Exploring the Potential for Drone Use in Firefighting: Addressing Forest Fires in Albania

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Chapter 1: Introduction

Forest fires pose a serious and growing threat to communities and ecosystems around the world. Each year, forest fires burn around 3.4 million km^2 of vegetated land globally (Royal Botanic Gardens, 2017). Up to 140000 km^2 of forest are lost to fires each year in the Balkan region alone (Nikolav & Nemeth, 2015). The length of fire seasons, as well as the frequency, size, and intensity of forest fires has been increasing over the past few decades due to climate change (North et al, 2015). Experts predict that more frequent droughts, higher temperatures, and less precipitation will likely increase the severity of forest fires in the future (Pausas & Ribeiro, 2013; World Bank, 2011; Raftoyannis et al, 2014).

For the past few decades, forest fires in Albania have increased in number and intensity (Nikolav & Nemeth, 2015). This is causing a multitude of Albanian environmental, economic and health concerns that will worsen if left unchecked (Palliser, 2012; Nikolav & Nemeth, 2015). Uncontrolled wildfires can cause soil erosion, release greenhouse gasses into the atmosphere, destroy forest habitats and reduce biodiversity (Palliser, 2012). Wildfires can spread past forests and reach arable land that the agricultural industry relies on. The smoke that pollutes the air can contaminate water and crops, lowering the market value of the next harvest (Barth, 2018). The wildfires also can cause serious harm to the Albanian people, both in the short term and long term. Hospitalizations from fire related causes have been on the rise in recent years as reported by the Tirana Times, and long-term respiratory issues have been shown to arise in urban and rural communities in close proximity to areas with exposure to wildfire pollution (Reisen, & Meyer, 2011).

Techniques utilized by Albanian emergency planners and firefighters to mitigate the harmful effects of forest fires have been moderately effective. Firefighters have different methods of fighting forest fires depending on their location and intensity, but these methods are focused on a case-by-case basis rather than preventing forest fires altogether (Andone, 2017). They monitor these fires to determine the most effective strategies to approach them (Andone, 2017). Fuel reduction and fire suppression are common forest firefighting methods,

but the former performs on a long-term scale while the latter is potentially dangerous to execute in Albania. (Molina-Terrén, Cardil, & Kobziar, 2016; North et al, 2015; Raftoyannis et al, 2014). These problematic areas have left Albania struggling to manage its raging forest fires.

Our group's sponsor, EXINN Technology Center has proposed using drones to make fighting forest fires in Albania more effective. While this technology can serve many purposes, studies have found that drones can play an instrumental role in fighting these fires, specifically by monitoring and extinguishing them (Boucher, 2015; Laksham, 2019; Rao, Gopi, & Maione, 2016). Drones are used for fire detection and monitoring in many countries, but efforts to develop drones to extinguish forest fires are a work in progress worldwide (Brocious, 2016; Restas, 2015). There are also drawbacks to using drones - training is required to employ them and they cannot carry much cargo (Rao et al, 2016). Various stakeholder perceptions of drones in forest firefighting will indicate the level of interest Albanians have in using drones for this purpose, and what the possible concerns are. This information will provide clues to how easily and successfully EXINN will be able to initially implement the forest firefighting drones, as well as aspects they may need to address during creation. EXINN hopes to create a drone whose primary purpose is extinguishing forest fires. It intends to market this product to government agencies in the Mediterranean region and private landowners in Albania. The company is currently developing a prototype of the drone, but little information on firefighting drone perception and implementation in Albania is available. Thus, EXINN has enlisted our team to find the answers to these inquiries and provide recommendations.

This project has three main objectives: identify opportunities where wildfire management can be improved by drones, establish stakeholders' willingness to use drones in forest firefighting, and determine the feasibility of using drones to address wildfires in Albania. The team will conduct interviews with key stakeholders, including government agencies such as the Ministry of the Interior, non-governmental organizations such as Horizon 2020 and Brigaid Community of Innovation, Albanian firefighters, and farmers impacted by forest fires. We will analyze the data received from these interviews using qualitative analysis. This analysis will be

vital to EXINN as it refines its prototype drone, offering insight into stakeholder perceptions of drones and the steps needed to implement this technology in Albania.

Chapter 2: Background

Albania currently faces many violent forest fires that are consuming the Mediterranean country. Determining drones' place in forest firefighting is a complex issue with multiple factors to consider. Initially we discuss the current trends of forest fires, as well as their impact on the areas they burn. The next section expands upon current methods used in Albania for forest firefighting. From there, we shift topics to how drones function, their strengths and weaknesses, overall perception, and application to managing forest fires. We end with a discussion of our sponsor's efforts towards this issue, and a description of the key stakeholders affected by this project.

2.1 Trends of Albanian Forest Fires

Year	Albania	Bulgaria	Croatia	Greece	R. of Macedonia	Slovenia	Serbia and Montenegro -Serbia-	Turkey	Total	Average
1988	121	101	/	1 898	126	/	25	1 372	3 643	455
1989	132	578	/	1 284	95	/	48	1 633	3 770	471
1900	269	208	/	1 322	241	/	98	1 750	3 888	486
1991	147	73	/	941	38	30	55	1 481	2 765	346
1992	659	602	/	2 042	235	40	44	2 117	5 739	717
1993	560	1 196	/	2 406	390	108	157	2 545	7 362	920
1994	585	667	/	1 763	195	66	70	3 239	6 585	823
1995	110	114	/	1 438	24	25	15	7 676	9 402	1 175
1996	490	246	/	1 508	90	50	45	1 645	4 074	509
1997	735	200	/	2 271	174	59	28	1 339	4 806	601
1998	601	578	/	1 842	151	151	78	1 932	5 333	667
1999	628	320	/	1 480	452	53	11	2 075	5 019	627
2000	915	1 710	7 797	2 581	1 187	98	281	2 353	16 922	2 115
2001	327	825	4 024	2 658	165	65	42	2 631	10 737	1 338
2002	140	402	4 692	1 400	59	60	112	1 471	8 336	1 042
2003	771	452	6 924	1 452	96	224	57	2 177	12 153	1 519
2004	143	294	2 855	/	73	/	5	1 762	5 132	642
Total per country	7 333	8 566	26 292	28 286	3 791	1 029	1 171	39 198	**115 666**	850
Average per country	*431*	*504*	*1 547*	*1 664*	*223*	*61*	*69*	*2 306*		

Remark: no data available from Bosnia and Herzegovina
Source: National Reports from Regional Balkan Wildland Fire Network/Global Wildland Fire Network International Technical and Scientific Consultation "Forest Fire Management in the Balkan Region", held 4-5 April 2005 in Ohrid, Republic of Macedonia.

Table 1: Number of forest fires in the Balkan Region 1988-2004 (Nikolov, 2006)

Table 1 demonstrates that forest fires in Albania have been steadily increasing for over 20 years, experiencing 7,333 forest fires overall during that time period (Nikolov, 2006). Albania's methods of defining economic and ecological costs due to forest fires record that over

20,891 hectares of land were lost between 1988 and 2004, as shown in Table 2 (Nikolov, 2006). Additionally, US $5.9 million was also lost between 1991 and 2003 (Nikolov, 2006). These methods are non-unified between regions, implying that the actual damage is most likely higher. Damages include soil erosion, emission of greenhouse gases, and significant forest degradation (Nikolov, 2006).

Year	Albania	Bulgaria	Croatia	Greece	R. of Macedonia	Slovenia	Serbia and Montenegro -Serbia-	Turkey	Total	Average
1988	256	462	/	/	/	/	76	18 210	19 004	4 751
1989	320	223	/	/	1 633	/	165	13 099	15 440	3 088
1900	417	1 041	/	/	5 760	/	646	13 742	21 606	4 321
1991	250	511	/	/	444	677	211	8 081	10 174	1 696
1992	1 011	5 243	/	/	9 390	426	215	12 232	28 517	4 753
1993	522	18 164	/	/	14 423	1 660	2 036	15 393	52 198	8 700
1994	705	18 100	/	/	5 802	912	435	38 128	64 082	10 680
1995	153	550	/	/	105	260	117	7 676	8 861	1 477
1996	410	2 150	/	/	986	288	209	14 922	18 965	3 161
1997	1 847	595	/	/	3 574	493	126	6 316	12 951	2 158
1998	680	6 967	/	/	1 889	1 353	919	6 764	18 572	3 095
1999	689	8 291	/	/	1 992	433	36	5 804	17 245	2 874
2000	3 675	57 406	129 883	/	37 928	265	7 476	26 352	262 985	37 569
2001	1 434	20 152	27 251	/	6 667	340	273	7 394	63 511	9 073
2002	690	6 513	74 945	/	659	160	1 373	8 413	92 753	13 250
2003	6 359	5 072	77 359	/	3 936	2 100	430	6 644	101 900	14 557
2004	1 473	1 137	8 988	/	1 584	/	12	4 876	18 070	3 012
Total	20 891	152 577	318 426	/	96 772	9 367	14 755	214 046	**826 834**	103 354
Average	1 229	8 975	63 685	/	6 048	720	868	12 591		

Remark: no data available from Bosnia and Herzegovina
Source: National Reports from Regional Balkan Wildland Fire Network/Global Wildland Fire Network International Technical and Scientific Consultation "Forest Fire Management in the Balkan Region", held 4-5 April 2005 in Ohrid, Republic of Macedonia.

Table 2: Burned area (hectares) of forest and other land in the Balkan region 1988-2004 (Nikolov, 2006)

Albanian forest fire studies show an average of 2,731 hectares burned annually between 2004 and 2013, damaging 200 hectares of olive trees and other crops, 15 houses, 4 high-voltage pylons, and injuring 23 people. One of the most severe forest fire seasons occurred in 2007, causing 1,190 fires which led to 2,700 hectares of state forests, 2,860 hectares of communal forests, and 310 hectares of private forests. In 2012, 440 cases of forest fires were reported, destroying 1,161.30 x 10^3 tonnes of biomass and causing 2,052.60 x 10^3 tonnes of CO_2 emissions (Mesquita, Monnier, Aleksic, & Nikolov, 2015; Nikolov & Nemeth, 2015). Table 3 illuminates notable forest fire numbers and damages over several years during this time period.

Year	2005	2006	2008	2010
Nr. Of Cases	174	176	348	246
Forest surface (he)	3241	1081	-	1133
Burned surfaces (he)	300	108	1483	1133
Burned pastures (he)	1740	303	2716	1741
Value of damage in /000 Lekë(Albanian Money)	31682	81317	139131	63733

Source: General Directorate of Forests and Pastures

Table 3: Forest fires in Albania (2005, 2006, 2008, and 2010) (Nikolov & Nemeth, 2015)

Studies from 2013 found that this fire season was milder than previous years, only burning 1,233 hectares with 9 fires. Table 4 demonstrates that this burned area was spread evenly "between forest/other wooded lands and other natural lands" (Schumuck, 2014).

Land cover	*Area burned*	*% of total*
Forest/Other Wooded Land	583.91	47.34%
Other Natural Land	570.52	46.25%
Agriculture	76.29	6.18%
Artificial Surfaces	2.75	0.22%
Total:	***1233.46***	***100%***

Table 4: Distribution of burnt area (ha) in Albania by land cover types in 2013 (Schumuck, 2014)

Despite the relatively mild fire season, the Tirana Times newspaper reported that the 2017 wildfire season was the worst recorded. Authorities discovered up to 20 hotspots in a week near Tirana, Elbasan, Fier, Gjirokastra, Berat, Durrës, and Korça out of 280 hotspots where state structures needed to intervene (Tirana Times, 2017).

Forest fires tend to consume the wooded land they burn, releasing large amounts of carbon monoxide and fine particulates into the air (Reisen, & Meyer, 2011). Long term human exposure can lead to asthma, lung damage, and respiratory diseases. When forest fires reach communities, they burn homes, livelihoods such as crops, and can even take lives, all of which harm the future of neighboring communities. Additionally, areas susceptible to forest fires

experience drastic reductions in biodiversity. The blaze can kill many flora and fauna, giving invasive species time to grow before the forest's biome can recover (Palliser, 2012). This upsets the delicate balance of the ecosystem, having potentially permanent effects on the fate of different species and landscapes.

2.2 Causes of Forest Fires in Albania

Human activity is the major cause of forest fires in the Mediterranean region, either through negligence, in the form of improper crop burning and land abandonment, or intentional fire setting (Raftoyannis et al, 2014). Figure 1 shows that 29% of forest fires in Albania occur due to negligence, 1% due to unusual and natural events, 9% due to arson, and 61% due to unknown factors, which Albanian forest fire statistics note as largely being human activity (Mesquita et al, 2015). Some of these unknown factors are due to indirect influence from media coverage. Media tends to focus on more dramatic or illegal causes of forest fires, such as land use change and arson, with little information on other causes. This implies that arson and land use change are the leading causes of forest fires, when this is not the case (Varela, Jacobsen, & Soliño, 2014).

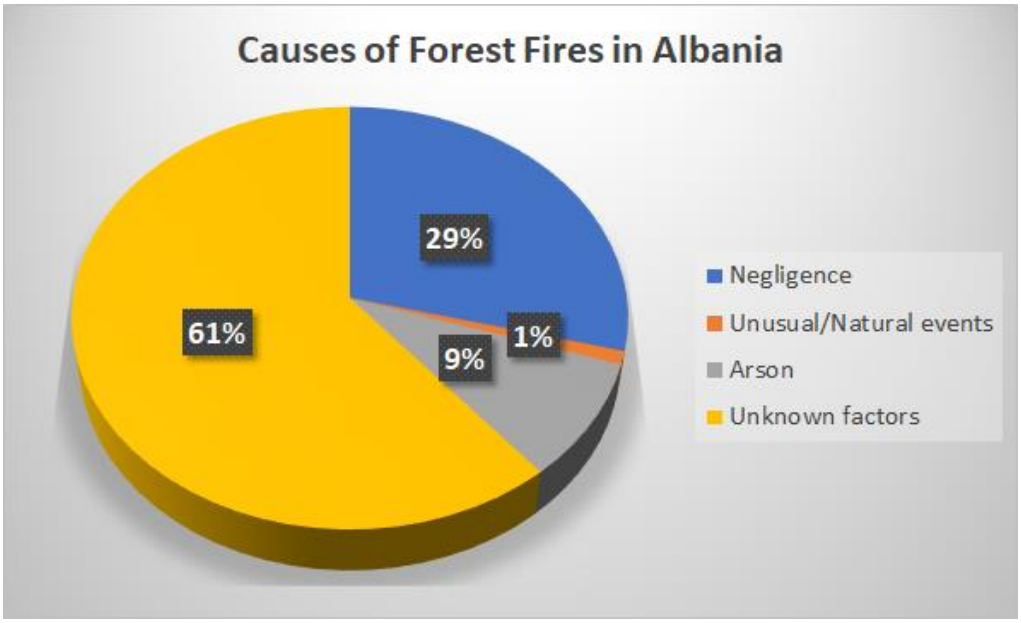

Figure 1: Causes of Forest Fires in Albania (Mesquita et al, 2015)

Farmland abandonment is one of the main human-related causes of forest fires in Albania. In Albania 40% of individuals work in agriculture, but this percentage is becoming mostly comprised of older individuals as younger generations migrate to cities in search of employment (Xanthopoulos, Nikolov, 2019). This has led to an increase of wild vegetation growing in previously cultivated lands, becoming grasslands and shrubs that create additional fuel for forest fires (Hernandez-Escobedo, Manzano-Agugliaro, & Perea-Moreno, 2017). In areas near Albania, rural population dropped 22% in 56 years but experienced an increase in burned area despite having a higher focus on fire suppression. This trend has been observed in many Mediterranean countries, particularly Greece (Xanthopoulos, Nikolov, 2019). This highlights the sheer volume of combustible biomass created by rural abandonment, and how it affects forest fires.

The climate in Albania varies by region and time of year, but generally consists of mild, rainy winters and hot, dry summers. The landscape of Albania consists of three zones: lowlands, hills, and mountains (see Figure 2).

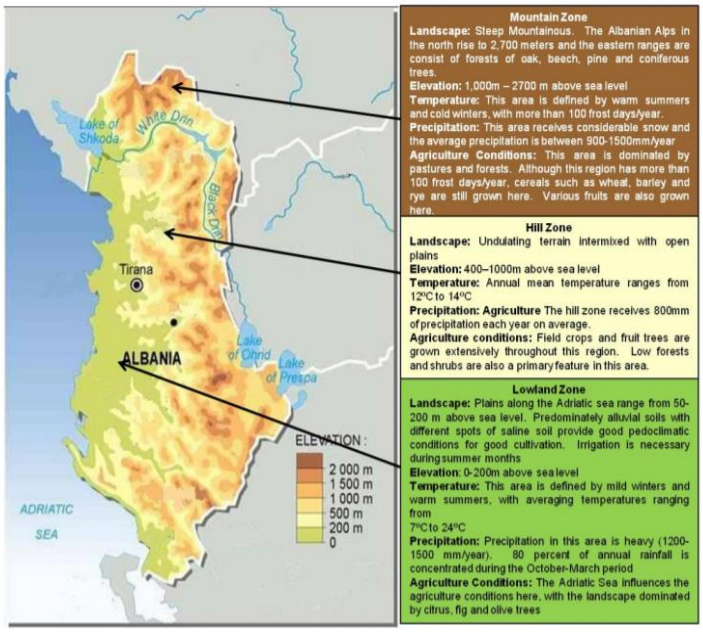

Figure 2: Geographic regions of Albania (World Bank, 2011)

The warm lowlands border the Adriatic Sea, averaging 12-18°C with an annual rainfall of 600-1000mm mostly outside of summer. Moving inland elevations rise to hills, and eventually mountains in the north and east. These regions possess colder winters and rainier summers. The mountains average 4-12°C and about 3000mm of rain throughout the year (World Bank, 2011).

Due to climate change, climate researchers expect Albania and other Mediterranean countries to experience an increase in temperature and a decrease in precipitation. By 2050, average temperatures are projected to increase by 2.3°C, or up to a staggering 57.5 % increase in the mountains, with a maximum of 3.1°C during the summer, a 77.5% increase. Simultaneously, researchers predict annual rainfall to decrease by 6.9mm with a maximum of 23.2mm, or 2.3% and 7.7% respectively. They predict that summers will produce more heat waves and drought, with an increase in varied seasonal precipitation (World Bank, 2011). This has the potential to drastically change the growing seasons in Albania, contributing to tree mortality and subsequently providing more fuel for forest fires. In addition, hotter, drier seasons combined with unpredictable rainfall contribute to longer fire seasons by directly affecting the diversity of an area's vegetation and its flammability (Raftoyannis et al, 2014). Climate change also affects an area's weather, and its unpredictable effects make modeling burnt areas to prepare for future forest fires difficult (Pereira, Hayes, Miller, & Orenstein, 2017).

Albania is located in the Balkan Peninsula with a landmass of 28,748 km^2, with nearly 40% being arable land and 36% forests (Albania National Tourist Agency, 2019; World Bank, 2011; Naka, Hammett, & Stuart, 2000). The coast is comprised of oak trees and maquis trees and further inland boasts beech trees and pine trees, but hills and steep mountains cover the rest of the country. Many different lakes cover the terrain, while rivers flow from the mountains to the sea. These locations are important for biodiversity, tourism, and hydroelectricity (Albania National Tourist Agency, 2019).

Elevation, vegetation, and land abandonment play a significant role in assessing the probability of forest fires. Areas with sudden changes in elevation, such as mountains, grows different shrubs and trees stacked over one another, placing them more closely together than

they would be on a flat surface. This allows fires to spread more rapidly, especially with bountiful vegetation. Without vegetation, fires have little to use as fuel in forests, and cannot travel effectively. If the vegetation consists of only a few species, there is little variation in the plant's ability to resist catching fire. As a result, there are no natural breaks that could slow a fire. This affects shrub and grasslands the most, as their high regeneration rate allows fuel to accumulate quickly (Oliviera, Moreira, Boca, San-Miguel-Ayanz, & Pereira, 2014).

Another vegetation related problem applies to Wild-Urban Interfaces (WUIs). WUIs are where urban areas border closely with wild forest or grassland areas. One example is Berat, which butts up against a forest covered mountain in the north and mixture of grasslands and forests in the south (Google Maps satellite view, 2019). WUIs near areas experiencing rural abandonment have left a wide range of dry fuel for forest fires to use, increasing their intensity and burn time. The close proximity of humans raises the probability of a forest fire having a human-related origin. Albania has the highest correlation between WUI proximity and forest fires in the Mediterranean region, especially near Berat, Gjirokastër and Korçë (Modugno, Balzter, Cole, & Borrelli, 2016).

Areas with little to no vegetation, less sunlight, and certain types of slopes inhibit the spread of forest fires. A lack of vegetation leaves forest fires with no fuel to burn, while less sunlight allows what vegetation has grown to capture more moisture. This makes the plants less likely to burn, even acting as a sort of natural barrier if they are sufficiently wet. Slopes facing northward at high elevations are less prone to fire, mainly due to moist vegetation and a lack of direct sunlight (Oliviera et al, 2014).

2.3 Current Methods of Forest Firefighting in Albania

Current methods of fighting forest fires vary depending on the climate and location of the fire. Firefighters play a unique role by fighting forest fires on the ground, in the air, and on a computer screen. During a fire water cannons fight the flames while cutting vegetation prevents further spreading. Helicopters also help bring in water, as well as drop fire retardant on the immediate areas, slowing spreading. Weather forecasting can determine intensity-

related factors, such as temperature, wind, relative humidity, and projected fire spreading. In situations where actively fighting could do more harm than good, forest fires simply burn out. After a forest fire has been extinguished, firefighters take inventory of lost items and damages, particularly near watersheds to avoid erosion (Andone, 2017). Although these methods are common, Albania's firefighting department is often too small and lacks the budget to perform them (Shuka, 2017).

Everyday citizens can take a more active role in preventing fires, but their methods are often misinformed. Forest fires burn many trees in their areas, harming biodiversity and reducing wood resources for nearby residents. To offset these factors, citizens plant foreign species of vegetation. However, they cannot thrive in their new habitat, or perhaps thrive too much and become invasive. Unsuitable soil conditions increase these effects and cause harmful competition between native and foreign species (Bego et al, 2017).

There are two main methods of fighting forest fires that Albanian firefighter use- fire suppression and fuel reduction. Fire suppression mainly takes the form of small controlled fires used to burn chosen areas of forest to prevent forest fires from spreading. These prescribed fires create breaks within forest vegetation, such as Figure 3 shown below.

Figure 3: An example of controlled burning (Oregon Department of Forestry, n.d.)

Although generally considered a more efficient economical solution, fire suppression is difficult to implement in Albania (Molina-Terrén et al, 2016). Albanian fire tracking technology and equipment has developed slowly with most central funding gone to directly fighting the flames with water. This, coupled with difficult terrain such as mountains, makes it too dangerous to attempt fire suppression in many areas. Fuel reduction is a preemptive method of fighting forest fires, where forestry staff removes dry debris and reduce overly dense sections of forest. These biomasses are closely monitored and burned so as to only burn smaller trees and shrubs, providing a natural thinning and increasing fire resistance (North et al, 2015). However, many consider this preemptive type of forest firefighting less important, causing most governments to be focused solely on immediate methods of forest firefighting (Raftoyannis et al, 2014; North et al, 2015). If improperly performed, fuel reduction will negatively affect the overall landscape and contribute to more frequent forest fires. Additionally, fuel reduction varies wildly in terms of economic efficiency, mainly due to wind orientation (Elia, Lovreglio, Ranieri, Sanesi, & Lafortezza, 2016).

Governmental parties such as the Ministry of Environment (MoE) and State Inspectorate of Environment, Forests, and Waters (SIEFW), Regional Forestry Services Directorate (RFSD), Directorate for Firefighting and Rescue Operations (DFFRO), Ministry of Interior, and Public Forest Service play large roles in determining the techniques used for firefighting and their consistency. However, the multiple different governmental levels these departments lie on prevents them from coordinating and managing effectively. MoE and SIEFW are responsible for laws regarding fire and forest protection on a national level, but Public Forest Service and RFSD actually oversee them, albeit only on a regional level. The DFFRO and Ministry of the Interior communicate with firefighters by district. This intricate system of regulating and reinforcing leaves little room for effective communication or coordination (Mesquita et al, 2015). Figure 4 demonstrates the DFFRO's function within the Department for Civil Emergencies Planning and Response communication hierarchy.

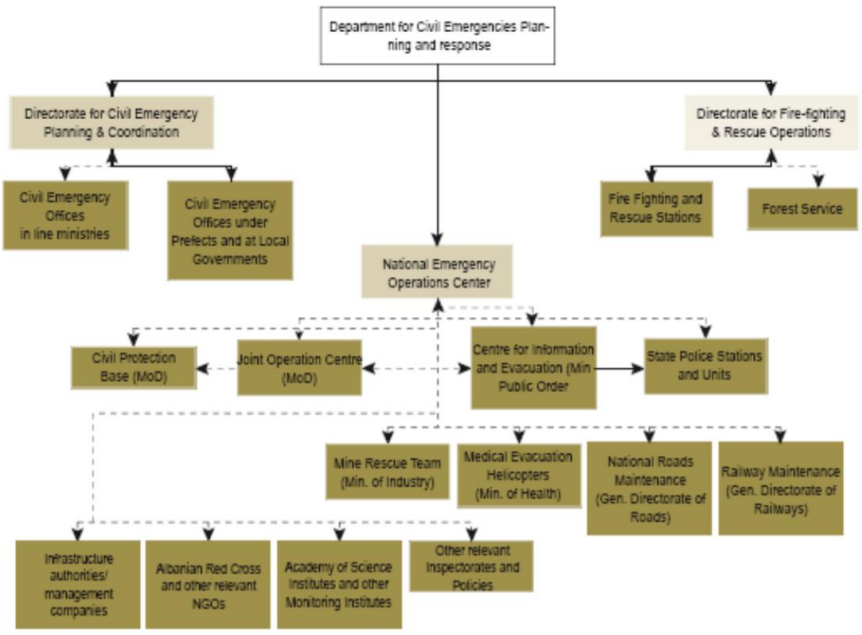

Figure 4: Organization of Department for Civil Emergencies, Planning and Response (Mesquita et al, 2015)

Currently there is little legislation present relating to the sustainability of forests, nor how they can be responsibly managed without exploiting the environment. Without proper instructional manuals available to the public, they exploit then abandon forest to dormancy, increasing the risk of forest fires (Mesquita et al, 2015). A lack of urgency from governmental parties highlights how present policies fail to account for the background information, intent, and consequences the general public considers when trying to fight forest fires (Naka et al, 2000).

Albania is a developing country with few financial resources, especially compared to other Mediterranean countries such as Spain and Turkey, making it difficult to resolve these issues (Shuka, 2017). Off-road vehicles used to battle forest fires are expensive and subsequently in short supply. Subsequently, the Public Forest Service uses them primarily for fighting active forest fires, as opposed to training firefighters. Currently, training only covers the basics of firefighting, and many firefighters are volunteers as opposed to individuals with professional qualifications (Mesquita et al, 2015). Despite this, firefighters maintain an air of professionalism as they adapt to a short supply of equipment.

A main issue confronted by volunteer firefighters is they lack insurance for potential difficulties and cannot afford special equipment. This results in hand tools being used to fight forest fires, with which volunteers struggle to make a lasting impact. The Forestry Service and the Fire and Rescue Training Center form these volunteer groups as a response to an impending forest fire, but they generally dissolve after the threat has been mitigated (Mesquita et al, 2015). The length of time a volunteer group remains active depends on how closely knit and active community members are. A closely-knit community will contribute with public and personal financial support and have great personal incentives to continue supporting the volunteer group (Górriz-Mifsud, Burns, & Marini Govigli, 2019).

At the moment, the central government carries a heavy responsibility of minimizing the damages caused by Albanian forest fires, leaving less time to conduct studies to analyze forest fires. As a result, the little data on forest fires available is limited to statistics from state authorities. Certain instances, such as satellite viewings in 2007, have been interpreted to show that damages were harsher than how they were reported in government records, highlighting the need for multiple, accurate data sources to compare with (Mesquita et al, 2015).

2.4 Drone Usage in Forest Firefighting

Drones, also known as unmanned aerial vehicles (UAVs), are aerial vehicles that operate solely by remote control or autonomous means. Size, altitude limitations, and distance limitations vary greatly based on design and purpose. For example, military drones possess fixed wings to accommodate large payloads, increasing their speed and efficiency, but lack the ability to hover in place (Rao et al, 2016; Lidynia, Philipsen, & Ziefle, 2017; Floreano & Wood, 2015). A second common type of drone is the quad copter, featuring multi-rotor systems, a lightweight plastic or metal frame, various cameras, sensors, and navigational tools, and are made of common, inexpensive materials. These drones are more popular among the general public because of their wide availability, maneuverability, and less space needed for take-off and landing. Gyroscopes are commonly used to monitor and correct their movement (Rao et al, 2016).

These many capabilities enable the application of drones to a variety of areas such as environmental monitoring, military use, delivery systems, film production, emergency responses, recreation, and firefighting (Boucher, 2015). Initially, the military used drones for equipment and bomb transportation, but drone companies have repurposed their product for commercial, civil, and personal uses. They are well-suited for delivery services, as they can quickly traverse difficult terrain and unlike satellites, their navigation systems are not as dependent on weather and cloud conditions (Laksham, 2019). This makes drones particularly popular for disaster relief efforts and photography/filming, where they can search areas too dangerous or time-consuming for humans or record high quality footage at high areas respectively (Laksham, 2019; Rao et al, 2016). These skills allow drones to be effectively used for monitoring forest fires from various angles to provide the most coverage, such as the drone shown in Figure 5.

Figure 5: An example of a drone using cameras and sensors for monitoring (AGLON IT, N.D.)

Currently this is the main use of firefighting drones- monitoring before and during a forest fire. By periodically viewing hotspots, or areas in forests that are significantly prone to fire ignitions, drones can detect forest fires more quickly than humans can, allowing more time for firefighters to react. During a forest fire, drones work alongside firefighters to gain a more

comprehensive view of how the fire is acting and how best to extinguish it (Restas, 2015). A Geographic Information System, or GIS, captures and stores data by dividing forest structures into five categories based on fire risk (see Table 5) (Jaiswal, Mukherjee, & Raju, 2002). Many determining factors are related to spatial relationships, such as topography and forest distance to settlements, which can be difficult for humans to determine accurately from the ground, especially in difficult terrain. This makes drones ideal for forest fire risk zone mapping, providing information to predict a fire's place or origin and probably track.

Fire risk zones	Degree of fire risk	Description of fire risk zones	Propn of total area (%)
I	Very high	Areas with bamboo and dry mix type of forest; high and very high ignition value on high and very high slopes	20
II	High	Areas with a forest type dominated by bamboo; high ignition value on high slopes	10
III	Moderate	Areas with mainly sal forest; moderate ignition value on moderate and high slopes	15
IV	Low	Areas with agriculture and less forest; low ignition value and moderate slope	55

Table 5: An example of a fire risk zone map constructed in Madhya Pradesh, India (Jaiswal et al, 2002)

While most drones are focused on the detection and monitoring of forest fires, there have been efforts to create drones capable of extinguishing forest fires. To aid in fuel reduction efforts, a team from the University of Nebraska is developing a drone that drops flammable ping pong balls to clear excess vegetation (Brocious, 2016). The drones inject glycerin into the powder filled balls moments before dropping them on grasses and shrubs. This will ignite a small, controllable fire to contain ongoing wildfires and keep them from increasing in intensity. The drone's ability to fly at lower altitudes compared to helicopters make the drops safer and more accurate, while also reducing the risk that firefighters may get injured.

Drones can suppress fires with water or chemicals, but they cannot carry enough water to put out a full forest blaze. IBM engineer Thomas Fey proposed a swarm of drones, using

satellite monitoring to roam and detect forest fires in order to extinguish them while they are still small (Frey, 2018). Researchers at Texas A&M University proposed an alternative solution requiring two drones, where the first drone monitors and the second carries fire extinguishing balls, as shown in Figure 6. High temperatures activate these balls, causing them to release environmentally friendly fire suppressing chemical powders. These trials show that the drones were able to effectively suppress grassland fires, though the researchers must conduct further tests to determine their effectiveness on timber litter, short needle litter, and chaparral vegetation (Aydin, Selvi, Tao, & Starek, 2019).

Figure 6: AFO and Elide fire extinguishing balls (Aydin et al, 2019)

Despite their many benefits drones have several limitations that may hinder their effectiveness in firefighting. Smaller drones are unable to carry heavy loads or travel long distances, limiting the amount of fire extinguishing material they can bring to remote areas (Laksham, 2019). Continuous monitoring and training are necessary to handle drones properly, and concerns about privacy, regulations, liability, public safety, and airspace interference greatly affect their public perception (Rao et al, 2016).

Drone perception is dependent on their use and is generally covered by the media as military acts with surveillance and combat. The general public views drones used for environmental and emergency purposes significantly more positively than drones used for recreation and personal photography (Aydin, 2019; Lidynia et al, 2017). Many surveys have shown the general populace is concerned about the loss of privacy and safety risks, partially due to a lack of regulation and enforcement. In regard to firefighting, fire chiefs are confident

drones could make the firefighting process more efficient, but are concerned about expenses, training, and meeting regulations (Russell, 2016).

2.5 Sponsors and WPI

Our primary sponsor is the technology and innovation development company, EXINN Technology Center. EXINN is developing a drone with firefighting capabilities as part of their Unified Fire Protection initiative, and plan to market it to both governmental third parties such as the army and firefighters, as well as private owners throughout the Mediterranean. The main objective is to have the drone extinguish flames, but EXINN is also considering supportive roles such as detection, monitoring, and live incident reporting. Their firefighting drone is currently in its prototype state, with further work focusing on the algorithms controlling movement and travel sensors.

Our secondary sponsor is the Agricultural University of Tirana, specifically the Forestry Management department via Professor Marsela Luarasi. She will be helping us find research and data connections concerning forest fire trends, specific areas most impacted by forest fires, and sustainable firefighting methods. In addition, the project team will work with Nixi Hara, an engineering graduate student who will assist with data collections and language translations.

Currently EXINN lacks data on local perception of firefighting drones and the feasibility of implementing a firefighting drone in Albania. Our project will explore these topics and search for related answers and suggestions. Endri Bahja, CEO of EXINN, has connections with multiple stakeholders such as the Albanian Ministry of the Interior, army and police forces, forest management experts, drone experts, and EU innovation programs like Horizon 2020 and Brigaid Community of Innovation. He has graciously offered to arrange meetings with these individuals and provide an office for our group to work in during our stay in Albania.

2.6 Summary

To address the rising number of forest fires in Albania and investigate the potential use of drones, it is critical to examine the issue from multiple perspectives. Albania is experiencing

severe impacts from forest fires in recent years due to human causes and its rough, mountainous terrain. Climate researchers predict the intensity of these fires to increase due to climate change, as the rising temperatures and declining precipitation levels contribute to drier fuel and more opportunity for quick fire spreading. Rural abandonment leaves forests overflowing with fuel. This, in combination with a lack of proper firefighting coverage, amplifies the negative impacts of forest fires in rural communities. Firefighters employ many techniques in Albania to immediately remedy the situation, such as helicopters and fuel reduction, but struggle due to a lack of funding, training, and equipment. Drone technology has many uses and unique strengths that firefighters could utilize in managing fires, especially regarding forest fires in remote areas. However, there is little information on the feasibility and public perception of forest firefighting drones in Albania. Our team will work with EXINN Technology Center and the Agricultural University of Tirana to collect this data and provide suggestions that EXINN may use while designing its firefighting drones.

2.7 Stakeholders

There are many different stakeholders that factor into our research. The first and most important of the stakeholders are the firefighters. Fire departments are underfunded and unequipped to deal with the growing intensity of fires in Albania, and through our interviews we will find out how the departments can incorporate drones into their strategies (Mesquita et al, 2015). We will also be interviewing army and police officers for a similar reason, as they form volunteer firefighting groups at times of natural disasters. Government employees such as those in the Ministry of the Interior and the Forestry Staff pass and enforce legislation that may influence drone implementation in firefighting, so it is vital we understand their perception of drones used for this purpose. Certain NGOs such as Horizon 2020 and BRIGAID are contributing to the development of EXINN's drone, and interviews with them will provide information on the possible direction of the drone's purpose and functionalities. Interviewing and working alongside EXINN's drone engineers will yield data on the drone's performance in trials. Finally,

we will be interviewing farmers in areas within close proximity to forest fires to identify their perception of firefighting drones for both personal ownership and firefighter usage.

Chapter 3: Methodology

The goal of this project is to determine the desired functions, feasibility, and potential for utilizing drones in Albanian forest firefighting. With the collected information and analysis, we will help EXINN assess the feasibility of using drones for this purpose and assist the organization in refining its drone prototype and marketing strategy to government agencies, NGO's, and firefighters, which could positively impact the effectiveness of firefighting in Albania. Our objectives to accomplish this are:

1. To identify opportunities for drones in current forest firefighting methods
2. To ascertain the perceptions of drones in forest firefighting
3. To determine the feasibility of using drones in firefighting efforts.

Our approach, including our project goals, objectives, methods and analysis techniques, and end product is shown below in Figure 7:

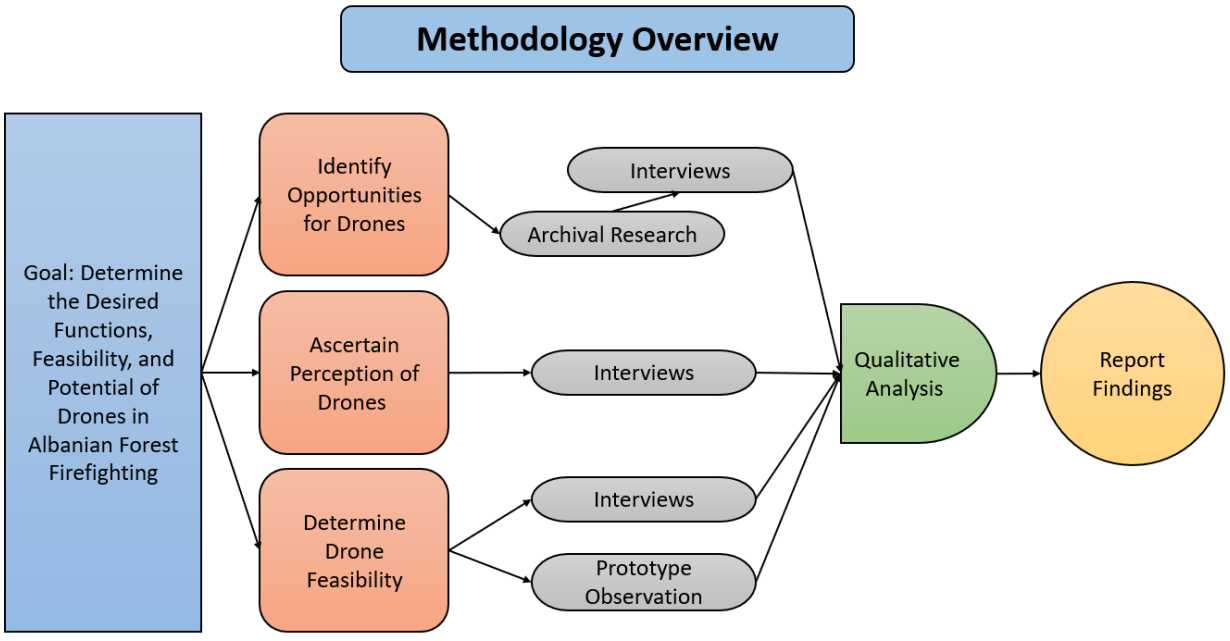

Figure 7: Methodology Overview

3.1 Identify Opportunities for Drones in Current Forest Firefighting Methods

Before looking into new methods of firefighting, it is imperative to understand the strategies that firefighters currently use in Albania to handle forest fires. Specifically, we'll examine the types of information that is collected when assessing the severity of fires, how this information is communicated among different involved groups, and the role this information plays in the kind of actions taken against fires. Observed factors like types of surrounding fuel, and intensity and spread of fires may play a role in whether firefighters take a more direct or indirect approach to combating the fire. These methods will be analyzed by taking note of their strengths and weaknesses. We will also take note of how technology is used by firefighters, how much training they receive, and how new technology is implemented into firefighting programs. By evaluating the effectiveness of their firefighting methods and identifying types of information needed when deciding how to fight fires, we can identify areas of improvement that could be addressed with the addition of new solutions and technology such as drones.

We will first carry out archival research on yearly reports and other such data related to forest fires in Albania and current firefighting techniques from all possible resources. Our team will consult with EXINN and contacts from the Agriculture University of Tirana such as Professor Luarasi to acquire this information. Specifically, our focus will center around fire prone areas in Albania, recent forest fire trends, and forest firefighting strategies used in Albania, including what data is needed to evaluate and fight fires. With this information, we may be able to create additional questions to ask in interviews.

Our group will then conduct semi-structured interviews with various individuals, such as government ministries, forestry officials, police, and firefighters identified by our sponsor. Interviews are appropriate for this objective since they allow us to directly communicate with and record opinions and insights from people knowledgeable about the state of firefighting in Albania.

When conducting these interviews, we plan to follow the general format detailed in Appendix A. We will have one or two team members leading the interviews and asking

questions, while the other members will take notes on the interviewees' answers, general attitude, and nonverbal cues. If given permission, we will record the audio of the interviews to refer to later and create partial transcripts of if necessary. We will also provide interviewees with the option for their answers to be confidential. If the interviewee does not speak English, we will make use of a translator. We will allocate about 60-90 minutes for each interview. The main questions which we hope to explore in carrying out these interviews are:

- What information is needed for firefighters to evaluate the severity of a fire?
- How do firefighters acquire this information?
- Is there any information that could be easier to obtain through the use of technology like drones?

A full list of interview questions for each type of stakeholder can be found in Appendices B, C, D, E, and F.

3.2 Ascertain the Perception of Drones in Forest Firefighting

How easily drones can be implemented into forest firefighting is deeply related to the perceptions around them. To gather this information, we will conduct interviews with various groups of individuals, primarily governmental parties, technology companies, firefighters who would use the drones, and EXINN engineers who are currently building the drone. If possible, we would like to determine a rural community severely impacted by forest fires then travel to that community and interview its members as well.

The primary goal of this objective will be to gather information to form conclusions about the following questions:

- How interested are Albanians in using new technology for forest firefighting?
- What concerns are there involving drone use in Albania?

- How do perceptions of drones vary between different groups?

A full list of interview questions for each type of stakeholder can be found in Appendices B, C, D, E, F, and G.

Many Albanians may not know a lot about drones, particularly related to forest firefighting, we will provide a description of drones, their skills, and potential drawbacks. Face-to-face meetings with governmental and companies, such as the Ministry of the Interior, Horizon 2020, and Brigaid Community of Innovation are graciously organized by EXINN. They, and EXINN engineers, will provide a general view of drones from experts in the field in terms of interest in using drones for firefighting and potential concerns surrounding this. Interviewing firefighters will highlight areas in current forest firefighting they feel drones could improve, but also how they might hinder the situation. Members of a community severely affected by forest fires would impart a cultural perception of drones. It is also important to comprehend if Albanians are interested in introducing new technologies to forest firefighting, or if they would rather improve old methods. Knowing whether individuals would be relieved to see a drone fighting forest fires or frightened by the device is imperative to identifying how they will be received.

3.3 Determining the Feasibility of Drone Use in Firefighting

Our final objective is to determine how feasible drones can be applied to firefighting in Albania. This concerns financial opportunities to build and purchase drones, receive proper training to operate drones, and whether their benefits outweigh their negative effects. While drones can travel quickly undeterred by landscape, they do possess limited distance range, are unable to carry extremely heavy loads, and malfunction and fall if their engines become clogged, potentially from forest fire particles. To determine this, we will focus on information that provides insight to the following topics:

- Are forest firefighting drones considered a worthy investment in Albania?
- Would drones operate effectively in Albania's terrain?
- Are drones a solution to current forest firefighting problems, or do their costs outweigh their benefits?

A full list of interview questions for each type of stakeholder can be found in Appendices B, C, D, E, F, and G.

Different groups can provide important data on these questions, each from a different perspective. Knowing how interested Albanian citizens are in using drones in forest firefighting may highlight how EXINN's drones need to be improved before they can be implemented. If drones are not considered a high priority this will make it significantly more difficult to implement them in forest firefighting. After having the costs and benefits of drones explained to them, firefighters will be able to recognize specific scenarios drones could assist with or hinder. Effectiveness of drone use is partially determined by how much training the individuals operating the drones receive, so learning how much drone training Albanian firefighters would be able to gain is imperative. All individuals will be able to provide information on how affordable they believe a drone is; EXINN would like to market their drones to both public and private owners, indicating a wide range of budgets.

We will also collect data through collaborating with EXINN's engineers to observe the prototype drone. This will provide us with firsthand knowledge of materials used, the complexity of creation, and firefighting capabilities. Our goal is to be able to witness a field test in an Albanian national park to obtain data on the drone's performance.

3.4 Data Analysis

After our studies are completed, we plan to analyze the results of provided data and conducted interviews. We will review over all collected data from interview notes and transcripts to determine which information requires more focus and analysis. Our team will use

pattern matching to find themes or patterns categorize information accordingly. The categories will be preset initially but also allow for new categories to emerge as new common themes are found in the data. Subcategories will be created if certain categories become very large or broad. Responses between and within groups of interviewees will be compared and contrasted to ascertain any patterns that are group dependent. From the discovered connections and themes, we will be able to extract interpretations and understand the significance of our findings (Renner & Taylor-Powell, 2003). With these results, we will be able to provide insight and suggestions on how EXINN could proceed with their forest firefighting drone prototype.

3.5 Estimated Timeline

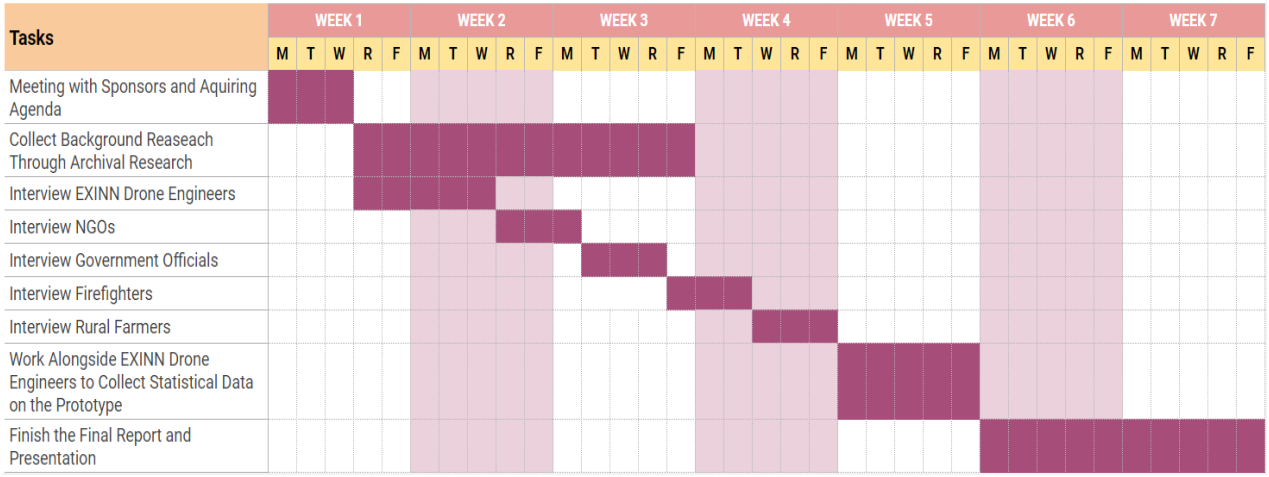

Figure 8: Proposed Project Schedule

As shown in Figure 8, we will first carry out archival research and meet with EXINN engineers before then conducting interviews with various stakeholders over the following few weeks. We will finish these by week 5 and then work on analyzing the data and finishing our report for the remainder of the time. This schedule is subject to change as interviewee availability is finalized.

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Appendix A: Interview Format

Introduction:

Hello!

Thank you for meeting with us. We are a team of WPI university students from the United States researching current forest firefighting techniques in Albania and the potential of using drones for firefighting. For this study, we are working with the company EXINN Technology Center, as well as faculty from the Agricultural University of Tirana. We would like to interview you about the current approaches and information needed to fight forest fires in Albania and learn about your thoughts on the use of drone technology. Your answers will be valuable to help us identify opportunities to use this emerging technology to fight forest fires and to assess under what conditions drones would be a feasible approach.

First, we would like to remind you that your participation in this interview is completely voluntary and you may opt out at any time. We will abide by any limits you request in regard to confidentiality. Would you like us to keep your name and any identifying information about you private? We plan to record this interview on one of our phones so that we could make sure that we do not miss any details. Do we have your permission to record this interview? If not, we are completely fine with just taking written notes on the interview. Do you have any concerns about how we will use the information we record from this interview? The report will be available online once it is finished and can be emailed to you in the future if you would like. Do you have any questions for us before we start this interview?

Questions:

Questions for each interview are specified in Appendices B, C, D, E, F, and G depending on who is being interviewed.

End of Interview:

That is all our planned questions for this interview. Do you have any questions or comments for us? Is there anything else that we should know about the topics discussed in this interview? Would you like to review the transcript of the interview? You can contact us directly at gr-EXINN-B19@wpi.edu. Thank you very much for your time.

Appendix B: General Interview Questions for All

1. What do you believe is the biggest challenge in regard to current forest firefighting?
2. What are your opinions on drone usage?
3. Do you have any safety concerns about the use of drones?
    a. If so, what are they?
4. Do you believe that drones could be used for fire prevention such as early detection and monitoring?
    a. If so, how could they be used and what tasks would they carry out?
    b. If so, do you think they would be more or less effective than alternative methods of fire prevention?
    c. If not, could you go into more detail about your concerns?
5. Do you think that drones extinguishing flames would be a good strategy to focus on, or do you believe another method of forest firefighting is a higher priority?
    a. If you believe another method has a higher priority, what method and why? Could this method involve drones?

Appendix C: Interview Questions for Government Officials

1. What are the current forest fire fighting strategies that are used in Albania?
2. What techniques do you feel are particularly effective?
    a. How are they effective?
    b. Are there specific areas you feel could be improved by drones?
3. Is there any type of technology similar to drones that is currently being used?
    a. If yes, how?
    b. If no, is any other type of technology used? How?
    c. Do many firefighters in Albania have access to this technology? If yes, do they receive special training on how to use it?
    d. Is this technology utilized in the field often?
    e. Do you believe drone technology could make firefighting more effective?
4. Are drones used at all in Albania to assist in situations after a natural disaster?
    a. If so, what sort of impact have they had?
5. What are the largest obstacles you predict when implementing drones in forest firefighting?
6. What steps would need to be taken to introduce drones into firefighting programs?

Appendix D: Questions for EXINN Engineers

1. Are drones used at all in Albania for disaster relief?
    a. If so, have people received training on how to use them?
    b. If so, how well do drones navigate Albanian forest terrain?
2. What kind of information can these drones collect?
    a. What kind of sensors are used?
3. Approximately how much cargo will your drones be able carry
4. What do you believe are the main benefits for using drones for firefighting? What potential issues could arise while using these drones?
5. How much testing has been done with your drone prototypes?
    a. What types of tests?
6. How much would the drone cost to make?
7. Does EXINN plan to have drones extinguish flames with water or other chemical flame retardants?
    a. How will the drones use this to extinguish the flames?
8. What kind of training would these drones require to maintain and operate?
9. Could these drones be placed into action quickly if firefighters were faced with an emergency? Do they require a long set-up time?
10. What are the largest obstacles you predict in implementing drones in forest firefighting?

Appendix E: Questions for BRIGAID and Other Non-Government Organizations

1. What are the current forest firefighting strategies that are used in Albania?
2. How effective are these strategies?
    a. Are there any specific parts that could be improved? If so, how do you think they could be improved?
    b. How well are firefighters equipped to deal with the increased intensity of forest fires?
3. What kind of technology is currently used for firefighting and how is it used?
    a. Do firefighters in Albania have access to this technology and if so, do they receive special training on how to use it?
    b. Is this technology utilized in the field?
    c. Do you believe technology can make firefighting more effective?
    d. Would you be willing to consider new technologies, or would you prefer to improve current methods?
4. Are drones used at all in Albania for disaster relief?
    a. If so, what sort of impact have they had?
    b. If so, have people received training on how to use them?
5. What are the largest obstacles you predict in implementing drones in forest firefighting?

Appendix F: Interview Questions for Firefighters

1. How long have you been a firefighter?
2. Can you explain the steps that you would take to detect and manage forest fires?
3. What kind of information is needed to do this?
4. How do you obtain this information?
    a. How difficult is it to obtain this information?
5. Are any organizations outside of firefighters involved with monitoring and fighting forest fires?
6. How frequently do you communicate with other firefighting departments?
7. What kind of equipment and preparation is present in your firefighting department?
8. Is there any type of technology similar to drones that is currently being used for firefighting?
    a. If so, how is it being used?
    b. If not, is any other type of technology used? How?
    c. Do many firefighters in Albania have access to this technology? If yes, do they receive special training on how to use it?
    d. Is this technology utilized in the field often?
    e. Do you believe drone technology could make firefighting more effective?
9. Do you think that drones could be used to extinguish fires?
    a. Why do you think this?
    b. Would you, as a firefighter, use drones to help extinguish fires?
10. Would you prefer a drone remotely controlled by a human, or controlled by another computer unit (AI)?
11. What are the largest obstacles you predict when implementing drones in forest firefighting?

Appendix G: Interview Questions for Farmers

1. Have forest fires had any kind of impact on your life?
    a. If so, what kind of impact?
2. Are you aware of forest fires that have occurred in nearby areas?
3. How have firefighters prevented and extinguished fires around this area?
    a. Have these efforts been successful?
4. What are your opinions on drone usage in Albania?
5. Do you have any safety concerns about the use of drones?
    a. If so, what are they?
6. How would you feel if drones were used to monitor or help extinguish fires in this area?
    a. Do you believe they would be successful?
    b. Would you prefer a drone remotely controlled by a human, or controlled by another computer unit (AI)?
7. Are drones affordable for you?
8. Would you ever be interested in using a drone yourself to help monitor or extinguish fires in this area?
    a. What requirements would you have for a personal drone?