Undergraduate Thesis Prospectus

An Innovative Design for Firefighting Aircraft

(technical research project in Mechanical and Aerospace Engineering)

California's Response to Global Warming

(sociotechnical research project)

by

Yicong Fu

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technical project collaborators:

Jemma Johnson
Jaylon Williams
Lama Khraibani
Logan Honts
Nick Martin
Quang Lam
Ryan Keough

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.

Yicong Fu

Technical advisor: Jesse Quinlan, Department of Mechanical and Aerospace Engineering

STS advisor: Peter Norton, Department of Engineering and Society

General research problem

How to mitigate global warming in the United States of America?

With an averaged 0.32°F/decade temperature increment since 1981 (Lindsey and Dahlman, 2021), the world is facing the challenge from climate emergencies due to global warming. The United States, as the top-ranking nation for Nominal GDP in 2020 (World Bank 2020) and the second largest CO_2 emitting nation sharing 14.02% of the world's total (Worldometer, 2016), carries huge responsibility of mitigating global warming through technological, economical, political, and educational measures. To achieve President Biden's plan of "100% clean energy economy and net-zero emissions no later than 2050" with his proposed 1.7 trillion-dollar federal investment in climate and environmental justice (Biden, 2021), it is crucial to develop new systems to minimize damage and learn from successful leading models to generalize nationally. The investigation of global warming mitigation in the USA will not only fulfill its own share of the climate responsibility but provide a reference for all other countries to tackle this issue internationally and collectively.

An innovative design for firefighting aircraft

How to design a responsive aerial firefighting aircraft operating in the United States of America with service entry in 2030?

Supervised by Dr. Jesse Quinlan, this is the capstone project for MAE 4650-4660 in the Department of Mechanical and Aerospace Engineering. Team members include Jemma Johnson, Jaylon Williams, Lama Khraibani, Logan Honts, Nick Martin, Quang Lam, Ryan Keough, and Yicong Fu (myself).

Introduction

Wildfire, a natural disaster attributed to global warming, reoccurs within the USA annually damaging about 3 to 10 million acres of land every year (NIFC, 2020). Massive personnel and equipment are used to suppress the wildfire, which sum up to over 2.3 billion dollars and 1.9 billion dollars annually for the past 5 and 10 years respectively (NIFC, 2020). In situations with large fire coverage or poor ground accessibility to the fire site, aerial firefighting is necessary for transporting and dumping water and retardant precisely. Federal agencies like the Department of Agriculture – Forest Service (USDA, 2021) and state agencies like the Department of Forestry and Fire Protection in California (Cal Fire, 2019) both own some small firefighting aircraft but still rely on leasing and contracting for planes with bigger capacities, known as large airtankers (LAT) and very large airtankers (VLAT). This increasing demand of wildfire suppression calls for an improved aerial firefighting aircraft design that is task-oriented and is capable of extinguishing and spread-preventing with lower cost, higher efficacy, safety, and efficiency.

Project goals

The goal of this project is to design a LAT to VLAT-class firefighting aircraft that meets the capacity, performance, and certification requirements stated in the AIAA RFP for the aircraft designing competition 2021 (AIAA, 2021).

Unusual constraints

The RFP limits the engine selection to the ones will be in service by 2028. A minimum of 4000 gallons of retardant capacity and multiple drop capability constrained the design to have large fuselage cargo space or add-on side tanks. Low stall speed requires the aerodynamic design to maximize lift generation. Heavy payload may require considerations of anhedral wing and H

tail configurations for additional stability and maneuverability. The objective of autonomous operation may constrain the addition of certain avionic control systems (AIAA, 2021).

State of the art

Current LATs such as C-130 and VLATs such as DC-10 are mainly retrofitted military and commercial transport aircraft that were originally designed for operations other than firefighting (USDA, 2021). These outdated airframes can be improved to have configurational and operational features specific to aerial firefighting. Current planes typically use only one type of engine for each airframe model for maintenance simplicity and manufacturing ease. However, smart combinations of turbofan and turboprop engines might benefit the fuel efficiency and low-and-slow performance (Cutler, 2017). Currently, VLATs/LATs and scoopers are mutually exclusive. The former carries more payload but need to be refilled at the base airport far from the fire site. Scoopers have smaller capacity but can refill in natural water source to achieve more drops in the same time frame (NIFC, 2021). More investigation into incorporating scooping capability in airtankers may improve the mission efficiency.

Method

Estimation and calculation will be based on the equations in *Fundamental of Aircraft and Airship Design: Volume 1 – Aircraft Design* (Nicolai and Carichner, 2010) and iterated in Matlab. Computer Aided Design (CAD) models will be constructed in OpenVSP and SolidWorks. Design verifications may involve computational fluid dynamics research in Autodesk CFD to visualize the aerial performance instead of experimentally testing a prototype.

Conclusion

The final product of this project will be a report consisting of technical description of the performance capabilities, operational limits, material selections, cost evaluations, and

certification compatibilities. This report will provide a new aerial firefighting aircraft design for future prototyping and manufacturing. In the next step, parts of the airframe will be prototyped and experimentally tested in wind tunnels. After assembly of the test aircraft, ground tests and flight tests will be conducted to gather actual performance data before contracting with airliner for mass production.

California's Response to Global Warming

How did Californian government and civilian cooperate to reduce their CO_2 emission?

Despite the trend of global warming, California, in the past 20 years, has achieved a continuous annual CO_2 emission reduction from 490 million tons to 420 million tons, staying lower than the 2020 limit since 2016 (CARB, 2021, Fig. 1). In 2019, California's GDP and population increased by about 62% and 25% respectively compared to 2000 statistics, while the CO_2 emissions per GDP decreased by about 45% (CARB, 2021, Fig. 2). This improvement was realized by drastic changes in transportation and electric power industry (CARB, 2021, Fig. 3), with the efforts in developing advanced systems like electric vehicles, improving public education by NGOs, and reinforcing legislation such the Assembly Bill 32 Scoping Plan. This revolution, however, is full of conflicts as shown in American Fuel and Petrochemical Manufacturers' responses to Governor Newsom's Executive Order N-79-20 (AFPM, 2020) and rectifications such as 2017 Scoping Plan Updates that evaluate the progress and feasibility of AB 32 to make future plans accordingly (CARB, 2017). How California civilians overcome the economic, cultural, legal, and psychological challenges to collaborate with the government is of vital importance for other states and nations to learn.

For wholistic and profound investigation, participants of different natures and with possibly opposing opinions should be documented, as 7 examples shown below.

1. University of California at Berkeley (UCB) represents the research universities that develop greener systems. UCB claims it is “developing renewable and sustainable energy sources, advancing new technologies to help curb energy demand, understanding the implications for climate change and the environment, and formulating appropriate and timely policy responses” (Berkeley Research, 2021).
2. Tesla represents the businesses that profit from electrification. Their public relations claim to combine “individually existing technologies” like “electric cars, batteries, and renewable energy generation and storage” to make “accessible and affordable” products (Tesla, 2021).
3. California Fuels and Lubricants (CFL) represents traditional petroleum companies that are seeking to adapt to electrification. Their public relations claim to provide low-emission and high-performance diesel for heavy-duty trucks (CFL, 2021).
4. California Air Resources Board (CARB) is a state government agency responsible for diminishing air pollution, mitigating climate change, and monitoring public health. Their agenda is to promote programs like Advanced Clean Cars, Community Air Protection, and Wildfire Protection. They endorsed California’s AB 32 Global Warming Solutions Act of 2006 (CARB, 2021).
5. American Petroleum Institute (API) is a “standard-setting” organization aiming to enhance “operational and environmental safety, efficiency and sustainability”. Their agenda is to represent the oil and natural gas industry and negotiate for strong and

viable public policies from the Congress, Executive Branch, and the general public (API, 2021).

6. Climate Resolve represents the NGOs that connect the communities of minority groups with policy makers to produce just and resilient plans for future. They are seeking to assist people of color and indigenous people to "obtain funding for climate solutions" and "ensure equitable implementation of climate legislation" (Climate Resolve, 2021).
7. Electric Auto Association is a volunteer organization that aims to accelerate the adoption of electric vehicles. They provide a platform to promote electric vehicle related technologies and educate the general public against misinformation such as undesirable performance of car batteries under bad weather (EAA, 2021).

Researcher have studied the California's effort in decarbonization. Manjur (2020) suggested a more stringent carbon reduction scheme than AB 32 to account for current loopholes of covered entities purchasing carbon offsets credits and banking allowances for future. Mercurio and Wong (2012) found that California Low Carbon Fuel Standard 2010 inherently discriminated Canadian producers per WTO's General Agreement on Tariffs and Trade and drew attention to equity of domestic laws. Boudet et al. (2021) pointed out that some California's electricity grid decarbonizing policies did not meet the public preference. For example, 24 percent would support a policy of "paying people to allow the utility to control aspects of their electricity use"; 37 percent would oppose it. This research demanded scrutiny of policies based on preference drivers such as age, race, education background, attitude to smart technologies, etc. Xu and Hobbs (2021) showed that California's current facility-based Border Carbon

Adjustment can be replaced with a facility-neutral deemed rate based on marginal units to improve state benefits.

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