Design of Hardware in the Loop (HIL) Simulation for Small Unmanned Aerial Vehicles (sUAV)

Gregory Enriquez[1]

[1]Aerospace Engineering Department Embry-Riddle Aeronautical University

EMBRY-RIDDLE Aeronautical University DAYTONA BEACH, FLORIDA

Abstract

The purpose for this project is to design a HIL simulation architecture in validating sUAV flight operations and functionality with self-autonomous mission integration using a ground control station (GCS) software called Qgroundcontrol. The sUAV used for this project is a Qwinout quadcopter drone.

Introduction

HIL simulation is a method used for development and tests of complex real-time systems by implementing hardware of the systems into the simulation. HIL simulation is important in system design because HIL simulation helps to validate and optimize the hardware utilized in the system. By optimizing and validating the hardware used in the system, factors such as cost and system failure can be minimized. For the HIL simulation project, the outcomes for this project are as follows:

1. Present a methodology in the design of HIL Simulation for sUAV with a quadcopter configuration with self autonomous mission capability.
2. Validate the flight controller's functionality (output signals, input signals, performance) as prescribed by the manufacture's company.
3. Provide a simulation model with a simulated environment integrated to train individuals in flying sUAV with utmost reliability.

Materials

The materials for this project are:

1. Qwinout quadcopter drone
2. Pixhawk Pix4 Flight controller
3. Windows 10 Desktop
4. Qgroundcontrol
5. Matlab & OpenVsp
6. Radiolink AT9 Transmitter

Figure 1. (Left) Radiolink AT9 Transmitter (Right) Qwinout Drone

Methodology

The methodology in the design of HIL simulation for the Qwinout quadcopter drone will be organized into 3 phases: Flight Dynamic Model (FDM), HIL Simulation Design, and HIL implementation with GCS Integration.

Phase I: Flight Dynamic Model

FDM of the quadrotor sUAV must first be developed and conceptualized. The FDM of a given system consists of equations that mathematically dictates the kinetics and the stability values of the system based on classical flight dynamic principles.

OpenVSP was used to create a computational fluid dynamic (CFD) model to evaluate the aerodynamic properties of the drone. Both the CFD model and the FDM were then implemented in the Matlab Simulink block diagram. The Simulink block diagram will be used for direct implementation into the HIL simulation architecture.

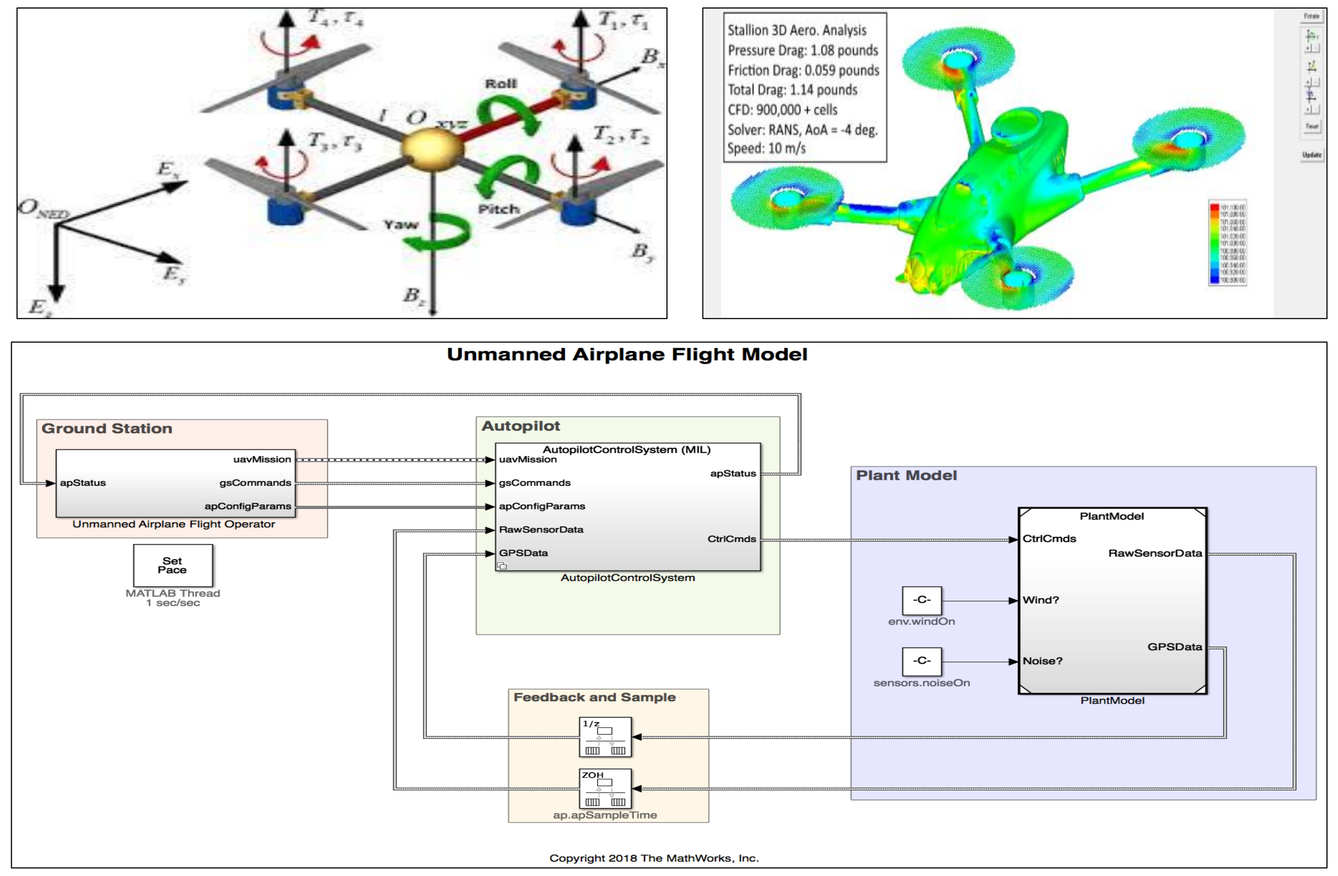

Figure 2. (Top leftmost) the general FDM of a quadrotor (Top Rightmost) CFD model of drone using OpenVSP (Bottom) Matlab Simulink Block diagram of the drone

Phase II: HIL Simulation Design

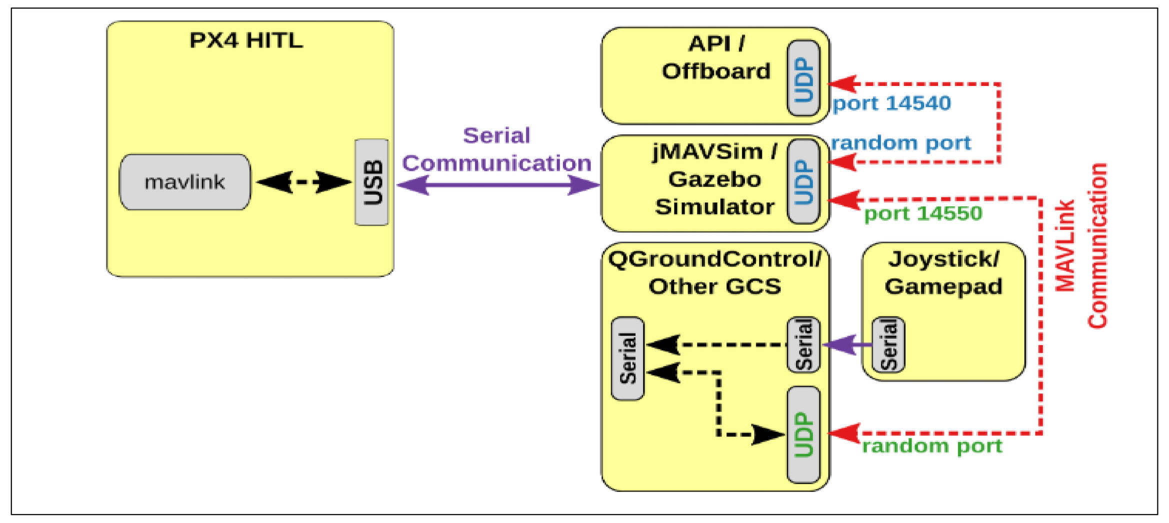

Figure 3. The general architecture of the HIL simulation design.

The architecture of the HIL simulation design was then established. The architecture consisted of the FDM from Matlab to be implemented onto the simulation structure. For the architecture to be fully made, all ports from the Matlab Simulink block diagram and the GCS must first be specified.

Phase III: HIL implementation with GCS Integration

For the final implementation, a model was created based on the actual geometry of the Qwinout drone for the Gazebo software. A separate desktop with windows 10 was used to run the HIL simulation which consisted of the Matlab Simulink Block diagram, Qgroundcontrol, and Gazebo.

Once all the software were ready to be executed, the flight controller was then directly implemented onto the simulation and the input device connected was the AT9 Transmitter. The model in the Gazebo then performed mission profiles predefined in the GCS and was then allowed to be manually controlled.

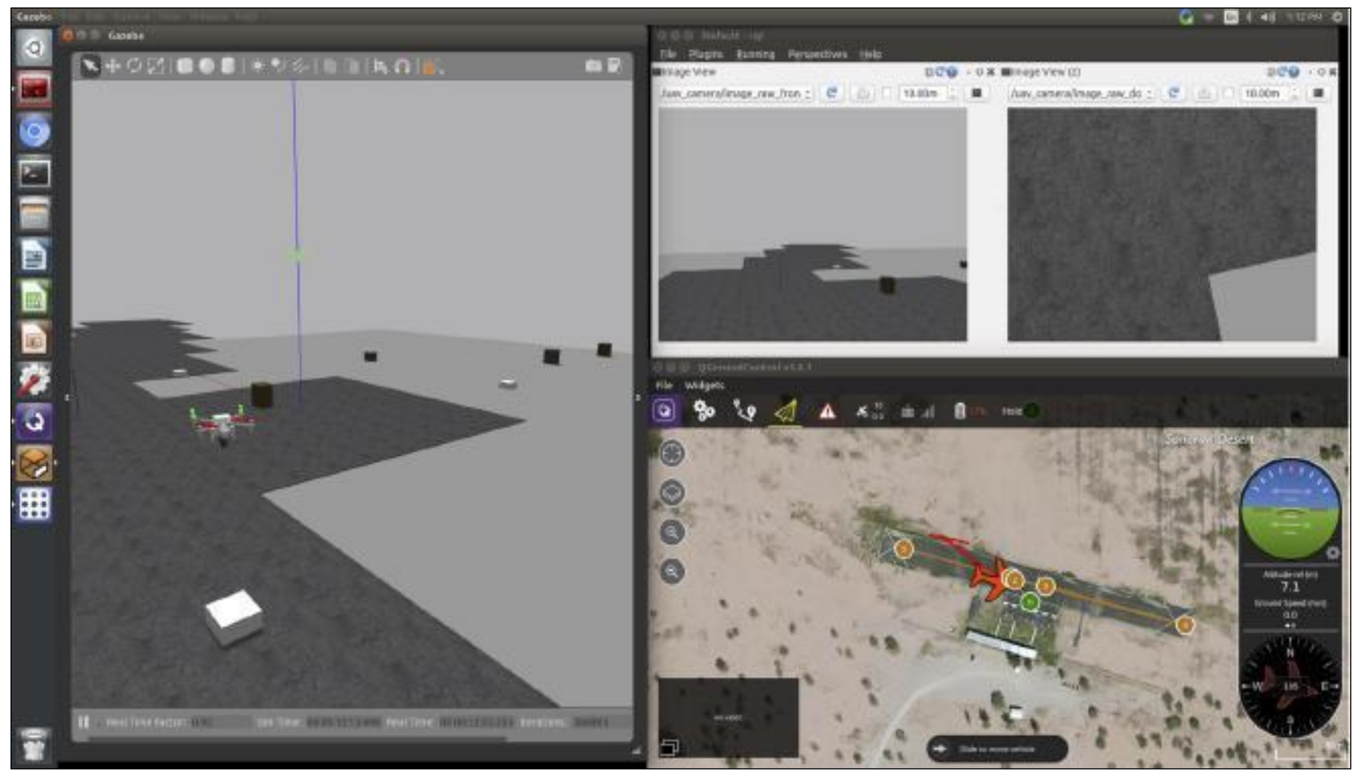

Figure 4. The User interface for the HIL simulation

Results

For the results, only phase I and II have been enacted. Phase III is currently in progress. For phase I, the stability values used for the stability model were calculated.

Cn Derivatives		CY Derivatives		Cl Derivatives	
C_{n0}	0	C_{Y0}	0	C_{l0}	0
$C_{n\beta}$	0.43	$C_{Y\beta}$	-0.49	$C_{l\beta}$	-1.26
C_{np}	-0.18	C_{Yp}	-0.068	C_{lp}	-0.95
C_{nr}	-0.015	C_{Yr}	0.33	C_{lr}	0.24

For Phase II, the model for Gazebo was created in order to be used for the 3D environment for the HIL simulation.

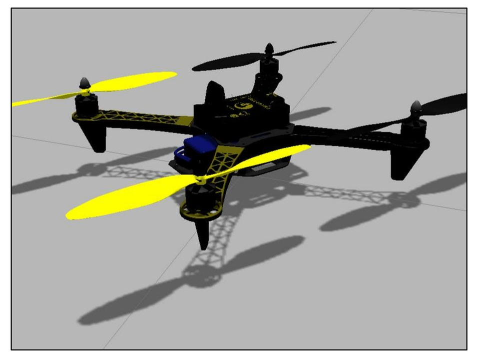

Figure 5. Gazebo Model of the Qwinout drone.

Conclusion

Phase I and Phase II have been completed. The FDM and the Aerodynamic model of the drone agreed well with the measurements obtained from the real flight testing of the drone. AS a result, the calculated models are acceptable to use for phase III: the HIL implementation with GCS integration.

Figure 6. Qwinout Drone during flight test..