Integrating Unmanned Aerial Systems for Enhanced Wildlife Hazard Assessments within Airport Environments.

2023-2024 ACRP Design Competition

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Design Challenge: Airport Safety, Operations, and Maintenance Challenges. Innovative Approaches to address wildlife issues at the airports, including bird strikes.

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Executive Summary

The executive summary addresses the design challenge dedicated to **Airport Safety, Operations, and Maintenance Challenges, Part C,** through the integration of Unmanned Aircraft Systems (UAS) technologies into the safety management of wildlife hazards to aviation.

Wildlife strikes pose significant risks to aviation safety, particularly in airport environments, necessitating proactive measures to mitigate these hazards. Traditional methods of wildlife hazard assessments are limited by logistical constraints and visibility challenges, highlighting the need for innovative solutions to enhance their effectiveness and efficiency. Through a comprehensive process involving the development of the concept of UAS operations, exploratory field campaigns, collaboration with industry experts, and completion of financial analysis, our team has identified key advantages of leveraging novel technologies in overcoming various limitations associated with current wildlife hazard management processes, especially during a wildlife hazard assessment. UAS offers unparalleled aerial perspectives, expanding observation capabilities, and providing access to remote or challenging terrains. The safe application of UAS technologies during a wildlife hazard assessments represents a transformative solution to enhance airport safety, operations, and management, ensuring safe airport operations for all stakeholders in the aviation industry.

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Problem Statement and Background

The aviation industry faces a persistent challenge in ensuring the safety of flight operations, particularly concerning the risk of wildlife strikes at and around the airport environment. Landmark events such as the emergency forced landing of US Airways Flight 1549 Airbus 320 into the Hudson River on January 15th, 2009, demonstrated to the world the severity of aircraft collisions with birds and other wildlife species. According to the Federal Aviation Administration (FAA, 2023), there were 272,016 wildlife strikes to aircraft in the U.S from 1990-2022. Eighty-one of those strikes resulted in a destroyed aircraft. In 2022, it was estimated that wildlife strikes cost the U.S. civil aviation industry approximately 67,848 hours of aircraft downtime and incurred $385 million in direct and other monetary losses annually." (FAA, 2023a).

Identifying hazards is a crucial aspect of ensuring aviation safety. When certain wildlife strikes incidents occur near an airport, the FAA requires Title 14 of the Code of Federal Regulations (CFR) Part 139 airport operators to carry out a Wildlife Hazard Assessment (WHA). This assessment, conducted by a Qualified Airport Wildlife Biologist (QAWB), involves various aspects such as identifying observed wildlife species, their populations, local movements, and patterns of occurrence throughout the day and year. Additionally, it entails pinpointing features surrounding the airport that might attract wildlife (FAA, 2018). Conventional data collection methods employed during a WHA, which rely on numerous assumptions (e.g., wildlife remains stationary before detection), often fall short in providing crucial information (e.g., wildlife activity during nighttime, solitary animal behaviors, and or bird activity at higher altitudes). It is important to note that there are health and safety hazards associated with interacting with wildlife in their natural habitats. Nonetheless, the WHA serves as the cornerstone for crafting a Wildlife Hazard Management Plan (WHMP). Airport operators' effective implementation of WHMPs has significantly reduced the risk of aircraft accidents due to wildlife strikes. However, scientific analyses of wildlife-strike data underscore the importance of adopting diverse strategies to mitigate such risks (Dolbeer et al., 2023). These strategies should encompass thorough research initiatives, the adoption of novel technologies or innovative enhancements to current ones, and proactive outreach and educational endeavors.

The utilization of Unmanned Aircraft Systems (UAS) is becoming increasingly widespread across research, commercial, and private sectors. Hamilton (2020a, 2020b, 2020c) and Prather (2019) have indicated that airport operators could apply UAS technologies in a variety of ways to mitigate the risk of wildlife strikes to aircraft. Cabrera et al (2021), for example, "explored the use of UAS technologies to identify wildlife and their habitats, an important component of wildlife hazard management and a critical activity to mitigate the risk of aircraft accidents resulting from wildlife strikes" (p. 3). Notwithstanding, according to Hamilton (2020a), Neubauer et al. (2015), and Prather (2019), certain UAS activities in proximity to airports continue to present a notable risk to the U.S. National Airspace System (NAS). A recent series of close calls involving manned aircraft and UAS near airports has garnered attention from both the FAA (2024a) and the public. Therefore, key aviation stakeholders are collaborating to develop new regulations for airspace use, new and revised UAS airworthiness standards, UAS operator medical certification standards, and safety protocols for UAS operations at and around the airport jurisdiction.

Previous research conducted under the Airport Cooperative Research Program (ACRP) has indicated that essential safety metrics for evaluating the advantages and safety implications of UAS operations within airport environments remain to be investigated (Hamilton, 2020c; Prather, 2019). Notably, the utilization of UAS technologies to aid airport operators in managing wildlife hazards is still in its infancy, and the formulation of a concept of operations (ConOps) represents a crucial initial phase in this endeavor.

Literature Review

Wildlife Strikes to Aircraft

In 2022, the recorded wildlife strikes on civil aircraft amounted to 17,190, marking a 10% surge from the previous year's tally of 15,639 (Dolbeer et al., 2023). Almost 7% of the total strikes caused damage to aircraft. Regarding monetary losses, 5,014 reports provided an estimate of direct aircraft repair costs ($929.1 million, mean = $185,292/incident), and 4,577 reports gave an estimate of other monetary losses ($134.3 million, mean = $29,348/incident) (FAA, 2023a). Interestingly, several wildlife-strike reports indicated major maintenance repairs but did not provide costs and aircraft downtime information. For example, in February 2022 a Boeing 767-300 encountered bird ingestion in Engine #1 and landing gear while climbing out of Metro Oakland International (CA). Two blades in the engine were reported damaged and had to be replaced. Time out of service reported as 24 hours (FAA, 2022).

Cleary and Dolbeer (2005) stated that "the dynamics of land use and habitat play pivotal roles in shaping the wildlife species and populations drawn to airport settings" (p. 43). Public airports typically feature expansive underdeveloped areas that serve as buffers for noise and safety measures. These spaces, however, also become prime spots for hazardous wildlife activities such as roosting, loafing, feeding, and reproduction. The FAA (2020) and researchers like Belant and Ayers (2014), and Cleary and Dolbeer (2005) have pinpointed various land use categories and features both within and around airport premises including water management facilities, wetlands, ponds, and lakes that can potentially attract hazardous wildlife. While some of these features may not pose risks to aviation operations individually, their combined effects can form bird flyways across the airport Area of Operations (AOA). The AOA is defined as “any area of an airport used or intended to be used for landing, takeoff, or surface maneuvering of aircraft” (Belant & Ayres, 2014). Identifying these attractants and subject them to evaluation by a QAWB to determine their impact on aviation safety is imperative. While numerous wildlife species can threaten airport operations, not all are equally hazardous, as highlighted by the FAA (2018). Airport operators should prioritize safety efforts for these hazardous wildlife species. Nonetheless, attention must also be directed towards species of significant mass (e.g., deer), those with habitat preferences aligning with airport AOAs, and birds exhibiting flocking behavior.

The current methods of wildlife hazard management in the context of airport safety involve a comprehensive process outlined in national policies and regulations such as the FAA Advisory Circular 150/5200-38 (FAA, 2018). This process begins with a WHA conducted by a QAWB. The assessment identifies and analyzes local and transient wildlife populations, natural habitats and man-made activities with the potential to attract hazardous wildlife to the airport AOA, as well as airport operations and wildlife-strike data to establish a scientific basis for the development, implementation, and or refinement of an existing WHMP. The WHMP must provide measures to alleviate or eliminate wildlife hazards to aviation operations and can become a part of the Airport Certification Manual (ACM) with the authorization of the FAA. While the WHA provides a risk analysis of wildlife hazards and suggestions for mitigation, the plan outlines the agreed-upon comprehensive efforts the airport will take to address these hazards. The QAWB, who conducts the assessment, will prepare most parts of the WHMP, but certain aspects require involvement from the airport, such as assigning responsibilities to personnel, committing funds, and purchasing equipment and supplies.

The FAA National Wildlife Strike Database (FAA, 2023a) provides valuable information, including a composite ranking of wildlife species based on criteria such as damage, major damage, and effect on flight. This ranking helps focus hazardous wildlife management efforts on species or groups that pose the greatest threats to safe air operations. It is emphasized that care should be taken to consider various factors such as mass, flocking or flight behavior, and habitat preferences when managing hazardous species. Combining hazard rankings with site-specific assessments allows airport operators to understand better the general threat level and consequences of certain wildlife species, facilitating the creation of a "zero-tolerance" list for immediate attention and mitigation. (FAA, 2018).

Gathering data during a WHA typically demands considerable time and labor. Currently, QAWBs rely on visual detection and recording of birds and other hazardous wildlife species within a limited quarter-mile radius for 3-5 minutes, facing challenges such as human tolerance to weather conditions, vision limitations, and fitness issues, which can compromise the efficacy of data collection (FAA, 2016; 2018). The adequate coverage of the sample area relies on several factors, including the airport's size, complexity, and physical features, which in turn determine the necessary number of observation points. The FAA (2018) recommends the QAWB should evaluate observation points in chosen locations within a five-mile radius of the airport's AOA if there are attractants that could potentially lead to dangerous wildlife activity in or around the approach or departure airspace. In addition, the Agency acknowledges that QAWBs should gather supplementary data and employ more rigorous data collection methodologies during a WHA.

Traditional WHA methods, relying on critical assumptions like wildlife staying stationary before detection, often fall short in providing crucial information, such as nocturnal wildlife activity, animals not congregating in groups, and or bird activity at higher altitudes (DeVault et al., 2013). Furthermore, there are inherent health and safety risks associated with on-site wildlife handling, such as trapping and marking mammals. Therefore, a multifaceted approach for mitigating the risk of aircraft accidents due to wildlife strikes is vital, and it should include research and innovation. Previous Airport Cooperative Research Program (ACRP) reports have suggested that UAS technologies could be applied to optimize the safety management of wildlife hazards at the airport environment (Hamilton, 2020a, 2020b, 2020c; Prather, 2019).

Unmanned Aircraft Systems

The civil UAS industry in the United States is undergoing rapid expansion. Presently, an increasing number of entrepreneurs are discovering novel and innovative applications for advancing UAS technologies. A number of ACRP reports have been published to aid airports of varying types and sizes, as well as their stakeholders, in comprehending UAS and their potential utilization, benefits, challenges, and influence on airport operations (Hamilton, 2020a, 2020b, 2020c). However, there is still a gap in airport operators' understanding of the full spectrum of benefits offered by UAS technology, including potential cost savings and operational enhancements. The operators may be uncertain about the safe practices associated with UAS applications on airport premises. In fact, the utilization of UAS technologies in and around airports is still at an early stage. Unfortunately, a recent uptick in close encounters between UAS and manned aircraft near airports, particularly in controlled airspace, underscores the potential safety risks posed by certain UAS operations to the NAS (FAA, 2024a; Wallace et al., 2022). These disruptions have forced inbound flights, for example, to divert to alternative locations, causing substantial delays in outbound flights.

The escalation in reports of UAS sightings from pilots, citizens, and law enforcement close to airports has notably risen over the past few years (FAA, 2023b). One notable instance occurred in 2018 when a security officer, finishing his shift, observed two drones at the Gatwick airport, in London. One drone was hovering above a vehicle within the airport complex, while the other was flying alongside the nearby perimeter fence. Recognizing the potential danger posed by unauthorized drone activity, the security officer promptly relayed the information to senior management. In response, Gatwick's only runway was swiftly closed, leading to a suspension of all flights for two days (Shackle, 2020). Furthermore, in July 2022, a drone was spotted at Reagan Washington National Airport, situated near the Pentagon and White House, leading to a 13-minute halt in flights and a 45-minute disruption in regular operations. Ninety flights faced delays, and seven were canceled due to this event. Merely a month later, a drone narrowly missed colliding with the windshield of a Delta flight landing at Orlando International Airport in Florida, coming within eight feet (McNabbon, 2023). These safety events underscore the pressing concern surrounding the risk of collision posed by unauthorized UAS activities at and around airports, prompting swift and significant measures to safeguard the safety of both aircraft and passengers.

A significant safety concern when operating UAS in an airport environment is the potential disruption to aviation operations, particularly during critical phases of flight such as takeoff, initial climb-out, approach, and landing. The Low Altitude Authorization and Notification Capability (LAANC) is a joint effort between the FAA and industry stakeholders. Its primary purpose is to facilitate the seamless integration of UAS into the NAS. According to the FAA (2024b), LAANC provides:

1. Drone pilots with access to controlled airspace at or below 400 feet;
2. Awareness of where pilots can and cannot fly; and
3. Air traffic management professionals with visibility into where and when drones will operate (para. 3).

The FAA (2015) is committed to ensuring the safety and efficiency of the global air transportation system. As they work to integrate UAS into the NAS, Neubauer et al. (2015) highlight the extensive effort required to establish airworthiness standards, regulate airspace use, and to define operational protocols for UAS in and around airports. This process demands significant time, deliberation, research, and testing before UAS can seamlessly integrate with other airspace users and airport operations. Authors deemed it necessary that airports looking for research and safe UAS activities should engage with area universities, implementing research with UAS (Neubauer et al., 2015). Consequently, comprehensive research and testing are essential prerequisites before allowing full integration of UAS with other airspace users and airport activities. Foremost, the effective use of UAS during a WHA (on and around airport premises) is still in its nascent phase, underscoring the importance of developing a concept of operations (ConOps) as a crucial step in this endeavor. The goal of this project is to develop a a Concept of Operations for applying UAS technologies during a WHA.

To achieve this goal, our interim objectives consist of:

1. Evaluating the advantages of employing UAS technologies in WHA compared to traditional data collection methods;

2. Establishing workflows and delving into best practices for integrating UAS technology in WHA procedures;

2. Implementing safety risk management (SRM) principles and protocols to mitigate risks associated with UAS operations within and around the airport environment; and

4. Identifying the projected operational expenses associated with UAS application for data collection during a WHA.

Team's Problem-Solving Approach to the Design Challenge

This project incorporates an interdisciplinary problem-solving approach, utilizing a combination of exploratory research and case study design methodologies. Our project aims to revolutionize WHA data collection processes within airport environments through the integration of innovative solutions by applying UAS technologies. To ensure the successful realization of this project, our team has developed a comprehensive system engineering approach that encompasses principles and concepts across data collection during a WHA, UAS operations, and scientific, technological, and management methods. This approach is designed to assess the feasibility and effectiveness of our innovative solution in the field of wildlife hazard management.

The initial phase of our system engineering approach involved an extensive literature review to gather insights into existing wildlife hazard management protocols and UAS operation methodologies. This review thoroughly examined relevant academic publications and industry reports, explored established systems and processes so our team could have an in-depth understanding of the regulatory framework governing UAS operations (FAA 2018; FAA, 2020a; FAA, 2023a; FAA, 2023d). By thoroughly investigating the FAA Serial Report Nº 29 (FAA, 2023a) and other FAA resources (FAA, 2024c, 2024d), we have gained valuable insights into historical wildlife strike incidents and guidance materials, contributing to our understanding of the challenges and gaps in existing wildlife management practices. Simultaneously, our team conducted a review of previous ACRP reports focusing on the safety management of wildlife hazards and on UAS operations at the airport environment (Allerton et al., 2015; DeFusco et al., 2015; DeFusco & Unangst, 2013; Hamilton et al. 2020a, 2020b, 2020c; Neubauer et al., 2015; Prather, 2019, Mead & Hunt, 2023; Rillstone & Dineen, 2013).

It is essential to emphasize that our project is an evolution of prior research endeavors (Cabrera et.al, 2021; Mendonca et al., 2021, 2022), by acknowledging and leveraging the findings of earlier studies, we ensure a seamless transition and progression in the pursuit of innovative solutions for wildlife management and UAS integration. Nonetheless, there are several differences between this research and Cabrera et al.'s (2021) and Mendonca et al. (2021, 2022) studies. For instance, our team collected data in the Class C airspace of Daytona Beach International Airport (KDAB) applying additional SRM protocols. This aspect will be further elucidated in a subsequent section of this report.

It is important to mention that, as part of our efforts to enhance our understanding of existing wildlife data collection methods, our team conducted interviews with industry professionals and QAWBs. These interviews yielded valuable insights into the current practices and challenges encountered by QAWBs in collecting wildlife data during WHAs, as well as the obstacles and potential benefits associated with implementing UAS technologies in and around airports. The insights gathered from these interviews not only deepened our comprehension of real-world scenarios but also played a crucial role in refining our system engineering approach.

The overarching purpose of our project is to develop a Concept of Operations (ConOps) that enhances data collection during WHA employing UAS technologies. In addition, prior to conducting UAS operations for data collection purposes, our team executed a hazard risk assessment and developed risk mitigation strategies applied to each flight. The assessment identified potential risks and hazards associated with UAS operations in the context of a WHA. By addressing these risks proactively, our system engineering approach prioritizes safety and seeks to mitigate potential challenges in the deployment of UAS for data collection during a WHA.

As part of our thorough feasibility assessment, our team conducted a cost-benefit analysis. This analysis delves into the financial implications of deploying our innovative solution for wildlife data collection during a WHA. By examining the costs incurred by U.S. airline operators and airport management due to wildlife strikes (Dolbeer et al., 2023), alongside the benefits associated with our proposed system, we aim to gain a comprehensive understanding of the economic feasibility of our approach. This data-driven analysis serves to inform decision-making processes and bolster the overall feasibility assessment.

Regular virtual meetings (Zoom) with a QAWB were integral to the interdisciplinary collaboration, providing essential technical expertise and guidance, especially in the organization of data for a WHA. For further details on the training and experience of a QAWB involved in implementing FAA-approved WHMPs at certificated airports, refer to FAA guidelines (2019). This interdisciplinary approach enhanced the project's problem-solving capabilities by bringing together diverse perspectives and expertise for a comprehensive and effective solution in wildlife data collection and UAS operations. This seamless integration of existing knowledge, insights from literature reviews, challenges identified in previous research, and the development of an innovative ConOps, initially designed by Cabrera et al. (2021) sets the stage for the next section of our interdisciplinary problem-solving approach.

Concept of Operations

The concept of operations (ConOps) in aviation, particularly concerning drone operations, outlines a detailed plan describing how a system or technology will be used in practice In the context of operating drones, ConOps delineates the specific methodologies for conducting flights, including flight patterns, airspace management, communication protocols, and safety measures. Additionally, it encompasses various aspects such as mission objectives, procedures, roles and responsibilities, operational constraints, flight patterns, airspace segregation, and contingency plans. ConOps, as defined by Hamilton et al. (2020a), is "a description of the nature of UAS operations and the resulting impacts on relevant stakeholders and the environment" (p. 3). It serves as a foundational document guiding operators, regulators, and stakeholders on how drone operations will be executed safely, efficiently, and in compliance with regulations and guidance materials (Maddalon et al. 2013; Valavanis & Vachtsevanos, 2015).

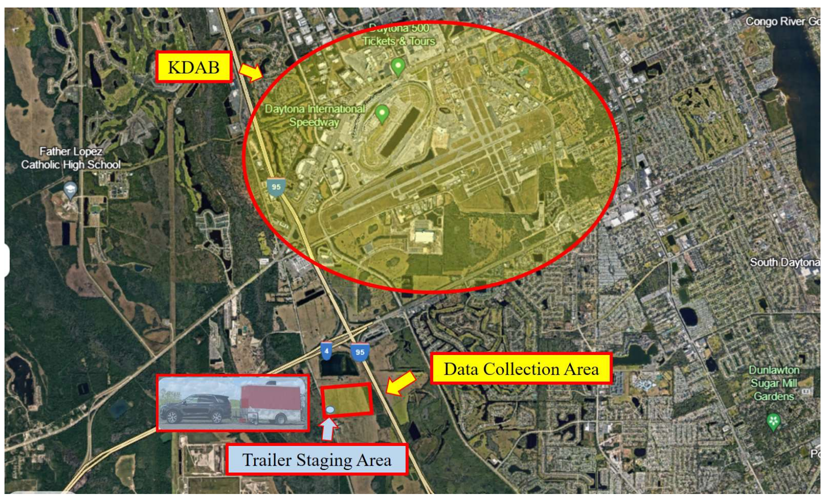
The development and ongoing refinement of the ConOps is a critical step in seamlessly integrating UAS technologies into the NAS, particularly within airport environments. To ensure the effectiveness and efficiency of our ConOps, our team leveraged key resources such as the FAA guidelines (2020a), ACRP reports by Hamilton et al. (2020a, 2020b) and by Prather (2019), and insights from Maddalon et al. (2013). Furthermore, to bolster our technical capabilities and ensure comprehensive support throughout the project, our team has established a partnership with Christopher B. Burke Engineering – Ltd. This collaboration has allowed us to benefit from the expertise of a QAWB who has provided technical guidance and support regarding a WHA. The QAWB has engaged with our team on a regular basis, primarily through virtual meetings conducted via Zoom. These interactions have enabled us to tap into their specialized knowledge and receive guidance on effectively addressing wildlife hazards within the airport environment, ensuring the safety and efficiency of UAS operations during a WHA. This collaborative approach, integrating both FAA guidelines and expert consultation, underscores our commitment to developing a robust and comprehensive ConOps for the seamless integration of UAS into the NAS, particularly within airport settings.

Data Collection Area

An exploratory field campaign has been conducted to streamlines the ConOps for a WHA utilizing UAS technologies (Cabrera et al., 2021). Data collection was conducted within a farmland area located approximately two nautical miles south (S29º 08’ 47’’ N81º 04’ 37’’) of Daytona Beach International Airport (KDAB) (see Figure 1), Florida's third busiest commercial airport, which has seen an average of 822 aircraft operations daily. Specifically, data were gathered within the KDAB Class C airspace (FAA, 2016).

Figure 1

Data Collection Area – Class C Airspace of KDAB



Note 1. Test flights have been carried out over a sample area covering approximately 340,000 square meters.
Note 2. Image obtained through Google Earth.

There were 1,510,650 aircraft movements at KDAB from January 2014 to December 2023. Approximately 2% (n=30,349) of these aircraft movements involved air carriers (FAA, 2024e). KDAB has experienced a very high volume of aircraft operations, characterized by a mix of air taxi pilots and pre-solo student pilots operating at this field (FAA, 2024e). Aircraft operations in the airport environment (e.g., traffic pattern) especially due to flight training is intense throughout the day. During this period, 432 wildlife strikes involving aircraft in or around KDAB have been documented, with approximately 5% (n=22) of these strikes resulting in aircraft damage (FAA, 2024e). Notably, 36% (n=155) of all strikes and 73% (n=16) of damaging strikes, where altitude data was available occurred within or near the airport environment (at altitudes ≤ 1,500 feet AGL) (Dolbeer et al., 2023).

The selected farmland area is surrounded by large trees, fields, and other farmlands, known habitats for various wildlife species including New World Vultures, Cattle Egrets, Great Egrets, Wild Turkeys, Sandhill Cranes, as well as roaming cattle and boars. It is important to reiterate that aircraft operations near this location have been intense, particularly associated with flight training activities, which has significantly added to the project's complexity.

Data Collection

Data were gathered on July 26th, August 21st, and October 6th, 2023. Several flights were undertaken at different times of the day and on different days of the week to capture the daily, seasonal, and other factors affecting wildlife presence in the surveyed region. The UAS was flown in two different ways: automatically in a basic grid pattern and manually. These flights have resulted in multiple overlapping images, providing researchers (and the QAWB) with enhanced insights into hazardous wildlife species, potential attractants (e.g., natural habitats), and their interactions, as suggested by Cleary and Dolbeer (2005) and by the FAA (2018). This approach has enabled researchers to visualize specific areas from various perspectives.

In the current study, researchers utilized a Parrot Anafi AI, equipped with a 6x zoom (48 MP camera), and DJI Matrice 210 (20 MP camera) drones to collect data. These highly versatile drones come with various safety and efficiency features, making them suitable for short and detailed missions. The endurance of these drones is approximately 27- 32 minutes. Nonetheless, batteries could be easily and quickly replaced in the field, enhancing the data collection process. Flights were executed utilizing the “FreeFlight 7 Software” via the smart controller, assisting researchers in creating flight plans and storing telemetry data from each mission. The software allowed the drone operator to oversee the UAS' flight on the ground control station's monitor, providing real-time updates such as altitude, velocity, ground position system (GPS) coordinates, estimated post-mission arrival time, and battery status.

Notably, the smart controller boasted a touch screen that exhibited the camera's live feed, enabling modifications to camera settings and flight parameters. To ensure uninterrupted visibility, the controller was linked via a High-Definition Multimedia Interface cable to a TV set housed within a trailer, safeguarding it from external elements. The Pilot-in-Command (PIC) operated the aircraft outside the trailer. Another team member inside the trailer monitored a TV set, recording observations such as wildlife activities and potential hazardous wildlife attractants on the Wildlife Survey – Airport Observation Sheet (WSAOS) (see Cabrera et al. [2021] for more information about the WSAOS). Concurrently, another team member, acting in the capacity of a QAWB, stood alongside the PIC and visually identified and documented the presence of birds and other wildlife species, as well as interactions between animals and identified habitats (FAA, 2018). Binoculars were utilized, if necessary, to complete another set of WSAOS. After each day of data collection, members of our team conducted a post-analysis of the images collected with the drone and updated, if necessary, the WSAOS completed by the person inside the trailer. Considering we flew the UAS "*N*" times each day of data collection, by the end of the day our team had "*N*" WSAOS completed by the person inside the trailer (based on drone observations - data) and "*N*" WSAOS completed by the person acting as a QAWB during a WHA. At last, a member of our team transcribed the quantitative and qualitative data and information from the WSAOS(s) into an Excel file for analysis. A mixed-method approach has been utilized during the analysis of the collected data. Quantitative and qualitative analyses have helped identify:

1. The workflows and best practices for applying UAS technologies during a WHA;

2. Whether the UAS is more effective (e.g., observing and identifying more animals as well as their behaviors; observing wildlife-habitat interactions) than the traditional WHA method (FAA, 2018);

3. Whether the UAS is more effective in identifying the land uses and habitats at the data collection area that are attracting hazardous wildlife to the airport environment than the traditional WHA method (FAA, 2018); and

4. The estimated operational costs of using drones to collect data during a WHA.

A crucial element of a ConOps is SRM (Hamilton et al., 2020a). Airport operators and other aviation stakeholders must grasp the inherent risk and presence of hazardous conditions in all aviation endeavors. The objectives of SRM encompass identifying and managing hazards, with the aim of averting adverse consequences or outcomes. Phrasing differently, the aims of SRM include identifying and addressing hazards, as well as preventing adverse consequences or outcomes (DeFusco et al., 2015).

Safety Risk Assessment and Mitigation

A safety management system (SMS) is “a tool to translate an organization’s concerns about safety into effective actions to mitigate hazards” (Ayres Jr. et al., 2009, p. 8). An SMS empowers an airport with the capability to anticipate and resolve safety issues before they escalate into incidents or accidents. An important pillar of an SMS is SRM. SRM involves a methodical, clear, and inclusive approach to handling safety risks across all levels and throughout the entirety of an operation and system lifecycle. It entails disciplined evaluation and management of safety risk. The safety risk management procedures ensure the identification and tracking of hazards until resolution, documentation of safety-related changes, assessment and analysis of risk, mitigation of unacceptable risk, evaluation of the effectiveness of risk mitigation strategies, and monitoring of changes/improvements to mitigate risk throughout their lifecycle (FAA, 2023c). As previously noted, UAS operations close to airports can present a significant risk to manned aircraft operations (FAA, 2024b).

An important step to operate UAS in controlled airspace is LAANC approval by the FAA (Wallace et al., 2020). We have obtained FAA LAANC approval before each data collection process. This LAANC approval process allowed our team to operate UAS legally and safely in areas where air traffic control is actively managing the airspace. Additionally, our team conducted disciplined site surveys before each flight (Adkins et al., 2020). This procedure assisted in the identification, of hazards and mitigation of the associated risks in the flight operations area. Care was exercised during the creation of each flight plan and the overarching data collection processes. While some challenges have been anticipated, our team acknowledges that some hazards and challenges may not have been foreseen. For the proactive identification of hazards and the mitigation of the associated risks, our team employed a Flight Risk Assessment Tool (FRAT) before each flight operation (Cabrera et al., 2021). Utilization of the FRAT was anticipated to facilitate proactive hazard identification and risk assessment, aiding pilots in making informed go/no-go decisions prior to each flight (FAA, 2016). During preflight briefings, our team openly deliberated on operational risks and collectively devised mitigation strategies, as emphasized by Adkins et al. (2020).

Researchers made use of a compact trailer outfitted with various equipment, such as an Automatic Dependent Surveillance – Broadcast (ADS-B) flight box (Cabrera et al, 2021), two television (TV) sets, and walkie-talkies to ensure the safe and efficient execution of UAS operations (Figure 2). The primary concern when operating UAS in an airport environment is the potential interference with manned aircraft operations (Wallace et al., 2019). To address the risks associated with manned aircraft operations during data collection, our team opted for an ADS-B flight box transmitting a Wi-Fi network accessible by cell phone or tablet. Once connected, researchers employed ForeFlight to monitor air traffic and identify manned aircraft in the data collection area (ForeFlight, 2023). By connecting a cell phone or tablet to a high-definition multimedia interface (HDMI) cable, the screen could then be mirrored onto a TV installed inside the trailer. This setup enabled our team to select any aircraft displayed on the live traffic feed and determine its altitude, speed, heading, and distance from the ADS-B flight box.

Figure 2

Trailer and Equipment Used during Data Collection

In summary, the implementation of this safety protocol ensured that our team could safely operate the drone amidst the presence of manned aircraft, mitigating potential risks effectively. At least one team member remained stationed inside the trailer throughout the data collection process, monitoring the live traffic feed and maintaining communication with the drone's pilot and visual observer via walkie-talkies. The objective was to heighten the team's situational awareness (Airbus, 2007), enabling the identification of threats, and thereby enhancing our team's aeronautical decision-making processes (FAA, 2016).

Furthermore, acknowledging the potential for conflicts between manned aircraft operations and UAS during the data collection process, our team also adopted other SRM procedures to mitigate this specific risk. These procedures included:

1. Implementation of geofencing (Wallace et al., 2018);
2. Utilization of a visual observer (Hamilton, 2020a); and
3. Ensuring UAS flights were conducted below 400 feet (AGL) (Cabrera et al., 2021).

In addition, our team determined that the presence of any observed flight activity within the data collection area, particularly at or below 1,000 feet AGL would be considered a determining factor for deciding whether UAS should not be flown. If a flight had already commenced under such circumstances, it was recommended that the flight be terminated immediately. It is worth mentioning that the visual observer was tasked with maintaining continuous visual contact with the drone and ensuring that it remains within line of sight at all times. The responsibility of the visual observer included actively scanning for the potential presence of manned aircraft during the data collection process. Crew resource management (CRM) principles, such as teamwork and threat-and-error-management (FAA, 2004) were ingrained throughout our project ethos. By embracing CRM, we aimed to enhance our aeronautical decision-making and bolster our team's situational awareness, ultimately prioritizing aviation safety and efficiency (FAA, 2024f). To ensure the competency of our pilots, we provided comprehensive training and ensured appropriate certification for drone operations. Throughout data collection, experienced drone pilots supervised the flights, mitigating risks such as loss of UAS control or signal interruption.

Another major risk during UAS operations has been the potential loss of UAS control, stemming from a lost link between the operator and the UAS. To address this scenario, the flight crew programmed the UAS to hover in place, allowing the operator time to reestablish the link. If re-establishment proved unsuccessful, the UAS would then autonomously return to a pre-established recovery area. As part of our risk mitigation strategy, our team conducted disciplined site surveys to identify multiple alternative recovery areas in case of an emergency at any phase of the UAS flight. Furthermore, we devised and assessed "lost link" scenarios in which the drone pilots were notified of a connection loss. Pilots experiencing the lost link were expected to promptly adhere to established procedures, including swiftly communicating with and notifying Air Traffic Control, and initiating the return-to-home procedure.

Figure 3

Initial Briefing and Post-Operations De-Briefing

Note 1. Initial briefing to include FRAT completion by the members of our team.
Note 2. Post-flight discussions on SRM.

Regular team meetings served as forums to discuss identified hazards, assess the effectiveness of risk mitigation strategies, and explore alternative approaches (Figure 3). These discussions not only heightened the situational awareness of our UAS pilots but also fostered a shared understanding of potential risks, enhancing overall flight safety. While we recognize that not all hazards can be completely identified or mitigated, we incorporated safety and performance buffers into our ConOps to uphold safety standards (Hamilton et al., 2020a). It is important to note that the ConOps will be subject to ongoing revision as necessary to address hazards and related risks identified during a WHA (Hamilton et al., 2020a).

Interaction with Airport Operators and Industry Experts

To bolster our research, the team engaged in interviews with three industry professionals well-versed in wildlife strike management within airport environments and or UAS operations.

Interview with Mr. David Castaneda

Mr. David Castaneda, Airport Certified Employee (ACE), Airport Wildlife Program Supervisor at Charlotte Douglas International Airport (KCLT), presented a positive stance on the integration of UAS in wildlife management. In an interview conducted on December 07th, 2023 at 1:00 pm (ET) with Mr. Castaneda, he acknowledged the effectiveness of current wildlife management practices at the airport, highlighting positive outcomes and reduced wildlife strikes. However, Mr. Castaneda indicated there is room for improvement, and envisioned advancements in technology, particularly UAS during a WHA. Mr. Castaneda expressed hope for future technological developments that can simplify the integration of advanced tools into their wildlife management practices. He envisions a more streamlined process where hiring or contracting someone with expertise in UAS technology could assist in surveying specific areas. While recognizing the potential of UAS for surveying areas with dense vegetation, Mr. Castaneda highlighted significant challenges related to the current WHA framework. Accessibility appears to be a significant concern, especially when trying to reach areas with water features or other wildlife attractants. This issue is compounded in undeveloped airports where access might be even more limited compared to developed ones. Another major challenge is visibility, as the dense brush and scrub can obstruct the biologist's view, making it difficult to identify and observe wildlife or plant species during a WHA. Mr. Castaneda also pointed out the lack of technology capable of seeing through dense vegetation, which further limits the biologist's ability to detect certain species and or environmental features. This limitation could result in incomplete surveys and assessments. Additionally, the risk of disturbing wildlife due to limited visibility is highlighted, suggesting that the biologist must be cautious to minimize disturbances during their studies.

Resource limitations, such as manpower, equipment, or funding, might also pose challenges in addressing these issues effectively. Lastly, safety concerns arise when accessing remote or densely vegetated areas, which could expose the biologist to hazards like hazardous wildlife, uneven terrain, or adverse weather conditions. Furthermore, it was pointed out that flying drones over the airport is complicated due to airspace restrictions and the necessity to coordinate with Air Traffic Control (ATC), a component he does not have the capacity to learn given his role's demands. Another major challenge is the limited personnel and manpower available for managing extensive airport lands and properties, with only Mr. Castaneda and one other airport wildlife supervisor handling these responsibilities. While there is a team of 40 operations officers, they primarily focus on incident response rather than the day-to-day and intensive wildlife hazard management tasks. This staffing constraint hinders their ability to effectively integrate drone technology into their operations. Mr. Castaneda expressed a hope for future advancements that could make drone technology more accessible and turnkey, allowing for hiring or contracting specialized UAS operators. He also emphasized the need for a regulatory framework defining parameters for UAS operations at airports, which could guide hiring decisions or training initiatives for staff in this emerging field.

Interview with Mrs. Cathy Boyles

Our team conducted an interview on December 08th, 2023 at 11:00 am (E.T.) with Mrs. Cathy Boyles - QAWB, Wildlife Program Manager, and Operations Department at Dallas Fort Worth International Airport (KDFW). Mrs. Boyles emphasized a dual approach to wildlife hazard management: proactive (strategic) and reactive (tactical). Proactive efforts involve habitat management, preventing access to the airfield, installing deterrent devices, and collaborating with contractors and designers to avoid wildlife attraction to the airport AOA. Mrs. Boyles also highlighted that targeted educational programs for employees and tenants also play a crucial role in preventing wildlife attraction.

Tactically or reactively, Mrs. Boyles expressed the airport has staff on the airfield 24/7 to observe, disperse, and harass wildlife using various methods such as propane cannons, pyrotechnics, and shotguns with bangers. When asked about the potential use of UAS for wildlife risk assessments, Mrs. Boyles highlighted the possible challenges, including the need for permits, potential discomfort from the public, and the importance of proper communication and permits for flying over public areas. She acknowledged the potential benefits of UAS applications during a WHA, especially as airport operators and Air Traffic Control (ATC) become more comfortable with their use. However, she noted that the cost-benefit analysis, including licensing, coursework, and training, must be considered.

In terms of communication, Mrs. Boyles stressed the importance of openness and engagement with all interested parties. She encouraged effective communication in the implementation of UAS projects, including open-door meetings and sharing information to address questions and concerns. Ms. Boyles' feedback underscores the importance of transparency and justification, specifically in site selection to help stakeholders, including biologists, better understand and support the project. She emphasized the importance of clear communication regarding the site area chosen for the project. She suggested that it would be beneficial to communicate whether the chosen site has high bird activity or lies along a major migratory path. By providing this information, it ensures that decisions related to the project are well-informed and based on relevant ecological considerations. In conclusion, Mrs. Boyles acknowledged the potential benefits of UAS in wildlife risk mitigation but emphasized the importance of careful planning, communication, and collaboration with all stakeholders to address challenges and ensure successful implementation.

Interview with Mr. Billy Nollen

On March 12th, 2023, at 11:30 am (E.T.), an insightful interview was conducted with Mr. Billy Nolen, a distinguished former American government official with a notable tenure as the acting administrator of the FAA from April 2022 to June 2023. Prior to his appointment as the acting FAA administrator, Mr. Billy Nolen held safety positions with prominent aviation entities such as American Airlines, Airlines for America, Qantas, and WestJet. Following his service at the FAA, Captain Nolen assumed the role of chief safety officer at Archer Aviation in June 2023. Mr. Nolen highlighted those traditional methods, like QAWB using binoculars, are being surpassed by advanced technologies and expressed optimism about the potential of UAS technology in gathering empirical data, both quantitative and qualitative, to improve aviation safety. He noted the varying degrees of wildlife risk across airports and acknowledged the evolving landscape where technology enables safer airport environments. With over 5,000 airports in the US, Captain Nolen stressed the rapid evolution of UAS technology, particularly in the commercial sector, such as delivery services by companies like Amazon and Starbucks.

Responding to a question about airport authorities investing in drone technology due to its low cost, Captain Nolen affirmed the interest, emphasizing the importance of leveraging technological advancements to mitigate risks effectively. He highlighted the role of UAS in providing accurate data on wildlife movements, aiding in informed decision-making for safety protocols. Captain Nolen commended the efforts of organizations like Embry-Riddle Aeronautical University in advancing research in this area, recognizing the potential for universities to differentiate themselves through such initiatives. He underscored the dynamic nature of technology, emphasizing the need for continuous adaptation and innovation in aviation safety practices. In conclusion, Captain Billy Nolen emphasized that technological advancements, particularly in UAS, present a timely opportunity to enhance airport safety through informed risk management strategies. He highlighted the critical role of data-driven approaches in improving safety protocols and recognized the potential for universities to contribute significantly to this evolving field.

Data Analyses

The quantitative and qualitative data and information from the WSAOS(s) were transferred by our researcher into an Excel file for analysis. Qualitative data also included the insights provided by the QAWB as well as from the interviews with airport operators and industry expert. A mixed-method approach was employed during the analysis of the collected data. Both quantitative and qualitative analyses were utilized to identify:

1. The procedural workflows and optimal strategies for integrating UAS technologies into Wildlife Hazard Assessments (WHAs);

2. The comparative effectiveness of UAS technology, including its ability to observe and identify a greater number of animals and their behaviors, as well as to monitor interactions between wildlife and their habitats, as compared to traditional WHA methodologies (FAA, 2018);

3.The comparative efficacy of UAS technology in identifying land uses and habitats within the data collection area that may attract potentially hazardous wildlife to airport environments, in contrast to traditional WHA methodologies (FAA, 2018); and

4. The estimation of operational expenses associated with employing drones for data collection purposes during WHAs.

Most significantly, our team assessed the strengths and weaknesses of the ConOps SRM protocols in identifying hazards and mitigating the risks associated with UAS operations in an airport environment.

Projected Impacts of Design and Findings

Our project design aimed to improve the existing data collection process during a WHA by safely integrating UAS into airport operations, leveraging their potential within airport wildlife management departments. In addition, the ConOps crafted by our team not only seeks to enhance current practices in WHA data collection but also lays the groundwork for future technological progress, guaranteeing the safe integration of this technology into the NAS. Ultimately, our overarching objective is to enhance aviation safety by mitigating wildlife strikes in airport environments.

To demonstrate the feasibility of our project design, we conducted comprehensive qualitative and quantitative analyses of collected wildlife data, along with a financial analysis. This approach enabled us to gain a deeper understanding of the efficiency of our developed UAS ConOps and assess its commercial potential. As part of the cost-benefit analysis, we formulated a framework to transition the design from concept to product implementation, ensuring a cohesive approach towards realizing our project's objectives.

Cost-Benefit Analysis

This section provides a thorough analysis of the costs and benefits linked to the incorporation of UAS technologies into WHA protocols. This analysis can be summarized in two stages: first, assessing the financial implications linked to wildlife strikes, and second, highlighting the financial benefits of the novel approach supporting enhanced wildlife data collection and hazard management process. The suggested design emphasizes the commercial potential of the developed ConOps and the leverage of UAS technologies in wildlife management.

Cost Assessment

The cost assessment of wildlife strikes underscores a significant economic burden on the U.S. civil aviation industry. As previously noted, there were 272,016 reported wildlife strikes involving civilian aircraft from 1990 to 2022. Of the 34,261 reports indicating adverse effects on aircraft or flights during this period, 13,220 provided estimates for aircraft downtime, totaling 1,207,721 hours with an average of 91.3 hours per incident. Furthermore, 5,014 reports estimated direct aircraft repair costs at $929.1 million, averaging $185,292 per incident. An additional 4,577 reports indicated other monetary losses amounting to $134.3 million, averaging $29,348 per incident (FAA, 2023a). These figures, however, only scratch the surface of the actual financial impact.

Some of the wildlife strikes can result in significant structural aircraft damage and serious injuries. For example, during the final approach, a bi-wing aircraft Schweizer G- 164B collided with a flock of birds, piercing the windscreen and striking the pilot, resulting in temporary blindness. Despite the pilot's attempt to initiate a go-around, the aircraft crashed onto the runway, nosed over, and ended up inverted. The pilot reported a cormorant as the bird that broke through the windshield. The fuselage suffered structural damage. The accident took place on January 2nd, 2009, at a private airstrip near Ferriday, LA. The National Transportation Safety Board conducted an investigation, ultimately concluding that the aircraft was destroyed in the accident (FAA, 2023a).

Another example is the incident that occurred on 12/03/2021, in Trenton Mercer Airport

(NJ). During takeoff, the aircraft DA-900 encountered a group of five geese flying at 2,000 feet AGL. One of the geese collided with the leading edge of the right wing, resulting in significant damage and the formation of a hole. Subsequently, either the same bird or another one impacted the #2 engine, causing blood and feathers to enter the engine. In response to the situation, the pilot declared an emergency and diverted the aircraft to Philadelphia International Airport (PHL), where the crew executed a safe high-speed landing without utilizing flaps or slats. Repair work included replacing the right inboard slat and addressing damage to the right inboard false spar skin panels. The incident resulted in the aircraft being out of service for 168 hours, with repair costs totaling $2,520,000. The bird was identified by the Smithsonian Division of Birds as Canadian goose. (FAA, 2023a).

Interestingly, the United States Air Force (USAF), where mandatory reporting requirements contribute to higher wildlife encounters reporting rates, reveals a different reporting landscape. The USAF annually records approximately 4,000 bird strikes, incurring direct costs exceeding $25 million. Notably, since 1985, the USAF has reported 22 lost aircraft and 33 fatalities, highlighting the concerning threat of the potential human and operational toll of wildlife strikes. (DeFusco et al., 2005).

Responsibility for damage resulting from wildlife strikes extends beyond the destruction of aircraft or harm to individuals aboard. In numerous cases, the aircraft might collide with a heavily trafficked roadway or occupied structures, leading to catastrophic consequences due to the initial impact and, at times, severe fires. Even in situations where there are no injuries or fatalities, the financial accountability for the destruction of buildings or vehicles on the ground can be significant (Dale, 2009; Mendonca et al., 2018). It should be emphasized that while the aircraft direct repair costs resulting from strikes are relatively straightforward, the broader category of "other" costs encompasses elements such as affected companies' reputation, revenue loss, fuel, aircraft inspection, crew lodging, and rescheduling, reflecting the multifaceted nature of the challenges posed by wildlife strikes. It should be underscored that while the direct repair costs for aircraft resulting from strikes are relatively straightforward, the broader category of "other" costs includes factors such as damage to companies' reputation, loss of revenue, fuel expenses, aircraft inspection, crew lodging, and rescheduling. This highlights the multifaceted nature of the challenges posed by wildlife strikes.

Benefit Assessment

With the goal of transitioning the project design to the implementation phase, our team has developed a detailed spreadsheet. This spreadsheet encompasses data pertinent to the acquisition of all necessary items crucial for realizing our ConOps, along with consequential costs. This breakdown of expenses includes UAS certification fees, one-time costs linked to equipment procurement, as well as direct expenses covering labor and operational outlays for a **single day of wildlife data collection**. In addition, understanding the expenses associated with implementing a project is crucial for conducting a comprehensive benefit assessment. For a clearer visualization of these costs, please refer to Table 1. Based on our calculations, factoring in a monthly schedule comprising four data collection sessions, the total monthly cost for enhanced data collection using UAS technology would be approximately $4,984. It is worth noting that the acquisition of the equipment necessary for the UAS operations is a one-time expense. Labor costs may experience a slight increase when involving a non-student employee.

Table 1

The Overall Cost of Data Collection (WHA) Leveraging UAS Technologies.

Service	Rate	Quantity	Total
FAA Part 107 License Exam	$175	5	$875
Direct Expenses One Day of Data Collection			
QAWB Efforts	$139/hour	5	$695
Drone operator (4 operators), student efforts	$12/hour	5	$240
Post Fight Data Processing and Analysis- Student efforts (2 students)	$12/ hour	10	$240
Utilization of Supporting trailer	$25/hour	5	$125
Gas for a Trailer Transportation	$4/gallon	10.2	$50
Flight data preparation professional - student efforts (1 student)	$12/hour	3	$36
		Total:	$1,386
One -Time Expenses: Equipment			
Parrot Anafi AI drone	$4,500	1	$4,500
DJI Matrice 210 drone	$6,999	1	$6,999
Drone Landing Pad	$17	2	$34
TV Screen	$145	2	$290
Baofeng 5W BF- 888s 4PCS Walkie Talkies	$75	1	$75
Tent	$55	2	$110
Camping Chair	$45	6	$270
Camping Table	$20	4	$80
Apexel 10-30×50 Binoculars High Power	$82	3	$246
HDMI cable	$20	3	$60
Stationary (pen/paper)	$70	1	$70
Trailer (Figures 2 & 3)	$11,000	1	$11,000
		Total:	$23,734
		Grand Total:	$25,995

This analysis reveals that integrating UAS into data collection during a WHA offers remarkable financial advantages. Lower-than-expected expenses underscore the cost efficiency of UAS technologies, indicating a transformative shift in managing wildlife-related risks in aviation. The reduced financial risk associated with lower expenses enhances the project's viability and attractiveness to stakeholders. This could lead to greater support and investment, facilitating the project's scalability and broader impact. Lower expenses also open opportunities for scaling the project more easily or expanding its scope. This scalability potential could lead to greater long-term benefits and overall project success.

Cost-Benefit Ratio

By comparing the annual costs of wildlife strikes to the expenses of UAS integration, it becomes evident that investing in UAS technologies offers a favorable cost-benefit ratio. The potential cost savings from mitigating wildlife strikes through enhanced wildlife monitoring and management during a WHA using UAS technologies could outweigh the initial investment in UAS integration by a significant margin. The non-financial benefits, such as improved safety and operational efficiency, further contribute to the positive cost-benefit ratio.

In conclusion, adopting UAS technologies for data collection during a WHA not only offers cost savings compared to the annual costs of wildlife strikes, but also provides numerous additional benefits. This underscores the compelling case for investing in UAS integration as a cost-effective and efficient solution for managing wildlife-related risks in aviation.

Findings

In pursuit of assessing the efficacy of UAS ConOps and associated workflows devised by our team, a comprehensive analysis combining qualitative and quantitative methodologies was undertaken. The qualitative analysis was facilitated through a collaborative engagement between our team and the QAWB. This collaborative effort provided invaluable insights into the precision of wildlife species detection achieved through UAS deployment, as well as facilitated the establishment of correlations between observed wildlife species and their respective habitats. Interviews with industry professionals enriched our qualitative analysis by providing nuanced perspectives on practical challenges and opportunities in UAS operations. These insights also validated qualitative findings, enhancing the robustness and credibility of our analytical framework.

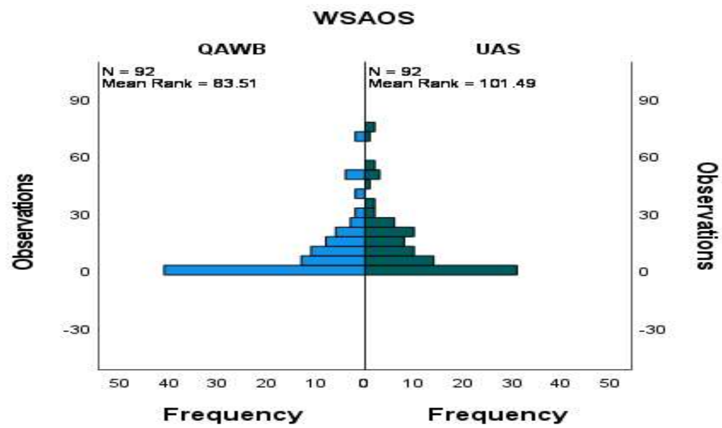
As previously indicated, data collection involving the utilization of UAS technologies in collaboration with QAWB (within a 2-nautical mile radius of KDAB) was meticulously documented in the WSAOS. This dataset encompassed crucial information, including the quantity and classification of observed species, altitude measurements (AGL) during both manual and autonomous flights, designated airport areas surveyed, prevailing weather conditions, as well as timestamps denoting the time and date of each observation). For the purpose of quantitative analysis, our team chose to utilize the quantitative data sourced from WSAOS and conduct a statistical examination.

Quantitative Analysis

A Mann-Whitney U test was run to determine if there were differences in the number of wildlife observations between the persons acting as the QWAB during a WHA and the number of wildlife observations applying UAS technologies. Distributions of the observation scores for the QAWB and the UAS were similar, as assessed by visual inspection. Median wildlife observation score was statistically significantly higher while applying UAS technologies (101.49) during a WHA than in wildlife observations by the "*QAWB*" (83.51) following the traditional WHA protocols, U=3405, z = -2.307, p = 0.21 (Dineen & Blakesley, (1973) (See Figure 4).

Figure 4

Independent Samples – Mann-Whitney U Test



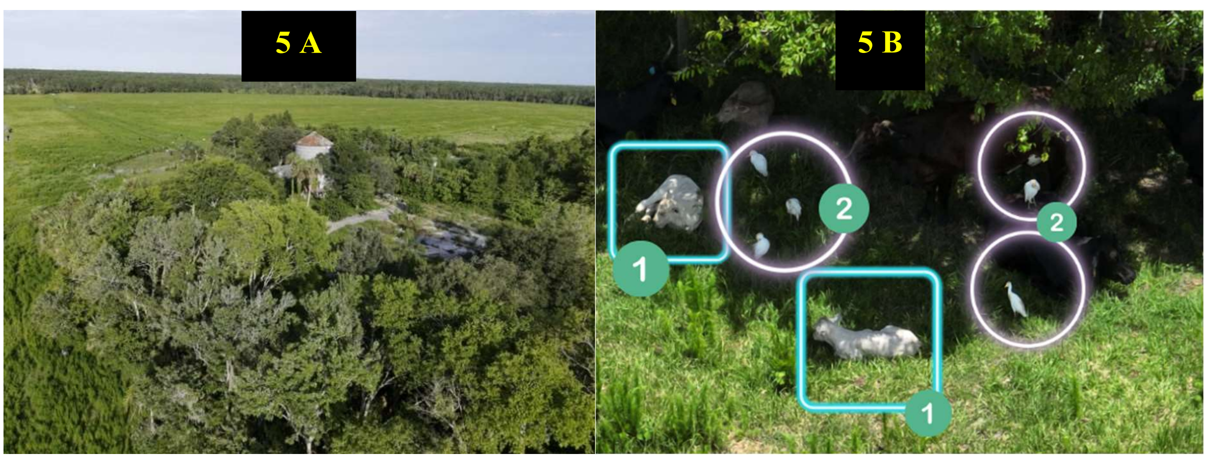
Qualitative Analysis

One of the primary discoveries of our study was the enhanced species identification capabilities offered by UAS technologies. Compared to traditional WHA protocols, UAS demonstrated the ability to identify a greater variety of species simultaneously. This improvement can be attributed to the unique vantage point and maneuverability of drones, enabling operators to access remote or challenging terrains that would otherwise be difficult to access or even inaccessible by a QAWB. This enhancement can be credited to the distinctive vantage point and maneuverability of UAS, allowing operators to reach remote or challenging terrains that would otherwise be difficult or even impossible to access by a QAWB. Our research highlighted the expanded survey coverage facilitated by UAS, particularly in areas such as wetlands, forests, and coastlines. This extended coverage resulted in a more comprehensive understanding of wildlife populations, the relationships between species and habitats and their distribution around critical infrastructures, as suggested by Cleary and Dolbeer (2005) and the FAA (2018). The deployment of UAS technologies during WHAs was found to enhance safety and operational efficiency. By enabling operators to conduct surveys from a safe distance, the risks associated with proximity to potentially hazardous wildlife were mitigated.

Our qualitative analysis also revealed significant advantages of utilizing drones for WHA, particularly in overcoming limitations faced by traditional methods. We observed instances where the grass height hindered the visibility of wildlife for QAWB on the ground, a challenge easily surmounted by drones with their aerial perspective. Comparatively, UAS provided a panoramic view, extending the field of observation to distances of up to half a mile, enhancing the detection capabilities beyond the reach of ground-based observers. For example, a tall area of grass or area overgrowth would inhibit the biologist from conducting WHAs, as seen in Figure 5. These findings are in alignment with the feedback our team received from Mr David Castaneda, Mrs, Cathy Boyles, and Captain Billy Nollen.

Figure 5

Manual Flights Observation in Areas with Large Vegetation within Airport Environments



Note 1: Image captured by UAS over the Data Collection Area (2 nautical miles south of KDAB)
Note 2: Information on different habitats and species could be obtained at the same time:
1. (Squared image) - Cattle.
2. (Circled image) - Cattle egrets.

Conversely – UAS enabled data collection even within areas with dense vegetation. The data was collected with encouraging accuracy. Habitats surrounded by structures make ground-based observations difficult, and human factors like vision limitations and fatigue can hinder the effectiveness of a WHA. Our research suggests that adopting a bird's eye view significantly helps overcome these challenges. Habitats surrounded by structures pose challenges for ground-based observations, while human factors such as vision limitations and fatigue can hinder the effectiveness of a WHA. Our research indicates that adopting a bird's-eye view significantly aids in overcoming these obstacles. These findings underscore the unique capabilities of UAS in expanding observation capabilities, overcoming geographical barriers, and enhancing the effectiveness of WHA.

Discussion

Our analysis encompassed both qualitative and quantitative dimensions to evaluate the effectiveness of UAS compared to the traditional methods (QAWB) during a WHA. Quantitatively, a Mann-Whitney U test indicated a statistically significant difference between wildlife observations applying UAS technologies compared to the traditional methods used by a QAWB (FAA, 2018) during a WHA. This quantitative insight is complemented by qualitative findings which highlight the unique advantages of UAS technology. UAS demonstrated enhanced species identification capabilities, expanded survey coverage, and increased safety and operational efficiency during WHAs. Notably, UAS offered a bird's-eye view, overcoming geographical barriers and challenges faced by ground-based observers, such as obscured visibility due to grass height or surrounding structures. These combined findings highlight the potential of UAS to revolutionize WHAs, offering comprehensive wildlife observation and improved safety measures in critical infrastructural environments.

The safe integration of UAS technologies into wildlife hazard management presents compelling safety and commercial potential, offering innovative solutions to address critical safety challenges in airport environments. To bring this design to a production and implementation state, several key processes must be undertaken. First, comprehensive market research and analysis are essential to identify target markets, assess competitive landscapes, and evaluate regulatory requirements. This step will inform strategic decisions regarding product positioning, pricing, and market entry strategies. Collaboration with regulatory authorities, airport operators, and industry stakeholders is crucial to navigate complex airspace regulations and gain necessary approvals for UAS operations. Investment in research and development is essential to enhance the technological capabilities of UAS, including advancements in imaging systems, autonomy, and safety features. Establishing strategic partnerships with manufacturers, suppliers, and service providers is important to facilitate the scaling and production of drone systems tailored to the needs of WHAs.

Finally, comprehensive training and certification programs for UAS operators and wildlife management professionals are imperative to ensure safe and effective operations. Through strategic planning, collaboration, and innovation, the commercial potential of integrating drones into wildlife hazard assessments can be realized, paving the way for safer and more efficient aviation operations worldwide.

Conclusion

In conclusion, our research endeavor dedicated to harnessing UAS technologies for wildlife hazard management within airport environments has yielded promising outcomes, poised to augment overall aviation safety. Through rigorous investigation, we have delineated procedural workflows and optimal strategies for the safe integration of UAS technologies into WHAs. Our research design shows how UAS technology enhances prevailing WHA methodologies, exemplifying its superior performance in observing and identifying wildlife behaviors, and monitoring interactions between wildlife and their habitats. Furthermore, UAS facilitates access to areas characterized by dense vegetation and wetlands, thereby further mitigating the risks associated with wildlife strikes in aviation. We acknowledge the potential application of UAS technologies alongside existing WHA protocols, as recommended by the FAA (2018). This presents an opportunity to augment the data collection process conducted by the QAWB, and thus aviation safety.

Significantly, UAS technology enhances the safety of QAWBs by facilitating data collection in areas of potential danger, such as habitats inhabited by hazardous wildlife. With these advancements, airports can proactively mitigate wildlife hazards, ensuring safer skies for all stakeholders. Looking ahead, sustained research efforts, collaboration (to include academia), and innovation will be imperative to refine UAS technologies and seamlessly integrate them into existing safety protocols. Through steadfast commitment to enhancing aviation safety, the integration of UAS into WHAs represents a significant advancement toward a safer and more efficient aviation landscape.

Appendix A: Contact Information

Faculty Mentor

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Appendix B: Description of the University

Embry-Riddle Aeronautical University (ERAU) is a renowned institution dedicated to aerospace and aviation education. With campuses in Daytona Beach, Florida, and Prescott, Arizona, as well as Worldwide online learning options, ERAU offers a comprehensive range of programs spanning from undergraduate to doctoral levels. Boasting state-of-the-art facilities and expert faculty with extensive industry experience, ERAU equips students with the knowledge and skills necessary for successful careers in aviation, aerospace engineering, space exploration, and related fields. The university's emphasis on hands-on learning, cutting-edge research, and industry partnerships ensures that graduates are well-prepared to make significant contributions to the rapidly evolving aerospace industry. The mission and purpose of the ERAU College of Aviation is to prepare graduates who will assume leadership roles in the global aviation industry and related fields through academic degrees and other educational programs from professional certifications through to Ph.D. ERAU's undergraduate and graduate aviation programs are consistently ranked among the best in the world by organizations such as U.S. News & World Report, Aviation Week, and The Princeton Review.

Appendix C: List of Airport Operators and Industry Experts

Billy Nolen

Former FAA Administrator

Chief Safety Officer of Archer Aviation

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Catherine Boyles

Wildlife Program Manager

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David Costaneda

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Appendix E. Evaluation of the educational experience provided by the project.

Students

1. Did the Airport Cooperative Research Program (ACRP) University Design Competition for Addressing Airport Needs provide a meaningful learning experience for you? Why or why not?

ACRP Design Competition has presented an invaluable opportunity for enriching learning experiences. Initially, exploring the diverse research topics across various categories on the ACRP website aided our team in identifying a potentially valuable research domain and area of focus. Recognizing that our research fills a specific scientific gap within the airport safety, operations, and maintenance domain and holds potential value for airport operators served as a driving force behind our collaborative endeavors. In addition, ACRP research guidelines provided valuable insights into the scope of work required for implementation. The structured research design recommended by ACRP not only aided our team in organizing the research effectively but also served as a valuable learning experience for future research endeavors or thesis projects.

Furthermore, the research design facilitated the development of academic writing skills, particularly in adhering to APA format requirements for tables, figures, and citations. Engaging with various APA standards enhanced our proficiency in academic writing. The ACRP research project cultivated critical thinking skills through activities such as brainstorming ideas, consolidating diverse information, conducting literature reviews, and analyzing data. These components collectively contributed to our overall growth and competence in research methodology. It is worth noting that during the implementation of this project, our team had the opportunity to attend several conferences (Boeing Center of Aviation and Aerospace Safety Open House Event, National Training Aviation Symposium), which enriched our skills related to presenting information effectively. The questions posed by conference attendees further challenged us to deepen our expertise in the subject matter.

Lastly, our collaborative efforts and the need to find solutions during field operations, interviews with industry professionals, and working with data sets significantly enhanced our problem-solving skills. These experiences underscore the holistic development and multifaceted learning opportunities provided by the ACRP research project.

2. What challenges did you and/or your team encounter in undertaking the competition? How did you overcome them?

Our team encountered various challenges during project implementation, notably navigating the regulatory framework for UAS operations in airport environments. Initially, obtaining approval from certified airports to test our wildlife data collection concept proved challenging. However, these challenges were successfully resolved through the development of flight safety risk assessments and hazard mitigation tools. Locating a suitable QAWB to assist with our research presented another hurdle. Consolidating data acquired during the practical stage of the project and transitioning to the writing phase also posed an interesting challenge, offering valuable learning experiences.

3. Describe the process you or your team used for developing your hypothesis.

Our team employed a comprehensive process for developing our hypothesis. We initiated by conducting thorough literature reviews to gain insights into existing research and methodologies. We also engaged in communication with industry experts to gather valuable perspectives and insights. While studying the regulatory framework governing UAS operations, we compared it with current Wildlife Hazard Assessments (WHAs) methodologies to identify potential areas for improvement.

We formulated our hypothesis based on our analysis of UAS's technical characteristics and the established Concept of Operations (ConOps). We posited that UAS technologies offer significant benefits that contribute to the enhancement of current wildlife data collection, management, and risk prevention strategies within airport environments. This hypothesis was informed by our interdisciplinary approach and synthesized knowledge from various sources, leading us to anticipate the positive impact of UAS integration in wildlife hazard management.

4. Was participation by the industry in the project appropriate, meaningful, and useful? Why or why not?

The engagement of industry stakeholders in the project was found to be appropriate, meaningful, and highly advantageous. Interviews conducted with industry subject matter experts yielded valuable insights into real-world operations and associated constraints, thereby enhancing our comprehension of pertinent issues. Specifically, conversations with Mr. David Castaneda and Mrs. Catherine Boyles, distinguished airport wildlife managers, illuminated the prevalent challenge of accessibility encountered during Wildlife Hazard Assessments (WHAs). This insight prompted our team to proactively seek solutions during field operations, thereby instigating the development and testing of practical measures to address this issue.

The interview with Mr. Billy Nollen, a former FAA administrator, proved to be particularly insightful in elucidating the current regulatory framework governing the safety management of wildlife hazards as well as the safety integration of UAS into the U.S. NAS. Mr. Nollen's support and acknowledgment of the rigorous innovations proposed in our research further bolstered our confidence and facilitated the progression of our research endeavors. The endorsement from such esteemed industry experts provided validation for our research direction and bolstered our efforts to garner support for the implementation of innovative solutions within the aviation domain.

5. What did you learn? Did this project help you with the skills and knowledge you need to be successful in entry in the workforce or to pursue further study? Why or why not?

Our involvement in the ACRP design project has been a transformative experience, offering invaluable insights and practical knowledge across various dimensions of the aviation industry. Through this endeavor, we have gained proficiency in technological advancements, navigated regulatory frameworks, honed academic writing and presentation skills, and cultivated critical thinking abilities. These acquired competencies have not only prepared us for successful entry into the aviation workforce but also positioned us as capable scholars ready to contribute meaningfully to the field.

Technological Advancements in Aviation: The project has provided us with continuous learning opportunities regarding the latest technological advancements in aviation and their practical applications for enhancing safety within the National Airspace System (NAS). This includes gaining proficiency in software utilization, acquiring procedural knowledge, and understanding the performance characteristics of the UAS utilized throughout the project.

FAA Regulatory Framework: Developing the Concept of Operations (ConOps) and ensuring its safe integration into the NAS demanded a comprehensive understanding of the current FAA regulations and compliance requirements. Analyzing FAA wildlife sighting reports and significant wildlife incident and accident reports prompted us to identify opportunities for proposing novel technological advancements. This learning experience has enhanced our competence as aviation professionals and instilled a habit of referring to the FAA as the primary authority for operational guidance throughout our careers.

Academic Writing and Presentation Skills: Engaging in this project and delving into the intricacies of UAS operations has positioned us as subject matter experts in this field. Presenting our research at conferences allowed us to interact with fellow researchers, gain credibility, and showcase our expertise within the domain. These acquired skills in academic writing and effective presentation will prove invaluable in our future industry endeavors. Furthermore, conducting research has cultivated our abilities as scholars and has sharpened our critical thinking skills. These attributes serve as foundational pillars that will continue to support us in real-life scenarios as we transition into the aviation domain.

Faculty

1. Describe the value of the educational experience for your student(s) participating in this competition submission.

Participating in the ACRP design competition provided significant educational value to my students involved in several keyways:

• Real-World Application: Engaging in a real-world challenge like this allowed students to apply theoretical knowledge gained in the classroom to practical, industry-relevant problems. This bridged the gap between academic learning and real-world application, enhancing their understanding and skills.

• Problem-Solving Skills: The complex nature of the challenges presented in the competition required students to develop critical thinking and problem-solving skills. They had to analyze the wildlife-hazard problem, conduct research, and propose innovative solutions to this safety issue affecting the aviation industry. This process helped students develop their ability to think creatively and analytically, skills that are highly valued by the aviation industry.

• Practical Experience with Emerging Technologies: Addressing challenges related to wildlife hazard assessment using UAS technologies provided students with hands-on experience with cutting-edge technologies. This exposure to emerging technologies not only enhanced their technical skills but also prepared them to adapt to technological advancements in their future careers.

• Professional Development: Participating in such competitions allowed students to develop important professional skills, such as project management, communication, presentation, and teamwork. These skills are essential for success in any professional environment and significantly enhance students' career prospects.

Overall, the educational experience gained from participating in the ACRP design competition went beyond traditional classroom learning, providing students with a holistic and enriching experience that prepared them for future challenges in their academic and professional endeavors.

2. Was the learning experience appropriate to the course level or context in which the competition was undertaken?

The learning experience from the ACRP competition was entirely appropriate for the students' course level and context. The competition's focus on real-world airport management challenges provided a practical application of their coursework, enhancing their understanding and skills in the field.

3. What challenges did the students face and overcome?

The ERAU students participating in the ACRP competition encountered multifaceted challenges, ranging from technical intricacies of employing UAS technology for wildlife hazard assessment to navigating regulatory compliance and safety risk management. To address these hurdles, the students engaged in thorough research, sought guidance from industry experts, and collaborated across disciplines to develop comprehensive solutions. Their efforts extended beyond practical problem-solving; they also crafted an academic-style report documenting their research process and findings, showcasing their ability to apply theoretical knowledge to real-world problems. Through their resilience and interdisciplinary collaboration, my students not only overcame the challenges presented by the competition but also gained invaluable insights and skills. Their experience highlights the importance of practical application, industry engagement, and scholarly communication in preparing students for future academic and professional endeavors. By successfully navigating complex challenges and producing a robust academic report, my team demonstrated their readiness to contribute meaningfully to the field of airport management and aviation safety.

4. Would you use this competition as an educational vehicle in the future? Why or why not?

I will consider using the ACRP competition as an educational vehicle in the future. The competition offers a unique opportunity for students to engage in real-world challenges related to airport management and aviation safety, providing them with hands-on experience and practical skills that are invaluable for their academic and professional development. By participating in the competition, students have the chance to apply theoretical knowledge gained in the classroom to solve complex, industry-relevant problems, bridging the gap between academic learning and real-world application.

Furthermore, the ACRP competition promotes interdisciplinary collaboration and fosters engagement with industry experts, enhancing students' ability to work in multidisciplinary teams and navigate complex regulatory frameworks. The competition's emphasis on innovative solutions and academic style reporting also cultivates critical thinking, problem-solving, and communication skills essential for success in today's competitive job market.

Additionally, the opportunity to interact with industry professionals and conduct research in partnership with academic advisors exposes students to current trends and challenges in the field of airport management, enriching their understanding of industry practices and future career opportunities.

5. Are there changes to the competition that you would suggest for future years?

Integrating "Advanced Air Mobility" (AAM) into the ACRP competition for future years would enhance its relevance and prepare students for emerging trends in the aviation industry. By incorporating AAM, students would explore cutting-edge concepts and address challenges related to integrating these technologies into airport operations (e.g., safety management of wildlife hazards to AAM) and airspace management. This multidisciplinary approach mirrors the evolving landscape of the aviation industry, fostering collaboration across various sectors and preparing students to drive innovation and address complex challenges. Enhancing industry partnerships, incorporating mentorship programs, and providing opportunities for hands-on testing would further enrich the educational experience and better prepare students to contribute to the future of aviation.

Appendix F: References

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