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The Wright Stuff: A Redesign of the 1905 Wright Flyer

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THE WRIGHT STUFF

A Redesign of the 1905 Wright Flyer

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MAE 4810
Senior Design Report

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Introduction

On the morning of December 17, 1903 Wilber and Orville Wright crossed a historic milestone by achieving the first powered flight controlled by a pilot. This event marked the beginning of a new era of flight. The flight was brief, a mere 12 seconds covering a distance of 120 feet, but by 1905 the brothers had developed a practical aircraft that could sustain flight as long as 38 minutes. This was the model that the Wright Brothers showcased at Paris and Washington DC in 1908, bringing them international recognition and fame, with the pilot and a passenger sitting upright on the wing.

The year 2003 marks the 100th anniversary of this monumental achievement. Although several groups around the nation are attempting to create exact replicas of the Wright Brothers’ aircraft, two professors at Utah State University had a different idea of how to pay homage to the grandparents of flight.

Dr. Dave Widauf and Professor Chuck Larsen entertained the idea of creating an aesthetically similar plane to the 1905 Wright Flyer while incorporating space-age materials and modern aerodynamic sciences. After presenting the idea to USU administrators, the project received an enthusiastic approval. The USU Wright Flyer project would be funded as a K-12 outreach program, culminating with participation in the 2003 festivities in Dayton, Ohio. It was determined that the Industrial Technology and Education Department would build the USU Wright Flyer. Construction would begin after a design team, consisting of ten senior engineering students from the Department of Mechanical and Aerospace Engineering, had completed the modified design.

Nick Alley, a graduate student in mechanical engineering, was assigned to be the project manager. Twenty-one students applied to be on the design team, of which ten were selected. Five students were responsible for the aerodynamic redesign of the USU Wright Flyer and the other five were responsible for the structural redesign. The process took two semesters, with the goal in mind to build the plane built during the summer of 2002.

It became the responsibility of the student design team to produce a working, full-scale, modified design of the 1905 Flyer. The USU Wright Flyer was to be a more stable and stronger aircraft than its 100-year-old predecessor. The USU Wright Flyer was to look amazingly similar to the 1905 Flyer, while incorporating characteristics that are necessary for modern, conventional aircraft. This report contains a complete, comprehensive review of the eight-month design process.
AERODYNAMIC
Design
Introduction

The characteristics of the 1905 Wright Flyer were ingenious and yet displayed the limits of the Wrights' understanding of flight mechanics and dynamics. They were great engineers, but luckily they were even better pilots. Today's level of aerodynamic properties in the subsonic realm are well understood and implementation of the now considered "basic" theories and principles of aircraft design are able to easily mend the shortcomings of the 100 year old design.

At the time, relatively little was known about the flight dynamics, and the 1905 Wright Flyer, though advanced for its time, was aerodynamically unstable by today's standards. The objective of USU Wright Flyer design team has been to research the characteristics of the original 1905 Flyer and improve the flight ability of the plane.

One of the major constraints placed upon the project was to retain the aesthetics of the original Flyer. This, of course, required the use of a canard-style biplane powered by two pusher propellers. The general dimensions of the aircraft were retained as much as possible so that the plane would look like the Wright Flyer from a distance to the average airplane enthusiast.

All of the powered aircraft that the Wrights' designed from 1903 to 1909 suffered from moderate to severe instability in pitch. Pitch stability was the first major goal for improving the Flyer. Stall speed was another characteristic worth exploring since the Wright Brothers' plane was stalled much of the time during flight, cruising at a relatively slow 28 mph. Higher design speeds would permit higher stall speeds, but also would increase the drag significantly.

These regulations and other governing parameters for safe flight helped to establish the following targets for the redesign:

1. Aesthetically similar to the original 1905 Wright Flyer
2. Stable in Pitch (Static Margin ≥ 8%)
3. Stall Speed no less than 15 mph under cruise speed

The Wright Flyer was an engineering marvel of its time, the first step into a whole new world. Naturally, since it was the first airplane, it left much to be desired in comparison to the aircraft of today. The flight characteristics of the original 1905 Wright Flyer could have been greatly improved by implementing just a few basic aerodynamic principles.
Tools of Analysis

In order to make improvements on the 1905 Wright Flyer Design it was necessary to perform an analysis on the original to understand quantitatively its flight characteristics. The necessary analysis was divided into two general areas, the individual parts of the aircraft (airfoils and bluff bodies) and the aircraft as a whole.

The analysis of the airfoils was done using two different computer programs: 1) a program developed by Dr. W. F. Phillips at Utah State University called AIRFOIL2001, and 2) an online program called CALCFOIL. AIRFOIL2001 uses an inviscid vortex panel numerical method to calculate lift and moment coefficients of an airfoil. This was used primarily as a quick preliminary analysis tool. CALCFOIL uses a simple viscous bubble method in conjunction with a vortex panel method to calculate the viscous drag and stall angle of attack of an airfoil in addition to the coefficients that AIRFOIL2001 calculates.

The data for the airfoils collected from CALCFOIL was then used in another program written by Dr. Phillips called WINGS2001. This uses Prandtl’s inviscid lifting-line theory to calculate the aerodynamic interaction between all parts of an aircraft. By entering the aerodynamic coefficients of each part of an aircraft, the flight characteristics of that plane can be analyzed in a variety of situations. Aerodynamic coefficients obtained from WINGS2001 were then used to calculate the stall speed, static stability and dynamic stability of the airplanes. Calculated values from WINGS2001 were in agreement with available historical or experimental data and flight performance of the 1905 Wright Flyer.

The Original 1905 Wright Flyer

All of the powered aircraft the Wright Brothers built up to 1909 suffered from moderate to severe instability in pitch. One major reason for the pitch instability of the 1905 flyer is its oversized canard control surface. This placed the aerodynamic center of the aircraft in front of the center of gravity by almost a foot and a half, as seen in Figure 1.1 (Hooven 1978). The other major contributing factor to the pitch instability is that the Wright Brothers preferred controllability rather than stability for fear of going into a stall dive. This caused the death of many would-be aviators including Otto Lilienthal, an inspiration to the Wrights and the father of modern aviation (Hooven 1978).
A modern measurement for pitch stability is the static margin, which, for modern conventional aircraft, should be around 5%. By contrast, the first iteration of the 1905 Flyer was approximately -23%. By 1908 the static margin had improved to -8%, which is still below -5%, today's limit for human-controlled aircraft (Hooven 1978). This instability can be observed in film footage of the airplane in flight, with the airplane constantly porpoising throughout the flight. This instability led to frequent “hard” or otherwise unplanned landings for the Wright Brother’s flyer. More often than not their planes needed some level of repair after this type of landing.

Another area of concern with the Flyer is the fact that the airfoils used were very thin and therefore extremely susceptible to stall. The canard’s ability to produce lift was only slightly better than that of a flat plate. Although it had a very ingenious mechanism to increase its camber as it was deflected upward, it still did not perform any better than a NACA 0002, while producing significantly higher drag. Also, in order to produce enough lift in steady level flight the wings had to fly at an 8° angle of attack, right on the verge of stall.

Another shortcoming of the 1905 design was its high parasitic drag. Both the wing and canard had blunt leading and trailing edges resulting in high drag coefficients. Also, all of the aircraft structure for the airplane had the same level of streamlining: nothing more than rounded corners on their woodwork. Wind tunnel data for the 1903 Flyer, which had the same general drag cross section as the 1905, showed that it developed approximately 125 pounds of drag in level flight at 28 miles per hour (NASA 1999). This could have easily been reduced by a factor of 2 or 3 using appropriate streamlining.

**Characteristics of Canard Aircraft**

In standard tail-configured aircraft the elevator often has negative lift in trimmed flight in order to counter the negative pitching moment of the main wing. With a canard-
configured aircraft the lift in trimmed flight is positive in order to counter the main wings' pitching moment. Thus the canard carries a percentage of the aircraft's weight. The canard configuration is more efficient in that both the canard and wing contribute to lifting the aircraft where in tail configured aircraft the main wing supports the aircraft's weight plus the negative lift created by the elevator. The absolute lift created is less for canards than tail-configured aircraft, which means less drag is induced.

For a canard-configured aircraft to be statically stable, the canard must have higher wing loading than the main wing and thus an airfoil with a high maximum lift coefficient. A statically unstable canard aircraft has a low wing loading on the canard and thus does not need to create much lift. The 1905 Wright Flyer was statically unstable and this is why it was able to fly with an airfoil that had such a low maximum lift coefficient.

One of the design criteria was to have a stall speed below the Federal Aviation Regulation (FAR) requirement of 40 mph minimum stall speed for an ultralight trainer. Minimum stall speed of a canard-configured aircraft is determined by the stall speed of canard. The high wing loading on the canard for stability increases the minimum canard stall speed, which increases the stall speed of the whole aircraft. Stability (high canard wing loading) and low minimum stall speed requirements are satisfied using an airfoil with a high maximum section lift coefficient. High maximum section lift coefficients are obtained for an all-flying canard predominantly by increasing the camber and thickness of the airfoil section. However if thickness and camber are increased dramatically the aesthetic design criterion is compromised.

Airfoil Considerations

The Wright Brother's performed airfoil analysis using rudimentary wind tunnel testing that was advanced for its time, however present-day technology allows for much improvement. Many different airfoil types including the NACA 4-digit and the USU 12-digit series were analyzed to evaluate lift, drag, moment, and stall characteristics. USU airfoils are designed for a uniform pressure distribution at zero angle of attack. The uniform pressure distribution minimizes adverse pressure gradients, drag, and probability of boundary layer separation, or stall.

Canard Airfoil Design

As previously described, the 1905 Wright Flyer canard airfoil is closely modeled as an all-flying NACA 0002. A NACA 0002 produces a very small maximum lift coefficient, approximately 0.25. As previously concluded, a higher lifting airfoil would need to replace the 1905 canard airfoil. The 1905 used an all-flying canard, meaning that the entire surface rotated to obtain a deflection. To satisfy aesthetics, the USU Wright Flyer also utilizes an all-flying canard.
Airfoil sections for the canard were optimized by first changing camber. Several aircraft were modeled in WINGS2001, the only difference being the camber of the canard airfoil. The camber was increased from 2.2% to 4.5%. Over this range, the static margin only decreased 0.6%, while the canard stall speed decreased 5 mph. Increasing camber had a desirable effect, which was to lower the stall speed without significant change in the stability. A camber of 4.5% was chosen because it was the highest cambered airfoil that would not take away from the aesthetic value of the design.

Next, an optimization of canard airfoil section thickness was made. Aircrafts with 8%, 9%, and 10% airfoil thickness were analyzed. Static margin dropped 0.06% from 8% to 9% thickness, and dropped 0.12% from 9% to 10% thickness. Stall speed dropped 0.85 mph from 8% to 9% thickness, and dropped 0.11 mph from 9% to 10%. Increasing thickness had a better effect from 8% to 9% than from 9% to 10% because there was a larger drop in stall speed and a smaller drop in static margin. Therefore a 9% thick airfoil for the canard was the best choice.

The USU 12-digit airfoil that corresponded to the 4.5% camber and 9% thickness was a USU 993009-3040.13 shown with the 1905 canard in Figure 1.2. Lift slope and maximum section lift coefficients were then obtained from CALCFOIL and compared to the NACA 0002 as shown in Figure 1.3. Obvious improvements in maximum section lift can be seen in this comparison.

An analysis of pressure distributions on the upper and lower surfaces of the USU 993009-3040.13 and NACA 0002 airfoils was done using AIRFOIL2001 to check for the presence of adverse pressure gradients. As previously mentioned, adverse pressure gradients can cause an abrupt stall. Both airfoils were analyzed at zero degree angle of

![Figure 1.2: 1905 Wright Flyer (top) and USU 993009-3040.13 (bottom) canard airfoil cross-sections.](image)
Figure 1.3: A section lift coefficient comparison between USU 993009-3040.13 and NACA 0002 airfoils.

attack and at a takeoff/landing condition of 10 degrees angle of attack as seen in Figure 1.4 and Figure 1.5 respectively. The obvious effects of camber can be seen as the change in pressure between the upper and lower surfaces in Figure 1.4. The USU airfoil has a smoother pressure distribution and the desired smaller pressure gradient near the leading edge of the airfoil section as seen in Figure 1.5.

Figure 1.4: The zero angle of attack pressure distribution for the USU 993009-3040.13 (left) and NACA 0002 (right) airfoil sections.
Main Wing Airfoil Design

The 1905 Wright Flyer main wing airfoil had a poor lift to drag ratio due to its thin shape and blunt leading edge. The main factors considered in selecting a new airfoil were the lift and stall characteristics along with the pitching moment created. Because of the large wing area with respect to the overall weight of the aircraft, it was not necessary to select a high lift airfoil. It was more important to select an airfoil that had an acceptable pressure distribution and good stall characteristics.

Airfoil Optimization and Analysis

There were several variables that were taken into account that affect the performance of an airfoil. These variables included airfoil thickness, location of maximum thickness, leading and trailing edge geometry, and camber. After much iteration a modified USU 402509-3040.13 airfoil was selected. It is shown in Figure 1.6 along with the 1905 Wright Flyer airfoil.

The USU airfoil has a much larger maximum thickness than its 1905 counterpart (9% of the chord length vs. 3.5%), which allows larger angles of attack before stall. The 1905 airfoil has very blunt leading and trailing edges and has a near constant thickness over the whole chord length. The USU airfoil is thickest at the quarter chord, tapers to a sharp point at the trailing edge and is smoothly rounded in the front. These characteristics reduce flow separation and allow the suitable pressure distribution shown in Figure 1.7.
Figure 1.6: 1905 Wright Flyer airfoil (top) and USU 402509-3040.13 airfoil (bottom)

Figure 1.7: Pressure distribution of modified USU 402509-3040.13 airfoil.

Due to the improved aerodynamic efficiency of the new airfoil design, it was not necessary to have such a highly cambered design. Even with less then half the camber of the 1905 airfoil, the lift characteristics of the modified USU airfoil are much more desirable. Figure 1.8 shows the predicted lift slopes of the two airfoils using data obtained from CALCFOIL. It can be seen that the USU airfoil has a higher maximum lift coefficient, and can achieve higher angles of attack before stalling.

The USU airfoil was modified slightly in order to reduce the forward pitching moment that is created by cambered airfoils. This was done in order to reduce the loading of the canard. The last 5% of the trailing edge was reflexed upward slightly 7 degrees which reduced the lift on the end of the airfoil. At high angles of attack the end section of the airfoil actually produced a small amount of negative lift. While this does reduce the lift efficiency of the airfoil, it is justifiable due to the low wing loadings required for flight. Figures 1.9 and 1.10 illustrate the slight design modification and how it drastically reduces the forward pitching moment coefficient.
Figure 1.8: Lift slopes of 1905 Wright Flyer and USU airfoil.

Figure 1.9: USU 402509-3040.13 airfoil with modified trailing edge.

Figure 1.10: Moment Slopes of 1905 and USU airfoils.
Longitudinal Static Stability

The improvement in the airfoils assisted in developing a more stable aircraft, but many more parameters needed to be studied. The most accurate representation of the airplane and its flight stability was found by modeling it in WINGS2001. However, when the affects of many variables needed to be explored, using WINGS2001 was very time consuming. In order to assist in the analysis, a computer program named STAB was developed to quickly approximate the static margin. STAB incorporated the basic equations that govern the longitudinal stability of an aircraft, including simple statics (Newton's Second Law), and basic flight mechanics, to compute the static margin. A free-body diagram similar to the one used in the derivation is shown in Figure 1.11. Though the program was designed to produce only an estimate of the static margin it proved to be quite accurate in its predictions when compared to the results found from WINGS2001.

When comparing a bi-plane to a conventional single-wing aircraft the non-dimensionalization process must be changed. The reference area must be doubled, to represent an area equivalent to both the top and bottom wings. The longitudinal reference length was also doubled to represent the two wings. Another factor of concern was that two wings in a biplane configuration do not create the same amount of lift (and therefore upwash on the canard), when placed together. In order to account for this inefficiency WINGS2001 was used to determine how a bi-plane configuration affected the lift of two wings. Then the lift and upwash created by the main wings were scaled proportionally (the scaling factor was 0.91).

Figure 1.11: Simplified free-body diagram of a canard aircraft (without vertical offsets).
In order to find the desired static margin, certain parameters of the plane were altered while others were held constant in order to retain aesthetics to the highest possible degree (such as the span and chord length of the main wing). After eliminating these and other parameters, the following remained as variables altered to find the ideal static margin:

- Location of the center of gravity
- Canard span
- Canard chord length
- Canard location.

After experimenting with many different configurations and values for the chosen variables, the following changes increased the static margin:

1. Moving the CG position further forward.
2. Decreasing the canard span.
3. Decreasing the canard chord length.
4. Moving the canard further aft.

Notice that changing all of these parameters in the manner specified also increases the wing loading on the canard surfaces, affecting not only the static margin but also the stall speed of the aircraft. The coupling of higher stall speeds with low static margins was a difficult obstacle to overcome. Figure 1.12 shows a plot generated using STAB. It represents a flyer with a canard span of 12.5 feet and the CG placed one foot in front of the leading edge of the main wing.

The following parameters were chosen from the preliminary analysis:
1. CG position = 1.0 feet forward of the main wing’s leading edge
2. Canard span = 12.5 feet
3. Canard chord length = 2.5 feet
4. Canard placement = 9.5 feet forward of the CG (referenced to the ¼ chord)
5. Static Margin = 8.0%

The 1905 Wright Flyer parameters for comparison:
1. CG position = 3 to 6 inches behind the ¼ chord of the main wing
2. Canard span = 15 feet, 7 ½ inches
3. Canard chord length = 3.125 feet
4. Canard placement = 11.2 feet forward of the CG (referenced to the ¼ chord)
5. Static Margin = -23%

Final results after analysis with WINGS2001:
6. CG position = 1.0 feet forward of the main wing’s leading edge
7. Canard span = 12.5 feet
8. Canard chord length = 2.5 feet
9. Canard placement = 9.5 feet forward of the CG (referenced to the ¼ chord)
10. Static Margin = 9.5%
Aerodynamic Drag Reduction

To improve the aerodynamic design of the 1905 Wright Flyer, a detailed analysis of structural parasitic drag of the original was performed. Once the characteristics of the original aircraft were understood, improvements could be recommended and designed.

The 1905 Wright Flyer

The aerodynamic drag forces that affected the 1905 Wright Flyer were estimated using a set of blueprints drawn under the direction of Wilbur Wright nearly forty years after the plane was flown. The main equation used in the analysis was the definition of the non-dimensional drag coefficient.

\[
C_D = \frac{\text{Drag Force}}{\frac{1}{2} \rho V^2 \text{Area}} \quad \text{(eq. 1.1)}
\]

The process was simply a matter of examining each part of the plane, estimating the frontal area of the part, then determining the best value for the drag coefficient. The
areas were estimated by measuring the blueprints and scaling the dimensions. The drag coefficients were determined by comparing each part to a list of geometries described in Fluid Mechanics by Frank M. White, and then choosing the geometry best describing the part. The aerodynamic forces calculated for each part were then added together to give an approximation of the total drag force exerted on the original aircraft during flight.

In using the drag coefficient equation, density was assumed to be \(0.0023769 \text{ slug/ft}^3\) (standard sea-level air density). The velocity used was 28 \(\text{mph}\), which is about the speed the Wrights are reported to have flown. The drag coefficients and corresponding geometries used are tabulated below in Table 1.1.

A large portion of the drag was actually developed by the main wings. The drag coefficients for the main wing, canard, and rudder were found using CALCFOIL. To be consistent with the derivation of their coefficients, the reference areas used in the drag force calculations were the planform areas. A spreadsheet was then used to organize the analysis of each part and calculate the drag forces (see Appendix A).

Although the Wright brothers had done a good deal of airfoil testing in the development of their plane, they seem to have been primarily interested in the lift produced by the surfaces they tested. It is not evident that they paid much attention to the aerodynamic drag caused by the many other parts on their flying machine. For example, the parasitic drag coefficient for the main wing airfoil on the original plane was estimated to be about \(C_{D_p} = 0.047\), while most modern commercial planes have wings with parasitic drag coefficients around \(C_{D_p} = 0.02\).

All of the flying machines designed and built by the Wright brothers developed relatively large aerodynamic drag from bluff bodies as well. The 18 struts between the main wings, and the 9 struts on the canard were all simply oval cylinders. The entire chassis was made of a similar cross section. Several hundred feet of wires and cables held the plane together. A round cylinder, such as a wire or cable, has a drag coefficient of 1.2. A small cylinder about 0.0625" diameter, such as a wire, creates the same drag force as a streamlined body that is six times as thick. There was much room for improvement in the structural/aerodynamic design of the world's first airplane.

<table>
<thead>
<tr>
<th>Round Nose Section</th>
<th>L/H</th>
<th>0.5</th>
<th>1.0</th>
<th>2.0</th>
<th>4.0</th>
<th>6.0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(C_D)</td>
<td>1.16</td>
<td>0.90</td>
<td>0.70</td>
<td>0.68</td>
<td>0.64</td>
</tr>
<tr>
<td>Flat Nose Section</td>
<td>L/H</td>
<td>0.1</td>
<td>0.7</td>
<td>2.0</td>
<td>3.0</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>(C_D)</td>
<td>1.90</td>
<td>2.70</td>
<td>1.80</td>
<td>1.30</td>
<td>0.90</td>
</tr>
<tr>
<td>Cylinder</td>
<td>(C_D)</td>
<td>1.20</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disk</td>
<td>(C_D)</td>
<td>1.17</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Main Wing</td>
<td>(C_D) Parasitic</td>
<td>0.047</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canard Wing</td>
<td>(C_D) Parasitic</td>
<td>0.030</td>
<td></td>
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</tr>
<tr>
<td>Rudder</td>
<td>(C_D) Parasitic</td>
<td>0.002</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 1.1:** Drag coefficients of varying geometries.
The reduction of drag for a more modern design was a straightforward process. The structural elements of the plane were redesigned with two objectives aside from the requirements of holding the plane together. The first periphery constraint was to maintain a form that would represent the 1905 Wright Flyer from about 100 feet away. The second periphery constraint was to reduce the aerodynamic drag.

By using stronger and more modern materials, along with better construction techniques, many extraneous structural elements were either eliminated, or their numbers reduced. The remaining parts were redesigned to reduce their frontal area or use geometries with smaller drag coefficients. In the case of the wings and canard, more efficient airfoils were used, thereby not only increasing the performance and stability of the plane, but also greatly reducing the parasitic drag. The final design of the main wing airfoil resulted in an impressive parasitic drag coefficient of $C_{Dp} = 0.0073$.

After the final structural design of the USU Wright Flyer was finished, a second spreadsheet (Appendix A) was developed to estimate the drag forces experienced in flight. Comparing the two spreadsheets shows the drag differences between the new USU flyer with the old 1905.

For the USU flyer the number of struts needed for structural support was reduced, the struts that remained were changed to have a streamlined cross-section, and all of the wires used to hold the plane together were eliminated. Figure 1.13 shows how these changes benefit the performance of the USU Wright Flyer. The 1905 fought approximately 120 pounds of aerodynamic drag at a cruise speed of 28 mph. The new aircraft at the same speed had only 55 pounds of drag. If the original aircraft had enough propulsive power to reach the design cruise speed of the new aircraft (45 mph) the drag would be 300 pounds. The new aircraft is estimated to induce only 120 pounds at cruise.

From a copy of the Wright brother's 1908 notebook, they recorded a static thrust from their propellers of 134 pounds (Ash 1999). Their propellers would produce less thrust at 28 mph, and the thrust must equal the drag in steady-level flight. So a prediction of 120 pounds of drag seems quite reasonable.

It is interesting to note the influence that a passenger had on the two airplanes. There is not much difference between flying with or without a passenger in the original aircraft. The drag from the 1905 airframe was so large that the second person didn’t make much difference. On the new aircraft however, the airframe drag is low enough that adding a passenger significantly adds to the over all drag.
The aerodynamic drag forces on the aircraft also produce a moment about the center of gravity. Since the majority of the aircraft's frontal area is above the center of gravity a pitching-up moment is produced. As the speed of the aircraft increases the pitching moment also increases. Figure 1.14 shows a prediction of how the positive pitching moment is expected to increase as a function of forward airspeed. At a cruise speed of 45 mph, the moment acting on the USU Wright Flyer should be about 700 ft-lb. The propellers, sitting two feet above the center of gravity will have to produce enough thrust to balance the expected drag force of about 125 lbf, thus producing a negative moment of 250 ft-lb. A remaining moment of 450 ft-lb is left acting on the aircraft. The possible stability problems due to the increased pitching moment were evaluated by adding an extraneous surface to the WINGS2001 model that would produce the same results as the total parasitic drag of the aircraft.

The detailed estimations of the drag forces and moments that are expected for both the 1905 and the USU Wright Flyer made it possible to find ways to improve the 1905 Wright Flyer and also predict the needs of the USU Wright Flyer. The thrust needed for take off and cruising flight were predicted, and values needed to predict the static stability of the aircraft were found.
Canard configured aircraft can be susceptible to an unrecoverable stall if the main wing stalls before the canard. If the wing were to stall first the aircraft would pitch backwards and there would be no way to restore the flow over the wings surface and regain level flight. When the canard stalls first the aircraft pitches forward and loses altitude (potential energy), which is exchanged for an increase in airspeed (kinetic energy). The boundary layer re-attaches to the canard surface inducing lift, which allows the pilot to pitch back the aircraft and return to level flight.

To verify a "canard first" stall, the new aircraft was balanced in WINGS200J at speeds ranging from 20 mph to 80 mph. Data from WINGS2001 showed that as the aircraft approached stall, the balanced angle of attack for the canard approached its maximum angle of attack at a faster rate than the wing did. Thus the canard would stall first. Downwash on the wing tends to decrease its absolute angle of attack and move away from stall, while upwash on the canard tends to increase its absolute angle of attack and move it closer to stall.

A "canard first" stall analysis was also done with respect to lift coefficients using the same method outlined above. The data also showed that as the aircraft approached stall the lift coefficient for the canard increased at a higher rate than that of the wing, thus the canard always stalled first. Static margin was found to increase with decreasing speeds. This verified that the aircraft would maintain good stability throughout its design speed range.

**Performance**

![Graph of drag moments as a function of airspeed.](image)

*Figure 1.14: Drag moments as a function of airspeed.*
The USU Wright Flyer performance analysis found in Appendix B was developed using equations based on Newton's second law (Phillips 2002), data obtained from WINGS2001, and the drag analysis (Appendix A). Results of this analysis are best presented graphically as: Figure 1.15 - Thrust Required/Available, Figure 1.16 - Power Required/Available, Figure 1.17 - Rate of Climb, and Figure 1.18 - Sink Rate. The analysis also found the USU Wright Flyer to have a stall limited minimum turning radius of 84.2 ft, and take off distance of 222.0 ft.

**Figure 1.15:** Comparison of thrust required to maintain level flight and thrust available given the chosen engine and propellers at standard sea level.

**Figure 1.16:** Comparison of power required to maintain level flight and power available given the chosen engine and propellers as standard sea level.
Figure 1.17: Rate of climb at standard sea level.

Figure 1.18: Sink rate at standard sea level.
Dynamic Stability

After finding the USU Wright Flyer to be statically stable it was necessary to ensure its dynamic stability. Many modern aircraft design projects are delayed because of problems with dynamic stability, as it can be a difficult characteristic of an airplane to predict (Phillips 2002).

The dynamic stability of an aircraft is found by determining how the airplane would respond to different perturbations from the equilibrium state. Just as a spring-mass system has different dynamic modes, so does an aircraft. The airplane is the mass and the atmosphere is the spring. The five main dynamic modes for an aircraft are:

1. Short-period
2. Long-period or Phugoid
3. Roll
4. Spiral
5. Dutch Roll

Each mode represents conditions that could either make the flight uncomfortable or, in some cases, dangerous.

In order to quantify an airplane’s characteristics in dynamic stability, the government has established a classification system that measures how an aircraft’s dynamic modes affect the quality of flight. Cooper and Harper (1969) developed a rating system that ranked an aircraft’s handling characteristics according to pilot opinion. A Level I rating in this system corresponds to an aircraft for which “pilot compensation (is) not a factor for desired performance.” Level 4, the lowest pilot rating, states “control will be lost during some portion of required operation” (Phillips 2002).

Different classes of aircraft and categories of flight phases are also taken into account when classifying an airplane’s dynamic flight capabilities. The USU Wright Flyer is a Class I aircraft, which means it is small, light, and used for training or “general observation.” The flight phase for the flyer will be a Category C, implying “gradual maneuvers” requiring “accurate flight-path control” (Hodgkinson 1999). Table 1.2 shows the requirements of a Level I pilot rating for each of the major dynamic modes given this particular aircraft class and flight category.

Just as a spring-mass system has a governing equation to describe its motion, so does an aircraft. A computer program named DYNSTAB was developed using the linearized equations of motion to find the properties of the different dynamic modes of an aircraft. DYNSTAB required as input a list of moments of inertia and derivatives characterizing the motion of an aircraft. The moments of inertia were found using solid models of the 1905 and USU Wright Flyers made with Autodesk® Mechanical Desktop© and Inventor©. The aerodynamic derivatives were found using WINGS2001 and
DYNSTAB was then able to find the dynamic flight qualities of both the USU Wright Flyer and the 1905 flyer (see Table 1.2).

As can be seen in Table 1.2, the USU Wright Flyer passed almost all of the requirements for Level I status in steady-level flight. The divergent spiral mode had a Level II doubling time, which is less than ideal. However, in the conditions the airplane will be flying in (visual flight reference or VFR), it should be only a slight inconvenience to the pilot, and not a dangerous quality.

The positive pitching moment of the 1905 Flyer, which resulted in static instability, prevents a proper prediction of its short-period mode. The spiral mode doubling time of the 1905 Flyer was just above the threshold of a Level IV pilot rating (4.0 seconds), resulting in a nearly uncontrollable aircraft.

The Level II spiral mode of the USU flyer gave rise to a study of the effects of how dihedral and a smaller rudder would effect the plane’s dynamic stability. Not mentioned earlier was the fact that the initial dynamic analysis did not consider the fact that under regular flight conditions the wings would have natural dihedral due bending in the wing spar. Ignoring the natural dihedral resulted in a doubling time of 9.54 seconds. Using a simple cantilever model, dihedral was placed in the wing representing the natural wing deflection during steady-level flight. The doubling time of the spiral mode was then found to be 12.62 seconds. The result was not only more pleasing, but also more realistic. The dynamic stability results shown in Table 1.2 for the USU Wright Flyer are actually the results obtained by incorporating the natural dihedral.

### Hodgkinson Classifications (1999)

**Aircraft Classification:** Class I  
**Flight Phase:** Category C

<table>
<thead>
<tr>
<th>Mode</th>
<th>Requirements for a Pilot Rating of Level I</th>
<th>USU Wright Flyer</th>
<th>Original 1905 Flyer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short-period</td>
<td>Range of $\zeta$</td>
<td>0.35 to 1.30</td>
<td>0.87156 n/a</td>
</tr>
<tr>
<td>Phugoid</td>
<td>Minimum $\zeta$</td>
<td>0.04</td>
<td>0.123455 0.52627</td>
</tr>
<tr>
<td>Roll</td>
<td>Maximum $1/\sigma$ (sec)</td>
<td>1.0</td>
<td>0.03733 0.08827</td>
</tr>
<tr>
<td>Spiral</td>
<td>Minimum Doubling Time (sec)</td>
<td>20</td>
<td>12.62</td>
</tr>
<tr>
<td>Dutch Roll</td>
<td>Minimum $\zeta$</td>
<td>0.00</td>
<td>0.46145 0.56481</td>
</tr>
</tbody>
</table>

**Key:**  
- Level I  
- Level II  
- Level IV

<table>
<thead>
<tr>
<th>Mode</th>
<th>Minimum $\zeta_0 R$</th>
<th>Minimum $\zeta_0 a_n$</th>
<th>Minimum $\omega_0$</th>
</tr>
</thead>
<tbody>
<tr>
<td>USU Wright</td>
<td>0.15</td>
<td>1.84903</td>
<td>4.00701</td>
</tr>
<tr>
<td>Original</td>
<td>1.35461</td>
<td>2.39834</td>
<td></td>
</tr>
</tbody>
</table>

**Table 1.2:** Hodgkinson (1999) classification comparison for Level I pilot rating. Values for the USU Wright Flyer and the original 1905 Flyer represent steady-level flight.
Another attempt to increase the doubling time of the spiral mode was to decrease the size of the rudder. The design team was hesitant to do so in the first place because of the negative effect it would have on the aesthetics of the airplane. Decreasing the chord length of the rudder was the best possibility. However, by reducing the rudder's chord length from 3.0 feet to 2.75 feet in the DYNSTAB model, the resulting doubling time was 12.68 seconds, only a 0.5% increase. Needless to say, the original rudder size remained in use.

Velocity is a large contributor to the quality of an aircraft's dynamic stability. Figure 1.19 represents the manner in which the velocity affects the doubling time of the spiral mode. The figure also presents the relationship between the spiral mode's doubling time and changes in climb angle. As one can see, high climb angles can cause the plane to plummet below the Level III threshold, placing the aircraft in a potentially dangerous situation.

In the continued study of airspeed effects, a phugoid mode of decreasing quality was found at lower speeds, as shown in Figure 1.20. A flight speed of 35 mph causes a higher climb angle to be potentially dangerous. With this and the potential spiral mode problems at lower airspeeds, it will be important for the pilots of the USU Wright Flyer to be gradual in their maneuvering. In take-off configuration, for example, the pilot must maintain a high speed and a low climb angle to secure safe handling of the aircraft.

The effects of bank angles were also studied, but found only to increase the dynamic stability of the aircraft within the realm of the USU Wright Flyer's flight conditions.

![Figure 1.19: Doubling time of the spiral mode amplitude as the climb angle changes for airspeeds of 45 and 55 mph.](image)
Figure 1.20: Damping rate of the phugoid mode as the climb angle changes for airspeeds of 35 and 45 mph.

Early in the year of 1905 the Wright Brothers added blinkers to their canard to keep the nose of the plane from sliding to the side when banking. The blinkers were small vertical plates that sat between the two canards. Little did the Wright Brothers know that the blinkers would also increase the dynamic stability of their aircraft. In the initial design phases of the USU Wright Flyer the blinkers were assumed to create more drag than they would assist in stability, and were therefore emitted. The small difficulties encountered in both the spiral and phugoid modes led to a decision to reapply the blinkers. Adding the blinkers raised the spiral doubling time to almost 18 seconds. They also had a small positive effect on the phugoid damping ratio, most likely due to the winglet effect the blinkers had on the canard. It is common for modern aircraft to use what is called a strake to create a similar stabilizing effect, due to the commonality of the divergent spiral mode. The actual application of the blinkers to the USU Flyer will be beyond the scope of our time frame.

The design of the USU Wright Flyer has been one to create a unique airplane — one to bring the past into the future. Had the goal of this design been to create a more conventional aircraft, different design criteria would have been established, and the performance in dynamic stability would have been greatly improved. However, it has been shown that the dynamic stability of the USU Wright Flyer surpasses the performance of the 1905 Wright Flyer. Due to the overall improvement and the competent performance of the new plane the less-than-ideal circumstances presented above, such as the spiral and phugoid modes, are permissible.
If design changes were possible, the first step in improving the dynamic stability would be to increase the airspeed. This alone would raise the dynamic stability pilot rating to Level I for all modes, and allow for steeper climb angles. Blinkers would also increase the dynamic stability, especially for the spiral mode. However, the effects of the blinkers are still small compared to simply increasing the airspeed.

Conclusion

The Wright Brothers’ work was ingenious for their time, laying the groundwork for the advancement in flight sciences for 100 years. As aerodynamic sciences have built upon their findings, this project has built upon their aircraft. The targets established at the beginning of this re-designing; an aircraft that appears as the 1905 Wright Flyer, positive pitch stability and a stall speed 15 miles per hour less than cruise have been accomplished according to the analysis completed thus far.

1. Aesthetically similar to the 1905 Wright Flyer (See Figure 1.21)
2. Stable in Pitch (Static Margin = 9.5%)
3. Stall Speed = 30 mph (2 people), 25 mph (1 person).

All of these results are based upon a 45 mph cruise speed and a 496 lbf aircraft empty weight. The relevant results of the aerodynamic design were passed along to the structural team members to bring the design to life as is detailed in the following chapters.

Figure 1.21: WINGS2001 models of 1905 and USU Wright Flyers. Clockwise from top left: 1905 Wright Flyer, USU Wright Flyer, USU Wright Flyer, USU Wright Flyer side view showing lift of airfoils (red), USU Wright Flyer top view.
Main Wing Design
Introduction

The main wing the 1905 Wright Flyer was ingenious in many ways. The spars, ribs, and struts were made of spruce and ash, making them light and easy to work with. The wings could be attached and detached easily using simple, modular hardware. The wing warping method designed to control the plane was ahead of its time. The exceptional designs invented by the Wright Brothers made their wing simple and light weight.

Although the original wing design was extraordinary, major changes were needed to accommodate the aerodynamic redesign. For example, the original airfoil was replaced by a thicker more efficient design. The simple change in the wing thickness necessitated changes in many other aspects such as the spars, struts and cabling system.

Despite these large changes, every care was taken to remain sincere to the Wright Brother's original wing design. Wing warping is the defining characteristic of the 1905 Wright Flyer wings. As will be shown, all designs of the USU Wright Flyer were done around wing warping in hope of honoring the great builders of a legacy.

Concept Requirements

1. Weight
   A. The final design must weigh less than 120 pounds without compromising safety and/or functionality.

2. Wing Warping
   A. When warped, the wings must keep an acceptable airfoil shape (minimal skin wrinkling).
   B. The design must accommodate a maximum pilot force of 70 lbf.
   C. The design must produce an acceptable roll rate.

3. Strength
   A. The wings must be built so that the deflection of the wingtips is 20 inches when the aircraft is in a 2.5g turn.
   B. The wing spars must be able to withstand a maximum distributed load of 525 lbf at the interfaces.

4. Aesthetics
   A. The aircraft must look like the 1905 Wright Flyer from a distance of 100 feet to a person that has a general knowledge of the design.

5. Interfaces with other parts of the airplane
   A. All interfaces must withstand all possible loads that could occur during normal flight and landing conditions.

6. Manufacturing
A. All designs must take into account the construction capabilities of the Utah State University Industrial Technology Department.
B. All designs must be capable of being manufactured within a reasonable time frame.

Wing Warping

1905 Wright Flyer Design

Initial wing warping ideas for the USU Wright Flyer were based on the warping devices of the 1905 Wright Flyer (see Figure 2.1). The 1905 Wright Flyer used two flimsy spars that could be deflected to warp the wing. Each rib was attached to two spars, one at the leading edge of the wing and one about four feet back. With a clever cable setup, the Wright Brothers deflected the back spar to achieve an acceptable rolling rate. The design worked well with the thin airfoil of the 1905 Wright Flyer.

USU Wright Flyer Design

Using the wing warping method designed by the Wright Brothers as a foundation, internal changes were made to accommodate the new airfoil shape. Several ideas considered were twisting a single spar, splitting a rib to include an elastomeric interface and twisting the leading edge of the wing with free floating ribs.

Twisting a Single Spar

This concept uses a single main spar to carry both the lifting loads and the wing warping loads. The spar would have a torsion load applied at the wingtip to cause the attached ribs to deflect.

Initial concepts using a twisting spar had some very appealing properties. Foremost was the elimination of the rear spar, which greatly reduced the overall weight of the wing structure. Control cables and rods would be located inside the wing structure, eliminating parasitic drag caused by external cables.

Several attributes of the Single Spar design were found to be unacceptable. First, the main spar would be subjected to continuous torsion and bending loads. Torsion loads would be further increased by the inherent moment caused by the wing. Such a combination of loads was frightening bearing in mind that if the spar failed the aircraft would crash. Second, no acceptable twisting mechanism was found to apply controlled warping.
Splitting the Ribs with an Elastomeric Interface

This concept splits the outer ribs near the quarter-chord and reattaches them with an elastomeric material effectively creating a large, internal aileron. A load applied to the back spar would bend the back portion of the ribs while the front piece remained rigidly attached to the main spar. Two rubber-like interfaces would hold the pieces together (Figure 2.2). This eliminates the constant loading of the main spar, allowing it to carry the lifting forces while the rear spar experiences only the predictable bending loads created by the control cables.

A mockup was built to analyze the feasibility of construction and locate any problems that were not originally taken into account. Motion was found to be acceptable, but the front and back rib pieces tended to separate. Applying retaining blocks to the edges of the ribs impeded this problem, but still left concern (Figure 2.3).

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**Figure 2.1:** The 1905 Wright Flyer wing warping detail from original drawings.

**Figure 2.2:** Split rib with elastomeric material.
Unfortunately, this design did not meet the requirement for simplicity. As the individual parts were considered, the design quickly grew too complex. This design required two to three separate D-tubes, elastomeric material that would run the entire length of the warping section, two spars, and four spar collars (Figure 2.4).
Twisting Leading Edge with Free-Floating Ribs

Work was then done to simplify the previous design. It was found that the leading edge of the airfoil was nearly three inches in diameter. Therefore, a three-inch diameter front spar was placed at the leading edge. This would strengthen the leading edge and effectively eliminate the need for the two heavy D-tubes, which could now be replaced with a single lightweight composite piece. The rib was also left as a solid piece that could rotate around the front spar, eliminating the need for the elastomeric material. Finally, simple wooden blocks bonded to the spar replaced the spar collars to constrain the ribs in the lateral direction.

This idea, consisting of only five main parts (the ribs, the back spar, the front spar, the leading edge, and the wingtip) is much simpler than the previous design, which incorporates ten. As shown in Figure 2.5, the outer seven ribs are free-floating over both spars and are bonded only to the slightly flexible leading edge. The wingtip simply constrains the distance between the two spar tips and is also free-floating. Control cables bend the back spar to provide the same warping motion as the 1905 Wright Flyer. Ironically, the best design found was nearly identical to the 1905 Wright Flyer, which is great testament to the ingenuity and engineering skill of the Wright Brothers.

Leading Edge Design

To achieve the flexibility for the required motion of the leading edge, the expertise of Dave Widauf and Charles Larsen was sought. According to their opinion, woven graphite laid up at a 45° angle would provide the needed strength and flexibility.

![Figure 2.5: Twisting leading edge idea detail.](image-url)
Determination of Required Wing Deflection

To ensure proper aileron size and placement it was necessary to model the USU Wright Flyer using WINGS2001. The process of studying the affects of aileron deflection entails matching a desired rolling rate with the required aileron deflection. If a large deflection is required the ailerons may be undersized or poorly located. Similarly, small deflections might indicate that the ailerons are too large.

The difficult part in obtaining assurance of proper aileron sizing and deflection is generating an accurate model of the airplane. For most aircraft it is not a problem because the ailerons have a specific location and size. However, it is difficult to model a warping wing.

WINGS2001 applies the same angle of aileron deflection on every flap designated as an aileron. With wing warping, the wing is most deflected toward the tips of the wing and the deflection decreases until the wing can be considered rigid, having no deflection. Since it was impossible to model this gradual decrease in deflection angle in WINGS2001, a different technique was used. First of all, the wing was broken up into sections as shown in Figure 2.6(a). After dividing the wing, the midpoint of each section was treated as a point on a cantilever beam. Next, the ratio of a section’s midpoint deflection compared to the maximum deflection was used as the percent of the chord of each section used as an effective aileron, as shown in Figure 2.6(a) and (b).

A rolling rate value $p$, commonly used for aileron sizing in low-maneuverability aircraft is shown non-dimensionalized as follows (Phillips):

$$\left(\frac{pb_{w}/2V_o}{\text{max}}\right) \geq 0.07$$

(eq. 3)

After placing this value into WINGS2001, the resulting rolling moment was then balanced by an opposing aileron deflection. At this balanced configuration, the aileron deflection required in the lifting line model was $5.4^\circ$, which corresponds to a wingtip deflection of 4.3 inches. A visual of the exaggerated wing warping used in WINGS2001 is shown in Figure 2.7.

Trailing Edge Design

1905 Wright Flyer Design

The Wright Brothers simply attached a wire, pulled as tight as possible, to the trailing edge of the ribs. This design did an adequate job, but still allowed the fabric to ‘dip’ and ‘bubble’ in flight.
Figure 2.6: (a) Visual of how the main wing was sectioned, and the percent chord used on each section as an effective aileron. (b) Cantilever beam model used to approximate the percent chord modeled as an aileron.

Figure 2.7: Exaggerated wing warping of the WINGS2001 model.
USU Wright Flyer Design

Great thought was given to this aspect of the design mainly because of a paper written by J. D. DeLaurier of the University of Toronto, “The Development of an Efficient Ornithopter Wing.” The DeLaurier-proposed ornithopter wing had many similar warping motions and requirements, namely the design required that the skin of a double-surface airfoil remained relatively unwrinkled. To achieve this, a sliding trailing edge was developed for the ornithopter wing.

“The essential feature is that the trailing edge has to be split, thus opening the ‘torque box’ formed by the airfoil’s cross section. Two unidirectional carbon fibre/epoxy strips are glued to the ends of the ribs to form the trailing edge. However, these are not glued to each other. Instead, clips are attached which prevent spreading of the trailing edge while allowing free relative lateral motion between the strips” as seen in Figure 2.8 (DeLaurier 1993).

Final Design

Upon further investigation, the motion of the USU Wright Flyer was considered small when compared to the ornithopter motion, and the shearflex trailing edge concept was retired. Therefore, a simple, off-the-shelf trailing edge was specified as seen in Figure 2.9.

Figure 2.8: Shearflex concept.
Spar Design

1905 Wright Flyer Design

The 1905 design, as mentioned in the ‘Wing Warping’ section, consisted of a rectangular arrangement of relatively flimsy spars that depended on cables for stiffness. Wing warping and weight seemed to be the reason behind the idea.

USU Wright Flyer Design

To accommodate the wing warping mechanics, two spars would be required: a main front spar that would carry most of the lifting load and a smaller, flexible back spar that would share some of the lifting load and provide the proper deflection motion for wing warping. Each spar would also require a high enough radial stiffness to bear landing loads at each of the chassis interfaces.

To meet the strength requirement stated above, the combination of the bending stiffness of the front spar, the back spar, and the cables would have to have a deflection of 20 inches while carrying a wingtip load of 60 lbf\(\left(\frac{\text{Weight} \cdot \text{LoadPercentage}}{4}\right)\). This test simulates a 2.5g load to the aircraft. In order to design to these specifications, several assumptions were made. First, since a canard-configured aircraft will always have some load being carried by the canard, a percentage of the load will be sustained by the canard. Second, the load on the wings will be equally distributed over both wings. Finally, the
addition of ribs, skin, and especially cables will carry a substantial percentage of the load. It was decided to model the load percentages as follows:

- Front Spar: 30%
- Back Spar: 20%
- Canard: 15%
- Cables/Ribs/Skin: 50%

**Front Spar Design**

To determine the size and layup to carry the aforementioned load, a simple cantilever model was used (much the same that was used to determine aileron deflection) where the chassis interface location was considered the rigid point of the cantilever (207 inches from the wingtip). The bending load would be placed at the wingtip (see Figure 2.10).

From the chosen wing warping design, the front spar would have to fit the ribs' leading edge of three inches in diameter. It was found that a 3.2-inch diameter tube would only change the leading edge by 0.01 inches. Therefore, a range of values was known for the outer diameter: 3.0 to 3.2 inches in diameter. The outer three ribs' leading edge radii decreased linearly as they were placed further from the center. The front outer spar diameter was reduced to fit this change.

All that was now required to complete the initial design was the inner diameter or thickness of the tube. To find this, the stiffness of the tube would have to be modeled. Composites have been known to have moduli that are difficult to predict. For help with this aspect, a paper written by Chan and Demirhan of The University of Texas at Arlington was consulted. It states that the bending stiffness of composite tube[s] can be obtained by using smeared modulus of the laminate and multiplying the moment of inertia of the tube. The expression is given as:

\[ EI = E_x \frac{\pi}{4} (R_o^4 - R_i^4) \]  

(eq. 2.1)

where \( E_x \) is the smeared modulus of the tube laminate and can be obtained by lamination. (Chan, Demirhan 1995) According to one of the composites donators, Bill Pratt of Patterned Composites Inc., the smeared modulus of the contributed material would be 95 to 100 MPa.

Armed with these assumptions and values, calculation was done to find the thickness of the tube to be ten laminate layers (.05 inches) on the inner section of the spar and twelve layers on the outer section of the spar (Appendix C).
Figure 2.10: Cantilever model used to size front and back spars.

The front spar's layup was done according to the suggestion of Bill Pratt. He suggested that multiples of four were required when using wavy composites to retain even curing properties. Therefore, four wavy layers, two $0^\circ$ layers, and then another four wavy layers were used for the inner section. This layup takes advantage of the ease of building, beauty, and torsional stiffness of the wavy graphite while retaining the good bending stiffness qualities of the $0^\circ$ layers. The front outer spar would use a twelve layer wavy design.

Back Spar Design

While the front spar was mainly designed to hold the bending forces of lift, the back spar was made to support lift, propeller forces, and to assist the warping motion. As can be seen in Figure 2.11, the back outer spar is a large, flexible glass tube much like a vaulting pole in order to provide the proper warping mechanics. The larger middle section of the spar was made to be a rigid anchor for the outer spar and a stiff connection for the engine struts.

Figure 2.11: Back spar assembly.
Again, the smearing method was used to calculate the proper thickness for the inner and outer tubes. The exact motion that would be caused by forces from lift, control cable, and/or propeller forces is unknown because of coupling effects, but has been accounted for in designs discussed in the ‘Interface Design’ section.

Thicknesses for the back spar pieces were found to be eight layers of graphite and a lay-up of eight wavy layers would be used (see Appendix C).

**Spar to Spar Interfaces**

Since the complete spar would be difficult to build as one piece, each spar would have to be made in section and attached together using interfaces. These consisted of shorter, stiffer graphite tubes made to slide into the ends of each spar section and would be filled with foam, wood or any acceptable filler. A filler was used to support the part from crushing since most spar locations have either a chassis interface or a wing strut interface or both.

At the locations where the diameter of the spar is reduced, a different insert would be used. A ‘spar cap’ was inserted into the end of the larger diameter spar having the smaller diameter spar adhered to the inner part. Consisting of a balsa center and spruce end caps, the spar cap would resist the bending loads of the smaller spar while remaining lightweight (Figure 2.12).

**Spar Weight**

Fortunately, the required stiffness of the spars resulted in a lightweight tube. The total weight of the front spar would be about 15 pounds (1/3 lb/foot). The total weight of the back spar drops to 12 pounds (1/4 lb/foot). This left 66 pounds for ribs, struts, connections and skin (see Appendix C). The final spar design follows in Figure 2.13.

![Figure 2.12: Spar cap assembly.](image)
Figure 2.13: Final spar assembly.

Rib Design

The two functions of the USU Wright Flyer ribs were to carry the lifting forces (bending loads) and to constrain the spars in the longitudinal direction (buckling loads). The ribs would form the airfoil shape, and require stiffness in every direction. Also, with over 60 ribs, weight was of great concern.

A number of ribs were manufactured by students of the ITE Department. Each rib consisted of a low-density foam core and a single layer of glass/epoxy adhered to the surfaces of the foam (Figure 2.14). Since the manufacturing method was proven, this general design was chosen for further analysis and modifications.

A simple test was done to determine the bending strength of the ribs (Figure 2.15). Weight was added in a suspended bucket until rib failure. One rib that was recorded to weighed less than 0.5 pounds carried a load of 142 pounds.

The load each rib carried was determined by taking the theoretical lift distribution from WINGS2001 and finding a polynomial to fit the curve (Figure 2.16). The largest rib load in a 2.5g maneuver was calculated to be 50 lbf, well below the tested 142 lbf. This relatively small value was expected because of the small wing loading.
Figure 2.14: Rib layup.

Figure 2.15: Rib testing method
This result left room for weight reduction and several more rib designs were tested, such as the “swiss cheese” design seen in Figure 2.17. Before this testing was done, it was decided that manufacturability would be sacrificed if holes were cut in the rib structures. If holes were cut the exposed foam would have to be covered by composite—a painstaking process for 60 ribs. Since this only reduced the weight of the wing by 3 pounds, it was decided to reduce the weight by using less foam and replacing the fiberglass skin with Kevlar.

Wing Strut Design

1905 Wright Flyer Design

The Wright Brothers used spruce sticks to provide a vertical constraint between the wings. Each strut had an eyebolt lashed to the end that was run though a hook fastened to each spar. This prevented the strut from applying any torsional forces to the spars.

USU Wright Flyer Design

Several aspects of the strut design were explored. First, since the strut cross-section with respect to the free-stream velocity was rather large, drag would be a major consideration. Second, a six-foot strut could be rather heavy and weight was an issue. Third, the struts would have to meet requirements for strength and manufacturability. Several ideas were considered.
Graphite, Cylindrical Tube with Graphite/Nickel Streamlined Fairing

To be consistent with the spar design, a cylindrical tube was initially chosen as the strut structure. The tube and fairing would be made of graphite/epoxy. Simple buckling calculations showed that a ¾-inch tube would be required to hold the loads. A nickel-coated fairing would be wrapped around the strut to reduce drag and provide aesthetics.

Graphite, Airfoil Shaped Tube

The second idea consisted of using an airfoil-shaped bar as a mandrel for the strut. Composite would then be laid around the mandrel and cured. Since the airfoil shape was wider and longer than the diameter of the cylindrical tube, the buckling resistance would be higher and there would be no need for a fairing. The only problem was that the concept was unproven.

With the help and expertise of Professor Charles Larsen, a method was developed to make a streamlined strut (Figure 2.18). This aspect of the USU Wright Flyer is perhaps the most innovative of the entire wing structure. By using this unique building scheme, the struts were created with an airfoil shape made from graphite and epoxy with a nickel surface to create the appearance of wood.
Configuration

The layout of the struts is nearly identical to the 1905 Wright Flyer with one exception: the USU Wright Flyer has added cross struts (see Figure 2.19). By doing this, the stress box was closed where the wings attach to the chassis to provide longitudinal stiffness and help carry the landing and thrust loads.

Figure 2.18: Streamlined tube made with wavy graphite.

Figure 2.19: Demonstration of the 'stress box'.

\[\text{Interface loads}\]
Strut Interface Design

With a finalized strut design, the last obstacle was to connect these struts to the spars. Each interface would have to withstand expected loads while not affecting the properties of the spar. Also, since the above mentioned loads were unknown before actual flight-testing, a modular design was developed to meet the requirements if unforeseen problems arose.

The first part of the design was a simple aluminum plate that would be bonded and strapped to the spar with epoxy and graphite strips. The plate could be bonded in any direction on the spar, providing modularity. Also, the effect on the spar properties would be minimal. Second, a simple aluminum tube would be welded onto the center of the plate. The support bar of the strut would then be inserted inside the tube and affixed to the strut by an epoxy/cotton filler (see Figure 2.20).

Weldament strength was a concern and strength calculations were done to determine that a 0.20x0.20 weld bead would provide strength to withstand the expected bending load of 421 pounds. Where needed, universal joints (Figure 2.21) were used instead of the inserted bar to protect the structure from repeating loading. These joints were constrained in twisting and axial directions, and still allow bending.

Figure 2.20: USU Wright Flyer interface assembly.
Cable Design

1905 Wright Flyer Design

The majority of the 1905 Wright Flyer wing stiffness was provided by a large matrix of cables. These cables were required because of the inherent flaws of the aircraft configuration such as large wings, no fuselage, and flimsy wing spars.

USU Wright Flyer Design

Structural Cabling

For aesthetic purposes, the inherent problems mentioned above were slightly improved but not avoided. Therefore cables were needed to add stiffness to the USU Wright Flyer wing box. The wing spars would be much stiffer than their 1905 predecessors, and the exact stiffness of the entire wing structure would be very difficult to analytically determine. It was determined to make a modular interface design that would allow different cable configurations.

Simple cable plates were designed to fit the bar of the strut interface (Figure 2.22), which could easily be added or removed to any strut interface. The one-pronged cable plate would accommodate a strut interface with only one cable connection while the two-pronged cable plate could fit two connections. It was estimated that the largest load to be carried by the structural cables would be 412 pounds and a 1/16-inch cable (break strength of 460 pounds) was specified.

Control Cabling

To provide routing for the cable design shown in Figure 2.23, another modular pulley idea was used (Figure 2.24). The pulley assembly was also attached to the strut interfaces via cable plates. The cable plates were then bent to the proper angles to prevent cable derailment. Standard 1/8-inch control cable was used on all control routing.

Conclusion

As was shown in the previous sections, many concepts of the USU Wright Flyer mimic the Wright Brothers' original wing design while accommodating the needs of the USU Wright Flyer. By doing this, the design remains true to the Wright Brothers' legacy while creating a safer platform.
Figure 2.22: USU Wright Flyer cable plates (one and two-pronged).

Figure 2.23: Control cable routing design.

Figure 2.24: USU Wright Flyer pulley assembly.
Canard Design
Introduction

The main objective of the USU Wright Flyer canard redesign was to make a strong, simple bi-wing canard, which looked like the 1905 Wright Flyer canard. A canard is the vertical elevator for the aircraft. The dominating problem was the design had to be flexible to accept aerodynamic design modifications and constraints which were undetermined at the beginning stages of the design. Also new material types were to be used and it was important to understand the different characteristics of innovative composite materials.

Concept

When designing a component of an aircraft such as the canard, it is critical to understand the loads and moments that it will experience during normal use and the maximum loads encountered. The initial estimation of the loads in flight was estimated as half the weight of the plane plus a safety factor of two. Resulting in a maximum load of 500 pounds, this was used to calculate stresses. In actuality, the final aerodynamic analysis predicts a trimmed flight load of 183.1 lbs and a 2.5G loading of 457.75 lbs. The 500-pound estimation was an adequate loading in comparison to the predicted values.

Preliminary Design

To allow the airfoil shape, size and location to be variable until aerodynamic analysis was complete meant the structure had to be able to accept a wide variety of constraints and dimensions such as chord length and thickness. A preliminary design package was created and presented to the customer, which incorporated the variability of the structural components and placement.

The initial design for the aerodynamics was finished on November 20 establishing specific parameters such as the chord length, mounting angle, span and distance from the leading edge of the wing. These numbers were later finalized on January 10 and all subsequent drawings that used preliminary design numbers were modified but the basic design did not change.

The 1905 Wright Flyer canard pivoted about the half-chord, which allowed for the varying camber as the angle of attack increased (see Figure 3.1). Canard design constraints were no ailerons, no airfoil deformation during changes in angle of attack, and pivoting about the quarter chord. Pivoting about the quarter chord allows the hinge pins to take most of the load. This minimizes the pitching moments or control forces, and reduces the input force required from the pilot.
Figure 3.1: Original canard changing airfoil shape as angle of attack varies.

Airfoil

The airfoil shape changed drastically as shown by Figure 3.2. The drawing package needed the correct airfoil shape for the construction of the foam core. To determine the dimensions of various components, an X-Y data point file for the airfoil was plotted in AutoCAD 2000 and then imported into Inventor. The airfoil shape was extruded as the basis for all subsequent parts.

The Original 1905 Canard Airfoil

The 2003 Canard Airfoil

USU 993009-3040.13

Figure 3.2: A comparison of the original canard airfoil versus the 2003 design.
Hinges

Vital structural components of the canard are the hinges, ensuring that both lifting surfaces rotate at the same angle. The shear loads on the hinge pins are small: 125 lbf (500 lbf being divided among the 4 hinges). The main spar was initially along the quarter chord for strength, but was moved forward properly locating the hinge pins. The main spar and hard plates are important mounting points; a collar and two plates were logical ways to mount to these components. A round collar was initially used to mount on a round support strut. The strut was changed to an airfoil cross-section to reduce drag. This required the collar to be changed to a plate that welded onto the strut. The new hinge assembly is shown in Figure 3.3.

Control linkages

Control linkages start with cables coming from the cockpit, running along the left skid from the control stick to a bell crank. The bell crank connects the cables to push-pull rods that connect to the hinge assembly. Hinges are coupled and are attached to the hard plates on one side of the strut supports. The hard plates and hinge assembly transfer the torque from the controls throughout the foam. The first idea was to form hard plastic to make these hard plates. A more suitable solution, considering cost and ease of manufacturability, was to bolt the hinge to half-inch plywood.

For the final selection, a bell crank was mounted on the support struts in between the two lifting surfaces of the canard to control angle of attack. Running parallel to the chassis struts, the control cables from the cockpit attach to the bell crank at a variable distance from the pivot point. This adjustability of control wires allows the pilot to set a desired deflection rate and stick force (see Figure 3.4).

Also seen in the figure are the push-pull rods attached to the bell crank, which connect to the hinge assemblies mounted in the lifting surfaces of the canard. A symmetric four-bar linkage was designed such that the angle of attack of each lifting surface was identical.

Structure:

The objective in the overall structure was to keep it as strong and as light as possible, while retaining a safety factor. The notion of designing a carbon fiber-truss-airfoil-shaped structure as rib supports with varying pressure loads was possible but unnecessary. The most feasible and modular design, from a manufacturing standpoint, was to use a solid foam core. Dave Widauf, an expert in composite fabrication, suggested several options that were available for construction. He mentioned several hybrid methods not generally found in engineering textbooks such as plastic or foam cores with fiberglass skins, D-tube spar and graphite shell, or shaped honeycomb with graphite layers similar to that used in F-16 fighter planes. A foam core rib reinforced with fiberglass skin was chosen for manufacturability, which includes the low cost of materials, little training needed for technicians, and no need for special equipment.
Figure 3.3: Final lower hinge assembly showing hinge pin.

Figure 3.4: Canard bell crank mounted to support strut.
Testing and Mockups

A full size mock up of one of the canard wings was built and assembled. An excellent job of covering the foam core with a graphite skin was done. Figure 3.5 gives a reference for how large the canard lifting surfaces are.

![Image](image.jpg)

Figure 3.5: Nate standing in front of the canard wing.

Final Design

Due to a sound preliminary design, the final design did not vary much from the initial ideas. Some materials and dimensions were modified, but most modifications were putting details into the assembly. To match the aesthetics of the original planform view of the canard, the wing tips had to be made in several pieces as shown in Figure 3.5. Each section has a different chord length of the same USU airfoil shape with a scaled down thickness and width. A template of the cross-sections for each piece had to be made so the foam cores could be hot-wired out. Each section is glued to the next and sanded for a smooth finish before being coated with a layer of fiberglass.
The location of the center of gravity, an important design constraint, needed to be moved forward. Weight was added to the canard to ballast the aircraft. As a result, steel was used for many components instead of hanging odd-looking items from the canard. The main spar is made of large steel tubing. The rear spar size and position were chosen such that the sum of the moments about the 1/4 chord was zero. With the added weight, the center of gravity was moved to the correct location, meeting the aerodynamic requirements of the aircraft.

*Figure 3.5: Diagram of the different foam sections of the canard end caps.*
RUDDER DESIGN
Preliminary Design

The design constraints for the rudder were to reduce weight and drag. The requirement of minimal drag set the rudder airfoil shape as a thin airfoil. The lifting surface needed to be symmetric with the objective that the lift coefficient must remain equivalent as angle of attack varied from one direction to the other. The NACA 0009 was selected, being symmetric and having a maximum thickness that is 9% of the chord length. From WINGS2001 the maximum lifting coefficient was found to be at $\alpha = 8^\circ$ and the maximum force for this angle of attack was found to be 130 lbs. Initial designs were established using this number as the preliminary maximum force on each panel.

The early design was composed of a simple foam core covered with one or two layers of fiberglass and resin depending on the strength test performed. The chord length, spar length, and the distance between centers were kept at the same dimensions as the 1905 Wright Flyer to retain aesthetics. The two rudder panels would no longer be joined as a rigid box pivoting about a center point, but rather rotate parallel to each other about the quarter chord (see Figure 4.1). There are many advantages of changing this design including minimizing the effects of downwash from one panel to the other, and having the center of pressure acting along the pivot points.

Figure 4.1: Top view of rudder pivoting at quarter chord.
The top and bottom cross plates connecting the two rudder panels could be made light and extremely strong by using a honeycomb core with several layers of carbon fiber lamina on the outside. Hard points inserted inside the honeycomb were needed to take the compressive loads caused by mounting the attach fittings to the plates. Bearings also had to be mounted inside the honeycomb to provide pivot points for the rudder panels.

The rudder initially was to attach by an aluminum channel that bolts to the rudder plates (see Figure 4.2) and glues to the main wing ribs. Standard dimensions for aluminum channel stock set the thickness of the plates and special wing ribs. Round aluminum inserts to fit in the carbon fiber tubes had to be tapered, such that the fittings would not cause stress risers at the uneven point of contact when in bending. The round inserts and aluminum channel were designed to weld together. Special care was given to the top attachments that must be welded on a slight angle of 6.6° in order to match the geometry of the original Wright Flyer.

Figure 4.2: Rudder attachments that bolt to the cross plates.
Testing and Mockups

Before any testing or building of prototypes, it was decided that a solid foam core added too much weight to the rear of the aircraft, and that a rib design would be lighter. A test mockup of the rib design is still being built. Due to fabrication length constraints the C-beam and leading edge are both constructed in two sections and later glued together as shown in Figures 4.3 and 4.4. Extensive testing will be done to ensure the two sections are properly bonded together.

A working prototype of a rudder panel was fabricated. End caps were changed from half-inch plywood to half-inch honeycomb with aluminum skin, which greatly reduced the weight. It was found that the Kevlar reinforced foam leading edge could be manufactured to be a full pound lighter than predicted. The rudder panel shown in Figure 4.5 weighed 3.5 lbs.

Figure 4.3: Rudder D-tube fabricated from more than one piece of foam.
Figure 4.4: C-beam and foam leading edge being glued together using epoxy-resin mix.

Figure 4.5: Prototype of one rudder panel that measures 81 inches in length and weighs 3.5 pounds.
Selection

Initially a large safety factor was invoked and later reduced considerably as the weight in the rear of the aircraft became the primary concern in attempting to move the center of gravity of the aircraft to a foot in front of the leading edge of the wing. Many parts were reduced in size making them lighter and weaker.

To reduce drag, support cables were initially removed from the design. The proper tube strength to hold the rudder rigid was derived such that the aero-elastic deflection was less than 4°. Sufficiently strong tubes were calculated to weigh 6 pounds at length of 9.5 ft. As prescribed by weight restrictions, this design was replaced by the use of support cables capable of withstanding the lateral forces created at maximum deflection. The support tubes are also only required to resist compressive loads, thus greatly reducing their size and weight. Included in the design selection was the shortening of the tube lengths from 9.5 ft to 8 feet to aesthetically match the changes done to distance the canard is from the wing. With the thinning and the shortening of the support tubes, each tube's final predicted weight is now 1.66 lbs. A symmetric, seven layer stacking sequence of \([0/\pm 20/0/\pm 20/0]\) was used in the calculation of loads with the primary concern of buckling. Later it was changed to a wavy composite.

Elaborate attach fittings that earlier served as cantilever beam-ends were reduced in size because there was no longer a need to withstand bending moment. The aluminum inserts, which were tapered to prevent a stress riser, were changed to thin steel tubing. The tubes bond to the inside of the support beams require holes to increasing the mechanical bond strength. Slits are milled in the side to allow attach plates to be welded in the tubing, see Figure 4.6. Where the support tubes attach on the wing spar, a single tab is welded to a collar that is glued and lashed to the spar. This provides ample strength and rigidity for mounting (see Figure 4.7).

Final Design

The final design consisted of a C-beam channel spar along the quarter chord that allowed one inch notched ribs to be glued to the inside of it. The ribs were made of foam covered in fiberglass or Kevlar to make them as light as possible. The C-beam consisted of two layers of bi-directional weave carbon fiber laid up inside two pieces of aluminum channel and pressed together during the curing process. The rudder endplates are made from half-inch aluminum covered honeycomb, and the pivot inserts were changed to lightweight Delrin plastic. The trailing edge could be purchased from the Spruce Aircraft catalog. Other components remain the same (see Figure 4.8).
Figure 4.6: Attach fittings that bolt to the rudder cross plates.

Figure 4.7: Attach fittings that mount to the rear wing spar.
Figure 4.8: Final rudder panel assembly.
Cockpit Design
Introduction

To fly the 1905 Wright Flyer, the pilot lay prone with his head forward as shown in Figure 5.1, his left hand operating the elevator control, and his right hand operating the rudder control. Lateral control was achieved by warping the wing tips in opposite directions via wires attached to a hip cradle mounted on the lower wing. The pilot shifted his hips from side to side to operate the mechanism (Smithsonian 2002). In 1907, the Wright brothers hastily adapted their 1905 Flyer with two seats and a more powerful engine as shown in Figure 5.2, as per request of the U.S. Army and the French.

Figure 5.1: 1903, Orville Wright flying prone.

Figure 5.1: 1907, Orville Wright flying upright.
Concept

The USU Wright Flyer was in need of a cockpit design, since the 1905 edition did not incorporate a literal cockpit. The customers set up guidelines for a cockpit design. The specified guidelines to design towards included:

1. Consider pilot ergonomics
2. Implement modern control mechanisms
3. Incorporate flight instrumentation
4. Modular mounting
5. Simple maintenance
6. Accommodate two people
7. Maintain overall aesthetics

The cockpit integration into the flyer needed to be accomplished without distracting from the original aesthetics of the 1905 Flyer. Early aerodynamic analysis illustrated a prone pilot impractical for the stability of the flyer. The seats needed to be placed on the center of gravity. This allows the location of the CG to remain unchanged even with weight differences in passengers.

Preliminary Design

To begin the cockpit design initial decisions were made to direct the design of the project. One decision was an open cockpit. Another was to use mechanical control mechanisms as opposed to radio signals or electrically driven controls. These decisions were the dominating factors in the design of the cockpit.

Cockpit Frame

The frame was the first component of the cockpit to be designed. The frame was first intended for an average man of about 6'0" in height. The layout and position of the pilot was similar to a small one-seat aircraft. Initially the frame was to be manufactured from carbon fiber tubing, but the resultant frame looked like a PVC structure (as shown in Figures 5.3 and 5.4.)

Figure 5.2: Line drawing of first frame design.
Figure 5.3: First frame design including control mechanisms.

Considering ergonomic issues, the arrangement of the pilot was changed to a more comfortable sitting position, as shown in Figure 5.5. The position change allows for a more pleasant flight for extended periods. In addition, it creates a place for the passenger to place his/her feet so interference with the rudder pedals does not occur.

Figure 5.4: Cockpit frame with modified sitting position.
The next major design modification was the frame material. Aesthetically the frame looked like it was constructed out of PVC pipe. Structurally the cockpit would be subject to tensile, compressive, and bending stresses. Carbon Fiber exhibits high tensile strength, however the bending strength of tubular composites is very difficult to predict and model. In consideration of the manufacturability of the structure, the material type of the frame was changed to aluminum (6061)-tubing stock, and high strength steel (AISI 4130), as shown in Figure 5.6. Changing the frame to isotropic, readily available materials, allowed for simpler design calculations and considerable simplification of the manufacturing plan.

Considering the stability of the USU Wright Flyer, the frame suspends between two aluminum chassis bars making the position of the travelers adjustable. Aerodynamic analysis positioned the location of the CG in front of the leading edge of the wing. To aid in moving the CG forward, the engine was proposed to mount on the cockpit structure. A practical place to mount the engine was between the pilot and passenger on the footrest plate as shown in Figure 5.7.

![Figure 5.5: Frame designed towards manufacturability.](image)

![Figure 5.6: Frame including the engine position](image)
Pitch/Roll Control System

The control stick, pitch, and roll mechanisms were the next components designed. Initial mechanism sketches were drawn as shown in Figure 5.8. The simple pitch and roll reactions were coupled, meaning that when the pitch mechanism was initiated a roll reaction occurred too. To solve the problem, the cable for the roll mechanism was placed along the center of rotation of the pitch mechanism as shown in Figure 5.9.

Figure 5.7: Control mechanism sketch.

Figure 5.8: Simple representation of mechanisms needed.
Modifications were made to the original control system. Shown in Figure 5.10, the straight stick was replaced with a curved stick to eliminate seat contact when pulled inward. Placing both control differentials outside the main rotation tube further simplified the design. Shown in Figure 5.11, the bell crank for the pitch mechanism was placed in line with its connecting device on the canard. The throw differential was moved to an external position due to size restraints.

Figure 5.9: Control system.

Figure 5.10: Final control system
**Rudder Control System**

The next component for design consideration was the rudder or yaw mechanism. An initial sketch shown in Figure 5.12 represents a possible mechanism. To bring the rotation in-house, a modular pedal set was considered. A floating bar connects the primary set to the trainees’ pedal set. The pilot’s pedal set incorporates the rudder control differential as shown in Figure 5.13.

Figure 5.11: Initial rudder mechanism drawing.

Figure 5.12: Modular rudder pedal set.
To reduce the number of parts included in the rudder pedal assembly, the system was revamped. Shown in Figure 5.14, the new configuration performs the same task as the modular set, but with simple movements and a design similar to many systems currently used in industry. The bell tabs allow for adjustable pedal movement versus rudder rotation.

Testing and Mockups

Cockpit Frame

The selection of the span bars, footrest bars, and chassis bar was based on a Microsoft Excel spreadsheet, which represents different shapes of possible stock bars and calculates maximum deflection and bar weight. To check the chosen bar geometry, a model of each worst-case scenario was performed using I-DEAS finite element method. Refer to plots in Appendix D.

The Control Systems

Throughout the cockpit design process, physical and 3-D computer models were useful design and visualization tools. Physical models brought attention to problems with actual movements. Shown in Figure 5.15 is a simple cotton swab and pin mockup of an initial design concept. The mockup illustrated coupling movements in the pitch and roll mechanism. Shown in Figure 5.16 is a balsa wood mockup of the cockpit system. The quarter scale model showed concerns with mounting the pitch and roll control assembly. The model brought attention to concerns with mounting the modular cockpit onto the chassis, and the effect of a solid footplate when flying at an angle. The computer models also illustrated physical problems such as control stick interference with the seat, size and mounting concerns.

Figure 5.13: Rudder pedals.
Pitch/Roll Control System

The final design of the pitch and roll control system, shown in Figure 5.18 is easy to integrate into the main cockpit frame. To mount the system, two pillow blocks bolt onto the chassis bars. The thin walled steel rotation tube has bell crank tabs welded on one end to control the canard movement, which also couples the primary and trainee sticks. Sideways control stick movement initiates the wing warp mechanism. The trainee control stick is coupled to the primary with a push-pull rod. The control stick is fabricated from tubular steel stock. All systems use pull-pull cable response, excluding coupling devices.

Rudder Control System

The final design of the rudder control system, shown in Figure 5.19 is simple and common to industry. A steel tube connects the right pedals together and another steel tube connects the left pedals together. The right and left pedals are coupled through a bell crank. The bell crank tabs use a push-pull rod to move the bell crank that in turn pulls the cable to rotate the rudder. The bell crank is located about one foot back from the pedal assembly. The pedal assembly is mounted using pillow block type mounts with dual holes to restrain the bars.

Figure 5.17: Final pitch/roll control system.

Figure 5.18: Final rudder control assembly.
Conclusion

The final cockpit design meets the criteria set by the customers. The cockpit is designed for two occupants, sitting upright. The pilot can easily reach the rudder pedals, and the footrest plate provides an area for the passenger’s feet. The coupled control mechanisms are purely mechanical, and are similar to systems currently used in industry. The necessary flight instrumentation is mounted on the control panel to meet Federal Aviation Regulations for ultra-light aircraft. The cockpit frame is mounted modularly using standard bolts and materials. The incorporation of high strength steel minimizes the amount of materials used and causes less distraction from the overall flyer aesthetics. The evolution of the design produced a more efficient, manufacturable cockpit.
Drive Train and Propulsion Design
Propellers

Requirements

Propeller selection was based on several requirements including aesthetics and thrust production. As much as possible, the propellers needed to look just like the propellers designed by the Wright Brothers. The propellers also needed to produce enough thrust to make the plane safe under all predictable conditions. The 1905 Wright Flyer incorporated two counter-rotating propellers, with eight-foot diameters. From a photo copy of Wilbur and Orville Wright’s 1908 Notebook, pg.13, the results of testing the original propellers show a static thrust between 132 and 136 pounds (for two propellers) when the propellers were turning at a speed of 350 rpm (Ash 2001).

Much has been accomplished in the development of propellers since the Wright brothers flew nearly 100 years ago, but the trends they observed are still valid today. A large diameter propeller, accelerating a large mass of air across a small velocity increment is most efficient. The Wright Brothers used the largest propeller possible considering their airframe structure. At low airspeeds, a small pitch to diameter ratio produces the most thrust per unit power: during low forward speed conditions, the rotational velocity of the blades is much larger than the forward velocity. The free stream velocity seen by the propeller blade sections is basically in the plane of propeller rotation. To keep the blades from stalling, the angle of attack of the blades must be measured relative to the direction of rotation and designed to be less than the stall angle. Since the velocity of the blade sections in the plane of rotation increases with the distance from the hub, the angle of attack of the blade sections must decrease with the distance from the hub. Stalled blade sections create large amount of drag and very little, if any, lift.

Selecting propellers for the USU Wright Flyer meant choosing propellers as close to the original eight-foot diameter as possible in order to maintain aesthetics. Minimizing forces such as P-factor and torque would require the use of counter-rotating propellers. Materials used for construction would need to be made of wood or at least finished to have the appearance of maple or mahogany. In accordance with the design goal of a lighter, stronger, more modern plane, the most modern and lightweight materials would have to be used.

Preliminary

The foremost concern with the propellers was finding a manufacturer that would build an eight-foot propeller, and do so with lightweight composite materials. Most propellers used for modern lightweight aircraft have a diameter between four and six feet and are made of heavy metals. Reducing the diameter from eight feet to six or less was strongly considered for purposes of availability.
Testing

Computer software that incorporates Propeller Blade theory and Goldstein Vortex theory was developed to further the understanding of each variable involved in propeller design. The main variables considered were diameter, pitch-to-diameter ratio, rotational speed, and desired cruise speeds. The main results considered were the power required to turn the propeller at take-off and cruise, and the thrust produced at take-off and cruise.

The advance ratio, $J$, is a variable that combines the forward airspeed of the plane, the rotational speed of the propeller and the propeller diameter, as shown in eq. 6.1.

(eq. 6.1)

After experimenting with the effects of each variable, and noting how each one affected the important results, several trends were found. Figure 6.1 shows the generic trends that power and thrust coefficients follow as functions of the advance ratio. Actual values of thrust and power are directly proportional to the coefficients. Conclusions drawn from the graphs include the fact that thrust produced drops off as velocity increases, which would indicate that for a given amount of power, a propeller driven plane would have a limiting maximum velocity.

Selection

The majority of the design of the final propellers was done in conjunction with CATTO PROPELLERS, a propeller manufacturing and design company located in San Andreas, California. Calculations showed that the thrust produced at cruise speeds was

Figure 6.1: Generic curves for Thrust and Power Coefficients.
nearly independent of propeller diameter. On the other hand, for static thrust, or take off thrust, more thrust was available with larger diameters. With this information, the selection of the propeller diameter was simple. Propellers with the same eight-foot diameter that the Wright brothers used would meet constraints for both aesthetics and thrust.

With the general size of the propeller selected other specific parameters such as the pitch-to-diameter ratio, airfoil sections, and lift distribution depended mainly on the weight of the plane, the engine to be used and the desired performance of the plane. The weight of the plane was assumed to be the maximum allowable under the FAR regulations described earlier. The selection of the Rotax 277 for the engine is discussed later on. The desired performance of the plane required the propellers to produce high thrust at takeoff and sufficient thrust to overcome drag at cruising speed.

In order to match the propellers and the engine, performance curves for the Rotax 277 were generated. Figure 6.2 shows the torque and power curves for the selected engine. Additional propeller software was developed to estimate the RPM at which the engine would run, the power that it would produce and the thrust that would be available to the plane under a variety of conditions. The interaction between the engine RPM and the propellers is quite complicated. The thrust required for steady level or climbing flight depends on the airspeed, and climb angle. The power available from the engine depends on throttle setting. If the power required by the propellers is less than what the engine is able to supply at a given throttle setting, the propeller RPM will increase, accelerating the plane until the drag forces on the plane and the brake power required to turn the propellers match the engine power. The propellers and transmission would need to be designed so that the propellers could turn at the RPM necessary while the engine was turning at the RPM that could provide sufficient braking power. After a brief evaluation of the engine- propeller combinations using the software developed at USU, Catto Propellers determined the actual blade section coefficients, using a program that they had developed which incorporated years of empirical data.

A 94-inch diameter propeller with a 70-inch pitch was selected. The design rotational speed is 800 RPM. Thrust data supplied by CATTO ranges from 280 pounds at static to 70 pounds at 60 mph. A curve fit to the data points provided is shown in Figure 6.3. A quick comparison of the thrust produced by the propellers and the expected drug forces of the aircraft evidently show that the 2003 Wright Flyer will have a top speed some where around 50 mph.

The propellers will be mounted using an SAE – 1 bolt pattern that is comprised of six 3/8-inch bolts. Catto Props found that space-age materials are not always the most appropriate. Sometimes Mother Nature does a pretty good job herself. Materials used for construction of the propellers include maple and mahogany, so the appearance will be similar to the propellers used on the 1905 version. Each propeller will weigh only eight pounds: quite impressive for such a large diameter.
Figure 6.2: Torque and Power curves for the Rotax 277 two-stroke engine.

Figure 6.3: Propeller thrust produced as a function of Airspeed.

Final

Catto Propellers was selected to manufacture the propellers to be used on the USU Wright Flyer. Craig Catto's extensive experience in the design and manufacture of light aircraft propellers was the main factor in their selection as propeller supplier. He demonstrated great proficiency in adapting a propeller to the engine that had been selected and the purposes of the plane. As a wonderful benefit, Craig Catto offered to donate everything needed to design and build the propellers.
Transmission

Concept

The two main requirements of the transmission assembly were speed reduction and the ability to counter rotate the propellers. In order for the propellers to rotate at 800 rpm, a seven to one speed reduction was necessary. The 1905 Wright Flyer used bicycle chains to transmit power from the engine to the prop shafts. One chain was twisted to achieve counter-rotation of one prop. The transmission needed to accomplish the same objective, without use of the twisted bicycle chain. The maximum weight of the transmission was limited to 30 pounds.

Preliminary

Drive belts were first considered as an alternative to chains. By using belts, efficiency could be increased while reducing noise and overall weight. Both toothed timing belts and grooved V-belts were taken into consideration. Other ideas for transmitting power from the transmission to the prop shafts included drive shafts with bevel gears on each end, cogged V-belts and serpentine belts.

Counter-rotation of props using belts of any kind left only two options. The first was to twist one of the belts over itself between the transmission and the prop shaft. The other was incorporate the use of an idler gear built into the transmission assembly as shown in Figure 6.4. The use of belts to transmit power would allow the use different sheave diameters to obtain the necessary gear reduction for the system.

Testing

Testing and analysis were conducted using belt design software provided by Gates Rubber Company. This design program provided several belt options, and illustrated their respective advantages and disadvantages. The program accounted for the design horsepower, maximum rpm of the smallest sheave, center-to-center distance between shafts and the type of leading. After reading these inputs, the program recommends a belt type, length, width and appropriate tension.

Selection

Poly-Chain toothed belts were selected to transmit power to the propeller shafts. Poly-Chain belts, shown in Figure 6.5, are timing type belts manufactured by Gates Rubber Company. While they require approximately 30 percent more tensioning force than standard V-belts, tensioned properly they can provide the safest power transmission possible.

After determining the horsepower that would be transmitted through the transmission, Rush Gears proved to be the best vendor for the gears needed to accommodate the necessary counter-rotation of the props.
Engine

Concept

The power plant selected would need to generate enough thrust to fly the plane at least 50 mph. The motor needed to have a high power to weight ratio and excellent reliability. The Wright Brothers flew the 1905 version on a 12 horsepower engine that weighed over 100 pounds. The USU Wright Flyer required an engine that could provide at least 25 horsepower and weigh half as much as the original.
Preliminary

Simple lightweight two-stroke engines power most aircraft in the ultralight category today. Because of this, first consideration was given to use of a Rotax two-cycle engine. The Rotax 277 provided 28 horsepower while weighing only 74 pounds, making it a viable option (see Figure 6.6). A fuel consumption rate of 1.8 gallons per hour would allow for a one-hour flight on less than two-gallons of fuel, as shown in Table 6.1. The availability and relatively low cost of this engine seemed to make it a practical choice.

Powering the USU Wright Flyer via electric motors was also strongly considered. The high efficiency, lightweight motors available today could provide the needed power to fly the airplane but weigh less than two-stroke engines in the same power range. By using electric motors, the transmission could be eliminated by attaching a motor directly to the prop shaft. This would also eliminate the need for belts and pulleys. Other advantages included increased reliability and noise reduction. The disadvantages of using electric motors were the high cost of the new technology and the reduction of flight duration. Even with the best available batteries, flight times would be reduced to around 25 minutes.

Figure 6.6: Horsepower and weight comparisons of various Rotax engines.

Table 6.1: Complete data for Rotax 277 two-cycle engine.
Final

After weighing the options, the Rotax 277 was selected as the best choice for the USU Wright Flyer. The Rotax 277 has been proven reliable in the ultralight industry. The high availability of this engine and its parts was also taken into consideration during the selection process. The analysis and modeling of the USU Wright Flyer showed that the Rotax 277 could provide sufficient power to propel the aircraft.

Support Structure

Concept

The support structure would need to provide support to the propeller drive shafts, transmission, and engine. The Wright Brothers used a system of four rods and eight cables to support each propeller drive shaft. Due to the high drag caused by cables, eliminating as much cabling as possible was an immediate consideration for the USU Wright Flyer. The main force the propeller support structure would have to withstand would be the axial force along the shaft. Other minor forces included drive belts turning the shaft producing lateral forces and vibrations. Any eccentricity in the propellers would also induce lateral forces. Due to the size of the propellers, excessive lateral motion could result in the propellers colliding with the main wing. Transmission and engine support systems would not only support their respective components, but also add rigidity to the wing and cockpit assemblies.

Preliminary

From the thrust curves of the propellers, the maximum expected thrust each would produce would be around 175 lb. The tension in the drive belts would be less than 150 lb. In order to support these loads, the system shown in Figure 6.7 was developed. Four rods support the thrust from the propellers while four other rods support the end of the shaft where the drive belts will be pulling and vibrating. In order to reduce the drag on the entire structure, a streamlined cross-section would be needed for the support shafts. The use of carbon fiber would allow for a larger streamlined cross-section while still keeping the weight low.

Transmission support could be provided by the strengthened wing ribs or by adding structural tubing between the front and rear spar. Early consideration was given to using tubing because of the high tension in the belts.

Engine support and placement varied throughout the design in order to accommodate proper placement of the center of gravity of the aircraft. Originally, the idea was to place the engine on the quarter chord of the main wing and support it and the transmission with the same structure. This location was gradually moved forward onto the floor of the cockpit to move the center of gravity forward.
Figure 6.7: Drawing of the Propeller support and drive system
Chassis Design
Introduction

The 1905 Flyer incorporated a chassis made up of spruce struts and skids assembled with bolts, screws and sheet metal fittings. The skids provided a large contact area, stabilizing the 1905 Flyer while on the ground. The chassis was interfaced with a track system that guided the plane during takeoff. When the Wright Brothers relocated their proving grounds away from the ceaseless winds of Kitty Hawk, North Carolina, the chassis-track takeoff system was reintegrated with a catapult system to obtain the needed airspeed required for lift off. The challenge of the USU Wright Flyer redesign was to incorporate space age materials in order to avoid, undoubtedly, the strut repairs made by the Wright Brothers in between flights. Also, the chassis needed to aesthetically look like the 1905 Flyer, but allow the USU Wright Flyer to take off and land like a conventional aircraft.

Concept

Aesthetics

In keeping with the aesthetics requirement for the overall look of the plane, the chassis design needed to keep the skids as part of the design. However, the geometry of the structural tubing attaching the skids to the rest of the USU Wright Flyer was largely unspecified. It was requested that the USU Wright Flyer incorporate composite tubing as the main component of construction.

Landing Gear

It was also determined in the early conceptual phase of the project that wheels would also need to be incorporated into the design of the new Flyer. Originally, the 1905 Flyer used the heavy winds at Kitty Hawk, North Carolina to create the needed lift as a man on each wing guided the Flyer down its track with the skids sliding across the sand. Later, when the Wright Brothers relocated their experimental proving grounds to a remote field near Dayton, Ohio, the Wright Brothers constructed a catapult system to give the Flyer the needed velocity to create the necessary lift for take off. Heavy winds and a catapult would not be available in takeoff of the USU Wright Flyer. The USU Wright Flyer would need to be able to take off on asphalt or cement and possibly a manicured grassy lawn. This would not be possible if the plane had to overcome the sliding friction of skids on any of the proposed take off surfaces. It was determined that the appearance of the USU Wright Flyer would need to suffer the addition of wheels.

Early flights of the 1905 Flyer undoubtedly saw the failure of many struts upon landing. The experiments at Kitty Hawk especially saw many broken components when the Flyer would execute improper landings, as well as perfect landings. This was due largely to the lack of any suspension system absorbing the impact forces during landings. It was also decided early in the conceptual phase that some sort of landing gear suspension system would be critical in extending the life of the USU Wright Flyer, as
well as avoiding embarrassing and timely repairs during the tour of the aircraft on its way to Dayton, Ohio for the 2003 festivities.

**Disassembly**

As part of a USU Outreach Program, the USU Wright Flyer needed to be disassembled for transport in semi-truck trailer. Using nylon locking bolts to attach the skids to the canard and wing would quite easily accommodate this requirement. The USU Wright Flyer would most likely be broken down into five pieces consisting of wings, rudder, canard and two skids.

**Preliminary Design**

From the beginning, emphasis was placed on interchangeability of parts. This was a lesson learned by Henry Ford and adopted since by all of manufacturing. Interchangeability would ease in the manufacturing of the parts as well as the assembly of the components during construction. Emphasis was also placed on adjustability, understanding that the scope of a systems integration project such as this one would, undoubtedly, lead to tolerances quickly stacking up and leading to inevitable conflicts. However, the built in adjustabilities of the design created their own unique complexities that further created problems for manufacturability and cost of construction. Early possibilities of solving the suspension problem included using a lightweight mountain bike shock in conjunction with a composite leaf spring. This was an impressive solution that included sliding linkages and hinged joints that would allow the rear part of the skid to compress upward independent of the wings and canard. Figure 7.1 below shows a conceptualization of the shocks and spring and the two-piece nature of the skid. A diagram of the sliding mechanism of the composite spring is also included.

Developing an accurate model of the mechanics of such a large composite spring proved inconsistent with the intuition of the team. Curved beam theory was the model equation used. This was found in *Mechanical Engineering Design*, Shigley, Mischke, pages 138, 140-142, 200-202.

\[ \delta = \frac{\pi FR^3}{2EI} = 382.8 \text{ in} \]

\[ F= \text{landing force, 1000 lb} \]
\[ R= \text{centerline radius of spring, 90.47 in.} \]
\[ E= \text{smeared modulus of elasticity for fiber lay-up, 12.2 E6 psi} \]
\[ I= \text{moment of inertia, 0.25 in}^4 \]
The smeared modulus of elasticity was taken from a program that calculated the value for different fiber orientations. A [0/90], gave the highest value that most closely resembled an isotropic material. The characteristics of an isotropic material would be desirable, given the possible angles at which the Flyer might land. The spring should behave the same regardless of the angle of impact. This value was used in the calculation. As demonstrated, the value of 382.8 in of deflection was quite inconsistent with design requirements. A finite element analysis of the design gave a deflection of 1040 in. Either the science was demonstrating the complete lack of feasibility of the design, or the science could not accurately model the unique characteristics of the composite design. It was determined that a mock up would need to be made to determine "hands-on" the true mechanics of the design.

Preliminary design showed that, unlike the Wright Brothers who flew their 1905 Flyer with the pilot lying prone on the wing, the USU Wright Flyer would require the pilots to be situated in a "cockpit" forward of the main wing. This arrangement would allow for correct placement of the center of gravity. Due to this new design requirement, some of the chassis struts would require being directly attached to the cockpit components. Struts that had previously been subjected to only "historical" loading, would now need to be reexamined for the additional loading of the weight of the cockpit itself, as well as a possible loading of 500 lb of pilot and passenger.
The preliminary design phase involved drawing early concepts in the Inventor CAD program. This allowed for a visual of conceptual designs in a real-life scale. Many early designs were plagued with complexity as might be expected, and later refined into simpler ideas as the team made suggestions. A good example of a part evolution in the chassis design involves the skid hard-point. This was a fitting to be attached to the skid on which to attach the struts. Figures 7.2, 7.3, and 7.4 show how the part went from a heavily machined design, to a lightweight cut and welded design.

Figure 7.2: Early hard-point design, note intense machining requirements.

Figure 7.3: Progressed hard-point design, note intense welding requirements.
During the preliminary design phase, much thought was given to the construction of the skids. Initially it was thought that the skids could be made out of space-age composites like the struts of the USU Wright Flyer. It was also considered that the hardpoints might be “splices” for different sections of the skid. Thought was given to covering the bottom of the skids with P-Tex, a material used to repair the bottom of skis and snowboards. The desire for a straight, stiff skid began to weed out the ideas of a multi-piece design. It was determined that each skid would at the most be made up of two pieces in order to facilitate the leaf spring linkage concept for the USU Wright Flyer suspension. However, before a final decision could be reached, a proof of concept mock-up of the composite spring would need to be made.

**Testing and Mockups**

*Composite Spring*

A mock up of the composite spring was constructed out of less expensive glass fibers. The spring was laid up in excess of 20 layers in a [0,90] configuration. During the curing of the spring the vacuum pump failed to work properly and the spring cured with serious spaces and voids. However, the mock up did demonstrate that the springs would be too heavy to be considered for the final design, and the mathematical models were showing serious problems in the rigidity of the structure subjected to our anticipated maximum landing loads. Figure 7.5 is a picture of the mock up leaf spring with a span near 100 in.

**Figure 7.4:** Final hard-point design, note little welding, mostly drilling and milling.
Composite Structural Tubing

The application of composite materials is generally for tension and torsion. The USU Wright Flyer would require most of the composite structural tubing to undergo compressive loading, magnified greatly during landing. Traditionally composite materials are not used in compressive loading applications because of the inaccurate predictability of the behavior of a composite member in compression. Analysis of such compressive loading was beyond the scope of a student engineer, and doctoral assistance was not readily available. Intuitively the ITE professors felt that their experience with composite materials warranted their use in the USU Wright Flyer. In order to back up a decision to use composite tubing in the strut structures of the USU Wright Flyer, three composite tubes of different geometries where tested in compression.

It was determined that the worst case scenario for the loading on one of the tube struts would be a fully loaded plane at 1000 pounds landing at two times the acceleration of gravity. This would cause the landing load of 2000 pounds to be distributed at 1000 pounds per skid assembly. If the entire load were taken by one strut, then it would need to be able to withstand 1000 pounds. The composite tubes to be used in the project are constructed of a “wavy” fiber made by Wavy Composites, Provo, Utah. Due to the nature of the even more unpredictable wavy composite construction, tests were invaluable. The three test specimens were fitted with steel pipe plugs that where glued in place with epoxy in order to be placed in the compression test cell. The three specimens were each loaded at a displacement rate of 0.0816 in /min. The tests were only limited by the failure of the epoxy bonds on the fittings. None of the tubes failed in the tests. Table 7.1 and Figure 7.6 give the specifications of each tube and the loading at which the epoxy bonds of the fittings failed.
<table>
<thead>
<tr>
<th>Tube Description</th>
<th>I.D.</th>
<th>O.D.</th>
<th>Maximum Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thin-walled</td>
<td>.882 in</td>
<td>.928 in</td>
<td>891 lb</td>
</tr>
<tr>
<td>Thicker-walled</td>
<td>.875 in</td>
<td>.945 in</td>
<td>689 lb</td>
</tr>
<tr>
<td>Damped</td>
<td>.875 in</td>
<td>.980 in</td>
<td>470 lb</td>
</tr>
</tbody>
</table>

Table 7.1: The three tubes placed in compressive testing.

Figure 7.6: Compressive loads in three dissimilar wavy composite tubes.

Although tests were only conducted on three dissimilar specimens, the results were very encouraging. As stated earlier, none of the tubes failed at the loads indicated, and each tube appeared quite intact upon later inspection. Later inspection also showed that the epoxy had only adhered to only 1/4 in of the fitting at the end of the tube and that the “swiss-cheese” feature of the fitting had not been properly “gooped” with epoxy.

Steel Structural Tubing

Using the AISC specifications for allowable loads in structural columns referenced in Mechanics of Materials, Timoshenko, pages 775-782, analysis was performed on the longest steel tube to be used in the chassis struts. Below are the equations used to calculate the allowable loads on a 46 in steel tube with a 1/16 in wall thickness.

\[
A_{\text{cross-sectional}} = \pi (r_o^2 - r_i^2) = 0.1841 \text{ in}^2
\]

\[
E = 29,000 \text{ ksi}
\]
\[
\sigma_{\text{allow}} = \frac{12\pi^2 E}{23(KL/r)^2} = 17,643 \text{ psi}
\]
\[
F_{\text{allow}} = \sigma_{\text{allow}} \times A_{\text{cross-sectional}} = 3,248 \text{ lb}
\]

With an allowable load of 3,248 pound, the steel struts are well suited for the design. As discussed earlier, it was assumed that in a worst case scenario a single strut might be subjected to a 1000 pound loading. The allowable load on the steel struts gives added security in the cockpit support areas where the struts will be applied.

**Weldments**

No physical tests of weldments were performed, however theoretical calculations were made. The smallest, simplest weld on the skid hard point was analyzed under a worst-case scenario to determine the overall integrity of the USU Wright Flyer's structural welds. A worst-case scenario would again involve a possible 2.0g landing. At 1000 pounds per skid assembly, it is assumed that the most a single weldament would have to take would be 500 pounds in bending. Below is a string of calculations to determine the nominal throat shear stress in bending, with a rectangular weld 1/8 in x 1 in. The equations were taken from *Mechanical Engineering Design*, Shigley, Mischke, pages 540-544.

\[
b = 0.125 \text{ in}
\]
\[
d = 1 \text{ in}
\]
\[
h = 0.0625 \text{ in}
\]
\[
c = \frac{d}{2} = 0.5 \text{ in}
\]
\[
F = 500 \text{ lb}
\]
\[
X = 0.75 \text{ in}
\]
\[
M = FX = 375 \text{ lb*in}
\]
\[
I_u = \frac{d^2}{6} (3b + d) = .229 \text{ in}^3
\]
\[
I = 0.707hI_u = .010 \text{ in}^3
\]
\[
\tau = \frac{Mc}{I} = 18.52 \text{ kpsi}
\]

Using fillet welds, the permissible stress in the AISC Code for weld metal using an AWS electrode number E60XX in shear loading is 18.6 kpsi. Compared to the shear stress value of 18.52 kpsi found in the above equations, this gives a safety factor of 0.996 in a worst-case scenario. This is an acceptable design, and despite theoretical calculations that sometimes don't correctly model real-life situations, welding a 1/8 in steel plate to a 1/16 in steel plate is intuitively strong enough for this lightweight aircraft.
Selection

It was determined that the structural tubing of the project would be a mix of wavy composite tubes, steel tubes and rectangular aluminum tubes. The selection was due to several factors.

First, using steel tubing in areas that would directly support the weight of the cockpit during landing was preferred because of the strength of steel needed in these critical areas. Next, the steel and aluminum tubes allowed for conventional drilling and mounting with nuts and bolts. This allowed for secure placement of cockpit elements. Composite tubes do not lend themselves to be drilled through and bolted without placing a wood core inside the tube in areas to be mounted in order to take the compressive hoop stresses. Such fabrication details did not mesh well with overall ease in manufacturing. Finally, the use of wavy composite tubing in the remaining struts of the chassis was preferred for weight savings as well as their demonstrated compressive strength.

The tubes that were tested had an approximate outside diameter of 7/8 in. The final tubes to be used in construction of the plane would be 1 40/1000 I.D. with approximately 40/1000 in gluing tolerance. The wall thickness on the final tubes was specified at 1/16 in. This diameter will still allow for streamlining later if the need to cut wind resistance is great enough. This decision is in stark contrast to an original proposal to have the tubes 2 I.D.

It was decided that all hardware and fittings, except for the cockpit aluminum tube, would be made out of steel. In general, steel is easier to weld than aluminum. The strength of steel in the heat-affected zone of the welds is not as affected as it is in the case of aluminum. Aluminum was chosen for the cockpit mounting tubes because of the weight savings over steel due to the size of the tube.

The desire to use composites for the skids, allowing the USU Wright Flyer to leave the wooden legacy of 1905 Flyer behind, was outweighed by the inability of composites to resist impact and abrasion well. The Wright Brothers had it “right” in selecting spruce for the skid material. Wood has great strength to weight ratio as well as good impact and abrasion resistance. The USU Wright Flyer skids, however, would be beefed up just a touch by adding in layers of Kevlar during the spruce laminating process. This will indeed add a touch of space-age design desired in the project as a whole.

All joints of the chassis were designed to incorporate a double-shear property allowing the maximum shear in the bolts to be doubled. The bolts specified have a 125,000 psi tensile rating. Generally, the maximum shear in metals is half the tensile strength. With the double shear property of the joints the shearing force in the bolts becomes approximately 125,000 psi, well over-designed for the application.
Conclusion

The final design (see Figures 7.6 and 7.7) is indeed somewhat along the lines of the New VW Beetle. It successfully pays homage to its predecessor, yet it exhibits the vast improvements that years of technological innovation have spawned. Indeed, the final chassis design most closely resembles the geometry and look of the original 1905 Flyer chassis better than any other component of the USU Wright Flyer. This is due largely in part to the lack of a need to improve its function. The chassis of the 1905 Flyer functioned well for its intended purpose, to hold the canard and wing together in flight and provide an aircraft to ground interface when taking off or landing. The wing, canard, and rudder design of the 1905 Flyer did not function well. The cockpit was poorly designed from a practical standpoint, and the motor was primitive to say the least. Hence these components saw a more serious overhaul in the USU Wright Flyer design than that of the chassis.

Figure 7.6: Final chassis design.
Figure 7.7: Final chassis design.
Wing Assembly
USE ASSEMBLY SHOWN IN DETAIL B FOR 8 INTERFACES INDICATED. USE ASSEMBLY SHOWN IN DETAIL A OTHERWISE.

DETAIL A

DETAIL B

(NOTE 1)
# Materials List for Wings

*ck spc* = check drawing specifications

| Item/Material   | Description | Qty     | Part # | Supplier        |
|-----------------|-------------|---------|--------|-----------------
| Aluminum Plate  | .04" thick  | ck spc  |        | Aircraft Spuce  |
| Aluminum Tube   |             | ck spc  |        | Aircraft Spuce  |
| Universal Joint |             | ck spc  |        | Aircraft Spuce  |
| Clevis Pin      |             | ck spc  |        | Aircraft Spuce  |
| Trailing Edge   |             | ck spc  |        | Aircraft Spuce  |
# Parts List for Wings

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<th>Part Number</th>
<th>Description</th>
<th>Qty</th>
<th>Type</th>
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<td>Assy, Wing</td>
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<td>top assembly</td>
</tr>
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<td>WF-10-200</td>
<td>Sub-assy, Lower Wing Planform</td>
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<td>Sub-assy, Upper Wing Planform</td>
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<td>Rib B</td>
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<td>cut &amp; laid up</td>
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<td>Rib D</td>
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<td>WF-10-315</td>
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<td>cut &amp; laid up</td>
</tr>
<tr>
<td>WF-10-400</td>
<td>Spar, Front, Middle</td>
<td>2</td>
<td>laid up</td>
</tr>
<tr>
<td>WF-10-401</td>
<td>Spar, Front, First Outer</td>
<td>4</td>
<td>laid up</td>
</tr>
<tr>
<td>WF-10-402</td>
<td>Spar, Front, Second Outer</td>
<td>4</td>
<td>laid up</td>
</tr>
<tr>
<td>WF-10-403</td>
<td>Spar, Front, Third Outer</td>
<td>4</td>
<td>laid up</td>
</tr>
<tr>
<td>WF-10-404</td>
<td>Spar, Back, Middle</td>
<td>2</td>
<td>laid up</td>
</tr>
<tr>
<td>WF-10-405</td>
<td>Spar, Back, First Outer</td>
<td>4</td>
<td>laid up</td>
</tr>
<tr>
<td>WF-10-406</td>
<td>Spar, Back, Second Outer</td>
<td>4</td>
<td>laid up</td>
</tr>
<tr>
<td>WF-10-407</td>
<td>Spar, Back, Third Outer</td>
<td>4</td>
<td>laid up</td>
</tr>
<tr>
<td>WF-10-408</td>
<td>Spar Interface, Front Inner</td>
<td>12</td>
<td>laid up</td>
</tr>
<tr>
<td>WF-10-409</td>
<td>Spar Interface, Back Inner</td>
<td>8</td>
<td>laid up</td>
</tr>
<tr>
<td>WF-10-410</td>
<td>Spar Interface, Front Outer</td>
<td>4</td>
<td>cut &amp; adhered</td>
</tr>
<tr>
<td>WF-10-411</td>
<td>Spar Interface, Back Outer</td>
<td>8</td>
<td>cut &amp; adhered</td>
</tr>
</tbody>
</table>
USU
WRIGHT FLYER
1903-2003

DRAWN BY: CKESPLIN

MATERIAL: PART DESCRIPTION: PART NUMBER: REV
WF-10-000A

DATE: 2/17/2002 SCALE: SIZE: SHEET 2 of 4
**NOTES**

1. **GENERAL STRUT/SPAR INTERFACE ASSEMBLY**
   
   REPRESENTED IN DETAIL A AND B. USE ON ALL SUCH ASSEMBLIES

2. ADHERE SPAR/STRUT INTERFACE PLATES TO SPAR WITH EPOXY AND ONE LAYER OF EPOXIED GRAPHITE AROUND THE FLANGES

3. REFERENCE AREAS TO ATTACH INTERFACE PLATES ACCORDING TO NAME. (EX. "FRONT MID STRUT INTERFACE SUB-ASSY" (ITEM 5) WOULD BE ADHERED IN THE "MID" SPAR/STRUT REGION ON THE FRONT SPAR)

4. BOND LEADING EDGE TO SPAR AND RIBS EVERYWHERE EXCEPT THE OUTER SEVEN RIBS WHERE IT IS ONLY BONDED TO THE RIBS.

5. USE ATTACHING HARDWARE AS NEEDED ON PULLEY ASSEMBLY. BEND 1-PRONG PLATE TO APPROPRIATE ANGLE TO PREVENT CABLE FROM SLIPPING OFF OF THE PULEYS.

6. USE CABLES AND CABLE PLATES TO CREATE A STRUCTURAL CABLE SETUP THAT WILL CREATE 2' OF DIHEDRAL. ATTACHING HARDWARE AS REQUIRED.

---

**Parts List**

<table>
<thead>
<tr>
<th>ITEM</th>
<th>QTY</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>14</td>
<td>WF-10-204A</td>
<td>SUB-ASSY, FRONT MID STRUT INTERFACE</td>
</tr>
<tr>
<td>6</td>
<td>28</td>
<td>WF-10-221A</td>
<td>STRUT CAP</td>
</tr>
<tr>
<td>7</td>
<td>10</td>
<td>WF-10-206A</td>
<td>STRUT</td>
</tr>
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<td>8</td>
<td>4</td>
<td>WF-10-205A</td>
<td>SUB-ASSY, FRONT END STRUT INTERFACE</td>
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<td>9</td>
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<td>WF-10-203A</td>
<td>SUB-ASSY, BACK END STRUT INTERFACE</td>
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<td>MS20271-B12</td>
<td>UNIVERSAL JOINT</td>
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<td>SUB-ASSY, BACK MID STRUT INTERFACE</td>
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<tr>
<td>12</td>
<td>2</td>
<td>WF-10-222A</td>
<td>X-STRUT</td>
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<td>13</td>
<td>4</td>
<td>WF-10-208A</td>
<td>CABLE PLATE, 1-PRONG</td>
</tr>
<tr>
<td>14</td>
<td>2</td>
<td>WF-10-216A</td>
<td>TRAILING EDGE, INNER</td>
</tr>
<tr>
<td>15</td>
<td>2</td>
<td>WF-10-217A</td>
<td>TRAILING EDGE, OUTER LEFT</td>
</tr>
<tr>
<td>16</td>
<td>2</td>
<td>WF-10-218A</td>
<td>TRAILING EDGE, OUTER RIGHT</td>
</tr>
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<td>17</td>
<td>2</td>
<td>WF-10-213A</td>
<td>LEADING EDGE, INNER</td>
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<td>18</td>
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<td>WF-10-215A</td>
<td>LEADING EDGE, OUTER RIGHT</td>
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<td>19</td>
<td>2</td>
<td>WF-10-214A</td>
<td>LEADING EDGE, OUTER LEFT</td>
</tr>
<tr>
<td>20</td>
<td>32</td>
<td>AN392-21</td>
<td>CLEVIS PIN</td>
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<td>1</td>
<td>05-04300</td>
<td>CONTROL CABLE</td>
</tr>
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<td>22</td>
<td>1</td>
<td>05-03500</td>
<td>STRUCTURAL CABLE</td>
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<td>1</td>
<td>1</td>
<td>WF-10-200A</td>
<td>SUB-ASSY, LOWER WING PLANFORM</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>WF-10-201A</td>
<td>SUB-ASSY, UPPER WING PLANFORM</td>
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<tr>
<td>3</td>
<td>6</td>
<td>WF-10-220A</td>
<td>ASSY, PULLEY</td>
</tr>
</tbody>
</table>

---

**USU**

**WRIGHT FLYER**

**1903-2003**
ASSEMBLY IS IDENTICAL TO WF-10-201 EXCEPT THAT CENTER RIB IS OMMITTED

DRAWN BY: CKESPILN

MATERIAL: WRIGHT FLYER 1903-2003

DATE: 2/17/2002

SCALE: SIZE: B SHEET 1 of 1
DETAIL A: RIB PLACEMENT

FREE FLOATING

BONDED TO SPARS

FREE FLOATING

(46.45)

DRAWN BY:
CKESPLIN

MATERIAL:

USU
WRIGHT FLYER
1903-2003

PART DESCRIPTION:
SUB-ASSY, UPPER WING PLANE

PART NUMBER:
WPFA-201A

DATE: 2/17/2002
SCALE: B
SIZE: SHEET 1 of 4

Rev A
HOLES ORIENTED AT MAXIMUM DISTANCE APART AS SHOWN

DETAIL B: SPAR CAP ALIGNMENT (NOTE 2)

DO NOT BOND WINGTIP TO CAP PIECES!!

DETAIL C: WINGTIP ASSEMBLY (NOTE 3)

USU WRIGHT FLYER 1903-2003

DRAWN BY: CKESPLIN

MATERIAL:  

PART DESCRIPTION: SUB-ASSY, UPPER WING PLATE

PART NUMBER: W603-201A

DATE: 2/17/2002

SCALE: B  SHEET 2 of 4
NOTES
1. BOND RIBS TO SPARS WITH STRUCTURAL ADHESIVE AS REQUIRED
2. BOND CAPS WITH STRUCTURAL ADHESIVE IN ORIENTATION AS SHOWN
3. OUTER 7 RIBS AND THE WINGTIP ARE FREE FLOATING. THE RIBS WILL BE
   RETAINED BY THE LEADING EDGE AND RETAINING BLOCKS. THE WINGTIP
   WILL BE RETAINED BY THE SKIN TENSION. PERFORM ON BOTH WINGTIPS.
4. BOND BLOCKS ON SPAR ONLY TO HOLD RIBS IN LOCATIONS SHOWN IN DETAIL A.
   MAKE BLOCKS TO FIT SPAR (BUILDER'S DISCRETION).

Parts List

<table>
<thead>
<tr>
<th>ITEM</th>
<th>QTY</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>2</td>
<td>WF-10-309A</td>
<td>CAP, WINGTIP-FRONT SPAR</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>WF-10-310A</td>
<td>CAP, WINGTIP-BACK SPAR</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>WF-10-308A</td>
<td>WINGTIP</td>
</tr>
<tr>
<td>8</td>
<td>18</td>
<td>WF-10-312A</td>
<td>RIB, MAIN, STRUCTURAL</td>
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<tr>
<td>7</td>
<td>2</td>
<td>WF-10-313A</td>
<td>RIB, A</td>
</tr>
<tr>
<td>8</td>
<td>1</td>
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<td>RIB, B</td>
</tr>
<tr>
<td>9</td>
<td>1</td>
<td>WF-10-316A</td>
<td>RIB, D</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>WF-10-317A</td>
<td>RIB, C</td>
</tr>
<tr>
<td>11</td>
<td>44</td>
<td>NONE</td>
<td>RIB RETAINING BLOCK</td>
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<td>12</td>
<td>4</td>
<td>WF-10-315A</td>
<td>RIB, MAIN</td>
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<td>WF-10-300A</td>
<td>SUB-ASSY, FRONT SPAR</td>
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<td>WF-10-301A</td>
<td>SUB-ASSY, BACK SPAR</td>
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USU
WRIGHT FLYER
1903-2003
NOTES
1. ATTACHING HARDWARE AS REQUIRED

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<td>WF-10-219A</td>
<td>PULLEY PLATE</td>
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<td>A-223</td>
<td>PULLEY</td>
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<td>WF-10-208A</td>
<td>CABLE PLATE, 1-PRONG</td>
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</tbody>
</table>

USU
WRIGHT FLYER
1903-2003

DRAWN BY:
CKESPLIN

PART DESCRIPTION:
ASSY, PULLEY

PART NUMBER:
WF-10-220A

DATE: 2/17/2002
SCALE: B
SIZE: 1
SHEET 1 of 1
NOTES
1. ASSEMBLE ACCORDING TO TABLE BELOW

<table>
<thead>
<tr>
<th>ASSEMBLY NUMBER</th>
<th>PLATE OF ASSEMBLY</th>
<th>TUBE OF ASSEMBLY</th>
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<tbody>
<tr>
<td>WF-10-202</td>
<td>WF-10-303</td>
<td>WF-10-307</td>
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<tr>
<td>WF-10-203</td>
<td>WF-10-302</td>
<td>WF-10-307</td>
</tr>
<tr>
<td>WF-10-204</td>
<td>WF-10-304</td>
<td>WF-10-306</td>
</tr>
<tr>
<td>WF-10-205</td>
<td>WF-10-305</td>
<td>WF-10-306</td>
</tr>
</tbody>
</table>

USU
WRIGHT FLYER
1903-2003

DRAWN BY: CKESPLIN

MATERIAL: Aluminum-6061

PART DESCRIPTION: STRUT INTERFACE PLATES

PART NUMBER: SEE TABLE

DATE: 2/17/2002

SCALE: | SIZE: B | SHEET 1 of 1

Utah State University Mechanical & Aerospace Engineering
1. USE MADERL AND BUILDING METHOD THAT CHUCK LARSEN WILL PROVIDE
2. LAYUP: WAVY
3. NOMINAL SIZE SHOWN. CUT TO BEST FIT.
1. CUT FROM .04" THICK PLATE (AIRCRAFT SPRUCE & CO. P/N. 03-31150)
2. PUNCH HOLES

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE
X = ±.1
XX = ±.03
XXX = ±.010
ANGLES ±1°

DRAWN BY:
CKESPLIN

MATERIAL:
Aluminum-6061

PART DESCRIPTION:
CABLE PLATE, 2-PRONG

PART NUMBER:
WF-10-207A

DATE: 2/17/2002

SCALE: B

SIZE:

SHEET 1 of 1
1. CUT FROM .04" THICK PLATE (AIRCRAFT SPRUCE & CO. P.N. 03-31150)
2. PUNCH HOLES

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE
X (.001)
XX (.001)
XX (.001)
ANGLES ±1°

DRAWN BY: CKESPLIN

USU
WRIGHT FLYER
1903-2003

MATERIAL: Aluminum-6061
PART DESCRIPTION: CABLE PLATE, 1-PRONG
PART NUMBER: WF-10-200A
DATE: 2/17/2003
SCALE: SIZE: B

Sheet 1 of 1
1. USE MADREL AND BUILDING METHOD THAT CHUCK LARSEN WILL PROVIDE
2. LAYUP: 4/WAVY
3. NOMINAL SIZE SHOWN. CUT TO BEST FIT.
1. USE LEADING EDGE OF RIBS AND SPAR AS A TEMPLATE FOR PIECE
2. USE WOVEN GRAPHITE AT A 45° LAYUP

DRAWN BY:
ERIC PETERSON

MATERIAL: graphite

WRIGHT FLYER
1903-2003

SCALE 1 : 1

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE
\[ \begin{align*}
X & = \pm 0.1 \\
XX & = \pm 0.03 \\
XXX & = \pm 0.010 \\
ANGLES & \leq 1°
\end{align*} \]
1. Use outer 54 inches of wing ribs and spar to create a template for part.
2. Use woven graphite at a 45° layup.

SCALE 1:1
1. Use outer 54 inches of wing ribs and spar to create a template for part.
2. Use woven graphite on a 45° layup.

Scale 1:1

Slightly tapered

WRIGHT FLYER
1903-2003

All dims are in inches unless noted otherwise:
X = ± .1
XX = ± .03
XXX = ± .010

Angles ± 1°

Drawn by:
Eric Peterson

Date: 2/17/2002

Material: graphite

Part description:
Leading edge, outer right

Part number:
WF-10-215A

Rev A

Scale: B

Sheet 1 of 1
1. CUT FROM AIRCRAFT SPRUCE & SPECIALTY CO. PN 03-48900
2. BEND AND CUT TO FIT TRAILING EDGE

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE
.X = ± .1
.XX = ± .03
.XXX = ± .010
ANGLES ± 1°

DRAWN BY:
ERIC PETERSON

DATE: 2/17/2002
SCALE: B

WRIGHT FLYER
1903-2003
1. CUT FROM AIRCRAFT SPRUCE & SPECIALTY CO. PN 03-48900
2. BEND AND CUT TO FIT TRAILING EDGE

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE
X = ± .1
XX = ± .03
XXX = ± .010
ANGLES ± 1°

DRAWN BY:
ERIC PETERSON

USU
WRIGHT FLYER
1903-2003

DATE: 2/17/2002
SCALE: B
SIZE: SHEET 1 of 1
1. CUT FROM AIRCRAFT SPRUCE & SPECIALTY CO. PN 03-48900
2. BEND AND CUT TO FIT TRAILING EDGE

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE
X = ±.1
XX = ±.03
XXX = ±.010
ANGLES ± 1°

DRAWN BY:
ERIC PETERSON

MATERIAL:
WRIGHT FLYER 1903-2003

USU

DATE: 2/17/2002
SCALE: SIZE: B SHEET 1 of 1
ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE
X = ± .1
XX = ± .03
XXX = ± .010
ANGLES ± 1°

DRAWN BY:CKESPLIN

MATERIAL:Aluminum-6061

PART DESCRIPTION: PULLEY PLATE
PART NUMBER: WF-10-219A

DATE: 2/17/2003
SCALE: SIZE: B SHEET 1 of 1
1. ADHERE WITH STRUCTURAL EPOXY

Parts List

<table>
<thead>
<tr>
<th>ITEM</th>
<th>QTY</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>WF-10-411A</td>
<td>SPAR INTERFACE, BACK OUTER</td>
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<td>1</td>
<td>WF-10-404A</td>
<td>SPAR, BACK, MIDDLE</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>WF-10-406A</td>
<td>SPAR, BACK, FIRST OUTER</td>
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<tr>
<td>4</td>
<td>2</td>
<td>WF-10-407A</td>
<td>SPAR, BACK, SECOND OUTER</td>
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<td>5</td>
<td>2</td>
<td>WF-10-409A</td>
<td>SPAR, BACK, THIRD OUTER</td>
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<td>6</td>
<td>4</td>
<td>WF-10-408A</td>
<td>SPAR INTERFACE, BACK INNER</td>
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USU
WRIGHT FLYER
1903-2003

DRAWN BY:
CKESPLIN

MATERIAL:
SUB-ASSY, BACK SPAR

PART DESCRIPTION:  
PART NUMBER:  
REV A

DATE: 2/17/2002
SCALE:  
SIZE: B  
SHEET 1 of 1
1. CUT PART FROM 5"x1.5" PLATE AIRCRAFT SPRUCE & SPECIALTY CO. PN 03-31150
2. BEND PLATE TO RADIUS

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

\[ X = \pm 0.03 \]
\[ XXX = \pm 0.010 \]
ANGLES \( \pm 1' \)

DRAWN BY: CKESPLIN
MATERIAL: WRIGHT FLYER 1903-2003

USU MECHANICAL & AEROSPACE ENGINEERING

DATE: 2/17/2002
SCALE: SIZE: B SHEET 1 of 1
1. CUT PART FROM 5"x1.5" PLATE AIRCRAFT SPRUCE & SPECIALTY CO. PN 03-31150
2. BEND PLATE TO RADIUS

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

\[ X = \pm 0.1 \]
\[ XX = \pm 0.03 \]
\[ XXX = \pm 0.010 \]

ANGLES \pm 1°

DRAWN BY:
CKESPLIN

MATERIAL:
Aluminum-6061

PART DESCRIPTION:
INTERFACE PLATE, FRONT OUTER-303A

DATE: 2/17/2002

SCALE: B

SIZE: SHEET 1 of 1
1. CUT PART FROM 5''x1.5'' PLATE AIRCRAFT SPRUCE & SPECIALTY CO. PN 03-31150
2. BEND PLATE TO RADIUS

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE
X = ± .1
XX = ± .03
XXX = ± .010
ANGLES ± 1°

DRAWN BY:
CKESPLIN

MATERIAL:
Aluminum-6061

PART DESCRIPTION:
INTERFACE PLATE, INNER

PART NUMBER:
WF-10-304A

DATE: 2/17/2002

SCALE: B

SIZE: SHEET 1 of 1
1. CUT PART FROM 5"x1.5" PLATE AIRCRAFT SPRUCE & SPECIALTY CO. PN 03-31150
2. BEND PLATE TO RADIUS

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

\[ X = \pm 0.1 \]
\[ XX = \pm 0.03 \]
\[ XXX = \pm 0.010 \]
\[ ANGLES \pm 1' \]

DRAWN BY: CKESPLIN

USU
WRIGHT FLYER
1903-2003

DATE: 2/17/2002
1. CUT FROM TUBE STOCK (AIRCRAFT SPRUCE & CO. P.N. 03-36400)

- R1.60

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

X = ± .1
XX = ± .03
XXX = ± .010
ANGLES ± 1°

USU
WRIGHT FLYER
1903-2003

DATE: 2/17/2002
SCALE: B
SIZE: 1
SHEET 1 of 1
1. CUT FROM TUBE STOCK (AIRCRAFT SPRUCE & CO. P.N. 03-36400)

DIMENSIONS:

- X = ± .1
- XX = ± .03
- XXX = ± .010
- ANGLES ± 1°

Unles otherwise noted.

R1.5

(A)
1. USE 1" TUBE AIRCRAFT SPRUCE & SPECIALTY CO. PN 03-36600
2. BUSHING, AIRCRAFT SPRUCE & SPECIALTY CO. PN: FB1620-06

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE
X = ± .1
XX = ± .03
XXX = ± .010
ANGLES ± 1°

DRAWN BY: CKESPLIN
MATERIAL: WRIGHT FLYER

USU
WRIGHT FLYER
1903-2003

DATE: 2/17/2002
SCALE: SIZE: B SHEET 1 of 1
ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE
X = ± .1
XX = ± .03
XXX = ± .010
ANGLES ± 1°

DRAWN BY: CKESPLIN

MATERIAL: SPRUCE
PART DESCRIPTION: CAP, WINGTIP-FRONT SPAR
PART NUMBER: WF-10-309A
DATE: 2/17/2002
SCALE: SIZE: B

USU WRIGHT FLYER
1903-2003
ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

\[ x = \pm 0.1 \]
\[ y = \pm 0.03 \]
\[ z = \pm 0.010 \]

ANGLES ± 1°

DRAWN BY: CKESPLIN

USU
WRIGHT FLYER
1903-2003

MATERIAL: SPRUCE
PART DESCRIPTION: CAP, WING TIP BACK SPAR
PART NUMBER: WF-10-310A
DATE: 2/17/2002
SCALE: B
SIZE: SHEET 1 OF 1
1. CUT PATTERN FROM 1" FOAM USING TEMPLATE WF-10-311-T1
2. COVER FOAM WITH 1 LAYER KEVLAR
3. FINAL WEIGHT MUST NOT EXCEED 0.45 LB
1. CUT PATTERN FROM 1" FOAM USING TEMPLATE WF-10-312-T1
2. COVER FOAM WITH 1 LAYER KEVLAR
3. FINAL WEIGHT MUST NOT EXCEED 0.45 LB
1. CUT PATTERN FROM 1" FOAM USING TEMPLATE WF-10-313-T1
2. COVER FOAM WITH 1 LAYER KEVLAR
3. FINAL WEIGHT MUST NOT EXCEED 0.45 LB
1. CUT PATTERN FROM 1" FOAM USING TEMPLATES WF-10-314-T1
2. COVER FOAM WITH 1 LAYER KEVLAR
3. FINAL WEIGHT MUST NOT EXCEED 0.4 LB

\[ \phi 2.25 \]
\[ \phi 1.52 \]

\[ \text{ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE} \]
\[ \text{\( X = \pm 0.1 \)} \]
\[ \text{\( XX = \pm 0.03 \)} \]
\[ \text{\( XXX = \pm 0.010 \)} \]
\[ \text{ANGLES \( \pm 1^\circ \)} \]

\text{DRAWN BY: CKESPLIN}

\text{MATERIAL: FOAM COMPOSITE}

\text{PART DESCRIPTION: RIB, B}

\text{PART NUMBER: WF-10-314A}

\text{DATE: 2/17/2002}

\text{SCALE: B}

\text{SIZE: B SHEET 1 OF 1
1. CUT PATTERN FROM 1" FOAM USING TEMPLATES WF-10-316-T1
2. COVER FOAM WITH 1 LAYER KEVLAR
3. FINAL WEIGHT MUST NOT EXCEED 0.35 LB

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE
X = ±.1
XX = ±.03
XXX = ±.010
ANGLES ± 1°

DRAWN BY:
ERIC PETERSON

MATERIAL: FOAM COMPOSITE
PART DESCRIPTION: RIB, C
DATE: 2/17/2002
SCALE: B
SIZE: SHEET 1 of 1

USU WRIGHT FLYER 1903-2003
1. CUT PATTERN FROM 1” FOAM USING TEMPLATES WF-10-318-T1
2. COVER FOAM WITH 1 LAYER KEVLAR
3. FINAL WEIGHT MUST NOT EXCEED 0.3 LB

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE
X = ± .1
XX = ± .03
XXX = ± .010
ANGLES ± 1'

DRAWN BY:
ERIC PETERSON

USU
WRIGHT FLYER
1903-2003

MATERIAL: FOAM COMPOSITE

PART DESCRIPTION: RIB, D

DATE: 2/17/2002

SCALE: SIZE: B SHEET 1 of 1
LAYUP: 4/NAVY, 2/0°, 4/NAVY

SECTION A-A
SCALE 1:1

10 LAYERS

Ø3.00

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

X = ± .1
XX = ± .03
XX = ± .010
ANGLES ± 1°

DRAWN BY:
ERIC PETERSON

USU
WRIGHT FLYER
1903-2003

DATE: 2/17/2002
SCALE: B
SIZE: SHEET 1 of 1
1. **LAYUP:** 4/MAVY, 2/0', 4/MAVY

**SECTION A-A**

**SCALE 1:1**

**ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE**

- $X = \pm 0.1$
- $XX = \pm 0.03$
- $XXX = \pm 0.010$
- ANGLES $\pm 1'$

**DRAWN BY:**

ERIC PETERSON

**USU**

**WRIGHT FLYER 1903-2003**
LAYUP: 12/ WAVY

SECTION A-A
SCALE 1:1

12 LAYERS
\( \phi 2.08 \)

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE
\[ X = \pm .1 \]
\[ XX = \pm .03 \]
\[ XXX = \pm .010 \]
ANGLES \( \pm ^\circ \)

DRAWN BY:
ERIC PETERSON

WASHINGTON FLYER
1903-2003

USU
WRIGHT FLYER
1903-2003

DATE: 2/17/2002
SCALE: B
SIZE: 1
SHEET 1 of 1

INCHES UNLESS NOTED OTHERWISE

\( X = \pm .1 \)
\( XX = \pm .03 \)
\( XXX = \pm .010 \)
ANGLES \( \pm ^\circ \)

DRAWN BY:
ERIC PETERSON

WASHINGTON FLYER
1903-2003

DATE: 2/17/2002
SCALE: B
SIZE: 1
SHEET 1 of 1
LAYUP: & WAVY

SECTION A-A
SCALE 1 : 1

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE
X = ± .1
XX = ± .03
XXX = ± .010
ANGLES ± 1'

DRAWN BY:
ERIC PETERSON

USU
WRIGHT FLYER
1903-2003

MATERIAL: Graphite
PART DESCRIPTION: SPAR, BACK, SECOND OUTER
PART NUMBER: WF-10-406A
DATE: 2/17/2002
SCALE: B
SIZE: SHEET 1 of 1
LAYUP: 12/WAVY

SECTION A-A
SCALE 1:1

12 LAYERS
Φ2.83
FOAM CORE

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE
X = ± .1
XX = ± .03
XXX = ± .010
ANGLES ± 1°

DRAWN BY:
ERIC PETERSON

USU WRIGHT FLYER
1903-2003

MATERIAL: Graphite
PART DESCRIPTION: SPAR INTERFACE, FRONT IN
PART NUMBER: USF-10-403A
REV A
DATE: 2/17/2002
SCALE: B
SIZE: SHEET 1 of 1
LAYUP: 12/WAVY

SECTION A-A
SCALE 1 : 1

12 LAYERS
ø2.36
FOAM CORE

ALL DIMS ARE IN INCHES
UNLESS NOTED OTHERWISE
X = ± .1
XX = ± .03
XXX = ± .010
ANGLES ± 1'

DRAWN BY:
ERIC PETERSON

USU
WRIGHT FLYER
1903-2003

DATE: 2/17/2002
SCALE: B
SIZE: SHEET 1 of 1
1. MATERIAL: PER DRAWING
2. ADHERE JOINTS WITH STRUCTURAL WOOD ADHESIVE

\[ \phi 2.97 \]

\[ \phi 2.16 \]

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

\[ X = \pm 0.1 \]

\[ XX = \pm 0.03 \]

\[ XXX = \pm 0.010 \]

ANGLES \( \pm 1' \)

DRAWN BY:
CKESPLIN

MATERIAL:

PART DESCRIPTION:
SPAR INTERFACE, FRONT OUTER-R-10-410A

PART NUMBER:

DATE: 2/17/2002

SCALE:
SIZE: B

SHEET 1 of 1
1. MATERIAL AS SHOWN
2. ADHERE JOINTS WITH GENERAL STRUCTURAL WOOD ADHESIVE

-1.5
-5.0
-1.5

SPRUCE
BALSA
SPRUCE

Ø2.47
Ø1.47

ALL DIMS ARE IN-INCHES UNLESS NOTED OTHERWISE
\[ X = \pm 0.1 \]
\[ XX = \pm 0.03 \]
\[ XXX = \pm 0.010 \]
ANGLES ± 1°

DRAWN BY: CKESPIN

USU
WRIGHT FLYER
1903-2003

DATE: 2/17/2002
SCALE: B

SIZE: B
SHEET 1 of 1
Canard Assembly
# Materials List for Canard

*ck spc= check drawing specifications*

<table>
<thead>
<tr>
<th>Item/Material</th>
<th>Description</th>
<th>Qty</th>
<th>Part #</th>
<th>Supplier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control Rod</td>
<td></td>
<td>4</td>
<td>AN67AC-1475</td>
<td>Aircraft Spruce Co.</td>
</tr>
<tr>
<td>Terminal Assembly</td>
<td></td>
<td>8</td>
<td>AN665-21(R/L)</td>
<td>Aircraft Spruce Co.</td>
</tr>
<tr>
<td>Rear Spar (4130 tube)</td>
<td>2 x 9ft</td>
<td>1</td>
<td>03-02300</td>
<td>Aircraft Spruce Co.</td>
</tr>
<tr>
<td>Main Spar (4130 tube)</td>
<td>2 x 9ft</td>
<td>1</td>
<td>03-09100</td>
<td>Aircraft Spruce Co.</td>
</tr>
<tr>
<td>10-32 Bolts</td>
<td></td>
<td>32</td>
<td>AN526-1032R16</td>
<td>Aircraft Spruce Co.</td>
</tr>
<tr>
<td>10-32 Nuts</td>
<td></td>
<td>32</td>
<td>AN365-1032A</td>
<td>Aircraft Spruce Co.</td>
</tr>
<tr>
<td>Clevis Pin</td>
<td></td>
<td>4</td>
<td>AN388-81</td>
<td>Aircraft Spruce Co.</td>
</tr>
<tr>
<td>3/8-24 Bolt</td>
<td></td>
<td>1</td>
<td>AN6-24</td>
<td>Aircraft Spruce Co.</td>
</tr>
<tr>
<td>3/8-24 Stop Nut</td>
<td></td>
<td>1</td>
<td>AN365-624A</td>
<td>Aircraft Spruce Co.</td>
</tr>
<tr>
<td>Bearing</td>
<td></td>
<td>1</td>
<td>KS6A-AN200</td>
<td>Aircraft Spruce Co.</td>
</tr>
</tbody>
</table>

# Parts List for Canard

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Description</th>
<th>Qty</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>WF-20-050</td>
<td>Control Adjust</td>
<td>1</td>
<td>cut &amp; drilled</td>
</tr>
<tr>
<td>WF-20-033</td>
<td>Linkage Mount</td>
<td>1</td>
<td>cut &amp; drilled</td>
</tr>
<tr>
<td>WF-20-030</td>
<td>Chassis Connect</td>
<td>2</td>
<td>cut &amp; drilled</td>
</tr>
<tr>
<td>WF-20-028</td>
<td>Control Mount</td>
<td>1</td>
<td>cut &amp; drilled</td>
</tr>
<tr>
<td>WF-20-025</td>
<td>Canard Supports</td>
<td>2</td>
<td>cut &amp; drilled</td>
</tr>
<tr>
<td>WF-20-022</td>
<td>Hinge Pin Shaft</td>
<td>12</td>
<td>cut &amp; drilled</td>
</tr>
<tr>
<td>WF-20-021</td>
<td>Spar Hinge Shaft</td>
<td>4</td>
<td>cut &amp; drilled</td>
</tr>
<tr>
<td>WF-20-020</td>
<td>Strut Hinge Plate</td>
<td>4</td>
<td>cut</td>
</tr>
<tr>
<td>WF-20-018</td>
<td>Hinge Bracket</td>
<td>6</td>
<td>cut &amp; drilled</td>
</tr>
<tr>
<td>WF-20-017</td>
<td>Linkage Bracket</td>
<td>2</td>
<td>cut &amp; drilled</td>
</tr>
<tr>
<td>WF-20-016</td>
<td>Canard Surface Right</td>
<td>2</td>
<td>hot wired,glued,shaped,layed up</td>
</tr>
<tr>
<td>WF-20-015</td>
<td>Canard Surface Left</td>
<td>2</td>
<td>hot wired,glued,shaped,layed up</td>
</tr>
<tr>
<td>WF-20-014</td>
<td>Canard Surface Center</td>
<td>2</td>
<td>hot wired,glued,shaped,layed up</td>
</tr>
<tr>
<td>WF-20-013</td>
<td>Canard Rib</td>
<td>8</td>
<td>cut, drilled, &amp; sanded</td>
</tr>
<tr>
<td>WF-20-007</td>
<td>Spar Hinge Assembly</td>
<td>4</td>
<td>weldment</td>
</tr>
<tr>
<td>WF-20-006</td>
<td>Strut Hinge Assembly</td>
<td>4</td>
<td>weldment</td>
</tr>
<tr>
<td>WF-20-005</td>
<td>Hinge Assembly Right</td>
<td>2</td>
<td>weldment</td>
</tr>
<tr>
<td>WF-20-004</td>
<td>Hinge Assembly Bottom</td>
<td>1</td>
<td>weldment</td>
</tr>
<tr>
<td>WF-20-003</td>
<td>Hinge Assembly Top</td>
<td>1</td>
<td>weldment</td>
</tr>
<tr>
<td>WF-20-027</td>
<td>Control Sub-Assembly</td>
<td>1</td>
<td>weld and bolt</td>
</tr>
<tr>
<td>WF-20-040</td>
<td>Canard Sub-Assembly</td>
<td>1</td>
<td>weld and bolt</td>
</tr>
<tr>
<td>WF-20-001</td>
<td>Top Surface Assembly</td>
<td>1</td>
<td>bolt</td>
</tr>
<tr>
<td>WF-20-002</td>
<td>Bottom Surface Assembly</td>
<td>1</td>
<td>bolt</td>
</tr>
<tr>
<td>WF-20-000</td>
<td>Canard Assembly</td>
<td>1</td>
<td>weld and bolt</td>
</tr>
</tbody>
</table>
Note: Weld Hinge Plates tangent to leading edge of supports and flush with top of supports.

Both Sides
Two Places 1/8" 1/8"

Foam can be cut out to create a compartment for adding weight to balance plane. Place weight as close to the 1/4 chord as possible.

Detail B
Scale 0.12:1

Parts List

<table>
<thead>
<tr>
<th>ITEM</th>
<th>QTY</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>8</td>
<td>AN665-21(R/L)</td>
<td>Terminal Assembly</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>AN673AC-1475</td>
<td>Control Rod</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>WF-20-040</td>
<td>Canard Sub-Assembly</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>WF-20-001</td>
<td>Canard Surface Assembly Top</td>
</tr>
</tbody>
</table>

USU
Wright Flyer
1903-2003

Drawn by: N. Holman

Material: Canard Assembly

Part Description: WF-20-000

Date: 2/17/2002

Scale: B
Sheet 1 of 1
GLUE 4 PLACES

COVER WITH DACRON AFTER FULLY ASSEMBLED

**Parts List**

<table>
<thead>
<tr>
<th>ITEM</th>
<th>QTY</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>WF-20-003</td>
<td>Hinge Assembly Top</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>WF-20-005</td>
<td>Hinge Assembly Right</td>
</tr>
<tr>
<td>3</td>
<td>16</td>
<td>AN526-1032R15 / AN36 5-1032A</td>
<td>10-32 Screws and Nuts</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>WF-20-014</td>
<td>Canard Center Surface</td>
</tr>
<tr>
<td>5</td>
<td>4</td>
<td>WF-20-013</td>
<td>Canard Rib</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>03-09100</td>
<td>Main Spar</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>03-02300</td>
<td>Rear Spar</td>
</tr>
<tr>
<td>8</td>
<td>1</td>
<td>WF-20-015</td>
<td>Canard Surface Left</td>
</tr>
<tr>
<td>9</td>
<td>1</td>
<td>WF-20-016</td>
<td>Canard Surface Right</td>
</tr>
</tbody>
</table>

**USU WRIGHT FLYER 1903-2003**

DRAWN BY: N. Holman

MATERIAL: Canard Surface Assembly Top

PART DESCRIPTION: Canard Surface Assembly Top

PART NUMBER: WF-20-001

DATE: 2/17/2002

SCALE: B

SIZE: B

SHEET 1 of 1
GLUE 4 PLACES

COVER WITH DACRON AFTER FULLY ASSEMBLED

<table>
<thead>
<tr>
<th>ITEM</th>
<th>QTY</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>WF-20-005</td>
<td>Hinge Assembly Right</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>WF-20-004</td>
<td>Hinge Assembly Bottom</td>
</tr>
<tr>
<td>3</td>
<td>16</td>
<td>AN526-1032R16 / AN36 5-1032A</td>
<td>10-32 Screws and Nuts</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>WF-20-014</td>
<td>Canard Center Surface</td>
</tr>
<tr>
<td>5</td>
<td>4</td>
<td>WF-20-013</td>
<td>Canard Rib</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>03-09100</td>
<td>Main Spar</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>03-02300</td>
<td>Rear Spar</td>
</tr>
<tr>
<td>8</td>
<td>1</td>
<td>WF-20-015</td>
<td>Canard Surface Left</td>
</tr>
<tr>
<td>9</td>
<td>1</td>
<td>WF-20-016</td>
<td>Canard Surface Right</td>
</tr>
</tbody>
</table>

DRAWN BY: N. Holman

USU
WRIGHT FLYER 1903-2003

DATE: 2/17/2002

SCALE: B

SIZE: B

SHEET 1 of 1
Parts List

<table>
<thead>
<tr>
<th>ITEM</th>
<th>QTY</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>WF-20-007</td>
<td>Spar Hinge Assembly</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>WF-20-005</td>
<td>Strut Hinge Assembly</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>WF-20-018</td>
<td>Hinge Bracket</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>WF-20-017</td>
<td>Linkage Bracket</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>AN396-81</td>
<td>Hinge Clevis Pin (1/8&quot;)</td>
</tr>
</tbody>
</table>
Parts List

<table>
<thead>
<tr>
<th>ITEM</th>
<th>QTY</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>WF-20-006</td>
<td>Strut Hinge Assembly</td>
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<tr>
<td>2</td>
<td>1</td>
<td>WF-20-007</td>
<td>Spar Hinge Assembly</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>WF-20-017</td>
<td>Linkage Bracket</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>WF-20-018</td>
<td>Hinge Bracket</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>AN396-81</td>
<td>Hinge Clevis Pin</td>
</tr>
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</table>

(1/8")
### Parts List

<table>
<thead>
<tr>
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<td>1</td>
<td>1</td>
<td>WF-20-007</td>
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<tr>
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<td>2</td>
<td>WF-20-018</td>
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</tr>
<tr>
<td>4</td>
<td>1</td>
<td>AN396-81</td>
<td>Hinge Clevis Pin</td>
</tr>
</tbody>
</table>

---

**USU**

**WRIGHT FLYER**

**1903-2003**

**DRAWN BY:**

N. Holman

**MATERIAL:**

**PART DESCRIPTION:** Hinge Assembly Right

**PART NUMBER:** WF-20-005

**REV:**

**DATE:** 2/17/2002

**SCALE:**

**SIZE:** B

**SHEET:** 1 of 1
<table>
<thead>
<tr>
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<th>DESCRIPTION</th>
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<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>WF-20-022</td>
<td>Hinge Pin Shaft</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>WF-20-020</td>
<td>Strut Hinge Plate</td>
</tr>
</tbody>
</table>

**USU**
**WRIGHT FLYER**
**1903-2003**

DRAWN BY: N. Holman

MATERIAL: Strut Hinge Assembly

DATE: 2/17/2002

SCALE: B

SIZE: SHEET 1 of 1
<table>
<thead>
<tr>
<th>ITEM</th>
<th>QTY</th>
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<th>DESCRIPTION</th>
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<tr>
<td>1</td>
<td>1</td>
<td>WF-20-021</td>
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</tr>
<tr>
<td>2</td>
<td>1</td>
<td>WF-20-022</td>
<td>Hinge Pin Shaft</td>
</tr>
</tbody>
</table>
8

USU 693006-3040.13: 30° CHORD

USE LINKAGE BRACKETS TO LOCATE
4 SMALL HOLES & MAIN SPAR HOLE

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE
X = ± .1
XX = ± .03
XXX = ± .010
ANGLES ± 1°

DRAWN BY:
N. Holman

MATERIAL:
Ply-Wood

PART DESCRIPTION:
Canard Rib

PART NUMBER:
WF-20-013

DATE: 2/17/2002

SCALE:
SIZE: B
SHEET 1 OF 1

USU
WRIGHT FLYER
1903-2003
NOTE: FOAM CAN BE CUT INTO CONVENIENT PIECES IN ORDER TO CREATE HOLES FOR SPARS. REASSEMBLE PIECES WITH APPROPRIATE GLUE. COVER FOAM WITH FIBERGLASS FOR ADDITIONAL STRENGTH.

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

\[X = \pm 0.1\]

\[XX = \pm 0.03\]

\[XXX = \pm 0.010\]

ANGLES \(\pm 1'\)

REFER TO CANARD RIB WF-20-013 FOR SECTION DIMENSIONS

DRAWN BY: N. Holman

MATERIAL: 4 Lb Foam

PART DESCRIPTION: Canard Center Surface

PART NUMBER: WF-20-014

DATE: 2/17/2002

SCALE: B

SIZE: SHEET 1 of 1
NOTE: TEMPLATE WILL BE PROVIDED FOR CHORDS OF 30", 26", & 17" TO CHECK AIRFOIL SHAPE. SAND A SMOOTH TRANSITION BETWEEN SECTIONS. COVER FOAM WITH FIBERGLASS FOR ADDED STRENGTH.

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE
X = ± .1
XX = ± .03
XXX = ± .010
ANGLES ± 1°

DRAWN BY:
N. Holman

MATERIAL: 4 Lb Foam

PART DESCRIPTION: Canard Surface Left

PART NUMBER: WF-20-015

DATE: 2/17/2002

SCALE: SIZE: B SHEET 1 of 1
NOTE: TEMPLATE WILL BE PROVIDED FOR CHORDS OF 30", 26", & 17" TO CHECK AIRFOIL SHAPE. SAND A SMOOTH TRANSITION BETWEEN SECTIONS. COVER FOAM WITH FIBERGLASS FOR ADDED STRENGTH.

REFER TO CANARD RIB WF-20-013 FOR SECTION DIMENSIONS

DRILL HOLE DEPTH 17" FROM LEFT SIDE

NOTE: ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

\[ X = \pm .1 \]
\[ XX = \pm .03 \]
\[ XXX = \pm .010 \]
ANGLES \( \pm 1' \)

DRAWN BY:
N. Holman

MATERIAL:
4 Lb Foam

WRIGHT FLYER
1903-2003

USU
Mechanical & Aerospace Engineering

DATE: 2/17/2002

SCALE: SIZE: B SHEET 1 of 1
ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

\[
\begin{align*}
X &= \pm 0.1 \\
XX &= \pm 0.03 \\
XXX &= \pm 0.010 \\
\text{ANGLES} &= \pm 1'
\end{align*}
\]

DRAWN BY:
N. Holman

USU
WRIGHT FLYER
1903-2003

MATERIAL: 4130 Alloy Steel
PART DESCRIPTION: Linkage Bracket
PART NUMBER: WF-20-017
DATE: 2/17/2002
SCALE: B
SIZE: SHEET 1 of 1
USE MATERIAL ALL READY AVAILABLE.
Drill 0.875" dia hole after assembled.

PRESS BEARING INTO WELDED PARTS AFTER PARTS ARE DRILLED OUT TO 0.875" DIA

---

**Parts List**

<table>
<thead>
<tr>
<th>ITEM</th>
<th>QTY</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>WF-20-033</td>
<td>Linkage Mount</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>WF-20-050</td>
<td>Control Adjust</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>KSBA-AN200</td>
<td>Canard Controls Bearing</td>
</tr>
</tbody>
</table>

---

**USU WRIGHT FLYER 1903-2003**

**DRAWN BY:**
N. Holman

**DATE:** 2/17/2002

**SCALE:** B

**SIZE:** B

**SHEET:** 1 of 1
INNER WIDTH JUST LARGE ENOUGH TO FIT OVER STREAMLINE SUPPORTS.
Drill 0.125" dia hole first to locate with other part then drill 0.675" dia hole after assembled.

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE
X = ± .1
XX = ± .03
XXX = ± .010
ANGLES ± 1°

DRAWN BY:
N. Holman

MATERIAL:
4130 Alloy Steel

USU WRIGHT FLYER 1903-2003

SCALE: SIZE: B SHEET 1 OF 1
DETAIL F
SCALE 0.12 : 1

DETAIL E
SCALE 0.16 : 1

Parts List

<table>
<thead>
<tr>
<th>ITEM</th>
<th>QTY</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>WF-20-002</td>
<td>Canard Surface Assembly Bottom</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>WF-20-027</td>
<td>Control Sub-Assembly</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>WF-20-025</td>
<td>Streamline Canard Supports</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>WF-20-030</td>
<td>Chassis Connect</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>AN6-24</td>
<td>Control Mount Shaft</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>AN355-624A</td>
<td>3/8-24 Step Nut</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>Spacer 1</td>
<td>Spacer 1</td>
</tr>
<tr>
<td>8</td>
<td>1</td>
<td>WF-20-028</td>
<td>Control Mount</td>
</tr>
</tbody>
</table>

USU
WRIGHT FLYER
1903-2003

DRAWN BY: N. Holman
MATERIAL: Canard Sub-Assembly
DATE: 2/17/2002
SCALE: B
SIZE: SHEET 1 of 1

Spacer 1 - Position controls appropriately with steel washers.
Notes: 1. Control Mount - Position for best alignment with controls and weld tangent to 1/4 chord of supports.
2. Support Mounts - Position for best alignment and weld tangent to 1/4 chord of supports.
3. Hinge Mount Plates - Weld tangent to leading edge of supports.

(Note: 1) BOTH SIDES

(Note: 2) TWO PLACES

(Note: 3) BOTH SIDES TWO PLACES
Drill 0.125" dia hole first to locate with other part then drill 0.875" dia hole after assembled.

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

X = ± .1
XX = ± .03
XXX = ± .010
ANGLES ± 1°

DRAWN BY: N. Holman

MATERIAL: 4130 Alloy Steel

PART DESCRIPTION: Control Adjust

PART NUMBER: WF-20-050

DATE: 2/17/2002

SCALE: SIZE: B SHEET 1 of 1
ORDER TO LENGTH FROM SPRUCE PART # AN873AC-1475

ORDER RODS WITH TERMINAL "ASSEMBLIES" SPRUCE PART # AN665-21 (R & L)

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE
X = ± .1
XX = ± .03
XXX = ± .010
ANGLES ± 1°

DRAWN BY: AIRCRAFT SPRUCE & CO.

USU
WRIGHT FLYER
1903-2003

MATERIAL: Stainless Steel, Austeritic
PART DESCRIPTION: Control Rod
PART NUMBER: AN873AC-1475
DATE: 2/17/2002
SCALE: B
SIZE: SHEET 1 of 1
Rudder Assembly
**Materials List for Rudder**

*ck spc= check drawing specifications*

<table>
<thead>
<tr>
<th>Item/Material</th>
<th>Description</th>
<th>Qty</th>
<th>Part #</th>
<th>Supplier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foam</td>
<td>1&quot;X30&quot;, 2&quot; sheets</td>
<td></td>
<td>ck spc</td>
<td>Hardware store</td>
</tr>
<tr>
<td>Kevlar</td>
<td>7&quot; length</td>
<td></td>
<td></td>
<td>?</td>
</tr>
<tr>
<td>Aluminum Skin Honeycomb</td>
<td>12&quot; X 30&quot;</td>
<td></td>
<td></td>
<td>ITE Dept.</td>
</tr>
<tr>
<td>Wood</td>
<td>1/2&quot; X 1 1/4&quot; X 5&quot;</td>
<td>2</td>
<td></td>
<td>ITE Dept.</td>
</tr>
<tr>
<td>Wood</td>
<td>1/2&quot; X 2&quot; diameter</td>
<td>4</td>
<td></td>
<td>ITE Dept.</td>
</tr>
<tr>
<td>Carbon Tubes</td>
<td>2&quot;X8'</td>
<td>2</td>
<td></td>
<td>ITE Dept.</td>
</tr>
<tr>
<td>Steel Tubing</td>
<td>2&quot; O.D. x 0.035&quot; wall</td>
<td>2 ft</td>
<td></td>
<td>ITE/IPACO</td>
</tr>
<tr>
<td>Steel Pins</td>
<td>3/8&quot;</td>
<td>1 ft</td>
<td></td>
<td>?</td>
</tr>
<tr>
<td>Plate Steel</td>
<td>5&quot; x 1/16&quot;</td>
<td>2 ft</td>
<td></td>
<td>ITE/IPACO</td>
</tr>
<tr>
<td>Plate Steel</td>
<td>4&quot; x 1/16&quot;</td>
<td>1 ft</td>
<td></td>
<td>ITE/IPACO</td>
</tr>
<tr>
<td>Plate Steel</td>
<td>3&quot; x 0.10&quot;</td>
<td>1 ft</td>
<td></td>
<td>ITE/IPACO</td>
</tr>
<tr>
<td>Aluminum Plate</td>
<td>1/8&quot; X 4&quot; X 4&quot;</td>
<td>2</td>
<td></td>
<td>ITE/IPACO</td>
</tr>
<tr>
<td>Push/Pull Control Rod</td>
<td></td>
<td></td>
<td></td>
<td>ITE/Aircraft Spruce</td>
</tr>
<tr>
<td>Bolt and Nut 1/4&quot;</td>
<td></td>
<td>8</td>
<td></td>
<td>ITE</td>
</tr>
<tr>
<td>Bolt and Nut 10-32</td>
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<td>2</td>
<td></td>
<td>ITE</td>
</tr>
<tr>
<td>Bolt (machine screw)</td>
<td></td>
<td>8</td>
<td></td>
<td>ITE</td>
</tr>
<tr>
<td>Nylon Washer</td>
<td>3/8&quot; hole</td>
<td>8</td>
<td></td>
<td>NW 2081</td>
</tr>
<tr>
<td>Delrin Stock</td>
<td>1/2&quot; X 2&quot; X 4&quot;</td>
<td>4</td>
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<td>?</td>
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<tr>
<td>Nylon Stock</td>
<td>1/4&quot; X 2&quot; X 2&quot;</td>
<td>2</td>
<td></td>
<td>?</td>
</tr>
<tr>
<td>Trailing Edge</td>
<td>1&quot;</td>
<td>14 ft</td>
<td></td>
<td>pg. 72</td>
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<tr>
<td>Dacron Covering</td>
<td>28 sq ft</td>
<td></td>
<td></td>
<td>ITE/Aircraft Spruce</td>
</tr>
</tbody>
</table>
# Parts List for Rudder

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Description</th>
<th>Qty</th>
<th>Type</th>
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<tbody>
<tr>
<td>WF-20-100</td>
<td>Rudder Assembly</td>
<td>1</td>
<td>assembly</td>
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<tr>
<td>WF-20-101</td>
<td>Rudder Surface Assembly</td>
<td>2</td>
<td>assembly</td>
</tr>
<tr>
<td>WF-20-103</td>
<td>Bottom Plate Assembly</td>
<td>1</td>
<td>assembly</td>
</tr>
<tr>
<td>WF-20-104</td>
<td>Top Plate Assembly</td>
<td>1</td>
<td>assembly</td>
</tr>
<tr>
<td>WF-20-105</td>
<td>Control Linkage Assembly</td>
<td>1</td>
<td>assembly</td>
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<tr>
<td>WF-20-130</td>
<td>Push/Pull Rod (round)</td>
<td>1</td>
<td>fit</td>
</tr>
<tr>
<td>WF-20-131</td>
<td>Control Plate</td>
<td>2</td>
<td>cut &amp; drilled</td>
</tr>
<tr>
<td>WF-20-141</td>
<td>Rudder Spacer Plate (bottom)</td>
<td>2</td>
<td>cut &amp; drilled</td>
</tr>
<tr>
<td></td>
<td>Hardware</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Glue</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Covering Material</td>
<td>2</td>
<td>attach</td>
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<tr>
<td>WF-20-111</td>
<td>Rudder D Tube</td>
<td>2</td>
<td>foam lay-up</td>
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<tr>
<td>WF-20-112</td>
<td>Rudder C Beam</td>
<td>2</td>
<td>bi-dir weave lay-up</td>
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<tr>
<td>WF-20-113</td>
<td>Rudder Hard Plate</td>
<td>4</td>
<td>cut, mill &amp; finish</td>
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<tr>
<td>WF-20-114</td>
<td>Rudder ribs</td>
<td>10</td>
<td>foam lay-up</td>
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<tr>
<td>WF-20-115</td>
<td>Rudder Trailing Edge</td>
<td>2</td>
<td>cut &amp; attach</td>
</tr>
<tr>
<td>WF-20-116</td>
<td>Rudder Pivot Block Insert</td>
<td>2</td>
<td>mill &amp; bond</td>
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<tr>
<td>WF-20-140</td>
<td>Rudder Pivot Block Insert Pins</td>
<td>4</td>
<td>cut &amp; bond</td>
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<td></td>
<td>Hardware</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Glue</td>
<td></td>
<td></td>
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<td></td>
<td>Covering Material</td>
<td>2</td>
<td>attach</td>
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<tr>
<td>WF-20-117</td>
<td>Cross Support</td>
<td>4</td>
<td>press-fit &amp; bond</td>
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<tr>
<td>WF-20-130</td>
<td>Bearing Assy</td>
<td>4</td>
<td>cut &amp; drilled</td>
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<tr>
<td>WF-20-131</td>
<td>Wood Circle</td>
<td>4</td>
<td>cut &amp; drilled</td>
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<tr>
<td>WF-20-119</td>
<td>Mount Point</td>
<td>2</td>
<td>cut</td>
</tr>
<tr>
<td>WF-20-120</td>
<td>Support Cables</td>
<td>4</td>
<td>attach fit</td>
</tr>
<tr>
<td>NW 2061</td>
<td>Nylon Washers</td>
<td>6</td>
<td>drill</td>
</tr>
<tr>
<td>WF-20-122</td>
<td>Bottom Beam Support</td>
<td>1</td>
<td>wavy comp. lay-up</td>
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<tr>
<td>WF-20-126</td>
<td>Top Beam Support</td>
<td>1</td>
<td>wavy comp. lay-up</td>
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<tr>
<td>WF-20-123</td>
<td>Wing Spar Mount Assy</td>
<td>2</td>
<td>weldment</td>
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<tr>
<td>WF-20-142</td>
<td>Wing Spar Mount Tube</td>
<td>2</td>
<td>rolled</td>
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<tr>
<td>WF-20-145</td>
<td>Wing Spar Mount Brace</td>
<td>4</td>
<td>weldment</td>
</tr>
<tr>
<td>WF-20-124a</td>
<td>Beam Attach Insert</td>
<td>2</td>
<td>cut &amp; milled</td>
</tr>
<tr>
<td>WF-20-125</td>
<td>Bot Rud Attach Assy</td>
<td>1</td>
<td>weldment</td>
</tr>
<tr>
<td>WF-20-135</td>
<td>Bot Rud Tube</td>
<td>1</td>
<td>milled</td>
</tr>
<tr>
<td>WF-20-129</td>
<td>Top Rud Attach Assy</td>
<td>1</td>
<td>weldment</td>
</tr>
<tr>
<td>WF-20-136</td>
<td>Top Rud Tube</td>
<td>1</td>
<td>milled</td>
</tr>
<tr>
<td>WF-20-137</td>
<td>Rud Attach Plate</td>
<td>4</td>
<td>milled</td>
</tr>
</tbody>
</table>
# Wright Flyer 1903-2003

**Parts List**

<table>
<thead>
<tr>
<th>ITEM</th>
<th>QTY</th>
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<th>DESCRIPTION</th>
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</thead>
<tbody>
<tr>
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<td>2</td>
<td>WF-20-101</td>
<td>Rudder Surface Assembly</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>WF-20-103</td>
<td>Bottom Plate Assembly</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>WF-20-104</td>
<td>Top Plate Assembly</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>WF-20-105</td>
<td>Linkage Assembly</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>WF-20-141</td>
<td>Rudder Spacer Plate (bottom)</td>
</tr>
</tbody>
</table>

**Drawing Information**

- **Drawn by:** J. Hofelitz
- **Date:** 2/17/2002
- **Scale:** B
- **Sheet:** 1 of 1
- **Material:** Rudder Assembly
- **Part Number:** WF-20-100a
- **Company:** Utah State University Mechanical & Aerospace Engineering
START WITH 3" LONG PIECE OF 2" DIA PIPE 0.035" THICK
MILL 2 PARALLEL 1/16" SLITS, 3/4" LONG, 1/2" APART
THROUGH MIDDLE, DRILL HOLES FOR BONDING

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE
.X = ± 0.1
.XX = ± 0.03
.XXX = ± 0.010
ANGLES ± 1°

DRAWN BY:
J. Holfeltz

USU
WRIGHT FLYER
1903-2003

MATERIAL:
Steel, High Strength Low Alloy

PART DESCRIPTION:
top2 rud tube

PART NUMBER:
WF-20-136

DATE: 2/17/2002

SCALE: | SIZE: B | SHEET 1 of 1
ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

\[ X = \pm 0.1 \]
\[ XX = \pm 0.03 \]
\[ XXX = \pm 0.010 \]
ANGLES ± 1°

DRAWN BY:
J. Holfeltz

USU
WRIGHT FLYER
1903-2003

MATERIAL:
RUDATECHASSY TA

DATE: 2/17/2002

SCALE: B

PART DESCRIPTION: RUDATECHASSY TA

PART NUMBER: WF-20-125

REV A

SHEET 1 OF 1
START WITH 3" LONG PIECE OF 2"DIA PIPE 0.035" THICK MILL 2 PARALLEL WITH CENTERLINE 1/16" SLITS, 3/4" LONG, 1/2" APART THROUGH MIDDLE, DRILL HOLES FOR BONDING

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE
.X = ± .1
.XX = ± .03
.XXX = ± .010
ANGLES ± 1°

DRAWN BY:
J. Hofstet

MATERIAL:
Steel, High Strength Low Alloy

PART DESCRIPTION:
bolt rod tube

PART NUMBER:
WF-20-135

DATE: 2/17/2002

SCALE: B

SIZE:

SHEET 1 of 1

USU
WRIGHT FLYER
1903-2003

Utah State University Mechanical & Aerospace Engineering
ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

X = ±.1
XX = ±.03
XXX = ±.010
ANGLES ± 1°

USU
WRIGHT FLYER
1903-2003

DRAWN BY:
J. Hofeleit

MATERIAL: carbon fiber

PART DESCRIPTION: Botton Beam Support

PART NUMBER: WF-20-122

DATE: 2/17/2002

SCALE: SIZE: B

SHEET 1 of 1
WRIGHT FLYER
1903-2003

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE
X = ± .1
XX = ± .03
XXX = ± .010
ANGLES ± 1°

DRAWN BY:
J. Holfeltz

MATERIAL:
Steel, High Strength Low Alloy

PART DESCRIPTION:
Nut attach plate

PART NUMBER:
WF-20-137

DATE: 2/17/2002

SCALE: | SIZE: B | SHEET 1 of 1

Utah State University
Mechanical & Aerospace Engineering
WRIGHT FLYER
1903-2003

PART DESCRIPTION:
2" PIPE STOCK

PART NUMBER:
WF-20-124a

REV

MATERIAL:
Steel, High Strength Low Alloy

DATE: 2/17/2002

SCALE:
SIZE: B

Sheet 1 of 1

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE
.X = ± .1
.XX = ± .03
.XXX = ± .010
ANGLES ± 1°
weld two straps together and weld to tube

Parts List

<table>
<thead>
<tr>
<th>ITEM</th>
<th>QTY</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>WF-20-142</td>
<td>BSSA Tube</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>WF-20-145</td>
<td>strap</td>
</tr>
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</table>

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

\[
\begin{align*}
X &= \pm 1 \\
XX &= \pm 0.03 \\
XXX &= \pm 0.010 \\
ANGLES &= \pm 1\degree
\end{align*}
\]

DRAWN BY: J. Holleiz

MATERIAL: Wing Spar Mount Bottom

DATE: 2/17/2002

SCALE: B

SIZE: 1

SHEET 1 of 1
TAKE 0.063 FLAT STOCK 6"X8"
ROLL 260 deg. AT 2.63" DIAMETER

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE
.X = ± .1
.XX = ± .03
.XXX = ± .010
ANGLES ± 1°

DRAWN BY:
J. Hoffeltz

MATERIAL:
Steel, High Strength Low Alloy

USU
WRIGHT FLYER
1903-2003

SCALE: B
SIZE: B
SHEET 1 of 1
ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

\[ X = \pm 0.1 \]
\[ XX = \pm 0.03 \]
\[ XXX = \pm 0.019 \]
ANGLES ± 1°

DRAWN BY: J. Holfeltz
MATERIAL: honeycomb, graphite skin

DATE: 2/17/2002
SCALE: B

USU
WRIGHT FLYER
1903-2003

Utah State University
Mechanical & Aerospace Engineering

PART DESCRIPTION: Cross Support
PART NUMBER: WF-20-117
REV
ALL PARTS ARE BONDED WITH ADHESIVE
ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

X = ± .1
XX = ± .03
XXX = ± .010
ANGLES ± 1°

DRAWN BY:
J. Holfeltz

MATERIAL:
Kevlar reinforced foam

PART DESCRIPTION:
Rudder D-tube

DATE: 2/17/2002

SCALE: B

SIZE: B

SHEET 1 of 1
2 layers of bi-directional weave weight should be 1 lb. may need to be manuf. in two pieces

DIMS ARE IN INCHES UNLESS NOTED OTHERWISE
.X = ± .1
.XX = ± .03
.XXX = ± .010
ANGLES ± 1°

DRAWN BY:
J. Hoffeltz

MATERIAL:
carbon fiber

PART DESCRIPTION:
Rudder C-beam

PART NUMBER:
WF-20-112

DATE: 2/17/2002

SCALE: B

USU WRIGHT FLYER
1903-2003

Utah State University Mechanical & Aerospace Engineering
ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

\[ X = \pm 1 \]
\[ XXX = \pm 0.03 \]
\[ XXXX = \pm 0.010 \]
ANGLES ± 1'

DRAWN BY:
J. Holifeltz

DATE: 2/17/2002

SCALE: B
SIZE: B
SHEET 1 of 1

USU
WRIGHT FLYER
1903-2003

MATERIAL:
Kevlar reinforced foam

PART DESCRIPTION:
Rudder Ribs

PART NUMBER:
WF-20-114

REV

Utah State University Mechanical & Aerospace Engineering
Parts List

<table>
<thead>
<tr>
<th>ITEM</th>
<th>QTY</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>WF-20-130</td>
<td>Push/Pull Rod (round)</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>WF-20-131</td>
<td>Control Plate</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>WF-30-207</td>
<td>Fork End</td>
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<td>Hardware</td>
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USU
WRIGHT FLYER
1903-2003

DRAWN BY: J. Hoffeltz
MATERIAL: Linkage Assembly
PART DESCRIPTION: Linkage Assembly
PART NUMBER: WF-20-105
DATE: 2/17/2002
SCALE: B
SIZE: SHEET 1 of 1
Parts List

<table>
<thead>
<tr>
<th>ITEM</th>
<th>QTY</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4</td>
<td>.25in bolt/nut</td>
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</tr>
<tr>
<td>2</td>
<td>1</td>
<td>WF-20-124a</td>
<td>Wing Spar Mount Bottom</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>WF-20-125</td>
<td>fuselage Assy 1a</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>WF-20-117</td>
<td>Cross Support</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>WF-20-118</td>
<td>Bearing</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>WF-20-119</td>
<td>Mount Point</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>NV2051 Spruce p. 134</td>
<td>nylon washers</td>
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<tr>
<td>8</td>
<td>1</td>
<td>WF-20-122</td>
<td>Bottom Beam Support</td>
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<tr>
<td>9</td>
<td>1</td>
<td>WF-20-124a</td>
<td>tube cmt</td>
</tr>
<tr>
<td>10</td>
<td>2</td>
<td>cross skin</td>
<td></td>
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USU WRIGHT FLYER 1903-2003

DRAWN BY: J. Hoefeltz

MATERIAL: Bottom Plate Assembly

PART DESCRIPTION: WF-20-103a

DATE: 2/17/2002

SCALE: B SHEET 1 of 1
Cockpit Assembly
# Materials List for Cockpit

*ck spc= check drawing specifications*

<table>
<thead>
<tr>
<th>Item/Material</th>
<th>Description</th>
<th>Qty</th>
<th>Part #</th>
<th>Supplier</th>
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<tr>
<td>Washer</td>
<td>1/4&quot; flat washer</td>
<td>186</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Nut</td>
<td>1/4&quot; locknut</td>
<td>96</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Bolt</td>
<td>1 1/2&quot; 1/4-20 grade 8 hex</td>
<td>78</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Bolt</td>
<td>2 1/2&quot; 1/4-20 grade 8 hex</td>
<td>12</td>
<td>0</td>
<td></td>
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<tr>
<td>Bolt</td>
<td>2&quot; 1/4-20 grade 8 hex</td>
<td>2</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Screw</td>
<td>1 1/2&quot; 1/4-20 flat screw</td>
<td>4</td>
<td>0</td>
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<tr>
<td>Pillow Block</td>
<td>UHMW Duo 3/4&quot; bore dia</td>
<td>2</td>
<td></td>
<td>IPACO</td>
</tr>
<tr>
<td>Pillow Block</td>
<td>UHMW 2&quot; bore dia.</td>
<td>2</td>
<td></td>
<td>IPACO</td>
</tr>
<tr>
<td>Steel Tubing</td>
<td>4130 -- (3/4&quot; OD X .063&quot; wall)</td>
<td>122.5</td>
<td>in</td>
<td>0</td>
</tr>
<tr>
<td>Steel Tubing</td>
<td>4130 -- (2&quot; OD X .049&quot; wall)</td>
<td>69</td>
<td>in</td>
<td>0</td>
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<td>Steel Tubing</td>
<td>4130 -- (1/2&quot; OD X .03&quot; wall)</td>
<td>28</td>
<td>in</td>
<td></td>
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<tr>
<td>Sheet Metal - Steel</td>
<td>4130 -- (.063&quot; thick)</td>
<td>459.5</td>
<td>in²</td>
<td>0</td>
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<tr>
<td>Sheet Metal - Aluminum</td>
<td>.018&quot; thick</td>
<td>54</td>
<td>in²</td>
<td>0</td>
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<tr>
<td>Honeycomb - Aluminum</td>
<td>(1/2&quot; thick, 18&quot;X12&quot;)</td>
<td>2</td>
<td></td>
<td>?</td>
</tr>
<tr>
<td>Rectangular Tube</td>
<td>aluminum (2&quot; X 1&quot; X 1/8&quot; wall)</td>
<td>247</td>
<td>in</td>
<td>0</td>
</tr>
<tr>
<td>Angle Stock</td>
<td>aluminum 2&quot;</td>
<td>20</td>
<td>in</td>
<td>0</td>
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<tr>
<td>Streamline Tube</td>
<td>4130 steel 1&quot;</td>
<td>138</td>
<td>in 03-11300</td>
<td>0</td>
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<tr>
<td>Steel Rod</td>
<td>push rod</td>
<td>38</td>
<td>in</td>
<td>0</td>
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<tr>
<td>Linkages</td>
<td>fork end (cable terminal)</td>
<td>4</td>
<td>MS20667-4</td>
<td>0</td>
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<tr>
<td>Linkages</td>
<td>fork end (rod terminal)</td>
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<td>AN151-32S</td>
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<tr>
<td>Linkages</td>
<td>eye end (cable terminal)</td>
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<td>MS20668-5</td>
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<tr>
<td>Linkages</td>
<td>fork end (rod terminal)</td>
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<td>AN665-34R</td>
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<tr>
<td>&quot;Tangs&quot;</td>
<td>1 prong 1/4&quot; (see wing parts)</td>
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<td></td>
<td>0</td>
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<tr>
<td>Spacer</td>
<td>nylon 5/16&quot; inside diameter</td>
<td>2.5</td>
<td>in</td>
<td>0</td>
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<tr>
<td>Bushing</td>
<td>1/4&quot; inner diameter (1.5&quot; long)</td>
<td>2</td>
<td></td>
<td>0</td>
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<tr>
<td>Bushing</td>
<td>1/4&quot; inner diameter(1.75&quot; long)</td>
<td>2</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Clevis Pin</td>
<td>atleast 1&quot; long</td>
<td>2</td>
<td></td>
<td>0</td>
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<tr>
<td>Cotter Pin</td>
<td>to fit clevis</td>
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<td></td>
<td>0</td>
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<tr>
<td>Cable Wire</td>
<td>steel 1/8&quot; diameter</td>
<td>?</td>
<td></td>
<td>0</td>
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<tr>
<td>Carbon Fiber</td>
<td>18&quot; X 12&quot; lamina</td>
<td>?(4)</td>
<td></td>
<td>ITE</td>
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<tr>
<td>Chair</td>
<td>pilot defined</td>
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<td></td>
<td>ITE</td>
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## Parts List for Cockpit

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<th>Part Number</th>
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<tr>
<td>WF-30-001</td>
<td>Span Bar Front</td>
<td>1</td>
<td>cut &amp; drilled</td>
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<tr>
<td>WF-30-002</td>
<td>Span Bar Back</td>
<td>1</td>
<td>cut &amp; drilled</td>
</tr>
<tr>
<td>WF-30-003</td>
<td>Foot Bar Front</td>
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<td>cut &amp; drilled</td>
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<tr>
<td>WF-30-004</td>
<td>Foot Bar Back</td>
<td>1</td>
<td>cut &amp; drilled</td>
</tr>
<tr>
<td>WF-30-005</td>
<td>Span Bar Support</td>
<td>8</td>
<td>cut &amp; drilled</td>
</tr>
<tr>
<td>WF-30-007</td>
<td>Streamline Rear Strut</td>
<td>2</td>
<td>cut &amp; weldament</td>
</tr>
<tr>
<td>WF-30-006</td>
<td>Streamline Small Plate</td>
<td>2</td>
<td>cut &amp; drilled</td>
</tr>
<tr>
<td>WF-30-013</td>
<td>Streamline Large Plate</td>
<td>10</td>
<td>cut &amp; drilled</td>
</tr>
<tr>
<td>WF-30-014</td>
<td>Streamline Left Front</td>
<td>1</td>
<td>cut &amp; weldament</td>
</tr>
<tr>
<td>WF-30-015</td>
<td>Streamline Right Front</td>
<td>1</td>
<td>cut &amp; weldament</td>
</tr>
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<td>WF-30-016</td>
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</tr>
<tr>
<td>WF-30-017</td>
<td>Streamline Right Back</td>
<td>1</td>
<td>cut &amp; weldament</td>
</tr>
<tr>
<td>WF-30-019</td>
<td>1/16” Tab</td>
<td>4</td>
<td>cut &amp; drilled</td>
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<tr>
<td>WF-30-021</td>
<td>Control Panel</td>
<td>1</td>
<td>cut &amp; drilled</td>
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<tr>
<td>WF-30-022</td>
<td>Long Panel Legs</td>
<td>2</td>
<td>cut &amp; drilled</td>
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<tr>
<td>WF-30-023</td>
<td>Short Panel Legs</td>
<td>2</td>
<td>cut &amp; drilled</td>
</tr>
<tr>
<td>WF-30-031</td>
<td>Foot Plate Fiber Lamina</td>
<td>4</td>
<td>layed up</td>
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<tr>
<td>WF-30-032</td>
<td>Hardpoint</td>
<td>8</td>
<td>drilled &amp; placed</td>
</tr>
<tr>
<td>WF-30-101</td>
<td>Control Case</td>
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<td>cut &amp; weldament</td>
</tr>
<tr>
<td>WF-30-102</td>
<td>Control Stick Mount</td>
<td>2</td>
<td>cut, bent &amp; drilled</td>
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<tr>
<td>WF-30-104</td>
<td>Round Section of Stick</td>
<td>2</td>
<td>cut &amp; bent</td>
</tr>
<tr>
<td>WF-30-105</td>
<td>Straight Section of Stick</td>
<td>2</td>
<td>cut &amp; drilled</td>
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<tr>
<td>WF-30-106</td>
<td>Short Section</td>
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<td>cut &amp; threaded</td>
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<tr>
<td>WF-30-110</td>
<td>Canard Bell Crank</td>
<td>2</td>
<td>cut, bent &amp; drilled</td>
</tr>
<tr>
<td>WF-30-112</td>
<td>Nylon Spacer</td>
<td>4</td>
<td>cut</td>
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<tr>
<td>WF-30-115</td>
<td>Push Pull Rod</td>
<td>1</td>
<td>cut &amp; threaded</td>
</tr>
<tr>
<td>WF-30-119</td>
<td>Nylon Spacer</td>
<td>2</td>
<td>cut</td>
</tr>
<tr>
<td>WF-30-121</td>
<td>Wing Warp Bell</td>
<td>1</td>
<td>cut, bent &amp; drilled</td>
</tr>
<tr>
<td>WF-30-201</td>
<td>Pedal Rod</td>
<td>2</td>
<td>cut &amp; weldament</td>
</tr>
<tr>
<td>WF-30-203</td>
<td>Pedal-Foot Interface</td>
<td>4</td>
<td>cut &amp; weldament</td>
</tr>
<tr>
<td>WF-30-204</td>
<td>Pedal Arm</td>
<td>4</td>
<td>cut, bored</td>
</tr>
<tr>
<td>WF-30-205</td>
<td>Rudder Tab</td>
<td>2</td>
<td>cut, bent &amp; drilled</td>
</tr>
<tr>
<td>WF-30-209</td>
<td>Nylon Spacer</td>
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<td>cut</td>
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<tr>
<td>WF-30-210</td>
<td>Rudder Bell Crank</td>
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<td>cut, bent &amp; drilled</td>
</tr>
<tr>
<td>WF-30-212</td>
<td>Push Pull Rod</td>
<td>2</td>
<td>cut &amp; threaded</td>
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</table>
SEATS TO BE MOUNTED AT ITÉ'S DISCRETION

DETAIL C
SCALE 0.24 : 1

DETAIL B
SCALE 0.24 : 1

DRAWN BY:
AMY HINTZE

USU
WRIGHT FLYER
1903-2003

PARTS LIST

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<tr>
<th>ITEM</th>
<th>QTY</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
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<tr>
<td>1</td>
<td>1</td>
<td>WF-30-001</td>
<td>SITTING AREA</td>
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<tr>
<td>2</td>
<td>1</td>
<td>WF-30-002</td>
<td>FOOT REST AREA</td>
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<td>3</td>
<td>1</td>
<td>WF-30-100</td>
<td>CONTROL ASSEMBLY</td>
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<td>4</td>
<td>48</td>
<td>WF-30-094</td>
<td>1/4&quot; FLAT WASHER</td>
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<td>5</td>
<td>20</td>
<td>4P254</td>
<td>1.5 1/4-20 HEX GRADE 8</td>
</tr>
<tr>
<td>6</td>
<td>4</td>
<td>4P258</td>
<td>2.5 1/4-20 HEX GRADE 8</td>
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<td>7</td>
<td>24</td>
<td>WF-30-093</td>
<td>1/4&quot; LOCKNUT</td>
</tr>
<tr>
<td>8</td>
<td>2</td>
<td>CHAIR</td>
<td>CHAIR</td>
</tr>
</tbody>
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ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE:
X = ± .1
XX = ± .03
XXX = ± .010
ANGLES ± 1'

DATE: 2/17/2002

SCALE: B

SIZE: B

SHEET 1 of 1
ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE
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XXX = ± .010
ANGLES ± 1°

DRAWN BY: AMY HINTZE

USU
WRIGHT FLYER
1903-2003

MATERIAL:
PART DESCRIPTION:
PART NUMBER:
REV
DATE: 2/17/2002
SCALE: SIZE:
SHEET 1 of 1
ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

X = ±.1
XX = ±.03
XXX = ±.010
ANGLES ± 1°

DRAWN BY:
AMY HINTZE

MATERIAL:
Aluminum-6061

PART DESCRIPTION:
SPAN BAR BACK

PART NUMBER:
WF-90-002

DATE: 2/17/2002

SCALE: B
SIZE: 1
SHEET 1 of 1
## Parts List

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<thead>
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<th>ITEM</th>
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<th>DESCRIPTION</th>
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<td>PANEL LEGS</td>
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<tr>
<td>2</td>
<td>1</td>
<td>WF-30-021</td>
<td>CONTROL PANEL</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>GRANGER SK177</td>
<td>1/4&quot; 10-24</td>
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**All dims are in inches unless noted otherwise:**

- X = ± .1
- XX = ± .03
- XXX = ± .010
- Angles ± 1°

---

**Drawn by:**
Amy Hintze

**Material:**
usu

**Part Description:**
CONTROL PANEL ASSM

**Part number:**
WF-30-020

**Date:**
2/17/2002

**Scale:**
size: B

**Sheet:**
1 of 1
ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

X = ± .1
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XXX = ± .010
ANGLES ± 1°
All dims are in inches unless noted otherwise.

X = ± 0.1
XX = ± 0.03
XXX = ± 0.010
ANGLES ± 1°

Drawn by: Amy Hintze

Utah State University  Mechanical & Aerospace Engineering

USU
WRIGHT FLYER
1903-2003

Material: Aluminum-6061
Part Description: Panel Legs
Part Number: WF-30-023
Date: 2/17/2002

Scale: B
Size: 1
Sheet: 1 of 1
HONEY COMB COMPOSITE PLATE
CARBON FIBER AND 1/4" ALUMINUM HONEYCOMB

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

\[X = \pm 0.1\]
\[XX = \pm 0.03\]
\[XXX = \pm 0.010\]
ANGLES ± 1°

DRAWN BY:
AMY HINTZE

DATE: 2/17/2002
SCALE: B
SIZE: SHEET 1 of 1
ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

\[ X = \pm 0.1 \]
\[ XX = \pm 0.03 \]
\[ XXX = \pm 0.010 \]
ANGLES \pm 1°

DRAWN BY: AMY HINTZE

USU
WRIGHT FLYER
1903-2003

MATERIAL: Aluminum-5061

PART DESCRIPTION: FOOT BAR FRONT

PART NUMBER: WF-30-003

DATE: 2/17/2002

SCALE: B

SIZE: SHEET 1 of 1
WRIGHT FLYER
1903-2003

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE
X = ±.1
XX = ± .03
XXX = ± .010
ANGLES ± 1°

DRAWN BY:
AMY HINTZE

MATERIAL:
Steel, High Strength Low Alloy

DATE: 2/17/2002
SCALE: B

PART DESCRIPTION:
STREAMLINE LEFT FR
PART NUMBER:
03-11300

REV

Sheet 1 of 1

USU
Mechanical & Aerospace Engineering

Utah State University
SAME AS DRAWING WF-30-009

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE
X = ±0.1
XX = ±0.03
XXX = ±0.010
ANGLES ±1°

DRAWN BY:
AMY HINTZE

MATERIAL:

Utah State University
Mechanical & Aerospace Engineering

USU WRIGHT FLYER
1903-2003

Parts List

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<thead>
<tr>
<th>ITEM</th>
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<th>DESCRIPTION</th>
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<td>STREAMLINE PLATE</td>
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SCALE: B
SIZE: SHEET 1 OF 1

DATE: 2/17/2002

REV
ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

X = ± .1
XX = ± .03
XXX = ± .010
ANGLES ± 1°

DRAWN BY:
AMY HINTZE

USU
WRIGHT FLYER
1903-2003

MATERIAL:
Steel, High Strength Low Alloy

PART DESCRIPTION:
STREAMLINE RIGHT FR

PART NUMBER:
03-11300

DATE: 2/11/2002

SCALE: SIZE: B SHEET 1 of 1
ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

X = ± .1
XX = ± .03
XXX = ± .010
ANGLES ± 1°

DRAWN BY:
AMY HINTZE

USU
WRIGHT FLYER
1903-2003

MATERIAL:
BACK FOOT REST

DATE: 2/17/2002
SCALE: B
SIZE: SHEET 1 of 1
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<td>50.00</td>
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<td>3.24</td>
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ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

X = ± .1
XX = ± .03
XXX = ± .010
ANGLES ± 1°

DRAWN BY:
AMY HINTZE

MATERIAL: Aluminum-6061

PART DESCRIPTION: FOOT BAR BACK

PART NUMBER: WF-30-004

REV

DATE: 2/17/2002

SCALE: SIZE: B SHEET 1 of 1

USU WRIGHT FLYER 1903-2003
TYPICAL

- X = ± .1
- XX = ± .03
- XXX = ± .010
- ANGLES ± 1°

DRAWN BY:
AMY HINTZE

MATERIAL:
WRIGHT FLYER
1903-2003

USU
MECHANICAL & AEROSPACE ENGINEERING
WRIGHT FLYER
1903-2003

<table>
<thead>
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<th>ITEM</th>
<th>QTY</th>
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<th>DESCRIPTION</th>
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<tr>
<td>1</td>
<td>1</td>
<td>WF-30-008</td>
<td>STREAMLINE PLATE</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>WF-30-013</td>
<td>STREAMLINE PLATE</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>03-11300</td>
<td>STREAMLINE LEFT FR</td>
</tr>
</tbody>
</table>

SCALE: SIZE: B SHEET 1 of 1

DATE: 2/17/2003

REV
SAME AS DRAWING WF-30-009

UNLESS NOTED OTHERWISE:

X = ± 1
XX = ± 0.03
XXX = ± 0.010
ANGLES ± 1°

DRAWN BY: AMY HINTZE

USU
WRIGHT FLYER
1903-2003

PARTS LIST

<table>
<thead>
<tr>
<th>ITEM</th>
<th>QTY</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>WF-30-013</td>
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</tr>
<tr>
<td>2</td>
<td>1</td>
<td>03-11300</td>
<td>STREAMLINE RIGHT BACK</td>
</tr>
</tbody>
</table>

DATE: 2/17/2002
SCALE: B SHEET: 1 of 1
ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE
X = ±.1
XX = ±.03
XXX = ±.010
ANGLES ± 1°

DRAWN BY:
AMY HINTZE

MATERIAL:
Steel, High Strength Low Alloy

DATE: 2/17/2002

SCALE:
SIZE: B

USU
WRIGHT FLYER
1903-2003
TYPICAL

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

X = ± .1
XX = ± .03
xxx = ± .010
ANGLES ± 1°

DRAWN BY:
AMY HINTZE

MATERIAL:
usu WRIGHT FLYER

REV

USU
WRIGHT FLYER
1903-2003

<table>
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<tr>
<th>ITEM</th>
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<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>WF-30-013</td>
<td>STREAMLINE PLATE</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>03-11300</td>
<td>STREAMLINE LEFT BACK</td>
</tr>
</tbody>
</table>

PART DESCRIPTION: STREAMLINE B RIGHT
PART NUMBER: WF-30-012
DATE: 2/17/2002
SCALE: SIZE: B

Sheet 1 of 1
Mount blocks so that reference line weld is on this face.

All dims are in inches unless noted otherwise:

- X = ± .1
- XX = ± .03
- XXX = ± .010
- Angles ± 1'

Drawn by: Amy Hintze

Material:

- WF-30-202 Single Pedal Assembly
- WF-30-206 Pillow Block
- AircraftSpruce AN161-32S Steel Clevis Fork
ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

X = ± .1
XX = ± .03
XXX = ± .010
ANGLES ± 1'

Parts List

<table>
<thead>
<tr>
<th>ITEM</th>
<th>QTY</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>WF-30-201</td>
<td>PEDAL ROD</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>WF-30-203</td>
<td>PEDAL - FOOT INTERFACE</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>WF-30-204</td>
<td>PEDAL - ARM</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>WF-30-205</td>
<td>RUDDER TAB</td>
</tr>
</tbody>
</table>

DRAWN BY: AMY HINTZE

MATERIAL: SINGLE PEDAL ASSEMBLY

DATE: 2/17/2002

SCALE: SIZE: B SHEET 1 of 1
ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

\[ X = \pm 0.1 \]
\[ XX = \pm 0.03 \]
\[ XXX = \pm 0.010 \]
ANGLES \[\pm 1°\]

DRAWN BY: AMY HINTZE

MATERIAL: 4130 STEEL

DATE: 2/17/2002

SCALE: SIZE: B SHEET 1 of 1
ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

\[ X = \pm 0.1 \]
\[ XX = \pm 0.03 \]
\[ XXX = \pm 0.019 \]
\[ ANGLES \pm 1' \]

DRAWN BY: AMY HINTZE

MATERIAL: 4130 STEEL

PART DESCRIPTION: PEDAL-FOOT INTERFACE

PART NUMBER: WF-30-203

DATE: 2/17/2002

SCALE: SIZE: B SHEET 1 of 1
ALL DIMS ARE IN UNLESS NOTED OTHERWISE

X = ± .1
XX = ± .03
XXX = ± .010
ANGLES ± 1°

DRAWN BY: AMY HINTZE

<table>
<thead>
<tr>
<th>MATERIAL:</th>
<th>PART DESCRIPTION:</th>
<th>PART NUMBER:</th>
<th>REV</th>
</tr>
</thead>
<tbody>
<tr>
<td>WRIGHT FLYER 1903-2003</td>
<td>CONTROL ASSEMBLY</td>
<td>WF-30-100</td>
<td></td>
</tr>
</tbody>
</table>

Parts List

<table>
<thead>
<tr>
<th>ITEM</th>
<th>QTY</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>WF-30-107</td>
<td>CONTROL ASSM</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>WF-30-101</td>
<td>CASE</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>WF-30-102</td>
<td>CONTROL STICK MOUNT</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>4P258</td>
<td>2.0 1/4-20 HEX GRADE 8</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>WF-30-110</td>
<td>CANARD BELL CRANK</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>MS20667-4</td>
<td>FORK END</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>WF-30-093</td>
<td>1/4 LOCKNUT</td>
</tr>
<tr>
<td>8</td>
<td>1</td>
<td>WF-30-115</td>
<td>PUSH PULL ROD</td>
</tr>
<tr>
<td>9</td>
<td>2</td>
<td>6254K85</td>
<td>UHMW PILLOW BLOCK</td>
</tr>
<tr>
<td>10</td>
<td>2</td>
<td>WF-30-084</td>
<td>1/4 FLAT WASHER</td>
</tr>
</tbody>
</table>

USU Mechanical & Aerospace Engineering

DATE: 2/17/2002

SCALE: SIZE: B SHEET 1 of 1
Note: WELD AFTER ASSEMBLY IS MOUNTED, FOR POSITIONING REASONS. PILLOW BLOCK MUST BE ON PRIOR TO WELD.

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

X = ± .1
XX = ± .03
XXX = ± .010
ANGLES ± 1°

DRAWN BY: AMY HINTZE

MATERIAL:

PART DESCRIPTION: REF. FOR WELDING
PART NUMBER: WF-30-100WELD
REV

DATE: 2/17/2002
SCALE: SIZE: B SHEET 1 of 1
SIDE VIEW

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE
X = ± .1
XX = ± .03
XXX = ± .010
ANGLES ± 1°

DRAWN BY:
AMY HINTZE

MATERIAL: Steel, High Strength Low Alloy

PART DESCRIPTION: CASE
PART NUMBER: WF-30-101

DATE: 2/17/2002
SCALE: SIZE: B
SHEET 1 of 1
ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

\[ X = \pm 0.1 \]
\[ XX = \pm 0.03 \]
\[ XXX = \pm 0.010 \]

ANGLES ± 1°

DRAWN BY: AMY HINTZE

MATERIAL: Steel, High Strength Low Alloy

PART DESCRIPTION: CONTROL STICK MOUNT

PART NUMBER: WF-30-102

DATE: 2/17/2002

SCALE: SIZE: B

USU WRIGHT FLYER 1903-2003

Utah State University Mechanical & Aerospace Engineering
ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

X = ± .1
XX = ± .03
XXX = ± .010
ANGLES ± 1°

USU
WRIGHT FLYER
1903-2003

MATERIAL: 4130 STEEL
PART DESCRIPTION: CANARD BELL CRANK
PART NUMBER: WF-30-110
DATE: 2/17/2002
SCALE: B
SIZE: SHEET 1 of 1
B••••

DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

X = ± .1
XX = ± .03
XXX = ± .010
ANGLES ± 1°

DRAWN BY: AMY HINTZE

MATERIAL: WRIGHT FLYER 1903-2003

USU MECHANICAL & AEROSPACE ENGINEERING

Parts List

<table>
<thead>
<tr>
<th>ITEM</th>
<th>QTY</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>WF-30-103</td>
<td>CONTROL STICK ASSM</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>AN665-34R</td>
<td>FORK END 2</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>MS20608-5</td>
<td>EYE END</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>WF-30-112 CATALOG</td>
<td>NYLON SPACER</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>WF-30-111 CATALOG</td>
<td>BUSHING</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>AN-395-33</td>
<td>5/16&quot; CLEVIS PIN</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>AN-380-2-3</td>
<td>3/4&quot; COTTER PIN</td>
</tr>
</tbody>
</table>

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

X = ± .1
XX = ± .03
XXX = ± .010
ANGLES ± 1°

DATE: 2/17/2002

SCALE: SIZE: B SHEET 1 OF 1
ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

\[
X = \pm 0.1
\]
\[
XX = \pm 0.03
\]
\[
XXX = \pm 0.010
\]
ANGLES \(\pm 1^\circ\)

DRAWN BY:
AMY HINTZE

USU
WRIGHT FLYER
1903-2003

MATERIAL:
CONTROL STICK ASSM

PART DESCRIPTION:

PART NUMBER:
WF-30-103

DATE: 2/17/2002

SCALE: B

SIZE: B

Sheet 1 of 1
ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

\[ \pm 0.1 \]

\[ \pm 0.03 \]

\[ \pm 0.010 \]

ANGLES \pm 1°

DRAWN BY:
AMY HINTZE

PART DESCRIPTION: RND SEC. OF STICK

PART NUMBER: WF-30-104

DATE: 2/17/2003

SCALE: B

SIZE: SHEET 1 of 1
ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE
.X = ± 0.1
.XX = ± 0.03
.XXX = ± 0.010
ANGLES ± 1°

DRAWN BY:
AMY HINTZE

MATERIAL: Stainless Steel, 440C

PART DESCRIPTION: BUSHING

PART NUMBER: WF-30-111 (CATALOG)

DATE: 2/17/2002

SCALE: B

SIZE: B

SHEET 1 of 1
ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

X = ± .1
XX = ± .03
XXX = ± .010
ANGLES ± 1°

DRAWN BY:
AMY HINTZE

MATERIAL:
Nylon-6/6

PART DESCRIPTION:
NYLON SPACER

PART NUMBER:
WF-30-112 CATALOG

DATE: 2/17/2002

SCALE:

SIZE: B

SHEET 1 of 1
MIRROR HOLE DIMENSIONS

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

\[
\begin{align*}
X &= \pm 0.1 \\
XX &= \pm 0.03 \\
XXX &= \pm 0.010 \\
ANGLES &= \pm 1^\circ
\end{align*}
\]

DRAWN BY: AMY HINTZE

MATERIAL: Steel, High Strength Low Alloy

PART DESCRIPTION: WING WARP BELL

DATE: 2/17/2002

SCALE: B

REV WING WARP BELL

USU WRIGHT FLYER 1903-2003

WF-30-121
Transmission Assembly
Materials List for Transmission
ck spc= check drawing specifications

<table>
<thead>
<tr>
<th>Item/Material</th>
<th>Description</th>
<th>Qty</th>
<th>Part #</th>
<th>Supplier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Square Tubing</td>
<td>4x4x72&quot;</td>
<td>2</td>
<td>88875k44</td>
<td>McMaster</td>
</tr>
<tr>
<td>Keyed Shaft</td>
<td>0.5x12&quot;</td>
<td>2</td>
<td>1497k61</td>
<td>McMaster</td>
</tr>
<tr>
<td>Hollow Rod</td>
<td>0.5x12&quot;, 1/8 wall</td>
<td>2</td>
<td>89965k85</td>
<td>McMaster</td>
</tr>
<tr>
<td>Ball Bearing</td>
<td>0.5x1.5x0.5&quot;</td>
<td>4</td>
<td>2329k37</td>
<td>McMaster</td>
</tr>
<tr>
<td>Sheave</td>
<td>24 tooth</td>
<td>2</td>
<td>P24-8MGT-30</td>
<td>Gates</td>
</tr>
<tr>
<td>Sheave</td>
<td>56 tooth</td>
<td>2</td>
<td>P56-8MGT-30</td>
<td>Gates</td>
</tr>
<tr>
<td>Spacer</td>
<td>0.5x1.0x0.25&quot;</td>
<td>6</td>
<td>3088A514</td>
<td>McMaster</td>
</tr>
<tr>
<td>Shaft Collar</td>
<td>0.5x2.0x1.0&quot;</td>
<td>2</td>
<td>6157k16</td>
<td>McMaster</td>
</tr>
<tr>
<td>Gear</td>
<td>36 tooth, 1.5&quot; face, steel</td>
<td>2</td>
<td>A636H</td>
<td>Rush Gears</td>
</tr>
<tr>
<td>Drive Belt</td>
<td>144 tooth, 30mm wide</td>
<td>2</td>
<td>B144-8MGT-30</td>
<td>Gates</td>
</tr>
<tr>
<td>Bolt</td>
<td>grade 8, 0.375 x 3.5</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nut</td>
<td>grade 8, 0.375</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Washer</td>
<td>grade 8, 0.375</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bolt</td>
<td>grade 8, 0.375 x 2.5</td>
<td>4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Parts List for Transmission

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Description</th>
<th>Qty</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>WF-40-002-602</td>
<td>Mounting Bracket</td>
<td>2</td>
<td>cut &amp; drilled</td>
</tr>
<tr>
<td>WF-40-002-603</td>
<td>Bearing Block</td>
<td>2</td>
<td>milled &amp; drilled</td>
</tr>
<tr>
<td>WF-40-002-604</td>
<td>Keyed Shaft</td>
<td>2</td>
<td>cut</td>
</tr>
<tr>
<td>WF-40-002-605</td>
<td>Support Shaft</td>
<td>2</td>
<td>cut</td>
</tr>
<tr>
<td>WF-40-002-606</td>
<td>Ball Bearing</td>
<td>4</td>
<td>N/A</td>
</tr>
<tr>
<td>WF-40-002-607</td>
<td>24 Tooth Sheave</td>
<td>2</td>
<td>N/A</td>
</tr>
<tr>
<td>WF-40-002-608</td>
<td>56 Tooth Sheave</td>
<td>2</td>
<td>N/A</td>
</tr>
<tr>
<td>WF-40-002-609</td>
<td>Shaft Spacer</td>
<td>6</td>
<td>N/A</td>
</tr>
<tr>
<td>WF-40-002-610</td>
<td>Shaft Collar</td>
<td>5</td>
<td>N/A</td>
</tr>
<tr>
<td>WF-40-002-611</td>
<td>Gear</td>
<td>2</td>
<td>Bored</td>
</tr>
<tr>
<td>WF-40-002-612</td>
<td>Drive Belt</td>
<td>2</td>
<td>N/A</td>
</tr>
</tbody>
</table>
# Wright Flyer Parts List

<table>
<thead>
<tr>
<th>ITEM</th>
<th>QTY</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
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<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>WF-40-002-600</td>
<td>Block and Bearing</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>WF-40-002-610 / McMaster# 6157K15</td>
<td>Shaft Collar</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>WF-40-002-609 / McMaster# 3088s514</td>
<td>Inner Race Spacer</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>WF-40-002-607 / Gates# P24-6MG-30</td>
<td>24 Tooth Sheave</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>WF-40-002-611 / Rush Gear# A939H</td>
<td>Gear</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>WF-40-002-609 / Gates# P96-6MG-30</td>
<td>96 Tooth Sheave</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>WF-40-003-604 / McMaster# 1497K61</td>
<td>Keyed Shaft</td>
</tr>
<tr>
<td>8</td>
<td>2</td>
<td>WF-40-002-608 / McMaster# 89968K64</td>
<td>Support Rods</td>
</tr>
<tr>
<td>9</td>
<td>2</td>
<td>WF-40-002-501</td>
<td>Mounting Brackets</td>
</tr>
<tr>
<td>10</td>
<td>4</td>
<td>Bolt 0.375 - 3.5</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>4</td>
<td>Nut 0.375</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>12</td>
<td>Washer 0.375 Reg</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>4</td>
<td>Bolt - 0.375 - 2.25</td>
<td></td>
</tr>
</tbody>
</table>

---

**All Dims are in Inches unless noted otherwise**

- X = ± .1
- XX = ± .03
- XXX = ± .010
- ANGLES ± 1°

**Drawing by:**

**Material:**

**Part Description:**

**Part Number:**

**Date:** 4/21/2002

**Scale:**

**Size:** B

**Sheet:** 1 of 1

---

**Utah State University Mechanical & Aerospace Engineering**

**WRIGHT FLYER 1903-2003**
DETAIL B
SCALE 0.70 : 1

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE
X = ± .1
XX = ± .03
XXX = ± .010
ANGLES ± 1°

DRAWN BY:
NC FILIMOEHALA

MATERIAL:
WRIGHT FLYER
1903-2003

USU
MECHANICAL & AEROSPACE ENGINEERING

PART DESCRIPTION:
TRANS BEARING BLOCK
PART NUMBER:
WF-40-002-603
REV

DATE: 4/21/2002
SCALE: B
SIZE:
SHEET 1 of 1
ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

\[ X = \pm 0.1 \]
\[ XX = \pm 0.03 \]
\[ XXX = \pm 0.010 \]

ANGLES \( \pm 1' \)

DRAWN BY:
NC FILMOEHLA.

USU
WRIGHT FLYER
1903-2003

MATERIAL:
KEYED SHAFT

PART DESCRIPTION:
PART NUMBER:
WF-40-002-604

DATE: 4/21/2002
SCALE: B
SIZE: 1
SHEET: 1 of 1
ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

\[ X = \pm 0.1 \]
\[ XX = \pm 0.03 \]
\[ XXX = \pm 0.010 \]
\[ \text{ANGLES} \pm 1^\circ \]

DRAWN BY:
NC FILMOEHALA

MATERIAL: WRIGHT FLYER
1903-2003

USU
Mechanical & Aerospace Engineering

PART DESCRIPTION: SHAFT BEARING
PART NUMBER: WF-40-002-006
REV

DATE: 4/21/2002
SCALE: B
SIZE: SHEET 1 of 1
ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE
X = ± .1
XX = ± .03
XXX = ± .010
ANGLES ± 1°

DRAWN BY:
NC FILMOEHALA

MATERIAL:
WRIGHT FLYER
1903-2003

DATE: 4/21/2002
SCALE: B

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Mechanical & Aerospace Engineering
ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

ANGLES ± 1'

DRAWN BY:
NC FILMOEHALA

MATERIAL:
usu WRIGHT FLYER 1903-2003

PART DESCRIPTION: SHAFT SPACER
PART NUMBER: WF-40-002-609

DATE: 4/21/2002
SIZE: B

REV
Propeller Assembly
Materials List for Propeller Support Assembly

<table>
<thead>
<tr>
<th>Item/Material</th>
<th>Description</th>
<th>Qty</th>
<th>Part #</th>
<th>Supplier</th>
</tr>
</thead>
<tbody>
<tr>
<td>4130 Normalized Tubing</td>
<td>1&quot; X 0.065&quot; wall</td>
<td>8 ft</td>
<td></td>
<td>Aircraft Spruce</td>
</tr>
<tr>
<td>Ball Bearings</td>
<td># 6305</td>
<td></td>
<td></td>
<td>Motion Industries</td>
</tr>
<tr>
<td>6061-T6 Aluminum</td>
<td>1.25&quot; X 4&quot; X 4&quot;</td>
<td>4</td>
<td></td>
<td>ITE</td>
</tr>
<tr>
<td>4130 Steel Round Stock</td>
<td>1 1/2&quot; dia. - normalized</td>
<td>1 ft</td>
<td></td>
<td>MIL-S-6758A</td>
</tr>
<tr>
<td>4131 Steel Round Tubing</td>
<td>1 7/8&quot; OD - 0.25&quot; wall - normalized</td>
<td>1 ft</td>
<td></td>
<td>Aircraft Spruce</td>
</tr>
<tr>
<td>6061-T6 Aluminum</td>
<td>round stock - 6&quot; diameter</td>
<td>1.5 ft</td>
<td></td>
<td>?</td>
</tr>
<tr>
<td>4131 Steel Plate</td>
<td>0.125&quot; thick X 6&quot; wide</td>
<td>1.5 ft</td>
<td></td>
<td>ITE</td>
</tr>
<tr>
<td>4132 Steel Strap</td>
<td>0.125&quot; X 3/4&quot;</td>
<td>12 ft</td>
<td></td>
<td>ITE</td>
</tr>
<tr>
<td>4133 Steel Strap</td>
<td>0.125&quot; X 5/8&quot;</td>
<td>12 ft</td>
<td></td>
<td>ITE</td>
</tr>
<tr>
<td>Steamlined Carbon Tubes</td>
<td></td>
<td></td>
<td></td>
<td>ITE</td>
</tr>
</tbody>
</table>

Parts List for Propeller Support Assembly

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Description</th>
<th>Qty</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>WF-40-009-03</td>
<td>Drive Shaft</td>
<td>2</td>
<td>cut and ground</td>
</tr>
<tr>
<td>Bearing - 6305</td>
<td>Drive Shaft Bearings</td>
<td>4</td>
<td>purchased</td>
</tr>
<tr>
<td>WF-40-009-06</td>
<td>Front Bearing Block</td>
<td>2</td>
<td>milled &amp; drilled</td>
</tr>
<tr>
<td>WF-40-009-04</td>
<td>Rear Bearing Block</td>
<td>2</td>
<td>milled &amp; drilled</td>
</tr>
<tr>
<td>WF-40-009-09A</td>
<td>Shive Hub</td>
<td>2</td>
<td>cut, drilled, keyed</td>
</tr>
<tr>
<td>WF-40-009-09B</td>
<td>Shive Hub Outer Collar</td>
<td>2</td>
<td>cut &amp; drilled</td>
</tr>
<tr>
<td>WF-40-009-09C</td>
<td>Shive Hub Inner Collar</td>
<td>2</td>
<td>cut &amp; drilled</td>
</tr>
<tr>
<td>WF-40-009-10A</td>
<td>Propeller Hub</td>
<td>2</td>
<td>turned &amp; drilled</td>
</tr>
<tr>
<td>WF-40-009-10B</td>
<td>Hub Backing Plate</td>
<td>2</td>
<td>water jet cut</td>
</tr>
<tr>
<td>WF-40-009-05A</td>
<td>Rear Support</td>
<td>8</td>
<td>layed up &amp; cut</td>
</tr>
<tr>
<td>WF-40-009-07A</td>
<td>Front Support</td>
<td>8</td>
<td>layed up &amp; cut</td>
</tr>
<tr>
<td>WF-40-009-05B</td>
<td>Rear Support Mounting Tab</td>
<td>8</td>
<td>cut, formed &amp; drilled</td>
</tr>
<tr>
<td>WF-40-009-07B</td>
<td>Front Support Mounting Tab</td>
<td>8</td>
<td>cut, formed &amp; drilled</td>
</tr>
<tr>
<td>WF-40-009-08A</td>
<td>Spar Mount Bar - Rear</td>
<td>4</td>
<td>cut, formed &amp; drilled</td>
</tr>
<tr>
<td>WF-40-009-08B</td>
<td>Spar Mount Bar - Front</td>
<td>4</td>
<td>cut, formed &amp; drilled</td>
</tr>
<tr>
<td>Flat sheet to wrap around</td>
<td>Sheet Steel 0.065&quot; (any type)</td>
<td>4</td>
<td>cut &amp; formed</td>
</tr>
<tr>
<td>spar to glue and lash</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The design of the hub is depending on the propeller design, and will be added later.

Note: Two Center bolts need to be safety wired together through head to prevent loosening.

DETAIL E
SCALE 1/3

DETAIL B
SCALE 0.35:1

Parts List

<table>
<thead>
<tr>
<th>ITEM</th>
<th>QTY</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>WF-40-002-507A</td>
<td>Mounting Assembly</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>WF-40-002-507B</td>
<td>Mounting Assembly</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>WF-40-002-503</td>
<td>Shaft Support Assm</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>WF-40-002-505A</td>
<td>Rear Support Assm - A</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>WF-40-002-505B</td>
<td>Rear Support Assm - B</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>WF-40-002-506A</td>
<td>Front Support Assm - A</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>WF-40-002-506B</td>
<td>Front Support Assm - B</td>
</tr>
<tr>
<td>9</td>
<td>1</td>
<td>WF-40-003</td>
<td>Propeller Designed by CATT O PROPS</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>WF-40-099-10A</td>
<td>In-House propeller hub design</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>WF-40-099-10B</td>
<td>hub back plate</td>
</tr>
</tbody>
</table>

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE
X = ± .1
XX = ± .03
XXX = ± .010
ANGLES ± 1°

DRAWN BY: Adam Richards

MATERIAL: Prop Support Assembly

DATE: 2/17/2002

SCALE: B SHEET 1 of 1

USU
WRIGHT FLYER
1903-2003

Utah State University Mechanical & Aerospace Engineering
SECTION B-B
SCALE 1:1

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE:
X = \pm 0.1
XXX = \pm 0.03
XXXX = \pm 0.010
ANGLES \pm 1^

DRAWN BY:
A Richards

MATERIAL:
Aluminum-5056

PART DESCRIPTION:
In-House propeller hub design

PART NUMBER:
WF-40-099-10A

DATE: 2/17/2002

SCALE: B

SHEET 2 of 2
ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

\(X = \pm .1\)
\(XX = \pm .03\)
\(XXX = \pm .010\)
ANGLES \(\pm 1^\circ\)

DRAWN BY:
A. Richards

MATERIAL:
Steel, High Strength Low Alloy

PART DESCRIPTION:
hub back plate

PART NUMBER:
WF-40-099-10B

DATE: 2/17/2002

SCALE: SIZE: B SHEET 1 of 1
After grinding shaft, press fit bearings to either the blocks or the shaft first, which ever is best.

Dimensions between blocks are critical.

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE
X = ± .1
XX = ± .03
XXX = ± .010
ANGLES ± 1°

.proto

A Richards

MATERIAL:

PART DESCRIPTION: Shaft Support Assy
PART NUMBER: WF-40-002-073
REV

DATE: 2/17/2002
SCALE: B
SHEET 1 of 1

USU
WRIGHT FLYER
1903-2003
Pilot hole: Q
Pilot hole cannot break into the inner diameter.

Dimensions apply AFTER anodizing the part.

Part is symmetric. Dimensions above apply below.

Snap Ring Groove
Use a DH0-62 Snap Ring

HELICOIL INSERTS
0.025° DEEP

4X 5/16 X 18UNC-2B
Pilot hole: Q
Pilot hole cannot break into the inner diameter.

Dimensions apply AFTER anodizing part.

snap Ring Groove
Use a DHO-62 Snap Ring

Part is symmetric dimensions above apply below.

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE
X = ± .1
XX = ± .03
XXX = ± .010
ANGLES ± 1°
Shaft needs to be ground down to given tolerance for bearing press fit, but only on the ends. Distance from end to be ground to tolerance is indicated.

Grind to tolerances from end to at least 4.5" from end.

Grind to tolerances from end to at least 6" from end.

NOTE: Finish grinding edge with a 45° taper to reduce stress concentrations.

Surface finishes apply only to the portion of the shaft that is ground to tolerance.

Revisions:
- REV A
  April 12, 2002
  - Added surface finish to bearing surfaces
  - Moved Propeller Hub bolt hole from 3" from end to 2.25" from end
- REV B
  May 1, 2002
  - Shortened the length of the shaft
  - Moved Propeller Hub bolt hole from 2.25" from end to 2.50" from end

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

X ± .1
XXX ± .03
ANGLES ± 1°

DRAWN BY:
A. Richards

MATERIAL:
4130 MIL-T-6738 Normalized

DATE: 2/17/2002

SCALE: B

USU WRIGHT FLYER 1903-2003
NOTE: For illustration only. This is a deep groove, double sealed ball bearing. It is a metric size, 25mm shaft and 62mm housing. Inch tolerances are given here.
ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE
X = ± .1
XX = ± .03
XXX = ± .010
ANGLES ± 1°

DRAWN BY:
Adam Richards

MATERIAL:
Steel, High Strength Low Alloy

PART DESCRIPTION:
Drive Sprocket Hub

PART NUMBER:
WF-40-099-06A

DATE: 2/17/2002

SCALE: 2:1

USU WRIGHT FLYER 1903-2003

Key Way 3/16" Wide 3/32" Deep

DETAIL B

SCALE 2 : 1

Key Way 3/16" Wide 3/32" Deep
Revisions:
- REV A April 12, 2002
  - Changed the OD dimension from 2" to 1.875"

Materials:
Steel, High Strength Low Alloy

USU
WRIGHT FLYER
1903-2003

DRAWN BY:
A Richards

MATERIAL:
Steel, High Strength Low Alloy

PART DESCRIPTION:
Hub Collar - Inner

PART NUMBER:
WF-40-090-09C

REV:
A

SCALE:
SIZE: B

DATE:
2/17/2002

Wright Flyer
1903-2003

All dims are in inches unless noted otherwise.

\[ X = \pm 0.1 \]
\[ XX = \pm 0.03 \]
\[ XXX = \pm 0.010 \]
\[ \text{ANGLES} \pm 1\" \]
Composite tube has a hard point here. A threaded insert is also included in the hard point for the clevis fork to screw into.

Note: Direction of airfoil is important.

ATTENTION:
Assembly WF-40-002-505B is assembled just like this assembly, except the airfoil must be turned the opposite direction.

Composite tube has a hard point at this end. The tab stem is attached by being inserted into the hard point resin before it hardens.

Inner bolt is drilled through the head for safety wire. Outer bolt will go all the way through the bearing block for a nut on the other side.

DETAIL D
SCALE 0.80 : 1

DETAIL E
SCALE 0.35 : 1

<table>
<thead>
<tr>
<th>PART</th>
<th>QTY</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>WF-40-099-05A</td>
<td>Rear Support</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>WF-40-099-05B</td>
<td>Rear support mount Tab</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>AirCraftSpruce AN161-46S</td>
<td>Steel Clevis Fork</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>AN5-6</td>
<td>Nut &amp; washers to fit</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>Bolt - 0.3125 - 0.875</td>
<td>AN Hardware</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>Washer 0.3125Reg</td>
<td>AN Hardware</td>
</tr>
</tbody>
</table>

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

\[ X = \pm 0.1 \]
\[ XX = \pm 0.03 \]
\[ XXX = \pm 0.010 \]
\[ ANGLES \pm 1^\circ \]

DRAWN BY:
A Richards

MATERIAL:
Rear Support Assm - A

DATE: 2/17/2002

SCALE: B

SHEET 1 of 1
NOTE: This part can be constructed two ways. Build a round tube of composite material, and then cover it with a thin airfoil. Or use the steel tubing as the mandrel to lay up the part as drawn.

ATTENTION: Wall thicknesses and layup methods will be determined after testing of parts.

Note: Dimensions are flexible, depending on the availability of streamlined steel tubing for mandrels.
0.125" Stock Material

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE
X = ± .1
XX = ± .03
XXX = ± .010
ANGLES ± 1°

DRAWN BY: Adam Richards

MATERIAL: Steel, High Strength Low Alloy
PART DESCRIPTION: Rear support mount Tab
PART NUMBER: WF-40-000-05B
DATE: 2/17/2002
SCALE: B
SIZE: SHEET 1 of 1
ATTENTION:
Assembly WF-40-002-5068 is assembled just
like this assembly, except the airfoil must
be turned the opposite direction.

Composition tube has a hard point here. A threaded insert is also included in the hard point for the clevis fork to screw into.

Composite tube has a hard point at this end. The tab stem is attached by being inserted into the hard point resin before it hardens.

Inner bolt is drilled through the head for safety wire.

Outer bolt will go all the way through the bearing block for a nut on the other side.

<table>
<thead>
<tr>
<th>ITEM</th>
<th>QTY</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>WF-40-099-07A</td>
<td>Front Support</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>AirCraftSpruce AN161-4 BS</td>
<td>Steel Clevis Fork</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>AN5-5</td>
<td>Nut &amp; washers to fit</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>WF-40-099-075</td>
<td>Bolt support mount Tab</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>Washer 0.3125Reg</td>
<td>AN Hardware</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>Bolt - 0.3125 - 0.875</td>
<td>AN Hardware</td>
</tr>
</tbody>
</table>

X = ± .1
XX = ± .03
XXX = ± .010
ANGLES ± 1°

DRAWN BY:
A Richards

MATERIAL:
Front Support Assm - A

PART DESCRIPTION:
Front Support Assm - A

PART NUMBER:
WF-40-002-5068A

DATE: 2/17/2003

SCALE: B
SIZE: SHEET 1 of 1
NOTE: This part can be constructed two ways. Build a round tube of composite material, and then cover it with a thin airfoil. Or use the steel tubing as the mandrel to lay up the part as drawn.

ATTENTION: Wall thicknesses and layup methods will be determined after testing of parts.

Note: Dimensions are flexible, depending on the availability of streamlined steel tubing for mandrels.

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE
.X = ± .1
.XX = ± .03
.XXX = ± .01
ANGLES ± 1°

DRAWN BY:
Adam Richards

USU
WRIGHT FLYER
1903-2003

DATE: 2/17/2002
SCALE: B
SIZE: SHEET 1 of 1
ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

X = ± .1
XX = ± .03
XXX = ± .010
ANGLES ± 1°

DRAWN BY:
Adam Richards

MATERIAL:
Steel, High Strength Low Alloy

DATE: 2/17/2002

PART DESCRIPTION: Fitting support mount TTB

PART NUMBER: WF-40-099-075

REV

SCALE: SIZE: B  SHEET 1 of 1
Spar Mounting Cup is made of 4130 steel, Normalized. It is cutout flat 0.063" X 4.5" X 6". It is then rolled as shown. The mounting plates are welded at the angles shown all the way around.

For mounting, the cup is glued and lashed in place on the rear spar. A vertical line runs through the center of the top and bottom rear spars. The center line of the mounting cup must be parallel to that line in order for the tabs to line up properly.
Spar Mounting Cup is made of 4130 steel, Normalized. It is cutout flat 0.063" X 4.5" X 6". It is then rolled as shown. The mounting plates are welded at the angles shown all the way around.

For mounting, the cup is glued and lashed in place on the rear spar. A vertical line runs through the center of the top and bottom rear spars. The center line of the mounting cup must be parallel to that line in order for the tabs to line up properly.

**Parts List**

<table>
<thead>
<tr>
<th>ITEM</th>
<th>QTY</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>WF-40-999-98C</td>
<td>Spar Mounting Cup</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>WF-40-999-03B</td>
<td>Spar Mount Plate - Front</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>WF-40-999-08A</td>
<td>Spar Mount Plate - Rear</td>
</tr>
</tbody>
</table>

**ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE**

X = ± .1
XX = ± .03
XXX = ± .010
ANGLES ± 1°

**DRAWN BY:**
A Richards

**MATERIAL:**

**PART DESCRIPTION:** Mounting Assembly

**PART NUMBER:** WF-40-002-507A

**DATE:** 2/17/2002

**SCALE:** SIZE: B SHEET 1 of 1

**USU MECHANICAL & AEROSPACE ENGINEERING**

**WRIGHT FLYER 1903-2003**
Note: Revisions
REV A - April 11, 2002
- Changed from 0.25" bar stock to 0.125"

This curve not required.

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE
.X = ± .1
.XX = ± .03
.XXX = ± .010
ANGLES ± 1°

DRAWN BY:
Adam Richards

MATERIAL:
Steel, High Strength Low Alloy

PART DESCRIPTION:
Spar Mount Plate - Rear

PART NUMBER:
WF-40-099-08A

DATE: 2/17/2002

SCALE: SIZE: B SHEET 1 of 1

USU
WRIGHT FLYER 1903-2003
Note: Revisions
REV A - April 11, 2002
- Changed from 0.25" bar stock to 0.125"

This curve not required
Chassis Assembly
<table>
<thead>
<tr>
<th>Item/Material</th>
<th>Description</th>
<th>Qty</th>
<th>Part #</th>
<th>Supplier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spruce Strips</td>
<td>1.75&quot; wide</td>
<td></td>
<td></td>
<td>Aircraft Spruce</td>
</tr>
<tr>
<td>Kevlar (lay up with spruce)</td>
<td>1.75&quot; wide</td>
<td></td>
<td></td>
<td>?</td>
</tr>
<tr>
<td>Carbon Tubes</td>
<td>1.40/1000&quot; I.D. x 1/16&quot; wall</td>
<td></td>
<td></td>
<td>ITE Dept.</td>
</tr>
<tr>
<td>Steel Tubing</td>
<td>1&quot; O.D. x 1/16&quot; wall</td>
<td></td>
<td></td>
<td>ITE/IPACO</td>
</tr>
<tr>
<td>Steel Tubing</td>
<td>7/8&quot; O.D. x 1/8&quot; wall</td>
<td></td>
<td></td>
<td>ITE/IPACO</td>
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<tr>
<td>Plate Steel (strapping)</td>
<td>1.75&quot; x 1/16&quot;</td>
<td></td>
<td></td>
<td>ITE/IPACO</td>
</tr>
<tr>
<td>Plate Steel (strapping)</td>
<td>1&quot; x 1/8&quot;</td>
<td></td>
<td></td>
<td>ITE/IPACO</td>
</tr>
<tr>
<td>Plate Steel (strapping)</td>
<td>4&quot; x 1/16&quot;</td>
<td></td>
<td></td>
<td>ITE/IPACO</td>
</tr>
<tr>
<td>Plate Steel (strapping)</td>
<td>3 3/8&quot; x 1/8&quot;</td>
<td></td>
<td></td>
<td>ITE/IPACO</td>
</tr>
<tr>
<td>Plate Steel (strapping)</td>
<td>2 3/4&quot; x 1/8&quot;</td>
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<td></td>
<td>ITE/IPACO</td>
</tr>
<tr>
<td>Plate Steel</td>
<td>2.1/2&quot; x 3/8&quot;</td>
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<td></td>
<td>ITE/IPACO</td>
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<td>Bolt</td>
<td>2 AN4-24</td>
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<td>ITE/Aircraft Spruce</td>
</tr>
<tr>
<td>Bolt</td>
<td>4 AN5-13</td>
<td></td>
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<td>ITE/Aircraft Spruce</td>
</tr>
<tr>
<td>Bolt</td>
<td>28 AN4-14</td>
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<td>ITE/Aircraft Spruce</td>
</tr>
<tr>
<td>Bolt</td>
<td>2 AN4-23</td>
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<td>ITE/Aircraft Spruce</td>
</tr>
<tr>
<td>Bolt</td>
<td>2 AN4-25</td>
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<td>ITE/Aircraft Spruce</td>
</tr>
<tr>
<td>Bolt (machine screw)</td>
<td>60 MS24694</td>
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<td>ITE/Aircraft Spruce</td>
</tr>
<tr>
<td>Nut</td>
<td>60 AN365-(match MS)</td>
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<td>ITE/Aircraft Spruce</td>
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<td>4 AN365-524A</td>
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<td>ITE/Aircraft Spruce</td>
</tr>
<tr>
<td>Nut</td>
<td>34 AN365-428A</td>
<td></td>
<td></td>
<td>ITE/Aircraft Spruce</td>
</tr>
<tr>
<td>Washer</td>
<td>5/16&quot; hole</td>
<td>8</td>
<td></td>
<td>ITE/Aircraft Spruce</td>
</tr>
<tr>
<td>Washer</td>
<td>1/4&quot; hole</td>
<td>72</td>
<td></td>
<td>ITE/Aircraft Spruce</td>
</tr>
<tr>
<td>Nylon Bushing</td>
<td>1/4&quot; hole x 1/2&quot; (shaped to size)</td>
<td>70</td>
<td></td>
<td>?</td>
</tr>
<tr>
<td>Aluminum Tubing (rect)</td>
<td>1&quot; x 2&quot; outside x 1/8&quot; wall</td>
<td></td>
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<td>ITE/IPACO</td>
</tr>
<tr>
<td>Aluminum Plate</td>
<td>1&quot; x 1/8&quot;</td>
<td>18</td>
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<td>ITE/IPACO</td>
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<tr>
<td>Aluminum Disks</td>
<td>1.25&quot; O.D. x 1/8&quot; wall</td>
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<td>Aluminum Tubing (circ)</td>
<td>1&quot; O.D. x 1/8&quot; wall</td>
<td>6</td>
<td></td>
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<tr>
<td>Matco Wheel</td>
<td>castered, solid rubber</td>
<td></td>
<td>P/N 06-01615</td>
<td>Aircraft Spruce</td>
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<tr>
<td>Azusalite Nylon Wheel</td>
<td>4&quot; wheel</td>
<td>2</td>
<td>P/N 06-02600</td>
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<td>Tire &amp; Tube Assembly</td>
<td>2 P/N 06-02800</td>
<td></td>
<td></td>
<td>Aircraft Spruce</td>
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<tr>
<td>Cannondale Shock</td>
<td>Lefty model</td>
<td>2</td>
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<td>Cannondale Corp.</td>
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### Parts List for Chassis

<table>
<thead>
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<th>Type</th>
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<tr>
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<td>Skid Hardpoint</td>
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<tr>
<td>WF-50-099-01A</td>
<td>Plate</td>
<td>2</td>
<td>cut &amp; drilled</td>
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<tr>
<td>WF-50-099-01B</td>
<td>Tab</td>
<td>20</td>
<td>cut, shaped &amp; drilled</td>
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<tr>
<td>WF-50-099-01C</td>
<td>Plate</td>
<td>2</td>
<td>cut &amp; drilled</td>
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<tr>
<td>WF-50-099-02</td>
<td>Fitting</td>
<td>26</td>
<td>cut, milled &amp; drilled</td>
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<tr>
<td>WF-50-099-02B</td>
<td>Disk</td>
<td>2</td>
<td>cut or stamped</td>
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<tr>
<td>WF-50-099-02C</td>
<td>Fitting</td>
<td>2</td>
<td>cut &amp; drilled</td>
</tr>
<tr>
<td>WF-50-099-03</td>
<td>Canard/Skid Hardpoint</td>
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<td>cut &amp; drilled</td>
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<td>Plate</td>
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<td>WF-50-099-04-01</td>
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<td>Plate</td>
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<td>WF-50-099-10B</td>
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<td>Cockpit Mounting Strut</td>
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<td>cut</td>
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<td>Tab</td>
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<td>WF-50-099-14F</td>
<td>Strut</td>
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<td>layed up &amp; cut</td>
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<td>WF-50-099-14G</td>
<td>Strut</td>
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<tr>
<td>WF-50-099-14I</td>
<td>Strut</td>
<td>2</td>
<td>layed up &amp; cut</td>
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<td>WF-50-099-14J</td>
<td>Strut</td>
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<td>cut, milled &amp; drilled</td>
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<tr>
<td>WF-50-099-18</td>
<td>Strut/Shock Mount</td>
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<td>WF-50-099-19</td>
<td>Strut/Shock Mount</td>
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<td>weldment</td>
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<tr>
<td>WF-50-099-19A</td>
<td>Mount</td>
<td>4</td>
<td>cut, milled &amp; drilled</td>
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</table>
ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

\[ \begin{align*}
X & = \pm 0.1 \\
XX & = \pm 0.03 \\
XXX & = \pm 0.010 \\
ANGLES & = \pm 1°
\end{align*} \]

DRAWN BY:
David Beck Christensen

MATERIAL:
usu WRIGHT FLYER 1903-2003

USU Mechanical & Aerospace Engineering

<table>
<thead>
<tr>
<th>PART DESCRIPTION</th>
<th>PART NUMBER</th>
<th>REV</th>
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<tbody>
<tr>
<td>Chassis Assembly</td>
<td>WF-50-000</td>
<td>A</td>
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DATE: 2/17/2002  SCALE: B  SHEET 1 of 1
Right side assembly is mirror image of the left.

<table>
<thead>
<tr>
<th>ITEM</th>
<th>QTY</th>
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<th>DESCRIPTION</th>
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<td>1</td>
<td>WF-50-000-00D</td>
<td>Rear Struts, Left</td>
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<tr>
<td>3</td>
<td>1</td>
<td>WF-50-000-00C</td>
<td>Middle Struts, Left</td>
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<td>4</td>
<td>1</td>
<td>WF-50-000-00B</td>
<td>Front Struts, Left</td>
</tr>
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</table>

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE
X = ± .1
XX = ± .03
XXX = ± .010
ANGLES ± 1°

DRAWN BY:
David Beck Christensen

MATERIAL:
Chassis Assembly

DATE: 2/17/2002

SCALE: B
SIZE: 1
SHEET: 1 of 1

USU
WRIGHT FLYER
1903-2003

Utah State University Mechanical & Aerospace Engineering
The skid is to be laid up as one piece, using layers of spruce and kevlar.

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE:

\[ X = \pm 0.1 \]
\[ XX = \pm 0.03 \]
\[ XXX = \pm 0.010 \]

ANGLES ± 1°

DRAWN BY:
David Beck Christensen

USU
WRIGHT FLYER
1903-2003

MATERIAL:

PART DESCRIPTION: Skid Hardpoint Placement
PART NUMBER: WF-50-000-00E

DATE: 2/17/2002
SCALE: B
SIZE: 1
SHEET 1 of 1

Utah State University
Mechanical & Aerospace Engineering
Skid to be layered spruce and kevlar, with spruce being the layer that comes in contact with the ground. Skid to be one continuous structure and made from a full size pattern. Dimensions here are only to give a rough size of the skid.

<table>
<thead>
<tr>
<th>ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE</th>
</tr>
</thead>
<tbody>
<tr>
<td>X = ± .1</td>
</tr>
<tr>
<td>XX = ± .03</td>
</tr>
<tr>
<td>XXX = ± .010</td>
</tr>
<tr>
<td>ANGLES ± 1°</td>
</tr>
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</table>

DRAWN BY: David Beck Christensen

MATERIAL: usu

WRIGHT FLYER
1903-2003

USU
Mechanical & Aerospace Engineering

DATE: 2/17/2002

SCALE: 1

SIZE: B

SHEET: 1 of 1
Carbon leaf spring to be bonded to skid hard point and "sandwiched" with another steel backing plate not shown.

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE
X = ± .1
XX = ± .03
XXX = ± .010
ANGLES ± 1°

DRAWN BY:
David Beck Christensen

USU
WRIGHT FLYER
1903-2003

PART NUMBER:
WF-50-000-006

REV
A

DATE: 2/17/2002

SCALE: B

SHEET 1 OF 1
Cross section of skid

Mounting instructions applicable to all skid hardpoints

Hardpoint to be bonded and bolted to skid

Countersunk screws into backing plate

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

X = ± .1
XX = ± .03
XXX = ± .010
ANGLES ± 1°

DRAWN BY:
David Beck Christensen

USU
WRIGHT FLYER
1903-2003

D MATERIAL:

PART DESCRIPTION:
Mounting Info

PART NUMBER:
WF-50-000-01A

REV
A

DATE: 2/17/2002

SCALE:

SIZE: B

SHEET 1 of 1
ALL DIMS ARE IN INCHES
UNLESS NOTED OTHERWISE
X = ±.1
XX = ±.03
XXX = ±.010
ANGLES ±1°

DRAWN BY:
David Beck Christiansen

MATERIAL:

DATE: 2/17/2002

SCALE: B

PARTS LIST

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<td>Tab, Mounting</td>
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<td>3</td>
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<td>WF-50-099-03B</td>
<td>Tube, Fitting</td>
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</table>

USU
WRIGHT FLYER
1903-2003

Mechanical & Aerospace Engineering

Utah State University
6 X Ø0.19 100 deg. countersunk holes

MATERIAL: Steel, Mild

PART DESCRIPTION: Plate, Mounting

PART NUMBER: WF-50-099-03C

DATE: 2/17/2002

SCALE: B

SIZE: 1

SHEET 1 of 1
ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

X = ±.1
XX = ±.03
XXX = ±.010
ANGLES ± 1°

DRAWN BY:
David Beck Christensen

USU
WRIGHT FLYER
1903-2003

MATERIAL:
Skid Hardpoint Assembly

DATE: 2/17/2002

SCALE: B
SIZE: 1
SHEET 1 of 1
ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE
X = ± .1
XX = ± .03
XXX = ± .010
ANGLES ± 1°

DRAWN BY:
David Beck Christensen

MATERIAL:
usu WRIGHT FLYER 1903-2003

Parts List

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<th>DESCRIPTION</th>
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<td>WF-50-099-01B</td>
<td>Tab, Mounting</td>
</tr>
</tbody>
</table>

DATE: 2/17/2002

SCALE: SIZE: B SHEET 1 of 1
Holes countersunk 100 deg.

2 X Ø0.19

0.38 TYP

0.38 TYP

0.06

1.75

3.00

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

X = ± 0.1
XX = ± 0.03
XXX = ± 0.010
ANGLES ± 1°

DRAWN BY:
David Beck Christensen

MATERIAL:
Steel, Mild

PART DESCRIPTION:
Plate, Mounting

PART NUMBER:
WF-50-099-108

DATE: 2/17/2002

SCALE: SIZE: B SHEET 1 of 1

USU
WRIGHT FLYER
1903-2003

Utah State University Mechanical & Aerospace Engineering
DETAIL C
SCALE 0.60 : 1

Tube to be "swiss-cheesed" on four sides as dimensioned below.
Fitting is to be "swiss cheesed" on all four sides as dimensioned below.

All dims are in inches unless noted otherwise.

- X = ± 0.1
- XX = ± 0.03
- XXX = ± 0.010
- Angles ± 1°

Usual WRIGHT FLYER 1903-2003

Drawn by: David Beck Christiansen

Material: Steel, Mild

Part Description: Tube, Fitting

Part Number: WF-50-099-02

Date: 2/17/2002

Scale: B

Sheet 1 of 1
ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE:

- X = ± .1
- XX = ± .03
- XXX = ± .010
- ANGLES ± 1°

DRAWN BY:
David Beck Christensen

MATERIAL:

USU
WRIGHT FLYER
1903-2003

PARTS LIST

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<td>WF-50-099-04A</td>
<td>Tube, Mount, Spar, Lead</td>
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<tr>
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<td>1</td>
<td>WF-50-099-06A</td>
<td>Tab, Mount, Spar, Lead</td>
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</tbody>
</table>

SHEET 1 of 1
radius to match outside radius of WF-50-099-04A

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE
X = ±.1
XX = ±.03
XXX = ±.010
ANGLES ± 1°

DRAWN BY:
David Beck Christensen

MATERIAL:
Steel, Mild

PART DESCRIPTION:
Tab, Mount, Spar, Lead

PART NUMBER:
WF-50-099-06A

DATE: 2/17/2002

SCALE: SIZE: B SHEET 1 of 1
Fitting to be "swiss-cheesed" on four sides as dimensioned below.

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

\[ X = \pm 0.1 \]
\[ XX = \pm 0.03 \]
\[ XXX = \pm 0.010 \]
ANGLES \( \pm 1' \)

DRAWN BY: David Beck Christensen

MATERIAL: Steel, Mild

PART DESCRIPTION: Tube, Fitting

PART NUMBER: WF-50-099-13

DATE: 2/17/2002

SCALE: B

SIZE: SHEET 1 of 1
Carbon Spring to be designed and constructed after the wheel arrives. Check Chassis Assembly drawing to get an idea of how the carbon fiber spring is supposed to function.

Matco Wheel Assembly (casted)
This spring will need to be fashioned after the arrival of the Matco wheels. It will need to be constructed much like the carbon fiber landing gear mount that Dave Widauf showed to David Christensen. It will need to have holes drilled to match WF-50-099-10B. It will be mounted by being "sandwiched" at the indicated locations, in between the skid and the mounting plate. Longer machine screws will also need to be used.

Approximately 3 inches of travel required.

---

**USU**

**WRIGHT FLYER**

**1903-2003**

**ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE**

\[ X = \pm .1 \]

\[ XX = \pm .03 \]

\[ XXX = \pm .010 \]

ANGLES ± 1°

**DRAWN BY:**

David Beck Christensen

**MATERIAL:**

Carbon Fiber

**PART DESCRIPTION:**

Castered Wheel Leaf Spring

**PART NUMBER:**

Carbon Spring

**DATE:** 2/17/2002

**SCALE:** B

**SIZE:** SHEET 1 of 1
carbon fiber tube, 1" I.D. X 1/16" wall
Fitting to be "swiss-cheesed" on four sides on both ends as dimensioned below.

R0.13

0.50
0.25

7.00

\( \phi 1.00 \)

0.06

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

\( X = \pm \, 0.1 \)

\( XX = \pm \, 0.03 \)

\( XXX = \pm \, 0.010 \)

ANGLES \( \pm 1° \)

DRAWN BY: David Beck Christensen

MATERIAL: Steel, Mild

PART DESCRIPTION: Fitting, Splice

PART NUMBER: WF-80-099-18

DATE: 2/17/2002

SCALE: B

SIZE: B

SHEET 1 of 1
carbon fiber tube, 1" I.D. X 1/16" wall

USU
WRIGHT FLYER
1903-2003

DRAWN BY: David Beck Christensen
MATERIAL: Carbon Fiber
DATE: 2/17/2002

SCALE: B

SIZE: SHEET 1 of 1

All dims are in inches unless noted otherwise:
X = ± .1
XX = ± .03
XXX = ± .010
Angles ± 1°
carbon fiber tube, 1" I.D. X 1/16" wall

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE
X = ± 0.1
XX = ± 0.03
XXX = ± 0.010
ANGLES ± 1°

DRAWN BY: David Beck Christensen

MATERIAL: Carbon Fiber

DATE: 2/17/2002

SCALE: B

PART DESCRIPTION: Shut

PART NUMBER: WF-60-099-14A2

REV

USU
WRIGHT FLYER
1903-2003

Utah State University Mechanical & Aerospace Engineering
carbon fiber tube, 1" I.D. X 1/16" wall
carbon fiber tube, 1" I.D. X 1/16" wall
ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE
.X = ± .1
.XX = ± .03
.XXX = ± .010
ANGLES ± 1°

DRAWN BY: David Beck Christensen

USU
WRIGHT FLYER
1903-2003

DRAWN BY: David Beck Christensen

PARTS LIST

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<th>ITEM</th>
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<td>2</td>
<td>WF-50-000-05</td>
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<td>WF-50-000-07</td>
<td>Tube &amp; Mount Assembly</td>
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<td>3</td>
<td>WF-50-000-06</td>
<td>Tube Fitting Assembly</td>
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<td>WF-50-000-02-01</td>
<td>Spar Hardpoint Assembly, Left</td>
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<td>5</td>
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<td>WF-50-099-04-01</td>
<td>Hardpoint, Spar, Leading Edge, Left</td>
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<td>6</td>
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<td>WF-50-099-11</td>
<td>Tube, Mounting, Cockpit</td>
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<td>Shock &amp; Wheel Assembly</td>
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<td>1</td>
<td>WF-50-099-02</td>
<td>Tube, Fitting</td>
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<tr>
<td>9</td>
<td>1</td>
<td>WF-50-099-14D</td>
<td>Strut</td>
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<td>CABLE PLATE, 1-PRONG G</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>WF-50-099-14F</td>
<td>Strut</td>
</tr>
</tbody>
</table>

MATERIAL:

PART DESCRIPTION: Middle Strut, Left
PART NUMBER: WF-50-000-00C
REV A

DATE: 2/17/2002
SCALE: B SIZE: SHEET 1 of 1
<table>
<thead>
<tr>
<th>ITEM</th>
<th>QTY</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>WF-50-099-14E</td>
<td>Strut</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>.25 washer</td>
<td>Washer, misc</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>Nylon Bushing</td>
<td>Bushing, Nylon</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>AN365-428A</td>
<td>Nut</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>AN4-14</td>
<td>Bolt</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>WF-50-099-19A</td>
<td>Mount, Shock</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>AN065-1032A</td>
<td>Nut</td>
</tr>
<tr>
<td>8</td>
<td>4</td>
<td>1/875 washer</td>
<td>Washer, misc</td>
</tr>
<tr>
<td>9</td>
<td>2</td>
<td>AN3-27</td>
<td>Bolt</td>
</tr>
</tbody>
</table>

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE
X = ± .1
XX = ± .03
XXX = ± .010
ANGLES ± 1°

DRAWN BY:
David Beck Christensen

MATERIAL:
usu

USU
WRIGHT FLYER
1903-2003

DATE: 2/17/2002

SCALE: B SIZE: SHEET 1 of 1
ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

$X = \pm 0.1$

$XX = \pm 0.03$

$XXX = \pm 0.010$

ANGLES $\pm 1^\circ$

DRAWN BY:
David Beck Christensen

MATERIAL:

USU

WRIGHT FLYER
1903-2003

PART DESCRIPTION:
Tube and Shock Mount Assem.

PART NUMBER:
WF-50-099-19

REV A

DATE: 2/17/2002

SCALE: SIZE: B SHEET 1 of 1
ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE
X = ± .1
XX = ± .03
XXX = ± .010
ANGLES ± 1°

DRAWN BY:
David Beck Christensen

MATERIAL:
Spar Hardpoint Assembly, Left

USU
WRIGHT FLYER
1903-2003

Parts List

<table>
<thead>
<tr>
<th>ITEM</th>
<th>QTY</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>WF-50-089-06</td>
<td>Hardpoint, Spar, Lead, Bottom</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>AN4-23</td>
<td>Bolt</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>Nylon Bushing</td>
<td>Bushing, Nylon</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>Nylon Bushing 2</td>
<td>Bushing, Nylon</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>AN365-426A</td>
<td>Nut</td>
</tr>
<tr>
<td>6</td>
<td>4</td>
<td>.25 washer</td>
<td>Washer, misc</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>AN4-25</td>
<td>Bolt</td>
</tr>
</tbody>
</table>

SCALE: SIZE: B SHEET 1 of 1

REV A
ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE
X = ± .1
XX = ± .03
XXX = ± .010
ANGLES ± 1°

DRAWN BY: David Beck Christensen

MATERIAL: Hardpoint, Spar, Lead, Bottom

PART DESCRIPTION: Tube, Mount, Spar, Lead

PART NUMBER: WF-50-099-06A

REV A

DATE: 2/17/2002

SCALE: SIZE: B SHEET 1 of 1
WRIGHT FLYER
1903-2003

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE
X = ± .1
XX = ± .03
XXX = ± .010
ANGLES ± 1°

DRAWN BY:
David Beck Christensen

PARTS LIST

<table>
<thead>
<tr>
<th>ITEM</th>
<th>QTY</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>WF-50-099-04A</td>
<td>Tube, Mount, Spar, Lead</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>WF-50-099-01B</td>
<td>Tab, Mounting</td>
</tr>
</tbody>
</table>

MATERIAL:
Hardpoint, Spar, Leading, Left

DATE: 2/17/2002

SCALE: SIZE: B SHEET 1 of 1
hole to be drilled during final assembly to match cross member.

All dims are in inches unless noted otherwise:

\[ x = \pm 0.1 \]
\[ xx = \pm 0.03 \]
\[ xxx = \pm 0.010 \]
\[ \text{Angles} \pm 1^\circ \]

**Parts List**

<table>
<thead>
<tr>
<th>ITEM</th>
<th>QTY</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>WF-50-099-11A</td>
<td>Bar, Support, Cockpit</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>WF-50-099-11B</td>
<td>Plate, Rectangular</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>WF-50-099-11C</td>
<td>Tab, Mounting</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>WF-50-099-02B</td>
<td>Plate, Circular</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>WF-50-099-02C</td>
<td>Tube, Fitting</td>
</tr>
</tbody>
</table>

**Material:**

- Tube, Mounting, Cockpit

**DRAWN BY:**

David Beck Christensen

**MATERIAL:**

- Tube, Mounting, Cockpit

**DATE:** 2/17/2002

**SCALE:** | **SIZE:** B | **SHEET:** 1 of 1
Hole to be drilled during final assembly in order to match with cross member.

Rect. Tubing 1" x 2" Outside x 0.125 wall

\[ \varnothing 0.25 \]

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

\[ X = \pm 0.1 \]
\[ XX = \pm 0.03 \]
\[ XXX = \pm 0.010 \]

ANGLES \pm 1°

DRAWN BY:
David Beck Christiansen

USU
WRIGHT FLYER
1903-2003

MATERIAL:
Aluminum-6061

PART DESCRIPTION:
Bar, Support, Cockpit

PART NUMBER:
WF-50-099-11A

SCALE: B

DATE: 2/17/2002

SHEET 1 of 1
Wheel will need to be machined to fit the unique shock spindle

<table>
<thead>
<tr>
<th>ITEM</th>
<th>QTY</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>P/N 06-6000</td>
<td>Azusa lite Nylon Wheel</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td></td>
<td>Lefty Shock Cannondale Ml Bike Sh ock</td>
</tr>
</tbody>
</table>

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

X ± .1
XX ± .03
XXX ± .010
ANGLES ± 1°

DRAWN BY: David Beck Christensen

MATERIAL: WRIGHT FLYER 1903-2003

USU
Mechanical & Aerospace Engineering

DATE: 2/17/2002
SCALE: B

SHEET 1 of 1
carbon fiber tube, 1" I.D. x 1/16" wall
carbon fiber tube, 1" I.D. X 1/16" wall

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE
X = ±.1
XX = ± .03
XXX = ± .010
ANGLES ± 1°

DRAWN BY:
David Beck Christensen

USU
Mechanical & Aerospace Engineering

WRIGHT FLYER
1903-2003

MATERIAL:
Carbon Fiber

DATE: 2/17/2002

SCALE: B

PART DESCRIPTION: Slit

PART NUMBER: WF-50-20914-F

REV

SIZE: B

SHEET 1 of 1
Carbon leaf spring to be bonded to skid hard point and "sandwiched" with another steel backing plate not shown.

<table>
<thead>
<tr>
<th>ITEM</th>
<th>QTY</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>WF-50-000-05</td>
<td>Skid Hardpoint Assembly</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>WF-50-000-01</td>
<td>Angled Hard Point Assembly</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>WF-50-000-06</td>
<td>Tube Fitting Assembly</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>WF-50-099-05-01</td>
<td>Hardpoint, Spar, Rear, Left</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>WF-50-099-08</td>
<td>Hardpoint, Spar, Rear</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>P_N 06-01815</td>
<td>Malco Wheel &amp; Carbon Spring</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>WF-50-099-14I</td>
<td>Tube, Strut</td>
</tr>
<tr>
<td>8</td>
<td>1</td>
<td>WF-50-099-144</td>
<td>Strut</td>
</tr>
<tr>
<td>9</td>
<td>1</td>
<td>WF-50-099-14G</td>
<td>Strut</td>
</tr>
</tbody>
</table>

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

X = ± .1
XX = ± .03
XXX = ± .010
ANGLES ± 1°
ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

\[ X = \pm 0.1 \]
\[ XX = \pm 0.03 \]
\[ XXX = \pm 0.010 \]
ANGLES \( \pm 1' \)

DRAWN BY:
David Beck Christensen

MATERIAL:
usu WRIGHT FLYER 1903-2003

Parts List

<table>
<thead>
<tr>
<th>ITEM</th>
<th>QTY</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>WF-60-099-01</td>
<td>Skid, Hardpoint</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>WF-60-099-01C</td>
<td>Plate, Backing</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>AN365</td>
<td>Nut</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>MS24694</td>
<td>Screw, Machine</td>
</tr>
</tbody>
</table>

USU
MECHANICAL & AEROSPACE ENGINEERING

DATE: 2/17/2002

SCALE: | SIZE: | SHEET 1 of 1
0.51 TYP

0.88 TYP

45° TYP

2 X

1 1/16 X

2 X

1

Parts List

<table>
<thead>
<tr>
<th>ITEM</th>
<th>QTY</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>WF-50-099-01A</td>
<td>Plate, Mounting</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>WF-50-099-01B</td>
<td>Tab, Mounting</td>
</tr>
</tbody>
</table>

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

X = ± .1
XX = ± .03
XXX = ± .010
ANGLES ± 1°

DRAWN BY:
David Beck Christensen

USU
WRIGHT FLYER
1903-2003
ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

X = ±.1
XX = ± .03
XXX = ± .010
ANGLES ±1°

DRAWN BY:
David Beck Christensen

MATERIAL:
Steel, Mild

PART DESCRIPTION:
Plate, Mounting

PART NUMBER:
WF-50-099-01A

DATE: 2/17/2002

SCALE: SIZE: B SHEET 1 of 1

USU WRIGHT FLYER 1903-2003

Utah State University Mechanical & Aerospace Engineering
ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

X = ±.1
XX = ±.03
XXX = ±.010
ANGLES ±1'

DRAWN BY:
David Beck Christensen

MATERIAL:
Steel, Mild

PART DESCRIPTION:
Tab, Mounting

PART NUMBER:
WF-50-000-018

DATE: 2/17/2002

SCALE:
SIZE: B

USU WRIGHT FLYER
1903-2003

REV A
ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

X = ± .1
XX = ± .03
XXX = ± .010
ANGLES ± 1°

DRAWN BY:
David Beck Christensen

MATERIAL: Hardpoint, Spar, Rear, Left

DATE: 2/17/2002

SCALE: SIZE: B SHEET 1 of 1
1/16" X 4" X 8" 4130 rolled 180 deg.

ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE

X = ± .1
XX = ± .03
XXX = ± .010
ANGLES ± 1°

DRAWN BY:
David Beck Christensen

WRIGHT FLYER
1903-2003
ALL DIMS ARE IN INCHES UNLESS NOTED OTHERWISE
X = ± .1
XX = ± .03
XXX = ± .010
ANGLES ± 1°

DRAWN BY:
David Beck Christensen

MATERIAL:
usu WRIGHT FLYER 1903-2003

USU
Mechanical & Aerospace Engineering

DATE: 2/17/2002
SCALE: B

Parts List
<table>
<thead>
<tr>
<th>ITEM</th>
<th>QTY</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>WF-50-099-05A</td>
<td>Tube, Mount, Spar, Rear</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>WF-50-099-06A</td>
<td>Tab, Mount, Spar, Rear</td>
</tr>
</tbody>
</table>
碳纤维管，1" I.D. X 1/16" 墙

所有尺寸以英寸表示，除非另有说明。

X = ± .1
XX = ± .03
XXX = ± .010
角度 ± 1°

绘制：David Beck Christensen

材料：碳纤维

日期：2/17/2002

比例：B

WRIGHT FLYER
1903-2003
carbon fiber tube, 1" I.D. X 1/16" wall

31.89
carbon fiber tube, 1" I.D. X 1/16" wall
**Original 1905 Wright Flyer Drag Calculations**


Important Notes:
1.) All aerodynamic areas are frontal unless otherwise specified.
2.) Any diagonal member is modeled using a vertical projection of the area.
3.) A YELLOW cell contains a changeable property.

**Air Properties (@ 1 atm, and 68 F):**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>velocity, $V =$</td>
<td>28 mph</td>
</tr>
<tr>
<td>density, $p =$</td>
<td>0.002377 slugs/ft$^3$</td>
</tr>
<tr>
<td>viscosity, $\mu =$</td>
<td>0.000000376 lb*ft/ft$^2$</td>
</tr>
<tr>
<td>kinematic viscosity, $v =$</td>
<td>0.000158183 ft$^2$/s</td>
</tr>
</tbody>
</table>

$$q_o = \frac{1}{2} \rho V^2 = 2.0053 \text{ slugs/ft}^2$$

characteristic Length

<table>
<thead>
<tr>
<th>Length</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.25 in</td>
<td>0.020833 ft</td>
</tr>
<tr>
<td>1 in</td>
<td>0.083333 ft</td>
</tr>
<tr>
<td>2 in</td>
<td>0.166667 ft</td>
</tr>
<tr>
<td>18 in</td>
<td>1.5 ft</td>
</tr>
</tbody>
</table>

Reynolds:

<table>
<thead>
<tr>
<th>Reynolds</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>541</td>
<td></td>
</tr>
<tr>
<td>216</td>
<td></td>
</tr>
<tr>
<td>492</td>
<td></td>
</tr>
<tr>
<td>38951</td>
<td></td>
</tr>
</tbody>
</table>

**Main Wing:**

<table>
<thead>
<tr>
<th>Part Description</th>
<th>Modeled as a...</th>
<th>$C_D$</th>
<th>Area (in$^2$)</th>
<th>Area (ft$^2$)</th>
<th>Quantity</th>
<th>Drag (lb)</th>
<th>Drag (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top Wing</td>
<td>Generic Wing</td>
<td>0.047</td>
<td>---</td>
<td>251.50</td>
<td>1</td>
<td>23.703</td>
<td>20.8%</td>
</tr>
<tr>
<td>Bottom Wing</td>
<td>Generic Wing</td>
<td>0.047</td>
<td>---</td>
<td>251.50</td>
<td>1</td>
<td>23.703</td>
<td>20.8%</td>
</tr>
<tr>
<td>Propeller Supports</td>
<td>Cylinder</td>
<td>1.2</td>
<td>32.81</td>
<td>0.23</td>
<td>8</td>
<td>4.386</td>
<td>3.9%</td>
</tr>
<tr>
<td>Struts</td>
<td>Rounded Nose Secti</td>
<td>0.8</td>
<td>70</td>
<td>0.49</td>
<td>18</td>
<td>14.037</td>
<td>12.3%</td>
</tr>
<tr>
<td>Wires (collective)</td>
<td>Cylinder</td>
<td>1.2</td>
<td>175.2</td>
<td>1.22</td>
<td>1</td>
<td>2.928</td>
<td>2.6%</td>
</tr>
</tbody>
</table>

Subtotal = 68.758

**Front Rudder (Canard):**

<table>
<thead>
<tr>
<th>Part Description</th>
<th>Modeled as a...</th>
<th>$C_D$</th>
<th>Area (in$^2$)</th>
<th>Area (ft$^2$)</th>
<th>Quantity</th>
<th>Drag (lb)</th>
<th>Drag (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top Wing</td>
<td>Generic Wing</td>
<td>0.03</td>
<td>---</td>
<td>41.50</td>
<td>1</td>
<td>2.497</td>
<td>2.2%</td>
</tr>
<tr>
<td>Bottom Wing</td>
<td>Generic Wing</td>
<td>0.03</td>
<td>---</td>
<td>41.50</td>
<td>1</td>
<td>2.497</td>
<td>2.2%</td>
</tr>
<tr>
<td>Control Shaft</td>
<td>Cylinder</td>
<td>1.2</td>
<td>76.5</td>
<td>0.53</td>
<td>1</td>
<td>1.278</td>
<td>1.1%</td>
</tr>
<tr>
<td>Blinksers</td>
<td>Rounded Nose Secti</td>
<td>0.8</td>
<td>22.3</td>
<td>0.15</td>
<td>2</td>
<td>0.497</td>
<td>0.4%</td>
</tr>
<tr>
<td>Struts</td>
<td>Rounded Nose Secti</td>
<td>0.8</td>
<td>33.75</td>
<td>0.23</td>
<td>9</td>
<td>3.384</td>
<td>3.0%</td>
</tr>
<tr>
<td>Wires (collective)</td>
<td>Cylinder</td>
<td>1.2</td>
<td>15.68</td>
<td>0.11</td>
<td>1</td>
<td>0.262</td>
<td>0.2%</td>
</tr>
</tbody>
</table>

Subtotal = 10.414

Total Drag = 79.172 lb

Drag (%) Total = 9.2%
1905 Flyer Drag Calculations Continued...

### Rear Rudder:

<table>
<thead>
<tr>
<th>Part Description</th>
<th>Modeled as a...</th>
<th>CD</th>
<th>Area (in²)</th>
<th>Area (ft²)</th>
<th>Quantity</th>
<th>Drag (lb)</th>
<th>Drag (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left Wing</td>
<td>Generic Wing</td>
<td>0.0017</td>
<td>---</td>
<td>17.40</td>
<td>1</td>
<td>0.059</td>
<td>0.1%</td>
</tr>
<tr>
<td>Right Wing</td>
<td>Generic Wing</td>
<td>0.0017</td>
<td>---</td>
<td>17.40</td>
<td>1</td>
<td>0.059</td>
<td>0.1%</td>
</tr>
<tr>
<td>Struts</td>
<td>Rounded Nose Sec</td>
<td>0.8</td>
<td>22.5</td>
<td>0.16</td>
<td>6</td>
<td>1.504</td>
<td>1.3%</td>
</tr>
<tr>
<td>Wires (collective)</td>
<td>Cylinder</td>
<td>1.2</td>
<td>15.58</td>
<td>0.11</td>
<td>1</td>
<td>0.262</td>
<td>0.2%</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.885</td>
<td>1.7%</td>
</tr>
</tbody>
</table>

### Engine and Drive Train:

<table>
<thead>
<tr>
<th>Part Description</th>
<th>Modeled as a...</th>
<th>CD</th>
<th>Area (in²)</th>
<th>Area (ft²)</th>
<th>Quantity</th>
<th>Drag (lb)</th>
<th>Drag (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Block</td>
<td>Rectangular Plate</td>
<td>1.2</td>
<td>250</td>
<td>1.74</td>
<td>1</td>
<td>4.178</td>
<td>3.7%</td>
</tr>
<tr>
<td>Radiator</td>
<td>Flat Nose Section</td>
<td>0.8</td>
<td>101.6</td>
<td>0.71</td>
<td>1</td>
<td>1.132</td>
<td>1.0%</td>
</tr>
<tr>
<td>Fuel Tank</td>
<td>Cylinder</td>
<td>0.8</td>
<td>76.56</td>
<td>0.53</td>
<td>1</td>
<td>0.853</td>
<td>0.8%</td>
</tr>
<tr>
<td>Drive Train</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Guide Tubes (collective)</td>
<td>Cylinder</td>
<td>1.2</td>
<td>200</td>
<td>1.39</td>
<td>1</td>
<td>3.342</td>
<td>2.9%</td>
</tr>
<tr>
<td>Sprockets</td>
<td>Disk</td>
<td>1.17</td>
<td>90.4</td>
<td>0.69</td>
<td>2</td>
<td>3.239</td>
<td>2.8%</td>
</tr>
<tr>
<td>Propellers (non-rotating)</td>
<td>Flat Plate</td>
<td>0</td>
<td>---</td>
<td>4.00</td>
<td>2</td>
<td>0.000</td>
<td>0.0%</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>12.744</td>
<td>11.2%</td>
</tr>
</tbody>
</table>

### Pilot:

<table>
<thead>
<tr>
<th>Part Description</th>
<th>Modeled as a...</th>
<th>CD</th>
<th>Area (in²)</th>
<th>Area (ft²)</th>
<th>Quantity</th>
<th>Drag (lb)</th>
<th>Drag (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orville</td>
<td>Human (sitting)</td>
<td>1.2</td>
<td>---</td>
<td>2</td>
<td>2</td>
<td>4.813</td>
<td>4.2%</td>
</tr>
</tbody>
</table>

### Airframe Structural Supports:

<table>
<thead>
<tr>
<th>Part Description</th>
<th>Modeled as a...</th>
<th>CD</th>
<th>Area (in²)</th>
<th>Area (ft²)</th>
<th>Quantity</th>
<th>Drag (lb)</th>
<th>Drag (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skids</td>
<td>Flat Nose Section</td>
<td>1.6</td>
<td>38.75</td>
<td>0.27</td>
<td>2</td>
<td>1.727</td>
<td>1.5%</td>
</tr>
<tr>
<td>Wires (collective)</td>
<td>Cylinder</td>
<td>1.2</td>
<td>96.78</td>
<td>0.67</td>
<td>1</td>
<td>1.617</td>
<td>1.4%</td>
</tr>
<tr>
<td>Control Wires (collective)</td>
<td>Cylinder</td>
<td>1.2</td>
<td>80.36</td>
<td>0.56</td>
<td>1</td>
<td>1.343</td>
<td>1.2%</td>
</tr>
<tr>
<td>Center Strut</td>
<td>Rounded Nose Section</td>
<td>0.8</td>
<td>14</td>
<td>0.10</td>
<td>1</td>
<td>0.156</td>
<td>0.1%</td>
</tr>
<tr>
<td>Vertical Struts (collective)</td>
<td>Rounded Nose Sect</td>
<td>0.8</td>
<td>728.1</td>
<td>5.06</td>
<td>1</td>
<td>8.111</td>
<td>7.1%</td>
</tr>
<tr>
<td>Horizontal Struts</td>
<td>Rounded Nose Section</td>
<td>0.8</td>
<td>63.75</td>
<td>0.44</td>
<td>3</td>
<td>2.131</td>
<td>1.9%</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>15.085</td>
<td>13.3%</td>
</tr>
</tbody>
</table>

**Total Drag Force** = 113.70 lb
USU Wright Flyer Drag Calculations

****Drag of wings **counted** on this sheet


Important Notes:
1.) All aerodynamic areas are frontal unless otherwise specified.
2.) Any diagonal member is modeled using a vertical projection of the area.
3.) A YELLOW cell contains a changeable property.

Air Properties (@ 1 atm, and 68 F):

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>velocity, $V$</td>
<td>45 mph</td>
</tr>
<tr>
<td>density, $\rho$</td>
<td>0.002377 slugs/ft$^3$</td>
</tr>
<tr>
<td>viscosity, $\mu$</td>
<td>0.0000000376 lb s/ft$^2$</td>
</tr>
<tr>
<td>kinematic viscosity, $\nu$</td>
<td>0.000158183 ft$^2$/s</td>
</tr>
</tbody>
</table>

$q_c = \frac{1}{2} \rho V^2 = 5.1795$ slugs/ft$^2$

Characteristic Length

<table>
<thead>
<tr>
<th>Length</th>
<th>Value (in)</th>
<th>Value (ft)</th>
<th>Reynolds #</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.25 in</td>
<td>0.020833 ft</td>
<td>8694</td>
<td></td>
</tr>
<tr>
<td>1 in</td>
<td>0.083333 ft</td>
<td>34778</td>
<td></td>
</tr>
<tr>
<td>2 in</td>
<td>0.166667 ft</td>
<td>69556</td>
<td></td>
</tr>
<tr>
<td>18 in</td>
<td>1.5 ft</td>
<td>626001</td>
<td></td>
</tr>
</tbody>
</table>

Main Wing:

<table>
<thead>
<tr>
<th>Part Description</th>
<th>Modeled as a...</th>
<th>$C_D$</th>
<th>Area (in$^2$)</th>
<th>Area (ft$^2$)</th>
<th>Quantity</th>
<th>Drag (lb)</th>
<th>Drag (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top Wing</td>
<td>usu 402509-3040.13</td>
<td>0.0073</td>
<td>---</td>
<td>230</td>
<td>1</td>
<td>8.6063125</td>
<td>5.7%</td>
</tr>
<tr>
<td>Bottom Wing</td>
<td>usu 402509-3040.13</td>
<td>0.0073</td>
<td>---</td>
<td>230</td>
<td>1</td>
<td>8.6063125</td>
<td>5.7%</td>
</tr>
<tr>
<td>Propeller Supports</td>
<td>Stream Lined Body</td>
<td>0.12</td>
<td>0.347222</td>
<td>16</td>
<td>16</td>
<td>3.452973</td>
<td>2.3%</td>
</tr>
<tr>
<td>Struts</td>
<td>Stream Lined Body</td>
<td>0.12</td>
<td>0.694444</td>
<td>16</td>
<td>16</td>
<td>6.905946</td>
<td>4.6%</td>
</tr>
<tr>
<td>Wires (collective)</td>
<td>Round Cylinder</td>
<td>1.2</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td></td>
<td></td>
<td><strong>27.751544</strong></td>
<td></td>
<td></td>
<td><strong>18.3%</strong></td>
<td></td>
</tr>
</tbody>
</table>

Front Rudder (Canard):

<table>
<thead>
<tr>
<th>Part Description</th>
<th>Modeled as a...</th>
<th>$C_D$</th>
<th>Area (in$^2$)</th>
<th>Area (ft$^2$)</th>
<th>Quantity</th>
<th>Drag (lb)</th>
<th>Drag (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top Wing</td>
<td>usu 993009-3040.13</td>
<td>0.0451</td>
<td>---</td>
<td>27.5</td>
<td>1</td>
<td>6.417451</td>
<td>4.2%</td>
</tr>
<tr>
<td>Bottom Wing</td>
<td>usu 993009-3040.13</td>
<td>0.0451</td>
<td>---</td>
<td>27.5</td>
<td>1</td>
<td>6.417451</td>
<td>4.2%</td>
</tr>
<tr>
<td>Struts</td>
<td>Stream Lined Body</td>
<td>0.12</td>
<td>0.166667</td>
<td>2</td>
<td>2</td>
<td>0.2071784</td>
<td>0.1%</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td></td>
<td></td>
<td><strong>13.042009</strong></td>
<td></td>
<td></td>
<td><strong>8.6%</strong></td>
<td></td>
</tr>
</tbody>
</table>
**USU Flyer Drag Calculations Continued...**

### Rear Rudder:

<table>
<thead>
<tr>
<th>Part Description</th>
<th>Modeled as a...</th>
<th>$C_D$</th>
<th>Area (in$^2$)</th>
<th>Area (ft$^2$)</th>
<th>Quantity</th>
<th>Drag (lb)</th>
<th>Drag (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left Wing</td>
<td>NACA 0009</td>
<td>0.0017</td>
<td>---</td>
<td>21</td>
<td>1</td>
<td>0.1849067</td>
<td>0.1%</td>
</tr>
<tr>
<td>Right Wing</td>
<td>NACA 0009</td>
<td>0.0017</td>
<td>---</td>
<td>21</td>
<td>1</td>
<td>0.1849067</td>
<td>0.1%</td>
</tr>
<tr>
<td>Struts</td>
<td>Round Cylinder</td>
<td>1.2</td>
<td>20</td>
<td>0.138889</td>
<td>1</td>
<td>0.8832432</td>
<td>0.6%</td>
</tr>
<tr>
<td>Wires (collective)</td>
<td>Round Cylinder</td>
<td>1.2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>1.2330567</strong></td>
<td><strong>0.8%</strong></td>
</tr>
</tbody>
</table>

### Engine and Drive Train:

<table>
<thead>
<tr>
<th>Part Description</th>
<th>Modeled as a...</th>
<th>$C_D$</th>
<th>Area (in$^2$)</th>
<th>Area (ft$^2$)</th>
<th>Quantity</th>
<th>Drag (lb)</th>
<th>Drag (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine</td>
<td></td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Engine Block Bluff Body</td>
<td></td>
<td>1</td>
<td>180</td>
<td>1.25</td>
<td>1</td>
<td>6.4743244</td>
<td>4.3%</td>
</tr>
<tr>
<td>Engine Fuel Tank Bluff Body</td>
<td>1</td>
<td>100</td>
<td>0.694444</td>
<td>1</td>
<td>3.5968469</td>
<td>2.4%</td>
<td></td>
</tr>
<tr>
<td>Drive Train</td>
<td></td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Drive Train Transmission Bluff Body</td>
<td>0.5</td>
<td>216</td>
<td>1.5</td>
<td>1</td>
<td>3.8845946</td>
<td>2.6%</td>
<td></td>
</tr>
<tr>
<td>Drive Train Sprockets Round Cylinder</td>
<td>1.2</td>
<td>28.25</td>
<td>0.196181</td>
<td>2</td>
<td>2.4366622</td>
<td>1.6%</td>
<td></td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>18.394428</strong></td>
<td><strong>10.8%</strong></td>
</tr>
</tbody>
</table>

### Pilot:

<table>
<thead>
<tr>
<th>Part Description</th>
<th>Modeled as a...</th>
<th>$C_D$</th>
<th>Area (in$^2$)</th>
<th>Area (ft$^2$)</th>
<th>Quantity</th>
<th>Drag (lb)</th>
<th>Drag (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orville Person</td>
<td></td>
<td>6</td>
<td>---</td>
<td>---</td>
<td>2</td>
<td>62.153514</td>
<td>41.1%</td>
</tr>
</tbody>
</table>

### Airframe Structural Supports:

<table>
<thead>
<tr>
<th>Part Description</th>
<th>Modeled as a...</th>
<th>$C_D$</th>
<th>Area (in$^2$)</th>
<th>Area (ft$^2$)</th>
<th>Quantity</th>
<th>Drag (lb)</th>
<th>Drag (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skids</td>
<td>Square Cylinder</td>
<td>2.1</td>
<td>12</td>
<td>0.083333</td>
<td>2</td>
<td>1.8128108</td>
<td>1.2%</td>
</tr>
<tr>
<td>Wires (collective)</td>
<td>Round Cylinder</td>
<td>1.2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>Control Wires (collective)</td>
<td>Round Cylinder</td>
<td>1.2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>Vertical Struts (collective)</td>
<td>Round Cylinder</td>
<td>1.2</td>
<td>271</td>
<td>1.881944</td>
<td>2</td>
<td>23.393892</td>
<td>15.5%</td>
</tr>
<tr>
<td>Diagonal Struts</td>
<td>Round Cylinder</td>
<td>1.2</td>
<td>65</td>
<td>0.451389</td>
<td>2</td>
<td>5.6110811</td>
<td>3.7%</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>30.817784</strong></td>
<td><strong>20.4%</strong></td>
</tr>
</tbody>
</table>

**Total Drag Force = 151.39 lb**
APPENDIX B
AIRCRAFT PERFORMANCE ANALYSIS

Thrust Required

\[
\begin{align*}
V &:= \begin{pmatrix} 5 \\ 15 \\ 25 \\ 35 \\ 40 \\ 45 \\ 50 \\ 55 \end{pmatrix} \text{ mph} \quad V_I &:= \begin{pmatrix} 5 \\ 15 \\ 25 \\ 35 \\ 40 \\ 45 \\ 50 \\ 55 \end{pmatrix} \\
V &:= \begin{pmatrix} 5 \\ 15 \\ 25 \\ 35 \\ 40 \\ 45 \\ 50 \\ 55 \end{pmatrix} \text{ mph} \quad V_I &:= \begin{pmatrix} 5 \\ 15 \\ 25 \\ 35 \\ 40 \\ 45 \\ 50 \\ 55 \end{pmatrix} \\
\rho &:= 0.0023769 \text{ slug/ft}^3 \\
C_{D_0} &:= 0 \\
C_{D_0} &:= 0.0411 \\
b &:= 40.5 \text{ ft} \\
R_A &:= \frac{40.5 \text{ ft}}{6 \text{ ft}} \\
S_w &:= 461.1 \text{ ft}^2 \\
W &:= 890 \text{ lb} \\
W_1 &:= 890 \\
e &:= 0.82 \\
\end{align*}
\]

Note: C_{D_0} was obtained from drag spreadsheet. The parasitic drag for steady level flight (50 mph) was then non-dimensionalized with respect to the main wings.

\[
T_R := \left( \frac{5 \rho \cdot V^2 \cdot C_{D_0}}{S_w} + C_{D_0} \cdot V + \frac{W}{S_w} \cdot \frac{V}{2} \cdot e \cdot R_A \cdot \rho \cdot V^2 \right) \cdot W
\]

Power Required

\[
P_R := \left( \frac{5 \rho \cdot V^3 \cdot C_{D_0}}{W} + C_{D_0} \cdot L \cdot V + \frac{W}{S_w} \cdot \frac{V}{2} \cdot e \cdot R_A \cdot \rho \cdot V^2 \right) \cdot W
\]

\[
P_{R1} := \left( \frac{5 \rho \cdot V^3 \cdot C_{D_0}}{W} \cdot \frac{W}{S_w} + C_{D_0} \cdot L \cdot V + \frac{W}{S_w} \cdot \frac{V}{2} \cdot e \cdot R_A \cdot \rho \cdot V^2 \right) \cdot W
\]

\[
P_R = \begin{pmatrix} 20.626 \\ 7.306 \\ 6.141 \\ 8.484 \\ 10.845 \\ 14.063 \\ 18.21 \\ 23.369 \end{pmatrix} \text{ hp}
\]

\[
P_{R1} = \begin{pmatrix} 20.626 \\ 7.306 \\ 6.141 \\ 8.484 \\ 10.845 \\ 14.063 \\ 18.21 \\ 23.369 \end{pmatrix} \text{ lhp}
\]
**Power/Thrust Available**

\[ T_A := 282.034 + 5.025 V_1 - 0.144 V_1^2 \]

Note: Thrust available (Te) data was obtained from propeller manufacturer.

\[ P_A := \frac{282.034 V_1 + 5.025 V_1^2 - 0.144 V_1^3}{550} \]

**Rate of Climb**

\[ V_c := \frac{P_A - P_{R1}}{W_1} \cdot \frac{550}{60} \]

**Power failure and gliding flight**

\[ V_s = \text{Sink Rate} \]

\[ V_s := \frac{C_{D0} \rho \cdot V^3}{2} + \frac{2 \cdot W}{S_w} + \frac{C_{D0} L \cdot V}{\pi \cdot c \cdot R_A \cdot \rho \cdot V} \]

The glide ratio for zero wind is equal to the Lift to Drag ratio. Assuming that the wright flyer will not be flying in windy conditions, we say that \( R_g = \frac{L}{D} = \frac{C_L}{C_D} \). \( C_L \) and \( C_D \) were obtained from WINGS2001 output after the plane was balanced.

\[ C_L := 0.241 \quad C_D := 0.05018 \quad \frac{R_g}{C_D} = 4.803 \]
Steady Coordinated Turn

\[ C_{L_{\text{max}}} = 0.706 \]  Added Cl of each surface when plane was balanced for 29 mph.

\[ V = 4.5 \text{ mph} \]  Design flight speed.

\[ n_{\text{maxS}} \text{ is the stall limited, Maximum allowable load on the wings.} \]
\[ r_t \text{ is the stall limited Minimum turning radius} \]

This equation does not account for tip stall.

\[
n_{\text{maxS}} = \frac{0.5 \rho V^2}{\omega} C_{L_{\text{max}}} \quad n_{\text{maxS}} = 1.894
\]

\[ r_t = \frac{\sqrt{\frac{V^2}{g \sqrt{n_{\text{maxS}}^2 - 1}}}}{r_t = 84.199 \text{ ft}} \]

PercentWingSpan := \frac{r_t}{b} \times 100

PercentWingSpan = 207.898

**** PercentWingSpan wing span is not very much, the inner wing could easily be stalling, so we have to try again using the equations that take tip stall into account.

The following equation finds the max load allowable on a wing, taking into account the bank angle and turning radius to avoid stalling the tip of the Inside wing (See Eq. 3.9.46 and the preceding paragraph, pg. 76.

When \( f(n_{\text{max}}) \) equals zero, \( n_{\text{max}} \) is the correct value =>

\[
f(n_{m}) := n_{m} - \left( \frac{b \cdot g}{2 \cdot V^2 \sqrt{\frac{n_{m}^2 - 1}{w}}} \right) - \frac{2 \cdot \sqrt{\frac{w}{S_w}}}{\sqrt{\rho \cdot V^2 \cdot C_{L_{\text{max}}}}} \sqrt{n_{m}^3}
\]

Over view graph:  
ZOOM view graph:

This is to verify a guess taken from the graph above:
Guess from graph:

\[ n_{\text{max}} = 2.32421 \]

\[ f(n_{\text{max}}) = n_{\text{max}} - \left( \frac{b}{2 \sqrt{2}} \right) \sqrt{\frac{n_{\text{max}}^2 - 1}{2 S_{\text{w}}}} - \sqrt{\frac{2 W}{\rho \cdot V^2 \cdot C_{\text{Lmax}}}} \quad f(n_{\text{max}}) = -0.565 \]

\[ r_t := \frac{\sqrt{2}}{g \cdot \sqrt{n_{\text{max}}^2 - 1}} \quad r_t = 64.53 \text{ft} \]

PercentWingSEMISpan := \( \frac{r_t}{b} \cdot 100 \)

PercentWingSEMISpan = 318.665

**The load on the wing structure is the weight of the plane times the load factor, \( n \).**

\[ \text{WingLoad} := n_{\text{max}} \cdot W \quad \text{WingLoad} = 2.069 \times 10^3 \text{lbf} \]

\( g \) forces on the wings:

\[ G_S := \frac{\text{WingLoad}}{W} \quad G_S = 2.324 \]

**Take Off Performance**

\[ g = 32.174 \frac{\text{ft}}{s^2} \]

\[ t_{\text{rotate}} := 1 \text{sec} \quad t_{\text{react}} := 2 \text{sec} \]

\[ V_{\text{hw}} := 0 \frac{\text{ft}}{\text{sec}} \quad V_{\text{stall}} := 44 \frac{\text{ft}}{\text{sec}} \quad V_{\text{LO}} := 1.1 \cdot V_{\text{stall}} \]

\[ \mu_T := .1 \]

\[ \mu_{\text{brakes}} := .1 \]

Note: Rolling and brake friction are unknown at this time. The values listed are an estimate. If \( \mu_{\text{brake}} = \mu_T \) then a zero brake analysis is being done.

\[ C_L := \pi \cdot e \cdot R_A \left[ \frac{1}{2 \cdot (\frac{16 \cdot hw}{b})} + \frac{1}{2} \left( \mu_T - C_{\text{Do.L}} \right) \right] \]

\[ C_L = 1.092 \]

\[ C_D := C_{\text{Do}} + C_{\text{Do,L}} \cdot C_L + \frac{\left( \frac{16 \cdot hw}{b} \right)^2 \cdot C_L^2}{1 + \left( \frac{16 \cdot hw}{b} \right)^2 \cdot \pi \cdot e \cdot R_A} \]

\[ C_D = 0.096 \]
\[ T_0 := \frac{T_s}{W} - \mu_t \]

\[ T_1 := \frac{T_1}{W} \]

\[ K_2 := \frac{T_2}{W} + \frac{\rho}{W} \left( C_L \mu_t - C_D \right) \]

\[ K_0 := 4K_0 - K_2 - K_1^2 \]

\[ f_s := K_0 \]

\[ f_{LO} := K_0 + K_1 \cdot V_{LO} + K_2 \cdot V_{LO}^2 \]

\[ f_{s2} := K_1 \]

\[ f_{LO2} := K_1 + 2K_2 \cdot V_{LO} \]

\[ K_w := \frac{1}{\sqrt{-K_R}} \cdot \ln \left( \frac{f_{LO2} - \sqrt{-K_R}}{f_{s2} + \sqrt{-K_R}} \right) \]

\[ K_T := \frac{1}{2K_2} \cdot \ln \left( \frac{f_{LO} - K_1 \cdot K_w}{f_s} \right) \]

\[ s_a := \frac{K_T - V_{hw} \cdot K_w}{g} \]

\[ s_g := s_a + \left( V_{LO} - V_{hw} \right) t_{rotate} \]

**Landing Performance**

\[ V_{TD} := 1.15 V_{stall} \]

\[ s_f := \left( V_{TD} - V_{hw} \right) t_{react} \]

\[ s_b := \frac{W}{S_w \cdot \left( C_D - \mu \cdot \mu_t \cdot C_L \right)} \cdot \ln \left( 1 + \frac{\rho \cdot V_{TD}^2}{2 \cdot \frac{W}{S_w \cdot \left( \mu \cdot \mu_t \cdot C_D - C_L \right)} \cdot \left( \frac{C_D - \mu_t \cdot C_L}{\mu} \right) \right) \]

\[ s_{g2} := s_f + s_b \]

**Take Off Distance**

\[ s_g = 221.943 \text{ft} \]

**Landing Distance**

\[ s_{g2} = 548.654 \text{ft} \]
% of Total Weight Carried (800 lbs) Assumptions

*Canard : 15%
*Front Spars : 30%
*Cables/Skin : 50%
*Back Spars : 20%

Calculations for front spar thickness and weight

\[
P := \frac{800 \text{ lbf} \cdot 30}{4} \quad \text{Assumed load on wingtip test (2.5 g load) [P(%)/number of spars]}
\]

\[
L := 207 \text{ in} \quad \text{Length of beam (assumed to be rigid at frame mount)}
\]

\[
a := 207 \text{ in} \quad \text{Distance down the beam that the deflection is measured}
\]

\[
\delta := 20 \text{ in} \quad \text{Deflection}
\]

\[
\rho := \frac{0.643065798 \text{ lb}}{\text{in}^3} \quad \text{Density}
\]

\[
d_o := 3.109 \text{ in} \quad \text{Outer diameter (should be within 3.0 to 3.2 inches diameter)}
\]

\[
R_o := \frac{d_o}{2} \quad \text{Outer Radius}
\]

\[
E_x := 100 \times 10^9 \text{ Pa} \quad \text{X-dir modulus of the graphite (in line with the fibers)}
\]

(El value required)

\[
\text{Stiffness} := \frac{P \cdot a^2}{6 \cdot \delta} (3 \cdot L - a)
\]

\[
\text{Stiffness} = 2.545 \times 10^4 \frac{\text{kg} \cdot \text{m}^2}{\text{s}^2}
\]

(Ri = inner radius according to smearing method)

\[
R_i := \sqrt[4]{\frac{4 \cdot \text{Stiffness} \cdot 4}{\pi \cdot E_x} + R_o^4}
\]

\[
R_i = 1.5 \text{ in}
\]
(Thickness)
\[ t := R_o - R_i \]

(Volume)
\[ V := \pi \left( R_o^2 - R_i^2 \right) \cdot 4.86 \text{ in} \]

(Weight)
\[ W_r := \rho \cdot V \]

(Diameter of Mandrel)
\[ d := R_i \cdot 2 \]

**Back Spar Calculations**

\[ P := \frac{800 \text{ lb} \cdot 20}{4} \]
\[ \rho := 0.0643065798 \frac{\text{lb}}{\text{in}^3} \]
\[ L := 207 \text{ in} \]
\[ a := 207 \text{ in} \]
\[ \delta := 25 \text{ in} \]
\[ R_o := \frac{d_0}{2} \]
\[ E_x := 90 \times 10^6 \text{ Pa} \]

(Stiffness required)
\[ \text{Stiffness} := \frac{P \cdot a^2}{6 \delta - (3L - a)} \]
\[ \text{Stiffness} = 1.358 \times 10^4 \text{ kg m}^2 \text{ s}^{-2} \]

(Ro = inner radius according to smearing method)
\[ R_i := \sqrt{\frac{-\text{Stiffness} \cdot 4}{\pi \cdot E_x}} + R_o^4 \]
\[ R_i = 1.215 \text{ in} \]

(Thickness)
\[ t := R_o - R_i \]
\[ t = 0.055 \text{ in} \quad \text{(About 10 layers)} \]

Assume that one must add 3 more 'strength layers' on the center 72 inches of the spar...

\[ t_i := t + 0.015 \text{ in} \]
\[ R_{ocenter} := R_o + t \]

(Volume)
\[ V := \pi \left( R_o^2 - R_i^2 \right) \cdot 414 \text{ in} + \pi \left( R_{ocenter}^2 - R_i^2 \right) \cdot 72 \text{ in} \]
\[ V = 262.328 \text{ in}^3 \]
\[ W_b := \rho \cdot V \]

(Diameter of Mandrel)

\[ d := R \cdot 2 \]

Total estimated spar weight

\[ \text{TOTAL}_{\text{spar}} := 2 \cdot W_b + 2 \cdot W_f \]

Rib Weight Calculations

\[ \rho_{\text{foam}} := 3716.5 \frac{\text{gm}}{\text{m}^3} \]

\[ N_{\text{ribs}} := 60 \]

\[ x_{\text{ribs}} := 69.576 \text{in} \]

\[ y_{\text{ribs}} := 2.5 \text{in} \]

\[ z_{\text{ribs}} := 0.5 \text{in} \]

\[ V_{\text{ribs}} := x_{\text{ribs}} \cdot y_{\text{ribs}} \cdot z_{\text{ribs}} \]

\[ m_{\text{foam}} := V_{\text{ribs}} \cdot \rho_{\text{foam}} \cdot N_{\text{ribs}} \]

\[ m_{\text{foam}} = 7.006\text{lb} \]

\[ \rho_{\text{kevlar}} := 0.0072 \frac{\text{gm}}{\text{cm}^2} \]

\[ \text{LAYER}_{\text{kevlar}} := 1 \]

\[ A_{\text{ribs}} := 0.1122 \text{m}^2 \]

\[ m_{\text{kevlar}} := \rho_{\text{kevlar}} \cdot \text{LAYER}_{\text{kevlar}} \cdot A_{\text{ribs}} \cdot N_{\text{ribs}} \]

\[ m_{\text{kevlar}} = 1.069\text{lb} \]

\[ \text{TOTAL}_{\text{ribs}} := m_{\text{foam}} + m_{\text{kevlar}} \]

\[ \text{TOTAL}_{\text{spars}} = 66.508\text{lb} \]

(adjust for epoxy)
APPENDIX D
I-Deas Beam Models

Figure 1 refers to p/n WF-50-099-11A. The chassis beam is loaded with 120-lbf at two points spanning ten inches. The 2 - 120-lbf loads (240-lbf) is due to two men standing on the Footrest assembly, estimating 240-lbf per passenger noting there are two chassis bars supporting the reaction.

Figure 2 refers to p/n WF-50-099-11A. The chassis beam is loaded with 120-lbf at two points spanning ten inches. The 2 - 120-lbf loads (240-lbf) is due to two men standing on the Footrest assembly, estimating 240-lbf per passenger noting there are two chassis bars supporting the reaction.
Figure 3 refers to p/n WF-50-099-11A. The beam is loaded with two horizontal forces of 120-lbf each, modeling two passengers sitting on the span bar. The distance between loads is about twelve inches. Assuming that the pilot and passenger are 240-lbf each and there are four mounting points, two on each chassis bar.

Figure 4 refers to p/n WF-30-003. The beam is loaded with 2 distributed loads of 120-lbf across 18 inches each, along with two point loads 20 lbf each for the engine. The distributed loads are if both the pilot and passenger are standing on the footplates. 120-lbf is approximately one half the weight of a large man (note: one half because there is a front and back beam supporting the foot plates.) The 20-lbf point loads are two engine mounts on the beam, estimated 80-lbf engine divided by four mounting points.
### Control Throw vs. Surface Deflection

**Component:** Canard  
**Action:** Elevation  
Need Canard rotation of +/- 15 degrees  

<table>
<thead>
<tr>
<th>Control Stick Throw (degree)</th>
<th>Cable Displacement (in)</th>
<th>Canard rotation @ 3.5&quot; radius (hole 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>hole 1</td>
<td>hole 2</td>
</tr>
<tr>
<td></td>
<td>(degree)</td>
<td>(in)</td>
</tr>
<tr>
<td>-30.0</td>
<td>-0.750</td>
<td>-1.000</td>
</tr>
<tr>
<td>-25.0</td>
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<td>0.000</td>
</tr>
<tr>
<td>5.0</td>
<td>0.131</td>
<td>0.174</td>
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<td>0.260</td>
<td>0.347</td>
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<td>0.388</td>
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<td>0.854</td>
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<tr>
<td>25.0</td>
<td>0.634</td>
<td>0.945</td>
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<tr>
<td>30.0</td>
<td>0.750</td>
<td>1.000</td>
</tr>
</tbody>
</table>

**Component:** Wing Warp  
**Action:** Roll  
Properties:  
<table>
<thead>
<tr>
<th>Stick Dimensions</th>
<th>hole 1</th>
<th>hole 2</th>
<th>hole 3</th>
<th>hole 4</th>
<th>hole 5</th>
<th>hole 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Vertical Height</td>
<td>15 in</td>
<td>3 in</td>
<td>4 in</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lg radius</td>
<td>12 in</td>
<td>8 in</td>
<td>6 in</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>sm radius</td>
<td>3 in</td>
<td>9 in</td>
<td>10.5 in</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Need: +/- 3 inches of cable travel.

### Component: Wing Warp Differential

<table>
<thead>
<tr>
<th>Control Side (attach at hole 1) (degree)</th>
<th>Bell Rotation (degree)</th>
<th>Wing Side (inch)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(degree)</td>
<td>(inch)</td>
<td>hole 2</td>
</tr>
<tr>
<td>-30.0</td>
<td>1.50</td>
<td>59.00</td>
</tr>
<tr>
<td>-25.0</td>
<td>1.27</td>
<td>46.43</td>
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<tr>
<td>-20.0</td>
<td>1.03</td>
<td>35.90</td>
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<tr>
<td>-15.0</td>
<td>0.78</td>
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<td>0.52</td>
<td>17.32</td>
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<td>8.59</td>
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<td>-0.52</td>
<td>-17.32</td>
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<td>-0.78</td>
<td>-26.34</td>
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<td>20.0</td>
<td>-1.03</td>
<td>-35.90</td>
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<td>-1.27</td>
<td>-46.43</td>
</tr>
<tr>
<td>30.0</td>
<td>-1.50</td>
<td>-59.00</td>
</tr>
</tbody>
</table>
Component: Rudder
Action: Yaw

### Properties:

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<tr>
<th></th>
<th>Pull Cable Differential</th>
<th>Rudder Coupler Radius</th>
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<tbody>
<tr>
<td>hole 1</td>
<td>1 in</td>
<td>2.512 in</td>
</tr>
<tr>
<td>hole 2</td>
<td>1.5 in</td>
<td></td>
</tr>
<tr>
<td>hole 3</td>
<td>2 in</td>
<td></td>
</tr>
<tr>
<td>hole 4</td>
<td>2.5 in</td>
<td></td>
</tr>
<tr>
<td>hole 5</td>
<td>3 in</td>
<td></td>
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</table>

Need Rudder rotation of +/- 15 degrees.

### Cable Displacement (in):

<table>
<thead>
<tr>
<th>Cable Displacement (in)</th>
<th>hole 1</th>
<th>hole 2</th>
<th>hole 3</th>
<th>hole 4</th>
<th>hole 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>hole 1</td>
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<tr>
<td>hole 2</td>
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<tr>
<td>hole 3</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>hole 4</td>
<td></td>
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</tr>
<tr>
<td>hole 5</td>
<td></td>
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</table>

### Rudder Deflection (degree):

<table>
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<tr>
<th>Rudder Deflection (degree)</th>
<th>hole 1</th>
<th>hole 2</th>
<th>hole 3</th>
<th>hole 4</th>
<th>hole 5</th>
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</thead>
<tbody>
<tr>
<td>hole 1</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>hole 2</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>hole 3</td>
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<tr>
<td>hole 4</td>
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<table>
<thead>
<tr>
<th>degree</th>
<th>hole 1</th>
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<th>hole 3</th>
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<td>0.95</td>
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<td>0.75</td>
<td>1.00</td>
<td>1.25</td>
<td>1.50</td>
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Quality Assurance

As with any manufacturing process there can be inconsistencies in the final product. In order to avoid these inconsistencies, quality assurance inspection forms were created for the purpose of tracking, documenting, and ensuring the quality of each and every part on the USU Flyer. A few examples of these forms are attached for reference. The purpose of each form explains why the quality assurance is needed for each part. The requirements list specific items that must be met in order for the part to continue in the manufacturing process. Four individuals (Technician, Design Engineer, Manufacturing Manager, and Project Manager) inspect and pass off these requirements to ensure that no faulty part continues in the process. If parts are not conforming to these requirements, their quality assurance forms can aid in determining the root cause of the non-conformance.
QUALITY ASSURANCE
Inspection and Certification Form

Sheet Number: ___________ Date: ___________

Part Number: WF-20-015

Description: Canard Surface Left

Purpose: a) Certify that left canard surface is manufactured according to specifications.
     b) Verify dimensions.
     c) Certify that the surface has the correct aerodynamic shape and size.

Requirements: Verify the correct material of the surface. Inspect the aerodynamic shape to verify that it is the correct shape and size and reduced accordingly. Verify that the spar holes are in the correct position as specified in the drawing.

<table>
<thead>
<tr>
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<th></th>
<th></th>
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</table>

Signatures:

__________________________ Date
Technician

__________________________ Date
Structural Engineer

__________________________ Date
Manufacturing Engineer

__________________________ Date
Project Manager
QUALITY ASSURANCE
Inspection and Certification Form

Sheet Number: __________               Date: ________________

Part Number: WF-30-101               Weight: ________________

Description: 4130 Steel control system main housing. The case supports control mechanisms for roll and elevation. It is attached to the chassis with large pillow blocks.

Purpose:  
a) Certify part has been anodized.  
b) Certify part is correct length.  
c) Certify all drilled holes are within tolerances of datum.

Signatures:

______________________________   ________________
Technician                        Date

______________________________   ________________
Structural Engineer               Date

______________________________   ________________
Manufacturing Engineer            Date

______________________________   ________________
Project Manager                   Date
QUALITY ASSURANCE
Inspection and Certification Form

Sheet Number: ____________ Date: ________________

Part Number: WF-50-099-03

Description: Skid to Canard hardpoint

Purpose:
   a) Check that four sides on tab are welded
   b) Check integrity of welds
   c) Check dimensions with drawing specifications
   d) Check overall part with drawing specifications

Requirements: This part is a weldament, consisting of three welded pieces and several drilled holes. It may or may not be painted at the time of this inspection.

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
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<th></th>
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Signatures:

_________________________________  _______________________
Technician                          Date

_________________________________  _______________________
Structural Engineer                  Date

_________________________________  _______________________
Manufacturing Engineer               Date

_________________________________  _______________________
Project Manager                      Date
The Wright Flyer Design Team

*Front Row (LR):* Nick Filimoehala, Jon Holfeltz, Carson Esplin, Ben Case, Wayne Goodrich, Eric Peterson, Nick Alley (project manager), Mark Karpowich (modeler), Adam Richards.

*Back Row (LF):* Amy Hintze, Nate Holman, David Christensen, Weston Allen (Draftsman).
Utah State University
Wright Flyer

The Structural Design

Center of Gravity & Power Trim

Casting the center of gravity and power trim are essential in the design of an aircraft. The center of gravity must be determined to ensure the aircraft's stability and control. The power trim determines the angle of attack required for lift, which affects the aircraft's performance.

The Project

The Wright Flyer was one of the first successful powered aircraft. Its design was a result of careful consideration of aerodynamics, materials, and structure. This project aims to replicate the Wright Flyer's design using modern materials and technology.

The Aerodynamic Design

Why the Wright Flyer Needs an Upgrade?

- Increased aerodynamic efficiency
- Improved stability
- Enhanced control

Structural Changes

- Improved fuselage design
- Reinforced wings
- Enhanced materials

Conclusion

The Wright Flyer was a significant achievement in aviation history. Its design and engineering principles remain relevant today, influencing modern aircraft design.
A Model of the 1905 Wright Flyer

Gluing Model

Building Model

Model being assembled.

Complete Model (1:4 scale)
Designing and Testing Ideas

Adam and Nick discuss the power train with Randy Chesley.

Carson and Chuck Larsen converse about the wing ribs.

Fiberglass leaf spring

Wing rib lay-up

Measuring the rib weight

Wing Warp concept in cardboard

Cockpit concept in pink

Mockup of cockpit concept
Prototyping

Wings and Carbon Fiber Tubes

Sponsor of Wavy Composites

Wavy carbon fiber lamina

Eric and Bill Pratt rolling fibers onto a spar.
Wrapping a cardboard mandrel

A wrapped mandrel

A streamline carbon fiber strut tube

Completed carbon fiber spars

Assembled wing section

Carson holding light wing section.

Too Easy!
Nate and Jon hot wiring a canard section out of foam.

Nate making canard airfoil template.

Nate sanding the canard

A canard end section

Canard mid-section
Canard center section covered in fiberglass

Nate is cutting out canard end plates.    

Jon and Nate designed and built the canard.

Surfs up, DUDE!

Canard on display
The Rudder

Jon is cutting the rib profiles.

Leading edge of a rudder section

Eric and Jon are gluing foam together.

Jon is cutting Kevlar to cover each rib.

Assembled rudder section

Finished rudder section
Random Shots

Carson -- ????

Jon at work

Eric - CHEESE!

Nick (the Boss)
“Prophet, Citizen, and Aeronautical Pioneer!”
USU engineering student Wayne Goodrich tweaks a quarter-scale replica of the original Wright Flyer, the Wright brothers' plane that flew the world's first powered flight. A full-size version will be built by USU students.

Marking a Milestone

USU students revamping historic plane for centennial fest

BY GREG LAVINE
THE SALT LAKE TRIBUNE

LOGAN — Even a century later, Utah State University, grad student Nick Alley marvels at the piloting skills of Orville and Wilbur Wright. The world-renowned brothers — who first built a plane that flew — have a new design.

USU engineering students are revamping historic Wright Flyer for centennial fest.

Alley, a senior in the Wood Science and Technology program, is part of a team of USU students working on a full-size replica of the first Wright Flyer. The team is led by senior Espen Engevold, who is also a member of the USU Wood Science and Technology program.

The replica will be similar to the original Wright Flyer, which was built in 1903. It will have a wingspan of about 25 feet and a weight of about 400 pounds.

The replica will be built from modern materials, such as carbon fiber and Kevlar, to make it more durable and easier to maintain.

The replica will be displayed at the University of Utah's Centennial Celebration, which is scheduled to take place in April 2002.

Alley said the project is an opportunity to learn about the history of aviation and to gain practical experience in the field.

The replica will be the first full-size Wright Flyer replica to be built in Utah. It will be the first full-size Wright Flyer replica to be built in the United States.

Alley said the replica will be a significant milestone in the history of aviation. He said it will be a great opportunity for students to learn about the history of aviation and to gain practical experience in the field.

Alley said the replica will be a significant milestone in the history of aviation. He said it will be a great opportunity for students to learn about the history of aviation and to gain practical experience in the field.
USU Project
More Than a Flight of Fancy

USU graduate student Nick Alley, left, and aviation program coordinator Dave Widauf show off a replica of the Wright Flyer.

USU Project
More Than a Flight of Fancy

"It was too good an opportunity to pass up," Alley said. "I've lost sleep over this. It's been really stressful."

The student designers have collectively logged about 4,000 work hours. Some of the soon-to-be graduating students will stick around this summer to build the plane.

Widauf said USU has big plans for the souped-up biplane. Once the plane is built, it will go on a barnstorming tour of Utah schools.

"Maybe we can light the fire in some kid's eyes to be an engineer," he said.

If money can be found, Widauf would like to show off the plane on the way to or from the Dayton flying festival. Just don't expect to see the Wright Flyer soaring over Interstate 80, as the plane will probably travel via truck.

"We're going to have an airplane flying, hopefully by the end of summer," Widauf said.
PLANE

Continued from B1

The two-year project set under way last semester and will culminate when the plane is flown during the Wright Flyer centennial celebration in Dayton, Ohio, in 2006.

The students spent 1,000 hours last semester getting to know everything about the original Wright plane, according to Nick Alley, a USU graduate student and the design project manager. Five of the 10 students are focusing on the structural aspect of the project, while the other five are working on the plane's aerodynamics. This semester, the students have built a quarter-scale model and soon will start work on the actual full-scale plane. The quarter-scale model was on display at "Dinoke 2002," a free high-tech exhibit at the Denver Dinosaur Park, through Feb. 22.

When they finish this plane, former So. Jake Gane wants to be the one in the pilot seat in at least one of its flights. They hope that flight will be further than the 120 feet the Wright brothers managed.

Gane, who says aviation has always been a part of his life, said it would complete his aviation career to fly a replica of the original Wright plane. Gane has flown all sorts of things, including hang gliders and experimental and home-built aircraft. In 1988, he had the opportunity to be the first person official to fly aboard the Space Shuttle.

And Gane said he's not worried about the safety of the plane.

"After all the things I've flown, I'm not the least bit concerned about crashing," he said. "I feel much safer in an airplane than a car."

Gane said he does recognize that these students face a challenge in demonstrating a plane identical to one built 100 years ago.

"There's a lot of differences in the way the Wright brothers flew and the aviation technology we have today," he said. "Not the same obstacles to overcome, but I'm confident they will overcome them."

The students themselves definitely recognize the challenges they face.

Alley said the design team is restricted more than anything else, because they want the plane to look like the Wrights' original. Another concern is making the Wrights' plane fly.

"The Wrights had very little understanding of aerodynamics," Alley said.

In the original plane, the center of gravity was behind the main wing. Alley said the team had to adjust the plane's weight so the tail end of the plane was as light as possible. Carbon fiber is in charge of the structure and design of the wings and has to deal with not only the stop-warping mechanism of the original plane to accommodate a new tail design but will have the opportunity to learn about aviation through specialized lesson plans and essay and art contests.

On its way to Ohio for the centennial, the full-size plane will follow a historical path, stopping to show off at various spots along the way. For the tour, the plane will have to fit in a 33-foot van, which means it will have to be disassembled and reassembled. Paskett said the plane's organizer is still working on an exact path and dates for the tour.

But for now, the students are just concerned about getting the plane off the ground.

"When we see the plane up and flying, it will really be worth all the effort we've put in," Case said.

E-mail: kalle@usu.edu
Senior mechanical engineering and aviation technology students are experimenting with "The Wright Stuff," to construct a modern-day replica of the 1905 airplane flown by the Wright brothers. Ten students from Utah State University were chosen to work on the project out of 21, said Nick Alley, the first-year master's student in mechanical and aerospace engineering, and the project's manager.

At a presentation Tuesday evening, Alley said the students have put in 8,000 hours to produce the research required to build a working aircraft.

"I hope everyone realizes what these students have done here," Alley said.

What they have done is to rebuild the original aircraft using modern materials to improve the stability, stall capability, drag, and to make it safer and more user-friendly, said Goodfield, a student working on the project.

"And it will be good working," Goodfield said.

Using computer programs and simulations such as Wing 2000, students studied the effects of their modifications.

Eric Peterson, a senior in mechanical engineering and they have had confidence in the reliability of the computer models predictions because they have been tested against wind tunnel experiments and compared to other programs.

Although the plane will actually be flown, these Wing 2000, aviation programs coordinate to the industrial technology and other departments, and the plane will not be making any cross-country flights because the fuel tank capacity will only allow the flights of about an hour, and the plane will not be able to handle cross winds more than five miles per hour.

"It's to prove a concept and to celebrate the Wright brothers," Widhaf said. "It fits all the ground and fits around a football field, we'll be happy."

Widhaf said ISU is the only organization to do anything like this.

There are three or four times doing exact replica, but they're not for dynamic value. We're doing something unique," Widhaf said.

The group is using local materials such as Kevlar and graphite because Widhaf said they thought there would be what the Wright brothers would use if they were building the plane today.

A quarter-scale replica model of the 1905 plane was displayed at the presentation, and students will begin full-scale construction of the USU version this summer.

Another student working on the project, Ben Cline, said the group hopes to have the plane fly by the end of summer, but it will all depend on how the building process goes.

To this point, Cline said many of the students have been putting in 30 to 30 hours each week, and many spend 60 hours over the Olympic break working on the project.

Widhaf said the students worked on the project out of "personal drive" because they only received two hours of credit for their participation.

Alley, the only female working on the project, said they have been required to spend 12 hours each week since September, even during school breaks.

"It's been a mix of work," Cline said. "But it's more than just a senior project. It's been really fun because of the magnitude of the project. It's an actual plane that will be used."

Alley said he used to watch videos and dreamed about it. Alley said, "But I also talked to the faculty." Hitchon said the enjoy seeing the models and mock-ups actually built.

"The best part is seeing your ideas and thoughts in real life," Hitchon said.

Already the group has been featured at several Olympic events and has received second place with their presentation at the Western Regional American Institute of Aeronautics and Astronautics Student Conference on April 4 through 6.

Eventually Widhaf said he hopes to use the plane to provide education and to get kids excited about technology, engineering and aviation.

"My vision is to have an outreach tour throughout Utah," Widhaf said.

Widhaf said the project will also highlight ISU and their mechanical engineering and aerodynamics programs.

"We've got a great program, here. I think we're one of the best kept secrets around," he said.

Tuesday the group presented their project to the university.

More information will be available in a few weeks on the group's Web site at www.uswright.org.
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