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DETECTING DRONE (UNMANNED OR UNCREWED AERIAL SYSTEM) THREATS AT STADIUMS (STADIA) AND PUBLIC VENUES:

FRAMING THE ISSUE

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Detecting Drone (Unmanned or Uncrewed Aerial System) Threats at Stadiums (Stadia) and Public Venues: Framing the Issue

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This technical paper will frame the issue of current and protentional threats to homeland security posed by Unmanned Aerial Systems (UAS), commonly and hereby referred to as drones, on public stadiums.[1] In the immediate post 911 environment, the US government weaponized drones for the targeting of terrorists.[2] This had numerous advantages including not risking US personnel (both pilot and support personnel near combat zones) and minimizing the physical infrastructure in place around the world needed for manned operations. The Predator and Reaper drones were effective in targeting terrorists both in terms of pattern of life surveillance, but also as a platform for hellfire missiles, and assassination.[3] Little thought was given to the fact that as this technology became more ubiquitous and cheaper, other states, terrorists, and criminals would eventually use this technology against US national and homeland security interests.

This technical paper will discuss these, and other threats posed to US critical infrastructure through the lens of drone threats to public stadiums and large gatherings, with an illustrative discussion of drone traffic over the *Astroworld* concert/festival. While drones were not used maliciously at *Astroworld*, mapping and analyzing the drone activity at this crowded and lethal public event, supplies a window into the complexity of drone detection, counter drone measures, and the challenges future security personnel will need to overcome to defend US critical infrastructure in an era of cheap ubiquitous drones.

Drones are not novel. Animals such as mules, have long been used as unmanned drones for smuggling operations, reducing the risk of arrest for human smugglers here on the Texas border dating to the 19th century and earlier.[4] Hobbyists have used remote controlled airplanes and helicopters for decades. What has changed in the 21st century is the cost of drones, their capabilities resulting from rapid advances in various technologies, and enhanced capabilities derived from free US government public utilities such as the global positioning system (GPS). These new technologies include software and internet-based interconnection of software development, the global positioning system (GPS), networked communication improvements, battery technologies, and the lower cost of electronic hardware such as semiconductors, computer processors, and other components. The reduced costs and weights of these technologies have made drones ubiquitous, and the future promises drone saturation with the Government Accountability Office (GAO) predicting more than 2 million drones by 2024 comprised of 800,000 commercial and more than 70% recreational.[5] This situation will and has called for increased regulation and government capacities to address it, a topic addressed here later and in the third technical paper of this series.[6]

Drones and Sporting/Mass Public Events

The United Nations has identified drone attacks on public stadiums and critical infrastructures as an emerging threat.[7] Scholars such as Robert J. Bunker have also identified the threat of terrorist and insurgent drones to mass events and the potential for mass casualties.[8] Scholars have identified the potential for terrorists to use drones to disperse chemical or biological weapons.[9] While these attacks may have a low probability of success, as so many biological and chemical attacks led by terrorists have failed, a potential attack may cause mass panic in a crowded stadium leading to crowd control issues and mass casualty events.

According to Federal Aviation Administration (FAA) regulations, drones are prohibited at public stadiums with more than 30,000 people. This includes one hour before and after scheduled play time for Major League Baseball (MLB), National Football League (NFL), National Association for Stock Car Auto Racing (NASCAR), and National Collegiate Athletic Association (NCAA) Division 1 Football. The FAA has developed public service announcements working with the stadium managers association (SMA) to remind people not to use drones in and around games.[10]

There are many examples of drones disrupting public stadiums and sports events, e.g., the 2017 crash landing of a drone in *PETCO* Park in San Diego, which nearly injured several fans.[11] Stadium security personnel and local law enforcement are limited in what they can do to counter drones. First, they cannot shoot drones down legally and even if they could that would pose public safety risks. Stadiums cannot hijack the drone through software and force it to land or jam its signal. Thus, they are typically forced to find the pilot and deter or mitigate the threat by dispatching security or law enforcement to the pilot.[12] Many individuals are unaware they have broken laws related to drones, but others do so intentionally at multiple public stadiums. The company, *Airsight* had already blacklisted one drone pilot at one stadium after an illegal flight which allowed the company to send an immediate alert to the stadium when the individual showed up at Wrigley Field.[13]

In a case study report on the *Camping World* Stadium in Orlando Florida, *Airsight* summarized their drone detections on the days of the Camping World Bowl Game, the Citrus Bowl, and the NFL Pro Bowl. In one incident, during the Pro Bowl, 2 unauthorized drones were detected across 3 flights and Orlando Police were alerted to the pilot location based on detection data provided.[14] Geofencing of a restricted area via geographic software mapping make these alerts possible. Sports stadiums are not the only areas where mass gatherings occur, and drones can be a potential threat. Areas such as the Las Vegas strip have also seen potentially dangerous drone activity. In one incident the FAA contacted a private drone detection company to identify a particularly dangerous flight. This is an example of the close cooperation between public and private entities necessary to critical infrastructure protection.[15]

Astroworld: The Travis Scott Concert

This three-part technical series of papers will discuss and analyze drone threats to public stadiums through the lens of the Astroworld event. The Astroworld Festival concert headlined by Travis Scott in Houston on 5 November 2021 resulted in 10 deaths as concert goers suffered injuries in the crowd against the stage as Travis Scott performed. There were also significant injuries earlier in the day as concert goers rushed barricades resulting in crowd related injuries.[16] Emergency personnel treated dozens for injuries at the concert and in local hospitals.[17] During the concert the Houston Police Department declared a mass casualty event in conjunction with the Houston Fire Department. While Scott claimed not to know the crowd injured concert goers, according to ABC News he stopped his set three times to point out injured individuals, but continued his set.[18] Previous Travis Scott Concerts had posed public safety issues and Scott had been accused of inciting violence at concerts in which “raging” was encouraged.[19] Scott had pleaded guilty to disorderly conducted charges resulting from inciting concert goers to jump barricades in 2015 and 2017.[20] The 2021 concert resulted in at least 30 lawsuits against Travis Scott and Live Nation, the company in charge of the event. The image below provides a visual representation of the area of the concert in red within the Houston geographic context. It is a 3D model of the relevant area generated by the authors.

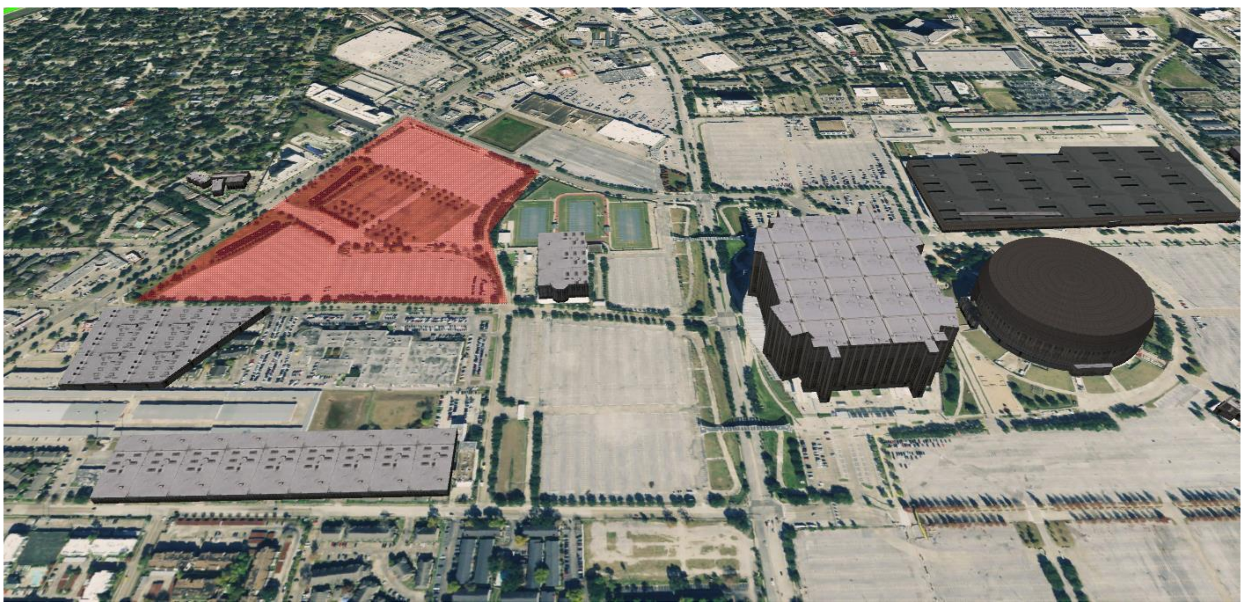

Figure 1. 3D Model of Astroworld Event and Environs (Festival Event Depicted in in Red).

The events of *Astroworld* Houston 2021 also precipitated a state of Texas commissioned taskforce producing a report to set up policies to prevent future concert mass casualty events.[21] The concert resulted in the detection of abnormally large drone traffic which points to possible threats to public security at public stadiums. Significant drone activity at an event like Astroworld could result in collisions between drones and emergency vehicles such as helicopters, harm crowds on the ground, or could be an attack site for terrorists or other malevolent actors.

Figure 2. A depiction of an intruder drone in close proximity to a rescue helicopter in a 3D Scene (Authors' elaboration).

The potential for drone traffic to damage or hinder emergency operators during mass casualty events are the types of situations emergency managers and incident commanders will need to prepare for as drones increase in ubiquity.

Exploratory Analysis of the Airsight Data Related to Astroworld

As part of this project on drone threats to public stadia, the Dallas based drone detection company *Airsight* provided the researchers with drone detection data derived from sites near the *Astroworld* event. The drone detection methods and layers will be discussed in-depth in technical paper 3 of this series, but a preliminary sense of the data is useful. The data included the dates of 4-7 November 2021, so that the researchers could assess patterns in the data prior to, during, and after the *Astroworld* Concert tragedy of 5 November 2021. The data set was narrowed to a half mile square radius around the *Astroworld* concert. Within these parameters, 12,666 data points were collected, though it should noted that a majority of these were the same drone, or drone flight, being detected at multiple points along its flight path. Despite this high number of data points only 25 unique drone IDs were present, while only 46 unique flight IDs were present in the period. This is consistent with *Airsight* analysis of their own data on other sporting events.[22] Figure 3 below breaks the data down by drone type, which are primarily Da-Jiang Innovations (DJI) drones, a ubiquitous Chinese manufactured brand.

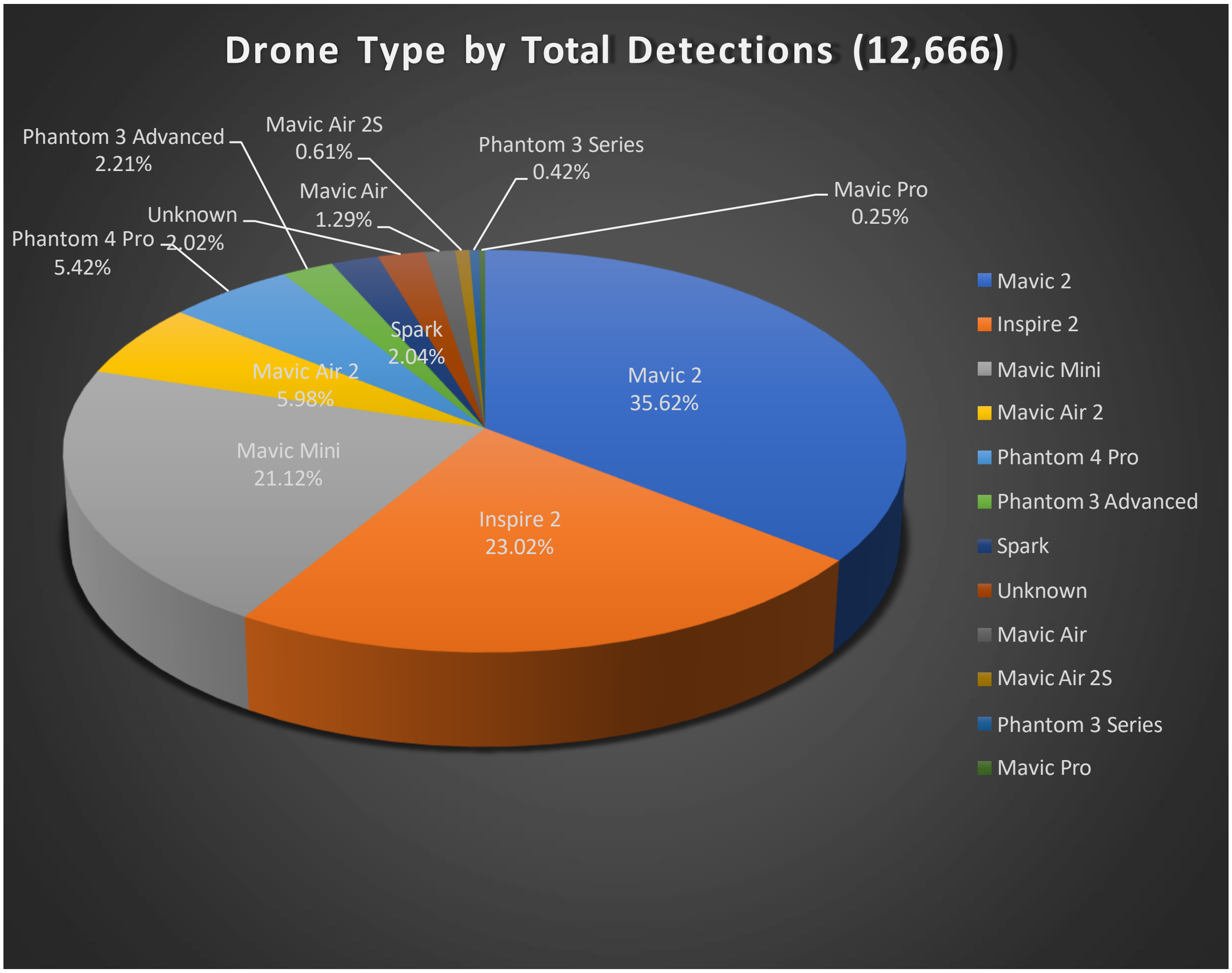

Figure 3. Drone Detections by Drone Type (Authors' Analysis)

Drone type trends can serve to alert incident commanders to the potential payload capacities and therefore threat types present in the operational environment. The Appendix to this technical paper contains numerous tables and charts summarizing the data. One table summarizes the altitude data for all flights, every time the drone was detected. We see the maximum altitude was 499.5 feet while the minimum detected was 3 feet below sea level suggesting there may have been topographically low points near the site or detection error issues. The average height of the drones across all flight detections was 36.87 feet across the full set of 12,666 detection over 46 flights.

One key finding was that drone activity increased during the event (evening of 5 November) and surged the day after the event on 6 November. Local news reported on crowds rushing the gates and injuries posted to local websites at 3:15pm on the day of the concert 5 November may have led to increased drone activity.[23] It is plausible that drone operators may have launched drones to survey the area based on these reports.

Much like closed circuit television (CCTV) footage, many drone detection systems monitor critical infrastructure, but detect other relevant data from surrounding events, allowing investigators to piece data together after the fact. This requires significant analytical capability to analyze disparate systems. In the near future artificial intelligence systems may play a key role in piecing these varying data streams together immediately after events and in real time. As the subsequent papers in this project will demonstrate, the *Astroworld* event on 5 November 2021, is a useful cases study in drone traffic. The primary uptick in drone traffic was the day after the event, suggesting media, hobbyists, personal injury lawyers, and law enforcement may have been particularly interested in surveilling and documenting the event in its aftermath. For a video analysis of drones over *Astroworld* during and after the event see the Institute for Homeland Security at Sam Houston website.

Conceptualizing Potential Homeland Security Drone Threat Actors: The Illicit, the Unwitting, and the Foreign Power

Here it may be useful to divide the discussion on potential drone threats into three categories, the *illicit*, the *unwitting,* and the *foreign power* or foreign power proxy. In the first category are malign actors such as terrorists, criminals, or corporate espionage actors, with violent or illicit profit-motive in mind. In the second category, the unwitting, are the unintentionally malign. These might include individuals wishing to have video footage of a major sports stadium event and be unaware of laws and regulations, or individuals flying drones unwittingly in restricted areas. While homeland security may tend to focus on the first category, the second category, the unwitting, through sheer numbers, is today the bigger problem for critical infrastructure, leading to jammed flight paths, damage from accidents, disruption from response security measures, etc. Drones in and around airports or the flight paths of manned emergency flight vehicles is also a threat to US critical infrastructure. The third category, *foreign power* or *foreign power proxy*, category includes state actors such as foreign governments engaging hybrid warfare and great power competition.[24] These activities may include, use of airspace, espionage, sabotage activities, information warfare dissemination, cyberthreats, etc. Foreign powers also seek plausible deniability and thus may use proxies such as organized crime actors to carry out their operations against the United States and its interests.[25]

Illicit non-state actors have already used drones to damage US homeland Security. These activities include Mexican organized crime groups (OCGs) using drones for surveillance of US law enforcement agency activities and movements to smuggle drugs in the United States.[26] Terror networks also use drones. These include terrorist bombings be they conventional, dirty bomb, chemical or bioweapon attack, or pre/post attack intelligence, surveillance, and reconnaissance (ISR). Terrorists have used drones to even the playing field in terms of costs. For example, in 2017, in Syria ISIS used a drone to drop a landmine inside a stadium. The resulting fire caused damage far more than the cost of the attack.[27] Corporate, nation state, or illicit network actors can use drones for espionage.

Illicit networks can use drones as loitering munitions as they have already been used in conventional battles.[28] The 2020 war between Azerbaijan and Armenia in which Azerbaijan decisively defeated the Armenians using Israeli designed loitering munitions made armies around the world take note of loitering munitions.[29] Loitering drone munitions are an emerging technology which have received significant social media and news attention due to the role they play in the 2022 Russian invasion of Ukraine. The announcement the US government military aid package to Ukraine in mid 22 would include the switchblade “kamikaze” drone system garnered significant attention. Brian Devereaux argues that loitering munitions systems should be treated separately from drones, because they are a “smart” or “loitering missile” as one manufacturer AeroVironment calls them.[30] These systems can loiter “30-60 minutes, while some Israeli systems can loiter for nine hours.”[31] Once airborne they cannot be recovered and will likely be expended quickly.

Similarly, drones can be used for aerial networking on the battlefield by both benevolent and malicious actors.[32] While this is most likely to be nation-state actors, the pattern is that what is the purview of the state rapidly succumbs to “the democratization of technology” be it for good or ill.[33] Drones can be used to disrupt flight paths for critical infrastructure such as airports or harass defenders of other critical infrastructures such as public stadia.[34] Drones can deliver contraband into prisons or play other roles in nefarious prison activity such as facilitating escapes. Nefarious actors can use drones to fly over physical infrastructure and become potential WIFI spoof cyber threats.[35]

Soon we can expect new drone-based threats including multiple simultaneous drone terror attacks[36] used in conjunction with other attack types such as those employed in Mumbai 2008.[37] While this “swarming” and “lethal autonomous weapon systems” (LAWS) technology will initially be developed by nation-states, non-state actors will inevitably replicate it.[38]

Counter-Drone Measures (C-UAS)

We can conceptualize drone counter measures/counter-unmanned aerial systems (C-UAS) along a continuum of impact upon the drone, the pilot, and society. At the low end of the spectrum are 1) physical barriers such as netting to prevent drone entry and or the dropping of contraband by drones into prisons. Drones can be 2) jammed via radio signals forcing them to land in place or return via pre-programed routes. Drones can be 3) blinded via directed energy weapons such as lasers if they are relying on optical sensors for piloting. 4) Drones can be spoofed to take control of and capture the drone. Drones can be 5) destroyed via directed energy weapons or projectiles. Drones are much like planes and can be shot from the sky in the same fashion via anti-aircraft fire.[39] This however is less viable outside wars zones and around civilian infrastructure. Firing projectiles in the air comes with the risk of where the munition will ultimately fall to the ground. 6) The drone pilot can be targeted, (questioned, warned, detained, arrested, incapacitated, or in the case of violent ongoing crime: killed (extreme)) before, during, or after an event which has, is, or will impact critical infrastructure security. All of the previously mentioned countermeasures may one day also be delivered by drones themselves, which may have the effect of allowing these processes to be more precisely delivered with minimal threat to innocents and automated through artificial intelligence systems.

The Regulatory Environment

As previously mentioned, the FAA has instituted numerous regulations related to drones including piloting license requirements, which are not onerous and not in person, requiring new drones to broadcast information about them and the pilot, and regulations banning drones in certain areas such as during major sporting events. As of 2022 only four federal government agencies (Department of Defense (DOD), Department of Justice (DOJ), Department of Homeland Security (DHS), and the Department of Energy (DOE)) are legally able to use certain counter drone measures in limited circumstances, which may include signal jamming wherein the drone is either preprogrammed to land or return home. There are other countermeasures depending upon the size and altitude of the drone. In the future we may see more directed energy weapons (lasers, microwave, etc.) used as counter drone measures. These types of measures may have the advantage of rapidly responding to drone swarms, which can overwhelm defenses. One of the key hindrances to practical counter drone measures, is the limited number of agencies and personnel with counter drone authorization. Most public stadia events will be under the purview of local and state actors, which under the current regulatory scheme must depend on the four federal agencies with these capabilities. Conversely, there are good reasons to limit the expansion of counter drone measures. Jamming technologies could disrupt commercial flights potentially disrupting passenger planes, or Life Flight public health infrastructure helicopter communications.

The second paper in this series discusses operational perspectives on responding to drone threats at public stadia while the third paper addresses the technical aspects of developing situational awareness and a common operational picture to counter potential drone threats. The third paper also concludes the series with policy recommendations.

Appendix

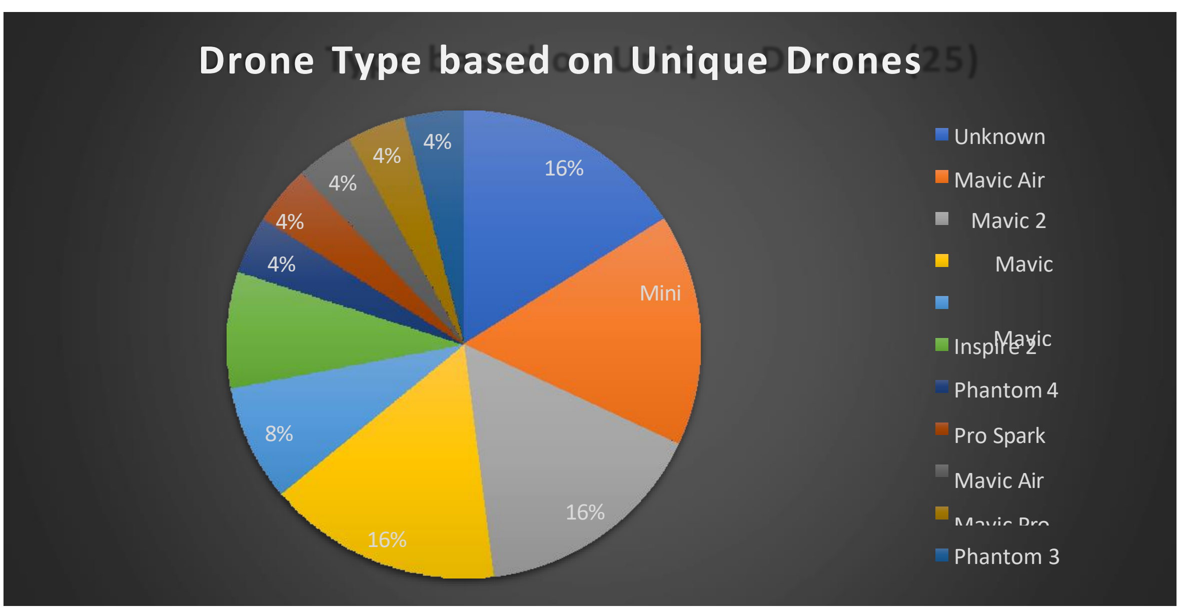

Figure 4. Drone Detections by Unique Drone (Authors' Analysis)

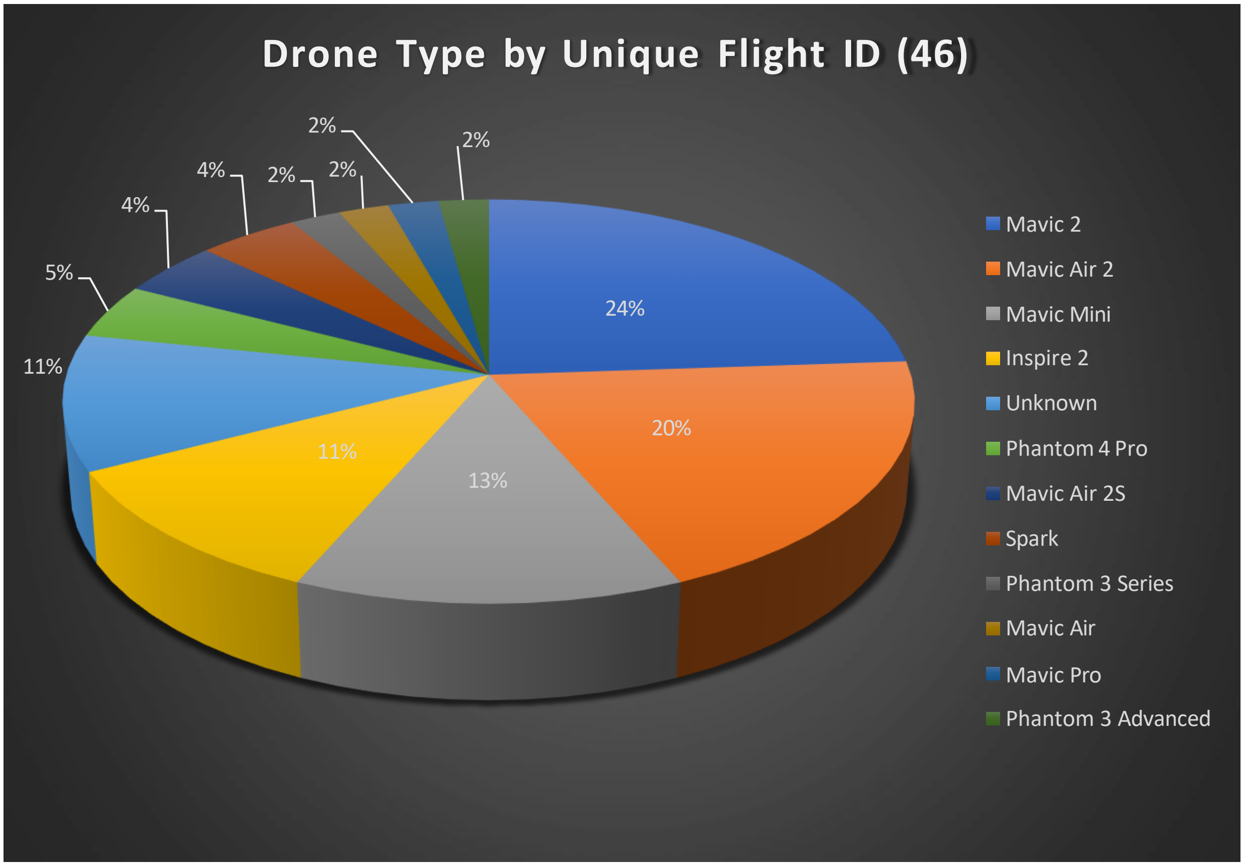

Figure 5. Drone Type by Unique Flight ID (Authors' Analysis)

Altitude in Feet	
Mean	36.8746408
Standard Error	0.52477079
Median	20.8
Mode	0
Standard Deviation	59.0594491
Sample Variance	3488.01853
Kurtosis	14.0155548
Skewness	3.24514193
Range	499.5
Minimum	-3.7
Maximum	495.8
Sum	467054.2
Count	12666

Confidence Level (95.0%)	1.02863014

Table 1: Analysis of Detected Drone Altitude

Speed	
Mean	0.99851571
Standard Error	0.02161973
Median	0
Mode	0
Standard Deviation	2.43315583
Sample Variance	5.9202473
Kurtosis	9.28448619
Skewness	3.09539026
Range	14
Minimum	0
Maximum	14
Sum	12647.2
Count	12666
Confidence Level (95.0%)	0.04237793

Table 2: Analysis of Detected Drone Speed

Author Bios

Nathan P. Jones is an Associate Professor of Security Studies in the college of Criminal Justice at Sam Houston State University. He is the author of Georgetown University Press's peer reviewed book *Mexico's Illicit Drug Networks and the State Reaction (2016)*. His areas of interest include organized crime violence in Mexico, drug trafficking organizations, social network analysis, border security, and the political economy of homeland security. Dr. Jones is also a Senior Fellow with the Small Wars Journal - El Centro, a Rice University Baker Institute Drug Policy and US-Mexico Center non-resident scholar, and the Book Review Editor for the Journal of Strategic Security. Prior to joining the Sam Houston State University Security Studies Department, Dr. Jones was the Alfred C. Glassell III Postdoctoral Fellow in Drug Policy at Rice University's Baker Institute for public policy, where his research focused on drug violence in Mexico.

Dr. John P. Sullivan was a career police officer, now retired. Throughout his career he has specialized in emergency operations, terrorism, and intelligence. He is an Instructor in the Safe Communities Institute (SCI) at the University of Southern California, Senior El Centro Fellow at *Small Wars Journal*, and Contributing Editor at *Homeland Security Today*. He served as a lieutenant with the Los Angeles Sheriff's Department, where he has served as a watch commander, operations lieutenant, headquarters operations lieutenant, service area lieutenant, tactical planning lieutenant, and in command and staff roles for several major national special security events and disasters. Sullivan received a lifetime achievement award from the National Fusion Center Association in November 2018 for his contributions to the national network of intelligence fusion centers. He has a PhD from the Open University of Catalonia, an MA in urban affairs and policy analysis from the New School for Social Research, and a BA in Government from the College of William & Mary.

George W. Davis Jr. specializes in providing technology solutions to the defense and public safety sectors. He is a specialist in geospatial Information Systems and Geospatial Intelligence (GEOINT). After the 9/11 2001 attacks at the World Trade Center he supported the Emergency Mapping and Data Center (EMDC), mapping the area around Ground Zero as well as most of Manhattan south of Canal Street. He served as Geospatial Information Coordinator for the New York Metro Chapter of Infragard. He has worked with the Department of Homeland Security (DHS), New York Police Department (NYPD), FBI, Los Angeles Sheriff's Department (LASD), the Lower Manhattan Security Initiative, and the Business Emergency Operations Center (BEOC) Alliance in New Jersey. Projects included mapping and aerial photography for several national and international disasters (Hurricanes: Charley, Katrina, Rita, Ike and Hugo), the Haiti Earthquake and the Sri Lanka Tsunami, using LIDAR, 3D Modeling software, Unmanned Aerial Systems (Drones), Thermal Imaging, Ground Penetrating Radar (GPR), GPS, and other remote sensing technologies.

Endnotes

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The Institute for Homeland Security at Sam Houston State University is focused on building strategic partnerships between public and private organizations through education and applied research ventures in the critical infrastructure sectors of Transportation, Energy, Chemical, Healthcare, and Public Health.

The Institute is a center for strategic thought with the goal of contributing to the security, resilience, and business continuity of these sectors from a Texas Homeland Security perspective. This is accomplished by facilitating collaboration activities, offering education programs, and conducting research to enhance the skills of practitioners specific to natural and human caused Homeland Security events.

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