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Applying UAS Technologies at Night during a Wildlife Hazard Assessment

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Airports operating under the Code of Federal Regulations Part 139 should conduct a wildlife hazard assessment (WHA) when some wildlife-strike events have occurred at or near the airport. The WHA must be conducted by a Qualified Airport Wildlife Biologist (QAWB). The required elements in a WHA include the identification of the wildlife species observed and their numbers and the location of features on and near the airport that could attract wildlife. The collection of data pertaining to mammal populations during a WHA is generally time-consuming, labor-intensive, and costly. Protocols to collect this data include trapping and marking animals and systematic surveys using a spotlight and/or night vision equipment. The purpose of this study was to investigate how UAS technologies could be effectively applied to streamline the QAWB efforts during a WHA at night. Researchers, including students, used a DJI Mavic 2 Enterprise Dual with visual and thermal cameras and a spotlight, as well as a Matrice 210 with a Zenmuse XT2 thermal camera to collect data. Data were collected in a farmland area located two nautical miles south of Daytona Beach International Airport. We applied multiple strategies to mitigate the risks associated with drone operations in an airport environment. The safe application of UAS to streamline the WHA process is anticipated to provide several benefits to the airport operator, including task completion in reduced time, enhanced level of accuracy during the data collection process, reduced risks for the QAWB, and cost efficiencies. Most importantly, researchers expect to develop benchmark safety protocols that can facilitate the effective integration of UAS into the airport environment.

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Background and Problem Statement

The Federal Aviation Administration (FAA) Wildlife Strike Database released a composite ranking of the fifty most hazardous wildlife species to aviation operations (FAA, 2018). Counterintuitively, the highest-ranked wildlife species on the list is not a bird but a terrestrial mammal: the White-tailed deer. Although terrestrial mammals only account for 2% of total reported strikes, their potential to cause irreparable damage to aircraft, injury, and/or cause casualties is substantial. For example, collisions with White-tailed deer destroyed 24 aircraft, caused 28 injuries with one fatality, and cost $56,078,745 in economic losses from 1990 to 2021. Previous studies have also identified a positive relationship between the body mass of an animal and the likelihood of a damaging strike (Dolbeer et al., 2023; Pfeiffer et al., 2018). Similarly, there is evidence that supports a higher risk of strikes with terrestrial mammals at night (Dolbeer et al., 2023). It stands to reason that most terrestrial animals listed in the FAA's wildlife composite ranking tend to be crepuscular (most active before sunrise and after sunset) or solely nocturnal. Herein lies an opportunity to enhance current Wildlife Hazard Assessments (WHA) during periods of darkness.

Under the Code of Federal Regulations (CFR) Part 139, whenever a wildlife strike occurs on or near an airport, the owning airport operators are required to conduct a WHA to develop an effective Wildlife Hazard Management Plan (FAA, 2018). The WHA is a formal assessment conducted by a qualified airport wildlife biologist (QAWB) to observe and identify wildlife species, quantify their numbers, track their movements, and identify locations around the airport that could be potential attractants to wildlife (FAA, 2020). This approach, however, has several limitations that could be mitigated with the innovative technology that unmanned aircraft systems (UAS) provide (Hamilton et al., 2020a, 2020b, 2020c). For instance, traditional ground-based exploration (often with the assistance of binoculars) does not offer a bird's-eye view of wildlife, nor are the locations necessarily conducive to reach by vehicle or on foot (e.g., wetlands, marshes) (Cabrera et al., 2021). Furthermore, these assessments fail to capture the nocturnal nature or congregations of large-massed animals that have emerged as more dangerous to aircraft operations.

Information obtained from the scientific analyses of wildlife strikes to aircraft has indicated that different safety strategies to mitigate such risks are vital (Misra et al., 2022; Tella & Mendonca, 2023). According to Mendonca et al. (2020), these strategies should include research and innovative use of current technologies. The purpose of this study was to explore the use of UAS technologies at night by developing and refining a concept of operations to support data collection and analysis during a nighttime WHA. The researchers hypothesized that the use of UAS technologies could streamline the WHA processes during periods of darkness and provide "sight" to benchmark safety protocols to facilitate the effective integration of UAS into the airport environment.

Methodology

Drawing from a previous UAS exploration study (Cabrera et al., 2021), the researchers implemented the Concept of Operations (CONOPs) by shifting the wildlife observation window to the hours of twilight leading into nightfall. The elements of the UAS CONOPs include methods of operation (e.g., flight plan) and Safety Risk Management (SRM) protocols (Hamilton et al., 2020a). Through the development of CONOPs for a WHA at night, the researcher conducted all applicable pre-mission checklists, which included hazard identification and risk mitigation. For example, prior to the night operations, a pre-mission brief was held to organize the team into their respective roles for the evening, and safety precautions were taken. Lastly, an after-action review (AAR) was held to refine the CONOPs for potential improvements to the processes and procedures.

Coupled with the technical assistance of a QAWB (via Zoom meetings), a small team of undergraduate students assisted with data capture, visual observing, flight operations, and data analyses. This study employed a DJI Matrice 210 with an XT-2 thermal camera to achieve the thermal imaging requirement. The team used a dedicated trailer to house the necessary equipment to ensure optimal research procedures, such as an Automatic Dependent Surveillance–Broadcast (ADS-B) flight box, in concert with ForeFlight to monitor neighboring manned air traffic; and two television monitors, one to display ForeFlight information, and the other, connected to the drone's controller via a high-definition multimedia interface (HDMI) cable to mirror the drone's screen. It is noteworthy to mention that at least one member of our team stayed inside the trailer during the entire data collection process monitoring the live traffic feed and communicating (i.e., walkie-talkies) with the drone's pilot and the visual observer (VO) (Cabrera et al., 2021).

Our team adopted SRM procedures to help mitigate the possibility of conflicts between manned aircraft operations and UAS during the data collection process by including Geofencing, a visual observer (Hamilton, 2020a, 2020b, 2020c), and by conducting UAS flights below 300 feet above ground level (AGL). Moreover, the person inside the trailer monitored one TV set and wrote down any necessary observations (e.g., wildlife activities) on a Wildlife Survey – Airport Observation Sheet (WSAOS) in coordination with the drone's pilot and VO (see Cabrera et al., 2021).

The site for the study is located 1.67 nautical miles south of the southernmost boundary of the Daytona Beach International Airport (KDAB). This location is in accordance with the recommended five statute mile radius of an airport's air operations area (AOA) (FAA, 2018). This farmland is surrounded by large trees, fields, and other farmlands that are prone to various kinds of wildlife species, including "large birds" (e.g., Sandhill Cranes) and especially cattle and boars roaming the field. Worth noting is that aircraft operations close to that location are intense (at ≥ 1,000 feet AGL), especially flight training (FAA, 2023). This factor added significantly to the complexity of this project as proof of concept to integrate UAS operations in the area successfully without incident.

To obtain the best possible outcomes, the test flights first used both automated and manual flight modes. The first mode was projected to provide a baseline of the area and thermal signatures of resting objects (e.g., presence and location of mammals) by scanning in a grid-like pattern via the "DJI GS Pro" software. This software allows the user to create flight plans track, and store telemetry data in real-time. The second mode of flight then shifted to manual operations whereby the pilot-in-command (PIC) would observe and loiter over areas of interest. A mixed method approach was utilized during the analyses of the collected data to identify what, if any, added benefits there were to the methodology of the research project. Qualitative analyses helped identify the following:

1. The workflows and best practices for applying UAS technologies during a WHA at night;
2. Whether UAS thermal imaging was effective in the detection of wildlife during periods of darkness and
3. Whether UAS thermal imaging was effective in identifying the land uses and habitats at the data collection area that are potentially attracting hazardous wildlife to the airport environment.

Significance of the Study

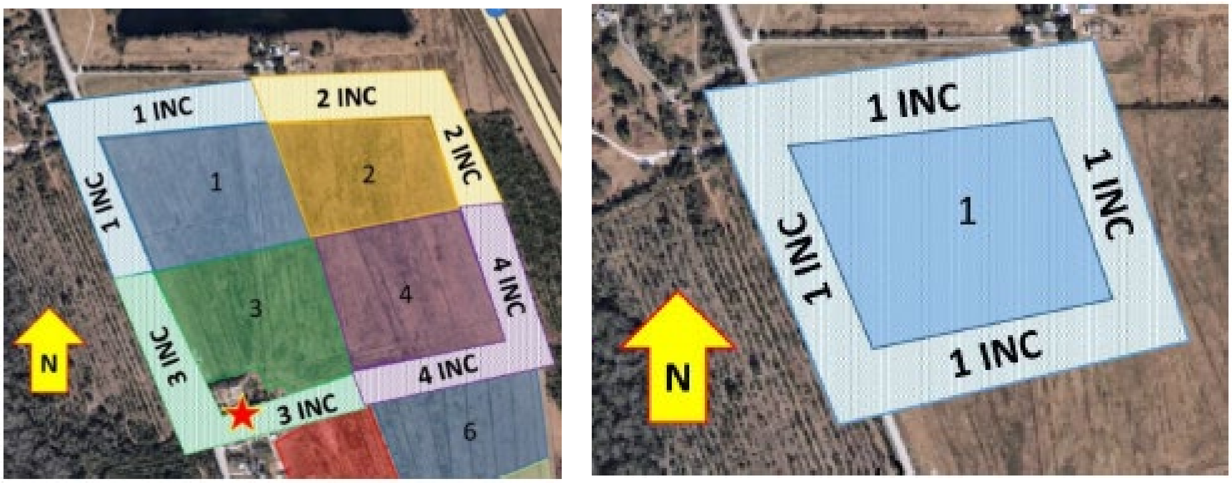
The most exciting aspect of this proof of concept is that it merged UAS technologies with WHA at night. To the knowledge of the researchers, this had never been done before. Thus, this project offered a unique opportunity to test the efficacy of thermal imaging to study the behaviors of terrestrial wildlife as well as possible environmental attractants for wildlife that are uncommonly observed during periods of low illumination. Historically, wildlife surveys conducted at night use trapping and animal marking techniques, which are highly invasive (FAA, 2018). Other methods call for night vision equipment that does not adequately penetrate the landscape or vehicle-mounted spotlights that potentially pose a hazard to low-altitude aircraft, other vehicles, or airport towers if pointed inappropriately (FAA, 2018). Hence, the use of UAS technology is a less intrusive means to assist with wildlife surveys and from an aerial perspective that extends beyond conventional practices. For our team, which included students, other benefits included collaboration in a research project addressing major safety issues afflicting the U.S. aviation industry, which is in alignment with the FAA (2022) mission (1), values (2), and vision (3):

1. Provide the safest, most efficient aerospace systems in the world;
2. Foster creativity and vision to provide solutions beyond today's boundaries and
3. Demonstrate global leadership in how the FAA safely integrates new users and technologies into the National Airspace System (NAS).

Key Findings

The findings from this study confirmed several key assumptions. One component of the CONOPS was to test flying at altitudes of 300, 200, 100, and 50 feet AGL in each quadrant of the research area, namely quadrants 1-4 (see Figure 1), to test the efficacy of thermal detection of animals. In Figures 2a and 2b, the presence of large-massed animals is clearly visible from as high as 300 feet AGL. The thermal signatures increased in visual clarity as the drone pilot descended to lower altitudes of observation (shown in Figures 2c and 2d).

Figure 1
Data Collection Area - Operational Quadrants



Note. The abbreviation “INC” is an adopted QAWB term for incidental or outside of the main area of observation.
Note 2. The color-coded areas were notional boundaries to help organize the observer’s notations for the WSAOS and were not exact dimensions.

Figure 2
Images of Cows Obtained with a Thermal Camera

Note. Images obtained at ~300 feet AGL (2a and 2b) and at ~50 feet AGL (2c and 2d)

As expected, the drone was not only able to detect the presence of animals at multiple vantage points, but it was also able to overcome obstacles such as dense vegetation by climbing above the terrain. Throughout the duration of this project, the operational area went through various phases of grass and weed heights. A QAWB could have to traverse through potential physical obstacles to obtain the images and other data that are necessary for a WHA. Dense vegetation, for example, could pose additional hazards for QAWBs by subjecting them to terrestrial dangers such as sinkholes/depressions or snakes that are hidden from view.

Traditional ground-based methods of WHA data collection are limited in their ability to capture crepuscular animals during periods of darkness. As referenced earlier, the use of mounted spotlights to capture retinal eye glint trapping and tagging animals are some of the current practices for nighttime WHAs (FAA, 2018). Though some of these means may still be viable, the evidence strongly suggests that the use of UAS technologies is very capable of bestowing "sight" for large-massed animals at night. To demonstrate the disparity of the naked eye and thermal imaging, a side-by-side comparison is presented in Figure 3.

Figure 3
Comparison between Naked eye (3a) and Thermal Imaging (3b)

Another item to note is that from the ground-based horizon, a QAWB may not detect the presence of animals with the naked eye or even with binoculars due to high vegetation and or man-made structures. Even with a high-powered flashlight, the detection of animals was not feasible. It was only upon overhead thermal detection that the presence of nearby animals was discoverable (see Figure 3b). In addition to the advantage of viewing animals without the use of spotlights and invasive trapping techniques (FAA, 2018), the UAS vantage points, coupled with a camera/video feature on the drone, demonstrate the benefit of recording the observed number of animals. Instead of relying on estimations of moving targets as suggested by the FAA (2018), the QAWB can revisit the images and provide a more detailed account of the numbers and species of animals detected (see Figures 2 and 3b). Moreover, without the advantage of drone technologies and thermal imaging, a QAWB could lose valuable data that might go unaccounted for.

Lastly, our findings suggested that the SRM protocols helped our team mitigate the risks associated with UAS technologies during a WHA at night. Nonetheless, we acknowledge that there are risks associated with UAS operations at and around an airport environment. Thus, the ConOps should be periodically revised to incorporate procedures that improve aviation safety and efficiency.

Limitations

Though this research project was viewed as a proof of concept, the ability to fully test the effectiveness of incorporating UAS technologies during a WHA at night could not be fully ascertained. The QAWB that was consulted for this project could not physically attend. Hence, this study attempted to simulate what a conventional WHA would entail. However, without the on-site expertise of a QAWB to confirm the observations, the WSAOS stood to lose some of its potency based on the inexperience of the researchers. Likewise, the research location, though ideal from the perspective of distance from the neighboring airport and the intent to safely operate near low-flying aircraft, had a limited diversity of animal species. This could be in part due to the heavily trafficked two-lane highway that lined the outer limits of the operational area. Relatedly, the relative size of the animal is also a factor. There were instances where a thermal signature was detected; however, due to its size and the inability of the XT-2 thermal camera to zoom in from its lowest prescribed altitude, the object could not be discerned. The only means to get closer to obtain a better view is to lower the drone, which can have an adverse effect.

Moving the drone closer to the animals posed another concern for detection and/or potential disturbance to the wildlife. The cows did not appear to show any agitation or signs of unease, regardless of the drone's proximity to them. That said, there was an occasion where two coyotes were observed. As the drone operator moved in closer to get a clearer thermal resolution, the coyotes would periodically stop, curious about the signature sound of the drone's humming propellers (some have equated to the sound of a beehive), and would attempt to flee. Thus, the presence of drones may not always prove to be discreet enough for all animal observations.

Though drones have much potential to be an asset to WHAs, they have limitations. Weather is a contributing factor to the success of a drone operation. There were several lightning storms and late afternoon to evening showers this past summer. The inclement weather meant that the drone could not operate under these conditions, but the ability to set up the operations trailer and equipment was compromised due to the muddy terrain of the study area. Furthermore, drones are not the only consideration but the people who must operate them. There were numerous high heat advisories that threatened to cause heat-related causalities to the research team if the warnings were not observed.

Conclusion

The purpose of this study was to explore the use of UAS technologies at night by developing and refining a concept of operations to support data collection and analysis during a nighttime WHA. Through the capabilities of UAS technologies, the team was able to obtain wildlife data and information in locations that were potentially difficult to access by ground-based means. Moreover, the drone's technologies were able to observe and identify animals that would be very challenging for historical QAWB methodologies due to natural structures (e.g., tall trees, dense vegetation). By way of aerial advantage and onboard camera/video, UAS can provide vital information capture that QAWBs could use for later analyses and accounting. Lastly, UAS technologies will not likely remove the QAWB from the WHA equation; rather, it would serve as another tool to facilitate more timely assessments, remove unnecessary risks to the QAWB over terrestrial limitations, and enhance the clarity to observe large-massed crepuscular animals at night.

Future Studies

The opportunity to use UAS technologies with the real-time supervision of a QAWB during an actual WHA during nightfall would greatly appreciate the validity of this technology. At present, this study was simulated based on the suggestions and guidance of a remotely located QAWB via Zoom. Only through the practical application of an actual WHA can UAS technologies be fully vetted by a QAWB to verify the efficacy of their potential benefit. Every effort should be made to assemble a team to assist a QAWB during a WHA or to host a QAWB to test the merits of UAS technologies for nighttime WHA. Lastly, future studies should collect data in a year timeframe to investigate the impact of the seasons of the year on the presence and behavior of terrestrial mammals in the data collection area.

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