ABSTRACT

MANASA, ALEXANDER JOHN. Design of Landing Gear Strut for the Vampire Light Sport Aircraft. (Under the direction of Dr. Charles E. Hall Jr.).

This paper covers the design of the main landing gear strut for the Vampire Light Sport Aircraft, owned by LSA America Inc. The purpose of this work was to improve upon the existing landing gear strut by decreasing its weight while meeting the ASTM strength requirements for light sport aircraft. This was done by analyzing iterations of the new design using ANSYS 'Static Structural' software. Once a design was found that did not to have stresses exceeding the fatigue stress of Aluminum 6061-T6, a physical model was constructed. A proposal for a static load and drop test was written and is available for future work. The aerodynamic drag of the strut was also analyzed, and a faring was made for the new design. The final weight of the new strut is 2.2 kg which is 42% lighter than the original 3.8 kg strut, saving 3.2 kg off the total aircraft weight. The reduction in drag due to the faring reduces the power required at cruise by about 1 kW (1.4 hp) over the original strut design.

Design of Landing Gear Strut for the Vampire Light Sport Aircraft

by
Alexander John Manasa

A thesis submitted to the Graduate Faculty of
North Carolina State University
in partial fulfillment of the
requirements for the degree of
Master of Science

Aerospace Engineering

Raleigh, North Carolina

2013

APPROVED BY:

Dr. Charles E. Hall Jr.
Committee Chair

Dr. Kara Peters

Dr. Arkady Kheyfets

DEDICATION

Dedicated to my parents Harold and Norma, and to my sisters Catherine and Stephanie

BIOGRAPHY

Alex Manasa was born to Harold and Norma Manasa in Dhahran, Saudi Arabia where his father worked as an accountant for the oil company Saudi Aramco. Soon afterwards, he and his family moved to Miami, Florida where his sisters Catherine and Stephanie were born. After living in Miami for seven years he moved to Anderson, South Carolina for four years, and then moved back to Dhahran for four more years. There he attended an American curriculum school where he was exposed to much cultural diversity. Upon graduating from Dhahran Middle School in 9th grade, Alex and his family moved to Charlotte, North Carolina and attended Charlotte Catholic High School. After graduating in 2007 he enrolled in North Carolina State University to study Physics, but later switched to Aerospace Engineering. Alex graduated in the spring of 2011 with a Bachelor of Science in Aerospace and a Minor in Physics and was immediately accepted in the graduate program at NCSU. There he studied to achieve a Master's Degree in Aerospace with a Minor in Mathematics.

ACKNOWLEDGMENTS

I'd like to thank my advisor, Dr. Chuck Hall, for giving me the opportunity to work on this project, as well as for all the classes I've had with him, especially senior design.

I'd like to thank the folks at LSA America, particularly Doug and Kyle, for providing this project and for all the help and advice they gave along the way.

I'd like to thank my parents for supporting me and my education throughout my life, and for not being "helicopter parents" during my time at NCSU.

Finally I'd like to acknowledge all my friends at NC State, particularly my Flight Research friends Lars and Robert. Without you guys, my time spent working on this project wouldn't have been nearly as enjoyable.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter 1: Introduction

The "Vampire Light Sport Aircraft" is a Light Sport Aircraft in its prototype stage. Originally developed by Sadler Aircraft, it was put up for sale in 2010 and bought by LSA America Inc. The Vampire LSA was designed to be a two-seat version of the original single-seat Sadler Vampire designed in the 1980's and is based off of the military ground-attack aircraft Sadler Piranha [1]. A picture of the single seat and two seat versions with their wings removed are shown in Figure 1.

Figure 1: Single-Seat Vampire (left) and Two-Seat Vampire (right)

Because the new Vampire was only in its prototype stage when it was acquired by LSA America, there are several aspects of the aircraft that have been considered for redesign including the landing gear, aft fuselage shape, engine, and fiberglass lay-up schedule. This paper covers the redesign of the main landing gear struts. Originally this project was to include the conversion of the caster nose wheel to a steerable nose wheel. However, this was dropped as the increased weight from the supporting structure around the wheel would more than cancel out any weight savings gained by the main gear redesign. The aircraft instead steers via braking.

In order for the Vampire to be in the Light Sport Aircraft category as defined by Chapter 4, Section 6 of the FAA Order 8130.2G [2], it must, among other things, have a maximum take-off weight of less than 600 kg (Note: In this document weight and force will be given by their mass equivalent in kilograms). However, upon acquiring the aircraft LSA America found that this limit was exceeded when fully loaded with two occupants. To help reduce the overall aircraft weight and achieve LSA certification, the landing gear struts were chosen to be redesigned to be lighter while still bearing the landing loads of the aircraft. The landing gear struts were chosen because they were made of steel tubing and plates welded together, which made for a heavy design. Aerodynamic drag produced by the fixed gear was also taken into consideration during the redesign. An additional requirement for the redesign was that the new strut must be compatible with the current design of the aircraft in that it attaches to the aircraft in the same way as the old strut. It must also be able to be manufactured by the personnel at LSA America.

Iterations for the new strut design were made using SolidWorks design software and then analyzed using ANSYS ‘Static Structural’ software. Changes between design iterations were made to keep the maximum principle stresses below the fatigue stress limit for Aluminum 6061-T6, while still maintaining a design that weighed significantly less than the original strut. After a suitable design was made on the computer, a physical test model was produced. A proposal for static and dynamic load tests on the strut was written to verify the integrity of the design. This test has been saved for future work.

The drag produced by the strut was analyzed by creating a model of the domain surrounding the strut and importing it into ANSYS 'Fluent'. The flow was modeled at the cruise condition to simulate drag, and a drag coefficient was found. The new strut design was analyzed with and without a faring and compared to the original strut design.

Chapter 2: Design Phase

2.1 Design Requirements

In order for an aircraft to be considered a Light Sport Aircraft, FAA Order 8130.2G [2] states that it must have fixed landing gear (unless it is amphibious or a glider), and that the gross weight of the aircraft is less than 600 kg. ASTM Standards give the static load requirements for testing the landing gear [3]. These static loads are shown in Figure 2.

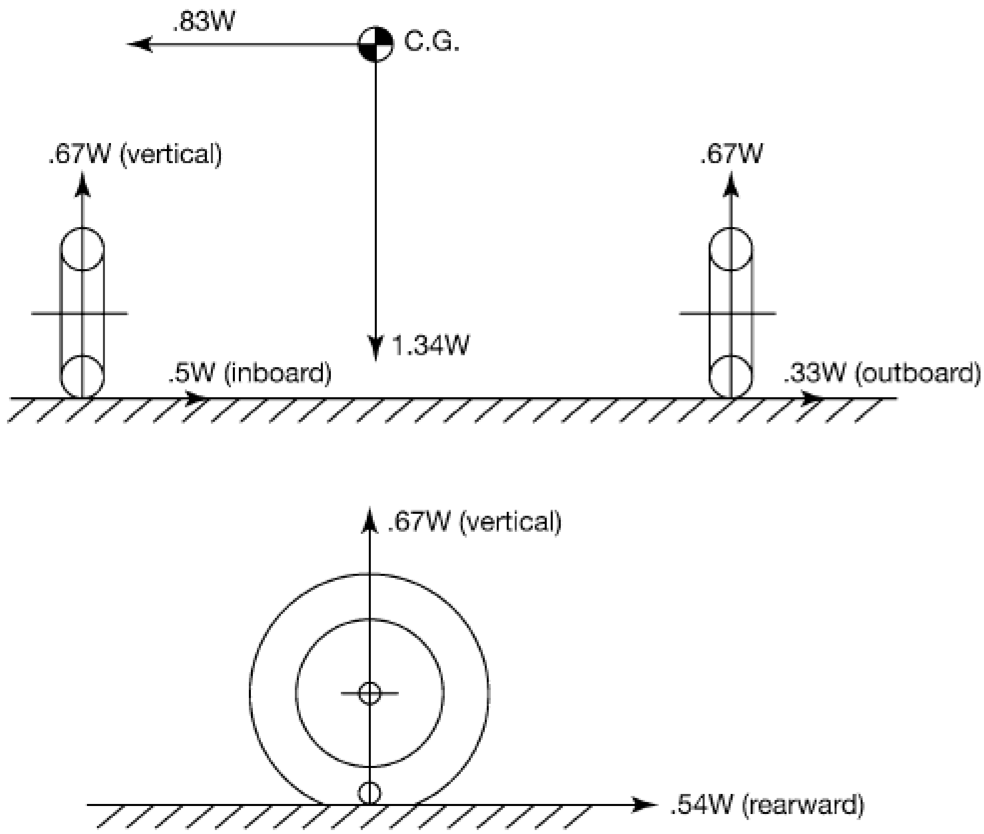


Figure 2: ASTM Landing Load Conditions [3]

In the figure, *W* stands for the weight, which for this aircraft is the maximum LSA weight of 600 kg. This figure shows that each wheel must be able to withstand a static loading of 0.67W in the vertical direction, 0.54W in the aft direction, 0.5W in the inboard and 0.33W in the outboard direction. Each of these force components are meant to simulate the different conditions on landing i.e. impact, braking, and any sideways forces resulting from a bad crosswind landing. These forces are summarized in Table 1.

Table 1: Static forces applied to wheel for landing simulation

Direction	Force Component	Force (kg)
Vertical	0.67 W	402
Aft	0.54 W	324
Inboard	0.50 W	300
Outboard	0.33 W	198

2.2 Material Selection

The original strut for the main landing gear was made from a steel pipe welded to steel plates such that it could mount to the wheel axle and to the aircraft. While undoubtedly cost effective, the design is relatively heavy with a mass of 3.8 kg. A three view drawing of this design made from a CAD model is shown in Figure 3, and a picture of the actual strut is shown in Figure 4.

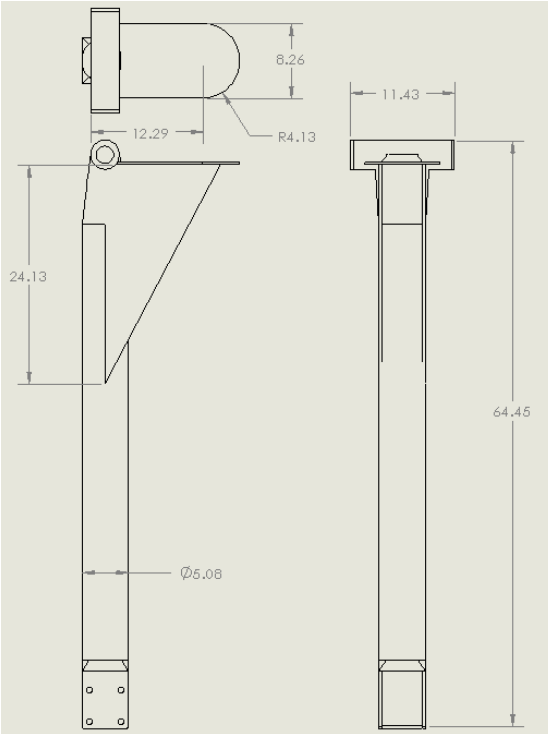


Figure 3: Three-view drawing of Original Strut (cm)

Figure 4: A free strut held next to a strut that's currently installed

To reduce weight, aluminum alloy was chosen as the primary material due to its relatively high strength to weight ratio, despite its higher cost. Initially Aluminum 2024-T4 was considered due to its high strength to weight ratio. However, Aluminum 6061-T6 was later chosen instead because of its lower cost and because it can be more easily welded, despite not being as strong as Aluminum 2024-T4. Both of these alloys are commonly used in aircraft construction. The tensile yield strength of Aluminum 6061-T6 is 276 MPa [4], and the strength of the weld is 124 MPa [5]. The fatigue strength for 10^4 cycles is about 200 MPa, taken from Yahr [6]. The convention for fatigue strength of a material is normally taken at 10^7 cycles, however because each landing only constitutes a single load cycle on the landing gear a lower number of cycles was considered appropriate. If the aircraft were to land on average up to five times per day every day for 50 years, the number of load cycles on the landing gear would be on the order of 10^4.

The only part of the strut not made from aluminum is the bronze bushings that interface between the strut and the airframe. These were left the same in order to keep the design of the strut-airframe interface area the same, and because they could be purchased from a supplier rather than being fabricated in house. A picture of the interface between the original strut and the airframe is shown in Figure 5

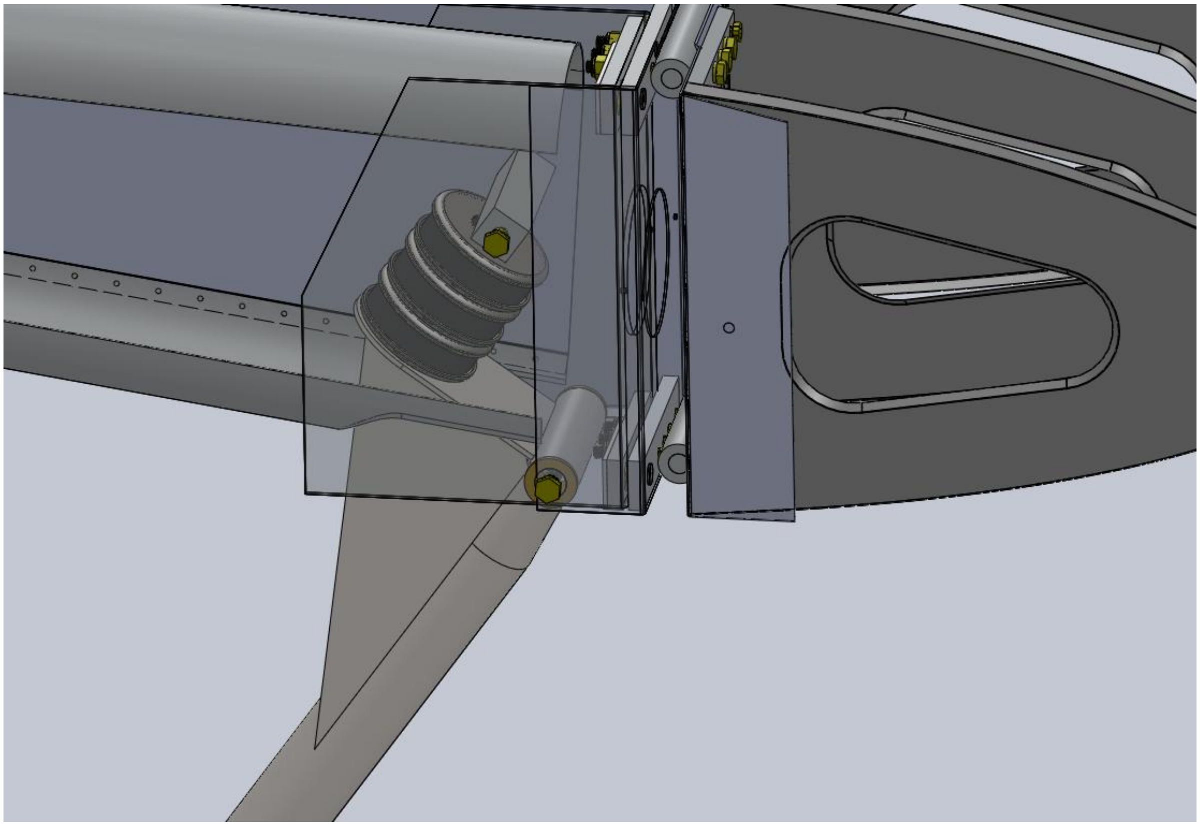


Figure 5: Strut-Frame Interface

In the figure, the strut is hinged parallel to the y-axis of the aircraft with the wheel trailing behind the hinge. Three rubber donuts are compressed between the shock plate on the strut and an aluminum bar inside the wing structure. These act as shock absorbers and were also left the same in the redesign. The entire strut-airframe interface is located inside the tail-boom section located just aft of the main wing spar. Figure 6 shows a perspective view of the aircraft, better displaying the location of the main gear.

Figure 6: Vampire LSA. Note main gear inside tail-boom

2.3 Computer Model and Structural Simulation

To create a new design for a new strut, a sequence of designs were made and analyzed on the computer. A CAD model was first made using SolidWorks. This model was then loaded into ANSYS ‘Static Structural’ for structural evaluation by applying the aforementioned static loads. The model was meshed in ANSYS using the auto-mesh feature, though refinements were sometimes added manually in areas where the stress changed rapidly, such as the side panels and weld fillets. The loads were applied to an analog for the wheel and axle to simulate the twisting caused by the off-center location of the wheel relative to the strut. This analog simulated the bolts attaching the axel to the strut, as well as the location of the wheel. Each component of the force was added to the bottom face of the analog, which corresponds to where the rubber of the tire meets the ground. Any compression of the rubber tire was not simulated. The model was constrained by defining frictionless supports inside the bronze bushings at the hinge, and a compression-only support on top of the shock support plate where the shock absorbers meet. The surface for the compression-only support was raised slightly in SolidWorks so that the specific region where the shock absorbers met the strut could be defined. This region is shown in Figure 8.

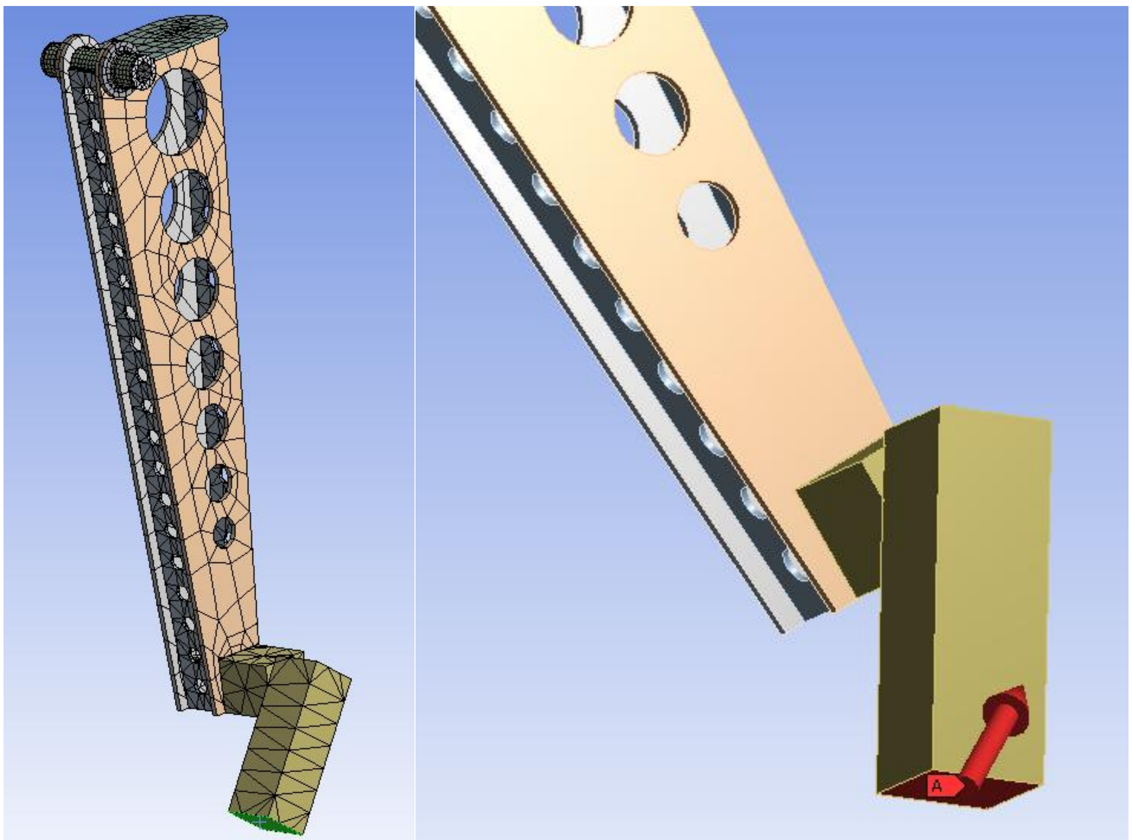


Figure 7: Mesh (Left) and Resultant Force applied to wheel analog (Right)

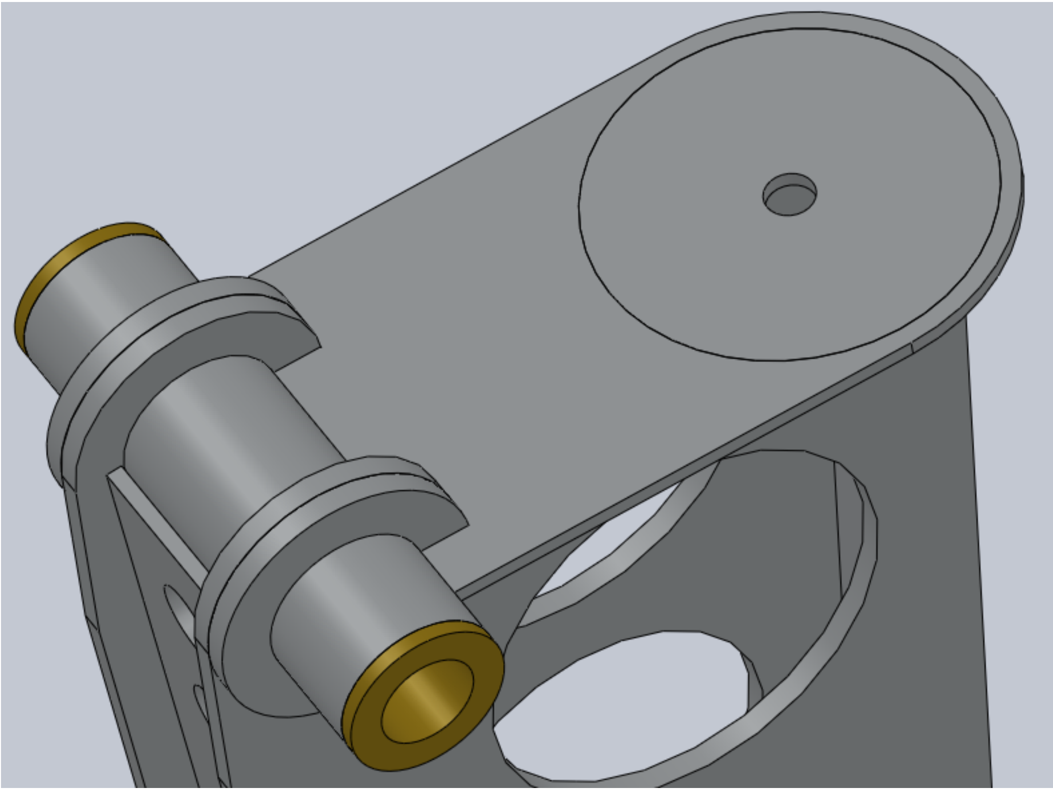


Figure 8: Circle (Top Right) defines surface for compression-only support

After each simulation the stresses on the model were analyzed by comparing them to the fatigue strength of the material. Adjustments to the next iteration were made accordingly. In areas of low stress, material was removed to save weight. In areas of high stress, material was added for additional strength. Welds were modeled with fillets and the lower strength of welds was taken into consideration during the analysis by assuming the fillets had a tensile strength of 124 MPa [5]. Figure 9: Stain vectorsFigure 9 shows the strain vectors for a strut without lightening holes cut in the sides. This shows that there is a high density of tensile and compressive loads on the front and aft faces, but few loads occurring in the middle. Holes cut in this area remove weight without significantly compromising the structural integrity. Examples of several early design iterations with stresses are shown in Figure 10.

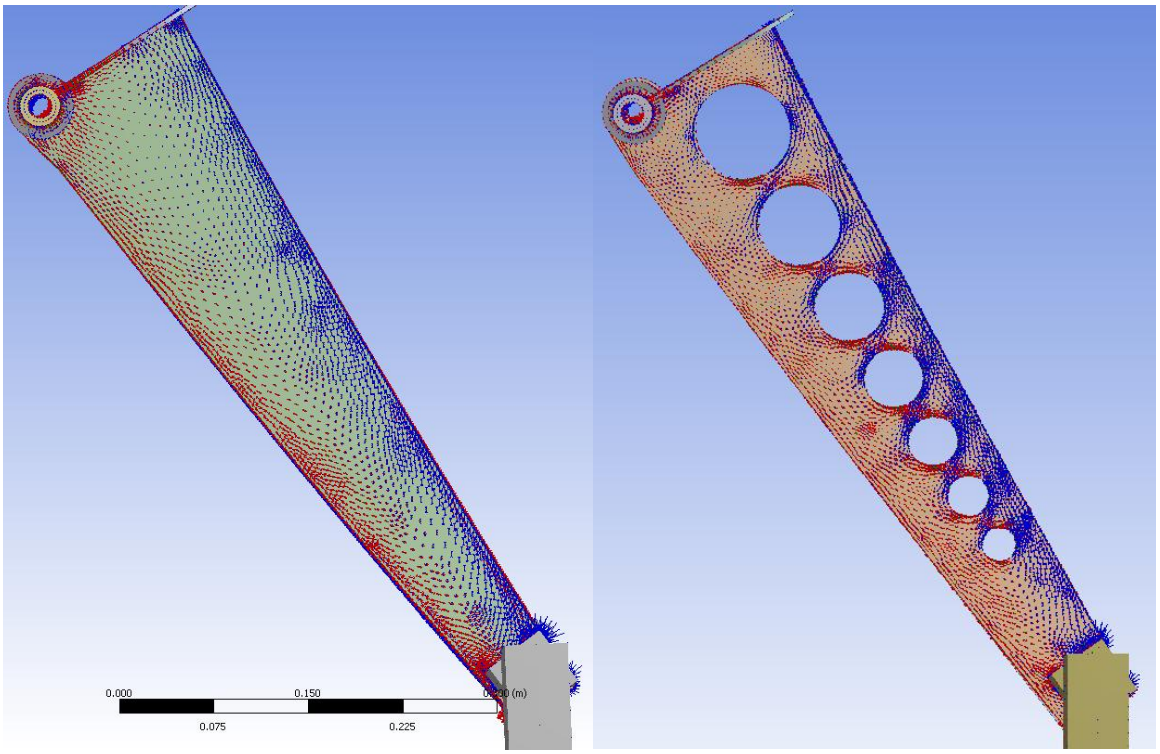


Figure 9: Stain vectors

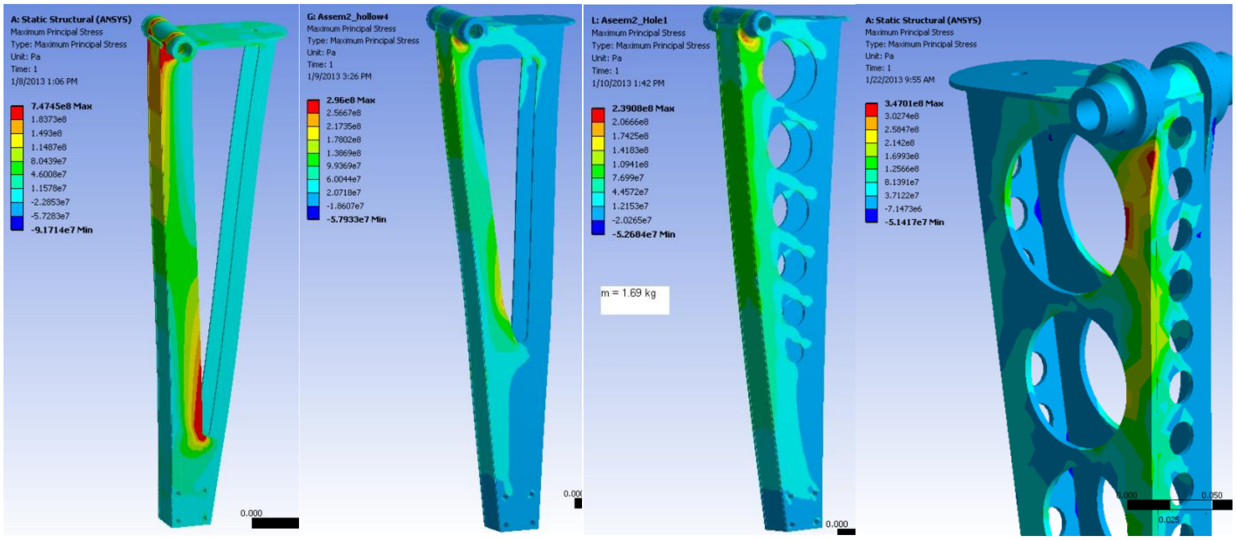


Figure 10: Evolution of Design

In the above examples, material is added to the lower portion between the first and second picture. The one large cut-out is then changed to several circular cut-outs. In the last picture, the interface between the side panels and hinge is increased in size, and additional lightening holes are cut out of the front and back facing panels.

After about 22 design iterations a design was finalized, which is shown in Figure 11. It was found during the analysis of the side loadings that the front part of the side panels had to be larger in order to transfer the loading from the axel to the hinge, hence the asymmetry in the side panels. The strut is primarily made with 3.18 mm (1/8”) and 4.76 mm (3/16”) thick aluminum sheet. The panels on the left and right side over hang the front facing panel to allow a corner weld to be made. Holes are cut out of the sides to lighten the structure by about 0.4 kg while keeping the loads well distributed. A three view drawing of the final design is also shown in Figure 11, and a stress plot shown in Figure 12. Three view drawings of each aluminum part are given in Appendix A.

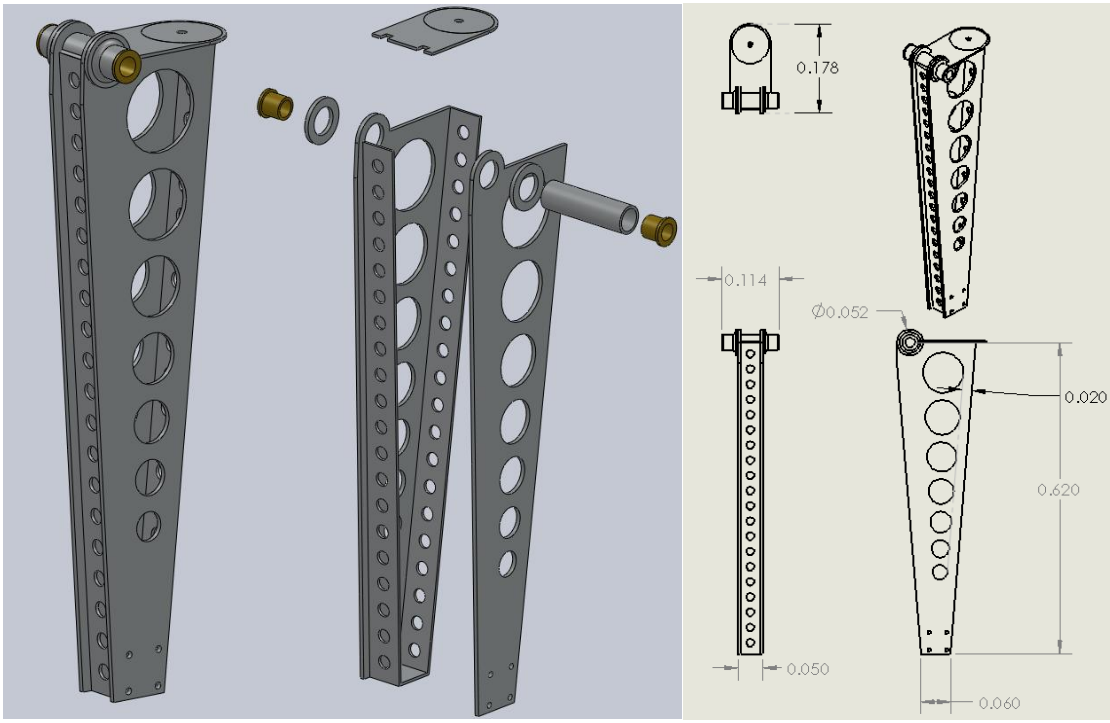


Figure 11: Drawing of Final Design. Dimensions in meters

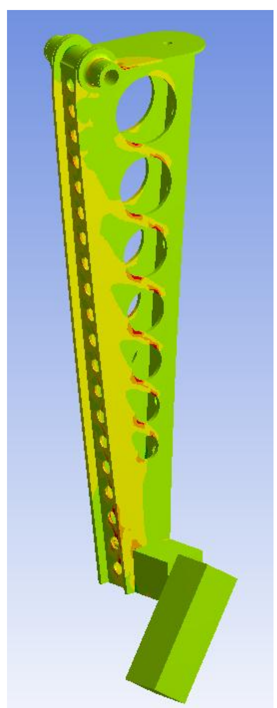


Figure 12: Stress Distribution of Final Design

Figure 12 shows the stress distribution for vertical and aft loading. The points of high stress (shown in red) are about 150 MPa, significantly lower of the fatigue stress of 200 MPa. They are located between the holes in the side panels and the front and back panels, as well as around the connection to the hinge piece. The rectangular piece shown attached to the strut at the bottom of the figure is the analog for the axle attachment.

2.4 Construction

The raw materials needed to construct two struts, not including welding materials or shipping costs, are as follows:

Table 2: Bill of Materials

Item	Amount	Cost per item	Source
0.125" Aluminum Sheet PN 03-30360	2' X 2' sheet (makes 3 sets)	$ 30.25	www.aircraftspruce.com
0.190" Aluminum Sheet PN 03-10050	2' X 4' sheet (makes 3 sets)	$ 104.95	www.aircraftspruce.com
1.25" Aluminum tube PN 03-37450	2 ft (makes 3 sets)	$ 7/ft	www.aircraftspruce.com
Bronze Bushings PN 1677k17	6	$ 8.04	www.mcmaster.com

The panels for the initial prototype were cut by hand from raw aluminum sheet and welded together. The three-view drawings for each part and an assembly guide are included in the Appendix.

Chapter 3: Aerodynamic Analysis

3.1 Analysis Setup

The drag of the strut was also considered during the design. Using ANSYS ‘Fluent’, the drag of the original strut, new strut, and new strut with a faring were analyzed. The faring had an airfoil shape which was the NACA 0020. This airfoil was chosen because it is relatively thick and is symmetric. The faring is assumed to be made of four layers of “2 oz” fiberglass, giving it a weight of about 0.11 kg. It is attached to the strut with small bolts screwed to the front lip of the side panels (not shown).

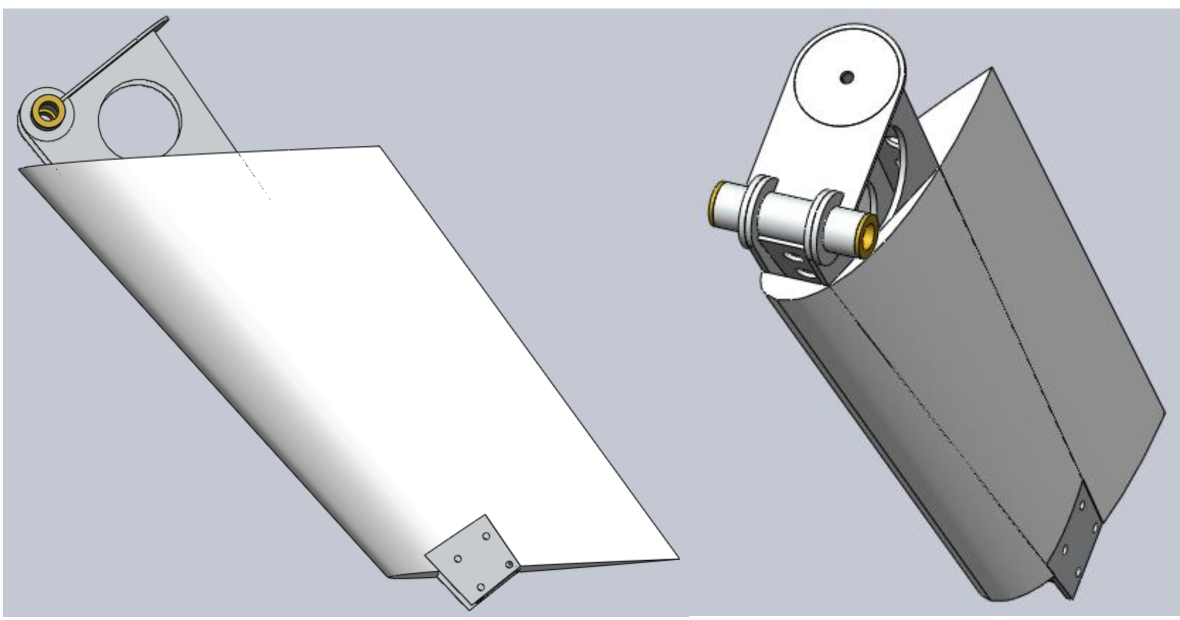


Figure 13: Strut with NACA 0020 faring

A model of the domain around the strut was modeled along with the strut itself in SolidWorks and then exported to ANSYS. Inner and outer domains were made so that the inner domain could manually be given a finer mesh. The strut was off set 35˚ from the vertical to match how it would be in flight. A picture of the strut in its domain is shown in Figure 14. Only one half of the domain was modeled because the ANSYS student license limits the number of elements used in the analysis to 1.5 million, and defining a symmetry plane allows a smaller volume to be used thereby allowing a higher mesh density and more accurate results. The top of the strut sticks out of the flow domain because it is hidden inside the airframe during flight.

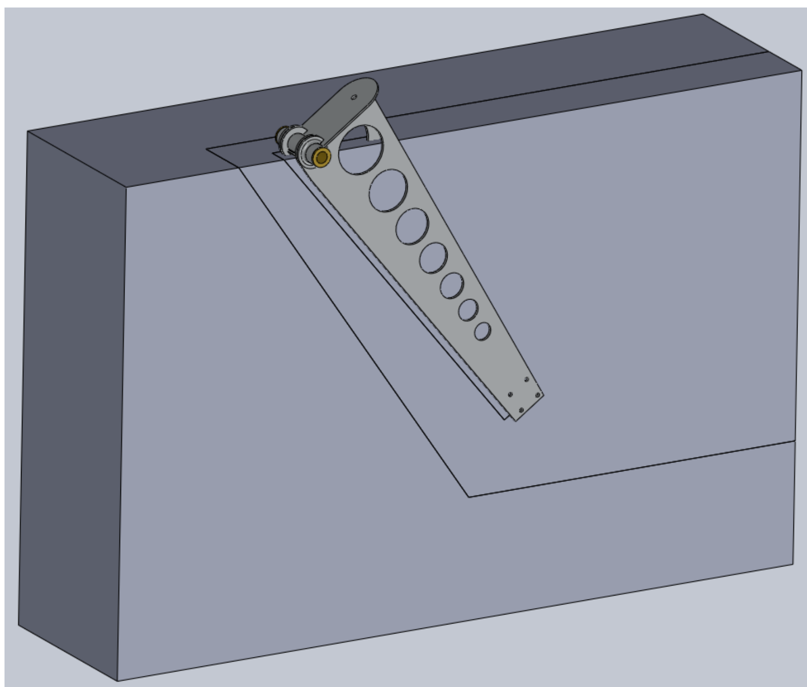


Figure 14: New strut modeled in flow domain

Once loaded into ANSYS, the strut was subtracted from the surrounding domain using the Boolean subtract feature in the geometry editor. Mesh densities were specified at the inlet, outlet, interface planes, and along the strut surface. The density of the mesh was successively increased going toward the strut surface, since the flow changes much more rapidly there. A picture of the mesh for the bare strut is shown in Figure 15. The mesh densities at each surface for the case in Figure 15 are given in Table 3. Similar mesh densities were used for the analysis of the original strut and the new strut with a faring.

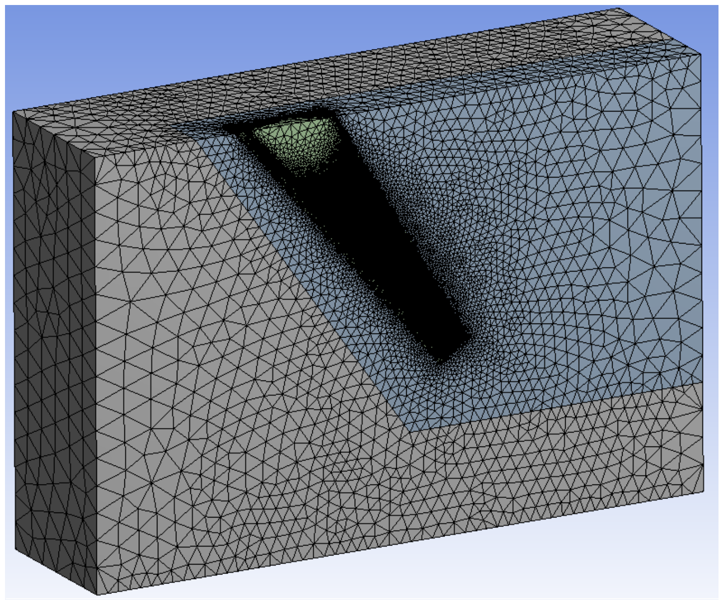


Figure 15: Mesh of the bare strut

Table 3: Mesh Densities for New Strut - Bare

Surface Name	Element Size (m)
Inlet	0.050
Outlet	0.050
Interface1_Inner	0.020
Interface1_Outer	0.020
Interface2_strut	0.003
Interface2_Inner	0.003
Strut	0.002
Number of Elements	1.28 e^6

After a mesh setting was found that did not exceed the 1.5 million element limit, the atmospheric conditions were set and the calculation was run. Runs typically took about 1500 iterations to converge. The atmospheric conditions applied to the analysis are given in Table 4:

Table 4: Atmospheric Conditions

Velocity	62 m/s
Pressure	90000 Pa
Density	1.088 kg/m^3
Temperature	288.15 K (15 ˚C)
Kinematic Viscosity	1.81e-5 kg/m-s

These values correspond approximately to what would be seen at a cruise velocity of 120 kts at 1000 m altitude (3000 ft) on a warm day.

3.2 Drag Results

The drag results and reference values used for each strut are given in Table 5. The amount of power required due to the drag by each strut at cruise is also given. This is calculated by multiplying the drag of the strut by velocity.

Table 5: Drag and Reference Values

	Cd	Drag (N)	Power Req. (kW), (hp)	Ref. Length (m)	Reynolds #
Original Strut	0.45	24	1.5 (2.0)	0.051	190,000
New Strut (bare)	1.17	63	3.9 (5.2)	0.107	400,000
New Strut (Faring)	0.29	16	1.0 (1.3)	0.313	1,170,000
Ref. Area (m^2)	0.026				

The reference length was determined by calculating the average width in the x-direction of a side panel, faring, or main tube in the case of the original strut. Figure 16, Figure 17 and Figure 18 show the velocity profiles surrounding each strut. The new strut with the faring has much less drag due to the reduced separated flow coming off the structure. In contrast, there is a significant amount of separated flow behind the top of the original strut where the triangular support pieces are located, as well as behind the new strut without the faring due to the flat faces and exposed holes. The new strut also has a significant amount of flow circulated inside the strut, whereas the flow inside the new strut with the faring is more stagnant.

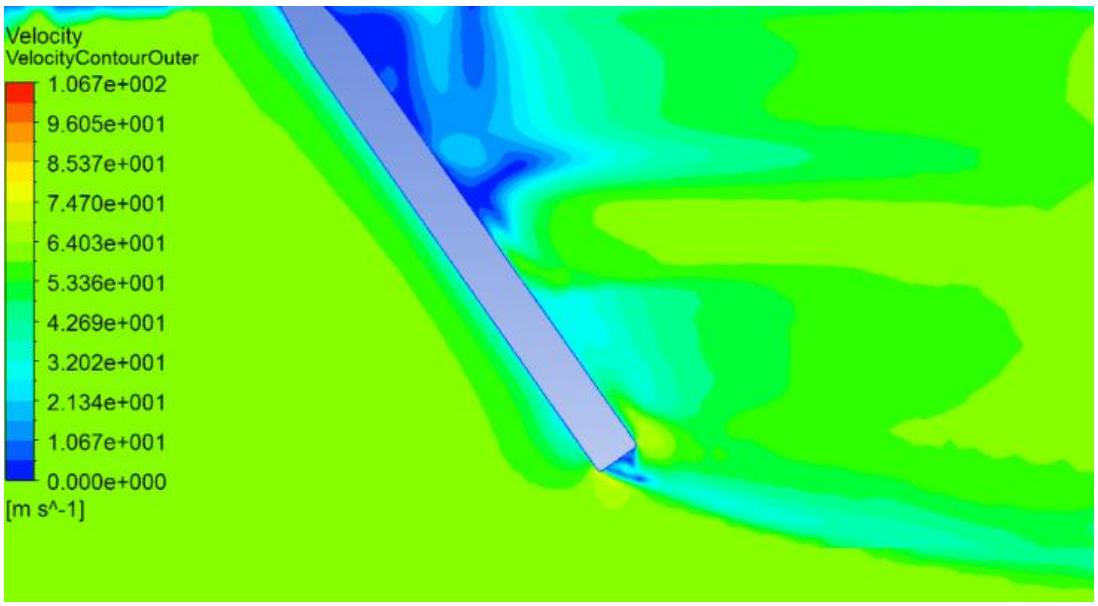


Figure 16: Original Velocity Profile

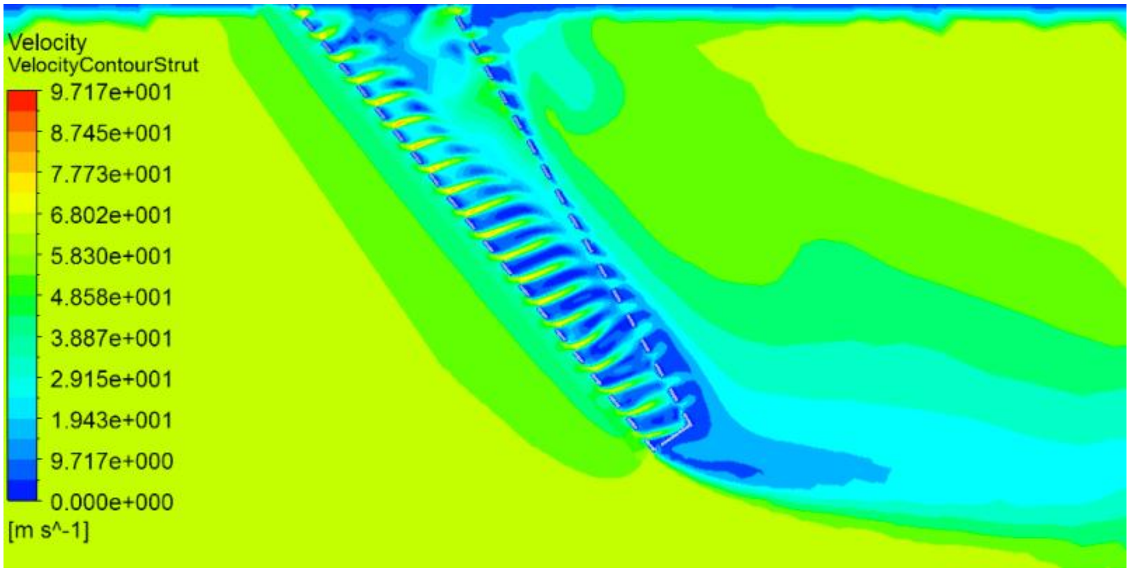


Figure 17: New Strut without faring velocity profiles

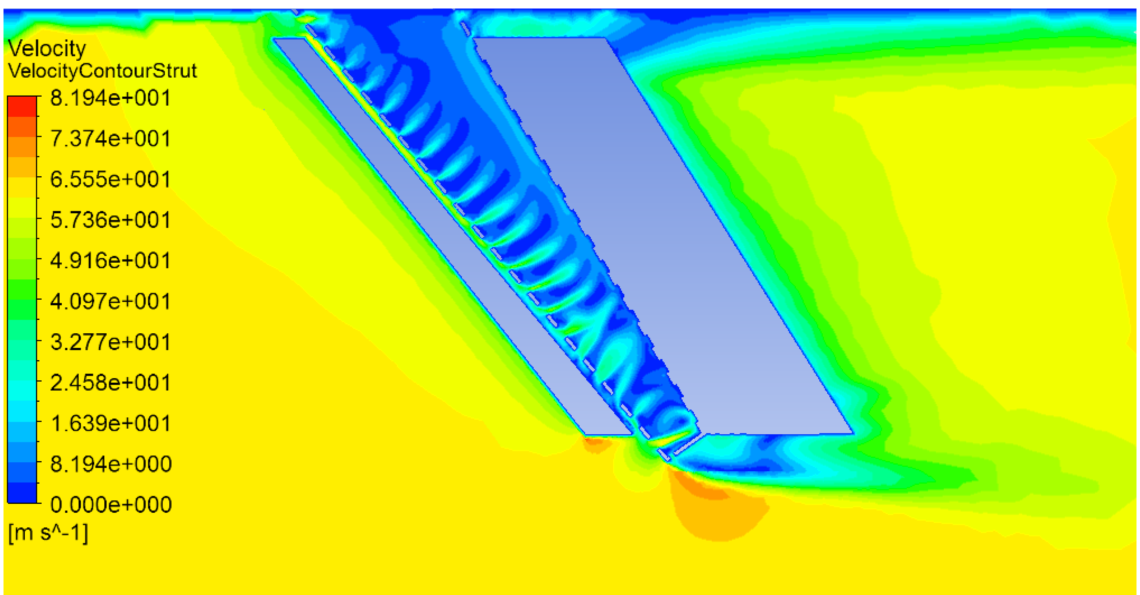


Figure 18: New Strut with faring velocity profile

Chapter 4: Load Test

4.1 Static Load Test

ASTM standards give the static loads that a landing gear strut must endure [3]. These loads are meant to simulate the impact of landing, friction from braking, and any sideways force that may result from a bad crosswind landing by applying a constant static load to the gear, as opposed to a dynamic load as in a drop test. The magnitude and direction of these forces are shown in Figure 2, which is repeated below.

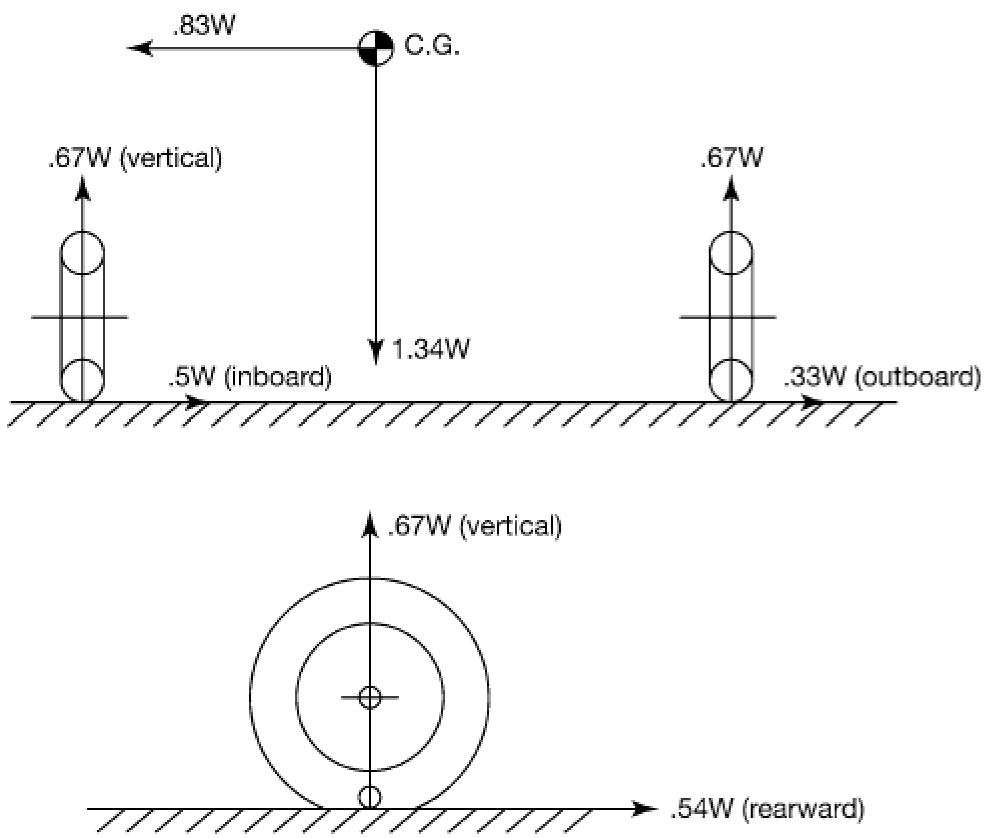


Figure 19: ASTM Landing Load Conditions [3]

To simulate these loads on a prototype strut, a static load test was designed. A rig was designed to apply the proper weight to the strut, which is shown in Figure 20 below. Strain gauges would be applied to the strut at regions of high stress and low gradient to compare the actual strain to the predicted strain found during the analysis. Measuring the strain in real time to known locations from the ANSYS analysis allows for direct comparisons that allow the tester to see how close the strain of the strut is getting to the fatigue strain as weight is applied, and allow the stoppage of the test if necessary.

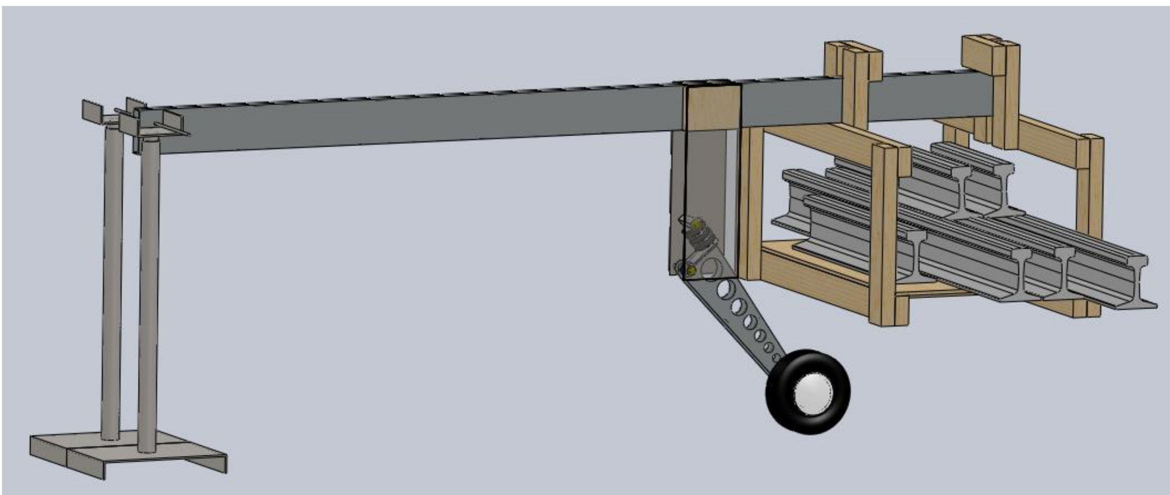


Figure 20: Load Rig

The rig was designed to make use of materials readily available to NCSU Flight Research. In the figure shown above, railroad track segments are used as ballast weight, held by a platform made of plywood and 2"x4" wood beam supports. An aluminum beam hinged at one end with the weights at the other applied the forces onto the strut. By using the beam as a lever arm, less ballast weight is required due to the mechanical advantage.

Three static load tests are to be done. The first simulates only the normal and aft components of the landing force, as in a normal straight landing, by angling the strut such that the normal force from the ground to the wheel is in the same direction as the sum of the normal and aft components. The second and third tests simulate a landing with a crosswind, one for the inboard case and one for the outboard case. A wedge placed underneath the wheel at an angle simulates the direction of the resultant force. A 37˚ wedge angle is used for the inboard and a 26˚ wedge angle for the outboard. The actual forces applied to the strut are calculated using Pythagoreans Theorem and are given in the **Error! Reference source not found.**.

Table 6: Strut Forces for Static Load Test

Load Case	Force on Strut (kg)
Normal and Aft	516
Inboard	597
Outboard	553

4.2 Drop Test

The rig used in the static load test can also be used in a drop test. The rig is used to hold the strut at a predetermined height that corresponds to 3.05 m/s (10 ft/s) vertical velocity [7] by lifting the weighted end and rotating it about the hinged end. When the wheel hits the ground, the rig will be level and have zero horizontal velocity. Any horizontal motion that occurs due to the compression of the strut and shock absorbers can be ignored because it will only rotate through a small angle. This height can easily be calculated using the principle of conservation of energy, where the total gravitational energy of the raised rig will equal the total kinetic energy once it hits the ground. By setting the equations for gravitational and kinetic energy equal to one another and solving for the height, the equation for height in terms of velocity becomes Equation 1.

$$h = \frac{\frac{1}{2}V^2}{g}$$

Equation 1

The variable *h* is the height, *V* is the velocity, and *g* is the gravitational acceleration of the Earth. To achieve the required vertical velocity of 3.05 m/s, a height of about 0.47 m must be used, measured at the center of gravity. A picture of how the rig would be set up for the drop test is shown in Figure 21.

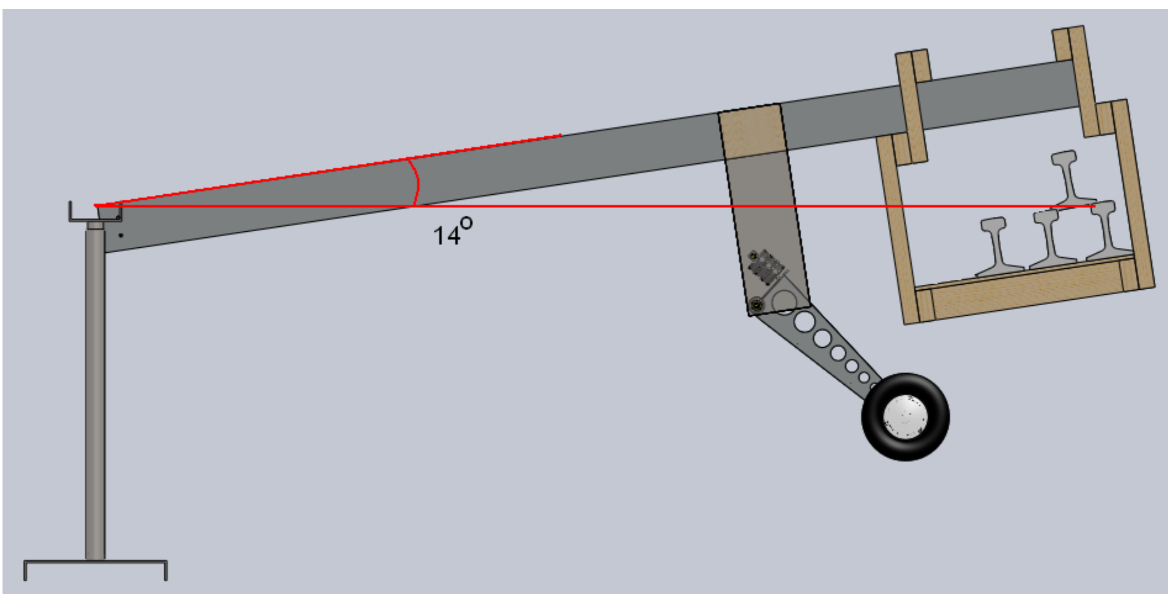


Figure 21: Drop Rig raised

4.3 Reduced Mass Method

During landing, the landing gear does not receive the full weight of the aircraft all at once because the wings still generate a significant amount of lift at touchdown. To compensate for this reduced force during a drop test, the reduced mass method from Milwitzky [8] is used. This method involves using less weight during the drop test in order to simulate lift being produced by the wings. The equation used to determine the amount of weight used for the test is given by Equation 2.

$$W_R = W_A \frac{h + (1 - K)d}{h + d}$$

Equation 2

In this equation W_R is the reduced weight that is used in the experiment, W_A is the amount of weight the individual gear would take when stationary on the ground, *K* is the wing lift factor and *d* is the mass travel. The wing lift factor *K* is assumed to be 2/3 [9]. In order to find the correct mass travel value that corresponds to the reduced weight, a correlation between weight and mass travel for the given test velocity must be found. Several different weights are initially used and the mass travel recorded using a high speed camera and ruler for each drop to find this correlation. Knowing that each gear will support less than half of the aircrafts total weight, a conservative guess of ¼ the weight of the aircraft can be used as a starting point, increasing the drop weight from there. Once this correlation is found, the reduced weight is plotted according to Equation 2 with the mass travel correlation. The intersection of these two lines gives the reduced weight to be used in the drop test. An example of this is shown in Figure 22 where the blue line is the correlation between weight and mass travel, the black line is an extrapolation of that line, and the red line is the reduced weight as a function of mass travel according to Equation 2.

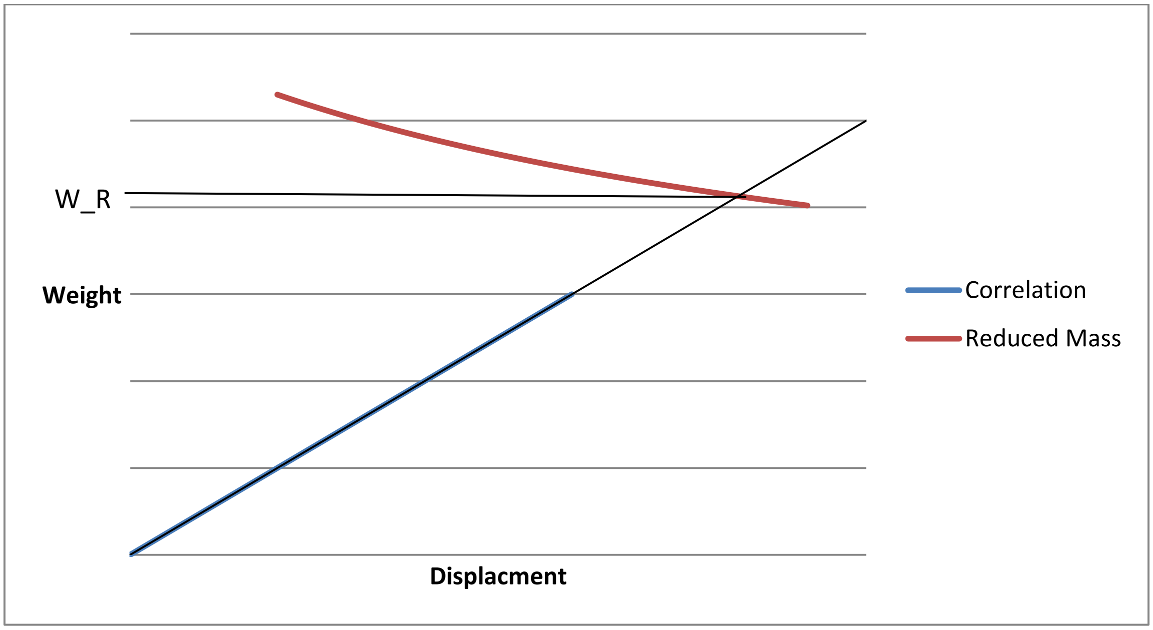


Figure 22: Example of Weight vs. Mass Travel

Chapter 5: Conclusion

The final design of the new landing gear strut for the Vampire Light Sport Aircraft weighs about 2.2 kg. Though more expensive, this design is 42% lighter than the original 3.8 kg strut, which saves 3.6 kg off the total aircraft weight between two struts. This weight reduction, combined with weight reductions from an alternate engine choice and fiberglass layup schedule, will help the Vampire achieve the 600 kg weight requirement for Light Sport certification. The reduction in drag due to adding a faring will also help increase range and endurance by reducing the overall power required at cruise by about 1 kW (1.3 hp).

Future work to be done regarding the landing gear strut is performing a static load test in order to prove that it meets the ASTM requirements. A drop test is not required, but will certainly give greater confidence in the integrity of the design.

REFERENCES

[1] Pew, G. *LSA Company for Sale, Sadler Vampire* AVFlash News, http://www.avweb.com/avwebflash/news/sadler_vampire_company_lsa_for_sale_light_sport_aircraft_202628-1.html 26 May 2010

[2] *Airworthiness Certification of Aircraft and Related Products*, FAA Order 8130.2G, Chapter 4, Section 6, 31 August 2010

[3] *Standard Specification for Design and Performance of a Light Sport Airplane*, ASTM Designation F2245-11

[4] *Aluminum6061-T6; 6061-T651* ASM Aerospace Specification Metals Inc. http://asm.matweb.com/search/SpecificMaterial.asp?bassnum=MA6061t6

[5] *Welding Aluminum*, http://www.sapagroup.com/pages/522511/Answer%20Book/11_Welding.pdf

[6] Yahr, G.T. *Fatigue Design Curves for 6061-T6 Aluminum* Engineering Technology Division, Oak Ridge National Laboratory, 1993. Figure 1

[7] FAA Federal Aviation Regulations Part 23 Section 473, *Ground Load Conditions and Assumptions*, 9 February 1996

[8] Milwitzky, B., Linquist, D.C., *Evaluation of the Reduced-Mass Method of Representing Wing-Lift Effects in Free-Fall Drop*, NACA Technical Note 2400, Langley Aeronautical Laboratory Langley Field, VA. July 1951

[9] Flügge, W., *Landing-Gear Impact* NACA Technical Note 2743, Washington, October 1952, pg 24

APPENDICES

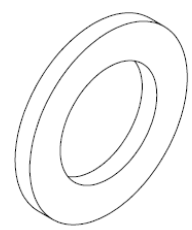
Appendix A – Three View Drawings of Strut Parts

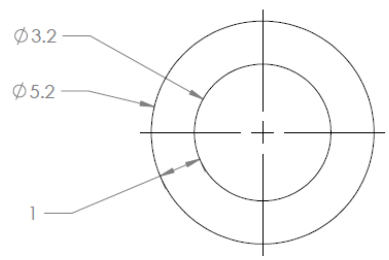
Part: Spacer
Material: Aluminum 6061-T6
3/16" Sheet
Source: www.aircraftspruce.com
P/N: 03-10060

Drawing units in centimeters (cm)

Notes:
Center hole diamter is 1.25"

Slides over Hinge

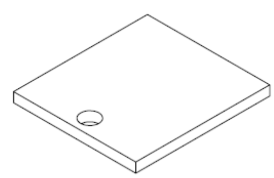


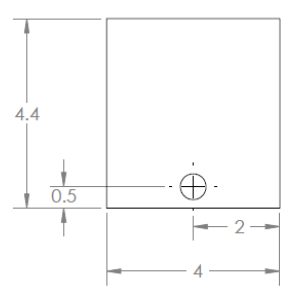


Part: Bottom
Material: Aluminum 6061-T6
1/8" Sheet
Source: www.aircraftspruce.com
P/N: 03-30360

Drawing units in centimeters (cm)

Notes:
Drainage hole is 1/4" diameter



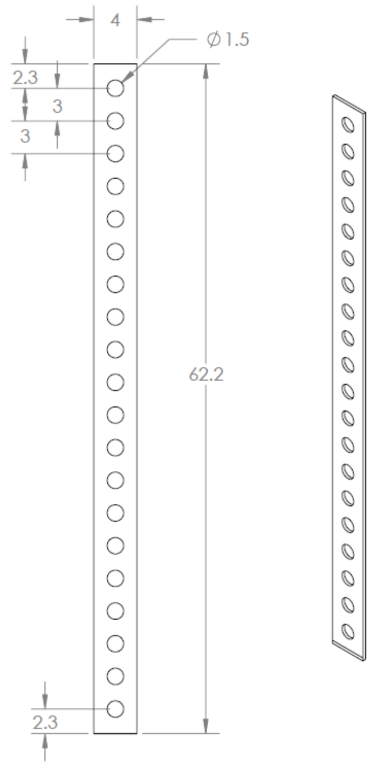


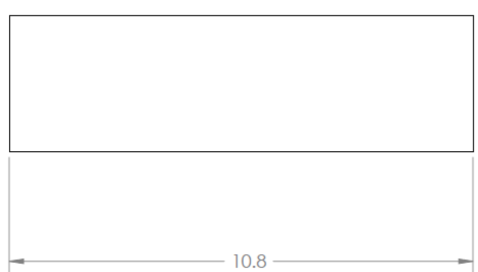
Part: Front/Back Panel
Material: Aluminum 6061-T6
1/8" Sheet
Source: www.aircraftspruce.com
P/N: 03-30360

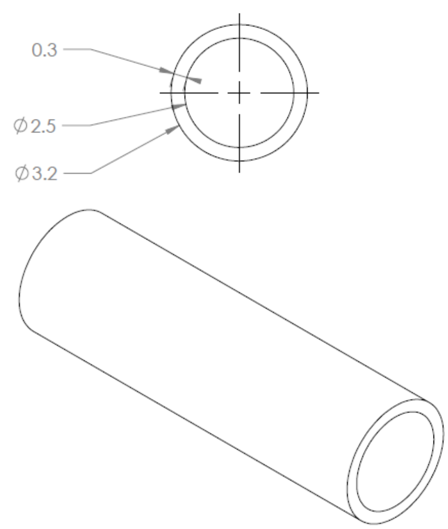
Drawing units in centimeters (cm)

Notes:
Holes are all the same diameter

Distance between each hole is constant



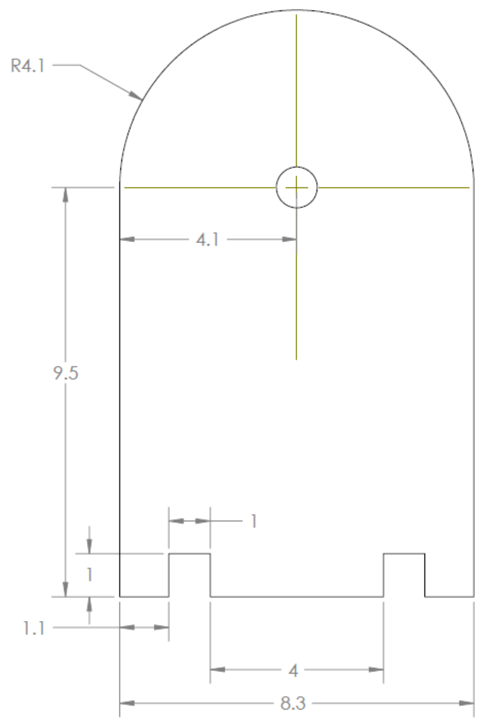


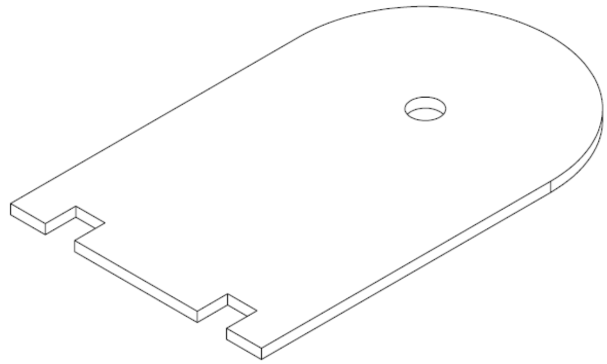


Part: Hinge
Material: Aluminum 6061-T6
Tube
Source: www.aircraftspruce.com
P/N: 03-37450

Units given in centimeters (cm)

Notes:
Length: 10.8 cm (4.25 in.)
Outer Diameter: 3.18 cm (1.25 in.)
Inner Diameter: 2.54 cm(1.0 in.)
Wall Thickness: 0.32 cm (1/8 in.)





Part: Shock Plate
Material: Aluminum 6061-T6
1/8" Sheet
Source: www.aircraftspruce.com
P/N: 03-30360

Drawing units in centimeters (cm)

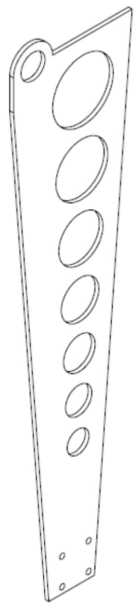
Notes:
Hole is 3/8" diameter

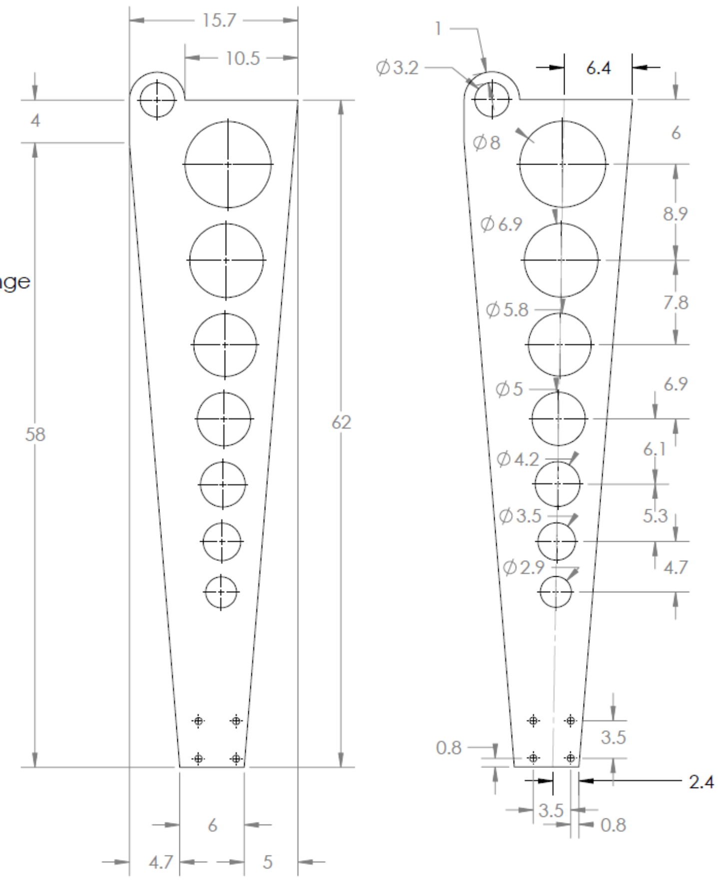
Part: Side Panel
Material: Aluminum 6061-T6
3/16" Sheet
Source: www.aircraftspruce.com
P/N: 03-10060

Drawing units in centimeters (cm)

Notes:
Bolt holes at bottom are 1/4" diameter, 1 3/8" apart

Hole at top left is 1.25", accomodates Hinge





Appendix B – Strut Assembly Guide

Alex Manasa
February 2013

Landing Gear Strut Manual
Vampire Light Sport Aircraft

This document contains the information needed to construct a landing gear strut for the Vampire LSA, including the raw materials and assembly process.

Bill of Materials

Item	Amount	Cost per item	Source
0.125" Aluminum Sheet Alloy 6061-T6 PN 03-30360	2' X 2' sheet	$ 30.25	www.aircraftspruce.com
0.190" Aluminum Sheet Alloy 6061-T6 PN 03-10060	2' X 2' sheet	$ 57.75	www.aircraftspruce.com
1.25" Aluminum tube Alloy 6061-T6 PN 03-37450	1 ft	$ 7/ft	www.aircraftspruce.com
Bronze Bushings PN 1677k17	2	$ 5.36	www.mcmaster.com

Total cost of materials: $105.72 (does not include shipping, taxes, or welding materials)

Parts to be made:

Part Name	Number required	Material
Hinge	1	1.25" Aluminum Tube
Shock Panel	1	0.125" Aluminum Sheet
Front/Back Panel	2	0.125" Aluminum Sheet
Bottom Panel	1	0.125" Aluminum Sheet
Side Panel	2	0.190" Aluminum Sheet
Spacer	2	0.190" Aluminum Sheet

Total weight of finished product should be about 2 kg.

1. Cut out all the parts.
2. Weld a Back Panel to the inner face of a Side Panel along the aft edge of the Side Panel.

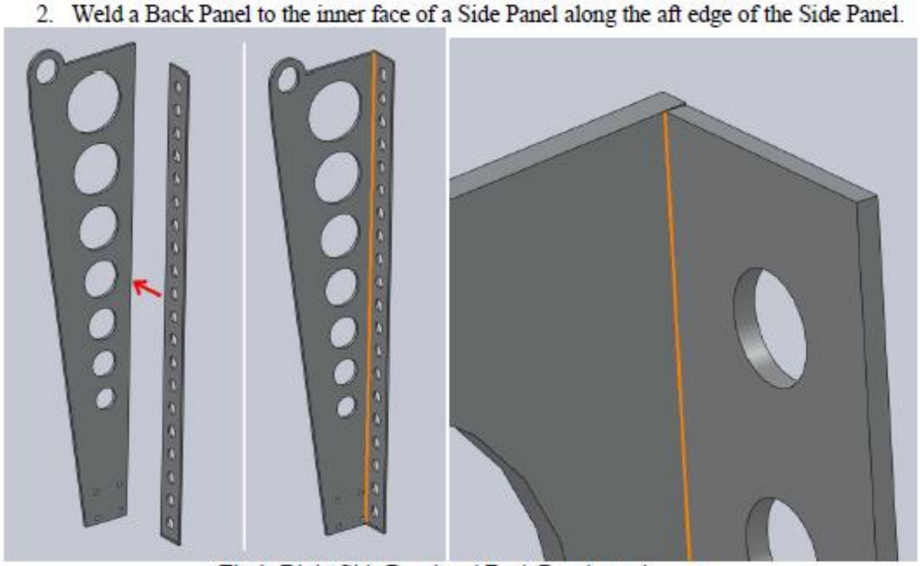


Fig.1: Right Side Panel and Back Panel attachment

3. Weld the Bottom Panel to the inner faces of the Side Panel and Back Panel along the bottom edge.

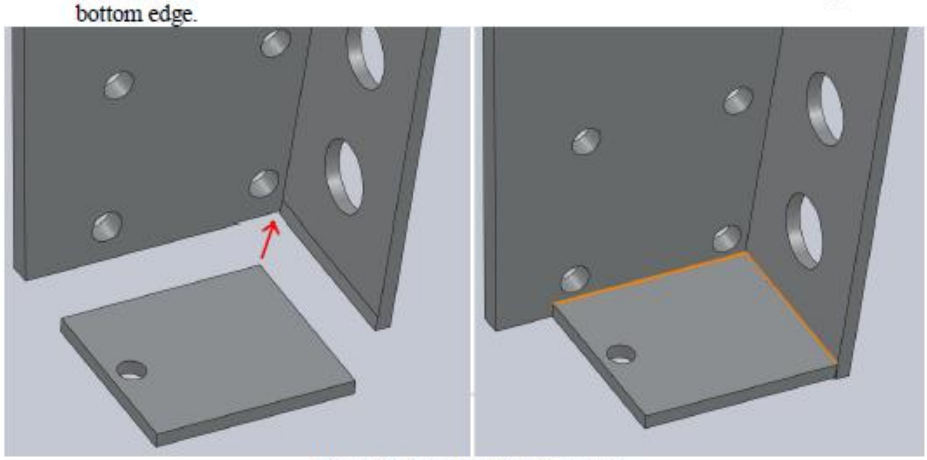


Fig. 2: Bottom Panel attachment

4. Weld the second Side Panel to the Bottom and Back Panels. The welds should be along the inside corners.

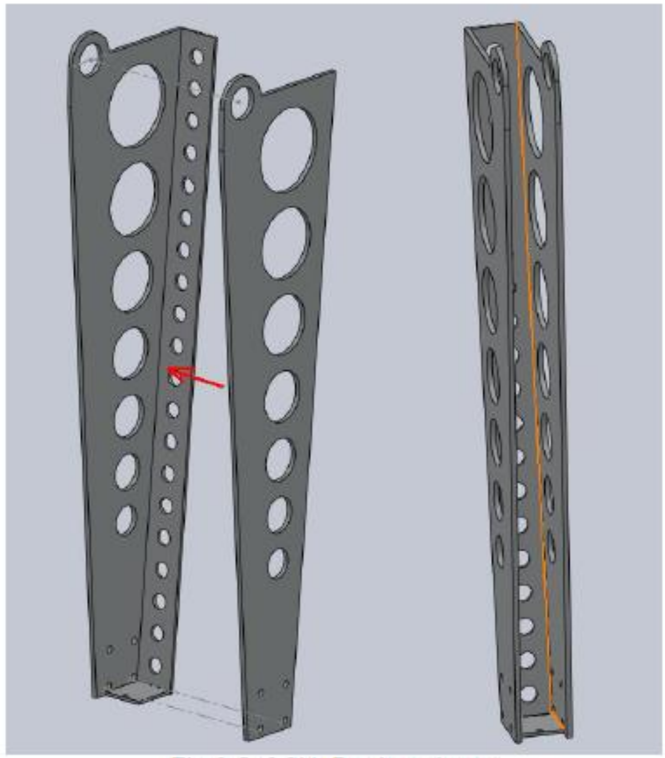


Fig. 3: Left Side Panel attachment

5. Weld Front Panel to the two Side Panels and Bottom Panel. There should be a constant 1cm space between the front face of the Front Panel and the leading edge of the Side Panels.

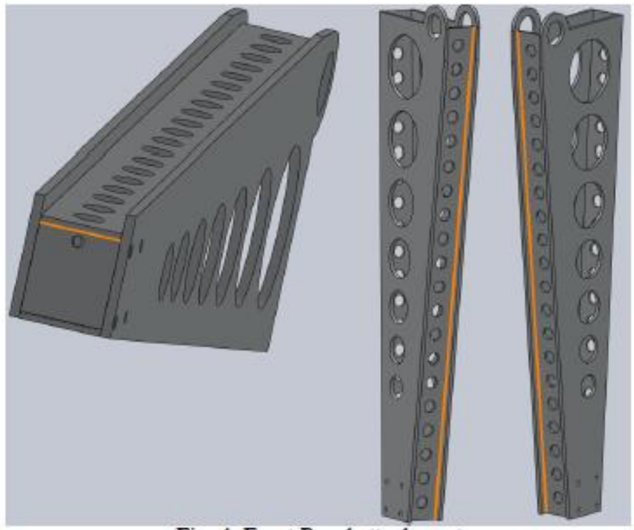


Fig. 4: Front Panel attachment

6. Weld the Spacers to the outside of the Side Panels, concentric with the hinge holes in the upper front corner.

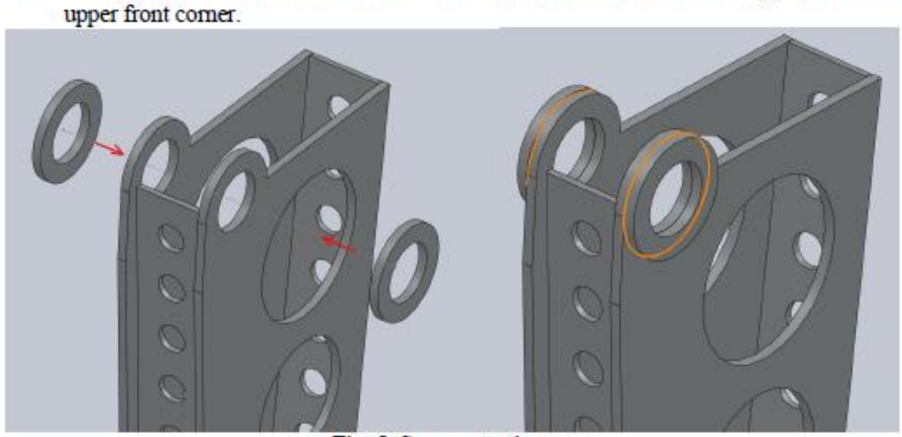


Fig. 5: Spacer attachment

7. Slide the Hinge through the hinge holes such that the end of the Hinge is 2.4cm away from the spacer. It should be even on both sides. Weld in place.

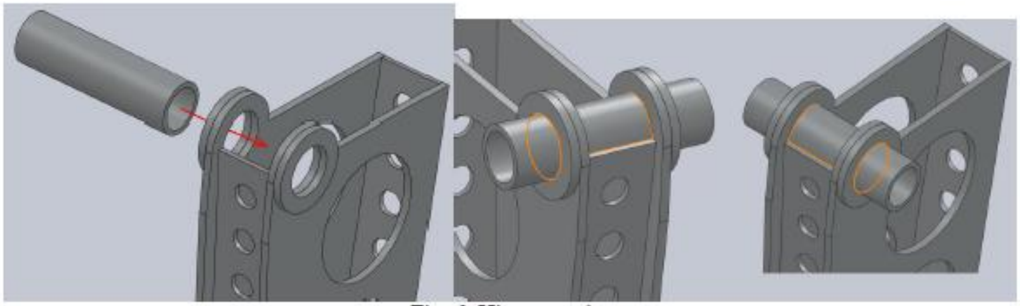


Fig. 6: Hinge attachment

8. Weld the Shock Plate to the top of the assembly such that it is up against the Hinge.

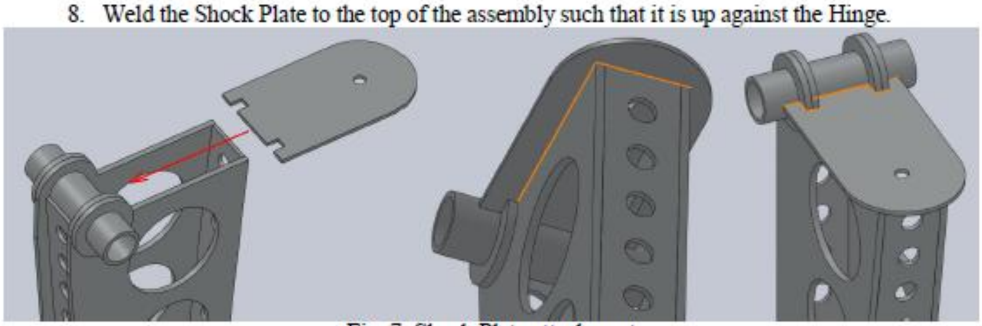


Fig. 7: Shock Plate attachment

9. Insert the Bronze Bushings into the sides of the Hinge.

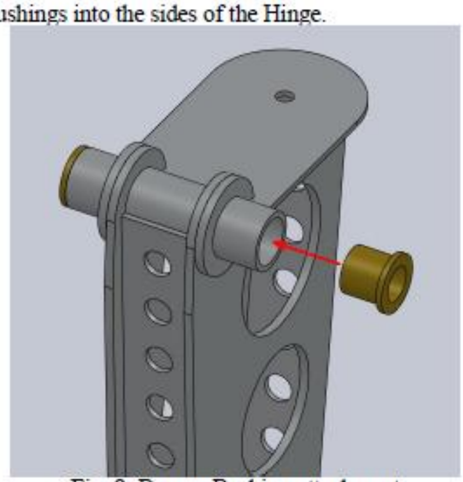


Fig. 8: Bronze Bushing attachment

The landing gear strut is now complete.