Boeing Drone: First Prototype Demo

Project 03

Team Hi-Jacks

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Project Description

- **Design, analyze, and manufacture a 3D printed drone frame that minimizes weight and maximizes flight time using set commercially available components.**

  - Sponsor: Boeing
  - Design material optimization
  - Thrust to weight ratio
  - Stress Testing

Design Description

- Current Design
  - Flimsy
  - Discs will be different material
  - Below weight requirement
  - Increased thrust to weight ratio

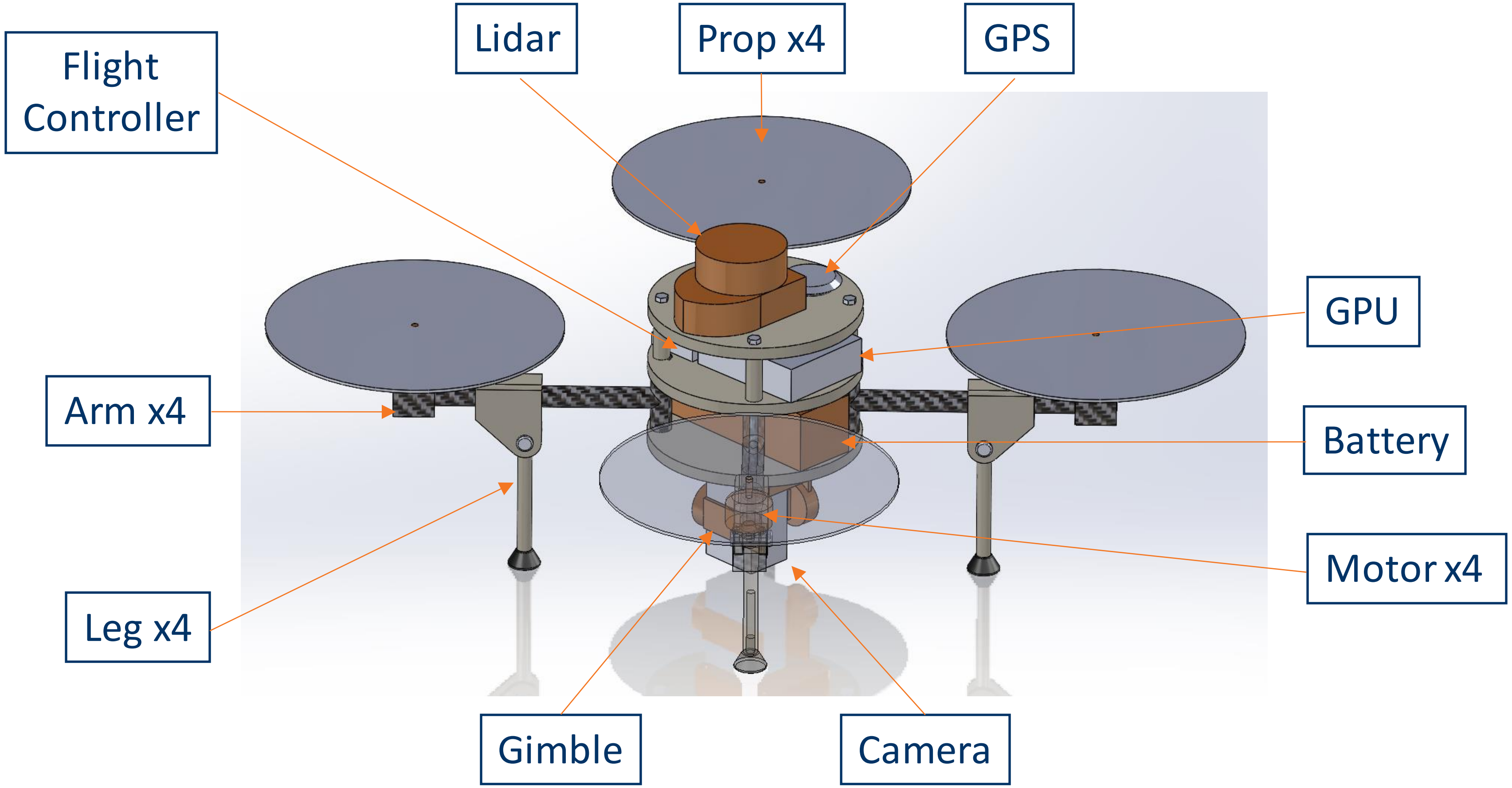

Figure 1: Full prototype with subsystems

Design Requirements

- Customer Requirements:
  - Lightweight\Optimized Thrust to Weight Ratio
  - Optimized Component Location
  - Low Cost
  - Minimal Hardware
  - Flight Capable
  - Easy to Manufacture
  - Strong Frame

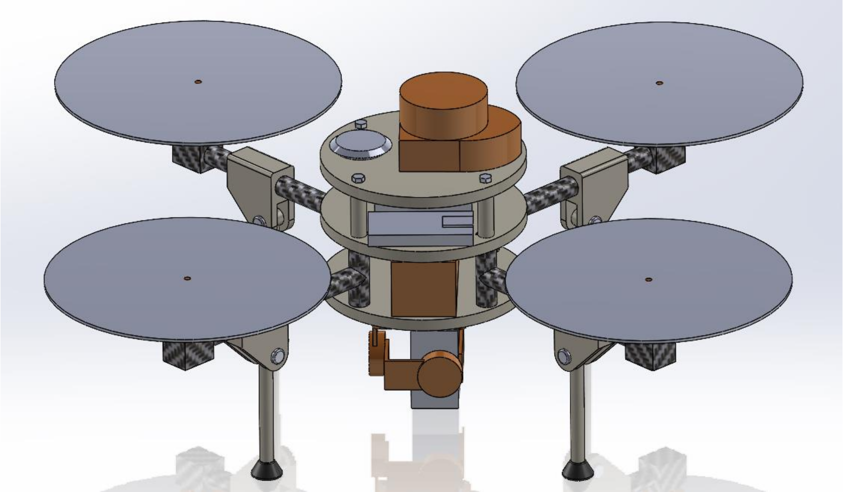

Figure 2: Prototype CAD

Design Analysis:

Analysis Done in CAD –

- Weight
  - Found from proposed material density and prototype volume
  - 0.96lbs for simple prototype
- Positioning
  - Parts for flight were dimensioned and CAD geometry was adjusted appropriately
  - Propellers are placed D/3 distance from other parts

Future Analysis –

- Stress
- Material Durability and Fatigue
- Crash Simulation
- Propeller Aerodynamics
- Cost

Prototype

- Total Cost:
  - $66.49

  taxes included

- Total Weight of 3D Printed Parts:
  - 501gm → 1.105lbs

- Total Configured Weight:
  - 435gm → 0.96lbs

Figure 3: Drone Frame Prototype

Prototype BOM

Table 1: Cost and Weight of Prototype Airframe

No.	Part	Weight [gm]	Cost	Quantity	Weight (total)	Cost (total)
1.	Plate no key	63	$8.76	2	126	$17.52
2.	Plate with key	61	$8.64	1	61	$8.64
3.	Arm	27	$4.32	4	108	$17.28
4.	Spacer	2	$1.44	4	8	$5.76
5.	Bolt	28	$0.69	4	112	$2.76
6.	Nut	3	$0.11	4	12	$0.44
7.	Washer	2	$0.17	4	8	$0.68

Not including tax

Design Validation: FMEA

Modes of Failures

- Keys on arms to hold in place
  - Cracking under stress
- Arms themselves
  - Not the correct length
  - Spacer hole too small for ¼” bolt
- Circular Discs
  - Warping
  - Small Cracking
  - Holes for ¼” bolts too small
- Spacers
  - Center hole too small for ¼” bolts

- Test Procedures
  - Stress Analysis
  - Cost Analysis
  - Material Durability and Fatigue
  - Propeller Analysis
  - Crash Analysis

Design Validation: FMEA

Table 2: Drone Frame Risk Assessment

Part # and Functions	Potential Failure Mode	Potential Effect(s) of Failure	Potential Causes and Mechanisms of Failure	RPN	Recommended Action
1	Impact Fracture	Flying debris and inoperative	Impact Loading	56	Increase plate infill
2	Impact Fracture	Flying debris and inoperative	Impact Loading	56	Increase plate infill
3	Impact Fracture and Low-Cycle Fatigue	Flying debris and erratic operation	Impact Loading	63	Increase arm thickness and key size
4	Impact Fracture	Poor appearance	Overstressing	100	Increase spacer thickness
5	Impact Fracture	Flying debris and inoperative	Impact Lodaing	105	Have spare backup parts
6	Impact Fracture	Erratic operation	Overstressing	18	Have spare backup parts
7	Impact Fracture and Ductile Rupture	Loss of stability	Overstressing	18	Have spare backup parts

Design Validation: Methods

- Stress
  - ANSYS
  - E-Calc
  - Hand calculations
- Material
  - Tensile Stress Tests
  - Compressive Stress Tests
    - Instron Device
- Cost
  - Weight analysis
  - Material cost
- Crash
  - E-Calc
  - Hand calculations

Schedule

- 11/6 Final Presentation outline
- 11/7 @ 2PM NAU students share Final Presentation and Report with the Boeing team
- 11/16 Final Report outline, BOM and CAD design
- 12/4 Final Prototype and Website check

Budgeting

- Total budget approved: $5300
- To be purchased:
  - Cost of the required parts for manual flight: $770.31
  - Body can have variable cost depending on material use and method of building. Maximum cost for 3D Printing at NAU MakersLab with PLA plastic: $340.
  - If considering to build drone with all parts mention it may cost up to $1194.28
- Money Spent:
  - First Prototype: $66.49 (501gm → 1.105lb)
  - NAU Capstone Fee: $265
- Budget Remaining: $4968.51

Part #	Part Name	Qty	Description	Functions	Material	Dimensions (in)	Cost ($)
1	Body	1	Body	Body	PLA		340
2	Hobbytown 40A ESC	4	Speed Controller	Control motor speed			55.99
3	Gemfan 9045 3-Blade Prop	4	Propeller	Provide lift	Glass Fiber Nylon	9	15.98
4	Battery Charger	1	Battery Charger	Charge battery			47.97
5	Battery Connector	1	Batter Connector	Connect battery to electronics			8.99
6	Socokin 6S Lipo Battery	1	LiPo Battery	Provide power	Lithium Polymer	6.06 x 2.03 x 1.89	73.99
7	iFlight XING 2814 880KV Motor	4	Motor	Spin propeller	Copper	Stator L: 0.551 Stator D: 0.787 Shaft D: 0.197	154.4
8	Flysky FS-i6X 2.4GHz RC Trans/Receiver	1	Remote Control	Control drone		6.85 x 3.5 x 7.48	72.99
9	Slamtec RPLIDAR	1	LIDAR Unit	Light detection and ranging		5.1 x 3.9 x 3.1	99.99
10	Arducam PTZ Camera	1	Camera Unit	First person control and recording			124.99
11	2-Axis Brushless Gimbal	1	Camera Gimbal	Stabilize camera		3.15 x 3.15 x 3.15	69.99
12	NVIDIA Jetson Nano GPU	1	GPU	Process visual data			129
				Total Cost Estimate:			1194.28
					Cost of Manual Flight Parts		770.31

Required component for footprint on design, cannot be altered (not required to purchase)

Required for manual flight, can be altered with similar component if unavailable

Thank You

Questions?

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Refereneces

[1] “Research guides: Creating at Cline Library: 3D Printing,” 3D Printing - Creating at Cline Library - Research Guides at Northern Arizona University. [Online]. Available: https://libraryguides.nau.edu/creating/3D-printing. [Accessed: 09-Oct-2022].

[2] G. Paulsen, “On-demand webinar: Best practices for metal 3d printing through Binder jetting,” Xometrys RSS, 24-Jan-2022. [Online]. Available: https://www.xometry.com/resources/blog/on-demand-webinar-3d-printing-metal-binder-jetting/. [Accessed: 09-Oct-2022].

[3] G. Paulsen, “On-demand webinar: Everything you need to know about vapor smoothing 3D prints,” Xometrys RSS, 20-Jan-2022. [Online]. Available: https://www.xometry.com/resources/blog/on-demand-webinar-vapor-smoothing-3d-prints/. [Accessed: 09-Oct-2022].

[4] S. Ngoh, “On-demand webinar: A deep dive into SLS 3D printing and high-performance materials,” Xometrys RSS, 20-Jan-2022. [Online]. Available: https://www.xometry.com/resources/blog/on-demand-webinar-deep-dive-sls-3d-printing/. [Accessed: 09-Oct-2022].

[5] S. Ngoh, “On-demand webinar: When to choose 3D printing vs. machining,” Xometrys RSS, 09-May-2022. [Online]. Available: https://www.xometry.com/resources/blog/on-demand-webinar-3d-printing-vs-cnc-machining/. [Accessed: 09-Oct-2022].

References

[6] “Articles,” Fictiv. [Online]. Available: https://www.fictiv.com/articles. [Accessed: 09-Oct-2022].
[7] “Research guides: Creating at Cline Library: 3D Printing,” 3D Printing - Creating at Cline Library - Research Guides at Northern Arizona University. [Online]. Available: https://libraryguides.nau.edu/creating/3D-printing. [Accessed: 09-Oct-2022].
[8] “Ansys Learning Hub - learn from experts at your own pace.” [Online]. Available: https://www.ansys.com/services/ansys-learning-hub. [Accessed: 10-Oct-2022].
[9] “Introduction to Ansys (Part1) : Starting Ansys Workbench,” YouTube, 24-Aug-2019. [Online]. Available: https://www.youtube.com/watch?v=C8WvCQpzT2A. [Accessed: 09- Oct-2022].
[10] “Introduction to Ansys (PART2) : Creating your first 3D model,” YouTube, 24-Aug-2019. [Online]. Available: https://www.youtube.com/watch?v=FwKkjAr9Kbk. [Accessed: 09- Oct-2022].
[11] “Introduction to Ansys (PART3) : Starting the mechanical interface,” YouTube, 24-Aug2019. [Online]. Available: https://www.youtube.com/watch?v=6QaFX1CG-ZE. [Accessed: 09-Oct-2022].
[12] “Introduction to stress analysis | ansys innovation courses.” [Online]. Available: https://courses.ansys.com/index.php/courses/stress-analysis/lessons/lesson-2-about- stressanalysis/. [Accessed: 10-Oct-2022].
[13] D. Durston, “SolidWorks equations - create more intelligent parts”. *YouTube*, 2013. Available: https://www.youtube.com/watch?v=r0lGDwCQKqU. [Accessed: Oct-9-2022].

References

[14] R. Wood, “Solidworks Design Tables Made Easy,” *GoEngineer*, 21-Mar-2022. [Online]. Available: https://www.goengineer.com/blog/solidworks-design-tables-made-easy. [Accessed: 09-Oct-2022].

[15] S. Durksen, “Using a multiple unit system in Solidworks equations,” *The Javelin Blog*, 14-May-2015. [Online]. Available: https://www.javelin-tech.com/blog/2015/05/multiple- unit-system-equations-video/. [Accessed: 09-Oct-2022].