# TigreSAT 2010 &2011
# June Monthly Report

## 2010-2011 TigreSAT Monthly Progress Report

### EQUIS ADS 2010 PAYLOAD

No changes have been done to the payload since it had passed all the tests, requirements and integration that are necessary for LSU HASP platform. The device to obtain the calibration equations is complete as shown in **Figure 1**. Calibration of the Magnetometer (at LSU) and Gyroscope were completed; this would leave us with calibration for the accelerometer (which should be done by next week). Note that no changes will be done to the payload's software, structure and electronics; this is just to obtain the equations to prepare for the science report.

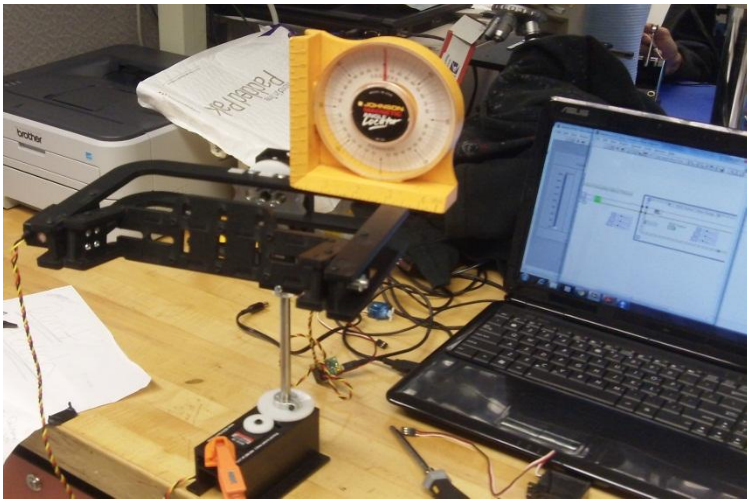

**Figure 1:** Calibration Device

### Gyroscope Calibration

To perform the calibration for the gyroscope it is needed to put the sensor in a constant angular velocity. Having the time and the angular velocity, will allow the data to be plotted as shown in **Figure 2**, which permit the determination of the offset calculation for the real data. Lab-View was used for the calibration routine on the calibration device. One pass from each axis of the data we gathered is on the charts below (it is on raw data versus time). This data was gathered in a constant velocity routine and in a loop of 900 degree per pass.

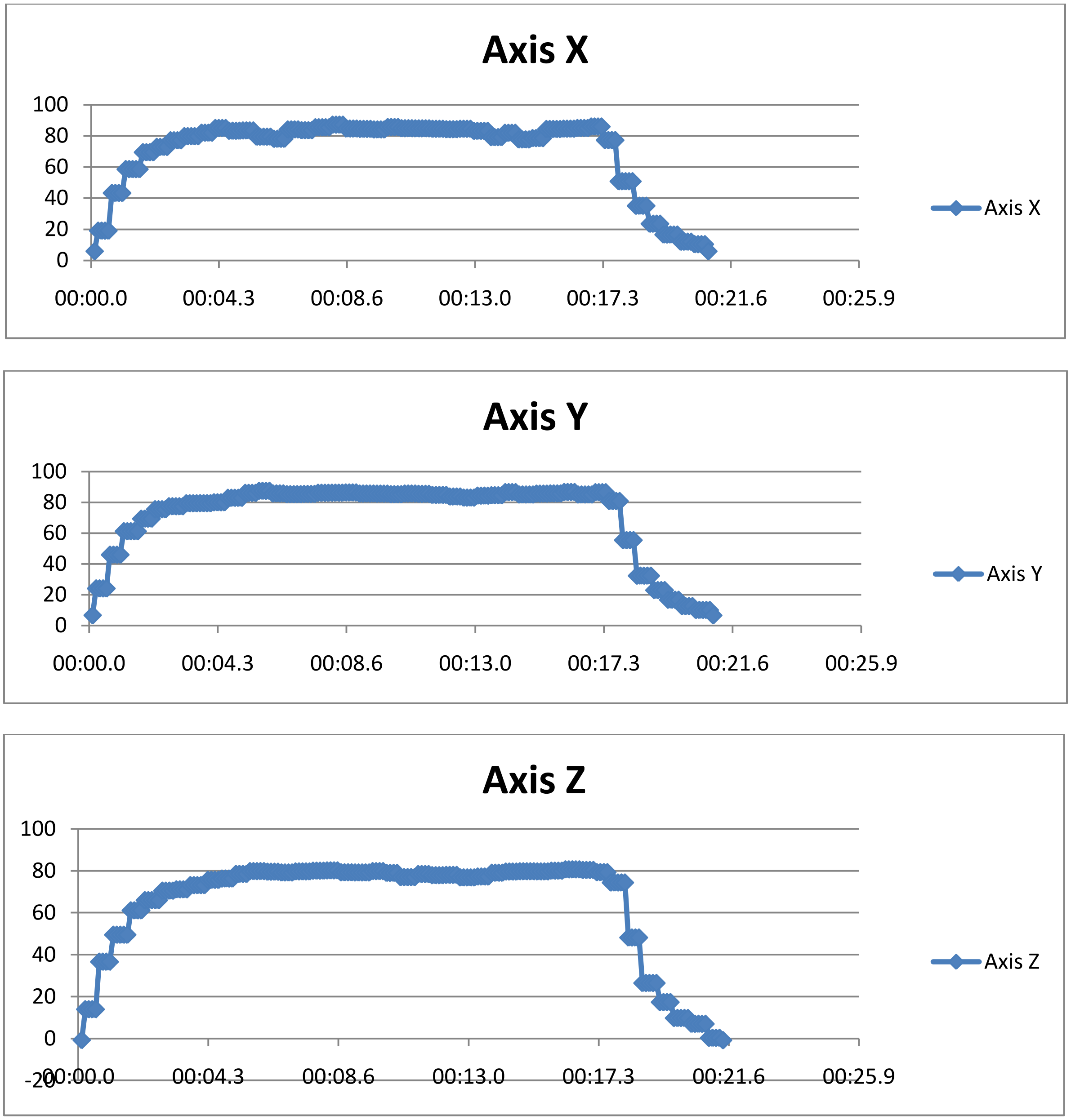


**Figure 2:** Data plots for X, Y, and Z for constant angular velocity

**Figure 3** shows what was done to complete the calibration process; this was done for each axis four times to ensure consistency.

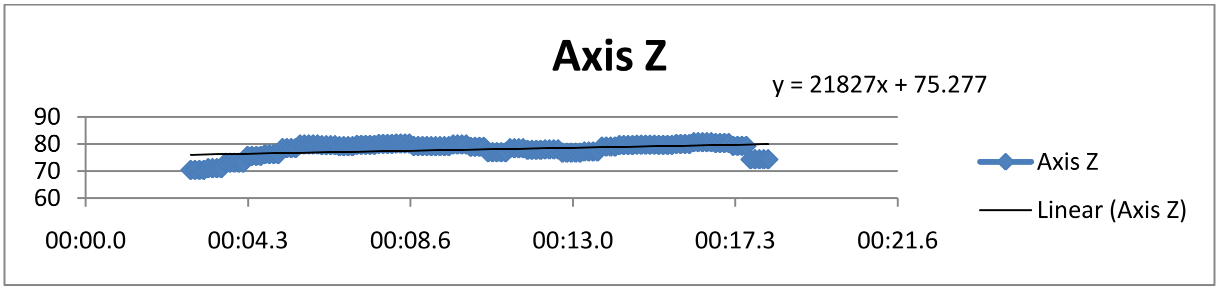


**Figure 3:** Calibration data and equation

The extraction of data from the Figure 2 is necessary to obtain the data where the angular velocity is fairly constant; this is demonstrated on the Z Axis as shown in **Figure 3.** In this figure, the vertical axis is counts and on the horizontal axis is the time in seconds (s). The linear fit equation obtained was:

$$Y= 21827x +75.27$$

This process is then going to be validated to ensure that the process was done correctly.

## TigreSAT 2011 PAYLOAD

During the month of June the TigreSAT project has worked on structure improvements thus reducing vibrations. The design of the Intermediate Success Criteria (ISC) is complete.

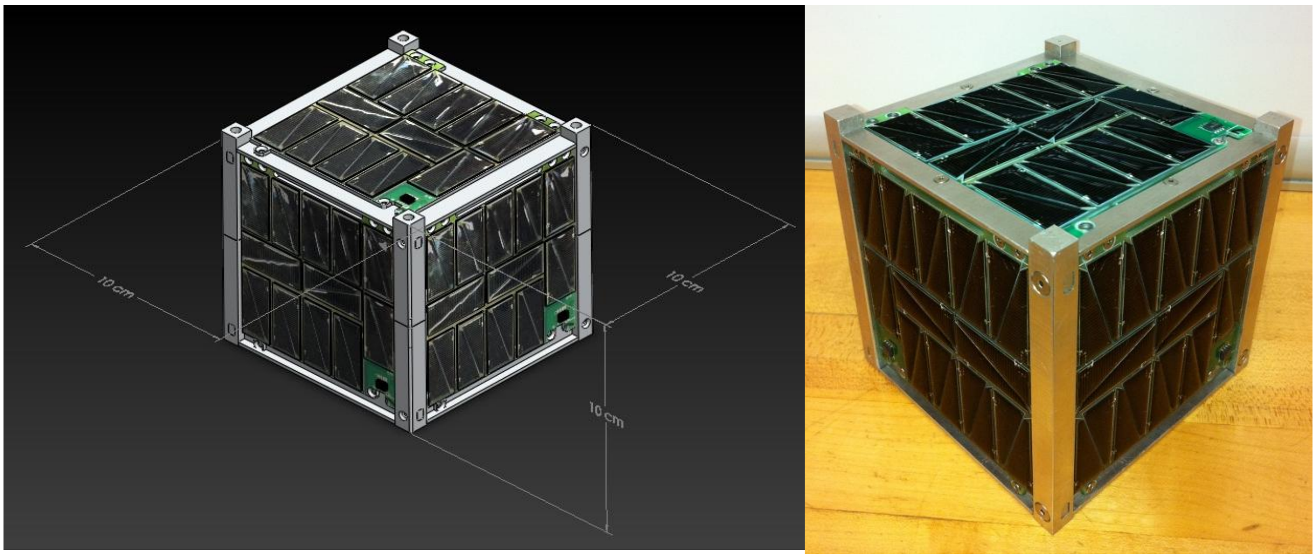


**Figure 4a(Left) and 4b(right):** Cad Drawing and Photo of the Cube

The photos of the cube with solar panels is taken only once and removed, due to their sensitivity as shown in **Figure 4a and 4b**. This is the completion of the option Intermediate Success Criteria (ISC) with the ADS with the atmega microcontroller of Minimum Success Criteria (MSC). The project consists of three mayor components: mechanical, electrical and software, which are explained below.

### Mechanical

When verifying how the structure was mounted last month we notice that there were some vibrations and it was necessary to perform some changes to the mounting structure of the TigreSAT that was mounted to the HASP mounting plate as shown in **Figure 5**. The payload has measured weight of 640.8g for the cube plus 195g for the new additional mounting bracket leaving the complete TigreSAT payload with a weight of 1302g with the HASP mounting plate. Vector analysis was performed and construction of the structure was done with Aluminum 6061-T6 material due to its low density and high strength resistant required to support 5g and 10g horizontally and vertically, respectively; thus satisfying the weight and force requirements for HASP.

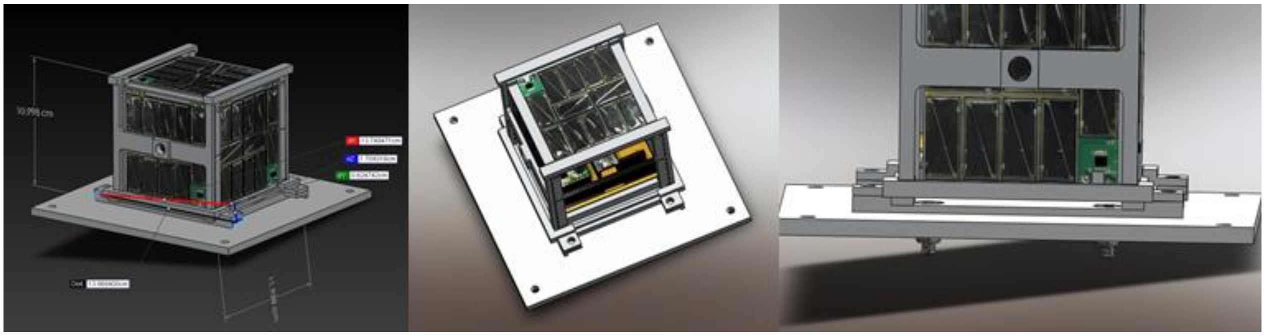

**Figure 5: Cube, Cage and Mounting Bracket with the HASP plate**

**Electrical**

Testing is an ongoing task to ensure that failure will not occur during the flight. Calibration of the ADS board has not been performed and shall begin immediately after testing has been completed. Currently, 70% of the board has been tested, and data has been received from the mayor sensors (accelerometer, gyroscope, magnetometer, and GPS).

Solar panel board needs additional testing and needs to be improved. Note this board will be isolated from the HASP power connections.

TigreSAT team will be testing a temperature sensor with a Gumstix. These boards are ready and are being used to test possible technology for the CubeSAT project.

## Software

Software for the ADS, temperature sensor, and Gumstix are done. Improvements on the code for the Solar panel need to be performed. No changes have been done to the code since completion of the PSIP.

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## Faculty and TigreSAT personnel

| ARIES HASP Students and Tasks | |
|---|---|
| **Students** | **Tasks** |
| Javier Espinosa | Leader, Electrical |
| Abdiani Rivera | Mechanical |
| Ana Espinal | Electrical |
| Jose Almonte | Sun Sensor |
| Joksan Flores | Solar Panel Characterization |
| Jose Fermin | Solar Panel |
| Juan Rosado | SDT, Gumstix |
| Jose G. Almonte | SDT |
| Mairim Nieves | ACS |
| Jorge Quinones | ACS,Calibration |
| Abel Torres | Calibration |
| Hugo Pastrana | Gumstix |
| Alexander Santiago | Mechanical |

| Faculty | |
|---|---|
| Dr. Hien Vo | P.I. |
| Otoniel Diaz | Prof. |
| Diego Aponte | Prof. |
| Dr. Andrés Díaz | Prof. |

**Table 1 Students and Faculty Member for TigreSAT**

**Maximum Success Criteria** (MSC)

TigreSAT project has the available resources to finish the final details to complete the Maximum Success Criteria (MSC) before July 31, 2011. The team is working really hard to complete this. If the MSC is completed, tested, and meets all the TigreSAT and HASP requirements and documentation. We would like to fly the MSC option mentioned in previous monthly report, only if the HASP personnel approve this change. The difference between the ISC and MSC is that it will be able to perform controls with the data obtained from the 1U cube and to allow simulation of the motion of pitch and yaw. The mechanical design has been completed and the implementation is as shown in the **Figure 6.** The mechanical structure with motors, slip ring, gears, belts, and vector analysis have been all put together and is 80% complete and also meet the weight requirement with a measured weight of 2780g. Thermal simulation has been performed and completed using the same insulation material (Kapton). To complete the MSC we need to adjust the gears and belt, and finish the control aspect. Also, the team needs to complete minimal aspect of the software. The software will take the data from the ADS (which is complete) and performed several calculation and send the signal for the movements, this will be added to the ADCS code. SCH and PCB for the ADCS electrical design is almost complete and soldering will be done in a week after manufacturing the SCH/PCB design. This Attitude determination and control system board will be in the bottom box of the structure.

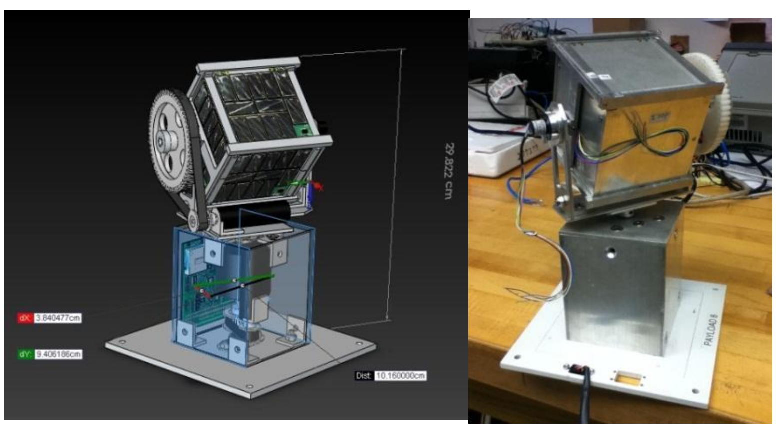

**Figure 6:** Maximum Success Criteria Mechanical Structure

**MSC description:**

This configuration consists mainly of two subsystems. The first subsystem is made for providing the pitch motion to the CubeSat. It is composed of a shaft running in two open ball bearings, a large timing belt pulley, and the structural cage that allows placing and removing the CubeSat. A DC motor provides the required rotational motion and a small slip ring allows the current through the moving CubeSat and the stationary box. The second subsystem involves the mechanism for the yaw motion. It is made of a shaft running in two sealed bearings, two timing belt pulleys that are moved by a DC motor, and a through bore slip ring. To support this mechanism and to protect both the electronics and mechanics components from low ambient temperatures, an enclosure aluminum box is used on the HASP plate. To protect these components from cold, the two subsystems are insulated with custom cover, Kapton layers, and resistive heaters. The total mass is 2.7 kg, mass will be reduce by decreasing the thickness of the walls of the bottom box, and the 1U cube will maintain the same mass as in the ISC.

## Attitude Control System (ACS)

The ACS has been in obtaining the calibrated data and converting it to real values and using Kalman filtering methods and developing the Transfer Function to perform all the necessary actions. **Figure 7** is one of the flow chart for the control. Several sections of this flow have greater flowcharts individually.

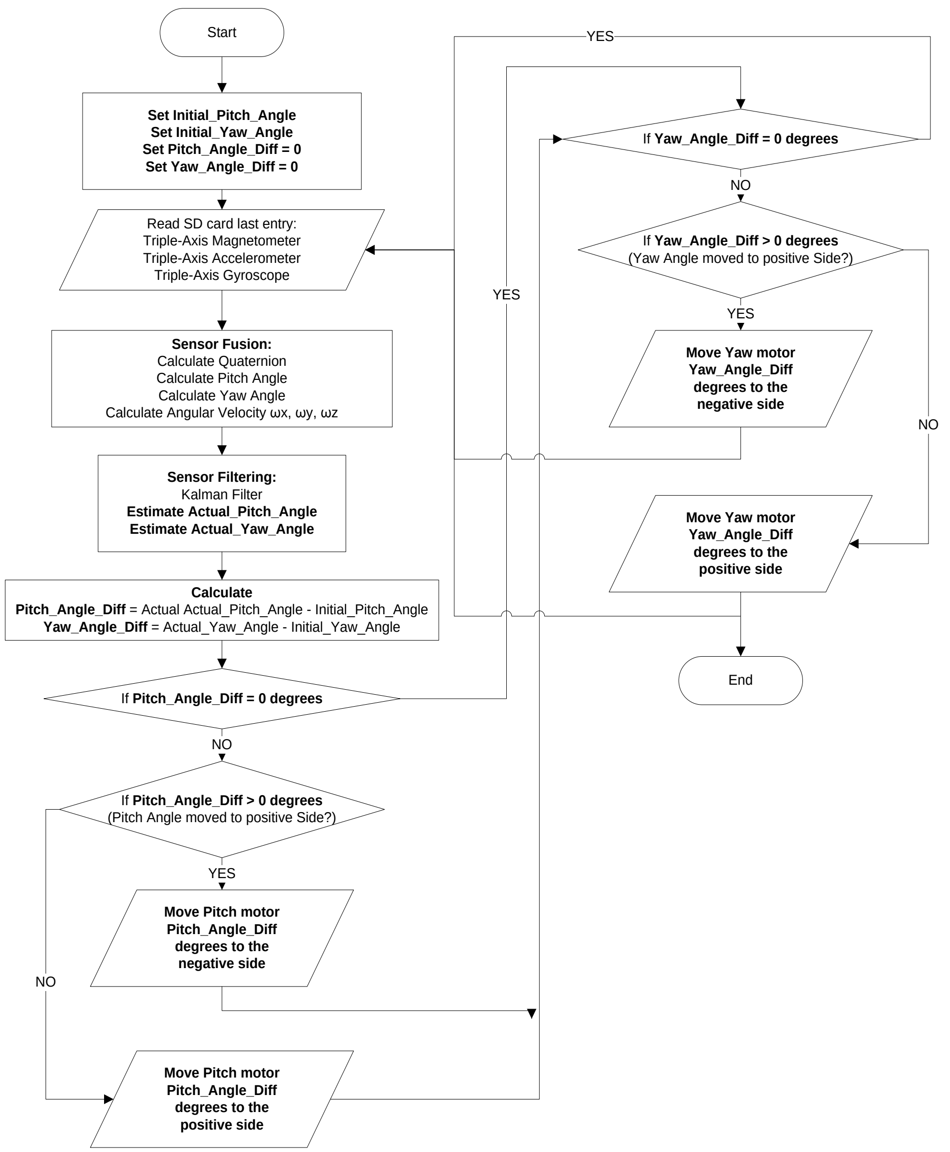


**Figure 7:** ACS Flow chart

Attitude Control System (ACS) will take charge of receiving the data from the Attitude Determination System (ADS) which consists of triple-axis gyroscope, triple-axis accelerometer, and triple-axis magnetometer to obtain and control the orientation and position of the CubeSat prototype through dc motors and encoders in two dimensions.

To obtain the orientation of the payload, the angular velocity, magnetic field, and acceleration parameters were transformed to quaternions and filtered using Complementary and/or Kalman filtering. To represent the orientation the quaternion convention was used:

$$\vec{q} = \mathrm{w} + \mathrm{x}i + \mathrm{y}k + \mathrm{z}j,$$

Kalman filtering is basically a set of mathematical equations that is implemented to the system to allow prediction and correction. Using this type of system, the measurement values can be estimated. This type of filtering has a high accuracy since the output values take in consideration the noise that is generated by the complete system and also the noise that is inherent with the measured data. To demonstrate that the Kalman Filtering process is performing as expected, a quaternion's simulation was made before and after filtering. The first algorithm was created using random input numbers and produced the following outputs as shown in **Figure 8**:

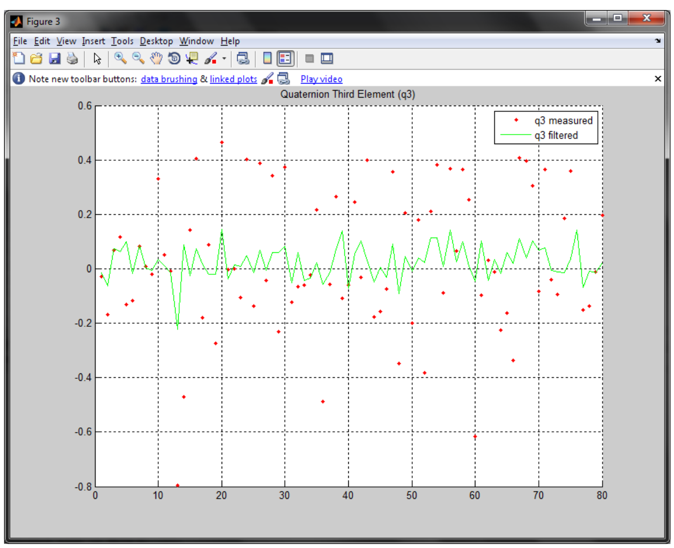


**Figure 8:** Quaternion output data vs. Filtered data through Kalman filter

**Control System**

This section describe the electrical and dynamic differential equations in order to obtain a clear and accurate transfer function G(s) that may allow the ACS team to design, simulate, and tune several control options in order to meet the required constraints and specific needs for the HASP.

The selected Maxon motors for the HASP platform have an input voltage limitation of +/- 15 volts. Therefore, is necessary to limit the voltage output using a saturation limit on the output of the designed controller.

For the MSC Pitch plant transfer function G(s) we get:

$$G(s) = \frac{\theta(s)}{V_m(s)} = \frac{K_{eq}}{s[J_{eqs}+B_{eq}]} = \frac{0.1587}{0.02668\, s^2 + 1.092\, s}$$

For the Yaw plant the transfer function G(s) is:

$$G(s) = \frac{\theta(s)}{V_m(s)} = \frac{K_{eq}}{s[J_{eqs}+B_{eq}]} = \frac{0.1533}{0.02712\, s^2 + 1.02\, s}$$

This system is evidently controllable with no steady-state error due to one of its poles located in the origin of the frequency domain. The system was simulated for a set of desired angle commands in order to have a better idea of the response behavior. The design of the two controllers Pitch and Yaw were built in Matlab and Simulink using the control toolbox. The team implemented a PID controller to ensure the stability of the system. The system has the limitation that the control action voltage applied to the motor needs to be adequately saturated so that it does not surpass its [-15 15]V limits.

It is been proven through simulation that the PID controller meet the requirement of the motor control voltage as shown in the figure below.

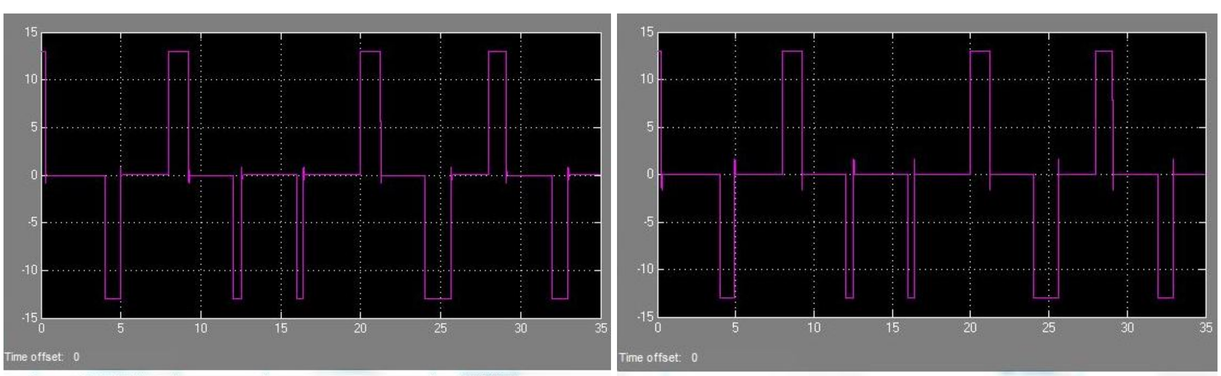


**Figure 9**: Pitch and Yaw PID motor control voltage

In **Figure 10** is a Simulink simulation of the Proportional Integrative Derivative (PID) controller for the Pitch transfer function G(s).

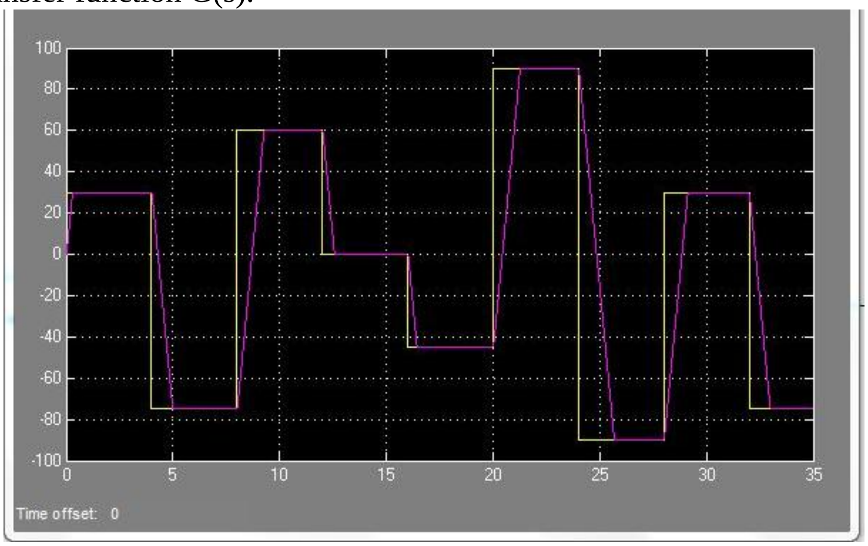


**Figure 10:** Pitch PID controller

In **Figure 11** is a Simulink simulation of the Proportional Integrative Derivative (PID) controller for the Yaw transfer function G(s).

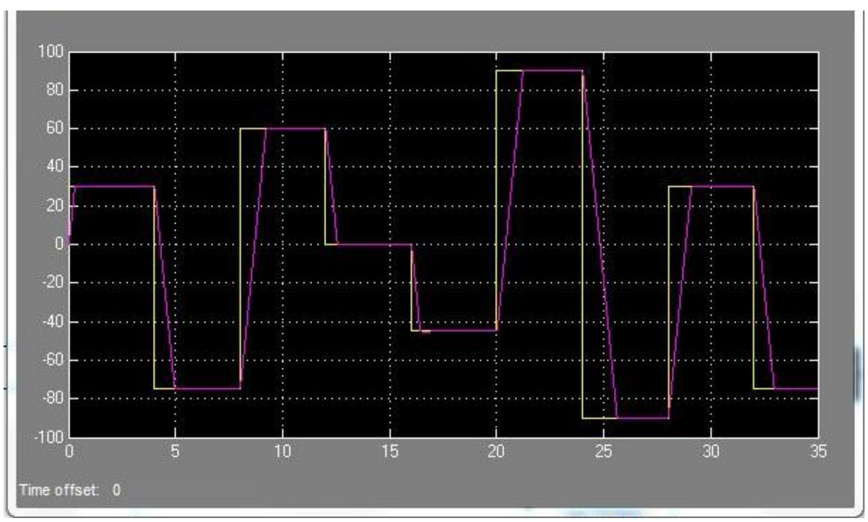


**Figure 11:** Pitch PID controller

It necessary to mention that the PID controller is simulated on discrete time. In addition, with a careful choice of state-feedback gains, it is evident that both overshoot and settling time are improved, even if the improvement in settling time seems affected by the compensated control voltages limitations to protect that that the motors do not exceed their limits.