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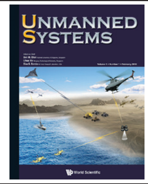

Analysis of Unmanned Aircraft Systems Sightings Reports: Determination of Factors Leading to High Sighting Reports

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Unmanned Aircraft System (UAS) growth in the past several years has been rising at a steady pace which has complicated the attempts to safely integrate them into the National Airspace System, as evidenced by an increasing number of UAS sighting reports being submitted to the Federal Aviation Administration. The analysis consisted of a mixed method approach using quantitative analysis of more than 9000 Federal Aviation Administration Unmanned Aircraft System Sighting reports from 2015 through 2019, as well as U.S. Census data, and weather data. The qualitative analysis focused on UAS regulation, and heatmap data of both population density and UAS sighting location density. The findings for the five states with the most and the least sighting reports show that major metropolitan areas, which have high population and population density, higher median household incomes, high percentage of college graduates, and are located in areas that have stable weather and negligible weather effects such as rain and high winds during the summer months, have both high and concentrated levels of UAS sightings.

Keywords: Unmanned aircraft system; UAS; UAS sightings.

1. Introduction

The public's desire to have greater access to operate Unmanned Aircraft System (UAS), which consists of an unmanned aircraft platform and its associated elements, is expected to make UAS more affordable and prevalent in the U.S. National Airspace System (NAS) [1,2]. With this anticipated rise in prevalence, the need to determine what factors lead to specific areas within the United States having a higher incidence of sightings of unauthorized UAS usage will be of great importance to ensure long-term integration into the NAS and public acceptance in their usage. For this paper, the term UAS will be considered synonymous with all terms such as model aircraft, small unmanned aircraft, small unmanned aircraft system (sUAS), unmanned aircraft, or drones as defined by the FAA and codified under 14 Code of Federal Regulation (CFR) 1.1 [3,4]. Previous research into UAS sightings include an analysis by Fort Hill Group, and an analysis of which months had the highest sightings, *Can the timeframe of reported UAS sightings help regulators.* This paper looks at the factors of federal and state regulations and guidance, community outreach/educational programs, U.S. Census data, and weather data, can result in a higher incidence of sightings of unauthorized UAS usage. Through these factors, other areas throughout the United States, and possibly around the world, can be identified to focus efforts to lower the incidence of unauthorized UAS usage. Those efforts can include more regulation, educational programs, or enforcement.

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2. Research Problem

The past several years saw a growth in the use of UAS throughout the world, including the United States [1]. While this growth has opened numerous possibilities for their future usage, it has brought a great deal of operational challenges to make them safe to use within the NAS [1]. Both the Federal Aviation Administration (FAA) and the Government Accountability Office (GAO) have listed

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potential risks that the use of UAS can pose to include the potential of unintentional collisions, damage to property, injury or death, and national security concerns [1,5]. If the risks surrounding UAS persist, it will only continue to lower the public's confidence in the usage of UAS, and in turn, lower the potential growth in UAS usage [6].

This paper determines what are the specific factors within federal and state regulations and guidance, community outreach/educational programs, U.S. Census data, and weather data that could contribute to a higher incidence of unauthorized UAS sightings using both quantitative and qualitative analysis.

3. Significance of the Study

The factors that are determined can be used to inform future decision-making for UAS guidance, regulation, and community education efforts that can be used to lower the number of unauthorized UAS flights within the NAS. This research and conclusions have broad implications for use by the federal and state legislators and decision makers as the FAA projects continued growth in the purchase and usage of privately owned UAS which could lead to a higher number of unauthorized UAS flights [1]. The resulting guidance and regulation will benefit future UAS pilots and civilians as it will allow safe integration into the NAS. This study will be able to be applied in how to best develop Federal, State, and Local regulations, laws, ordinances, and guidance, community outreach, and educational efforts to lower the incidence of UAS sightings.

4. Delimitations

Delimitations on the project consist of only considering UAS regulations and guidance, the FAA UAS sighting reports for the 50 states of the United States and District of Columbia; U.S. territories will not be included. The FAA has 56 months of UAS sighting data published, from November 2014 through June 2020 [7]. However, the sighting data from 2014 and 2020 will be removed from the study for the data to have complete annual datasets to show potential trends in the data. In addition, the sightings from 2020 will be removed due to a possibility of skewed data due to the COVID-19 pandemic [8]. Of the provided data types, date/time, city, state, and summary, only the date, city, and state will be used for the data analysis. The primary factors that will be used to inform the conclusion will include federal and state regulations and guidance, community outreach/educational programs, U.S. Census data, and weather data. These delimitations will narrow the scope of the study to ensure overall accuracy and relevance to the data, results, and conclusion.

5. Limitations and Assumptions

For limitations, the sighting reports may include legally flown UAS as the reporting system can take in reports from civilians [9]. This limitation is managed as the sighting reports from civilians are routed to the FAA through local law enforcement and first responders [9]. The UAS sighting data are limited as the FAA has only 56 months of UAS sighting data published, starting from November 2014 going through June 2020 [7]. The sighting data can also be limited as only individuals familiar with UAS who know how to file a report, or those who care to file a sighting report on unauthorized UAS usage will make it into the reported data. This can potentially lower the number of sightings as unnoticed unauthorized flights or flights that are not reported are not included in the data.

With the advent of the COVID-19, there may be a variation in the sightings data for the months reported in 2020 [8]. This variation might be seen, where there could be a high number of sightings due to the perceived safety of outdoor activities during the pandemic which could lead to more people wanting to fly their UAS outside. The other side of the spectrum could be lower sightings due to high joblessness and uncertainty with future income which could translate to fewer UAS being purchased or a desire not to risk an expensive UAS during a flight. This limitation will be managed by not including the sightings reports for 2020.

An additional limitation is UAS regulation. The limitations are in relation to timeframe which UAS regulation is implemented, how UAS regulation is enforced, and the amount of UAS regulation at a state, local, and tribal level. The UAS sighting data collection spans five years, from January 2015 through December 2019, where during that time, there will be instances where new regulations are put in place. This limitation will be managed by listing the date in which the UAS regulation was implemented and will allow the study to see if any notable changes happened when a new regulation or guidance was put in place. The way UAS regulation is enforced is another major factor, the United States has a piecemeal law enforcement network across the states and municipalities. Each have different levels of funding, staffing, and priorities. One specific state or local law enforcement agency may make the enforcement of UAS regulation more seriously than others. It will be assumed that enforcement will be a factor in how. The final factor of UAS regulation is the amount of UAS regulation. Other levels of government, such as State, local, and tribal may take UAS unauthorized usage more seriously. Because they take it more seriously, they will pass more regulation.

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The available census data can also limit the usefulness of the results. The census data used are also nearly 10 years old, taken in 2010, which might not be representative of the current population. The size and population of each state as those with the higher population densities could have a higher rate of UAS sightings and the opposite effect for lower population densities. The general population census data of a state can inform the sightings based on average salary, cost of living, population density, and so forth. For information used in the study, there are no limitations as all the required data for analysis, UAS regulations, UAS sightings, census data, and weather reports are publicly available and can be used without the need to seek prior authorization.

Other factors can include weather, in both the number of months in which there is favorable weather to fly UAS and changes of weather. Each state has different weather patterns, which will be one of the factors that will be determined by the analysis of this paper. The weather data that are collected are limited by microclimate, which can be any climatic condition in a relatively small area and can differ in large areas such as cities [10]. It will be assumed that the weather data collected will be a general average for across a selected area.

The assumptions of the paper include that all the listed UAS sightings are accurate and true sightings in geographical location and time of day, each sighting is individual and not reported more than once, and the sighting is an unauthorized flight of a UAS and is seen as an issue to public safety. These assumptions will ensure the accuracy of the data that will be processed for the determination of a conclusion.

6. Definition of Terms

Geographic Information System (GIS)	A system where geographic information is stored in layers and integrated with geographic software programs so that spatial information can be created, stored, manipulated, analyzed, and visualized (mapped) [11].
Geospatial	Geospatial is defined as the collective data and associated technology that has a geographic or locational component [11].
Model aircraft	As defined by the FAA means an unmanned aircraft that is (1) Capable of sustained flight in the atmosphere; (2) Flown within visual line of sight of the person operating the aircraft; and (3) Flown for hobby or recreational purposes [3].
National Airspace System (NAS)	The NAS is defined by the FAA as the common network of U.S. airspace; air navigation facilities, equipment and services, airports or landing areas; aeronautical charts, information and services; rules, regulations and procedures, technical information, and manpower and material [12].
Small unmanned aircraft	As defined by the FAA means an unmanned aircraft weighing less than 55 pounds on take-off, including everything that is on board or otherwise attached to the aircraft [3].
Small Unmanned Aircraft System (sUAS)	As defined by the FAA means a small unmanned aircraft and its associated elements (including communication links and the components that control the small unmanned aircraft) that are required for the safe and efficient operation of the small unmanned aircraft in the national airspace system [3].
Unmanned Aircraft (UA)	As defined by the FAA means an aircraft operated without the possibility of direct human intervention from within or on the aircraft [3].
Unmanned Aircraft System (UAS)	The FAA defines a UAS as an unmanned aircraft platform and its associated elements - including communication links, sensors, software, and power supply - that are required for safe and efficient operation in the (NAS) [1,14].

7. List of Acronyms

CFR	Code of Federal Regulation
COVID-19	Coronavirus disease 2019
FAA	Federal Aviation Administration
GAO	Government Accountability Office
GIS	Geographic Information System
NAS	National Airspace System
sUAS	small Unmanned Aircraft System
UA	Unmanned Aircraft
UAS	Unmanned Aircraft System

8. Literature Review

The most relevant areas of research that apply to this study were topics on UAS sightings and regulation. This review is important to determine what other research has been conducted on UAS sightings. Federal, State, and Local regulations, laws, ordinances, and guidance that have been put in place to reduce or eliminate unauthorized UAS operations, thereby reducing the risk of mid-air collisions with manned aircraft. The literature review will also address community outreach, technological mitigations, and educational efforts.

8.1. *UAS sightings*

A UAS sighting that should be reported is considered by the FAA to be any witnessed unauthorized drone operations or drone operation that appears dangerous or is being used to commit a crime [7]. The FAA encourages everyone, including private citizens, to report any UAS sighting they deem reportable, which are available to the public without permission [7]. But those reports only encapsulate UAS sightings that fit the FAA's definition of a reportable sighting. These reports do not give a general sense for how often UAS are used or seen in the United States.

The Pew Research Center, which is a nonpartisan fact tank that informs the public about issues, attitudes, and trends though conducting public opinion polling, demographic research, media content analysis, and other empirical social science research, conducted a study on the U.S. population's perception of UAS [6,14]. The polling was conducted on UAS sightings mid-2017, just as the FAA was predicting a compound annual growth rate of around 68% in the purchase and usage of UAS within the United States, based on 1.1 million UAS in use between 2016 and 2017 [15]. The timing of the Pew Research study was aligned as the usage of UAS within the United States was increasing, which would make their presence more noticed by the public and make the study more representative of current trends. Pew Research utilized their American Trends Panel (ATP), which is a nationally representative panel of randomly selected adults within the United States [16]. For the study, the ATP consisted of 4135 respondents who were asked a series of questions about UAS [16]. The responses they received stated that 8% personally owned a UAS and 59% said they had seen a UAS operate within the past year [6]. This study shows that there may be a significant amount of UAS usage within the United States that have been witnessed and not reported, their usage was not noticed, or their usage did not meet the FAA's reporting guidelines. Those percentages do not align with the FAA data that indicated there had only been 3882 total reported sightings in 2016 and 2017 [7].

In addition to gaining a general sense of how many people owned or have seen a UAS, the Pew Research study also gathered from respondents how they would feel if they were to see a UAS fly near their home, as well as what rules should apply to the use of UAS [6]. When the respondents were asked how they would feel if they saw a UAS flying close to where they live, allowing for respondents to choose more than one option, 58% said they would be curious, 45% interested, 26% nervous, 18% would be indifferent, 15% would be excited, and 12% would be angry with 11% scared [6]. When it comes to rules that should apply to the usage of UAS, the respondents had a variety of opinions, as seen in Fig. 1.

This type of information can inform what the public's general level of involvement, as people who have the least interest might not report or know when a UAS is flying when or where it is not allowed. These types of polls can give a good understanding of what regulation could be used to mitigate the usage of UAS. This polling has implications on the data analysis as it could be considered that the representative data is only a small portion of the total usage of UAS within the United States.

In addition to the polling, Pew Research conducted an analysis of the FAA drone sightings reports from across the United States at time of the polling [6]. The analysis of those reports showed that during the first nine months of 2017, the FAA had received an average of 155 reports per month [6]. Compared to the previous time period in 2016, there was a 24% increase in sightings each month, and an 86% increase during the same time period in 2015 [6]. The general trend of sightings shows a definitive increase in the number of UAS sightings based on average number per month.

It can be seen from this review that adding both the implications that the representative sighting data is only a small portion of the total usage and that the general trend of sightings shows a definitive increase, there is a great deal of UAS usage in the United States that is not noticed. This has significant impacts on the results as it should compound the need to determine what external factors are causing such a high incidence of UAS sightings.

The company Fort Hill Group, which produces products relating to human factors, safety, and data and risk analysis for government and industry clients, to include the FAA, conducted a safety analysis and developed two interactive

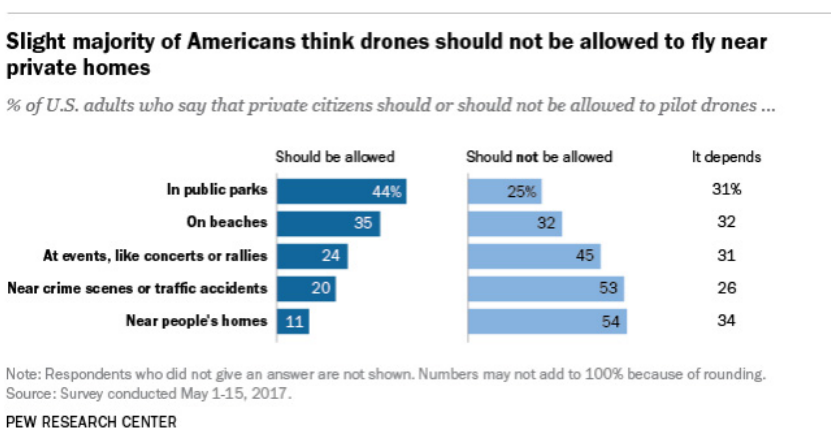

Fig. 1. Percentages of U.S. Population opinions on what rules should apply to UAS usage [6].

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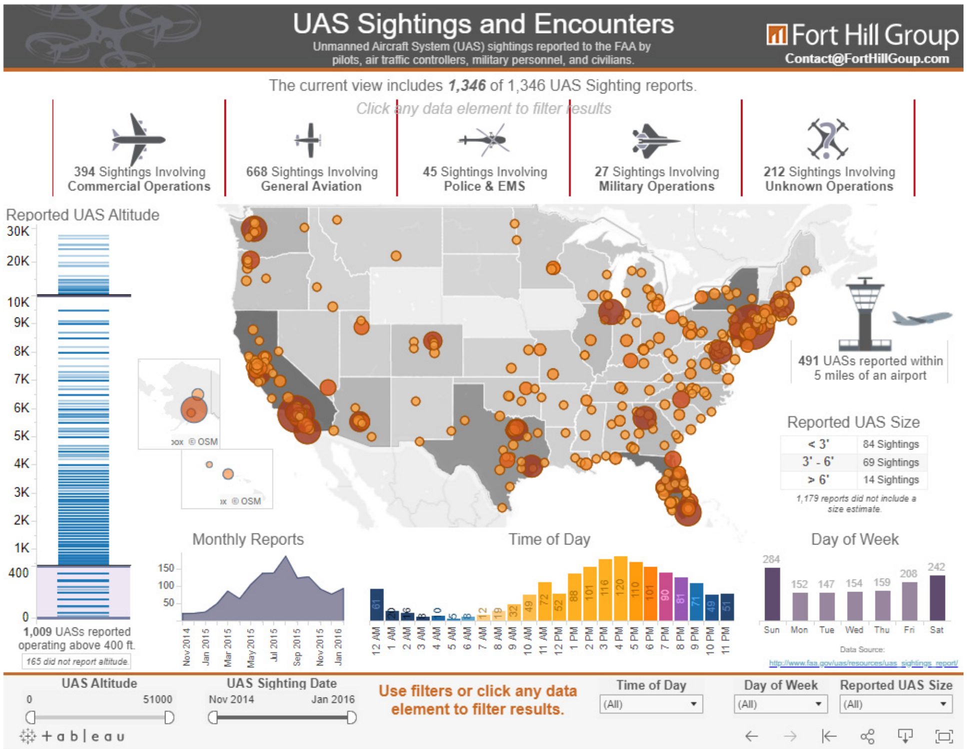

Fig. 2. Screen capture of interactive UAS sightings and encounters portal [17].

visualizations on UAS sightings that delves into the different situations using the summaries of reported sightings [17]. For their analysis, they utilized the FAA's *UAS Sightings Report*website, the same reports used in the quantitative analysis for this paper. Their report sample used all the sightings from November 2014 through January 2016, which totaled 1346 sightings [17]. Their first interactive graphic gives an overall view of all the reported sightings, as seen in Fig. 2.

The analysis that was included from the first interactive visualization included

- Geographic heatmap of all sightings;
- Who reported the sighting in terms of commercial operator, general aviation, Police & EMS, military operation, or unknown;
  - With general aviation aircraft having the highest with 668 total sightings.
- The reported altitude of the UAS;
  - 1009 UAS were reported operating above 400 ft with the highest reported at 28,000 ft near Jacksonville, Florida. *
- Time of report to include a sightings per month, time of day, and day of week;
  - August 2015 had the highest number of sightings with 186 total; 4:00 PM was the most common time that UAS were reported with a total of 120; and Sunday had the most sightings throughout the week with a total of 284.*
- The reported UAS size; and
  - Three feet was the most common size of UAS seen with only 164 reports including the size of UAS. *
- How many were reported within five miles of an airport
  - 491 UAS were reported within 5 miles of an airport [17]. *

*All the data derived from the reports, such as UAS operating altitude or UAS size, are based on estimates made by the person reporting the sighting.

The second interactive graphic dealt with UAS sightings near aircraft and airports and explored what happened in those situations, as seen in Fig. 3.

Their analysis of UAS Sightings near aircraft and airports included

- The number of sightings in proximity to an airport in both altitude vertically and distance horizontally, with the most sightings, 24 of them, happening between 1.0 and 1.5 miles away between an altitude of 0 and 500 feet; *
- What type of airspace the sighting occurred, with 228 occurring in unclassified airspace;

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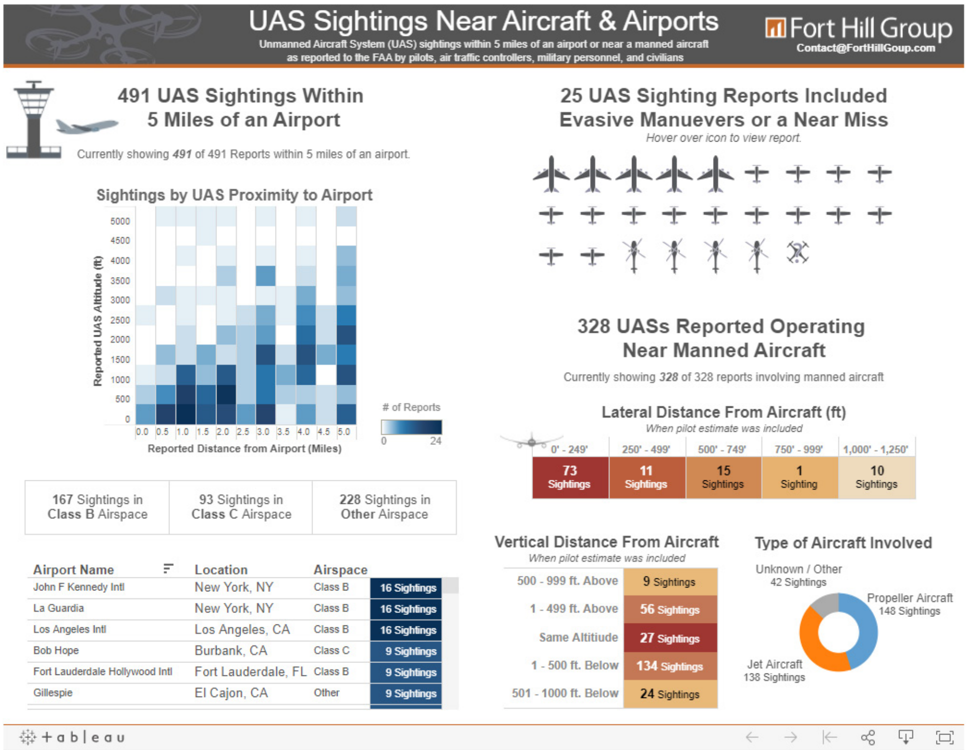

Fig. 3. Screen capture of interactive UAS Sightings near aircraft and airports portal [17].

- Which airports had the highest number of sightings with John F Kennedy International having 16 sightings; and
- The number of close encounters with aircraft which included;
  - 25 reports which required evasive maneuvers or was a near miss;
  - 328 reports near manned aircraft with 73 being within 249 feet laterally and 134 between 1 and 500 feet below the aircraft; and *
  - The type of aircraft involved which were mostly propeller driven aircraft [16].*

*All data derived from the reports, such as UAS operating altitude or UAS size, are based on estimates made by the person reporting the sighting.

Safe operation of a UAS outdoors is dependent on the local weather conditions. In The Drone Camera Handbook by Ivo Marloh [18], one way to operate a UAS safely is to avoid flying during adverse weather conditions, such as high winds and reduced visibility, and flighting during temperate weather conditions. Marloh's [18] suggestion is to operate in the early mornings or mid-afternoon, when the weather is generally stable and has better light quality. The suggestion of flight in the afternoon can be backed up by the analysis conducted by Fort Hill Group, where the most common sightings during the day were in the mid-afternoons with a peak of 4:00 pm local time [17].

Additional analysis on UAS sightings was conducted by Pitcher and Whealan-George using the same UAS sightings data from the FAA was conducted on data between July 2015 and June 2018 [19]. Their analysis looked into what time of the year UAS were most likely to be seen across the United States in order to allow regulators to determine which time of year to best use the resources [19]. They took the three years of data and averaged each month to come up with the average sightings per month during the year [19]. Those averages were then tested using the Chi-Square Goodness-of-Fit test to determine which months were statistically relevant from the other months, as found in Fig. 4 [19].

Their results determined that the months of June and May had the highest number of sightings and January and December had the least number of sightings with all four months considered to be statistically relevant from the other months [19]. That analysis concluded that more resources should be planned to be used during June and May, with fewer being resources being allocated for January and December [19].

8.2. *UAS regulation*

As the use of UAS has increased, numerous regulations have been implemented at the federal, state, and local levels to keep the flight of UAS as safe as possible. Federal regulation

Table 2

Total Sightings Chi-Squared Test from July 2015 - June 2018

Month	Sightings (Avg)	Percent from Expected
January	103	13%
February	144	1%
March	153	0%
April	168	0%
May	216	11%
June	268	43%
July	187	3%
August	183	2%
September	143	1%
October	159	0%
November	117	7%
December	92	18%

Fig. 4. Chi-Square Goodness-of-Fit testing by month from data spanning July 2015–June 2018 [19].

is administered by the FAA, which has implemented numerous regulations such as [4,13,20–23]

These documents along with others spell out the federal government's responsibilities when handling UAS. Part 107 deals with the regulations associated with UAS. Operating rules for UAS are under Title 14 Part 107 Subpart B of the Code of Federal Regulations and include rules such as [20].

In addition to the federal government enacting regulations like those found in Table 1, state and local governments enact their own regulations. An example of state regulations would be those enacted by the state of California which can be found in Table 3 [24].

In the United States, there are three main levels of government, federal, state, and local [25]. Under the Tenth Amendment, all powers not granted to the federal government are reserved to the states and the people [25]. The way the governing body is established has implications when it comes to the determination of how the NAS is managed and who makes determinations on how UAS are regulated. The FAA was established to be responsible for the safety of civil aviation [13]. In those responsibilities, the FAA [26] "issue and enforce regulations and minimum standards covering manufacturing, operating, and maintaining aircraft. We certify airmen and airports that serve air carriers". The individual states and localities have very broad powers to regulate UAS when it relates to privacy, crime, and public safety [27]. While the FAA has domain to determine what happens in the NAS, which is considered to be all airspace from the ground up, they do not have the ability to regulate what happens just above the ground, and

Table 1. Federal regulation examples.

Federal Regulations	
Title 14 CFR Part 107	Small Unmanned Aircraft Systems deals with all rules associated for small unmanned aircraft systems that weigh less than 55 pounds, it does not apply to aircraft under 14 CFR Part 101.
Title 14 CFR Part 101	Moored balloons, kites, amateur rockets, unmanned free balloons, and certain model aircraft deals with all other unmanned craft that are not under 14 CFR Part 107.
FAA AC 91-57B	Provides safety guidance for those operating UAS for recreational purposes.
FAA AC 107-2	Provides guidance for conducting sUAS operations in the NAS in accordance with 14 CFR Part 107.
FAA Order 2150.3B	Describes the "authority, responsibilities, policies, guidelines, procedures, objectives, and legal aspects of the Federal Aviation Administration's compliance and enforcement program."

Table 2. Operating rules for UAS.

Title 14 Part 107 examples	
107.13	Registration of UAS
107.27	Flight cannot be under the influence of drugs or alcohol
107.29	Operation during the night is prohibited
107.39	Operation over humans not in control of the UAS is prohibited
107.31	Keep the UAS within line of sight
107.41; 45; 47	Operation is prohibited in specific Air Traffic Control airspace or other restricted airspace
107.43	Operate within the vicinity of airports
107.51(a)	Flight may not exceed 100 miles per hour
107.51(b)	Flight cannot be higher than 400 feet above ground level (AGL)

Table 3. California UAS Regulations [24].

State	Regulation	Regulation Details
California	California Department of Parks & Regulations (Cal. Code Regs. title. 14, §4351) // 2015	This state regulation prohibits the use of a drone within State Park wilderness areas, cultural preserves, and nature preserves. It is important to check the regulations of each State Park as they may have their own posted regulations.
	AB 856 // 2015	This law prohibits entering the airspace of an individual in order to capture an image or recording of that individual engaging in a private, personal, or familial activity without permission. This legislation is a response to the use of UAS by the press in covering celebrities and other public figures.
	SB 807 // 2016	This law provides immunity for first responders who damage a UAS that was interfering with the first responder while he or she was providing emergency services.
	AB 1680 // 2016	This law makes it a misdemeanor to interfere with the activities of first responders during an emergency.
	PO 925-19-32 // 2019	This regulation states that no person shall launch, land or operate a model aircraft or UAS within any park unit in the Orange Coast District (Bolsa Chica State Beach, Huntington State Beach, Corona del Mar State Beach, Crystal Cove State Park, Doheny State Beach, San Clemente State Beach, and San Onofre State Beach).
	AB 2655 // 2020	This law prohibits first responders from taking pictures of a crime scene without a valid reason. This includes any type of photography, including the use of drones.

in turn do not have the ability to regulate UAS that operate 500 feet AGL and below as it is in the jurisdiction of the state where they have authority over lands, roads, and waterways [27, 28].

One regulation that the FAA has implemented was the requirement of all UAS to be registered the same as any civil aviation aircraft [29]. While the registration requirement was later overturned by the United States Courts of Appeals, 19 May 2017, for most hobby and recreational UAS, it did give the opportunity to study the effect of having a regulation [29]. In this paper, *An Analysis of Unmanned Aircraft Registration Effectiveness* Pentz and Tang [29] found that requiring UAS to be registered played a role in the reduction of unauthorized and careless operation of UAS. They conclude that this may be due in part by the ability for authorities to trace the UAS back to the operator so that there is the ability to provide education, hold the operator accountable, and to know when and where UAS are used [29]. This is evident as the FAA has listed public safety agencies, such as local law enforcement, who are in the best position to deter, detect, and investigate unauthorized or unsafe UAS usage [30]. The study did not find that there were negative consequences when UAS were required to be registered, which only supports the need for such regulation as the authors suggest [29]. The requirement to register UAS was later brought back on 12 December 2017 by the *National Defense Authorization Act for Fiscal Year 2018*. The FAA has registration requirements for UAS that fit three criteria

- All drones must be registered, except those that weigh .55 pounds or less (less than 250 g) and are flown exclusively under the Exception for Recreational Flyers;
- Drones registered under part 107 may be flown for recreational purposes as well as under part 107; and
- Drones registered under the Exception for Recreational Flyers cannot be flown for Part 107 operations [31].

These regulations, and others, are the primary way that the operation of UAS can be safely integrated into society and the NAS. While the federal government has a limited capability to pass down direct regulation, it does not have the ability to maintain overall order with the governance of UAS usage. It has already shown that the federal requirement for registration decreased the number of incidents involving UAS [29]. In terms of the results of the research, the regulations at the state level should play a significant role in how individual states rank against one another in numbers of UAS sightings, especially as states have broader powers to regulate their usage [27].

8.3. *Community outreach and education*

In order to reach UAS operators, regulators and industry can use community outreach and education in order to promote UAS safety [32]. There are many ways that have been used to reach out to include the B4UFLY mobile application, Low Altitude Authorization and Notification Capability (LAANC), FAADroneZone, Air Map, DJI Geo-fencing, and the Academy of Model Aeronautics.

The B4UFLY mobile application gives operators an interactive map that shows where UAS can and cannot be flown geographically such as in the Special Flight Rules Area around Washington D.C., it does not however give operators the ability to obtain airspace authorizations, which LAANC

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provides [33]. LAANC is the FAA's data exchange that is used to support UAS integration into the NAS [34]. The way it supports integration is by automating the application and approval process for UAS to use controlled airspace by gaining the required authorization [34]. There are several UAS Service Providers for providing LAANC capabilities, one such provider is AirMap, which has provided over 120 thousand LAANC authorizations as of 2019 [34, 35]. Other applications that inform operators on how to safely operate their UAS include technology such as geofencing, like that provided by DJI, one of the world leaders of UAS manufacturing [36]. A geofence is a smart technology that creates a virtual fence around restricted areas and airspace [36]. This type of technology is built directly into many brands of UAS, such as DJI, and will restrict the flight of the craft in the event which is being used in a restricted airspace [36]. In addition to applications, the FAA provides resources on their website such as directions to get the LAANC page and their FAADroneZone [37]. The FAA-DroneZone is the primary way for operators to register their UAS, either under Part 107 guidelines or under the Exception for Recreational Flyers, and receive their crafts N-number, which is the crafts registration number that all aircraft have [38]. Outside of government and industry resources, there are also community-based organizations such as the Academy of Model Aeronautics (AMA) [39]. The AMA is the world's largest model aircraft association that was organized "for the purpose of promotion, development, education, advancement, and safeguarding of modeling activities" [39].

9. Method

This study uses a mixed method research design of archival UAS Sighting Report data using quantitative descriptive statistical analysis to determine which states and which months have a higher number of sightings. Once the quantitative research is completed, a qualitative research approach will be used to determine what outside factors, such as federal and state regulations and guidance, U.S. Census data, and weather data may moderate the states and months that are selected from the quantitative research as having a higher number of sightings from the UAS sighting data. Using this research approach, the conclusion will highlight what regulatory, educational, and community outreach efforts would be best used to lower the number of unauthorized usage of UAS. The mixed method research approach used in this analysis is appropriate as it entails both analysis of the numerical UAS sightings data and qualitative analysis of UAS regulations, census data, heatmap images, and weather.

9.1. *Data collection*

Data collection included various sources from peer-reviewed journal articles, academic textbooks, federal data sources, weather reporting agencies, and federal and state UAS regulations, and the development of an interactive UAS sightings heatmap. A general search of peer reviewed journal articles using both the Hunt Library and popular search engines was used to research subjects like the topic of the paper for the literature review and to support the conclusions. The cloud program Google Drive, Docs, Sheets, and other Google Drive functions were used for all the works completed to include writing, data collection, and analysis.

For the UAS sighting data, the FAA published all their recorded data from November 2014 through June 2020 in on their website at (https://www.faa.gov/uas/resources/public_records/uas_sightings_report/) which includes data from all 50 states and the District of Columbia [7] and collected November 2020. These reports itemlist each sighting based on the date and include the city/state, and a summary of the UAS sighting. Of the provided data, only the data pertaining to the date and location were used. The data sets were published by the FAA at the end of each period. The UAS sighting reports from the FAA website, where a collection of 18 Microsoft Excel documents were downloaded and collated onto a single spreadsheet, as shown in Appendix A. Each document had the sightings broken down based on set blocks of time. The first three documents used unstandardized blocks of time with the first spanning from 13 November 2014–20 August 2015, the second from 21 August 2015–31 January 2016, and the third spanning 1 February 2016–31 March 2016. The remaining Excel documents used standardized blocks of time starting 1 April 2016 based on three months increment yearly quarters using the U.S. government fiscal year layout as shown in Appendix A [7].

For UAS regulations, federal regulations were accessed from the *Electronic Code of Federal Regulations* website (https://ecfr.federalregister.gov/) under U.S.C. Title 14 Part 101 and Part 107 pages. Supplemental information for federal regulations came from FAA AC 107-2 and 91-57B. State regulations were collected from the website UAV Coach (https://uavcoach.com/drone-laws-in-united-states-of-america/), which is a private company that provides individuals with knowledge, resources, and training to pass the FAA Aeronautical Knowledge Test to become a UAS pilot [40]. As part of their website, they have collected all the current UAS regulations at both the federal and state levels throughout the United States [24]. The regulations that were examined were all the federal regulations as well as the regulations for the states that had the highest and with the lowest reported sightings. The state laws will be examined for similarities or differences. Appendix B has a full list of all UAS regulations for each state as of 22 November 2020.

Census data were collected directly from the U.S. Census using the 2010 Census, and published to their website from their data profile manager, which gives numerous census statistics for the entire United States as well as individual states [41]. The states that were examined were those that had the highest and lowest reported sightings. Data collected for comparison for each state included median household income, poverty rate, median age, education rate percentage of both High School graduates and Bachelor graduates, employment, population, and population density [41]. The U.S. Census data were extracted from the U.S. Census website based on the five states that had the highest and the five states that had the lowest reported sightings.

Heatmap data will use the interactive *U.S.A Population Density Map* website, powered by Esri using ArcGIS, to view population distribution and density across the United States [42]. Esri is the developer of ArcGIS, which is a Geographic Information System (GIS) software used to create mapping and spatial analytics [43]. The development of the interactive UAS sightings heatmap was subcontracted out to a freelance developer using Fiverr, an online marketplace for freelance services [44]. The program developer's name is Stefan, username stef777, using QGIS to create the UAS sightings heatmap, which is a free and open-source geographic information system [45]. The heatmap for population density for use in the comparison used the *Snip & Sketch* tool with Microsoft Windows 10 and be used to gather the required images, both of individual states and of the whole country, from the interactive *U.S.A Population Density Map* website [42]. The images will then be cropped and edited to improve size (Figs. D.2, D.4, D.6, D.8, D.10, and D.12). The UAS sightings heatmap was a Chrome HTML Document that uses an internet browser to view the interactive document. The specified requirements for the developer are

- That the data points to be listed by the date of the sighting;
- Make it interactive with the ability to hover over each point to see the information such as the date, location, and summary;
- The data should only be within the 50 states and DC. Any points outside of it that, such as other countries or U.S. territories, the data point needs to be changed and logged; and
- To include a heatmap and point cluster dots that show number of instances in a given area with the ability to switch between the different results.

Due to complexity, the ability to view the summary of each sighting was removed from the requirements. Services rendered cost $41.80, $36.00 for the developer costs and tip, with a $5.80 service fee by the Fiverr company. The data points were organized by date of the sighting and used the city and state information for the determination of the location points on the map. The UAS sightings heatmap displayed three types of results, a heatmap, point clusters, and individual points. All three results are overlaid with a map of the United States and allow the result types to be selected individually or in different combinations. The heatmap result gives a scale from red to green with areas that are red having a high number of sightings scaling down to green with the number of UAS sightings. The point cluster result type gives a large dot that gives a number with how many sightings are grouped together in one area. The final result type gives individual red dots on the map for each sighting that can be clicked to show the date, city, and state of the individual sighting. For use in the comparison, the *Snip & Sketch* tool with Microsoft Windows 10 was be used to gather images, both of individual states and of the whole country, from the UAS sightings heatmap. The images will then be cropped and edited to improve size (see Figs. D1, D3, D5, D7, D9, and D11).

The weather data that will be used include the mean temperature, total precipitation, visibility, and mean windspeed [46]. The data from The Old Farmer's Almanac website are collected from the National Climatic Data Center Global Surface Summary of the Day, which takes an average of daily readings from the reporting weather stations in the requested area [46]. The Global Surface Summary of the Day is created from the Integrated Surface Hourly data set from the U.S. Air Force Climatology Center from over 9000 stations [47]. The data will be representative of Downtown Los Angeles, which is South East of Griffith Observatory, and North East of Los Angeles International Airport. These data can be limited as the sampling locations cannot be representative of the entire area in question, the entirety of Los Angeles, and the sampled data comes from the multiple weather stations in which locations are not static throughout the data collection period. This limitation is mitigated as the data used is an average of readings from across the weather stations.

UAS sightings report sampling included 18 Excel documents that were downloaded from the FAA UAS Sightings Report website [7]. The UAS regulations, both federal and state regulations, U.S. Census data, and heatmaps do not include a sampling plan as it is a part of the qualitative analysis. The weather data were sampled based on the quantitative analysis of the states and month, then localized using the UAS heatmaps and a search within the master sighting data. The city that has the highest reported sightings, in the state with the highest reported sightings, was selected for data collection. All information that is available will be reviewed for relevance for the conclusion.

9.2. *Data treatment and analysis*

The analysis conducted on the data used a mixed method approach using both quantitative and qualitative approaches. The quantitative analysis was conducted on the UAS sighting and U.S. Census data using Chi-Square Goodness-of-Fit tests to determine results. The qualitative analysis was used federal and state regulations, heatmap analysis, and weather data.

9.2.1. *Quantitative analysis*

Once the UAS sighting data were collected, cursory edits were made to the individual documents for better organization so that they could be collected into a single Google Sheets document. Such edits include switching columns so that data types would align and remove or change of incomplete data. In the instances where the location data were not complete, such as the city or state, the summary for the sighting was reviewed to determine if the location could be determined. There was only one instance, in the FY2020_Q1_UAS_Sightings document, where a sighting was removed as the location was not able to be determined based on the summary. There was also an instance where there was a line item called "Duplicate Record", within the UAS_Sightings_report_1Apr-30Jun16, document that was removed as it did not have data to be used. Appendix A has a detailed account of edits made to the individual documents.

Once all cursory edits were completed in the individual documents, all the data were collected on a single Google Sheet document for the analysis. It was determined that prior to analysis, the data had to be further edited to allow for a proper analysis. Such edits included removing data were outside the scope of the analysis, adjusting capitalization errors of the state and cities, as well as misspelling. Instances of data outside the scope of the analysis included sightings from Canada, Bahama, U.S. Virgin Islands, North Mariana Islands, and Puerto Rico which were all removed. Capitalization errors were fixed using either the Find and Replace function in Google Sheets, or the embedded cell function PROPER, which takes a word string within a cell and properly formats the capitalization. The instances of deletion of data and other edits made to the data once the data were compiled into one document can be found in Table 4.

Once all edits to the data were completed, the data were organized using pivot tables. The first pivot table, Table C.1, organized all the sightings for the five years into each state and the District of Columbia to rank them based on number of sightings. This was to determine which states would be selected for analysis. The second pivot table, Table C.2, was used to organize the five years of sightings based on month to determine which months had higher number of sightings compared to the others. This was used to determine which months of the year the United States reported the highest numbers of UAS sightings in the determination for the weather analysis. The final pivot table, Table C.3, was used to organize the sightings by state, and broken down into each month and achieved a balance of Tables C.1 and C.2 to determine which months had a more sightings for each state. This was used to determine which months of the year the selected states reported the highest numbers of UAS sightings in the determination for the weather analysis. For Tables C.1–C.3 number of sightings were tested to determine statistical relevance using a Chi-Square Goodness-of-Fit test.

The U.S. Census data were collected into a spreadsheet and grouped together in rows based on state in Table C.4. The columns were based on the data types of median household income, poverty rate, median age, education rate percentage of High School graduates and College Bachelor graduates, employment percentages, population, and population density [41]. A Chi-Square Goodness-of-Fit test was conducted on the data to determine which Census type was statistically relevant as seen in Table C.5. Population density was calculated by dividing the population and landmass as provided from the Census data [41]. Due to the results gathered from the Chi-Square Goodness-of-Fit testing, the averages of California, Florida, New York, Texas, and New Jersey were compared to the averages of Vermont, Delaware, South Dakota, Iowa, and Wyoming to seek additional clarification.

Table 4. Edits made to data once compiled.

Edit Made	Reason for Edit
Removed 10 instances of sightings in Canada	Outside of Location Scope for Research
Removed 1 instance of a sighting in Bahama	Outside of Location Scope for Research
Removed 4 instances of sightings in U.S. Virgin Islands	Outside of Location Scope for Research
Removed 1 instance of a sighting in Northern Mariana Islands	Outside of Location Scope for Research
Removed 68 instances of sightings in Puerto Rico	Outside of Location Scope for Research
Changed 2 instances of misspelling	Louisiana was misspelled Twice
Changed the capitalization of state name data type	Better readability

Column	A	B	C	D	Percent from Expected
List of Variables	Observed Sample Distribution	Column A minus Expected Distribution	Column B Squared	Column C divided by Expected Distribution	Column D divided by Chi-Square
Var a	*a*	*a-d*	*Ba^2*	*Ca/d*	*Da/e*
Var b	*b*	*b-d*	*Bb^2*	*Cb/d*	*Db/e*
Var c	*c*	*c-d*	*Bc^2*	*Cc/d*	*Dc/e*
Var ...	...	*...-d*	*B... ^2*	*C... /d*	*D... /e*

Expected Probability Distribution is average of Column A
d

Chi-Square equals sum of Column D
e

Fig. 5. Visualization of Chi-Square Goodness-of-Fit test spreadsheet formulas using Google Sheets.

Chi-Square tests are used to compare how well an observed frequency distribution fits to an expected distribution, with a Goodness-of-Fit test involving levels of a single nominal variable [48]. If the completed Chi-Square Goodness-of-Fit test meets or exceeds the set critical value, which was set at $p = 0.05$, the test is considered accurate to ensure that the assumptions were met for the Chi-Squared analysis. All Chi-Squared Goodness-of-Fit testing was conducted using the same long form spreadsheet math programming in Google Sheets as visualized in Fig. 5 [48].

The expected probability distribution (d) is calculated by finding the average of the observed sample distribution in Column A $(a, b, c, \ldots)$. The observed sample distribution in Column A $(a, b, c, \ldots)$ for each instance to be analyzed is subtracted from the expected distribution (d), in Column B with the result *Ba. Ba* is then squared in Column C, the result, *Ca.* The result of *Ca* was divided by the expected distribution (d) for the result *Da* in Column D.Chi-Square was determined by summing all the results in Column D $(Da + Db + Dc + D \cdots)$ to have the result *e*. To determine the percent from expected, Column D (*Da)* was divided by Chi-Square (e). The percent from the expected determines how statistically relevant is the observed sample distribution $(a, b, c, \ldots)$, the further away the percent from expected is from 0.00%, the more statistically relevant the observed sample distribution $(a, b, c, \ldots)$ is from expected probability distribution (d). To determine the significance of the test in whether it should be used, Chi-Square (e) is compared to a Chi-Square Critical value distribution table [48].

The weather data from each day's summary page were collected into a spreadsheet and grouped together in columns based on weather type, mean temperature, precipitation, visibility, and mean windspeed [47]. That data will then be organized with the rows for the data collection based on the day and month for all five years and columns based on the average, range, median, and mode. Table C.8 has a detailed account of each month of the assembled weather data.

9.2.2. *Qualitative analysis*

For UAS regulations, the state regulations for the selected states from the quantitative analysis were grouped together in Appendix B by the state and were organized based on the year of enactment. These data were reviewed to compare the states that had high counts of UAS sightings and the states that had lower counts of UAS sightings.

The development process for the UAS sightings heatmap took the UAS sighting data, which was organized by the date of the sighting, and used the city and state information for the determination of the data points on the map. Those data were then provided to the freelance developer for development of the program using the following process (Stefan, personal communication, 25 November 2020):

- geolocate - convert address from (city, state) to coordinates (latitude, longitude);
- load points as CSV file into QGIS; export as GeoJSON file format;
- created webmap using Leaflet, a JavaScript library;
- count number of sightings for each location to know the hot and cold points;
- used plugins to show the points as clusters and as heatmap; and
- used a text editor to write the code for the Webmap.

The analysis of the heatmaps used a side-by-side comparison between the developed UAS sightings heatmap and the Esri ArcGIS *U.S.A Population Density Map* [42]. This was accomplished by using the images collected using the *Snip & Sketch* tool and visually comparing the nation as a whole and the top five states with the highest UAS sightings selected from the quantitative analysis (see Fig. D.1 through

Fig. D.12). This comparison will be able to determine if there is a connection between areas with high population density and areas with high UAS sightings. The development of the UAS heatmap may be limited by the accuracy of the location data put into the results and the abilities of the developer. Without having an active hand in the development, it is unknown if the results are 100% accurate.

10. Results

10.1. *UAS sightings results*

There was a total of 9467 sightings between 1 January 2015 through 31 December 2019 as shown in Table C.1. The five states that had the highest and the five states that had the lowest reported UAS sightings within the United States are shown in Table 5.

There was a total of 51 rankings for the analysis that was conducted as it used the 50 states and Washington D.C. to determine if the number of sightings in these 10 states were statistically significant, a Chi-Squared Goodness-of-Fit test was conducted on the results found in Table C.1. The results determined that the number of reported sightings for each state were statistically significant from the other states as seen in the Chi-Square summary in Table 6 and will be used for all the analyses completed.

With a Chi-Square of 25780.3891 and a Degree of Freedom (DF) of 50, the critical value using $p = 0.05$ is 67.50. With Chi-Square being larger than the critical value, the test conducted can be accepted as valid. The expected distribution was used to determine the percent from expected for the statistical relevance of the total sightings for each state. In conducting the Chi-Squared Goodness-of-Fit test on Table C.1, the analysis included the percent from the expected for each state. The percent from the expected results for the selected states to be analyzed for the qualitative research can be found in Table 7.

Table 5. Selected states from quantitative analysis of 50 states and D.C.

Ranking	State	Number of Sighting Reports
1	California	1709
2	Florida	1104
3	New York	915
4	Texas	781
5	New Jersey	363
47	Vermont	12
48	Delaware	12
49	South Dakota	12
50	Iowa	9
51	Wyoming	3

Note: Adapted from "UAS Sightings Reports" [7].

Table 6. Summary of Chi-Square test on Table C.1.

Number	Degree of Freedom	Chi-Square	Expected Distribution
9467	50	25780.3891	185.6275

Note: Adapted from "UAS Sightings Reports" [7].

Table 7. Chi-Square results for selected states based on UAS sightings.

Ranking	State	Number of Sighting Reports	Percent from Expected
1	California	1709	48.49%
2	Florida	1104	17.62%
3	New York	915	11.12%
4	Texas	781	7.41%
5	New Jersey	363	0.66%
47	Vermont	12	0.63%
48	Delaware	12	0.63%
49	South Dakota	12	0.63%
50	Iowa	9	0.65%
51	Wyoming	3	0.70%

Note: Adapted from "UAS Sightings Reports [7].

Further analysis of UAS sightings included a review of the number of sightings for each quarter from 2015 through 2019 found in Fig. 6. This analysis was used to look at how well UAS regulation plays a role in UAS sightings.

Figure 6 shows a general increase in sightings each year, with spikes that happen during quarter two and three of each year, with a slight decline starting in quarter four of 2018. The spikes during quarters two and three each year can be seen from the averages taken in Fig. 7.

These spikes show that there are more sightings between April and September during the year. Further evaluation of the states and months with the highest and the

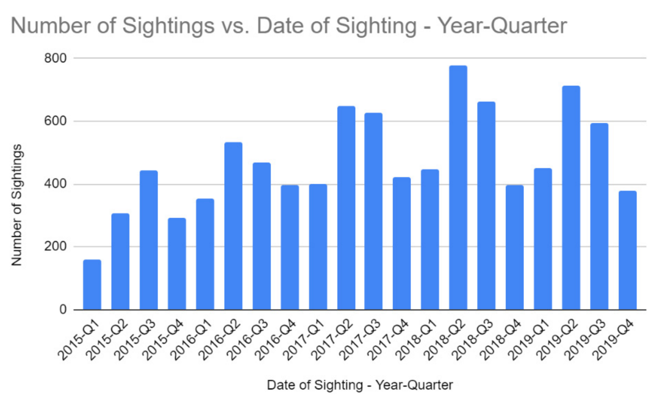

Fig. 6. UAS sightings broken down by year-quarter from 2015–2019 [7].

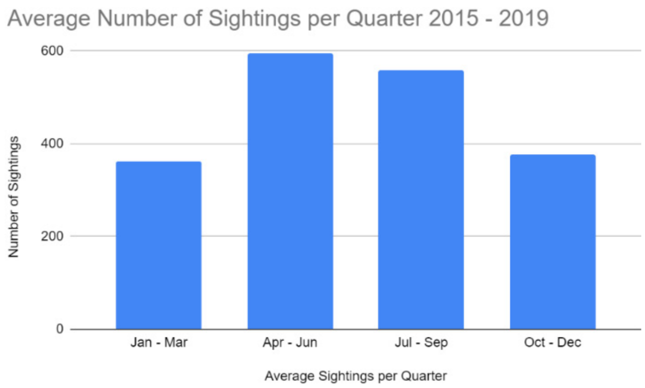

Fig. 7. UAS Sightings broken down by year-quarter from 2015–2019 [7].

lowest number of UAS Sighting Reports was conducted by considering state regulations, U.S. Census data, heatmap analysis, and weather data analysis.

10.2. *UAS regulations results*

During the qualitative review of the state regulations, from the 10 states that were selected from the quantitative analysis, there was very little evidence that regulations impacted the use of UAS. The regulations enacted by the selected states dealt with the privacy of individuals, property, wildlife, and first responders, protections for the first responders and law enforcement, how first responders and law enforcement can use UAS, additional restrictions on where UAS cannot be used to include protected areas, emergency scenes, and critical infrastructure.

10.3. *U.S. census results*

Using the U.S. Census factors of median household income, poverty rate, median age, education rate percentage of both High School graduates and Bachelor graduates, employment, population, and population density, the testing showed the results varied across Table C.4. With a degree of freedom of 9 for all factors, the critical value using p=0.05 is 16.919, only the factors of median household income, population, and population density meet the critical value which shows their tests as valid. But some difference can still be seen between the different factors, even if all the Chi-Square Goodness-of-Fit tests cannot be accepted as wholly accurate in Table C.5. Differences can be seen where the five states, California, Florida, New York, Texas, and New Jersey, that have the highest number of UAS sightings have higher median household income, higher median age, higher percentage of college graduates, and higher populations and population density. But those states also have contradictory levels of higher poverty rates and lower percentage of high school graduates in relation to the median household income and college graduate metrics.

Because the Chi-Square Goodness-of-Fit tests cannot be considered accurate, the averages of California, Florida, New York, Texas, and New Jersey were compared to the averages of Vermont, Delaware, South Dakota, Iowa, and Wyoming to seek additional clarification as seen in Table C.7. From those averages, the top five states of California, Florida, New York, Texas, and New Jersey had higher averages of median household income, poverty rate, college graduates, population, and population density.

10.4. *Heatmap results*

When comparing the UAS sightings heatmaps with that of the population heatmaps, it can be seen that there is a clear connection between areas with higher population density and areas that have a high cluster of UAS sightings. From viewing Figs. D.1 and D.2, the hotspots of UAS sightings are around the most major metropolitan areas. This observation can be clearly seen in the case of California, with Figs. D.3 and D.4, where the two major hotspots in the state, with both population density and UAS sightings, are located around Los Angeles and San Francisco.

10.5. *Weather results*

To determine if particular months were statistically relevant from the rest of the year due to weather, a Chi-Square Goodness-of-Fit test was conducted on Tables C.2 and C.3. From Table C.2, the months that had the highest sightings were June, July, and May. The Chi-Square Goodness-of-Fit test was conducted to determine if June, July, and May were statistically relevant from the other months. The summary of the Chi-Square Goodness-of-Fit test on Table C.2 can be found in Table 8.

With a Chi-Square of 756.4613 and a degree of freedom of 11, the critical value using $p = 0.05$ is 19.68. With Chi-Square being larger than the critical value, the test conducted can be accepted as valid. From the Chi-Square Goodness-of-Fit test on the months shows that the three months with the highest reported sightings June, July, and May, were statistically relevant as seen in the results in Table 9.

Table 8. Summary of Chi-Square test on Table C.2.

Number	DF	Chi-Square	Expected Distribution
9467	11	756.4613	788.9167

Note: Adapted from "UAS Sightings Reports" [7].

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Table 9. Chi-Square results on total UAS sightings per month.

Month of Sighting	Number of Sighting Reports	Percent from Expected
January	463	17.80%
February	602	5.85%
March	744	0.34%
April	769	0.07%
May	975	5.80%
June	1232	32.90%
July	1049	11.33%
August	965	5.20%
September	784	0.00%
October	780	0.01%
November	627	4.39%
December	477	16.30%

Note: Adapted from "UAS Sightings Reports" [7].

When the Chi-Square Goodness-of-Fit tests were conducted on Table C.3, Vermont, Delaware, South Dakota, Iowa, and Wyoming did not have a large enough Chi-Square to meet the critical value using $p = 0.05$, which is 19.65, the results of which can be seen in Table C.3. As a result, only California, Florida, New York, Texas, and New Jersey allowed the results to be reliable. The Chi-Square Goodness-of-Fit results of which can be seen in Table C.3. To lower the total weather sample data, the states of California and Florida were selected to be used to determine what weather best represents the normal for high UAS sightings, as seen in Table 10.

These results show that for California, the three months of June, August, and July, had the highest number of sightings throughout the year, June was the most statistically relevant from the expected distribution outside the rest of the year. This result will be used to examine what kind of weather California experienced in the month of June between the years 2015 and 2019 that made that month so relevant. For Florida, the three highest months were March, May, and April. Each of those three months are considered statistically relevant from the rest of the year based on the results of the percent from expected.

To gather the localized area for the weather data analysis, the state of California, with the month of June selected, as they contained the highest number of UAS sightings that were statistically relevant from 2015–2019. Using the UAS heatmap, and a search of all the collected UAS sighting data, the city of Los Angeles was selected, which had a total number of 329 sightings directly in the city, and 1106 in the vicinity around the city based on the UAS heatmap results. This results in the best representative weather analysis for when UAS is most seen as the Los Angeles area contains

Table 11. Los Angeles, CA weather data June 2015–2019.

	Mean Temperature	Total Precipitation	Visibility	Mean Windspeed
Average	68.87°F	0.00 in	8.86 mi	1.69 mph
Range	62.7°F	0.00 in	5.4 mi	0.46 mph
	85.4°F	0.01 in	10 mi	3.11 mph
Median	68.10°F	0.00 in	9.30 mi	1.61 mph
Mode	66.00°F	0.00 in	10.00 mi	1.61 mph

Note: Adapted from "Weather History Archive" [46].

Table 10. Chi-Square results for months in California and Florida.

Month of Sighting	California		Florida	
	Number of Sightings	Percent from Expected	Number of Sightings	Percent from Expected
January	98	14.68%	84	1.43%
February	156	1.37%	108	5.71%
March	149	0.32%	122	20.07%
April	127	1.77%	113	9.83%
May	130	1.15%	117	13.94%
June	232	59.73%	102	2.23%
July	162	2.85%	71	9.83%
August	166	4.14%	79	3.77%
September	131	0.97%	62	20.07%
October	127	1.77%	82	2.23%
November	121	3.41%	70	10.79%
December	110	7.82%	94	0.09%
Grand Total	1709		1104	
Expected Distribution	142.42		92	
Chi-Squared	94.34		48.74	

Note: Adapted from "UAS Sightings Reports" [7].

over 11.68% of all UAS sightings in the United States and 64.72% in all of California. The base results of the analysis can be found in Table 11.

The results show the weather data from each day of June 2015–2019 are the representative of the weather that is seen when UAS sightings are the highest. Table C.8 has a detailed account of each month of the assembled weather data.

11. Conclusion

Major metropolitan areas, which have high population and population density, higher median household incomes, high percentage of college graduates, and are located in areas that have stable weather and negligible weather effects such as rain and high winds during the summer months, have both high and concentrated levels of UAS sightings.

This heatmap results can mean one of two things, there are either more instances of unauthorized UAS flights in those high population areas, or there are more people around to witness and report such sightings and it does not signify why the selected states have higher occurrences of UAS sightings, just that there are clusters of more UAS sightings around major metropolitan areas (see Fig. D.1 through Fig. D.12).

Because the Chi-Square Goodness-of-Fit tests on the U.S. Census data could not be considered accurate, the averages of California, Florida, New York, Texas, and New Jersey were compared to the averages of Vermont, Delaware, South Dakota, Iowa, and Wyoming to seek additional clarification as seen in Table C.7. From the results of the averages, all of the metrics, except for higher median age, back up the results of the Chi-Square Goodness-of-Fit testing conducted on the U.S. Census.

Federal and State regulations, other registration, did not indicate a relationship with the frequency of UAS sightings. Pentz and Tang [29] reported a reduction from 4.81 incidents per day to 3.31 during the times when registration was and was not required in 2017. Although there was a significant increase in sightings starting in 2018, once the registration requirement was reinstituted on 12 December 2017, the number of sightings did not continue to rise in 2019. The reintroduction of the requirement for registration could have led to the stagnation of sightings seen in 2019, as there seems to be no other regulation at the federal level instituted. In addition, in the review of the dates of enactment of these regulations as shown in Appendix A compared to a breakdown of the number of UAS sightings, there did not appear to be a direct connection with an enactment of a regulation and a corresponding lower number of sightings as seen in Table C.6.

Previous research and analysis conducted by Pitcher and Whealan-George [19], using UAS sightings data from the FAA, from July 2015–June 2018, found that summer months, particularly May and June, had a higher statistical relevance than other months for number of UAS sightings, which was consistent with the result of this study that include the most recent 2019 data.

12. Recommendations

The FAA should create targeted advertisements to educate users through major social media platforms such as Facebook and Instagram, to promote mobile applications such as the B4UFLY, in areas with high sightings using the demographics from the analysis of the census data. The FAA can also request notifications be sent to operators within mobile applications that are used to operate UAS or those that deal with UAS, such as B4UFLY. Such notifications would be sent during times when the weather conditions are favorable to fly, as found from the weather analysis, targeting the locations from the census and heatmap analysis, to alert UAS operators if there are temporary flight restrictions in the local area or other relevant information prior to operation.

For direct prevention, expanding requirements for geofencing in UAS that are sold in the U.S. that meet registration requirements, would keep UAS from being used in many unauthorized areas. Require that all UAS that meet registration requirements have an easy to use manual and direct resources to go to for information to be registered. Make registration with the FAA a required part of setting up the UAS to use mobile applications to fly and waive the fee to incentivize more UAS to be registered. Have the same mobile applications introduce LAANC, B4UFLY, and other FAA educational material. Have notifications on the UAS application when the operator is flying in a manner that exceeds established regulations such as over 100 MPH or above 400 feet AGL. If the operator does not follow the notifications, the UAS will land automatically.

For future research, data collection and analysis should be conducted considering the 2020 Census results to see if there is any relationship with UAS sightings. The weather analysis can be expanded to include additional areas in the United States that experienced high UAS sightings which will give a better perspective with more data points of what weather types UAS are seen most frequently. Future research can also involve additional UAS sightings from the FAA outside the selected five-year period. Such as data from 2020 and 2021 during the COVID-19 pandemic to determine if there is a significant difference in the number of sightings.

More than just the federal government can work towards lowering the incidence of unauthorized UAS usage to include lower government entities such as State, Local, Tribal, law enforcement, and first responders. Areas that have been indicated from this research as having high incidence of UAS usage can invest in training for what law enforcement and first responders can do when they see an unauthorized UAS flight. Additionally, signage can be erected in protected areas about proper UAS usage. The federal government can also specify a minimum requirement for the lower government entities on the enforcement, training, and prioritization for UAS usage across the country.

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Appendix A

UAS Sighting Document Names from FAA, the Time Periods Covered, Data Types included in Documents, and Edits made to Data Prior to being Compiled

Document Name from FAA Website	Time Period Covered		Edits to Data
UASEventsNov2014-Aug2015	11/13/2014	8/20/2015	Organized the data by date in descending order. Dares from 11.13/2014-12/31/2014 were outside the scope of the data and were removed. Date and Time cells changed to remove time so that it would align with rest of data. Column order was changed to align with rest of data.
UAS_Sightings_report_21 Aug-31 Jan	8/21/2015	1/31/2016	Organized the data by date in descending order. Date and Time cells changed to remove time so that it would align with rest of data. Column order was changed to align with rest of data.
UAS_Sightings_report_1 Feb-3 lMarl6	2/1/2016	3/31/2016	Date and Time cells changed to remove time so that it would align with rest of data. Column order was changed to align with rest of data.
UAS_Sightings_report_1 Apr-30 Jun 16	4/1/2016	6/30/2016	Removed mention of "Duplicate Record" from data that did not include informtion.
UAS_Sightings_report_1 Jul-30 Sep 16	7/1/2016	9/30/2016	
UAS_Sightings_reportl70331	10/1/2016	12/31/2016	
UAS_Sightings_report_Jan_Mar2017	1/1/2017	3/31/2017	
UAS_Sightings_report_Apr_Jun2017	4/1/2017	6/30/2017	Organized the data by date in descending order. Column order was changed to align with rest of data.
FY2017_Q4_De-identification_ Redaction_l1192017	7/1/2017	9/30/2017	
FY2018_Q1_UAS_Sightings	10/1/2017	12/31/2017	
FY2015_Q2_UAS_Sightings	1/1/201S	3/31/2018	
FY2018_Q3_UAS_Sightings	4/1/201S	6/30/2018	Column order was changed to align with rest of data.
FY2018_Q4_UAS_Sightings	7/1/2018	9/30/2018	Column order was changed to align with rest of data.
FY2019_Q1_UAS_Sightings	10/1/2018	12/31/2018	Column order was changed to align with rest of data.
FY2019_Q2_UAS_Sightings	1/1/2019	3/31/2019	Organized the data by date in descending order. Column order was changed to align with rest of data.
FY2019_Q3_UAS_Sightings	4/1/2019	6/30/2019	Organized the data by date in descending order. Column order was changed to align with rest of data.
FY2019_Q4_UAS_Sightings	7/1/2019	9/30/2019	Organized the data by date in descending order. Column order was changed to align with rest of data.
FY2020_Q1_UAS_Sightings	10/1/2019	12/31/2019	Column order was changed to align with rest of data. Removed sighting that did not include location data.

Appendix B

Table B.1. State UAS Regulations [24].

State	Regulation	Regulation Details
California	California Department of Parks & Regulations (Cal. Code Regs. title. 14, §4351) // 2015	This state regulation prohibits the use of a drone within State Park wilderness areas, cultural preserves, and nature preserves. It is important to check the regulations of each State Park as they may have their own posted regulations.
	AB 856 // 2015	This law prohibits entering the airspace of an individual in order to capture an image or recording of that individual engaging in a private, personal, or familial activity without permission. This legislation is a response to the use of UAS by the press in covering celebrities and other public figures.
	SB 807 // 2016	This law provides immunity for first responders who damage a UAS that was interfering with the first responder while he or she was providing emergency services.
	AB 1680 // 2016	This law makes it a misdemeanor to interfere with the activities of first responders during an emergency.
	PO 925-19-32 // 2019	This regulation states that no person shall launch, land or operate a model aircraft or UAS within any park unit in the Orange Coast District (Bolsa Chica State Beach, Huntington State Beach, Corona del Mar State Beach, Crystal Cove State Park, Doheny State Beach, San Clemente State Beach, and San Onofre State Beach).
	AB 2655 // 2020	This law prohibits first responders from taking pictures of a crime scene without a valid reason. This includes any type of photography, including the use of drones.
Florida	Florida Administrative Code 40C-9.320 // 2004	This state code prohibits drones from taking off or landing on District lands unless authorized by a Special Use Authorization.
	SB 92 // 2013	This law defines what a drone is and limits the use of drones by law enforcement. Under this law, law enforcement may use a drone if they obtain a warrant, there is a terrorist threat, or “swift action” is needed to prevent loss of life or to search for a missing person. This law also enables someone harmed by an inappropriate use of drones to pursue civil action.
	SB 766 // 2015	This law prohibits the use of a drone to capture an image of privately owned property or the owner, tenant, or occupant of such property without consent if a reasonable expectation of privacy exists.
	Florida Administrative Code 5I-4.003 // 2016	This state code prohibits drones on managed lands, including Florida state parks and forests, except at a runway or a helispot and only with authorization from the Department of Agriculture and Consumer Services. Authorization shall be based upon a determination that the take-off or landing will not endanger the health, safety or welfare of any person; potentially damage the forest resources; or interfere with management objectives of that forest as provided in that forest’s management plan. Authorization from the Service is not required in an emergency or for Service official business.
	HB 1027 // 2017	This law pre-empts local regulation of UAS so that only the Florida Legislature can make laws concerning the use of drones in the state, but allows local governments to enact drone ordinances related to nuisances, voyeurism, harassment, reckless endangerment, property damage, or other illegal acts. This law also prohibits the operation of drones over or near critical infrastructure in most instances, as well as prohibiting the possession or operation of a weaponized UAS.

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Table B.1. (*Continued*)

State	Regulation	Regulation Details
New York	OPR-PCD-018—New York Parks, Recreation and Historic Preservation // 2015	The launch, landing, and operation of UAS is allowed in state parks and historic sites only with prior written approval by the agency through a permit authorizing the specific time, location, and type of use. OPRHP retains sole discretion to determine whether to approve or deny requests to launch an Unmanned Aircraft System. The detailed criteria OPRHP will use in determining whether to issue a permit are provided below, and conditions are provided in the attached sample permit. Any launch or operation of a UAS that has not received prior approval from OPRHP through issuance of a written permit is prohibited. OPRHP will actively enforce this procedure and other relevant agency statutes, regulations, and guidelines.
Texas	Texas Administrative Code §65.152 // 2005	The use of drones to hunt, drive, capture, take, count or photograph any wildlife is unlawful except with an Aerial Management Permit (AMP) and a Land Owner Authorization (LOA).
	HB 912 // 2013	This law enumerates 19 lawful uses for unmanned aircraft, including their use in airspace designated as an FAA test site, their use in connection with a valid search warrant, and their use in oil pipeline safety and rig protection. This law also creates two new crimes: (1) the illegal use of an unmanned aircraft to capture images, and (2) the offense of possessing or distributing the image.
	HB 2167 // 2015	This law permits individuals in certain professions to capture images used in those professions using UAS as long as no individual is identifiable in the image.
	HB 1481 // 2015	This law makes it a Class B misdemeanor to operate UAS over a critical infrastructure facility if the UAS is not more than 400 feet off the ground.
	SB 840 // 2017	This law permits telecommunications providers to use UAS to capture images. It also specifies that only law enforcement may use UAS to capture images of real property that is within 25 miles of the U.S. border for border security purposes. The law also allows a UAS to be used to capture images by an insurance company for certain insurance purposes, as long as the operator is authorized by the FAA.
	HB 1424 // 2017	This law prohibits UAS operation over correctional and detention facilities. This law also prohibits operation over a sports venue except in certain instances.
	HB 1643 // 2017	This law prohibits local governments from regulating UAS except during special events and when the UAS is used by the locality.
	Texas Parks & Wildlife Policy	Drones are not allowed in Texas State Parks without a permit except for in two parks with specified zones for flying remote-controlled aircraft (including drones): Lake Whitney and San Angelo. You can request a filming permit for your craft at any park by contacting that park. Allow several weeks for the park to review your request.
New Jersey	New Jersey State Park Service Policy // 2015	This policy prohibits the operation of drones within all lands and waters managed by the State Park Service unless prior approval has been granted by the Assistant Director, State Park Service in accordance with N.J. A.C 7:2-1.4(b).
	SB 3370 // 2017	This law: • Allows UAS operations that are consistent with federal law. • Specifies that UAS owners or operators of critical infrastructure may apply to the FAA to prohibit or restrict the operation of UAS near the critical infrastructure. • Establishes that operating a UAS in a manner that endangers the life or property of another is a disorderly person offense.

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Table B.1. (*Continued*)

State	Regulation	Regulation Details
		• Establishes that it is a fourth-degree crime if a person "knowingly or intentionally creates or maintains a condition which endangers the safety or security of a correctional facility by operating an unmanned aircraft system on the premises of or in close proximity to that facility." • It makes it a criminal offense to operate a UAS in a way that interferes with a first responder. • Defines operating a UAS under the influence of drugs or with a BAC of 0.08% as a disorderly person offense. • Pre-empts local governments from regulating UAS in any way that is inconsistent with this law.
Vermont	SB 155 // 2016	This law regulates the use of drones by law enforcement and requires law enforcement to annually report on the use of drones by the department. This law also prohibits the weaponization of drones.
Delaware	HB 195 // 2016	This law makes it illegal to fly a drone over events with more than 5000 people in attendance, including sporting events, concerts, automobile races, festivals. It also makes it illegal to fly a drone over critical infrastructure, which includes but is not limited to: oil & gas refiners, power plants, military facilities, government buildings, and water treatment facilities. Finally, this law prohibits cities and towns in Delaware from creating their own drone laws by claiming pre-emption for the creation of all such laws for the Delaware General Assembly. In addition to the above law, the Delaware state website states that drones are generally prohibited in Delaware state parks, but may be allowed to fly under special circumstances as determined by the director of the Division of Parks & Recreation.
South Dakota	SB 22 // 2017	This law exempts UAS that weigh less than 55 pounds from aircraft registration requirements.
	SB 80 // 2017	This law: • Requires that UAS operation complies with all applicable FAA requirements. • Prohibits operation of drones over the grounds of correctional and military facilities, making such operation a class 1 misdemeanor. If a drone is used to deliver contraband or drugs to a correctional facility, the operator is guilty of a class 6 felony. • Modifies the crime of unlawful surveillance to include intentional use of a drone to observe, photograph, or record someone in a private place with a reasonable expectation of privacy and landing a drone on the property of an individual without that person's consent. Unlawful surveillance is a class 1 misdemeanor.
Iowa	HB 2289 // 2014	This law makes it illegal for a state agency to use a UAS to enforce traffic laws. This law requires a warrant, or other lawful means, to use information obtained via UAS in a civil or criminal court proceeding.
Wyoming	SF 170 // 2017	This law requires the Wyoming Aeronautics Commission to develop rules regulating where unmanned aircraft can take-off and land. The commission is also permitted to develop reasonable rules regulating the operation of unmanned aircraft through coordination with the unmanned aircraft industry and local governments. This law also specifies that the commission does not have the power to regulate unmanned aircraft operation in navigable airspace, and makes it unlawful to land an unmanned aircraft on the property of another person, but operators can pilot an unmanned aircraft over their own property.

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Appendix C

Table C.1. Chi-Square results of total number of sightings for each state.

State	Number of Sighting Reports	Percent from Expected	State	Number of Sighting Reports	Percent from Expected
Alabama	81	0.23%	Montana	21	0.57%
Alaska	60	0.33%	Nebraska	13	0.62%
Arizona	331	0.44%	Nevada	174	0.00%
Arkansas	27	0.53%	New Hampshire	22	0.56%
California	1709	48.49%	New Jersey	363	0.66%
Colorado	202	0.01%	New Mexico	35	0.47%
Connecticut	90	0.19%	New York	915	11.12%
Delaware	12	0.63%	North Carolina	230	0.04%
District of Columbia	147	0.03%	North Dakota	18	0.59%
Florida	1104	17.62%	Ohio	132	0.06%
Georgia	276	0.17%	Oklahoma	77	0.25%
Hawaii	60	0.33%	Oregon	108	0.13%
Idaho	33	0.49%	Pennsylvania	263	0.13%
Illinois	315	0.35%	Rhode Island	32	0.49%
Indiana	59	0.34%	South Carolina	106	0.13%
Iowa	9	0.65%	South Dakota	12	0.63%
Kansas	26	0.53%	Tennessee	124	0.08%
Kentucky	79	0.24%	Texas	781	7.41%
Louisiana	80	0.23%	Utah	91	0.19%
Maine	25	0.54%	Vermont	12	0.63%
Maryland	98	0.16%	Virginia	183	0.00%
Massachusetts	220	0.02%	Washington	270	0.15%
Michigan	164	0.01%	West Virginia	22	0.56%
Minnesota	90	0.19%	Wisconsin	58	0.34%
Mississippi	33	0.49%	Wyoming	3	0.70%
Missouri	72	0.27%			

Note: Adapted from "UAS Sightings Reports" [7].

Table C.2. Total sightings per month.

Month of Sighting	Number of Sightings
January	463
February	602
March	744
April	769
May	975
June	1232
July	1049
August	965
September	784
October	780
November	627
December	477
Grand Total	9467

Note: Adapted from "UAS Sightings Reports" [7].

Table C.3. Chi-square results of total Sightings per month for selected states

Month of Sighting	Califorina		florida		New York		Texas		New Fersey		Vermont		Delaware		South Dakota		Iowa		Wyoming	
	Number of Sightings	Percent	Number of Sightings	Percent	Number of Sightings	Percent	Number of Sightings	Percent	Number of Sightings	Percent	Number of Sightings	Percent	Number of Sightings	Percent	Number of Sightings	Percent	Number of Sightings	Percent	Number of Sightings	Percent
January	98	14.68%	84	1.43%	26	11.40%	46	13.94%	10	13.71%	1		0.00%	1	0.00%	1	0.00%	0	4.59%	0 1.47%
February	156	1.37%	10S	5.71%	30	9.65%	46	13.94%	8	16.56%	1		0.00%	2	10.00%	1	0.00%	0	4.59%	0 1.47%
March	149	0.32%	122	20.07%	53	2.44%	65	0.00%	27	0.35%	1		0.00%	1	0.00%	:	16.67%	0	4.59%	0 1.47%
April	127	1.77%	113	9.83%	63	0.79%	78	6.39%	25	0.92%	2		16.67%	0	10.00%	0	16.67%	2	12.76%	0 1.47%
May	130	1.15%	117	13.94%	86	0.43%	89	21.89%	43	5.44%	2		16.67%	1	0.00%	0	16.67%	3	41.33%	2 72.06%
June	232	59.73%	102	2.23%	166	36.36%	88	20.10%	60	29.60%	1		0.00%	2	10.00%	2	16.67%	1	0.51%	1 13.24%
July	162	2.85%	71	9.83%	132	14.03%	74	3.04%	52	15.82%	1		0.00%	S	10.00%	2	16.67%	0	4.59%	0 1.47%
August	166	4.14%	79	3.77%	119	8.25%	60	0.99%	44	6.32%	0		16.67%	1	0.00%	0	16.67%	1	0.51%	0 1.47%
September	131	0.97%	62	20.07%	89	0.73%	66	0.03%	27	0.35%	1		0.00%	3	40.00%	1	0.00%	2	12.76%	0 1.47%
October	127	1.77%	82	2.23%	78	0.01%	70	0.93%	25	0.92%	2		16.67%	0	10.00%	1	0.00%	0	4.59%	0 1.47%
November	121	3.41%	70	10.79%	50	3.11%	51	7.59%	29	0.05%	0		16.67%	1	0.00%	1	0.00%	0	4.59%	0 1.47%
December	110	7.82%	94	0.09%	23	12.80%	48	11.17%	13	9.95%	0		16.67%	0	10.00%	1	0.00%	0	4.59%	0 1.47%
Grand Total	1709		1104		915		781		363		12		12		12		9		3	
Expected Distribution	142.42		92.00		76.25		65.08		30.25		1.00		1.00		1.00		0.75		0.25	
Chi-Squared	94.34		48.74		290.57		40.15		98.85		6.00		10.00		6.00		16.33		17.00	

Note: Adapted from "UAS Sightings Reports" [7].

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Table C.4. U.S. census data for United States and selected states.

Location	Median Household Income	Poverty Rate	Median Age	Education High School Grad	Education College Grad	Employment	Population	Population Density
United States	$65,712	12.30%	38.5	88.60%	33.10%	60.20%	328,239,523	92.92
California	$80,440	11.80%	37	84.00%	35.00%	60.30%	39,512,223	267.24
Florida	$59,227	12.70%	42.4	88.40%	30.70%	56.20%	21,477,737	517.41
New York	$72,108	13.00%	39.2	87.60%	37.80%	60.50%	19,453,561	490.20
Texas	$64,034	13.60%	35.1	84.60%	30.80%	61.70%	28,995,881	114.23
New Jersey	$85,751	9.20%	40.2	90.30%	41.20%	62.70%	8,882,190	1,483.73
Vermont	$63,001	10.20%	42.8	93.10%	38.70%	63.10%	623,989	70.77
Delaware	$70,176	11.30%	41.4	90.30%	33.20%	58.80%	973,764	691.45
South Dakota	$59,533	11.90%	37.7	92.10%	29.70%	65.40%	884,659	11.88
Iowa	$61,691	11.20%	38.5	92.60%	29.30%	64.30%	3,155,070	56.92
Wyoming	$65,003	10.10%	38.1	94.50%	29.10%	61.90%	578,759	6.01

Note: Adapted from "UAS Sightings Reports" [7].

Table C.5. Chi-square results of census data for selected states

State	Median Household Income		Poverty Rate		Median Age		Education High School		Education College		Employment		Population		Population Density	
	Observed Observations	Percent from Expected	Observed Observations	Percent from Expected	Observed Observations	Percent from Expected	Observed Observations	Percent from Expected	Observed Observations	Percent from Expected	Observed Observations	Percent from Expected	Observed Observations	Percent from Expected	Observed Observations	Percent from Expected
California	$80,440	20.89%	11.80%	0.52%	37	9.19%	84.00%	28.99%	35.00%	1.21%	60.30%	2.18%	39,512,223	41.09%	267.24	0.57%
Florida	$59,227	10.78%	12.70%	8.27%	42.4	18.28%	88.40%	1.60%	30.70%	4.68%	56.20%	43.01%	21,477,737	4.57%	517.41	1.13%
New York	$72,108	2.21%	13.00%	12.92%	39.2	0.00%	87.60%	4.05%	37.80%	10.40%	60.50%	1.51%	19.453.561	2.75%	490.2	0.75%
Texas	$64,034	2.26%	13.60%	25.32%	35.1	31.38%	84.60%	23.25%	30.80%	4.35%	61.70%	0.07%	28.995.881	15.36%	114.23	3.46%
New Jersey	$85,751	42.72%	9.20%	30.37%	40.2	1.69%	90.30%	0.27%	41.20%	33.69%	62.70%	2.25%	8.882.190	0.72%	1.483.73	65.03%
Vermont	$63,001	3.56%	10.20%	9.70%	42.8	23.20%	93.10%	9.84%	38.70%	15.27%	63.10%	3.98%	623.989	7.85%	70.77	4.73%
Delaware	$70,176	0.59%	11.30%	0.23%	41.4	8.54%	90.30%	0.27%	33.20%	0.07%	58.80%	11.12%	973,764	7.40%	691.45	5.39%
South Dakota	$59,533	10.05%	11.90%	0.92%	37.7	4.34%	92.10%	4.84%	29.70%	8.53%	65.40%	23.50%	884.659	7.51%	11.88	6.77%
Iowa	$61,691	5.62%	11.20%	0.52%	38.5	1.00%	92.60%	7.12%	29.30%	10.40%	64.30%	12.13%	3.155.070	4.85%	56.92	5.18%
Wyoming	S65.003	1.31%	10.10%	11.25%	38.1	2.38%	94.50%	19.78%	29.10%	11.40%	61.90%	0.26%	578.759	7.91%	6.01	7.00%
Expected Distribution	$68,096.40		11.50%		39.24		89.75%		33.55%		61.49%		12,453,783.30		370.98	
Chi-Squared	10,713.19		0.02		1.39		0.01		0.05		0.01		143,092,809.94		5,132.75	

Note: Adapted from "U.S. Census" [41].

Table C.6. Yearly UAS sightings totals from selected states.

Year	California	Florida	New York	Texas	New Jersey	Vermont	Delaware	South Dakota	Iowa	Wyoming
2015	267	130	130	76	53	0	1	1	0	0
2016	372	183	146	142	67	1	4	0	2	0
2017	371	246	232	172	72	2	1	5	2	0
2018	396	288	223	184	92	5	3	0	0	1
2019	303	257	184	207	79	4	3	6	5	2
Totals	1709	1104	915	781	363	12	12	12	9	3

Note: Adapted from "UAS Sightings Reports" [7].

Table C.7. U.S. census averages of the selected states.

	Median Household Income	Poverty Rate	Median Age	Education High School	Education College	Employment	Population	Population Density
Top Five	$72,312.00	12%	38.78	87%	35%	60%	23,664,318.40	574.56
Bottom Five	$63,880.80	11%	39.7	93%	32%	63%	1,243,248.20	167.41

Note: Adapted from "U.S. Census" [41].

Table C.8. Los Angeles weather data grouped by year and month June 2015–2019.

	Mean Temperature				Total Precipitation				Visibility				Mean Windspeed			
Year-Month	Average	Range	Median	Mode	Average	Range	Median	Mode	Average	Range	Median	Mode	Average	Range	Median	Mode
2015-Jun	68.88°F	63.90°F 76.10°F	68.45°F	63.90°F	0.00 IN	0.00 IN 0.01 IN	0.00 IN 0.00 IN	8.85 MI	5.70MI 10.00 MI	9.35 MI	10.00 MI	1.59 MPH	0.46 MPH	2.76 MPH	1.50 MPH	2.07 MPH
2016-Jun	69.66°F	62,80°F 85.40°F	68.55°F	66,00°F	0.00 IN	0.00 IN 0.00 IN	0.00 IN 0.00 IN	8.35 MI	5.40 MI 10.00 MI	8.30 MI	10.00 MI	1.77 MPH	0.58 MPH	2.76 MPH	1.73 MPH	1.96 MPH
2017-Jun	69.79°F	64.90°F 77.30°F	69.10°F	68.60 ^{c}F	0.00 IN	0.00 IN 0.01 IN	0.00 IN 0.00 IN	8.80 MI	5.60 MI 10.00 MI	9.30 MI	10.00 MI	1.87 MPH	0.92 MPH	3.11 MPH	1.84 MPH	1.38 MPH
2018-Jun	68.37°F	64.80°F 72.10°F	68.75°F	66.10°F	0.00 IN	0.00 IN 0.00 IN	0.00 IN 0.00 IN	9.20 MI	6.50 MI 10.00 MI	9.60 MI	10.00 MI	1.60 MPH	0.81 MPH	2.88 MPH	1.44 MPH	1.15 MPH
2019-Jun	67.65°F	62,70°F 75.50°F	66.90°F	66.40 ^{c}F	0.00 IN	0.00 IN 0.00 IN	0.00 IN 0.00 IN	9.11 MI	6.70 MI 10.00 MI	9.45 MI	9.80 MI	1.65 MPH	1.15 MPH	2.65 MPH	1.61 MPH	1.27 MPH

Note: Adapted from "Weather History Archive" [41].

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Appendix D

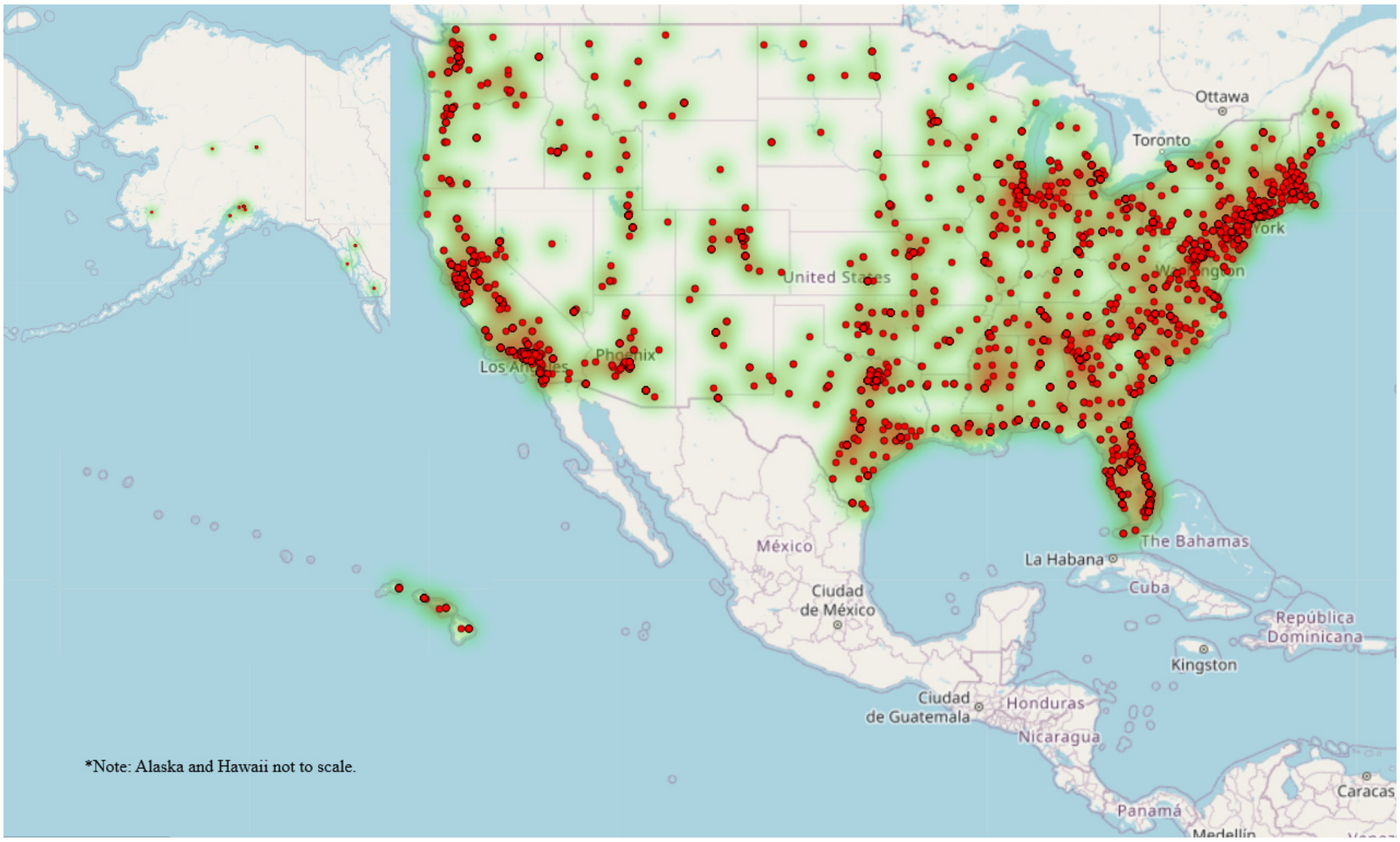

Fig. D.1. UAS Sighting Heatmap – Nation.

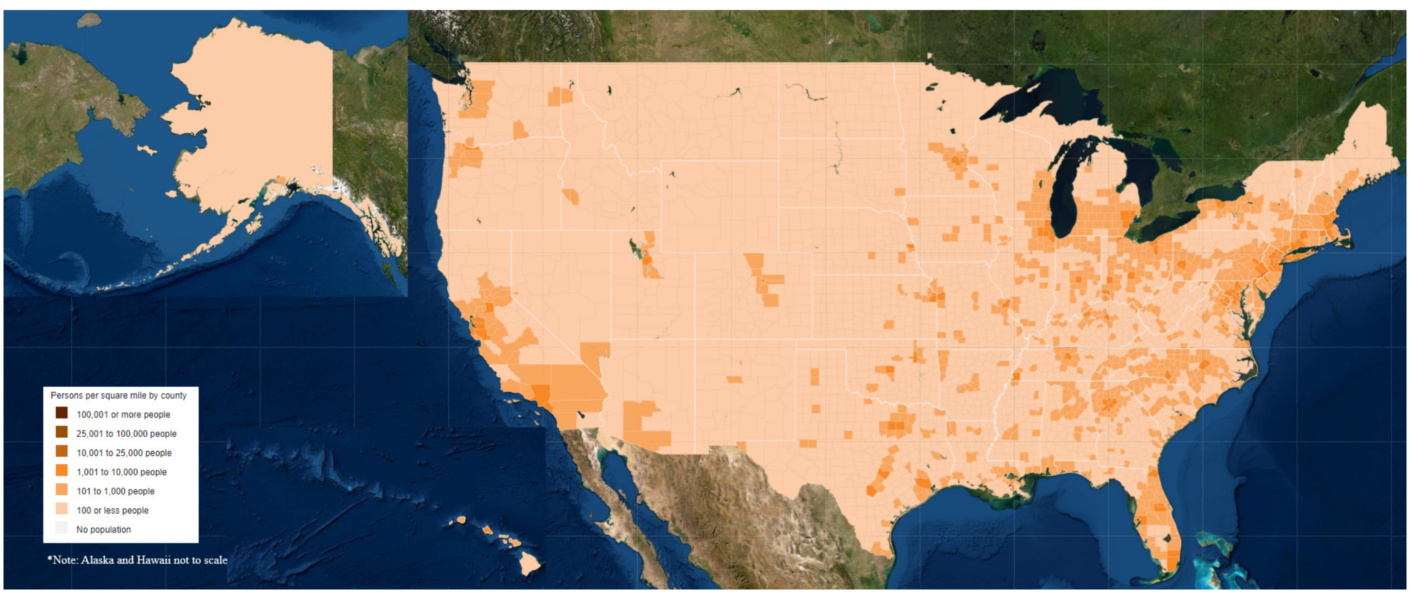

Fig. D.2. U.S. Population Density Map – Nation [40].

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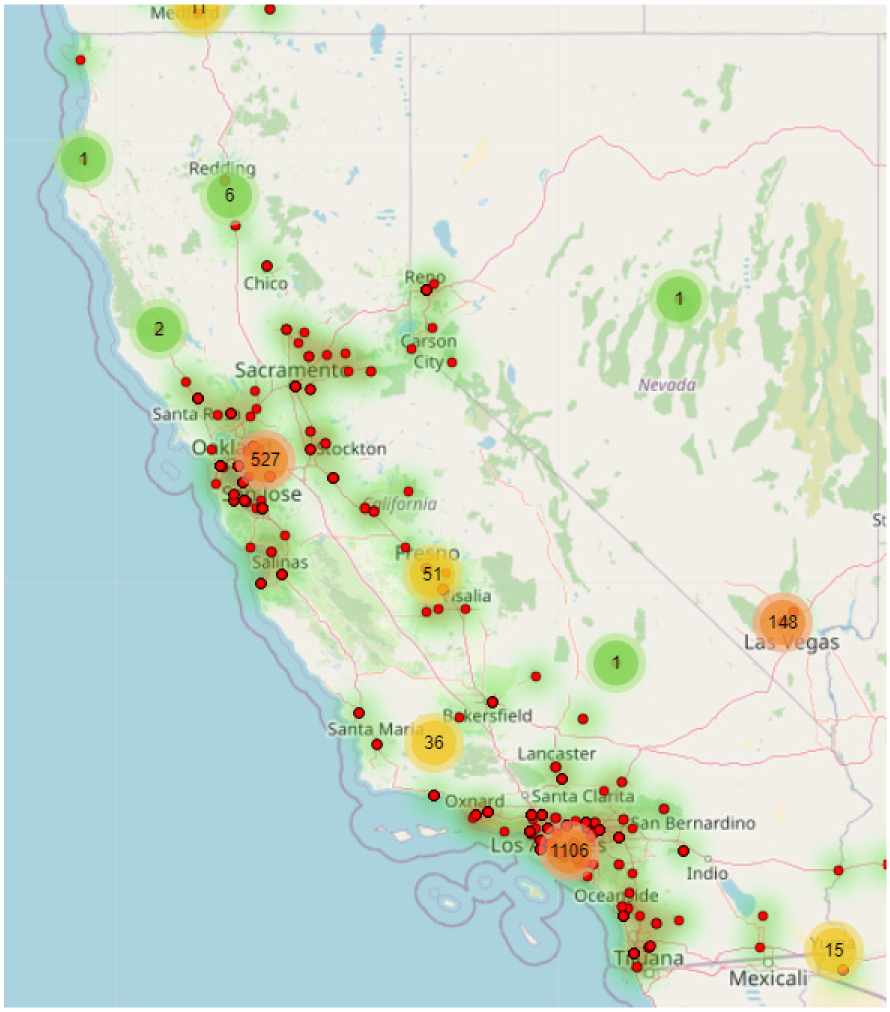

Fig. D.3. UAS Sighting Heatmap – California.

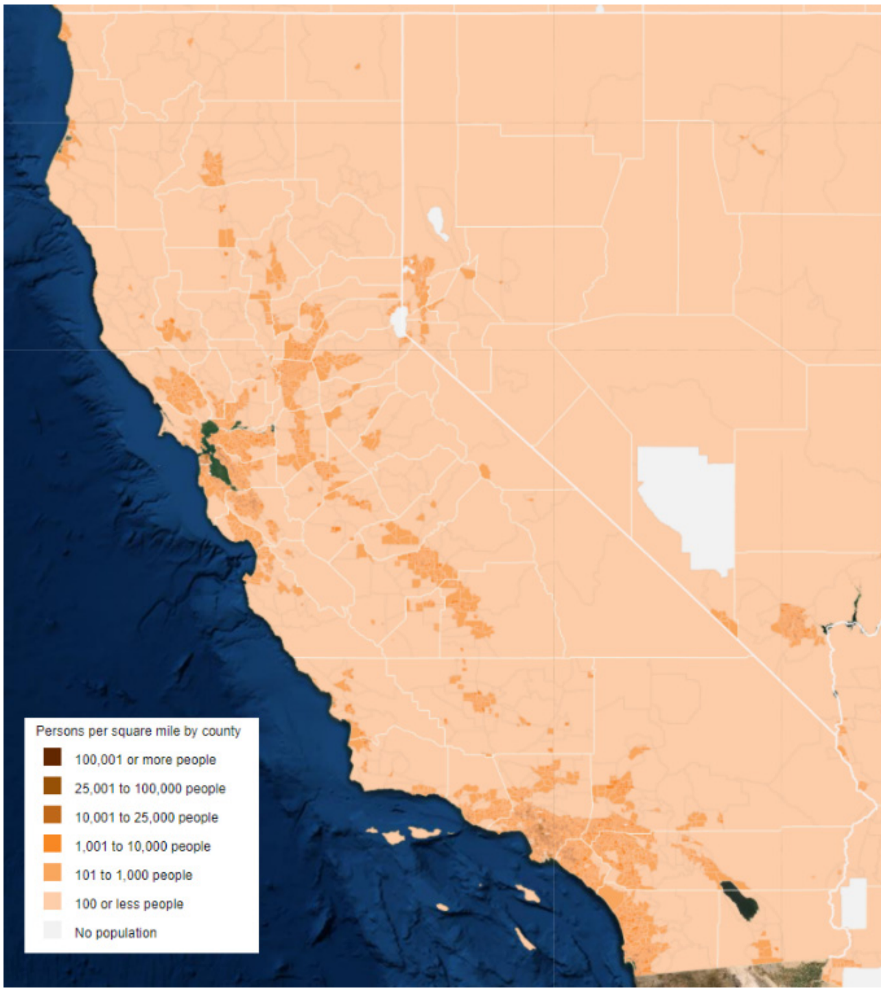

Fig. D.4. U.S. Population Density Map – California [42].

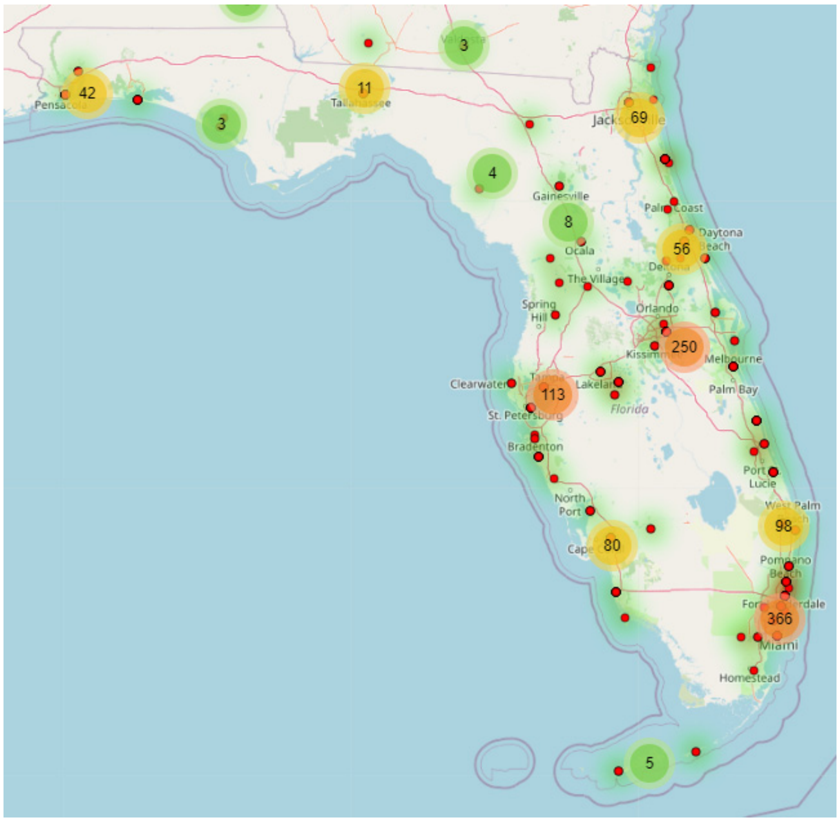

Fig. D.5. UAS Sighting Heatmap – Florida.

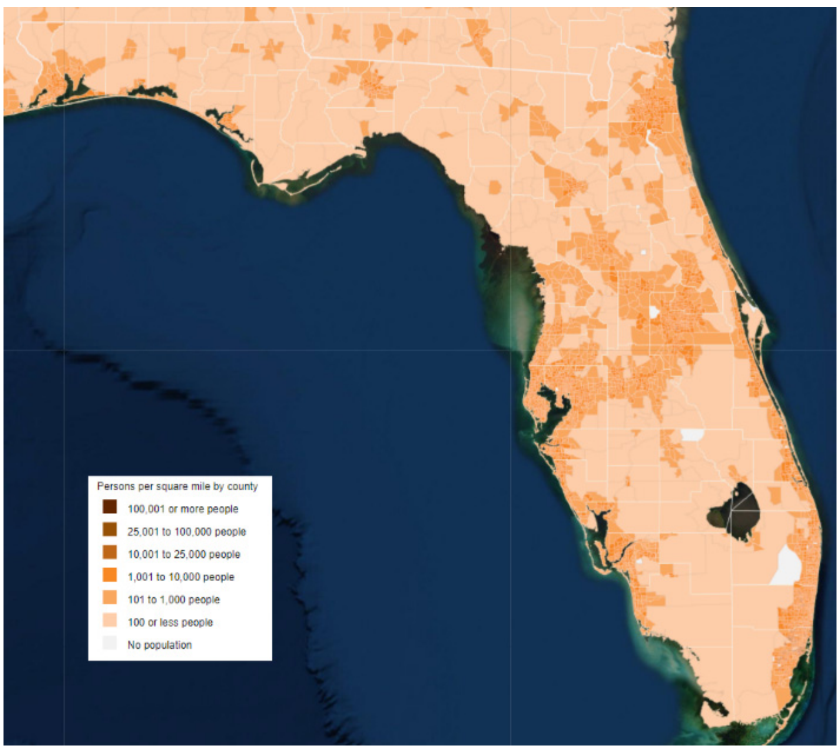

Fig. D.6. U.S. Population Density Map – Florida [42].

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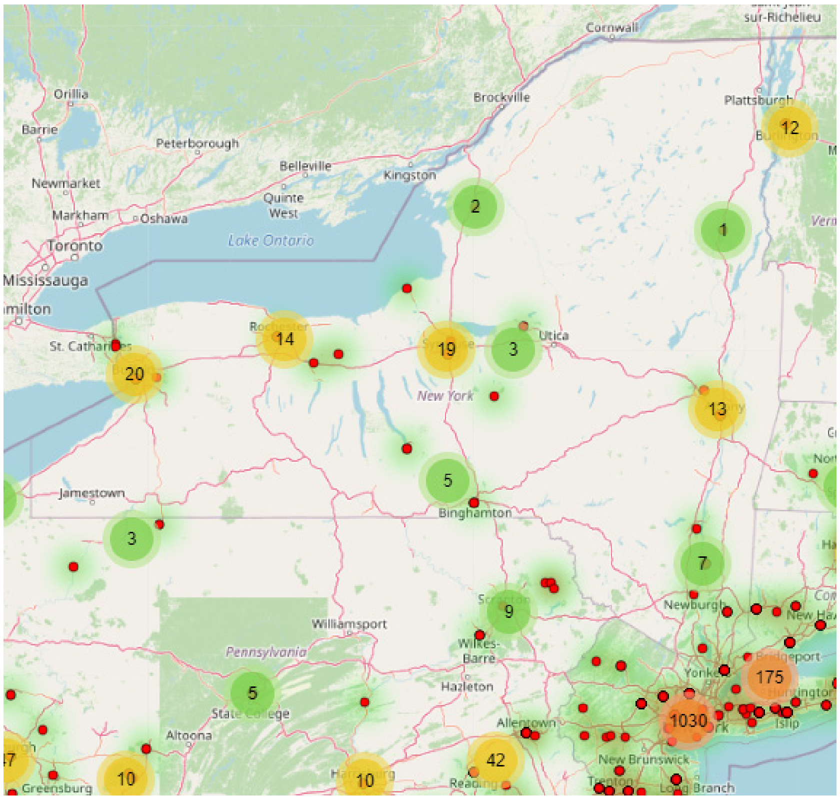

Fig. D.7. UAS Sighting Heatmap – New York.

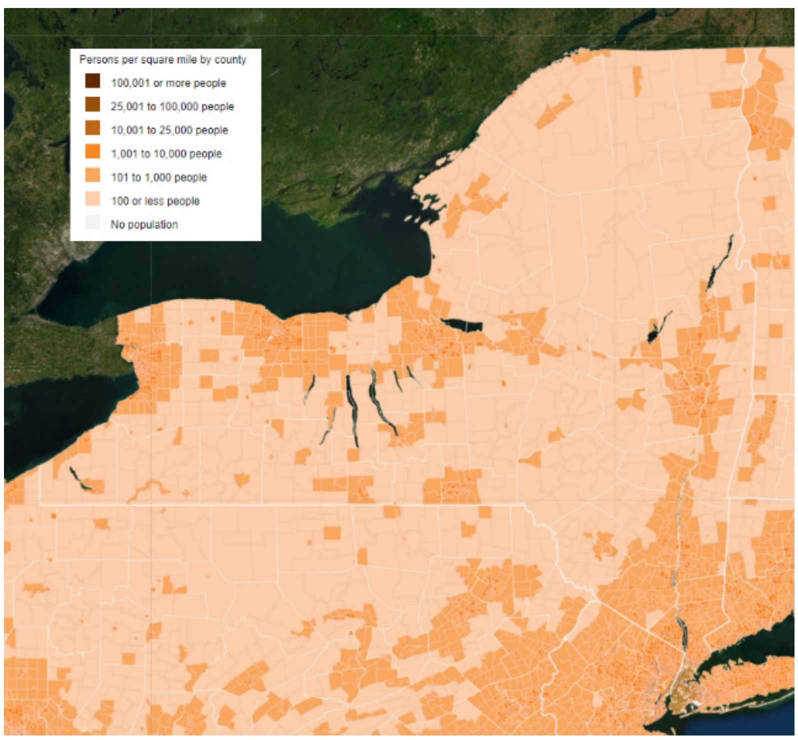

Fig. D.8. U.S. Population Density Map – New York [42].

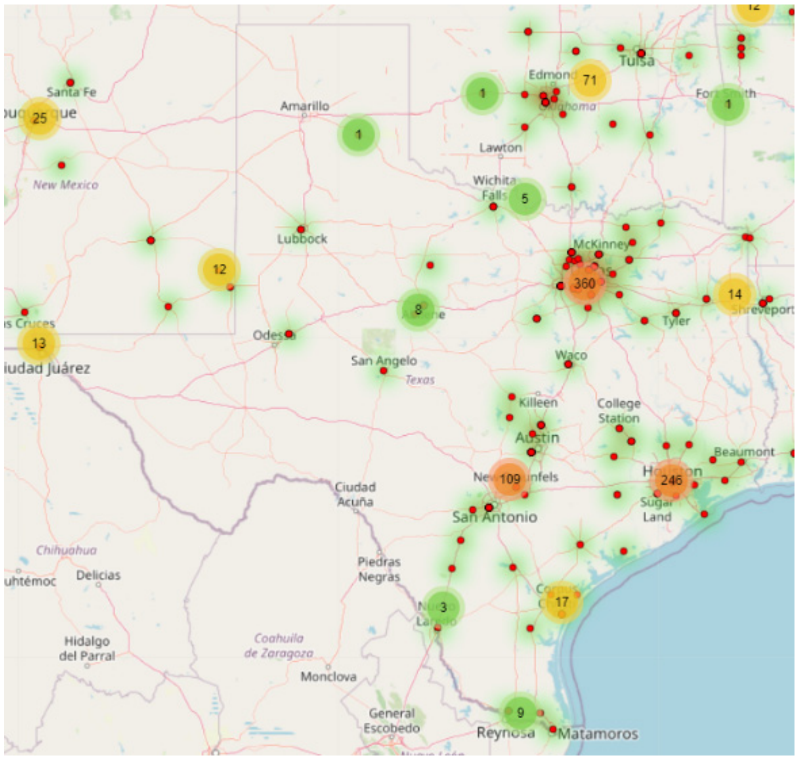

Fig. D.9. UAS Sighting Heatmap – Texas.

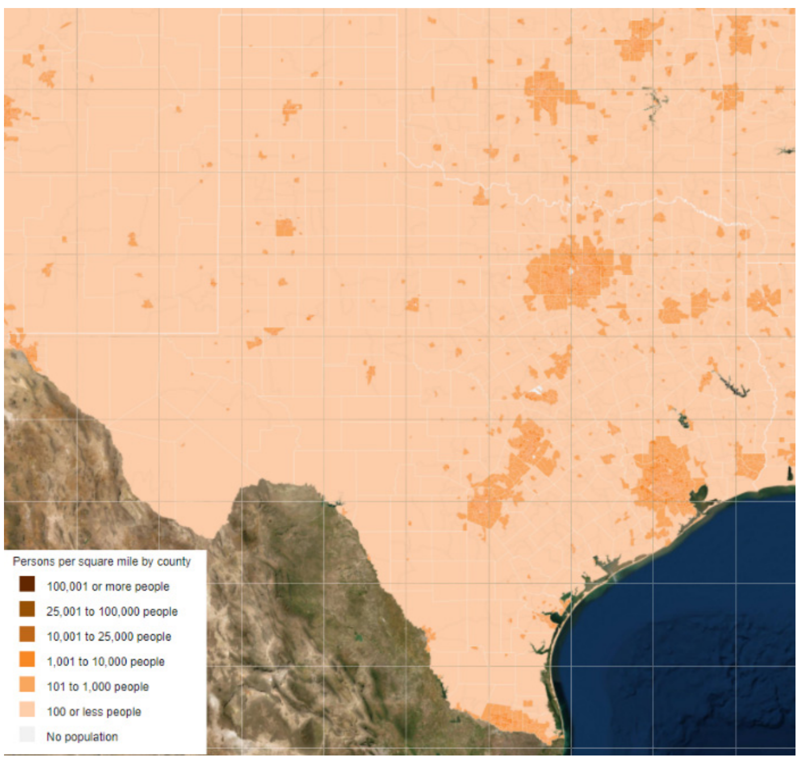

Fig. D.10. U.S. Population Density Map – Texas [42].

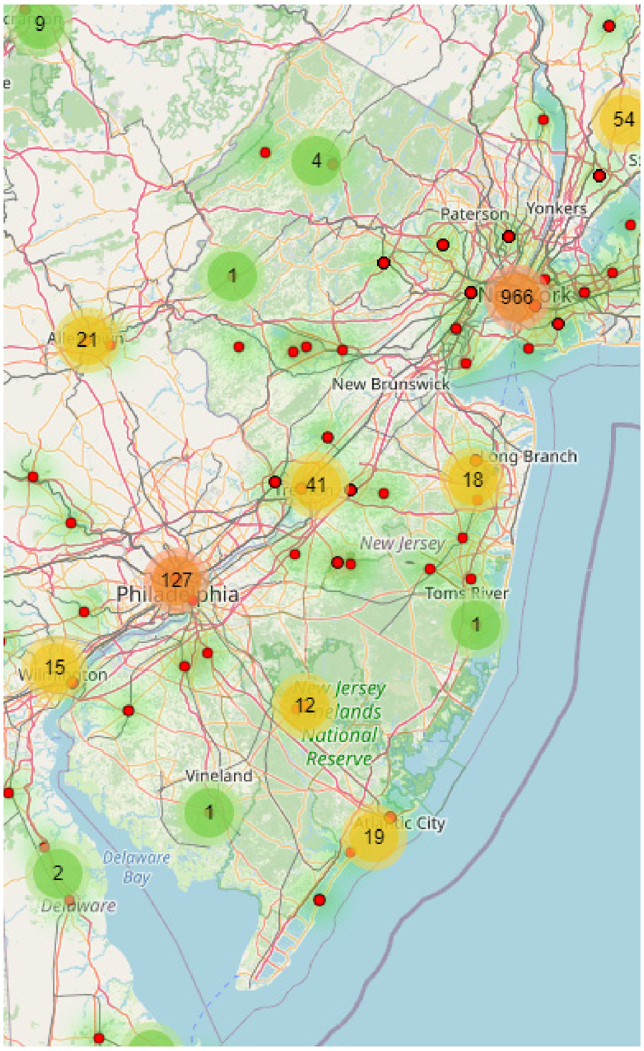

Fig. D.11. UAS Sighting Heatmap – New Jersey.

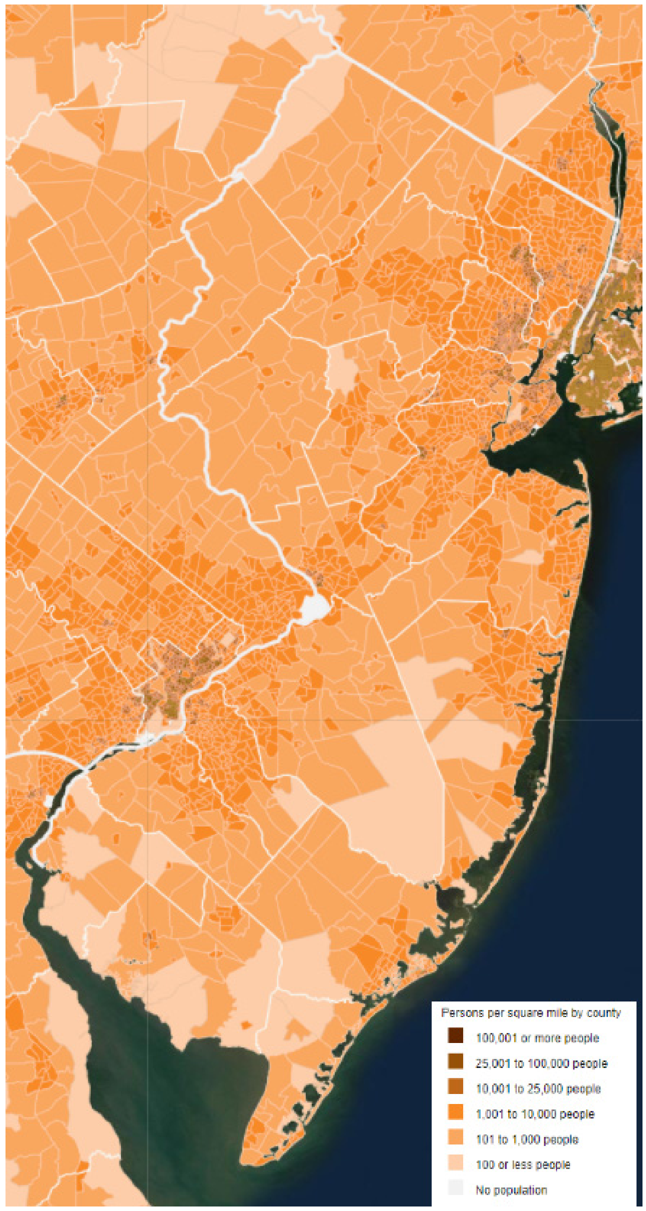

Fig. D.12. U.S. Population Density Map – New Jersey [42].

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