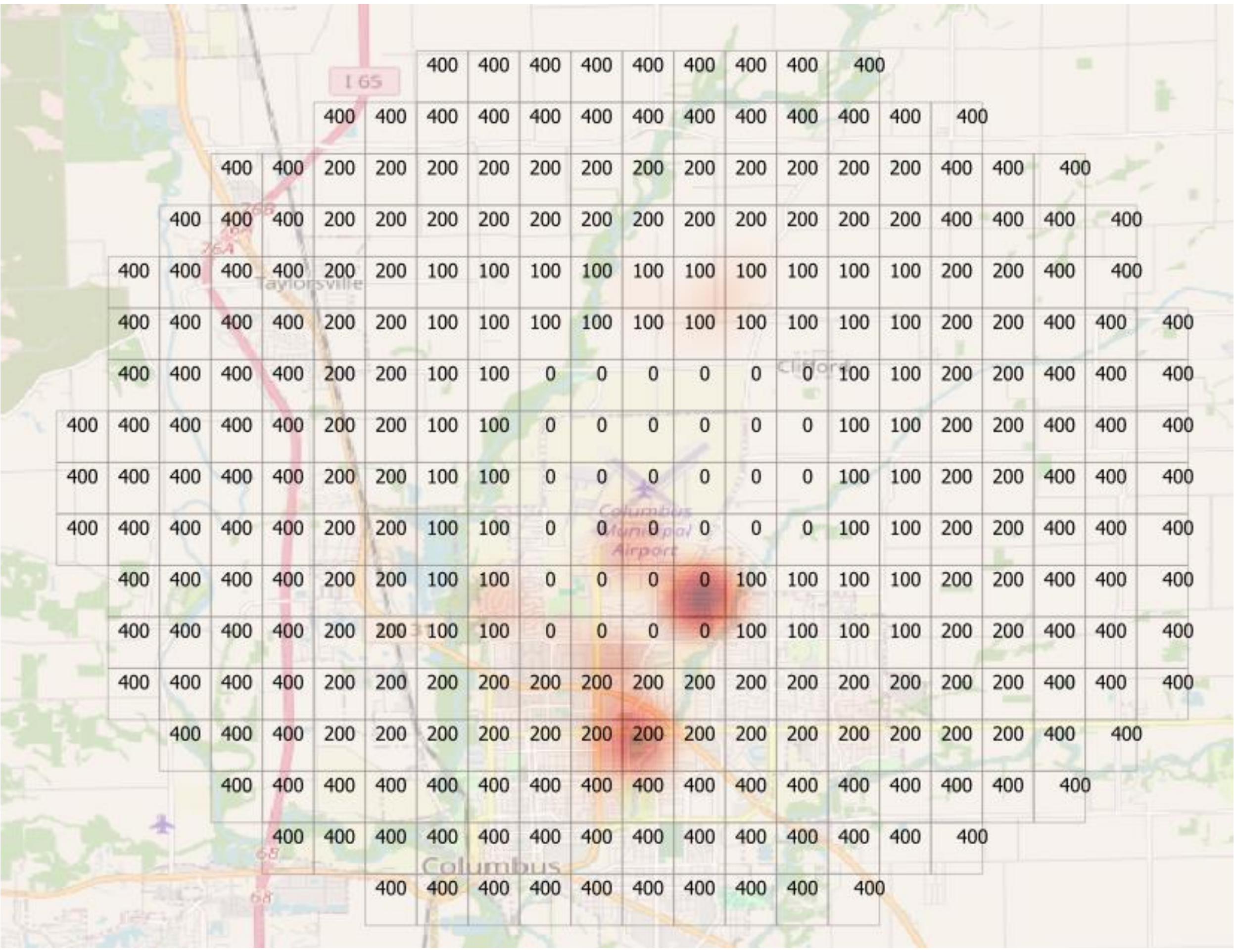


Figure 130. sUAS Activity Hotspots near Columbus (BAK).

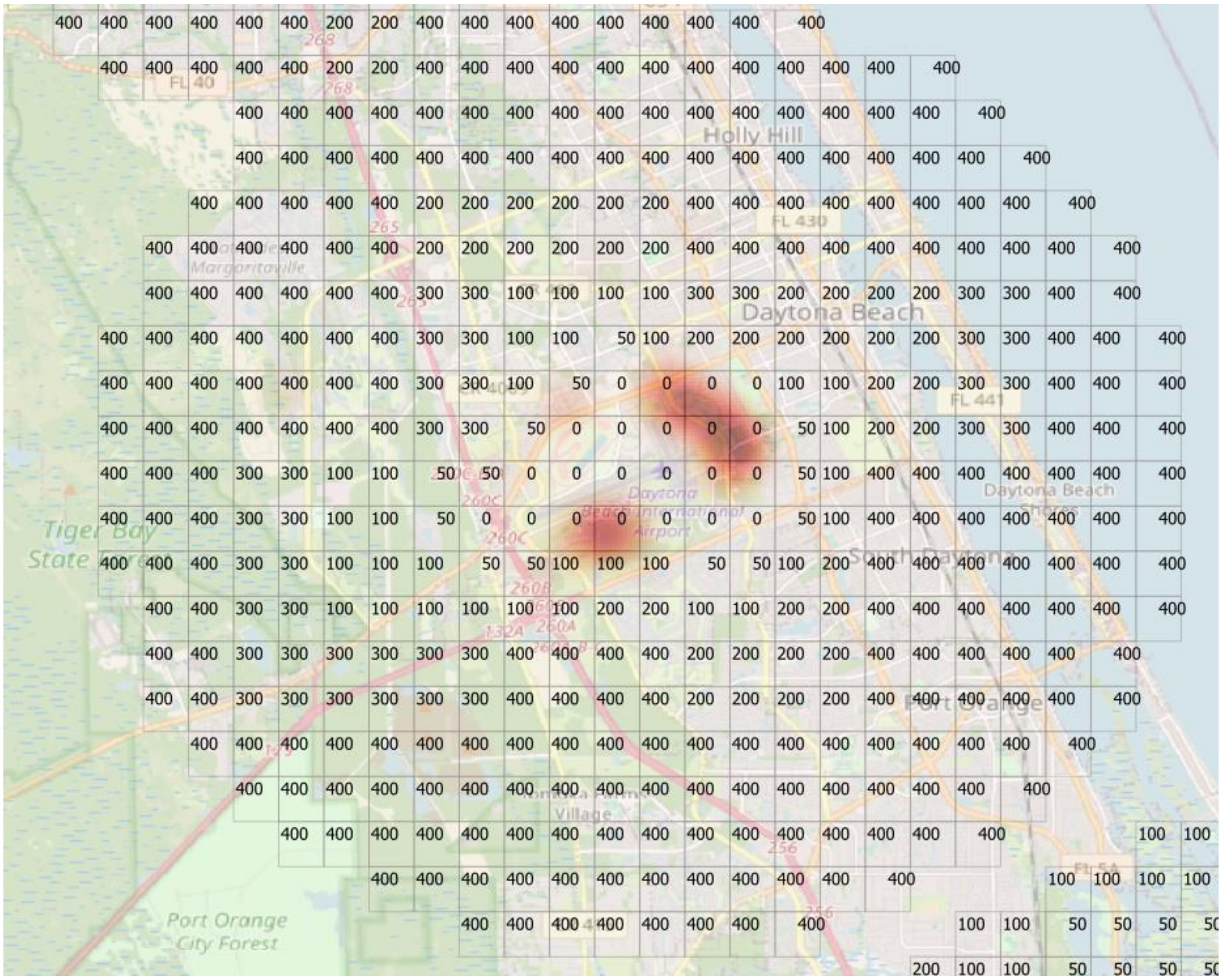


Figure 131. UAS Activity Hotspots near Daytona Beach, FL (DAB).

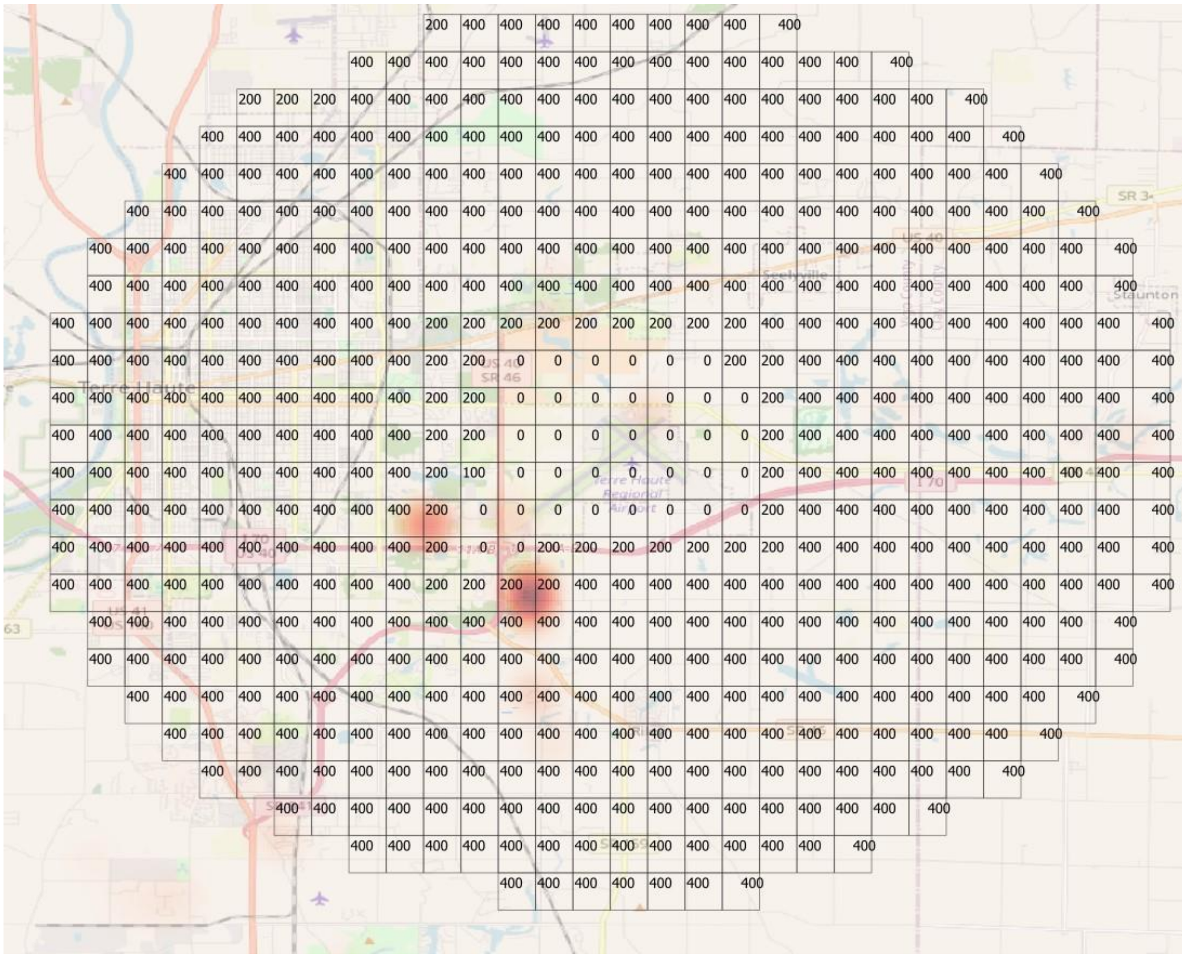
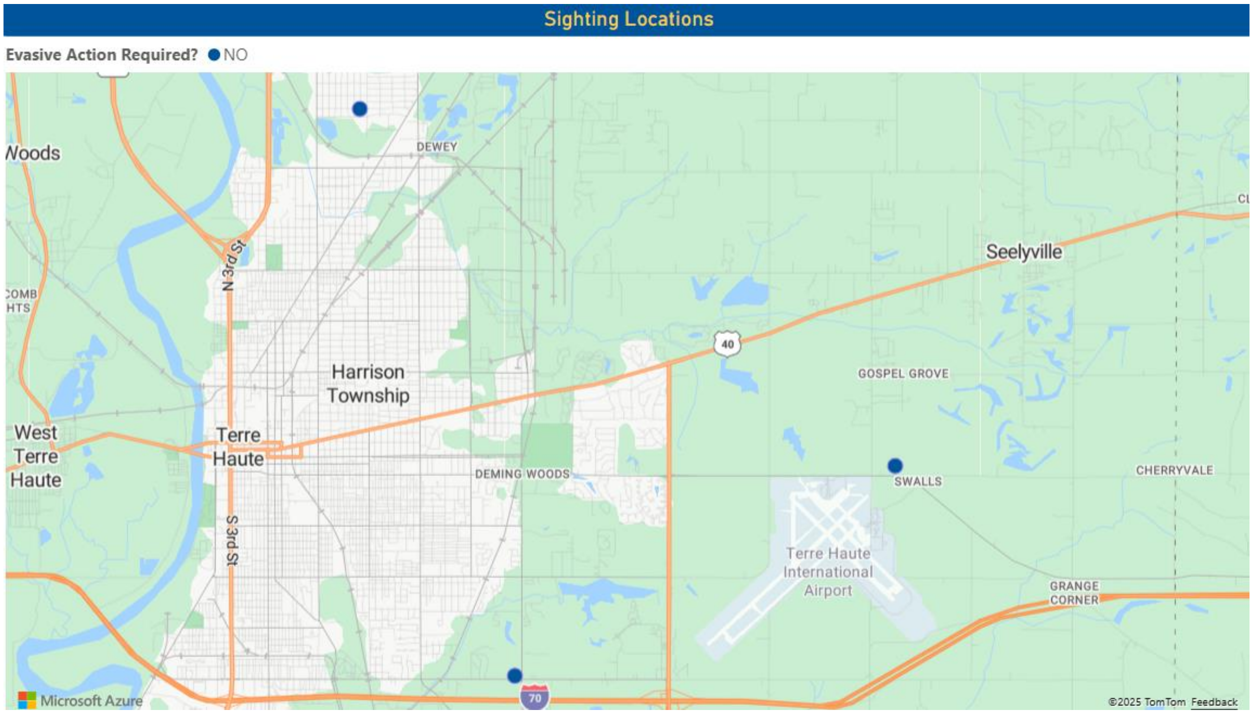


Figure 132. UAS Activity Hotspots near Terre Haute (HUF).

3.4.4 Comparing sUAS Hotspots and Sighting Report Locations

The purpose of this assessment is to leverage sUAS hotspots identified from the previous research task to determine if possible correlations can be made with sUAS sighting report locations. This may aid researchers and policymakers to determine if sUAS operational hotspots are predictive of future sighting reports and therefore, potential safety issues.

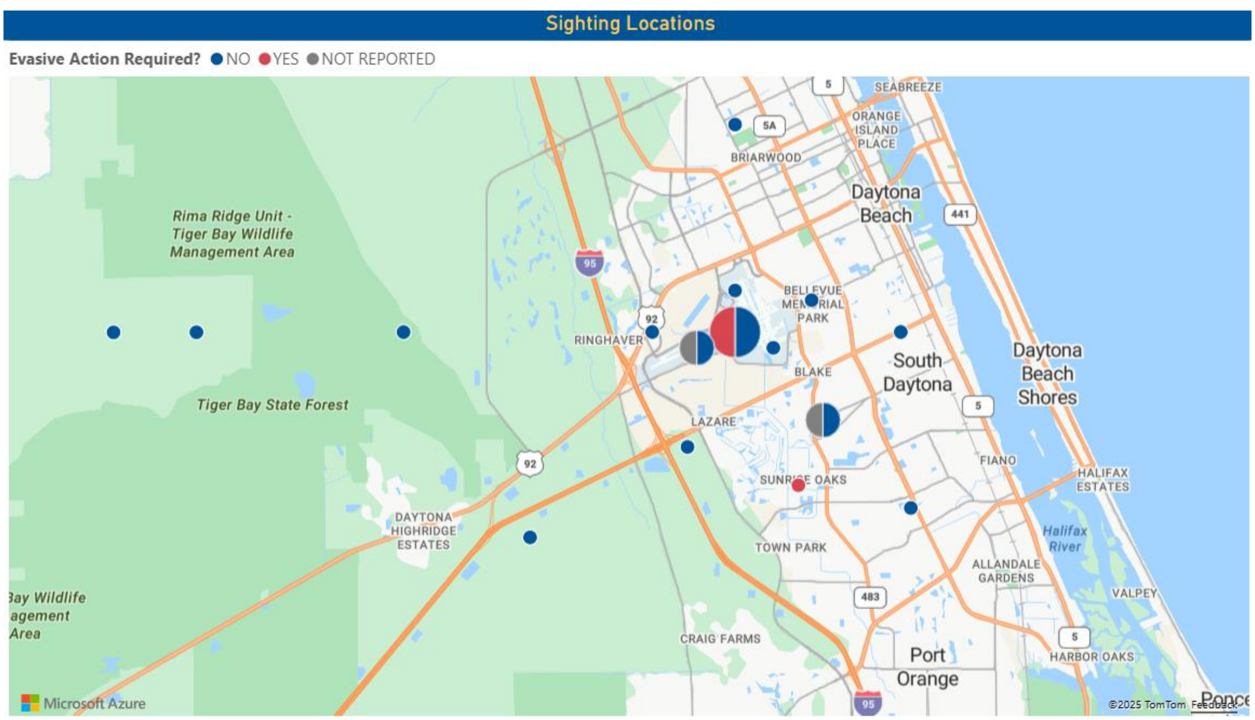
For Columbus (BAK), three UAS sightings were reported to the FAA's UAS Sightings Report database from November 2014 to September 2024 (see Figure 133). Of all reported sightings, none of the aircraft reported taking evasive action. None of the sighting reports occurred in the first three quarters of 2024.



Note: Total sightings: 3; within 5 NM of airport: 2; Evasive Action: 0.0%.

Figure 133. Sighting Report Locations in proximity to HUF, 2014-2024.

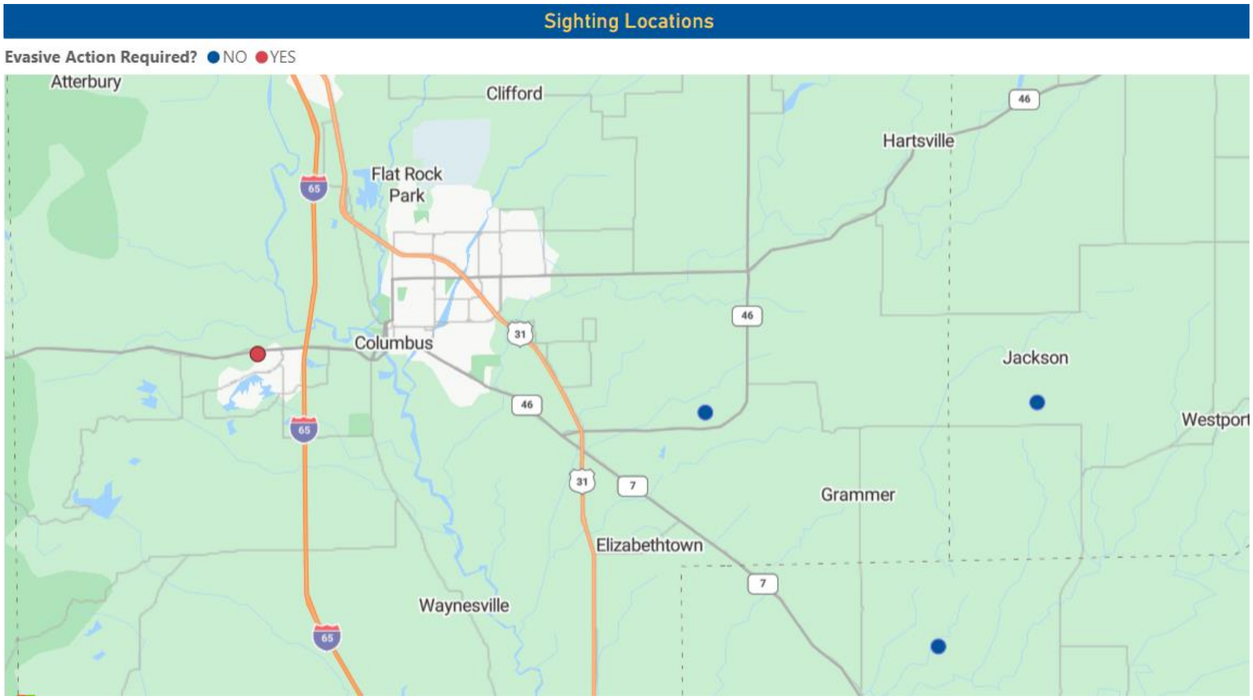
From November 2014 to September 2023, 21 UAS sightings were reported to the FAA's UAS Sightings Report database, which included five in the first three quarters of 2024 (see Figure 134). Of all reported sightings, 14.3% (*n*=3) of aircraft reported taking evasive action.



Note: Total sightings: 21; within 5 NM of airport: 16; Evasive Action: 14.3%.

Figure 134. Sighting Report Locations in proximity to DAB, 2014-2024.

A total of four UAS sightings were reported to the FAA between November 2014 and September 2024 (see Figure 135). Of all reported sightings, 25.0% (*n*=1) of aircraft reported taking evasive action. None of the reported sightings occurred in the first three quarters of 2024.



Note: Total sightings: 4; within 5 NM of airport: 0; Evasive Action: 25.0%.

Figure 135. Sighting Report Locations in proximity to BAK, 2014-2024.

When comparing the sighting report locations presented in Figure 133 (BAK), Figure 134 (DAB), and Figure 135 (HUF), the research team did not note significant prediction of sighting report locations, based on available Remote ID hotspot data presented in Figure 130 (BAK), Figure 131 (DAB), and Figure 132 (HUF). The variability of sUAS sighting reports did not allow further conclusions, given the limited available sightings data available for the sample locations.

3.4.5 sUAS Operations in Temporary Flight Restriction Zones or No-Drone Zones

The purpose of this assessment was to evaluate sUAS operations being carried out in established TFR or No Drone Zone areas.

According to the FAA (2019), sUAS are prohibited from flying within Prohibited, Restricted, or TFR areas. During the sampling period, the research team recorded one TFR FDC 4/6973 implemented for VIP movement and activity within the Indianapolis area on July 24, 2024, from 15:15 UTC-19:15 UTC (11:15 – 15:15 Local Time, EDT). The applicable restriction locations and provisions are outlined in Table 14.

Due to the Remote Identification sensors' positioning, the research team could only detect sUAS activity within Area B, which had an enforcement time of 15:45-18:15 UTC (11:45-14- 5 Local Time, EDT). Figure 136 shows all detected remote ID messages received during the enforcement period. During the TFR enforcement period, the research team detected two platforms, a Mini 4 Pro and M30T. A third M3T was operating just before the enforcement period, and their Remote ID message count was included in the reporting information (see Table 15).

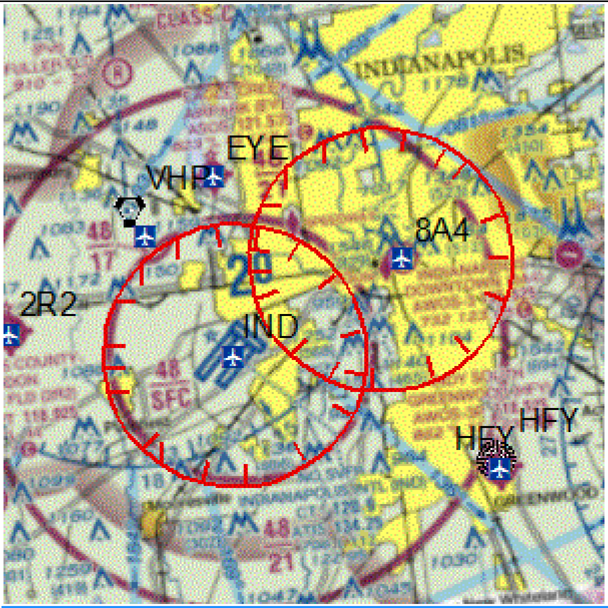
Telemetry data for detected platforms relative to the center point of TFR Area B is displayed in Figure 137. A street view of sUAS detections is provided in Figure 138. Figure 139 contained an aerial view of the same location and includes both sUAS telemetry and operator launch locations (depicted by red box icons). It appears that two flight telemetry clusters are confined to some form of observation or activity along a roadway south of the protected location. The research team suspects that this may represent local law enforcement sUAS activity; however, this cannot be confirmed.

The research team plotted the distance from the protected area, and the accompanying sUAS altitude to observe for anomalous flight behavior (see Figure 140). Most altitudes were confined to 400 feet AGL or less, with some activity extending to 430 feet. Due to the extent of surrounding structures, it is possible operations conducted above 400 feet were overhead these structures and may still be in compliance with 107.51(b) requirements. It was noted that some sUAS operations were conducted particularly close to the protected area (within .1 NM). However, as previously stated, this may represent law enforcement sUAS flight operations.

The research team also plotted sUAS distance from the protected area and sUAS speed to evaluate anomalous speed changes (i.e. rapid acceleration or deceleration) as a sUAS approached the protected area (see Figure 141). The preponderance of operational speeds was less than 30 mph, representing normal operation speeds for DJI platforms. The research team did not note any sustained rapid acceleration or deceleration changes, with most flight telemetry behavior remaining relatively consistent. There was evidence of momentary acceleration changes, however, these appeared to be minimal.

The research team conducted further telemetry analysis of the two flights detected in operation during the enforcement period (see Figure 142). Flight telemetry pathing and altitude elements were added, with contextual 3-D building heights included. The western flight operation appears well-positioned for surveillance/observation, with an unobstructed view of the protected area. The research team reiterates its suspicion that this flight represents law enforcement flight activity. Conversely, the eastern flight activity has a relatively poor observation angle from which to view the protected area. The research team is slightly more concerned about the flight offset than the launch location/operator position (approximately two blocks). This flight's positioning and observation angle suggest it does not support law enforcement or security operations.

Table 14. NOTAM FDC-4/6973, July 24, 2024, Indianapolis, IN.



NOTAM Number :	FDC 4/6973
Issue Date :	July 24, 2024 at 1326 UTC
Location :	Indianapolis, Indiana
Beginning Date and Time :	July 24, 2024 at 1515 UTC
Ending Date and Time :	July 24, 2024 at 1915 UTC
Reason for NOTAM :	Temporary flight restrictions for VIP Movement
Type :	VIP
Replaced NOTAM(s) :	4/5240: due to time correction

Affected Area(s)

Area A
Airspace Definition:

Center: On the BRICKYARD VORTAC (VHP) 149 degree radial at 6.8 nautical miles. (Latitude: 39º43'02"N, Longitude: 86º17'40"W)

Radius: 5 nautical miles

Altitude: From the surface up to and including 4999 feet AGL

Effective Date(s):

From July 24, 2024 at 1515 UTC (July 24, 2024 at 1115 EDT)
To July 24, 2024 at 1645 UTC (July 24, 2024 at 1245 EDT)

Area B
Airspace Definition:

Center: On the BRICKYARD VORTAC (VHP) 106 degree radial at 9.7 nautical miles. (Latitude: 39º46'02"N, Longitude: 86º10'01"W)

Radius: 5 nautical miles

Altitude: From the surface up to and including 4999 feet MSL

Effective Date(s):

From July 24, 2024 at 1545 UTC (July 24, 2024 at 1145 EDT)
To July 24, 2024 at 1815 UTC (July 24, 2024 at 1415 EDT)

Area C Airspace Definition:

Center:	On the BRICKYARD VORTAC (VHP) 149 degree radial at 6.8 nautical miles. (Latitude: 39º43'02"N, Longitude: 86º17'40"W)
Radius:	5 nautical miles
Altitude:	From the surface up to and including 4999 feet AGL

Effective Date(s):

From July 24, 2024 at 1730 UTC (July 24, 2024 at 1330 EDT)
To July 24, 2024 at 1915 UTC (July 24, 2024 at 1515 EDT)

Operating Restrictions and Requirements

No pilots may operate an aircraft in the areas covered by this NOTAM (except as described).

EXC THE FLT OPS LISTED BLW:

1. ACFT ARR OR DEP AIRPORTS OR HELIPORTS WITHIN THE TFR.
2. LAW ENFORCEMENT, FIREFIGHTING, AND MEDEVAC/AIR AMBULANCE FLIGHTS ON ACT MISSIONS.
3. ACFT OPS NECESSITATED FOR SAFETY OR EMERGENCY REASONS.
4. ALL ACFT APPROVED TO OPERATE WI THE TFR MUST BE SQUAWKING AN ATC DISCRETE CODE AT ALL TIMES WHILE IN THE TFR AND MUST REMAIN IN TWO-WAY RADIO COM WITH ATC.
5. UAS OPERATORS WHO DO NOT COMPLY WITH APPLICABLE AIRSPACE RESTRICTIONS ARE WARNED THAT PURSUANT TO 10 U.S.C. SECTION 130I AND 6 U.S.C. SECTION 124N, THE DEPARTMENT OF DEFENSE (DOD), THE DEPARTMENT OF HOMELAND SECURITY (DHS) OR THE DEPARTMENT OF JUSTICE (DOJ) MAY TAKE SECURITY ACTION THAT RESULTS IN THE INTERFERENCE, DISRUPTION, SEIZURE, DAMAGING, OR DESTRUCTION OF UNMANNED AIRCRAFT DEEMED TO POSE A CREDIBLE SAFETY OR SECURITY THREAT TO PROTECTED PERSONNEL, FACILITIES, OR ASSETS.
6. THE SYSTEM OPERATIONS SUPPORT CENTER (SOSC), IS THE COORDINATION FACILITY FOR GOVERNMENT AGENCIES AND IS AVAILABLE DAILY FROM 0700-2300 EASTERN, PHONE 202-267-8276 FOR COORDINATION.
7. THE FAA RECOMMENDS THAT ALL AIRCRAFT OPERATORS CHECK NOTAMS FREQUENTLY FOR POSSIBLE CHANGES TO THIS TFR PRIOR TO OPERATIONS WITHIN THIS REGION. OPERATORS MAY REVIEW THE TFR DETAILS ON THE INTERNET AT HTTPS://TFR.FAA.GOV/ OR HTTPS://WWW.1800WXBRIEF.COM. IF QUESTIONS REMAIN, CONTACT FLIGHT SERVICE AT 800-992-7433.

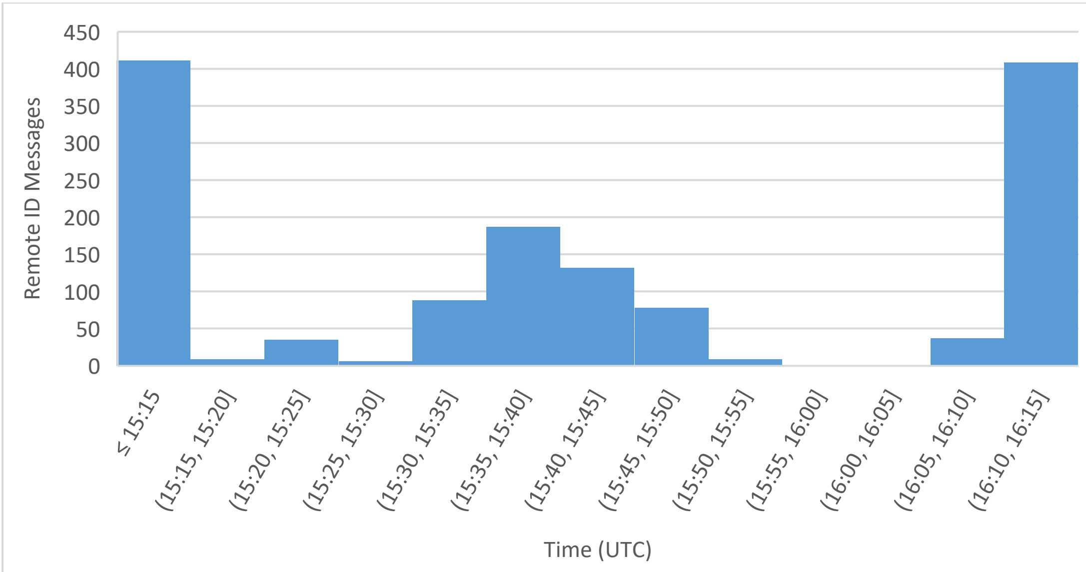


Figure 136. sUAS Activity During TFR Enforcement Time.

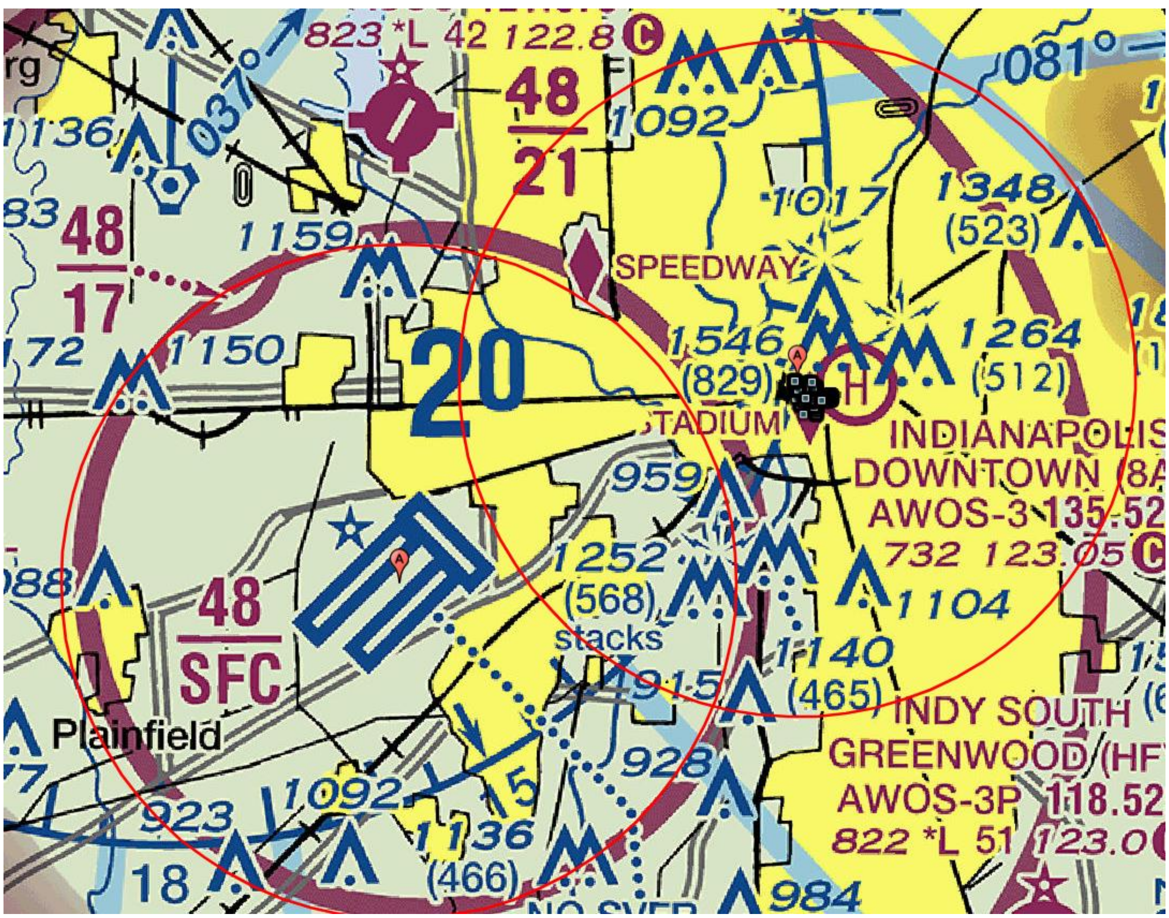


Figure 137. Visual Depiction of TFR Areas with Overlaid sUAS Detections.

Table 15. Table of Detected Platforms During TFR.

Platform	Remote ID Messages
Mini 4 Pro	445
M30T	912
M3T	42

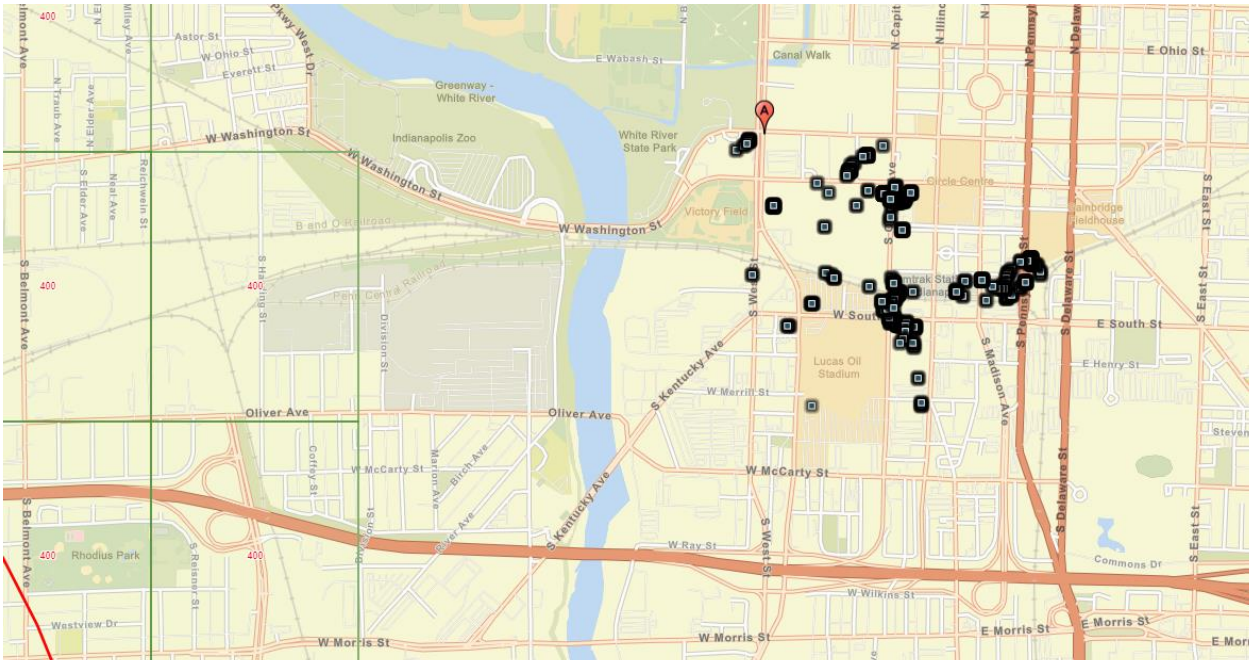


Figure 138. Street View of Detected Platforms During TFR.

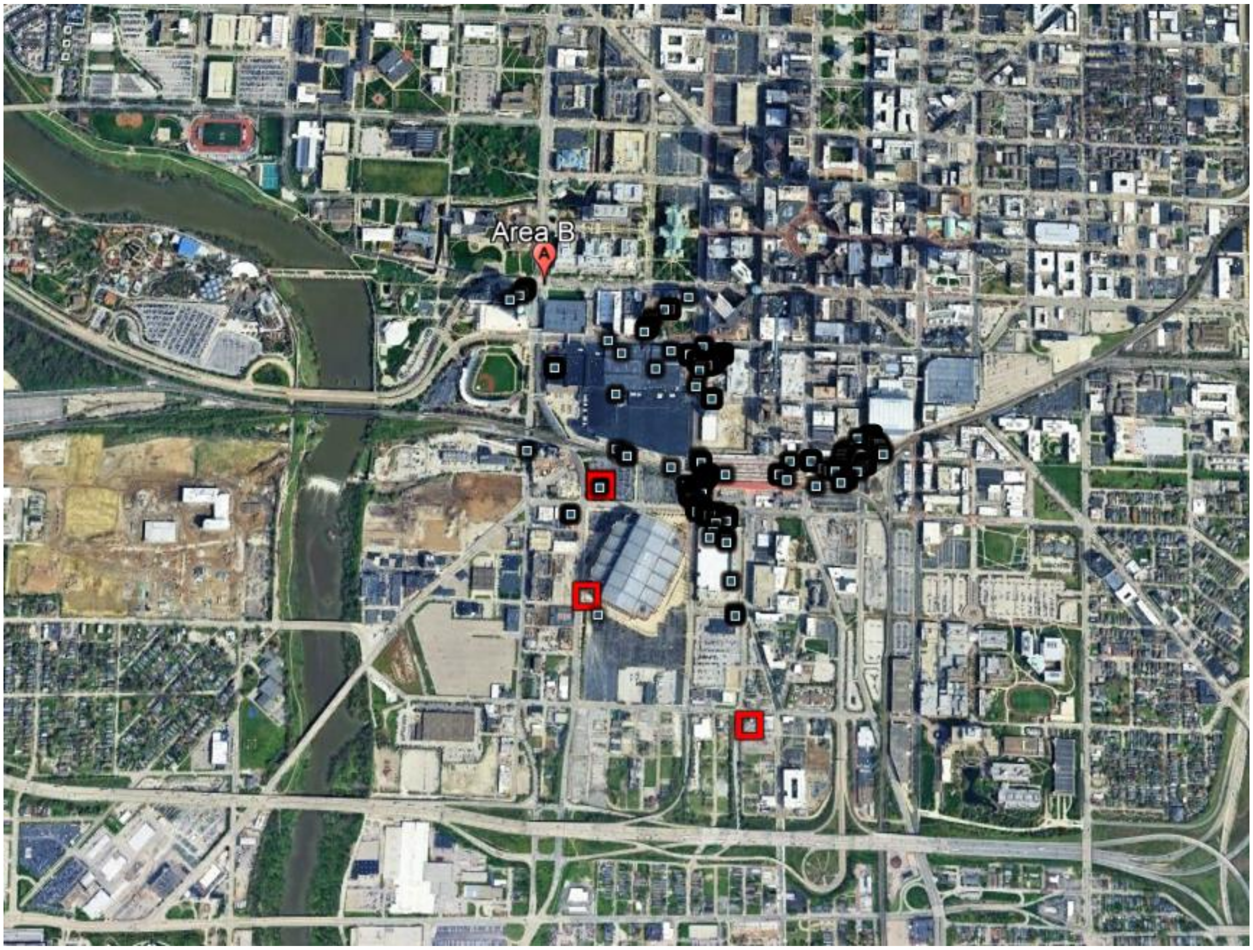


Figure 139. Protected TFR Area, sUAS Detections, and Launch Locations.

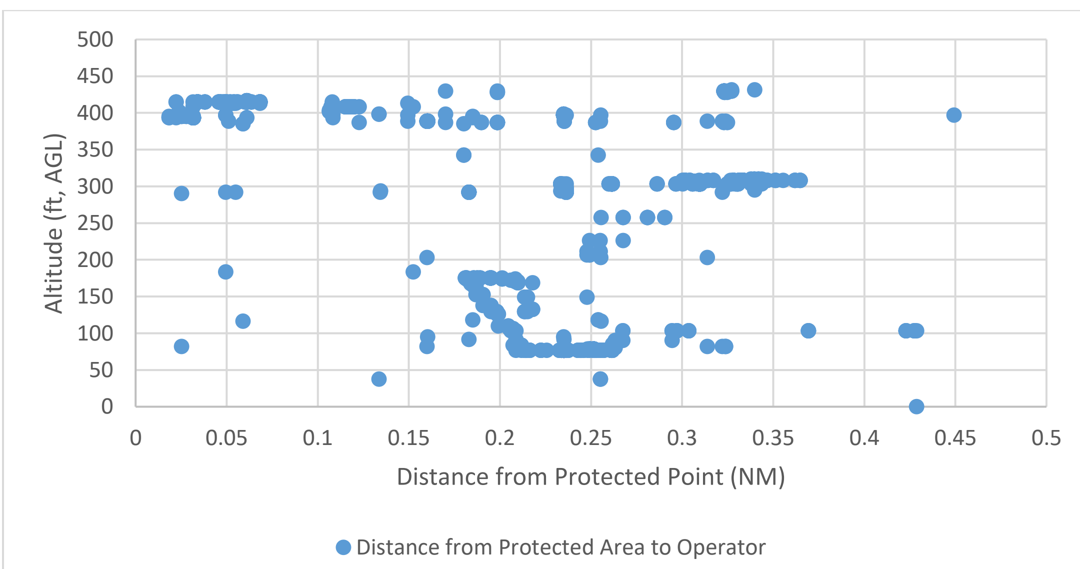


Figure 140. sUAS Detections During TFR (Distance and Altitude).

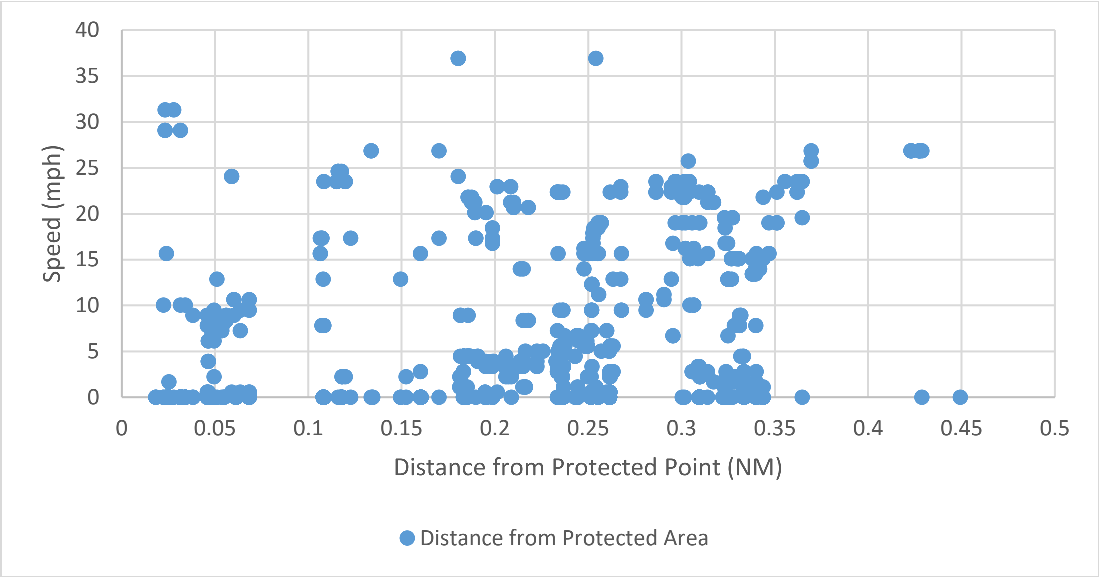


Figure 141. Distance from TFR Protected Area (NM) and sUAS Speed (mph).

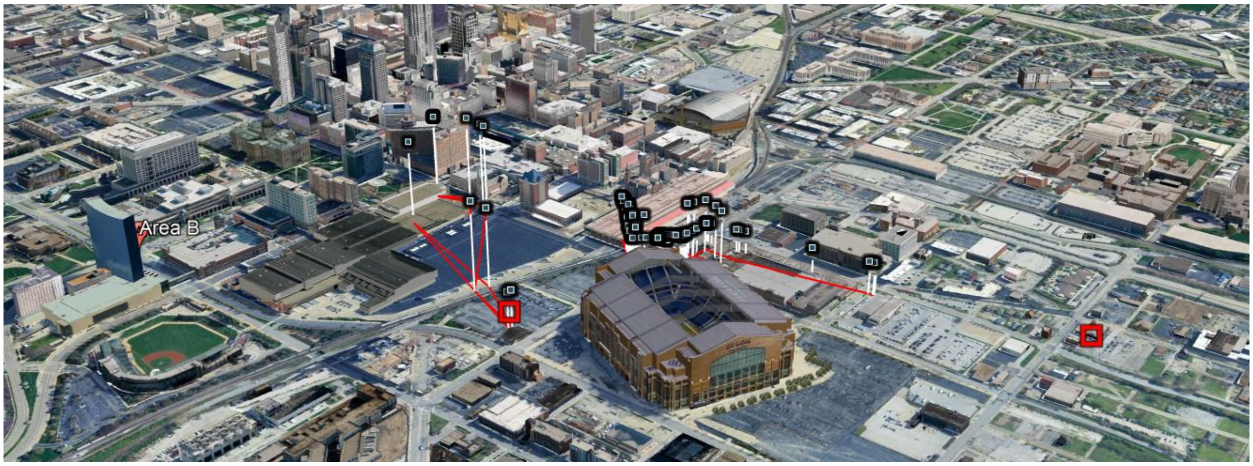


Figure 142. 3-D Visual Depiction of TFR Protected Area.

3.4.6 sUAS Operations Near Critical Infrastructure

The purpose of this research task was to assess the type and extent of sUAS operations being carried out near selected critical infrastructure locations. Critical infrastructure locations were identified using the DHS HIFLD. Selected critical infrastructure for evaluation was based on FAA (2021d) guidance for locations where sUAS operations would be restricted, including prisons and correctional facilities and related areas.

The research team evaluated sUAS flight operations carried out in proximity to critical infrastructure, focusing on prisons, correctional facilities and sporting venues. The researchers caveat that sUAS detections in these areas do not necessarily constitute illegal or unauthorized activity. Moreover, the research team did not have access to any sUAS authorization data, in which to correlate approval of various detected sUAS activity.

In Columbus, Indiana, sUAS operations were noted near the Bartholomew County Jail, however, flights did appear to overfly the jail property or facilities (See Figure 143). No flights were noted around the Bartholomew County Juvenile Detention Center.

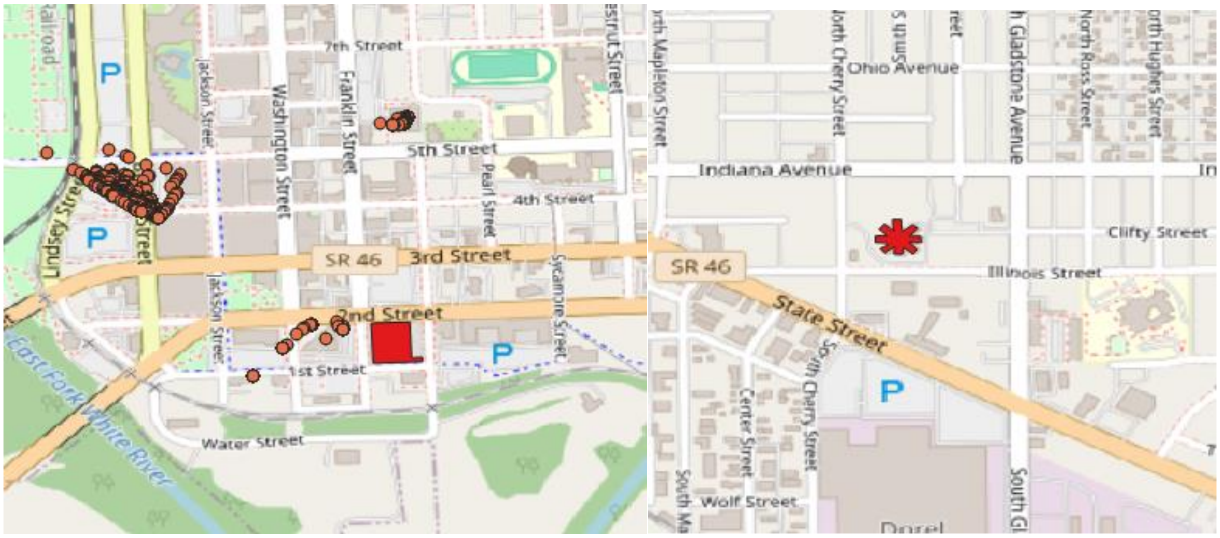


Figure 143. Bartholomew County Jail, Columbus, IN (West); Bartholomew County Juvenile Detention Facility (East).

In Terre Haute, Indiana, the research team identified one suspect flight originating from a fast food facility east of the U.S. 41 highway. The flight proceeded westbound over the Federal Correctional Institution Terre Haute facility and continued northeast over the Virgo County Jail (see Figure 144).

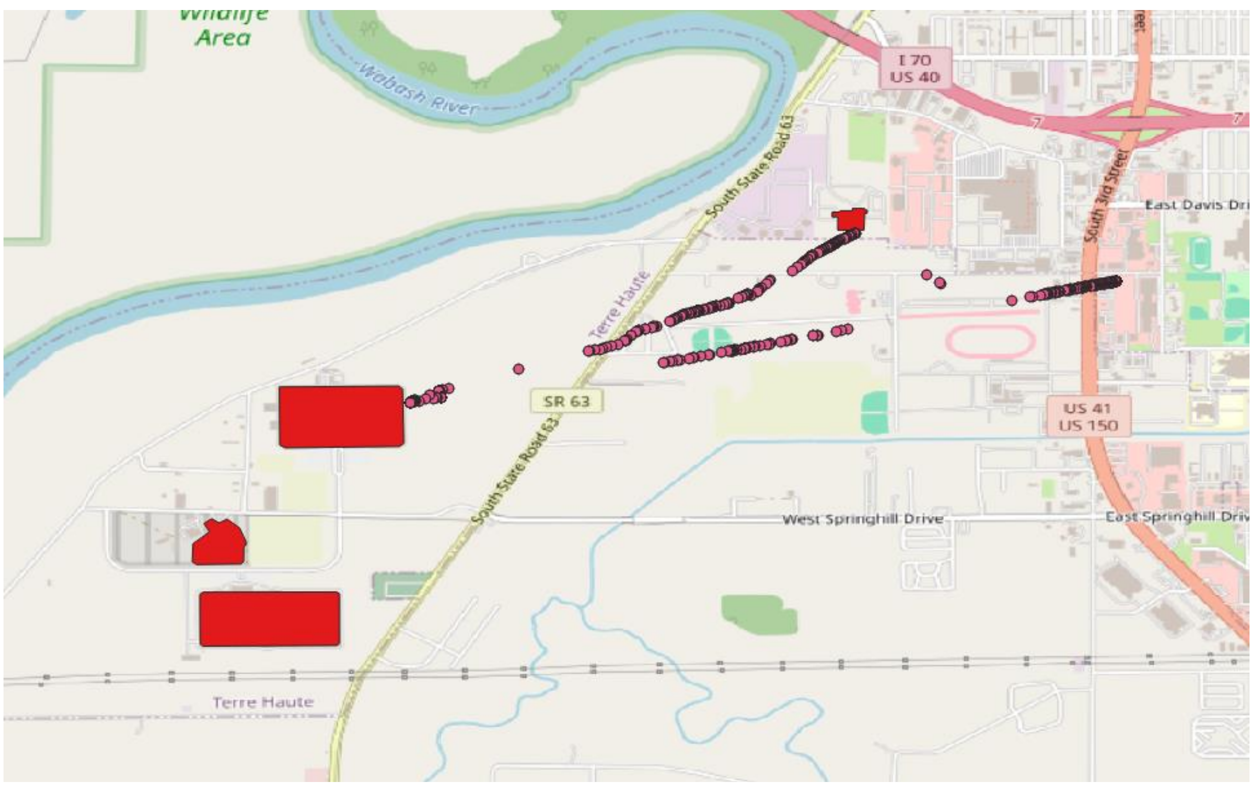


Figure 144. Federal Correctional Institution Terre Haute (West); Vigo County Jail (East), Terre Haute IN; Origination Point: Fast Food Restaurant (East).

No sUAS flights were noted near the Tamoka Correctional Facility in Daytona Beach, Florida (see Figure 145). Due to the relatively short range of Remote ID sensors, it is likely that this facility was too far out of range.

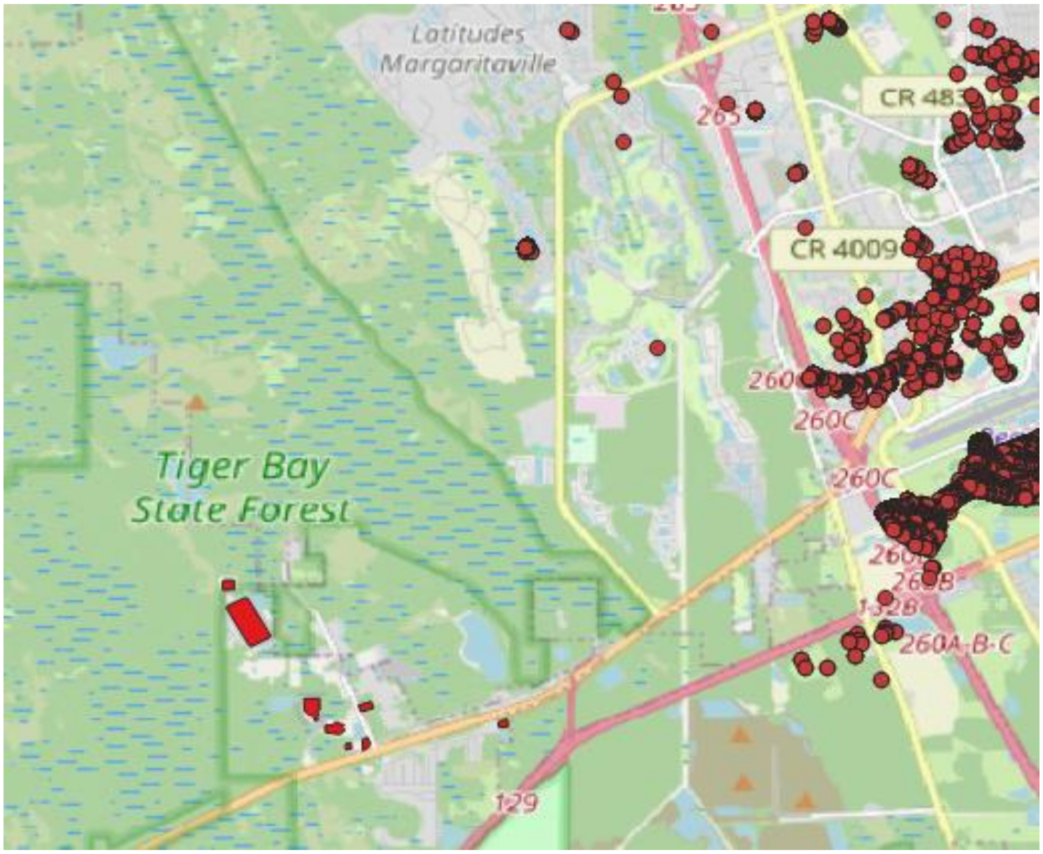


Figure 145. Tamoka Correctional Institution, Daytona Beach, FL.

A great deal of sUAS activity was noted around the Daytona Beach International Speedway, primarily originating from parking lots and other areas in proximity to the venue (see Figure 146). The research team did not evaluate if the facility was in active use at the time of flights.

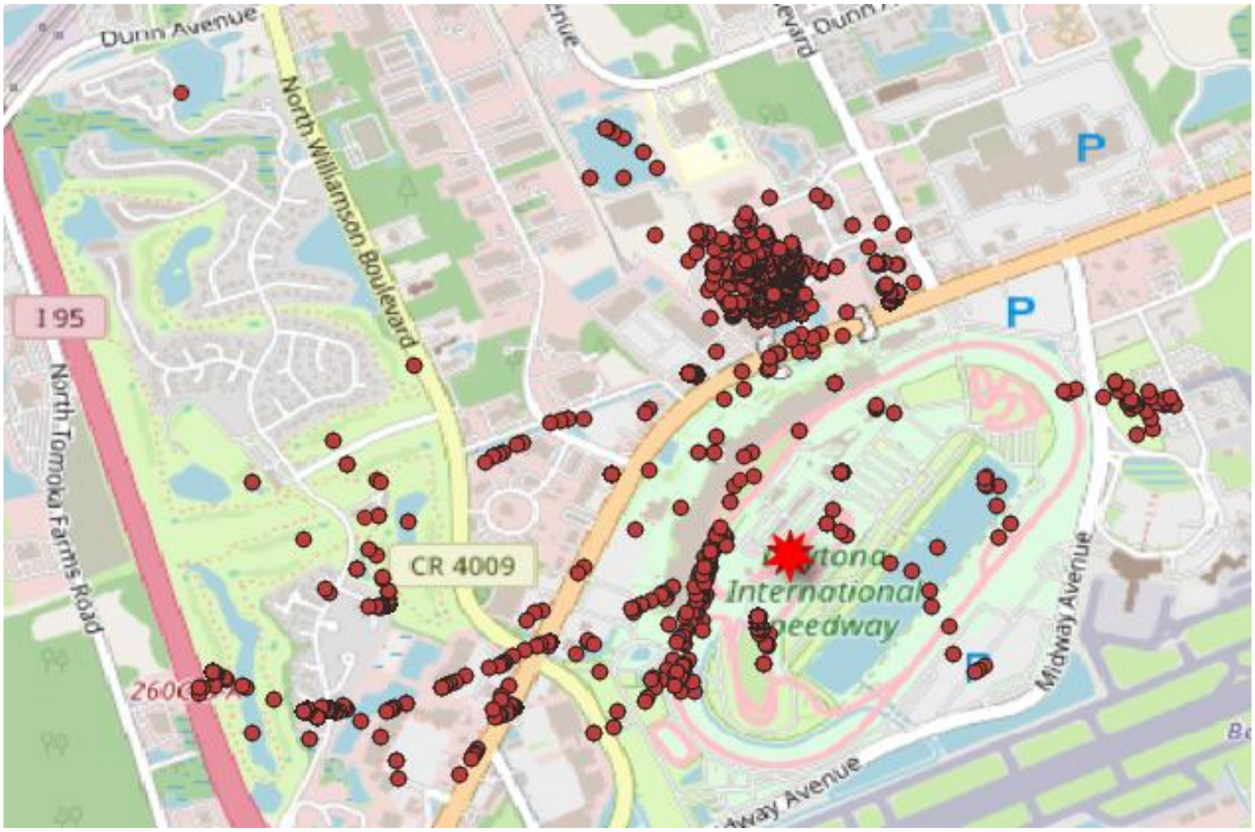


Figure 146. Daytona International Speedway, Daytona Beach, FL.

3.4.7 Potential Implications of Geofencing on TFR Protection

Geofencing refers to the use of virtual boundaries applied to designated geographical areas. Geofencing is designed to improve safety and security, ensure regulatory compliance, and protect public safety and privacy. On January 13, 2025, DJI updated its geofencing system to all enterprise drone products in the United States to align with FAA-designated areas (DJI, 2025). Previously, geofencing imposed restriction or prohibition for sUAS operations within certain geographic areas. Under the new implementation, these areas will be depicted as *Enhanced Warning Zones*, with an in-app alert used to notify operators flying near controlled airspace. Geofencing no longer implements flight restrictions, thereby putting the burden of compliance on the individual operator.

Since this new policy was implemented following the conclusion of this study, it is unknown exactly how this change will influence sUAS operations. The authors predict that given the large extent of DJI platforms in current operation, coupled with evidence of sUAS flight over restricted areas, such as prisons, military installations, and other critical infrastructures, the removal of geofencing restrictions will likely increase incursions into Temporary Flight Restricted Areas, No Drone Zones, Critical Infrastructure, and other protected areas. It is further likely that additional incursions will also affect protected aeronautical activities, such as airports, heliports, controlled airspace, special use airspace, and other related areas.

3.5 Task E: Forecasting Industry Growth and Potential Advanced Air Mobility Implications

This task intended to leverage data gathered throughout this project to inform upon industry growth, development, and further sUAS integration efforts.

3.5.1 Impacts to Urban Air Mobility (UAM) / Advanced Air Mobility (AAM) and Unmanned Traffic Management (UTM)?

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

- Ideal working altitudes that provide maximum de-confliction from both manned aircraft and sUAS traffic
- Geographical locations or characteristics in which UAM / AAM are likely to be adversely impacted by either air traffic or sUAS operations density
- Level of sUAS activity in proximity to heliports (which is likely to have similar characteristics to vertiports)
- The average radius of influence of normal sUAS activity
- Times of diminished sUAS activity (applies primarily toward AAM package delivery operations)

The findings of this project yield several potential impacts on AAM. In December 2024, the FAA updated Engineering Brief 105A, Vertiport Design, Supplemental Guidance to Advisory Circular 150/5390-2D, Heliport Design. FAA guidance for vertiport design reasonably mirrors the configuration of existing heliports (FAA, 2024b). It is highly likely that sUAS challenges experienced by heliports are *also* likely to be encountered at vertiports. As indicated from the previously presented data, it is not uncommon for heliports to encounter proximate sUAS traffic within .5 NM. The large footprint and visual indicators of airports are generally easy to recognize, and most individuals will have a general awareness of their presence. Conversely, the general profile of heliports—size, footprint, configuration, markings, signage, and related indicators—may not adequately alert sUAS operators to the presence of conflicting heliport operations. Unless a helicopter is currently *on the landing pad*, the only visual indicators of the presence of a heliport include ground markings, lighting, windsock, and other indicative infrastructure (antennas, fueling infrastructure, communications equipment, etc.). Unless sUAS operators know what they are looking for, they may not recognize the presence of nearby heliport activity. Complicating this issue is that heliports are often embedded within other urban infrastructure, such as atop or nearby buildings or other structures that may inadvertently camouflage a heliport's presence. Moreover, even with preflight planning tools, such as airspace familiarization using sectional charts, LAANC facility maps, and other related informational tools, the locations of heliports are *not currently depicted*, creating a potential gap in situational awareness for sUAS operators. This gap leaves sUAS operators inadequately aware and prepared to address potential nearby, low-altitude airspace hazards. In major urban areas, it is not uncommon to have up to 40 aerodromes—most of which are heliports—within a 10 NM radius. The research team recommends future 14 CFR §107 and 49 USC §44809 testing and training requirements include material that includes resources to check for nearby heliports, as well as best practices for visual recognition of heliport operations.

To illustrate the challenge of heliport identification, the research team included overhead imagery of a medical facility in the Daytona Beach area as an exemplar (see Figure 147). Note the extent and complexity of structures and other activity in the area. Moreover, in this image, the facility actually has *two* geographically-separated landing pads—a rooftop landing pad to the north depicted by white cross superimposed over a red background. This elevated, primary landing pad is unlikely to have many visual indicators observable from the ground.

Figure 147. Halifax Health Medical Center Complex, Daytona Beach, FL.

The second landing pad is on the south side of the buildings, somewhat shielded by the surrounding trees and parking lot. The landing pad is identified with a white cross, although without background coloration.

It is likely this landing pad is designed as a backup or auxiliary, used for mass casualty incidents or for use while the primary pad is occupied.

Perhaps more concerning is that UAS Facility Maps do not appear to account for heliport operations. In the case of the depicted medical facility, LAANC authorizations are available up to 100 feet AGL over the primary landing pad (the southern auxiliary pad is contained within a 0-ft UASFM grid).

Succinctly, the research team believes there is a training and reference gap to aid operators in complying with 14 CFR §107.43, which states, "No person may operate a small unmanned aircraft in a manner that interferes with operations and traffic patterns at any airport, heliport, or seaplane base."

An evaluation of sUAS operational altitudes collected from Remote ID data, suggests that sUAS flight activity occurs most heavily at altitudes between 100-500 feet AGL (*n*=87.0%), with a strong concentration of activity at 400 feet AGL (*n*=23.9%). The research team emphasizes that a sizable proportion (*n*=22.4%) of sUAS activity takes place *above* the maximum altitude of 400 feet AGL authorized by 14 CFR §107.51(b) and 49 CFR §44809(a)(6). A separate evaluation of LAANC approval activity at the sampled airports suggests that approvals' preponderance includes altitudes between 150-400 feet AGL.

Based on these findings, it is recommended that AAM operations consider flight operations at altitudes above 500 feet AGL and exhibit extreme caution during phases of flight that lower altitudes. Although integration of Remote Identification is still lagging behind implementation goals, it is recommended that AAM craft implement some form of Remote ID or other form of detect and avoid system for detection and airspace awareness to enable early identification and avoidance of potential airborne collision conflicts from sUAS.

Of further note, the research team questions the validity of LAANC activity as an effective measure of overall sUAS operations and locations within the NAS. Preliminary assessment indicates a disparity in the concentrations of LAANC approval activity vs. Remote ID activity. The research team believes this disparity may be at least partially explained by sUAS activity authorized under either Part 91 Certificates of Authorization or Part 107 Airspace Authorizations, which currently have no effective measure of quantity or extent. In several cases, these operations require advanced notification to the affected air traffic control tower facility to enhance situational awareness of controllers. The research team recommends that the FAA consider alternative reporting of airspace authorization and COA activity using the LAANC system. In lieu of contacting ATC, the research team recommends the implementation of an electronic reporting tool that feeds into the LAANC system under a new category of *pre-approval* that would meet the requirement of ATC notification. The key advantage of this modification is collecting vital activity information to better inform the agency of the extent of airspace authorization and COA activity. Moreover, this approach has the added benefit of centralizing disparate sUAS activity information within a singular system for subsequent evaluation.

The research team recommends that AAM operations generally avoid low-level overflight over residential neighborhoods. Multiple studies of sUAS origination locations consistently show these areas as having disproportionately elevated sUAS activity. Moreover, activity in these areas likely represents recreational / hobbyist operations rather than Part 107 (commercial) activities. As a general conclusion, recreational operators are likely to be less knowledgeable and aware of sUAS rules, nearby aeronautical activities, and potential hazards, primarily due to the lower training threshold required for operation, mainly the Recreational UAS Safety Test (TRUST) course.

An assessment of sUAS Remote ID data suggests that nearly 80% of sUAS operations are carried out within a footprint of .3 NM from the operator at or below 300 ft AGL. The proportion of activity carried out beyond this range and altitude is relatively limited. Any ability to offset sUAS operations—precisely the operator's location—beyond .3 NM or more would likely provide substantial protection from sUAS interference with AAM operations.

Small UAS operations are significantly diminished during darkness, with more than 80% of flights carried out during daylight hours. Only about 3.5% of sUAS flights were carried out during morning hours—between midnight and morning civil twilight. This five to six hour timeframe appears to be the most ideal for carrying out AAM package delivery with minimal interference from sUAS operations. The research team recommends explicitly limiting AAM delivery operations between midday and early evening, as these times tend to represent the peak operating hours for sUAS and incur an elevated risk of potential interference or aerial encounters.

The authors further highlight that the preponderance of sUAS activity exhibits extremely short flight durations. This means that sUAS operations are likely to appear with little advanced warning. The potential silver lining to this finding suggests that sUAS operational interference is equally possible to end as quickly as it begins. When alerted to potential sUAS interference, AAM operators should consider implementing risk avoidance procedures by either delaying operations or potentially holding outside the risk area. The risk posed by sUAS operations will probably cease after a short delay period.

3.5.2 Impact to Air Routes

The research team assessed sUAS activity near established air routes to determine the proximity of operations and potential interference based on sUAS activity location, altitude, and operation. Case studies were based on available findings.

Officially designated as *Very High Frequency Omnidirectional Range (VOR) airways*, but known more commonly as *Victor airways*, are a series of low-altitude air routes in the National Airspace System that generally extend from 1,200 feet AGL to but excluding 18,000 feet MSL (FAA, 2024a). The width of Victor airways generally extends 4 NM on each side of the airway centerline; however, it may extend further if the airway length exceeds 102 NM to protect angular accuracy errors. Victor air routes are predicated on either VOR or VORTAC navigation facilities (FAA, 2024a), and generally run between these facilities on established radial extensions. Victor airways are designated by a "V" prefix followed by a one to three-digit designation.

An analysis of operator locations revealed a substantial number of sUAS operations took place within lateral proximity to Victor airways (see Figure 148, Figure 149, and Figure 150). The research team overlaid a 4 NM circular radius indicator over points along airway corridors. These indicators are designed to provide the reader with a visual depiction of the extent of airspace encompassed by the respective airway. It is important to note that the circular indicators merely show an encompassing radius from a single point along the airway. The true extent of each airway extends 4 NM along the entire trajectory of the respective airway.

Although several detected sUAS operations fall within the lateral confines of Victor airways, they are less likely to intersect the vertical limits of these airways. Of the 6,037 flights that contained altitude reporting information, only 138 (n = 2.3%) reported a maximum altitude over 1,200 feet AGL, the minimum altitude threshold for Victor airways. Instantaneous Remote ID altitude data paints an even more optimistic picture. Based on nearly 4.3M instantaneous Remote ID messages that contained altitude data, only 15,387 (n = 0.36%) indicated flight at or above 1,200 feet AGL. Taken into context with the previous maximum flight altitude data, this means that even though a few flights exceed 1,200 feet AGL, the duration of exposure time spent at those altitudes appears relatively limited. Moreover, it is unlikely that manned aircraft would operate at the lowest threshold of Victor airways. First, manned aircraft flying at low altitude are less capable of receiving VOR signals necessary to maintain Victor airway navigation due to the Earth shielding FAA's curvature (2023). This limitation may encourage manned aircraft pilots to fly at higher altitudes. However, the transition to more advanced navigation equipment, such as GPS, makes pilot adherence to

Victor air routes less likely, in favor of direct navigation. As a result, manned aircraft may not strictly adhere to Victor air routing, if direct navigation is shorter, timelier, or more efficient.

The research team assesses that the aircraft flying along Victor air routes *within the prescribed altitude limits* are unlikely to encounter conflicting sUAS traffic. The research team asserts, however, that aircraft can encounter sUAS traffic during elevation to join or exit descent from Victor airways. This risk increases as an aircraft approaches 400 feet AGL and below, where the preponderance of sUAS operations were detected.

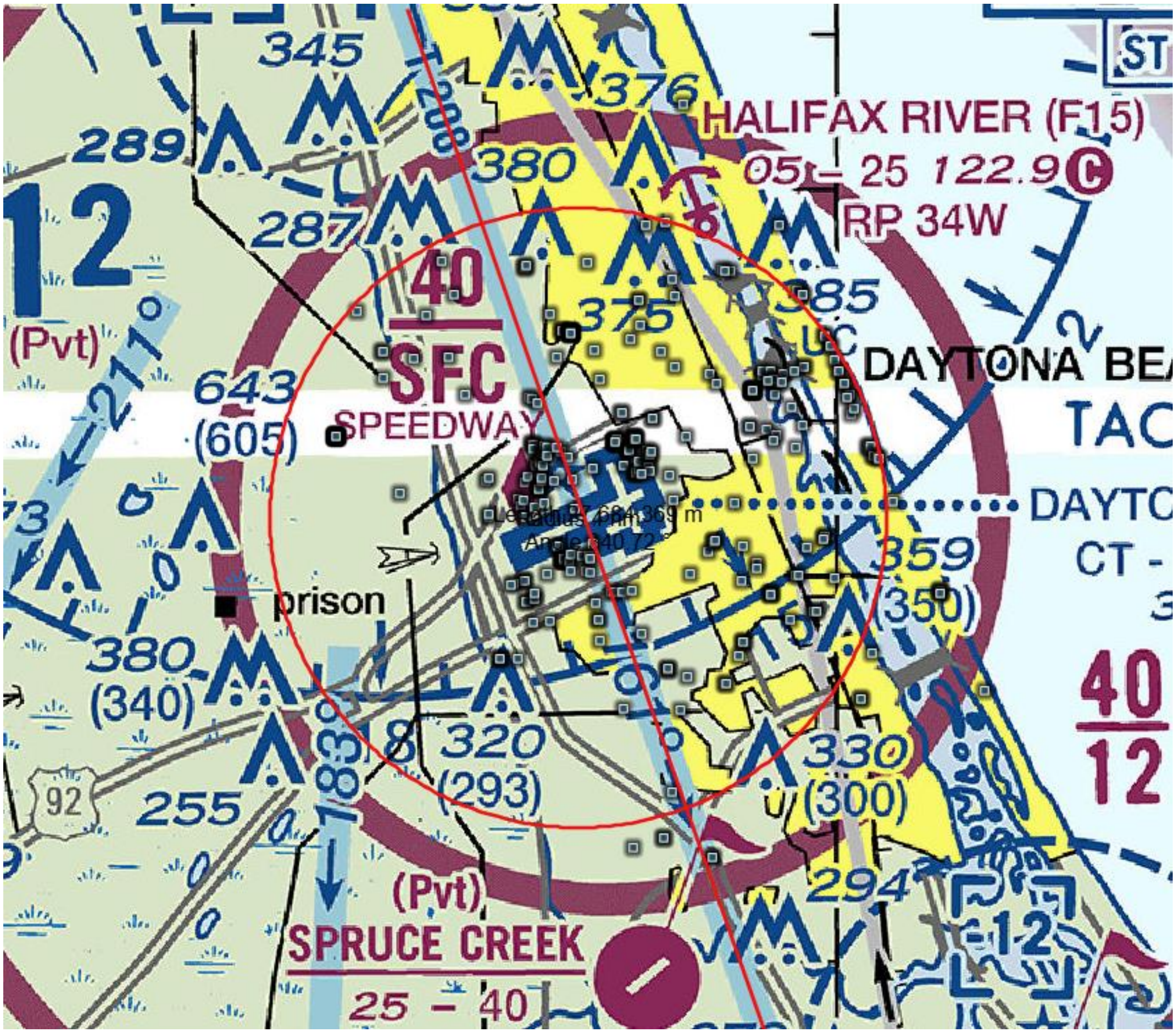


Figure 148. Air Routes in Proximity to DAB.

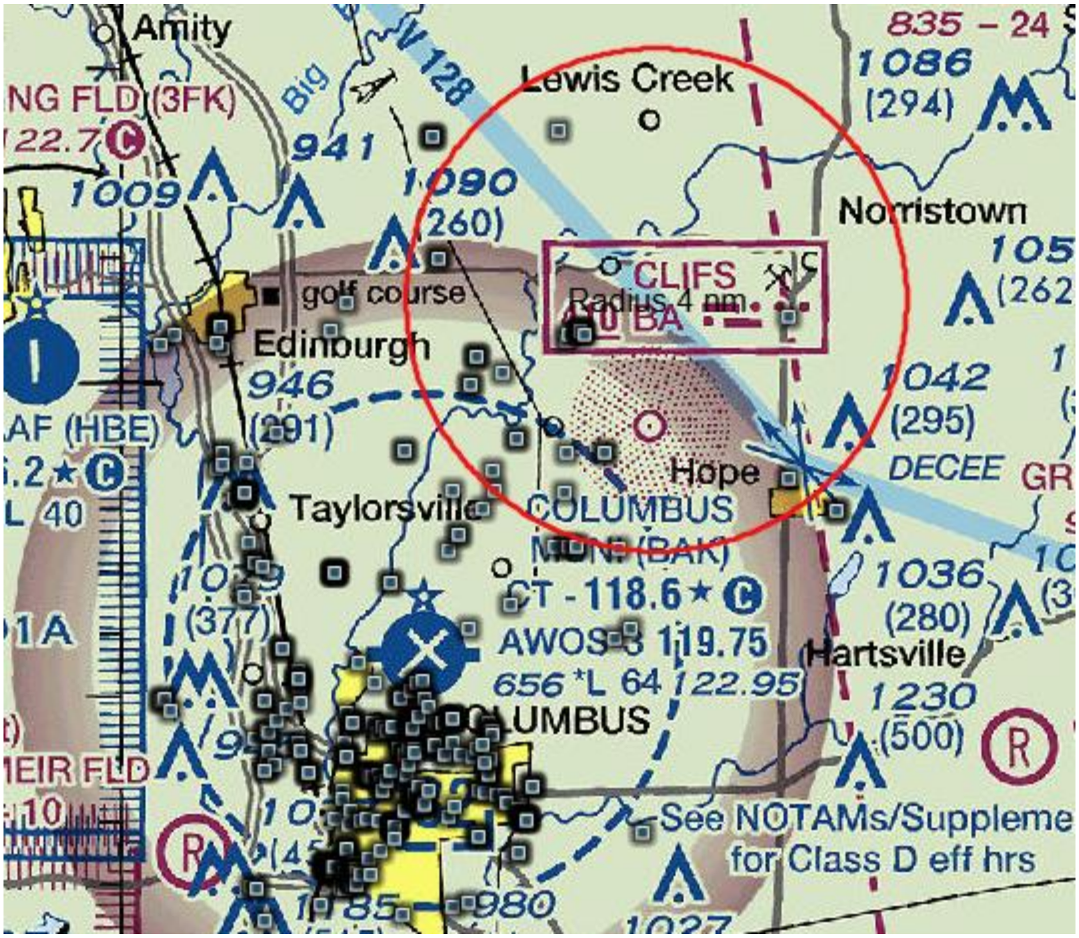


Figure 149. Air Routes in Proximity to BAK.

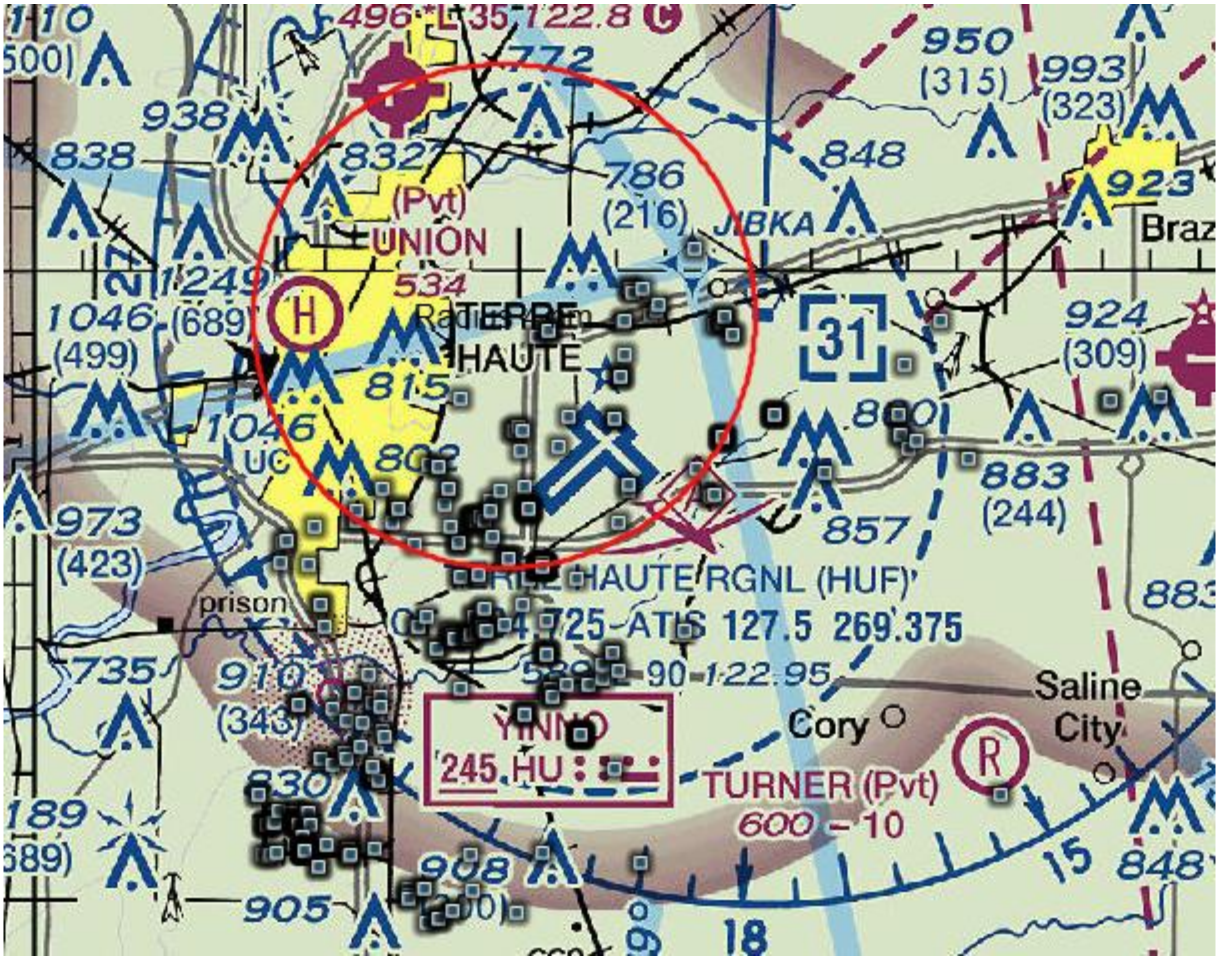


Figure 150. Air Routes in Proximity to HUF.

3.5.3 Communicating sUAS Traffic Conditions

The purpose of this research task was to explore various methods of communicating unusual or elevated sUAS activity to airspace users.

Currently, air traffic controllers convey situational awareness of proximate traffic in the form of *traffic advisories*, "issued to alert pilots to other known or observed air traffic which may be in proximity to the position or intended route of flight of their aircraft to warrant their attention" (FAA, 2025, p. T-8). Advisories are generally based on: "1) visual observation, 2) observation of radar identified and non-identified aircraft targets on an ATC radar display, or 3) verbal reports from pilots or other facilities" (FAA, 2025a, p. T-8).

Specific procedures for providing advisory information of known UAS activity are based on ATC judgment. "If known, [the report should] include position, distance, course, type of unmanned aircraft (UA), and altitude" (FAA, 2025a, p. 2-1-16). ATC guidance is to "issue UAS advisory information for pilot-reported or tower-observed activity" when in the controller's judgement, "their proximity warrants it (FAA, 2025a, p. 2-1-16). Continued reports are recommended "to potentially impacted aircraft for at least 15 minutes following the last report" (FAA, 2025a, p. 2-1-16).

The research team believes that ATC controllers are ill-equipped to provide UAS advisory information. Generally, sUAS craft are usually too small to be reliably detected and identified by ATC radars, which typically include models such as the Airport Surveillance Radar (ASR)-4, and Air Route Surveillance Radar (ARSR)-4. These systems are generally supported by secondary surveillance systems designed to detect aircraft transponder beacons, including Mode A, Mode C, and Mode S. Moreover, UAS detection systems, such as Remote ID detection technology, are not widely deployed and available to air traffic controllers for reference. Finally, other informative information about sUAS activity, such as approval data from the LAANC system, is not generally available to tower controllers for real-time reference, absent special conditions (such as a coordinated, approved UAS operation in a zero UASFM grid). As a result, the only methods currently available to air traffic controllers to become aware of sUAS activity include: 1) receipt of an aircraft [or other third party] report of a sUAS sighting or activity; 2) direct ATC observation of sUAS activity; 3) awareness of a pre-coordinated UAS activity or operation; 4) receipt of a notification call via phone advising of a UAS activity [IAW COA, waiver, or airspace authorization requirement]; or 5) notification via phone or radio by a UAS operator who is experiencing a fly-away or emergency *and* reports the event to ATC.

Based on currently established reporting methods of UAS activity reporting, the research team recommends transitioning from *directed traffic alerts*, which provide notification and location relative to a single aircraft, to prioritizing *broadcast alerts*, that provide widespread notification and location using common reference points.

The research team believes the current reporting strategy articulated in JO 7110.65BB is adequate. However, it does not fully understand the mechanism that will be used to provide situational awareness and subsequent notification to ATC personnel of the presence of abnormal sUAS traffic conditions.

Another possible broadcast that can enhance situational awareness for nearby pilots is to include a simple broadcast message upon initial aircraft contact, integrated into the existing automatic terminal information service messages or initial aircraft contact with “LAANC active” or “proximate UAS operations” or similar plain-language phraseology indicating UAS operations are active within the terminal area.

4 CONCLUSIONS

The analysis of Remote ID data provides a valuable foundation for understanding small UAS traffic patterns, enabling a data-driven approach to assessing their impact on the NAS. By codifying traffic trends, this study supports predictive modeling for future UAS operations, enhances situational awareness, and informs risk-based decision-making. The insights gained from Remote ID data not only facilitate hazard identification but also contribute to proactive safety assessments, helping to mitigate potential conflicts between UAS and crewed aircraft. As UAS integration continues to expand, leveraging this data will be critical for shaping regulatory frameworks, enhancing airspace management, and ensuring the long-term safety and efficiency of the NAS.

The following elements summarize the critical technical conclusions derived from this project:

Remote ID Signal Range Limitations: Remote Identification detection was effective only within a limited range. This suggests that current Remote ID technology may be insufficient for large-scale airspace surveillance, particularly in detecting non-compliant operators.

Lack of Comprehensive sUAS Tracking Data: The absence of a centralized system for tracking all sUAS flights remains a critical issue. Many flights go undetected due to the lack of mandatory transponders or tracking requirements, making it difficult for authorities to assess airspace risks and enforce regulations accurately.

Elevated Traffic During Holidays: Data showed a spike in sUAS operations immediately prior, during, and after holidays. This finding suggests primarily recreational/hobbyist operations. It is possible that public events could also prompt additional Part 107 operations, as well, however, the authors assert the majority of activity likely represents recreational operations.

Platform Utilization: Detected sUAS traffic suggests operators prefer smaller, newer, more capable platforms. DJI platforms, known for their reliability, user-friendly design, and affordability dominate sUAS traffic detections.

***Small UAS Traffic Expanding*:** Data suggests continued rapid growth of sUAS operations—particularly non-recreational/commercial operations. While recreational/hobbyist operations appear to be plateauing, commercial operations continue to expand unabated. The authors assert commercial operations will spike further upon the release of additional sUAS integration measures, such as routine BVLOS flight rules.

Altitude Compliance and Exceedances: The study found a significant proportion of sUAS flights occurring at or near the 400-foot ceiling permitted by regulations. However, many recorded flights exceeded 500 feet AGL, indicating a potential risk for conflicts with manned aviation operating in the same airspace.

sUAS Traffic Concentration in Residential Areas. Many sUAS operations originated from low-density residential areas, suggesting primarily recreational usage. This poses a challenge for aviation safety, as crewed aircraft operators may not recognize these areas as high-risk zones for potential drone encounters.

Short Duration of sUAS Flights: Most recorded flights lasted under 35 minutes, with the majority under five minutes. This indicates that sUAS operations are often brief, which may limit the time available for air traffic management interventions but also means that risks may be transient and localized.

Potential Risks Near Aerodromes: A substantial number of sUAS flights occurred near airports and heliports, with some exceeding the altitude limitations. This presents a safety hazard, particularly in high-traffic areas where manned aircraft operate at low altitudes during takeoff and landing.

Limited sUAS Operations at Night: Most sUAS flights occurred during daylight hours, with minimal activity between midnight and morning twilight. This suggests that nighttime operations, such as commercial package delivery, could face fewer sUAS conflicts but may require additional safety measures due to reduced visibility conditions.

Influence of Weather on sUAS Operations: The study found that most sUAS flights occurred in calm weather, with few operations conducted during precipitation or high winds. This suggests that adverse weather naturally limits drone activity, which could be essential for integrating sUAS into regulated airspace. A small number of operations, however, still occur during adverse weather conditions.

LAANC Airspace Protection Limited: While UAS Facility Map maximum altitudes are designed to effectively segregate sUAS traffic operating in controlled airspace from nearby manned aviation operations, data suggests that a sizable proportion of sUAS operations are exceeding UASFM grid maximum altitudes, in some cases by up to 500 feet.

Disparity Between LAANC Approvals and Actual Operations: The research found discrepancies between LAANC approvals and actual Remote ID data. This finding suggests that a substantial portion of sUAS operations in the NAS are not conducted under LAANC approval, such as certificates of authorization or airspace authorizations. Alternatively, this may also suggest that sUAS operations occur without proper authorization, raising concerns about compliance with airspace regulations and the effectiveness of current tracking systems. Further study is needed to clarify this disparity.

Removal of DJI Geofencing Poses Potential Safety and Security Risks: DJI's recent policy shift to remove geofencing restrictions presents a strong likelihood of increased incursions of protected areas previously shielded by geofencing, including prisons, military installations, critical infrastructure, airports, heliports, controlled airspace, and special use airspace.

Potential Risks Exist Near Heliports: Data suggests that heliport locations are encountering higher levels of sUAS traffic. Operators may not be aware of the presence of heliports, since their locations are often masked by urbanization and are not generally plotted on aeronautical references used by Remote Pilots.

Recommendations for Urban Air Mobility: To mitigate risks, the study recommends that UAM operations occur at altitudes above 500 feet AGL and avoid overflights of residential neighborhoods. Implementing Remote ID or detect-and-avoid technologies for UAM could enhance safety by reducing potential conflicts with sUAS flights, which tend to be concentrated at lower altitudes.

These findings underscore the importance of leveraging Remote ID data for a comprehensive understanding of UAS activity in the National Airspace System. By analyzing traffic patterns, identifying operational risks, and assessing safety implications, this study provides key technical insights that inform airspace management and policy development.

5 RECOMMENDATIONS

Building on the key technical conclusions, this section outlines actionable recommendations to enhance the safe and efficient integration of small UAS into the National Airspace System. The insights gained from Remote ID data analysis highlight areas where policy refinements, technological advancements, and operational guidelines can improve airspace management and risk mitigation. By implementing these recommendations, stakeholders—including regulators, industry members, and UAS operators—can proactively address emerging challenges, support data-driven decision-making, and foster a more resilient and scalable framework for UAS operations. Several recommendations are actively planned for inclusion in the follow-on project, ASSURE A83, *Drone Traffic Analysis*, starting in late 2024.

Research Recommendations

Unknown Remote ID Effectiveness: Remote ID has several identified limitations; however, few studies exist to fully codify the capabilities and limitations of this technology. It is recommended to further study the following elements of Remote ID: 1) range; 2) coverage capabilities; 3) antenna configurations; 4) implications of signal interference and shielding; and 5) other related, applicable factors. This analysis is currently planned for implementation in the follow-on study.

Limited Sampling Prevents Broad Generalization: The results of the current study are exploratory in nature. Limited sampling prevents applying statistical inference to the NAS as a whole. The authors recommend continued expansion of sUAS detection initiatives to further inform NAS-level implications. Such an expansion is currently slated for the follow on study.

Operational Recommendations

***Heliport Plotting*:** Implement heliport plotting on sectional and raster charts. Include heliport locations on common, online reference resources, such as the FAA's ArcGIS online references.

***Broadcast sUAS Traffic Alerts*:** Recommend air traffic control use of broadcast, rather than directed traffic alerts, to maximize situational awareness of manned air traffic to the location of sUAS activity.

Augmentation of FAA Advisory Circular Information: Recommend augmenting guidance for sUAS collision avoidance in FAA Advisory Circular (AC) 90-48E, *Pilots' Role in Collision Avoidance*. Suggest specific recommendations for avoiding low-level overflight of residential areas and flight below 500 feet AGL. Suggest including recommendations for spotting not only airborne aerial vehicles, but also ground-based evidence of sUAS activity, such as personnel, vehicles, tarps, landing pads, and related materials. Recommend providing augmented guidance in AC 107-2A, *Small Unmanned Aircraft System*, to aid operators in enhancing the conspicuity of both their aerial vehicle and operations area. These recommendations may be further informed by the results of ASSURE A74 research, *Increase Small UAS Conspicuity in Terminal Environments.*

Provide and Promote Enhanced Training for sUAS Operators via FAA WINGS Pilot Proficiency Program: Leverage operational recommendations derived from authoritative sources, such as ASSURE, to produce additional operational training aids specific to UAS operators. Recommend separating these courses into a unique section to make WINGS UAS-centric courses easier to differentiate from manned pilot courses.

Consolidate Flight Reference Material into a Singular sUAS Operations Hub Website: sUAS operators use a multitude of references, online tools, and related materials to support mission preparation and planning. However, these tools are often found on separate websites and can be difficult to locate. Recommend implementing a singular sUAS Operations Hub, designed to consolidate online resources for sUAS operators, such as links to NOTAMs, TFRs, airspace tools (such as the FAA's ArcGIS online/UAS Data) filing DROTAMs, UAS Facility Maps/LAANC, authoritative weather information, sunrise/sunset times, and related material. While resources like B4UFLY offer some of these tools to operators, access to all necessary planning information is generally not available on these sites.

The recommendations outlined in this section provide a clear pathway for enhancing safe and secure UAS operations. By implementing these strategies, the FAA can improve safety, efficiency, and compliance while fostering innovation and supporting continued UAS industry growth. Ultimately, these recommendations serve as a foundation for informed decision-making and proactive improvements that will drive sustained safety and further integration of UAS operations in the NAS.

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