UNIVERSITY OF CALIFORNIA, IRVINE

HENRY SAMUELI SCHOOL OF ENGINEERING

DEPARTMENT OF MECHANICAL AND AEROSPACE ENGINEERING

UCI Rocket Project Avionics Final Report 2014 - 2015

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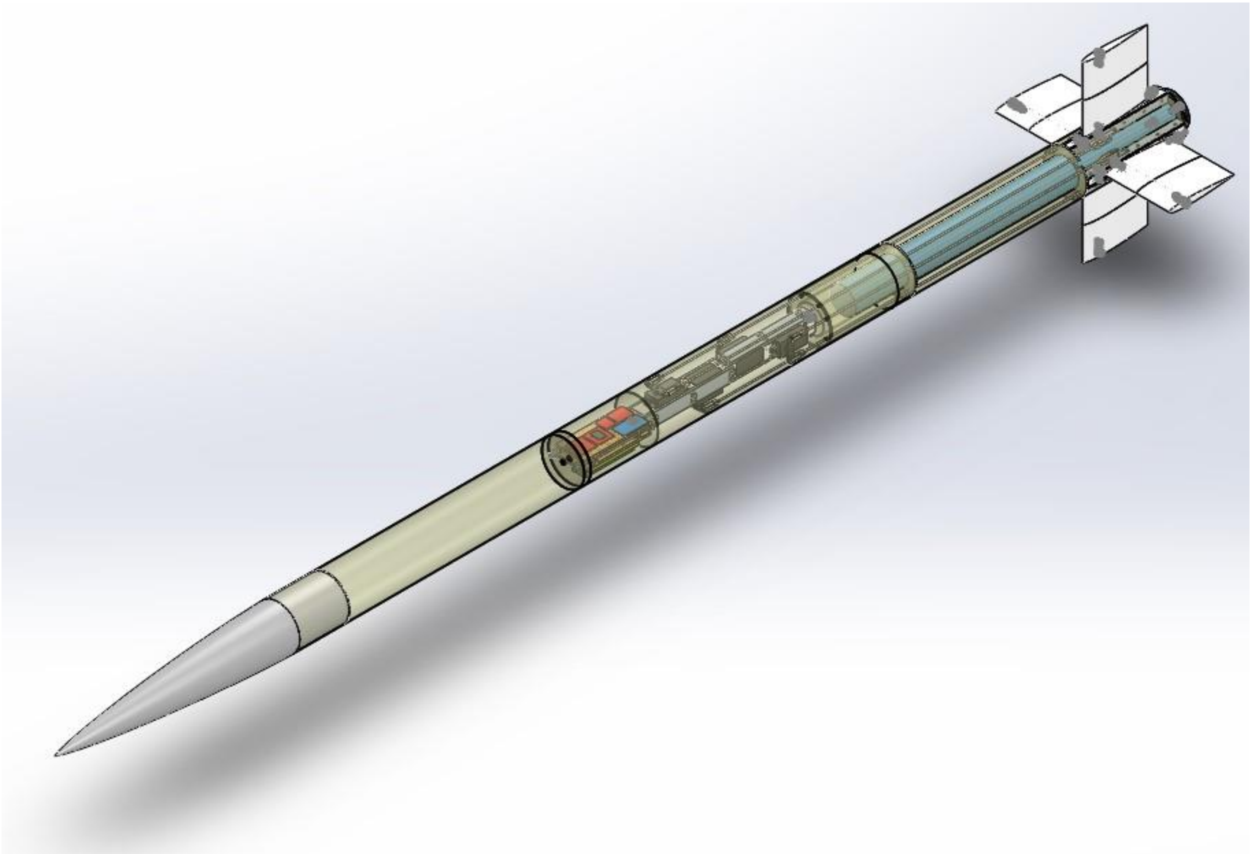
Introduction

A rocket can deviate from the desired flight path for a number of reasons; most often this is cause by errors in manufacturing or wind gusts. In order to ensure that a rocket stays on the desired flight path the rocket must have a stabilization system. There are two principle types of stabilization system for rockets: passive and active. A passive system usually employs fins to stabilize the rocket during flight. This type of system, although adequate for sounding rockets, is incapable of providing enough control over the flight trajectory for more advanced rocket experiments. Active stabilization systems can provide the control needed to ensure that a desired flight path is followed. There are several type of active control systems for rockets; some include compressed gas while others use actuated fins. With an active control system, not only can the rocket counteract wind gusts but it can also correct for small manufacturing errors that may cause the rocket to deviate from the desired trajectory.

Objective

The goal of this year's project was to develop an active control system that will guide the rocket's trajectory in order for it to stay on its intended flight path. The system will consist of sensors the obtain data about the rocket in six degrees of freedom, a flight computer that takes the data from the sensors and determines the necessary output to servo motors which actuate the fin tips that control the rocket. The focus was placed on mechanical design and electronic component selection. With this in mind it was intended to test the fin tip actuation system and roll control. In attempt to make the project feasible in the time allowed, full roll, pitch, and yaw control will be done in another year's project; as well as fin geometry optimization.

Design

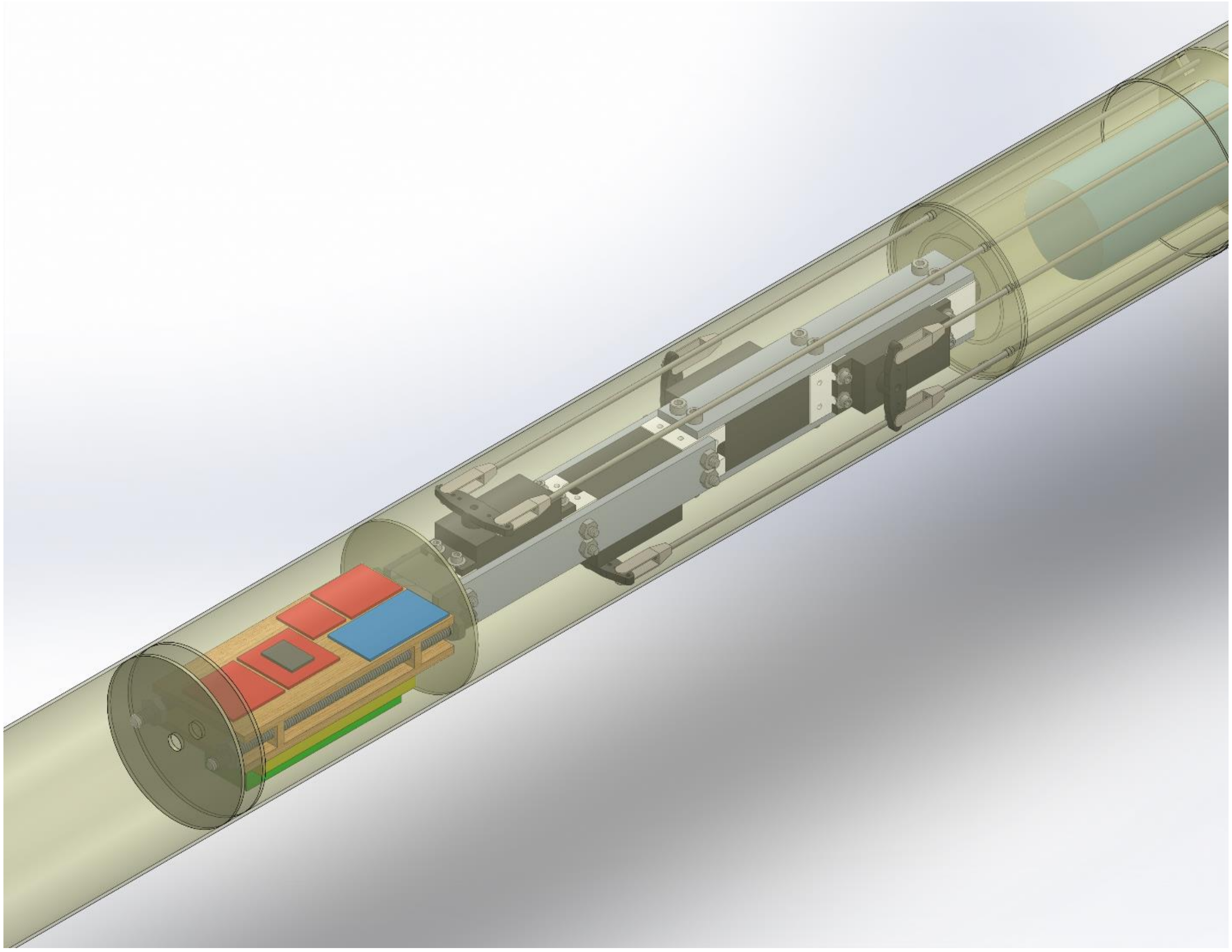


The design is entirely new and different from previous year's rockets. Since we are building a rocket to test our control system we will use a much smaller rocket to minimize our costs. We have bought a standard rocket kit where it will be modified to house our control system. These modifications require us to purchase additional parts and fabricate custom parts such as the fins and actuation system components. Our rocket is broken into three sections the rear assembly which contains the fins, the middle assembly which holds the electronics module, and forward assembly which contains the recovery system. The fins will be actuated with a set of servos that are connected to a bar at the base of their corresponding fins. This bar is then connected to a rod which goes through the fin base and into the actuating fin where it is constrained from rotating by pins.

Forward Assembly

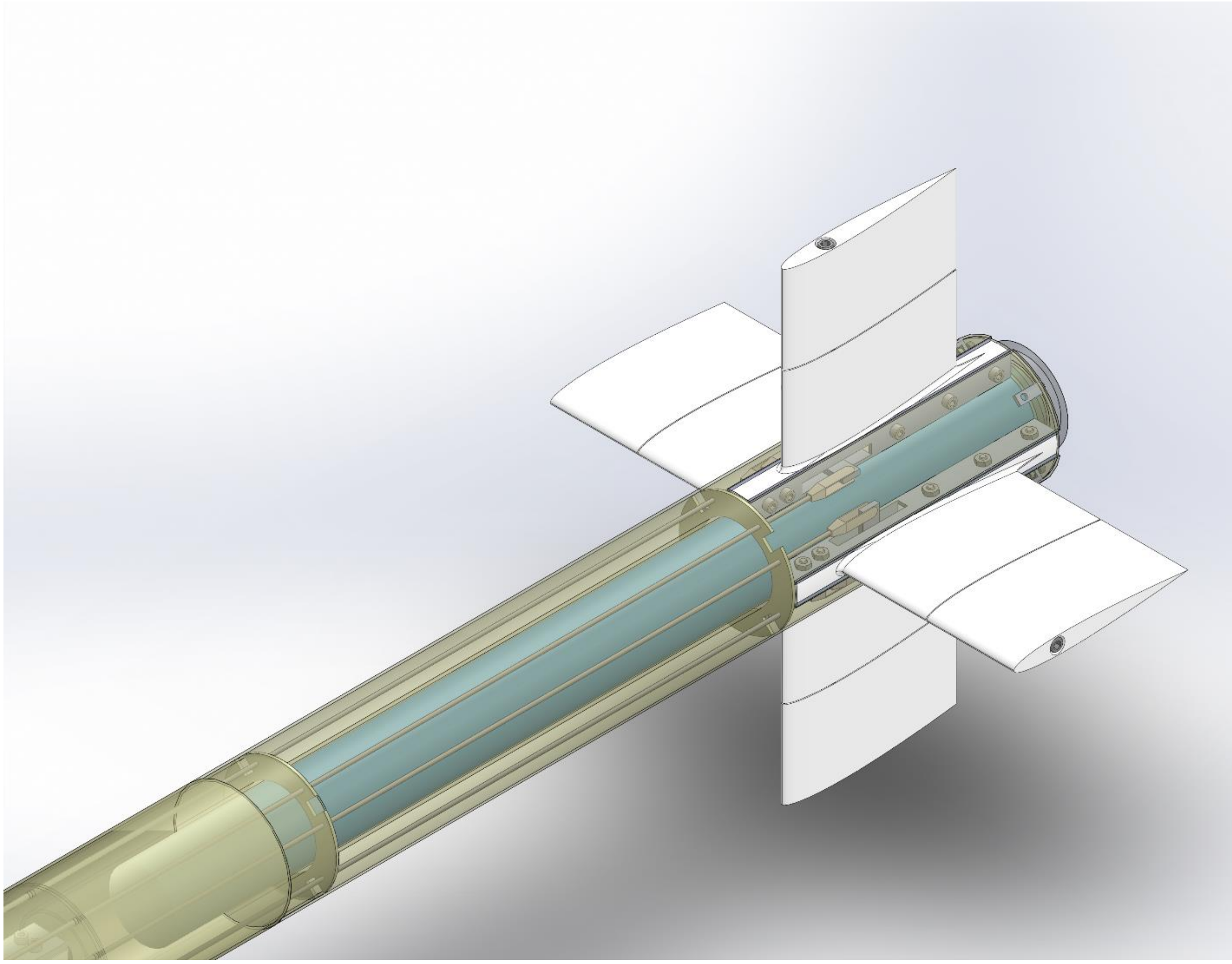
The forward assembly consists of the body tube and nose cone. These components came with the rocket kit and need to be modified to fit the fin assembly. The body tube is 2.6" in diameter and is made of fiberglass and the nose cone has an aluminum tip with a fiberglass body.

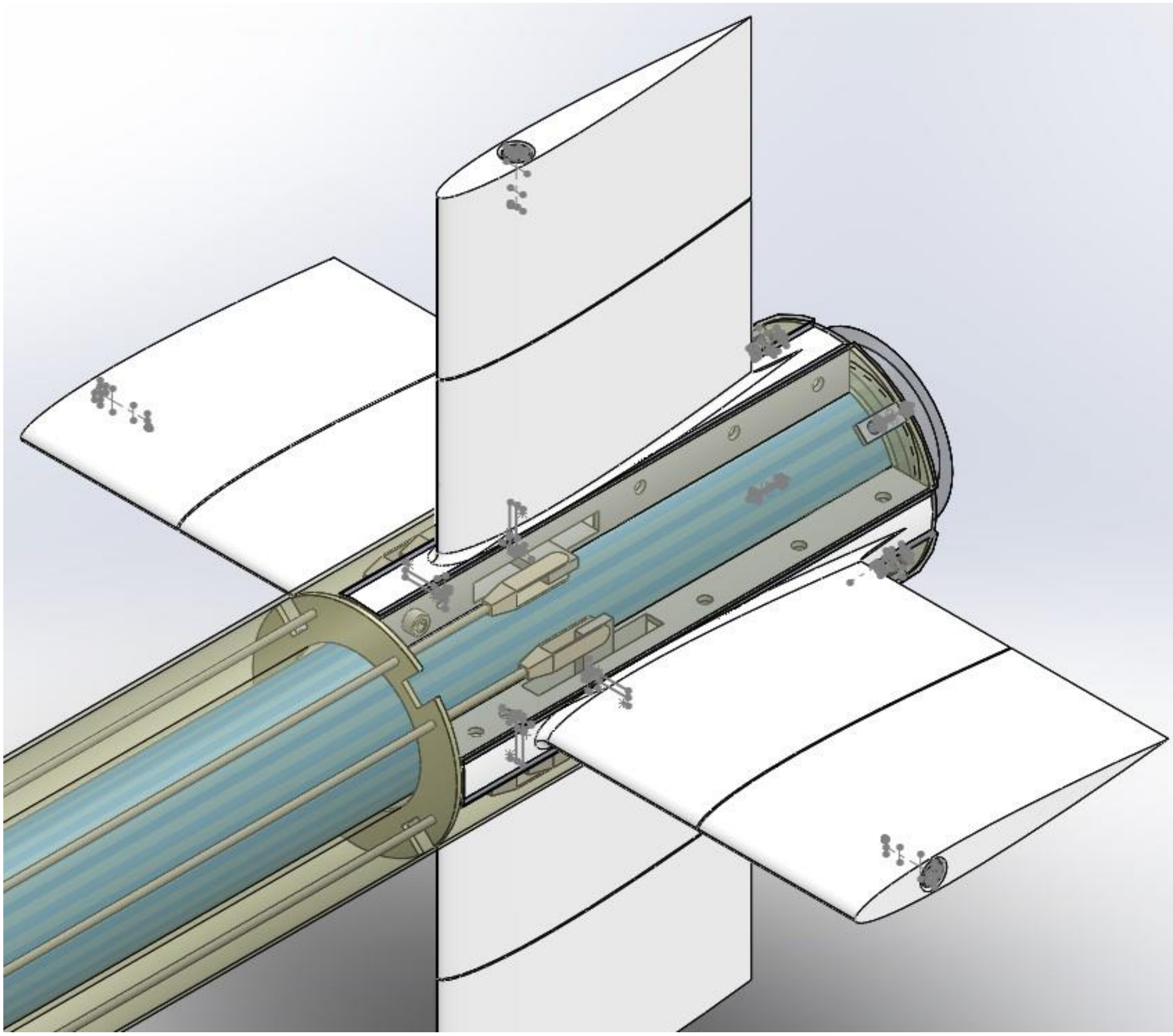
Middle Assembly

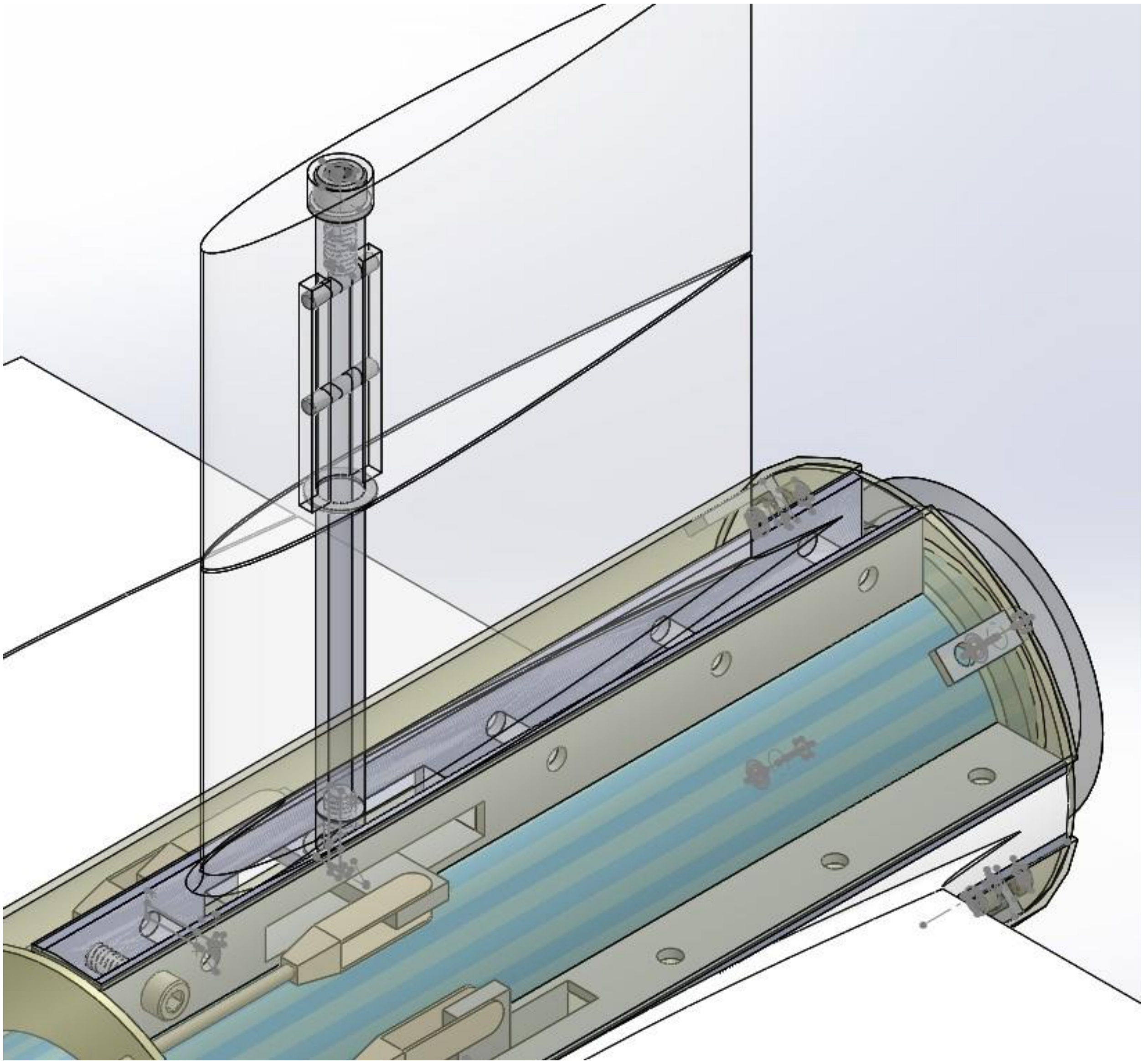


The middle assembly houses the electronic components such as the flight computer, sensors and servo motors. The servo motors are mounted in the rear to be as close to the fins as possible. The control rods which actuate the fins are very thin which means they are prone to buckling. To prevent buckling the rods are constrained by centering rings with holes drilled which hold the rods in place without impeding movement in the axial direction. The servo motors are positioned in a manner that they do not interfere with each other; this is achieved by alternating the orientation of each one by 90 degrees. Each servo will actuate the fin in a push pull system through the servo horn. The servo motors are fastened to 3D printed blocks which when secured with aluminum bars holds the servo motors in position. The electronics are located just forward of the servo motors and are as close to the servo motors as possible in order to have the gyroscope as close as possible to the center of gravity of the rocket, this also minimizes the length of wires needed.

Rear Assembly







The major components in the rear assembly are the rocket motor, fin assemblies and control rods. The rear assembly also has miscellaneous components such as retaining and centering rings, fasteners and mounts. The fin assembly is one of the most complex pieces on the rocket and requires careful manufacturing. The fin bases and fin tips were 3D printed due to the intricate curvature and in order to obtain the desired geometry. The fin assemblies are designed to be removable from the rocket body tube. This was done in order to allow the rocket to be easily retro fitted with different fins for a fin geometry optimization project to be done another year.

Electronics

The electronics are critical to the project success as they will determine the overall control of the rocket. The sensors that can be used to measure these forces are a three axis gyroscope, three axis accelerometer, and an altimeter. The microprocessor used in the flight computer is a Parallax Propeller. This microprocessor was chosen mainly because of its speed and the fact that it has 8 parallel processors and this is ideal for multitasking needs. The rocket travels at very high speeds and this requires the flight computer to obtain data from all the sensors, analyze that data, and send an output signal to the servo motors very fast.

Control

Classical and modern control theory will be used to develop the control laws. A transfer function will be used to determine how the control system will respond to these disturbances. The transfer function is an equation that is a function of all the outputs over the inputs. With this transfer function care is needed to adjust the gains to prevent over damping and under damping. If under damped is present in the system the system will act erratically to the smallest disturbance and adjust the fins too far or overshoot the desired position. An over damped system will not react fast enough and impede the overall performance of the fins. Controls theory provides us with the tools necessary to determine the laws that govern a particular system. It is a graphical interpretation of how the system changes when varying a certain parameter. The root locus can give an idea of how changing the gains will affect the stability of the system. Using this knowledge we can determine the most desirable gain that will give us the quickest and most accurate response. Another tool that will be used consistently will be Routh-Hurwitz stability criterion. Not only does this criterion determine if the system is stable, but it also determines the range of gains that can be used to keep the system stable. Obtaining the root locus and applying the Routh-Hurwitz criterion can give an idea of how changing the gains will affect the stability of the system and allow us to determine the proper values that will result in a robust control system.

Recovery System

Once the rocket reaches maximum altitude (apogee) the control system ignite a charge that will pressurize the nose cone causing it to detach and release the parachute. Our parachute will be tied off aft of the center of gravity of the rocket to ensure that the nose cone with the metal reinforced tip hits the ground first. The reason for this is to minimize the chance of damage to the fins when landing.

Bill of Materials

PART NUMBER/NAME	DESCRIPTION	VENDOR	QTY.	COST	NOTES
Rocket Kit		Madcow Rocketry	1	$ 185.17	
3D Printed Parts		Fabworks	13	$ 168.08	
coupler	fiberglass	Madcow Rocketry	1	$ -	included with rocket kit
bulkhead	fiberglass	Madcow Rocketry	1	$ -	included with rocket kit
tube_rear	fiberglass	Madcow Rocketry	1	$ -	included with rocket kit
rear_assembly_mount	aluminum	McMaster	4	$ -	made from left over u-channel
91835A520	captive nut	McMaster	4	$ 6.85	pack of 10
91251A106	screw, 4-40, 1/4"	McMaster	4	$ 8.50	pack of 100
bulkhead	fiberglass	Madcow Rocketry		$ -	included with rocket kit
block_outer_2	3D print	Fabworks	2	$ -	included with 3D printed parts
92196A317	screw, 1/4"-28, 1/2"	McMaster	2	$ 7.42	pack of 50
90473A205	nut, 1/4"-28	McMaster	2	$ 3.14	pack of 100
servo_motor	digital, high torque	HobbyKing	4	$ 61.97	
servo_horn	plastic	HobbyKing	4	$ -	included with servo motors
90107A004	washer, ID .109", OD .250"	McMaster	16	$ 2.73	pack of 100
92196A186	screw, 3-56, 3/4"	McMaster	16	$ 10.05	pack of 50
clevis	steel, with retainer clip	Radical RC	8	$ 6.99	pack of 12
block_inner_2	3D print	Fabworks	2	$ -	included with 3D printed parts
block_center_2	3D print	Fabworks	1	$ -	included with 3D printed parts
bulkhead_main_sled	fiberglass	Madcow Rocketry	1	$ 4.50	
bar_89755K26	1/8" x 3/4" x 6"	McMaster	4	$ 5.04	4 ft
90480A011	nut, 10-24	McMaster	2	$ 1.72	pack of 100
90760A007	nut, 6-32	McMaster	12	$ 2.61	pack of 100
92196A166	screw, 6-32, 1-1/4"	McMaster	12	$ 6.65	pack of 50
accelerometer_ADXL377	200g limit	Sparkfun	1	$ 24.95	
604-00060	analog-digital-converter	Parallax	2	$ 7.00	
altimeter_SCP1000	pressure sensor	Parallax	1	$ 19.99	
battery	6V, high current	not pruchased	1	$ 15.00	estimate cost
gyroscope_L3G4200D	angular rate sensor	Parallax	1	$ 29.99	
microSD_breakout	for micro SD card	not pruchased	1	$ 14.99	estimate cost
microSD_card	2GB	Parallax	1	$ 7.99	
propeller_quickstart	main CPU board	Parallax	1	$ 34.99	
sled	plywood, for electronics	Madcow Rocketry	1	$ -	included with rocket kit
95475A459	sled rail	Madcow Rocketry	2	$ -	included with rocket kit
90480A011	sled nut	Madcow Rocketry	2	$ -	included with rocket kit
bulkhead_main_sled	fiberglass	Madcow Rocketry	1	$ 4.50	
tube_motor	38mm x 24"	Madcow Rocketry	1	$ 28.00	
u_channel_9001K6	1/16" x 1/2" x 1/2" x 6"	McMaster	4	$ 5.48	4 ft
centering_ring_blank	2.6" x 38mm	Madcow Rocketry	1	$ -	included with rocket kit
retainer	aeropack 38mm	Madcow Rocketry	1	$ 25.00	
centering_ring	2.6" x 38mm	Madcow Rocketry	2	$ 11.00	
fin_base_NACA-0010_c_100	3D print	Fabworks	4	$ -	included with 3D printed parts
fin_tip_NACA-0010_c_100	3D print	Fabworks	4	$ -	included with 3D printed parts
90585A228	screw, 8-32, 1/2", CS 82deg	McMaster	4	$ 3.10	pack of 10
shaft_arm	aluminum	McMaster	4	$ -	made from left over: bar_89755K26
shaft_89955K519	OD .250, ID .120, 4"	McMaster	4	$ 14.23	3 ft
91545A230	washer, ID .173", OD .375"	McMaster	4	$ 1.60	pack of 5
98019A241	washer, ID .199", OD .315"	McMaster	4	$ 7.82	pack of 10
90145A438	dowel pin, 3/32", 1/2"	McMaster	8	$ 7.34	pack of 50
91251A182	screw, 8-32, 7/16"	McMaster	4	$ 10.00	pack of 50
95606A410	washer, ID .250,	McMaster	4	$ 8.49	pack of 100
clevis	steel, with retainer clip	Radical RC	8	$ 6.99	pack of 12
motor	casing and closures	None	1	$ -	Dave will lend
rod_1	2-56, 30"	Radical RC	2	$ 1.78	
rod_2	2-56, 30"	Radical RC	2	$ 1.78	
rod_3	2-56, 30"	Radical RC	2	$ 1.78	
rod_4	2-56, 30"	Radical RC	2	$ 1.78	
tube_forward	2.6" x 48" fiberglass	Madcow Rocketry	1	$ 70.00	
nose_cone	fiberglass	Madcow Rocketry	1	$ -	included with rocket kit
bulkhead_main	fiberglass	Madcow Rocketry	2	$ 9.00	
parachute	nylon, 50"	Madcow Rocketry		$ 25.00	
parachute blast protector	9" x 9"	Madcow Rocketry		$ 7.00	
propellent	38mm motor	not pruchased	1	$ 100.00	estimate cost
		SUBTOTAL		$ 987.99	
		TAX/SHIPPING		$ 148.20	
		GRAND TOTAL		$1,136.19	

Future Work

After finishing the fabrication and assembly, the control laws must be developed and they must be programmed into the flight computer. Then ground test procedures must be developed in order to test the control system before launch. Once the ground testing is finished a test launch can be performed in order to determine if the control system functions as desired. If the test launch is successful then development can begin on the control laws for full roll, pitch, and yaw control. Another aspect of design that should also begin is the optimization of the fin geometry.

Conclusion

The project this year had an overall positive outcome. The mechanical design, being very intricate, was very time consuming and it took many iterations to get it finished. Fabrication began late spring and there was not enough time to complete it by the end of the quarter. The fabrication will be completed over the summer as well and the control laws and programming. There should be a test launch performed mid to late summer. Post launch analysis will also be done including any failure analysis if failure should occur.

References

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[3] Barrowman, James. Calculating the Center of Pressure of a Model Rocket. Estes-Cox Corp: Educator.com, eBook.

[4] Dorf, Richard, and Robert Bishop. Modern Control Systems. 12 ed. Prentice Hall: Print.

[5] Previous Rocket project reports and information on the UCIRP Google drive