# Unmanned Aerial Systems in the Fire Service: Concepts and Issues

Dr. Ronald T. Wakeham & Dr. John C. Griffith

Embry-Riddle Aeronautical University FL, Worldwide Campus

Abstract

This study summarized current thinking on the application of Unmanned Aerial Systems (UASs) in the Fire Service. Potential use of UASs to save lives, provide safety and save property has generated preliminary research in three major areas of the fire service to include aviation, structure and wildland scenarios. Roadblocks to the effective use of this technology include possible command and control issues and governmental actions both in and outside of the U.S. to limit the use of UASs due to aviation safety concerns. The relationship between number of fires and firefighter deaths was examined resulting in a weak correlation further emphasizing the need for tools to enhance situational awareness and command and control at fire scenes. Recommendations include continued field testing on UASs, surveying fire chiefs to assess opinions on UAS implementation, and coordination between the FAA and fire chiefs in regulation development on UAS technology use in the fire service.

*Keywords*: Unmanned Aerial Systems (UASs), incident command systems, fire, firefighter deaths, emergency services, National Airspace System integration.

## Introduction

It is the mission of any fires service to save life and property. Along with extensive fire fighter training, concepts such as situational awareness and command and control are used to make firefighting more effective and safe. Other efforts involve community education on how to prevent fires in the first place. The relationship of the number of fires in the U.S. and firefighter deaths is one way to determine suggested actions for future firefighter safety. In addition, the possible use of Unmanned Aerial Systems (UASs) to enhance situational awareness and command and control seems prudent as well (Davis, 2013; Foster, 2014).

## Problem Statement

This study looked at two related problems. First, researchers attempted to determine if the number of responses to fires was an adequate predictor of firefighter deaths. If not, the U.S. fire service should continue to explore the use of new technologies to protect life and property. Secondarily, in a world of non-segregated airspace, researchers explored the question if UASs can become viable firefighting tools. UASs show great promise in commerce and public services operations such as firefighting. The technology appears to be moving faster than the ability to regulate the use of UASs to ensure public safety. The National Park Service has banned Unmanned Aerial

Systems from national parks citing examples of how UASs have caused problems. In September of 2013, an unauthorized unmanned aircraft flew above a full amphitheater at Mount Rushmore. In April of 2014, a loud UAS crashed in the Grand Canyon National Park. In Zion National park, a UAV disturbed a herd of bighorn sheep causing adults and younger sheep to be separated (Gabbert, 2014a). Unauthorized UAS flights impacting firefighting have occurred as well. According to 49 U.S.C. 40103(b)(2), the Federal Aviation Administration (FAA) is responsible for safe operations from "the ground up" to protect life and property (FAA, 2014a).

## Significance

The number of fires has decreased from over 1.68 million in 2002 to 1.24 million in 2013. This decrease has been very steady. Firefighters have responded to 447,500 fewer fires in 2013 than in 2002 (NFPA, 2014a). During the past 12 years, the number of firefighter deaths has averaged around 87 per year. An unsettling note is that even though the total number of fires has decreased, the number of fatalities increased to 97 in 2013. Although there is a relationship between number of fires and firefighter deaths, one major question to determine is if the pattern of firefighter deaths is adequately explained by the number of fires. As has been evidenced in recent wildland fires, integration of UASs into firefighting operations has the potential to save life and property by speeding up disaster assessment and decision-making processes (Davis, 2013). UASs could possibly give incident commanders a better view of emergency situations providing better situational awareness and command and control.

## Literature Review

### FAA Rules on Drones

Unmanned Aerial Vehicles (UAVs) can be broken down into three different groups; model aircraft, use by business and use by state and local governments. UASs are currently governed by FAA requirements which require operation by certified pilots. An exception to this rule for a certified pilot is model aircraft which cannot be flown over altitudes of 400 feet, must be within sight of the operator and must be used for recreational purposes only. Commercial and business uses of UASs do not fall under the rules for model aircraft (Department of Transportation, 2014). Businesses require an approved Special Airworthiness Certificate-Experimental Category in order to operate UASs (FAA, 2014b). The FAA is developing regulations to augment current guidance by the end of 2015 that is expected to increase the use of drones by businesses. However, state and local governments can apply for a waiver, known as a Certificate of Waiver (COA) or Authorization which are approved on a case by case basis (Davis, 2013; FAA, 2014a).

The FAA has designated six UAS test sites during 2014. These sites offer controlled environments to test the operation, procedures for communication with Air Traffic Control systems, air worthiness and other safety related data needed for UAS integration to include drone fire suppression aircraft (Dorr and Duquette, 2014; FAA, 2014c). The test sites will operate at least until 2017 in support of the FAA Modernization and Reform Act of 2012. Locations are shown in Figure 1 below.

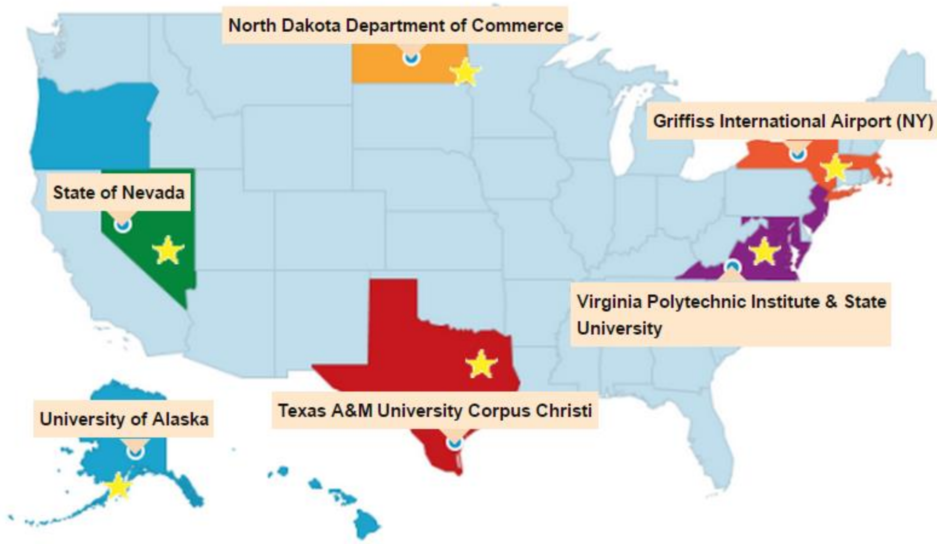


*Figure 1.* FAA UAS test sites established in 2014. "Test Sites". FAA, Unmanned Aircraft Systems (2014c).

The civilian use of UASs near fire operations is very closely monitored. The U.S. Department of the Interior and National Forest Service issued a safety alert warning incident management teams to be watchful for civilian piloted UASs which could come in conflict with firefighting efforts. The Two Bulls fire near Bend Oregon was cited as one such situation where a civilian piloted UAS had the potential of inhibiting response efforts. The warning advised quick reporting of any such UASs due to safety reasons (IA SA 14-03, 2014).

The FAA and other government agencies have taken significant regulatory steps to ensure civilian or corporate UASs do not interfere with firefighting efforts mainly for safety reasons. However, fire services have struggled to leverage this new technology for supporting firefighting activities, mainly due to regulatory requirements. The National Forest Service purchased two drones at a value of $100,000 in 2007 that are still not being used due to the complexity of getting FAA approval. The FAA requirement of the drone to be in visual range at all times of the pilot is difficult when fire and smoke are involved (Chaney, 2013; Gabbert, 2014b).

In one unusual case, Alaska was able to use a drone in 2009 to identify the extent of a 447,000 acre blaze just north of Fairbanks. The conditions did not allow for manned flight over the affected area. The University of Alaska at Fairbanks' UAS Integration program allowed the Alaska Bureau of Land Management to use the drone which allowed the incident command team to identify the boarders of the fire as well as hotspots without jeopardizing lives. FAA approval took 4 days (Barringer, 2013).

The Alaska Bureau of land management has further experimented with communications and crash avoidance measures with UASs and manned aircraft using an InSitu A-20 drone. The exercises have focused on visual identification of drone aircraft by manned aircraft in the area as well as communications between drone ground controllers. In a controlled environment, it took an Alaska Fire Service aircraft 10 minutes to spot the InSitu A-20 drone which had bright orange painted wings flying beneath the manned aircraft. Outfitting the plane with a transponder is another idea being considered as well as enhanced communications between drone ground control and airborne manned aircraft in the area (McCaa, n.d.).

The Austin Texas city council has just approved a four year test on robotics with Texas A&M and the Austin Fire Department. Central to this test is the use of small UASs at fire scenes to enhance the ability to see the scope of fires using regular and infrared technologies. Led by Assistant Chief Richard Davis, the Austin fire department has had to clear several legal hurdles in order to test this concept to include FAA requirements and state laws regarding the protection of privacy. The Fire department will ensure that only pilots who meet FAA requirements will operate the equipment (Foster, 2014). Davis (2013) further discussed how UASs could support the real-time information requirements of the Incident Command System (ICS). His National Fire Academy report emphasized the importance of accurate initial assessment in order to decide which assets to deploy in an emergency (fire, emergency medical assistance, and police). Incident Commanders would know the scope of the area and by using infrared equipment, could locate hotspots and where victims were located. Drones could also provide information on the location of deployed and personnel. Davis added that UAS could help Incident Command Teams in assessing hazardous material situations if equipped with the appropriate sensing devices (2013).

**UAS Use Abroad**

Australia is also known to have strict UAS guidance similar to the U.S. South Australia's county fire department has indicated it will cease fire fighting operations if a drone is spotted. Low flying helicopters could potentially suck the drone into the engine or crash if the drone came in contact with the tail rotor (Gabbert, 2014a). According to David Pearce, Aviation Operations Manager of the South Australia fire service; "If the drone is sucked into the intake of the jet engines, or goes into the tail rotor, then it's probably curtains for the helicopter" (Gabbert, 2014a, para. 5).

The European Organization of Civil Aviation Equipment EUROCAE Working Group, specifically Work Group (WG) 73 has also been working on ways to allow UAS operations in non-segregated airspace. The work group is formulating guidance on airworthiness certification, UAS command, control and communications systems and UAS sense and avoid systems. Each of those main issues have an international group working on producing guidance (Amato, n.d.).

**Summary**

Throughout its history, the U.S. Fire Service has attempted to protect life and property while at the same time, minimize firefighter deaths and injury. It seems obvious that reducing the number of fires should reduce firefighter injuries and deaths, however the details of that relationship need further exploration. Additionally, the possible use of UASs as a firefighting tool is in the beginning stages. The U.S. and international governments are struggling with the guidelines by which UASs can be used in business, public and public safety applications such as firefighting. The main concern is use of UASs in a non-segregated environment with manned aircraft. Additionally, UASs are becoming less expensive and easier to operate. The technology may be moving faster than the ability to regulate its use. The FAA however, has designated six test cites to help integrate UASs into the national aerospace system. Key components of this test include command and control of the drones, development of detect and avoid systems, airworthiness, human factors and integration with air traffic control (FAA, 2014d). Fire departments are experimenting with UASs in Montgomery County Maryland, Austin Texas and Alaska and as technology improves, UASs are becoming less expensive to procure (Clemens, 2014; Davis, 2013).

## Hypothesis

$Ha_1$ There is a strong positive linear relationship between the number of fires and firefighter deaths

## Methodology

In order to interpret the relationship between number of fires and firefighter deaths from 2002 through 2013, a Pearson's r correlation coefficient was used. The coefficient of determination and p value were evaluated to determine if number of fires was a good predictor of firefighter deaths (Gay, Mills, Airasian, 2006).

Raw data were taken from the National Fire Protection Association for the years 2002 through 2013 representing the last 12 years of recorded data post 9/11.

## Results

Data were calculated for the 12 year period both with, then without, the Yarnell Hill fire data to determine the strength of relationship between the number of fires in the U.S. and firefighter deaths. This analysis was completed using Statdisk version 12 and presented as figures to allow easy visualization of the annual data next to the correlation analysis (Triola, 2014). Figure 2 shows the data including the Yarnell Hill Fire.

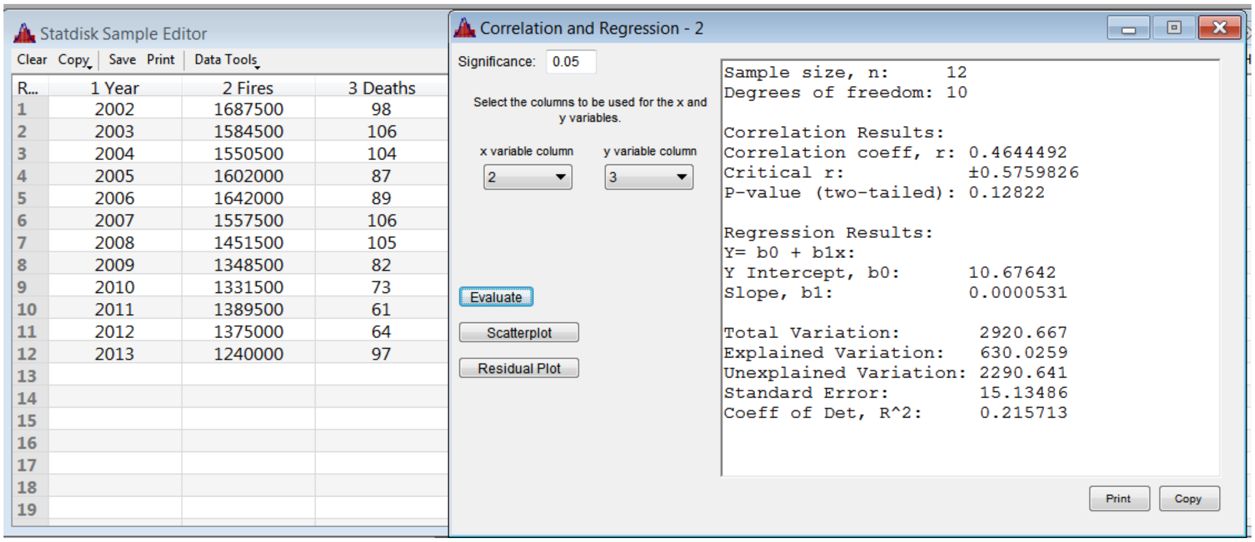


*Figure 2*. Total number of fire responses compared to firefighter deaths from 2002 through 2013. Raw data taken from "Firefighter Activities, Injuries and Deaths" *National Fire Protection Association*, 2014a, p.1 and "Firefighter Deaths". *National Fire Protection Association* 2014b, p.1. Data computed using Statdisk [Version 12]. Triola, M. (2014).

The data show that although there is a weak relationship between number of fires and firefighter deaths (r=.464, $R^2$=.216, p=.128 at α=.05), much of the variation is not explained by the number of fires alone. The null hypothesis would be retained in this case since the correlation is weak.

The data were re-run subtracting the 19 deaths from the 2013 data which accounted for the Yarnell Hill fire in Arizona (NFPA, 2014b, p. 1). The results were shown in Figure 3.

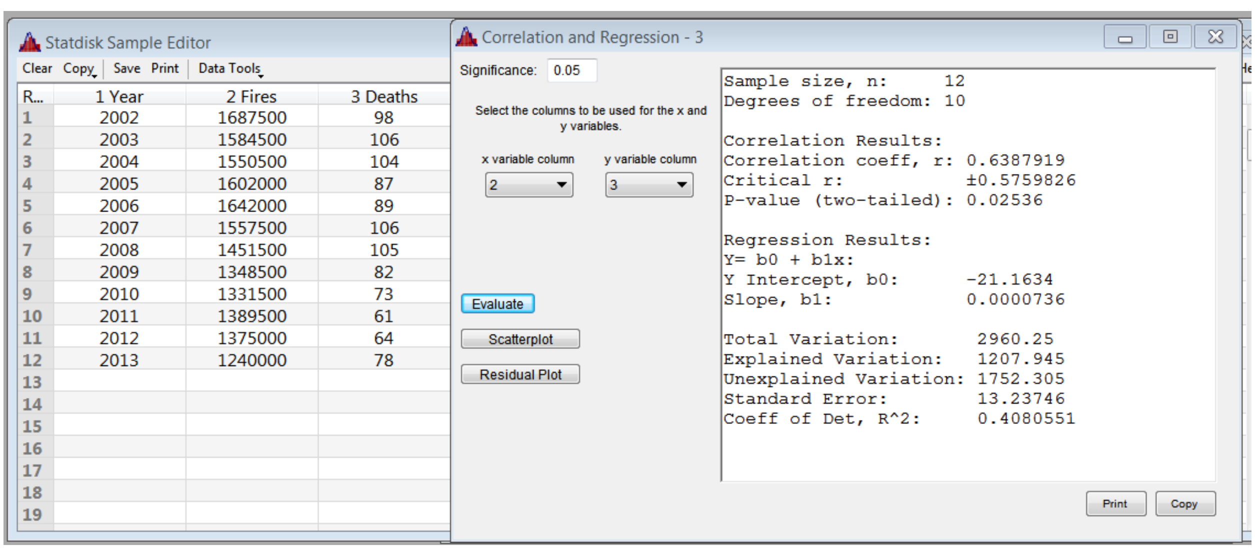


*Figure 3*. Number of fire responses compared to firefighter deaths from 2002 through 2013 excluding the Yarnell Hill Fire (19 deaths). Raw data taken from "Firefighter Activities, Injuries and Deaths" *National Fire Protection Association*, 2014a, p.1 and "Firefighter Deaths". *National*

*Fire Protection Association* 2014b, p.1. Data computed using Statdisk [Version 12]. Triola, M. (2014).

The results of the test without the Yarnell Hill fire deaths yielded a stronger correlation (r=.639, $R^2$=.408, p=.025 at α=.05). This test would reject the null hypothesis, however, according the coefficient of determination, almost 60% of the variation in firefighter deaths is still not explained by number of fires alone.

## Conclusions

One could argue on the strength of relationship between the number of fires and firefighter deaths, but even with the Yarnell Hill fire deaths excluded, other variables are involved as well, even if they are difficult to define. Firefighters receive outstanding training on how to combat fires. Before ever facing a real fire, firefighters have faced simulated situations that encourage them to rely on their training. However, the complexity of situations firefighters face are not linear. Some situations are far more complex than others which result in more risk of injury or death. For this reason, it is hypothesized that these data support the argument by Davis (2013) for better situational awareness and command and control at the fire or disaster scene. Effective situational awareness and command and control can put firefighters in a position to effectively save life and property without injury or death. This argument also supports the idea to employ any tools that can make command and control more effective. Although UASs are still being developed as are their guidelines for use by the FAA and EUROCAE, UASs can become an effective tool to increase situational awareness and support effective command and control.

## Recommendations for Further Research

Recommendations for further research should include real time experimentation with drones. Emphasis must be placed on airworthiness of the drone, command and control of the drones and crash avoidance. Manned aircraft must be aware of drone location at all times and the piloting and information feedback of drones in a fire situation should be designed so as not to overwhelm operators with information

Fire chief attitudes toward use of drones should be explored to determine if or how much a culture change would be required to implement this new technology.

The FAA and fire chiefs' associations must work together on guidance for drone use in firefighting.

Drone development needs to focus on light, easy to deploy, inexpensive drones that provide images through easy to use systems. These qualities are a necessity for drone deployment and use in the fire service.

Drones should also be designed to operate within large structures to preview a situation before firefighters are sent in to areas that have unknown involvement of fire and smoke.

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