Light Sport Aircraft Control Systems, Folding Wings, and Landing Gear

Senior Project Final Design Report

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Abstract

The airplanes currently used for medical mission work are typically expensive, require long runways and large storage areas. This project is an attempt to provide a new product for this purpose that will reduce the capital demands of such an airplane. The goal of this project is to design and build the landing gear, brakes, wing folding mechanism, and control system for a Light Sport Aircraft. The priorities in designing are low cost, durability, simplicity, and ease of use.

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Acknowledgements

We would like to recognize a number of people for their significant contribution to our project. First, we want to thank the Messiah College Flying Club for providing the project to work on. Fellow students Joshua Joyce, Tyler Miller, and Jonathan Shenk provided valuable insights and help throughout the duration of the project. Our shop technician, John Meyer, helped us extensively with the manufacturing of project components. Finally, our project advisor Don Pratt guided us all year, providing valuable information and creative solutions to help us with the problems we faced.

1 Introduction

1.1 Description

The Light Sport Aircraft (hereafter LSA) being constructed by the Messiah College Flying Club is built to be a low cost, rugged aircraft. The purpose of our senior project was to determine the specifications for, design, build, and install the landing gear (including the braking system), wing folding mechanism, and control systems for this plane. The tricycle landing gear needed to be able to withstand a hard landing of a fully loaded aircraft without suffering damage. The brakes needed to be able to stop the plane safely in case of an aborted take-off. The folding wing mechanism had to be simple, reliable, and easy to operate while still being able to withstand full flight loads and turbulence. The goal was for one person to be able to remove a few bolts, then rotate the wing into a storage/transport position where the chord of the wing is perpendicular to the ground, and the span of the wing is parallel to the tail boom. The control system for the aircraft had several components. First, the system needed to incorporate dual controls. There are rudder pedals and a stick on both the pilot and passenger sides of the aircraft which move in sync with each other. The rudder pedals have an assembly built to connect them to the tail cartridge which controls the tail surfaces. The stick controls both the ailerons and the elevator, and is incorporated with the mixer system, which moves the ailerons into different flap positions. Because the aircraft is going to be used primarily in rural areas, the control system, wing folding mechanism, and landing gear were designed for a long service life and simplicity in maintaining and repairing.

1.2 Literature Review

There are three main methods of manipulating the flying surfaces on an aircraft. Older aircraft and small planes tend to use mechanical systems involving components such as cables, pulleys, and rods. Hydro-mechanical systems combine mechanical controls with force-enhancing hydraulics. This system tends to be used on larger aircraft dealing with significant forces, such as the Lockheed SR-71. Most large modern aircraft utilize the so-called “fly-by-wire” approach to their control systems. This essentially uses computers to control the airplane. Signals sent from the pilot controls are analyzed by a computer, which then sends the appropriate signal to the flying surfaces. For an aircraft such as the LSA, most of these planes utilize control systems that are either entirely mechanical or are a combination of mechanical and hydraulic systems. We used an entirely mechanical system for deflecting the control surfaces.

Folding wings have been used for decades, primarily on naval aircraft intended for use on aircraft carriers and other places where saving space during storage is a significant benefit. Folding surfaces (either wings or tail) are relatively rare on most general aviation and land-based aircraft, but are more common on kit and experimental planes. The benefit of a smaller “footprint” is usually not worth the added cost, complexity, and weight of the folding wings for these planes. For ultralights and light sport aircraft, this is a somewhat more popular characteristic, and many small private planes have begun to be produced in recent years with this feature. Most of these designs involve the wings being swung in plane with the chord so that they are simply pointing back toward the tail. We found many examples of this, such as the Rocky Mountain Wings Ridge Runner III (Reference 1). A less common folding method is to have the wings rotate so the chord is perpendicular to the ground while swinging the tip back toward the tail. This would be better for our application, as it creates an even smaller footprint. One aircraft that has the wings fold up before rotating back is the Zenithair STOL CH 701 (Reference 2). A plane we found where the wings rotated down before folding was the Remos G-3 (Reference 3). The geometry of our attachment points is slightly different then either of these aircraft, so our wing folding solution also had to be somewhat different.

Landing gear on small planes vary as greatly as the aircraft that they support. From the single skid on certain gliders to the massive, multi-wheel folding designs on large jets and space shuttles, landing gear are designed to meet the specific needs of the aircraft of which it is a part. The two main restrictions on the level of complexity of our landing gear are FAA regulations and cost. By law, LSAs are required to have fixed landing gear. The two standard fixed landing gear configurations are tail-dragger and tricycle gear. A tail-dragger has two primary wheels close to the front of the plane, and a small wheel or castor on the bottom by the tail. The plane is usually steered on the ground by differential braking. Tricycle gears have a single nose wheel in the front and two main wheels near the center. Steering is usually done with the rudder pedals, which also turn the nose wheel. Our aircraft is of the tricycle design, similar to small Cessnas. Many light tricycle gear planes use a single fiberglass main gear, such as the Remos G3. While this is an extremely good option, it is a little outside our price range costing about $1000 (Reference 4). Thus, we decided that designing and building our own landing gear was the best option.

1.3 Solution

1.3.1 Control Systems

The following description is referring to Figure 3 in the appendix. The control systems were designed as dual controls. Since one of the potential uses for this airplane is student instruction, dual controls allow a student to practice flying while the instructor can still retake control in an emergency. Due to the immense complications and added cost and weight, there was no redundancy built into the control systems. Instead, both the pilot and the copilot position have rudder pedals and a control stick, which connect to a single point heading toward the control surfaces (turquoise tube). Moving the control stick side-to-side causes a tube running back along the floor of the plane to rotate, tilting a differential bracket behind the cockpit (purple bracket). This bracket is attached to push rods running to control horns, which in turn are connected to the ailerons (green tubes on right). Moving the control stick forward and backward results in pulling on cables that are routed inside the tail boom tube, and cause the elevator to move up and down via a series of gears and pulleys in a self-contained unit at the back end of the tail boom tube. Pushing on the rudder pedals causes additional cables to move, turning the rudder via that same self contained unit. The nose wheel turns simultaneously with the rudder.

A handle on the tail boom tube is connected to another tube running back to the aileron differential connecting bracket (purple bracket). When the handle is turned, the tube rotates and causes the bracket to raise or lower. This activates the flaps. The controls are designed such that the flaps and ailerons can both be operated without interfering with the functionality or mobility of each other.

1.3.2 Landing Gear

The style of landing gear chosen for the LSA is a tricycle configuration. The design for the front gear which we chose to implement was a telescoping shaft, which slides through tubes welded to the frame of the LSA. There is also a tube connected to the shaft which the rudder pedals are connected to via two push rods. This allows the LSA to be steered on the ground by the rudder pedal system (Fig 7). The suspension for the front landing gear is also connected to this tube. For the first few flights we have decided to use shock cord as the spring material for the suspension of the front gear. This will allow those testing the LSA to determine the proper spring constant for the front suspension experimentally. Then, after the spring constant has been determined a front spring can be procured, providing a more permanent solution. The main gear is a linked pivot system utilizing a fiberglass pultruded rod as the main spring. The rear suspension is made up of two steel legs which pivot and a steel tube for housing one or more fiberglass rods (Fig 4,5, 11). We decided that using two or three fiberglass rods would solve the problem which we had in finding a single acceptable rod. Two rods in parallel will add strength and thus give us the desired spring rate. The fiberglass pultruded rod assembly will be supported by bump-stops if the LSA is subject to a particularly rough landing.
The brakes which are installed on the LSA are mechanically actuated drum brakes from Azusa (Reference 8). The drums for these brakes are mounted to the wheel rims by bolts and 1 inch spacers, and the caliper insert is mounted to the axle by bolts attaching to a welded plate. These brakes are actuated by a cable-in-sheath method found on many mechanical braking systems. The cable runs into the cabin of the LSA, is mounted to the main boom tube with a clamp, and is actuated by a handle.

1.3.3 Wing Folding

The final design of the wing folding mechanism makes use of a two stage process. In the first step, the trailing edge of the wing rotates up (Fig 10b). To achieve this motion, the bolts connecting the main and trailing spars to the fuselage must first be removed. The wing is then free to pivot about an axis running from the strut/main spar connection to the fuselage/main spar connection. In the second step, the wing slides down while being rotated to the rear of the aircraft (Fig 10c, d). In order to maintain correct geometry throughout these processes, the strut connections at the wing must be able to rotate about 2 axes, and the strut connection at the fuselage around 3 axes. The main spar/fuselage connection must be a translating rotating joint, which could be built a rail sliding through a pivoting hook. The only tools needed to complete this operations is a wrench for removing bolts.

2 Design Process

2.1 Control Systems

The goal of the control system is to separate stick movements into two distinct groups, and to send those movements to the appropriate control surfaces. Forward and backward stick movement control the elevator, while side-to-side control the ailerons. Keeping these motions separate was the challenge for this system. In our first design (Fig 1), the sticks pivoted inside a gimble type device, which allowed for full rotation about two axes. A cross tube connecting the outer shell of the gimbles transferred fore and aft motion between the sticks. A tube running toward the back of the aircraft carried the aileron motion. Pushrods connected the bottom of the sticks to a control horn on this tube. This achieved dual purposes of turning side-to-side stick movement into rotation of the aileron tube, and transferring motion between the two sticks. The main problem encountered with this design was that the pushrods constrained the sticks from moving freely. As the stick was pushed forward, the rods would hold onto the bottom of the sticks, effectively causing the top of the stick to move in a slight arc. The result is that forward/backward and side-to-side movements of the stick were not independent in this design, which was undesirable.

Our second design (Fig 2) kept some of the aspects from the original system, while changing some things to correct for previous problems. The gimble setup for mounting the stick was kept the same, as was the aileron tube running toward the rear of the aircraft. The pushrods from the previous design were eliminated, which helped to solve the stick arc issue. A new box like mechanism was created to transfer sideways stick movement to the aileron tube. This design allowed the stick to slide forward and backward within the stationary box, but for the box to rotate with side-to-side stick movement. A method for activating flaps was also a part of this design. The aileron tube had a universal joint half way along its length. If the far end of the tube was lowered or raised, the initial position of the ailerons would change accordingly. While this design solved the problem of stick arc, it created a situation where sliding would be occurring often. As this could cause excessive wear on parts, this design was also not desirable.

Our final design (Fig 3) was a combination of the first two iterations with a few small changes. The rotating box from the second design was eliminated because of the wear issue, and two pushrods similar to the first design were put in place. It was determined that while these rods would still cause some stick arc, that change would be less then 1° from vertical, which is an acceptable amount. The gimble mechanism was also changed, so that the fore/aft movement axis and side-to-side movement axis no longer intersect. A new flap mechanism was designed, controlled by a second tube surrounding the aileron tube. The elevator system was created during this iteration also, as a series of pushrods connected to control horns and pulleys. This final design eliminated the wear problem of the second design, and reduced the amount of stick arc experienced in the first design to an acceptable level

2.2 Landing Gear and Brakes

While designing the main landing gear, our group looked at three different options: having both gear legs fixed, connected the legs together with a spring (Fig 5) and placing a fiberglass rod between the legs (Fig 4, 11). It was decided that because this aircraft would be operating from dirt and grass fields, having some form of shock absorption would be best. This choice eliminated the option of having a fixed gear. We then looked at the difference between having a spring and a fiberglass rod span the gap between the gear legs. When the aircraft makes a turn while on the ground, it will tend to roll toward the outside. Having a spring between the gear legs would tend to increase this amount of roll in turns, because it pushes down on the inside wheel (which has less weight on it) artificially adding a torque to the fuselage. A fiberglass rod would have the opposite effect in a turn. The inside wheel will be pulled off the ground because of the bending moment in the rod, which will cause the plane to level out. For this reason, we determined that a fiberglass rod is best for this application.

For the nose gear, we again examined four different possibilities: a fixed gear, a spring (Fig 6), rubber inserts, and shock cord. A fixed nose gear was eliminated for the same reason as a fixed nose gear, the need for shock absorption on rough airstrips. Rubber inserts were eliminated because they provide only minimal vibration dampening, not the large deflection required in the original specifications. A spring seemed ideal, in that we could specify the exact size and spring constant we wanted. However, finding the exact product we were looking for turned out to be difficult, and ordering a custom spring would have been extremely expensive, so this option was eliminated. Our final choice for the nose gear was to use shock cords. These are a good alternative to springs, as they are cheap, readily available, and easily adjustable.

For the brakes, our group looked at three different options: none, disk, and drum. While not having brakes is a viable alternative for many small aircraft, the desire for the LSA to be a STOL capable aircraft made brakes a necessity. Disk brakes seemed well suited for our application, as their functionality doesn't degrade if they are wet or dirty. However, mounting disk brakes to the existing wheels turned out to be a major challenge, and the caliper would end up being very exposed. We selected drum brakes in the end, as they are cheaper then disk brakes, easily found, and are much simpler to mount.

2.3 Wing Folding

There were three major design iterations that the wing folding mechanism went through during its development. Our first idea (Fig 8) was to have the rear spar attached to the fuselage through a joint capable of rotation on two axes. The main spar would be disconnected, allowing the wing tip to drop down and rearward. We quickly discovered that leaving the strut attached in this configuration would cause an impossible final wing position, with the tip pointed more downward then rearward. The second method we looked at for folding the wings (Fig 9) involved detaching the rear spar, rotating the trailing edge down, then folding the whole wing toward the back of the aircraft. For a while, this appeared to be an optimal solution as it would be easily operable by one person. Upon performing some more detailed calculations, we observed that the path along which the wing moved would cause it to hit the fuselage in multiple places. The only way to prevent this would be to add another step where the wing is first pulled away from the fuselage. However, the additional hardware required for this step would be too complicated to be practical. In our third and final design iteration (Fig 10), the rear spar is disconnected and the trailing edge rotated up. The wing is then free to slide down along a rail at the root of the wing, while swinging the tip toward the back. This design appears to solve the geometry problems experienced by the first two iterations, but may be difficult for a single person to operate, which was one of our original goals for the wing folding.

3 Implementation

3.1 Construction

We started the year by updating a previous full-scale mock-up of the LSA frame. We then used this frame for brainstorming ideas for both the wing folding mechanism and the control system. This gave us the ability to check clearances and feasability of design for the various ideas which we discussed. We found that the flap mechanism which last year's senior project was not a stable design, and not very efficient. Also the control system itself operated off some of the same ideas which we eventually chose for our final design, but needed much work to be fully functional. The wing folding design was from last years senior project was no longer assembled, so we had no physical representation of that design. One of the big issues which we dealt with both in the mock-up and designing phases was how to create the control system in such a way that it would be compact and out of the way, while still performing every function needed safely. Once we had a fairly solid idea of how things could fit into the frame, we began to focus on doing more analysis of our ideas than physical checks. All of the mock-up work was done during the fall semester. During the spring semester we constructed the final design of the control system, and installed that system into the plane. Because of time restraints we were forced to use temporary mock-up parts in some places. We have also installed the brake system which we selected. One of the major things we learned in the spring semester is how many details have to be worked out before a design can be implemented. Once we had the key design points down, we had to determine all of the connection and mounting details for various components before we could start the final construction. The final construction itself was started later than was desired, but we did construct nearly all components of our project which were possible. One of the issues we had to deal with in our final construction was the quality of workmanship needed for aircraft grade parts. Because our group only began learning how to machine pieces this year, many of our initial parts with were below acceptable standards with insufficient accuracy and many sharp edges. Eventually our fabrication skills began to improve, but there was not enough time left to redo the necessary parts. At the end of construction, our systems were operational and accurate of how the final product will be, but some portions will have to be rebuilt with better tolerances before the aircraft is flight worthy.

3.2 Operation

This project had five main objectives at its conception, along with a short list of specifications. During the design and construction stages, all parts were built based on theoretical predicted behavior under certain conditions. The testing we did was carried out post-construction to determine whether or not we had met these goals

3.2.1 Brakes

The specifications for the braking system were that it stop a 1000lb plane traveling at 50mph in 300 feet, and be able to hold the aircraft stationary while spooling up the engine during takeoff (estimated 400lbs of thrust). To test the static holding requirement, we activated the brakes via the handle, then applied force to the fuselage. We found that the aircraft began rolling forward at a force much less then 400lbs, meaning that we did not achieve our original objective. This result could be due to excessive play in the brake system through the stretching of cables, and the brakes themselves could still be capable of achieving the necessary holding force. We are unable to test the dynamic stopping power as the aircraft is not yet capable of traveling at 50 mph.

3.2.2 Main Landing gear

The original criteria for the main landing gear were that it be capable of absorbing a 4g impact of a 1000lb aircraft without permanent damage. We determined that no single system would give us the results we desired, and proceeded to build a system suitable for a 2g impact. After 2g is reached, the system is designed to bottom out on rubber stops, while still sustaining no damage. We determined through theoretical calculations that the fuselage should drop 1.1" under 1g loading, and 2.7" under 2g loading. We did not perform a physical test here, as the fiberglass rods necessary for the system were not obtained. When the main landing gear is finished, we anticipate that it will meet our 2g deflection objective.

3.2.3 Nose gear

For the nose gear, the objectives stated that it experience 1in of deflection under 150lbs, and 3in of deflection under 450lbs of force. Because low quality bungee cords are temporarily attached to the nose gear as placeholders, this objective was unable to be tested. When shock cords are attached in the future, we anticipate that it will meet the original criteria.

3.2.4 Control system

The specifications for the control system were unique in that they were mostly geometrical constraints. The system was designed so that full deflection of ailerons and elevator would occur at 25 degrees of stick movement. The control stick was also designed to travel within a 1ft box. The ailerons were specified to move 15 degrees down and 25 degrees up at full stick deflection. The criterion for the flaps is that they lower the initial aileron position by 30 degrees. All of these were testable simply by moving the appropriate device, and recording the deflection at the specified distance. We found that all deflections were very close to their required values. When we account for the extra play in our system due to a few temporary parts which were quickly built, we can anticipate that the finished system will meet our objectives. The control system is also specified to provide 4lbs feedback to the pilot per g, but this test was not carried out as it requires flight data.

3.2.5 Wing folding

The original stated objectives for the wing folding system are that it can be operated by one person in 10min or less with no special tools. As this system was only designed and not built, physical testing is impossible. Determining the operation will have to be carried out in the future when the system is eventually constructed.

3.2.6 General

In addition to the operational criteria of the above systems, we determined two additional specifications for this project. First, time between lubrication of joints is 50 hours. Secondly, MTBF is 600 flight hours. Testing could not be done in these areas as they require flight data.

4 Schedule

Our proposed schedule, as well as the actual dates of completion of tasks, is found in the appendix in the form of a Gantt chart. While we were able to complete all tasks in time that had external deadlines—in this case, dates that assignments were due—much of the rest of the schedule was inaccurate. The main area in which the schedule fell apart was in the area of design. We had originally hoped to have the last of our designing done in January, with the bulk of it done in December. Instead, we finished most of our designs in April. As a result of this, our construction and testing timelines were thrown off. Construction was supposed to be done by mid-March, but we were still in the process of constructing the control systems in May. Similarly, we hoped to be testing our parts of the airplane before May, but some of this was never accomplished. Contributing to the missed deadlines were three main factors. First, none of the goal finish dates were chosen with any accurate data to back them up. We had never done a project like this before, and so all the estimates of how long things would take were simply guesses. Second, the amount of time it took us to do the preliminary mockup revision was disproportional to the level of its importance, spending a large portion of the time in the fall working on getting the model to more accurate dimensions. Third, being required to meet class deadlines threw off our initial planning considerably. We went into the project planning to do mockups of everything that we were designing, and using the mockups to guide us toward final designs. However, with the rough draft of the design report (EDR) due November 11, we could not continue with our original schedule. At this stage, we were still working on the designs of the folding wings, and had to abandon that work in order to meet the requirements of the report.

Finally, the manner in which the project had to be run in order to be a class made it impossible to follow the typical process of engineering projects. The start of the project was defining the objectives and specifications, before we knew how accurate or realistic those goals would be. Typically, a project begins with designs and prototyping, then revises the designs and develops specific objectives. However, due to the nature of the class, this was not a possibility.

5 Budget

A brief breakdown of expenditures by material type can be seen here. A more detailed breakdown including where the material was used can be found in the appendix.

$51.33	Steel Tube
$26.97	Steel Plate
$17.85	Aluminum Tube/rod
$79.95	Hardware (bolts, nuts, rod ends)
$110.73	Brakes
$286.83	*Total*

6 Conclusions

Overall, our project made some great success. There were some areas which did not develop as far as we would have hoped, but there were some extenuating circumstances which prevented the development of those designs.

6.1 Control Systems

The control systems which we designed and constructed came together very well. All of the components fit fairly well and work as designed. There are some issues with play in a couple of the joints, but these are minor and can be easily fixed or improved. There are also a few joints in the rear vertical tie-rods which need to be constructed, and the flap actuation system needs to be designed and constructed. In terms of our objectives, we did achieve all of the goals which we had set out for each section of the control system, and the system is close to being able to be tested for additional reliability objectives.

6.2 Landing Gear/ Brakes

On the landing gear and brakes systems, we made fair progress. We did select a braking system, design the mounting and actuating mechanisms and construct and install this system. We were only able to do minor testing of our objective, and further testing is an area which can be suggested for future work. For the suspension of the landing gear, we finished the design of both the front and rear suspension, and assembled a prototype front suspension. Because we did not have enough time to finish the construction of these parts we were not able to do any testing for the objectives. We did notice however, during a fully loaded test run for the engine, with the rear suspension fixed, that the frame for the rear suspension was deflecting due to the loading. This indicates that eventually the rear suspension will need to be assessed for strength and possibly redesigned.

6.3 Wing Folding

The design of the wing folding mechanism was not completed. This was because the final design of the wings has still not been finished. Because of this we still do not know some of the critical dimensions which are essential to the design of a wing folding mechanism. We did spend a considerable amount of time in conceptual design of the mechanism, and came up with a plausible design which may be applicable to the wings which are being built. Because we did not construct the wings we were not able to verify whether or not we did meet our objectives.

7 Recommendations for Future Work

The next step for this project after our group is to finish up the areas of the project that we did not complete. For example, a very viable option for another project could be to focus solely on the wing-folding mechanism. Our team made some significant progress in this area, but there are still major issues which need to be resolved before the wings can fold reliably and quickly. Another design detail which we were not able to include is the removable passenger control stick. This would create more cargo space, and allow a stretcher to be put in place, which is one of the primary purposes for building the LSA. Another option for future work would be to determine a viable maintenance schedule for the various systems which make up the LSA. This would allow the LSA to be deployed into the field in a much more operative manner, giving the operator and mechanic specific guidelines for the maintenance of the aircraft. More work could also be done on the brakes, by continue designing the system which would be more reliable and effective. There are also a few small details which need to be finished up before the control system is full functional. As mentioned in the construction section, the amount of play and friction in the control system can be assessed and dealt with. The design and construction of the flap handle and related parts also need be designed and constructed. The vertical push rods need to have ends machined and installed. Also the cross-tube for the control system needs to have stops welded into place to restrict lateral movement in the bearing surfaces. When working on these projects, it is important to star early, especially on construction. This helps in staying on schedule and continually making process

References

1. www.realflying.com

2. www.zenithair.com

3. www.remos.com

4. Aircraft Spruce
   452 Dividend Drive
   Peachtree City, GA 30269
   770-487-2310
   www.aircraftspruce.com

5. 886A Lebanon Street (rear)
   Monroe, Ohio 45050
   1-800-676-6636
   www.Appcokarting.com

6. Dillsburg Aeroplane Works
   114 Sawmill Rd
   Dillsburg, PA 17019
   717-432-4589

7. World Cup Ski and Cycle
   4500 Gettysburg Road
   Mechanicsburg, PA 17055

8. www.azusaeng.com/brakes/5brk.html

Appendices

Detailed Budget

	Total	Source	Use
Steel Tube (4130)			
.3125" x .035" x 18"	$3.15	Dillsburg Aeroplane Works	Rudder cable guides
1.25" x .058" x 6"	$1.55	Dillsburg Aeroplane Works	Flap tube mounts
1.125" x .035" x 48"	$10.40	Dillsburg Aeroplane Works	Flap tube, Upper aileron mounts
.875" x .058" x 6"	$1.35	Dillsburg Aeroplane Works	Bolt on control horns
.75" x .035" x 78"	$13.00	Dillsburg Aeroplane Works	Aileron tubes
1" x .035" x 60"	$11.50	Dillsburg Aeroplane Works	Cross tube, Sticks
.375" x .058" x 12"	$2.80	Aircraft Spruce	Bolt guides
.625" x 11"	$7.58	Dillsburg Aeroplane Works	Axle
.625" x .058" x 60"	$0.00	Messiah College Flying Club	Control system mounting
Steel Plate (4130)			
.125" x 2" x 24"	$9.20	Dillsburg Aeroplane Works	Control horns
.125" x 4" x 18"	$11.25	Dillsburg Aeroplane Works	Control horns, Stick boxes
.190 x 4" x 6"	$6.52	Dillsburg Aeroplane Works	Brake plate mounting
Aluminum Tube/ Rod (6061T6)			
.625" x .058" x 78"	$12.35	Dillsburg Aeroplane Works	Control system pushrods
.5" x 66" (solid)	$5.50	Dillsburg Aeroplane Works	Control system pushrods
Hardware			
.1875" Rod Ends (4)	$15.80	Dillsburg Aeroplane Works	Control system
.25" Rod Ends (10)	$35.00	Dillsburg Aeroplane Works	Control system
Assorted Bolts and Nuts (Temporary)	$29.15	Lowes, Home Depot	Control system
Brakes			
Shoes - Azusa 5" (pair)	$53.92	Appcokarting.com	Brake system
Drum - Azusa 5" (pair)	$18.76	Appcokarting.com	Brake system
Shipping	$9.78	Appcokarting.com	
Cables (3)	$8.97	World Cup Ski and Cycle	Brake system
12ft Housing (sleeve)	$12.00	World Cup Ski and Cycle	Brake system
Adjustment Barrels (2)	$5.98	World Cup Ski and Cycle	Brake system
Tax	$1.32	World Cup Ski and Cycle	
	$286.83	**Total Cost**	

Figures

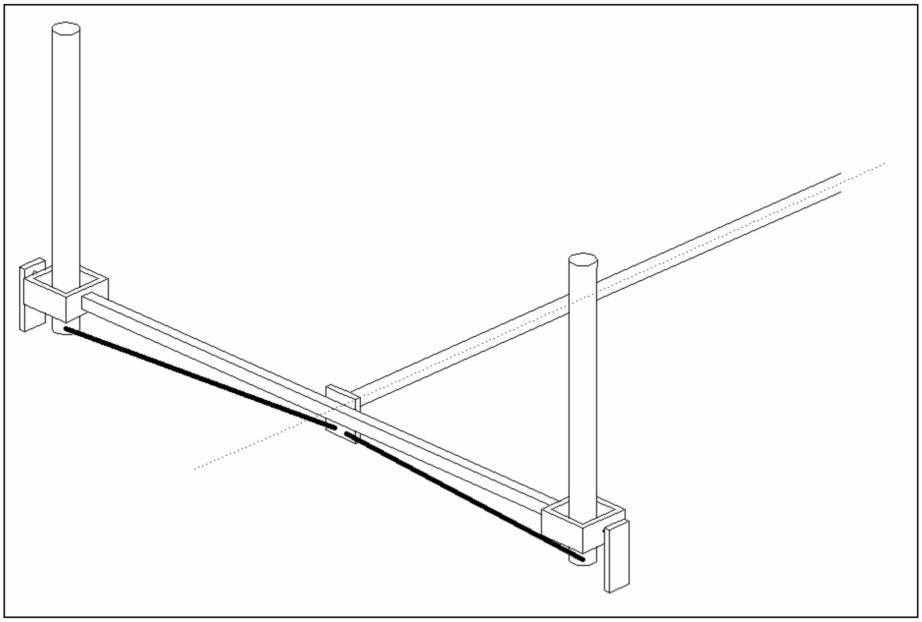


Figure 1

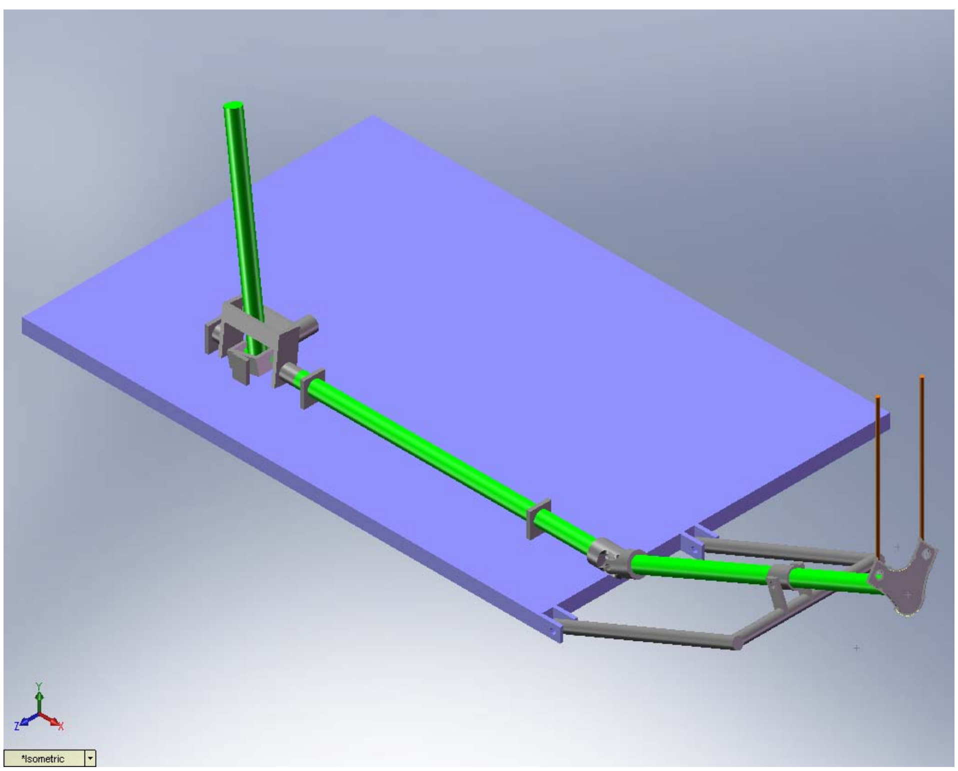


Figure 2

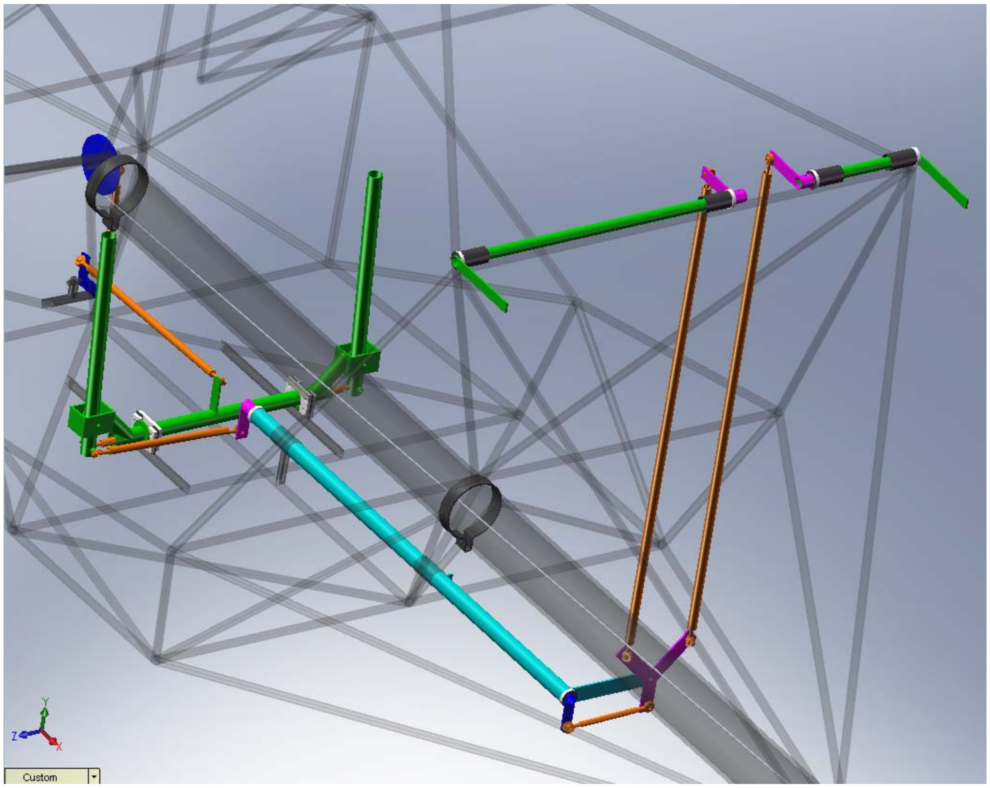


Figure 3

Figure 4

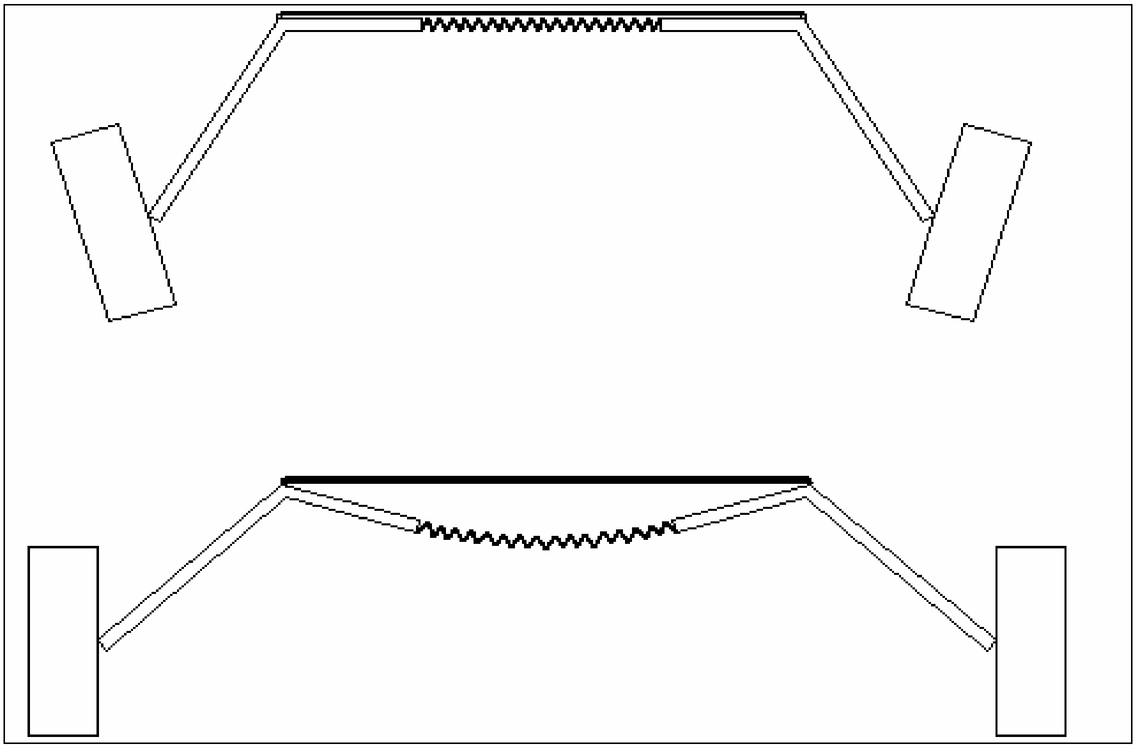


Figure 5

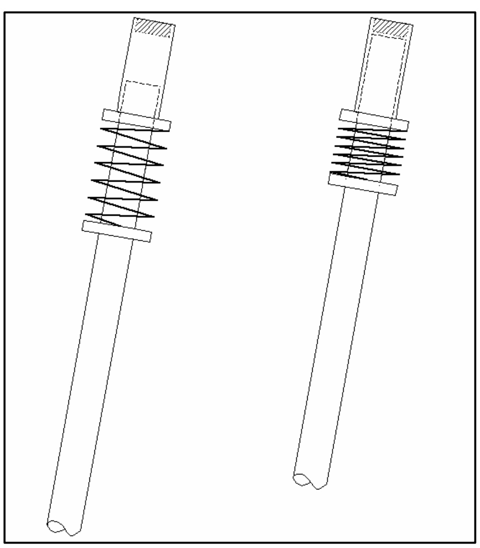


Figure 6

Figure 7

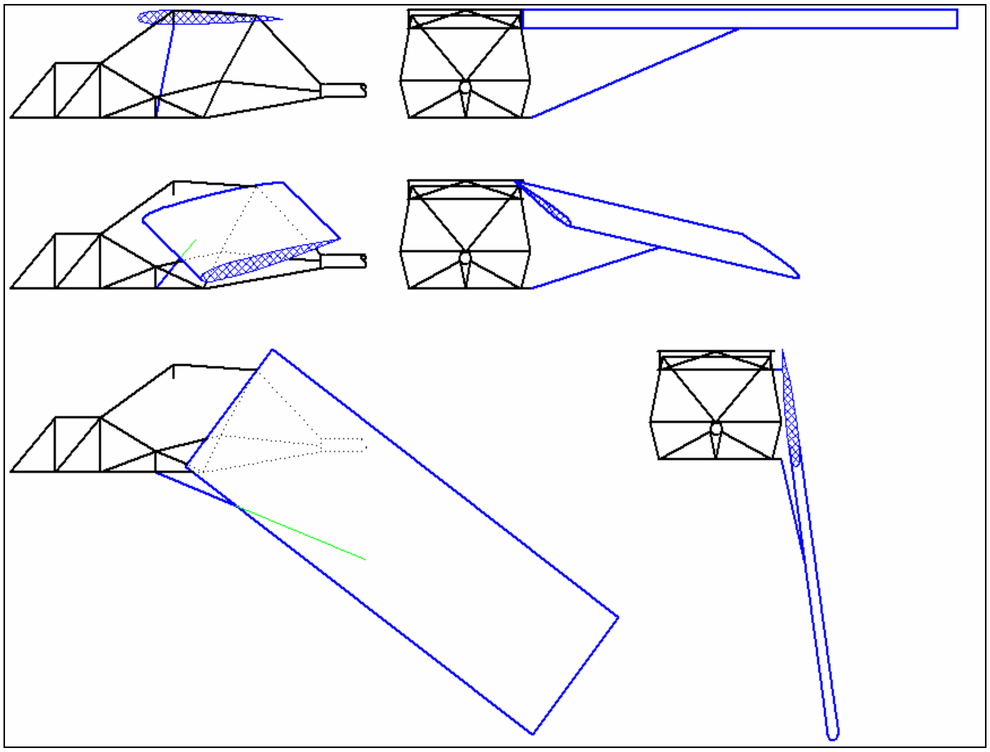


Figure 8

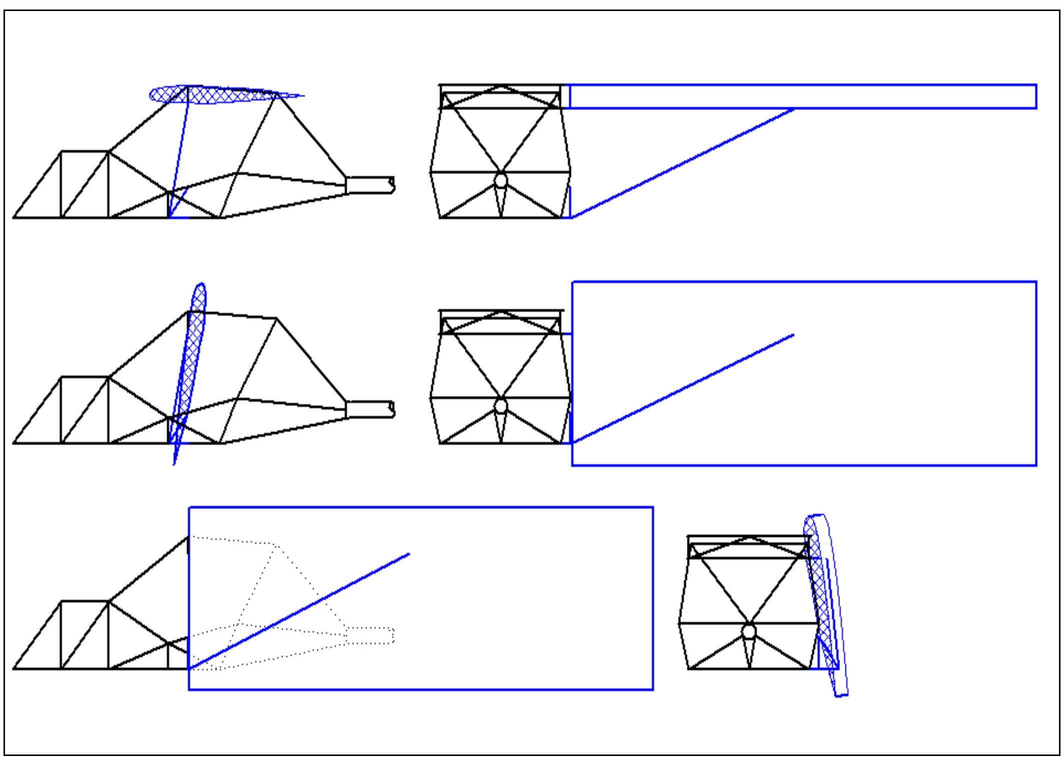


Figure 9

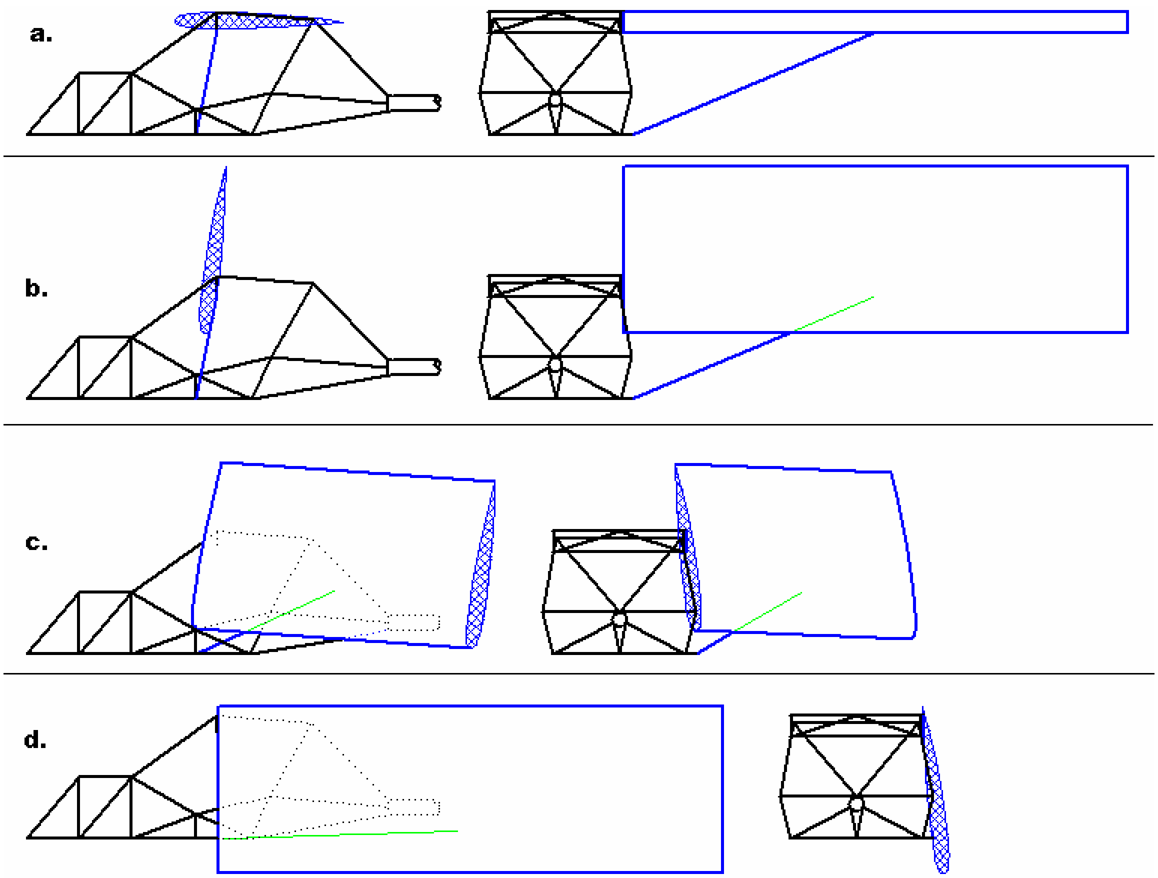


Figure 10

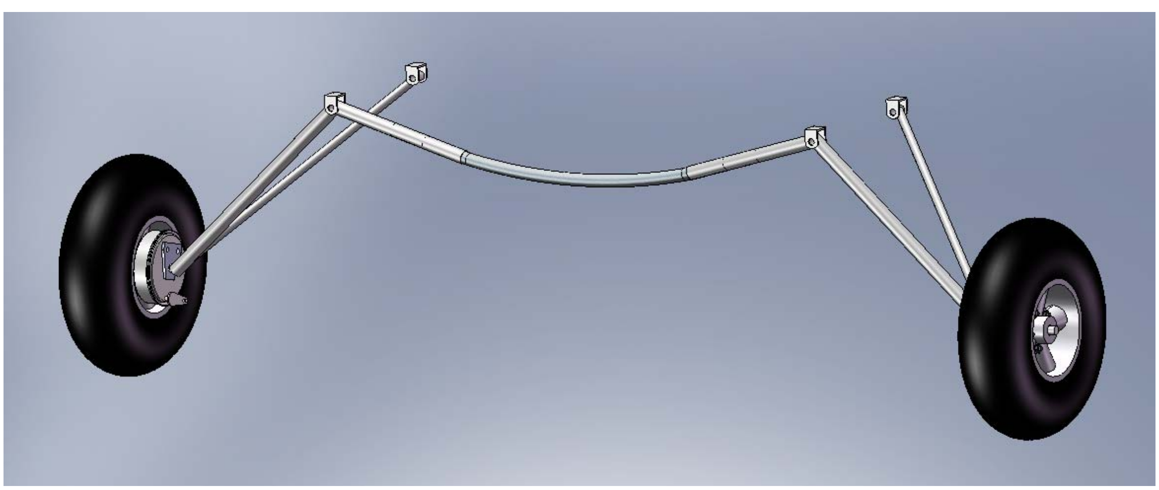
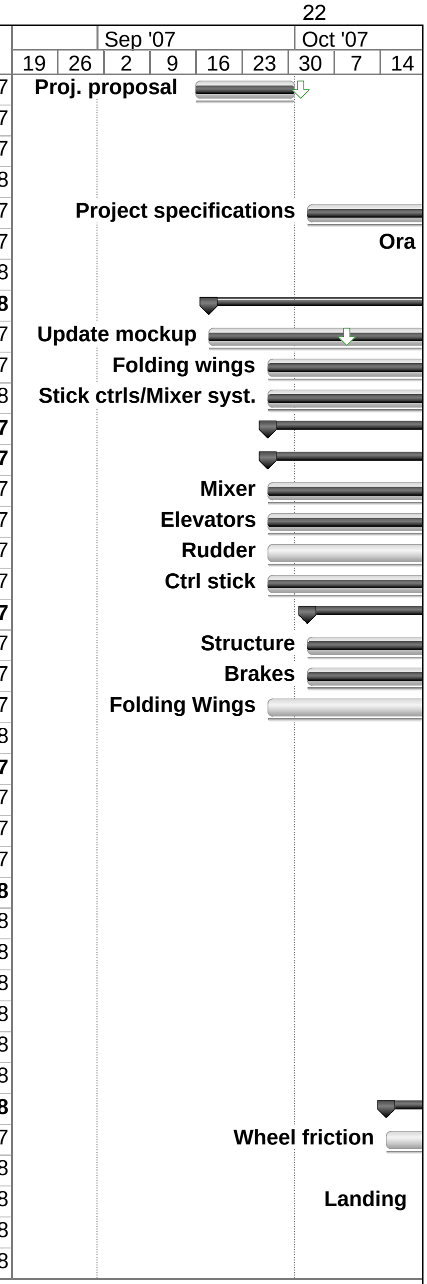
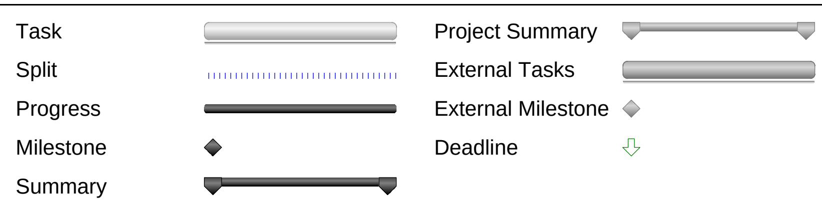


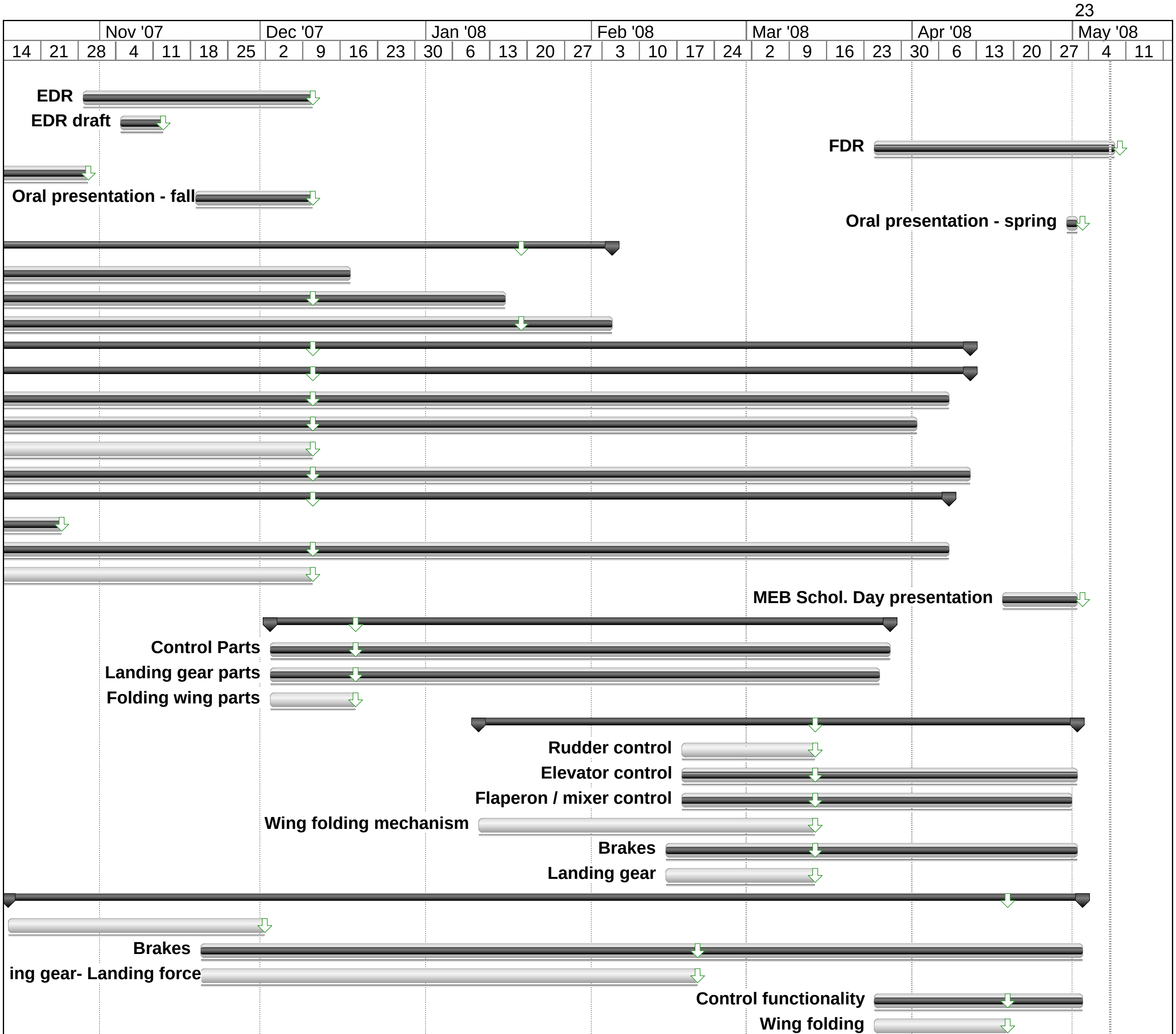
Figure 11

ID	Indicators	Task Name	Start	Actual Finish	Deadline
1	✓	Proj. proposal	Sun 9/16/07	Sun 9/30/07	Mon 10/1/07
2	✓	EDR	Mon 10/29/07	Mon 12/10/07	Mon 12/10/07
3	✓	EDR draft	Mon 11/5/07	Mon 11/12/07	Mon 11/12/07
4	✓	FDR	Tue 3/25/08	Thu 5/8/08	Fri 5/9/08
5	✓	Project specifications	Wed 10/3/07	Mon 10/29/07	Mon 10/29/07
6	✓	Oral presentation - fall	Mon 11/19/07	Mon 12/10/07	Mon 12/10/07
7	✓	Oral presentation - spring	Wed 4/30/08	Thu 5/1/08	Fri 5/2/08
8	✓	**Prototype construction**	**Tue 9/18/07**	**Mon 2/4/08**	**Fri 1/18/08**
9	✓	Update mockup	Tue 9/18/07	Mon 12/17/07	Mon 10/8/07
10	✓	Folding wings	Thu 9/27/07	Tue 1/15/08	Mon 12/10/07
11	✓	Stick ctrls/Mixer syst.	Thu 9/27/07	Mon 2/4/08	Fri 1/18/08
12	!	**Design**	**Thu 9/27/07**	**NA**	**Mon 12/10/07**
13	!	**Control Systems**	**Thu 9/27/07**	**NA**	**Mon 12/10/07**
14	✓	Mixer	Thu 9/27/07	Mon 4/7/08	Mon 12/10/07
15	✓	Elevators	Thu 9/27/07	Tue 4/1/08	Mon 12/10/07
16	▦	Rudder	Thu 9/27/07	NA	Mon 12/10/07
17	✓	Ctrl stick	Thu 9/27/07	Fri 4/11/08	Mon 12/10/07
18	✓	**Landing gear**	**Wed 10/3/07**	**Mon 4/7/08**	**Mon 12/10/07**
19	✓	Structure	Wed 10/3/07	Wed 10/24/07	Wed 10/24/07
20	✓	Brakes	Wed 10/3/07	Mon 4/7/08	Mon 12/10/07
21	▦	Folding Wings	Thu 9/27/07	NA	Mon 12/10/07
22	✓	MEB Schol. Day presentation	Fri 4/18/08	Thu 5/1/08	Fri 5/2/08
23	!	**Order Parts**	**Mon 12/3/07**	**NA**	**Tue 12/18/07**
24	✓	Control Parts	Mon 12/3/07	Thu 3/27/08	Tue 12/18/07
25	✓	Landing gear parts	Mon 12/3/07	Tue 3/25/08	Tue 12/18/07
26	▦	Folding wing parts	Mon 12/3/07	NA	Tue 12/18/07
27	!	**Construction**	**Fri 1/11/08**	**NA**	**Thu 3/13/08**
28	▦	Rudder control	Mon 2/18/08	NA	Thu 3/13/08
29	✓	Elevator control	Mon 2/18/08	Thu 5/1/08	Thu 3/13/08
30	✓	Flaperon / mixer control	Mon 2/18/08	Wed 4/30/08	Thu 3/13/08
31	▦	Wing folding mechanism	Fri 1/11/08	NA	Thu 3/13/08
32	✓	Brakes	Fri 2/15/08	Thu 5/1/08	Thu 3/13/08
33	▦	Landing gear	Fri 2/15/08	NA	Thu 3/13/08
34	!	**Testing**	**Mon 10/15/07**	**NA**	**Fri 4/18/08**
35	▦	Wheel friction	Mon 10/15/07	NA	Sat 12/1/07
36	✓	Brakes	Tue 11/20/07	Fri 5/2/08	Wed 2/20/08
37	▦	Landing gear- Landing force	Tue 11/20/07	NA	Wed 2/20/08
38	✓	Control functionality	Tue 3/25/08	Fri 5/2/08	Fri 4/18/08
39	▦	Wing folding	Tue 3/25/08	NA	Fri 4/18/08



Project: GanttChart.mpp
Date: Thu 5/8/08





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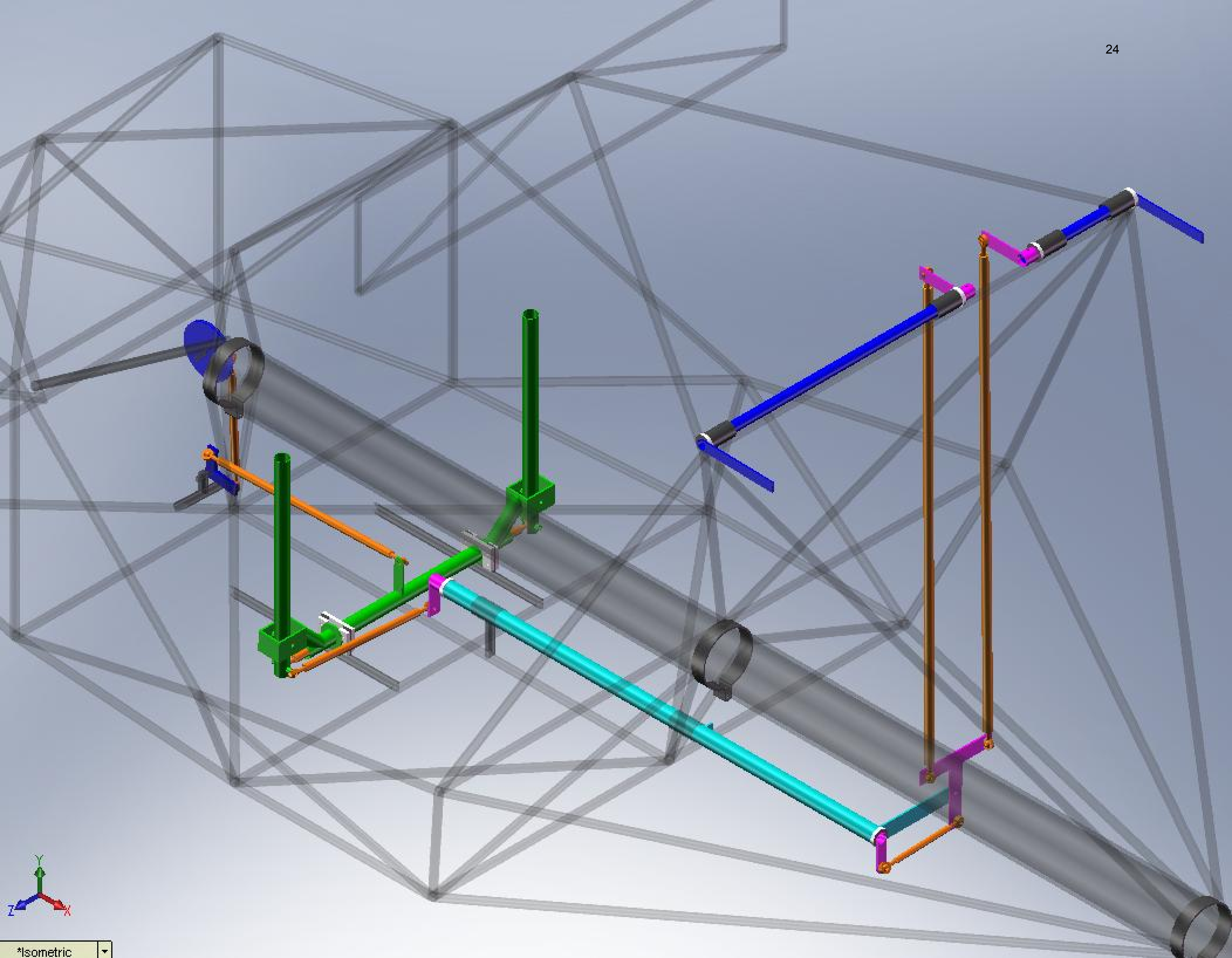
Date: Thu 5/8/08

Task		Project Summary	
Split		External Tasks	
Progress		External Milestone	
Milestone		Deadline	
Summary			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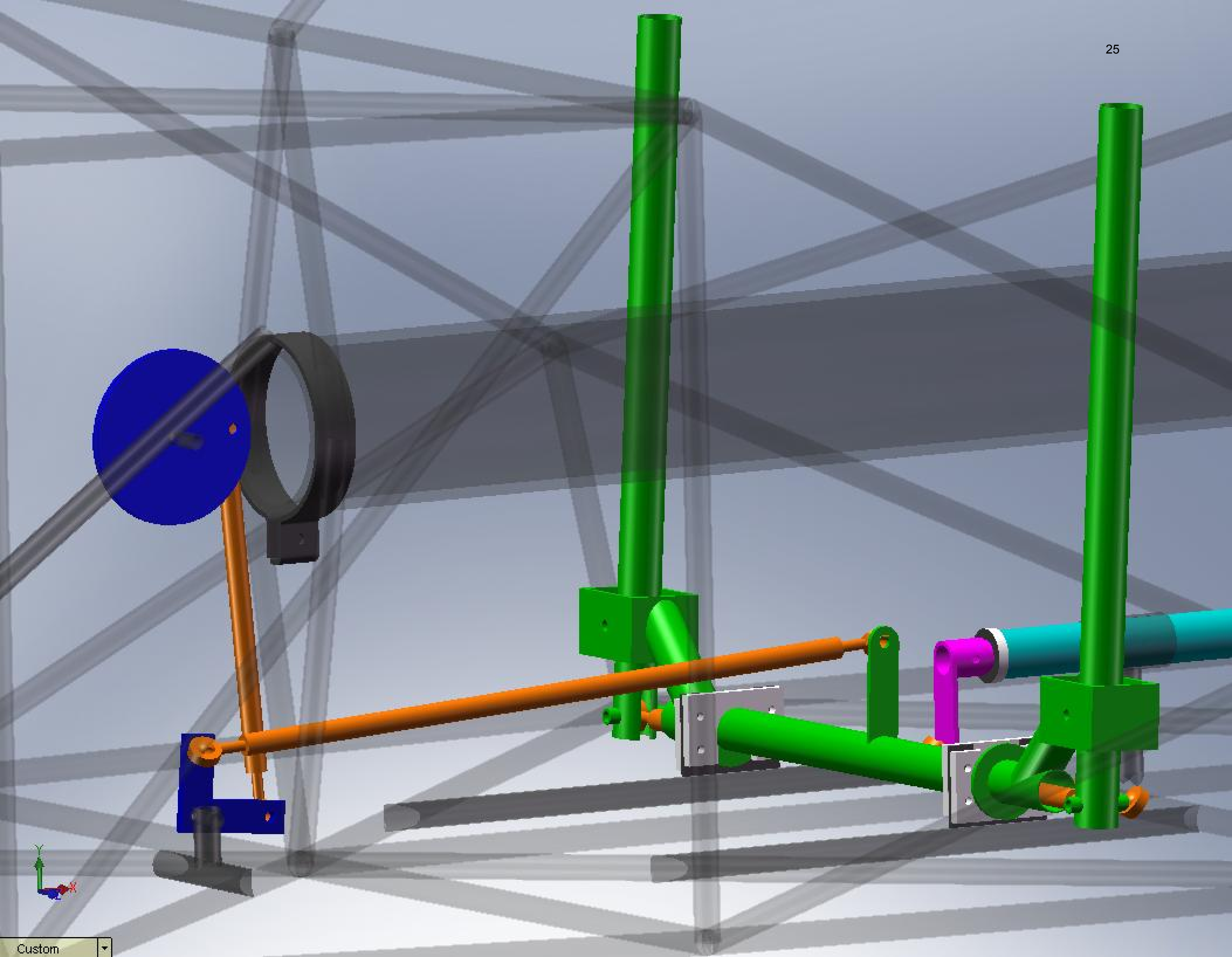
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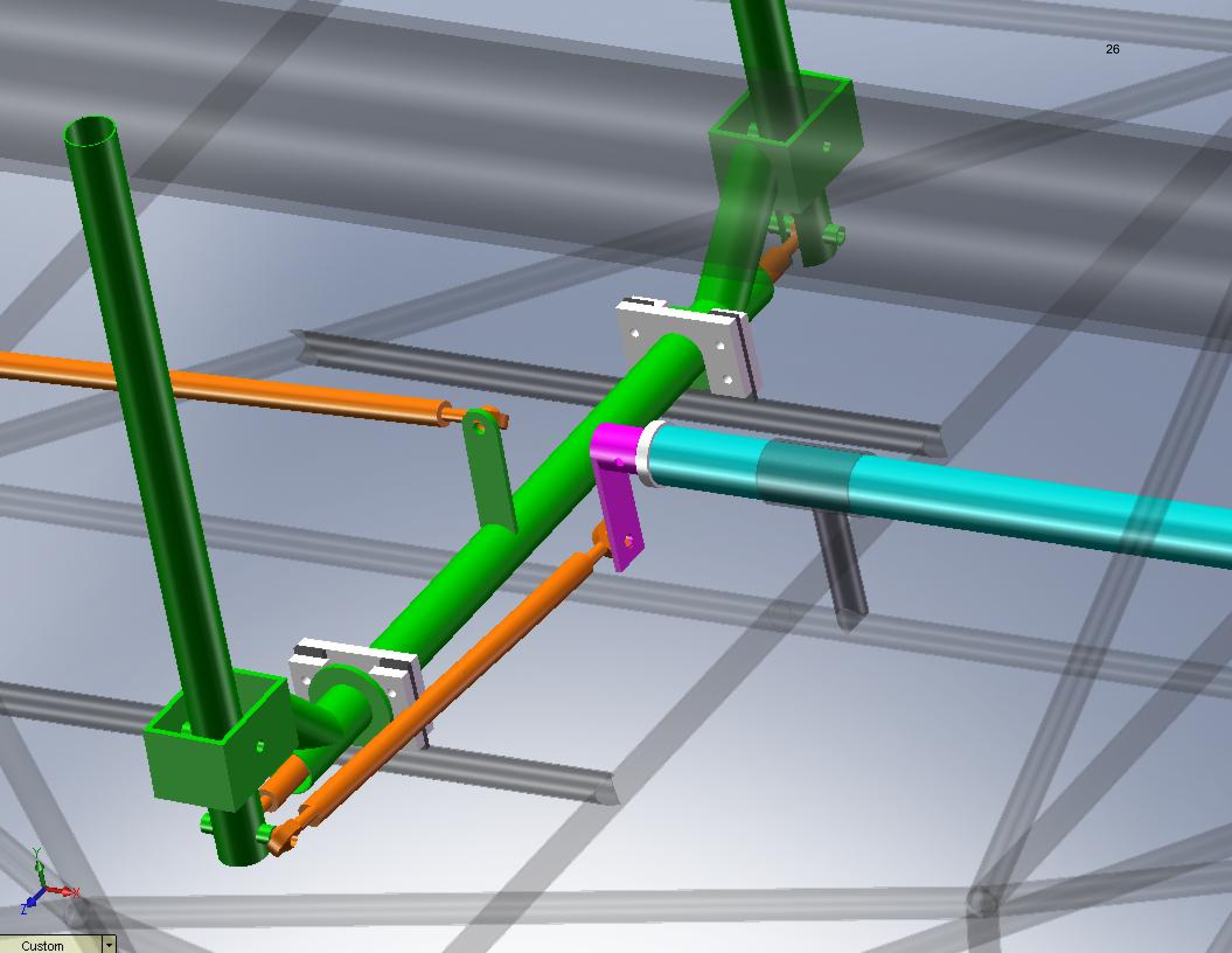
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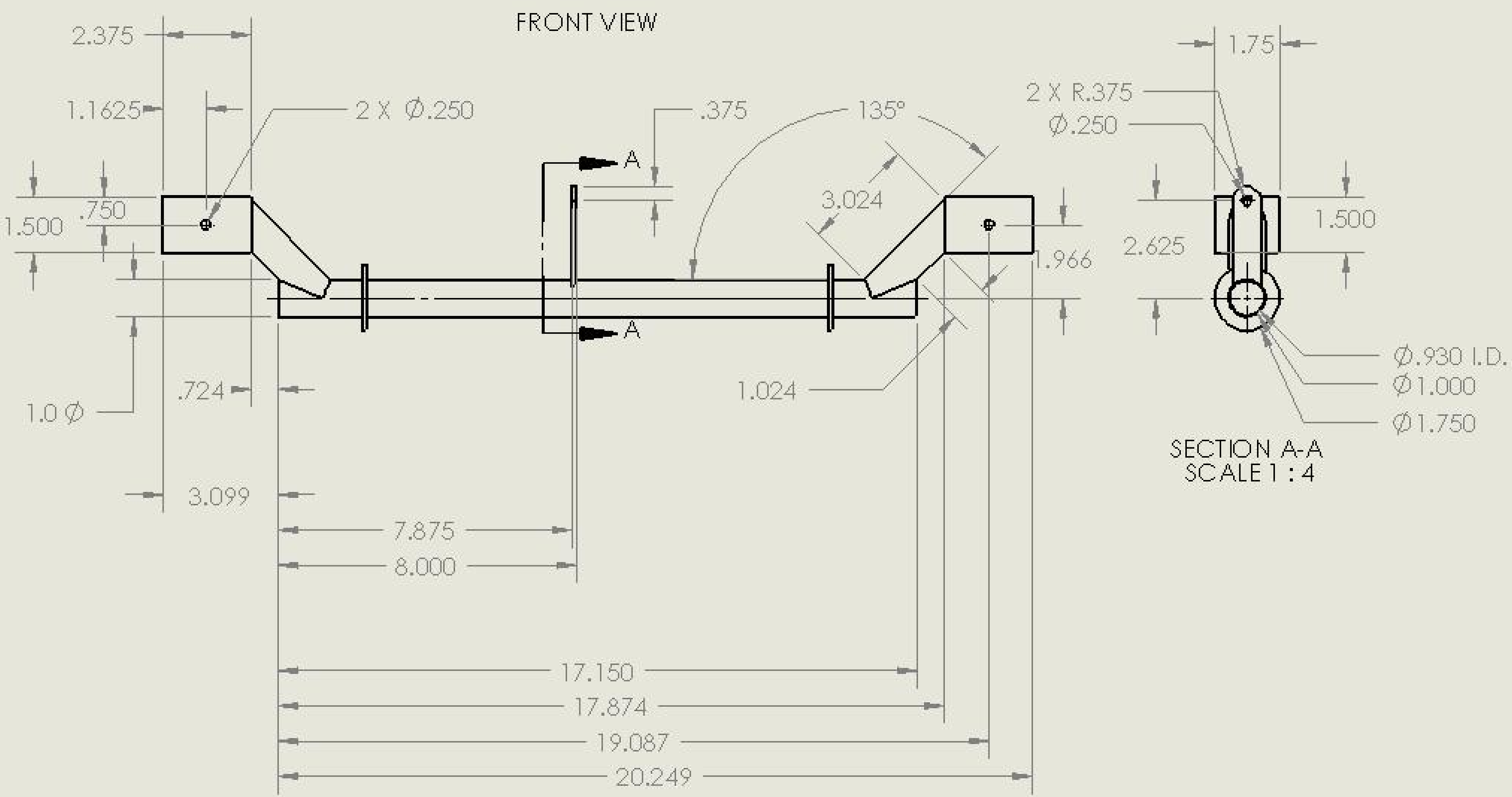

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TITLE:

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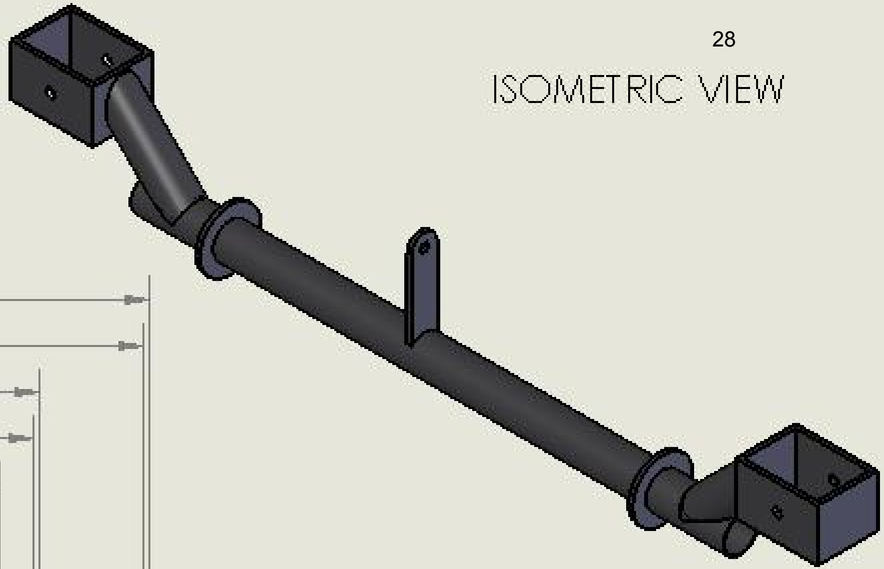
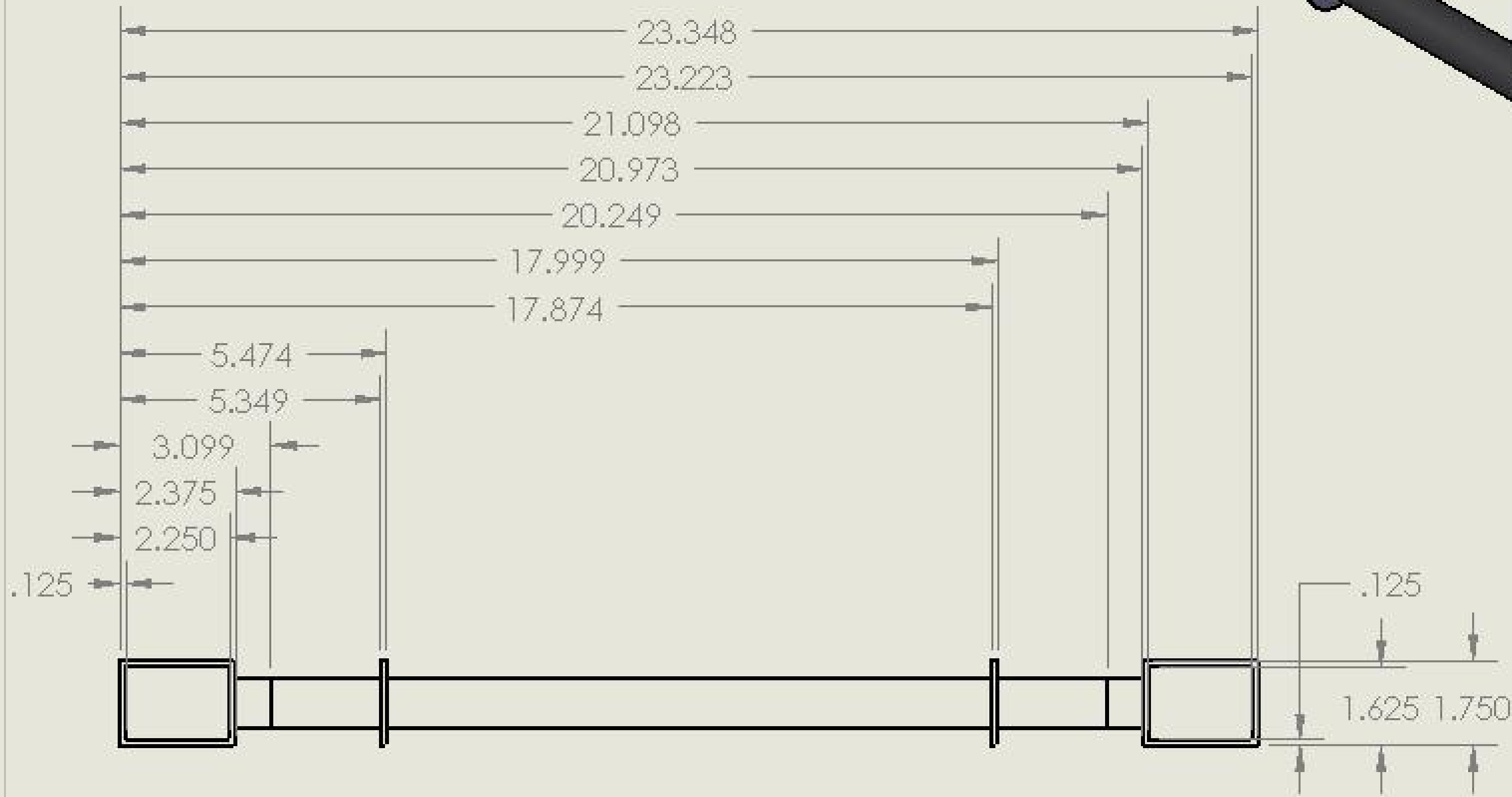
ISOMETRIC VIEW



TOP VIEW



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TITLE:

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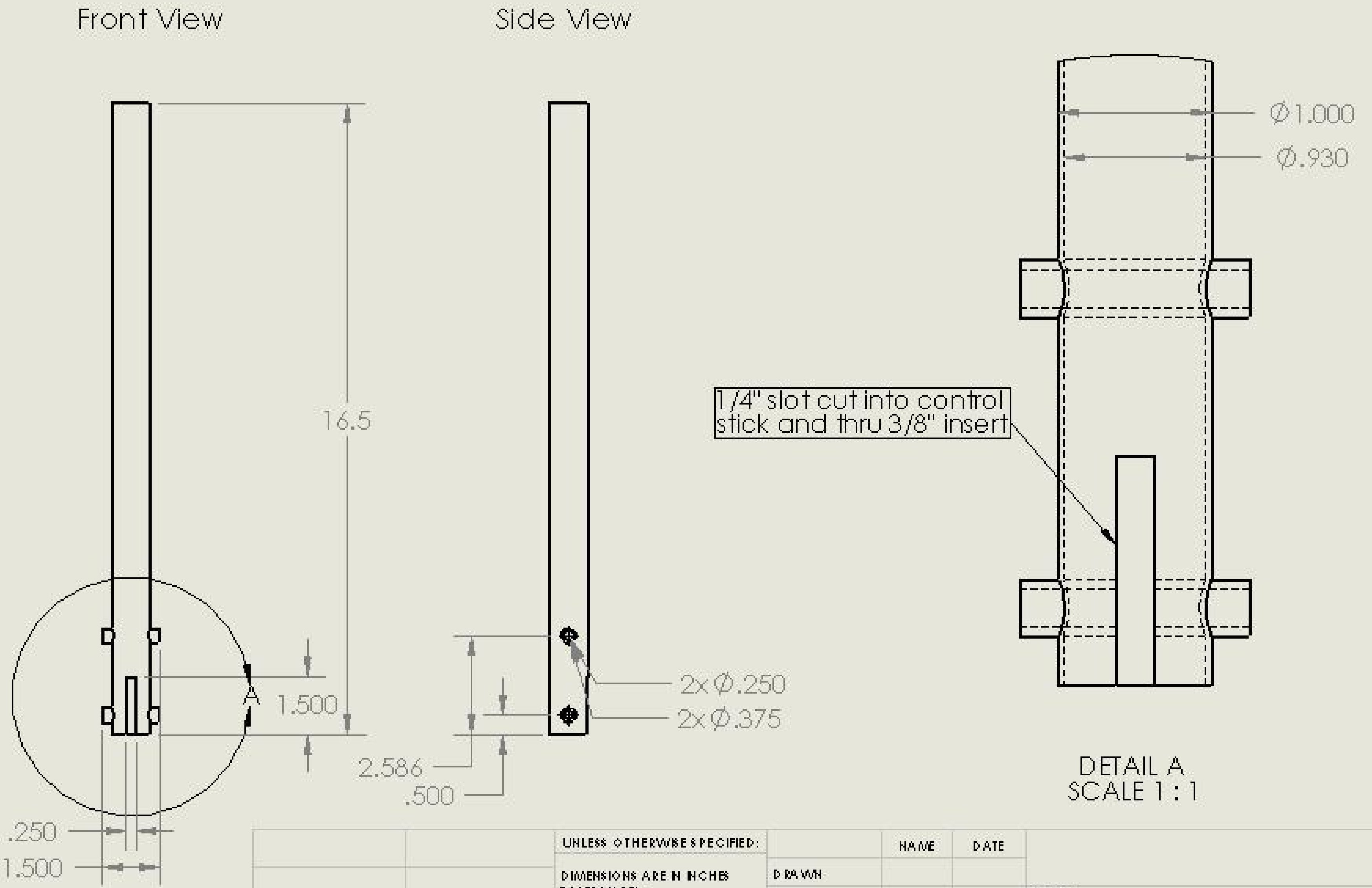

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COMMENTS:

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TITLE: Control Stick

SIZE A | DWG. NO. | REV

SCALE: 1:4 | WEIGHT: | SHEET 1 OF 1

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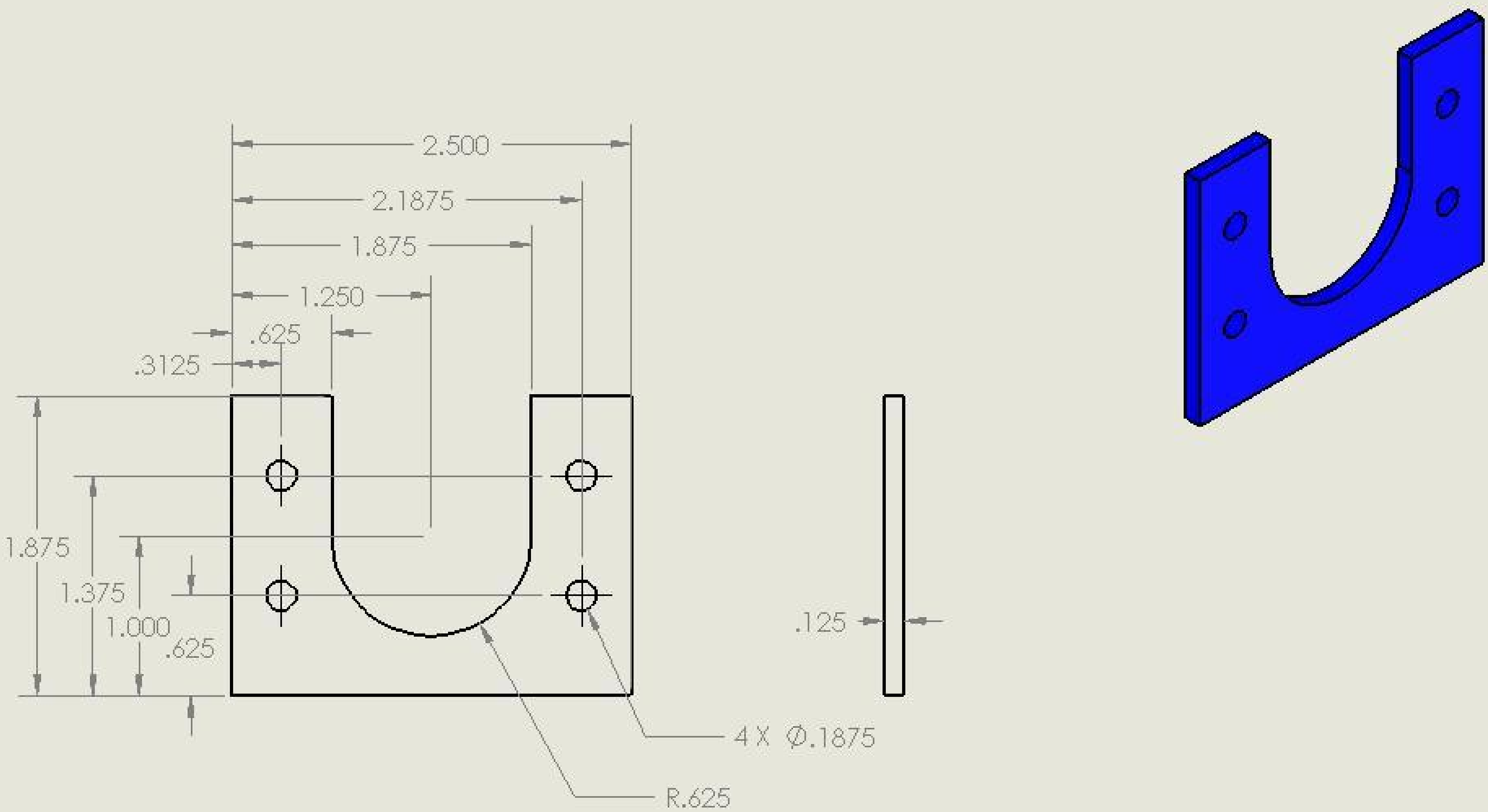

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Q.A.		

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TITLE:

Cross Tube Bracket

SIZE	DWG. NO.	REV
A		

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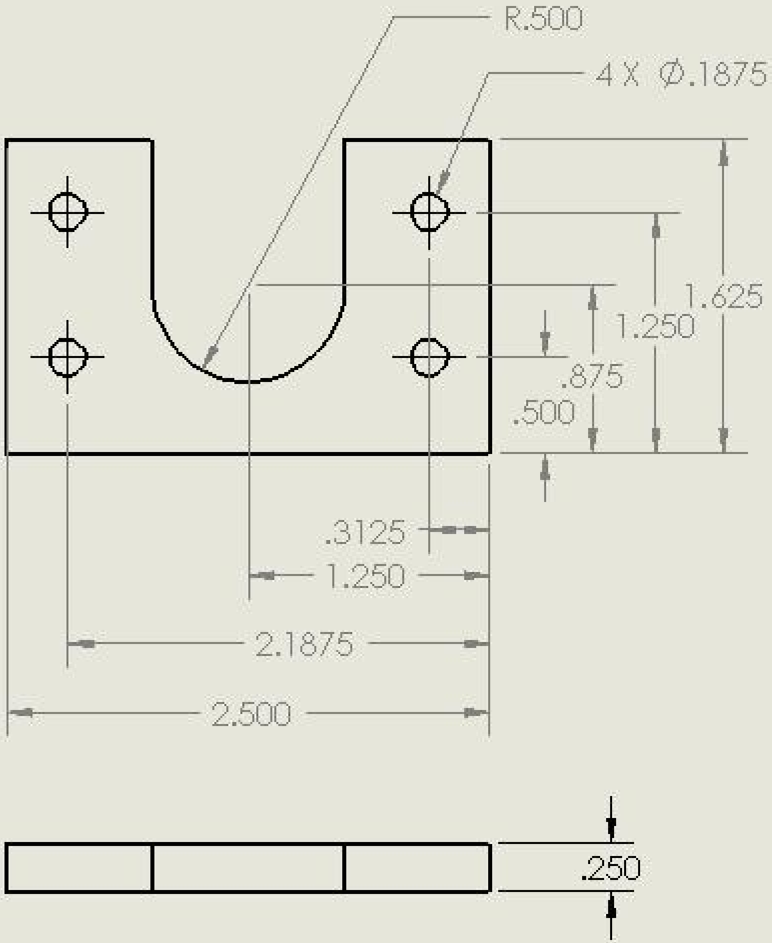

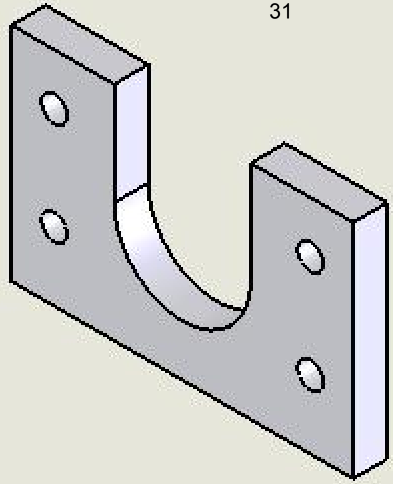

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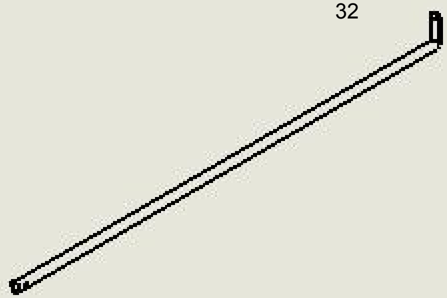

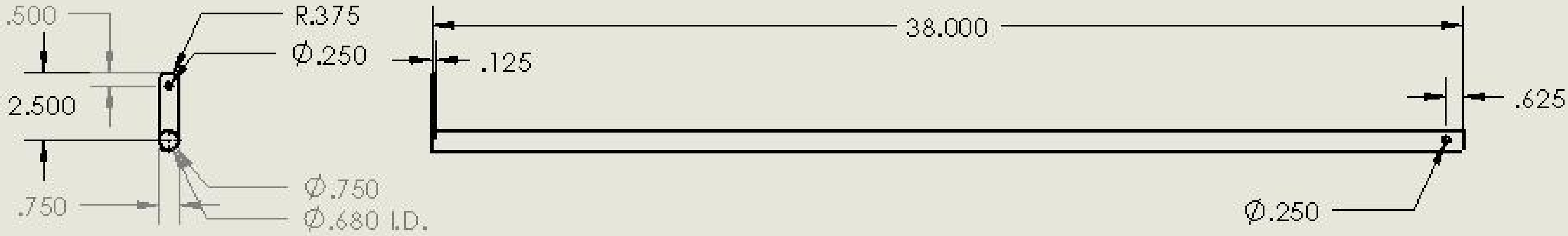

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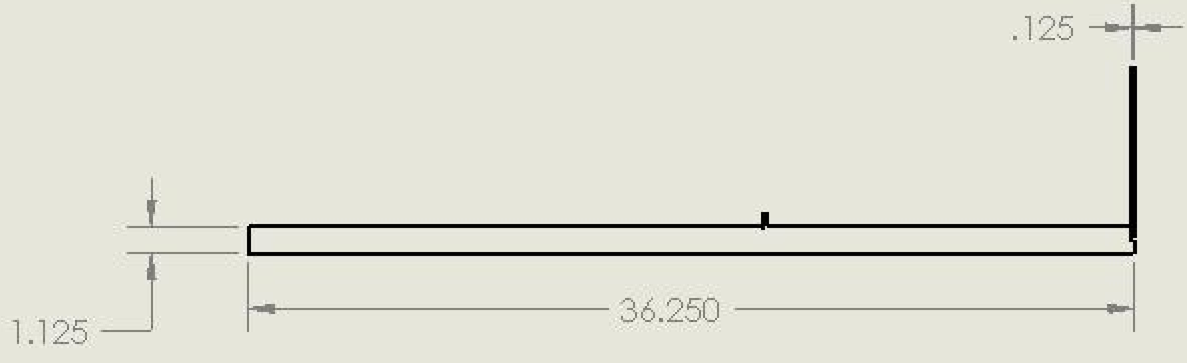

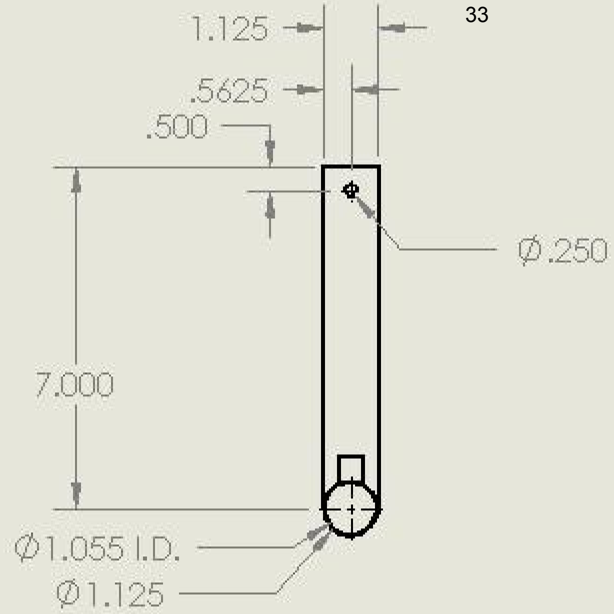

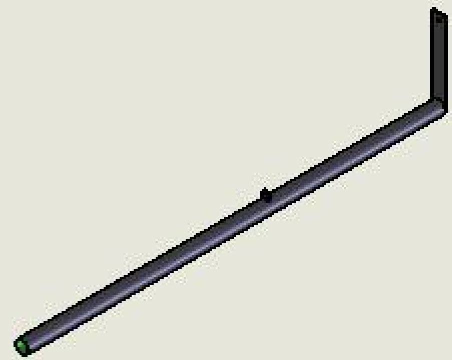

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COMMENTS:		

TITLE: Flap Tube

SIZE	DWG. NO.	REV
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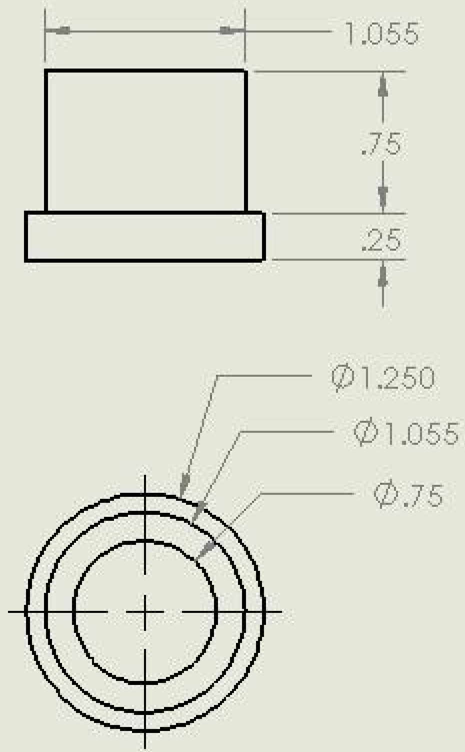

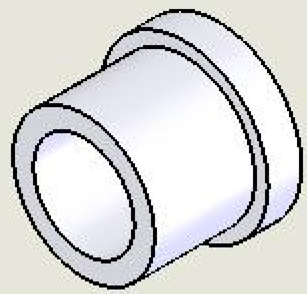

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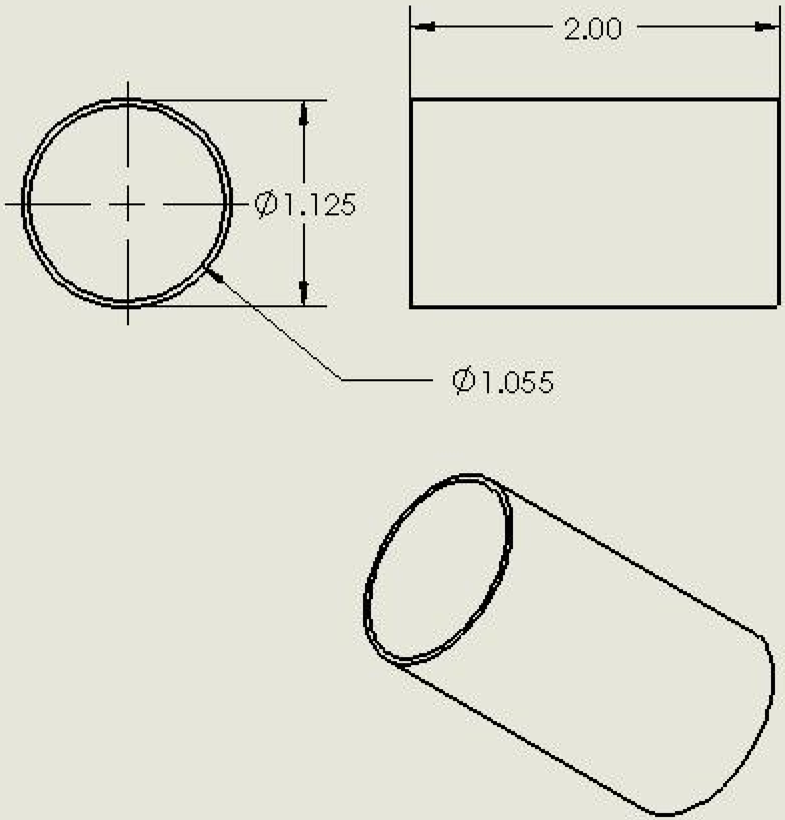

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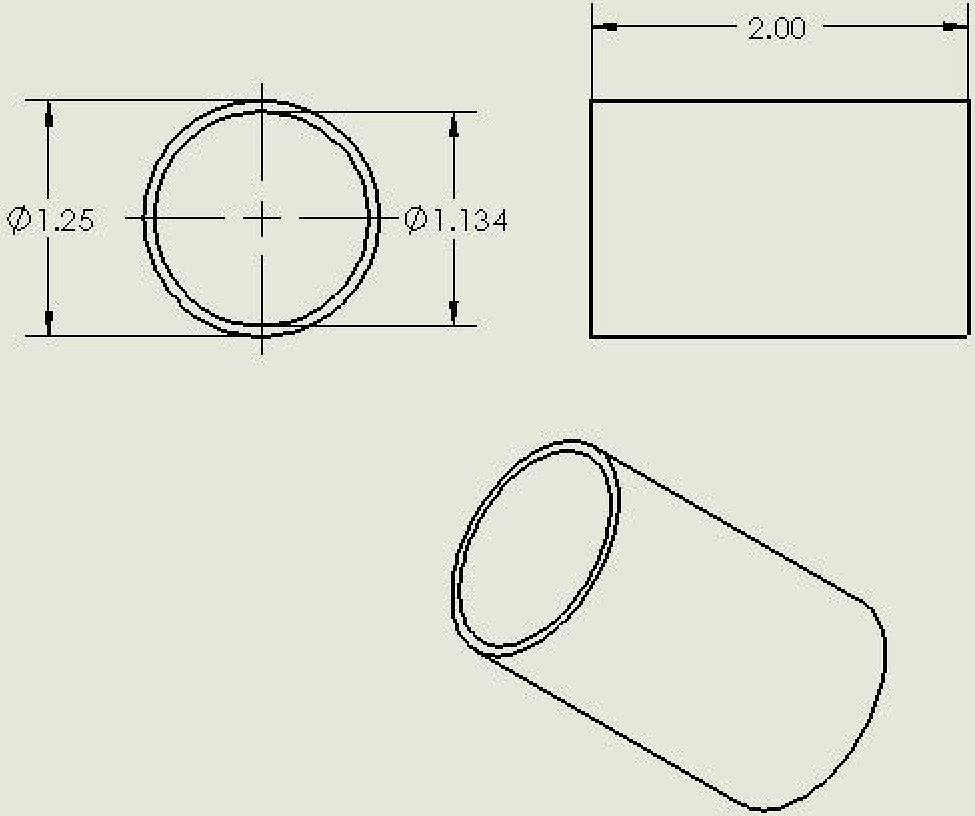

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Q.A.		

COMMENTS:

2 total

TITLE:

Flap Tube Holder

SIZE A | DWG. NO. | REV

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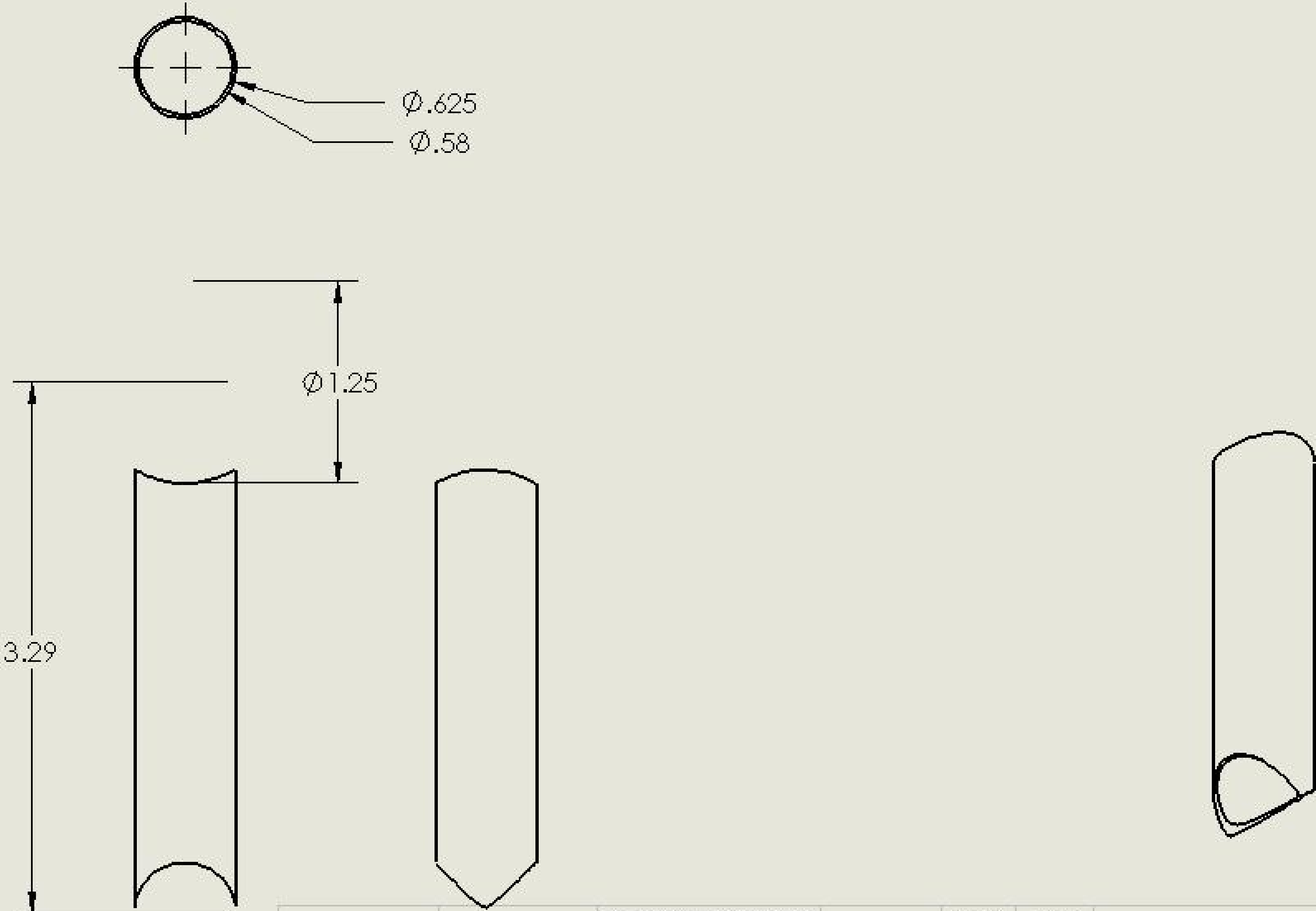

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		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
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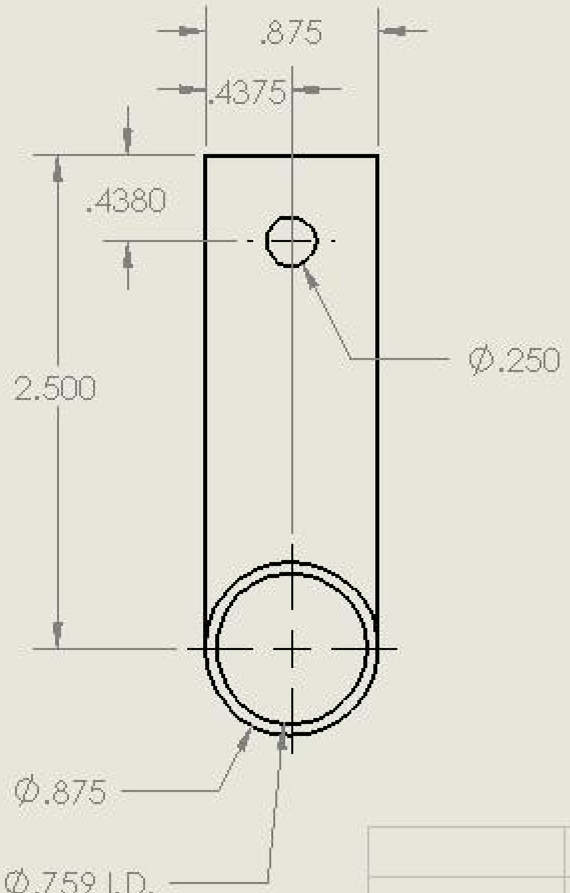

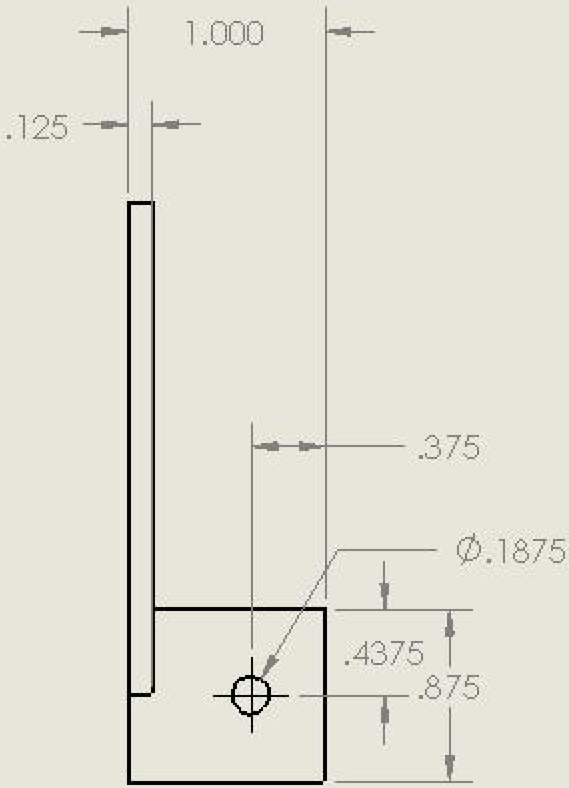

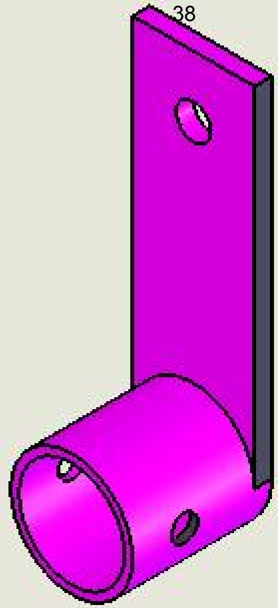

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	NAME	DATE
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MFG APPR.		
Q.A.		

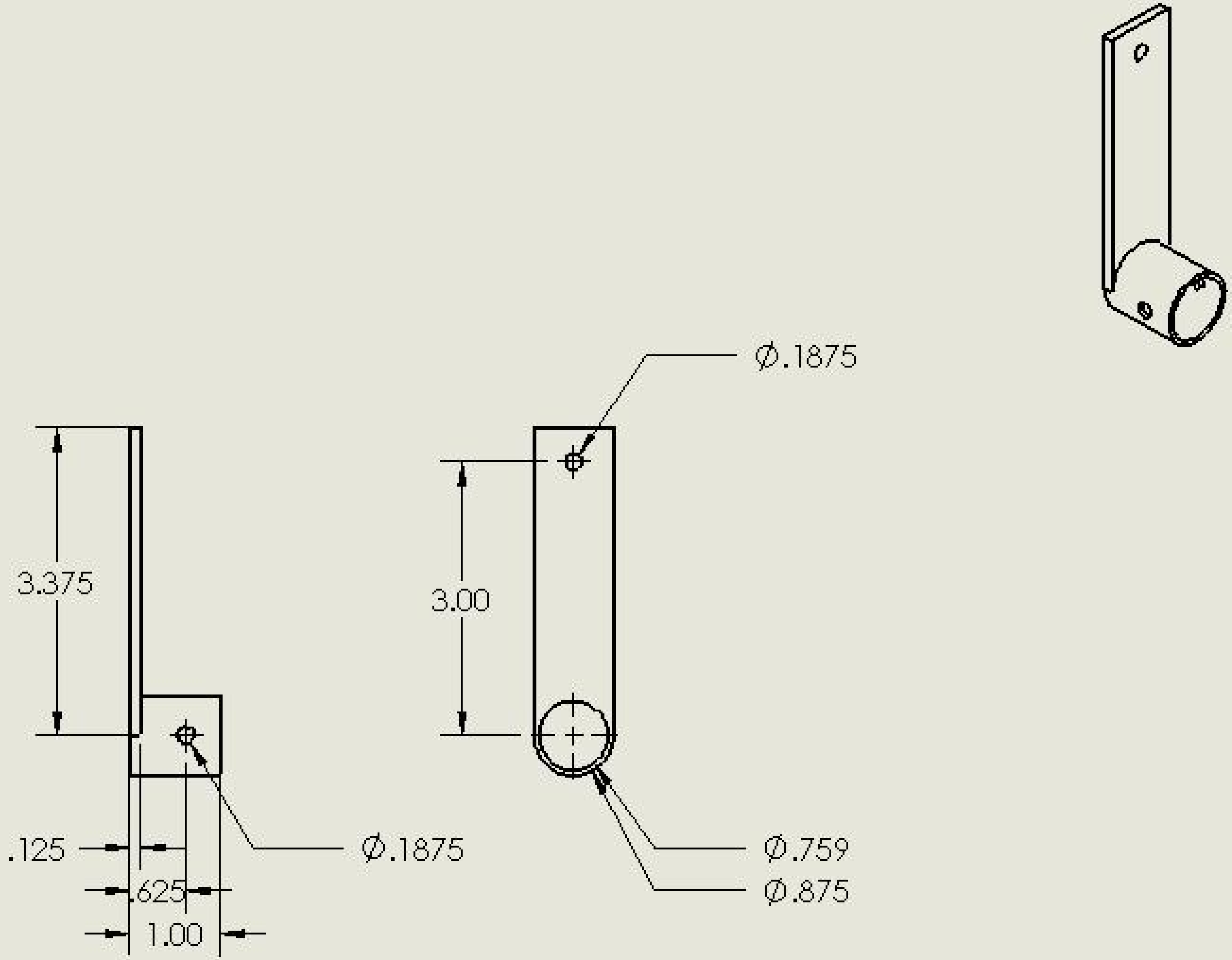
COMMENTS:

TITLE: Lower Bolt-on Aileron Control Horn

SIZE	DWG. NO.	REV
A		

SCALE: 1:1 WEIGHT: SHEET 1 OF 1

5 4 3 2 1



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TITLE: Upper Bolt-on Aileron Control Horn

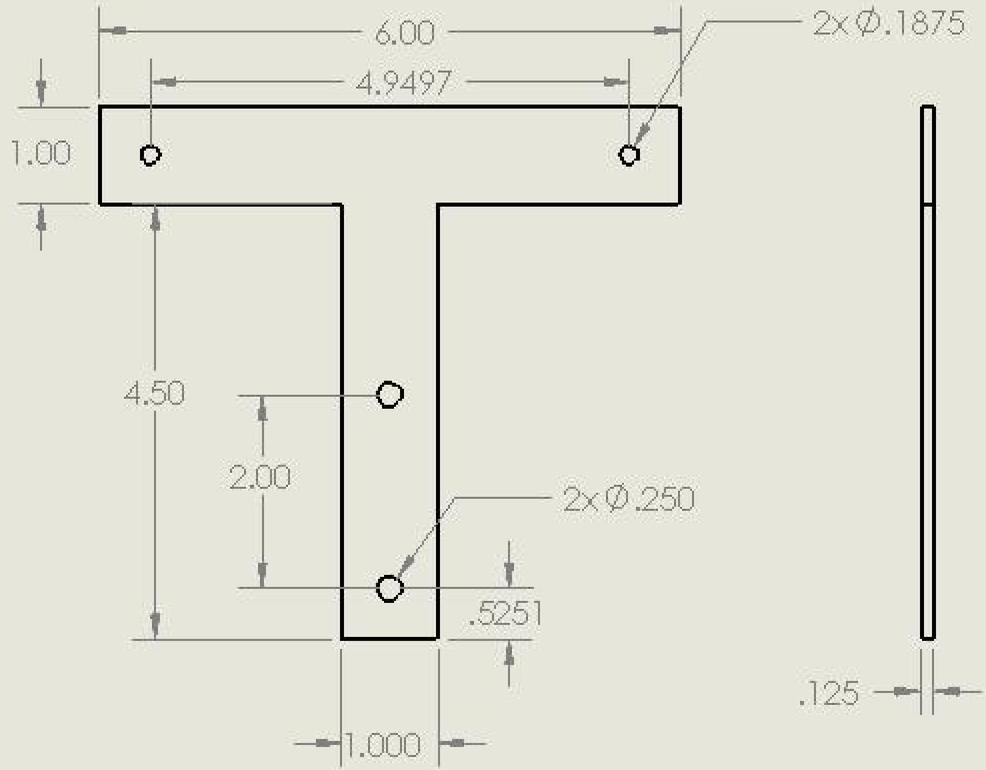
SIZE	DWG. NO.	REV
A		

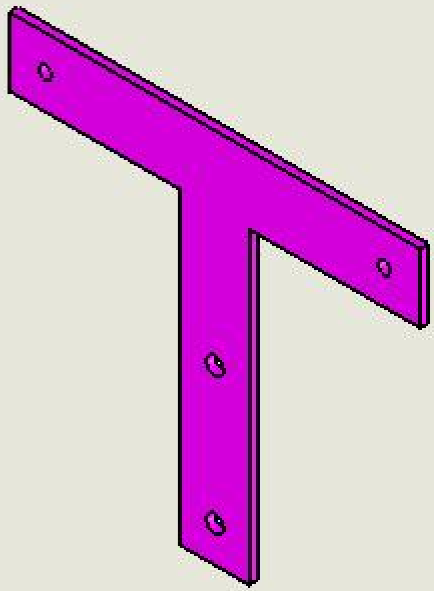
SCALE: 1:2 WEIGHT: SHEET 1 OF 1

5 4 3 2 1

FRONT VIEW

SIDE VIEW





		UNLESS OTHERWISE SPECIFIED:		NAME	DATE
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN		
			CHECKED		
			ENG APPR.		
			MFG APPR.		
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
		MATERIAL	COMMENTS:		
NEXT ASSY	USED ON	FINISH			
APPLICATION		DO NOT SCALE DRAWING			

TITLE: **T Bracket**

SIZE **A** | DWG. NO. | REV

SCALE: 1:2 | WEIGHT: | SHEET 1 OF 1

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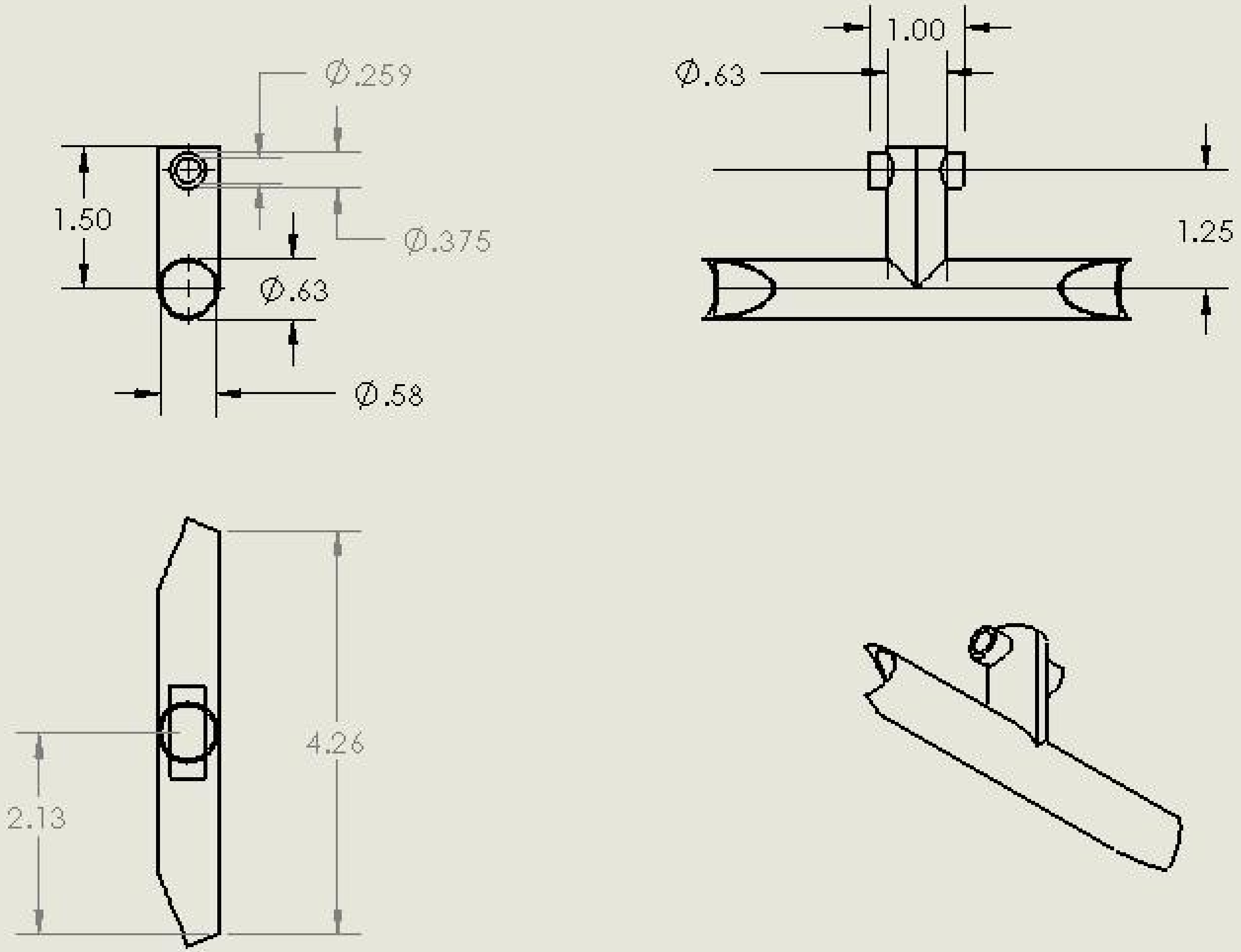
5 4 3 2 1



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NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		
COMMENTS:		

TITLE: Elevator Pully Support

SIZE	DWG. NO.	REV
A		

SCALE: 1:2 WEIGHT: SHEET 1 OF 1

5 4 3 2 1