# Exploring the Usage of Drones to Assist Firefighters During Emergency Situations

**by**

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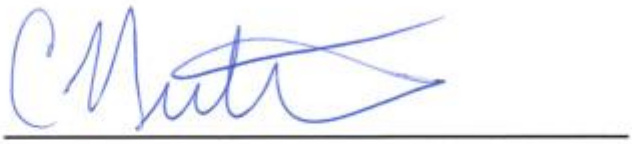

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# Ethics Statement

The author, whose name appears on the title page of this work, has obtained, for the research described in this work, either:

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## Abstract

In the near future, emergency services within Canada will be supporting new technologies for 9-1-1 call centres and firefighters to learn about an emergency situation. One such technology is drones. To understand the benefits and challenges of using drones within emergency response, I conducted a study with citizens who have called 9-1-1 and firefighters who respond to a range of everyday emergencies. Results show that drones have numerous benefits to both firefighters and 9-1-1 callers which include context awareness and social support for callers who receive feelings of assurance that help is on the way. Privacy was largely not an issue, though safety issues arose especially for complex uses of drones such as indoor flying. The results point to opportunities for designing drone systems that help people to develop a sense of trust with emergency response drones, and mitigate privacy and safety concerns with more complex drone systems.



**Keywords**: Emergency calling; Drones; Firefighters; Surveillance.

## Dedication

I dedicate this thesis to my family and friends who always supported me, believed in me even when I didn’t.

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I am grateful to my senior supervisor, Dr. Carman Neustaedter for his constant guidance, support, enthusiasm, motivation. His guidance made research easier and more enjoyable for me. I also learned a lot as a professional and as a student from him. I hope I can pass on what I learned from him in future. I greatly thank him for everything.

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## Publications

Materials, ideas from this thesis have appeared in the following publication:

**Khan, N.**, & Neustaedter, C. (2019). An Exploratory Study of the Use of Drones for Assisting Firefighters During Emergency Situations. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems* (p. 272). ACM.

**Khan, N.**, & Neustaedter, C. (2019) Exploring Drones to Assist Firefighters During Emergencies, *Proceedings of the CHI 2019 International Workshop on Human-Drone Interaction.*

**Khan, N.**, Neustaedter, C., & Antle, A. (2019). Flight Chair: An Interactive Chair for Controlling Emergency Service Drones. In *Extended Abstracts of the 2019 CHI Conference on Human Factors in Computing Systems* (p. LBW1320). ACM.

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# Chapter 1.

# Introduction

People in Canada and the United States place a telephone call to the number 9-1-1 to report emergencies. Since the late 1960s, 9-1-1 has served people in emergency situations. To this day, people primarily depend on telephone calls to report an emergency even though video communication technologies such as Skype are prevalent. Heavily depending on telephone calls could be challenging for the caller and the call-taker as it could cause misinterpretations of the situation, low accuracy for location tracking, anxiety and stress, and communication issues (for example, because of different accents and dialects from the caller's end) (Neustaedter et al. 2018; Singhal and Neustaedter 2018). This often makes the job more stressful for the call taker (Forslund et al. 2004). In the coming years, Canada will be shifting towards Next Generation 9-1-1 (NG911) services which will allow people to use text-messaging, video calling, sharing photos or videos during a 9-1-1 call. Yet the challenge is that these technologies will still likely leave emergency call takers and dispatchers with an incomplete understanding of an emergency situation and more information will still be valuable for first responders to know about (Neustaedter et al. 2018; Singhal and Neustaedter 2018).

My work explores the use of additional technology in the form of *drones* to provide first responders with information about everyday emergencies called in by citizens. By everyday emergencies, I mean incidents such as house or structural fires, hazardous material incidents (Hazmat), vehicle accidents, and medical emergencies which are small in scale. This contrasts emergencies such as search and rescue, disaster response, etc. Drones are small scale, aircraft that are remotely controlled and provide video recording and/or streaming features. I have chosen to explore drones given their likely ability to provide important contextual information about an emergency situation (Jones et al. 2016). For example, if an emergency is called in to a 9-1-1 call centre, one could imagine a drone flying to the emergency (either automatically or controlled by an operator) and providing a birds-eye view of the situation and sharing it with 9-1-1 call takers and, subsequently, first responders. Such a scenario has the potential to provide first responders with additional information such as the overall condition of the emergency and specifics of the location

that a 9-1-1 caller may be unable to provide. In this work, I have chosen to focus on firefighters as they handle and respond to a range of emergency situations, including car accidents and hazardous material situations, in addition to fire response. To date, there has not been any investigation into how drone systems should be designed to best match firefighters' needs when responding to 9-1-1 emergency calls nor the benefits and challenges that might be raised by citizens about drone use during these situations.

## 1.1. Background

In North America, placing a phone call to the number 9-1-1 has been the primary way to report emergencies for several decades (Whallen 1995). Yet the reality is that such calls can create miscommunication, mental stress, and ambiguity (Forslund, Kihlgren, and Kihlgren 2004; Neustaedter et al. 2017; Pettersson, Randall, and Helgeson 2004; Svennevig 2012). A lack of information from callers might make it more difficult for call takers to decipher the nature of a situation (e.g., medical symptoms of an injured person). We also know that call takers prefer speaking to the person requiring the emergency service directly to get the most accurate information (Forslund, Kihlgren, and Kihlgren 2004). Other difficulties include hoax 9-1-1 calls, calls from people with mental impairments, calls from deaf or blind people, and callers not being able to accurately describe the situation (e.g., knowing how to describe specifics of a fire) (Forslund, Kihlgren, and Kihlgren 2004; Neustaedter et al. 2018; Singhal and Neustaedter 2018). Callers sometimes feel like they are not being heard properly by the call takers of emergency services which can lead to frustration and hostile callers (Svennevig 2012). Given these challenges, research has shown that if the call takers were able to see what is actually happening in the scene instead of being completely dependent on callers, call response may be more efficient (Neustaedter et al. 2018; Singhal and Neustaedter 2018).

There have been some investigations of next-generation technologies for emergency response. For example, studies have explored the benefits and challenges associated with people using video calling (akin to Skype) to talk with 9-1-1 call takers/dispatchers (Neustaedter et al. 2018; Singhal and Neustaedter 2018). Video calls were seen as being valuable in many cases for callers, call takers, and first responders (firefighters, paramedics, police etc.). Yet there were challenges in capturing the 'right' video, seeing video of gory/traumatic situations, and supporting callers who sometimes

did not want to be shown on video because of privacy concerns. Such privacy concerns are found more broadly for video streaming in public settings (Brubaker, Venolia, and Tang 2012; Singhal et al. 2016) where people may not react positively to being captured on camera (Boyle, Neustaedter, and Greenberg 2009; Neustaedter et al. 2017; Procyk et al. 2014; Singhal et al. 2016) and in unfavorable circumstances (Buhler, Neustaedter, and Hillman 2013; Kim, Junuzovic, and Inkpen 2014; Neustaedter et al. 2015; de Vasconcelos Filho, Inkpen, and Czerwinski 2009). While there is literature around video calling for conferencing and emergency services, there is a lack of investigation into the benefits and challenges associated with using video-enabled drones for everyday emergencies and how such systems should be designed.

Previous literature on public acceptance of technologies such as closed-circuit television (CCTV) show people are more accepting of this kind of technology mostly due to the ignorance of their privacy breach (Dixon, Levine, and McAuley 2003; Honess and Charman 1992). More closely to my research, studies show people can socially adapt to drone in public spaces over time (Cauchard et al. 2015) and there are privacy concerns due to inconspicuous data collection (Wang et al. 2016). Although the shape and design of the drone can shape people's privacy perception of drones (Chang, Chundury, and Chetty 2017). Therefore, I wanted to explore more about the privacy and safety concerns associated with drones and also tried to understand its connection to the appearance of the drones for emergencies.

Drones have the potential to be effective for emergency situations by providing a bird's eye view(Jones et al. 2016). A study suggests that drones can be socially adopted and accepted (Cauchard et al. 2015); however, a lack of regulatory frameworks calls for an investigation into how drones should be used (Kerasidou, Büscher, and Liegl 2015). Concerns related to drones for public services involve using them as weapons (Wall 2016). Studies have also explored how public acceptance of drones improves when there are no weapons associated with a drone (Boucher 2015). Some firefighters in the USA are using drones to help them figure out how to put out fires on the scene (Aerones firefighting drones, 2019; How firefighters are using drones to save lives, 2019). Drones have also been used for the assessment of post disaster scenes (Adams, Levitan, and Friedland 2012). Automated External Defibrillator (AED) equipped drones have been studied to enhance cardiac arrest response times (Claesson et al. 2017; Pulver, Wei, and Mann 2016) and drones have been studied to transport blood and medical supplies to

hospitals (Thiels et al. 2015). Drones were studied for search and rescue operations in mountains (Silvagni et al. 2017) and architectures have been developed for utilizing drones in search and rescue (Cacace et al. 2016; Naidoo, Stopforth, and Bright 2011). Here they have, again, been shown to be valuable for saving lives by providing medical supplies and locating a lost person.

Firefighters attend a range of emergencies from fires to hazardous material incidents to motor vehicle accidents (Kales et al. 2007). Previous research on first responders explored the importance of information sharing with the firefighters (Ludwig, Reuter, and Pipek 2013). First responders saw the importance in seeing a situation for themselves. Mobile applications and text messaging application were also explored to help firefighters communicate during an emergency (Bergstrand and Landgren 2011; Betz and Wulf 2014). However, there has not been any studies that aimed at using drones to assist firefighters during emergencies.

## 1.2. Research Questions

My work explores the topic of emergency response drones through an interview and scenario-based study of emergency situations with firefighters and people who have experience in calling 9-1-1 to report emergencies. As I have mentioned earlier, I focus on ‘everyday emergencies’ such as automobile accidents, fires, and injuries that a citizen might call in to 9-1-1, as opposed to disaster response, crisis management, or search and rescue. Such everyday emergencies tend to happen more frequently and are not explored in the related work when it comes to the use of drones. My goal was to answer several research questions.

**Question 1: How might firefighters make use of drone footage in an emergency?** Previous research looked into the necessity of information sharing between first responders (firefighters and police officers) and emergency control centres during emergency situations (Ludwig, Reuter, and Pipek 2013). Results showed that first responders valued seeing a situation for themselves. However, the focus was not on the use of drones as a medium to share information. Mobile applications have also been explored to share information with call centres and found to be valuable (Bergstrand and Landgren 2011). Other mobile applications explored text messaging between firefighters

for communication where a historical record and pre-defined messages were valuable (Betz and Wulf 2014). Thus, there is a lack of research on drone usage by firefighters for everyday emergencies.

**Question 2: What benefits and challenges do 9-1-1 callers feel exist for drones that capture video of an emergency situation?** Studies involving drones with everyday people largely focused on the privacy and security issues (Chang, Chundury, and Chetty 2017; Uchidiuno, Manweiler, and Weisz 2018; Wang et al. 2016). These works mainly focus on people's privacy perceptions of drones. CCTVs were also studied (Dixon, Levine, and McAuley 2003; Honess and Charman 1992) which shows people's acceptance of it. However, in most cases people are unaware of the fact that their privacy is being breached. Therefore, we were interested to see what 9-1-1 callers think about the idea of drones being used in emergencies.

**Question 3: How should drone systems be designed to aid firefighters during an emergency?** Drones are able to provide overall views of a scene in high resolution (Jones et al. 2016). Although a lack of regulatory frameworks calls for an investigation into how drones should be used (Kerasidou, Büscher, and Liegl 2015). Some firefighters in the USA are using drones to help them figure out how to put out fires on the scene (Aerones firefighting drones n.d.; How firefighters are using drones to save lives, 2019). Drones have also been used for the assessment of post disaster scenes (Adams, Levitan, and Friedland 2012). Automated External Defibrillator (AED) equipped drones have been studied to enhance cardiac arrest response times (Claesson et al. 2017; Pulver, Wei, and Mann 2016) and drones have been studied to transport blood and medical supplies to hospitals (Thiels et al. 2015). Drones have been extensively studied to help in search and rescue (SAR) situations (Cacace et al. 2016; Naidoo, Stopforth, and Bright 2011; Silvagni et al. 2017). Drone have proven valuable in these situations due to their mobility and services. However, none of these works explored how a drone should be designed to aid firefighters during emergencies.

## 1.3. Research Objectives

My primary goal for this thesis is to explore the design opportunities to assist firefighters during emergency situations. To achieve this goal, I address the following objectives, where each one maps to the corresponding question in Section 1.2

**Objective 1: Investigate the ways firefighters would like to use drone video footage when responding to emergencies.** In Chapter 3, I present an exploratory study to investigate how firefighters might find the usage of drones useful while responding to everyday emergencies. I was interested in finding out how they expect the presence of drones on the scene, how they want to view the information shared by the drones, how they want to control the drone, and what benefits and challenges they anticipate due to the presence of a drone on the scene. For example, in addition to sharing footage, firefighters often expressed their needs to have the drones equipped with different sensors such as gas sensors, or swarm of mini drones.

**Objective 2: Investigate the benefits and challenges for 9-1-1 callers of a drone capturing images and recording videos during emergencies.** The series of questions for the 9-1-1 callers in my study aimed at understanding what benefits and challenges people feel exist for such a system that can capture image and video. Surprisingly people showed a sense of trust on such drones when they imagined themselves in an emergency situation. Design suggestions around socio-technical issues lead to the need for filtering out people or properties that may not be of interest to the emergency. To handle the safety concerns, drone software needs to be able to land the drone safely in the event of a possible crash and avoid obstacles.

**Objective 3: Designing a proof of concept drone system based on the prior objectives.** Finally, as a proof of concept, I developed a software prototype with a drone that contains features based on my study. Then, along with an undergraduate videographer, I created a video showcasing the design ideas coming from my thesis research. For example, as part of the drone design, I modified the appearance of a commercial drone to conceptualize it as an emergency drone which signifies the attempt to support public trust by providing a prominent appearance. Other features include blurring/unblurring people's faces to support privacy protection.

## 1.4. Methodological Approach

My research focuses on understanding how drones could be used for assisting firefighters during everyday emergencies. This topic fits into the field of Human-Computer Interaction (HCI). HCI is a multi-disciplinary field investigating human factors of computing systems to understand how to design computational devices that are both usable and useful for individuals (Dix, 1998). Within HCI, this work is an empirical study. Methodologically, this work borrows from Grounded Theory. As I have briefly mentioned, the design space of my research is relatively less explored. Thus, I had to depend strongly on the data from the user study I conducted and the theory emerged from this data. Therefore, the end product of this work is a set of suggestions which point to the design opportunities that exist for drones to assist firefighters during everyday emergencies.

This thesis is guided by a set of previous literature based on emergency service, firefighters, drones, and privacy. My research adopts a qualitative approach where I try to understand how emergency response drones should fit in to assist firefighters during emergencies. Therefore, the knowledge is grounded in the views of the participants (Creswell and Poth 2018). Ultimately, I develop my own meanings that correspond to my experiences based on the interaction with the participants. Qualitative studies are useful when a researcher intends to collect the meanings of participants and makes interpretation of that data (Creswell 2014). The qualitative study design was meant to help understand how drones should work to assist firefighters during emergencies while taking into account the benefits and challenges citizens would face. For that, people's views were relied upon through open-ended questions from which patterns emerged.

As mentioned before, I adopted a qualitative approach to my thesis. Through a semi-structured exploratory study where 9-1-1 callers and firefighters were interviewed. The semi-structured interview was helpful since it allows the interviewer and interviewee to expand on the open-ended questions merging from the interview (Schensul, Schensul, and LeCompte 1999). I sought to understand how such systems should be designed; and the benefits and challenges associated with it. We recruited 21 participants through snowball sampling (word-of-mouth), social media (posts on Facebook), and contact directly with emergency response centres within our city. Participants were in two groups: everyday citizens who were experienced with calling 9-1-1 to report emergencies and

firefighters. I conducted semi-structured interviews with participants either in-person or online through a video communication system (Skype). The interview was structured in two phases. First, the interview focused on understanding their past experiences with 9-1-1 related calls and how they think drone could help in those situations. The second phase of the study focused on understanding participant reactions to actual drone-like video footage of everyday emergencies. This is described more in Chapter 3.

## 1.5. Organizational Overview

In Chapter 2, I provide a literature review. My discussion focuses on four areas. Firstly, I discuss the current practices of 9-1-1 services and demonstrate the challenges associated with it. Then, I talk about the works that look into Next Generation 9-1-1 (NG911). The third area focuses on people's acceptance of technologies in terms of privacy. This is further divided into two subsections: people's perceptions of CCTVs and drones. Then, I discuss the existing works about firefighters and the use of technologies to aid them during emergencies. Finally, I look into how drones are being used for emergencies (disaster response, search and rescue, etc.).

In Chapter 3, I discuss the exploratory study I conducted with 21 participants where they were categorized in two groups: everyday citizens who were experienced with calling 9-1-1 and firefighters. It was a semi-structured scenario-based study.

In Chapter 4, I discuss the results of the study, which includes the emerged themes around basic usage of drones for everyday emergencies, benefits and challenges around designing such system.

In Chapter 5, I discuss the results and identify design opportunities for future which centres around designing drones to support trust; designing to better support communication between drone dispatchers and firefighters; designing drones to support camera work and autonomous vs. manual control; considering designs to support multiple and possibly indoor drone usage. I also discuss the prototype I designed with a recreational drone as a proof of concept of the results of my study.

In Chapter 6, I conclude my thesis by revisiting my research goals and reflecting on how I achieved each one. I also list my research contributions and suggest areas for future work and the limitations of my study.

# Chapter 2.

# Related Work

In this chapter, I explore the related work in the area. First, I review the current practices of emergency services and some of the shortcomings. Second, I review some of the work that investigates next generation technologies for emergency services (Next Generation 9-1-1). Third, I review the literature related to drones that describe how drones can provide useful views; how drones can be useful in various scenarios such as disaster response, search and rescue, everyday emergencies, etc. Fourth, I review literature that explores communication technologies for firefighters. Finally, I review literature that investigated people's privacy perception of drones and CCTV surveillance.

## 2.1. Emergency Service

In North America, placing a phone call to the number 9-1-1 has been the primary way to report emergencies for several decades (Whallen 1995). However, depending primarily on telephone calls can sometimes create miscommunication, mental stress, and ambiguity for both callers and call takers (Forslund, Kihlgren, and Kihlgren 2004; Neustaedter et al. 2018; Pettersson, Randall, and Helgeson 2004; Svennevig 2012).

### 2.1.1 Difficulties for the call taker and caller

Forslund et. al., (2004) analyzed the stressful situations of the emergency service operators in Sweden. They interviewed the emergency operators to find out what causes a difficult situation. The operators talked about diffused symptoms which made it difficult for them to decipher symptoms (i.e. medical symptoms of a patient or a person suffering from an injury). Lack of information may frustrate call takers and often they have to be too dependent on callers to dispatch the proper emergency response (i.e. ambulance, police, fire trucks or a combination of those two or more). In those situations, the call takers often describe themselves as "powerless". The operators find it easier to deal with the emergency service seeker directly. Other difficult situations include hoax calls, especially from children. Calls from people with mental impairment, deaf or blind people, foreign language speaking people make it difficult for the operators to extract information.

Svennevig., (2012) talks about how the caller often feels like he/she is not being heard properly by the call takers of emergency services. This often develops a frustration for the caller and sometimes the caller acts hostile. The caller often displays a sense of urgency. This urgency leads to *misalignment* and *disaffiliation*. By misalignment, the author points to the event when the call taker fails to get a proper understanding of the situation due to the caller not being able to provide information requested by the call taker. Misalignment results in misinterpretation of the activity. This often results in continued interrogation of the caller and may lead to hostile situations where callers become uncooperative. This is defined as *disaffiliation* by the author. Disaffiliation of the caller is caused by the caller's frustration with operator's questions. Callers sometimes curse at the operators and when the operators politely ask the callers not to curse or remain calm, it frustrates the callers even more. The frustration of the caller develops in a few stages. When the call taker asks for information like what is happening, the caller often fails to describe the actual scenario due to a sense of urgency. Therefore, the operators face a difficult situation to come up with a decision.

(Neustaedter et al. 2018; Singhal and Neustaedter 2018), point to some of the difficulties that may arise when reporting an emergency on a telephone call. These include information inaccuracy due to the caller not being able to describe the situation or relaying incorrect information, situations where people cannot speak, or people not being able to speak English properly.

It is apparent that phone calls alone are not sufficient to handle every 9-1-1 situation. Inclusion of media such as text messaging or picture/video sharing could improve the communication between caller and call taker, and ultimately this would enable first responders (i.e. firefighters) to get more accurate information while they are traveling to emergency. Researchers have investigated video calling for NG9-1-1 which I am going to describe in the next section.

### 2.1.2 Next Generation 9-1-1 (NG9-1-1)

Neustaedter et al., (2018) envisioned how video calling might be incorporated within emergency services over the next few years. They explored possible design implications, benefits and challenges of video calling in such scenarios. They conducted an observational study and contextual interviews within three emergency response call

centers in Canada. Their study shows how video calling can provide additional context about an emergency and be beneficial to call takers and first responders. This has the potential to overcome information inaccuracies that may arise when callers cannot easily speak, for example, if they are injured, children, elderly, etc. However, their study also points to challenges involving the possibility of information overload, mental stress on call takers, and privacy challenges. For example, call takers and dispatchers are both physically and mentally occupied when they receive a call. They have to communicate with the caller and input information on the computer. Additional video footage could cause information overload for the call takers. Callers expressed privacy concerns in situations when they would not want to be seen (i.e. scenarios involving sexual harassment). Call takers, on the other hand, expressed concerns around seeing traumatic, gory scenes on a video call. Emergency video calling was compared to existing commercial video chatting software such as Skype. The authors recommend emergency video calling as a continuum where audio would still be the primary means of communication between callers and call takers and the sharing of video-based media varies from being turned off and not utilized, to the use of images or video clips as part of an audio call, to live video of a scene. They further emphasize the need to support intricate camera work that is controlled to achieve better understanding of the situation.

Singhal et al., (2018) also explored video calling for emergencies where their research was focused on the needs and reactions of the emergency service seekers. They explored this space by interviewing everyday citizens in Canada who had the experience of calling 9-1-1 to report emergencies. Similar to the previous research I described, this study demonstrates the benefits and challenges of video calling. But the major difference here is that the perspective of the callers is emphasized. Results show that callers can benefit in various ways such as describing contextual information about the emergency; showing the situation directly to the call takers in cases when speaking capability is obstructed by barriers such as panic or language; and, receiving video-based instructions and assistance from call takers. The challenges include privacy concerns around anonymity; consent, culture and gender-based biases; and, camerawork. For example, callers may not be properly dressed or want to remain anonymous because they might feel like being a woman would affect getting help. This study recommends 9-1-1 video calling as a collaborative act where callers are fine to give up decision-making control about the information that might be shared to the call taker. This means the caller will

follow the instructions from the call taker to show the proper footage. Moreover, the socio-technical challenges (i.e. privacy, safety) must be considered while designing for this space.

In the next section, I describe research done on firefighters that focused on their work practices and explored different technologies to help them communicate on the scene.

## 2.2. Firefighters


**Figure 2.1 The inside of a firetruck**

Firefighters respond to a range of emergencies which include fire, hazardous material, vehicle accidents, medical emergencies etc. (Kales et al. 2007). They learn about an emergency situation from the emergency call centres and when they are on the way to an incident, textual information is displayed in the laptop of the firetruck with additional information shared over radios (Neustaedter et al. 2018; Valecha et al. 2013; Wyatt 2003) [Fig. 2.1 and 2.2]. The laptop, as shown in Figures 2.1 and 2.2, is controlled and viewed by the

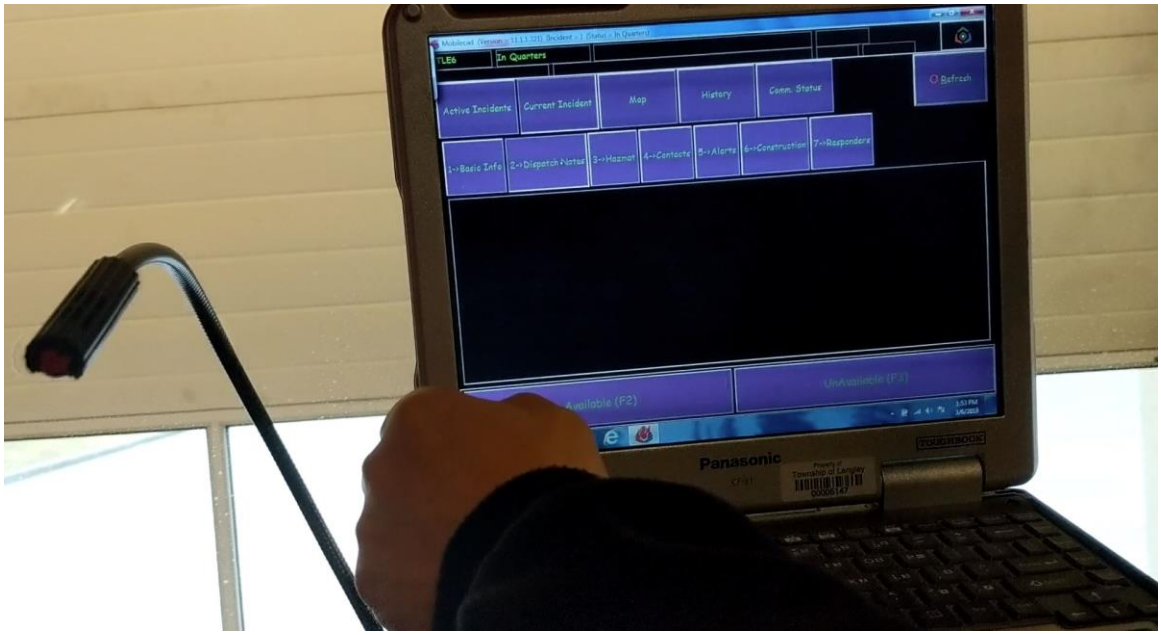


**Figure 2.2 Computer Aided Dispatch (CAD) software**

captain as he/she sits in the front beside the driver. This limits the firefighters' perception of an emergency since they have no visual information (Ludwig, Reuter, and Pipek 2013). Firefighters attend emergencies ranging from fires to hazardous material incidents to motor vehicle accidents They size-up the scene upon arrival (Jiang et al. 2004). Information is relayed in a hierarchical order from high ranked officers to subordinate officers over radio (Camp et al. 2000). When attending to an emergency service seeker (i.e., an injured person), first responders usually depend on their workplace experiences and tacit knowledge when making decisions (Wyatt 2003).

Previous research looked into the necessity of information sharing between first responders (firefighters and police officers) and emergency control centres during emergency situations (Ludwig, Reuter, and Pipek 2013). The authors argued that the information circulation in an emergency requires improvisation and articulation due to the unpredictable nature of the scenario. For example, the dynamic, unpredictable nature of the emergency may require them to have changing roles as opposed to maintaining a strict rank hierarchy. This, in turn, may support articulation of information. The authors developed an interaction prototype based on android devices to support communication in these situations. Results showed that first responders valued seeing a situation for themselves. Results showed, the accuracy of request and reports can be improved by using an appropriate metadata structure in addition to creating multimedia-based information content. Requirements of trusted and fast information need to be respected in

support concepts although they may even be contradictory. The coordination strategy of the emergency response organization also shapes the way this interaction needs to be designed.

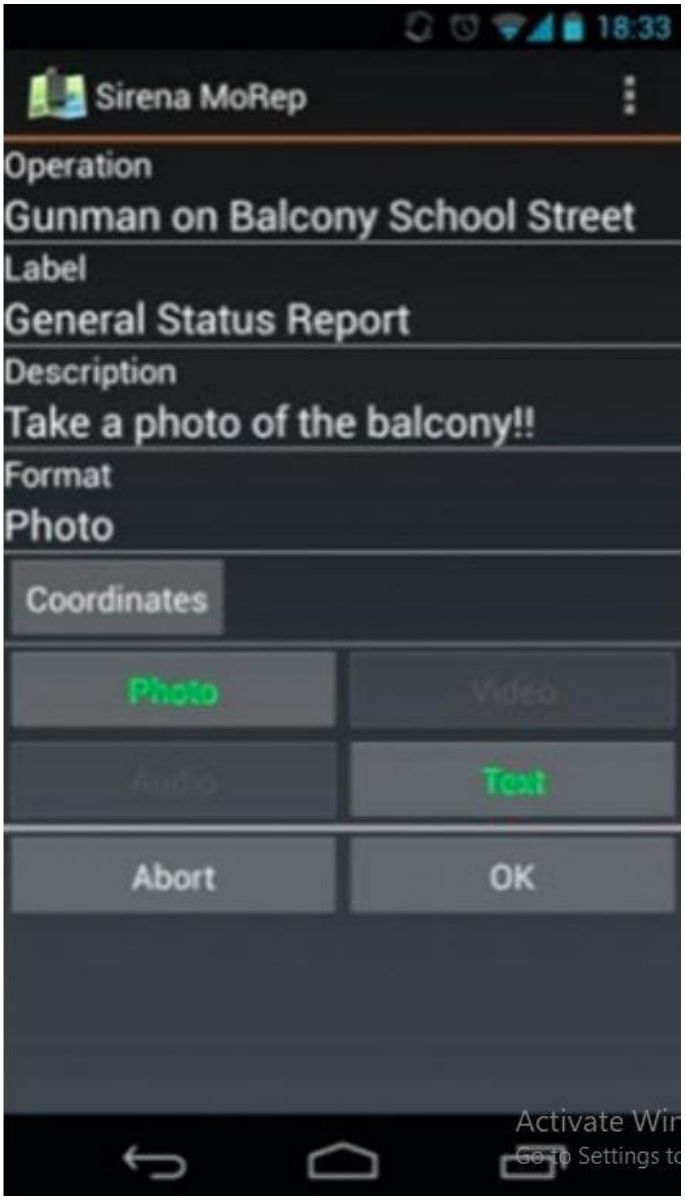


**Figure 2.3 Mobile application to support communication between first responders**

Source: Publications (Ludwig et al. 2013)

The Android application runs on Android phones as well as Android tablets. The idea here is to use these devices to support communications between the users (first responders). Users could make requests for information during the emergency. First responders on-site can fill in the information (textual and visual information) which can be viewed by the person who requested the report. The status report is also shown on a Google Map view along with navigation options. One screenshot of a status report is shown in Figure 2.3.

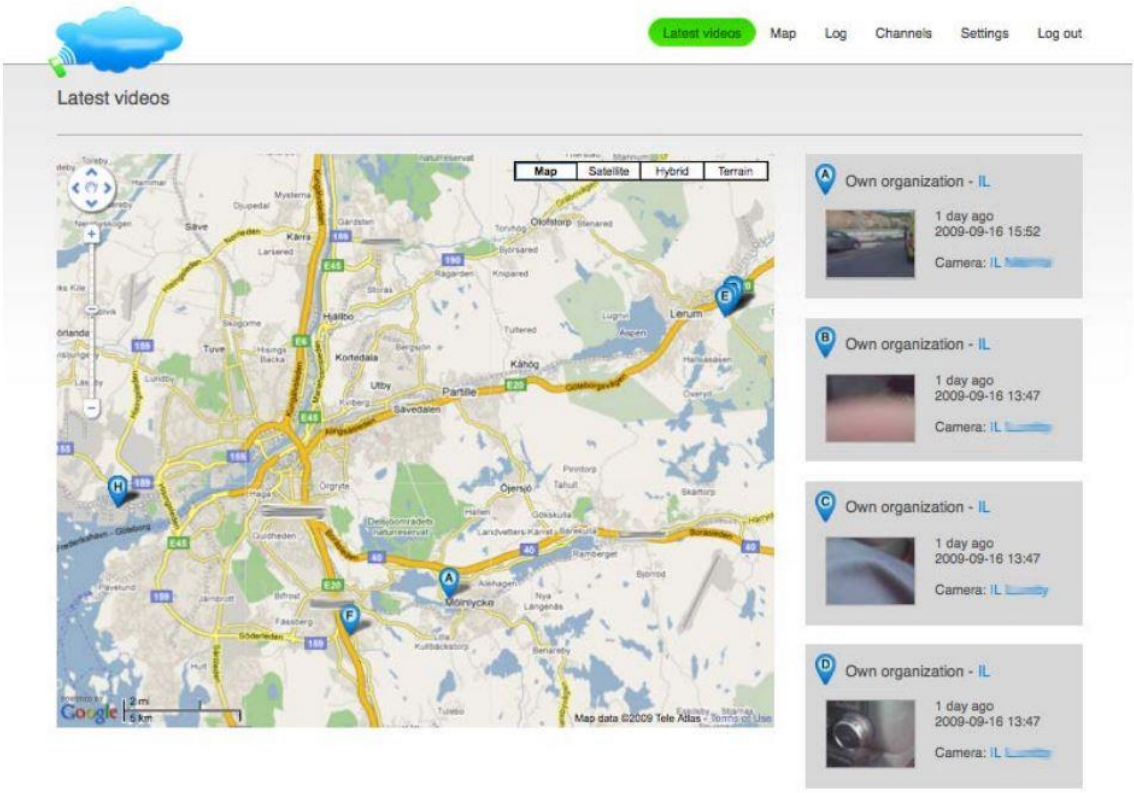


**Figure 2.4 Live video broadcasting of emergencies**

Source: Publications (Bergstrand et al. 2011)

Bergstrand and Landgren (2011), explored live video broadcasting during emergencies. The idea was to capture the emergency using a mobile device which can be viewed on a web interface (Fig. 2.4). This study shows how live video broadcasting can open up for collective negotiations of the broader meaning of a situation. The authors argue that making sense of an ambiguous and complex situations is often a collective effort which depends on efficient verbal communication. Visual reports of emergencies might provide better understanding of the situation and thus enable better coordination.


**Figure 2.5 EmergencyMessenger**

Source: Publications (Betz et al. 2014)

Betz and Wulf, 2014, conducted a five year long ethnographic study with firefighters in Germany. With this study, they found out the benefits and challenges of radio communication among firefighters during emergencies. Radio communication can be hampered if the signal is distressed inside the emergency scene (building materials blocking the radio signals), or someone trying to talk with helmets on. Also, only one person can talk at a time on the channel. They created a text-messaging based communication device called EMERGENCY-MESSENGER (Fig. 2.5) for indoor emergencies under harsh conditions while wearing breathing masks. This device is aimed at overcoming the shortcomings of voice over radio communication. For example, when someone speaks over the radio, the intended person has to answer immediately. Otherwise, the flow of communication may break. Answering immediately can be

problematic in cases when the situation is misjudged and a wrong decision or information is relayed.

As can be seen, literature around firefighters clearly point to the needs for firefighters to be directly be involved to control how they get the information during emergency. But it's not clear how systems involving drones should be designed for firefighters. Next, I talk about existing drone research that looked into the usage of drone for supplying materials during emergency, disaster response, search and rescue etc.

## 2.3. Drones

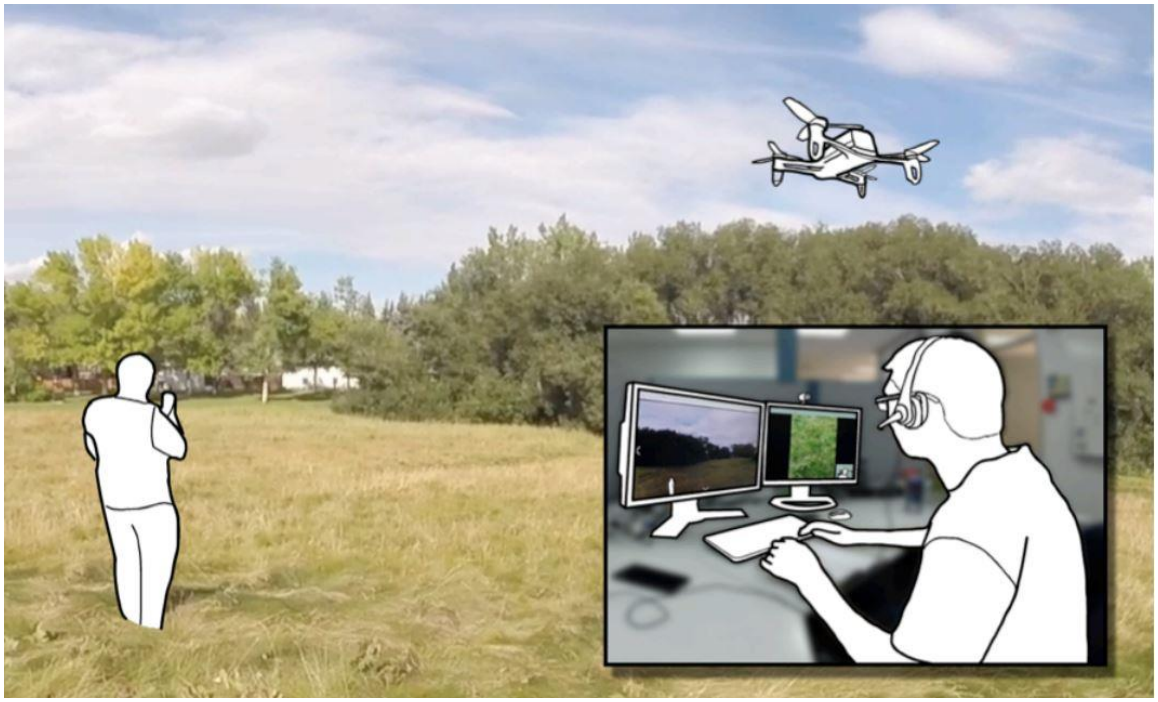

**Figure 2.6 Mobile video-conferencing with drones providing video footage to the indoor person**

Source: Publications (Jones et al. 2016)

I have explored studies on drones for video communication and human interaction with drones which is the focus of my thesis. Jones et al., (2016) studied semi-autonomous drones for video conferencing where an outdoor user (with a smartphone) is connected to an indoor user (with desktop computer) as depicted in Figure 2.6. The indoor user in this case has control over the view of the drone which provides the indoor person with a bird's eye view. Their work illustrates the benefits of providing the remote user with a view that

is elevated, manipulable, and decoupled from the outdoor user. It shows how people can overcome challenges in communicating using drones as a tool as drones can provide sufficient view to the remote user. Results show that remote people (indoor users with a desktop computer) found it very useful and helpful although limited drone controls do not allow remote users to have complete independence. They also found that drones could play a promising role for sharing experiences such as showing life events. This study showed an indoor person experiencing the outdoor through a drone footage while controlling the views from a desktop computer. This can be aligned to the scenario of an emergency situation where the caller for an emergency service is imagined as the outdoor person and the call taker is the indoor person. Drones may provide better and more accurate information to the call taker of emergency services.

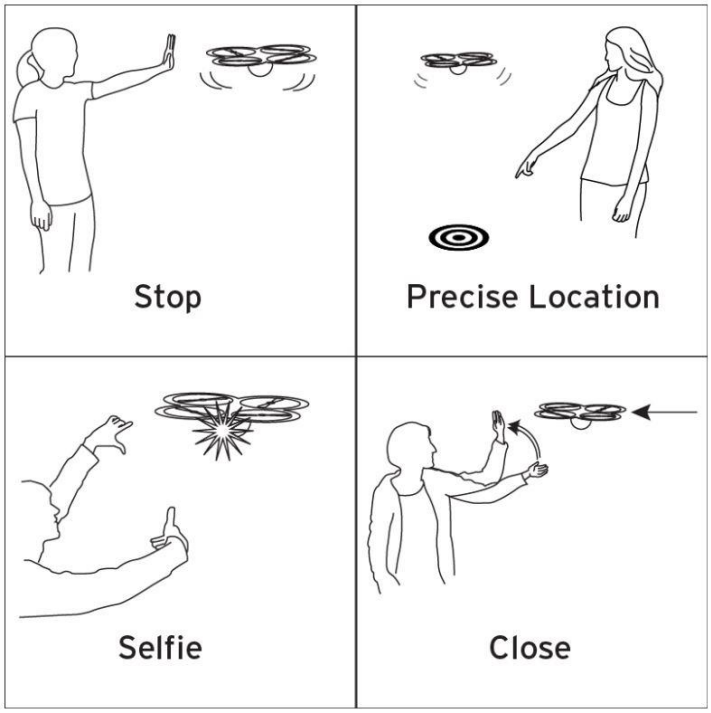


**Figure 2.7 User suggested gestures to interact with drones**

Source: Publications (Cauchard et al. 2015)

Cauchard et al., (2015) offer design insights for human-drone interaction (HDI). They talk about personal drones which are gesture controlled. In Figure 2.7, some of the gestures defined by users to control drone functionalities are shown. They report that users felt extremely comfortable interacting with drones and propose multimodal drone interaction. Their important finding, which is vital for my study, is that drones can be socially adopted and accepted. Results show users were comfortable with the interactions

although they initially felt discomfort. Over time, users became more comfortable using voice commands with drones. Most people expressed a discomfort with drones due to factors such as propeller noise and the wind generated by the propellers. This study provides insightful design guidelines for HDI although they do not talk about privacy concerns. Based on this work, it is reassuring that people may socially accept and be comfortable with drones for emergency services. However, people may not feel comfortable with drones flying around the city and capturing information.

Kerasidou et al., (2015) discuss ethical issues regarding civil use of drones. They draw on the stereotypical meaning of aerial drones as weapon systems which influenced European Union (EU) policy makers to seek regulatory frameworks for the civil use of drones where the idea was to have complete human controls on drones and not allow any autonomy. According to the authors, this can be problematic because it doesn't take into consideration that "*the human and the technical augment each other in ways that distribute agency and responsibilities within a socio-technical assemblage"* (Kerasidou, Büscher, and Liegl 2015). This hints at the necessity of handing over some responsibilities on the technology to accomplish a goal better. To exemplify this statement, the authors point out the necessity of automating many processes and practices for the safe flying of drones.

(Wall 2016)) looks at weaponized drones where he compares those drones to the routine police surveillance and killing of members of the "dangerous classes" in the United States (specific classes of people marked as a threat to security by the police). In this paper, he mentions how unmanned state of violence is influenced by political and legal force that assimilates to the routine of policing in domestic territory. Wall argues that drones police violence is to be taken more seriously than drones. This means the drone can be harmful if the controller does not use it for the right purpose. The takeaway from this work in my opinion is that drones are as dangerous to the society as the person who has the power or control over the drone.

Boucher (2015) explored contemporary strategies in Europe for creating public acceptability of drones. Concerns had been raised about people rejecting the civil use of drones because of its association with controversial applications such as policing and border control. In this paper, the author calls for the demilitarization of drones. This includes - clearly communicating the project of civil drones to public, developing vocabularies, and avoiding the term “drone” since it is highly associated with militarized applications. In this way, it is up to the people to accept technology. Boucher argues that the burden of acceptability should be with the technology (drone). That said, the strategies should aim at transforming the technology into something that is acceptable to the public rather than asking the public to accept it.

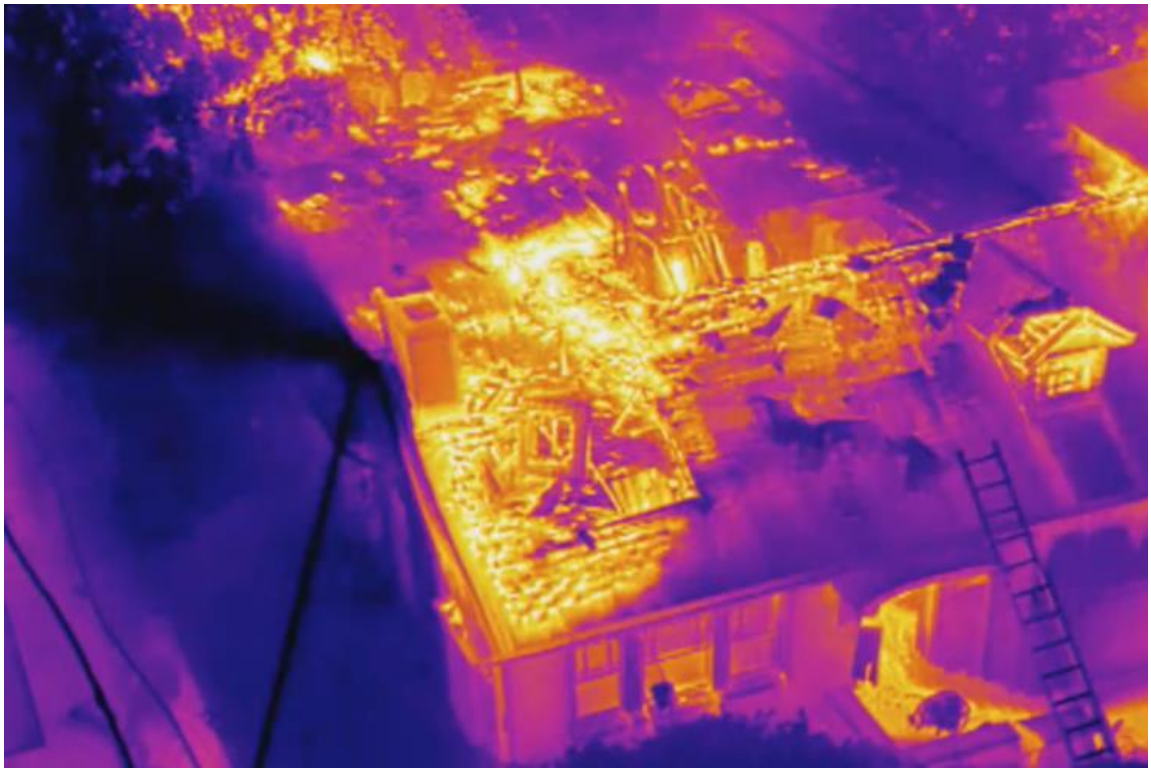

**Figure 2.8 Thermal Images can tell firefighters which part is the hottest**

Source: CNBC (Accessed on May, 2019)

Drones have been designed and developed to fight fires (Aerones firefighting drones, 2019). This type of drone can reach up to 300 meters in six minutes and spray water where a typical ladder reaches about 70 meters. With this technology, firefighters can put out fires in high rise buildings without having to risk a firefighter’s life on a ladder. Some fire departments in the United States are using drones to quickly understand an

emergency and make better decisions (How firefighters are using drones to save lives, 2019). They are using drones equipped with gas sensors and thermal cameras. These help them strategize their plans and take better action. For example, with the thermal imaging available, firefighters can be deployed to the hottest area of the emergency (Figure 2.8).

**Figure 2.9 AED equipped drone sent to a victim of cardiac arrest**

Source: Publications (Claesson et al., 2016)

Claesson et al., (2016) explored the usage of drones to deliver automated external defibrillators (AED) to victims of cardiac arrest. The use of AED prior to arrival to the hospital can significantly increase the chance of a victim's survival. Placing the drones strategically across the vicinity and leveraging the high velocity of drones, it may turn out to be a critical lifesaving element. Figure 2.9 shows a drone delivering an AED.

**Figure 2.10 Artist's depiction of a medical supply drone**

Source: Publications (Thiels et al., 2015)

Thiels et al., (2015) explored the usage of drones to supply medical products such as pharmaceutical and blood derivatives to hospitals, mass casualty scenes, and offshore vessels. Their feasibility analysis reveals the cost and time effectiveness of drones compared to motor vehicles and manned aircrafts which are usually used to transport emergency medical products. In Figure 2.10, a sketch of the blood supply drone is shown.

Adams et al., (2012) presents a case study representing the ability of drones to capture high quality imagery to investigate post-disaster scenes. The authors say that ground-based imagery can hinder important views and typical aerial imagery such as capturing from the roof of a structure may not provide the desired overall picture. Aerial photos from drones for post-disaster imagery is shown to be order of magnitudes better than capturing photos from the roof or from the ground.


**Figure 2.11 Post disaster picture of a structure captured by a drone**

Source: Publications (Adams et al., 2012)

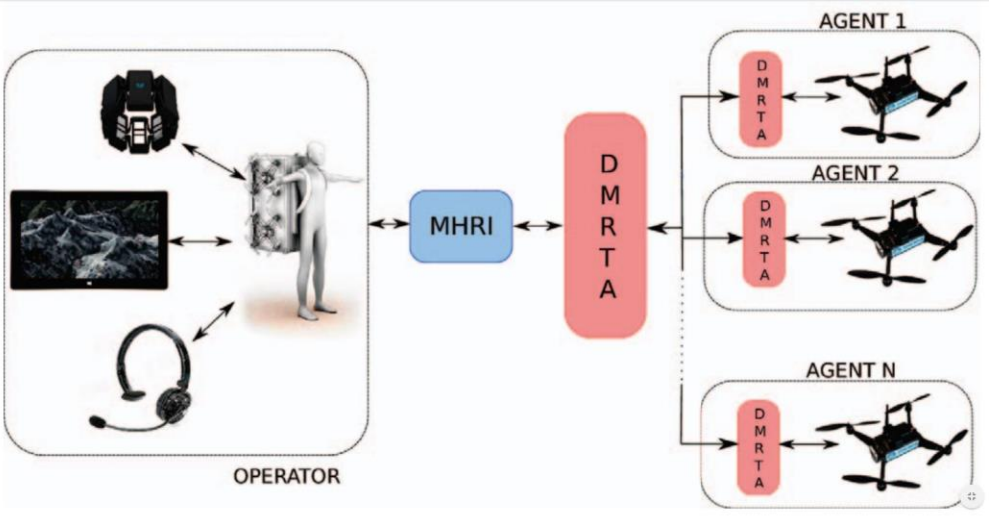


**Figure 2.12 The overall control architecture. The Multimodal Human-Robot Interaction (MHRI) module allows the human to interact with the agents, which are supervised by a Distributed Multi-Robot Task Allocation System (DMRTA).**

Source: Publications (Cacae et al., 2016)

Cacae et al., (2016) developed a system with multiple drones to assist in search and rescue (S&R) scenarios. The operator is not fully dedicated to controlling the drone which allows the operator to be involved in search and rescue tasks. The proposed architecture allows the operator to communicate with the drones using vocal and gestural inputs. The operator was assumed to wear light wearable devices, such as a headset, a gesture control armband, and a touch enabled mobile device. This would allow the operator to monitor the situation and control the drones. Initial tests with this framework proved to be encouraging to locate a lost person. Naidoo et al. (2011) designed and developed a drone specifically suited for search and rescue scenarios. Their only focus was on designing drones based on mathematical simulations and controlling the stability of the drone in different environments. Their design architecture is shown in Figure 2.12. Next, I explore privacy issues regarding public surveillance.

## 2.4. Privacy and Video

As mentioned in the previous sections, we see the need to address privacy and safety concerns when designing technologies that capture information in public places (Neustaedter et al. 2018; Singhal and Neustaedter 2018).

Dixon et al., (2003) conducted a study to find out public reactions to CCTV surveillance and street drinking bans. People's attitude towards CCTV surveillance was more positive than a street drinking ban. CCTV surveillance provided a sense of safety among civillians. The support was higher in busy locations rather than residential areas. The authors argue that CCTV surveillance could bring unintended consequences. For example, the proliferation of CCTV technology may gradually weaken people's sense of civic responsibility towards one another. Typically, people's acceptance is based on them being unaware of the capabilities of the surveillance system and the usage of the information (Honess et al., 1992).

Singhal et al., (2016) conducted *in situ* interviews to find out how people feel about being recorded or streamed through various devices such as smartphones and wearable devices like Google Glass in public settings. People's reactions were different to Google Glasses as opposed to smartphones. For example, people would avoid a path if they knew that they were being captured by a smartphone. On the other hand,

they would not do the same if it was Google Glass. The reason behind it was the more obvious nature of smartphones recording or capturing people rather than the subtlety of camera usage in Google Glass. This is one of the reasons participants in the study were more cautious with information and data when they felt like someone nearby was using Google Glass. Some participants of the study did not have any concerns with being recorded in public. Others expressed concerns if the recording would take place in a place such as a restaurant. The concerns raised by participants involved their activities, places, and gender. For example, participants would not want personal activities to be captured, or if they were in a personal place (i.e. home) Other concerns include the gender of the person who is doing the recording or streaming in a public space. However, all of the participants accepted being recorded in public setting if the recorder had prior permission.

Wang et al., (2016) conducted a qualitative study in the US to understand people's privacy perceptions of civilian drones. The authors argued that little was known about people's perception of drones in terms of privacy although extant literature suggested that drones invade people's privacy. Their study found out two important issues with drones, which are: powerful yet inconspicuous data collection, hidden and inaccessible drone controllers. Due to this, people's privacy can be easily breached. Participants, therefore, demanded to be notified when a drone was present nearby and to be asked for explicit permissions before recording. Based on the findings of the study, the authors proposed the following high-level privacy principles for drones: making both the drones and their controllers more discoverable, approachable, and accountable; enabling communication between drone controllers and ordinary citizens/bystanders; making drone designs sensitive to local social and cultural norms. Authors propose feedback systems such as a flashlight to let people know when they are around. This way people can be aware of a drone surveilling them. The authors argue that the controllers of the drone should be held responsible for the actions of the drone because of the capability of drones to breach people's privacy. This issue is heightened by the duality of drone which implies that, metaphorically, the "flying eyes" (drones and their controllers) can enter and peek into people's private spaces and lives together.

Chang et al., (2017) explored people's perception of privacy and security issues involving drones. This study makes drone design recommendations and regulations to enhance individual privacy and security. Wang et al., (2016) mentioned drones color, size,

speed, noise shapes people's perception of privacy and security. Chang et al. (2017) show evidence that drone movements, camera location, data recording capabilities, and feedback lights affect privacy and security perceptions. The authors recommend investigating how to make effective use of geo-fences, designated spaces for drones, and drone design to enhance positive drone perceptions and better protect users' privacy and security from drones.

Yao et al., (2017) also explored privacy issues around drones. It is important to understand the privacy perception of people around drones because it would provide insight into how to design drones for flying in public settings. The authors thus try to understand how the current technology of drones affects bystander's privacy. This would enable to make design recommendations for privacy friendly drones. The study mentions that participants' had a similar idea around identifying what are public and private spaces. Most of the participants agreed that privacy may not be achievable in public spaces. However, they felt it would be better if the drone controller would ask for permission while capturing data. This study also shows the idea of privacy breach is somewhat exaggerated since participants thought drones could not breach privacy any more than a powerful DSLR camera could. Participants also thought drone regulations would be useful for reasonable and considerate drone usage. These results suggest that people treat safety as their highest priority and the privacy issues around drones are overstated.

In another study done by Yao et al., (2017), they intended to find out the pros and cons of eight privacy mechanisms which they defined to preserve the privacy of bystanders being captured by drones.

In the surveys, the explored privacy mechanisms were as following:

- Deletion request: Drone controllers can receive requests from bystanders to delete a photo that was captured of the bystander or anyone related or anything owned by the bystander. This would be done via a mobile app.

- Gesture opt-out: Bystanders use gestures to opt out of being recorded. For example, two hands pose as X.

- No-fly-zone: Someone can choose his own address to be listed as a no-fly-zone for drones. If a drone approaches that area, there will be a warning.

- Owner registration: Every drone owner must be registered with the government.

- Controller-bystander app: A mobile app notifies bystanders around the drone of its presence, purpose, etc. Drone owners can also be contacted by bystanders.

- LED license: The drone will use a visible color blink sequence of its LED lights to serve as its unique “license” and the bystander can use a mobile app to capture the color blink sequence, identify the drone, and look up the information about the drone.

- Privacy policy: The privacy policy should include information about how drones are used, such as what kinds of drones controllers use; where, when and why they fly the drones; what kinds of data the drones will capture (e.g., pictures or videos) and for what purposes; how long the recorded data will be retained; how the recorded data will be processed and/or shared to others; and, if citizens have questions about their drone use, how to contact them.

- Automatic face blurring: Drones automatically being able to detect faces and applying obfuscating filters such as blurring to protect the privacy of bystanders.

Out of these eight mechanisms, authors found out that Owner registration and Automated face blurring received the highest support from the participants. Participants also suggested using a different combination of those eight mechanisms depending on the scenario.

| Mechanisms | Pros | Cons |
|---|---|---|
| **1. Deletion request (Delete)** | + Helpful if requests are respected (both) | - Too much work for bystanders (both)<br>- Controllers can ignore or reject requests (both)<br>- Too many requests (controller) |
| **2. Gesture opt-out (Gesture)** | + Good solution if people know about it (both) | - Too much work for bystanders (both)<br>- Have to learn the gesture (both)<br>- No need for opt-out (both) |
| **3. No-fly-zone (Zone)** | + Simple and requires little effort (both)<br>+ Add control over controllers (bystander)<br>+ Similar to do-not-call list (both) | - No law enforcement (both)<br>- Practical issues due to proximity of homes (both)<br>- Large amount of data (controller) |
| **4. Owner registration (Register)** | + Practical in tracking down controllers (both)<br>+ Similar mechanisms in other domains (both)<br>+ Discourage irresponsible use (bystander)<br>+ This mechanism is already in use (controller) | - Not directly protect privacy (both)<br>- Privacy issue for controllers (controller) |
| **5. Controller-bystander app (App)** | + Enhance controller-bystander communication (both)<br>+ Improve controller accountability (both) | - Too much work for bystanders (both)<br>- Privacy issues for controllers (both)<br>- Responses not guaranteed (bystander) |
| **6. LED license (LED)** | + Help identify controllers (both) | - LED patterns can be changed or hacked (both)<br>- Phone camera cannot recognize the pattern (both)<br>- Not directly protect privacy (both)<br>- Too many possible patterns (controller) |
| **7. Privacy policy (Policy)** | + Give bystanders peace of mind (controller)<br>+ Provide information about drone use (controller)<br>+ Hold organizations more accountable (bystander) | - People rarely read privacy policies (both)<br>- Not directly protect privacy (bystander)<br>- Policy not followed (bystander) |
| **8. Automatic face blurring (Blur)** | + Effective in hiding people's identity (both)<br>+ Make people feel more secure (bystander)<br>+ Need little effort, turn on by default (both) | - Conflict with controllers' purpose of use (both)<br>- Slow or inaccurate facial recognition (controller)<br>- Can be turned off (both) |

**Table 1. The pros and cons of each mechanism suggested by controllers and bystanders. We denote each point as raised by bystanders only, controllers only, or both. Mechanisms 1-6 and 3-8 were studied in survey one and two, respectively. Data about mechanisms 1-2 was from survey one, while data about mechanisms 3-8 was from survey two because it had more detailed mechanism descriptions and a wider range of feedback than survey one.**

**Figure 2.13 Pros and cons of the privacy mechanisms**

Source: Publications (Yao et al. 2017)

The pros and cons of each of these mechanisms is presented in Figure 2.13. Based on these findings, they impose three important questions: how much effort a mechanism demands from a bystander or controller; how practical a mechanism is in reality; and, how effective a mechanism is in practice.

Uchidiuno et al., (2018) also found similar results while exploring privacy expectations in people. Their study explored how privacy-preserving technology in drone design can mitigate privacy fears. They identify several classes of privacy-preserving technological solutions and evaluate their efficacy through a survey of 7,200 people on Amazon Mechanical Turk. They found that technology that prevents data collection in sensitive situations had the greatest impact on people. This study informs the controllers of drone and regulations rather than bystanders.

Six classes of privacy-preserving technological interventions for drones were examined based on a review of the literature and the authors' own intuitions which are similar to the privacy mechanisms of the study done by Yao et al. (2017).

- Class 1 – Prevent Data Capture. Prevent the physical capture of data by blocking, obstructing, or reorienting the drone or the data capture apparatus. Examples: no-fly zone, pointing the camera away from sensitive areas.

- Class 2 – Physical Desensitization. Data are allowed to be captured, but physical means cause it to become desensitized. Example: fly with camera pointed away from sensitive areas.

- Class 3 – Computational Desensitization. Data are allowed to be captured, but computational means cause it to become desensitized. Example: Blur detected faces.

- Class 4 – Indicate Collection. An indication is given for when and/or what kinds of data are being collected. Example: LED to indicate data collection.

- Class 5 – On-Demand Query. Individuals possess the means to query a nearby drone as to its owner, operator, and/or purpose. Example: drone bystander app.

- Class 6 – Trusted Indicator. A drone possesses a physical or digital emblem or certification of its trustworthiness. These emblems may be issued by a regulatory agency (e.g. the FAA in the US) or via crowdsourced means. Example: owner registration.

Study results show that class 1 and class 5 were most popular choices among the participants.

Based on these literature, I wanted to understand people's privacy and safety perceptions of emergency response drones and how they feel about the appearance and different functionalities of such drones as part of my own research.

## 2.5. Summary

The primary means of communication for emergency services in North America is still telephone calls. This often creates miscommunication, mental stress, and ambiguity. A lack of information from callers might make it more difficult for call takers to decipher the nature of a situation (e.g., medical symptoms of an injured person). On the other hand, callers sometimes feel like they are not being heard properly by the call takers which can lead to frustration and hostile caller. Given these challenges, research has shown that video calling might improve the overall emergency response. Investigations of next-generation technologies for emergency response explored the benefits and challenges of video calling to report emergencies. While there is literature around video calling for conferencing and emergency services, there is a lack of investigation into the benefits and challenges associated with using video-enabled drones for everyday emergencies and how such systems should be designed.

Drones have the potential to be effective for emergency situations by providing a bird's eye view. Studies involving drones provides us insight into the usefulness of drones for everyday emergencies although none of the research has looked into using drone footage to help firefighters during emergencies. Research on firefighters has looked into the usefulness of information sharing with firefighters directly and allowing them to control what information they need to see. Smartphone applications were also explored to help them communicate on the scene.

Literature on public surveillance systems such as closed-circuit televisions (CCTV) points to the possibility of invading the public's privacy. Yet many people are still accepting of CCTV surveillance despite the possibility of privacy breach. Typically, people's acceptance is based on them being unaware of the capabilities of the surveillance system and the usage of the information. Literature around people's privacy perception of drones surface the need for regulatory frameworks for drone usage in public. For these reasons, I decided to explore the privacy and safety issues associated with drone surveillance for emergency situations in our study.

In the next chapter, I describe the exploratory study I conducted where I interviewed firefighters and everyday citizens who had experience with calling 9-1-1 to report emergencies.

# Chapter 3. User Study Method

In this chapter, I discuss the method used to explore the usage of drones to assist firefighters during emergencies. I conducted an exploratory qualitative study where I interviewed eight firefighters, one civilian member of the police, and twelve everyday citizens who were experienced with calling 9-1-1 to report emergencies. Since it is relatively unexplored how drones might be useful to firefighters and the other benefits and challenges of having drones flying around an emergency, it was important to interview both firefighters and everyday citizens. For this study, it was important to get own reactions of each of the participants which is why the qualitative approach. Thus, the method described in this chapter addresses all of my research questions and research objectives.

## 3.1. Participants

I recruited 21 participants in total through snowball sampling (word-of-mouth), social media (posts on Facebook), and contact directly with emergency response centres within our city. Participants were in two groups.

***1. Everyday People:*** First, I included everyday people who had previously called 9-1-1. This group included 6 males and 6 females with an age range of 18 to the late 60s. Four participants lived with children and partners, one participant lived with parents, four participants lived with their partners, and two participants lived alone. All participants knew what a drone was and five reported that they had used one before. Participants called 9-1-1 an average of 4.2 times (median=2, range 1 to 15). Three participants called for all types of emergencies (medical, fire, police), two called for medical and fire emergencies, two called for only a fire emergency, one called for medical and police emergencies, and four participants called for only medical emergencies. The fire incidents involved house fires, vehicle fires, and a gas leak. Medical emergencies involved someone having a stroke, panic or anxiety attack, drug overdose, asthma attack, and injury. Police emergencies involved robbery in stores, domestic violence of neighbors, and threats at work.

***2. Firefighters:*** Second, I recruited eight firefighters. These participants had an age range of 36 to 65 with firefighting experience ranging from 5 to 40 years

**Table 3.1 Participant Description (Everyday Citizens)**

| ID | Age | City | Marital Status | No. of Children in Household | Other people at the household | No. of 9-1-1 calls |
|---|---|---|---|---|---|---|
| P1 | 36-49 | Whitby, ON | Married | 3 | None | 3 |
| P2 | 25-30 | Surrey, BC | Single | 0 | Mother | 1 |
| P3 | 18-24 | Richmond, BC | Single | 2 | Roommate | 3 |
| P4 | 31-35 | Maple Ridge, BC | Married | 2 | None | 2 |
| P5 | 25-30 | Vancouver, BC | Married | 0 | None | 2 |
| P6 | 31-35 | Vancouver, BC | Partnered | 0 | None | 1 |
| P7 | 50-56 | Maple Ridge, BC | Divorced | 0 | None | 10+ |
| P8 | 65+ | Kelowna, BC | Married | 0 | None | 1 |
| P9 | 31-35 | Vancouver, BC | Common-Law | 2 | Brother, Mother | 12 |
| P10 | 25-30 | Vancouver, BC | Common-Law | 0 | Roommates | 1 |
| P11 | 31-35 | Vancouver, BC | Single | 0 | None | 3/4 |
| P12 | 50-65 | Vancouver, BC | Single | 0 | None | 3 |

**Table 3.2 Participant Description (Firefighters and police)**

| Participant ID | Age | City | Rank | Experience (Years) |
|---|---|---|---|---|
| F1 | 36-49 | Calgary, Alberta | Network Engineer (Drone Operator) | 5 |
| F2 | 50-65 | Langley, BC | Deputy Chief | 40 |
| F3 | 50-65 | Langley, BC | Assistant Chief | 29 |
| F4 | 50-65 | Kelowna, BC | Civilian Member of the Police | 34 |
| F5 | 50-65 | Port Coquitlam, BC | Assistant Chief | 28 |
| F6 | 50-65 | Richmond, BC | Chief | 31 |
| F7 | 50-65 | Langley, BC | Captain / Acting Platoon Captain | 28 |
| F8 | 31-35 | Richmond, BC | Emergency Training Management Officer | 2 |
| F9 | 50-65 | New Westminster, BC | Chief | 34 |

(average=26.5 with median=31). Two participants had extensive experience with using drones for emergency situations; they operated and used drones for investigating emergencies on site. Our participants were ranked Fire Captain, Assistant Fire Chief, Deputy Fire Chief, Chief, Civilian member of the police, and network engineer for operating drones. While not our direct demographic target, I was contacted by a police officer during our recruitment period because he had extensive experience in using drones for emergencies. He was a civilian member of the police whose specialty was technology. One of his roles was to take requests to launch drones for helping police with emergencies. Given this experience, I interviewed him as well. This meant, in total, I conducted the study with nine first responders (8 firefighters, 1 police).

I have presented a summary of the participants in Tables 3.1 and 3.2 listed below. Table 3.1 contains information regarding everyday citizens. Table 3.2 holds information regarding the firefighters and the police.

## 3.2. Method


**Figure 3.1 The Inside of a Firetruck**

I conducted semi-structured interviews (Creswell 2014; Creswell and Poth 2018; Schensul, Schensul, and LeCompte 1999) with each participant. Interviews were conducted in-person with local candidates living within Vancouver, BC, Canada. Participants living outside of our city, but within Canada, were interviewed through a video communication system (Skype). I audio-recorded and took notes to summarize each of the interviews. Interviews lasted between 25 and 75 minutes. Questions were different for 9-1-1 callers and first responders given their backgrounds and differing needs. I structured the interview in two phases:

***1. Context:*** The first phase of the interview focused on the experience of people who called 9-1-1 for emergency services and the recent calls that the first responders attended. I asked them to describe these situations to provide us with knowledge of their experiences. After that, we asked all participants, if a drone was able to share video of the emergency with a 9-1-1 call centre, “What should it capture?” I also asked, “How would you feel about using a drone for this situation? What benefits do you see? What

challenges might emerge? What concerns would you have, if any?" Depending on their answers, I probed with additional questions.

I found that when recruiting and conducting our study that participants who called 9-1-1 more often (more than 4 times) could not remember every call situation. Therefore, when interviewing them they talked about the situations that they remembered within the previous five years. Participants tended to describe these situations quite vividly, thus, it is likely that their reflections of the events were mostly accurate. Yet my results do come with the caveat that all participants were talking about reflections and memories of the past where recall may not be entirely accurate.


**Figure 3.2 Screenshot from each video shown to participants. From top left: two fire incidents, one incident of an injury inside an apartment, two hazardous material incidents, two accidents.**

Source: YouTube (Video links in: http://clab.iat.sfu.ca/drone-study-videos)

***2. Video Scenarios:*** The second phase of the study focused on understanding participant reactions to actual drone-like video footage of everyday emergencies. I told participants

that they could imagine that a drone flew to each emergency location once a situation was called into a 9-1-1 call centre. Video would then be streamed from the drone to the call centre for call takers and dispatchers to see. This video footage would then, in turn, be shared with firefighters who were traveling to the location (viewing it in their firetruck) as a means to prepare them and help deal with the emergency situation. Firetrucks in our city all contain a laptop in the front that shows textual information about the emergency the firetruck is traveling to (Figure 3.1). For the most part, the use of drones was described as being something that would occur outside, where drones could fly within public spaces. Yet I also told participants that they could imagine more futuristic situations where a drone could possibly fly indoors to, for example, share footage of a medical emergency (e.g., a fall, a heart attack).

Because I could not engage participants in actual live emergencies, I used seven video clips of emergencies that were publicly available on YouTube. I edited each video clip to be 30 seconds in length. Figure 3.2 shows a still image depicting each video. The videos were categorized and purposely selected to be in four groups representing a range of emergency situations: fire, hazardous material, vehicle accident, and injury in an apartment. Four of these videos were actually captured by a drone while three of the videos were filmed with a smartphone. I used the smartphone videos to provide a different camera perspective of an incident in order to gauge reactions from participants. The videos had diverse characteristics such as providing aerial views, ground level views, and a combination of both views. I also included linear camera movement, circular movements, semi-circular movements, and a combination of linear and circular movements. Views were a mixture of close up and far out views. Given the exploratory nature of our study, I did not control for which videos contained which type of camera footage as might be found in a controlled study. Instead, I purposely included a large amount of variations in the video footage to gauge people's reactions to varied situations and camera work. Trying to control for different types of video footage in the scenes would have meant I could explore far fewer variations and scenarios.

I showed participants each video one-by-one and asked participants a series of questions about the video. Videos were shown in the order presented in Figure 3.2, from left to right, and top to bottom. Again, our study was meant to be exploratory and not controlled, so I did not randomize the order of scenes. Controlling scene order and using all possible permutation orders would have restricted the number of scenes I could show

participants. When participants viewed the scenes, I wanted to understand what benefits they thought the drone would offer and how comfortable they would be with the drone capturing the video footage. For example, I asked people who called 9-1-1, “How would you feel about the drone if you were the victim in this incident?”, “How would you feel if this incident occurred to [a neighbor, a friend, a family member, a stranger]?”, “How would your reaction change if the drone captured audio too?” I also asked questions about drone movement and control, e.g., “Would you like to suggest any drone movement patterns?”, “Do you think the drone should be autonomous or should it be controlled by a human?”, “When do you think the drone should stop capturing the scene?” Lastly, I asked about possible privacy and safety issues, e.g., “Do you have any privacy or safety concerns?” For firefighters, I was interested in understanding how the drones might benefit their work, what challenges they would introduce, and how drones should best be designed to support their work needs. For example, I asked, “What information can you gather about this situation with the current drone footage? How would it help you, if at all?”, “What can you not see that you would like to see?” The remainder of the questions were similar to the ones I asked the 9-1-1 callers as to whether they had safety or privacy concerns, what cameras views were best, etc. After the video questions were completed, I asked all participants where they felt the drones should be located, how they should appear visually, and what kinds of situations they thought drones worked best and worst for. A full set of interview questions is in Appendix. B.

## 3.3. Data Collection and Analysis

All interview data was transcribed and analyzed using thematic analysis to draw out the main and recurring themes. My approach to Thematic Analysis (Spradley, 1980) involved a seven-phase process:

**1. Summarizing the interviews**: This phase involved summarizing each of the interviews immediately after completing it. Even though the whole interview was recorded by audio, I wanted to anticipate what themes might emerge. This phase allowed me to get a sense of the important aspects of my study and probe future participants based on those aspects. For example, after the first two interviews, which were with 9-1-1 callers, I understood that I should probe the participants specifically with questions about two-way communication with the drone.

**2. Understanding the data**: In this phase, I went through the transcripts of the interviews and, sometimes, the audio clips of the interviews. The first phase already gave me a basic understanding of the data. However, in this phase, I read and re-read the scripts to understand the data better.

**Table 3.3 Data Analysis (Open Codes)**

| | |
|---|---|
| benefits | audio |
| limitations | stop capturing |
| camerawork | appearance |
| drone control | suggestions |
| privacy | location |
| safety | current use |
| concern | infrastructure |
| other people | ethics |
| assessment | resource management |
| drone types | selective situations |
| recording video | challenges |
| manpower | information overload |
| challenging scenes | |

**3. Coding**: In this phase, I labeled the data with codes to identify the important findings regarding drone usage to assist firefighters during emergencies. I coded the entire dataset for the later stages of analysis. For example, codes included “benefits”, “suggestions”, “audio”, “two-way communication”, “privacy”, “safety”, “appearance”, “drone control”, “camerawork”, etc. A complete list of the codes is presented in Table 3.3. I found groups of themes related to the benefits and basic usage of drones; challenges related to privacy, safety, the limitation of drones, and needs of callers; drone control; appearance; and, initial locations of drones.

**4. Generating themes:** I examined the codes and identified the significant broader patterns of meaning (potential themes).

**5. Reviewing themes**: I merged some of the themes to ensure they told a coherent story. I basically checked the themes against the dataset. I combined, split, or discarded some of the themes which I found from the previous phase.

**6. Defining and naming themes:** I developed a detailed analysis of the themes. I determined the focus and scope of each of the themes so that I could place relevant participant quotes to enhance the richness of the story.

**7. Writing up**: I contextualized the analysis and put it together in relation to existing literature and my research questions.

## 3.4. Summary

In this chapter, I discussed the method of my study that entails how I recruited the participants and how I collected and analyzed the data. I interviewed 21 participants. Twelve participants were everyday citizens with experience calling 9-1-1 to report emergencies. The interviews lasted between 25 and 75 minutes. Questions were different for everyday people and firefighter groups given their backgrounds and needs. I structured the interview in two phases.

**Context:** The first phase focused on the experience of both of the groups. We asked them to share details about the previous emergencies and asked how they would feel about drones capturing those situations; how they would want the drone to capture the scene; what they would not want captured etc.

**Video Scenarios:** The second phase of the study focused of understanding participant reactions to actual drone like footage of emergencies. I collected various footage of emergencies which were publicly available on YouTube (Fig. 1-7), clipped each footage to 30 seconds in length, and showed it to participants where I asked them to imagine themselves in the scene. The videos were categorized and purposely selected to be in four groups representing a range of emergency situations: fire, hazardous material, vehicle accident, and injury in an apartment. I showed participants each of the video

scenarios one-by-one and asked them a series of questions about the videos. Videos were shown in the order presented in Figure 3.2. The questions sought to understand the benefits, challenges, and the usage of drones for emergencies.

**Data Collection and Analysis:** I audio recorded all interviews which were later transcribed for richer analysis. My data analysis involved seven phases.

In the next chapter, I present the results of the study.

# Chapter 4. Study Results

In this chapter, I describe the themes that demonstrates how firefighters might use drones during everyday emergencies and how everyday citizens feel about drones in those situations. Then, I present some design and socio-technical challenges that were described during the interviews.

For quotes, I refer to each caller by P# (P followed by a number) and each first responder by F# (F followed by a number). For additional anonymity, I decided to keep the age and gender of the participants undisclosed which is why I used age ranges and kept participant genders undisclosed (shown in Table 3.1 and 3.2). For simplicity, in our results I refer to 9-1-1 callers as simply callers, and the firefighters and police officer as first responders. In cases where fire fighters or police responders gave different thoughts, I describe them separately.

## 4.1. Benefits and Basic Usage of Drones

The first responder participants talked about how they already used drones for a limited number of emergency situations. For example, several fire departments used drones to investigate incidents such as large-scale structural fires and wildfires.

> *There was a large-scale condo fire in a neighboring municipality. The fire investigator and myself were called out, uh, in order to gather aerial video and photos of the scene to provide additional perspective on the scene. -F1*

> *Some fire departments have their own drones and trained personnel to pilot the drone while some fire departments hire drone and licensed pilot to investigate the scene. -F5*

> *Some fire departments are deploying their own drones that they can control. And it can be very handy as the incident progresses. Especially in the back of our second and third operational period. -F5*

*Forest fires really move on quickly. So, we did actually, hire somebody to come and bring a drone. He was a commercial applicant of using drones and it [investigation] was very successful in the end. -F6*

Drones were also used for police emergencies such as search and rescue, and crime investigation. Drones were not yet used for everyday emergencies that were typically called into 9-1-1 call centres, given the newness of the technology and a lack of understanding for how drones could best be used and designed for these situations. The police officer described drones as being cost effective compared to a helicopter and capable of capturing images in a high resolution (4K). According to him, drones also saved time since getting the drone to an emergency scene was faster than finding a helicopter pilot and traveling there.

*We've had several drone incidents the last week. One was a search and rescue in Vancouver Island looking for a missing person. Another one we had was this week as well, was a, um, for a major crime fall, uh, six months after the fact, the major crime unit wanted to take photographs of the location. So those are two that are just this week. -F4*

*So, where drones are valuable for us is it's cost effective. They are because we do have our own helicopter fleet as well, but they're restricted to certain elevations as well as their, uh, camera equipment is not high def or 4k like we have on our drones and it takes a while for them to get going right. By the time they get known notification, get to pilot, get the go through the preflight stuff and all that. Whereas in a missing person case, sometimes time is sensitive. So. if we have somebody that's a drone pilot, that's in the area, uh, they could get up and running really quick. So that's kind of like the advantage of, of the drones for us. -F4*

All participants talked about a number of benefits associated with using drones when they were shown the seven emergency scenes, though some situations were seen as being more useful than others. I discuss these in detail next.

### 4.1.1. Fire Emergencies

All participants felt drones were useful for fire-related emergencies when they watched the two fire scenes (Scenes 1 and 2). Callers felt drones would be helpful in these kind of situations by providing call centres and first responders with a full picture of the situation. Callers talked about other benefits including locating the nearest fire hydrants, ensuring an appropriate amount of resources were sent, and firefighters being able to detect the location much faster by locating the drone. While callers were speculating about these advantages, the overall benefit was that callers felt an increased sense of trust in the first response being received because of the drone and its capabilities. They perceived the additional capabilities as enhancing the emergency response team. For example, callers talked about having mental piece of mind when they saw the drone, knowing that help was coming and 9-1-1 call centres knew more details about the situation.

> *I would be happy because I'm comparing it to the situation when there is no drone to capture anything. So, it's always better that they're getting more data so they can plan better to help me. -P4*

Firefighters found the drones to be useful in fire emergencies as a tool for size-up. They all analyzed the videos and discussed how they would pre-plan to handle emergencies such as what was shown to them. For example, firefighters talked about how they would position their apparatus to contain explosions, create rescue plans, park their vehicles, establish a safe-working zone, locate fire hydrants, etc.

> *This is a residential structure fire. Um, if there are occupants inside the building, it's not a survivable atmosphere, so, uh, they would not survive. So that would change the tactics as far as managing the fire that the risk to benefit of sending firefighters in is such that I would protect exposures and then have the fire work its way into the middle of the fire. But I would start from the outside and work it in. -F2*

> *That would be what we would call a defensive fire, so we're not going to go inside that building obviously because it's completely involved in and fire. Unfortunately, anybody inside the building would no longer be alive and that's a shame, but at least it informs us what we could do for other people. -F6*

One firefighter pointed out how he saw a truck near the building in the drone video, which gave him a sense of the size of the structure on fire. He thought these visual indicators would be useful. Firefighters also talked about how they often lacked a view from the top. They found having an 'eye in the sky' very useful and it would save them valuable time considering the time sensitive nature of the emergencies. They described how they often sent firefighters on the roof with a ladder to get a view from the top. Using a drone instead of a person or a helicopter would be beneficial in terms of safety, time, and cost. However, firefighters felt they would not need drones for small fires, i.e. a kitchen fire.

The police officer talked about how drones could be helpful in similar situations to move people and property (vehicles for example) to a safe location and help firefighters gain strategic information.

### 4.1.2. Hazardous Materials

In situations involving hazardous materials (Scenes 4 and 5), callers thought the drones would be useful for capturing information from locations where it might be harmful for humans to go. Callers were satisfied as long as the drone would be there to 'help.' Firefighters found the drones to be the most useful in hazardous material situations. Drones could help firefighters manage the site better, ensure public safety, and manage traffic because they'd be able to see any backups or patterns. Most firefighters emphasized the drone being able to detect placards/signs on vehicles involved in such incidents to find out the characteristics of the chemicals that might be spilled. They also said that drones should have sensors that would be capable of detecting the nature of any chemicals.

> *I need to identify the markings on the vehicle so that I can contact the carrier or see the placards. -F2*

Other benefits included determining the appropriate amount of resources to send. Firefighters pointed out that sometimes too many resources might exacerbate a situation. They also talked about displaying how long the drone had been recording the scene to determine their strategy. Longer time periods might mean differing chemical reactions or problems. The police office said that the drones could be useful for traffic management.

### 4.1.3. Vehicle Accidents

One of the accident videos demonstrated a situation where there was no injury and the situation was stable (Scene 6) and, in another video (Scene 7), there was a trapped person inside a vehicle. Callers felt drones could help first responders regulate traffic, provide instructions of what to do next (described more in a later section), capture information for insurance claims, and illustrate that someone was coming to help the victims. However, two callers said they would not want the drone to be at the scene, if the accident was their fault.

> *I'm scared to be identified as it was my mistake. That makes me bad, but obviously that's what I want. If it's going to police, I don't want to be identified in a video. -P9*

Firefighters felt that in car accidents without any injury, drones could help inform dispatchers to send the appropriate resources to a location. In situations with injuries or trapped victims, they wanted the drone to monitor the situation from a distance which is what they call ‘doing the outer circle.’ The outer circle is normally done by a person from a distance to find out if there are any broken car parts or injured people. Firefighters felt that if the drones could do this for them, they would be able to focus on the injured person. They cautioned that they did not want drones to get too close to the scene once they arrived, as they could get in their way. The police officer talked about detecting witnesses in such scenarios with the help of drone footage and how they can be helpful for insurance claims.

> *What we would want captured by the drone is just a strategic overview of the incident. Sometimes we'll use traffic cameras, there's cameras on the coast. -F5*

### 4.1.4. In-Home Medical Emergencies

After seeing the video of the drone flying out to an apartment complex with a medical emergency (Scene 3), participants had mixed feelings about drones for medical emergencies. Callers who had their own children at home reflected on their experiences and thought drones would help assess the severity of the incident. Of course, drones would then need to be able to actually enter an apartment or house, which would be

difficult with present-day technologies. Other participants did not think drones would be able to help in medical emergencies. Instead, they talked about other information that they thought might be more useful for call centres and first responders to know about, such as physiological data. This information was not something they thought drones could capture.

> *I would want them to know the intensity of my anxiety or whatever at that moment, intensity of my distress and my physiological readings, like my heart rate and breath being shallow and things like that. That I can imagine sharing with them, but, but my surroundings, that's, I don't see anything about my surrounding. -P2*

Two callers talked about using Google Maps instead of drones to get traffic details and location specifics. Three callers thought drones would be able to find out the entrance to apartment complexes.

Firefighters found drones to be useful to get traffic information for in-home medical emergencies. This could help them to travel effectively and efficiently to the location. Yet one firefighter was concerned that the drone might confuse them if it was not pointing to the correct entrance or multiple apartments or homes were seen in the drone's video. Firefighters suggested that having a building number on the roof would help them to detect the correct building. For example, while watching Scene 3, F5 said:

> *What we understand from that is there are two significant entrances to buildings. We're not sure which one is the right one depending on our mapping and things we have in the truck or in the ambulance or whatever it is we're responding with. -F5*

## 4.2. Design Needs and Challenges

Within the aforementioned situations, participants talked about ways that drones would need to be designed and realized in order for the benefits of drones to be achieved. They also talked about further challenges that might arise related to privacy and safety. I describe these results next.

### 4.2.1 Appearance and Location

First, participants talked about emergency response drones in ways that made them visually distinct from existing commercial drones that one might buy in a store or be available to consumers. Callers suggested appearances for emergency service drones that were different from existing commercial drones in order to make them stand out and be identifiable, much the same way that a fire truck clearly shows the public it is for handling emergencies. Four callers suggested using lights, while others suggested using bright colors. There were suggestions for drones to have design patterns like a fire truck or a police car. The appearance of the drone was important to callers because they wanted to be certain that the drone was sent for emergency services and there to help them, as opposed to being a drone sent by a stranger or non-trusted figure.

> *The drone color should be prominent because when I am in an emergency, I am panicking and it's going to be hard for me to know if the drone is from 9-1-1. -P2*

Firefighters and police also suggested similar design patterns in terms of colors and appearance. They noted that drones are relatively small, which might make it difficult to see them. They said it would be important to detect them from a distance. Participants also commented that drones have to be very light and so adding heavy lights or sirens may not be possible. Thus, it would be important to find a way to distinguish the drone visually with lightweight materials.

> *Creating payload or weight on a drone or on any kind of aircraft is an issue. The more weight you create, something would be taken away from what other things it could it do. -F6*

Six callers suggested drones should be able to go inside of a house or a vehicle in case of emergencies. This meant that they would need to be very small in order to maneuver through doorways and around obstacles. Such a small size could exacerbate the need to make the drone's appearance easily distinguishable and understandable at a distance. Callers also suggested drones that were tolerant to heat and possibly resistant to fire.

> *It would be very hard to find out my apartment for the first time. If the drone could go and find where is A100, that would be very useful. –P3*

Firefighters suggested using different types of drones for different scenarios. For example, they felt that drones equipped with sensors to detect and analyze different chemicals would be important for situations involving hazardous materials. The caveat is that, while important, the 'right' drone would need to be sent out to an emergency and knowledge of the specific situation would need to be known in detail a priori.

> *You may also have something like a gas sensor on it [drone] to determine, uh something that's being expelled from the tanks. -F2*

First responders thought that 'mini' drones could be useful in certain scenarios where the drone could go inside a building and figure out if there was any people inside. By 'mini' they referred to drones that were about the size of one's hand. First responders even talked about swarms of mini drones that could communicate with each other and save firefighters from exposure to fire or explosions.

> *I know some of the mini drones can form a swarm and do the mapping of the layout themselves and they can interact with each other. They can work great to rule out if there's anybody who is inside the building. -F7*

Callers felt drones should be located in places that already represented 'authority' and emergencies, such as at firehalls, police stations, and the rooves of hospitals. Callers felt that it was important that drones be located where they could see them in order to create a sense of safety. Three callers felt drones should be strategically located throughout the city in order to be able to reach any location in the shortest time possible. Other recommendations included locating the drones in a safe area where drones would not be stolen.

> *I think you should divide an area vertically and horizontally and calculate how many intersections you need to locate the drones so that they can go anywhere in the desired time. -P1*

First responders thought that firehalls were a good place to locate drones since firehalls were already strategically located in a city such that they are in close proximity to most areas. However, there were noticeable limitations described for cases where emergencies occurred on highways or railways that might be outside of a city and away from firehalls. Five first responders commented that there should be a risk-hazard-

vulnerability analysis to locate the drones strategically. Others noted issues with flying near airports, which I talk about more later.

> *So, your main highways, [north of the city] seems to get a lot of rescues, I think you need to do a risk hazard evaluation to determine that. And then there are the issues about drones flying around airports. -F2*

The police officer felt statistical data of emergency calls should be taken into consideration to geographically locate the drones because using too many drones might be expensive. This type of analysis might limit the number of drones that are necessary.

### 4.2.2 Capturing the Scene

I talked with participants about the camera views and flight paths that they thought would be ideal for drone footage of emergencies. All participants except two callers talked about the drone circling around the emergency scene from a high height to provide an overview of the incident. In some cases, callers suggested a combination of high views and close up circling around a scene. Participants felt that multiple cameras could be useful to capture a scene from all sides in a short amount of time, though some recognized associated cost issues.

> *I would want the drone to give me a bird's eye view and then come down to see if there are any victims. -P8*

> *I guess if there's multiple drones, I don't know if that would have got different angles at the same time as opposed to just one. Of course, that's probably more expensive. -P6*

Firefighters wanted the drones to do a size-up of an emergency scene for them. That is, they wanted the drone to approach a structure from the front side and rotate around it clockwise. The height of the drone depended on the structure where they would capture from a height of several hundred feet if it was a large structure. If it was just a house, they suggested capturing it from ~50-60 feet above. In the case of hazardous materials and car accidents, firefighters felt that the drone had to fly low and circle around the incident from a safe distance. This would allow them to see how many people were injured and get a sense of what the injuries might entail. When drones are dispatched to

residences, they felt that it would be helpful for them to fly to a building's entrance or show multiple entrances to them. The police officer also talked about circling around the scene.

> *Depending on the scenario, I would do a 360 from 10 feet, 30 feet, 60 feet to provide additional perspective to investigators. -F1*

Thermal images were pointed out as very important by the firefighters. Thermal images have the capability to provide heat signatures and possibly show if any humans are inside a structure.

> *We would use the thermal camera to see if this house on the other side of the street is about to catch fire or if there is someone inside. Sometimes the thermal cameras show temperature and we could act on it. I think that's very helpful. -F6*

Callers and firefighters both thought that drones should support a combination of autonomous and manual camera control and flying features. Callers felt there were many possible scenarios that could happen during an incident and a drone may not be smart enough to capture everything that is necessary on its own in an automated fashion. Callers were more comfortable with a drone that combined human control with automated flying. Again, this created feelings of trust in the technology and the emergency response.

> *If the drone could let him [pilot] know, "I can't get in, there's a fence" or "this place is too hot, I shouldn't enter", it would be very helpful and also keep the drone from getting destroyed. -P1*

Firefighters generally felt the same way and preferred a combination of autonomous and manual control features. However, they felt it was more important to gain manual control of the drone once they arrived on scene. They could then look at specific things of interest.

> *It should launch automatically, do a 360 for us in clockwise direction starting on the alpha side of the building, that is the address side of the building and from that point on, it should be manual. -F1*

### 4.2.3 Two-way Communication

I probed participants about the possibility of drones streaming or recording audio in addition to video. Callers suggested that drones should not only have audio, but that there should be two-way communication as well. Callers thought they would find it comforting if the drone was able to provide instructions to them at the scene. This might be done, for example, by a 9-1-1 call taker, dispatcher, or a first responder, who could speak through the drone using a form of two-way audio system. This builds on previously reported ideas that callers saw the drone as a way to comfort and help them, and not just provide video surveillance data. Callers pointed out cases where the situation could get chaotic or they might feel panicked. Here they felt that drones could be used as a tool to help calm them down.

> *I think it would be helpful in terms of maybe like broadcasting a message for everyone to like get clear, move out of the way, help is on the way or even providing instructions like from the situation like CPR. -P10*

That said, some participants thought that audio or two-way communication could distract firefighters from doing their duty and might reduce the resources available for dealing with the actual situation at hand.

> *I would be worried, you know, it could take a person or two and maybe they don't have that many people to attend to the victims. -P7*

Firefighters felt that audio or two-way communication might cause information overload if call centres were trying to communicate with them through the drone. However, they found value in being able to talk with dispatch centres in case they had questions with them. Some firefighters and the police officer thought that audio may not be useful because the sound could be drowned out by the drone's propeller noises or not be heard if the drone was high in the sky.

> *There's conversation happening in the firetruck and we're talking on the radio, we're listening to the radio. So, my initial reactions in this application, likely not for audio. However, if it was available and we could, you know, push, push a button and raise the audio. -F7*

### 4.2.4 Privacy

I anticipated that callers may be concerned about drones being used as a form of public surveillance, especially if they were bystanders of a situation and the emergency did not involve them directly. Yet all but two callers did not have any privacy concerns about drones capturing an emergency scene. Callers were willing to accept that emergency service drones were around and used because of the emergency nature of them. This sentiment held true regardless of whether the emergency incidents involved themselves, their family, friends, or strangers.

> *When I am going inside an operation [room], I don't think about my privacy. I only think about my life. I think these are similar. To me, life is more important than privacy. -P1*

Two participants expressed concerns about a drone getting too close to their property and capturing people in a situation where they would not normally want to be captured. They also worried about a drone coming into their home and capturing the inside of the house because their physical appearance and activities may not be favorable at that moment. They felt this could be traumatic for the victim. Other concerns related to capturing an apartment included the condition of the victim and other activities going on. For example, if someone calls for a drug overdose, being captured by a drone might be harmful for them in terms of law.

> *I don't want the drone to capture my apartment. Because you never know what they are doing inside. There could be police with them and it will look bad. -P11*

Other than those types of situations, callers did not have any privacy concerns provided that the drone was for emergency services. Firefighters thought that there should be regulations for capturing public information with drones. They felt that captured information should be stored in a secured manner and not end up in public spaces, e.g., online. They pointed out that if a firefighter takes a picture of an emergency, it becomes public property and people have the right to access that information. There were also concerns with unintentional collection of data.

*There is so much private information that you may gather, not that you're trying to gather that but you may invade privacy, it starts to become an overriding problem. Um, I think this is another issue, not that it would stop you from using it, but when you have that much data, how do you have these stored safely, securely. -F7*

In addition, firefighters expressed concerns with seeing drone footage containing graphic scenes involving death and damage to a victim's body. They felt like this type of footage should be shared only with the first crew members that arrive on the scene and others should be protected from seeing such footage. Other concerns involved seeing people getting injured or dying when firefighters cannot do anything about it. They felt these types of situations could cause them to have post-traumatic stress disorder.

*If someone is sitting on the balcony and dying, we are seeing it as we go to the scene, and we can do nothing about it, we don't want to see it. If someone dies, that's a very bad day for us. I don't want to see that and I want to protect my crew from seeing that. – F8*

### 4.2.5 Safety

As one might expect, participants had several safety concerns with drones. First, there were concerns by both callers and first responders about hackers infiltrating the information and using it to 'create chaos.' Three callers were worried that the drone might hit their motor vehicles in which case they would need to be compensated. There were ecological safety concerns with the possibility of drones interfering with flight patterns of birds or destroying bird habitat.

*If hackers get access to the drones and causes interruptions to stream video to 9-1-1 people, it would be very dangerous and they could learn from the videos how to create situations out of control. -P1*

Firefighters talked about how it is important to have a flight plan and make sure drones do not interfere with airplanes. They felt that it was necessary for trained firefighter pilots (as opposed to inexperienced firefighters) to handle drones around an emergency otherwise the drone could get destroyed. There were also safety concerns related to the drone falling on people accidentally.

*We fly this into the fire zone, it gets impacted by the fly ash and fall on someone and hits them. No one wanted that to happen. And if we do this daily, it's going to happen. -F6*

One firefighter was concerned that if drones did portions of their work for them (e.g., scene size-up), firefighters may begin to neglect their own duties. For example, physically walking around the scene to do a size-up is mandatory for firefighters, given current policies, even if a drone does it for them. There was concern about the drones recording video for future review since firefighters' decisions and judgements on the scene might be questioned by people or investigators. They pointed out that, when on the scene, they do what they think is best and have to make decisions very quickly.

*So, it would be difficult, I think, you know, if somebody had possession of footage after and we ended up in court, it would be a lot of questions and sometimes those questions would be healthy and sometimes those questions will not be healthy. -F5*

## 4.3. Summary

This chapter surfaced the usefulness of drones for both firefighters and people seeking emergency services. Some challenges with emergency service drones and socio-technical issues also surfaced. I present a summary of the results below:

**Benefits and Basic Usage**

Our first responders pointed out how drones are already being used by some firefighters to get an overall view of the scene. Firefighters currently use drones for large scale structural fire emergencies or wildfires.. Participants thought drones would be most useful for fire incidents. Firefighters thought drones could be useful to size-up the scene. Firefighters thought drones could be particularly useful for situations involving hazardous materials with the ability to detect placards on vehicles. Drones were also seen to be useful in cases when it was dangerous for a human to come near a scene. During vehicle accidents, participants thought drones could be useful to help regulate traffic and investigate the scene for evidence which might be helpful for post-investigation. For in home medical emergencies, participants with children at home thought drones would be

useful to assess the scene while two participants thought Google Maps would do the job well. Firefighters thought drones could help with traffic information, pointing out entry and parking areas in such scenarios.

**Design Needs and Challenges**

Participants, both callers and firefighters, thought emergency service drones should have a prominent appearance which would make them feel more comfortable in the event of an emergency. Emergency response drones need to be equipped with different sensors and need to be of different sizes depending on the situation. Locating the drones strategically around a vicinity is important because a drone should not take more than a minute to arrive to a scene during an emergency.

Firefighters specifically wanted the drone to circle around a scene counterclockwise starting from the address side of the building. They also thought drones should be autonomous in part with manual controls since firefighters wanted to be able to request specific views.

Callers felt that the emergency response drones should be equipped with both microphone and speakers for two-way communication between. Callers thought they would find it comforting if the firefighters would be able to provide instructions through the drones. That said, some participants thought two-way communication could distract firefighters from doing their work. Firefighters thought this could cause information overload and they would use it rarely.

Privacy was not largely an issue among the callers. Firefighters also did not have any privacy concerns but they pointed out unintentional data collection may cause privacy breach. They also showed genuine concerns in the event of seeing someone die on the drone footage when they cannot do anything to help that person. Safety issues involved drone being stolen or getting hacked. Some participants thought drones could hit someone on duty or interfere with air traffic.

In the next chapter, I interpret and discuss the meaning of the results.

# Chapter 5. Discussion & Design Opportunities

My study points to a range of design possibilities and challenges associated with drones and everyday emergency response. I created a design video based on my study which serves as a proof of concept (http://clab.iat.sfu.ca/drone-study-demo). There, I have summarized the findings of the study and presented some designs ideas which I will be discussing throughout this Chapter. After that, I also describe a software prototype I designed. Throughout this step, I adapted the *Research through Design (RtD)* methodology (Zimmerman, Forlizzi, and Evenson 2007) where I used the design and the process of creating it to generate new knowledge that builds on the lessons from my aforementioned study. *RtD* methodology employs design practice with the intention of generating new knowledge (Zimmerman, Forlizzi, and Evenson 2007). The produced knowledge here is more of a proposal than a prediction. *RtD* produces theory and solves problems in the form of design (Fallman 2003; Gaver 2012).

**Figure 5.1 Distinct appearance for emergency response drones**

## 5.1. Drones as a Trusted Companion

First, when callers talked about the emergency situations presented in the videos, they described a great deal of trust associated with the drone and what it represented, an authority figure who they equated with help. Prior literature has explored people's social acceptance of drones in situations not involving everyday emergencies (Cauchard et al. 2015). My study moves beyond these acceptance models and situations to illustrate that people even begin to see drones as somewhat of a companion in an emergency situation. For example, just seeing a drone coming was seen as being comforting. Compared to literature around public video streaming (Claesson et al. 2017; Neustaedter et al. 2017, 2018; Singhal et al. 2016), I noticed a high level of acceptance for drones with video cameras, providing that they are streaming emergency situations. This was regardless of whether participants were a victim, family member, friend, or a stranger/bystander to an emergency. Issues didn't arise until people thought about the possibility of doing something that may be considered illegal, or if they were possibly at fault for an accident.

When it comes to the design of such emergency response drones, it becomes clear that they should be recognizable as such: systems associated directly with help and emergency response. Participants suggested that drones should feature a prominent appearance that is easily distinguishable from commercial or recreational drones (Figure 5.1). If drones are clearly visible as emergency response drones, then people will likely trust them and value the work that they do for first response. Of course, there may be people who try to avoid drones if they are doing something suspicious or illegal activities and a prominent visual appearance may make such avoidance easier. I also saw more pragmatic needs emerge such as design challenges around the weight of drones and longer battery lifetimes. Firefighters pointed out that it would be beneficial if drones could have different functionalities to detect chemicals or components in the air, detect heat signatures, access indoor locations, or go into challenging locations. Having all those functionalities in a single drone could be quite challenging to design, at least currently.

Callers also talked about drones in a way that somewhat personified them as emergency responders in and of themselves. That is, they saw drones as a tool that might allow them to talk with actual 9-1-1 dispatchers or even first responders where the drone would act as an embodiment for a person. This represents an interesting design

opportunity and one that could profoundly change the workflows and capabilities of emergency response. Thus, it requires very cautious design and interactions with many different stakeholders to understand if and how such designs would work and what workflows would need to be changed within emergency response protocols so that work processes stay efficient. For example, two-way communication through a drone could create information overload challenges for 9-1-1 call centres and first responders. Yet the benefit is that two-way communication through a drone could present valuable new opportunities to provide instructions to people at the scene of an emergency, or mechanisms to calm people who are in distress.

## 5.2. Capturing an Emergency

**Figure 5.2 Example of a far-out view**

Source: YouTube

Capturing an emergency situation with a drone starts with the challenge of initially locating drones and where they start their journey from in order to reach an emergency location. Callers valued drones placed in areas of authority that resonated with notions of help and existing emergency services, e.g., fire halls. This builds further on the notion of trust that citizens would place in emergency response drones. Firefighters pointed to the pragmatics of ensuring drones are close to as many locations as possible. Once arriving at a scene, I notice further design requirements around the camera work needed to

adequately capture the scene.  Desirable views involved a mixture of close-up and far-out video (Figure 5.2 and 5.3), with various flying patterns to size-up the scene, gain broad contextual awareness, and monitor situations on the go.

**Figure 5.3 Example of a close-up view**

Source: YouTube

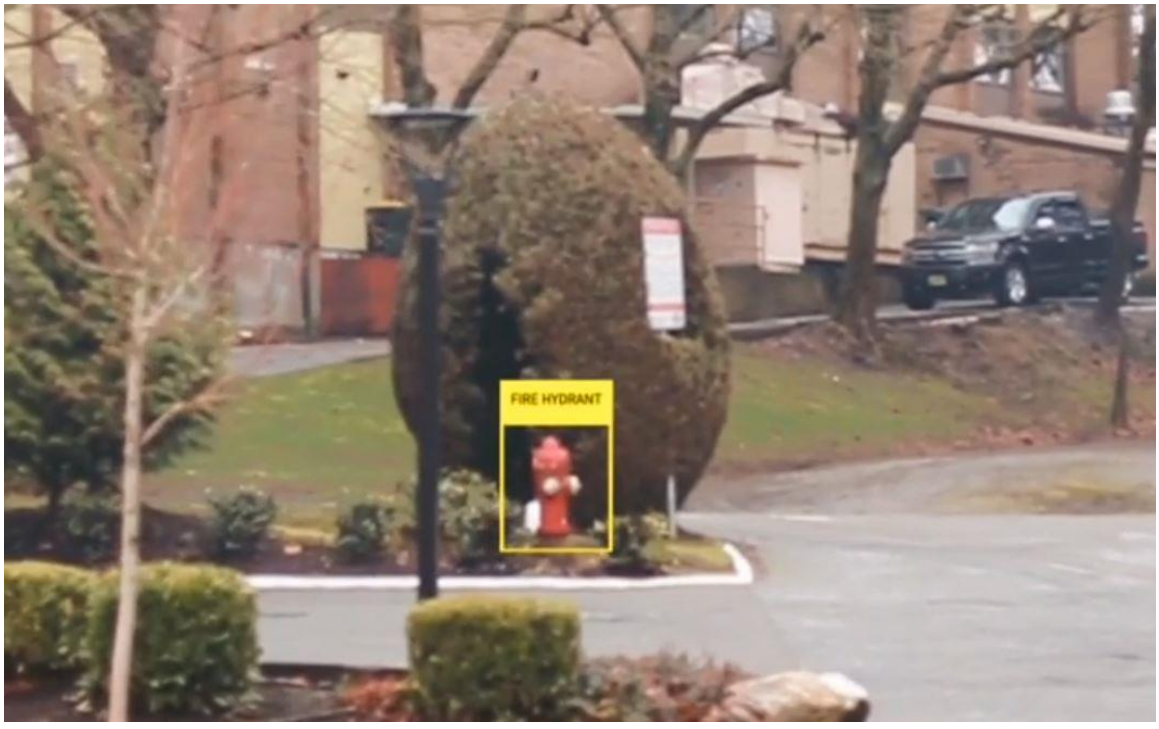


**Figure 5.4 Automatically detecting important object on drone footage**

Arguably more interesting is the way in which such views might be obtained. I probed participants about autonomous vs. manual control and predominantly saw the need for both. From the perspective of firefighters, this was for pragmatic reasons and the ability to ensure the right information was captured. From the perspective of callers, again, the element of trust arose where the combination of autonomous flying and manual control helped create feelings of trust. Based on this, one could then imagine autonomous drone features that might, for example, cause the drone to fly to a designated location and first capture a 360-degree view automatically. Image processing software might mark important objects around the scene, e.g., a fire hydrant or damaged vehicle (Figure 5.4). 9-1-1 call takers or dispatchers might then be able to take control of the drone and capture footage of particular interest to them. Firefighters might be able to communicate with these individuals and request additional footage. Again, one would need to be cautious about changing workflows and creating additional work and possibly information overload.

Within these drone behaviours and camera work, privacy concerns were somewhat minimal for participants, at least in the basic cases of drones being flown outdoors and capturing somewhat mundane details about an emergency, e.g., its location, who is around, what is wrong. The sense of an emergency's needs superseding privacy was evident. Yet some participants suggested more complex scenarios involving multiple drones, drones that could fly indoors, drones that might be small and highly mobile, and drones that recorded video footage rather than just streamed it to 9-1-1 call centres and first responders. While safety issues and drone flight paths are clearly an issue in the outdoors, especially around airports, issues around indoor flight, swarms of drones, and recording video footage create more contentious situations for emergency response drones. This raises legal issues for both callers and first responders, and possibly additional stress with seeing footage that may be considered gruesome.

Overall, this suggests design opportunities for future work to more deeply dive into how drone systems can be designed for these more complex situations. Participants saw value in such advanced drones and drone capabilities, but clearly there are issues that designs will need to mitigate. For example, how can drones fly safely indoors with large amounts of objects and people around? Do privacy concerns increase when drones become even smaller and are less visible, or when they are part of larger swarms of drones? There are also likely situations that design work will not be able to address. These will involve additional training (e.g., how does one fly swarms of drones?), public policy

(e.g., where can drones fly?), and updates to operational workflows (e.g., who is responsible for flying drones?). These all point to valuable future research and design work. In the next section, I describe a prototype I designed to explore some of the discussion points from this chapter.

**Figure 5.5 Parrot Mini Drone**

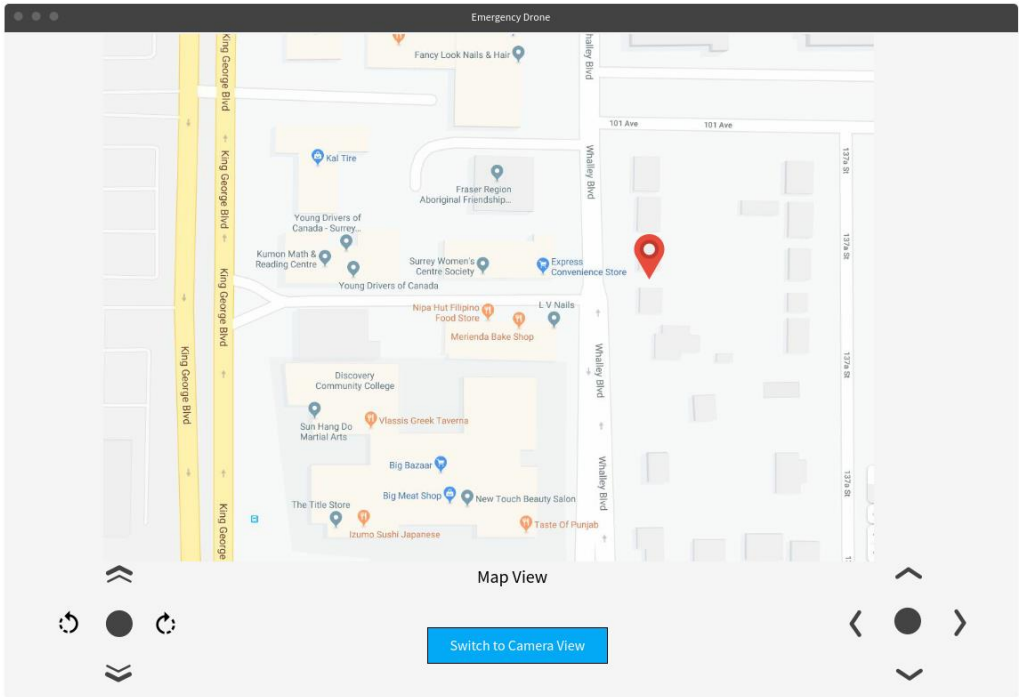


**Figure 5.6 Map view in the prototype**

## 5.3. Technical Implementation

Based on the aforementioned interpretations of the results, I designed a prototype with a recreational mini drone (Figure 5.5). This drone has the capability to connect to a laptop or a phone via Bluetooth technology. For my prototype, I developed a web application. With this prototype, I have generated knowledge which might be useful for academic designers and researchers in this design space. I discuss these in this section along with the design and features.

### 5.3.1. Drone Appearance

In order to conceptualize the distinct look for emergency response drones, I decorated a recreational drone with RGB lights (Figure 5.1). In this process, I attempted to use strips of LED lights but found that they did not have prominent appearance. After trying different types of LED lights, I decided to use strobing LED lights which appear prominent during daytime and nighttime.

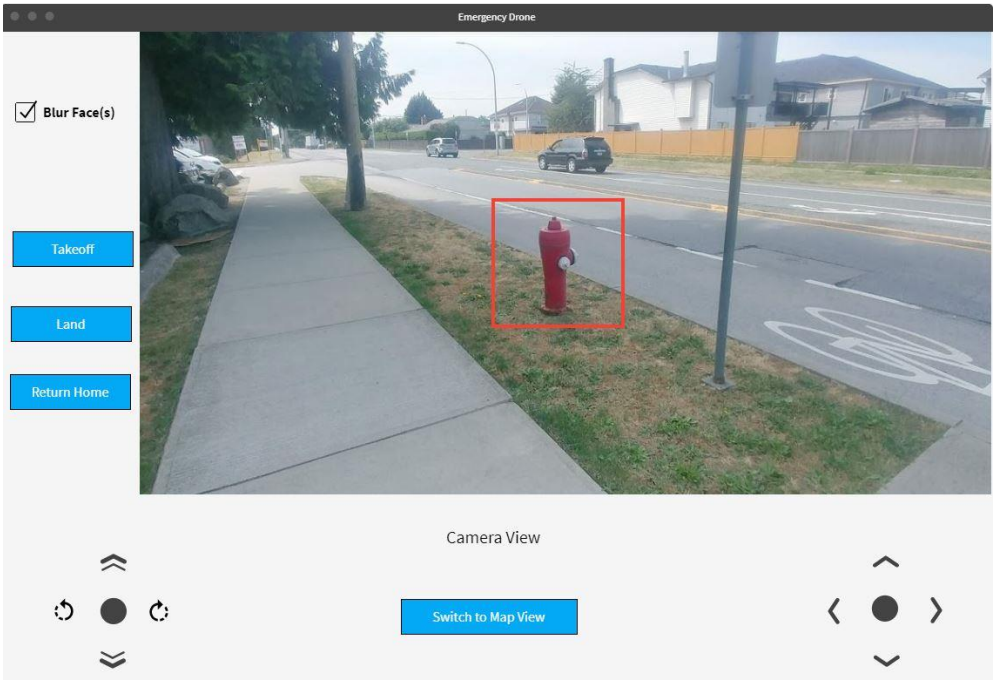


**Figure 5.7 Detecting important objects (i.e. fire hydrant)**

### 5.3.2. Map view

The results point to the need for drones to automatically fly to the emergency scene and circle around the scene continuously circle around the scene unless firefighters request a different view. I have designed my prototype to support this feature. As can be seen in Figure 5.6, a Google Map view is loaded on the screen for the drone application I developed. The user can click anywhere on the map and a marker will pop up on that location. This denotes the destination where the drone is supposed to arrive. For the purpose of the prototype, when a user clicks on the map, the drone automatically flies to a predefined location rather than the actual location since the drone we have used (Figure 5.5) does not have a GPS sensor. Upon reaching the predefined location, the drone circles around the scene continuously unless instructed otherwise. Upon implementation, I realized this feature requires significant amount of technical implementation and research in future. It starts with teaching the drone to be intelligent enough to take a safe route to the destination while following the regulations. Then, when the drone reaches the scenario, it needs to be taught to centre the emergency so that it can circle around the appropriate area of interest

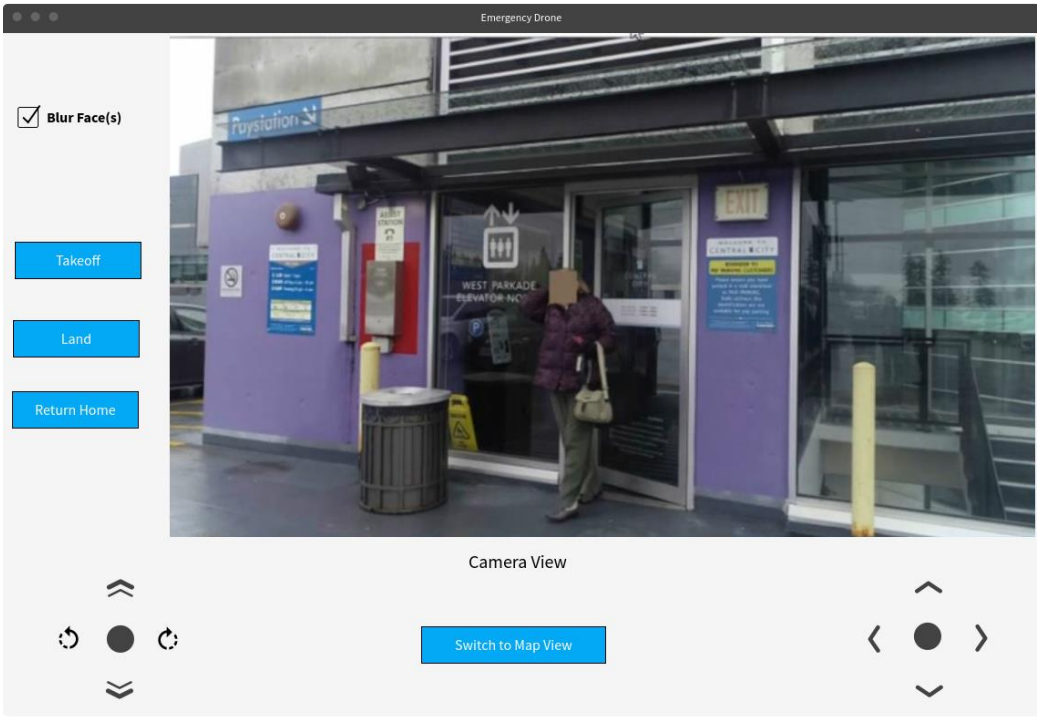


**Figure 5.8 Blurring face on the drone footage**

### 5.3.3. Drone Control

As can be seen from the results, there should be a combination of automatic and manual controls for emergency response drones. Even though the drone should fly out automatically and circle around the emergency scene, there needs to be a way to control drone movements. I have introduced this feature in my prototype where the user can manually control the drone movements. Throughout Figures 5.6 and 5.7, the buttons in the bottom-left and the bottom-right corners of the user interface control drone movements such as rotation, height, braking, and moving left/right, etc. The layouts for the drone movement buttons conform to the standard layouts for drone remote controllers. In Figure 5.7, the buttons on the left allow the user to land or takeoff the drone (labelled as “Takeoff” and “Land”). There is also an additional button, “Return Home,” which brings the drone back to the starting point. This is important because when the drone has served its purpose, it should safely return to its origin. The buttons “Switch to Map View” and “Switch to Camera View” allow the user to switch between the camera footage and seeing the Google map.

The user has to use mouse buttons to click on the drone movement buttons to control drone movements. The challenge here is that the user can only click one button at a time. This means if the user wants to move the drone forward while banking left, much like a semi-circular movement, it would not be possible with mouse clicks. This challenge is overcome by the use of touch screen-enabled displays. Another alternative would be the use of keyboard keys to control the drone movements.

### 5.3.4. Image Processing

My study results show the need to mark important objects such as fire hydrants, safe parking spots, etc. In this prototype, I have used image processing techniques to detect and mark fire hydrants automatically when they appear on the drone footage (Figure 5.7). Since this is a proof of concept, I have only detected fire hydrants because more research is needed to identify the complete list of objects which may be of interest to firefighters during an emergency. While implementing this feature, I found it difficult to detect fire hydrants when the drone was capturing from high enough where the fire hydrant is not clearly visible. To detect fire hydrants efficiently from a high height, more sample data and research is necessary which I did not look into during this research. Therefore,

my prototype is only able to detect fire hydrants where it is clearly visible as shown in Figure 5.7.

To protect the privacy of bystanders in the general public, the faces of people are automatically blurred when detected in the drone's video footage (Figure 5.8). There is a checkbox on the top-left corner that allows the user to blur or unblur the faces. By default, this checkbox is selected so that the faces will be blurred unless the user unchecks the box. It is important to note that people's faces are not clearly visible if the drone captures them from a far-away distance, such as being high in the sky. In those cases, privacy may not be much of an issue anyways since faces would be harder to see.

### 5.3.5. Next Steps

As can be seen in the results, emergency service drones have other design needs which are not present in the technical implementation. For example, drones require a longer battery life which is very difficult in the present. We imagine drone battery life will improve significantly in the future. Different sensors such as a thermal imaging camera and gas sensors should be available in the drone for different emergencies which I could not implement due to the functional limitation of the drone. Emergency response drones may need to be controlled remotely from a distance which is prohibited by current regulations. Also, two-way communications through emergency drones can be enabled by quipping the drones with microphones and speakers. Present commercial and recreational drones do not offer such functionality. This needs to be changed to allow emergency response drones to be in effect in the future.

## 5.4. Summary

This chapter details how drones could be designed so that they can be a trusted technology in the event of an emergency both to everyday citizens and firefighters. I present a summary of this chapter below.

**Drones as a Trusted Companion**

Callers showed a great deal of trust in emergency drones. Drones can be thought of as companions in emergencies. Compared to literature around public video streaming

[9], we see a high level of public acceptance of drones. Therefore, emergency service drones should be clearly recognizable. Callers also talked about drones in a way that somewhat personified them as emergency responders in and of themselves. That is, they saw drones as a tool that might allow them to talk with actual 9- 1-1 dispatchers or even first responders where the drone would act as an embodiment for a person. Although there is a possibility of information overload on call takers or first responders because of two-way communication.

**Capturing an Emergency**

Capturing an emergency starts with the challenge of initially locating drones. Most participants valued drones placed in areas of authority that resonated with notions of help and existing emergency services, e.g., fire halls. Once arriving at the scene, we see further design requirements around the camera work needed to adequately capture the scene. Desirable views involved a mixture of close-up and far-out video, with various flying patterns to size-up the scene, gain broad contextual awareness, and monitor situations on the go. Also, a combination of autonomous vs. manual control could ensure the capturing of the 'right' information. Image processing software might mark important objects around the scene such as fire hydrants or damaged vehicles.

**Technical Implementation**

I designed and developed a prototype with a recreational mini-drone as a proof of concept for the results of the study. This prototype illustrates features such as drone camerawork, automated vs. manual controls, object marking, and privacy blurring for video feeds.

In the next chapter, I review the research contributions this thesis puts forward and add some final words.

# Chapter 6. Conclusion

This final chapter summarizes the research contributions in this thesis. First, I reiterate the research questions which I presented in Chapter 1. I then describe my research contributions by outlining how I achieved each of my thesis objectives from Chapter 1. Lastly, I discuss opportunities for future work in the field of drone usage for firefighters.

## 6.1. Research Questions

Chapter 1 outlined three research questions within the area of using drones to assist firefighters during emergencies while also considering the socio-technical issues. The overarching problem that this thesis addressed is: *we do not know how to design the system with drones and the drone itself to assist firefighters while also tackling the socio-technical issues*.

**Question 1: How might firefighters make use of drone footage in an emergency?**

**Question 2: What benefits and challenges do 9-1-1 callers feel exist for drones that capture video of an emergency situation?**

**Question 3: How should drone systems be designed to aid firefighters during an emergency?**

## 6.2. Thesis Contributions

To address each of the aforementioned research questions, I completed the following objectives which offer research contributions:

**Objective 1: Investigate the ways firefighters would like to use drone video footage when responding to emergencies.** In Chapter 3, I presented an exploratory study to investigate how firefighters might find the usage of drones useful while responding to everyday emergencies. I was interested in finding out how they expect the presence of drones on the scene, how they want to view the information shared by the drones, how

they want to control the drone, and what benefits and challenges they anticipate due to the presence of a drone on the scene. The results show that firefighters find the visual information useful which is often missing while they are travelling to an emergency. They find the idea of drone arriving on the scene before them and share the live footage in the fire truck. In addition to sharing footage, firefighters often expressed their needs to have the drones equipped with different sensors such as gas sensors, or swarm of mini drones. Firefighters value the drones more in situations involving fire and hazardous material while they also display interest for drone usage for other types of emergencies as well. The camerawork that firefighters are mostly interested in is an overall view of the scene where the drone circles around the scene from different height levels ranging from about 50 metres to 200 metres. They also want to be able to request a specific view in case they need it.

These results extend the existing literature by providing an insight into designing emergency response drones. Previous literature points to the need to have video information available for emergency service workers (Neustaedter et al. 2018; Singhal and Neustaedter 2018), but does not describe how drones may fit into the situation. Also, previous literature shows firefighters value seeing the situation for themselves and keeping themselves updated about the emergency through technology (Betz and Wulf 2014; Jiang et al. 2004; Ludwig, Reuter, and Pipek 2013). However, it was not clear how firefighters may want to use live video information and how they might want to see the information using the drone. Drone studies do not point to proper camera work and controls for emergency situations (Adams, Levitan, and Friedland 2012; Cauchard et al. 2015; Jones et al. 2016). My study goes beyond these prior works by describing how firefighters may want to view the drone footage during emergency situations (i.e. camera work, drone control).

**Objective 2: Investigate the benefits and challenges for 9-1-1 callers of a drone capturing images and recording videos during emergencies.** Chapter 4 outlines the benefits and challenges of emergency response drones as perceived by 9-1-1 callers. Result show people express a sense of trust with drones when they imagined themselves in an emergency situation and privacy breach was not a concern for the majority of participants in my study. Design suggestions around socio-technical issues lead to the need for filtering out people or properties that may not be of interest to the

emergency. To handle safety concerns, drone software needs to be able to land the drone safely in the event of a possible crash and avoid obstacles.

Previous research shows the benefits and challenges of video calling (Neustaedter et al. 2018; Singhal and Neustaedter 2018), but does not provide any insight into drone usage. My study specifically details the benefits and challenges that people feel exist in relation to emergency response drones. Literature around CCTV cameras and drone surveillance surfaced privacy concerns among public (Boyle, Neustaedter, and Greenberg 2009; Chang, Chundury, and Chetty 2017; Uchidiuno, Manweiler, and Weisz 2018; Yao et al. 2017). But this literature did not articulate how people might react to a drone that captures video solely for emergency purposes. Also, it is not clear from the literature when and how privacy issues need to be handled in the event of an emergency. My study reduces that gap by providing information around privacy controls for emergency response drones.

**Objective 3: Designing a proof of concept drone system based on the prior objectives.** Finally, as a proof of concept, I developed a video and designed a software prototype with a drone which I described in Chapter 5. For the video, I modified the appearance a commercial drone to conceptualize it as an emergency response drone which signifies the attempt to support public trust by providing a prominent appearance. Other features include blurring/unblurring people's faces to support privacy protection. In the software prototype, I wanted to have a few concrete design ideas that surfaced from the study such as marking important objects, protecting privacy through obfuscation filters, etc.

Previous work provides insights into the usefulness of drones. For example, drones are able to provide overall views of a scene in high resolution (Jones et al. 2016). Some of the literature calls for a regulatory framework for drones usage (Kerasidou, Büscher, and Liegl 2015). Some firefighters in the USA are using drones to help them figure out how to put out fires on the scene (Aerones firefighting drones, 2019.; How firefighters are using drones to save lives, 2019). Some of the previous works built systems with drones for search and rescue scenarios (Cacace et al. 2016; Naidoo, Stopforth, and Bright 2011). The focus of those works was technical implementation rather than designing systems for emergencies. Overall, none of the previous works explain how systems with drones can be implemented to assist firefighters and leverage drone

cameras. My study goes beyond the prior work by considering the human factors and generating design suggestions and opportunities in this space. Based on my those results, I designed proof of concepts in the form of a video and an application to address the gap.

## 6.3. Limitations and Future Work

While this study presents promising opportunities in this design space, there are clear limitations. Caller reactions were based on the video scenarios as opposed to real life situations. If the callers would find themselves in a real emergency situation, they might have reacted differently. For example, they might not even notice the drone or be concerned about the drone at all. Firefighters viewed the videos and reacted to them in a much calmer environment than they would typically be used to during an emergency. If they had seen the video of a real emergency situation, they might have been more concerned about reaching the scene and tackle the emergency situation rather than seeing video footage. The video scenarios may also have somewhat limited participants' imaginations and reactions to emergencies because I could only choose a narrow set of scenes. There are an infinite amount of different emergency situations. If participants were shown a different video other than what I showed them, they could have react differently. I tried to pick a variety of scenarios that firefighters generally get called to in order to mitigate this limitation.

The study was conducted within Canada and it may be the case that participants' reactions are indications of the culture within the country more broadly. For example, the culture in Asian countries is different and the people in those countries may have a completely different perception of emergency response drones. Also, snowball sampling to find the participants could have biased their responses because the participants could have shared similar characteristics and traits. Also, participants could have tried to share their views in favor of the researcher rather than expressing their honest views. Firefighting and 9-1-1 calling practices may also be more specific to our country, though it is known that firefighting practices and emergency response is somewhat homogenous across Canada, the United States, and the UK based on prior research (Betz and Wulf 2014; Ludwig, Reuter, and Pipek 2013; Svennevig 2012; de Vasconcelos Filho, Inkpen, and Czerwinski 2009). Firefighting apparatus and practices are different in many countries

around the world. Together, these limitations suggest future work exploring additional reactions and thoughts from participants in other countries and cultures more broadly.

## 6.4. Final Words

Technology is prevalent almost everywhere in the modern world. Emergency services should leverage different technologies to more efficiently serve people. Drones are an example of one such type of technology. Learning how to operate a drone is fairly easy and not cumbersome. Drones have limitations such as the shorter length of battery backup and not allowing control from long distances due to both the technology and regulations. We can safely assume these will change in the coming future and that the usage of drones may be more prevalent. Drones also present some challenges since it can interfere with the airspace of commercial airplanes or helicopters. Technology could address this issue by detecting a commercial or recreational drone in the airspace so that flying near airspaces should not be troublesome. Some recreational drones already have very good obstacle detection and avoidance mechanisms; this is a start to help safety concerns.

This thesis presents an exploratory study of firefighters and everyday citizens who are experienced with reporting emergencies to find out how drones can assist firefighters during emergencies. This study also explores the socio-technical issues that might arise due to the presence of video capturing drones in public. Throughout my research, I discovered how drones can be useful not only to firefighters, but also to emergency service seekers in the event of an emergency. Drones can be a constant eye in the sky in the event of an emergency that looks after the victims and helps firefighters handle emergencies better. While doing this, privacy and safety issues, including other social issues, must be considered when designing drones for emergency services.

Hopefully, this thesis will inspire future researchers and designers to design and develop technologies with drones to assist emergency service workers such as firefighters, police, paramedics, call takers / dispatchers, and everyday citizens during emergencies. I hope my study results will provide suggestions and directions to those researchers and designers exploring this area. I look forward to the time when people call to seek emergency services and a drone flies out in a ‘flash’ and assists both emergency service workers and emergency service seekers.

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# Appendix A. Ethics Approval

SFU
OFFICE OF RESEARCH ETHICS
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Director 778.782.6593
Associate Director 778.782.9631
Manager 778.782.3447

**Amendment Approval - Delegated**

**Study Number:** 2017s0043
**Study Title:** Mobile Video Calling for Emergency Situations

**Amendment Approval Date:** 2018 May 7
**Principal Investigator:** Neustaedter, Carman
**SFU Position:** Faculty
**Expiry Date:** 2019 January 30
**Supervisor:** n/a
**Faculty/Department:** Interactive Arts & Technology

**SFU Collaborator:** McGee, Josh; Jones, Brennan; Khan, Nafiz; Dash, Punyashlok.
**External Collaborators:** n/a
**Research Personnel:** Singhal, Samarth
**Project Leader:** n/a

**Funding Source:** n/a
**Grant Title:** n/a

**Document(s) Approved in this Amendment:**

- Change in Study Team Members

The amendment(s) for ethical review and the document(s) listed above have been reviewed and the procedures were found to be acceptable on ethical grounds for research involving human participants.

Please note that approval of the amendment(s) does not change the expiry date on the current SFU REB approval of this study. The approval for this study expires on the **Expiry Date. An annual renewal form must be completed every year prior to the Expiry Date. Failure to submit an annual renewal form will lead to your study being suspended and potentially terminated.**

**This letter is your official Amendment Approval documentation for this project. Please keep this document for reference purposes.**

**The amendment to this study has been approved by an authorized delegated reviewer.**

# Appendix B. Consent Form

FACULTY OF COMMUNICATION, ART AND TECHNOLOGY
School of Interactive Arts + Technology

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**Informed Consent Form**

**Research Project Title:**
Mobile Video Calling for Emergency Situations

**Ethics Application Number:** 2017s0043

**Document Version:** Amendment Version 2, Oct 23, 2017

**Investigators:**

- Carman Neustaedter, SIAT, Simon Fraser University
  604-754-1191, carman@sfu.ca

This consent form, a copy of which is made available to you, is part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, you should feel free to ask the investigator(s). Please take the time to read this carefully and to understand the information.

**Purpose**

The goal of our research is to understand how mobile video calling and other new technologies might be useful in emergency situations and how we can design technologies to best meet the needs of end users.

## Participant Recruitment and Selection

To be recruited for this study, you must be over 18 years of age and work as an emergency medical dispatcher (EMD), emergency first responder (e.g., paramedic, firefighter, police), or first aid trainer; be taking a first aid class as a student; or, have called 9-1-1 to report an emergency situation.

## Study Method

We will use a combination of methods:

1. **Observations of first aid classes and interviews:** We will observe first aid classes to understand the practices that first aid instructors teach people for helping in emergency situations. This will allow us to see and understand what practices might be easy or difficult to communicate over video calls during emergency situations. Observations will transpire over the duration of the class. The researcher will act as a participant in the class and also observe the activities of others who are in the class. At the start of the class, the researcher will introduce himself to the class and explain the study and his role in observing the class. Permission to observe the class will be given by the class instructor and each person in the class will be given a consent form; if someone does not consent to participate, the researcher will not collect observational data about that person.

   We will interview first aid instructors about their teaching practices and emergency response outside of the class time. Interviews will take no more than one hour.

2. **Interviews with EMDs and first responders and observations of EMD call centres:** We will conduct one-on-one interviews with EMDs and first responders where we ask them questions about their work practices and needs and how they are trained to talk with callers. Interviews will take less than an hour. We will also observe work activities over several hours at one or more EMD call centres, with the permission of the call centre.

3. **Interview with people who have called 9-1-1:** We will conduct one-on-one interviews with people who have called 9-1-1 in the past to understand the situation around their call and how they interacted with call takers. We will ask them for feedback about the use of future technologies as a part of 9-1-1 calls.

**Benefits and Risks**

Participants will not benefit directly by participating in the study. The risks of the study are expected to be none or minimal. We ask that participants not reveal confidential information about specific incidents (e.g., patient names). You will be asked to recall past 9-1-1 calls or emergency situations that might be distressing or traumatic. You are free to share as much or as little about such situations depending on your comfort level. If you would like additional professional support, we suggest contacting one of the following counseling services:

- Family Services of Greater Vancouver, 604-874-2938, http://www.fsgv.ca
- SFU Counseling Services (for SFU students), 778-782-4615, https://www.sfu.ca/students/health/services/counselling.html
- SFU Employee and Family Assistance Program (for SFU Staff) https://www.sfu.ca/human-resources/faculty/benefits/efap.html
- Crisis Centre of BC, 604-872-331, http://crisiscentrechat.ca

If you agree to participate, you will be free to withdraw at any time for any reason. However, data collected up to that withdrawal point may still be retained and used by the researchers.

Research results, such as published papers, can be obtained by contacting any of the investigators:

- Carman Neustaedter 604-754-1191, carman@sfu.ca

## What Happens to the Information I Provide?

No one except the researchers and their assistants will be allowed to see or hear any of your data.

Confidentiality will be strictly maintained. Any data collected will be labeled with an anonymous participant ID.

We will not record audio or video of class activities. If there is a portion of a first aid class (e.g., a teaching activity) that would be valuable to have on video recording for analysis purposes, we will have the instructor recreate the training activity after class during their interview for recording purposes. Video will be recorded in a manner so that the participant's identity is not revealed. We will collect images and video of work practices in 911 call centres, with the permission of the centres. Confidential data within the images and video will be masked to obscure it.

Refusal to participate or withdrawal/dropout after agreeing to participate will not have an adverse effect or consequences on the participants.

All information collected will be anonymized. No identifying information will be kept alongside the data. The collected information will be digitally recorded and transcribed. After the audio is transcribed, we will destroy the recordings. Transcriptions, audio, and video will be kept on an external hard drive and stored in a locked cabinet in the secure office of the principal investigator at the School of Interactive Arts and Technology until 2020 or until the study analysis is completed. At this point, it will be permanently destroyed.

Public presentations of the results will primarily present the results in an anonymized form. Where individual participant data is disclosed, such as exemplar comments via quotes, we will ensure that the selected data does not suggest participant identities. Video recordings may be used in anonymized form (e.g., participants will be blurred out) for presentations; otherwise, it will be destroyed immediately after analysis.

**Acceptance of this Form:**

Your signature on this form indicates that you 1) understand to your satisfaction the information provided to you about your participation in this research project, and 2) agree to participate as a research participant.

You are free to withdraw from this research project at any time. You should feel free to ask for clarification or new information throughout your participation.

To accept this form, please write your name, date, and signature below.

Name _____

Signature _____

Date _____

MM/DD/YYYY

**Questions/Concerns:**

If you have any questions about the study, please contact Carman Neustaedter at carman@sfu.ca.

If you have any concerns or complaints about your rights as a research participant and/or your experiences while participating in this study, you may contact Dr. Jeffrey Toward, Director, Office of Research Ethics at jtoward@sfu.ca or 778-782-6593.

# Appendix C. Interview Questions

## Study Plan

The goal of this study is to explore how drone footage might help firefighters during first response of an emergency situation. This includes helping firefighters gain more accurate information about an emergency, provide location specifics, pre-plan strategies, and mentally prepare for the situation while traveling to it. We will demonstrate a few video footages of car accidents, fire incidents, hazardous material, medical emergency and ask you a few questions so that we might figure out how to design the system.

A drone is an aircraft without a human pilot aboard which is controlled remotely. For this research, we consider drones with audio/video recording capabilities along with image capturing. Here is a small video to give you an idea about the type of drone we are talking about.

The study is composed of an initial interview, followed by demonstration of a few video clips. After that, we will ask you some questions.

If you feel uncomfortable at any point of the study you are free to quit without any repercussions.

Do you have any questions at this point?

- **Consent form**

I am going to record our conversation from this point. We will begin by a small interview to obtain your demographic information and about 911 calls…

### 1. Background interview

**QUESTIONS FOR FIREFIGHTERS**

a. How old are you? Do you have any kids? How many? What is your marital status?
b. How long have you been a firefighter? What rank are you?
c. Can you tell me about a recent call you attended? What happened? How did you learn about the situation before you arrived?

d. Imagine if a drone were able to fly to the scene and provide 911 call centres and first responders with video footage of the scene before they arrived. What would you think of this? What would you want captured, if anything?

**QUESTIONS FOR PEOPLE**

a. How old are you? Do you have any kids? How many? What is your marital status?
b. How many times have you called 911 previously?
c. If you called 911 before, can you please describe the situations?
d. Did firefighters show up during any of those incidents?
e. Imagine if a drone were able to fly to the scene of the situation you just talked about and provide 911 call centres and first responders with video footage of the scene before they arrived. What would you think of this? What would you want captured, if anything? Why?

I will now demonstrate a few videos of different emergency situations.

**2. Video demonstration**

Some of the characteristics of video footage are listed below:

| File name | Emergency Type | | | |
|---|---|---|---|---|
| Fire far out | Fire | Far out | Linear | Aerial |
| Fire close up | Fire | Close up | Linear | Ground level |
| Hazmat far out | Hazmat | Far out | No movement | Ground level |
| Hazmat close up | Hazmat | Close up (with far out) | Linear/Circular | Ground level/Aerial |
| Accident far out | Car crash | Far out | No movement | Ground level |
| Accident close up | Car crash/medical | Close up | Half circle | Ground level |

| | | | | |
|---|---|---|---|---|
| Injury in house | Person Injured (Concept) | Close up / Far out | Linear / Circular | Aerial |

These videos showed some of the emergency situations and their surroundings. I am going to ask you a few questions.

## QUESTIONS FOR FIREFIGHTERS

Imagine you are the first responder in those situations and you are seeing the drone video while you are driving to the scene.

I am going to show you videos of fire breakout, car crash and hazmat. You will see two videos of each of these categories. After showing you each pair of a category, I am going to ask you a few questions.

a. What information can you gather about this situation? How would it help you, if at all?
b. What can you not see that you would like to?
c. How would you change the drone's positioning or movements, zoom, angle to get better information? Would you like to adjust it in real time? Why or why not?
(PROVIDE INSIGHT ON DRONE FLIGHT PATHS FOR DIFFERENT SITUATIONS).
d. Would you like to suggest any drone movement pattern? For example, it could be any specific pattern such as capturing the scene in a zigzag pattern, drone following a person around, etc.
e. Would it be valuable for the drones to capture audio? How would your reaction changes if the drones also captured audio?
f. Do you think the drones should be autonomous or do you prefer having control over the drone?
g. At what point should the drone stop capturing video of the scene?
h. How do you think the drones should look like so that people realize it is sent by 911?

## QUESTIONS FOR PEOPLE

Imagine you noticed drones flying around emergency situations and sending the video to 911 call centres and first responders. Maybe you were walking by or this incident took place next to your home.

I am going to show you the videos one by one, and after each video, I am going to ask you a few questions. Please ignore the watermarks on some of the videos.

a. How would you feel about the drone if such an incident occurred to you where you were the victim? How would you react?
b. How would you feel about the drone if such an incident occurred to your neighbor? Or a family member or a friend? How about a stranger?
c. How, if at all, would your reaction change if the drones also captured audio?
d. Would you like to suggest any drone movement pattern? For example, it could be any specific pattern such as capturing the scene in a zigzag pattern, drone following a person around, etc.
e. Do you think the drones should be autonomous or should a person have control over the drone?
f. At what point should the drone stop capturing video of the scene?
g. Do you have any privacy concerns? If so, what would they be? Why?
h. Do you have any safety concerns? If so, what would they be? Why?
i. How would you like to identify the drone sent by 911?

For Hazmat videos, instead of imagining yourself as a victim, imagine you were driving by the incident. The robbery video is going to help us extend our research for future where we might try to integrate drones for police emergencies.

**3. Checklist**

**QUESTIONS FOR FIREFIGHTERS**

- In what type of situations would you use drones? How and why? When wouldn't you need drones?
- Where do you think the drones should be initially located? Do you want to carry the drones with you to the scene or do you prefer drones to be located in key locations such as fire stations, police stations etc. so that you can send out the drones ahead and gather information?
- What do you think about involving call takers when controlling the drones for communication? Should call takers control the drones? Who should control them?
- Are there any types of situations that you would prefer to not watch from drone footage that might make you uncomfortable?
- How do you feel about including audio capture in drones?
- Should the drones record video for future review?

**QUESTIONS FOR PEOPLE**

- How would it concern you if you saw drones flying around for emergency situations?
- When would you feel uncomfortable about drones capturing videos of emergency situations and why?
- Where do you think the drones should be initially located? Should first responders bring them or should they be based in key locations such as fire stations, police stations, etc? Or community landmarks/stores?
- Would do you think should control where the drone flies and what it captures? A person? A machine/computer?

- How do you feel about including audio capture in drones?
- How do you feel about drones recording video for future review?

Is there anything else you would like to tell me?