AIAA DESIGN CHALLENGE: DEVELOPMENT OF AN AERIAL FIREFIGHTING AIRCRAFT

THE SOCIAL SHAPING OF AEROSPACE TECHNOLOGY IN THE MID 20TH CENTURY

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By
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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

Human activity is destroying the only known habitable planet. Due to primarily irresponsible fossil fuel consumption, the growing greenhouse gas concentration in the atmosphere is causing planetary warming ("NASA," 2021). Since 1950, the average global temperature has increased by over 0.75 °C ("The Learning Network," 2020). A result of this is an increase in range and severity of dramatic weather patterns. The impacts of climate change is causing record-setting heat waves, worsening storms, and droughts which are all are fuel for wildfires. Human civilization in arid regions and wildfires have always coexisted. However, wildfires are appearing larger and more frequently as planetary temperatures rapidly rise. Seen in Figure 1, environmental destruction due to wildfires in the United States has been maintaining positive growth since the 1980's.

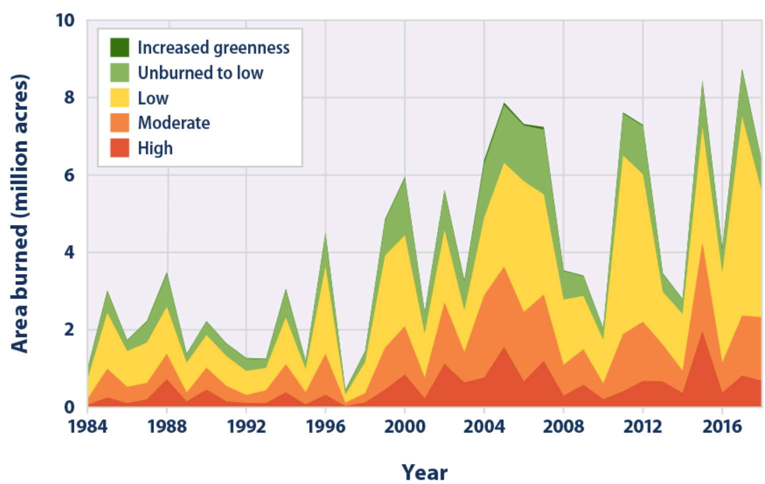

Fig. 1. Wildfire Damage in the USA ("The Learning Network," 2020)

The insurgence of wildfires occurring around the world demands government agencies to funnel more of their annual budgets into firefighting. Since 2005, Californian wildfire spending has more than tripled and as of 2020, has surpassed 3 billion dollars (Beam, 2021). Demonstrated in recent wildfires such as the 2018 California Campfire that burned 153,336 acres of land, ground fighting methods of the past are becoming less effective ("Earth.org, 2021). This poses a significant obstacle for firefighting organizations. Their solution: move firefighting into the sky by developing state-of-the-art aerial firefighting technology.

The relationship between wildfires, human civilization, and aerial firefighting is a clear and current example of how societies shape technological innovation. This phenomena relates to the theory that is known as social shaping of technology, or SST. Defined by Williams (1996) in *The Social Shaping of Technology,* SST describes how technological design and implementation are influenced by a wide spectrum of sociopolitcal factors. In other words, SST declares that technological artifacts are not neutral and that their design is influenced by dominant social and political values (Kidd, 2012). SST is most evident in times where political and social sentiments are strong. In international history, this intensity occured in the 1950's and 60's during the Cold War. While my technical topic will discuss the development of an aerial firefighting aircraft, I will also investigate how aerospace technology is shaped by the social and political environments from which they originate.

Design of an Aerial Firefighting Aircraft

By August of 2021, California saw, “more than twice as many acres of land [burned] by wildfires compared,” with an annual average taken from a five-year study (Horton & Goodman, 2021, p.1). Regions outside of the United States are also experiencing this. According to Deutsche Welle (2021), Russian regions such as Yakutia, “where 144 fires are burning over 578,000 hectares,” are experiencing wildfires of record-setting destructiveness. With this, expansion in aerial firefighting technology is needed (p.1).

Currently, there exist three principle issues that deter many organizations from aerial firefighting. One of these is safety. Low visibility from smoke and debris make the flight conditions of aerial firefighting missions extremely dangerous. Recently in Australia, incidents where damage or death occurred have been increasing. Accidents peaked in the years that saw some of the worst wildfires in the country’s history (Thorn, 2020).

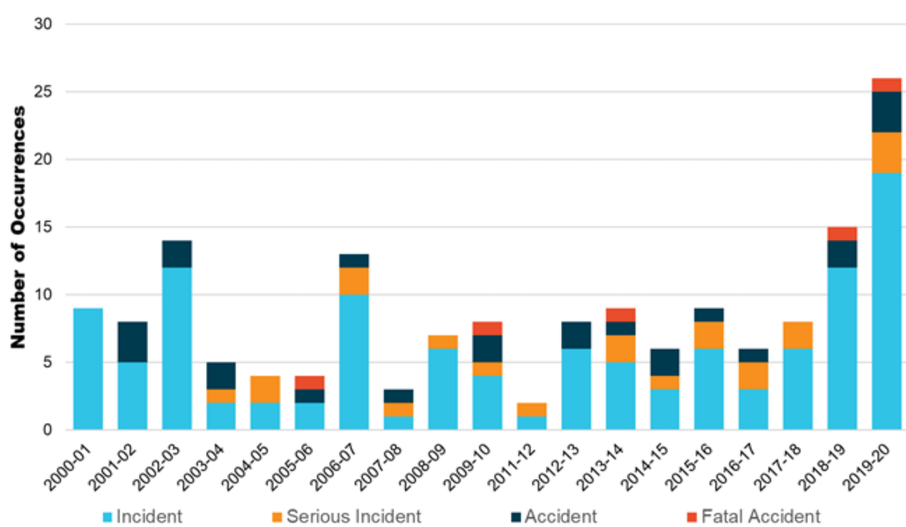

Fig. 2. Yearly Aerial Firefighting Accidents in Australia (Thorn, 2020)

Another issue is night flight capabilities. Removing sunlight in addition to the low quality of air leads to an increase in accident risk. This is concerning because the lower temperatures and windspeeds at night are much better for extinguishing fires (Langfield, 2021). Unfortunately, the planes in service today do not have sufficient imbedded night-vision technology. The final obstacle is environmental efficiency. Many of the firefighting aircraft in service today were produced in the twentieth century and are highly fuel-inefficient (Cal Fire, 2019). In order to not add more fuel to the fire, new aerial firefighting aircraft must be designed with environmental preservation as a objective. Alongside addressing these three design drivers, the concept plane must meet a set of design requirements.

According to Corbets (2021), The American Institute for Aeronautics and Astronautics outlined a list of requirements for their challenge to design an aerial firefighting aircraft. The plane must be designed for entry into service in 2030. Engines incorporated into the design must already exist or be in service by 2028. The airplane must have a minimum fire retardant capacity of 15,000 L, capabilities for multiple drops per flight with a minimum of 7,500 L each drop, and a retardant reload rate of 1,900 L/min. The aircraft must be able to release payload at a velocity of 278 kph at a maximum altitude of 92 m. At maximum payload, the aircraft must be able to fly a minimum distance of 370 km. With no payload, the aircraft is required to fly a minimum of 3,700 km. After a payload drop, the aircraft must dash at 555 kph. The aircraft must also takeoff under 2,400 m. Finally, the aircraft must have capabilities for visual and instrumental flight, anti-icing technology, and must satisfy Federal Aviation Administration requirements as listed in FAA 14 Part 25.

In order to meet the requirements and design drivers, key aerodynamic elements of existing cargo planes will be combined with fuel efficient modifications and specialized technology. A current cargo aircraft, popular in Siberian aerial firefighting, is the Ilyushin Il-76 (Deutsche Welle, 2021). Aerodynamics aspects of the Il-76 that make it a reliable aircraft are anhedral, or downward sloping wings, short takeoff and landing capabilities, and a large payload capacity. New features and technology in consideration for the design are the use of composites, a clear cockpit, winglets, and infrared sight capabilities. With no deviation from the current climate trends indicated in the near future, it can be estimated that wildfires will continue to get worse. This threatens the lives and livelihoods of those who reside in at-risk areas. Design of a novel aerial firefighting aircraft will ensure that humanity is able to efficiently contain and extinguish the growing wildfires before they become too uncontrollable.

Sociopolitcal Influencers of Aerospace Design

The aerospace innovations that emerged from the USA and the USSR during the Cold War were revolutionary. New spacecraft allowed astronauts to escape the bounds of the planet for the first time in human history. New aircraft allowed for more skilled aerial combat and increased global passenger travel. While the societal implications of aerospace technological change are important to understand, the political and social factors that inspired the technological change cannot be overlooked. This idea of technologies being social products is the fundamental assertion of SST. In *The Social Shaping of Technology (SST)*, Williams (1996) presented the idea that every, "stage in the generation and implementation of new technologies involves a set of choices," indicating that the design of new technology is very deliberate and intended to satisfy specific values of their environments (p. 866).

Investigating the case of mid-twentieth century aerospace technology as a reflection of SST, the human and social elements in consideration are the USSR and the USA. Discussed in *A Brief History of the Cold War* (Edwards & Spalding, 2016), the USSR was in the midst of establishing a new government following the death of Joseph Stalin (Gibney, 2021). In his secret speech delivered to the Congress of the Communist Party of the Soviet Union, the newly appointed leader, Nikita Khruschev, urged lawmakers to prioritize the recentering of core Maxist-Leninist ideals of equality, humanity, and military empowerment of the state (Khruschev, 1956). Alongside this, social values that have stereotypically defined the various Soviet states remained dominant. These values include resourcefulness and general paranoia of potential enemies (Mikheyev, 1987).

Across the globe, the Americans were in the Golden Age of Capitalism (History.com Editors, 2010). This time period is characterized by great economic prosperity. During the

Golden Age, there was an expansion in disposable income, new companies, and corporate power. American lawmakers saw it a priority to emphasize the core capitalist values of hierarchy, prioritization of capital accumulation above all else, and competition. Just like in the USSR, classic American cultural values including opulence, greed, and achievement saturated society (Mikheyev, 1987).

Despite distance between ideologies of the USA and the USSR, one unifying factor was an explosion of aerospace innovation. The technical elements of this case are the air and spacecraft that emerged from the USA and USSR during the Cold War. Two of the most notorious are the American Saturn V rocket and the Soviet N1 rocket (Wade, 2019). With one rocket reaching the stars and the other ending in catastrophic failure, they were the grand finale of the Space Race (History.com Editors, 2010). Popular Soviet aircraft were the Tupolov Tu-104 passenger plane and the Mikoyan MiG-29 combat plane (MiGFLUG, 2016). Their American counterparts were the Boeing 707 and the McDonnell Douglas F/A-18 (Cummins, 2020).

The drivers of aerospace innovation were very different and reflected their political atmospheres. Comparing the aerospace technology of both nations, it is widely acknowledged that, "the Russians [built technology] like tanks, The U.S. Air Force and the West [built technology] like fine watches," (MiGFLUG, 2016, p.1). The air and space industry in the USA was commercial whereas the Soviet industry was civil. As a result, technology in the USA often demonstrated capitalist values such as the use of highly specialized and individually purchased instruments, popularity of contracting private business to build government technology, enthusiastic collaboration between engineers, and an emphasis on aesthetics and marketability (Boeing, 2021). Technology was designed around maximizing profit. Conversely, Soviet aerospace technology often served to empower the state, not the corporation. The same analysis can be done on the N1 to see Soviet cultural influences such as an use of outdated N1 fuel as a result of suspicion and paranoia between head engineers, use of state military technology, and prioritization of function over aesthetics and marketability.

Acknowledging the design choices between rival technologies within the USSR and the USA is easy. Understanding the reason for the differences is more complex. Kidd (2012) describes SST as the ability of sociopolitcal values to shape technology. This concept appeared as a criticism of another widely discussed theory known as technological determinism, or TD, that presents the idea that societies change as a result of changing technology. The central idea of SST counters this with the claim that the changes are mutual (Williams, 1996). Because of the potency and polarity of sociopolitcal values in the USSR and the USA, the air and spacecraft of the era feature design choices that are reflective of the two societies. The distance between sociopolitcal climates explains the distance in technoligcal design. From appearance, function, strengths, and weaknesses, design differences between aerospace technology produced in the USA and USSR reflect the opposing ideologies. This relationship confirms the theory that artifacts are not neutral but embodiments of their environments.

The Motivating Question

Throughout history, many sociopolitical ideologies have existed. While an obvious observation is that sociopolitcal ideologies mainly influence the people in which they are dominant, it is important to acknowledge that they also influence other characterisitcs of society. One of these characteristics is technology. Considering this idea, the question arises of how do different political and social structures influence aerospace design? Probing this question is significant for two reasons. One is the lethality of aerospace technology. Missiles, drones, and other aerial weapons are developed to inflict maximum destruction (AeroContact, 2021). They have historically been and continue to be used by the most powerful countries in imperialist conquests to subjugate other nations. Investigating the fundamental question will indicate which societies, based on their dominant social and political beliefs, are likely to advance aerospace technology for harm or for good. Additionally, determining how social and political structures influence aerospace design will reveal what future aerospace technology may look like or be able to do.

In order to analyze this question, data on various aerospace innovations from the United States of America and the Soviet Union during the mid-twentieth century will be collected. Specific aerospace innovations that will be considered are the American Saturn V rocket and the Soviet N1 rocket as well as Boeing aircraft and Tupolev and Ilyushin aircraft of the era. This data will include aspects of different air and spacecraft including body dimensions, internal features, capabilities, and intended purpose in order to collect information on differences in design. Observation and interviews will also be collected to further investiage design differences. Counts of events will also be considered to determine any significant decisions or events in the design process. Data on the political and social values of the United

States and the Soviet Union will also be considered. This data can be in the form of speeches given by political figures, government documents on laws or rulings, written pieces about societal values published during the era, and other secondary source documents. These cases can be compared and studied to determine the dominant social and political views during the Cold War. These values can then be used to interpret the design choices made in the aerospace innovations in order to answer the questions of what effect do specific political and social ideologies have on air and spacecraft.

Conclusion

Currently, aerospace technology is diversifying both on and off the planet. Inovation in air and spacecraft had unlimited potential to benefit humanity. However, with aerospace advancement, humanity has also increased its ability to self-destruct. Understanding the influence of social and political structures on technology will allow governments to predict possible threats in the form of aerial vehicles. Aerial technology emerging from different sociopolitical cultures will have design choices reflective of the dominant governing and societal values. Knowing the different values will result in different strengths and weaknesses will give defense organizations an advantage in case of an attack. In analyzing mid-twenthieth century aerospace technology from the USSR, design choices that embody military strength, lack of commercial influence, and function over appearance are likely to be found. Considering American aerospace technology, concepts such as profit maximization, corporate power, aesthetics and marketability, and commercial competition are likely to be embodied.

In a time of such international volatility, being able to anticipate potential threats an important ability. Understanding the effects of political and social values on aerospace design is the ultimate connection in knowing what was, and what is to come.

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