SAVED (Smart Autonomous Visual Emergency Drone) - Supplementary Materials

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1. Introduction

This file includes the graphics, figures, tables, and equations associated with SAVED, a Smart Autonomous Visual Emergency Drone, designed by DisastAir. A thorough mathematical analysis will be included for the testing of the computer-designed prototype, and a financial forecast has been included for the development and distribution of the SAVED Drone.

2. Graphical Renderings of SAVED

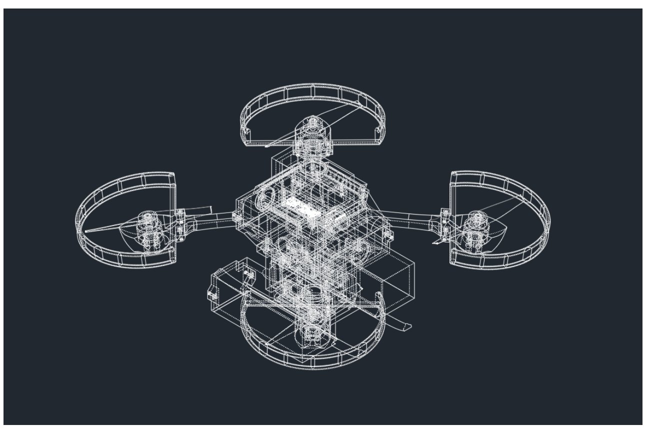

Fig. 1. Wire Frame Render of SAVED

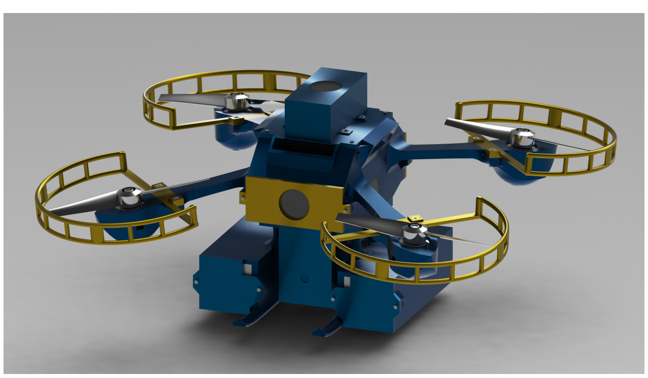

Fig. 2. Render of SAVED from an Isometric Perspective

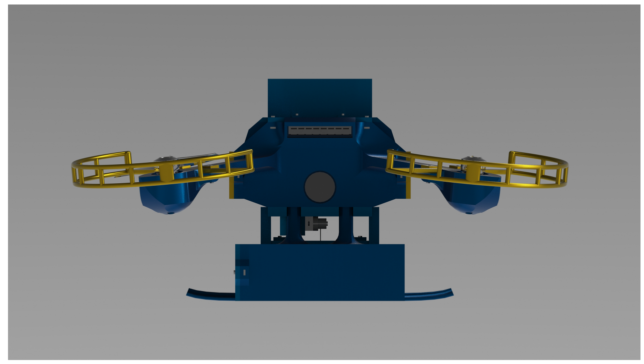

Fig. 3. Render of SAVED from Right

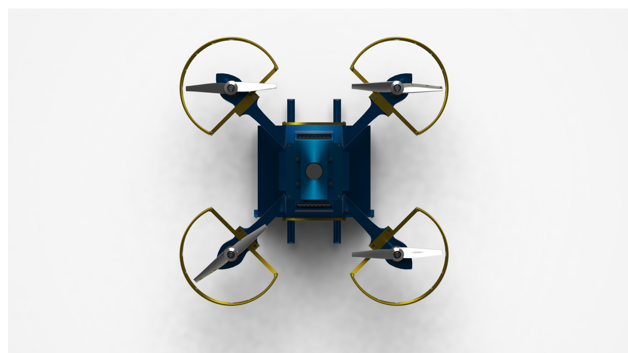

Fig. 4. Render of SAVED from a Bird's Eye Perspective

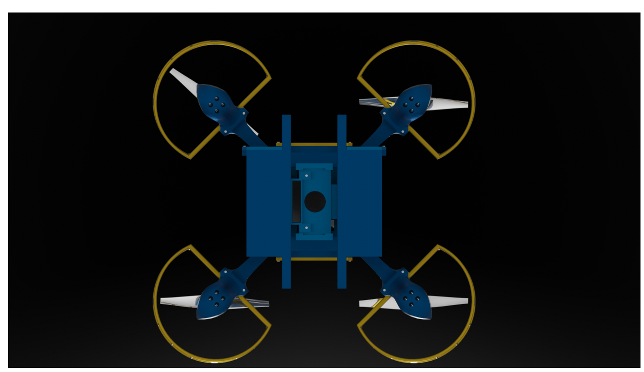

Fig. 5. Render of SAVED from Bottom

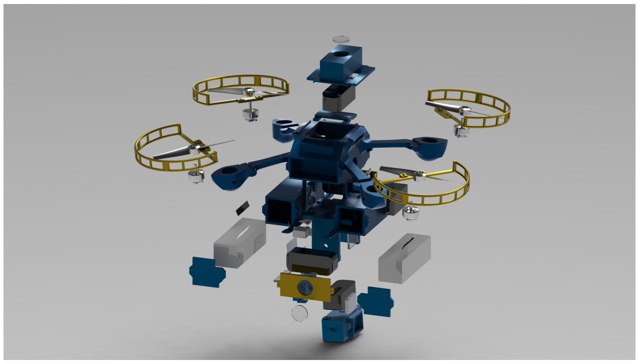

Fig. 6. Exploded Diagram Render of SAVED

3. Equations and Principles that Influenced Aspects of Component Optimization and Design of SAVED

- Pitching Moment Reduction [1]
- Measurements of a Propeller
  - $pitch = \frac{0.75*\pi*diameter*height}{width}$ [2]
  - Note: All measurements are measured at the cross-section of the propeller, at the 75% location between the center hub and its propeller tips.
- Newton's Second and Third Law
- Dynamic Equilibrium
- Six Degrees of Freedom (6DOF)
- Euler's Angles, see Appendix A [3]
- Quadrocopter's Motion Equations

$$\text{Linear Velocity or } v^b = \begin{bmatrix} u \\ v \\ w \end{bmatrix} = \begin{bmatrix} longitudinal velocity \\ lateral velocity \\ normal velocity \end{bmatrix} \quad (1)$$

$$\text{Angular Velocity or } \omega = \begin{bmatrix} p \\ q \\ r \end{bmatrix} = \begin{bmatrix} rollrate \\ pitchrate \\ yawrate \end{bmatrix} \quad (2)$$

$$\text{Force} = \begin{bmatrix} F_x \\ F_y \\ F_z \end{bmatrix} \qquad \text{Momentum} = \begin{bmatrix} L \\ M \\ N \end{bmatrix} \quad (3)$$

$$\text{Inertial Frames or} = \begin{bmatrix} \phi \\ \theta \\ \psi \end{bmatrix} = \begin{bmatrix} bankangle \\ pitchattitude \\ heading \end{bmatrix} \quad (4)$$

$$\text{Navigation Coordinates} = \begin{bmatrix} x \\ y \\ h \end{bmatrix} = \begin{bmatrix} longitudinal position \\ lateral position \\ height \end{bmatrix} \quad (5)$$

[4]

- The Lift Equation

$$L = \frac{C_l \, \rho \, V^2 \, A}{2}$$

[5]

- Propeller Design Principles and Articles Related to this Topic:
  - High-Lift Propeller System Configuration Selection for NASA's SCEPTOR Distributed Electric Propulsion Flight Demonstrator [6]
  - Propeller Design Requirements for Quadcopters Utilizing Variable Pitch Propellers [7]
- Propeller Lift Calculations and Articles Related to this Topic:
  - Performance of Propellers [8]
  - A thrust equation treats propellers and rotors as aerodynamic cycles and calculates their thrust without resorting to the blade element method [9]
- Motor Loads [10]
- Blade Element Theory [11]
- Adaptive Control of Drones [12]
- Drone Dynamics [13][14]
- Flight Controllers, Gyro Stabilization, and IMU [15]
- Dimensionality Reduction [16]
- Open Source Code Repositories and Existing Resources
- Tree-Based Image Processing Techniques

4. Technical Figures and Tables

4.1 Force Diagrams

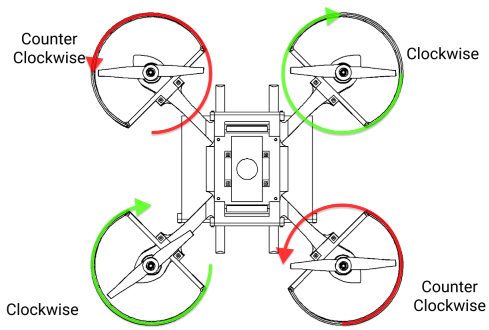

Fig. 7. Diagram of Motor Positioning and Rotational Direction.

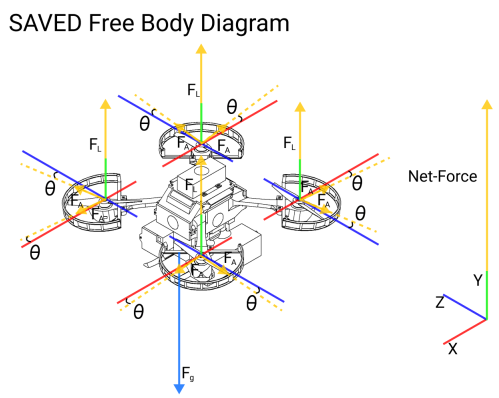

Fig. 8. Free Body Diagram of Force Vectors Acting on SAVED under Ideal Condition.

4.2 Structural Analysis of the Frame

Figure 7 shows the stress levels of the frame of the drone when gravitational force is exerted under standard atmospheric pressure, simulated through ANSYS Discovery STUDENT.

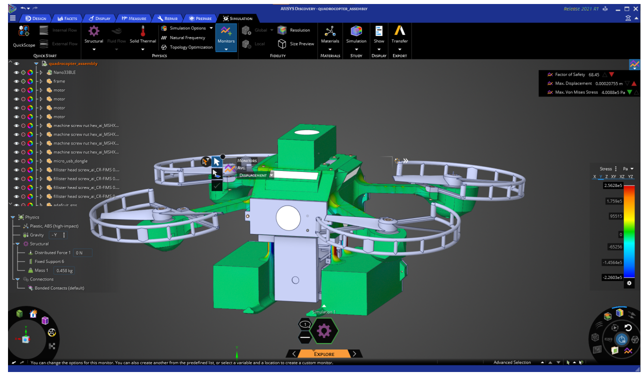

Fig. 9. Finite Element Analysis of the frame

4.3 Computational Fluid Dynamics (CFD) Analysis of the Propeller

SAVED is a quadrocopter with two sets of propellers, where both sets produce identical lift and are anti-symmetric to each other. Therefore, it is critical to calculate the thrust performance of the propeller.

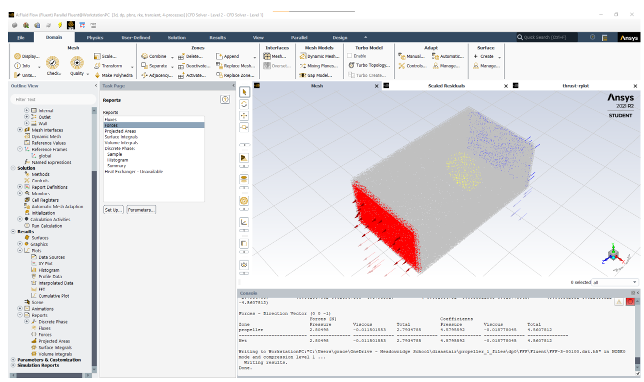

Fig. 10. Experimental Setup Apparatus of the Simulation, in ANSYS Fluent Student.

The simulation takes place in ANSYS Fluent Student. The apparatus is consist of two enclosure bodies, rotating domain - a cylindrical disk with the prop, and static domain - a large enclosure simulating as a wind tunnel. All fluids are set to air and all solids are set to aluminum (ABS is not applicable to student versions). When simulating, the rotating domain is spinning at 20000 RPM, under standard atmospheric conditions. It will run through 100 time steps (0.00005s per time step, with 15 maximum iterations each).

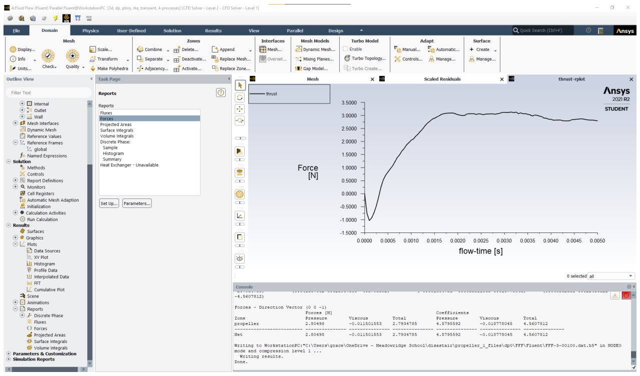

Fig. 11. Thrust Plot of the Propeller.

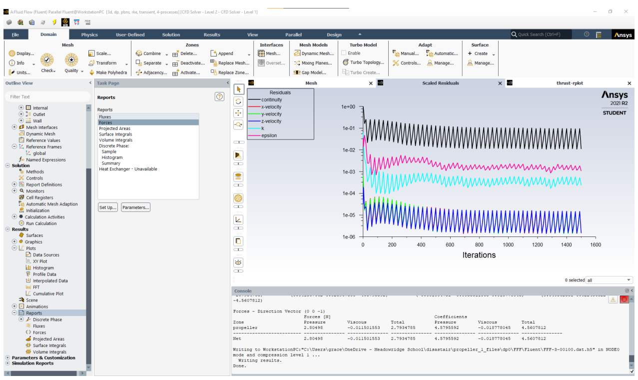

Fig. 12. Scaled Residue Plot of the Propeller

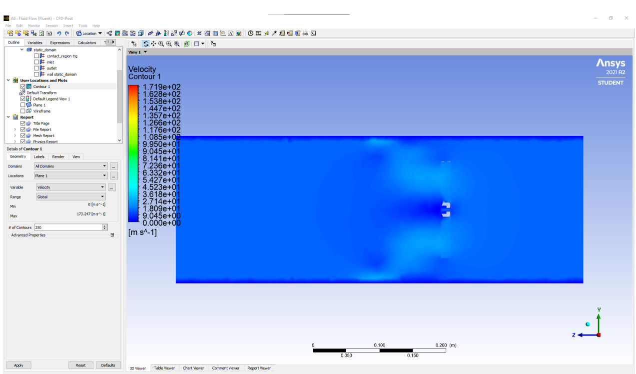

Fig. 13. Flow Visualization Contour of the Propeller

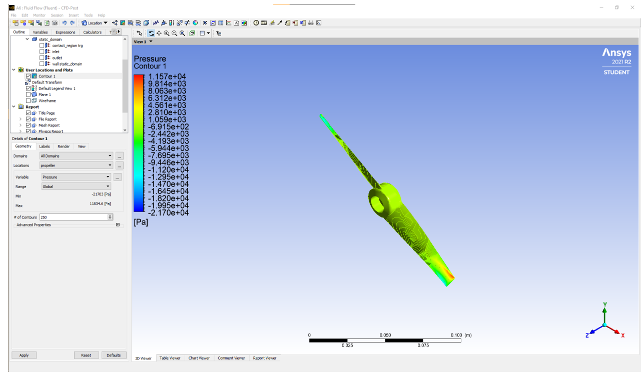

Fig. 14. Surface Pressure Visualization of the Propeller

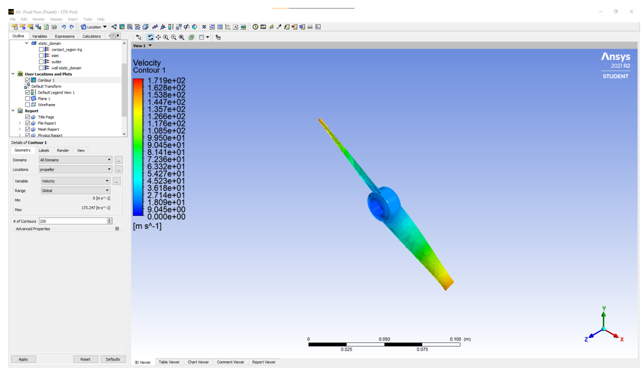

Fig. 15. Surface Deformation of the Propeller

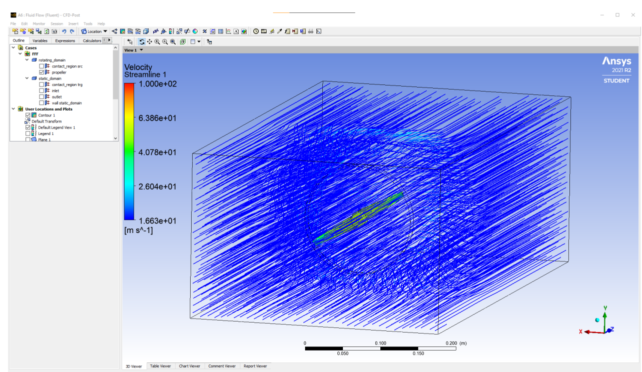

Fig. 16. Flow Visualization of the Propeller

Forces (N)			Coefficients		
Pressure	Viscous	Total	Pressure	Viscous	Total
2.80498	-0.01150	2.79348	4.57956	-0.01877	4.56078

Table 1. Performance of Propeller under Standard Atmospheric Conditions at 20000 RPM.

4.4 Control Schematics and Electrical Wiring Diagram

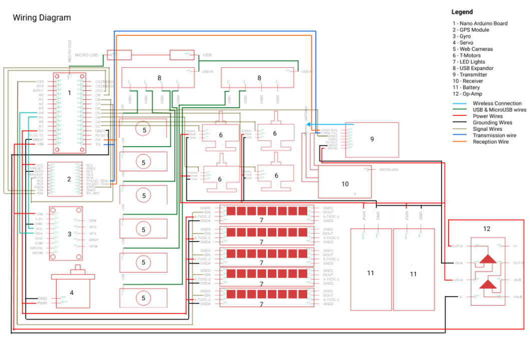

Fig. 17. Wiring Diagram of SAVED, not drawn to scale

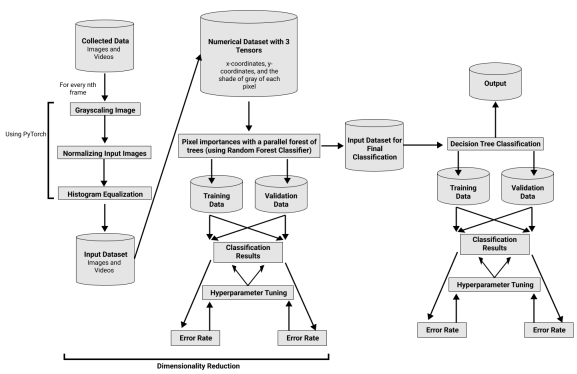

Fig. 18. Prospective Machine Learning Schematics of SAVED

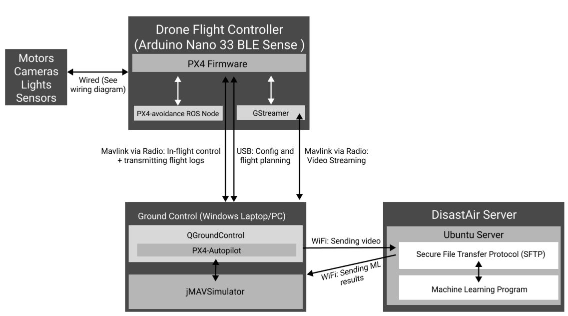

Fig. 19. Flight Control Schematics of SAVED.

5. Financial Forecast Figures and Tables

5.1 Nomenclature

$$WC = Working\ Capital$$

$$TA = Total\ Assets$$

$$RE = Retained\ Earnings$$

$$EBT = Earning\ Before\ Tax\ and\ Interests$$

$$S = Sales$$

5.2 Charts and Equations

The Altman Z equation:

$$1.2\left(\frac{WC}{TA}\right) + 1.4\left(\frac{RE}{TA}\right) + 3.3\left(\frac{EBT}{TA}\right) + 1.0\left(\frac{S}{TA}\right)$$

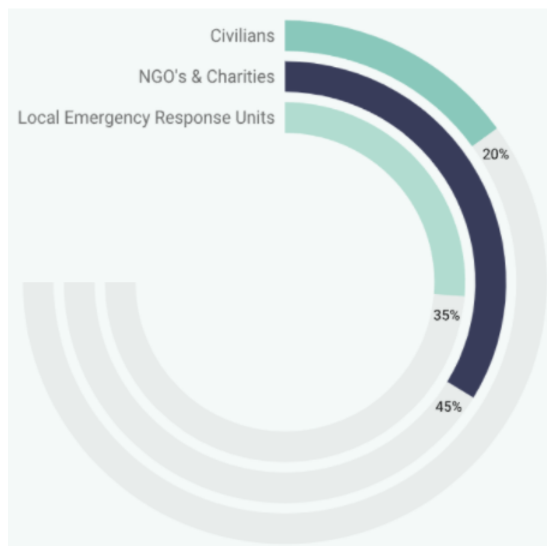

Fig. 20. Target Market of SAVED.

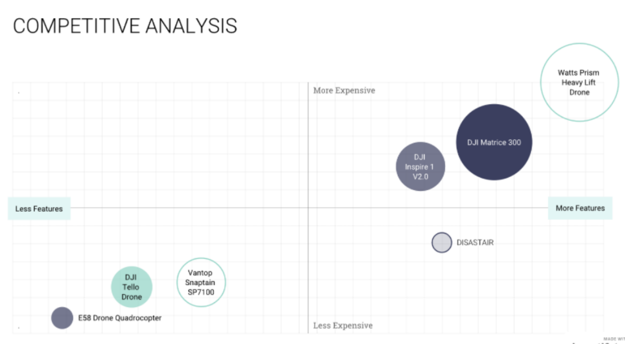

Fig. 21. Competitive Analysis of SAVED.

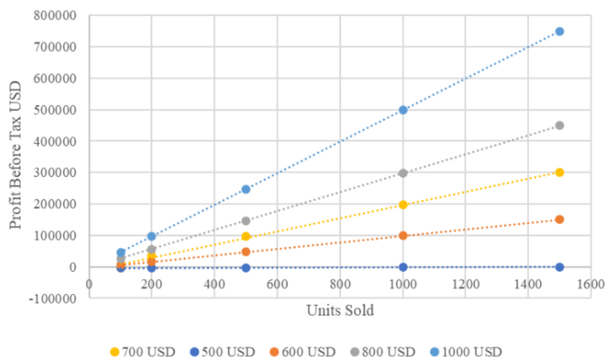

Fig. 22. Projected Profit of SAVED at Different Price Points.

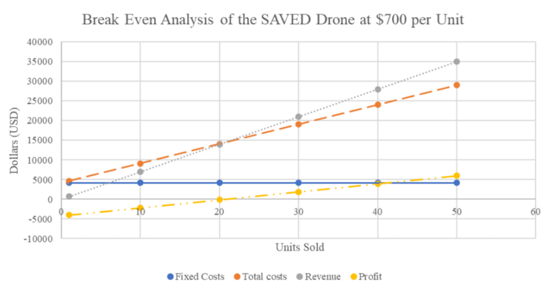

Fig. 23. Break Even Analysis of SAVED at $700 per Unit.

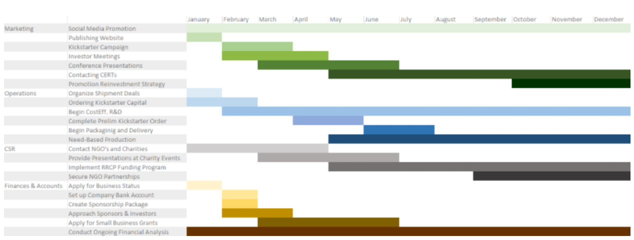

Fig. 24. Implementation Timeline.

6. Links to Additional Files

CAD Files of the Prototype:
https://github.com/GraceYuMeadowridge/Disastair-SAVED_CAD_repo

Bill of Materials:
https://github.com/DisastAir/Disastair_Additional_Files/blob/master/SAVED_technical_specs.xlsx

Other Files (including the source file of all the figures featured in this document):
https://github.com/DisastAir/Disastair_Additional_Files

7. Appendix

7.1 Appendix A - Euler's Angles

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} cos(\theta)cos(\psi) & -cos(\phi)sin(\psi) + sin(\phi)sin(\theta)cos(\psi) & sin(\phi)sin(\psi) + cos(\phi)sin(\theta)cos(\psi) \\ cos(\theta)sin(\psi) & cos(\phi)cos(\psi) + sin(\phi)sin(\theta)sin(\psi) & -sin(\phi)cos(\psi) + cos(\phi)sin(\theta)sin(\psi) \\ -sin(\theta) & sin(\phi)cos(\theta) & cos(\phi)cos(\theta) \end{bmatrix} \begin{bmatrix} b_1 \\ b_2 \\ b_3 \end{bmatrix}$$

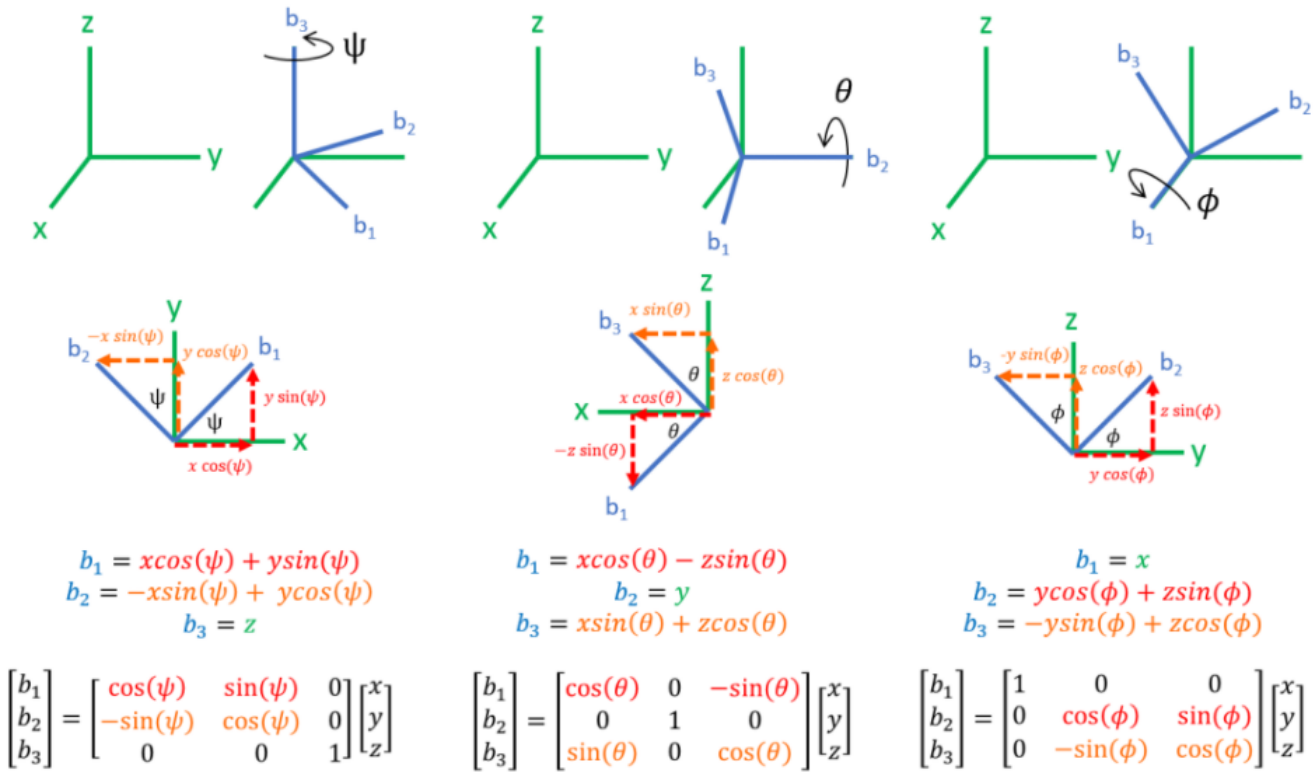

Fig. 25. Diagram of Euler's Angles and its Corresponding Mathematical Explanation [3]

References

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[2] S. Vorkoetter. (2002). "Propeller basics," [Online]. Available: `http://www.stefanv.com/rcstuff/qf200203.html` (visited on 12/30/2021).

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