Flight Dynamics Simulation

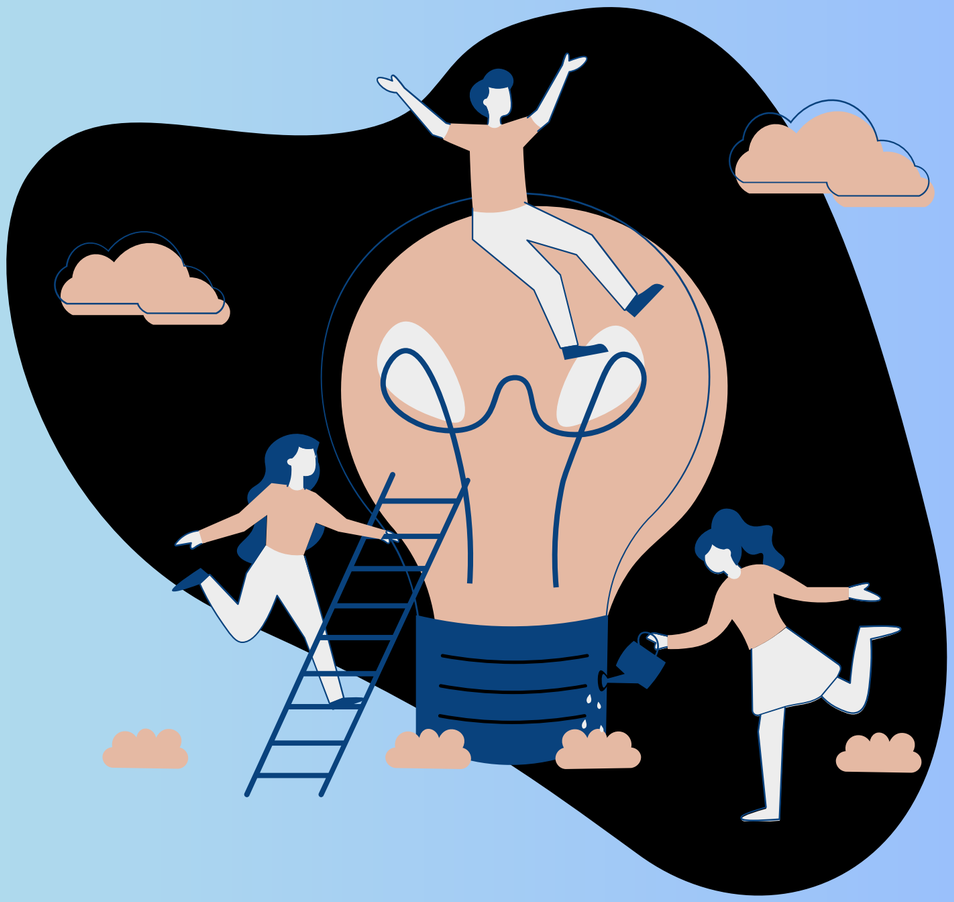
T-637-GEDE Final Project

Keith Kwok, Hong Jing Toh, Aleksander Folfas

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



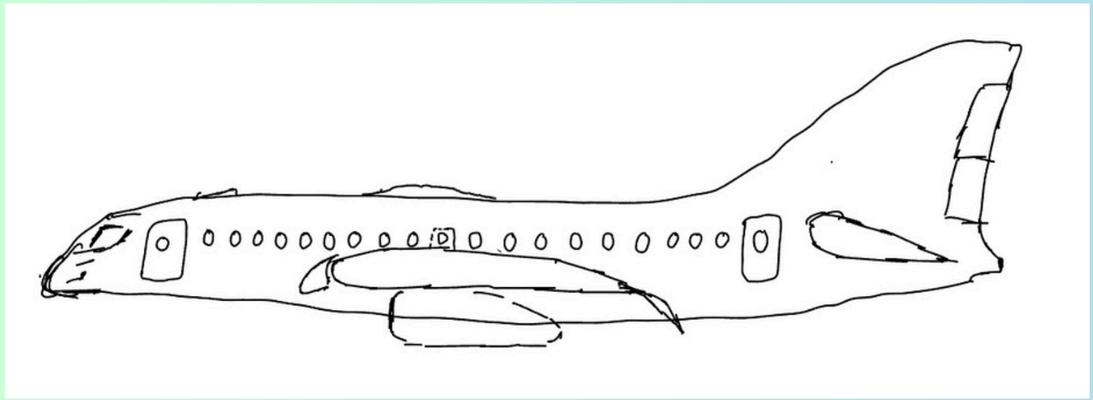
Related Work

Microsoft Flight Simulator

GTA V

FlightGear Flight Simulator

Technical Features



- Aerodynamics Equations
- Climbing
- Turning
- Simulation Model

Aerodynamics equations

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

where:

ρ = Density of Fluid (kg/m^3)
V = Velocity of Body (m/s)
S = Wing Area (m^2)
C_L = Coefficient of Lift

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

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

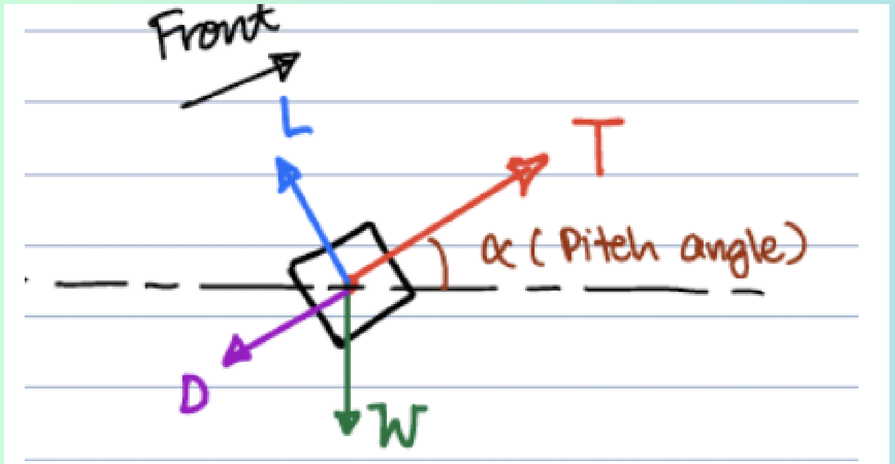


Figure 3: *Free body diagram of a climbing body*

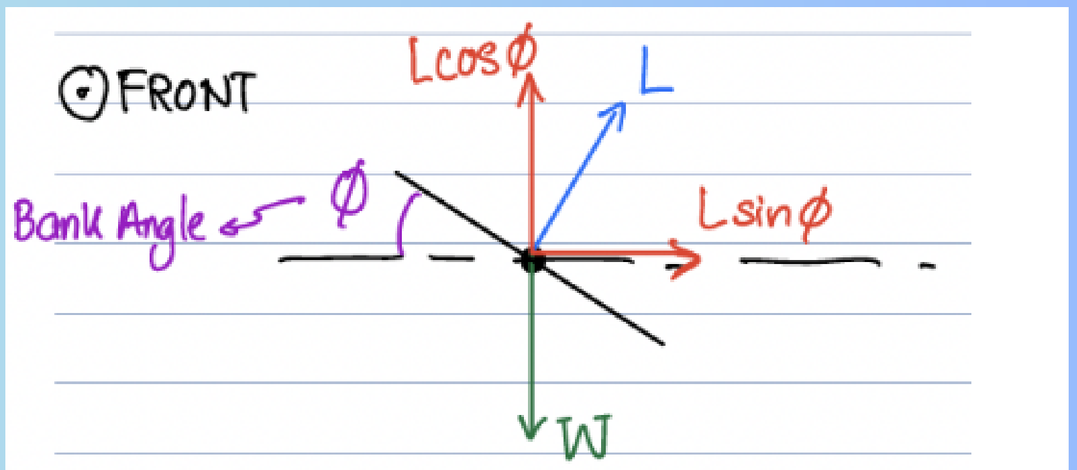


Figure 4: *Free body diagram of a turning body*

Free body Analysis

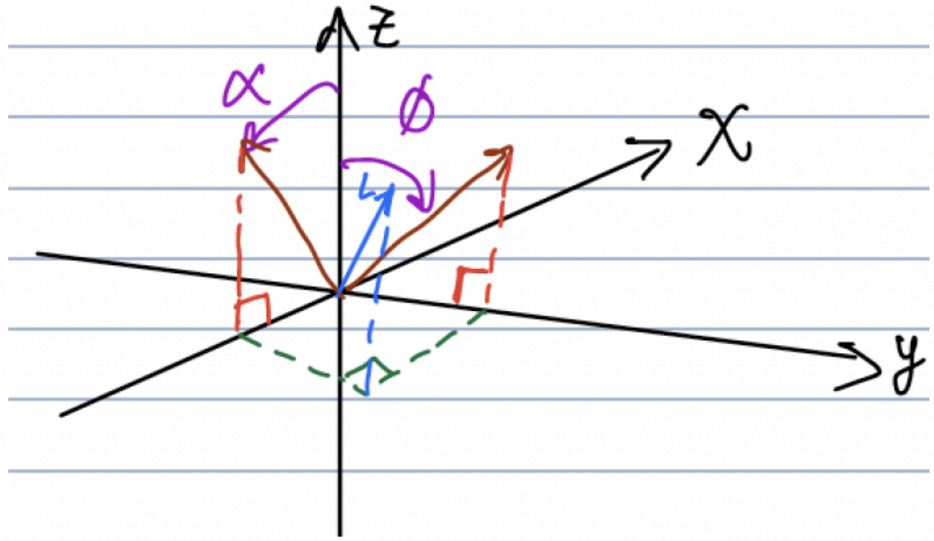


Figure 5: *Resolution of lift force based on the pitch and bank angle*

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

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

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

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

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

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

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

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

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

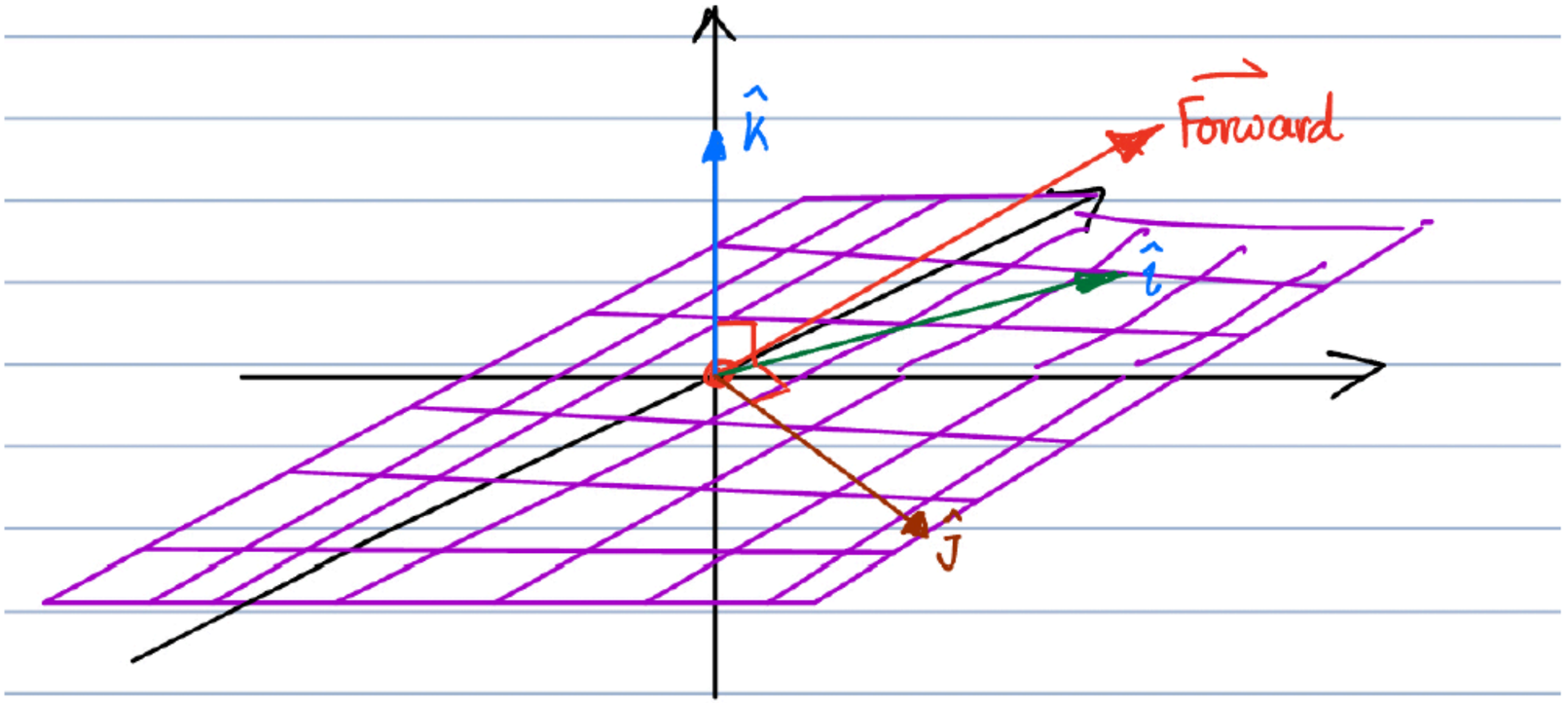
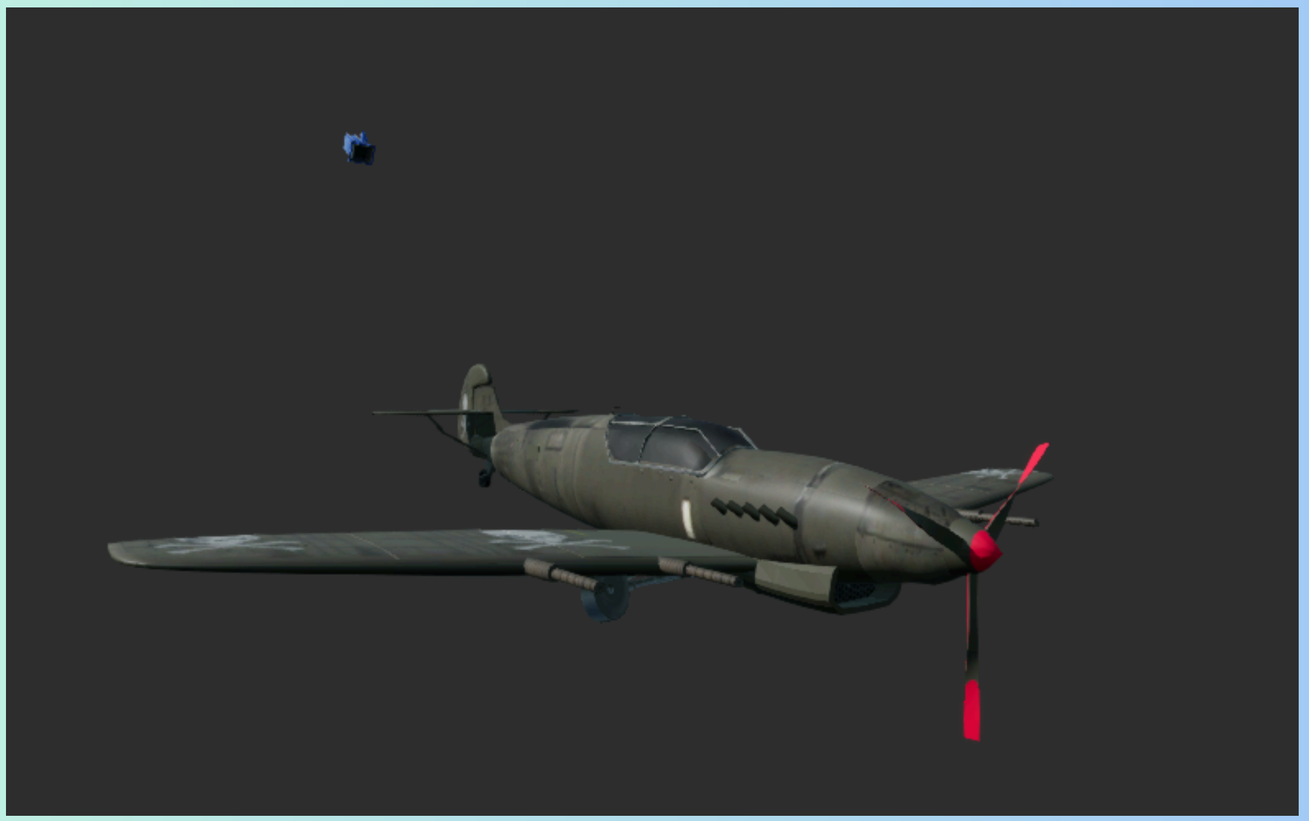


Figure 6: *Basis vector to apply forces*

Airplane model



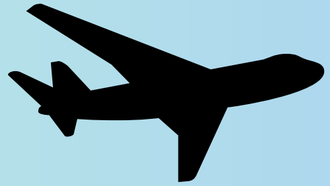
https://free3d.com/3d-model/world-war-2-aircraft-46520.html

Inputs used in simulation

World Inputs:

Density

Gravitational Acceleration



Flyable Object Inputs:

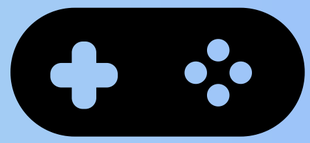
Mass

Wing Area

Coefficient of Lift

Coefficient of Drag

Frontal Area



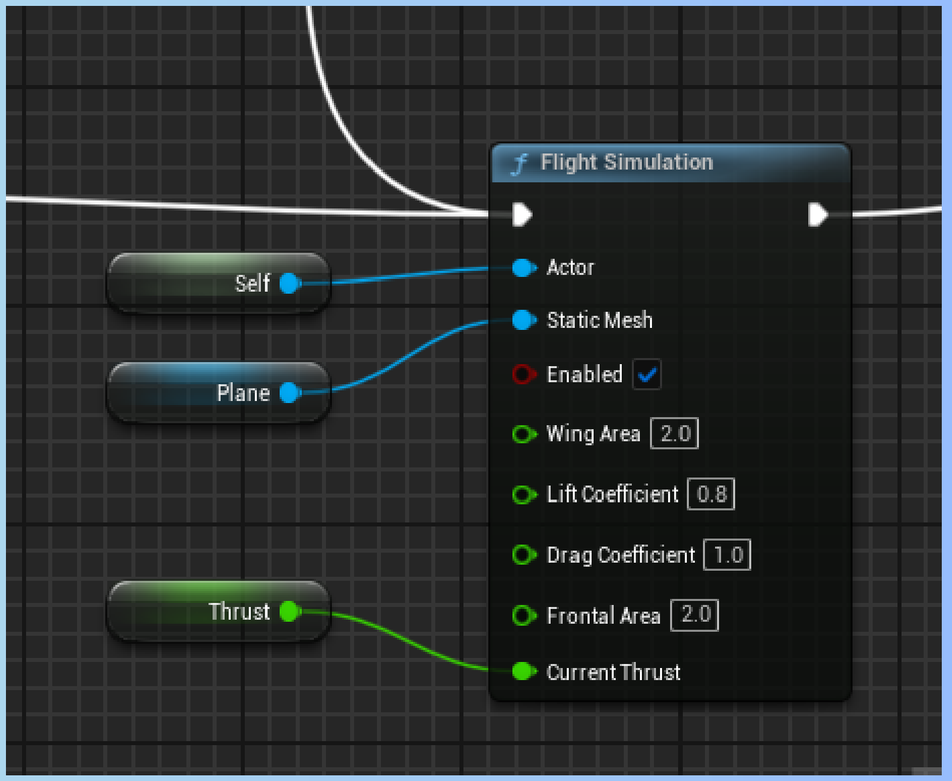
Player Inputs:

Thrust

Roll

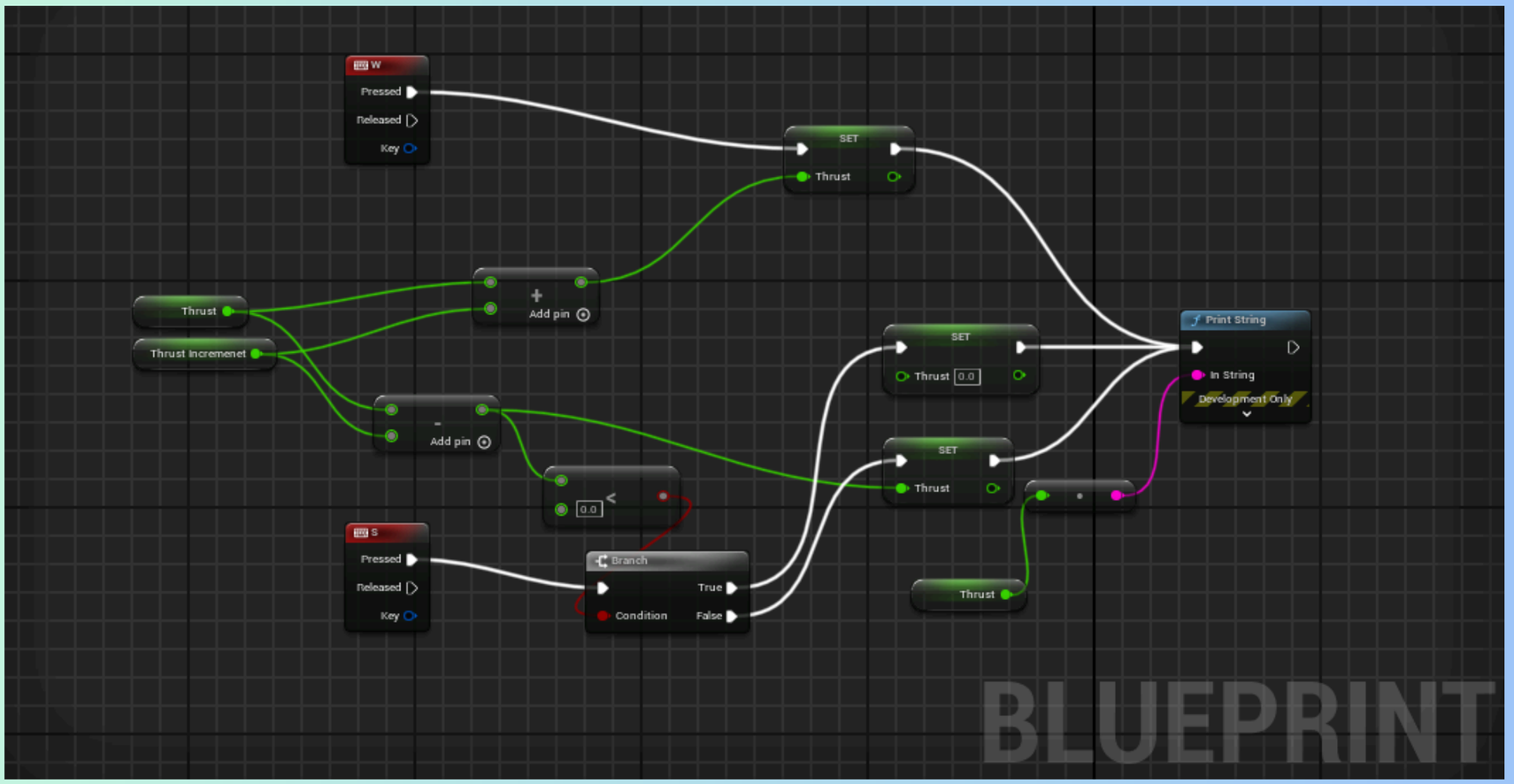
Pitch

Flight Simulation function

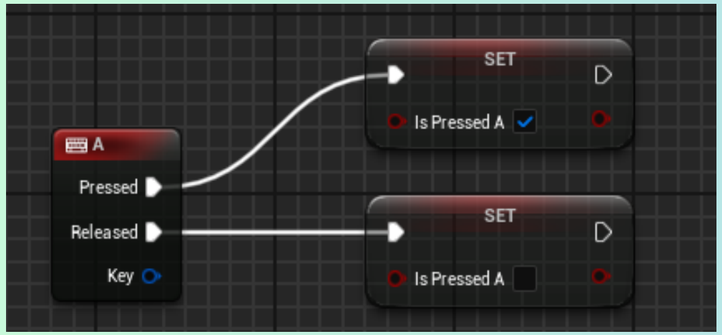


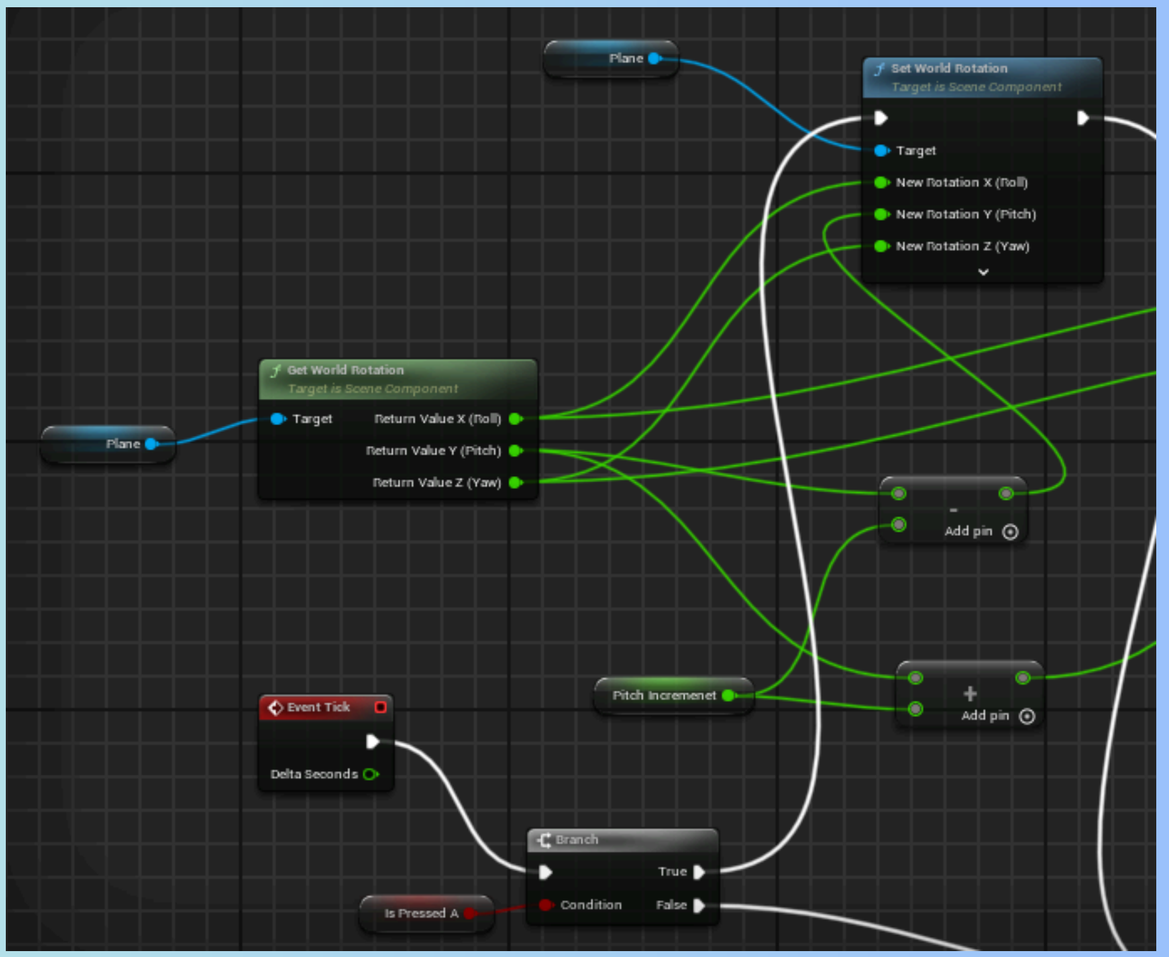

```
UCLASS(Blueprintable)
class UFlightSimPluginBPLibrary : public UBlueprintFunctionLibrary
{
    GENERATED_UCLASS_BODY()

    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