Unmanned Aerial Vehicle Programs in the Fire Service: An Examination of Their Effectiveness and Challenges in Implementation

A Dissertation
submitted to the Graduate School
Valdosta State University

in partial fulfillment of requirements
for the degree of

DOCTOR OF PUBLIC ADMINISTRATION

in Public Administration

in the Department of Political Science
of the College of Humanities and Social Sciences

March 2020

Lindsay Judah

M.P.A., Valdosta State University, 2015
B.A.S., St. Petersburg College, 2013
A.S., Tallahassee Community College, 2011
A.A., St. Petersburg College, 2008

This dissertation, "Unmanned Aerial Vehicle Programs in the Fire Service: An Examination of Their Effectiveness and Challenges in Implementation," by Lindsay Judah, is approved by:

Dissertation Committee Chair

Michael Charter, D.P.A.

Committee Member

Burton A. Clark, Ed.D.

Vivechkanand "V" Chunoo, Ph.D.
Assistant Professor at University of Illinois at Urbana-Champaign

Associate Provost for Graduate Studies and Research

Becky K. da Cruz, Ph.D., J.D.
Professor of Criminal Justice

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ABSTRACT

Unmanned Aerial Vehicle (UAV) programs are entering the fire service more frequently than ever before. Each agency adopts an implementation approach that is compatible with its organizational culture. Public safety agencies, specifically fire departments, experience program development in a variety of ways. Fire departments throughout the United States make decisions and create policy; sometimes with limited research beforehand, leading to inefficient and/or ineffective program implementation.

The purpose of this research study is to identify cost-effective program development and implementation methods. Fire departments interested in developing a UAV program will benefit from this study's findings because they will have an improved idea of the many factors to consider when creating guidelines, determining budgetary needs, and selecting equipment. Generating buy-in from city/county management, department directors, and fire chiefs is critical to the long-term success of any program implementation strategy. Community outreach and involvement is also extremely beneficial toward the success of a fire department UAV program.

It is the researcher's goal to share data on current fire department UAV programs, an evolving application of technology in the industry of public safety deserving of data collection and continuous research. The study attempts to answer three specific research questions: 1. How are fire departments currently implementing UAV programs? 2. How can fire service UAV program development be most cost-effective? 3. How can fire service UAV program development and implementation maximize efficiency? The information discovered will improve cost-effectiveness, enhance program development, and support successful program implementation.

LIST OF FIGURES

ACKNOWLEDGEMENTS

I owe the success of completing this dissertation to the guidance of my dedicated chair and committee. I appreciate the editing efforts from several professors and classmates. My professional community, specifically my immediate supervisors throughout my career who have been very supportive of my academic endeavors. To my family and friends who have remained continuously supportive of my educational goals for the past fourteen years. I am tremendously grateful for the boundless encouragement along this journey; for this milestone would have been much more difficult to achieve without inspiration from each of you.

DEDICATION

This document is dedicated to my mother, Carolyn. You have sacrificed much for my personal and professional development. Thank you for all that you've given me in this life. I will always admire your unwavering love for our family, your many accomplishments and your service to our country, Retired Master Chief Petty Officer (U.S. Navy, 1980-2003).

Thank you for sharing this quote and perspective with me years ago.

> *Society as a whole benefits immeasurably from a climate in which all persons, regardless of race or gender, may have the opportunity to earn respect, responsibility, advancement, and remuneration based on ability.*
>
> - Sandra Day O'Connor

With Love, Lindsay

Chapter I: INTRODUCTION

Background

Australian teenagers and a suicidal Florida woman have something unexpected in common. Their lives were saved by innovative application of Unmanned Aerial Systems (UAS) programs. In the first account, two teenage boys were swimming off New South Wales on the far north coast of Australia when they were observed in distress by shore-side beachgoers. Locally-employed lifeguards were conducting Unmanned Aerial Vehicle (UAV) training at the time of the incident. Within 70 seconds of notification, the UAV, "Little Ripper," was hovering over the teens and deployed a self-inflating rescue pod (Romo, 2018). Importantly, the National Fire Protection Association states an initial arriving engine company should arrive within 240-seconds to 90 percent of incidents (NFPA, 2010). By reducing the response time to just over a minute, UAS technology greatly increased these boys' chances of survival.

Training and implementation of deescalating techniques is a growing trend in law enforcement. In February 2018, a suicidal woman drove from Cocoa Beach, Florida, to Stafford County, Virginia, with little money to her name. She made her way to a Walmart parking lot and began to consume vodka and unidentified pills. She then brandished a silver revolver and pointed at a civilian as well as law enforcement officers. Instead of arriving on scene and engaging in lethal force, two UAVs were deployed by the local Special Weapons and Tactics (SWAT) Team. This allowed law enforcement officers an opportunity to maintain communication with the negotiator and a close visual on the suspect (Hetherington, 2018). The application of this technology ultimately ended

in a safe outcome for all: no civilian lives, law enforcement lives, or suspect lives were lost. On average 100 Americans are killed by guns every day. Utilizing strategic deployment of UAV technology prevented the unnecessary, but potential, demise of citizens and/or law enforcement officials (CDC WISQARS, 2017).

What is an Unmanned Aerial Vehicle (UAV)? The United States Department of Transportation (USDOT) and Federal Aviation Authority (FAA) advisory circular from June 1996 describes a UAV as, "an air vehicle that does not carry a human operator, and is capable of flight beyond visual line of sight under remote or autonomous control for civil (non-Department of Defense) purposes." UAVs can be classified as expendable or nonexpendable. A UAV is considered nonexpendable if engaged in operations other than hazardous or oceanic meteorological observation operations (Accardi, 1996). UAV application as it relates to this research study involves the use of expendable unmanned aircraft.

The applications and technology associated with UAVs have expanded in record time, both in the private and public sectors. As of March 2020, Bard College has identified 1,578 UAV programs including state and local police, sheriff and fire departments, and emergency services agencies across the US (Gettinger, 2020). In 2016, more law enforcement agencies implemented UAS programs than in the previous five years combined (Frazier, 2018). Subsequently, numerous fire departments across the United States are implementing multi-dimensional UAV programs. For example, the Austin Fire Department has developed a Robotic Emergency Deployment (RED) team, which is the first metropolitan fire department to work with the Federal Aviation Authority (FAA) to develop a UAS program. The RED team initiative began with

relationships among external partners such as the National Institute of Standards and Technology (NIST) to identify industry standards for the use of robotic equipment as well as operator capability (AFD Red Team, 2019). An emerging trend that has gained significant traction following natural disasters, including the aftermath of hurricanes Harvey, Irma, and Michael. Fire department UAV programs have the ability to significantly impact municipalities throughout the nation at the public administration level.

This developing technology can be an asset to all public safety agencies. Due to the notable variety of UAV program applications, numerous agencies are implementing utilization across the country. A few examples are Austin, Texas; Chula Vista, California; Cobb County, Georgia; Coral Springs-Parkland, Fort Lauderdale; and Orlando, Florida are just a few examples. The Federal Aviation Authority (FAA) requires departments with UAS programs to acquire a Certificate of Waiver or Authorization (COA) when an assigned UAS is completing government functions. These departments, and many others like them across the United States, are leading the charge in identifying areas for effective deployment of UAVs.

However, little research exists to determine the effectiveness of UAV programs, the potential application for UAV programs, and technological advances associated with UAVs. It is essential to remain informed when identifying useful resources as they become available, especially true when taxpayer funding is responsible for the allocation of new assets. Effective and efficient implementation of state-of-the-art programs encompassing technology offers a tremendous potential of opportunity to decrease long-term financial burden for municipalities throughout the United States.

Purpose Statement

Limited research has been completed regarding UAVs in general, and fire department usage in particular. Few departments have systematically tested implementation of UAV programs. Identifying cost-effective program development and implementation methods currently used will address this shortcoming of existing knowledge. If research is completed prior to program development, fire departments interested in developing a UAV program will have a framework on which to base their decisions. This study attempts to meet these important aims.

Fire department funding can be a challenge each budget year. The continued focus to achieve more with less is prevalent in the fire service industry. If fire departments have more documentation accessible regarding best practices, advances, as well as the limitations of this technology, it is probable funding will be more easily awarded and better utilized. Collecting information on UAV capabilities, FAA requirements, NFPA standards, and technology available is time-consuming and expensive. The goal of this research is to identify and organize information regarding program development, implementation, and program maintenance to aid in efficiency for departments seeking to create or sustain an existing UAV program.

Research Questions

1. How are fire departments currently implementing UAV programs?
2. How can fire service UAV program development be most cost-effective?
3. How can fire service UAV program development and implementation maximize efficiency?

Problem Statement

Introduction

Fire departments throughout the State of Florida and across the United States make decisions and create policy, sometimes with very little documented information to support rationale. Fire department leaders commonly establish new policies, approve purchases, instate new equipment, or require changes in past practices which shift organizational culture. One of the most recent developments in the fire service as it relates to new equipment and technology is the evolution and implementation of Unmanned Aerial Vehicle (UAV) programs.

Numerous fire departments have identified this equipment as a feasible resource and began formulating plans for implementation of UAV programs at their respective organizations. One problem with the adoption of this innovation is the limited information available for fire departments to determine the cost-benefit relationship (numbers/cost, time, and budgeting prioritization), associated risks, and functionality of this newer technology. The purpose of this study is to help limit fire departments continuing to "reinvent the wheel" by creating new policies, purchasing new equipment, and enforcing change to existing procedures without consulting existing documentation.

Fire department administration and municipal leaders have a high level of (fiscal) responsibility and should assume limited liability to ensure safe practices are employed with each approved program. Without supplementary research, these known priorities have limited attestation. The topics described below include technical and operational considerations, command and control, safety concerns for the public and firefighters, public support, overall effectiveness, and acquisition.

Technical and Operational Considerations

There are many applications of UAV technology in the fire service industry. Undoubtedly, technical and operational considerations should be determined in the development phases of the department's UAV program. One example of a very specific application was researched at the University of Nebraska-Lincoln (UNL). Assistant Professor Carrick Detweiler determined a method for maintaining wildland: UAVs were equipped with a ping pong-sized ignition ball which was delivered to a predetermined area and cleared underbrush. This research was conducted on public lands in coordination with Department of the Interior, Homestead National Monument, and National Park Service in April 2016. This method was previously utilized by manned aircraft. The ignition ball contained a chemical compound intended to burn where dropped for two minutes to serve as an ignition source. Continued research is expected through Carrick and his team at UNL (Petrillo, 2016). The shift to using UAVs for the purpose of intentionally set wildland fires may be much safer and cost-effective as compared to using manned aircraft for similar tasks.

Command and Control Issues

UAV programs can provide a broad view of a scene, identify additional reconnaissance, and add an additional element of safety. At the command and control level, these technologically advanced devices are an additional 'tool in the toolbox.' To demonstrate, Mr. Zacc Dukowitz is the current marketing director for UAV Coach, an online UAV industry resource. In April 2018, he identified seven ways fire departments utilize UAVs in the field: to assess risk and danger, to respond to disasters; to save lives; to make emergency deliveries; to create pre-fire plans; to conduct investigations; and to

create training materials. It is likely as the UAV program implementation continues to expand that the areas of utilization will continue to develop (Dukowitz, 2018).

Safety Concerns for the Public and Firefighters

Many concerns may plague citizens, as well as public safety personnel, as they relate to the program development and implementation of UAVs. It is essential to conduct and document cases of success and failure as this rapidly growing technology proliferates in communities. Advisory councils and pilot studies are currently being conducted by the Department of Homeland Security as well as the FAA. The combination of professional research and documented real-time incidents involving UAVs will aid in improving efficiency of UAV applications for the fire service industry.

Cost

A variety of UAVs are available for purchase at different pricing tiers. A public safety agency can easily determine if they are interested in developing a UAV program. However, purchasing equipment can prove more challenging than initially expected. The technological capabilities of these devices also vary dramatically, including camera quality, infrared capability, payload capacity (ability to carry objects, such as a flotation devices), and software compatibility. Device purpose and mission intent will likely impact the type of UAV equipment selected by an organization.

Mike Uleski is the Chief Public Safety Instructor at DARTdrones, a leader in UAV training and consulting service. He is also a Sergeant at Daytona Beach Police Department who is cross-trained as a law enforcement officer, firefighter, and EMT. His background includes studying Aeronautical Sciences at Embry-Riddle Aeronautical University. Additionally, he possesses a commercial pilot certificate and has 17 years of

experience building and flying remote-controlled aircraft. His article for *Police One* in 2018 described a variety of considerations when selecting a UAV for a public safety agency. His seven considerations include anticipated flight time, weather capabilities, sensor availability, payload installation and deployment capability, dual-operator capability, manufacturer support, and associated cost. This includes the need for accessories, additional batteries, and related training (Uleski, 2018). Each of these considerations were taken into account in the present study.

Public Support

Chula Vista Police Department has created a successful approach for establishing public support. Civilians, community members, and local stakeholders can quickly dispel the possibility of a UAV if their questions are not answered, and they are not included in the development phase of the program. Each community will likely have a variety of concerns regarding the implementation of a UAV program. Some members of the community may express concern with privacy while others may be concerned with weaponized UAVs. It is important for program leads to ensure accurate information is disseminated to all community members. Dispelling rumors and emphasizing anticipated positive outcomes can be helpful during discussions with local stakeholders. Chula Vista Police Department hosted local meetings, reached out to community groups, and even set up a FAQ webpage as well as a question/comment box on their website. These steps can greatly improve overall program development and increase program potential (City of Chula Vista, 2019).

Overall Effectiveness

Charles Werner is the Chief of the Charlottesville, Virginia Fire Department and has participated in the Virginia Department of Emergency Management. He is also the chairman of the International Public Safety Association UAS Committee, National Council on Public Safety UAS, and an advisor on public safety UAS to the National Center of Security and Preparedness at the University of Albany. As a subject matter expert in the field of public safety, specifically the fire service industry, he has identified UAS as an essential tool for enhancing situational awareness and the overall public safety mission (Werner, 2018).

One application he has found to be extremely beneficial to ground-level personnel and incident commanders alike is the use of UAVs for dropping items, such as a personal floatation device. Responding to major flooding events and determining areas of greatest impact are other instances where UAVs provide real-time information and assist decision-makers in deciding where to send limited and valuable resources. Furthermore, community impact has proven to be effective in assisting public safety personnel. Having 'eyes in the sky' in the field of public safety is proving successful in many approaches. UAV deployment is also increasing the number of multi-discipline missions and enhancing overall organizational effectiveness (Werner, 2018).

UAV program lead personnel from Cobb County Fire Department provided insight based on their experience with creating and managing the agency's UAV program. The effectiveness they have experienced has been very positive. They described a variety of instances where UAVs were successfully deployed throughout the county, including a hostage situation with their 'med ops' team (similar to a SWAT

medic), as well as in residential and commercial fires, hazardous material incidents, and water rescues along the Chattahoochee River (Willis, 2018).

Acquisition

Captain Scott Mlakar with the Willoughby Fire Department shared his funding insights related to the UAV program he leads in Lake County, Ohio. Funding is commonly very limited for fire departments as the majority of calls for service do not create revenue streams. Captain Mlakar developed and shared a presentation with the local fire department and surrounding area public safety stakeholders to include the Lake County Narcotics Team Chief. After the presentation, the Narcotics Team Chief expressed interest in the potential of developing a UAV program to combine efforts by fire and law enforcement assets (Mlakar, 2019).

The initial program began with forfeiture money acquired by the narcotics team and local hazardous materials funding. The UAVs can be used for gathering information and assisting with hazardous materials incidents. Thus, additional financial support was applied for at the local level. Captain Mlakar described the process to include submitting an application or "wish list." Upon submission the area committee of local public safety stakeholders selected which items and organizations in the area received funding based on need and documented risk assessments (Mlakar, 2019).

The second funding request incorporated forfeiture money acquired by the narcotics team, local hazardous materials funding, and financial assistance from the Local Emergency Planning Committee (LEPC). LEPC funding is distributed from the State and collected from chemical companies. The money collected and distributed by LEPC must be used for training and sometimes is approved for equipment. Additional funding

streams may be available for organizations developing or maintaining a UAV program, to include Assistance to Firefighters Grant (AFG), Department of Justice grants which have strict guidelines and donations are even collected for some programs (Mlakar, 2019).

Summary

The problem statement provides an array of information to identify important concepts which may need consideration when developing a fire department UAV program. The specific topics covered were technical and operation considerations, command and control, safety concerns for the public and firefighters, public support, overall effectiveness, and acquisition. Each component is described in further detail to ensure the concept is considered by fire department agencies evaluating development and implementation of a UAV program.

The prominent challenge for many fire department agencies is due to a lack of clear, concise, and consistent information. Agencies have experienced tremendous difficulty when they've attempted to implement a UAV program and avoided managing critical concepts, such as fostering public support throughout the community. Additionally, cost can be grossly underestimated if essential factors of a UAV program are not contemplated early. Program development may require creative financial support avenues such as forfeiture funds, grants, or LEPC funding. The overarching goal is to better define essential components involved with fire department UAV programs, identify how fire departments are currently implementing UAV programs, determine any cost-effective strategies associated with UAV program development, and recognize areas which may enhance effectiveness of program implementation.

Importance of Research

This research study is descriptive in nature and is intended to illustrate existing information available about UAV programs and the fire service. Moreover, I included available material on existing fire department UAV program application and uses, learning opportunities, and considerations offered by current UAV program leads. Compiling the available information, conducting interviews with UAV program leads, and acquiring survey responses helped identify how fire departments are currently utilizing UAV technology.

Limited research exists regarding UAVs and associated fire department programs. Few fire departments have undertaken testing of a UAV program. Identifying cost-effective program development and implementation methods currently used will bridge this gap. In turn, this will provide information and possibly an informative opportunity for fire departments interested in developing a UAV program.

Decisions in all industries can often become costly. Many city and county governments address lowering fire department funding each year. The continued focus to accomplish more with less is prevalent in the fire service industry. It is likely available funding will be better utilized if fire departments have more informational material accessible regarding current practices, advances, as well as the limitations of this technology. Collecting information on UAV capabilities, FAA requirements, National Fire Protection Association (NFPA) standards, as well as the available technology is time-consuming and can become costly. When interested fire departments have more data readily available, the budget request and development process may be more cost-effective.

Research Design

The research study incorporates five elements. First, identifying existing UAV program models currently in operation for fire departments across the United States and stakeholder interviews with available agency UAV program leads. Second, reviewing existing data from the FAA and NFPA 2400 regarding fire department UAV programs. Then determining program development of existing UAV programs. Next, identifying UAV fire department program implementation success examples. Finally, collecting survey responses to determine how fire departments are currently utilizing UAV technology, and ascertaining anticipated future changes associated with survey respondents' UAV programs.

Limitations

This study has research limitations beginning with funding. All research included in this study was conducted by a doctoral student with no outside funding sources. There were no incentives, such as a monetary incentive provided to participants who offered their experiences with the researcher. Additional constraints include limited existing vetted research to include journal articles and approved dissertations. The research is also limited to studying existing fire department UAV programs which represent a majority of career (paid) fire departments.

A convenience sample approach was applied for stakeholder interviews with fire departments currently operating UAV programs. The convenience sampling approach was utilized to complete research in an efficient and timely manner, requesting information from fire department UAV program leads. For the purpose of this research, fire departments with established UAV programs will participate in a questionnaire based

on geographical location to best capture the UAV presence throughout the United States. Lastly, UAV technology and its public safety applications are ever-progressing. Compiling data will establish beneficial information to share with the industry at large.

Theoretical Orientation

The implementation theory will support this research. There are two types of implementation theories: One is the top-down approach to implementing policy, where policymakers develop programs to be implemented by personnel. Another approach is the bottom-up implementation theory, in which personnel may formulate ideas and share tactics with policymakers to create change. The implementation theory will be described by identifying challenges associated with each approach as it relates to the application of UAV programs in the fire service. This study also incorporates Moore's Diffusion Model and Search Theory, both of which are described in the following sections.

There are many theories concerning program implementation. In this case the top-down and bottom-up approach to implementation has been researched for many years. Sabatier (1986) analyzed the two approaches critically and provided suggestions based on his findings, which noted strengths and weaknesses to each approach. One area which was identified early on is that implementation policy research is typically conducted in a four- to six-year window. The suggestion by Sabatier starts with a ten- to twenty-year look in place of the more common shorter timeframe (Sabatier, 1986).

Initially the top-down approach was analyzed and received a generous amount of criticism as identified by the bottom-uppers, recognizing six distinct conditions that needed to be present for the top-down approach to gain effectiveness. The six conditions were clear and consistent objectives, adequate causal theory, structure to the implementation process which enhanced agreement of officials and target groups,

officials who were committed and skillful in their trade, support from interest groups and, lastly, consideration of socio-economic conditions. Customarily, policymakers can have a significant impact through selecting officials, determining incentives and gathering support. One critique commonly associated with the top-down approach is that many officials in the top echelon focus heavily on the program components versus the strategies and implementation of a more dynamic model (Sabatier, 1986). If this approach is utilized and strategies or implementation are overlooked, the personnel responsible to carry out the mission may experience challenges.

The fire service continues to evolve and regularly experiences top-down and bottom-up approaches toward program implementation. A few more recent examples of the bottom-up approach which have impacted today's fire service include risk management and the fire service. In addition to risk management, the improved understanding of Post-Traumatic Stress Disorder (PTSD) and the need for mental health awareness, peer support and self-care are current fire service topics. Another example is decreasing firefighter carcinogenic exposures by implementing decontamination initiatives, improving post-fire hygiene, and thoroughly understanding occupational hazards associated with the fire ground.

One example of this involves the Tucson Fire Department. The organization elected to participate in a Risk Management (RM) study with University of Arizona which involved three topics. The study was participatory in nature, requiring fire service personnel direct involvement. The RM approach involved three common tasks associated with the profession: patient transport, fireground operations, and physical exercise. Out of the 25 personnel affiliated with this study, 4% or one participant was at

the rank of Chief (Deputy Chief). The other 24 participants were Captains, Engineers, Firefighters, Paramedics or Inspectors (Poplin, 2015). The participants working with University of Arizona would appear to be a bottom-up approach.

Another instance of fire department's experiencing program implementation via a bottom-up approach references mental health, peer support, and PTSD. Fire service professionals ranging from the rank of Engineer to Battalion Chief collaborated and created the Florida Firefighter Safety and Health Collaborative (FFSHC). This initiative has gained great momentum by increasing awareness and providing resources not only to firefighters but also to mental health clinicians. This group of professionals have worked to create conversations and decrease stigmas associated with mental health in the fire service. Additionally, they have created programs to encourage local mental health clinicians such as employee assistance program workers, mental health counselors, and psychologists to become more familiar with the job responsibilities associated with first responders. Raising awareness for this cause has now led many fire service organizations to develop peer support teams and policies associated with managing programs to improve personnel mental wellness (FFSHC, 2019). The FFSHC provides another example of a bottom-up approach to program implementation, ultimately influencing change in the fire service.

A final example of program implementation in the fire service involves cancer awareness, decreasing firefighter carcinogenic exposure, developing decontamination procedures, and better understanding of occupational hazards associated with the fireground. The FFSHC has been instrumental in this work. The individuals who developed the collaborative began working with the Sylvester Comprehensive Cancer

Center at the University of Miami's Miller School of Medicine to research firefighter cancer (FFSHC, 2019). This led to including the State of Florida at the Florida State Fire College to expand awareness of these health hazards from new recruits completing entry-level training to existing and retired Florida firefighters. Over 4,000 decontamination kits were developed and dispersed throughout 2018 and 2019 to over 400 Florida fire departments (Farrar, 2018). This grass-roots approach from firefighters, awareness, to funding and program implementation has greatly impacted the fire service. Numerous education materials are now available for fire service professionals to bring change to their respective organization (NBOH, 2019).

In addition to the top-down and bottom-up approach to implementation, this study leverages the diffusion model of innovation. This is an academic way to measure the contagiousness of an idea, innovation, or product. An example of this model derives from a corn seed experiment which took place in Iowa in the 1930s. A particular seed was known to have superior growing potential as compared to the traditional seed. However, it was only utilized by a handful of farmers in the first few years of its development. Over the next decade, additional farmers chose to use the new corn seed, and by 1941 all but two of the original 256 farmers studied were using the seed (Gladwell, 2002).

The diffusion model consists of four categories. The initial category (closest to the time of innovation creation) consists of the Innovators; those adventurous individuals (2.5%) willing to assume risk and desire revolutionary change. This group is followed by Early Adopters (13.5%), who are similar to the Innovators, and are typically the individuals to purchase newer options. In this case new seeds, or in the case of UAVS,

program leads/supporting departments are willing to create the plan as they go and typically incur greater costs because the devices are not mainstream yet. The Early Adopters commonly observe the studies conducted by the Innovators and follow suit. The next category consists of the Majority, including both Early (34%) and Later (34%) majorities. These groups of individuals often deliberate, and are skeptical and seek to limit risk, or wasted money and time. Lastly, the Laggards (16%) bring in the stragglers to join participating in the new concept after a considerable amount of time (Gladwell, 2002). Figure 1 depicts these groups graphically and in relationship to one another along dimensions of frequency over time.

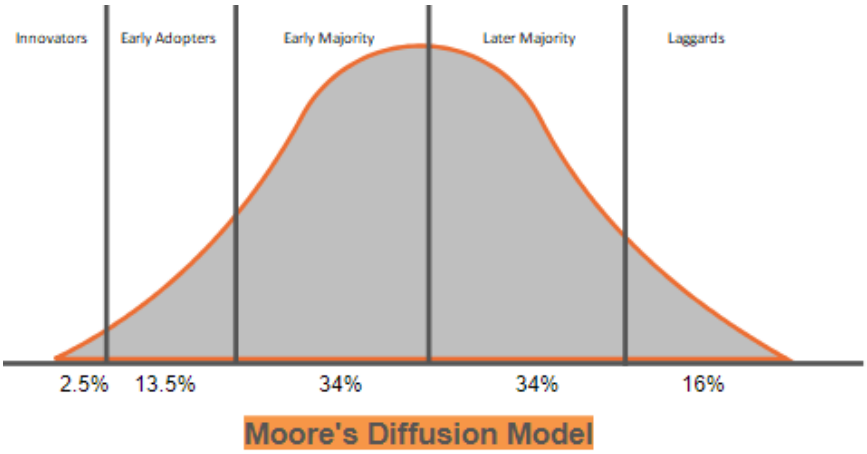

Figure 1: Moore's Diffusion Model (Adapted from Moore, 1991).

Modern search theory was originally introduced during World War II to assist with the detection of enemy submarines. Much of this work was completed by the Operations Evaluation Group of the Office of the Chief of Naval Operations, Department of the Navy (Enslow, 1966). Applied search theory is associated with improving the probability of success by utilizing available resources in the shortest period of time. Effectively deploying resources is conducted by defining search areas, detecting relevant objects, and determining associated environments (Ferguson, 2008).

The United States Coast Guard implements these measures by using tools and statistics which have proven to significantly increase the preservation of human life. Search and Rescue (SAR) actions are regularly carried out by military personnel assigned to these operational tasks. Land and maritime searches differ due to the differences in grids, topography, and vegetation. Geographical Information System (GIS) and real-time aerial viewpoints significantly improve the efficiency of an active SAR mission (Ferguson, 2008).

The early application of United States Coast Guard SAR planning began in 1957. During this time, a doctrine, otherwise known as an *SAR manual*, was developed. There was limited computer use during this time and hand calculations were utilized, ultimately becoming what was known as the *Classical Search Planning Method* (CSPM). In 2001, this tool was still implemented during SAR missions. However, around 1970 much of the manual content was shifted to a computerized version. This was known as the Computer Assisted Search Planning (CASP) system (Frost & Stone, 2001).

Despite the modernization attempts, three shortfalls emerged. The search theory and computer simulation were not as advanced, attempts to apply typical and complex search scenarios were inconsistent with basic theory and, the tools were not keeping up with the pace of significant detail and accuracy changes as it related to new knowledge of drift behavior and detection. The objective of the United States Coast Guard proposal at this time was to identify the current status of SAR planning and the need for additional technology. This added technology would deliver an advantage to those awaiting rescue due to better-quality planning tools (Frost & Stone, 2001).

Fire service agencies continuously make decisions and create policy for a variety of programs. One of the more recent programs as it relates to new equipment and technology is the use of UAVs. Program development may require creativity as it pertains to funding. The overall goal is to better define components, identify current implementation practices, determine strategies with UAV development, and recognize areas which may enhance effectiveness of existing UAV programs. It is important to understand the theoretical approach and how it may influence program development and/or success. The next chapter will review current literature covering the fire service and UAV programs.

Chapter II: REVIEW OF LITERATURE

Introduction

Fire departments throughout the State of Florida and across the United States make decisions and create policy, sometimes with very little documented information to support their actions. It is common for fire department leadership to adopt new policies, approve purchases, and initiate the use of new equipment, or require change in past practices, thereby shifting organizational culture. One of the most recent developments in the fire service as it relates to new equipment and technology is the evolution and implementation of Unmanned Aerial Vehicle (UAV) programs (Drone Responders, 2019).

Many fire departments have identified this equipment as a feasible resource and began formulating plans for implementation of UAV programs at their respective organizations. There is limited information available for fire departments to determine the cost-effectiveness, associated risks, and functionality of this newer technology. Few fire departments will likely continue to 'reinvent the wheel' by creating new policies, purchasing new equipment, and enforcing change to existing procedures without documented current practices. The literature review will include an overview of UAV technology implementation by local public service agencies, regulatory issues surrounding UAV use by local agencies, organizational factors affecting UAV use and effective implementation, selected case studies about agencies that are currently using this technology, literature on how other agencies are implementing this technology and

its prospects and challenge, conference and learning opportunities, and a detailed overview of a fire agency UAV program.

Regulatory issues surrounding UAV use by local agencies

National Fire Protection Association (NFPA) 2400

The National Fire Protection Association (NFPA) released the 2019 edition of NFPA 2400, entitled *Standard for Small Unmanned Aircraft Systems (sUAS) Used for Public Safety Operations*. Users of this standard are encouraged to reference federal, state, and local laws and regulations. The standard is comprised of six chapters: Administration, Referenced Publications, Definitions, Organizational Deployment and Considerations for sUAS, Professional Qualifications for sUAS Public Safety Personnel, Maintenance of sUAS and Annexes A-E (NFPA, 2019).

Many definitions are provided in the NFPA 2400 standard. A selection of definitions include crew readiness, data acquisition, designated operations area, digital media evidence, incident command system, maintenance program, payload drop, positive aircraft control, remote pilot in command, small unmanned aircraft, sUAS program, sustainable life cycle, and visual observer (NFPA, 2019). Chapter four of the document establishes minimum requirements a public safety entity is required to consider for a sUAS program. In particular, Designated Operations Area (DOA) is defined as the operating area, volume of airspace to include Above Ground Level (AGL) and Mean Sea Level (MSL) for the assigned geographical needs of a given public safety mission. A Remote Pilot In Command (RPIC) is an individual qualified to conduct the sUAS operation with final authority and responsibility. A risk assessment should always be completed by the RPIC, including evaluating crew readiness, weather conditions,

environmental conditions, regulatory requirements, potential hazards and operating conditions.

Chapter four continues with additional information regarding the selection of sUAS in regard to organizational needs. NFPA 2400 lists four considerations including operational requirements, minimum systems configuration and specifications, quantitative data demonstrating sUAS capabilities, and sustainable life cycle. Six operational applications are listed in Chapter four. These operational applications include firefighting, search and rescue, hazardous materials response, emergency medical services, law enforcement and other (ancillary public safety services shall identify what functions are supported by sUAS operations) (NFPA, 2019).

Chapter five lists pre-flight, in-flight, and post-flight information. Each component is to be considered when planning ahead, evaluating conditions, and identifying any issues upon completion of a flight. Proper storage and maintenance should also be deliberate. Chapter six lists additional information regarding maintenance and acceptable recordkeeping. Maintenance should be closely monitored to ensure all equipment is airworthy (i.e., ready to fly). Recordkeeping is an essential component due to the possible sensitive material which may be captured and recorded. Proper implementation will likely require evaluation of retention policies and laws associated the respective Authority Having Jurisdiction (AHJ) (NFPA, 2019).

Annex A provides explanatory material to include the definition of a small unmanned aircraft as it relates to FAA guidelines. 14 CFR Part 107 is the FAA guideline for small unmanned aircraft. Part 107 identifies 55-lbs as the weight limit for sUAS. NFPA states these are the parameters unless otherwise specified by the AHJ. NFPA also

outlines manufacturer considerations to be made prior to acquisition of UAV. These considerations are length of time manufacturer built/sold sUAS, length of time sUAS have been sold by manufacturer, availability of repair services, number of systems delivered, number of systems currently in use by public safety departments, feedback from existing customers, and recorded performance data (NFPA, 2019).

National Institute of Standards and Technology (NIST) developed a proficiency guideline for RPICs. This assessment includes the ability to maintain position and rotate, orbit a point, land accurately, avoid obstacles, and fly straight and level. The assessment involves five-gallon buckets, lumber and printed targets. NIST also developed a proficiency guideline for payload functions. This assessment includes point and zoom cameras, identify objects, inspect objects, map wide areas and drop accuracy. This assessment is also comprised of five-gallon buckets, lumber and printed targets (NFPA, 2019). Images of these types of assessments can be seen in Figures 2 and 3 provided below.

Figure 2: NIST Testing (NFPA, 2019).

Figure 3: NIST Testing (NFPA, 2019).

Although the NFPA 2400 standard references Part 107, FAA guidelines have provided minimal clarity to sUAS programs both in military and public safety organizations. To assist in this area, the U.S. Congress passed the FAA Modernization and Reform Act of

2012 (FMRA). FMRA enlisted the FAA to complete a five-year assessment and evaluation plan and in 2013 a "roadmap" was developed. This roadmap was to include three perspectives: accommodation, integration, and evolution to aid in civilian, military and public safety UAV use in National Airspace (Mumm, 2015). In addition to the NFPA 2400 document, on October 24, 2019 NFPA shared a news release which stated nearly one million dollars in fire prevention and safety grant funding was received from Federal Emergency Management Agency (FEMA) to develop a public safety drone compliance program. The project is expected to generate best practices in creating successful drone programs (NFPA, 2019). Developing an understanding for the NFPA 2400 standard can familiarize fire department agencies with concepts necessary to implement a UAV program; a core concern of this study's Research Question 3: How can fire service UAV program development and implementation maximize efficiency?

FAA Guidelines

The FAA provides a guide to approved UAS application for public safety and government users. The FAA operates utilizing guidelines which include 14 CFR Part 107. Part 107 allows for flight of UAS under 55-lbs, at or below 400 feet AGL (line-of-sight operations only). FAA also requires UAS programs to acquire a Certificate of Waiver or Authorization (COA) when UAS is completing government functions. Emergencies, such as a natural disaster, can dictate the issuance of a speedy COA. The "speedy COA" is known as a Waiver and Authorizations Supporting Emergency UAS Operations.

In addition to the Part 107 and COA, UAV pilots must receive FAA authorization to fly near airports. It is possible for an organization to apply for Low Altitude

Authorization and Notification Capability (LAANC). Furthermore, UAV pilots shall not fly over people or at night unless additional waivers are acquired through FAA. However, current guidelines which are under review (FAA, 2019a).

FAA lists two methods for starting a UAS program. The first option is the identification of personnel to complete FAA drone pilot certificate program, thus allowing the Fire Department to operate by guidelines intended for sUAS programs. Secondly, an organization can acquire an FAA Certificate of Authorization (COA) to function as a "public aircraft operator" which then self-certifies pilots and UAVs (FAA, 2019a). The first step in this process is to request the organization's legal department to draft a Public Declaration Letter. Certifying the respective agency as a government entity, the letter to be sent to the FAA. Upon receipt and approval, the FAA sends a user ID and password to the UAS COA Online Application System. At this point the appointed individual completes the application (FAA, 2019a). Incorporating FAA Guidelines assists fire department agencies interested in implementing a UAV program, which in this study, has implications for Research Question 2: "How can fire service UAV program development be most cost-effective?" and Research Question 3: "How can fire service UAV program development and implementation maximize efficiency?" Following the guidelines set forth by this federal agency is essential for any fire department agency interested in establishing a UAV program.

Organizational factors affecting UAV use and effective implementation

In March 2018, the FAA released a forecast for fiscal years 2017-2038. This forecast anticipated the number of small-model UAS to double from 1.1 million vehicles in 2017, to 2.4 million vehicles by 2022. The FAA determined public acceptance of this technology will directly impact the growth, a projected up to 3.2 million vehicles in

operation by 2022 if widely accepted. Additionally, small non-model UAS (commercial) are expected to dramatically increase from 2017's expected 110,604 vehicles, to 2022's 451,800 vehicles. The FAA determined regulatory changes and widespread commercial purposes of this technology will directly impact their speed of growth. The FAA also anticipated the number of remote pilots will increase from 2017 with 73,673 remote pilots, to 2022 with 301,000 (Price, 2018).

In March 2019, Oklahoma State University acquired the first FAA approval in the United States to fly UAV swarms in the national airspace. Typically, a pilot for every UAV. However, in this case one pilot and visual observers (for safety) can operate a swarm of up to 20 UAVs. Dr. Jamey Jacob with Oklahoma State University began researching swarm flights four years ago with his team. He believes this research can positively impact many areas, from infrastructure monitoring, agriculture, package delivery, and national security, to airspace operations and weather (Douglas, 2019).

The phrase "Smart City" has become a common way to describe technology-driven, advanced communities which have rapidly emerged in recent years. Many city leaders readily identify the necessity for economic growth, increased population, and sustainability conditions in their communities. Improved Information and Communication Technology (ICT) has been recognized as a successful route when pursuing these community-based needs. Eight opportunities for the application of UAV programs have been acknowledged to make a positive impact on Smart Cities. These eight opportunities include

1) Geo-Spatial and Surveying Activities–Optimizing the flow of reliable data collected by relatively low-cost devices which possess low power consumption qualities and deliver high performance. Management of large fires, geo-spatial, land surveying and Geographic Information System (GIS) are just a few environmental areas that UAVs have the potential for reduce manpower and influence cost reduction.
2) Civil Security Control–Implementation of UAV use in public safety areas to include live video streaming with a proactive approach to mitigating crisis. This initiative aligns with the idea of reducing cost and increasing operational efficiency.
3) Traffic and Crowd Management–In tandem with 2) Civil Security Control, this UAV opportunity emphasizes that safety and security can be enhanced even in cities/communities that are not considered or striving to be a "Smart City." These devices can be involved with policing activities, forensic mapping software, and integration applications.
4) Natural Disaster Control and Monitoring–Emergency situations such as earthquakes, fires, and floods can be controlled more efficiently. The deployment of UAVs in emergency situations may decrease the loss of life, especially in areas that cannot be easily accessed by first responders.
5) Agriculture and Environmental Management–Air and gas monitoring can be executed by UAVS. Additionally, crop growth, fertilization and watering can be completed with the use of UAVs.
6) Urban Security–Full technical coverage can be offered by UAVs for widely-attended urban events. This can assist in running a smooth, large-scale event.

7) Big Data Processing–Smart infrastructure requires advanced technology. With the application of UAVs, GIS information can be integrated, time series data can be distributed, and lastly, modeling and simulation can be achieved accurately and quickly.
8) Coordination Between Heterogeneous Systems–Sharing of information can be completed quickly through the UAV, to the controller and then to another UAV or system (Mohammed, 2014).

If communities are going to move forward along these dimensions, better information is needed regarding the use and regulation of UAVs/UASs. Studies like the one presented here can be instrumental in filling this informational gap.

Overall welfare of public safety personnel and community members can be enhanced by the allocation and implementation of UAVs used at traffic incidents, in addition to many other emergency scenes. Although crime scene reconstruction may appear to be a safety advantage only applicable to law enforcement personnel, it also decreases the risk of fire department personnel remaining on scene for extended periods of time. The John Hopkins Applied Physics Laboratory received an award from U.S. Department of Justice to study the operation evaluation of unmanned aircraft systems for automobile crash scene reconstruction (John Hopkins University, 2018). If the investigative portion (see yellow arrow in Figure 4) of the accident is shortened, the overall scene time can be decreased. This leads to reduced injuries or fatalities of community members as well as first responders who would otherwise be impacted by remaining at this scene for a longer duration.

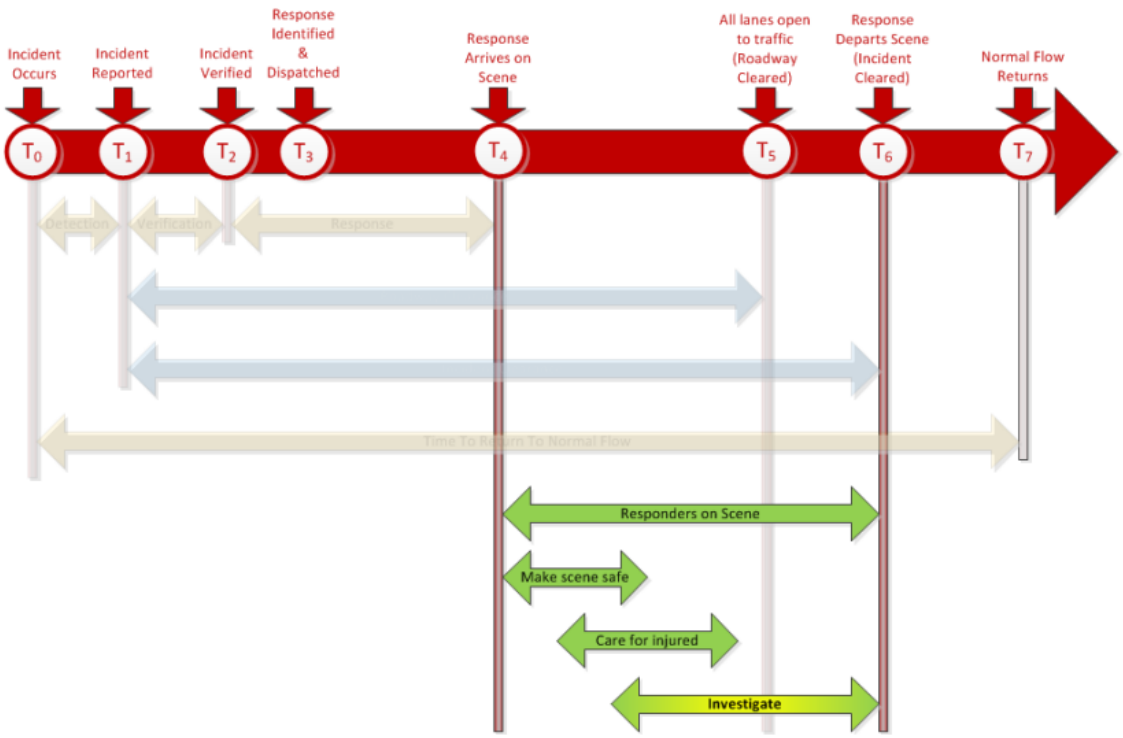

Figure 4: Timeline of Traffic Incidents (John Hopkins University, 2018).

Operating UAVs for crime scene reconstruction decreases the amount of time public safety personnel are required to work in a potentially dangerous environment (NCJRS, 2018). Additionally, road closures increase the likelihood of secondary crashes, ultimately compromising the safety on the roadway for civilians. Since utilizing this technology reduces responders' on-scene time, its adoption should be strongly considered. Supplementary research on the effectiveness of this investigative approach (John Hopkins University, 2018) is still needed. Understanding instances where UAV programs are currently utilized assist fire department agencies interested in implementing a UAV program, which relates to Research Question 1: "How are fire departments currently implementing UAV programs?" of this study.

Case studies on agencies currently using UAV technology

North Metro Fire Rescue Department (NMFRD) has had an established UAS program for one year. In January 2019, the department tested a new feature –infrared technology and a 100-decibel speaker. NMFRD Firefighter Jeff Burke began testing their UAV capabilities by responding to a mannequin placed under ice in a frozen body of water. The team was inspired by a story which originated in New York City, when service dispatched call for two small children; one child went underwater while playing near a frozen body of water. A news helicopter in the area was able to identify where the child was located due to its perspective above the water. NMFRD then applied this information to its UAS program. The department began completing training scenarios using a pool noodle homemade manikin and practiced spotting it with the UAV from varying elevations. This initiative has been shared with local news outlets to encourage community members to refrain from going out on ice to save people and/or pets because NMFRD is trained for these emergencies (Kruegel, 2019).

Hanyang University funded three researchers to integrate indoor UAVs, fire hazards, and building evacuations. The research included a prototype, the UAV- assisted Emergency Monitoring and Response (UAV-EMOR) system. The concept includes indoor/outdoor assigned UAVs, decreasing the blind spots of fixed cameras within a facility. The research concluded that a beacon can be placed in a smart ID card for each employee within a building, allowing tracking of personnel. Additionally, a beacon can be placed on the indoor UAV for identifying hazards, capturing images, and relaying information (Seung-Hyun, Jung-In, & Jinseok, 2017).

Laramie County Fire Chief Jason Caughey interviewed Manny Muzquiz (Operations Chief with Laramie County Fire District) and Nick Siemens (Director of the

Laramie County Community College Fire Science) to determine how advanced technology would be beneficial toward the effectiveness, efficiency, and overall performance of firefighters. Director Siemens stated the UAV use initially began as a marketing tool, starting with videos of training which were collected and used to recruit new students at the local fire academy. It was noted that UAVs also provide an "eye in the sky" for observing numerous operations at one time during training scenarios. Director Siemens suggested that personnel will be informed of the functionality/purpose of the UAVs as well as safely conducting fireground operations near these expensive pieces of equipment. As with many job performance requirements, it is important to monitor situational awareness when training near UAVs (Caughey, 2018).

The New York City Fire Department (FDNY) is embracing emerging technology and has a growing UAV program. Firefighter Michael Leo shared his experience in a FireHouse magazine article. His first experience with flying a UAV for emergency responses purposes was during a full-scale Urban Search and Rescue (USAR) training exercise at the Guardian Center in Georgia. His 10-minute flight enabled him to relay valuable information to Command Staff while incurring no risk to front line personnel. He was able to identify the location of 11 victims and the best route to their location, determine structural integrity of damaged buildings and pinpoint whereabouts of existing hazards (Leo, 2019).

During Firefighter Leo's training flight experience, the New York Fire Department Operations Center (FDOC) was working with a vendor to determine capabilities of tethered UAVs. Previously, the FDOC utilized cameras on tall poles. However, UAV technology provided a 200-foot aerial vantage point with a more detailed

view of the incident. The footage captured by the tethered UAV was shared by a live feed from the Command Tactical Unit (CTU) to the FDOC. These findings led to the beginning of the FDNY UAV program. The approach of FDNY was "Crawl-Walk-Run" (Leo, Pg 1, 2019). This terminology is mentioned frequently during workshops and a variety of information sharing platforms.

A few issues overcome by the FDNY include congested national air space, ground congestion, radio frequency interference, privacy concerns, and tall dense buildings. Leo explained that a critical component of the success of the FDNY UAV program is the progressive vision and support provided by leadership. Many agencies assisted in their program development to include the Austin Robotic Emergency Deployment (RED) team as well as guidance from the National Institute of Standards and Technology (NIST). Now that the FDNY team has collected data and identified risk factors, they're better prepared to implement untethered UAV operations (Leo, 2019).

FDNYPro is a podcast available online. Captain Michael Leo and Battalion Chief Anthony Pascocello were interviewed on September 30, 2019. Additional information was provided regarding the FDNY UAV/Robotics program. The program has now been in effect for over three years; the first operation at a fire was on March 6, 2017, at Crotona Park North in the Bronx, New York. These technologies have greatly improved situational awareness on scene and have the capability now to share real-time information with incoming resources (FDNYPro, 2019).

Furthermore, FDNY is utilizing Emergency Integrated Lifesaving Lanyard (EMILY) sonar equipped drones in the waterways. These devices are capable of completing surface water rescues and side-scanning sonar. This improves safety for fire

department dive teams which may be placed in dangerous conditions when diving near piers. The sonar capability provides intelligence to pinpoint divers' locations (FDNYPro, 2019). These devices have also been deployed in the Bahamas to survey storm damage following Hurricane Dorian landfall (Navy Live, 2019), as well as donated by the U.S. Navy to the Norfolk Fire-Rescue in support of underwater search and rescue efforts (Norfolk-Fire Rescue, 2019).

Fire management has been in need of technological advances and changes in operating procedures. Manned aerial vehicle fatalities account for 26% of all firefighter deaths in the United States since 2000. Furthermore, over 50% of the United States Forest Service (USFS) budget is accounted for to mitigate wildfires (Twidwell, 2016). Unfortunately, this same funding was previously being utilized for fire management and associated research which has since drastically decreased. The USFS has launched efforts to determine the benefits of a strong UAV program to enhance capabilities and lower costs associated with fire management (Twidwell, 2016).

The U.S. Department of Defense noted many benefits in 2013 regarding UAV utilization. Twenty-four-hour observation took place at the California Rim Fire. The utilization of UAVs allowed for earlier spotfire detection which afforded ground personnel an opportunity to frequently get ahead of the fire and anticipate condition changes. This panoramic view also influenced decisions for more effective staging areas for personnel and resources based on the captured footage. An additional safety feature provided to ground personnel is that the UAVs are capable of performing as a radio transmitter in remote areas where ground personnel are often left without communication (Twidwell, 2016).

In 2017, the Orlando Fire Department (OFD) completed training with the FAA to operate their new UAVs safely. These new pieces of equipment were secured to enhance the OFD's arson and bomb squad's response capabilities. An example of an incident the UAVs would be useful at would be reports of a suspicious package, said Captain Trenton Campbell. The deployment of a UAV would decrease the amount of time on scene and increase situational awareness for public safety personnel dispatched to the scene. The UAV can provide a closer, quicker look at the incident and assist in an effective risk-assessment. In addition to the linkage between the UAV and arson and bomb, the UAVs are expected to assist in search and rescue missions, damage assessments, and other emergency situations (Doornbos, 2017).

Polk County Sheriff Office (PCSO) instituted its UAV program in January 2018. The program is called the Aerial Response Team (ART). During daytime hours, ten UAVs in operation in five patrol districts. During the nighttime hours, three UAVs are in operation. One reason there are fewer in operation during nighttime hours is the UAVs are nearly 20x the cost of the UAVs which are in operation during the daytime. The cost is approximately $1,250 (daytime) and $23,000 (nighttime). The origin of the wide variance in cost has to do with the specific capabilities of the UAVs (Berkowitz, 2018).

The increased cost for nighttime UAVs is associated with the technology required to engage in a purposeful flight. Additionally, ample lighting is required to illuminate the UAV in accordance with FAA guidelines. Many organizations are resorting to glow-in-the-dark decals and red/white/blue flashing lights. The technology device manufacturer, FLIR systems, sells radiometric or thermal imaging cameras which range in cost from

$2,500 - $6,600. DJI and Yuneec also produce and sell similar nighttime camera products for up to $7,100 (Lee, 2018).

PCSO deploys UAVs for a variety of reasons, including fleeing suspects, K-9 deployment, and missing persons. Preliminary evidence suggests over $100,000 of savings can be attributed to UAV deployments over helicopter deployment. It is also quicker to deploy the UAVs from PCSO's perspective. There are several documented cases of suspects being found in wooded, and otherwise difficult-to-access areas; in addition to a student was missing from a local university, someone yelling for help was located in a swamp, and emergency medical services personnel reached the man with ART's assistance (Berkowitz, 2018).

Hurricane Irma made landfall in the Florida in 2017 and left devastation for miles. FAA quickly completed 132 airspace authorization requests by UAV owners to ensure safe operations were managed. As one example, the Air National Guard utilized UAVs to complete aerial surveys, instead of their more common task, combat operations. The more modern day, "windshield surveys" are being completed by UAVs, allowing decision-makers to identify more quickly, where resources should be allocated to preserve the most lives. Another example was U.S. Customs and Border Protection deployed UAVs to assist in mapping areas along the east coast of the United States (FAA, 2017).

Widespread use of UAVs impacts private sector operations as well. One example is Airbus Aerial, which assisted insurance companies in collecting data for quicker assessments and claim distribution. Jacksonville Electric Authority (JEA) deployed UAVs to assist in power restoration and crew safety monitoring. Implementing this

technology allowed JEA to conduct damage assessments in record time. In fact, they completed the assessments within 24-hours post storm. A similar operation was conducted by Florida Power and Light (FPL). Overall, the data is very telling when considering the impact UAVs have on systems especially after natural disasters (FAA, 2017).

An editorial released by FEMA in February 2019 shared advances with the inclusion of UAVs with cardiac emergency care, delivering Automated External Defibrillators (AEDs). There are many potential benefits to AED deliveries. It is estimated that the UAV can fly up to 62 mph in the direction of a caller's GPS location. Many communities lack static AED locations in residential areas, a problem potentially remedied by the tactical deployment of UAV technologies. It is possible this service would be always available, unlike static AED locations which may be locked during non-business hours. UAV camera capability could share additional information for dispatch to update emergency responders in real-time (USFA, 2019).

Articles, cases, and other documentation continue to surface related to UAV use throughout fire department agencies. Overall, it is helpful to identify what mission's organization have completed utilizing their UAS equipment in the field. Understanding instances which UAV programs are currently utilized will assist fire department agencies interested in implementing a UAV program, reference Research Question 1: How are fire departments currently implementing UAV programs?

How other agencies are implementing this technology and its prospects and challenge

There are many civilian concerns with implementation of UAV programs in public safety applications. Civilian sector buy-in is essential for effective UAV programs in each respective community. Initially informing the public of the potential for program development can be helpful. The Chula Vista Police Department incorporated this approach when the department began to create its UAV program. Additionally, question-and-answer sessions are often beneficial to organizations seeking to utilize UAVs in the field (City of Chula Vista, 2019).

Alan Frazier conducted research with the University of North Dakota School of Law. He determined the civilian public has potentially been misled in the past regarding the capabilities of UAVs and their associated security risks. He described Hollywood's portrayal of UAVs is far different than the realistic capability of this technology. The current UAV camera offers 10-20 megapixels which is a moderate resolution. This is not advanced enough to support popular concerns around facial recognition software and other technologically advance surveillance (Frazier, 2018).

Current FAA regulations require line of sight flight, which is the only operation approved without extensive additional approval. This approval or waiver is known as Beyond Visual Line of Sight (BVLOS). However, with existing guidelines a line of sight can be characterized by approximately one half-mile radius. It is unlikely to acquire any type of facial recognition at this distance. Additionally, the battery life on these devices can be limited to about 30 minutes. This timeframe proves to be inadequate for random flights for surveillance. A number of court cases have materialized after evidence has been purposefully sought out by law enforcement using aerial methods. A selection of

cases includes United States v. Causby (1946), Kyllo v. United States (2001), California v. Ciraolo (1986), Dow Chemical v. United States (1986), Florida v. Riley (1989) and United States v. Jones (2012). As of 2016, Jonathon Hauenschild stated, ". . . there are over 750 introduced or enacted laws [in the U.S.] where 'autonomous aerial system,' 'autonomous aerial vehicle,' or 'drone' are mentioned in the text" (Frazier, 2018). This area of research will likely continue to be improved and refined.

Frazier discussed recommendations for law enforcement agencies at the end of his "*Hunting with Drones"* article. He described areas where law enforcement can encourage organizational acceptance, community understanding, and program effectiveness. These areas include engaging and educating the public, policies and procedures; initial and recurrent training; internal investigations and coordinating with prosecutors and judges. Encouraging community feedback is important and can be done by utilizing existing advisory panels and advertising forums.

During the inception phase of the UAV program, it is important to ensure factual information is provided to the public. Policies and procedures need to be created and consistently implemented. This is especially important with information storage and potential evidence collection. Supervisors must ensure training is thoroughly documented. If any policies or procedures are violated, or unforeseen instances take place, it is essential to conduct internal investigations. Understanding legal principles and ensuring open communication is available with prosecutors and judges is important for the success of law enforcement UAV programs (Frazier, 2018). Understanding challenges associated with UAV program implementation is helpful for any organization

developing a UAV program, which is relevant to my Research Question 1: How are fire departments currently implementing UAV programs?

Conference & Learning Opportunities

The Association for Unmanned Vehicle Systems International (AUVSI) hosted an annual conference from April 29-May 2, 2019. The conference highlighted all new electronic devices, and collaborated by discussing top issues, regulations and policies. There were over 150 sessions scheduled and over 300 speakers covering trending topics. These sessions are organized into a variety of educational tracks at this conference. One such educational tracks is "Public Safety UAS." This two-day program presented an opportunity to engage with numerous public safety practitioners. Panel sessions and presentations led by subject matter experts and experienced emergency responders were planned to share lessons learned and considerations to make with the attendees' respective organization (AUVSI, 2019).

AUVSI will be hosting an "all things unmanned" expo known as *Xponential* from May 4-7, 2020 at the Boston Convention and Exhibition Center. It will cover products both unmanned as well as autonomous systems. Their marketing suggests attendees will be immersed in new ideas, from construction to defense. Keynote speaker presentations can be viewed on their website - www.xponential.org (AUVSI Xponential, 2019).

The UAS DRONES Disaster Conference hosted an annual conference April 11-12, 2019 in Miami, Florida, by Airborne International Response Team (AIRT). The National Hurricane Center at Florida International University in Miami is home of the flagship of the UAS DRONES Disaster Conference. This was the second annual conference which exhibits advancements made in the UAS industry, specifically as it related to public safety and disaster management. Several learning opportunities were

offered to include workshops, live flight demonstrations and a marketplace. Attendees included leaders, planners, operators, law enforcement, police, fire, search and rescue, emergency medical services, government, emergency management, academia and industry as well as non-governmental organizations (UAS DRONES, 2019).

The 2019 International Conference on Unmanned Aircraft Systems (ICUAS) was hosted in Atlanta, Georgia, on June 11-14, 2019. The conference was scheduled for one full-day of workshops and tutorials, then three full days of technical content. Participants were from academia, industry, federal and state agencies, government, the private sector, practitioners and engineers. Themes for this conference include autonomy and resilience. Challenges, payloads, communications, swarms, safety, and operational constraints are just a few of the topics covered (ICUAS, 2019).

The Commercial UAV Expo hosted their annual conference October 28-30, 2019 in Las Vegas, Nevada. This was the fourth year for this conference and was expected to provide meaningful information to over 3,000 professionals. This conference is known for the UAV information regarding emerging technology, trends, and developments. More than 60 experts were on-site to provide data on workflow, security, robotics and more (Commercial UAV Expo, 2019).

Piedmont Virginia Community College is hosting the 2020 National Public Safety UAS Conference March 2-4, 2020 in Crozet, Virginia. This is a three-day conference including professionals from various public safety disciplines to include disaster relief, emergency services, fire rescue, law enforcement, public safety, as well as search and rescue. Enrollment is limited to 200 attendees which must be public safety personnel or sponsored by public safety personnel (PVCC, 2019).

The Energy Drone + Robotics Coalition (EDRC) is hosting a summit June 10-11, 2020 at The Woodlands, Texas. This conference is focused on energy operations with UAVS, Robotics, Data and Automation. Though this conference is oriented toward the energy industry, there is value in studying UAVs from an interdisciplinary approach (EDRC, 2019).

Additionally, on April 16, 2019, the FAA initiated a free live webinar series to help drone operators understand how to operate in the National Airspace System and assist in successful application for an airspace authorization. The Webinar Series is titled *Airspace and Airspace Authorizations*. Topics addressed during these webinars include Why airspace matters, How to read Notices to Airmen (NOTAMs), Temporary Flight Restrictions (TFRs), Unmanned Aircraft Systems (UAS) Facility Maps, What an airspace authorization is, when you need one, and how to get one, and how public safety agencies can fly drones during emergencies. Registration for the webinars is only open to the first 1,000 attendees. The scheduled dates of these webinars include: April 16, 18, and 25, 2019, May 9 and 23, 2019, June 13 and 27, 2019, July 18, 2019, and August 1 and 13, 2019 (FAA, 2019b). More information for the webinars, including the registration link and recordings, can be found at: https://www.faa.gov/uas/resources/webinars/.

In addition to the numerous conference opportunities available and anticipated expansion in participation and attendees, there are informal social media groups, on platforms such as Facebook, which often house conversations about current issues experienced by pilots, requests for assistance in completing FAA forms, recommendations for equipment and applications, along with sharing of policies and procedures. A selection of such Facebook groups includes Commercial sUAS Remote

Pilots, DARTdrones Public Safety sUAS Program Development, Fire Drones, Florida Drone Pilots, and Search and Rescue Drones. Identifying learning and networking opportunities in the UAV field as it relates to public safety organizations assist fire departments seeking information regarding UAV program development. This also improves the fire department agency's success, when program leads are able to learn from potential challenges which have already been encountered by another agency elsewhere, providing an avenue to answer Research Question 2: How can fire service UAV program development be most cost-effective.

Detailed overview of a fire agency UAV program

On the morning of June 29, 2019, I conducted an in-person interview with a Central Florida Battalion Chief. We met at the local training facility where a full-scale exercise was taking place involving a USAR mobilization for a simulated bridge collapse on vehicles with entrapped victims. At the time of my arrival, this Central Florida Battalion Chief was flying the M210 around the full-scale exercise. He described the various functions of the M210, including its thermal imaging capabilities (which was set to white hot). He shared with me at the time of this interview; there were 16 UAVs in their program with two on-call personnel as well as eight FAA Part 107 pilots. The team is anticipated to continue to grow to provide an *always-on* resource in the near future. At the time of the interview, there were two pilots assigned per shift, and the goal was to increase that number to four per shift. The rank of pilots varied, to include Lieutenant, Engineer and Firefighter. All equipment was situated amongst the two on-call personnel (training personnel). The goal was to increase the number of trained pilots as well as assign equipment to on-duty Battalion Chief vehicles. Depending on the dispatch notification received, the on-shift personnel would be attached to the response. Pilots

would respond to the scene, report directly to the Battalion Chief, and determine the appropriate equipment to deploy based on the needs of the specific incident. Currently, the Battalion Chief's role is to bring the equipment to the incident. There is one Incident Command Technician on-duty in the county at all times. The Battalion Chiefs are not assigned a Battalion Chief Aide to fly the UAVs on arrival. At the time of this interview, the county was divided into seven battalions; the Battalion Chiefs supervised six or seven stations, or approximately 40 personnel.

This Central Florida Battalion Chief presented the current equipment available as well as the configuration of where the equipment was stored. Equipment was located in two secure pick-up trucks with Tonneau covers. These vehicles were assigned to the two on-call personnel associated with the UAS program. Ideally, he would like to see the vehicle transition to a van with easy access to computer screens for viewing as well as a controlled environment with air conditioning. Sixteen UAVs are in operation at this Central Florida FD: the models include Inspire, Matrice 210 (M210), Mavic Enterprise, Mavic Pro, Parrot Disco and Phantom. Additionally, the department has underwater capability with Remote Operated Vehicles (ROVs). The program gained substantial community and management support following the devastation of Hurricane Irma in the Central Florida region. The UAVs were able to provide reconnaissance to the Emergency Operation Center with a livestream feed, which documented important intelligence and identified the need for specific resources in areas impacted by the storm, such as boats to employ rescues. In at least one documented rescue case involving the UAVs, a mother and son were trapped in an apartment. Water rose in the apartment up to the second story and all communication lines were down. The team noticed movement

on the apartment blinds when flying the UAV around the property and provided the information to ground crews. This instance of rapid reconnaissance was really what influenced buy-in for development of the program to where it is in 2019.

Specific details regarding existing UAV equipment capability is described below as it pertains to the incidents this organization responds to using their UAV devices. The "Inspire UAV" is typically used for air monitoring and has gas monitor attachment capability. Additionally, this device can drop a mustang survival personal flotation device; the payload capability is about three pounds. The Matrice 210 (M210) has a variety of functions and add-ons such as thermal camera and zoom lens camera. The battery life for operations using the M210 is about 40 minutes. The Mavic Enterprise UAV has thermal capability. The Mavic Pro Platinum has backpack capability helpful for personnel if they need to walk to a location and then put the UAV in the air. Portable enhanced thermal capability may be the preferred tactic for a search and rescue for many agencies with access to this technology. The iPad Mini or Crystal Sky Display can be used with this UAV. The Mavic Pro is commonly utilized for quick flights to acquire information; the device is smaller and requires limited setup which allows quicker incident arrival to flight time. The Phantom is most frequently utilized for initial training purposes. The Parrot Disco is a fixed-wing aircraft which can be used during wildland fires. The benefit of this aircraft allows the aircraft to be placed in an orbital pattern which allows for monitoring the progress of the fire. It has a flight time of approximately 40 minutes.

An FAA Part 107 license is the initial training required by this Central Florida Fire Department to be considered for a pilot designation. Additional prerequisites

include six years of department experience, limited disciplinary action in past 18 months, State of Florida, Instructor I certification, State of Florida, Hazardous Materials Technician (preferred), ICS courses, and a recommendation letter from a Lieutenant and Battalion Chief which identifies effectiveness on scene, pertinent certifications, and ability to follow directions. After approval, the candidate is required to complete a 40-hour department specific training course, with 32 hours of documented flight-time in this 40-hour course. Some of the criteria addressed includes 3D capabilities, airspace Microsoft ICE software utilization, flight maneuvers, and map familiarization. The candidate must also renew their FAA Part 107 license every two years at an approved FAA testing location. Once pilot designation is achieved, quarterly training is conducted. Furthermore, documentation of three-day flights and three-night flights must be documented. The region is densely populated and includes a number of airports. All pilots use the Low Altitude Authorization and Notification Capability (LAANC) UAS website (app) and follow-up with a phone call to the air traffic control tower. This partnership has proven to elicit positive results for UAV flight requests and accountability. Furthermore, numerous weather reporting resources are utilized. These resources include Aviation Weather Center, METeorological Aerodrome Reports (METARS), Hover (flight app), and the UAV forecast (app). Drone Sense is also a resource used for flight tracking information. All documentation must be managed appropriately for record-keeping purposes.

This Central Florida Fire Department has developed a UAS program which provides a variety of technologically advanced methods for performing safer operation as well as saving lives and property. They have incorporated augmented reality (AR) into

its UAS operations. The use of AR can enhance the UAV pilot's ability to fly safer; for example, identifying power lines in the vicinity and areas in need of further searching during a search and rescue mission. With AR, the RPIC can be immersed into the UAV flight view while maintaining safe flight patterns and ensuring distractions in close proximity do not negatively impact the mission.

Moverio BT-300FPV is the model of AR smart glasses utilized by this Central Florida FD. The smart glasses allow review of flight statistics and UAV video feed while piloting. These smart glasses are compatible with DJI products and can fit over many styles of prescription eyeglasses. Available reviews state they are lightweight, easy to wear, and functional in direct sunlight. The smart glasses use an android operating system, and the battery life is typically six hours with a full charge (Epson, 2019).

Having the opportunity to see and learn directly from an established program lead clarifies the variety of components that are brought together to create a successful UAV program. It is important to consider all aspects of the program when in the development stages, including laws, qualifications, training, and specific applications which align with department need, as well as determining specific necessary equipment. The information provided during this interview addressed a variety of responses to all three Research Questions 1: How are fire departments currently implementing UAV programs? 2: How can fire service UAV program development be most cost-effective? 3: How can fire service UAV program development and implementation be maximize efficiency?

Summary

A few fire departments throughout the State of Florida and across the United States have created policies, procedures, requirements for a UAV program. The fire

departments referenced earlier have identified this equipment as a viable resource which has proven helpful in a variety of circumstances. Unfortunately, the information available is limited as it pertains to fire departments determining cost-effective strategies and associated risks. Pending further information, it is likely fire departments will continue to 'reinvent the wheel' with varying access to current practices. The literature covered in this section included an overview of UAV technology implementation by local public service agencies, regulatory issues surrounding UAV use by local agencies, organizational factors affecting UAV use and effective implementation, selected case studies about agencies currently using this technology, literature on how other agencies are implementing this technology, as well as its prospects and challenge, conferences and learning opportunities, and a detailed overview of a fire agency UAV program. The next section will review the methodology used for this research study; limitations, procedures, and potential outcomes will also be described.

Chapter III: METHODOLOGY

Overview

The study approach incorporates five elements to answer the research questions. The first element is identifying existing UAV program models currently in operation for at least 10 fire departments across the United States and conducting stakeholder interviews with available agency UAV program leads. The second element is reviewing existing data from the FAA and NFPA 2400 regarding fire department UAV programs. The next element is determining the areas of UAV fire department program development which were challenging or identified as short falls. Followed by determining the areas of UAV fire department program implementation success. The final element consists of sending out surveys to determine how fire departments are currently utilizing their UAVs, as well as what anticipated future uses the program leads foresee.

Procedures

The information identified from articles, first-person reports and survey responses will answer Research Question 1: How are fire departments currently implementing UAV programs? The information from survey responses will be provided in the findings section. Many of the articles published and information provided by first-person reports suggest similar outcomes.

The information identified from articles, information from developed for current UAV programs and survey responses will answer Research Question 2: How can fire service UAV program development be most cost-effective? The results from this

material may decrease time required for research prior to purchase of equipment, overall UAV program needs, and policy development. If current UAV programs share existing guidelines additional time may be saved. Sharing of information may also limit unnecessary purchases of UAV equipment which may not be applicable to the fire department UAV program scope.

The information shared via survey responses will answer Research Question 3: How can fire service UAV program development and implementation maximize efficiency? Understanding how current UAV programs carry out various tasks improves program development by idea sharing, which carries over to improved efficiency of UAV program implementation.

Survey participation was requested through direct contact with UAV program leads, International Association of Fire Chiefs (IAFC) KnowledgeNet Forum request for participation, inquires via fire department webpage contact us sections, Florida Fire Chief Association (FFCA) request for participation; requests for participation was also sent out to U.S. Fire Administration TRADENet. All respondents who expressed interest in completing the survey received the link through Valdosta State University-Qualtrics.

A total of 40 UAV leads were recruited via Qualtrics. The Qualtrics survey was initially sent out on August 28, 2019 at 5:00pm EDT. The survey was open for three weeks, closing on September 18, 2019 at 5:00pm EDT. A total of 19 respondents provided information toward this data collection. The results will be provided in the next chapter.

Potential Outcomes and Importance of Research Findings

Specifics regarding current fire department UAV programs will be identified upon data dissemination, providing a template of current practices based on a sample of at least ten fire departments with UAV programs. The sample size of at least ten fire departments will improve the potential variety of information. Additionally, if numerous fire departments are performing similarly, deploying similar equipment or requiring similar qualifications this may lead to a beneficial direction for a fire department considering development of a UAV program.

Methods for UAV program cost effectiveness will be determined based on current fire department UAV program data. Fire department personnel may implement and maintain their UAV programs differently. Identifying beneficial methods for UAV program implementation will provide valuable end-user information. This positively impacts fire departments considering developing a UAV program. Information sharing improves existing programs in areas not previously considered by a UAV program lead.

Information regarding UAV program development and implementation efficiency will be determined based on current fire department UAV program data. Fire department UAV programs may differ in application. Departmental and community needs vary based on many influences such as hazard, location, population, and topography. Existing fire department UAV programs vary from arson/bomb squads, commercial building fires, hazardous materials reconnaissance, and law enforcement partnerships, to swift water rescue and vehicle extrication. Identifying beneficial methods for UAV program implementation will provide end-user information to enhance service provided to the

respective community considering UAV program development. This information may encourage fire departments to consider additional uses for their existing UAV program.

Approach

A qualitative research approach was utilized; interviewee responses assisted the researcher in identify general patterns. The rationale for this approach is due to limited available quantitative information. Additionally, it is helpful to gather information from the source, in this case from UAV program leads to understand applications of UAVS, equipment used and success stories associated with the implementation of this technology in the public safety sector, specifically the fire service industry. Determining the numerous applications of UAV programs is a trending topic in the fire service. These UAV programs significantly impact municipalities throughout the nation at the public administration level. Improved understanding of how UAV programs have developed in law enforcement and the military, and in combination with how existing fire department UAV programs are being implemented, will help identify current practices which may lead to industry leaders establishing best practices.

Completing this qualitative research required an understanding of components associated with at least 10 fire department UAV programs. Fire department selection was based on geographical locations using the United States map below with the commonly referenced five regions. The United States map below (Figure 5) is colored by the five most common regions: West is red, Midwest is blue, Southwest is dark grey, Southeast is white, and Northeast is light grey. The results section of this research study shows each state represented via UAV program lead survey responses with hashmarks over the respective state.

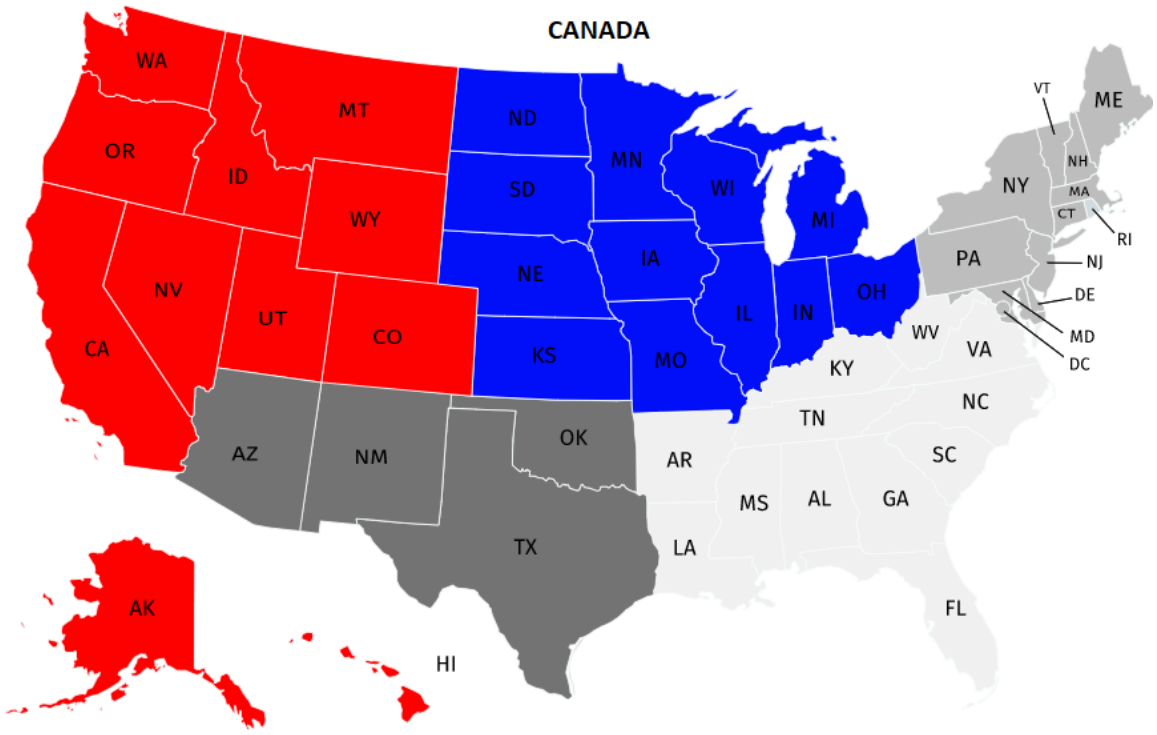

Figure 5: United States map with five commonly referenced regions (Judah, 2019).

An improved understanding was established by fire department UAV program managers identifying areas where they have lost or damaged equipment, where they were inefficient with their program development, and possibly where existing shortfalls reside. Assessing this information will improve cost-effective decision-making for fire departments developing UAV programs in the future.

Research study results are shared within the document below in a meaningful manner, applying modern data visualization, and infographic techniques. The qualitative data, summarized UAV program lead survey responses are also listed in the results section. Each Qualtrics Survey Question is referenced by the associated Research Question(s).

Limitations

This research study has research limitations beginning with funding. All research included in this study was conducted by a doctoral student with no outside funding sources. It would have been possible to complete additional research in additional locations and/or for a longer duration with additional funding. Additional survey responses may have been collected if individuals were compensated for their feedback.

Additional limitations include limited existing vetted research to include journal articles and approved dissertations. The research was also limited to studying existing fire department programs which represent a majority of career (paid) fire departments. The information available regarding volunteer fire department UAV programs is limited. Due to the limited documentation for fire-based UAV programs, current practices and applications utilized by law enforcement will also be referenced.

A convenience sample approach was utilized for stakeholder interviews with fire departments currently operating UAV programs. For the purpose of this investigation, fire departments with established UAV programs were asked to participate in a questionnaire based on geographical location to best capture the UAV presence throughout the United States. For purposes of transparency, the limitation regarding this sampling style demonstrates the participants are not randomly selected.

UAV technology and its public safety applications are ever-evolving. Due to the nature of this rapid development, it is anticipated that policies, procedures or training recommendations will change as technology advances and case studies are shared among fire departments. Compiling data will prove helpful for the industry; however, it is likely

additional research will be needed as the technology is modified and fire department use of the UAVs continues developing.

Summary

Many approaches were considered when determining the appropriate methodology for this research study. I applied a descriptive approach to this study to ensure existing materials were considered, as well as current subject matter experts and regulatory concerns. Each research question will be addressed to include

1. How are fire departments currently implementing UAV programs?
2. How can fire service UAV program development be most cost-effective?
3. How can fire service UAV program development and implementation maximize efficiency?

The results derived from the research, interviews and survey feedback will be provided in the next chapter. Additionally, information related to the research questions will incorporate the theoretical framework to include top-down and bottom-up approach to program implementation.

Chapter IV: RESULTS

Overview

The purpose of this qualitative research study was to identify information available about UAV programs and the fire service. Many topics were reviewed leading up to the conversations and survey distribution. The topics reviewed included technical and operation considerations, command and control, safety concerns for the public and firefighters, public support, overall effectiveness, and acquisition. Information was also identified to include UAV capabilities, FAA requirements, National Fire Protection Association (NFPA) standards.

Protection of Data

All information collected for this research study is password-protected. No specific information to include names of individuals or organizations have been released without prior approval. All data collected through Qualtrics is password protected and accessed through Valdosta State University's data management system.

Descriptive Data

Analysis of research data has been completed using a descriptive approach. Survey participation was requested through means of direct contact with UAV program leads, International Association of Fire Chiefs (IAFC) KnowledgeNet Forum request for participation, inquires via fire department webpage contact us sections, Florida Fire Chief Association (FFCA) request for participation, and request for participation was also sent

out to U.S. Fire Administration TRADENet. All respondents who expressed interest in completing the survey received a link through Valdosta State University-Qualtrics.

Institutional Review Board approval was gained by Valdosta State University. The Qualtrics survey was developed and reviewed prior to submission to the IRB. The survey had 26 questions total (Appendix B). The last four questions are more general questions specific to respondents versus content about the UAV programs they manage. All raw data collected through Qualtrics for each survey question was succinctly summarized below as well as the survey questions relation to each respective research question.

Trustworthiness/Credibility

Consideration was made by limiting the timeframe in which data was collected. This three-week window limited responses to a specific timeframe. Ideally no significant challenges, concerns, or notable events occurred during this time which may skew survey responses. To the researcher's knowledge, no known UAV events occurred during this timeframe.

The survey instrument was original to the data specifically identified for this research. The survey respondents were a part of a convenience sample; however, no one was compensated for their participation. Additionally, all information provided to UAV program leads completing the Qualtrics survey was identical. The emails were generated through the data collection tool, and the consent and following survey questions were formatted the same for each participant. The researcher is aware of investigator bias and is sharing descriptive information in the results section. This material has been

summarized from the individual raw data responses; however, all information is factually based on the data provided to the researcher through the Qualtrics survey.

All participants communicated with the researcher prior to receiving a survey link. It was hoped that each participant would agree to completing the survey once the Qualtrics survey link was received. One hundred percent of the 19 participants agreed to complete the survey. The findings from their responses are enclosed below. This question was provided in accordance with the Institutional Review Board (IRB) requirements outlined by Valdosta State University. IRB Basic Course completed prior to beginning research project in accordance with Valdosta State University requirements. Appendix A.

Summary of Findings

Most of the participants (approximately 58%) identified their respective UAV programs were operational from one-to-three years. Some (approximately 21%) had UAV programs for at least three, and as many as five, years. Few (approximately 11%) had UAV programs for either less than a year or more than five years. Identifying this information regarding the length of time these UAV programs have been in place is in reference to Research Question 1: How are fire departments currently implementing UAV programs? It is essential to understand which operational phase each fire department agency is currently experiencing. It is reasonable to believe that communicating with fire department agencies with a UAV program which has been in place a longer duration of time may aid fire department agencies just beginning a UAV program. Identifying this information at the beginning of the survey can also assist in understanding the potential in a variety of responses to the questions listed below. A

response from a fire department agency who has been operational with their UAV program for more than five years may respond in additional detail as compared to a fire department agency just getting started or operational less than one year.

Figure 6: Stacked Bar Chart of UAV programs (Judah, 2019).

Twenty-six percent of respondents elicited assistance from fire department agencies with operational UAV programs. Austin FD was specifically mentioned as a fire department agency where assistance was sought, as well as an EMS agency, social media groups, and a police department. Twenty-six percent of respondents did not elicit assistance from an outside agency, business, or partner with a college/university. Two respondents worked closely with Skyfire Consulting near Atlanta, Georgia, and one respondent sought out assistance from FlyMotion near Tampa, Florida. At least three respondents stated their fire department agency provided assistance to agencies beginning to develop a UAV program. Two respondents sought out assistance from a consulting agency to complete their Jurisdictional Certificate of Waiver (COA) forms. Identifying information as it relates to cost-effective program development and most efficient methods for program development and implementation references Research Question 2: How can fire service UAV program development be most cost-effective? as well as Research Question 3: How can fire service UAV program development and implementation maximize efficiency? Efficiency and cost-effective decision-making can be improved by determining methods existing UAV program leads have gone about

acquiring information and obtaining assistance from various outside subject matter experts, such as consultants.

The majority of respondents (84%) stated their UAV program was funded by the fire department operating budget. Another twenty-six percent of respondents stated their UAV program was funded at least partially by donations. Fewer respondents, 21%, stated their UAV programs were funded at least partially by Department of Homeland Security funding. It is important to ascertain what funding sources are successfully sought and acquired for UAV programs, which may lend to discovering funding sources which have not been sought out previously, such as forfeiture funds. Just one respondent stated their UAV program is at least partially funded by forfeiture funds, this may be a consideration other UAV program leads can make when seeking out funding for program development or enhancement which relates to Research Question 1: How are fire departments currently implementing UAV programs? 2: How can fire service UAV program development be most cost-effective? And 3: How can fire service UAV program development and implementation maximize efficiency? Securing funding for establishing and/or maintaining UAV programs impacts the implementation, cost-effectiveness as well as overall program efficiency.

Figure 7: Bar Chart of UAV program funding sources (Judah, 2019).

Additional survey questions inquire about additional funding sources utilized by respondents' UAV programs not previously indicated. Additional UAV funding sources included grants and paying costs out-of-pocket for aircraft and 107 certifications. Grants for this technology included a federal grant, fire foundation grant, an innovation capital grant from a city program, and local electric membership cooperatives. A unique donation source mentioned was the donation of a UAV. One participant noted

> One donation aircraft was received by a local contractor who made the contribution after we discovered a potential serious safety issue with tilt-up construction concrete panel that a brace had broken, the brace was discovered by a construction site flight with a UAV. Ultimately, we identified the unsecured panel, it was supported and secured without incident. The construction company was extremely appreciative and made the donation.

Fire department agencies often have opportunities to support their communities in a variety of ways. As illustrated, one example where a construction site flight where trained eyes were able to identify a significant problem before a catastrophic event occurred. The content provided herein relates to Research Question 1: How are fire departments currently implementing UAV programs? 2: How can fire service UAV program development be most cost-effective? And 3: How can fire service UAV program development and implementation maximize efficiency? Creative funding sources or donation opportunities may be available for an organization with a limited fire department operating budget. Having the ability to network and search for additional prospects may aid in establishing and/or maintaining UAV programs impacts the implementation, cost-effectiveness as well as program efficiency.

Over 78% of respondents stated their UAV program required operators to complete a fire department specific program related to the utilization of UAVs. Additionally, 74% of respondents stated their UAV operators were required to obtain an FAA Remote Pilot Certificate. Three respondents identified alternative certifications were required by their fire department. This question relates to Research Question 1: How are fire departments currently implementing UAV programs? And 3: How can fire service UAV program development and implementation maximize efficiency? Understanding what certification requirements are in place by the respondent's respective organization may assist UAV program leads who are developing or improving their program to determine what requirements they should consider.

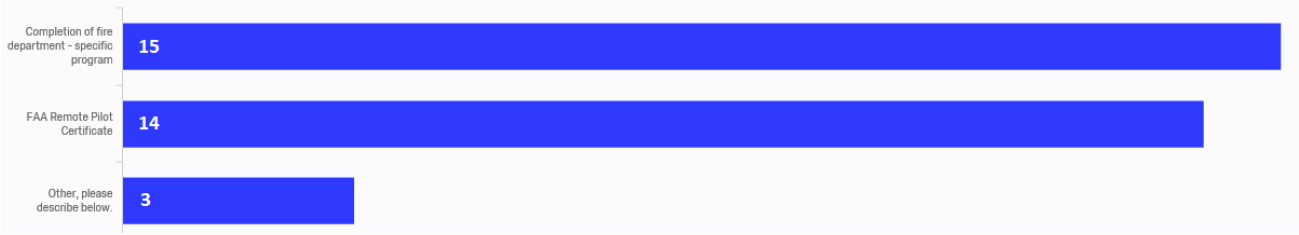

Figure 8: Bar Chart of UAV program training requirements (Judah, 2019).

Eight respondents stated specialized courses, such as special operations, hazardous materials, and incident management classes were required of their UAV operators. Some planned to send all UAV operators through the FAA Part 107 Pilot Certificate program and will soon initiate department-specific training opportunities. Upon receiving a night waiver, one UAV program lead planned to instruct courses related to this type of flying. One respondent supported the overall research problem statement; "Lack of standardized qualifications and training led us to choose this as a minimum, but with the evolving information we will be modifying our requirements in the near future."

It is important fire department agencies remain flexible, adjusting their programs as more standardized qualifications and training develop. This content will likely be more definitive after the NFPA FEMA grant for UAV programs is completed. Lastly, one respondent from Canada stated their UAV operators are required to complete the Transport Canada Advanced Pilot certification as well as advanced internal competency evaluations. This question and responses align closely with Research Question 1: How are fire departments currently implementing UAV programs? And 3: How can fire service UAV program development and implementation maximize efficiency? As mentioned previously, understanding certification requirements and remaining flexible as more standardized approached are developed will remain essential for continued success of fire department UAV programs.

Responses regarding the number of UAV operators for fire department agencies ranged from one to over sixty with an average of 13 and a median of 10 UAV operators. One respondent stated their UAV operators are employed by different agencies; three are fire departments, three are public works, and two are parks and recreation personnel. Lastly, one respondent stated they currently have 10 UAV operators with future expansion planned to include six additional personnel. This information aligns with Research Question 1: How are fire departments currently implementing UAV programs? It is important for UAV program leads who are planning to develop a program or improving their existing program to understand how many UAV operators may be involved. Accessing this material for the context of defending a need for personnel, possibly for a larger fire department agency may be helpful.

Thirty-seven percent of respondents stated they have both COA and UAV operators have FAA Part 107 certification, otherwise known as dual certified team. Fewer respondents, 21%, stated they have a COA or FAA Part 107 certification for their UAV operators the time of investigation. One respondent stated the reason their fire department agency does not have a COA is because the airspace does not require it. Another participant reported applying for a COA; however, they are experiencing extreme difficulty with acquiring approval by FAA in the New Jersey area. An additional respondent stated, ". . . the city obtained a blanket COA under their name for the police department. I was told that all we need is approval from the city (letter) stating that we have approval to fly under the existing COA." This information relates to Research Questions: 1. How are fire departments currently implementing UAV programs? 2. How can fire service UAV program development be most cost-effective? As well as 3. How can fire service UAV program development and implementation maximize efficiency? It is important to understand how existing UAV programs are operating as it relates to legalities. The legal department at an organization considering the implementation of a UAV program may want to review current practice by other agencies. Consulting the legal department early when developing policy and requirements may aid in the swiftness of program approval. Understanding the legalities and up-front cost to certify UAV operators must be known early on when determining start-up and program expansion costs. Depending on the UAV program and COA vs. FAA Part 107 will also impact flight capabilities. This is important to be aware of as it relates to implementation strategies.

Just over half of respondents, 55%, stated their fire department currently have night flight procedures. Whereas 31% of respondents currently have BVLOS procedures incorporated into their UAV program. Eight participants cited currently-developing BVLOS procedures or planning to do so in the near future. Some of the respondents were delayed in implementing BVLOS and/or night flight procedures due to a lack of required additional training. One respondent noted the training needed specifically is in regard to visual observers for night operations. One respondent stated, ". . . very specific guidelines in our operational manual exist for these flights, with a constant pilot intervention to find an alternative LZ if needed." Two respondents were awaiting installation of anti-collision lights on their UAVs prior to implementing night flight operations. Another participant provided a detailed explanation for their planned approach when encountering a need for night flight operations:

> We do have a procedure for flying at night which will be implemented once we receive our COA with night flight exemption. The procedure includes steps we will follow to ensure night operations are conducted in a safe manner. Examples include staffing additional visual observers, having anti-collision lighting, only flying at night with FLIR equipped UAVs, and procedures in the event a visual observer loses sight of the UAV or the UAV loses connection with the remote. Policy aside, we have and will fly at night without a waiver in support of a life-saving mission.

Understanding UAV program development and implementation is essential for new UAV program leads as well as established UAV program leads interested in ensuring their approach is most effective with the industry standard as more standardized

information becomes available. The concepts of both BVLOS and night flight operations may be new to some fire departments considering the development of a UAV program. It is also important to consider the additional components required for these UAV operations to include training, lighting, and additional personnel to fill positions such as visual observer. This information relates to both Research Question 1: How are fire departments currently implementing UAV programs? And 3: How can fire service UAV program development and implementation maximize efficiency?

The types of incidents requiring UAV response (see Figure 9) listed below are in frequency order. The most popular type, which was recognized as an incident type in which all UAV program lead respondents, stated they utilize UAVs on, are training evolutions. Captured footage can be a valuable training aid for the department as well as other organizations if the information is shared. Additionally, the captured footage can be seen used for recruitment. The next most common incident types are hazardous materials, large-scale events, as well as search and rescue with 95% of respondents stating UAVs are employed for these incidents. The next three incident types were identified by 90% of participants as instances in which the UAVs are deployed by their respective organization. The three incident types include commercial and residential fires, pre-incident planning, and water rescues. Other incident types identified by UAV program leads include brush/wildland fires, post-fire investigations, traffic incidents, high-rise fires, recruitment, explosive ordinance disposal, hostage, and barricade situations (SWAT). Understanding UAV program development and implementation is essential for new UAV program leads as well as UAV program leads interested in ensuring their UAV application and use is most effective with equipment and staffing

capabilities. When UAV program development is taking place, it is important for the fire department agency to consider the expectations of the team: What type of incidents are a priority? It is possible that incident type and priority may change as an agency determine team capability and accessible equipment. It may also be beneficial to partner with neighboring departments who have differing capabilities. An example of this is with the hostage and barricade situations (SWAT) incidents. It is possible the local law enforcement agency calls upon the fire department for UAV assistance. This content relates to Research Question 1: How are fire departments currently implementing UAV programs? 2: How can fire service UAV program development be most cost-effective? As well as 3: How can fire service UAV program development and implementation maximize efficiency?

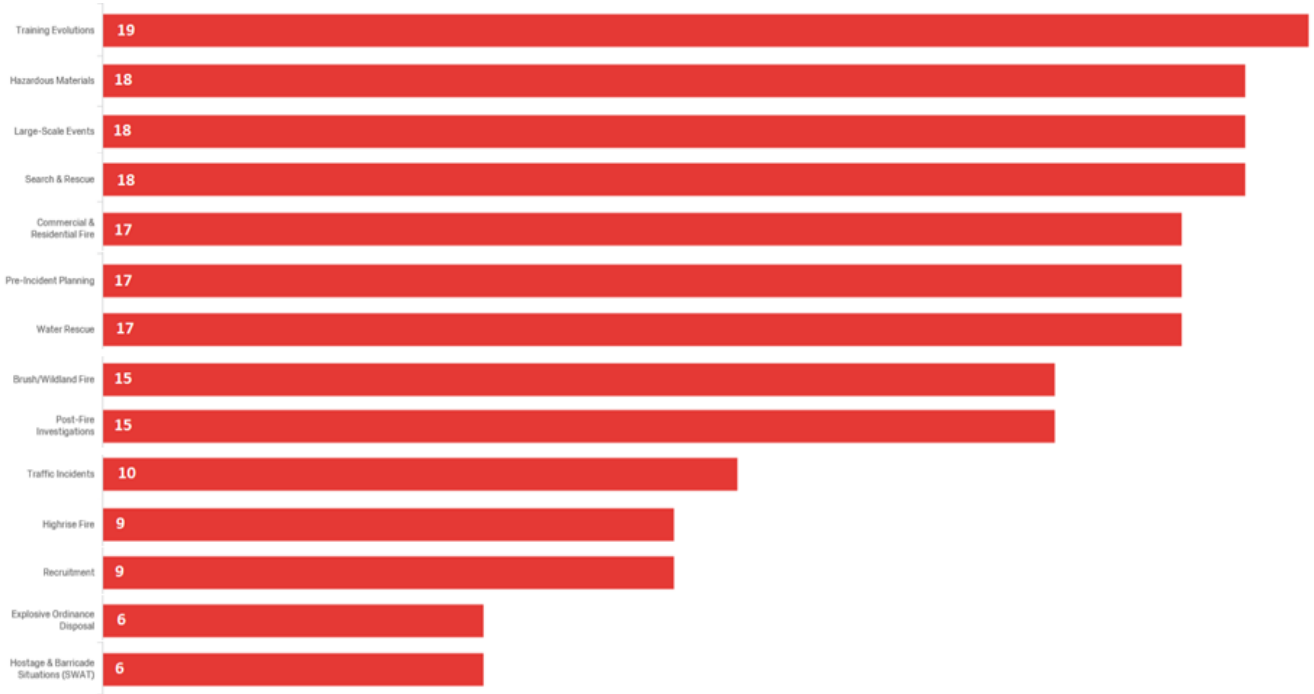

Figure 9: Bar Chart of UAV fire department applications (Judah, 2019).

In addition to incident types, sample members provided a variety of instances where their UAV program would utilize their equipment. Two respondents stated they assist water departments in their local area as it pertains to infrastructure, storm water tracking specific to road and bridge water run-off. Another respondent shared their agency assists with emergency management, damage assessments, such as assessing bridges for structural damage following earthquakes. They also partner with other city departments for their needs and city promotional video/photos and community education events. One respondent stated one of their largest uses has been spring flooding from the ice-jammed river which runs through the city. These missions span many days and over 30 miles of river, assessing ice and water conditions. Another example provided included pre- and post-storm damage assessments. Assistance has been provided to the local police department by flying the UAVs for accident and crime scene mapping. Special operation were mentioned as an incident type in which one of the respondents stated their UAV program deploys for, specifically trench and rope rescue. Another respondent stated they have deployed their UAVs for brush clearance operations. Lastly, a respondent stated that in addition to damage assessment, severe weather, GIS mapping, training and planned events, the agency deploys their UAV fleet to assist county maintenance department with roof inspections of county buildings, and they respond to calls for assistance from law enforcement agencies looking for suspects/fugitives in woody or brushy areas. Understanding UAV program development and implementation is essential for new UAV program leads as well as UAV program leads interested in ensuring their UAV application and use is most effective with equipment and staffing capabilities. It may also be beneficial to partner with neighboring departments who have

differing capabilities. Calls for service can increase dramatically once the area is familiar with the accessibility to UAV equipment and personnel. In these instances, it can become critical to determine what operations will be conducted by the corresponding fire department agency. The information listed relates to Research Question 1: How are fire departments currently implementing UAV programs? 2: How can fire service UAV program development be most cost-effective? As well as 3: How can fire service UAV program development and implementation maximize efficiency?

Just over half of the respondents, 55%, stated their agency's deployment strategy includes always-on (24/7) accessibility. The other 45% of respondents stated their deployment strategy is more of an on-call approach. A variety of deployment strategies were received by respondents and will be shared below. One respondent's fire department is entirely volunteer; their UAVs are stored on two apparatus and each of the Chief vehicles are equipped with Mavic Pros. Another respondent stated their UAV equipment is ready and kept in a storage room. Callback for personnel is completed using an application called Active 911 and Mutual Aid Box Alarm System (MABAS). One respondent stated they have converted a surplus aid car and store the entire program inside one of fire stations. Another respondent stated each shift pilot has initial operational UAV on the engine company, and more complex platforms can be called out when needed with a one-hour response. One respondent stated their organization has two, two-person teams strategically placed on opposite ends of the county and operate on a 40-hour work week schedule, as well as availability on call for extended operations.

Many respondents stated a incorporating a combination of personnel, both on-shift and staff. One example is utilizing two, 40-hour personnel on-call who complete

emergency management and fire investigation functions. If those two personnel are not accessible due to already being dedicated to an incident, a secondary trained team is approved to acquire staged UAV equipment. The remaining responses cover 24/7 capability and deployment strategies. Four respondents stated some form of participation from their agency's Battalion Chief vehicles. One agency's deployment strategy utilizes the hazmat apparatus, which is continually staffed. This apparatus responds to all hazmat incidents, structure fires and all other UAS requests. Another respondent stated the agency stages equipment in four corners of our county with pilots and larger aircraft on their hazmat unit. A separate respondent stated their UAV program is available 24/7 with two firefighters and one company officer from their headquarters. Another respondent stated their larger equipment, such as the Matrice 200, is kept with the emergency managers' office at the main fire station.

The last example appears to tap into fire prevention resources. The agency has investigators on 24-hour shifts. The investigators response vehicle is setup with the UAVs, as well as large video monitors which can be operated as needed. The fire department photographer carries a UAV to capture essential photos on scenes when the investigators are preoccupied. The Fire Marshal and Deputy Fire Marshal are also on-call and carry UAVs equipment. As a UAV program lead, it is helpful to be aware of a variety of deployment strategy that work for fire department agencies. At this time there is not a set method which must be implemented. It is possible as the fire department agency or UAV program develop the deployment strategy with shift, possible from on-call to a 24/7 capability. This information is related to Research Question 1: How are fire departments currently implementing UAV programs? 2: How can fire service UAV

program development be most cost-effective? And 3: How can fire service UAV program development and implementation maximize efficiency?

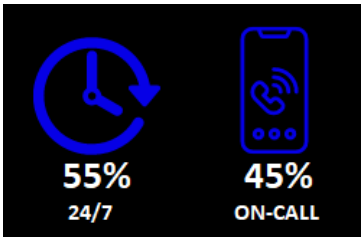

Figure 10: UAV deployment models (Judah, 2019).

At the time this survey was completed, 63% of respondents stated their fire department experienced loss or damage to UAV equipment. Upon speaking with agencies, it became apparent that sometimes minor damage could be repaired quickly with little to no cost. However, it is important to consider the cost of loss or damaged UAV equipment for each fire department agency contemplating the development of a UAV program. These topics are important to navigate before the incident occurs, as many UAV operators will share that it is not an *if* the agency will experience loss or damage, but more of a *when* will it occur. This information pertains to Research Question 1: How are fire departments currently implementing UAV programs? And 2: How can fire service UAV program development be most cost-effective?

Five respondents stated that the agency's UAV equipment is all insured. One agency specified that the equipment is insured to not only cover the loss but the difference in cost to a comparable project. One agency uses VFIS insurance for their UAV equipment. Forty-two percent of respondents stated that there is incident review following any damage or loss of UAV equipment. The personnel responsible to conduct the review/investigation vary from UAV Program Manager, Deputy Chief, Chief of Department, and Safety Committee. Additionally, one respondent specified if any

personnel are injured during the UAV equipment damage or loss, the health and safety committee also completes a review of the incident. If necessary, the agency may communicate directly with the UAV equipment manufacturer to ensure they are aware of faulty equipment. Overall, most damage reported was minor and repaired in-house. However, one detailed incident involving damaged UAV equipment was shared by a respondent who

> . . . had a new pilot, during training, violate one of our guidelines and fly with a less than 100% battery, he lost focus and ran the UAV to the minimum, where the UAV settings were not properly set at Pre-flight, and the aircraft started toward a tree, the pilot took back control, and made a rough landing causing several hundred dollars damage. An accident investigation was completed, and corrective actions made to ensure the highest level of safety. To date our team has logged over 1 billion flight feet with no other incidents.

It is important to consider the cost of loss or damaged UAV equipment for each fire department agency contemplating the development of a UAV program. Additionally, it is essential to communicate with the agency's legal department to determine if insurance is required or advised on purchases over a certain dollar value. These topics are important to navigate before possible incident occurs. This information pertains to Research Question 1: How are fire departments currently implementing UAV programs? And 2: How can UAV program development be most cost-effective?

In order to understand current implementation of fire department UAV programs, the UAV program leads were requested to share their existing equipment cache. The most frequent response for equipment brand was DJI. There is a variety of DJI

equipment available. Additionally, it is expected that equipment options will continue to expand as the industry continues to flourish. The most frequent UAV type provided by respondents, with 49 mentioned, was DJI Mavic. One UAV program lead mentioned the agency has five Mavic's total; however, one is dedicated to training. Variations of this equipment were referenced, such as Air, Enterprise Dual, Platinum, Professional, and Zoom. The DJI Phantom was mentioned 14 times by respondents. One agency UAV lead specified their DJI Phantom is for training purposes only and is not insured. DJI's M100 and M600 were mentioned one time. The M200 was cited four times, whereas the M210 was mentioned ten times. One agency UAV lead specified, "budget plan in place to replace with upgrade unit in 2020, possible M210 or other comparable." DJI's Inspire was cited ten times. One agency UAV program lead stated that the Inspire has interchangeable video and thermal, and they're the go-to UAV for the majority of operations. The other equipment mentioned were DJI Goggles, Hoverfly Live Sky Tethered (3), Parrot Be-Bop (2), Parrot Disco, fixed wing (2), Parrot Thermal Pro (2), Spark (3), Typhoon H Yuneec, XT FLIR Camera (1), and XT2 FLIR (2).

This content is affiliated with Research Questions 1: How are fire departments currently implementing UAV programs? 2: How can fire service UAV program development be most cost-effective? And 3. How can fire service UAV program development and implementation maximize efficiency? Becoming aware of the types of products being utilized by fire department agencies may be helpful when requesting equipment for a respective agency. Additionally, this information shows that DJI appears to be the predominant company providing UAVs for public safety application. Reviewing what other fire department agencies are utilizing may help in steering an

agency away from using equipment which may not be practical. Efficiency can be difficult to determine as it pertains to equipment purchases, especially with purchasing of technology. It is likely the equipment utilized in 2019 may be outdated by 2021 with advancement in technology, important to note as it relates to budgetary restraints.

It is important for UAV program leads to ensure their UAV software is updated. There are a variety of methods in which this can be successfully completed. The responses range from daily to weekly and as needed to when the device is turned on. This activity can be done by a variety of personnel. Respondents stated pilots may complete the updates, shift investigators, UAV operators, emergency manager, UAS Coordinator or team lead, and one respondent specifically mentioned a team subject-matter expert for each UAV system. One respondent shared that their UAV program manager obtains technical assistance from lab specializing in drone forensics as needed. This information is helpful to ensure UAV program leads complete various updates when necessary. Device program updates is something that if overlooked can cause undesirable challenges for the fire department agency. This information pertains to Research Question 1: How are fire departments currently implementing UAV programs? And 3: How can fire service UAV program development and implementation maximize efficiency? Understanding how existing UAV programs are managed as it pertains to software updating is helpful to ensure a prospective agency ensures this is defined during program development. Additionally, by reviewing other agency approaches, a potential fire department agency considering a UAV program may find an efficient method for software updates they may not have considered previously.

The two most frequent responses to questions about successful UAV operations involve fire related incidents, such as commercial and manufacturer buildings, as well as search-and-rescue incidents. The next most frequent responses involved hazmat incidents and incidents involving suicidal persons. One success story involved the investigation of a potential building collapse that could not be assessed from the street. The UAV footage resulted in an emergency condemnation of the building and immediate demolition due to public safety hazard. The same agency also utilized thermal images of a large commercial fire to direct crews that were unable to find the seat of the fire and assisted their city video production office with aerial imagery. Additionally, one respondent mentioned their agency's UAV equipment is frequently summoned to document LEPC exercises.

Another respondent shared that their fire department agency has completed multiple fatal fire investigations, and three police jurisdictions call out UAV resource on all fatal accidents. One agency stated they supported interior assessment of an industrial explosion with the State Fire Marshal office and OSHA. One respondent shared that their agency has supplemented line of duty death investigations with the use of UAV equipment. Another respondent shared they've utilized the UAV equipment to complete post-fire review and searches of drowning victims. One respondent stated

> Our department was an early adopter of UAS augmented hazmat response in the fire service. We've enjoyed being a leader in this industry. We've been fortunate to have many success stories but the biggest impact UAS has had in our response doesn't usually make headlines. It's because our systems are used for the dull, dirty and dangerous parts of our response. The information gathered gives us an

enormous amount of information that was otherwise difficult or dangerous to obtain with personnel.

Additional feedback identified a respondent stated they have experienced tremendous success responding to SWAT calls in mountainous terrain. Utilizing FLIR camera technology equipped personnel with pertinent information involving a suspect shooting a long rifle. This incident ended with the suspect being safely apprehended. Furthermore, a couple was out bike riding in a rural country area. The woman collapsed from a heart attack and the husband performed CPR. Subsequently, dispatchers were able to triangulate their GPS coordinates and deploy a UAV to the location which led rescue personnel to the location to render aid and transport. Lastly, an example was shared regarding the use of UAV in coordination with helicopters and brush truck operations in the midst of extinguishing a fast-developing wildland fire. Understanding the variety of potential applications for UAV equipment may be able to increase buy-in from senior staff. The versatility of this equipment is displayed in these success stories as well as in the specific applications listed in previous responses. This data is related to Research Questions 1: How are fire departments currently implementing UAV programs? And 3. How can fire service UAV program development and implementation maximize efficiency?

Thirty-one percent of respondents indicated they experienced challenges with education/buy-in and funding for their respective UAV program. Respondents went on to share that agency administrators, city officials, and department buy-in is really where the challenge is presented. Whereas 12% identified FAA, interference, training and public perception as challenges they've experienced as it relates to their agency's UAV

program. One respondent stated that their deployment model has been challenging because half of their fire district is controlled airspace. Another noted the necessity of educating fire and police personnel to request UAV resources early. As it pertained to planning and development, one respondent noted their initial grant grossly underestimated time requirements. Three respondents shared ongoing challenges associated with radio interference and radio frequency spectrum saturation which has impacted their effectiveness and range. Lastly, one respondent stated managing the perceived fear of public perception has been challenging to navigate. Overall, these challenges may be experienced by an agency currently developing or already implementing a UAV program. It is significant to document various challenges to help avoid "blind spots" for agency UAV program leads who may have not encountered potential issues. Identifying existing challenges can also help with transparency for supporting personnel to buy-in and understand potential issues which may arise. This information relates to Research Questions 2 and 3 of the present study.

A variety of software options and applications can be downloaded to assist in preparing for and/or completing a UAV mission. Six respondents shared that their fire department UAV program used B4UFLY. This application is available for free on Apple and Android devices. The application provides information regarding whether it is safe to fly or not and interactive maps are available with filtering options. Information is also available that provides insight on the area's critical infrastructure, special use airspace and temporary flight restrictions. 800WXBrief, Airmap, DJI Go, Drone Deploy, Drone Sense, KittyHawk, LAANC, Litchi, Map Pilot, National Weather Service, Pix4D, SARTopo, UASidekick, and UAV Forecast. One agency stated that their department

asks personnel to avoid sharing IT, software applications, and protective systems information. Two agencies shared their overall expectation regarding pre- and post-flight information gathering and documentation. The use of checklists was also shared and should be strongly considered by agency's developing UAV programs. This information pertains to Research Question 1: How are fire departments currently implementing UAV programs? And 3: How can fire service UAV program development and implementation maximize efficiency? It is imperative to consider available resources. Cost may cause an agency to use a different software program. It is also possible monthly costs for software will prohibit an agency from considering utilization of a specific resource. It may be possible to request a trial period to determine if the software or service is practical for the respective agency prior to commitment and purchase. Documentation of flights is an important aspect to consider when developing and/or maintaining a UAV program. Software and use of checklists may contribute to concise documentation. Brief descriptions of the applications, phone numbers and software
are provided in Appendix D.

The amount, type, and complexity of information stored will depend on the documentation required by the respective agency's UAV program and legal team. It is important to ensure all data is captured in compliance with the agency's retention policy, if applicable. It is possible, depending on the state of the UAV program, the data captured could be open to public records request or logged as evidence depending on the authority having jurisdiction. Agency UAV program leads indicated they are saving data a few different ways: by cloud-based technology, SD cards or the agency server as indicated by Figure 11. It is important to identify roles and responsibilities when

developing as well as maintaining a UAV program, to include data capturing and storing procedures. The information pertains to Research Questions 1: How are fire departments currently implementing UAV programs? And 3: How can fire service UAV program development and implementation maximize efficiency?

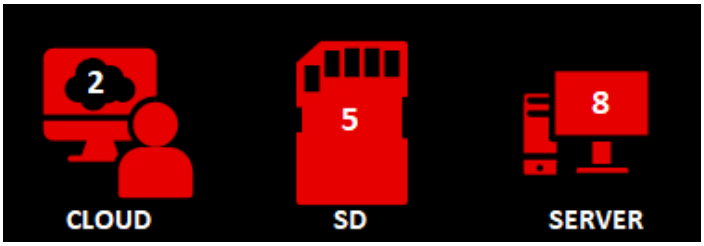

Figure 11: UAV data storage (Judah, 2019).

Thirty-eight percent of respondents referenced expected advancement or changes to equipment. Thirty-three percent of respondents referenced expected increased number of operators and advancement of technologies/capabilities. Fewer, just 22% of respondents, referenced expected advancement or changes to the fire department budget. Some respondents mentioned anticipated changes with the budget regarding operations coordinator position, additional training opportunities, upkeep and maintenance costs, as well as funding for specific equipment, such as a DJI Matrice with FLIR Camera. Other respondents expect changes to their deployment model, becoming a 24/7 resource to their organization. Another respondent stated they plan to incorporate live streaming capability. Another agency is working to implement an enterprise level CAD with integrated semi-autonomous system available for public safety dispatches.

It is helpful to review a variety of agency approaches and expected areas of growth. Whether they UAV program lead has one year of experience or more than five

years of experience, it is always helpful to review available information as well as current practices. This information relates to Research Questions 1: How are fire departments currently implementing UAV programs? 2: How can fire service UAV program development be most cost-effective? And 3: How can fire service UAV program development and implementation maximize efficiency? The methods utilized by organization, cost-effective strategies or areas requiring more attention as well as development and implementation approaches are covered when considering what agencies are interested in incorporating into or expanding their UAV program capability.

The remaining survey items were questions specific to respondents' vis-a-vis content about the UAV programs they were responsible for. This question inquired as to which state the agency is located in which they're a UAV program lead. One of the goals of this research project was to receive representation throughout the country, as opposed to one specific region or state. The United States map in figure 12 is coded by the five most common regions: West is red, Midwest is blue, Southwest is dark grey, Southeast is white, and Northeast is light grey. The states with hashmarks are represented in this study. Although this study derived from a convenience sample, four of the five regions were represented with respondents. Additionally, one respondent represented a UAV program located in Canada. Overall, the locations represented in the study include: California, Canada, Colorado (2), Florida (4), Georgia, Indiana, Michigan, New Jersey, New York, North Carolina, Ohio (2), Oregon, and Washington (2).

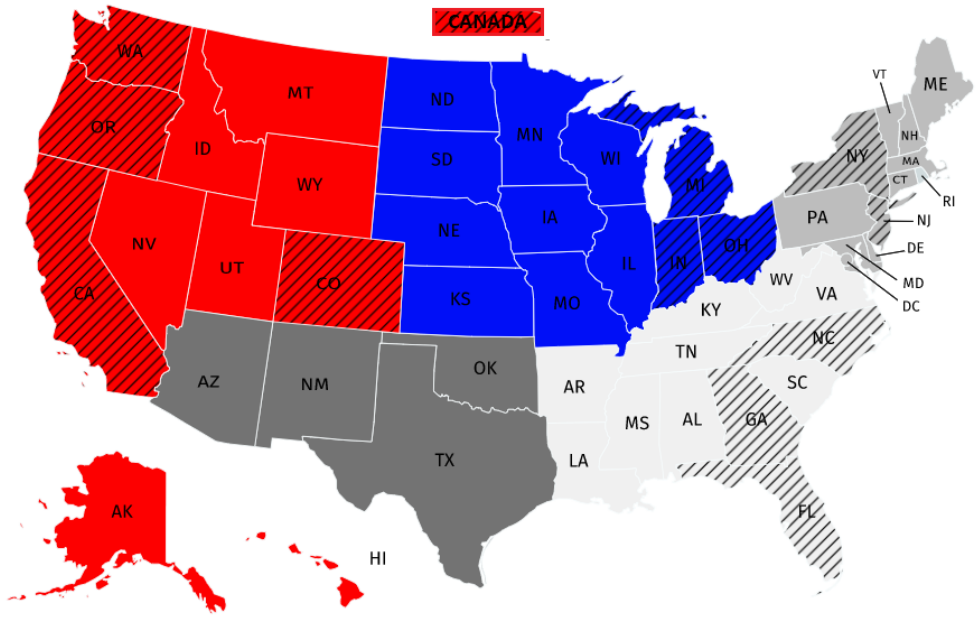

Figure 12: United States map with five commonly referenced regions (Judah, 2019).

Additionally, as depicted in Figure 13 below, 14 respondents were from career fire department agencies, 4 respondents were representing combination fire department agencies and 1 volunteer fire department agency was represented throughout this study.

Figure 13: Bar Graph for fire department type (Judah, 2019).

From figure 14, there appears to be no connection between the size of the agency and the likelihood of their being a UAV program. Seven respondents shared that their agency has between one and five fire stations, whereas six respondents shared that their agency has greater than twenty-one fire station. This information may be helpful to

disprove claims that an organization with just a few stations are not able provide UAV resources to their community.

Figure 14: UAV program and number of fire stations (Judah, 2019).

One of the goals from this research was to link the implementation theory to fire department UAV programs. It may be helpful to identify the rank of each UAV program manager. Nine UAV program managers are at the Chief Officer level, while ten program managers are below the Chief Officer level. The ranks specifically represented throughout this study include Fire Chief, Former Fire Chief, Deputy Chief of Operations, Deputy Chief (2), Assistant Chief, Deputy Fire Marshal (2), Battalion Chief, Emergency Manager, Captain (3), Senior Training Officer, Engineer (2), and Firefighter (3).

Summary of Findings

The goal for survey completion was initially described as at least 10 respondents. The researcher documented 19 total survey respondents for the survey which was to be completed only by UAV program leads. The number of participants may seem low; however, of the thousands of fire departments throughout the United States, there are not many documented fire department UAV programs.

Descriptive

Four demographic questions were included as part of the data collection process. The information included location of the UAV program, type of fire department (career, combination or volunteer), how many fire stations per agency and the rank/position of the survey responder. Overall, 12 states were represented as well as one respondent located in Canada. The UAV program locations included California, Canada, Colorado (2), Florida (4), Georgia, Indiana, Michigan, New Jersey, New York, North Carolina, Ohio (2), Oregon, and Washington (2). Of the 19 respondents, 14 represented a paid fire department UAV program. Four UAV program leads represented a combination fire department, and one volunteer agency was included in this study. There were five categories to select from as it related to the number of fire stations represented the UAV program lead. Seven respondents indicated their organization had one to five fire stations. Six respondents noted their organization represented more than 21 fire stations. The rank/position represented by this study includes Fire Chief, Former Fire Chief, Deputy Chief of Operations, Deputy Chief (2), Assistant Chief, Deputy Fire Marshal (2), Battalion Chief, Emergency Manager, Captain (3), Senior Training Officer, Engineer (2), and Firefighter (3).

How are fire departments currently implementing UAV programs?

More than half of the respondents stated their organization's UAV program was operational for three years or less. This helps confirm that the technology is relatively new, and it is likely additional research will be necessary on this topic in years to come. Additionally, it is useful to know that some of the respondents stated their organizations UAV program has been operational for more than three years. This information is

pertinent as it relates to interested fire departments seeking UAV program assistance from existing UAV program leads.

Current UAV program leads indicated several methods of UAV program funding. Over 80% of respondents stated at least one method of funding for their agency's UAV program included the fire department's operating budget. Other funding sources listed included donations, forfeiture, homeland security, and local emergency planning committee funds. It is helpful for existing UAV program leads to identify this information in the event an interested agency has not considered alternative funding sources.

Standardization of certification requirements has been a discussion point for many UAV program leads. Over 75% respondents stated their agency's UAV program requires UAV operators to complete a fire department specific program, whereas just over 70% stated their UAV operators are required to obtain the FAA Remote Pilot Certificate. UAV program leads also indicated specialized courses are required of some agency's UAV operators to include hazardous materials, incident management, and night flight training. Understanding how fire departments are currently navigating the certification requirements can be helpful for an agency developing a program as well as enhancing an existing fire department UAV program.

In addition to individual certification requirements for UAV operators, one of the survey questions inquired about the agency's approach to over team documentation. Nearly 40% of respondents stated they acquired both a COA and FAA Part 107. Additional rationale was provided by some UAV program leads to include the agency's airspace did not require a COA. Another respondent stated they have applied for a COA

but are experiencing extreme difficulty with acquiring it in the New Jersey area. It is beneficial to understand what fire department agencies with existing UAV programs are doing as it relates to documentation. Communicating with existing UAV program leads and coordinating with the FAA may be helpful to an agency considering the development of a UAV program.

The respondents indicated a variety of responses for the number of UAV operators they have involved with their respective UAV program. The average of the 19 responses was 13 UAV operators. However, a few responses indicated more than fire department personnel are involved with the UAV program. Examples include emergency management, parks and recreation, and public works personnel. It is valuable to understand how fire department agencies are currently implementing their UAV program and how many UAV operators are necessary.

More than half of the respondents stated they have night flight operation procedures. Just over 30% of respondents stated they have beyond visual line-of-sight procedures. Some respondents stated delays in incorporating these procedures were connected to needs for additional training. It is advantageous to learn what procedures existing UAV programs are implementing into their response capabilities.

Fourteen different incident types were listed among UAV program leads. Of the incident types which UAVs are deployed to, training evolutions were noted by all 19 respondents. The next most common response for UAV deployment was hazardous materials, large-scale events as well as search and rescue. In addition to the list of incident types, respondents provided other instances where their agency deploys UAVs. The incident types included assisting the water department such as infrastructure and

road/bridge water runoff. Other uses include promotional videos, community events, flooding, law enforcement assistance and special operation deployments. Considering how current UAV programs deploy their equipment may be helpful for agencies considering developing of program of their own.

Just over half of respondents stated having 24/7 UAV deployment capability. The remaining respondents stated that their deployment strategy is more of an on-call approach. Many deployment strategies were shared to include utilizing frontline apparatus, battalion chief vehicles, training, or fire investigator personnel and the emergency managers office. Understanding existing deployment strategies may be helpful for an agency new to UAV program development, as well as an agency considering a change to their UAV deployment capability.

Over 60% of respondents experienced loss or damage of UAV equipment. It is possible minor repairs can be made in-house. However, it is important to note that agencies considering the development of a UAV program will likely need to communicate with their agency's legal team for guidance on insurance requirements. Research applicable to this topic may also include considering the process when an incident occurs, will a committee review the incident, who will be represented on the committee?

Respondents shared descriptions of the equipment currently being utilized at their respective organization. The most frequently mentioned UAV (49 instances) was the DJI Mavic. The DJI Phantom, M100, M200, M210 and M600 were also mentioned. Additional equipment was listed via survey responses to include DJI Goggles, Hoverfly tethered UAVs, Parrot and Typhoon H Yuneec. It is likely this information will be

outdated quickly, given the rapid advancement in technology. However, one respondent specifically noted they had a budget plan in place for replace and upgrade of equipment. Additional costs for replacements and upgrades may be something to think about as a new agency considering a UAV program.

UAVs require frequent software updates; respondents provided how this is managed at their respective organization. Responses indicated that updates were managed from daily to weekly by a variety of personnel to include UAV operators, UAV program leads, fire investigators, and emergency management personnel. Details related to software updates were identified by fire departments with existing UAV programs and how they manage the need.

Numerous success stories involving the deployment of UAVs have been shared by survey respondents. These incidents range from search-and-rescue to commercial building fires, to identifying a major safety issues on a construction site. Some respondents represent agencies which have had operational UAV programs for more than five years. Lending to the potential for more incident responses, fine-tuning what works for their agency and establishing well defined perimeters for the team. One agency has been heavily involved with the implementation of effective hazardous materials deployment and research.

Respondents provided insight about applications their UAV operators utilized when preparing for or completing a mission. Just over 30% of survey responses indicated B4UFLY was a go to application for their agency. Many agencies shared the expectation of UAV operators using checklists, as well as requirements associated with

completing pre- and post-flight documentation. It will be important for FAA guidelines to be followed as more standardization is defined.

Preserving data and storage considerations may need to be determined early in the program development stages. The storage of information may be dictated by the agency's Information Technology department. Three methods of saving information were shared by respondents: cloud-based, secure digital (SD) card and local servers. Depending on the authority having jurisdiction, the data collected may need to be treated as evidence. These are the methods agencies are currently implementing as it pertains to data storage.

Current UAV program leads identified anticipated advancements and changes to equipment at their agency over the next 12 months. Nearly 40% of respondents stated they anticipated an increased number of UAV operators as well as technological advancement of equipment to include capabilities. Less than 25% of respondents stated they anticipate changes in additional positions, budget (for maintenance and upkeep) and training opportunities. Other agencies reported their deployment model is expected to transition to a 24/7 resource as well as expressing interest in live streaming capability.

How can fire service UAV program development be most cost-effective?

Results indicated that over 25% of respondents sought out assistance from existing fire department UAV programs. Considering consultation from existing fire department agencies with UAV programs or consultants such as Skyfire or FlyMotion may improve overall cost-effectiveness for agencies contemplating the application of this technology.

Current UAV program leads indicated several methods for UAV program funding. Over 80% of respondents stated at least one method of funding for their agency's UAV program included the fire department operating budget. Other funding sources listed included donations, forfeiture, homeland security, and local emergency planning committee funds. It is helpful for existing UAV program leads to identify this information as it may help locate funding opportunities not considered previously. Additionally, it was noted by at least one respondent that their initial funding request grossly underestimated the true cost of the program. When considering cost-effectiveness, it is important to understand associated costs as well as what options may be available for funding either for new or existing UAV programs. Communicating with agencies currently operating UAV programs may provide additional insight as to cost considerations for an agency developing a program.

In addition to individual certification requirements for UAV operators one of the survey questions inquired about the agency's approach to over team documentation. Nearly 40% of respondents stated they acquired both a COA and FAA Part 107. Additional rationale regarding department certification requirements was provided by some UAV program leads to include responses such as, the agency's airspace did not require a COA. Whereas another respondent stated they've applied for a COA but are experiencing extreme difficulty with acquiring it in the New Jersey area. It is beneficial to understand what fire department agencies with existing UAV programs are doing as it relates to documentation. This is likely an area where communicating with existing UAV program leads and coordinating with the FAA may be helpful to an agency considering the development of a UAV program. Communication with UAV program leads as well

as the FAA may improve cost-effectiveness for fire departments considering UAV program development.

A variety of 14 different incident types listed for UAV program leads. Of the incident types which UAVs are deployed to, training evolutions was noted by all 19 respondents. The next most common response for UAV deployment was hazardous materials, large-scale events as well as search and rescue. In addition to the list of incident types, respondents provided other instances in which their agency deploys UAVs. The incident types included assisting the water department such as infrastructure and road/bridge water runoff. Other uses include promotional videos, community events, flooding, law enforcement assistance and special operation deployments. Considering how current UAV programs deploy their equipment may be helpful for agencies considering developing of program of their own. Understanding early what the UAV equipment is capable of and determining what priorities the interested agency has may improve cost-effectiveness when creating an outline for their UAV program. Ensuring guidelines are created to determine applicable department-specific UAV incident types may trim the possibility of scope creep.

Just over half of respondents stated that their agency has 24/7 UAV deployment capability. The remaining respondents stated that their deployment strategy is more of an on-call approach. Many deployment strategies were shared to include utilizing frontline apparatus, battalion chief vehicles, training or fire investigator personnel and the emergency managers office. Understanding existing deployment strategies may be helpful for an agency new to UAV program development, as well as an agency considering a change to their UAV deployment capability. Considering the deployment

capability is important when developing a UAV program as it may increase operating costs using either a 24/7 or on-call strategy. An evaluation of cost/benefit may be advantageous as it pertains to deployment strategies and need for equipment.

Over 60% of respondents stated their organization has experienced loss or damage of UAV equipment. It is possible minor repairs can be made in-house. However, it is important to note that agencies considering the development of a UAV program will likely need to communicate with their agency's legal team for guidance on insurance requirements. Collaboration may also include considering the process when an incident occurs; will a committee review the incident, who will be represented on the committee? Determining this in the development phase may improve cost-effectiveness for the UAV program. It is helpful to have the detailed defined before an incident occurs, much of the preparation and proactive planning lends toward long-term cost savings.

Respondents shared the equipment currently being utilized at their respective organization. The frequently mentioned UAV (49 instances) was the DJI Mavic. The DJI Phantom, M100, M200, M210 and M600 were also mentioned. Additional equipment was listed to include DJI Goggles, Hoverfly tethered UAVs, Parrot and Typhoon H Yuneec. It is likely this information will be outdated before too long given the rapid advancement in technology. However, one respondent specifically noted the department's budget plan for the UAV program includes replacement and upgrade of equipment. Equipment options are important to consider when pinpointing cost-effective approaches. Determining anticipated use of UAV equipment and aligning this with the capability as well as budget restraints are important considerations.

Just over 30% of respondents indicated that they've experienced challenges associated with education, buy-in and funding. Specifically, they've experienced challenges with buy-in from administrators, city officials as well as department personnel. Fewer respondents identified challenges with FAA, interference, training and public perception. Embracing these challenges and communicating with existing UAV program leads may aid an interested organization in cost-effective approaches where appropriate.

Current UAV program leads identified anticipated advancements and changes to equipment at their agency over the next 12 months. Nearly 40% of respondents stated they anticipated an increased number of UAV operators as well as technological advancement of equipment to include capabilities. Less than 25% of respondents stated they anticipate changes in additional positions, budget (for maintenance and upkeep) and training opportunities. Other agencies reported their deployment model is expected to transition to a 24/7 resource as well as interest in live streaming capability. It may be helpful for new UAV program leads to consider these anticipated changes when determining costs associated with the program.

How can fire service UAV program development and implementation maximize efficiency?

Results indicated that over 25% of respondents sought out assistance from existing fire department UAV programs. Existing fire departments with UAV programs may be able to guide interested agencies. If the budget allows, professional consultants such as FlyMotion or Skyfire may enhance program development and implementation efficiency for agencies considering the application of this technology.

Current UAV program leads indicated there are several methods being utilized for UAV program funding. Over 80% of respondents stated at least one method of funding for their agency's UAV program included the fire department operating budget. Other funding sources listed included donations, forfeiture, homeland security, and local emergency planning committee funds. It is helpful for existing UAV program leads to identify this information as it may help locate funding opportunities not considered previously. Additionally, it was noted by at least one respondent that their initial funding request grossly underestimated the true cost of the program. When considering program development and implementation efficiency, it is important to understand associated costs and consider alternative funding opportunities, which may improve overall efficiency.

Standardization of certification requirements has been a discussion point for many UAV program leads. More than 75% respondents stated their agency's UAV program requires UAV operators to complete a fire department specific program; as compared to just over 70% stated their UAV operators are required to obtain the FAA Remote Pilot Certificate. UAV program leads also indicated specialized courses are required of some agency's UAV operators to include hazardous materials, incident management and night flight training. Understanding how fire departments are currently navigating the certification requirements can be beneficial for when considering UAV program development and implementation efficiency. Determining minimum requirements for UAV operators is essential toward program development to include safety of operators as well as bystanders. Additional information on this subject is likely to surface upon

completion of the NFPA FEMA grant involving research on UAV programs and the fire service.

In addition to individual certification requirements for UAV operators one of the survey questions inquired about the agency's approach to over team documentation. Nearly 40% of respondents stated they acquired both a COA and FAA Part 107. Some provided additional rationale UAV program leads to include the agency's airspace did not require a COA. In another example, a respondent stated their agency has applied for a COA but are experiencing extreme difficulty with acquiring it in the New Jersey area. It is beneficial to understand what fire department agencies with existing UAV programs are doing as it relates to documentation. This is likely an area where communicating with existing UAV program leads and coordinating with the FAA may be helpful to an agency considering the development of a UAV program. Communication with UAV program leads as well as the FAA may ease the program development phase and improve overall implementation strategies early on.

More than half of the respondents stated they have night flight operation procedures. Just over 30% of respondents stated they have beyond visual line of sight procedures. Some respondents stated they delay in incorporating these procedures is the need for additional training. It is advantageous to learn what procedures existing UAV programs are implementing into their response capabilities. Understanding capabilities and considerations from existing UAV programs which may be practical for a new UAV program to take on may streamline program development as well as implementation efforts. Implementation and direction is especially important as it relates to night flight

and beyond visual line of sight operations due to the increased amount of training and FAA guidelines.

Fourteen different incident types listed for UAV program leads. Of the incident types which UAVs are deployed to, training evolutions was noted by all 19 respondents. The next most common response for UAV deployment was hazardous materials, large-scale events as well as search and rescue. In addition to the list of incident types, respondents provided other instances in which their agency deploys UAVs. The incident types included assisting the water department such as infrastructure and road/bridge water runoff. Other uses include promotional videos, community events, flooding, law enforcement assistance and special operation deployments. Considering how current UAV programs deploy their equipment may be helpful for agencies considering developing of program of their own. Early determination of priorities the interested agency has as it pertains to UAV deployment and incident types will aid in program development and overall implementation.

Just over half of respondents stated that their agency has 24/7 UAV deployment capability. The remaining respondents stated that their deployment strategy is more of an on-call approach. Many deployment strategies were shared to include utilizing frontline apparatus, battalion chief vehicles, training or fire investigator personnel and the emergency managers' office. Understanding existing deployment strategies may be helpful for an agency new to UAV program development, as well as an agency considering a change to their UAV deployment capability. Deployment strategies are critical when considering program development and implementation. The selected

deployment model will ultimately determine when UAV resources are available for personnel as well as the community.

Respondents shared the equipment currently being utilized at their respective organization. The frequently mentioned UAV (49 instances) was the DJI Mavic. The DJI Phantom, M100, M200, M210 and M600 were also mentioned. Additional equipment was listed to include DJI Goggles, Hoverfly tethered UAVs, Parrot and Typhoon H Yuneec. It is likely this information will be outdated before too long given the rapid advancement in technology. However, one respondent specifically noted the had a budget plan in place for replace and upgrade of equipment. Program development and implementation strategies will be depending on the UAV equipment available. Selection of appropriate equipment will be beneficial to overall UAV program effectiveness.

UAVs require software updating, respondents provided how this is managed at their respective organization. Responses indicated that updates were managed from daily to weekly by a variety of personnel to include UAV operators, UAV program leads, fire investigators, and emergency management personnel. This is a detail which fire departments with existing UAV programs have identified how they manage the need. Deciding on these details during the program development phase can improve UAV program implementation.

Numerous success stories involving the deployment of UAVs have been shared by survey respondents. These incidents range from search and rescue to commercial building fires, to identifying a major safety issues on a construction site. A couple of the respondents represent agencies, which have had operational UAV programs for more

than five years. The more established UAV programs have an advantage from the potential for more incident responses, fine-tuning what works for their agency and identifying well-defined perimeters for the team. One agency has been heavily involved with the implementation of effective hazardous materials deployment and research. Reviewing instance where UAV equipment was successfully operational on incidents may better prepare a new UAV program lead for what may emerge.

Just over 30% of respondents indicated that they have experienced challenges associated with education, buy-in, and funding. Specifically, they've experienced challenges with buy-in from administrators, city officials as well as department personnel. Fewer respondents identified challenges with FAA, interference, training and public perception. Understanding these challenges may exist will be important when considering program development. It may be helpful to get ahead of the potential challenge and encourage more education to foster buy-in early in the developing phase.

Respondents provide insight as to what applications their UAV operators utilized when preparing for or completing a mission. B4UFLY was noted as a go to application for a number of agencies. Many agencies shared the expectation of UAV operators using checklists, as well as requirements associated with completing pre- and post-flight documentation. It will be important for FAA guidelines to be followed as more standardization is defined. Utilizing appropriate applications, following specific guidelines and organizing information are important considerations when discussing program development and implementation. Many applications are inexpensive; however, some may be costly and should be researched prior to purchase. Identifying this information early will help streamline the UAV program.

Preserving data and storage considerations may need to be determined early in the program development stages. The storage of information may be dictated by the agency's Information Technology department. Three methods of saving information were shared by respondents to include cloud-based, secure digital (SD) card and local servers. When determining program direction (prior to implementation) it may be essential for UAV program leads to identify what local jurisdiction requirements are as it pertains to data and/or evidence collection and security.

Current UAV program leads identified anticipated advancements and changes to equipment at their agency over the next 12 months. Nearly 40% of respondents stated they anticipated an increased number of UAV operators as well as technological advancement of equipment to include capabilities. Less than 25% of respondents stated they anticipate changes in additional positions, budget (for maintenance and upkeep) and training opportunities. Other agencies reported their deployment model is expected to transition to a 24/7 resource as well as interest in live streaming capability. It may be valuable to understand what changes are anticipated by current UAV program leads if an agency is considering developing a program. Agencies which have been operational for a couple years may transition to different deployment models and acquire the latest and greatest equipment. As a relatively new UAV program it may be more beneficial to adopt an implementation model which has room for growth, a crawl-walk-run approach.

Chapter V: CONCLUSION

Study Background

This descriptive research study was intended to illustrate existing information available about UAV programs and the fire service. Moreover, the researcher provided existing material from current fire department UAV program application and uses, learning opportunities and considerations which have been made by current UAV program leads. Additionally, I conducted interviews with current UAV program leads and acquired survey responses from 19 participants.

Limited case studies, documentation, and research is readily available on fire department UAV programs. The goal was to identify cost-effective program development and implementation methods currently to begin bridging this knowledge gap. If fire departments have more data accessible regarding advances, current practices, as well as the limitations of this technology, it is likely buy-in and program funding may be more easily achieved. Collecting information on UAV capabilities, FAA requirements, National Fire Protection Association (NFPA) standards, as well as the available technology can prove time-consuming and expensive.

If collaborative research is completed by fire departments considering a UAV program prior to program development, the organization may have an opportunity to build a framework to base their decisions. This study attempts to meet these important aims by compiling information from 19 UAV program leads through the United States and Canada.

Research Summary

Three research questions were answered in this study:

1. How are fire departments currently implementing UAV programs?

2. How can fire service UAV program development be most cost-effective?

3. How can fire service UAV program development and implementation maximize efficiency?

Based on the 19 responses, 16 of those respondents lead UAV programs utilizing funding from the fire department operating budget. Fifteen respondents stated their organization requires completion of fire department specific training for all UAV operators. Fourteen of 19 respondents stated their organization required all UAV operators to complete the FAA remote pilot certificate. Seven of the 19 respondents stated their organization acquired both a COA and FAA Part 107. Over half of the respondents stated their organization conducted night flight operations and have UAV resources available 24/7. This current information on UAV program implementation may aid fire departments considering establishment of a program in determining what areas may need additional consideration.

A variety of methods can be applied to improve cost-effectiveness as it relates to fire department UAV programs. These factors include decreasing the time required for research prior to purchase by sharing available resources for fire departments in the infancy stages of program development. Next is to limit time developing original procedural protocols and determining appropriate incidents to deploy UAVs by utilizing resources currently available. Another opportunity to improve cost-effectiveness is to limit unnecessary purchases of UAV equipment which may not be applicable to the fire department UAV program scope.

At least 19 fire departments are currently operational with their UAV program and willing to share information given the results of this research. Additionally, resources are shared daily as it relates to UAV programs in public safety. Many resources are becoming available with no cost via online platforms. Firms are available to assist agencies in program development and equipment purchases. Both Fly Motion and Skyfire Consulting were referenced as firms utilized by respondents to this survey. Austin Fire Department (TX) has assisted organizations with their program development and implementation. AFD has one of the longest standing operational fire department UAV programs and the personnel have been willing to share their experiences with agencies interested in developing UAV programs. Twelve of 19 respondents stated they've experienced loss or damage to UAV equipment. Understanding areas of cost savings or potential loss is imperative for fire departments to consider when developing a UAV program.

UAV program development and implementation may improve efficiency by reviewing what current programs have already instituted at their respective organizations. Although community needs differ based on geographical location and potential target hazard areas, it is possible to gain fruitful insight from the UAV program leads who responded to this research survey. Suggestions associated with improved efficiency included identify adequate funding sources early and track data to encourage continued program support. Understanding technology continues to expand and UAV equipment may become outdated quickly. Research existing programs, attend conferences, communicate with the FAA, include the public early on and determine the best implementation tactics for a program at your respective agency.

Additionally, on October 24, 2019 NFPA shared noted funding would be available through fire prevention and safety grants to develop a public safety drone compliance program.

Theoretical

The theoretical positioning of this research involved review of implementation theories. Both the top-down approach to implementing policy, where policymakers develop programs to be implemented by personnel, as well as the bottom-up implementation theory, in which personnel may formulate ideas and share tactics with policymakers to create change were examined throughout this research. The results of this research provide an example of the fire service industry effecting a program by applying a bottom-up implementation approach.

A few challenges have been noted as it pertains to this type of implementation approach and fire department UAV programs. Creating buy-in by administrators and department personnel was remarked as a current challenge experienced by UAV program leads. It is understood that top-down implementation theory may be recognized as policymakers focusing more heavily on the program components versus the strategies (Sabatier, 1986). The fire service has experienced numerous alterations to equipment, policy, strategy, and tactics initiating from a bottom-up approach. As previously mentioned, awareness in areas such as cancer, mental health, peer support, and risk management have been changed predominantly by a bottom-up approach. Fortunately, in the case of UAVs, this is another example of more of a bottom-up approach to implementation. Areas where fire service personnel have achieved great strides such as cancer, mental health and peer support, and risk management may provide experience to improve buy-in and change as it relates to the implementation of UAVs.

The diffusion model also informed this project. This model is an academic way to measure the contagiousness of an idea, innovation, or product (Gladwell, 2002). The diffusion model has four categories: The initial category consists of the Innovators; these are the adventurous individuals (2.5%) willing to assume risk and desire revolutionary change. Followed by the Early Adopters (13.5%), who are similar to the Innovators and are typically the individuals to purchase new options, in the case of UAVS, they are willing to create the plan as they go and typically incur greater costs because the devices are not mainstream yet. The Early Adopters commonly observe the studies conducted by the Innovators and follow suit. The next category is the Majority, often characterized by the Early (34%) and Later (34%) majorities. These groups of individuals often deliberate, and are skeptical and seek to limit risk, or wasted money and time. Lastly, the Laggards (16%), bring in the stragglers to join participating in the new concept (Gladwell, 2002).

In the instance of UAVs in the fire service it is believed that existing UAV programs are still in an early adopter phase. As more information, enhanced equipment, and better understanding of the capability UAVs have becomes available it is likely the programs will become more popular throughout the fire service. While speaking to some UAV program leads, they've indicated the technology was previously considered "cool" or "cutting edge", now those fire department expect the UAV resource on many calls of significance and it has been more difficult for the UAV operators to take time off work. This demand has led to the training of more UAV operators.

Recommendations for Future Research

This research study was completed over the course of 18 months by a doctoral student with no defined research budget. It is possible this research can be expounded upon in a

variety of ways. In fact, the researcher hopes that a variety of studies are completed as it pertains to UAVs and the fire service. This research could be completed by a graduate student as well as an Executive Fire Officer (EFO) candidate. The areas, which may benefit from additional research currently, include defining fire department UAV program limitations before purchasing equipment and implementing a program and determining specific application or uses for fire department UAV programs. As well as identify available consultant services or firms which may decrease start-up costs for fire departments interested in developing a program, find methods for encouraging budgetary changes at the city/county management level to support development and enhancement of UAV programs and pinpoint data/track program success to aid in research of program effectiveness, potential cost savings and continued program support/justification.

Additional research involving UAVs and fire department program implementation should consider communicating with agencies who have not already participated. Additionally, if there was a budget available it may be possible to acquire added participants if they were provided compensation for their time. Supplementary participation may aid in discovering additional material. It would be interesting to complete a study in a specified timeframe, such as three years and ask similar questions to trend changes in fire department UAV program development and implementation.

Other areas of research related to public safety and UAVs which may be studied include differing theoretical approaches such as public policy and technology in the field of public safety. A study on UAV equipment variations which best suit the needs for fire department agencies may be beneficial to field users and administrators alike. Research on tethered versus non-tethered UAVs for the field of public safety may result in an

improved understanding of the benefits each of these provide. Research on cybersecurity and use of UAVs at emergency incidents may provide added insight to the field of public safety. Much of the research would benefit from an interdisciplinary approach such as incorporating city/county administrators, information technology, military and public safety personnel.

If another researcher followed these recommendations, additional information may be determined, to include insight from agencies who have not previously shared their UAV program approach. Adding additional awareness after elapsed time may provide lessons learned which have not been previously addressed. Furthermore, public policy and public safety continue evolving. The evolution of public policy and safety will likely impact UAV program advancement and overall utilization. The opportunity to implement UAV technology with incident response may enhance the likelihood for agencies to document positive outcomes such as the aforementioned Australian teenagers and a suicidal Florida woman.

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Appendices

Appendix A

IRB

Appendix A

Institutional Review Board (IRB) Basic Course completed prior to beginning research project in accordance with Valdosta State University requirements.

Appendix B

Key Terms

Appendix B

Key Terms

- Above Ground Level (AGL)
- Aerial Response Team (ART)
- Airborne International Response Team (AIRT)
- Assistance to Firefighters Grant (AFG)
- Association for Unmanned Vehicle Systems International (AUVSI)
- Automated External Defibrillator (AED)
- Beyond Visual Line of Sight (BVLOS)
- Certificate of Authorization (COA)
- Command Tactical Unit (CTU)
- Computer Assisted Search Planning (CASP)
- Designated Operations Area (DOA)
- Embry-Riddle Aeronautical University (ERAU)
- Federal Aviation Authority (FAA)
- Federal Emergency Management Agency (FEMA)
- Florida Firefighter Safety and Health Collaborative (FFSHC)
- Florida Power and Light (FPL)
- Geographical Information System (GIS)
- Information and Communication Technology (ICT)
- International Conference on Unmanned Aircraft Systems (ICUAS)
- Jacksonville Electric Authority (JEA)
- Local Emergency Planning Committee (LEPC)
- Low Altitude Authorization and Notification Capability (LAANC)
- Mean Sea Level (MSL)

- METeorological Aerodrome Reports (METARS)
- National Fire Protection Association (NFPA)
- National Institute of Standards and Technology (NIST)
- New York City Fire Department (FDNY)
- New York Fire Department Operations Center (FDOC)
- North Metro Fire Rescue Department (NMFRD)
- Notice to Airmen (NOTAM)
- Orlando Fire Department (OFD)
- Polk County Sheriff Office (PCSO)
- Remote Pilot In Command (RPIC)
- Robotic Emergency Deployment (RED)
- Search and Rescue (SAR)
- Temporary Flight Restrictions (TFRs)
- UAV assisted Emergency Monitoring and Response (UAV-EMOR)
- United States Department of Transportation (USDOT)
- United States Forest Service (USFS)
- University of Nebraska-Lincoln (UNL)
- Unmanned Aerial Systems (UAS)
- Unmanned Aerial Vehicle (UAV)

Appendix C

IRB Forms & Survey

Appendix C

IRB Form

Institutional Review Board (IRB)
For the Protection of Human Research Participants

PROTOCOL EXEMPTIONREPORT

Protocol Number: 03859-2019 **Responsible Researcher:** Lindsay Judah

Supervising Faculty: Dr. Michael Charter

Project Title: *Unmanned Aerial Vehicle Programs in the Fire Service: An Examination of Their Effectiveness and Challenges in Implementation.*

INSTITUTIONAL REVIEW BOARD DETERMINATION:

This research protocol is **Exempt** from Institutional Review Board (IRB) oversight under Exemption **Category 2**. Your research study may begin immediately. If the nature of the research project changes such that exemption criteria no longer apply, please consult with the IRB Administrator (irb@valdosta.edu) before continuing your research.

ADDITIONAL COMMENTS:

- *In order to satisfy consent requirements, the researcher (you) must read aloud the Research Statement at the start of the interview. A copy of the statement must be provided to the participant.*
- *Upon completion of this research study all data (data list, interview notes, email correspondence, etc.) must be securely maintained (locked file cabinet, password protected computer, etc.) and accessible only by the researchers for a minimum of 3 years.*

☒ ***If this box is checked, please submit any documents you revise to the IRB Administrator at irb@valdosta.edu to ensure an updated record of your exemption.***

Elizabeth Ann Olphie *06.28.2019*
Elizabeth Ann Olphie, IRB Administrator

Thank you for submitting an IRB application.
Please direct questions to irb@valdosta.edu or 229-253-2947.

Revised: 06.02.16

Interview IRB Exemption

You are being asked to participate in an interview as part of a research study entitled *"Unmanned Aerial Vehicle Programs in the Fire Service: An Examination of Their Effectiveness and Challenges in Implementation,"* which is being conducted by Lindsay Judah a student at Valdosta State University. The purpose of the study is to identify existing Unmanned Aerial Vehicle (UAV) programs in the fire service to identify effective implementation methods, equipment usage and uses of UAVs. You will receive no direct benefits from participating in this research study. However, your responses may help us learn more about help us learn more about documented success stories of UAV use in the fire service, effective implementation strategies and the variety of equipment utilized. There are no foreseeable risks involved in participating in this study other than those encountered in day-to-day life. Participation should take approximately 30 minutes. Your participation is voluntary. You may choose not to participate, to stop responding at any time, or to skip any questions that you do not want to answer. You must be at least 18 years of age to participate in this study. Your participation in the interview will serve as your voluntary agreement to participate in this research project and your certification that you are 18 years of age or older.

Questions regarding the purpose or procedures of the research should be directed to Lindsay Judah at ljudah@valdosta.edu. This study has been exempted from Institutional Review Board (IRB) review in accordance with Federal regulations. The IRB, a university committee established by Federal law, is responsible for protecting the rights and welfare of research participants. If you have concerns or questions about your rights as a research participant, you may contact the IRB Administrator at 229-253-2947 or irb@valdosta.edu.

Topics to cover during in-person interview:

- Airspace Information
- Deployment Model
- Equipment
- Pilot Requirements
- Team Capabilities
- Training Components

Qualtrics Survey IRB Exemption & Survey

Exemption acquired via application with VSU - Institutional Review Board (IRB).

You are being asked to participate in a survey research project entitled "*Unmanned Aerial Vehicle Programs in the Fire Service: An Examination of Their Effectiveness and Challenges in Implementation*," which is being conducted by Lindsay Judah, a student at Valdosta State University. The purpose of this study is to identify existing Unmanned Aerial Vehicle (UAV) programs in the fire service to discover effective implementation methods, equipment usage, and uses of UAVs. You will receive no direct benefits from participating in this research study. However, your responses will help us learn more about documented success stories of UAV use in the fire service, effective implementation strategies, and the variety of equipment utilized. There are no foreseeable risks involved in participating in this study other than those encountered in day-to-day life. Participation should take approximately *30 minutes* to complete. This survey is anonymous**.** No one, including the researcher, will be able to associate your responses with your identity. Your participation is voluntary. You may choose not to take the survey, to stop responding at any time, or to skip any questions that you do not want to answer. Participants must be at least 18 years of age to participate in this study. Your completion of the survey serves as your voluntary agreement to participate in this research project and your certification that you are 18 or older. You may print a copy of this statement for your records.

Questions regarding the purpose or procedures of the research should be directed to Lindsay Judah at ljudah@valdosta.edu. This study has been exempted from Institutional Review Board (IRB) review in accordance with federal regulations. The IRB, a university committee established by federal law, is responsible for protecting the rights and welfare of research participants. If you have concerns or questions about your rights as a research participant, you may contact VSU's IRB Administrator at 229-253-2947 or irb@valdosta.edu.

- I agree
- I disagree, discontinue survey at this time

The questions below inquire about your perceptions and experiences as a fire department UAV program lead.

For how long has the UAV program been in existence at your fire department?

- Less than 12 months
- 13 - 36 months
- 37 - 60 months
- More than 60 months (5 years)

Was your fire department provided assistance by a fire department with an existing UAV program, a college/university, or a consulting firm when the program initially began? If so, please describe.

How is your fire department UAV program funded? (Select all that apply)

- ☐ Donations
- ☐ Forfeiture Funds
- ☐ Fire Department Operating Budget
- ☐ Homeland Security

If a different source of funding is utilized by your fire department, please describe.

What certifications are required by UAV operators affiliated with your fire department?

- ☐ Completion of fire department - specific program
- ☐ FAA Remote Pilot Certificate
- ☐ Other, please describe below.

If additional certifications and/or programs are required of UAV operators at your fire department, please share details.

How many UAV operators are currently participating in the UAV program at your fire department?

Did your fire department acquire a COA and/or FAA Part 107? What was the rationale for this decision?

Is there a current procedure for your fire department for flying Beyond Visual Line of Sight (BVLOS) or flying at night? If so, please describe.

For what type(s) of incidents are the UAVs deployed by your fire department? (Select all that apply)

- ☐ Brush/Wildland Fire
- ☐ Commercial & Residential Fire
- ☐ Explosive Ordinance Disposal
- ☐ Hazardous Materials
- ☐ Highrise Fire
- ☐ Hostage & Barricade Situations (SWAT)
- ☐ Large-Scale Events
- ☐ Pre-Incident Planning
- ☐ Post-Fire Investigations
- ☐ Recruitment
- ☐ Search & Rescue
- ☐ Training Evolutions
- ☐ Traffic Incidents
- ☐ Water Rescue

If your fire department deploys UAVs for purposes not listed above, please describe.

At your fire department, from where are the UAVs stored and deployed?
Example: Please identify deployment strategy such as 24-hour accessibility, on-shift personnel acquire UAVs at fixed location or use of on-call personnel.

Has your fire department experienced loss or damage of any UAV equipment?

- ○ Yes
- ○ No

If so, how was the loss or damaged equipment mitigated?
Example: Is there a committee to review incidents? Specific insurance policy on the equipment?

Please list the UAVs in operation (and quantity) at your fire department.
Example: DJI Inspire (3), M210 V2 (1), Parrot Disco (1)

What is the process for updating the UAV software? Where are personnel directed to acquire technical assistance?

Please describe any success stories you have regarding the UAV program at your fire department.

Please describe any challenges experienced with the UAV program at your fire department.

Please list the applications operators at your fire department use when preparing for/completing a mission. Example: flight, weather or UAV apps

Please describe the process implemented at your organization as it relates to the data captured while flying UAVs. Example: software experiences, cloud based system used for saving information

Do you expect any advancement or changes to the UAV program at your fire department in the next 12 months? Example: Changes in technology, cost/benefit, deployment strategy, number of operators

In what state is your fire department located?

Is your fire department career, combination or volunteer?

- Career
- Combination
- Volunteer

How many fire stations does your fire department have?

- 1-5
- 6-10
- 11-15
- 16-20
- 21+

What is your rank/position within your fire department?

Thank you for your time. I appreciate your contribution toward this research project. If you wish to share any additional information, such as news story links, protocols and/or training manuals, please feel free to email ljudah@valdosta.edu.

Respectfully,
Lindsay Judah

Appendix D

Additional Resources

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Additional Resources

- Chula Vista Resource: A previously recorded webinar can be viewed here, https://www.policemag.com/webinars/drones-as-a-first-responder-the-new-model-shaping-the-future-of-public-safety

- FAA Part 107: https://www.faa.gov/uas/commercial_operators/part_107_waivers/

- West Chicago Fire District Forms are available through Assistant Chief Tim Leidig. The documents are very thorough and include UAV Policy, Pre-Flight Checklist, Emergency Procedures, Mission Report and Accident Report. His email is tleidig@wegofpd.org

- Brief descriptions of the applications, phone numbers and software:

1800WXBrief.com: FAA Flight Services, Temporary Flight Restrictions, and weather

Airmap: Aeronautical data, situational awareness, digital authorization, and traffic alerts

DJI Go 4: DJI products, real-time image transmission and editing/sharing aerial images

Drone Deploy: Automated capability, repeatable flights, instant offline maps, support for numerous UAV platforms, measure and export data

DroneSense: Live streaming capability, pre-fire planning intelligence, map/update,

KittyHawk: Flight logging, checklists, asset tracking, live streaming, situational awareness (FAA Approved)

LAANC: Low Altitude Authorization and Notification Capability. Collaboration between FAA/Industry. Utilized in FAA UAS Data Exchange, provides airspace authorization.

Litchi: DJI Products, autonomous flight app, VR mode, also available at flylitchi.com

Map Pilot: Helps create and fly optimal flight paths, collects data in high resolution, numerous features available

National Weather Service/NOAA: weather information

Pix4D: UAV mapping tool, photogrammetry software, 3D models, DJI products

SARTopo: High quality mapping, USGS, aerial imagery, non-public maps

UASidekick: NOTAMS, LAANC, developed by aviation pilots for UAS pilot, safer skies

UAV Forecast: Good to fly app, no-fly zones, 24-hour forecast, set limits