Design and Development of Drones for Lightshow and Multi-Utility FPV

Presented to: Professor Ravishankar Balliga

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Overview of this keynote

A. Company Overview

- Company name – Peryton Technologies L.L.P.
- Company mission statement: To strive to build state-of-the-art technologies which reduces friction between the customer and their needs
- Company vision statement: To be the most customer-centric aerial technology company where business and individuals can be served alike

B. Project Overview

- Project goal: To build a prototype of 2 drones – one for lightshow and one for multi-utility FPV
- Objectives:

1. The frame must be as small as possible,
2. The frame must be compatible with the pre-determined components,
3. The frame must be easily manufacturable and scalable,
4. The frame must be structurally strong enough to withstand all the loads on it and must have a factor of safety (FoS) of more than or equal to 1.5,
5. The frame must be aesthetic.
6. The object-detection software should be able to take in the video feed directly from the drone and process it on an on-site computer.
7. The software must be able to properly detect most, if not all, the objects in the frame
8. **Find ways to increase the flight time of the UAV**

C. My role in the project

- Design and development of the frame of the UAV
- Selection of components and materials
- To keep design considerations and manufacturability in mind
- Oversee manufacturing and testing of prototype

C.1: Objectives and Methodology

- Methodology was a highly iterative approach
- Developing drones is a very complex projects and thus requires engineers from multiple disciplines
- Hence, a lot collaboration was required at each level
- As a result, the design changed overtime

C.1: Objectives and Methodology

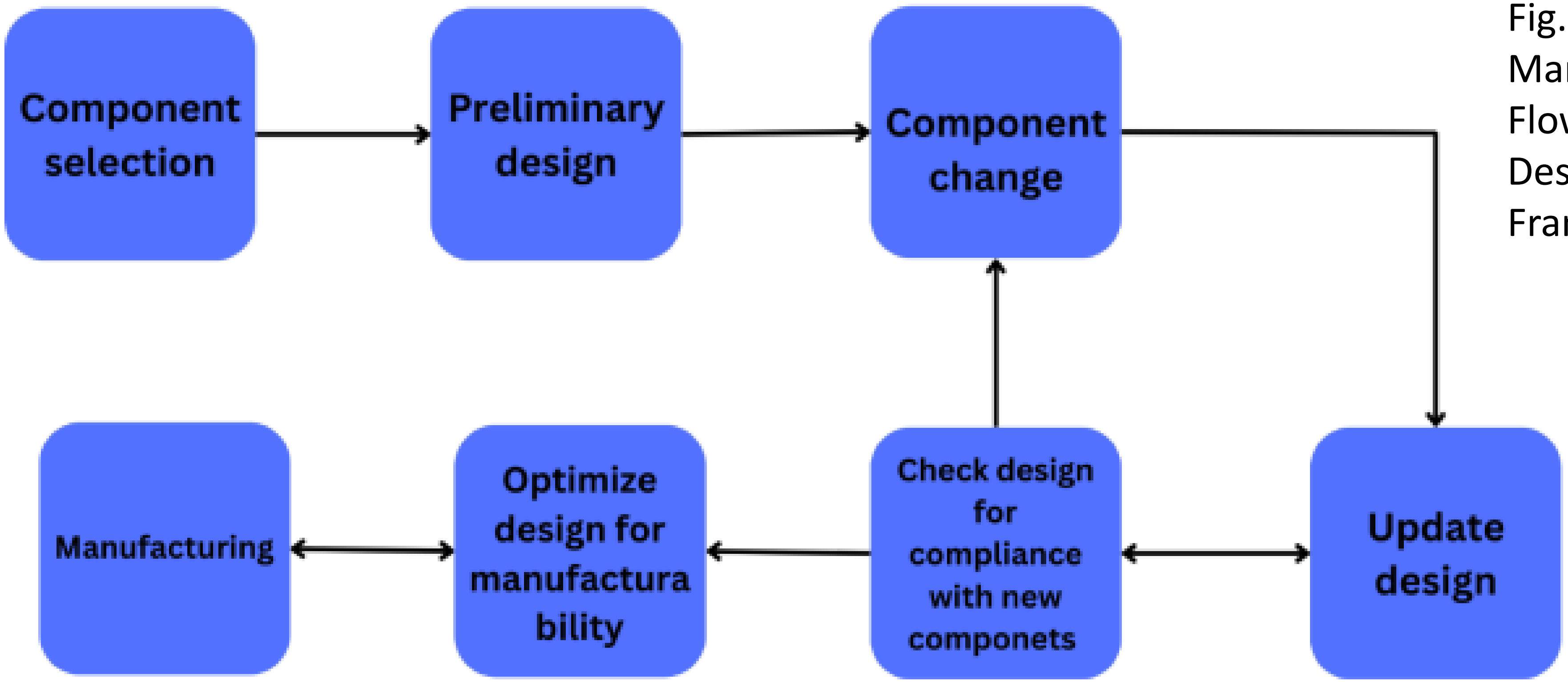


Fig. 1. Iterative Manufacturing Flowchart Used When Designing The UAV’s Frame

E: Evolution of the drones so far

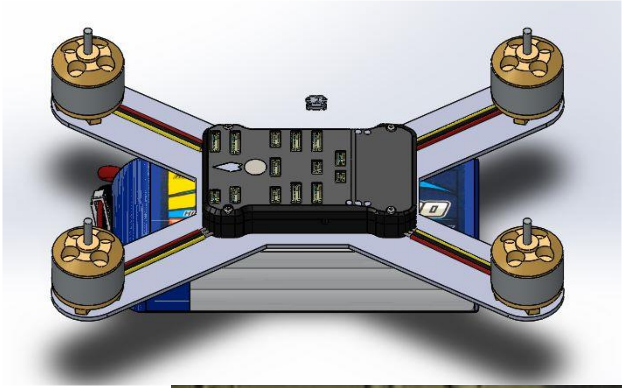
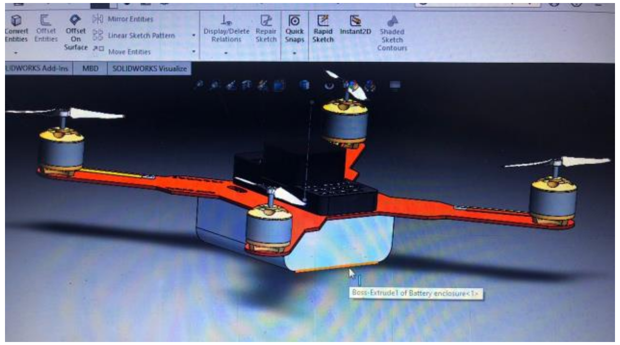
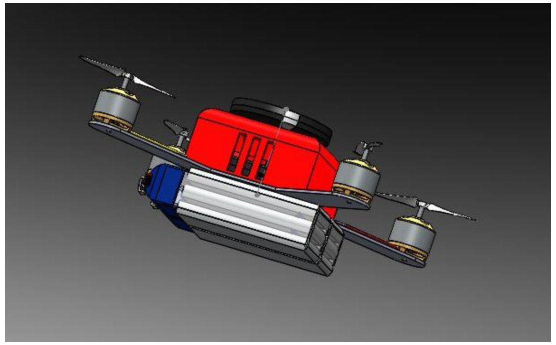
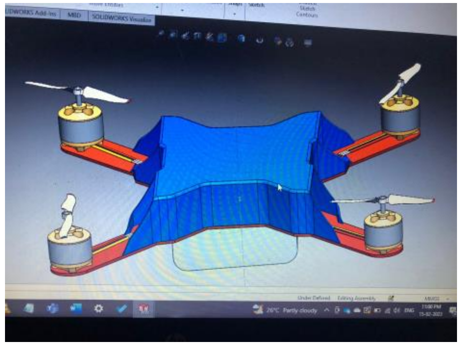






Fig. 5. Evolution of design of drone frame thus far

C.1.1: Evolution of the drones so far

Fig. 6. Evolution of design of drone frame thus far

F: Component (Material) Selection

- Scope of my work was mostly limited to the material choice and methods of manufacturing
- Materials considered for prototyping:
  - Balsa wood
  - Carbon fibre composites
  - ABS or PLA plastic
- Materials considered for other components:
  - Acrylic

G: Design considerations

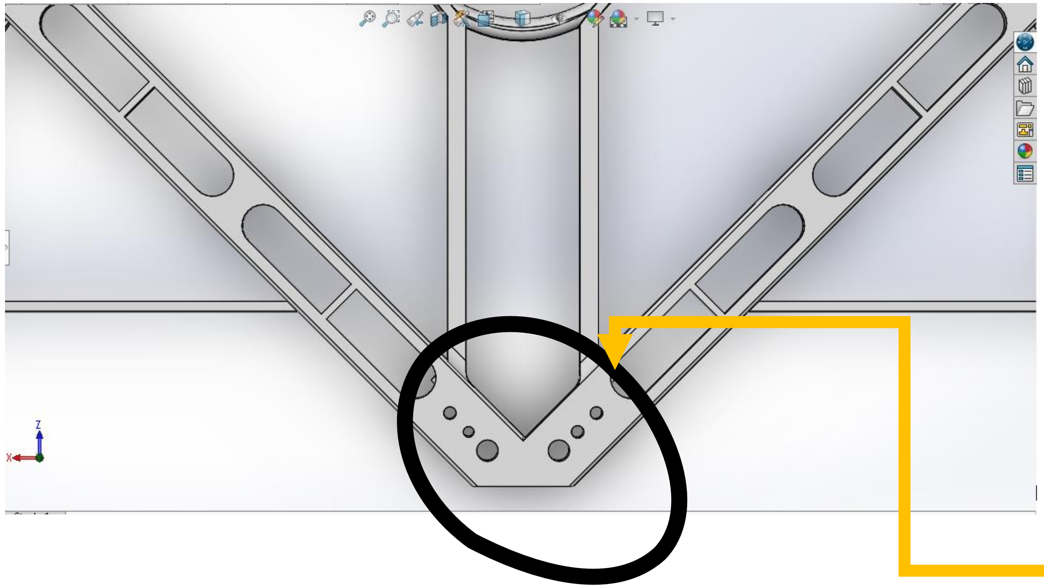


Fig. 7. Considerations such as fillet radius and hole dimensioning kept in mind when designing the frame

Hole diameter is to be 3 mm, but I have given a tolerance of ±0.5 mm

G: Design considerations (…cont'd)

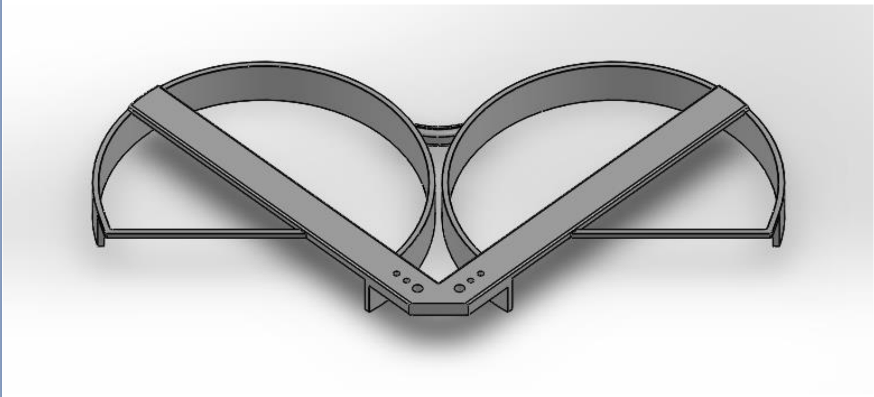


Fig 8.: Result of not giving enough tolerance leads to manually fixing the part

H: Calculation for force applied to the arms of the frame

- Force on the end of each arm was calculated using the Gabriel-Staples Two Blade Propeller Thrust Equation:

$$\boldsymbol{F = 4.39 * 10^{-8} * RPM * \left[\frac{d^{3.5}}{\sqrt{p}}\right] * \left[4.23 * 10^{-4} * RPM * p - vo\right]}$$

- Operating conditions being 6 in. dia. And 3 in. pitch @ 44,000 RPM, the thrust (force at the end of the arm) is calculated to be 26.9 ~ **27 Newtons (per arm)**
- Detailed calculation can be found in the report

H.1: Determining which materials can sustain this load

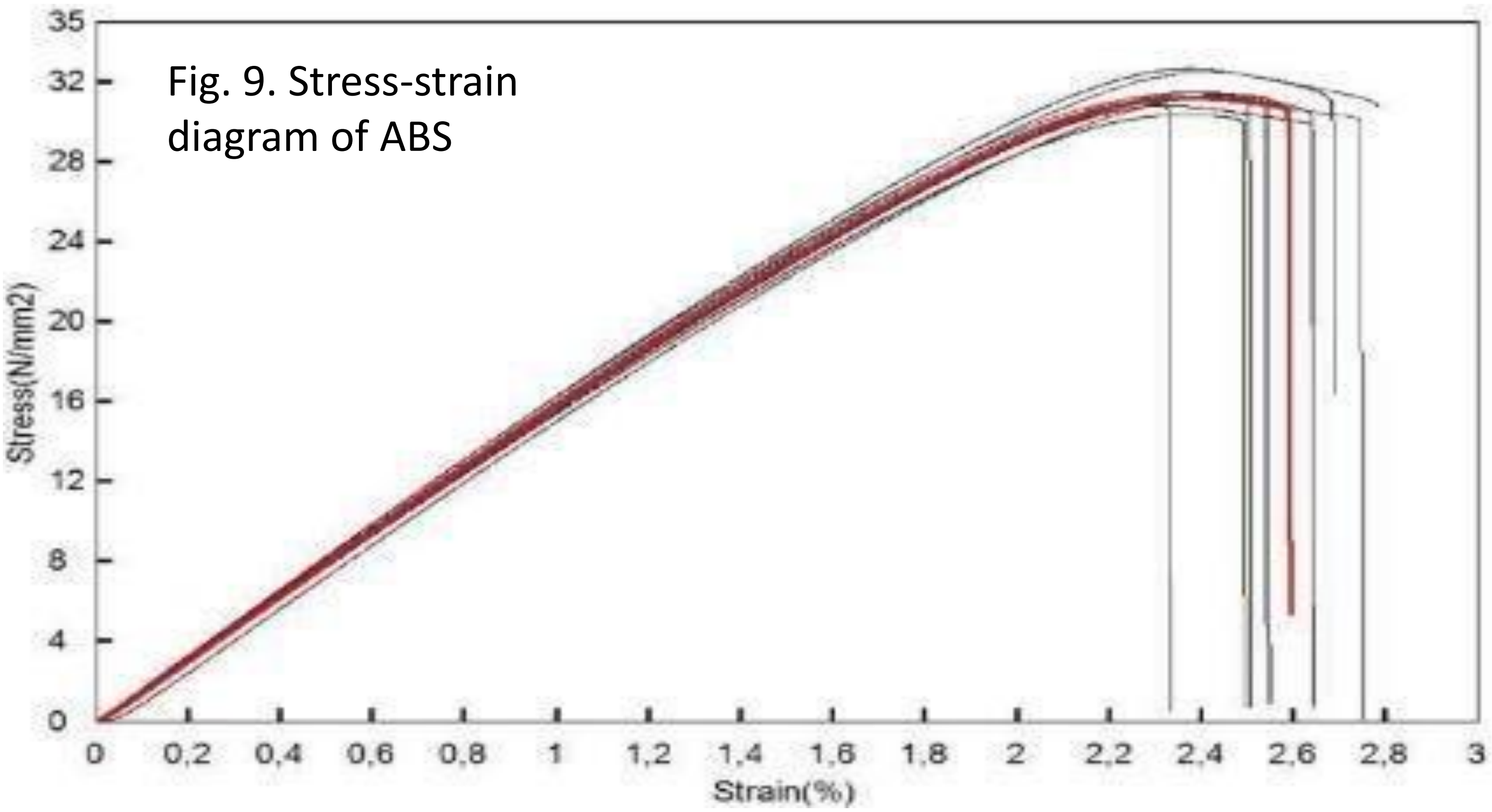
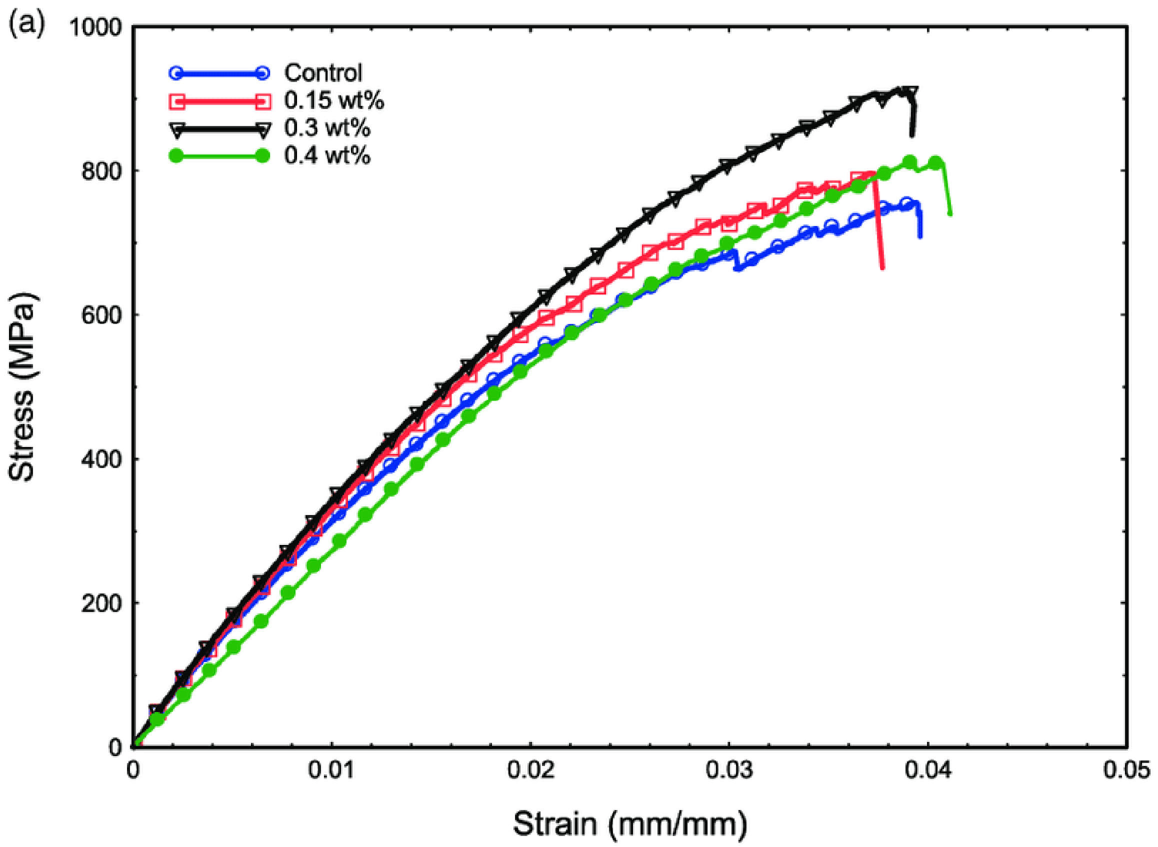


Fig. 9. Stress-strain diagram of ABS

- Stress-strain diagram of ABS and PLA plastic. Yield stress is around 32 N/mm^2 which is more than the required 27 Newtons, hence, it is an acceptable material.

H.1: Determining which materials can sustain this load



- Stress-strain diagram of a typical carbon fibre composite. Yield stress is around 800 N/mm^2 which is also more than the required 27 Newtons, hence, it is an also acceptable material.

Fig. 10: Stress-strain diagram of carbon fibre

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I: Tools and Manufacturing Methods

- Abrasive Water Jet Machining (AWJM) was used to machine carbon fibre sheets of thickness 2.5 mm and 3 mm into a small prototype
- Fusion 360 and SolidWorks were used to model and extract the DXF files required to machine the sheets (the DXF files contain the G-Codes for the AWJ machine)
- Additionally, SolidWorks's Topological Study was used to create organic design using generative design manufacturing

I: Tools and Manufacturing Methods

Video 1: Waterjet machining a 5 mm thick CFRP plate

I: Tools and Manufacturing Methods

Fig. 11.: 3D printers used for printing the components

I.1: Issues faced during manufacturing

- Most issues were faced by only the 3D printer
- Issues such as de-lamination due to insufficient heat and thus improper fusion existed
- This resulted in a lot of delays as each print took around 9 hours to complete

Fig. 12: defective 3D print caused by delamination

J.1: Lightshow drone testing

- Main factors measured during lightshow testing were manoeuvrability, flight time and connectivity
- Due to an error in the flight controller, the entire UAV lost control and was lost. Not much footage could be recovered

Fig. 13: Testing of drone lightshow

J.2: FPV drone testing

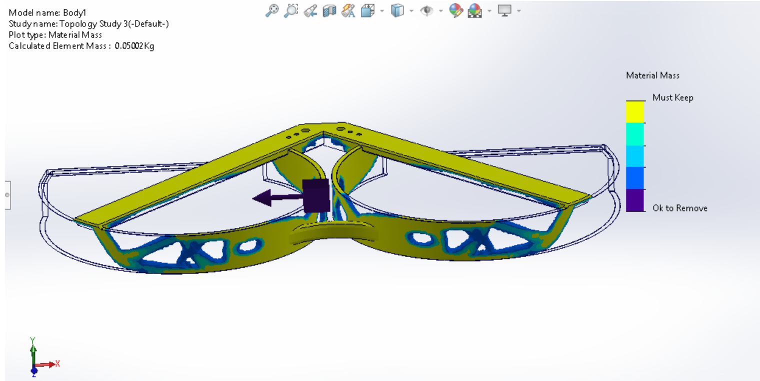
- Testing was done to ensure that the manufactured components performed to satisfactory levels:
- During testing, it was found that the weight of the propeller guards was too much
- The failure in the motor was hence caused due to overloading and overheating

Video 2: Testing footage showing motors failing due to overloading

K. Using AI and modern tools to improve the output

- AI tools such as computer vision and generative design were used in the process.
- Computer vision was used to create a basic object detection software that could be used for obstacle avoidance and surveillance
- Generative design is a modern design and manufacturing method that allows engineers to optimize their models for several parameters such as best stiffness-to-weight ratio, minimizing mass, and minimizing maximum displacement by utilizing organic shapes in order to satisfy these parameters

K.1: Modern tools: Generative design



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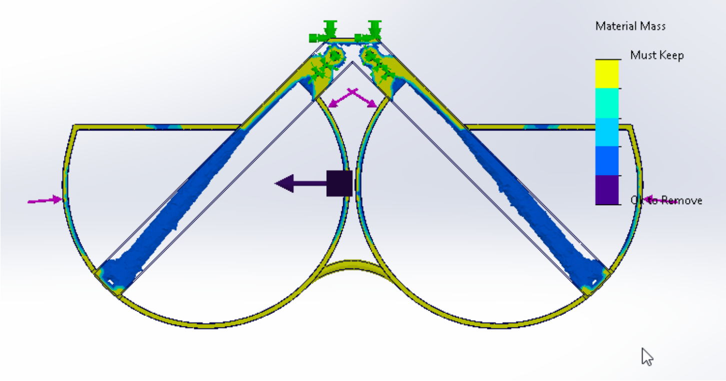

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Fig. 14: Using generative design to create the model of the propeller guards

K.2: Improving design for a better flight time

- The propeller guards were re-designed in order to reduce overheating and increase flight-time
- By using the new the new propellers, the flight time increased by 45% (~3 minutes to ~4.35 minutes)

Model 1: 3D Model of the propeller guard

K.2: Improving design for a better flight time

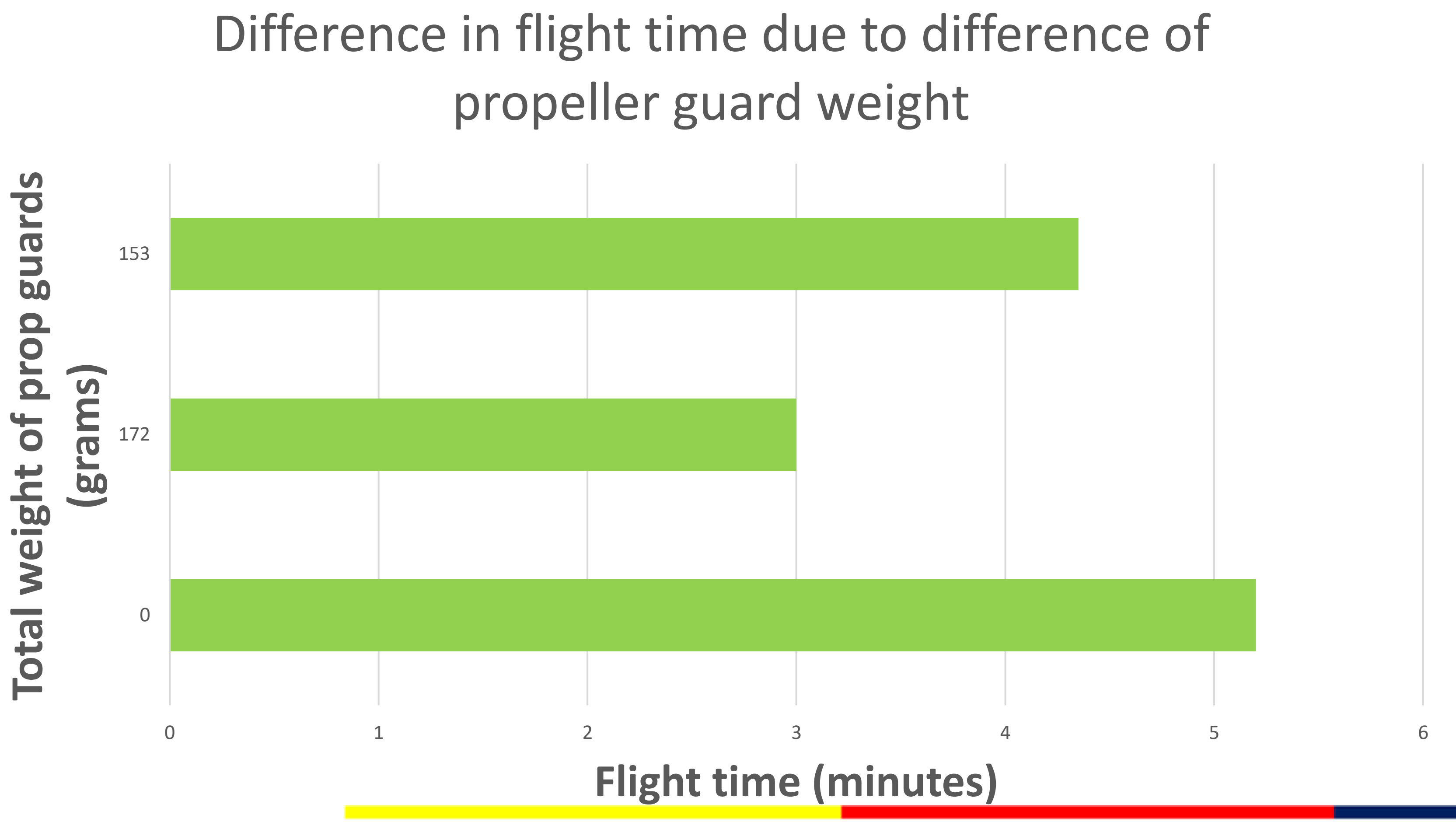


Fig. 15: Difference in flight time due to difference of propeller guard weight

K.3: Cost analysis after design improvement

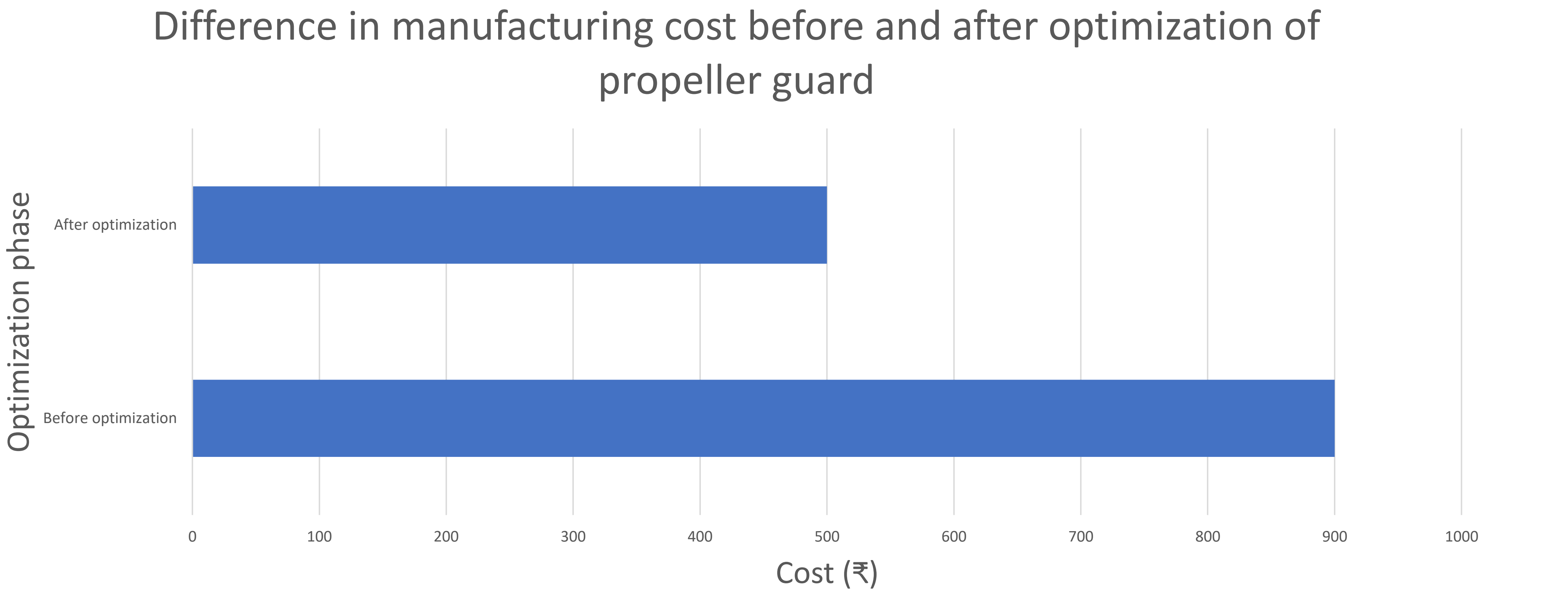
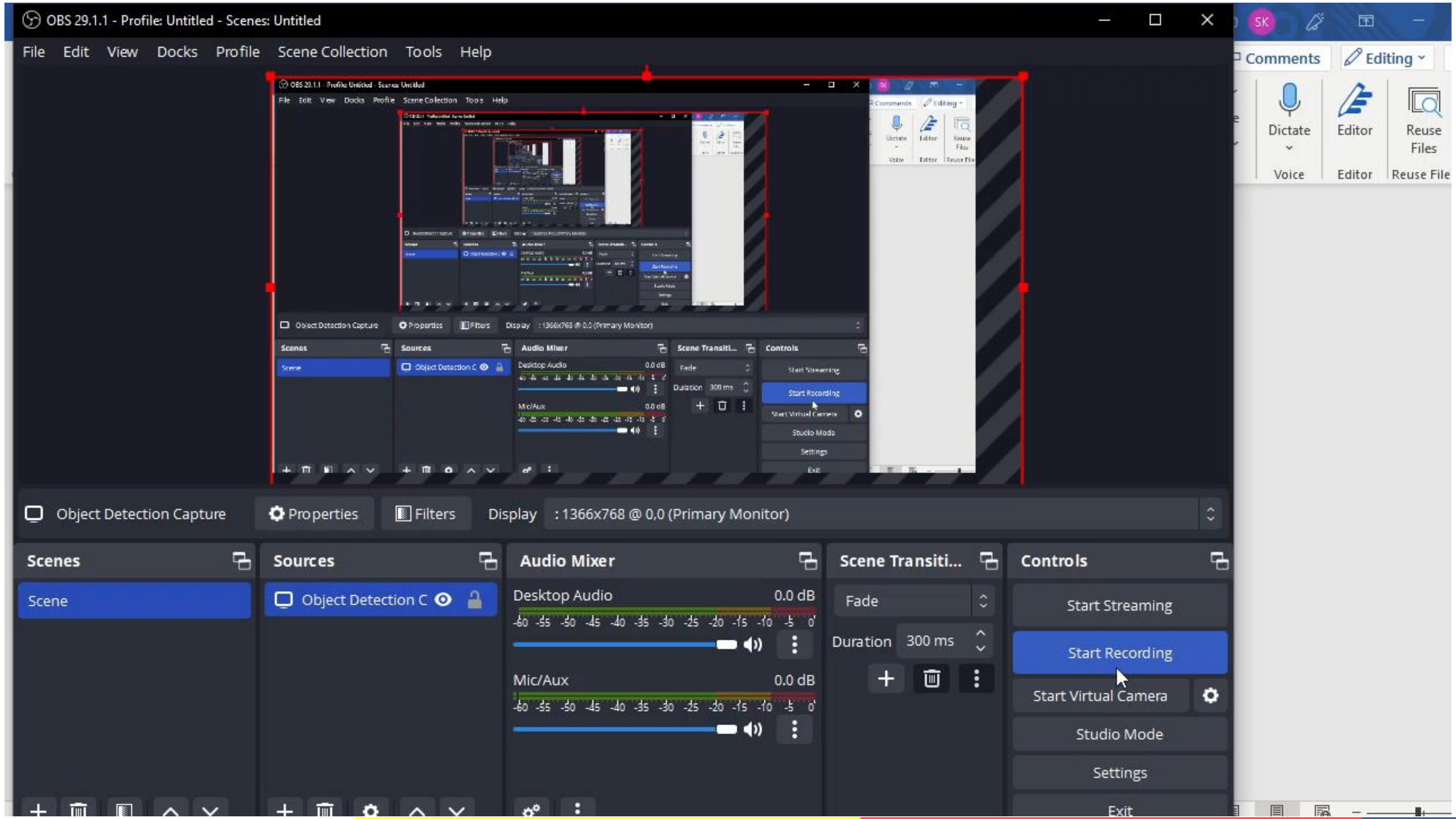


Fig. 16: Cost analysis after design improvement

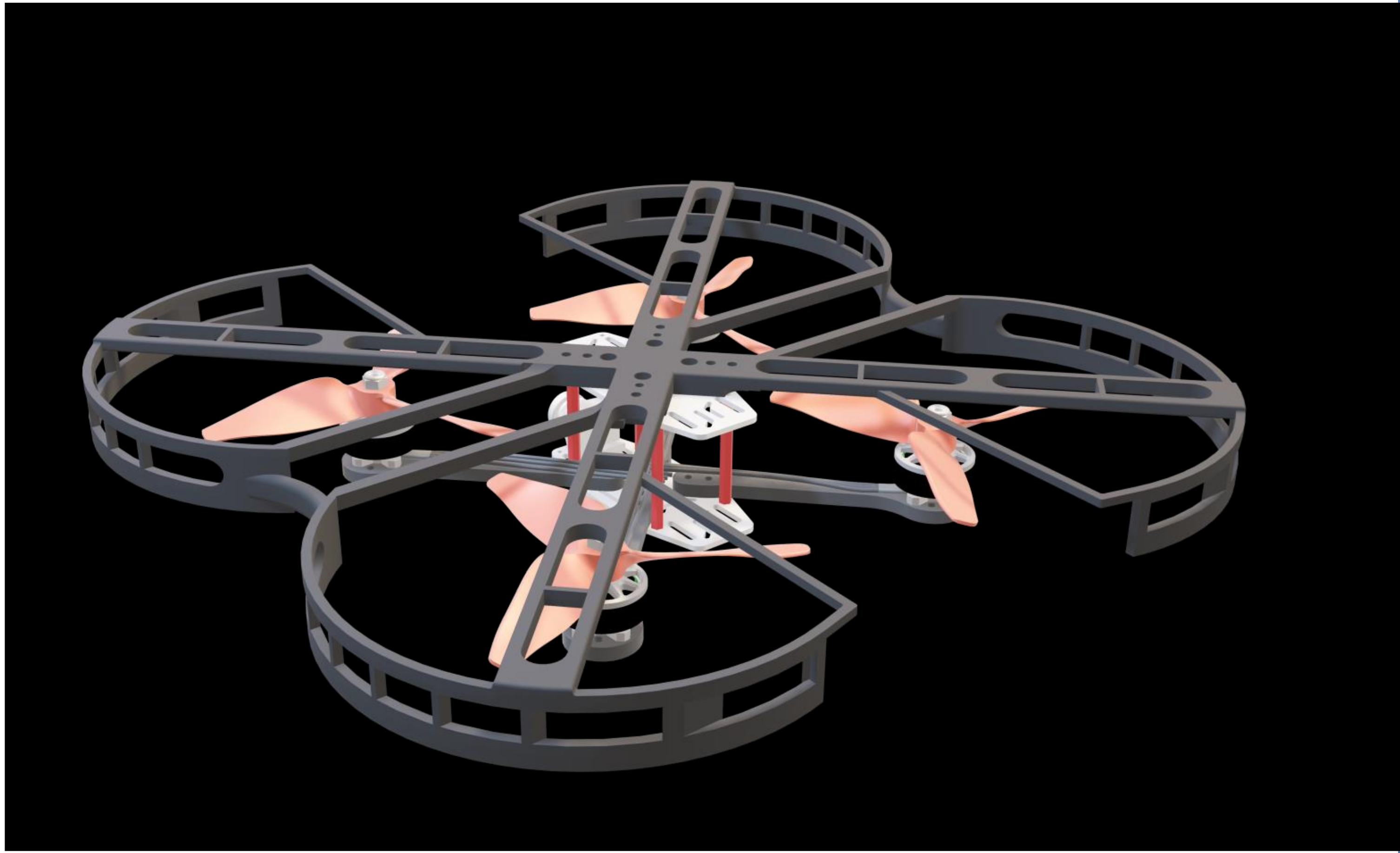
K.4: Modern tools: Computer vision using AI

Video 3: Demo of object detection software



Final assembly

Model 2: 3D model of the final assembly of the FPV drone



- The final assembly brings all the individual components together
- Not show here are the battery module and the electronics
- It takes around just 30 minutes to complete the entire assembly
- The weight of the entire drone when assembled together is ~518 grams

The Final Product

- Top speed: 50 km/hr
- Thrust to weight ratio: 1.26
- Maximum flight time: 5 minutes

L: References & Appendix

References

- The complete list of references can be found at this link: https://docs.google.com/document/d/1jEVvUh-lGcioiB15MZEFTxzrnQuOTtTUN_nT8z6kEps/edit?usp=sharing

Appendix

- Link to corresponding report:
- Link to corresponding AWJM video: https://www.linkedin.com/posts/activity-6981814243012558850-RAFA?utm_source=share&utm_medium=member_desktop