AIAA 2021-2022 Undergraduate Aerial Firefighting Aircraft

(Technical Paper)

Prison Inmates as Firefighters: California's Controversial Policy

(STS Paper)

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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 may wildfires be combated more safely and effectively?

As the planet's climate continues to change, and the frequency of wildfires increases, areas around the world like: California, Australia, or Israel face higher risks. There are many ways to combat these fires from both the aircraft and firefighter squads. While the solution to this can be a high-tech one, there are low-tech solutions dependent on manpower. The social impact of these wildfires grows in importances as property damage increases.

AIAA 2021-2022 Undergraduate Aerial Firefighting Aircraft

Can purpose built aircraft increase the efficiency of aerial firefighting?

The American Institute of Aeronautics and Astronautics (AIAA) has started a design competition to create a Responsive Aerial Firefighting Aircraft (RAFA). This RAFA will increase the efficiency of the Californian fire department by helping control the spread of wildfires. The MAE department is in charge of organizing teams of engineers with Professor Quinlan advising. The team of collaborators consists of: Brendan Whalen, Grace Vidlak, Jackson Wray, Jamie Graham, Joe Orrico, Kevin Moccia, Spencer Barnes, and team leader Haley Knowles.

As many of the current methods of aerial firefighting are becoming too costly and too old to use, a new aircraft must be developed to help prevent the impact of wildfires. Many of the current aircraft are past their service limit and are used as a last resort. It's also anticipated by researchers that fires occur more frequently over the next fifty years (AIAA, 2021). By increasing the efficiency of aerial firefighting, the threat and damage can be minimized.

The goals of this project are to minimize the operations cost, minimize the production cost, and make the aircraft reliable and available. Operations and production costs can be reduced by using appropriate materials and designing a modular structure. A reliable and available aircraft must be easy to produce and maintain with a low risk of critical failure. All constraints are listed in the Request For Proposal document (See Appendix A). The highest priority constraint deals with the payload capacity of the aircraft as it must hold at minimum 4000 gallons of flame retardant. An equally important constraint is the payload drop speed as it must be less than 172 mph which could cause stalling. The payload and drop are the driving factors for much of the design considerations. There are optional objectives in addition to the requirements such as higher payload capacity, slower drop speed, or drone capabilities.

The modern day firefighting aircraft tankers consist of reformatted passenger planes and WWII planes. These passenger planes, called Tankers, are retrofitted with large tanks and dispensary equipment that the fuselage is not designed for. Examples of these Tankers would be the Mcdonnell Douglas DC-10 and the Boeing 747-Supertanker. There also exists Scooper type aircrafts like the Canadair CL-215. While they can be used effectively, they are used as a last resort due to the cost of deployment. More in line with the RAFA would be the Modular Airborne Firefighting Systems (MAFFS) for the Hercules C-130 as it's operational cost is less than other Tankers. With purpose built aircraft, the size and operational costs of deploying aircrafts could be reduced.

Various software will be necessary to model and analyze the aircraft. Programs like OpenVSP and Solidworks will be used to generate a 3D model of the aircraft. Programs like Flight Optimization System (FLOPS) alongside Solidworks and Autodesk CFD will provide analysis of the aircraft aerodynamics and structural integrity. To provide a cost estimate, the Advanced Aircraft Analysis (AAA) software will be used. This program uses the well known Roskam method for cost estimation.

By successfully designing a cost efficient, reliable aircraft, the loss of forests to wildfires can be minimized. A potential next step would be to develop a new fire retardant to increase in effectiveness and reduce the impact on the environment.

Prison Inmates as Firefighters: California's Controversial Policy

How are the California Department of Corrections and other organizations determining the conditions in which inmates fight wildfires in California?

Wildfires pose a risk to both human life and the environment in terms of extent of damage as well as contributing to the climate emergency. According to Blanch et al. (2017), "Human-started wildfires accounted for 84% of all wildfires." The spread of these fires must be limited as much as possible as it's beyond what's beneficial to the environment. Additionally, there is a monetary motivation for fire prevention as Wang (2020) estimates that in 2018 the total economic damage of fires that season was approximately $148.5 billion.

The major participants include the Californian Department of Correction (DoC) and prisoners they employ at the Fire Camps. The DoC has enlisted 1,600 prisoners to aid in Total Fire Suppression efforts in 2021. These inmates must be non-violent offenders and are not assigned to the Fire camps, they must volunteer (DoC 2021). A third participant, the ACLU, advocates for better prison conditions, and they recognize these Fire Camps as a potential form of exploitation as prisons are kept at high capacity to keep these Fire Camps running. While many prisoners want to work, there is a vast power difference which could lead to abuse (Fathi, 2018). No inmate is forced to take the Fire Camp assignments, but the alternative is to sit in a cell. However, the prisoners may not feel as though they're being exploited. *The Guardian* quotes a former prisoner, “I am proud to have served on my firefighting crew.” The individual speaking was a lead engineer for her squad and was earning 37 cents an hour (Mota 2020).

Secondary participants would include Cal Fire, Californian fire department, and FEMA. Cal Fire is the main firefighting department for 36 of California’s 58 counties. They are also responsible for 31 million acres of privately owned land (CAL FIRE). When disaster strikes, and an individual’s home is destroyed, the Federal Emergency Management Agency (FEMA) supports them. After historic fires erupted in 2020 FEMA issued a press release stating, “More than $103 million in federal disaster assistance has been disbursed to help homeowners, renters, and businesses recover.” Working with the Inmate Firefighters is the California Conservation Corps. While not technically a part of Cal Fire, the CCC is an alphabet organization dedicated to conservation and protection for wilderness all over California (CCC).

Researchers have studied the increase in wildfire frequency recently. According to Blanch et al. (2017), by compiling data from the US Forest Service Fire Program it was found that from 1992 - 2012 84% of wildfires nationwide were human caused. The length of the fire season caused by humans is triple that of the lightning-caused fire season (Blanch et al., 2017). This data was collected three years prior to California’s record breaking wildfires in 2020. According to Wang (2020) these wildfires have a significant monetary impact. For 2020 this cost was roughly $148.5 billion with 22% of that estimated as health costs. Lelieveld (2020), has shown that increase in air pollutants like smoke can lead to a lower life expectancy. They labeled wildfires as an avoidable pollutant as they can be limited or prevented if handled properly.

Part of handling wildfires in California involves using inmate workers as a cheap source of labor. Bird (2020) has shown that California’s overpopulated prisons hold a large number of non-violent offenders because of drug related crimes. California's Proposition 47, was intended to reduce this number by converting a drug offense from a felony to a misdemeanor. Bird's findings were an overall decrease in rearrests for people sentenced for drug possession, but a small increase for person-related offenses like assault. The other aspect to consider is the mental health of prisoners. Laura Wallis (2015) discusses the lack of care for prisoners' mental health and quotes Lorry Schoenly, "Research clearly shows a link between mental illness and repeated incarcerations." The study she references involved a survey for 18,000 inmates, 18% of whom were taking medication for mental health before their sentence started. The environment prisoners are held in certainly does not help inmates with severe mental illness (Wallis, 2015).

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Appendix

A: AIAA RFP Constraints

General Requirements

- Entry Into Service (EIS)
  - [R] 2030
  - [R] Use existing engine(s) or one that is in development will be in service by 2028, or at least two years prior to the airplane EIS.
  - [R] Assumptions on at least specific fuel consumption/efficiency, thrust/power and weight must be documented.
- Fire Retardant Capacity
  - [R] 4,000 gal
  - [O] 8,000 gal
  - [R] Multi-drop capable; minimum 2,000 gal per drop
  - [R] Fire retardant reload >= 500 gal / min
  - [R] Retardant density of at least 9 lbs / gal
- Payload Drop
  - [R] Drop speed <= 150 kts
  - [O] Drop speed <= 125 kts
  - [R] Drop altitude <= 300 ft AGL
- Design Radius with Full Payload
  - [R] 200 n mi
  - [O] 400 n mi
- Design Ferry Range (No Payload)

- [R] 2,000 n mi
- [O] 3,000 n mi

- Dash Speed (After Payload Drop)
  - [R] 300 kts
  - [O] 400 kts
- Field Requirements
  - [R] Balanced field length <= 8,000 ft @ 5,000 ft MSL elevation on a +35°F hot day
  - [O] Balanced field length <= 5,000 ft @ 5,000 ft MSL elevation on a +35°F hot day o Certifications
  - [R] Capable of VFR and IFR flight with an autopilot
  - [R] Capable of flight in known icing conditions
  - [R] Meets applicable certification rules in FAA 14 CFR Part 25 • All missions below assume reserves and equipment required to meet applicable FARs
  - [O] Provide systems and avionics architecture that will enable autonomous operations
    - Provide a market justification for choosing to either provide or omit this capability
    - Determine how the design would change with this capability