

Flight Dynamics Simulation

T-637-GEDE Final Project

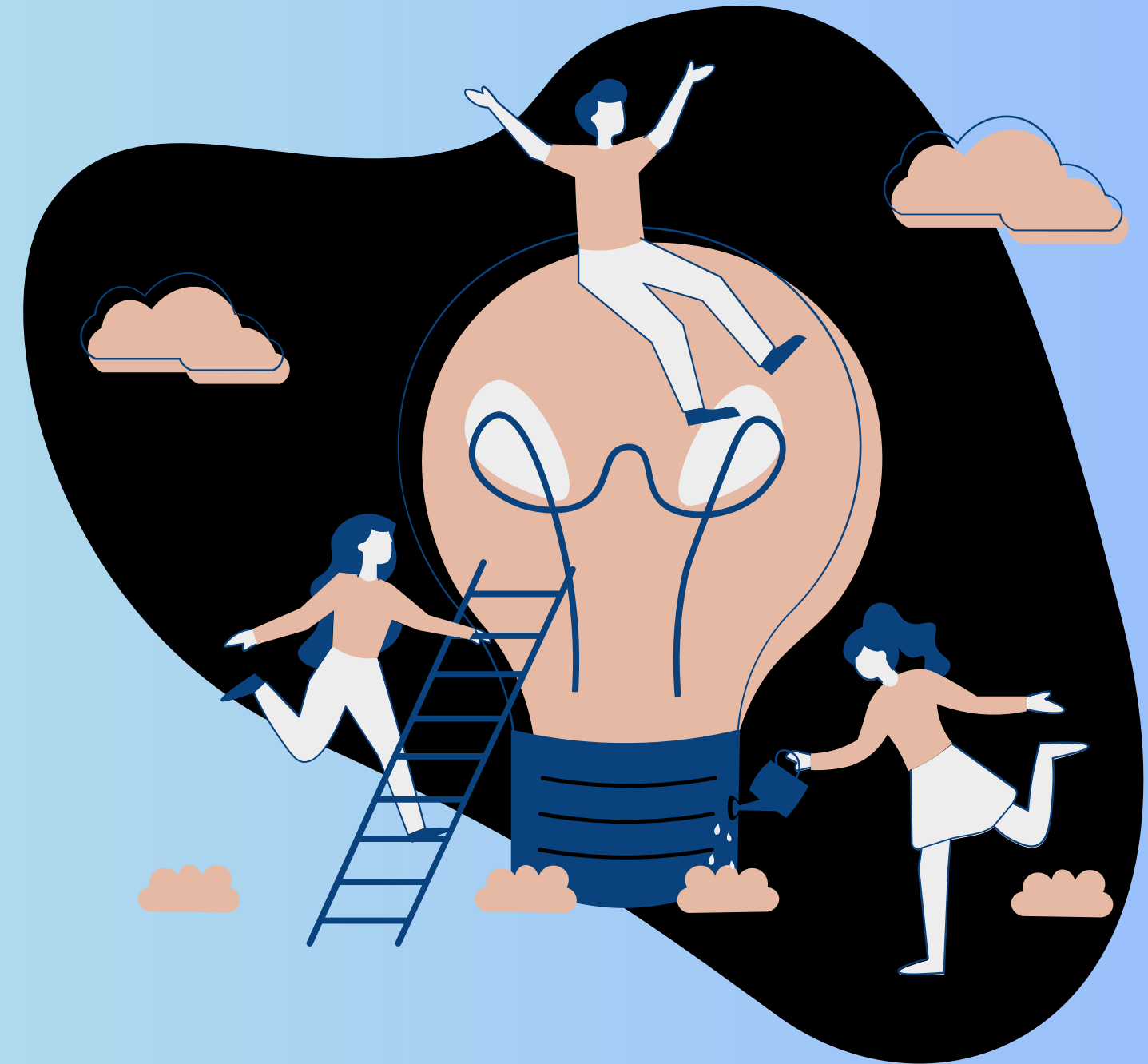


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Purpose

To create a custom physics engine that:

- Simulates realistic flight movements
- Combines simplified game physics with complex aerodynamics equations
- Enchants gamers and aviation enthusiasts



Related Work



Microsoft Flight
Simulator

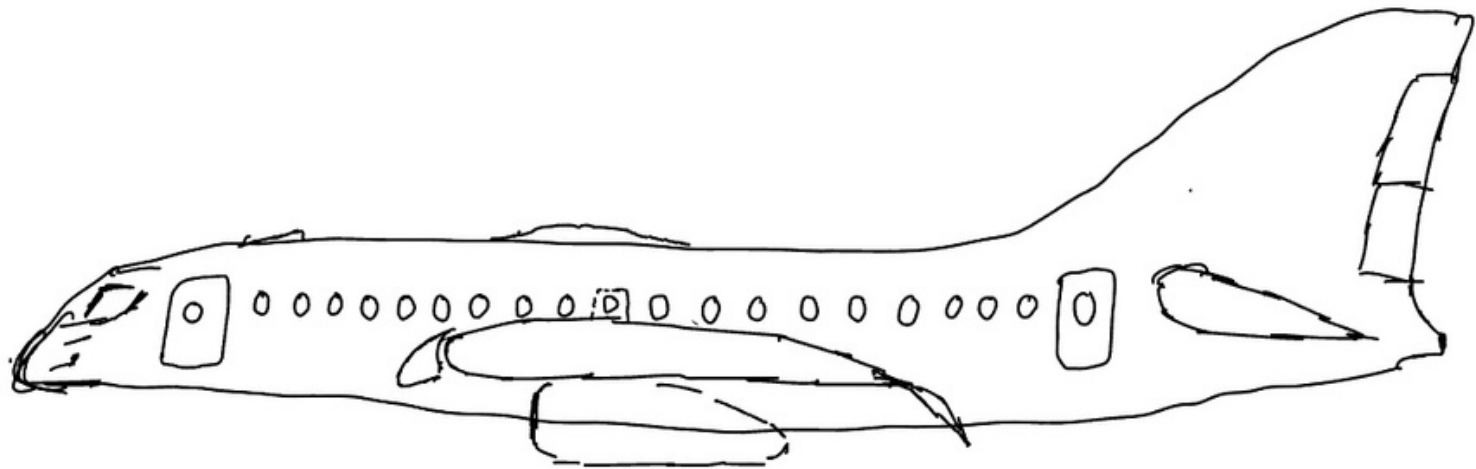


GTA V



FlightGear Flight
Simulator

Technical Features



Aerodynamics Equations

Climbing

Turning

Simulation Model

Aerodynamics equations

$$Lift(L) = \frac{1}{2}\rho V^2 SC_L \quad (1)$$

where:

ρ = Density of Fluid (kg/m^3)

V = Velocity of Body (m/s)

S = Wing Area (m^2)

C_L = Coefficient of Lift

$$Drag(D) = \frac{1}{2}\rho V^2 AC_D \quad (2)$$

where:

ρ = Density of Fluid (kg/m^3)

V = Velocity of Body (m/s)

A = Frontal Area (m^2)

C_D = Coefficient of Drag

$$Weight(W) = mg \quad (3)$$

where:

m = Mass of Body (kg)

g = Acceleration due to Gravity (m/s^2)

Free body Analysis

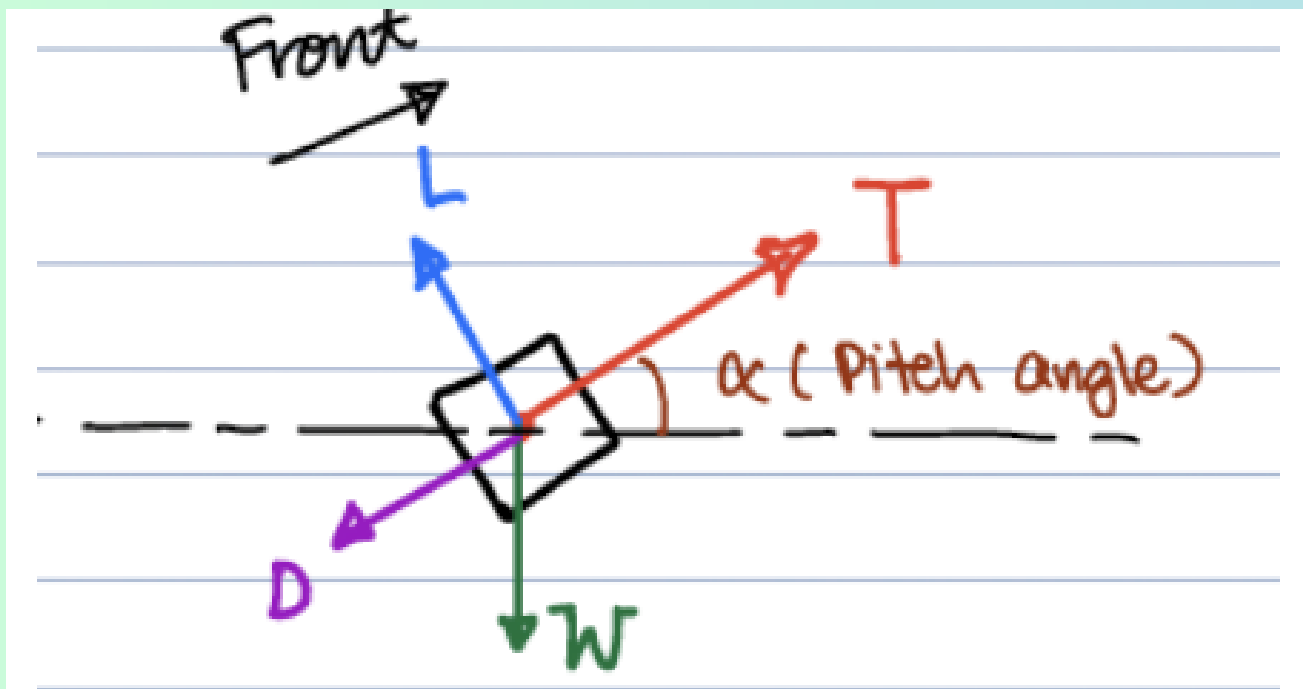


Figure 3: Free body diagram of a climbing body

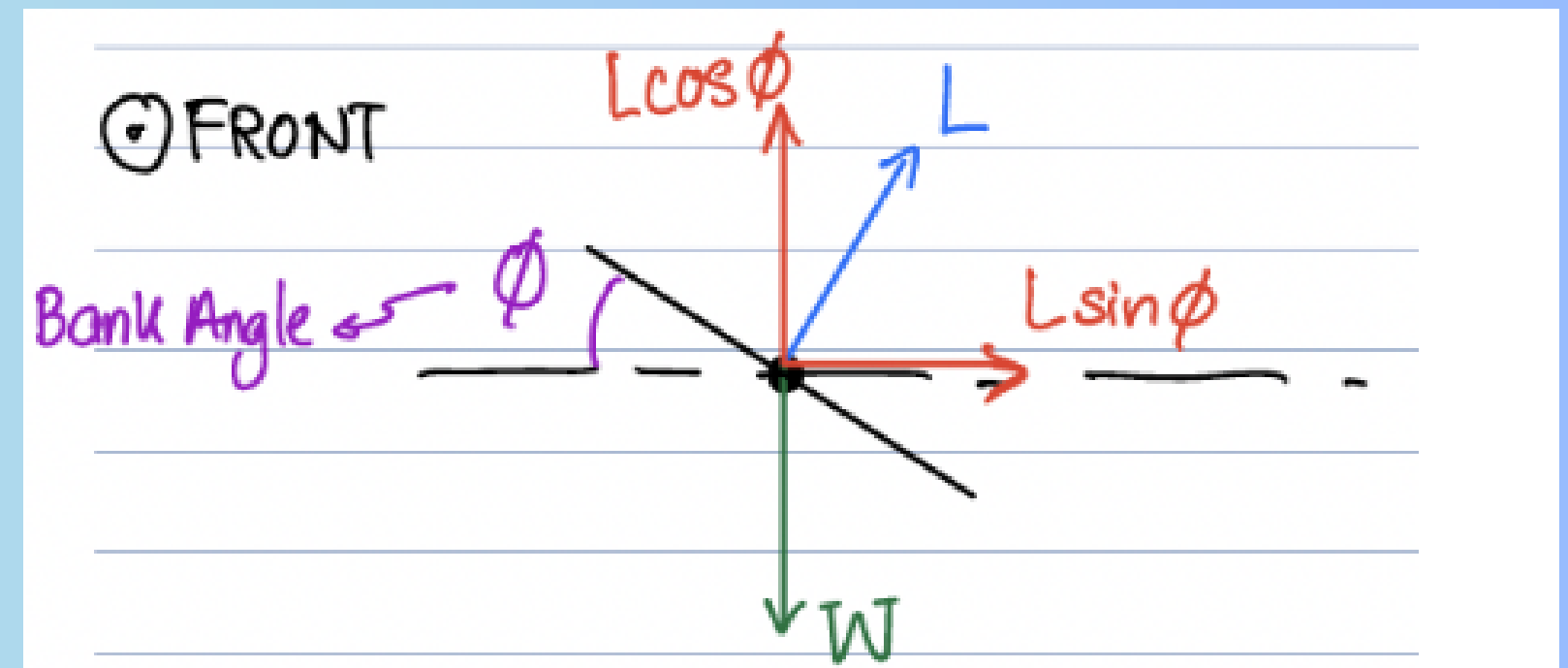


Figure 4: Free body diagram of a turning body



Free body Analysis

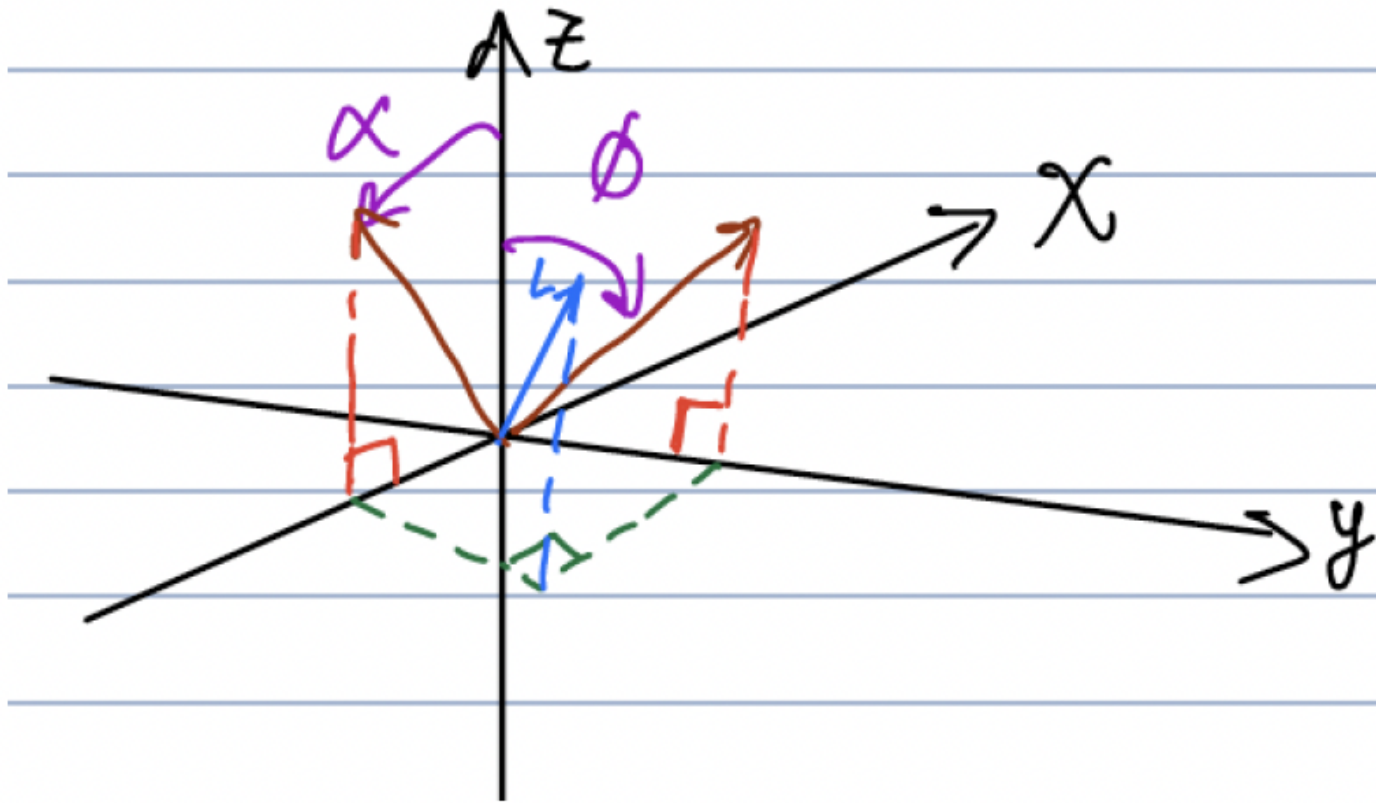


Figure 5: Resolution of lift force based on the pitch and bank angle

$$L_{pitch} = L \cos \alpha$$

$$L_{roll} = L \cos \phi$$

$$L_{vertical} = L \cos \alpha \cos \phi$$

$$L_{side} = L \cos \alpha \sin \phi$$

$$F_{forward \text{ due to pitch}} = -L \sin \phi$$

$$F_{vertical} = L \cos \alpha \cdot \cos \phi + T \sin \alpha - D \sin \alpha - W \quad (15)$$

$$F_{forward} = T \cos \alpha - L \sin \alpha - D \cos \alpha \quad (16)$$

$$F_{side} = L \cos \alpha \cdot \sin \phi \quad (17)$$

Assumptions

- Drag and lift coefficients are fixed
- Parasitic and Induced drag can be modelled by drag coefficient
- Density of fluid remains constant with altitude
- Yaw, pitch and roll forces are negligible
- Airflow is always from the front of the body and parallel to the horizontal
- Centre of gravity does not affect the moments of the body
- All forces act upon the centre of mass of the body.
- Yawing is not possible
- Wing area is kept constant relative to the relative wind

Relative Forces

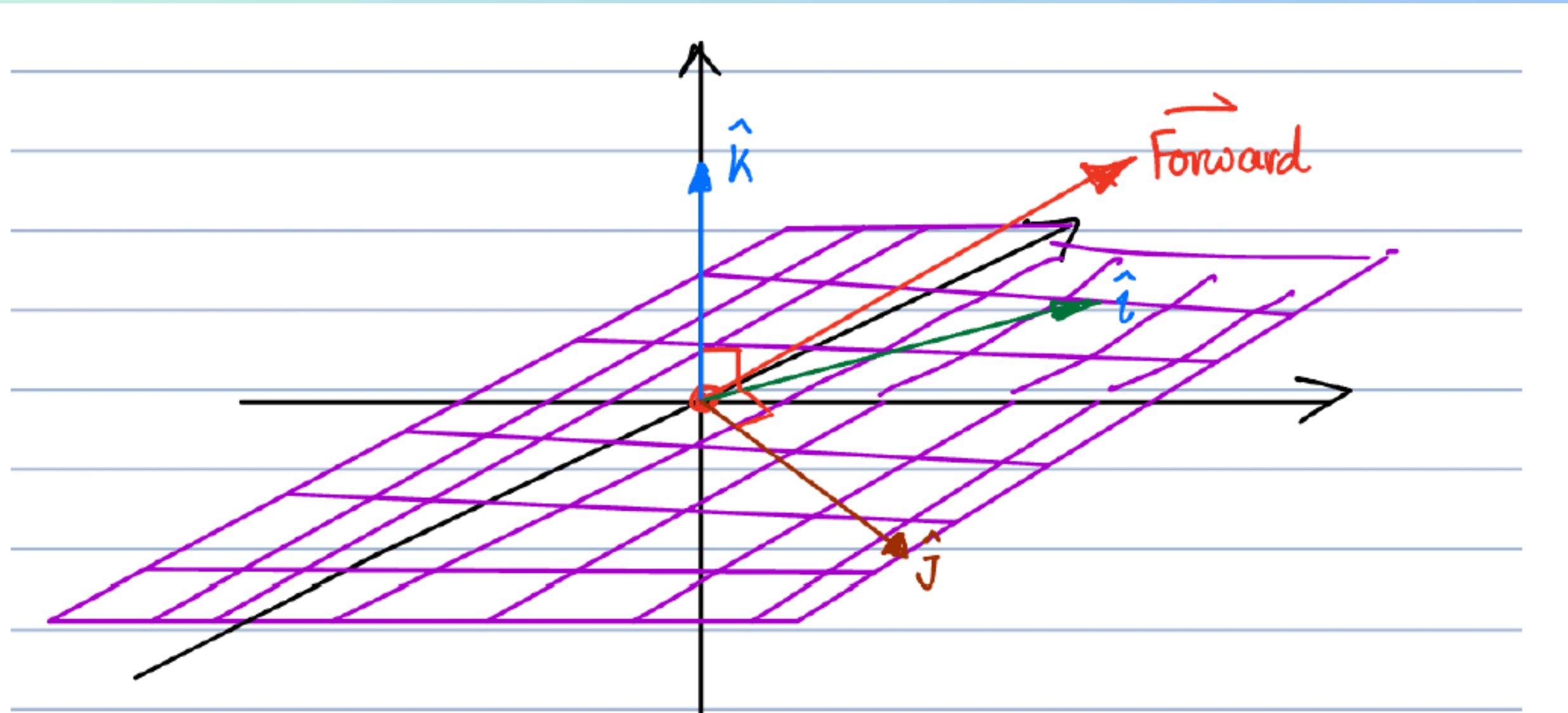
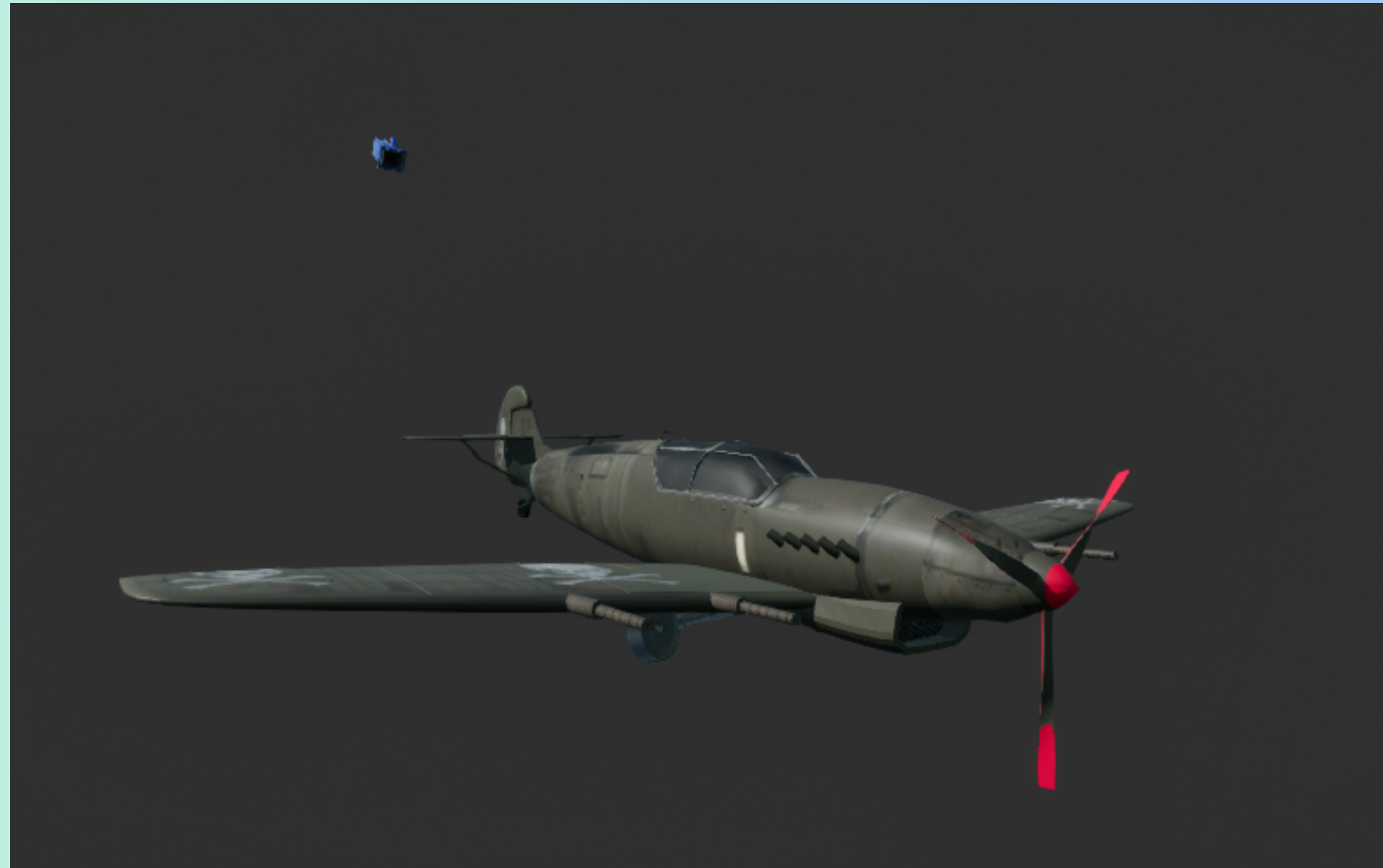


Figure 6: *Basis vector to apply forces*

Airplane model



<https://free3d.com/3d-model/world-war-2-aircraft-46520.html>

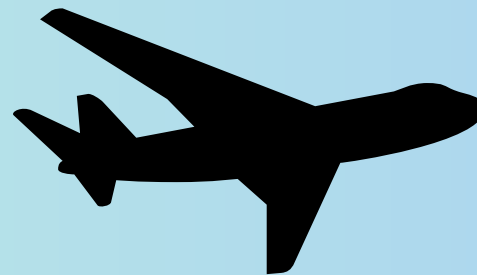
Inputs used in simulation



World Inputs:

Density

Gravitational Acceleration



Flyable Object Inputs:

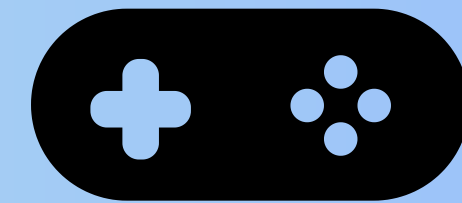
Mass

Wing Area

Coefficient of Lift

Coefficient of Drag

Frontal Area



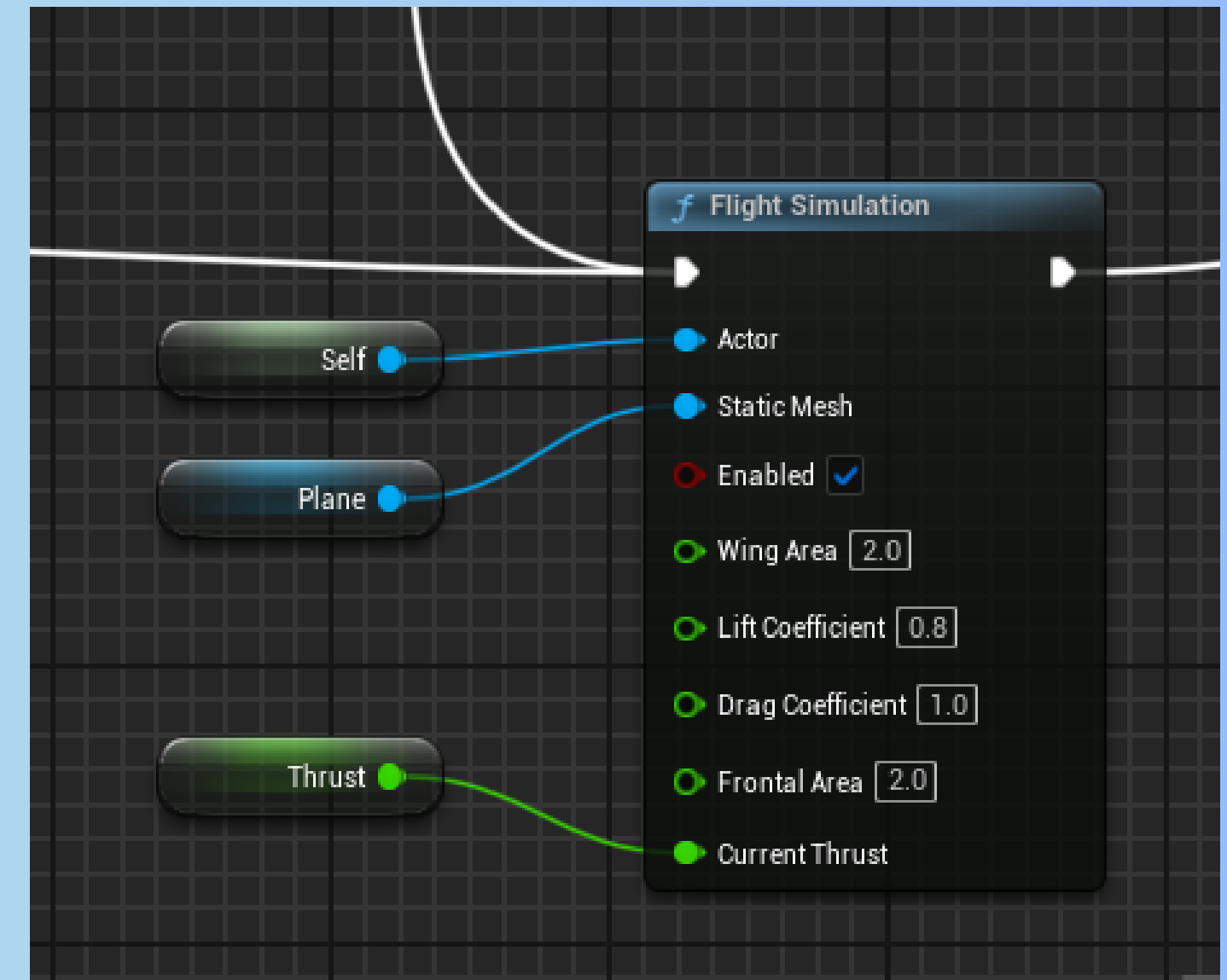
Player Inputs:

Thrust

Roll

Pitch

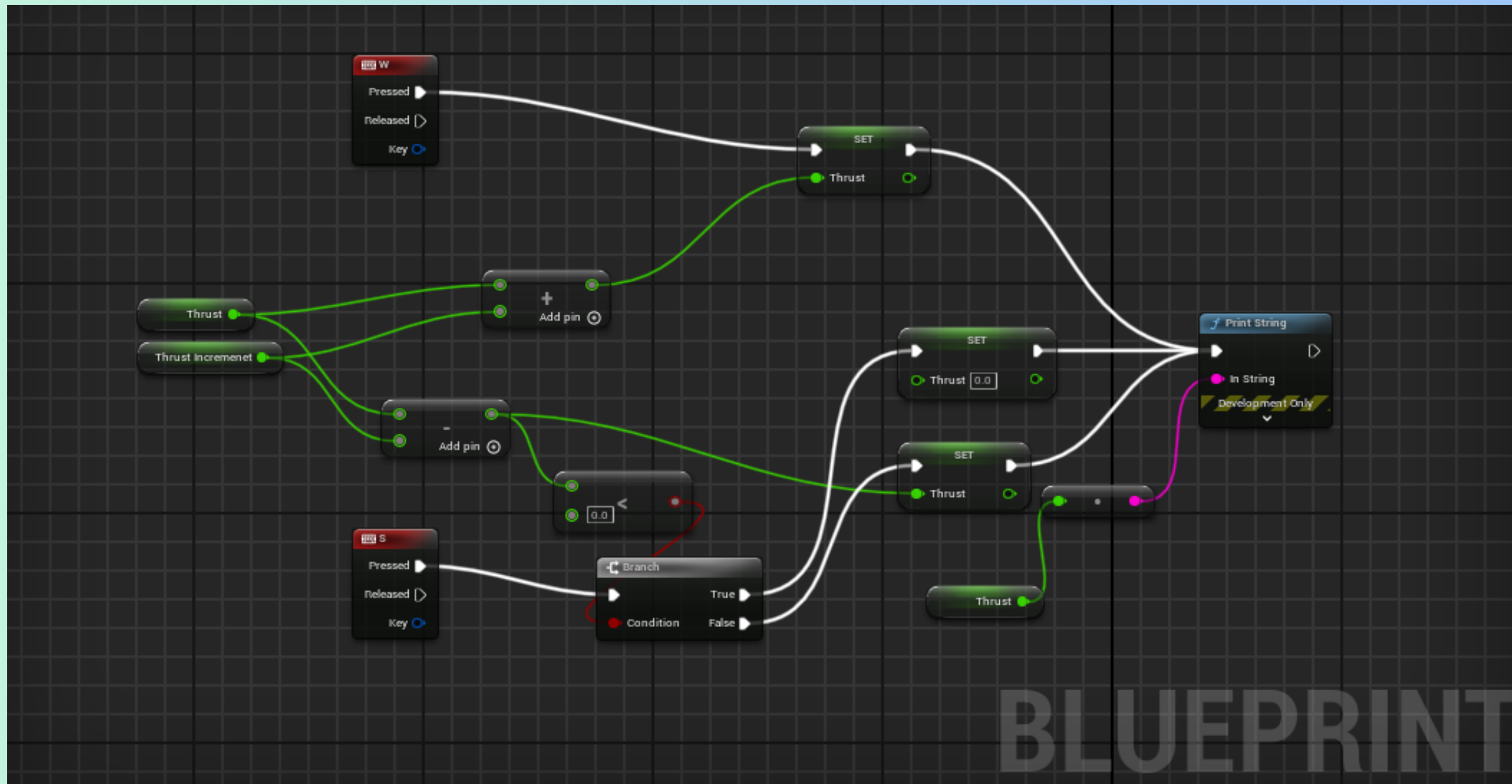
Flight Simulation function



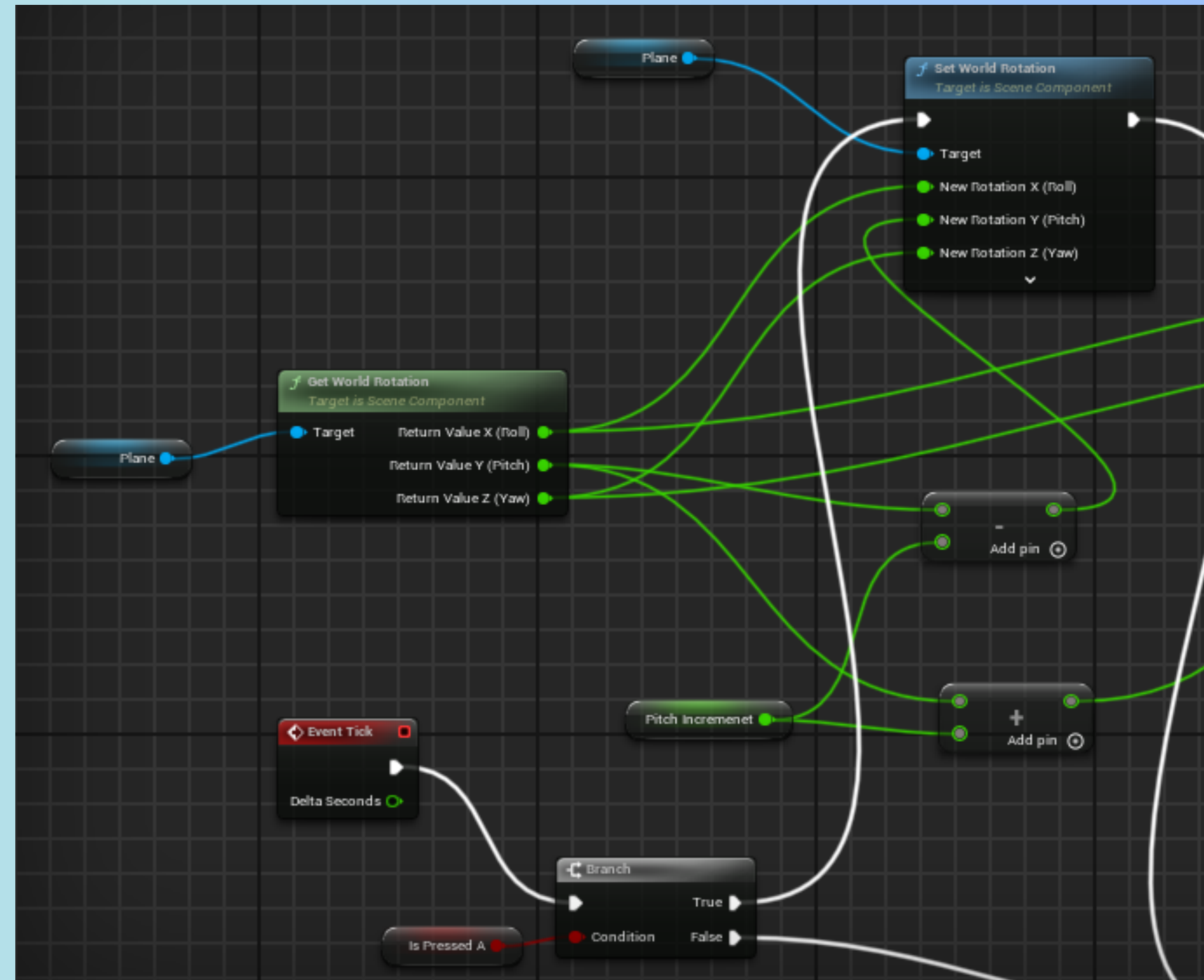
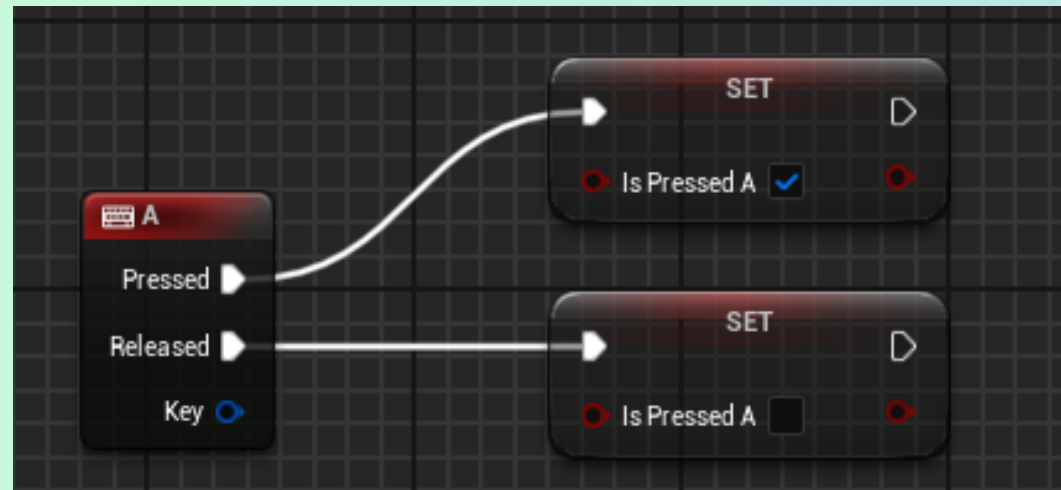
```
UCLASS(Blueprintable)
class UFlightSimPluginBPLibrary : public UBlueprintFunctionLibrary
{
    GENERATED_UCLASS_BODY()

    UFUNCTION(BlueprintCallable)
    static void FlightSimulation(AActor* actor, UStaticMeshComponent* StaticMesh, bool enabled,
                                float wingArea, float liftCoefficient, float dragCoefficient, float frontalArea, float CurrentThrust);
};
```

Blueprints - thrust



Blueprints - pitch/roll



Conclusion

