SDSU College of Engineering
Aerospace Engineering

Project Katzalcoatl: VTOL Delivery Drone

MISSION PURPOSE

With the rise of delivery drone technology in the past decade, many companies such as Amazon and DHL are experimenting in utilizing Unmanned Aerial Vehicles (UAVs) to deliver to houses or business too difficult or inefficient to deliver to by ground vehicle. Most of these drone concepts are of multirotor concept to ensure Vertical Takeoff and Landing (VTOL) capability. However, this configuration leads to less efficiency, thusa smaller potential delivery range and a slower aircraft.

Project Katzalcoatl seeks to design a multirotor-fixed wing hybrid UAV capable transforming between configurations mid-flight to achieve both VTOL capability while optimizing range and speed.

OBJECTIVES

Primary Aircraft Objectives
- Achieve stable hover and demonstrate control in VTOL configuration
- Achieve stable flight and demonstrate control in Fixed-Wing configuration
- Achieve reliable transformation between VTOL and Fixed-Wing configuration
- Achieve reliable transformation between Fixed-Wing and VTOL configuration

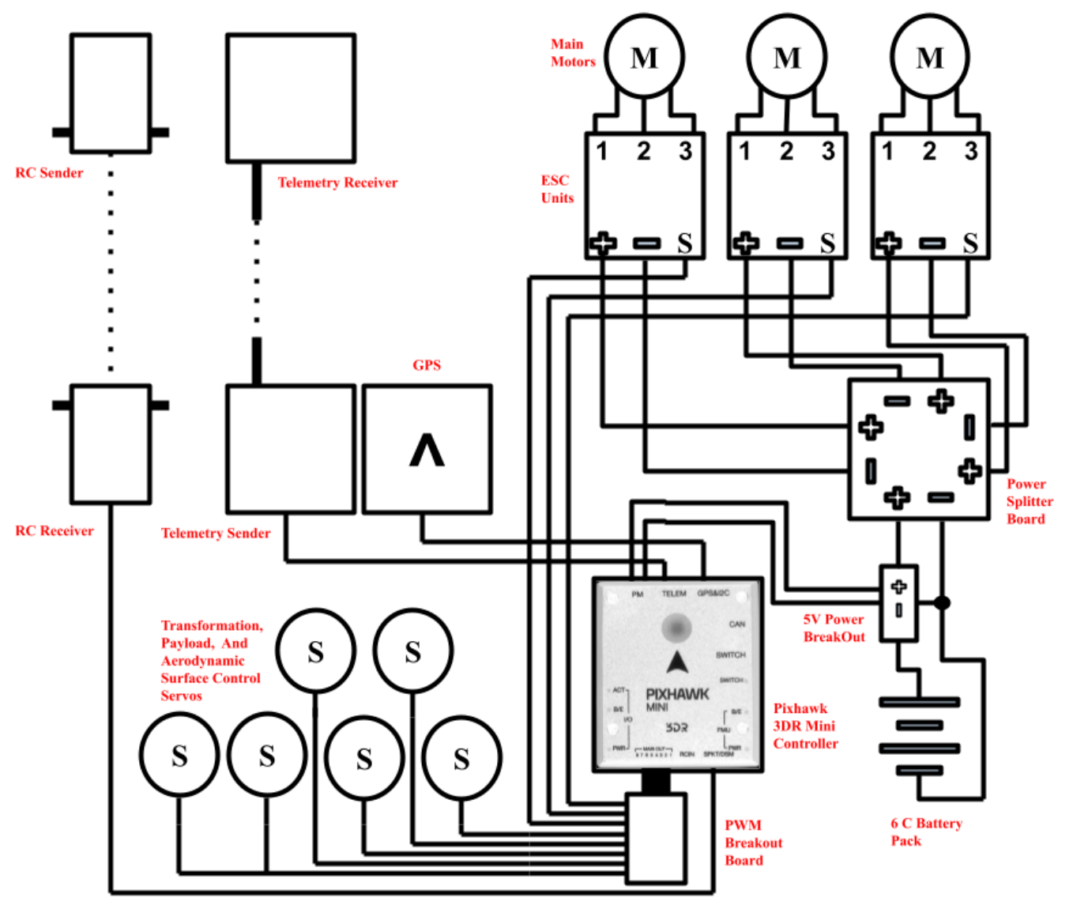
Secondary Aircraft Objectives
- Fit a 5-pound, 6” x 8” x 10” delivery box inside with remote deploying
- Achieve a total round-trip range of 15 miles
- Achieve a Fixed-Wing mode speed of 60 miles per hour

CONFIGURATION AND SIZING

Parameter	Configuration	Description
Wing	Top-mounted, rectangular planform	Primary focus on manufacturability. Wing sized to produce 15 pounds of lift at speeds of at least 30 mph.
VTOL Motor Layout	Inverted Tricopter, Isosceles Configuration	Tricopter VTOL configurations require the minimum number of motors necessary for stable hover and VTOL control. Inverted such that the rear two motors may assimilate with the horizontal tail and the front motor may extrude from the fuselage, minimizing weight and drag effects
Tail	Conventional	Focus on manufacturability. The rod connecting the two rear motors may double as the horizontal stabilizer’s tail, increasing structural integrity and minimizing weight
Landing Gear	Four mirrored carbon fiber legs	Focus on replacability and minimizing weight. The aircraft takes off and lands in VTOL configuration, thus wheels are not necessary

- •Fuselage: 0.93 lbs ------- 10%
- •Wing: 1.75 lbs ----------- 19%
- •Motors: 3.14 lbs --------- 34.1%
- •Landing Gear: 0.11 lbs – 1.2%
- •Avionics: 3.29 lbs -------- 35.7%

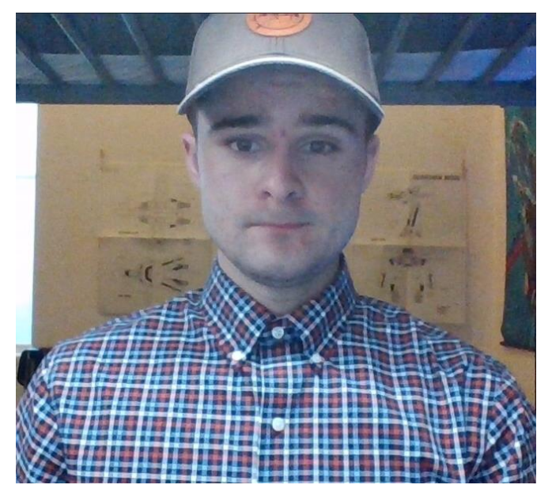
AVIONICS



A diagram of the avionic system used in our drone is pictured on the right. In order to achieve tri copter flight, three BLDC motors are connected to their own ESC units. ESC units are powered in parallel from the battery and are commanded by PWM signals given by the Pixhawk. The Pixhawk 3DR mini is the center of this system, taking in position, orientation, as well as acceleration information in from the GPS and its internal sensors. PWM signals sent to the ESCs are altered dynamically to stabilize the drone based on sensor readings and a PID control loop. PWM signals are also sent from the Pixhawk to control servos used when shifting flight modes and controlling aerodynamic surfaces. The Pixhawk is powered by its own supply 5V drawn from the battery. User input is communicated via an RC receiver unit connected to the Pixhawk. The Pixhawk also streams telemetry data back to a computer for analysis through a telemetry radio module. The Pixhawk is configured with the ArduPilot software running a modified Tri Copter Q-Plane configuration. This software configuration allows for the required behaviors for fixed wing and tri-copter flight as well as the switching between them.

TEAM MEMBERS

Jeremy Johnson
Chief Engineer



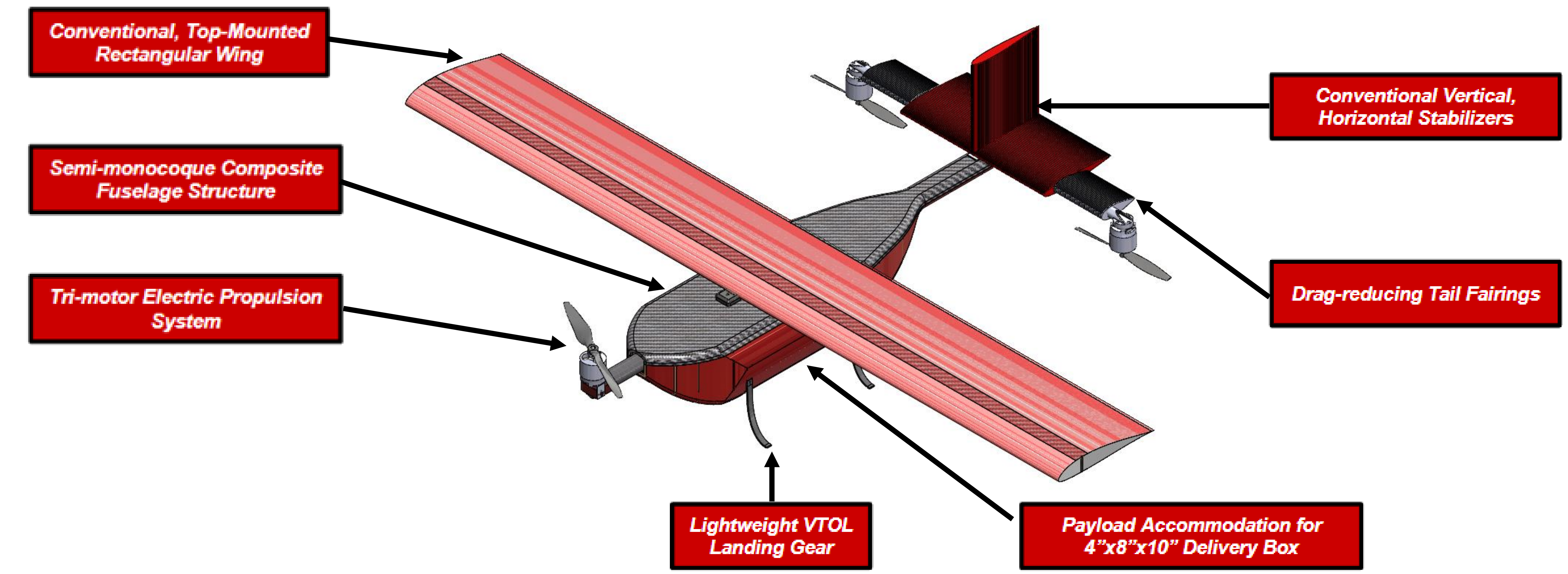
Thomas Hubbard
Avionics Specialist

Skylar Kinney
Aerodynamics Specialist

Lillian Locken
Propulsions Specialist

Daniel Black
Mechanisms Specialist

AIRCRAFT OVERVIEW



Conventional, Top-Mounted Rectangular Wing

Semi-monocoque Composite Fuselage Structure

Tri-motor Electric Propulsion System

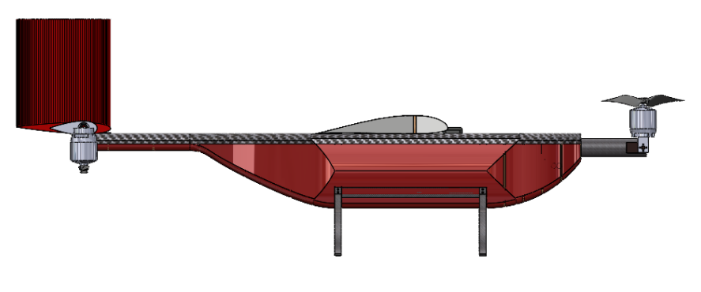
Conventional Vertical, Horizontal Stabilizers

Drag-reducing Tail Fairings

Lightweight VTOL Landing Gear

Payload Accommodation for 4”x8”x10” Delivery Box

MISSION PROFILE



1. Load package

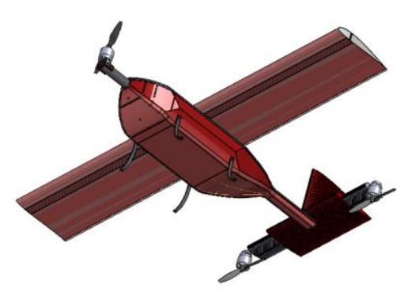
2. Takeoff in VTOL mode

3. Convert from VTOL to Fixed-Wing

4. Fly to destination in Fixed-Wing

5. Convert from Fixed-Wing to VTOL

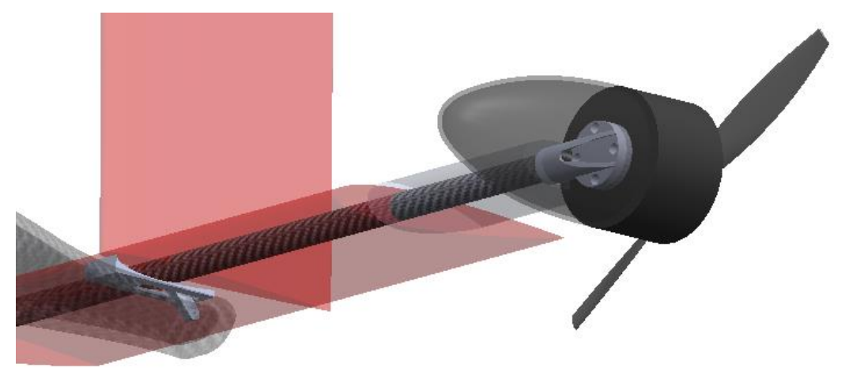
6. Land, Drop off package



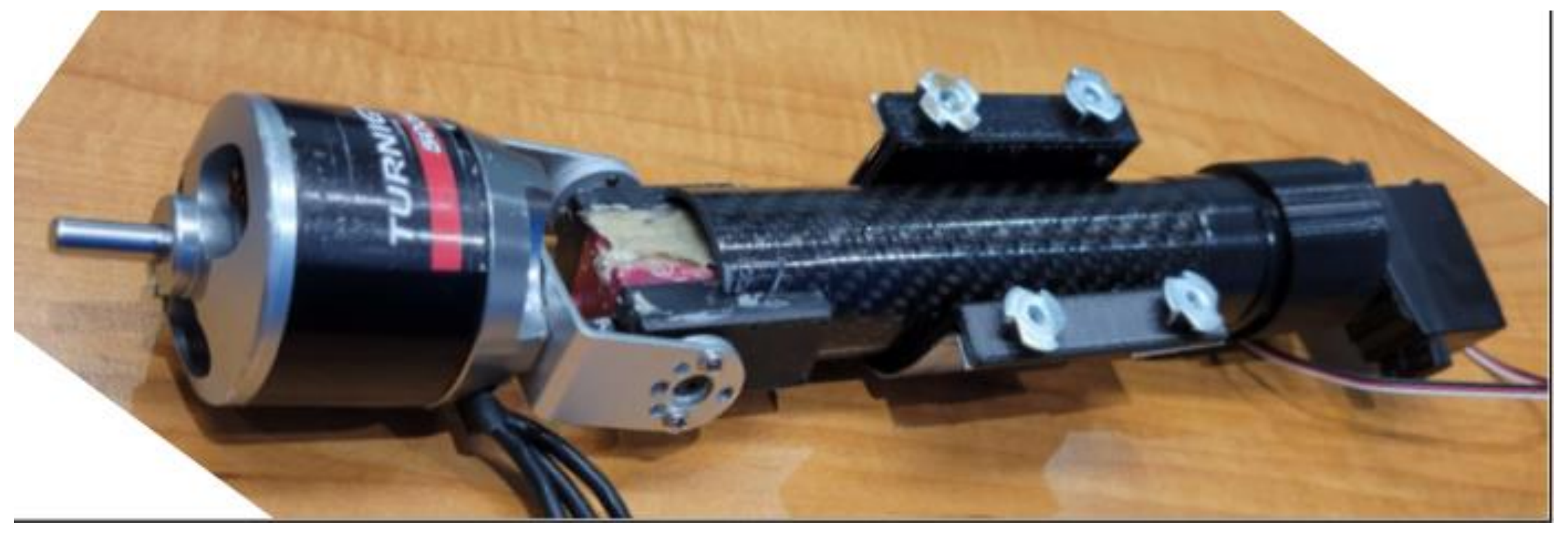
7. Repeat 2-6 , return to origin

MECHANISMS

Tilt-Rotor Mechanisms - Katzcoatl boasts two robust 90º rotating mechanism systems. The Front mechanism consists of a bracket and 20kg-cm torque servo that rotates 90º (up and forward). The rear mechanism is housed within the empennage and rotates the back two rotors through a spar. A 20kg-cm servo is utilized to complete its transition. These systems are given the same control input to transform the aircraft from hover to forward flight mode.



Yaw Control Mechanism - The 3 propeller design of the aircraft makes it necessary to introduce a yaw control mechanism to keep the craft stable. This mechanism features a 20kg-cm servo that connects to the front tilt mechanism via an in-line shaft. The mechanism allows about 80 degrees of motion to yaw the aircraft left and right.



Bay Door Mechanism - The bay doors of Katzcoatl open down and outwards to deliver the package. This mechanism movement is achieved with lightweight servos controlled by the flight controller.

PROPULSIONS

The propulsions system is designed prioritizing range and efficiency which is why we opted for a tri-copter formation as opposed to a quadcopter. Furthermore, this is the logic behind our decision to use only the front motor in forward flight as it is the most efficient choice. The battery, motor, propeller combination has been designed around the Turnigy G60 motors we had on hand. The specifications for each of these is shown below.

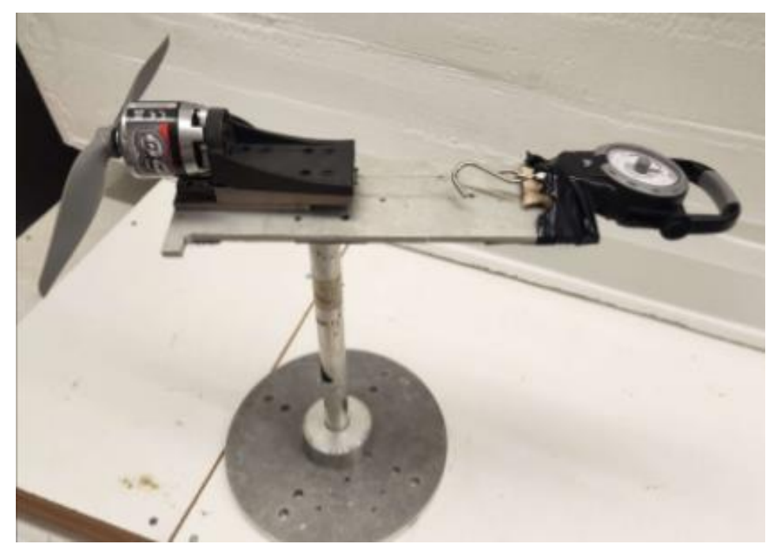
Propulsions Configuration Overview

Components	Type	Number	Specifications
Battery	5000 mAh LiPo	x 1	Max discharge rate: 300 A 22.2 V 35 C 6S
Motors	Turnigy G60	x 3	500 KV 11100 RPM
Propellers	13” x 8” (front) 10” x 6” (back)	x 1 x 2	Estimated thrust: 10.47 lbs Estimated thrust: 3.9 lbs

The image below shows our static thrust stand which gives the motor the capability to slide forward and pull on the fish scale, giving us thrust in pounds. The table shows the results of our static thrust test for each propeller. Furthermore, we are currently working on a more formal thrust test in the wind tunnel where we test varying incidence angles.

Static Thrust Test

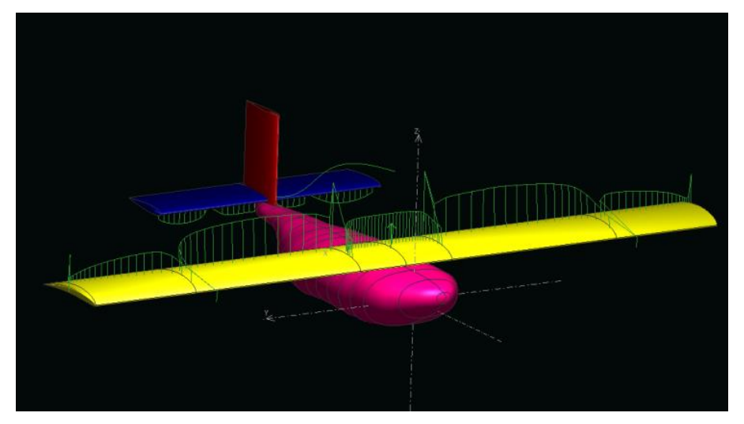
Propeller	Estimated Thrust	Actual Thrust
13” x 8”	10.47 lbs	8.3 lbs
10” x 6”	3.9 lbs	3.3 lbs
Total Thrust:	18.26 lbs	14.89 lbs

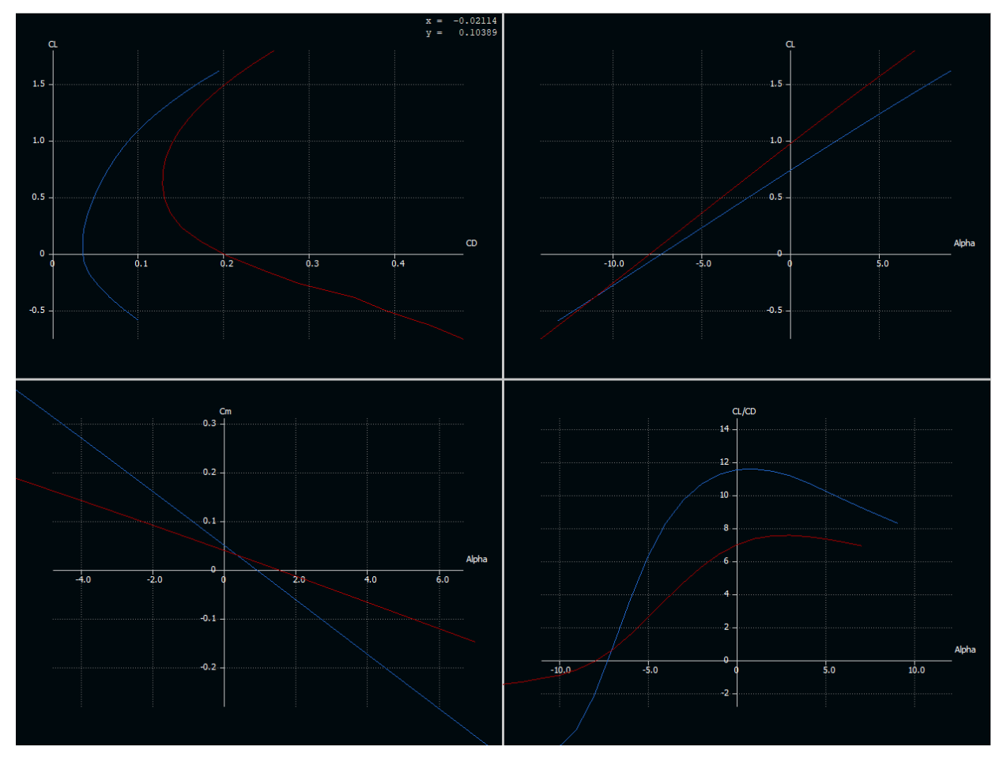


AERODYNAMICS & STABILITY

For the following Aerodynamic and stability analysis we used XFLR5 to determine what was the most optimal wing design for Katzalcoatl. The following graphs represents the aerodynamic characteristics for the original design and the redesign. The original design (DAE-31) is in red while the redesign is in blue (SD7037). Some of the major differences is the coefficient of moment and the Cl/Cd vs alpha values. It is noticeable that the SD 7037 produces a higher Cl/Cd vs Alpha value then the DAE-31 and has a larger moment coefficient. Lastly the induce drag for the DAE-31 is significantly bigger meaning that there is more drag using this airfoil

Aerodynamic Analysis Comparison	DAE-31 (Priliminary Desing)	SD-7037 (Redesing)	Precent Diffrence
Coefficent of Lift	0.972	0.738	24.07%
Moment Coefficent	0.39	0.51	30%
Coefficent of Lift / Coefficent of Drag Vs Alpha	6.992	11.52	65%
Coefficent of Drag	0.139	0.064	54%





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