Mechanical Engineering

Team 19F11
Aero Micro

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Date: 2/28/20

Subject: Implementation Memo I

1 Implementation

The purpose of our senior capstone is to design and manufacture a small fixed-wing aircraft that can compete in the SAE Aero Micro competition. The objectives of this memo are to provide a detailed description of our manufacturing process to date and future manufacturing tasks. So, this memo contains a detailed description of the manufacturing steps taken, design changes, future tasks, schedule, and project budget.

1.1 Manufacturing

The manufacturing processes for our small unmanned aerial vehicle (SUAV) will be broken down into the wings, the fuselage, the empennage, and the carbon fiber rod. The calculations made during this manufacturing process will also be told below.

Wings

The manufacturing of the team's wings begins with the team taking the g code to the laser cutter at Coconino Highschool where the wing ribs were cut in the shape of a Clark Y airfoil.

Figure 1: Rib profile

After getting the wings laser cut, they were taken to 98c where wooden dowels were run through the ribs then, using wood glue, fastened in place at thirteen ribs per section at a total of four sections of the wings as shown below in Figure 2.

Figure 2:Wing Section

The wingspan connectors were created out of two ribs and two four inch dowels as shown in Figure 3.

Figure 3: Wingspan connectors

To be able to control the plane, ailerons and an elevator were created by trimming the inner ribs to size to allow the ailerons to fit with the same shape as the wing as shown in Figure 4.

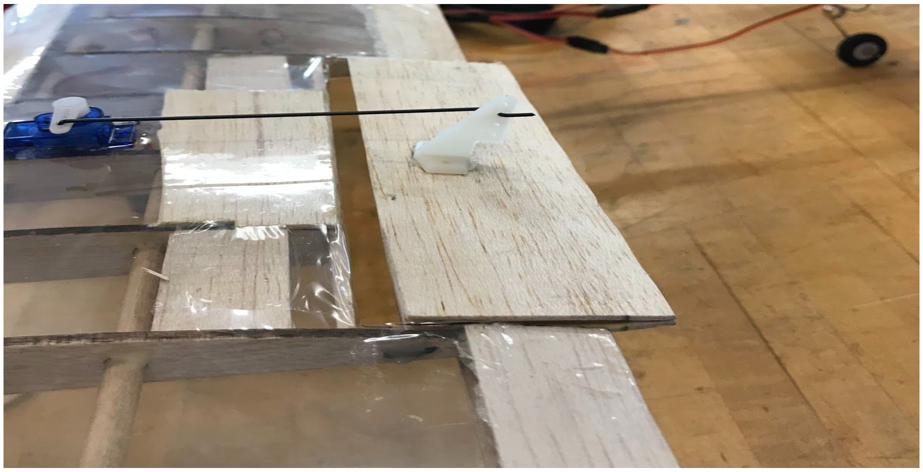

Figure 4: Ailerons

After each of the frames of the wings were manufactured they were finally ready for monokoting. Monokote is plastic shrinkwrap material that is used to take shape of the wing rib profile, with the use of a low temp iron and heat gun the team covered the entirety of the wings.

Fuselage

The fuselage was created with the use of 3D printing in the cline library. The fuselage stores; the motor, electronic speed controller, battery, and the receiver so it was dimensioned to fit each of these as shown in Figure 5. A shaft collar design was added to the rear of the fuselage for a carbon fiber rod to be bolted in place to connect the Fuselage to the empennage.

Figure 5: Fuselage with internal components.

Empennage

The empennage is the rear of the plane and includes; the tail wing, 3D printed shaft collar, landing gear and rudder. The manufacturing of the tail wing was described above in the wings section. The 3D printed shaft collar was created to slide over the carbon fiber rod and to be fastened with a bolt and nut. The landing gear attaches to the shaft collar along with the servo motor for steering which was glued in place with hot glue. The rear wing was bolted into the shaft collar and the holes were made using a hand drill with a 3 millimeter drill bit.

Carbon Fiber Rod

The team's design uses a carbon fiber rod to connect the fuselage to the empennage. The rod was cut to size at 12 inches using the vertical band saw. Then holes were made in the carbon fiber rod using the mill with a 3 millimeter drill bit for a bolt and nut connection as shown in Figure 6.

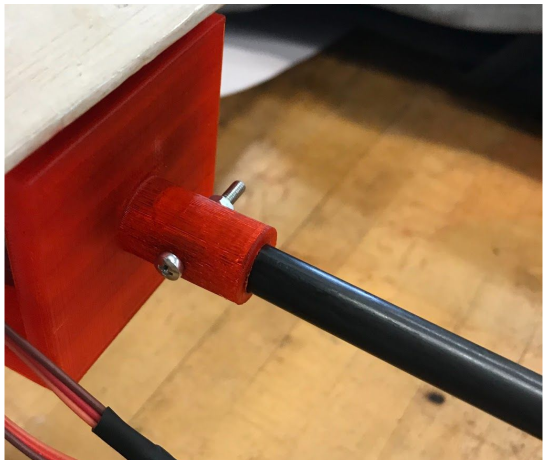

Figure 6: Carbon fiber rod connected to fuselage

Calculations

The calculations made for the manufacturing of the plane included calculating volumes, weights, and center of gravity. The volume taken by the internal components of the fuselage had to be taken into account when designing the fuselage prior to 3D printing as shown above in Figure 5. One of the customer requirements was that the plane must have an all up weight below ten pounds in our analyses last semester the planes all up weight was calculated to be about six pounds. For the center of gravity the team accounted for the majority of weight to be in the fuselage which stores heavier components including the motor and battery. The team set the empennage a foot back from the fuselage to get a center of gravity under the front wings which is where it should be for a glider SUAV.

1.2 Design Changes

Through manufacturing the plane, our team discovered that some aspects of the original design would not work. Similarly, the original design did not account for all aspects needed for a successful flight. So, our team implemented six design changes to ensure desired flight performance. All six design changes are described in detail below.

1.2.1 Design Iteration 1: Modified Fuselage Geometry

The original fuselage geometry attempted to provide external mounting surfaces for the motor, wings, front landing gear, and carbon fiber rod. Furthermore, the original fuselage attempted to internally house the drive subsystem and wiring. Upon manufacture, the fuselage proved successful in external mounting. However, the inside geometry of the fuselage failed to hold the drive subsystem, as the speed controller wiring contacted the motor housing. This was unacceptable, as the entire motor housing spins when the motor turns. The overall design for the original fuselage frame is provided below in Figure 7.

Figure 7: Original Fuselage Geometry

So, the fuselage was successfully redesigned with enough space to comfortably hold the battery, speed controller, receiver, and motor. In order to achieve this, the length of the fuselage frame was increased by 1 inch, while the height and width remained constant. Furthermore, a wall was designed inside the fuselage to separate the motor from the other drive components. This dividing wall successfully prevented wiring from contacting the motor housing. A comparison of the first and second iteration of the fuselage is provided in Figure 8.

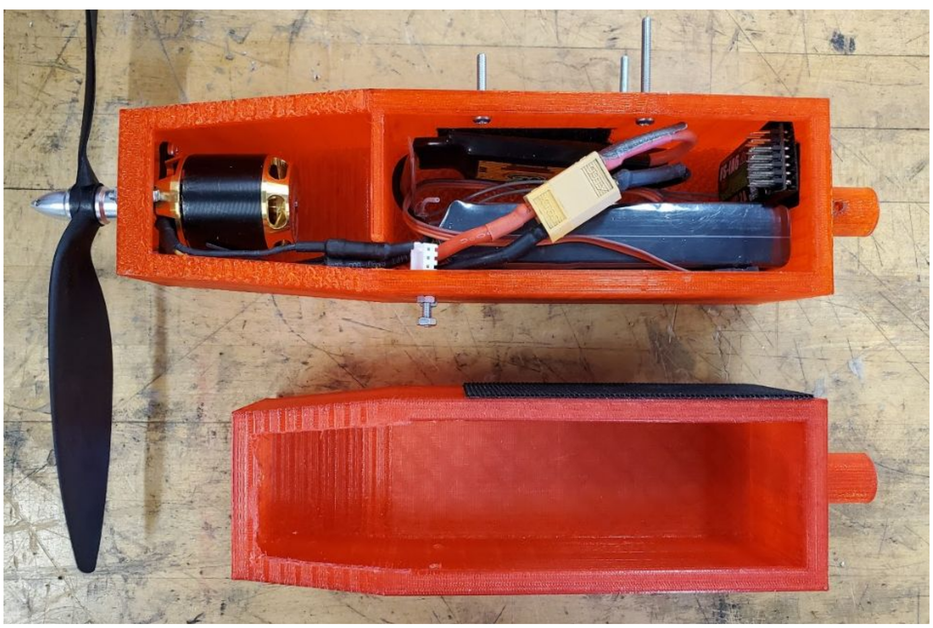

Figure 8: Fuselage Redesign Compared to Original Fuselage

1.2.2 Design Iteration 2: Addition of Elevator to Tail Wing

Initially, the team had planned only using the ailerons and rudder to control the plane but after further inspection of other SUAV's in a glider setup we realized that using the speed of the motor and the lift generated from the airfoils to control the elevation of the glider would not be enough. The task of adding the elevator was not a problem at all, the team used the same method of manufacturing the elevator as they did with the ailerons by trimming the interior blades with the vertical band saw and using a pinned connection on the outer ribs as shown in Figure 9. The team believes that the chances of a controlled flight have increased with the addition of the elevator.

Figure 9: Elevator

1.2.3 Design Iteration 3: Change in Rudder Mounting and Hinging

The final component that was decided upon was how the rudder to tail wing connection. There would be no permanent connection because the wing height and the rudder height exceeds that of the required box all components must fit into. After several brainstorming sessions we realized that the plastic on the coating of the servo motors hot glue binds very well with the thin balsa wood.

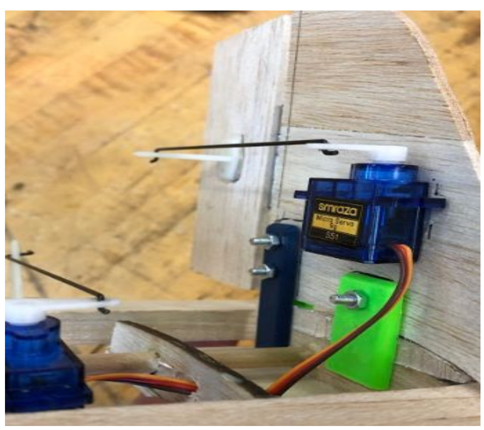

Figure 10: Left side Rudder with servo motors

We decided that if there are 3-D ABS plastic tabs on either side of the rudder then it would be efficient to make and it would hold the rudder in the desired position. Neither of the tab connections will interfere with the rudder servo motor or the elevator servo motor. The rudder tabs are referred to in figures 10 and 11, where it shows exactly how the rudder mounts onto the tail wing. The rudder mechanism rotates around a vertical axis, which is a hinge. The metal is then hot glued onto the balsa wood. The servo motor is on the right side of the rudder, which actuates the flap to turn left or right during flight.

Figure 11: Right side Rudder

1.2.4 Design Iteration 4: Re-Designed Wingspan Connectors

When it came to how the sections of the wings were going to be connected the team had initially planned to use velcro, but after seeing the lack of rigidity of the velcro the team decided on using the connector shown in Figure 12. The part is created from two ribs glued together with two extra holes drilled for 4 inch dowels to be glued in place. The wingspan connector uses two ribs from the wing section on either side to take on the moment found at the center of the connection which proves to be very sturdy and much more rigid than the initial use of velcro.

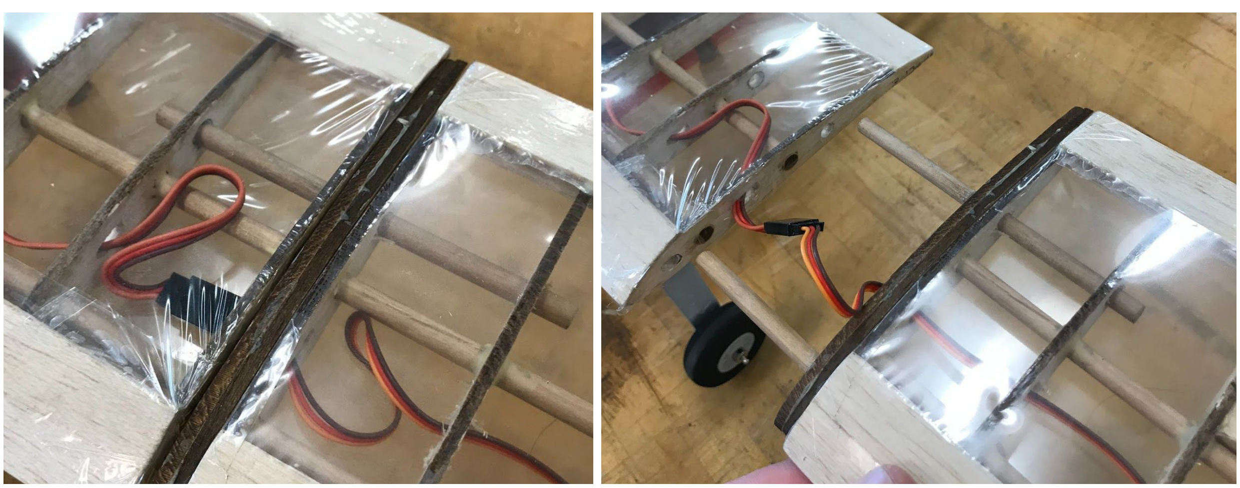

Figure 12: Wingspan connector

1.2.5 Design Iteration 5: 3D-Printed Tail Wing and Rear Landing Gear Mount

In order to mount the carbon fiber rod to both the rear landing gear and tail wing, the original design featured a 3D-printed rectangular prism with a hole for the carbon fiber rod. The top of the prism was glued onto a sheet of balsa, which connected to the tail wing. The bottom of the prism was also glued onto balsa, which connected to the rear landing gear and servo for steering. The original tail wing and landing gear mount is provided below in Figure 13.

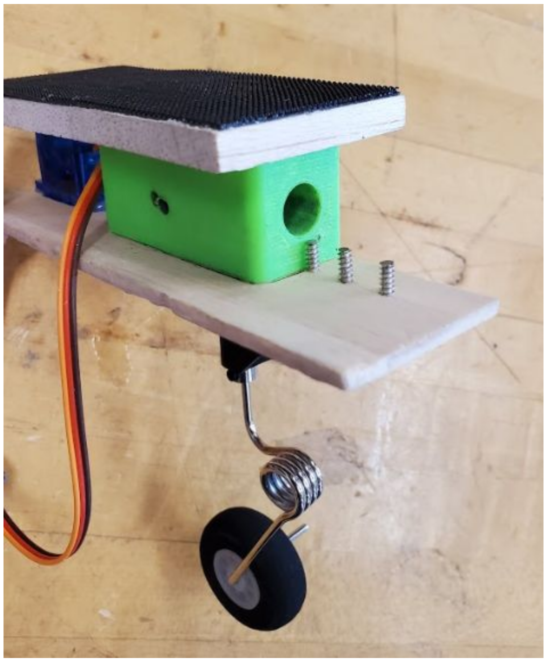

Figure 13: Original Tail Wing and Rear Landing Gear Connector

Upon manufacture, the connection between the prism the carbon fiber rod proved successful. However, the bottom connection that links the prism to the landing gear using a sheet of balsa showed low durability. So, the prism was redesigned to include one uniform piece of 3D-printed material. The redesigned tail wing and rear landing gear mount successfully joined the carbon fiber rod, tail wing, and landing gear using one connector. The new connector is shown below in Figure 14.

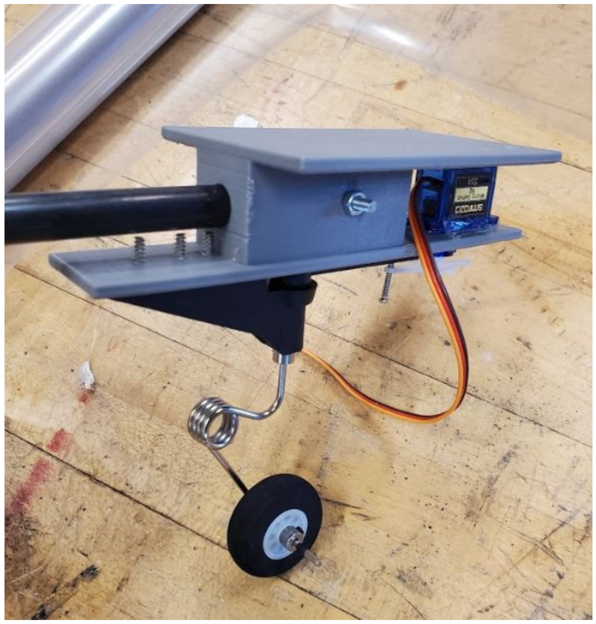

Figure 14: Redesigned Tail Wing and Rear Landing Gear Connector

1.2.6 Design Iteration 6: Bolted Connections at Front and Rear Wings

The original design attempted to connect the bottom of the front wing to the top of the fuselage using heavy-duty velcro. Upon manufacture, the velcro performed well in axial and moment loading. However, the velcro repeatedly failed in shear loading due to induced drag from the propeller. The shear failure caused the wing to wobble, which is unacceptable in flight. Similarly, the tail wing was connected to the rear connector using velcro. The front and rear velcro connections are shown in Figure 15.

Figure 15: Velcro Wing Connections

The solution to the velcro connections was to simply bolt the front and rear wings to the fuselage and the rear connector, respectively. While the bolted connections require more assembly time, the durability and functionality of the wings is greatly improved. The front wing was bolted to the fuselage frame using four M3x20mm machine screws, and the rear wing was bolted to the top of the rear connector using four of the same screws. The bolted connection on the front and rear wings exists in the same location as the previous velcro, shown in Figure 15.

2 Future Implementation

The first manufacturing phase is complete and it spanned over three weeks. The team will perform a flight test on March 6th, and we are prepared for some aspect of the aircraft to not perform well; this eventually means that that component will break, but we will have a better understanding of how to manufacture on a small scale, so the manufacturing time will be a fraction of the time it took previous. Due to the budget that is given, the team has already purchased everything that is required, but the material necessities will change after the testing procedures.

2.1 *Further Manufacturing and Design*

The final manufacturing components for the completion of the first design was performed on February 26th. The week of March 2nd is when all the testing procedures will be performed; the test procedures are the weight/center of gravity test, thrust test, assembly test and then finally the flight test on friday, March 6th. The areas in the aircraft that we are looking to modify after the test flight will be the empennage/tail dragger and the wing connections. The primary reason for the suspicions is due to the reliability in the material while manufacturing the aircraft. If the wing ribs fracture during flight, then the team will be able to produce a more efficient wing frame based on the fact that there were several modifications that were conducted during the manufacturing of the first iteration. The next set of wing ribs will have a more detailed CAD design, which will decrease the manufacturing, compared to the first design, by at least half.

2.2 *Schedule Breakdown*

The schedule breakdown is essentially one assignment or presentation a week until the end of the semester. The important deadlines are the Final Presentation and UGRADS deadlines, and the deadline for these are the last two weeks of April. All of the testing procedures are conducted the first week of March, and then the final product must be completed by the week of March 23rd. All of the team assignments are displayed with corresponding due dates below in figure 16.

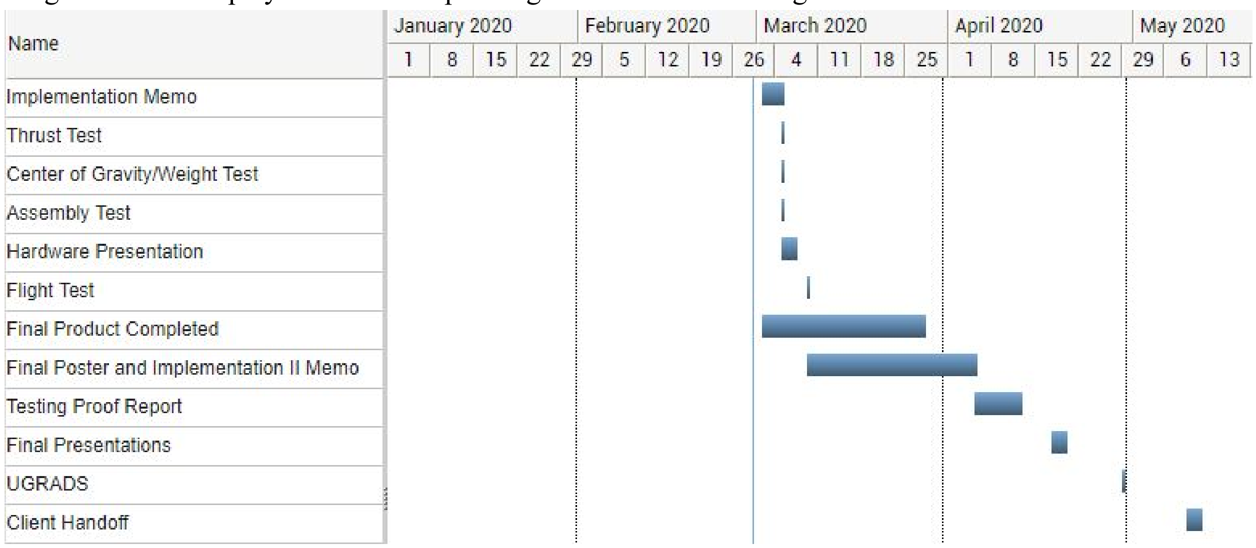

Figure 16: Gantt Chart

2.3 *Budget breakdown*

The manufacturing budget has not been changed since the beginning of the academic year. The limit to the budget that was donated by W.L. Gore is two thousand dollars. Based on the first iteration of our design we have purchased twenty-seven items, shown in Table 1, that have totaled to a little over than a quarter of our overall budget. There are left over parts depending on the component that was purchased, so it will be used to manufacture a second or third iteration. The main components, such as the drive system, motor, and controller will be reused because those components will not be damaged due to the numerous flight tests. We will be spending money on equipment that will be used for the NAU SAE Aero teams in the future.

Table 1: Bill of Materials

Team: Prop Dogs

Part #	Part Name	Qty	Description	Functions	Material	Dimensions	Cost ($)
1	Propeller	1	APC Electric SF 8x4.7	Creates thrust	Plastic	8" diameter	2.45
2	Electric Motor	1	Scorpion HK-2520-1880 KV	rotates the propeller	Aluminum	1"x.8" (Cylindrical)	80
3	RC Controller/Receiver	1	Black controller	Controls the electrical components	Plastic, Metal, electrical Wiring	6"x6"	230
4	Servo Motor	3	Miuzei SG90	Converts the Mechanical motion into digital	Plastics, and metal	1"x1" and 8" wire	11.95
5	Wing frame	2	Small stick components for the frame	Creates Lift	Balsa Wood	1/8" x 1/8" x 36"	19.18
6	Fuselage Frame	1	ABS cage	Houses drive subassembly	ABS	2.75"x6.5"x2.5"	8.35
7	Snaps	10	Metal fasteners	Connects the parts of the plane	Plastic	Diameter = 7/16"	7.99
8	Air Foil (Shrink wrap, tape)	1	Film	Creates an aerodynamic design	Polyethylene	2'x180'	11
9	Wiring	1	Thin, copper wiring	Actuates the Electrical Components	Copper/Aluminum	75"	5.91
10	Battery	1	Lumenier 1800mAh Lipo Battery	Stores Voltage	Plastic, Metal, electrical Wiring	4.1"x1.34"x.079"	20
11	Adhesive	1	Glue	Holds the internal frame in place	glue	N/A	2.47
12	ESC	1	Scorpion Commander 15V 45A	Trasnmits appropriate Amperage to Motors	Plastic, Metal, electrical Wiring	2.83"x1.18"x0.32"	60
13	PVC Pipe	1	Payload PVC	Payload	PVC	2"D x 12"	9.25
14	Wheels	3	Small rotating wheels	Prevents plane from crashing when landing	rubber/metal	3" outer D	4.56
15	Mount fasteners	26	Misumi M2 socket head screws	Fastens plate steel to control surface	Steel	M2x0.4 x 10mm L	10
16	Control horn fasteners	6	Home depot screws	Fastens control horn to control surface	Steel	2-56 thread x 5/8"L	4
17	Shaft collar	4	Tailwing & fuselage to CF rod mount	Connect tail wing/fuselage frame to CF rod	Steel	3/8"ID x 1/2"OD	1.02
18	Plate steel	1	1/16 inch plate steel	Connect fuselage frame to CF rod	Steel	12"x12"x1/16"	0
19	Shaft collar	2	Fuselage frame to front landing gear mount	Connect fuselage frame to front landing gear	Steel	3/16"ID x 7/16"OD	2.27
20	Motor mount	1	Purchased x-mount	Mount motor to fuselage frame	Aluminum	19mm x-mount	6.5
21	Propeller adapter	1	Purchased adapter	Connect motor shaft to propeller	Aluminum	6mm x 4mm	6.5
22	Wing rib birch sheet	26	Laserable wood sheet	Wing ribs support wing frame	Birch	12"x24"x1/8"	4.95
23	Silicone tubing	1	5 ft tubing length	Interference fit for wing assembly	Silicone	1/4"ID x 1/2"OD	$8.90
24	Wing shafts	1	3 ft solid steel rod	Axis of rotation for ailerons and rudder	Steel	1/8" dia x 3 ft	$2.45
25	Control horns	10	Nylon micro control horns	Connect push/pull rod to aileron or rudder	Nylon	20x11mm 4 Holes	7.98
26	Push/pull rods	10	Small push/pull rods 4.72" length	Translate servo rotation to ailerons	Steel	1.2mm dia x 120mm L	$6.98
27	Landing gear rods	1	36 inch zinc rod	Connect fuselage to wheels	Zinc-plated steel	3/16 in. x 36 in	3.3
				Total Cost Estimate:			**537.96**