Summary Section:

The purpose of this analysis is to determine the equations of motion for a blimp that is operating in a simulation. These equations of motion will help define orientation for the blimp in 3 dimensional space within the simulated program.

The figures below show the shape of a blimp with a possible gondola attachment.

Figure 1: Complete Blimp assembly

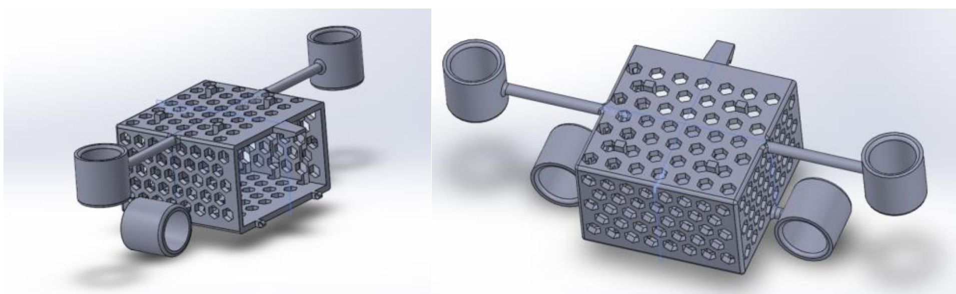


Figure 2: Possible gondola electronics carrier.

Results:

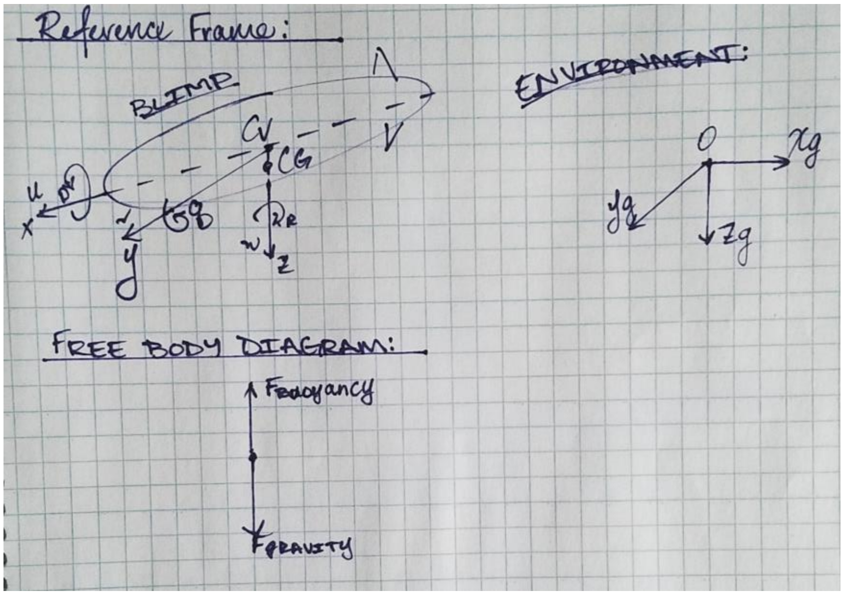
The results of this analysis is to formulate a set of dynamic equations proof to be useful in analyzing the model as a whole and to implement a simulation.

Evaluation:

The model will be directed on a six-degree freedom axis at the beginning. The inclusion of more complex topics like air resistance will not be evaluated.

Formulation Section:

Schematics:



Given:

-Schematics

-Journal documented examples

-Euler Angles (Φ, θ, Ψ)

Find:

The dynamical equations of a blimp.

Assumptions:

-No effect from aeroelastic effect

Solution:

$F_g = Force\ Gravity$

$F_p = Force\ Propulsion$

$F_b = Force\ Generalized\ (Aerodynamics)$

$F_k = Force\ Kinematics$

$M = [M_x, M_y, M_z] = \ Sum\ of\ Moments$

$m = Total\ mass$

$\dot{x} = Velocity\ Vector\ (6\ DOF)$

$\omega = [p, q, r] = \ \dot{\theta} = Angular\ velocity$

$\propto = [p, q, r] = \ \dot{\omega} = Angular\ velocity$

$v = \ \omega\ \times r = Velocity$

$a = \propto \times r + \ \omega\ \times (\omega\ \times\ r) = Acceleration$

$\eta^I = [\dot{x}, \dot{y}, \dot{z}] = Linear\ velocity\ internally$

$\eta^B = [u, v, w] = Body - fixed\ frame$

$\dot{A} = (\dot{A})_{xyz} + \ \omega\ \times A = Time\ Derivative\ of\ any\ vector$

$f = [f_x, f_y, f_z] = Translational\ Forces\ from\ motors$

$\tau = [\tau_x, \tau_y, \tau_z] = Translational\ Moments\ from\ motors$

$$I = \begin{matrix} I_x & -I_{xy} & -I_{xz} \\ -I_{yx} & I_y & -I_{yz} \\ -I_{zx} & -I_{zy} & I_z \end{matrix} = moment\ of\ inertia\ about\ center\ of\ mass$$

A summation of all the forces acting on the blimp:

$F = \Sigma\ F_g + \ F_p + \ F_b + \ \ F_k = Sum\ of\ Forces$

Considering the above defined variables and regards to the information about Euler Angles and 3 Dimensional space, the 6 DOF dynamics can be determined by:

$$m\left(\dot{\eta^B} + \omega \times \eta^B\right) = F + f + I\dot{\omega} + \omega \times (I\omega) = M + \tau$$

Due to symmetry the inertia matrix can be simplified:

$$I = \begin{matrix} I_x & 0 & 0 \\ 0 & I_y & 0 \\ 0 & 0 & I_z \end{matrix}$$

The portion of the equation of $\omega \times (I\omega)$ can be removed due to identity moment of inertia. So above equation can be determined as:

$$m\left(\dot{\eta^B} + \omega \times \eta^B\right) = F + f + I\dot{\omega} + = M + \tau$$

$$m\left(\dot{\eta^B} + \omega \times \eta^B\right) = F + f + \left(\begin{matrix} I_x & 0 & 0 \\ 0 & I_y & 0 \\ 0 & 0 & I_z \end{matrix}\right)\dot{\omega} + = M + \tau$$

So since everything is related to that direction in which it is acting, the General Dynamic Model Equation:

$$M\dot{x} = F + F_b + F_g\left(\lambda_{1,3}, \lambda_{2,3}, \lambda_{3,3}\right) + F_p$$

Answer:

$$M\dot{x} = F + F_b + F_g\left(\lambda_{1,3}, \lambda_{2,3}, \lambda_{3,3}\right) + F_p$$

Conclusion:

The general dynamic kinematics equation is listed above where the forces acting on the blimp are primarily gravity in the downward direction. While thrusters and buoyancy are acting in the upward direction.

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