AIAA 2021-2022 UNDERGRADUATE RESPONSIVE AERIAL FIREFIGHTING AIRCRAFT

A DISCUSSION OF THE CURRENT STATE OF WILDLAND FIREFIGHTING IN THE UNITED STATES

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

Being from California, having the occasional wildfires in my area was something I had grown up with. Trees on Mount Diablo, a mountain seen as the centerpiece of my town, seemed to never get a break from wildfires. We were surrounded with trees burned to crisps on road trips and hikes on the mountain and would have the occasional ashes from the mountain rained onto us under a yellow-tinted sky during recess. Having to evacuate our home gave a sensation of uncertainty to me. I was young when I lived in California and I didn't know exactly what was going on, but I never learned about the actual effects these fires caused until I got older.

What I had not realized was these fires are not the reality everywhere. I was just in one of the hotspots for wildfires, and it is unlikely most people have even been directly impacted by one in their lifetime. There has been a massive increase in their occurrence, with the same fires getting larger and more intense each year (*Six trends to know about fire season in the western U.S.*, 2021). Many regions have experienced droughts in recent years, largely being due to the ongoing increase in temperature throughout the world. These areas become so dry that it is not only easy to start a wildfire, but it gives the fires the ability to easily spread and become harder to put out (*Wildfires and climate change*, 2021).

A multitude of large wildfires have been witnessed just in the past few years. The Australian bush fires lasted for almost a year. According to the Center for Disaster Philanthropy, record breaking temperatures and fire sizes were recorded in multiple areas of Australia - with over 46 million acres of land burned just during the 2019-2020 wildfire (*2019-2020 Australian Bushfires*, 2020). The Amazon rainforest wildfires lasted for almost a year as well, which were largely caused by recent deforestation efforts. However, the California wildfires are intriguing. Living in the United States, it seems as if every year a new wildfire in California takes over headlines in the news. Wildfires in this area have not only been occurring at an increasing rate,

but they also have started to affect civilian lifestyle as they are starting to spread more than they used to. The civilian death rate has seen an increase just in the past few years, and, according to a UCSB Emlab study, the estimated value of structure losses have skyrocketed in this same time span as well (*Long-term trends in wildfire damages in California*, 2019).

Regardless of the reason why fires are becoming more common, it is clear the current method for fighting fires needs to be reevaluated. As mentioned earlier, fires are not only becoming more common, but are also becoming more intense and harder to fight. More land mass and civilized areas are getting destroyed. To revamp the firefighting process to better cater to the more intense wildfires occurring today, there are both technological and social problems that must be addressed. By considering both the technical and social aspects of this socio-technical challenge, the larger issues of modern aerial firefighting can be tackled instead of focusing solely on one aspect. The intention of this research will be to figure out how the current firefighting system in place is flawed, and to see which actors in the world are causing the fires. I will be outlining the process my technical design team and I are using to develop a specialized firefighting aircraft, which will be done by studying existing aircraft and seeing how they can be improved to fit the needs of modern firefighting missions. I will also be addressing the social issue of the more intense fires in recent years by applying actor-network theory, as I will study the entirety of the firefighting system in place in California and what has gone wrong with it in the past few decades.

Technical Problem

As previously stated, the number and intensity of wildfires around the world have recently been drastically increasing. However, it does mean that there has never been a better time than right now to start designing aircraft specifically for aerial firefighting. The majority of

aircraft used for modern wildfires tend to be modified commercial or military airframes with extra equipment. Due to a lack of effort to create technology solely meant for aerial firefighting, firefighting aircraft used in modern missions are not specialized to fight fires. Firefighting aircraft used right now to fight fires have external or internal additions to its original design that create inefficiencies, which makes the firefighting process harder than it should be. For example, the DC-10 aircraft is a passenger aircraft. However, this same aircraft has been modified to be capable of carrying 9,400 gallons of payload (such as water or fire retardant) to be used towards fighting wildfires (*Firefighting Aircraft Recognition Guide*, 2009). An attached tank has been added to the bottom of this plane to give the aircraft a way to unload the payload through a controllable slit. However, this attachment increases the overall drag on the aircraft, which creates stability issues throughout the aircraft, making flying the aircraft difficult. As a result, difficulty in controlling an aircraft will make aerial firefighting difficult when there are multiple other responsibilities, other than flying an aircraft, a pilot has. Creating a new aircraft specifically meant for fighting wildfires will not directly solve the planet's wildfire problem, (due to social problems), but it is impossible to solve the problem as a whole by only investigating and fixing the social issues of the California wildfires. Designing a new aircraft for these fires, however, is an excellent step forward to control larger fires that do not seem to halt anytime soon. Technology available today gives engineers the ability to create an optimized aircraft specifically suited to fight wildfires, so it is a technical solution well within reach. Every aircraft tends to have a specific purpose rather than having an aircraft that

Figure 1: Standard view of DC-10 aircraft

fulfills multiple purposes, so getting all these specific purposes implemented onto one aircraft will be challenging. Larger aircraft, such as the DC-10, are specialized at holding large loads of firefighting payload and can travel at very high speeds (10Tanker, 2021). However, the DC-10 aircraft is extremely flawed when mobility, precision and accuracy, overall efficiency, and cost all come into consideration. However, smaller aircraft such as the CL-215 carry significantly less payload but are much more flexible due to their good mobility and ability for sudden speed changes. They can also scoop water (as a payload) from a large enough body of water, rather than needing to land and refill at a far away station. This can be much more time efficient than a bigger plane taking much more time to refill before it can make another drop, which can be crucial in missions with a tight time frame.

To help fix the technical problem of aerial firefighting's technology being up to date, my aircraft design group will be designing a new firefighting aircraft to keep up with fighting fires with large intensities that have been started to be seen in modern day. The new aircraft that will be designed in our technical project will meet multiple requirements to give it as much of a diverse usage as possible. For example, the aircraft will be large enough to hold at least 4000 gallons of 9 lbs/gal retardant. Additionally, it will be mobile enough to travel 300 knots, while having the ability to quickly slow down to 150 knots at 300 foot elevation to drop the payload. My group and I will be creating three-dimensional aircraft designs through Open-VSP, an aircraft design software. It will be ensured that this will be a safe and effective design through making lift, drag, and thrust calculations, and further testing the design through computational fluid dynamics software.

To present a new design for a firefighting aircraft, I will be creating a proposal with seven other students throughout the year in MAE 4650 and MAE 4660 to meet all the given

requirements for the new aircraft. This proposal will include a written description and graphical representation of our design, geometric description, performance analysis, statements and descriptions of each major component of the aircraft, and a business case analysis. The group will have regular check-ins with each other and with our capstone project advisor Jesse Quinlan to ensure the proposal is finished with effort in a timely manner.

STS Problem

As mentioned earlier, California has been a host area of multiple large wildfires per year - which rate does not seem like it will slow down anytime soon. Higher temperatures in California have been encouraging a drier climate. Specifically in Southern California, the average temperature has increased 3 degrees in the past century (*State Key Findings*, 2021). By the end of the 21st century, we are expected to see a 5.6 to 8.8 degree increase in temperature as well. Higher temperature means the rate of water evaporating into the air is increasing, which takes it away from soils and surface water.

This is why California has seen so many droughts recently. There is less humidity in the air, and as a result, less precipitation. This makes it much easier for fires to start. Fires start from the combination of heat, fuel, and oxygen (*Elements of fire*, 2021). These areas are filled with dried up trees and soil, which act as fuel. Therefore, all it takes is just a little bit of heat to get a large fire started. However, what is to blame as a result of this area becoming so dry? The simplest answer is global warming. Anybody who has been paying attention to recent news will know not just California, but the entire planet, has been rapidly increasing in temperature each year (*Climate change: Global temperature*, 2021). Additionally, climate change is causing the rain patterns to change everywhere in the world, but is severely altering it in parts of California. According to a study from Stanford University, rain patterns in the east coast have been changing

at an extreme rate - a rate only possible through human caused global warming (*Causes of California drought linked to climate change, Stanford scientists say*, 2014). It only makes sense California's rain pattern has seen extreme rate changes like this - areas in California have gone from consistent rain seasons to a couple rain storms a year. The change in rain patterns is not just existent in the United States eastern coast, but has been seen throughout the world. Although there are technical issues with modern firefighting techniques, the whole problem will not be solved without addressing the social implications of wildfires, which means figuring out what is causing the fires to increase in both intensity and occurrence.

Climate change can be connected to many different issues, including government policy, ethical decisions by humans, and even the occurrence of natural climate change throughout long periods of known history. I argue that poor decisions made by both government and society have highly factored into the wildfire season getting significantly worse, and will use actor-network theory, the theory where social and technical existences can have connections to each other in networks, to identify the human and non-human actors which have resulted in the recent extreme wildfire seasons. Using actor-network theory, I will first analyze how the occurrence of more wildfires is due to global warming by connecting wildfires to natural, non-human actors. I will then use governmental figures, policies, and research peoples' ethical roles in society to describe how there are multiple smaller factors at fault for rapid climate change.

Conclusion

To support the management of the severe increased rate of wildfires in recent years, I will analyze and solve the proposed technical and STS problems I have previously stated. I will be designing a new aircraft designed specifically for firefighting purposes, and does so more efficiently than aircraft used today. I will additionally use actor-network theory to make full

connections between increasing wildfires in California, global warming, and the key actors that cause global warming to occur. The results of each project should complement each other, as the technical project will help contain the larger fires that are seen in modern day, while the STS project will find which actors really are to “blame”. Solving the problem of wildfires will take a long lasting effort, but one of these problems being solved is not possible without the other. Fighting newer and stronger wildfires effectively can only go so far if they get more severe in the future. Trying to just solve the issue uphand socially will do nothing when the fires are getting worse and there is no efficient aircraft to fight the wildfires. The ability to fight and reduce the more intense wildfires will be possible when both the mentioned technical and social issues are solved.

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