Mission Report CLTP-8

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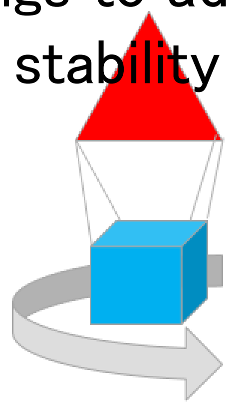
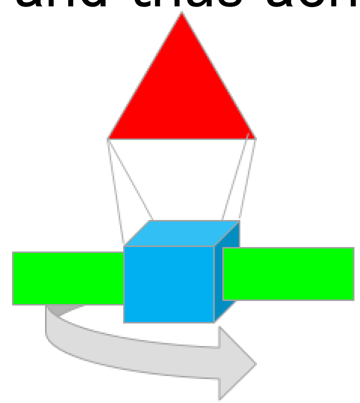
CLTP-8 Mission Statement

The onboard gyroscope, measures the angular velocity of the hepta-sat in three axis, roll (x), pitch (y) and yaw(z)

My mission concerns the measurement and in a way the stabilization of the yaw rate of change (in the z axis) by deploying wings to add drag area and thus achieve passive aerodynamic stability as such:



Measure yaw rate without wings



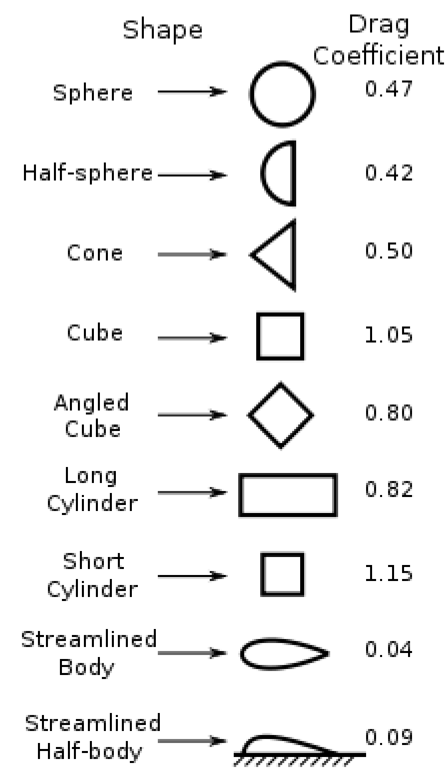
Measure yaw rate with wings

Premise

$$\dot{\theta}_{nowings} >> \dot{\theta}_{wings}$$

CLTP–8 Drag Force

Drag Equation: $D = \frac{1}{2}\rho v^2 C_d A$



Measured Drag Coefficients

<u>Where:</u>

D is the drag force in Newtons

P (rho) is the density of the atmosphere at flying level in $\frac{Kg}{m^3}$

V is the velocity of the airflow impacting the hepta-sat in the x axis in $\frac{m}{s}$

C_d is the coefficient of drag of the hepta-sat

A is the effective area of the reference side of the hepta-sat in m^2

<u>Calculation:</u>

P = 1.2 $\frac{Kg}{m^3}$

V = 1.0 $\frac{m}{s}$ (Theoretical prediction)

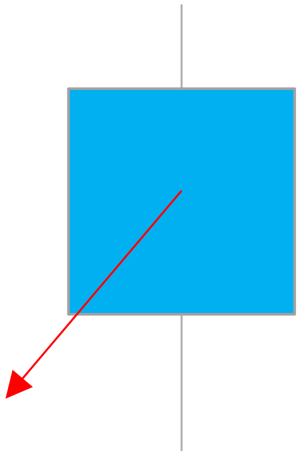
C_d = 1.05

A = 0.01 m^2 (No wings)

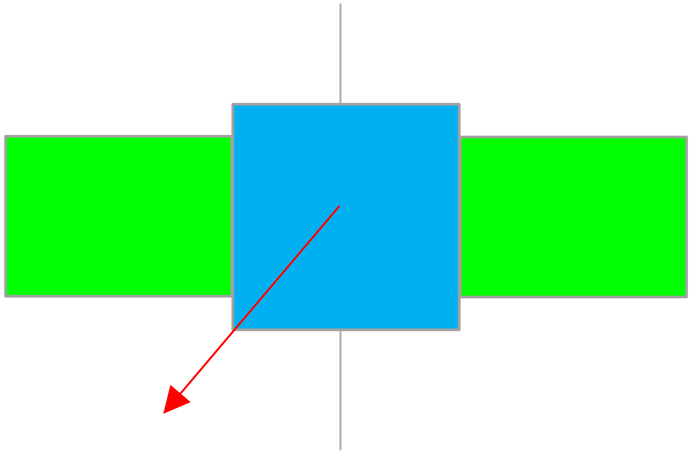
A = 0.03 m^2 (Wings)

CLTP-8 Theoretical Calculation

Theoretical drag force with 1 $\frac{m}{s}$ wind



Theoretical Drag Force
6.3 x 10^{-3} Newtons



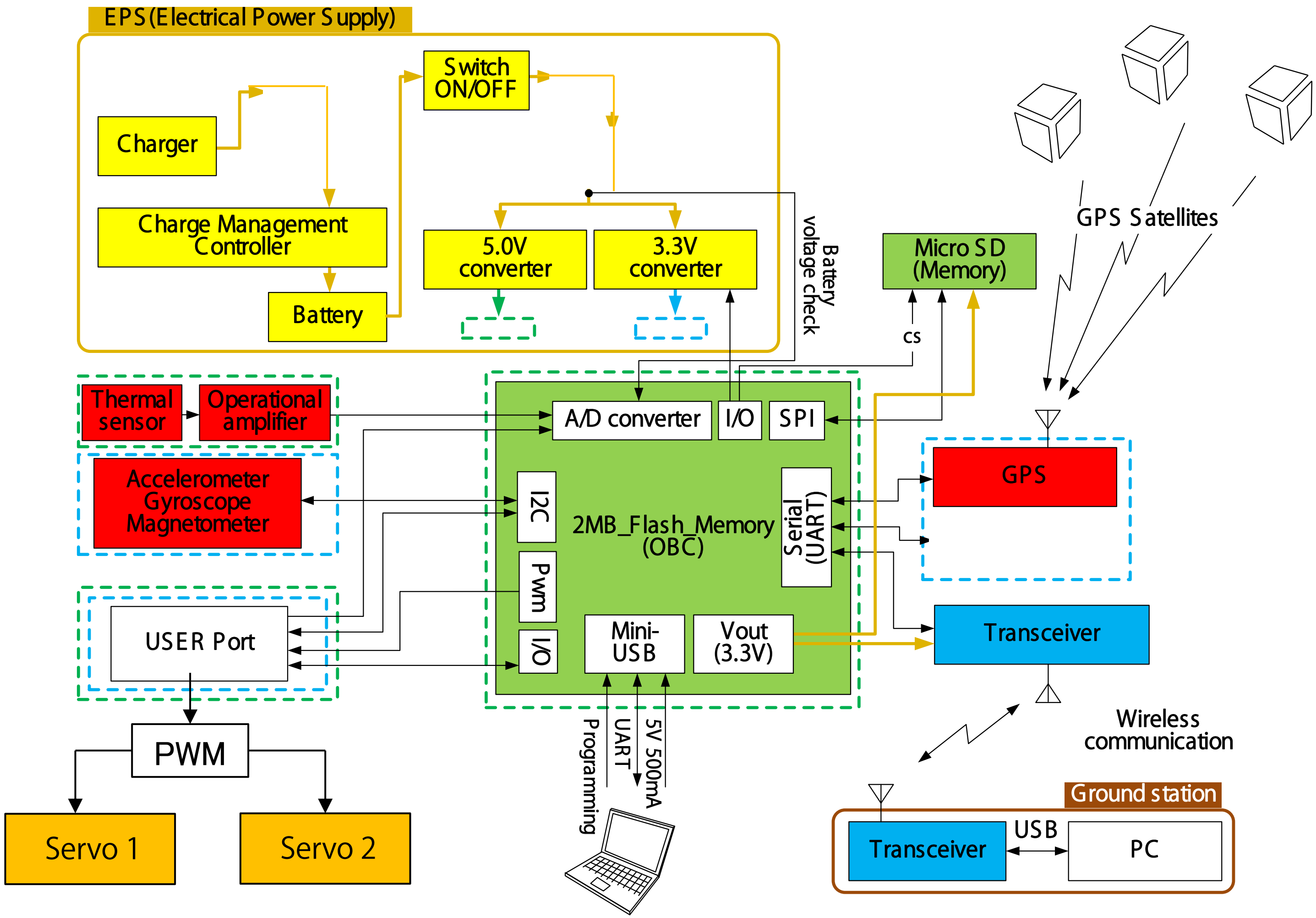
Theoretical Drag Force
18.9 X 10^{-3} Newtons

About 3 times
the drag force

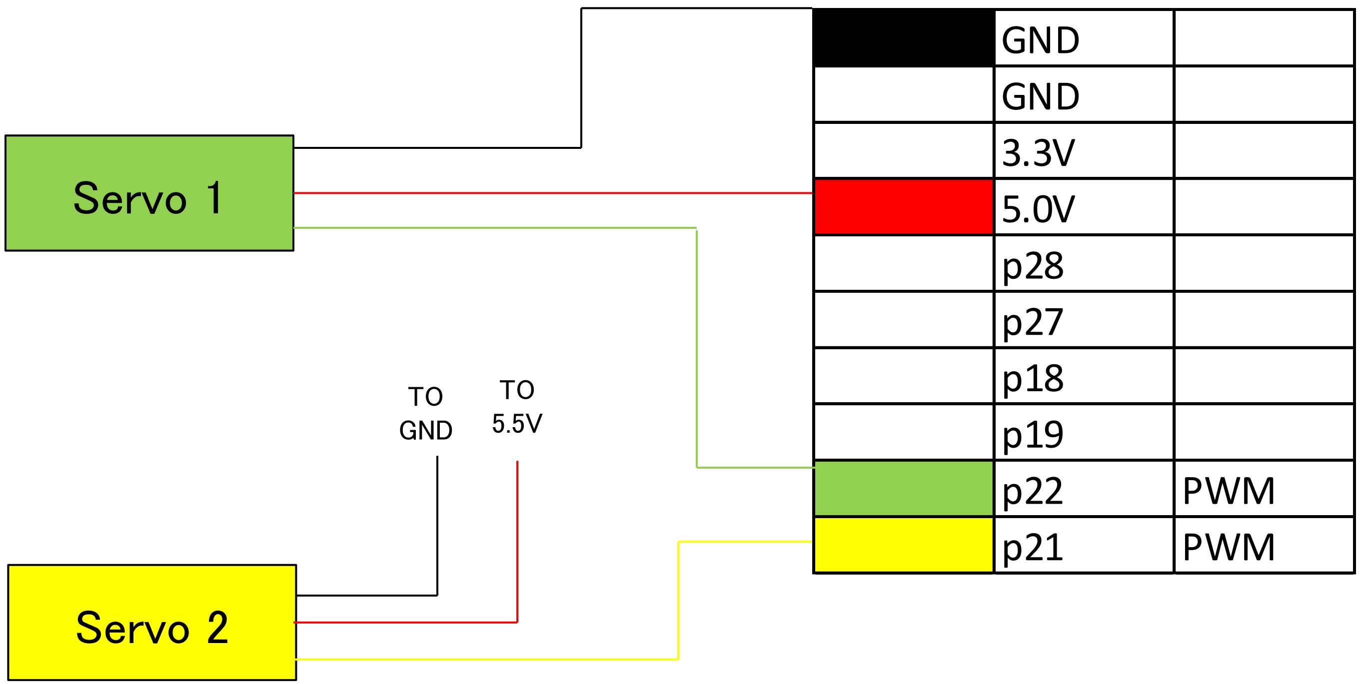
CLTP-8 Mission Requirements & V&V

No	Phase	Requirement	Required Function	Verification Way	Result
MR-1	Preparation Phase	Send uplink ok command to Hepta-Sat	GRND	Observation	OK
MR-2		Receive uplink confirmation from Hepta-Sat	GRND	Observation	OK
MR-3		Sense angular acceleration	SENSOR	Check MBED	Ok
MR-4		Sense position	SENSOR	Check MBED	Ok
MR-5		Sense battery voltage	COMM	Check MBED	Ok
MR-6		Sense Hepta-Sat temperature	COMM	Check MBED	Ok
MR-7	Flight Phase	Transmit Housekeeping data continously (voltage & position)	COMM	Check GRND	Ok
MR-8		Transmitt angular acceleration data continuously	COMM	Check GRND	Ok
MR-9		Store angular acceleration data in SD	C&DH	Check SD	SD Malfunctioned
MR-10		Store GPS data in SD	C&DH	Check SD	SD Malfunctioned
MR-11	Mission Phase	Send Wing Deployment Command	GRND	Check MBED	Ok
MR-12		Receive Wing Deployment Command	COMM	Check GRND	Ok
MR-13		Deploy Wing	SERVO	Observation	Ok
MR-14		Send Deploy Wing Confirmation	COMM	Check MBED	Ok
MR-15		Receive Deploy Wing Confirmation	GRND	Check GRND	OK
MR-16		Send Wing Stowing Command	GRND	Check MBED	Ok
MR-17		Receive Wing Stowing Command	COMM	Check GRND	Ok
MR-18		Stow Wing	SERVO	Observation	Ok
MR-19		Send Stow Wing Confirmation	COMM	Check MBED	Ok
MR-20		Receive Stow Wing Confirmation	GRND	Check GRND	Ok
MR-21	Analysis Phase	Process Gyro Data	LOG	Analysis	Analysis
MR-22		Yaw Rate Decreased?	LOG	Analysis	Analysis

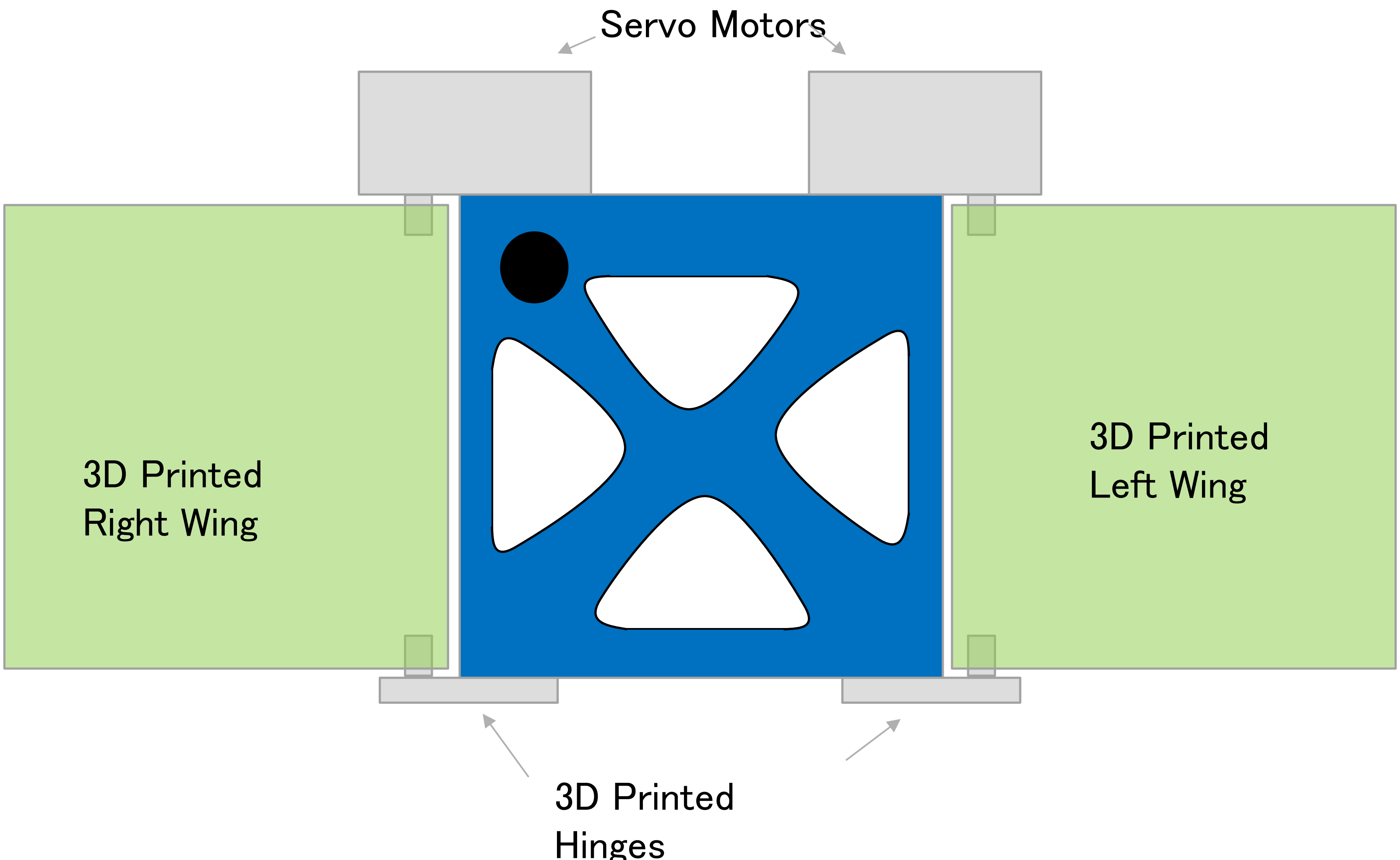
CLTP-8 System Architecture



CLTP-8 Payload Electrical Design



CLTP-8 Payload Mechanical Design



CLTP-8 Payload Programming

```
#include "Servo.h"
Servo myservos[]={p21,p22};

//Command 1 = Stow Wing
   if (rcmd == '1') {
   position = 1.0;
   xbee.printf("Command Stow Wing¥r¥n");
   xbee.printf("position = %.1f¥r¥n", position);
   myservos[0] = position;
   myservos[1] = abs(position - 1);
              } // Close if rcmd==1

//Command 3 = Open Wing
   if (rcmd == '3') {
   position = 0.0;
   xbee.printf("Command Deploy Wing¥r¥n");
   xbee.printf("position = %.1f¥r¥n", position);
   myservos[0] = position;
   myservos[1] = abs(position - 1);
              } // Close if rcmd==3
```

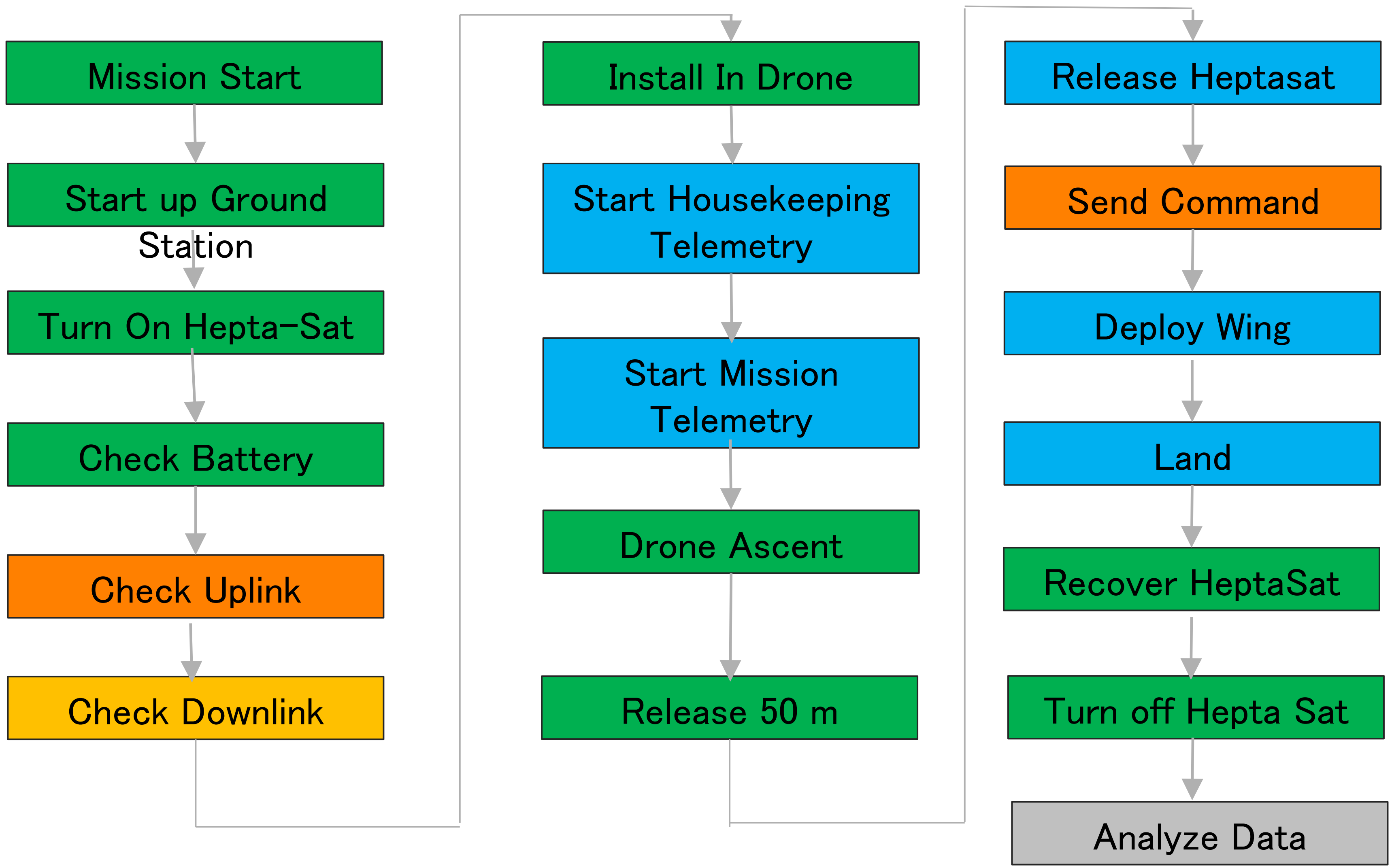
Servo Library from Mbed website

Pin 21 & 22 PWM Ouput

Command executed confirmation

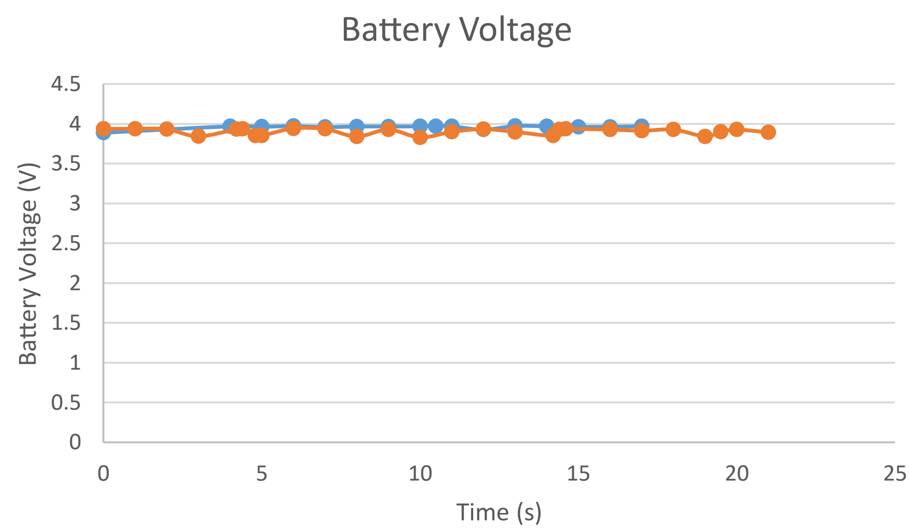
Servos must rotate in opposite directions

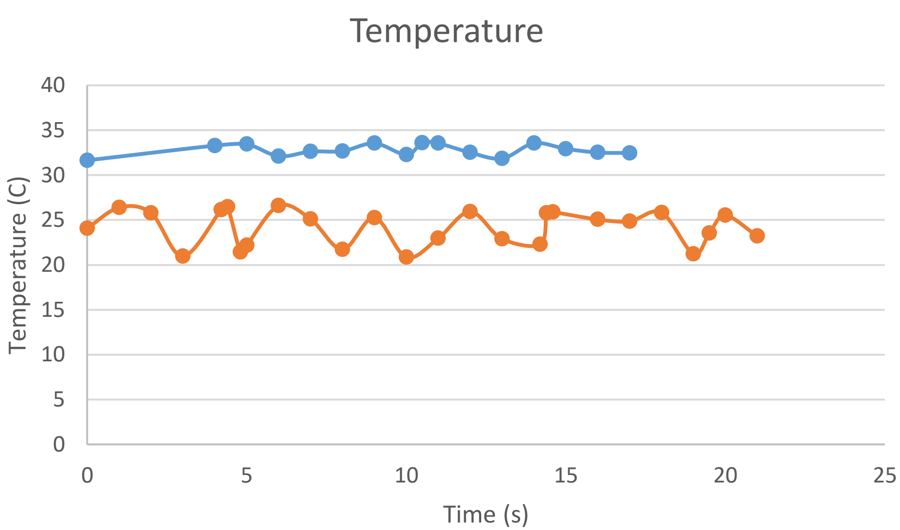
CLTP-8 Mission Background



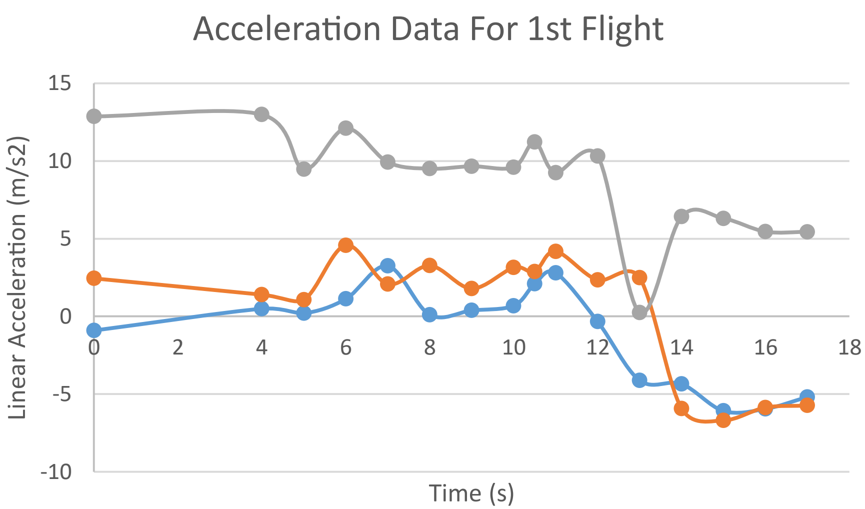
Wing Deployment During Flight

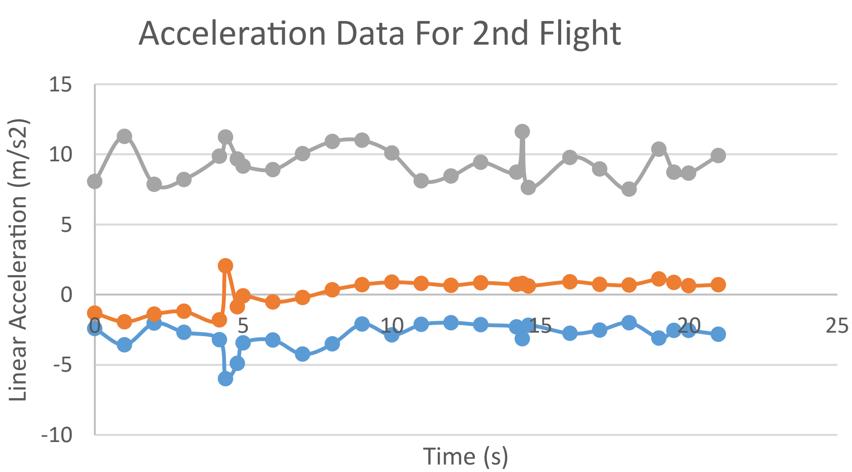
Housekeeping Data





Acceleration Data



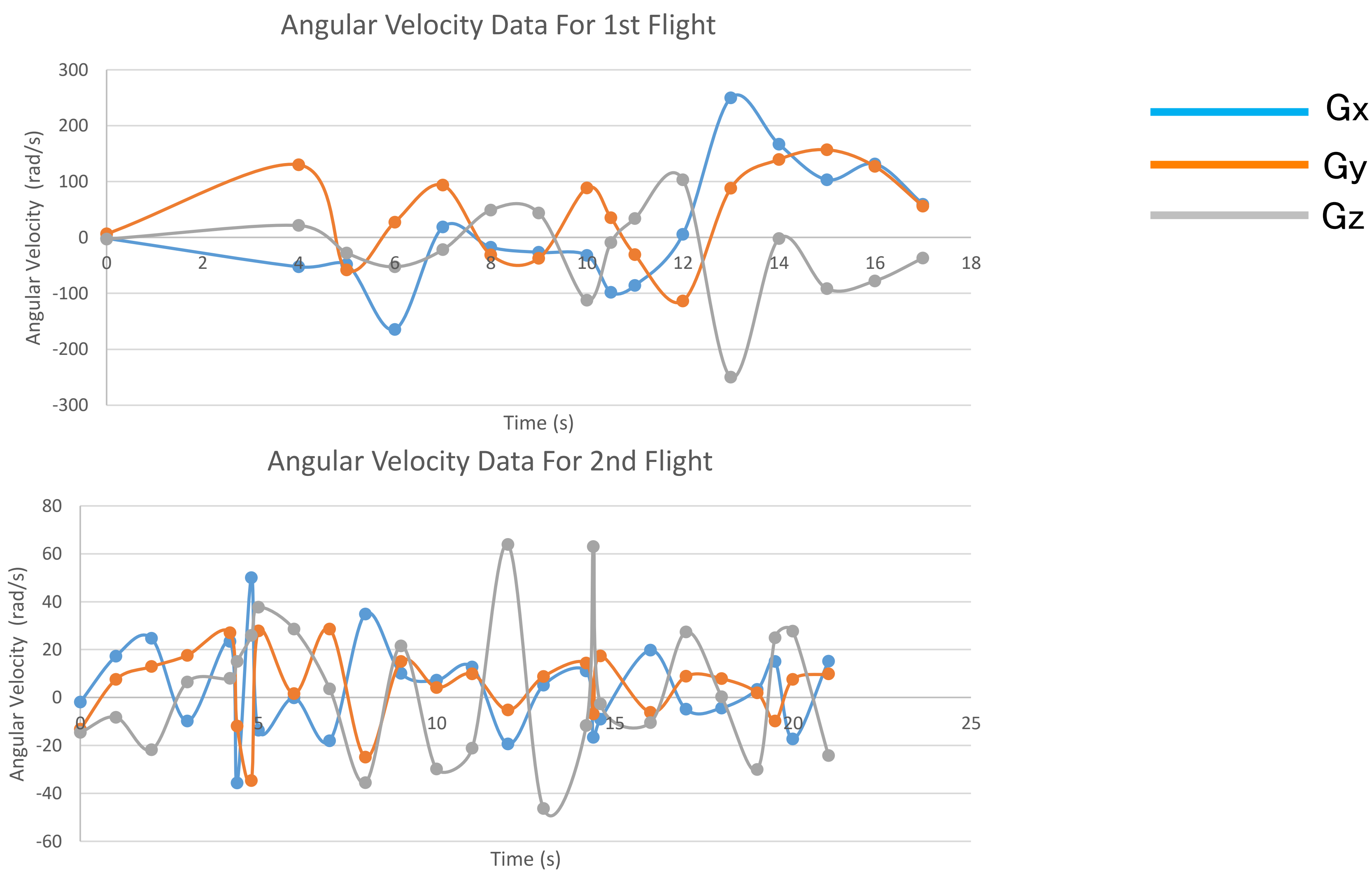


Ax

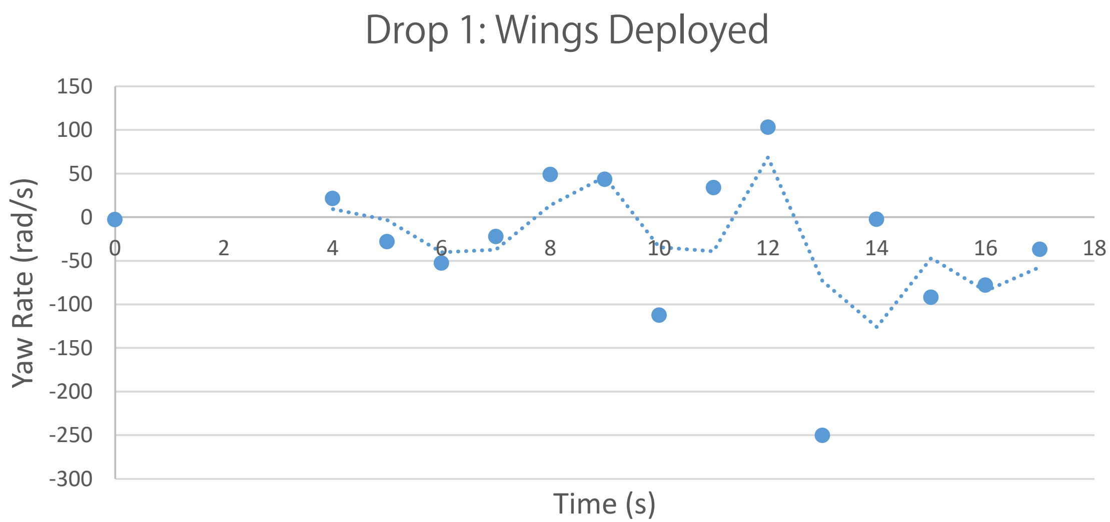
Ay

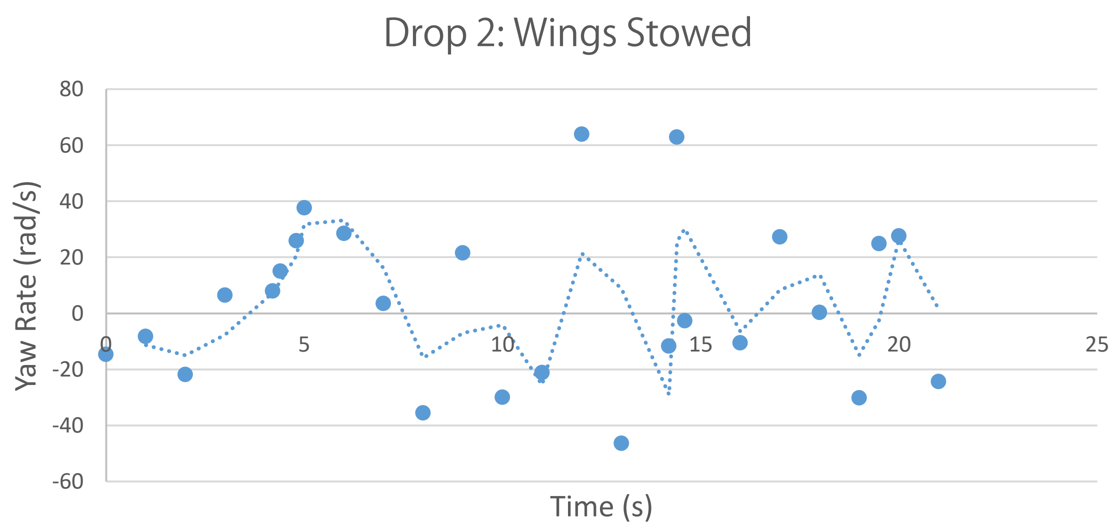
Az

Acceleration Data



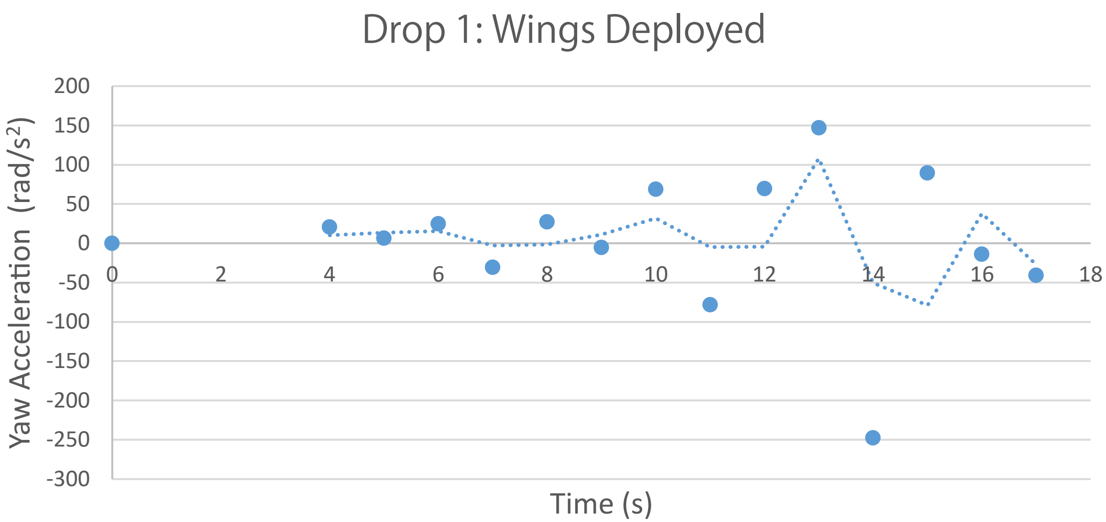
CLTP-8 Yaw Rate Analysis

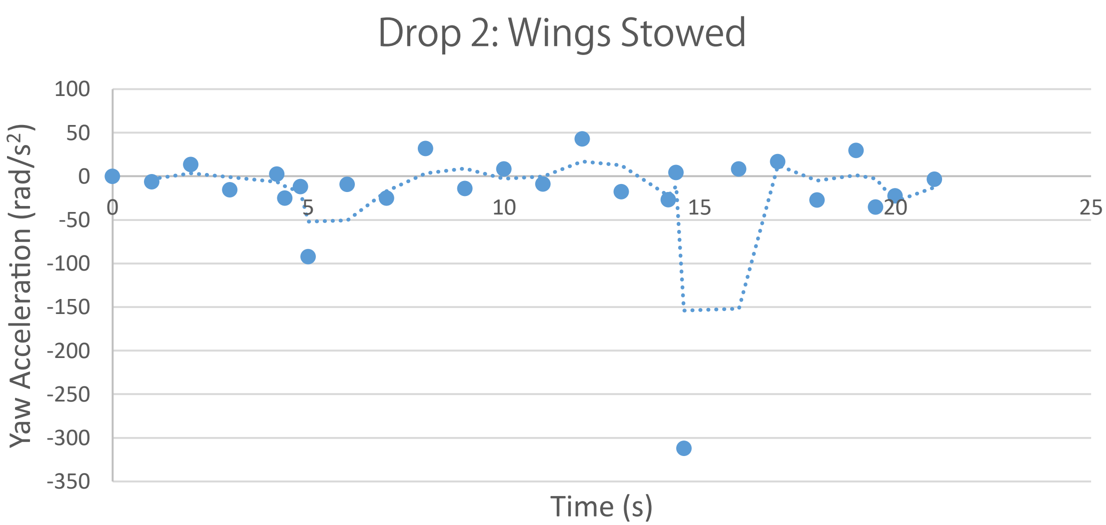




- Plot of yaw rate of change, during hepta-sat flight.
- Yaw rate remains mostly below 50 $\frac{rad}{s}$ during both flights. (to give you an idea that is 7.95 Hz, cycles per second)
- It does seem that when the wings were deployed yaw change was more subtle.

CLTP-8 Yaw Acceleration Analysis





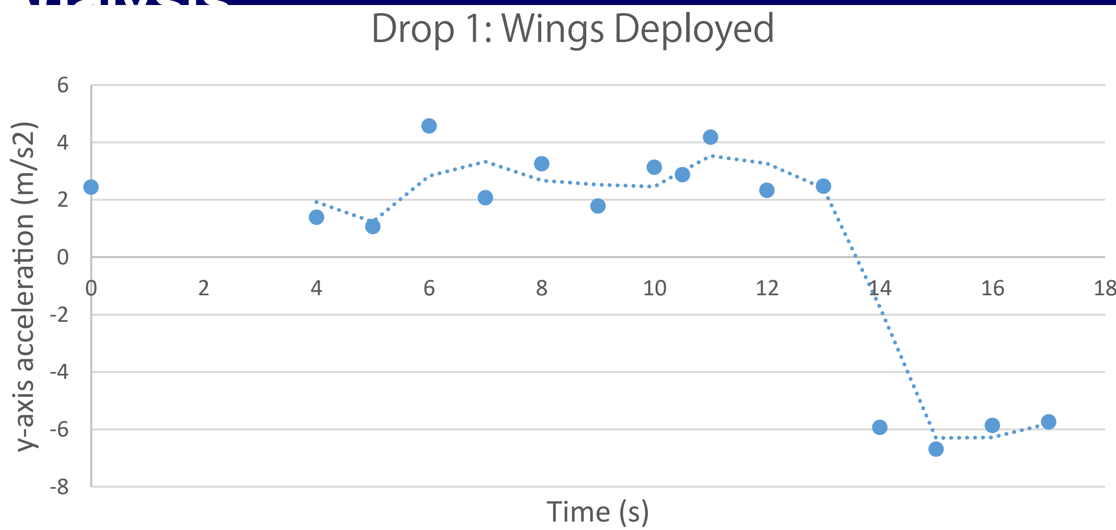
Since

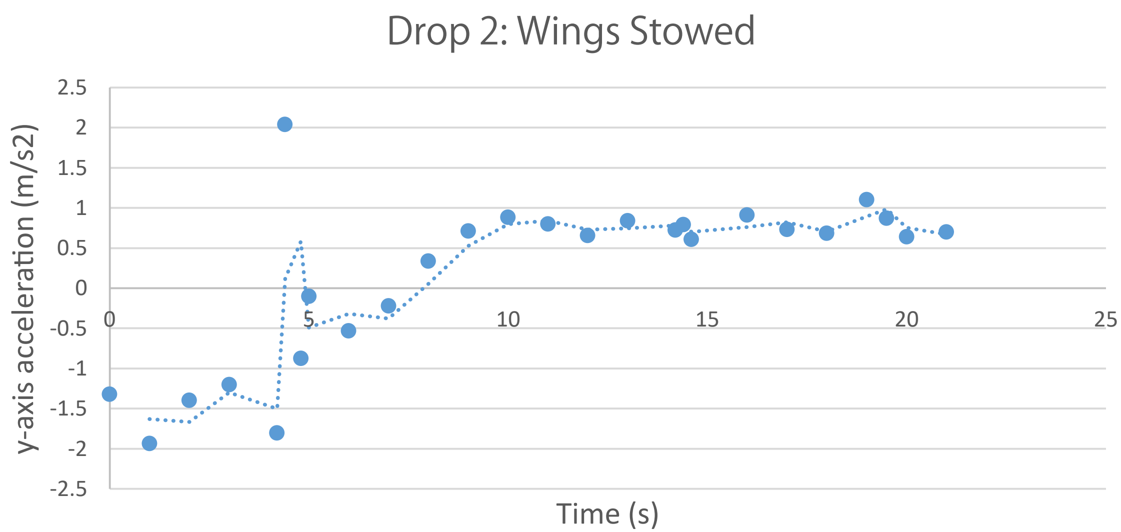
$$\alpha = \frac{d\omega}{dt}$$

- I also plotted the rate of change of yaw rate, in other words the angular acceleration.

- Angular acceleration remains below 50 $\frac{rad}{s^2}$ in both flights, except possible cases of strong wind gust.

CLTP-8 Y-Axis Acceleration Analysis





- I also plotted the y-axis acceleration, this axis is perpendicular to the wings and observed the influence of the wings on the acceleration of the hepta-sat.
- This confirms that the wings produce about 3 times drag force due to tripling reference area.

CLTP-8 Conclusion

Parameter	Criteria	Evaluation
Minimum Success < 100%	(1) Receive housekeeping data (2) Receive angular acceleration data (3) Receive uplink confirmation	ok ok ok
Full Success 100%	(4) Deploy wings during flight (5) Store Gyro Data in SD Card (6) Store GPS Data in SD Card	ok no* no*
Extra Success > 100%	(7) Confirm Mission Hypotesis (8) Landing without breaking wings	inconclusive** ok

* However, Gyro and GPS data was successfully transmitted to the ground station. This function was added as a backup because my SD card malfunctioned during pre-flight tests.

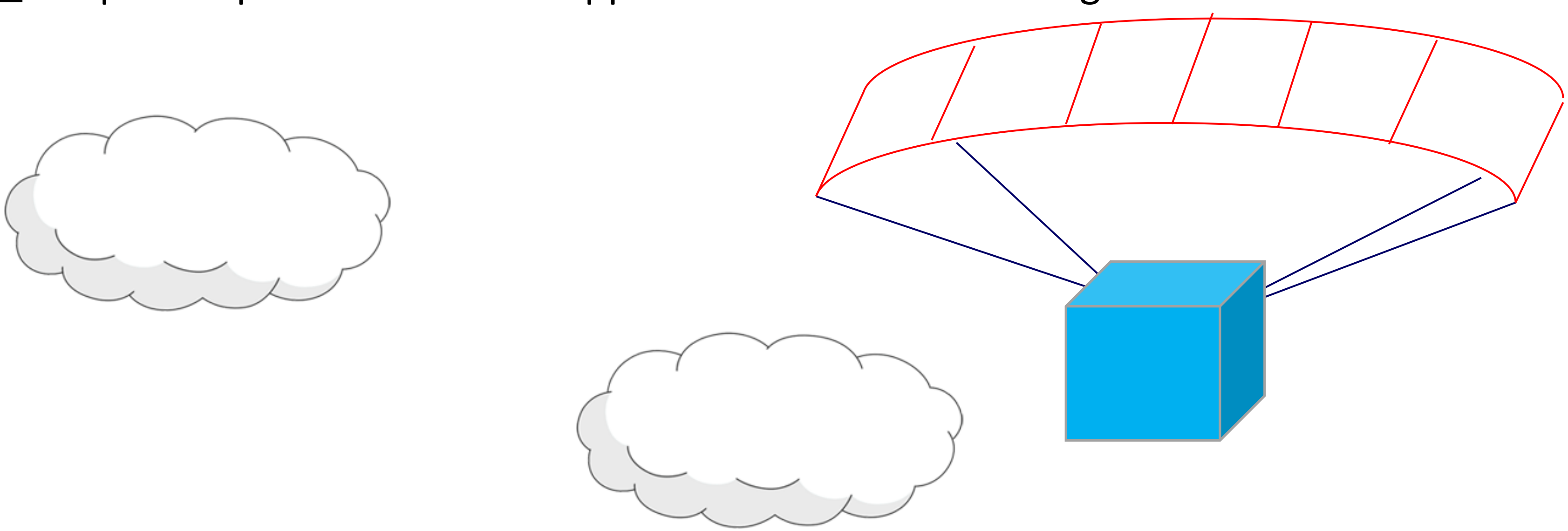
** yaw rate reduction was observed, but more tests need to be done to conclusively determine if deploying wings reduce yaw rate. Yaw acceleration, was observed to reduce.

CLTP-8 Recommendation for Future Work

Further Work

- ☒ Will do a 6dof numerical simulation of an hepta-sat flight
- ☒ By adding wings to hepta-sat and adding feedback control, the flight trajectory could be moderately controlled.
- ☒ Even better using a paraglider and trying the "land on target" competition.

- ☒ Hepta-sat provides limitless opportunities to use our imagination.



CLTP-8 Feedback for CLTP-8

Recommendation for Future CLTP

- ☒ Allow one day of launching, then one day of re-do and another day of launching.
- ☒ Make launching preparations faster, by having the hepta-sats ready in batches.
- ☒ Find a bigger launch area to allow for higher altitude releases.
- ☒ Consider launching with rockets to simulate real launch conditions more accurately.
- ☒ Consider more thorough one-to-one verification & validation tests to correct problems on spot.
- ☒ Consider preparing a pre CLTP manual to teach basics of coding and give coding examinations to ensure participants know how to code basic programs.

Just as a thought

- ☒ Consider a more advanced and in depth training to teach cubesat development, because many programs lack the "hands on" part and that is were CLTP excels, so adding a more in depth training with hands-on philosophy will surely allow participants more advanced level of competence in satellite design & development.

A Special Request

UNISEC/Prof. Yamazaki: Please come to El Salvador, we need your help in establishing a space systems engineering program. We want to become a spacefaring nation.

Thank you

どうもありがとうございます

Thank you so much for letting me be part of this amazing program and the honor of getting to know each and every one of you.

Torogoz (Momotus momota) National bird from El Salvador