Undergraduate Thesis Prospectus

The Next Generation of Firefighting Aircraft

(technical research project in Aerospace Engineering)

How Californians Are Dealing with Water Shortages

(sociotechnical research project)

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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General Research Problem

How can the United States best adapt to the effects of human-induced climate change?

There is no denying that climate change will shape the 21st century. The United Nations Intergovernmental Panel on Climate Change stated in its sixth assessment report that "It is unequivocal that human influence has warmed the atmosphere, ocean and land. Widespread and rapid changes in the atmosphere, ocean, cryosphere and biosphere have occurred" (IPCC, 2021). The IPCC also estimates that global surface temperature increased by 1.07 ℃ from 1850-1900 to 2010-2019, and states this warming is driven by emissions from human activities. In the United States, the effects of climate change have been apparent, for example, in vast wildfires in California, compounded by protracted drought conditions. A 2021 poll conducted by the Energy Policy Institute at the University of Chicago and The Associated Press–NORC Center for Public Affairs Research showed that 59% of Americans view climate change as an extremely or very important issue (EPIC). However, the legislative response has been slight. President Joe Biden states his latest version of the Build Back Better bill will "set the United States on course to meet its climate goals," but provisions phasing out fossil fuels from the electric grid and assessing fees to methane-emitting oil and gas producers were struck down by senators from his own party (Milman, 2021).

The Next Generation of Firefighting Aircraft

What is the most effective design for a next-generation specialized firefighting aircraft?

My technical advisor is Dr. Jesse Quinlan, a Senior Aerospace Engineer at NASA Langley and a part-time Mechanical and Aerospace Engineering professor. My other capstone

team members are Spencer Barnes, Joseph Orrico, Kevin Moccia, Grace Vidlak, Kobi Vance, Brendan Whalen, Jackson Wray, and Team Lead Haley Knowles.

As climate change continues, the number and intensity of wildfires is expected to rise over the next century. In the US alone, researchers project that "fire potential is expected to increase in the Southwest, Rocky Mountains, northern Great Plains, Southeast, and Pacific coast" (Liu, 2013). According to the American Institute of Aeronautics and Astronautics, the majority of current aerial firefighting vehicles are modified civilian or military aircraft, where compromises and inefficiencies arise from differences from the aircrafts' original mission (AIAA, n.d.). For example, the DC-10 Air Tanker is a converted McDonnell Douglas DC-10-30 passenger jet with payload tanks attached to the bottom of the existing fuselage to avoid compromising the structural integrity of the aircraft (10 Tanker, n.d.). During peak seasons, the USFS uses US Air Force C-130s fitted with USFS-supplied Modular Airborne Fire Fighting Systems, which requires no major structural modifications to the aircraft but at the cost of payload capacity (Forest Service). By designing a purpose-built firefighting aircraft, the specifics required for aerial firefighting missions can be accounted for and optimized.

The aircraft will have an Entry-Into-Service (EIS) date of 2030 and function as an "airtanker" that can drop at least 4,000 gallons of fire retardant onto wildfires. Several minimum requirements need to be met, such as making the aircraft multi-drop capable, having a full payload range of 200 nautical miles, and meeting applicable certification rules in FAA 14 CFR Part 25. Besides EIS, most requirements have further objectives/goals to achieve, like having an 8,000 gallon fire retardant capacity, a full payload range of 400 nautical miles, and the systems and avionics architecture to make the aircraft unmanned. To develop the understanding of the methods, techniques, and workflows required to design aircraft, the capstone advisor has devoted

time in the course to teaching aircraft design principles. He also assigned smaller projects related to the overall design challenge like the Concept Ideation and Initial Takeoff Gross Weight Estimation projects, which built upon each other and required the use of taught design principles and software like MATLAB and OpenVSP. Inter-team cooperation was facilitated through the State of the Art Report and Presentation, where members from different teams collaborated to research state of the art aerial firefighting concepts. Further work includes concept development trade studies, 3D model construction, aerodynamic performance analysis, and cost estimates. Simulations will be conducted on 3D models to determine the effectiveness of the structural design and material selection, but no physical prototypes will be built. The conclusion of this project will result in a full technical proposal containing all relevant aspects, features, analyses, costs, and flight characteristics for a specialized airtanker. This will allow aircraft manufacturers to determine if specialized aerial firefighting vehicles are feasible to develop instead of continuing to convert existing airframes.

How Californians Are Dealing with Water Shortages

How have social groups in California responded to water shortages resulting from more frequent and intense droughts?

The most populous state in the United States has a unique relationship with water. Areas of Northern California can see over 100 inches of precipitation per year, while regions of Southern California only receive a few inches (Water Education Foundation, 2021). According to the U.S. Census Bureau (2020), over half the population lives in the southern counties colloquially known as “SoCal,” meaning the populous and arid South must source much of their water from hundreds of miles away. However, perfect droughts, where all of a region’s water

sources experience drought at once, are expected to increase in frequency and duration (Woodhouse et al., 2020). The region's rising temperatures will increase drought intensity, further reducing water supply (Shukla et al., 2014). How have social groups in California responded to the threat?

Researchers have investigated the impacts of droughts in arid regions. Groundwater can be a reprieve. Water storage and conveyance infrastructure, though extremely expensive, can effectively build drought resilience (Schwabe and Connor, 2012). Tzanakakis et al. (2020) recommend better water management: "urban water supply requires improved administration and operation of the domestic water distribution networks". Brodt et al. (2006) urge proponents of sustainability to organize interest group coalitions. According to Citrin and Stoker (2018), public trust in government institutions in the US has declined, which may limit public support for the policy responses that water shortages require.

The California State Water Resources Control Board (CSWRCB), a branch of the California Environmental Protection Agency, guides regional water control boards and oversees statewide water rights, disputes, protection plans, and quality standards (CSWRCB, 2018). The California Department of Water Resources (DWR), a department of the California Natural Resources Agency, manages California's water resources, overseeing the development and renewal of the California Water Plan and protecting and restoring the Sacramento-San Joaquin River Delta. The DWR also plans, designs, constructs, operates, and maintains the California State Water Project (SWP), a water storage and delivery system that provides clean water to 27 million Californians and 750,000 acres of farmland, aids in water management during floods and droughts, and generates hydroelectric power (CDWR, n.d.).

The Metropolitan Water District of Southern California (MWD) is a regional wholesaler that owns and operates the 242 mile long Colorado River Aqueduct and multiple water treatment plants. In turn, MWD sells this water to 26 member agencies, such as the City of Los Angeles and the San Diego County Water Authority, which supplies 19 million Southern Californians with potable water (MWDSC, 2020).

Among environmental advocacies, the Water Education Foundation (n.d.) publicizes California's water issues. The California Water Impact Network (n.d.) publishes research on California's water issues and pursues litigation. The California Sportfishing Protection Alliance (n.d.) pursues litigation and conducts habitat restoration projects. AquAlliance (n.d.) pursues litigation and documents well monitoring in Butte, Colusa, Glenn, and Tehama counties. In 2015, CSWRCB approved a series of Temporary Urgency Change Petitions (TUCPs) that relaxed salinity standards to divert more water from the Sacramento-San Joaquin River Delta, or California Delta, for agriculture. In response, CSPA, C-WIN, and AquAlliance jointly sued, prevailing in 2020. The settlement requires CSWRCB to comply with the Public Trust Doctrine for California Delta Plan requirements and TUCPs, implement a temperature management process for the Sacramento River, and consider California Fish and Game Laws for fish below dams (CSPA, C-WIN, & AquAlliance, 2020).

In California, agricultural enterprises demand water and are politically influential. California's almond industry produces 80% of the world's walnuts and generates $6 billion annually, but water has threatened harvests. During the 2021 drought, some farmers tore out almond trees for less water-intensive crops (Nuccitelli, 2021). Joe Del Bosque, a farmer in the San Joaquin Valley, left a third of his farmland unplanted to save water for his almond trees, and may still need to uproot 100 of his 600 acres of almond trees. Jim Jasper, who owns Stewart &

Jasper Orchards, noticed that many of his neighbors stopped irrigating their almond orchards altogether, noting that “There's one orchard here that's drying up because they just didn't have the money to buy the water. And we're seeing this all over the valley” (Associated Press, 2021).

Many drought-afflicted California residents are also striving to secure their access to water. In Northern California, water diversions can dry up vital local creeks. According to a Shasta County resident: “We have no water for fire suppression and the fish and wildlife are dying. We have put out water for the wildlife near our property” (Becker, 2021). During the 2012-2016 California drought, 2,600 households in small, rural communities reported losing access to water because their wells ran dry. Many of these same households are in regions experiencing drought in 2021 (Escriva-Bou & Pauloo, 2021).

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