

# Light Sport Aircraft Control System and Wing-Folding Design

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**May 11, 2007**

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## **Abstract**

The Light Sport Aircraft Folding Wing Mechanism and Control System Design Team, which consists of three team members, David Roncin, Chris King, and Nathan Swanger, developed designs for the folding mechanism and control system of the Messiah College Flying Club's light sport aircraft. We built these systems with the club's specifications and desires for integration in mind. The folding mechanism was designed to reduce the amount of space the plane requires for storage, and the control system was designed to help facilitate the folding movement and provide reliable means to control the plane in flight conditions. A cartridge style tail system was also designed to allow the elevator of the aircraft to detach for storage and maintenance purposes. Our project group's faculty adviser was Dr. Donald Pratt.

## **Acknowledgements**

We extend our thanks and appreciation as a group to Dr. Donald Pratt, who has helped us with the refinement of our initial designs. We would also like to thank him for the countless hours spent talking with us as a group and helping us to learn more about aircraft and the design process.

We would also like to extend our appreciation to the members of the Messiah College Flying Club, who have designed the fuselage that will be used to house our completed designs.

## **Description of the Problem**

The problem that our project addressed was the need of a wing folding mechanism design and control system design for the Messiah College Flying Club. Specifications were generated from data given to us by Dr. Pratt and the Flying Club. Based on desired performance characteristics of the aircraft, we were given numbers related to the movement of the control surfaces. These numbers, along with the expected maintenance of the light sport aircraft, allowed us to come up with thirteen specifications used in our design process. A complete listing of the specifications is located Appendix Table 6. We used these specifications throughout the course of our design process. To measure the final design we came up with five objectives. These are, one, develop a tail design such that the tail is not the width limiting factor. Two, develop a wing folding and unfolding mechanism and technique where a single person can have the wings and tail attached and ready in less than fifteen minutes with basic tools. Three, design and build a linked dual control system with passenger control stick removable by a pin or can unscrew. Four, design all parts so that the MTBF is two years; a yearly inspection would catch the potential for failing parts. Finally, the systems will need lubrication and a basic maintenance check only twice a year. While not all of these are accomplished at this point we feel that with more time all of these objectives can be achieved with our current design.

## Literature Review

From review of *Light Airplane Design* by L. Pazmany and *Pazmany PL-4A Construction Manual* by L. Pazmany we have found the two solutions that he uses for the control system design for light sport and ultralight aircraft are push-pull cables, sheathed cables or aluminum or steel tubes. As aluminum is lighter than steel it is preferred when cost isn't directly a factor. We have utilized these two practices and integrated them into a mixed control system that will use push-pull cables to move the elevator.

There are also two different types of landing gear that are used, tail dragger or tricycle. The Flying Club has already decided on using tricycle style gear as it will have better ground control. This essentially makes the plane easier to control at high speeds while allowing it to make sharp turns at lower speeds. This type of steering is very difficult to utilize with a tail dragger as the back wheel and the rudder are linked, similar to how Pazmany does it in his PL-4A aircraft (Pazmany). Some of the advantages of a tricycle landing gear are that small wing incidence allows for faster acceleration and in turn a shorter takeoff (Pazmany). The disadvantages are increased drag and increased weight of the aircraft.

We haven't yet been able to find an example of a commercially available aircraft that also has detachable elevator and rudder aside from sail planes. This however does not mean they do not exist. We were also made aware while reading Pazmany that the deflection of a tail does not have any significant affect on the aircraft when actuated past 25 degrees in either direction, this again being dependant on the style of tail (Pazmany).

As stated in Pazmany's *Light Airplane Design* folding a low cantilever wing is very difficult as it requires very strong and secure joints. Our light sport utilizes a top wing design which allows for a much simpler wing folding mechanism similar to many of Kolb's (<http://www.tnkolbaircraft.com/>) aircraft. They simply disconnect from the control system and fold back. Typically, cantilever wings fold back on two axes using a universal joint on the trailing edge at the wing root. This means that the person folding has to bear the full weight of the wing while folding it. We have seen a few aircraft that have struts and the wings only fold back horizontally on a hinge at the bottom of the strut and at the wing root trailing edge, leaving a fairly wide "folded" aircraft. However this is not a common occurrence. Some aircraft will simply have the strut detach and require two or more people to fold, what we have tried to work around. Our design combines both of these folding methods, implementing the use of the struts to help support the weight but also folding vertically to further narrow the plane width (Figs. 5.1-5.4).

While there seems to be many methods to connect the control system to the aileron and flaps or in our case the flaperons, Pazmany seems to use push-pull cables, sheathed cables or tubes. Because these two methods seem fairly simple and reliable our design uses these at various stages of the design process. The use of flaperons and our particular mixer design require a solid connection to the flaperons from the control system, essentially dictating that tubes must be connected to the inside end of the flaperons.

## **Alternative Solutions**

Throughout the design process potential ideas were developed, many of which were chosen for one reason, then later abandoned for another. There was no aspect of our project where we did not rework a design at some point.

Our main alternative design for the wing folding mechanism is a circular type bracket that fits around the main spar and allows the wing to rotate and pull out from the central hub in one motion. Once it reaches the fully twisted state the spar will have cleared the clearance holes in the hub shaft enough that it can then fold back on the pin that it twisted about. This alternative design also allows for any pitch down or up of the wing as it folds back because the angle is set by the pin wing section rotates about in the hub shaft (Fig.6.1).

Alternative design for the flaperon mixer is to use a tube in bearings that runs the width of the cockpit behind the control shaft and would rotate upwards or downwards, raising and lowering the point of attachment of the rods that run over and up to both flaperons (Fig.6.2).

Alternative rudder pedal design would be to duplicate our final system but use two control hubs on each separate shaft and then link the two respective ones together to allow for individual adjustment of pilot and passenger sides, rather than adjusting both sides at once.

The only alternative design we have for the tail boom is to set the shafts just through the boom with all components such as bearings and control horns be externally mounted. This would allow for easier maintenance; however our current cartridge design should allow easy access to the bearings and cartridge.

## **Design Process**

Initial designs and plans were focused around accomplishing the various goals and specifications that we and the Flying Club came up with. Initial steps in this process were in acquiring plans for the fuselage as we would have to work around constraints based on its design. We also spent time in the library trying to find information about aircraft design and if there were any particular specifications we would need to keep in mind during the initial design process. Kolb's website was fairly useful for seeing the type of designs we were responsible for developing. Many of our designs needed to be slightly altered over the course of the project due to changes made by the Flying Club to the design of their frame. Making sure they all would fit into the frame of the aircraft was very important to the completion of our designs.

Once we completed the initial paper work such as our project proposal and Gantt chart we were free to start coming up with ideas for how to split up the work and exactly what to do about the problems we had to address. At the same time we were introduced to the idea of working on the rudder and elevator designs as well. We would be responsible for coming up with a way to control both of these control surfaces. Initial designs for the tail section started off very crude, and were pretty much just a series of rods stuck through the boom tube with control horns on the outside. The control surfaces also at this point did not have to be removable and so were mounted to the boom tube.

The first step in the design of our control system was to solve the problem of mixing the two inputs to the control system and producing two outputs. Once this was accomplished designs were drawn up and work began on the full scale mock up. Our design included two control sticks, one removable, connected together by two supports and then attached to the control shaft. Initially the Flying Club had indicated that they would use separate flaps and ailerons for controlling the aircraft. However this eventually changed when the Flying Club decided to use a combination of the two known as flaperons. This meant we had to combine the mixer we had been brainstorming into our control system design. After looking at how some other planes accomplished this (Fig. 6.2) we came up with the idea of raising and lowering the point of the attachment of the rods that would run up to the flaperons. This would allow the deployment of flaps by the sliding motion of one lever that would raise or lower the shaft at the rear, Fig.1. The advantage to this design is the simple motion that is required and the good feedback that the system gets from the flight surfaces in the form of force required to push the lever. The drawback to this however is that the control shaft must have joints added to it to allow this elevated motion while still being able to turn the controls. As with all of our designs, CAD drawings can be found in the Appendix Figure 1.

The rudder control design also went through a fair amount of change. It started out as a large plate that would be mounted on top of another plate and would slide forwards and backwards when a pin would be released. Both controls would be linked together by connecting rods and would move along a base plate. This plate would have hole in set positions where spring loaded pins could engage, locking the rudder assembly in place. Eventually we decide to modify this design due to the massive plate that would be used. The next design used smaller tracks that would house bearings for the link shafts and would be pinned to the corresponding tracks on the floor of the aircraft. As we started work on the full scale mock up, we made a major change to our design. Some pipe joints that we had been using to mount the link shafts together gave us the idea of using a collar type system that would have a spring loaded pin inside it that would have the control horns attached to both sides of it to allow tension from both directions. This allowed the pilot to pull the pin and then adjust the pedals until the pin snaps in. This drastically simplified the design for the rudder pedals and will save material in the long run. This also allowed us to position the unit on the top of the front of the fuselage (Fig. 2.2).

Originally there was not a lot of design work that was needed for the tail section of the aircraft. The decision was made that cables would run along the outside of the boom tube and be attached to exterior control horns on the elevator and rudder. However the Flying Club decided that they would like to use an all flying tail surface, or a stabilator. This meant we had to take another look at the tail section of the aircraft. The design that we decided on was a cartridge style design. It would be housed inside the boom tube and have removable bearing housings to allow the entire surfaces to actuate. Once the cartridge is installed into the boom tube with this design the bearing housing will not be able to work loose due to vibration because the boom tube prevents the screws within the cartridge assembly from backing out. This was desired to ensure that the elevator would remain functional during operation. The control system is connected to the tail cartridge through the use of Teleflex cables and one push-pull cable. The Teleflex cables attach to the rudder pedal control hub and travel down the boom tube to the rudder

control horn (Fig. 2.2). The push-pull cable attaches at the top of the control stick assembly (Fig. 1). The push-pull cable then travels beneath the boom tube to the back of the cockpit, where it then enters the boom tube and runs to the control horn at the back of cartridge. Both control horns located within the cartridge are fitted on a stub tube between the bearing housings (Fig. 3). The cartridge was also designed such that both the elevator and the rudder can be removed from the tail for storage or travel (Figs. 3-4)

The next step we took was brainstorming ideas for the wing folding mechanism. Before work began on the design, the most recent version of the fuselage I-DEAS frame was obtained from Flying Club. By looking at the shape of the fuselage and measuring a few of the dimensions, we were able to get a better idea of how much space we had to work with. A ¼ scale wood model was also construct to help visualize the task of folding. The triangular top of the fuselage and the fact that it is wider at its base proved to be the two most difficult physical obstacles to work around.

The design presented in the fall semester Engineering Design Report focused only on the hinge to attach the wing to the root section. The 6" main spar (it has since been reduced to 5") would be attached through a set of rings that would pivot upwards 90° and then swing back on a hinge (Fig. 5.1). A full-scale wood model of this hinge was made to show at the fall presentation. This was beneficial to visualize the folding, but didn't help to prove the design's worthiness. At this point, we knew that some of the skin covering the root section would have to be removed in order to fold the wings, and this hinge design required removal of approximately a 14" section all the way across the root section. For this fall report, attachment of the spars to the tip of the triangle on top of the fuselage was not considered. Motion of the struts that support the wings was minimally considered for this initial design; we knew the strut would attach to the center of the wing, but how it was involved in the folding process became priority towards the end of the project.

At the beginning of spring semester, it was decided that this initial hinge design should be drawn in with the fuselage, root section, struts, and wings. Since we knew there would be redesign occurring and drawing would have to be changed fairly quickly, the free software Google SketchUp was chosen over I-DEAS because parts could be drawn, rotated, and deleted much more easily. At first, just the attachment triangle, root section, and wings were drawn in both the folded and unfolded positions (Fig. 5.2). The struts were attached at a point directly underneath the folding hinge and it seemed like the folding motion would work. The struts, however, would have to elongate (we called it telescope) over 18" as the wing folded backward. This telescoping happens from a combination of the center axis of the main spar being raised up about 3" plus the main spar swinging away from the root section about 5". If the strut telescopes, it would no longer support the weight of the wing while folding, leaving the person folding it having to lift it all on their own; this caused concern for meeting our objective of one person being able to fold the wings. From this first SketchUp drawing, it was also realized that the wings would not be able to physically move between the two positions; allowing the wings to swing down 90° would cause the trailing edge of the wings to hit the wider base of the fuselage.

After becoming aware of these two problems, the entire fuselage frame was transferred between the two software applications to make sure any new designs would physically fit with the fuselage. In order to overcome issue of the trailing edge hitting the

fuselage, the idea of having an angled rib was presented. The ribs of the root section were moved inwards 5” and the spar was allowed to rotate in the hinge ring to eliminate the upward motion of the main spar axis. Also, an assembly for attachment of the main spars to the fuselage triangle was designed (Fig. 5.3). In order for the wings to fold, bolts going through the H shape will need to be removed (shown in light blue), as well as a section of the rear spar (shown in orange). The main spar will rotate down a little further than 90°, then the hinge (shown in red) can swing back to complete the folding of the wings. Once these new designs were produced, we obtained approval to construct the full scale mockup of this part of the project. Even though the strut wasn’t figured out, we hoped being able to move and measure something full size would prove whether a telescoping strut could be eliminated or if that was impossible. After the non-functioning prototype was completed, the SketchUp file was changed to match, including four models in different stages of folding.

### **Implementation of Design**

The majority of our design implementation was based on work in the Low Street garage. Following some scale models made from Legos and wooden sticks we desired to explore our ideas with a more realistic model. Initially we began by testing our ideas using electrical conduit. We created a mock wooden rib and a spar to get an idea of how large the wing would be. We then add on a wooden root section to attach the mock wing. This initial setup was however scrapped due to a change in the fuselage shape during the fall semester. Because of the amount of changes experienced with the evolving project we decided to return to more adaptable mock models.

Using Legos, we created a model of our control system design. Although the pieces did not allow a completely accurate version of our design we were able to see and fix some problems in our system. The biggest problem we found was the tendency for members to seize due to their limited rotation. This problem was corrected by adding u-joints in our design where needed.

After answering some of the problems we were confronted with by the Lego model we returned to the mock airframe and made an actual size model. In order to keep project costs down we used less expensive materials, like PVC and wooden dowels to create our models. During this process our designs changed and we implemented new ideas to improve our system. One of the major changes we made was the rudder pedal adjustment design from sliding to pivoting about a single point. This idea focused around a spring loaded pin that would allow our rudder cable to be mounted in a fixed position.

Following the creation of a full size mock control system we began work on the folding wing aspect of the project. In order to simulate the full wing we cut out plywood ribs to the correct airfoil. The angle ribs were made by projecting a shadow of the normal rib 20° against a wall and tracing it on paper. Using cardboard carpet tubes to simulate the main spar, we created a model wing (minus the skin and most ribs) to replicate the wingspan of the aircraft. This allowed us to see how the wing would fold and roughly how long the aircraft would be. The mockup was also instrumental in seeing if the folding system could possibly work without having the strut telescope, which was one of the more difficult aspects of the folding wing mechanism design. It was found that if a separate hinge is added approximately 14” away from the fuselage, which becomes



parallel to the fuselage when unfolded and a bolt can be put through into the fuselage, the strut does not need to telescope. Also, the strut will be attached forward of the main spar, which was desired for keeping the wings from sweeping back too much in flight (Fig. 5.4.).

We learned a lot from our mockup processes, mainly how every component would interact with each other. This was crucial for analyzing the effectiveness of our designs, so that we might look into redesign of certain aspects that were not satisfactory.

### Gantt Chart

The major impact to the project's schedule was the introduction of new responsibilities and changes made to previously specified designs, such as changes made to the fuselage and moving from rib design work to the tail cartridge. These setbacks generally caused major changes to our current design, and constituted the majority of design changes pre-full scale mockup (Fig. 8).

### Budget and Production Cost

<b>Project Spending Limit</b>		<b>\$500.00</b>
<b>Project Purchases</b>		
<b>Item</b>	<b>Description</b>	<b>Price</b>
1	Bearings	\$44.80
2	Cartridge	\$95.39
3	4130 Tubing	\$186.96
4	Wood	\$40.51
5	Hinges	\$14.56
6	Fixtures / Miscellaneous	\$8.97
7	PVC	\$20.69
8	Gorilla Glue	\$2.94
<b>Total Cost of Purchases = \$414.82</b>		

<b>Estimated Prototype Cost</b>		
<b>Item</b>	<b>Description</b>	<b>Price</b>
1	Bearings	\$44.80
2	Cartridge	\$95.39
3	4130 Tubing (.095 " wall)	\$140.00
4	Fixtures / Miscellaneous	\$50.00
5	Cable Sheathing	\$35.00
6	7 x 7 (1/16") Stainless Steel Aircraft Cable	\$8.00
7	Teleflex Cable	\$75.00
<b>Estimated Total Cost = \$448.19</b>		

The critical components of our project contribute to the majority of our budget. The budget (Shown Above) takes into account the cost of prototyping our project.

Approximately \$60 worth of materials will not be needed for the final design. The wood and PVC used will be replaced with steel tubing. Along with these changes the final design will require less steel than originally budgeted. During the prototyping phase we overestimated the amount of steel needed by about \$90. This brings the total final project cost down to \$340. This cost could further be reduced about \$20 by ordering parts earlier and with slower shipping. Machining costs are not covered in this budget but should be taken into account due to the labor required.

## **Conclusions**

Over all we feel that our project has achieved an acceptable level of accomplishment. We did not have enough time to construct and a fully functioning prototype of the control system or wing folding mechanism. However this is not a significant problem as the actual frame has not been completed by the Flying Club as of yet. We have also started work on a tail cartridge prototype in John Meyer's shop in the basement of the Frey Academic building. As we have found from our non-functional prototypes, made of inexpensive materials our designs meet the specifications that were given to us by the Flying Club and have met the following objectives we laid out at the beginning of the academic year.

The objective of developing a tail design such that the tail is not the width limiting factor was successful as our tail design incorporates a removable elevator and rudder. Our second objective of developing a wing folding/unfolding mechanism and technique where a single person can have the wings and tail attached and ready in less than fifteen minutes with basic tools was about half met as we believe from the mock up that one person can fold the wing, we currently have no way of testing the time allowance that is needed. Our third objective to design and build a linked dual control system with passenger control stick removable by a pin or can unscrew was completely met. The design only requires the passenger side stick to have to be removed to allow the stretcher to fit in place. Our fourth and fifth objectives, design all parts so that the MTBF is two years; a yearly inspection would catch the potential for failing parts and the systems will need lubrication and a basic maintenance check only twice a year, can not be tested at this point as actual functioning prototypes will be needed to perform this type of analysis.

With a design oriented project it is hard to quantify the amount of time that will be spent just brainstorming ideas to look into. The majority of time is spent on this endeavor and looking into the functionality of your design. It is also very important to never back yourself into a corner, where you are stuck with a certain design because something else that you have already decided on has certain requirements. We also learned how to go about the process that is coming up with a design from scratch.

Good communication is essential to preventing conflict between parties involved in design, construction or purchasing. Over the course of this project we also got to see the ordering process and learned that some parts take a while to ship once they are ordered.

Our biggest lesson was that your final design isn't always what you had drawn up before you start work on models, mockups and prototypes. Using prototypes allowed us to make helpful modifications on our design ideas. Often times it was hard to visualize

how a certain part will function with another. The prototyping process allowed us to test our ideas while using inexpensive materials.

### **Future Work**

The plane as a project has much more that needs to be accomplished before it can fly. As far as the aspects that we are responsible for there is some work that we anticipate will need to be accomplished in the future.

Finite element analysis will need to be done on both the control system and the wing hinge. The control systems will likely not be subjected to large forces however it would be nice to know what will be expected. Also the material choice could potentially be changed if the forces prove to be small enough. The hinge analysis will be needed to show the stress concentration in the hinge and if they need to be reinforced for use in the actual aircraft. Also fatigue testing will need to be done on the actual hinge once one is constructed so that MTBF can be estimated, and a plan for inspection can be formulated.

Along these same lines the control system will have to be constructed out of a more suitable material than what was used for the mock up. Material selection should be assisted by the FE analysis done on the control system design.

We wanted to include plans for a trim tab system to be incorporated into the control system; however time did not allow such. This would be one area that the Flying Club should invest time designing as it will make flying the aircraft extremely more enjoyable. A trim tab prevents the pilot from having to hold back pressure on the control stick during flying.

Also as stated in our alternative design for the rudder pedals, we would like to see a change made to allow for independent rudder control. However this is purely an ergonomic change.

## Bibliography

### General Design Information

1. Aircraft Detail Design Manual / [by S.J. Dzik], [TL671.2 .D95 1988](#), [Dzik, Stanley J.](#)

This book shows different examples of aircraft design. We looked at examples related to aircraft control systems. One system displayed went over the layout for front and rear dual controls (Dzik, 17). This design utilized tubing and cables. Some of the concepts shown can be used for our design using sheathed cables. For more reliability we can remove the free cables and replace them with a pair of sheathed cables. This book is also displays multiple ways to connect joints.

2. Kolb Mark III Extra Assembly Manual (compact disc)

This source contains PDF files of the assembly procedure for a Kolb Mark III aircraft. This source is significant because it illustrates the design elements we will need to deal with in the future, like rib profile, folding mechanism parts, and control system elements.

3. <http://tnkolbaircraft.com>

The New Kolb Aircraft's home page

4. AeroCrafter: The Complete Guide to Building and Flying Your Own Aircraft  
[TL514 .A37 2001](#)

Oshkosh, Wis.: AeroCrafter, c2001.

This magazine is mainly useful for referencing other light sport and ultra light aircraft. There are also several articles that are related to do-it-yourself aviation that could be useful when constructing our models or prototypes. There is also a finance calculator located on the cd-rom disc that accompanies the magazine that could be useful in setting up a preliminary budget.

5. Aircraft welding / Compiled and Prepared by Paul Poberezny and S.H. "Wes" Schmid.  
[TL671 .P63 1994x](#)  
[Poberezny, Paul H. \(Paul Howard\), 1921-](#)

This book demonstrates various techniques for welding steel and aircraft quality aluminum. This could prove useful if we decide to weld the ribs in position on the main spar as apposed to gluing them.

6. Light Airplane Design Course I and II.  
[TL671.2 .L54 1970x](#)

Theses two books contain helpful information on complete airplane design. In our case we will focus on various drawings related to wing construction. We saw a method of constructing wing ribs that involved the use of a wooden jig to properly align the individual ribs on the main spar. Drawings of folding wings were also displayed in this manual. These manuals will allow us to visualize different methods of wing design.

7. Light Airplane Construction  
[TL671.2 .P382 1970x](#)

### [Pazmany, Ladislao.](#)

This manual describes multiple techniques for rib manufacturing. The manual also covers leading and trailing edge wing construction. Some of the leading and trailing edge drawings shown differ from the Kolb design. We noticed that instead of a large center spar tube, two smaller tubes of the same side were used at the leading and trailing edge. The larger center spar tubing was replaced with T brackets. This along with other ideas will allow us options for our wing design.

### **Control mixing literature**

1. <http://www.zenithair.com> (assembly manual drawings of control system)

The website for the STOL CH 701 includes manuals for the control system the manufactures installed. The design has integrated (motorized) flaperons.

### **Rib profile/construction literature**

1. <http://mysite.mweb.co.za/residents/dwg/wings/wings.html>

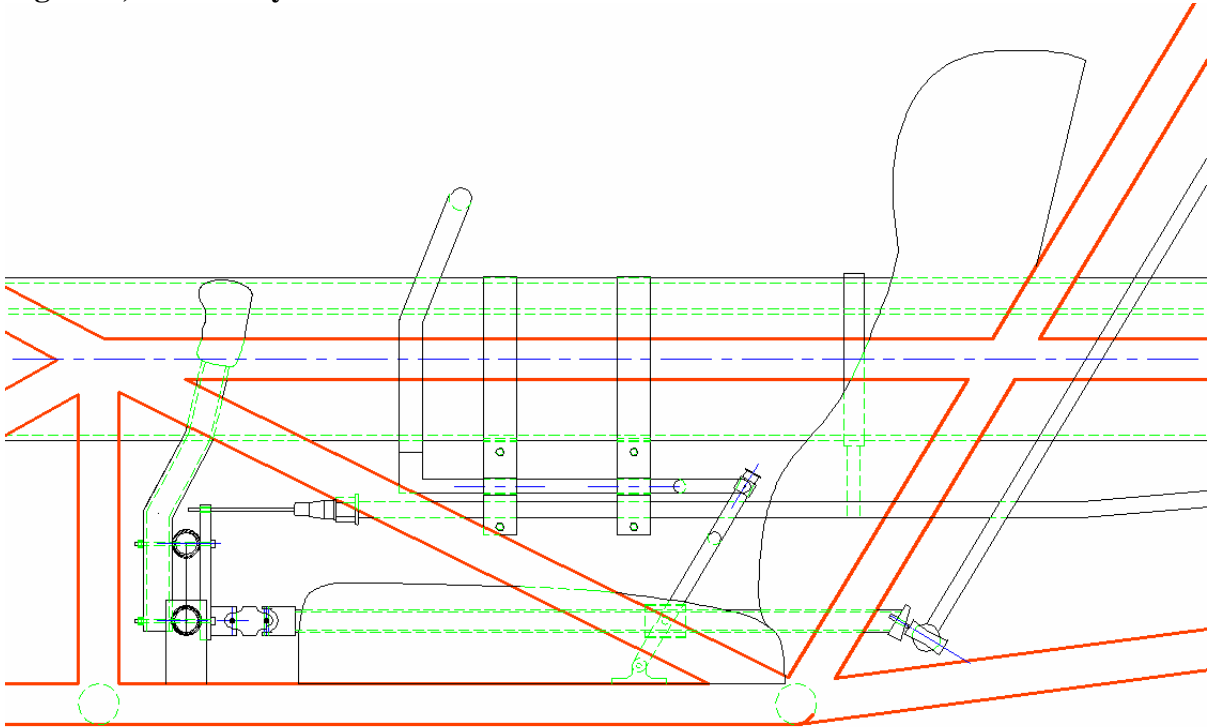
This site offers various pictures throughout the construction of an ultra light wing using glue as a method for securing the ribs to the main spar.

2. [http://en.wikipedia.org/wiki/NACA\\_airfoil](http://en.wikipedia.org/wiki/NACA_airfoil)

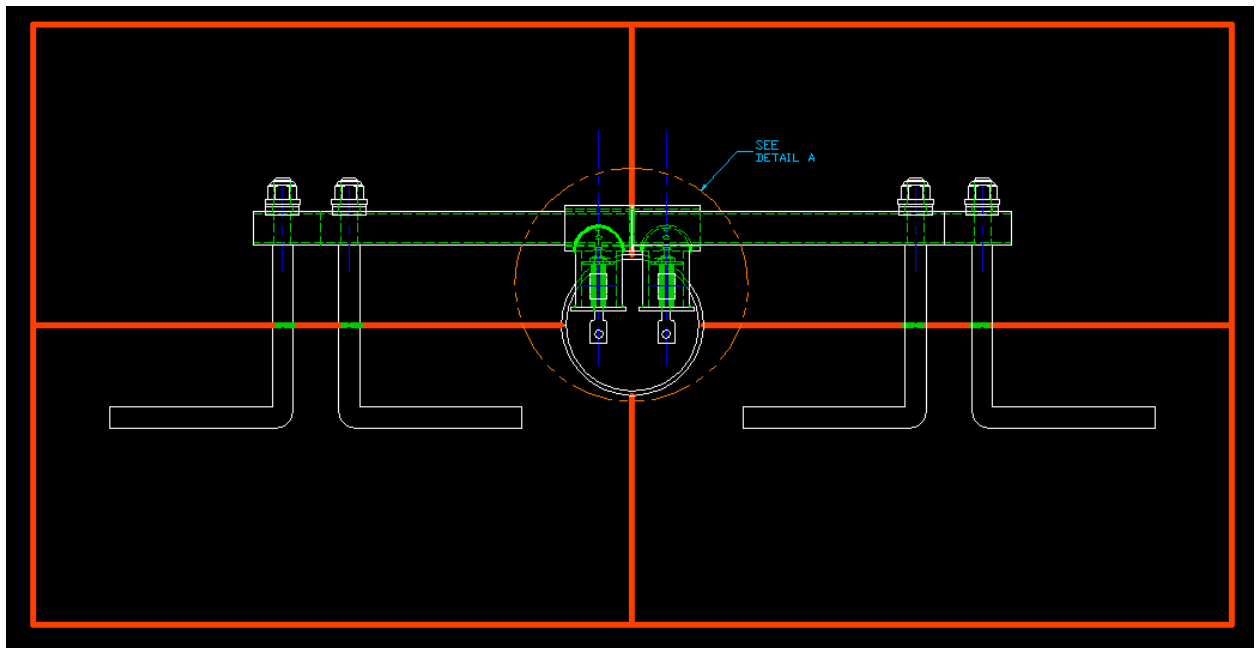
This web site various information about both the number of and the various uses for the different NACA airfoil profiles. This site and others like it could be very useful should we decide that a NACA airfoil would be suitable for our applications.

## Appendices

**Figure 1; Control System**



**Figure 2.1; Adjustable Rudder Pedals**



**Figure 2.2**

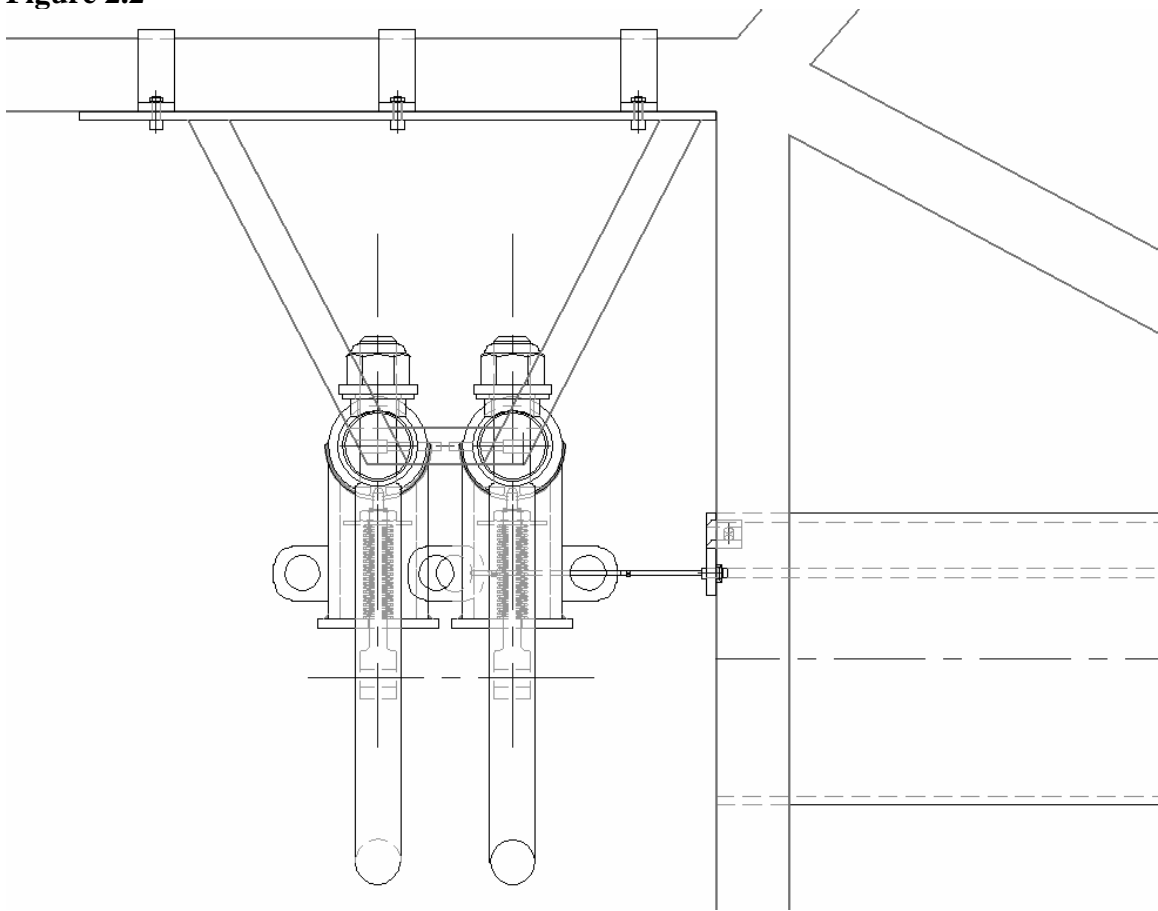


Figure 3; Tail Cartridge Assembly

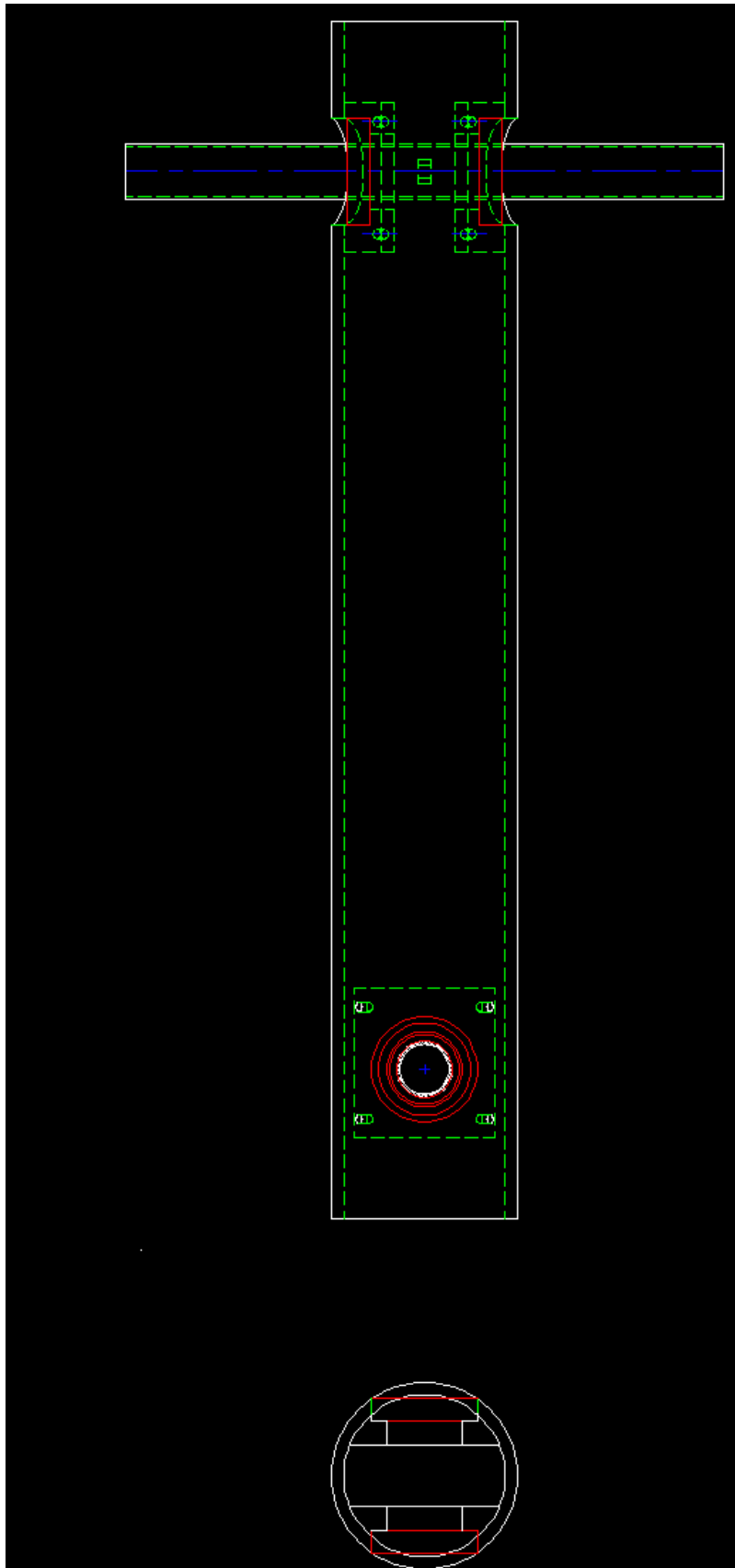
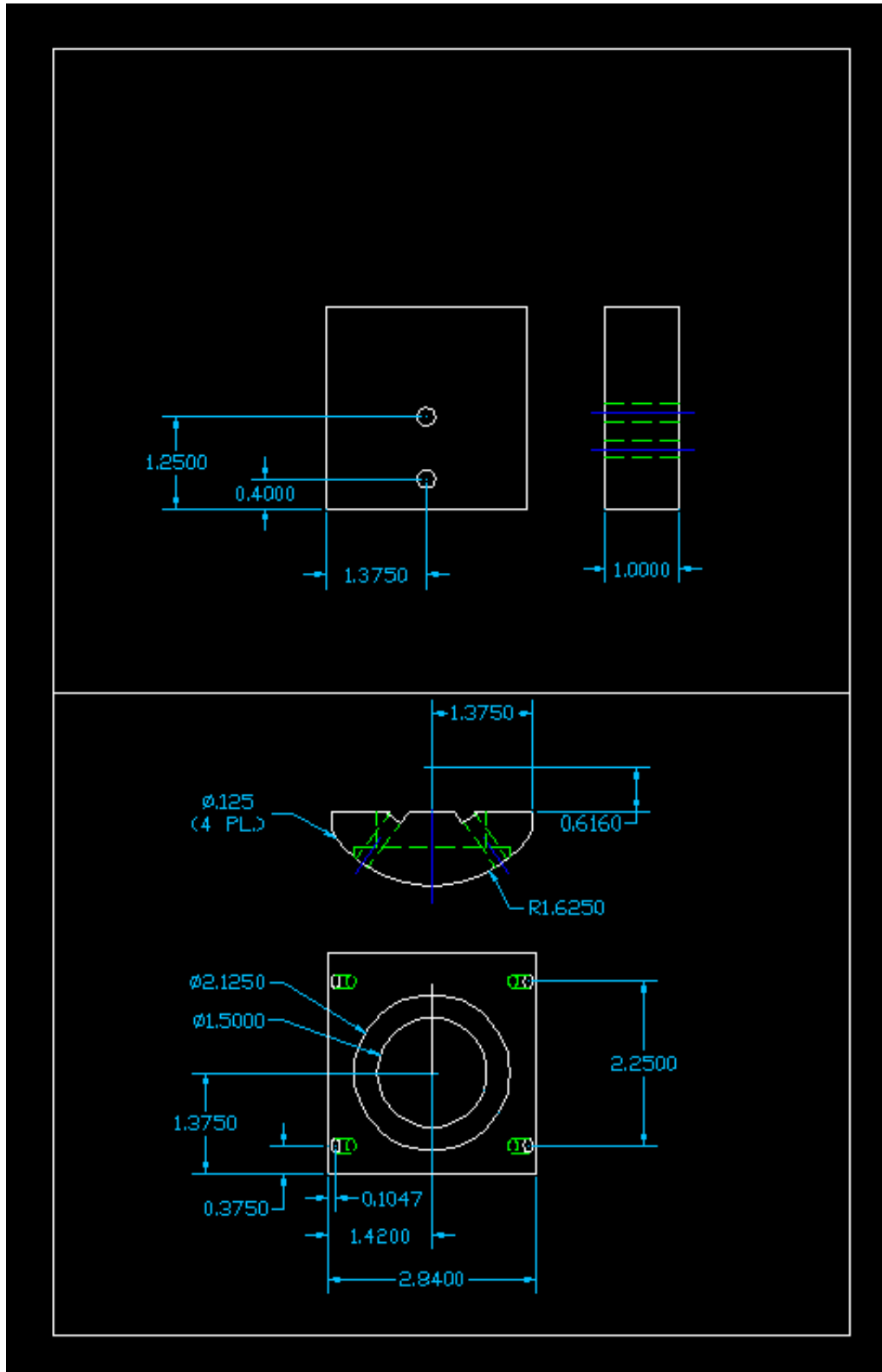


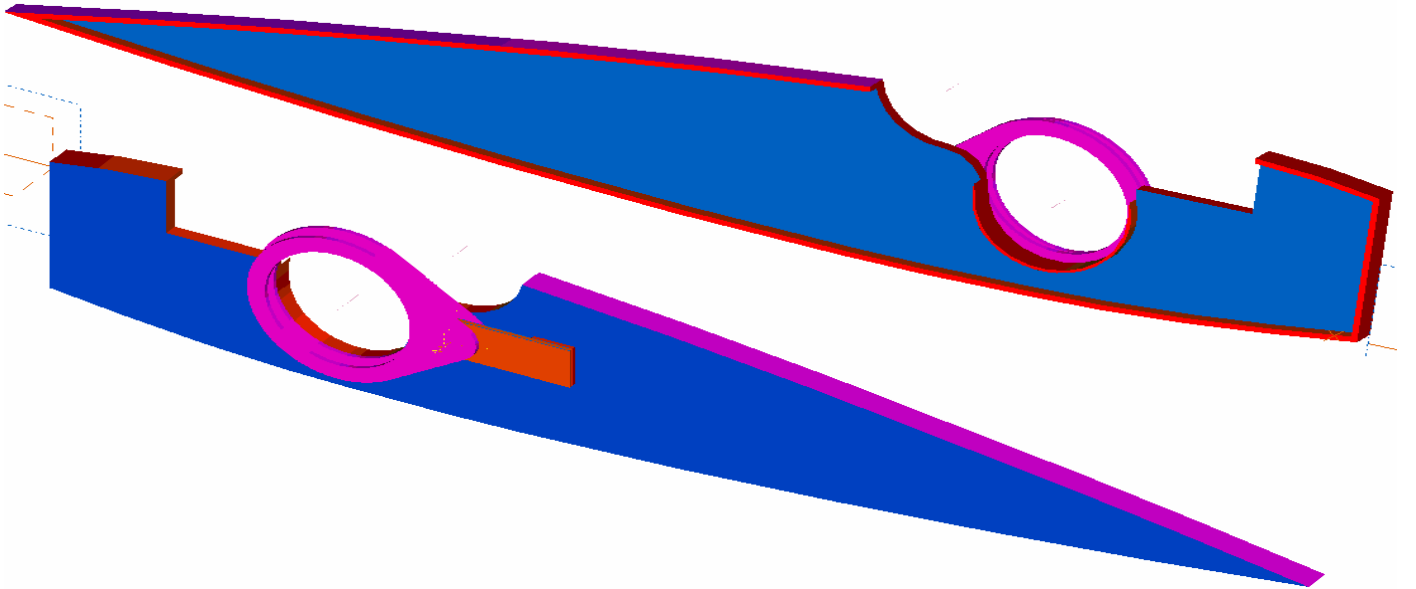


Figure 4; Bearing Housing

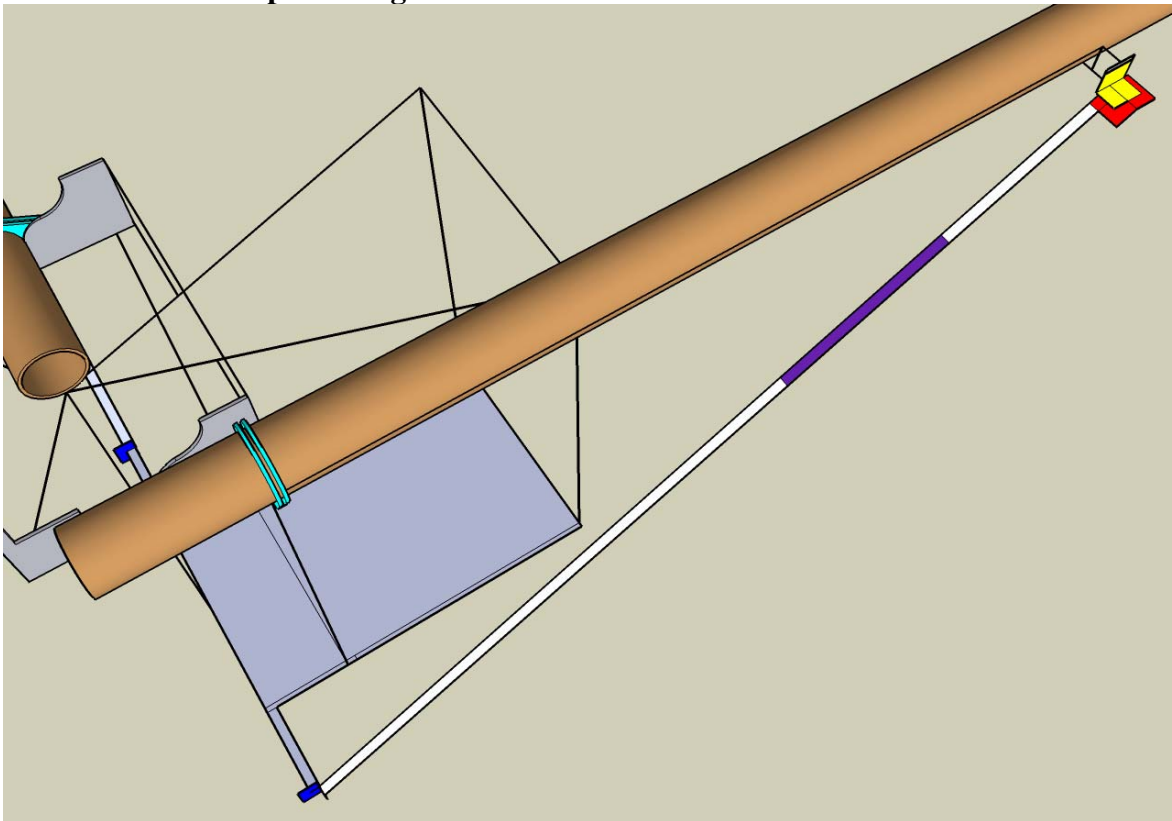


**Figure 5; Folding Wing Mechanism**

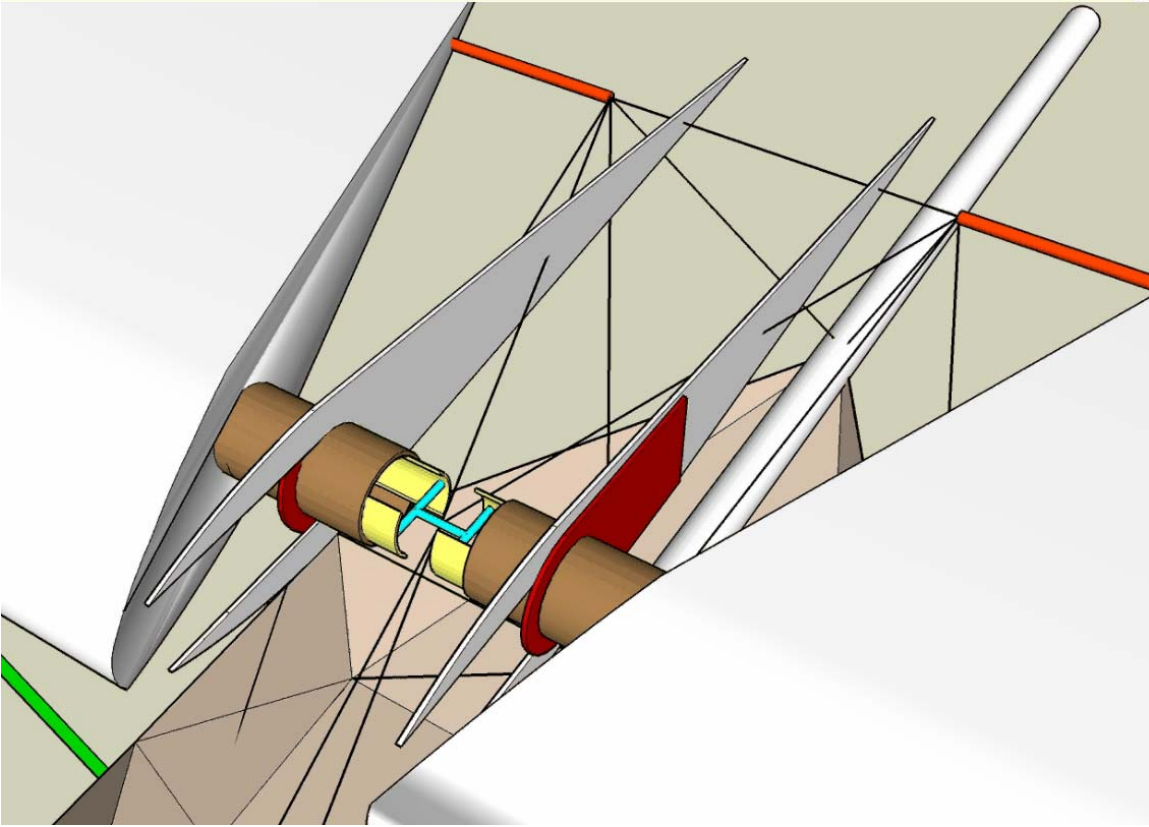
**5.1 Fall Semester Hinge Design**



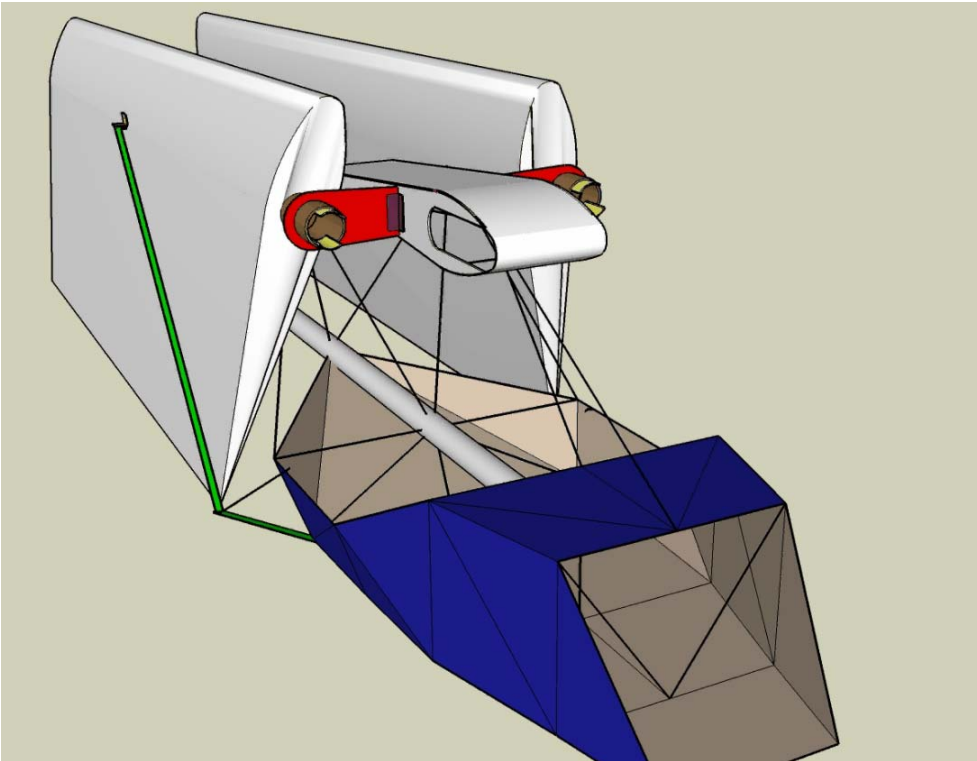
**5.2 Initial SketchUp drawing**



### 5.3 Angled Rib and Triangle Attachment Assembly

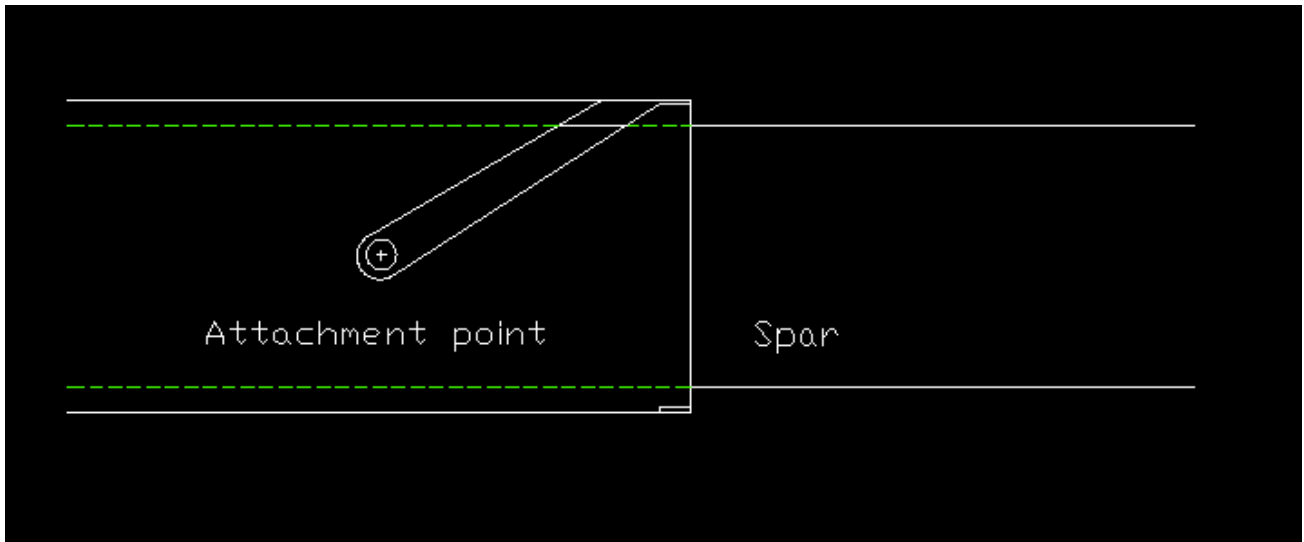


### 5.4 Strut Joint

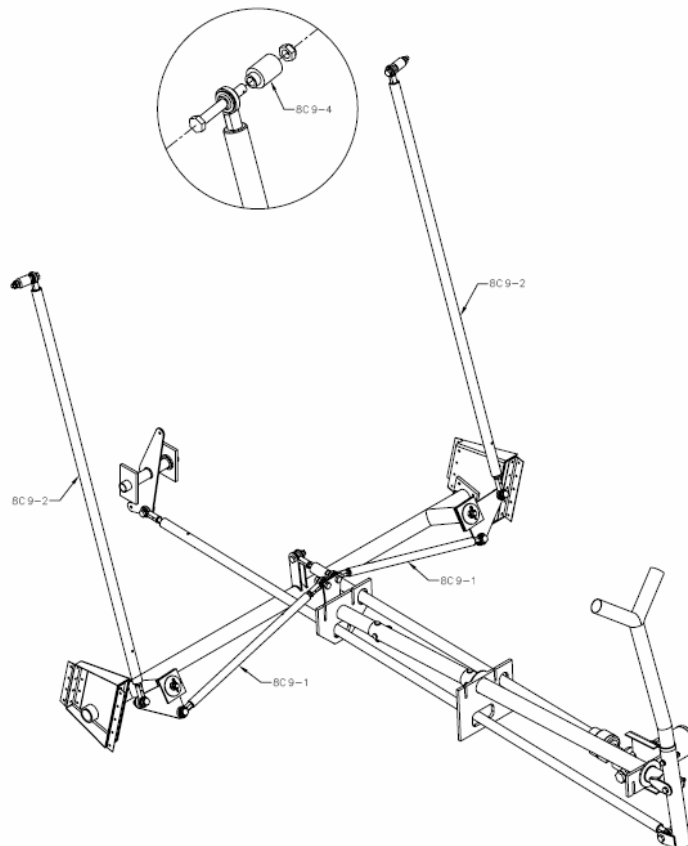


**Figure 6; Alternate Design**

**6.1 Alternate Spar Folding Design**



**6.2 Alternate Flaperon Mixer Design**



## Figure 7; Specifications

### LSA Folding wings and controls System Spec Sheet

1. Task of wing folding should be accomplished by one person.
2. Wing folding should take no more than 15 minutes with basic tools.
3. Bi-annual maintenance requirement
4. Wings should fold to a degree where propellers limit the width of plane for storage.
5. Struts should be able to fold with the wing or detach from the wing for folding.
6. The main Spars need to be securely joined at the hub to balance bending moment generated by the wing.
7. Flaps should have 8° of positive movement and 5 ° of negative movement.
8. Ailerons should have 10 of positive and 15-20° of negative movement in both directions.
9. Elevators on tail should fold or detach for storage and the tail should not interfere with wing folding process.
10. Elevator must have the ability to be trimmed in flight.
11. Control system needs to be a linked dual control.
12. Tail profile need to counter act the pitching moment caused by the airfoil.
13. Control system parts should remain intact at all times excluding the passenger side controls. Passenger side controllers must be removable to accommodate a passenger lying down.

**Figure 8; Gantt Chart**

