Design of a Personal Aerial Vehicle

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Abstract

The purpose of this project was to research, design, and analyze a personal aerial vehicle. One focus of this objective was modeling and structurally analyzing the frame, which had to be lightweight, yet strong enough to withstand the stresses of the application. This was accomplished while also identifying other compatible components to complete the design. In pursuit of this goal, similar technologies were examined, allowing for a unique, yet practical, interpretation of this new technology. A tenth-scale prototype was designed and fabricated to assist in determining the electrical components necessary and to act as a functioning example of how a full-scale vehicle might operate. Finally, recommendations on future action were outlined to allow for further development of the technology.

Objectives

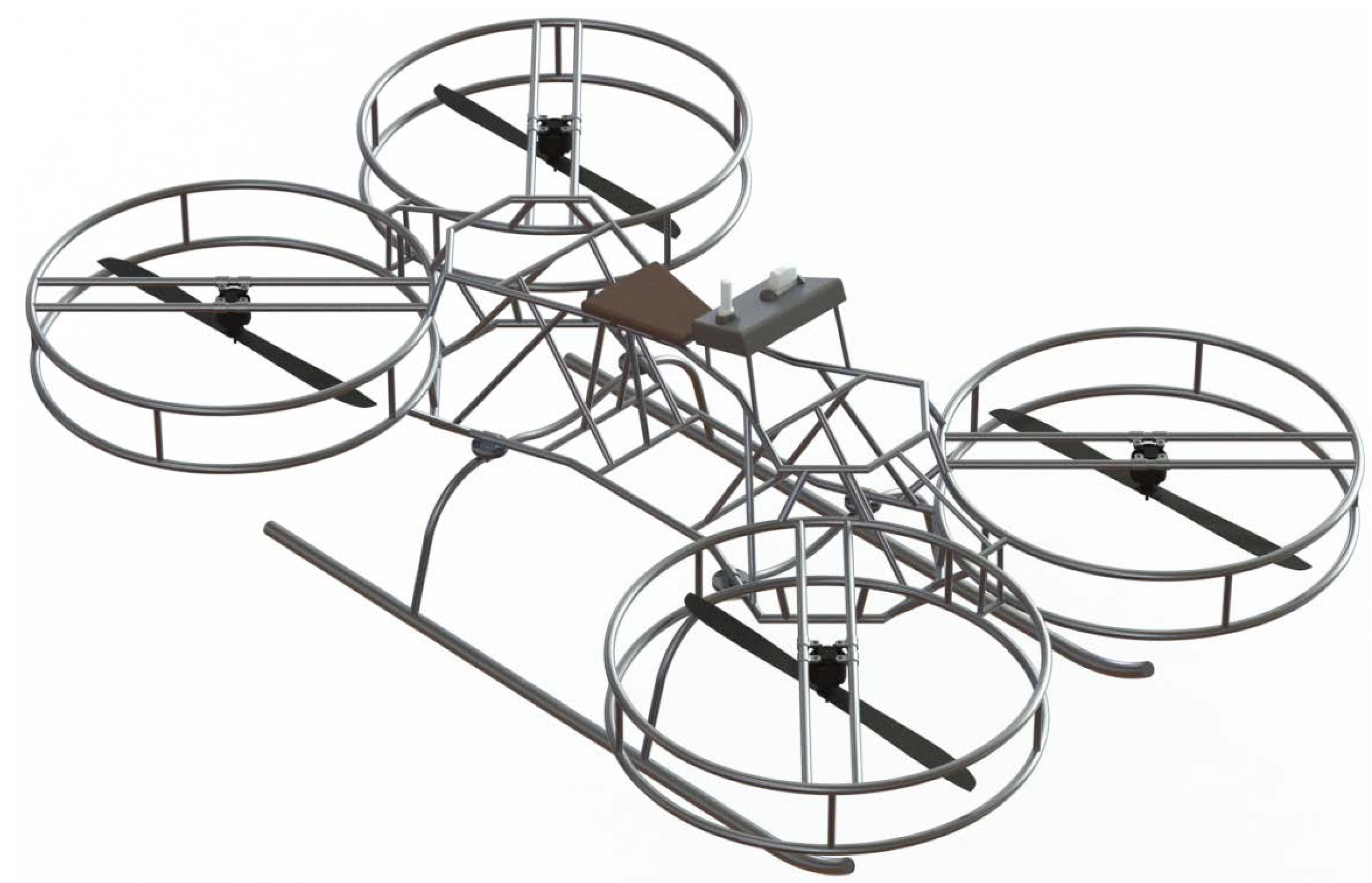
- Design, model, and analyze the frame in SolidWorks.
- Identify the necessary electromechanical components.
- Design and fabricate an operational tenth-scale prototype.
- Suggest modifications and improvements for future designs.

Prototype Design

- The 5-inch, low pitch propellers proportionally approximate the size and shape of the full-scale (48-inch) propellers.
- The electric brushless outrunner motors have an excellent power-to-weight ratio of 2.08 kW/lb_f.

- The battery has a high capacity-to-weight ratio of 4900 mAh/lb_f.
- The electronic speed controls are lightweight (0.15 lb_f) and can handle a current draw of 20A.
- The flight control board is only 0.02 lb_f and 2.01 in^2, with features including a gyroscope and an accelerometer for auto-leveling.

Vehicle Design



- The frame was designed to be a barebones structure that could house the components and hold a user weighing up to 250 lb_f.
- The frame is made out of tubes of Aluminum 6061-T6, an alloy that has good workability, can be easily welded, and has high corrosion resistance.
- This alloy is also strong, with a yield strength of 40,000 psi, while remaining lightweight, with a density of 0.0975 lb_f/in^3.
- After searching for the most powerful electric brushless outrunner motors on the market, a 9800W motor was selected for this application.
- The 48-inch diameter carbon fiber propeller chosen for this vehicle was calculated to need a 10.25-inch pitch to produce the required thrust.
- The 14S (51.8V), 5000mAh battery selected for this vehicle provides the necessary power, but only allows for a flight time of a couple of minutes.

Maximum Total Weight of the Vehicle and the User:

$$W_{total} = 140\ lb_f + 250\ lb_f = 390\ lb_f$$

Required Thrust per Propeller:

$$T = \frac{390\ lb_f}{70\%} \div 4\ propellers = 139.29\ lb_f$$

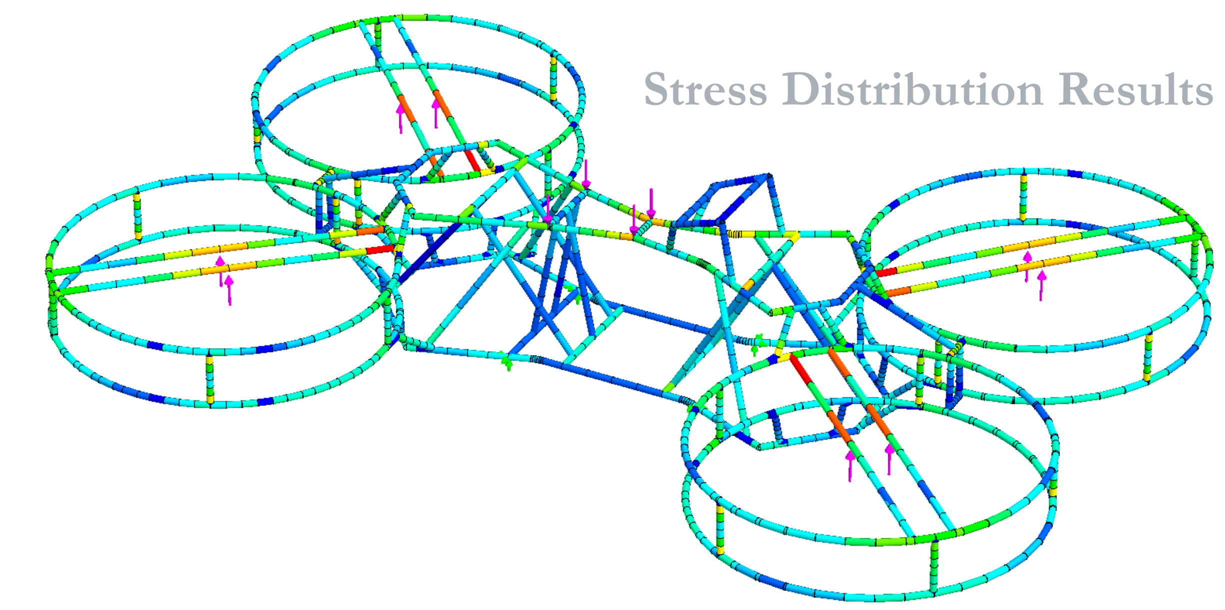
Maximum Propeller Tip Speed:

$$V_{max} = 767\ mph \times 0.85\ Mach = 651.95\ mph$$

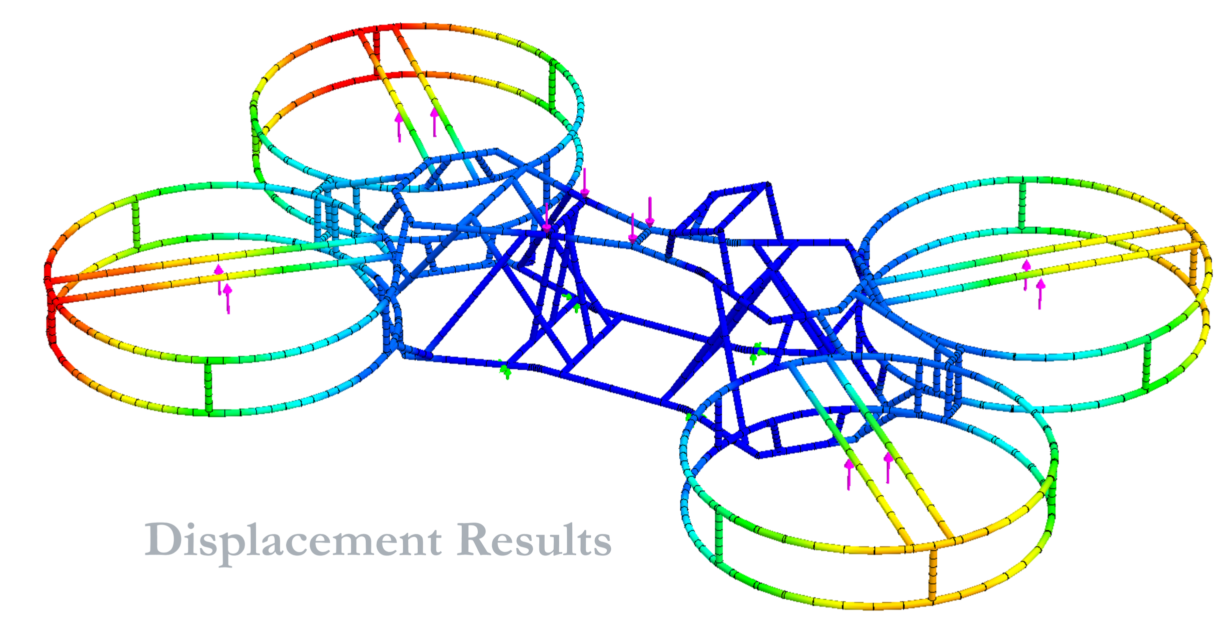
Maximum Propeller Rotational Speed:

$$RPM_{max} = \frac{651.95\ mph}{\pi \times 48\ in} \times \frac{63360\ in/mile}{60\ min/hr} = 4565.49\ rpm$$

Structural Analysis



- The frame was designed to have a Factor of Safety of at least 2.
- Maximum simulated stress was 17,134 psi at the inside joint of the motor supports, giving the frame a Factor of Safety of 2.33.
- The frame was designed to deflect no more than 1.5 inches.
- Maximum simulated displacement was 1.41 inches at the end of the motor supports and propeller housings.



Future Work

This project was the first iteration of a design, and therefore did not produce a comprehensive vehicle. Some future improvements can be made:

- The frame can be made from a stronger, lighter composite material.
- A higher-capacity battery would allow this vehicle to be more feasible, but the weight of the battery still needs to allow for adequate thrust.
- The steering system and heads-up display need to be designed.
- Safety measures were not a focus for this project and therefore need to be addressed before a human can safely ride this vehicle.
- Finally, a full-scale prototype should be fabricated once the above topics are addressed in order to test the vehicle's operation in practice.