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1. Safety Notice

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NOTICE: I WILL PURSUE, WITH EXTREME PREJUDICE, ALL CASES WHERE THE ABOVE PROVISIONS APPEAR TO HAVE BEEN VIOLATED!
Max. Empty Weight: 254 Lbs.
Max. Pilot Weight: 250 Lbs. (CG shown w/ 225 Lbs. pilot)
Max. Speed: 63 Mph
Fuel Load: 5 Gallons (CG shown w/ full fuel load)
Engine: Rotax 447 w/ type "B" gear box, 503DC Max.
Propellor: 60" to 64" Powerfin
Range: Approx 45-55 Miles
3. Purpose

The purpose of this document is to provide an understanding of what is necessary to build an autogyro. This document is written with the assumption that the reader has a fair degree of experience with rotary winged aircraft, specifically, autogyros.

4. Acknowledgments And Sources

4.1 The GyroBee

First and foremost, I must thank Ralph E. Taggart (Gyrobee@aol.com), designer of the GyroBee gyroplane. If it were not for his efforts, I would have not had the inspiration to go forward with the design of the Hornet. The GyroBee documentation package, on which the Hornet airframe documentation package is based, can be downloaded for free from Mr. Taggart’s GyroBee website at http://taggart.glq.msu.edu/gyro/. I strongly suggest that you download a copy to use as a reference when you read this document.

Although specific references to the Hornet are not made in the GyroBee documentation package, almost all of the below mentioned disciplines will translate very easily. Portions of the following information and paragraphs, have been extracted (copied, lifted, stolen, etc.) from the original GyroBee documentation, with Ralph’s permission of course. Thanks Ralph!

4.2 Internet Resources

Many of the design considerations and changes made to the Hornet were as a result of a few different online resources, forums, news groups, and discussion boards. However, one such source stands out among the rest – www.Rotorcraft.com. This site is by far one of the single best sources of technical information and personal opinions regarding gyros. Other sites like Rotorcraft.com are now popping up around the Internet, many of which have several of the same people visiting, including myself.

Do to irreconcilable personal issues that the webmaster of Rotorcraft.com is experiencing, Rotorcraft.com may be deactivated in the future. As a fallback to Rotorcraft.com, the Rotary Wing Forum (www.rotaryforum.com) has been created. However, please continue to show support for Rotorcraft.com by visiting as often as you visit the Rotary Wing Forum. Thank you!

5. General

5.1 Events leading up to the Hornet

In Ypsilanti, MI, located on the grounds of Willow Run airport is the Yankee Air Force Museum. This is where I saw my first gyro plane up close. Because I lived so close to the airport, I spent a fair amount of time studying the old Bensen gyro. After several months of poking around this strange little craft, I became active in a local Popular Rotorcraft Association chapter (PRA chapter 63, The Central Michigan Gyroplane Club, Maple Grove Airport, Fowlerville, MI). Shortly after I joined the club, I somehow managed to get
“volunteered” as their new Vice President, for 2 terms no less. I didn’t realize being drafted could be so enjoyable. For a time, I was also the Vice Safety Officer and Co-Librarian. Part of my duties as the Vice Safety Officer required me to also be an FAA Aviation Safety Counselor at the Detroit FSDO, which just happened to be located right next door to the YAF.

During my time at PRA 63, I had been exposed to many different gyros - Air Commands, Dick DeGraw’s Gyrhino, the GyroBee, and later on, the HoneyBee. I was immediately drawn to the GyroBee and HoneyBee because of the simple construction techniques used to build these gyros. I had been playing with a number of radically different gyro ideas, but they were all too big and complex to have any hope of ever being completed.

So I decided to start with something smaller and a little less complex. I would use the experience gained from the smaller project as a base for bigger design projects. Even though the GyroBee and HoneyBee are simple aircraft, I determined that an even simpler variation could be designed. This is the reason that I decided to design the Hornet.

5.2 Limitations

It is extremely important to understand that this document should not be used as a construction manual. To fully understand this document, a level of gyro experience and knowledge is required. A general knowledge of gyro flight characteristics, basic aerodynamics, and a good mechanical aptitude are absolute minimums. If you don’t understand these areas, then by no means should you attempt to build a gyro using any part of this document.

If your intention is to build a Hornet, despite all previous warnings, you must have a solid understanding of why the aircraft is configured the way it is. If you don’t understand some of the critical design choices that were made, it is quite possible that any modifications you make will result in an aircraft that is dangerous to fly!

6. Design Considerations

6.1 Hornet Specific Components

As you go through this document, keep in mind that most of the holes in the parts are Hornet specific. Hornet specific assemblies such as the nose wheel assembly, rudder pedal assembly, joystick assembly, landing gear assembly, seat assembly, fuel tank, and tail feathers all have mounting holes that may be different than what may be commonly used on other gyros. Though it may be possible to mount components designed and supplied by other entities, adaptors, additional bracing or mounting holes may be required to facilitate their mounting. With the addition of these components comes a variation in the overall weight of the aircraft. Typically, ultralight aircraft are very close to the FAA mandated 254-pound weight limit, and these added components could make the aircraft illegal to fly as an ultralight. Although the basic weight of the Hornet is some 15-20 pounds less than the maximum weight limit, the addition of a battery, lights, instrumentation, brakes, etc., could easily make up this difference, and then some.
6.2 Static Stability

6.2.1 Forces Acting On A Gyro

As with all aircraft, there are four (4) main forces acting upon a gyro - lift, gravity, thrust, and drag. Besides these forces, there are other factors that must be taken into consideration, such as the center-of-gravity (CG), the center-of-drag (CD), and the rotor-lift-vector (RLV).

6.2.1.1 Center Of Gravity

The CG is easy enough to understand. It is the point where there is an equal amount of weight in all directions. Everything with mass has a CG, and if you were to somehow balance a gyro on a post at the CG, the gyro would not move. You could push the gyro around with your finger and (for the purpose of the document) it would not fall off of the post. In other words, a body with mass, has a CG, and that body will attempt to rotate about its CG when a force is applied to the body that is not directed through the CG. If the applied force is not passing directly through the CG, the body will rotate about the CG.

6.2.1.2 Center Of Drag

The CD is a little harder to describe. Every item on a gyro that is in the air stream produces drag. This drag is distributed across the frontal area of the gyro. At some point vertically, there is an equal amount of drag above and below. This point is commonly referred to as the center-of-drag (CD). On a gyro, the CD is almost never in close proximity to the CG vertically. Because most gyro’s are controlled through the use of an offset gimble style rotor head, as the pilot pitches the gyro up and down, the location of the CD will also change up and down. Because the CD is rarely on a horizontal plane with the CG, drag can influence the pitch of the gyro.

The drag on a gyro as it fly’s through the air is essentially constant, except for the rotor blades because of their rotation. As a general rule of thumb, thrust and drag will cancel each other out at a specific airspeed. Joystick control inputs in pitch influences the angle-of-attack (AOA) on the rotor disk, causing the amount of drag produced by the rotor disk to change. The higher the AOA, the higher the drag, and conversely. Therefore, as rotor drag increases, airspeed will decrease until the total drag of the gyro becomes equal to thrust. If the rotor disk AOA is lowered to zero degrees, causing the blades to become unloaded, drag on the rotor disk and blades becomes virtually nil, and the CD be at a lower position. This lower rotor disk AOA will also allow the gyro’s airspeed to increase, which will increase the drag on the remaining portions of the gyro causing the CD to drop even more.

6.2.1.3 Rotor Lift Vector

The RLV is the combination of two (2) forces; the lift created by the rotor blades, and the drag on the rotor blades. The RLV is more theoretical in nature, but often proves to be a simpler method of design and explanation then trying to separate lift and drag forces. Since drag is to the aft, and lift is up, the RLV falls on an angle somewhere between these two (2) forces. The higher the drag on the rotor blades, the more the RLV angle swings forward. The greater the lift on the rotor blades, the more the RLV swings aft. The RLV
always passes directly through the center of the teeter bolt of the rotor head. A simple way to visualize the RLV is to tape one end of a piece of string to a small weight, like a block of wood. Let the wooden block rest on a table and then pick up on the other end of the string until there is no slack in the string. The string represents the RLV, and your hand is the rotor blades, more specifically, the teeter bolt where the rotor blades are attached. If you move your hand to the right (which represents an increase in drag) but allow the weight to continue to make contact with the table, the string holds a straight line at some angle between the weight and your hand. If you lift your hand (increase in lift) the weight will try and swing under your hand.

On a gyro, the RLV must pass behind the CG to maintain static stability. If the RLV passes through the CG, the gyro becomes very sensitive. If the RLV passes forward of the CG, the gyro becomes unstable, forcing the pilot to constantly make control corrections to keep from crashing. However, this RLV aft of the CG relationship is not the only condition that needs to be maintained.

### 6.2.2 Lift To Drag Ratio

The RLV is a product of the relationship between the lift and drag characteristics of the rotor blades. This ratio is what engineers refer to as the lift-to-drag (LD) ratio. The more efficient (less draggy and higher lift) the rotor blades are, the higher the LD ratio and the more vertical the RLV becomes, and conversely for less efficient blades. The LD ratio of a set of rotor blades can greatly effect the handling characteristics of a gyro because if the RLV is too far behind the CG of the gyro, the gyro will feel nose heavy all of the time. To counter this, a pitch spring is used to apply a pitching-up force to the rotor head so that the pilot doesn’t have to hold back pressure on the joystick during flight. However, if the rotor blade LD ratio is too low, causing the RLV to pass either directly through or in front of the CG, the gyro will be either very sensitive to fly, or even worse, uncontrollable.

### 6.2.3 Thrust Line

The thrust line is simply the thrust produced by the propeller as the engine spins it. The thrust line passes directly through the center of rotation of the propeller. If you refer back to the paragraph on the CG, if a force is applied to a mass, and that force doesn’t pass directly through the CG, a rotation force will result. Conversely, if the force is passing directly through the CG of the mass, it will move in the direction of the force without rotating or spinning. With the gyro, if the thrust line doesn’t pass directly through the CG, the gyro will want to rotate about the CG. If the thrust line is above the CG, the gyro will want to pitch nose down. The best possible design for any gyro is to have the thrust line pass directly through the CG. This will remove one of the many negatives that adversely effect stability.

### 6.2.4 Centerline Thrust

There has been a great deal of attention surrounding the topic of gyros and Centerline Thrust (CLT) lately. CLT is the condition where the engine thrust line passes directly through the CG. Some will argue that all gyros should have CLT. However, it’s difficult to deny that there are a large number of gyros currently flying that do not have CLT.

In the case of the gyro, at low airs speeds where there isn’t a great deal of drag, and with the rotor unloaded, any amount that the thrust
line is offset from the CG will cause the gyro to pitch and/or yaw. However, seeing how it is difficult to simultaneously have low or zero forward airspeed with an unloaded rotor, this is not a situation that occurs all that often. Again, some will argue that this can and does occur with a high degree of frequency. But if this were true, there would be much fewer gyros flying today because of crashes. Besides, it is impossible to have the thrust line passing directly through the CG at all times anyways. The thrust line is always going to be off a small amount. How much is too much? No one can answer. All that can be done is to get as close as possible and supplement with a horizontal stabilizer.

6.2.5 Horizontal Stabilizer

There are a several factors that go into the size and placement of a Horizontal Stabilizer (HS). Many of the same people that have been screaming about the necessity of CLT, have also been screaming about the necessity of having a HS, and for the most part, everyone agrees that an effective HS is a must. I also agree! However, there’s a debate that has been raging for some time now about the location of the HS, especially with pusher gyros. Some people feel that the only safe gyro is one that has a HS fully immersed (where the HS is located directly in-line with the centerline of the propeller spinner). I disagree! And here’s why.

The job of the propeller is **NOT** to provide airflow like a box fan. The job of the propeller is to move an aircraft, such as a gyro in this case, forward at a speed sufficient to get the aircraft in question flying. That is why a propeller is shaped like a wing, and not like an automotive radiator fan. A propeller is meant to fly just like a wing does. Propwash is merely a by-product of the propeller’s flight, and just like an airplane’s wing, there is drag. This drag causes the propwash to be in the shape of a corkscrew or helix. The severity of the helical shaped propwash depends on the LD ratio of the propeller itself, engine RPM, pitch, and a few other factors that I’m not going to get into.

This is the cause of the first problem we have with an immersed HS – Dissymmetry of Lift! If the HS in question is mounted directly in-line with the spinner centerline, then the HS is going to see different angles of attack between the left half and the right half. In fact, the AOA is going to be different across the entire HS. Concrete evidence of this can be found by simply feeling the effect the propwash has on the vertical stabilizer (which is not tall enough to span the entire diameter of the propeller) of a gyro during take off, when the throttle is wide open - the tail of the gyro will be pushed in the direction of the propwash, requiring the pilot to counter the yaw with rudder pedal input. If this same condition holds true for the HS (and I’ll bet you it does), then all that you’ve made is a good wind straightener.

The second problem with mounting the HS in the propwash is that the propwash is pulsating. During the development of the JU-87 Stuka in the 1930’s and 1940’s, the German military thought that if the radiator was moved to a point right up behind the propeller, that the cooling capacity of the radiator would increase and they could keep the engine cool. What they found is totally opposite. The radiator had to be moved farther away from the propeller, not closer. The reason this problem occurred in the first place is because each time that a propeller blade passed by the radiator, the radiator would see a pulse of high velocity air, but the dwell time between blades, where there was very little flow, negated the high velocity airflow. With limited success, the Germans even tried longer chord length propellers in an attempt to force more air through the radiator. The resultant sum of the propwash was less than anticipated, and the same is true for an immersed HS. About the time the British were developing the Spitfire fighter, they already had experience
with this same type of problem. This is why the radiators for the Spitfire were mounted under the wing outside the arc of the propeller. Other aircraft followed suit such as the P-51.

The tail feathers and the pilot feel these same pulses. The pilot can usually feel this pulsation because the pulses are being transmitted from the tail feathers to the airframe. It’s usually described as a vibration. Therefore, the best location of the HS is as far away from the propeller as possible. This will also provide a greater leveraging force, and will increase the stabilizing effect that the HS has on the gyro. But this becomes a problem with pusher gyros because moving the HS farther aft also places the vertical stabilizer closer the rotor blades, increasing the chances that a rotor blade will strike the vertical stab.

The third problem with an immersed HS is turbulence caused by up-stream clutter – stuff forward of the propeller. Turbulent flow is defined as "...a flow characterized by turbulence, that is, a flow in which the velocity varies erratically in both magnitude and direction with time." Turbulence is caused by an "...abrupt change in direction of the airflow...", which is commonly know as "separation of flow", or "flow separation". Keep in mind however, that a helical prop wash isn't necessarily classified as a "turbulent" flow. But, if the incoming airflow is turbulent, the prop wash will be as well. Generally, gyro’s are fairly noisy aircraft, and this turbulence passing through the propeller is the primary cause for much of the noise, which can be easily heard from the ground.

Airflow separation causes a great deal of turbulence and drag. Turbulence, and the resulting drag, is unwanted and is detrimental to aircraft and many other items that pass through air such as; cars, trucks, golf balls, and bullets, just to name a few. Though it is possible to predict with a certain degree of accuracy when and where flow separation and the resulting turbulence will occur, calculating the magnitude and the effects that turbulence will have on an object is, for the most part, impossible. Especially, after it passes through the propeller.

I would suggest that you read the article posted on my website for more detail on immersed horizontal stabilizers – http://www.geocities.com/donshoebridge/h-stab.html.

Since the RLV is be behind the CG, the gyro will try and fly in a nose down attitude all of the time. To counter this to some degree, the HS must provide down force to help hold the nose up. This is done by lowering the leading edge of the HS by a small amount, which the Hornet has. The final HS configuration is not currently available. Extensive flight-testing will have to be performed on the prototype aircraft to fully complete the tail feather design.

6.2.6 Bunt-Over’s and Drag-Over’s

A Bunt-Over (also known as a Power Push Over or PPO) is typically defined as a nose down pitching event that is caused by having the thrust line above CG, usually occurring when the rotor blades are unloaded. Similar to the Bunt-Over is the Drag-Over. Also a nose down pitching event, which is typically caused by airframe drag, where the CD is well below the CG.

The element common to both events is an unbalanced condition. By definition, the only real difference between these two events is the presence or not of propeller thrust. Even if the thrust line is below the CG, with power on, if the gyro noses over, it’s considered a Drag-
Regardless of your point of view, the fact of the matter is that there is an imbalance of forces. And the only way to counter this condition is to have a lower thrust line AND an effective horizontal stabilizer.

### 6.2.7 Center Of Equilibrium

All aircraft, as they fly, will try to maintain equilibrium. The combination of all of the previously mentioned forces must be arranged in a particular manner so as to not cause an aircraft to be unstable. There is a point in space where all these forces balance out and is what I refer to as the center-of-equilibrium (CE). The CG, CD, RLV, the thrust line, and forces generated by the tail feathers are the primary forces that must be balanced out. With all of these forces working against each other, the resultant CE will be relatively neutral, but it will move around a small amount. The dynamic motions of the gyro usually cause this movement as it flies. The amount the CE moves must be kept in check by either the pilot through control inputs or by aerodynamic surfaces (such as stabilizers), or some combination of the two. The more the CE moves around, the more corrective actions are required by the pilot. The more effective the stabilizers are, the less the CE moves around, resulting in a shorter training cycle and less pilot workload.

The envelope where the CE must remain is a combination of aircraft inertia, pilot reaction time and experience, and controls authority. If at anytime the CE falls outside of this theoretical envelope, the gyro will depart controlled flight, resulting in a crash, and subsequently serious injury or death. Therefore, the larger the CE envelope is, the easier the gyro is to fly. The smaller the envelope, the harder it is to fly. It is generally accepted that the best possible condition for any gyro is to have a CLT condition, the RLV behind the CG by some amount, and have a HS to dampen any remaining out of balance conditions that may be present.

### 6.2.8 Final CG Location

The final CG location of the Hornet will depend on several different factors. However, pilot weight and fuel load will have the greatest effect on the CG location. With regard to fuel load, because of the location of the fuel tank, as fuel is burned off, the CG will move forward and up. Figure 1 shows how the CG might change with varying pilot weights. The lighter the pilot, the higher and farther aft the CG will be, and conversely for a heavy pilot.

It is very important to note that any variation in the Hornet’s design will alter the location of the CG. Figure 1 is specific for the Hornet as it is currently configured within SolidWorks, and it does not include battery weight, lights, instruments, etc. The chart is for reference only. Because gyros of this type are so short coupled with regard to controllability, and the fact that small changes in weight can have large effects in the CG location. It cannot be stressed enough that any design variation of the Hornet from its current configuration would make a completely different aircraft. With any homebuilt aircraft, be it fixed or rotary wing, every time the aircraft is flown, the pilot is a test pilot. Even though every effort will be made to document the flight characteristics of the Hornet, any variations away from the Hornet’s original design by builders will make the flight data useless.
7. Fabrication

7.1 Craftsmanship

If you have ever watched experienced pilots examining home-built aircraft at a fly-in, you will notice that they tend to be very picky
about craftsmanship. The reason is quite simple. Sloppy work doesn't just impair the appearance of an aircraft, it can render it unsafe. If you were ever an aircraft mechanic in the military, or still are, Uncle Sam makes absolutely sure that you understand this. Building your own aircraft can be immensely satisfying, but you shouldn't even start such a project unless you are committed to doing the job right. This means the highest standards of craftsmanship using the proper tools for the job. Sloppy work can ruin up to $700 of quality aircraft materials. If you mess things up, you will not even be able to sell what's left, because anyone that knows what they are doing wouldn't touch used material. If you've done this sort of project before, you can skip what follows, otherwise stay with me for some detailed advice.

Just because there are no mandated inspection requirements for Part 103 aircraft, does not mean that we are not dealing with life and death issues. Nature and gravity don't know about the regulations! It's usually best to have several different sets of eyes look over your aircraft prior to its first flight. Make sure you ask for input from others with experience!

7.2 Materials

Only aircraft grade steel and aluminum alloys and hardware should be used to build an aircraft. Materials and hardware available from other sources such as hardware stores are not suitable, and **will eventually fail and kill you!** Legitimate aircraft suppliers such as Aircraft Spruce and Specialty Company, Wickes Aircraft Supply, Leading Edge Airfoils (LEAF), California Power Systems, and other suppliers advertising in magazines such as Kitplanes and Rotorcraft stock the proper materials and should be your only source for materials and hardware unless you really know what you are doing.

7.3 Cutting Tubing and Angle Stock

Although you can cut everything needed with a hacksaw, the job would not be fun and it would also take forever! A powered band saw is the ideal tool for most of the work. Since it doesn't pay to buy such a tool for building one aircraft, see the later section on Getting Help if you don't have a band saw. Be sure to allow for the blade width when cutting the pieces - **the finished size should match the prints!** All cuts should be carefully dressed with a fine file and steel wool since sharp edges can concentrate stress and lead to the formation of cracks.

7.4 Drilling

Drilling tubing, sheet, and angle stock is the most critical operation you will do on an aircraft construction project. Holes must be placed with **absolute precision** or the parts **will not fit** when assembled. You cannot do this job with a hand drill. A good drill press with an adjustable fence is ideal. Holes, particularly those drilled through tubing, must be absolutely true. This is particularly so with holes drilled near the edge of square tubing. These are positioned with only 1/32 clearance from the tubing wall. **If you score the inside wall surface when drilling, the entire piece must be discarded!** If you are not sure about the precision of the drill press, take the time to make some simple drilling jigs to assure proper placement of holes. Alternatively, you can center punch the hole location on both sides of a tube (assuming you do the job very accurately), pilot drill from both sides with a 1/16 bit, and then finish-drill to size from...
both sides. If you don't have the proper equipment or are unsure about your skills, see the later section on Getting Help. Quality drill bits and how you use them are important. **Be sure of the finished holes size specified on the print.** An investment in half-a-dozen carbide drill bits of each size is a good idea. A good drill index will have most of the sizes required. Drill the holes gently so the bit cuts the metal instead of punching through. Use cutting oil to make for an even cleaner job and the bits will last longer. Once holes are drilled, de-burr them, both to assure a snug fit for the attachment hardware and to avoid concentration of stresses that can lead to cracks.

### 7.5 Welding

Several of the Hornet's sub-assemblies do require welding. Gas, arc or MIG welding will do just fine for all of the necessary welds. TIG welding, used mainly for welding aluminum, is not required. Even though TIG does provide a stronger weld, nothing on the Hornet is critically important enough to warrant TIG welding. A person that has been welding for several years can only do good TIG welding. A wire fed MIG welder is quick and relatively easy to do. For welding 4130 steel, many people swear by gas welding. The reason for this is that 4130 generally is supplied already heat-treated. High heat welding will anneal the steel and remove the strength gained from the heat-treating process. For this reason, where maximum strength is essential, gas welding is used on flight critical items such as a fuselage and wing attachment points. Gas welding also wins out over MIG and arc welding because of the stresses that are built up by the high heat of MIG and arc.

### 7.6 Machined Parts

Even though there has been a great deal of time spent trying to reduce the number of parts in the Hornet, the penalty of such an effort is that there is a higher number of machined parts than the GyroBee. Simply removing parts from an aircraft is not possible. Something must take the place of the removed parts. In this case, a single machined part takes the place of several individual parts. This method of parts reduction sometimes increases the complexity of the overall project, but in return, it reduces the final assembly time and makes for a cleaner, lighter weight system.

### 7.7 Wet Lay-up Composites

There are a few components on the Hornet that require the use of composite construction, specifically the seat, the vertical stabilizer, the rudder, the horizontal stabilizers, and the floor plate. The techniques used in their construction are the same as found in the GyroBee documentation package outlining the construction what has become known as the Watson Tail (reference the section titled Catching A Bee By The Tail, by Mr. Wayne “Doc” Watson). Although the materials used are a little different than those in the GyroBee documentation package, the methods are, for the most part, the same. The main difference between the Watson tail and the Hornet tail is the type of epoxy resin used, and the Hornet uses Kevlar instead of fiberglass, will also utilize a structural epoxy system known as Poly Epoxy. This was selected based on its superior strength and hardness (Aircraft Spruce & Specialty Co. P/N 01-07906). This epoxy will be used on all composite components used on the Hornet. As for the reason why Kevlar was chosen over fiberglass, there are 2 specific reasons; 1) Kevlar has a higher strength-to-weight ratio than fiberglass, and therefore, the Hornet composites will weight
less because thinner material is used, and 2) some people are allergic to fiberglass and they cannot work with it. All Hornet composite structures will use 1.8 Oz per square yard, plain woven, bi-directional Kevlar. One drawback to using Kevlar is the fact that because it is so strong, special cutting tools are required to cut the cloth.

There is a very good article about composites that can be found at http://exp-aircraft.com/library/alexande/composit.html.

7.8 Getting Help

Your best source of help on a project of this sort is your nearest PRA or EAA chapter. Members will often have the proper shop tools (or the Chapter may be so-equipped), they know how to use them, and they can give you advice at all stages of construction. If that sort of assistance is not available locally, consider checking in with the metal shop at your local high school, vocational center, or community college. You may be able to get training on and use of the equipment. It is also possible that the teachers may think that the project would be a good one for students, so you might end up with some help. You must get an experienced PRA member or EAA designee to look over your project prior to test flying. They may be able to spot problems you have overlooked! Even if it is not convenient, arranging for periodic inspections as the project proceeds can usually spot problems early on, where they will take less time and money to fix!

7.9 Finishing

Bare aluminum will oxidize, become dirty, and show fingerprints from handling if not finished prior to assembly. In order of difficulty and cost, the finishing options are;

7.9.1 Clear Urethane

Polish the parts with fine steel wool, degrease, and finish with one or more coats of clear urethane paint. This will provide a natural-metal finish, yet protect the metal surface. Since the finish is clear, this option has the least potential to show defects and therefore, is suited for hand application.

7.9.2 Anodizing

The aluminum parts can be anodized to provide a color finish. With technology advancements, color options are getting better, and the effect is excellent, as is corrosion protection. Several color options are available, but there may be a set-up charge for anything that is not your basic vanilla colors such as black, red, blue, clear, etc.

There is a variation of anodizing called "hard coating" that can also be done. Typically more expensive, it is very durable and generally does not have as much of a metallic transparent look about it, as compared to regular anodizing. Other variations of anodizing can include flat or satin surface textures or Teflon impregnation where surface wear might be a concern.
One final note... Anodizing is not a long term finishing option and the colors will fade over a 3-5 year time span. In extreme cases, almost all of the color will be gone resulting in a very pale metallic finish. Blue and red seems to fade the most, where black fades the least.

### 7.9.3 Painting

The parts can be painted in any colors desired. Each piece will need to be finished with extra fine sand paper, degreased, primed, and then color-painted. You may be able to arrange for painting at a local auto body shop, which eliminates a lot of work. There is a very wide range of possible color combinations, and auto paints are very durable. If a super smooth finish is desired, sanding with 1000 to 1500 grit wet sand paper, and then use of a automotive rubbing compound will provide a mirror like finish. **WARNING:** Do not use rubbing compound on spray-can enamel paint finishes, because some rubbing compounds will attack the paint and ruin the finish! Rubbing compounds will not attack lacquer, automotive, or epoxy finishes.

### 7.9.4 Powder Coating

This is probably the most expensive option but will probably provide the best results. There are many excellent colors and textures available. Sometimes it’s possible to order free samples of the powder coating material direct from the manufacture. However, to do so might require the clout of the company that would actually be performing the powder coating service. This is well worth looking into. A search on the Internet for powder coat will generate several big name paint companies such as Sherwiin-Williams. Quite often, sites such as this will show samples of the powder coatings available.

### 7.10 Purchasing Hornet Parts

Currently, there isn't any company or individual that I know of that is producing retail Hornet parts. For most people, some of the more complicated parts in this document will require machinery that is larger and more expensive than just your typical drill press. However, in the near future, I may be a source for some of these components. My primary focus will be on those parts that require milling, turning (lathe), or welding. Right now, simple tube parts are at the bottom of the list. But this can change depending on which parts people request the most. So the more feedback that I get from people, the more motivated I will be. Eventually, I would like to kit the Hornet, complete with all of the standard marketing bells and whistles like custom colors, power plant options, etc.
7.11 Workspace

7.11.1 General Workspace

There are 2 major benefits to having your workspace close to home; 1) it’s likely that you will spend more time working on your gyro, and 2) it’s more likely that other members of your family will become involved, and help you. Having your workspace located away from home by some 20-30 minutes will take away from the total time that you are able to spend on building. Also, if you know that you have to drive to and from the workspace each time you want to work on your gyro, you’re likely to be less motivated to get off the couch. So if at all possible, you should have a workspace at home. A 2-car garage should do nicely.

Typically, gyros don’t take up a large amount of space when complete. A space that is 25+ feet deep, 8+ feet high and 7+ feet wide will fit most gyros. By comparison however, during the build process, a larger space is required. But obviously this also depends on how many of the actual parts of the gyro you will fabricate yourself. Let’s assume that you have a similar situation to mine. I have an extra 2-car garage that measures 25’ x 25’. The garage is un-finished, but at least it does have electricity. There is no heat of any kind, except for what my body gives off, and what Mother Nature can provide in the way of solar heating the roof, which isn’t much. But hey, at least I can call it my own cave. Obviously, for the composite work that I need to do, I will need to have some form of heat.

Securely attached to one wall, I’ve built a workbench that is 24” deep and a little over 14 feet long. This bench will be used for most of my work on the Hornet. I plan on mounting a cut-off saw to this bench at one end. This will provide a large enough surface for cutting the long pieces of tubing for the landing gear and the airframe. Sharing this space will be a drill press and a bench grinder. A lathe or vertical mill would be nice to have, but is well outside of my budget for this project.

7.11.2 Environmental Health And Safety Considerations

There is going to be a degree of sanding, painting, and working with different chemicals, including lubricants, cleaners, primers, epoxies and adhesives. There is also going to be a bit of work with power tools and hand tools. As slight as these seem, they may not kill you outright, but you could easily lose a finger, lose the use of one or both eyes, have an allergic reaction to a solvent, or suffer sometime in the future because of your exposure to a chemical. Planning is the best prevention. Your work area must have adequate ventilation. An exhaust fan is a good investment. When you are working in this area, wearing of safety glasses is a minimum. Good shoes or boots, and a pair of work gloves should also be worn. When handling chemicals, solvents and epoxies, wear latex or rubber gloves, and wear some form of a breathing apparatus like a surgical mask or a respirator like the type used in spray painting. If possible, include an eye wash station in your workshop. A well-stocked first aid kit and an approved and serviceable fire extinguisher are a must! Do not use compressed air to clean of work areas as this can cause metal shavings and shards of fiberglass and Kevlar to become projectiles, which can result in serious eye damage even if using eye protection. Instead, use a shop vacuum to prevent loose debris from becoming small missiles. And the one thing I think we are all guilty of… use tools in the manner they were intended. A pair of pliers does not double as a hammer! Just like a car key was not meant to clean your ears.
### 7.11.3 Composite Fabric Cutting Table

A specific table for cutting your composite fabrics will be a must. I once saw a great homemade, fold-up table on the TV show “A Plane Is Born” (Discovery Wings, DishNetwork channel 195). To make this table, build a frame out of 4-pieces of 2 x 6 lumber. This frame should have an inside measurement of at least 62” wide x 50-60 inches tall. Since most bolts of composite fabric measure 60 inches wide, the frame must be a little larger. Cover one side of this frame with a piece of 1/2” MDF trimmed to the outside of the frame. Lag bolt this frame to the wall of your workshop with the bottom about 30-36 inches up from the floor. The open side of this box should be facing outward. Using another piece of MDF, make a door that is the same size as the first piece of MDF and attach it with hinges along the bottom edge of the 2 x 6 frame. Make sure you add a latch of some kind to the top edge of the door so that you don’t have to make an unnecessary trip to the hospital! This door will double as your working surface.

Open the door and lower it down so that it is parallel to the floor. Use a bubble level for this. Support the door in this position with sawhorses or something. Using 2 x 4 lumber cut 2 pieces that will extend from the floor to the door. These will be the legs. Close the door and attach the legs to the door using hinges. With the door in the up and locked position, the legs should hang down against the door. When you open the door, the legs will automatically swing out and support the door, making it your work surface.

Almost all of the fabric that you will be cutting will be at a 45-degree angle. To make this job a little easier, cover the inside surface of the door with a piece of 1/8” thick high-density polyethylene or something similar like Plexiglas. I would suggest using contact cement for this and here’s why. Once the plastic is secured to the work surface, using a circular saw with the blade set to a depth 1/8”, cut an “X” across the entire surface at 45-degrees from the edges of the work surface. The center of the cross should be somewhere in the middle of the work surface. Then make 2 more cuts across (side-to-side) the work surface – one close to the frame on the wall, and the other farthest from the frame. These cuts in the plastic will allow you to cut your fabric easier and more accurately because the lower blade of a pair of scissors will follow the groove.

Through the 2 x 6 sides, drill a series of holes (2 to 3 per side) large enough for a piece of 1/2” conduit to pass from one side to the other. The holes should be about 7/8” diameter. Make sure that the holes from one side to the other are somewhat lined up with each other. Cut pieces of 1/2” conduit to a length so that there will be about 2 inches protruding out both sides when passed through the frame. These pieces will be used to hang your Kevlar and/or fiberglass fabric. The lowest set of holes should be about a foot or better from the bottom. This will allow a space to store your epoxies and other liquid materials.

Once all of that is done, wire in a 25-watt light bulb into one of the lower corners inside of the frame. When you are not doing any composite work, keep the door closed and the light on. This light will provide enough heat to keep your fabrics from absorbing any moisture and keep your liquid components from crystallizing if the outside air temperature drops significantly.

### 7.11.4 Composites Lay-Up Table

A second table should be constructed for doing your resin mixing and basic lay-ups. The size of the table should be at least 6-12 inches larger in all directions than the largest composite component on the Hornet. A minimum table size should be about 48” X 36”. The...
table should be located in an area that allows access to all sides. If space allows, the table can be made large enough to provide the space required for dispensing and mixing the epoxies. This can be done almost anywhere in close proximity of the Lay-Up table. Mixing should NOT be done on the cutting table because you will drip some of the epoxy and you do not want any of the epoxy getting into the bolts of fabric.

Dispensing the epoxies in the proper ratios isn’t all that difficult. Composite material suppliers usually have simple hand pumps that screw directly onto the top of the epoxy resin and hardener cans. Dispensing this material doesn’t require much bench space, and since the size of the pieces of foam on the Hornet are small compared to an airplane wing, only small amounts of epoxy will be mixed each time. What this means is that you only need enough space for the cans to sit while you are walking around with a cup of epoxy in one hand and either a stir stick or a squeegee in the other.

Referring back to the Environmental Health And Safety Consideration, I mentioned adequate ventilation. For an extra degree of protection, add a vent/exhaust hood over the table that exhausts to outside. This way, you will not breath any fumes from the epoxy. Also, once epoxies are mixed, they will heat up. In some cases, like when too much hardener is used, the heat can be enough to cause a fire. Follow the manufacturers mix ratios closely and make sure you have a fire extinguisher handy (just in case).

8. The Drawings

8.1 General

All information concerning the fabrication of any components will be on the following drawings. Pay close attention to the material call out in the title block of each sheet in the bottom right hand corner. There will be a list of parts in the top left hand corner of the different assembly drawings, which will provide you with the necessary quantities required for assembly. The part numbers that appear on all of the drawings are for my own benefit so that I can keep everything organized. If you need to contact me about a part or drawing, please specify the part number. Also, if you find a typo or if there are dimensions missing, let me know so that I can make the corrections and repost this document. Thanks!

8.2 SolidWorks

The following drawings were produced using SolidWorks. SolidWorks is a 3D solid model engineering software used by over 150,000 designers and engineers world wide. The base package isn’t cheep! Unlike AutoCAD or a paint program, specific dimensional values can be entered which will drive the size and location of parts and features. SolidWorks is a highly automated design package. It can be thought of as a virtual reality design tool – if the parts fit in SolidWorks, then they’ll fit in the real world, so long as the parts are made correctly.

8.3 Drop Keel Airframe
When I started the Hornet design, the keel and tail boom were fabricated as a single piece of 2x2x.125 wall 6061-T6 aluminum tube, which ran from the nose wheel assembly to the tail feathers. After some consideration, I decided to follow the GyroBee/HoneyBee designs a little closer and split the keel into two separate pieces. In doing so, I was able to lower the engine by 2 inches, effectively creating a small “drop keel”. But this also added a small amount of weight – about 1.5 pounds or so. This may not seem like a lot of weight. However, for every pound that I can take off, the more fuel-efficient the Hornet becomes, not to mention better performance.

There is a slight down side to following the design of the Bee family of gyros where separate keel and tail boom tubes are used. Because the tail boom tube and the keel tube overlap, it increases the weight of the aircraft by a small amount. Lowering the engine by the height of the keel tube (2 inches) helps to close the distance between the CG and the thrust line, but it only changed a small amount - some value less than 2 inches. Since the drop in thrust line is so small, I don’t believe that the additional aluminum tube or work required to drop the engine by only 2 inches is really worth it. Which brings me to the next point. What about a true drop keel?

Just for the fun of completely changing the Hornet design, I added a gap of 4 inches between the tail boom and the keel tube. To clean up the look of the airframe, I cut the front of the tail boom back to a point just in front of the propeller. I then spanned the area between the cluster plates and the front side of the tail boom with another piece of 2x2x.125 wall 6061-T6 tube, and joined everything together with plate aluminum. Whatever tail boom drop I added to the airframe, I removed the same amount off the height from the mast tube, and added length to the landing gear. When I ran a CG calculation, I found that 4 inches of tail boom drop, does not equal 4 inches of CG/thrust line offset change – it was only about 2.5 inches.

I was worried that by dropping the tail boom and adding the necessary parts to make the drop keel idea work, I would be adding too much weight. In fact, just the opposite was true. The empty weight of the Hornet actually dropped by 2.5 pounds! Therefore, I dropped the tail boom another inch, for a total of 5 inches. As it stands right now, with a 225 pound pilot in the seat and a full tank of fuel (5 gallons), the completed Hornet should have a CG/thrust line offset of less than 1/2 an inch.
UNLESS OTHERWISE SPECIFIED:
1. DRILL THESE HOLES THRU ENTIRE TUBE, CAN BE DRILLED FROM EITHER SIDE.
2. USING PREVIOUSLY DRILLED 0.200 HOLES AS A PILOT, DRILL THESE HOLES
THRU ONLY ONE WALL OF THE TUBE, DO NOT DRILL THRU BOTH WALLS OF TUBE
INSURE THAT YOU ARE DRILLING THE CORRECT SIDE OF THE TUBE!

HOLE USAGE

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<td>FLOOR PLATE</td>
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<td>C</td>
<td>JOYSTICK ASSEMBLY</td>
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<td>D</td>
<td>RUBBER FEED ASSEMBLY</td>
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<td>LANDING GEAR ASSEMBLY - main strut attachment point</td>
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<tr>
<td>F</td>
<td>LANDING GEAR ASSEMBLY - landing gear assembly</td>
</tr>
<tr>
<td>G</td>
<td>LANDING GEAR ASSEMBLY - main shaft attachment point</td>
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<tr>
<td>H</td>
<td>LANDING GEAR MOUNTING HOLE</td>
</tr>
<tr>
<td>I</td>
<td>CENTER PLATE MOUNTING HOLE</td>
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<tr>
<td>J</td>
<td>LANDING GEAR ASSEMBLY - main shaft attachment point thru center plate</td>
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Φ.250 - 0X

Φ.195 - 4X

1.150 - 2X

0.750 - 2X

Φ.230 - 10X

1.150 - 0X

1.000 - 0X

0.750 - 2X

2.000 - 0X

1.750 - 0X

1.000 - 0X

281 - 0X

70-00003

K KILL TUBE

HORNET

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8.4 Landing Gear

The first thing that stood out about the Bensen style gyros, to include the GyroBee and HoneyBee, was the stiffness of the landing gear system. The “Bee” family of gyros at least had some form of shock system through the use of bungee cords or fiberglass rods. The Bensen’s had nothing - the wheels are hard mounted to the end of aluminum rectangular tubing. Flying these gyros from hard surface runways was no problem. But what about people’s back yards, grass strips, etc? Rough surfaces tend to bang these aircraft around quite a bit. All of the systems that I had seen thus far had room for improvement. This is where I started my design efforts.

Designing the landing gear lead me down several different roads. I knew I wanted to have the landing gear flexible up and down by as much as 3-4 inches (full travel being about 3-times the aircraft’s maximum gross weight). This would allow for less than perfect landings and rough fields. The biggest challenge in designing a landing gear for an aircraft as light as a gyro is what to use for springs. I looked at a pile of different options – fiberglass leaf springs, coil compression springs, Belleville washers, compressed air, oleo struts, rubber disks, etc. Each one of them had their own special problems to consider, with weight being the biggest problem for each, except for the compressed air design. The biggest problem with air was what do you do if you had an air leak in the system while you are flying, and you didn’t know about it? The lack of holding force on the landing gear could cause a serious accident at the time of landing. At the very least, you would have to rebuild your gyro.

By now, you’re probably asking yourself, “what does this talk about landing gears have to do with the airframe?” Plenty! The entire time that I was designing the Hornet, my target specifications were those outlining what an ultralight aircraft is. In other words, part 103 of the FAA Federal Aviation Regulations was my target – a single seat aircraft with an empty weight of no greater than 254 pounds, a fuel capacity of no greater than 5 gallons, and a top speed no greater than 63 miles per hour. This specification dictated the forces that the landing gear had to be capable of absorbing.

8.4.1 Mains

By comparison to most other gyros, the initial design of the main landing gear for the Hornet was quite wide – 7 feet. A narrower stance would have no impact on the flight characteristics. However, it would degrade the ground rollover angle. Most damage in typical gyro accidents occurs when a pilot touches down in a "crabbed" angle, often when executing an off field landing with the engine out. All too often, the gyro will tip over, destroying the blades and severely damaging other parts of the airframe. A wider gear stance can make any gyro more immune to such rollover accidents. But there is a limit as to how wide you should go. At some point in time, you will have to trailer your gyro to a different location. Most trailers are in the 6-7 foot range. However, many of the 7 foot wide trailers have obstructions where the trailers wheels reside. Loading and unloading a gyro with a 7 foot stance is difficult to deal with in this case. Therefore, after a trip to Rotors Over Carolina in October of 2003, and witnessing this problem firsthand, I decided to narrow the landing gear of the Hornet to 6 foot.
AXLE MOUNT BLOCK

PART GROUP
70 - Bracing, Supports, Frames, and Brackets

DIMENSIONS AND TOLERANCES
UNLESS OTHERWISE SPECIFIED
ALL DIMENSIONS ARE IN INCHES

LINEAR
XXX ± .01
XXX ± .005
XXX ± .001

ANGULAR
X.XX ± 0.5°
X.XX ± 0.1°

NOTE:
1.00
.625

.625

.630

.257 THRU 2 PLACES

6061-T6 ALUMINUM

DO NOT SCALE DRAWING

CREATED WITH SolidWorks

REV - THIRD ANGLE

D. SHOEBRIDGE
1:1 SIZE B

D. SHOEBRIDGE
31 MAY 03

D. SHOEBRIDGE
1 OF 1

Copyright 2003 – Donald T. Shoebridge
TUBE THREADED INSERT

DIMENSIONS AND TOLERANCES
UNLESS OTHERWISE SPECIFIED
LINEAR
XXX ± .01
XX ± .005
X ± .001

ANGULAR
XXX ± 0.5°
XX ± 0.1°
X ± 0.01°

ALL DIMENSIONS ARE IN INCHES

DO NOT SCALE DRAWING

6061-T6 ALUMINUM

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8.4.2 Nose Wheel Assembly

The majority of the nose wheel assembly is made from 4130 steel. As you can see in the drawings, the nose wheel assembly resembles a child’s 12" bicycle front fork and wheel assembly. You are correct. If you feel that stealing the front-end from your child’s bike will be well received by your spouse, then by all means, have at it. You will have to make some small modifications that will allow you to connect the nose wheel steering push rods to the forks, but that shouldn’t be too much of a problem.

All of the headset components on a bicycle will work in the nose wheel assembly, including a front brake and wheel. All of these components can be purchased from a local bike shop, or even a large retail outlet such as K-Mart and Walmart. There are different sizes of headset bearings, so make sure you buy the right size.
8.4.3 Tail Wheel Assembly

The origin of the Hornet tail wheel assembly came from an uncomfortable sound that I once heard coming from a Honeybee gyro. The sound came from the area of the cluster plates when the pilot climbed out of the seat and the tail wheel came to rest on the ground. The sound resembled that which comes from a well-used backyard swing set when a child is swinging on it. Kind of a metallic creaking sound.

Now I don’t know about you, but I value highly the aluminum plates that connect all of the square and rectangle aluminum tubing together, as well as the tubing itself. This creaking sound tells me that something is moving, and upon visual observation of the tail boom as the gyro settled back on the tail wheel, you could see the tail boom pivot at the cluster plates a small amount – at least a inch at the tail wheel. Considering the close tolerance holes in the aluminum plates and tubes, I’d bet that the holes on this particular Honeybee were oval in shape from all of the pounding that the tail wheel received.

After that little eye opening encounter, I was visiting a friend of mine in Richmond, Indiana. There were a few other people visiting that had brought their gyros. One custom built gyro there was an all welded steel tube design that had a spring loaded tail wheel. I talked to the pilot briefly about his tail wheel and he stated that it was well worth having. That clinched it! The Hornet was going to have a spring loaded tail wheel.

Early on in the design of the Hornet, I started to design the tail wheel assembly first. My hopes were that GyroBee and Honeybee owners would build (or buy) the Hornet tail wheel for use on their own gyros. I posted the drawings on my website for a short time, but didn’t receive any feedback as to if anyone had actually built one. So I gave up on pushing the tail wheel design by itself and continued on with the remainder of the Hornet design.

The current Hornet tail wheel assembly is a little different than the early tail wheel that I had originally posted on the website. However, the only differences are the two swing arms that hold the wheel itself. If you have already built the early Hornet tail wheel assembly, you may still be able to use it. You just have to make sure that there is enough clearance between the top of the wheel and the bottom of the rudder. A minimum of about 2-2 1/2 inches of space for the wheel to travel is required.
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<td>26-00093</td>
<td>AXLE BOLT W/ GREASE HOLE</td>
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<td>1</td>
<td>27-00002</td>
<td>FLAT WASHER - AN960-416</td>
</tr>
<tr>
<td>11</td>
<td>5</td>
<td>26-00014</td>
<td>NUT MS21042-4 (1/4-28)</td>
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<tr>
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<td>1</td>
<td>26-00016</td>
<td>NUT MS21042-6 (3/8-24)</td>
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8.5 Composite Seat

The Hornet will utilize a composite seat made from several different pieces of foam. The individual foam pieces will be covered in a wet lay-up fashion with epoxy and Kevlar on the outer surface. These individual pieces are then bonded together in a jigsaw puzzle fashion. This arrangement provides excellent strength, lightweight, and a great deal of mounting flexibility because of all the flat surfaces.

The seat has a single 2-inch wide "spine". This spine fits in between the diagonal braces and the engine mounts. Because strength was one of my primary design concerns, I incorporated the composite seat as part of the Hornet’s airframe assembly, making it an integral part of the airframe’s structural integrity. The seat provides added triangulated support between the mast tube, the diagonal braces and the engine mounts. In the airframe drawings there is a gap between the forward ends of the engine mounts and the diagonal braces. The seat bridges this gap and ties everything together.

As for myself, I’m not the smallest guy in the world. I don’t fit very well into the seat tanks that are so popular now a days. In my opinion, the seat tanks don’t have the best ergonomics. The simple, flat and square design of the Hornet’s composite seat has many advantages that the seat tanks do not address. With this composite seat, the seat cushions are easy to make and can have covers in any color, with any decoration, logo, print, etc. Also, any type or thickness of padding can be used. Eventually, I would like to sell completed seats. In the future, there will be a few different seat designs with varying heights to choose from which will bolt directly to the existing mounting holes on the airframe. A future option might be a ground adjustable seat height mechanism.

One of the biggest benefits of the composite seat design is the ability to mount additional controls, radios, or other pilot gizmos and gadgets. If you’re anything like myself, I like lots of switches and knobs, and this seat allows for the addition of lots of extra stuff. However, mounting this stuff is not just a matter of drilling a couple holes and running some screws through. Because when you tighten the screws, the composite outer shell will be crushed. In the Hornet seat design, I’ve added 2 Garolite/Phenolic insert into the seat bottom plate – one on the left, and one on the right. These inserts provide a strong mounting point to which the throttle or other flat plate style device can be mounted. If additional holes are required, additional inserts will be needed. The inserts can be made from many different materials such as Phenolic, Garolite, or aluminum. As long as the compressive forces of the bolt and nut are applied to the insert material, and not the foam core, you’re all set.

Installation of additional inserts is simply a matter of drilling or milling an opening large enough to accept the insert, securing the insert in-place using epoxy, and applying a fiberglass or Kevlar patch over the insert with more epoxy. Once the epoxy has had time to cure, the insert can be drilled so that a bolt can be inserted. If the insert is small in size, such as a piece of 1 inch round aluminum stock, it’s a good idea to have the insert drilled before bonding into the seat. This will reduce the risk of the insert breaking loose when you drill it. One is rule of thumb about composites to keep in mind, the more surface area the better. In other words, the more surface area of the insert that makes contact with the Kevlar or fiberglass, the stronger the insert will be. Therefore, using a simple round or square plug as an insert would not be a good idea because there isn’t enough surface area contacting the outer surface of the composite.
SEAT BACK MAIN ANCHOR BLOCK

DIMENSIONS AND TOLERANCES
UNLESS OTHERWISE SPECIFIED
LINEAR = XXX ±.01
ANGULAR = X° ±.51

ALL DIMENSIONS ARE IN INCHES

FILE NAME: 70-00030.SLD Drawing

DO NOT SCALE DRAWING
CREATED WITH: SolidWorks

MATERIAL: GAROLITE, GRADE XX
ENG: D. SHOEBRIDGE
SCALE: 1:1
SIZE: B
HEAT TREAT: APRV
DATE

Printed on Monday, November 17, 2003
8.6 Flight Controls

Through the unfortunate experiences of others, I’ve learned a very valuable lesson about flight controls. Flight controls are the most important link between you and the aircraft. They must be reliable! Your life depends on it. Over-killing the design of the flight controls is not a bad thing, so long as they retain freedom of movement and are smooth. Except for a small number of less critical items, all of the components that make up the flight controls on the Hornet are fabricated with welded 4130 steel. There is a small weight penalty for this, but I figured that the gains in reliability far out weighed any penalty.

8.6.1 Floor Plate

The floor plate assembly is a foam core, Kevlar, and epoxy wet lay-up sandwich, with 4130 steel threaded inserts bonded into the bottom surface. This structure will be strong enough to allow you an easier means of ingressing and egressing the gyro, by providing a wide and secure place to stand. It also supports your feet when your feet are resting on the rudder pedals. The Hornet airframe is designed to accept the mounting pattern of the floor plate. Other airframes will require drilling holes in the keel tube for mounting. Except for the material quantities, the floor plate can be fashioned in the same manner as the Watson Tail Feathers. In general, the construction instructions for the of the Watson tail feathers are the exact same as those that will be employed for the Hornet floor plate. Instructions for the building of the Watson Tail Feathers can be found in the GyroBee documentation package. When the composite construction is complete, my suggestion would be to apply a large piece of grip tape to the top surface. This should be plenty of friction to keep your feet in-place while flying.
ITEM NO. | PART NUMBER | DESCRIPTION
--- | --- | ---
1 | 02-0000000 | FLOOR PLATEambi.
2 | 26-00001 | THREADED CONDOSER INSERT FEMALE 10-32
3 | 26-00020 | BOLT ANTIHISTA
4 | 41-00001 | KEVLAR PLAIN WOVEN BID. 36" WIDE, 1.8 OZ./SQ. YD
8.6.2 Rudder Pedals

The final design of the rudder pedals for the Hornet was based on the yaw pedals of the Bell UH-1, better known as the Huey. The actual dimensions are not exactly the same as the Huey’s, but the design intent is the same. Most gyro pedals are flat, which urge the pilot’s feet to lay flat in them, with the pivot point set fairly high. The problem is when a rudder input is made, depending on the amount of input, the pilot could have one foot severely pointed, and the other foot pointed back at an extreme angle. This is obviously not a very comfortable position for the pilot’s feet to be in. Also with a typical gyro pedal, they are designed as "one size fits all". People with legs that are either longer or shorter than the gyro design originally called for, puts the pilots feet in an awkward position right from the beginning, making long flights cumbersome. With the Hornet pedals, in conjunction with the floor plate, the pilot can place his or her feet at any angle that is most convenient and comfortable. There are two versions of the Hornet rudder pedals - one for the GyroBee, and one for the Hornet. There are 2 differences between the two variations; 1) The Hornet version has the addition of a mounting tang to hold an instrument pod, and 2) the Hornet version mounts directly to the keel tube, whereas the GyroBee version is spaced wider to allow for the Nose Wheel Cheek Plates. The Hornet pedals are constructed from welded 4130 thin wall tube, yet weigh only 2.1 pounds, which includes all of the hardware and 2 rod ends.
<table>
<thead>
<tr>
<th>ITEM NO.</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>11-00002</td>
<td>RUDDER PEDAL ASSY</td>
</tr>
</tbody>
</table>

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8.6.3 Joystick Assembly

One of the biggest complaints that I’ve been hearing from people is the inability to rest your arm on your lap while still maintaining a grip on the joystick. Hopefully I’ve taken care of this problem with my joystick design.

I designed the Hornet joystick with several ideas in mind. One idea focused on a simple means of adjusting the joystick to the pilot. I accomplished this through the use of a couple of rod ends attached to opposite ends of the length of 4130 tube (P/N 56-00005 – Pitch Tube Assembly). If the position of the stick grip is not in a position of the pilot’s liking, simply pull one of the AN bolts, break a piece of safety wire, loosen a jam nut and screw in (or out) one of the rod ends. Once reassembled, the stick grip will be in a different position. Turning the rod ends in will move the stick grip closer to the occupant.

The basic configuration and construction technique of the joystick came from two different sources; 1) the UH-1 Huey and 2) a Piper Cub. I wanted a military looking joystick (like the Huey), but it also had to be simple (like the Cub). Although, the Cub design was a little too wimpy for my tastes, so I beefed it up a bit.

Pitch and roll inputs will be a bit docile in this current configuration. The Control Fork Weldment is purposely narrower and shorter than some of the more common gyro control systems. I consider this to be an initial design. Reason being, I’m not quite sure exactly how the Hornet will fly and I didn’t want to have the controls overly sensitive. A story about old and bold pilots comes to mind.

In keeping with the simple and rugged design approach, the majority of the joystick assembly is fabricated from welded 4130 steel tube. Yes, it is a bit heavier but it is much stronger and will not fatigue like that of aluminum. I wanted to have a higher degree of confidence with regard to the flight controls.

There are other joystick assemblies available from several different companies, but the bolt mounting hole pattern for the Hornet joystick will be different. If you are going to build a Hornet, and you already have a joystick assembly, don’t drill the holes in the keel tube until you know exactly where your third-party joystick assembly should be positioned.
**DIMENSIONS AND TOLERANCES**

**UNLESS OTHERWISE SPECIFIED**

**LINEAR**

- X: ±0.01
- X: ±0.005
- X: ±0.001

**ANGULAR**

- X*: ±0.5°
- X*: ±0.1°

*ALL DIMENSIONS ARE IN INCHES*

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<th>PART NAME</th>
<th>PITCH TUBE</th>
<th>DRAWER</th>
<th>MATERIAL</th>
<th>HEAT TREAT</th>
<th>FINISH</th>
<th>CREATE WITH</th>
<th>SCALE</th>
<th>THIRD ANGLE</th>
<th>SHEET</th>
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<tr>
<td>56-00004</td>
<td>PITCH TUBE</td>
<td>D. SHOEBRIDGE</td>
<td>4130 STEEL</td>
<td>SOLIDWORKS</td>
<td>2:1</td>
<td>B</td>
<td></td>
<td></td>
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**Printed on Thursday, June 12, 2003**
ITEM NO. | QTY. | PART NO. | DESCRIPTION
---|---|---|---
1 | 2 | 08-00005 | ROD END, 1/4-28 FEMALE, .25 BORE
2 | 2 | 56-00003 | THREADED TUBE END
3 | 1 | 56-00004 | PITCH TUBE
4 | 2 | 26-00088 | HEX JAM NUT, 1/4-28 DRILLED

ATTACH THREADED ENDS VIA WELDING, THEN FINISH SMOOTH. ENDS CAN ALSO BE EITHER BOLTED OR RIVETED BY DRILLING HOLE THRU PITCH TUBE AND END. DO NOT USE ALUMINUM! (BOTH ENDS)

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8.6.4 Rotor Control

Rotor control is accomplished through four short push rods. Why four? If two long push rods were used between the control fork and the rotor head, because of the distance that they would have to span, during flight they would shake a great deal. So to eliminate this from happening, I added two push rod swing arms – one to either side of the mast, about half way between the rotor head and the control fork. Then I added two push rods between the control fork and the push rod swing arms (lower push rods), and two more push rods between the push rod swing arms and the rotor head (upper push rods). The four push rods are exactly the same as the Pitch Tube Assembly except that the overall length is different. The length of the lower push rods is a know value. However, the distance from the push rod swing arms to the rotor head is a different matter. Depending on which rotor head is selected for installation, the correct length of the upper push rods will change.
ITEM NO. | QTY. | PART NO. | DESCRIPTION
---|---|---|---
1 | 2 | 08-00005 | ROD END, 1/4-28 FEMALE, .25 BORE
2 | 2 | 56-00003 | THREADED TUBE END
3 | 2 | 26-00088 | HEX JAM NUT, 1/4-28 DRILLED
4 | 1 | 56-00010 | LOWER PUSH PULL TUBE

ATTACH THREADED ENDS VIA WELDING, THEN FINISH SMOOTH. ENDS CAN ALSO BE EITHER BOLTED OR RIVITED BY DRILLING HOLE THRU PITCH TUBE AND END. DO NOT USE ALUMINUM! (BOTH ENDS)

Copyright 2003 – Donald T. Shoebridge
ATTACH THREADED ENDS VIA WELDING, THEN FINISH SMOOTH. ENDS CAN ALSO BE EITHER BOLTED OR RIVETED BY DRILLING HOLE THRU PITCH TUBE AND END. DO NOT USE ALUMINUM! (BOTH ENDS)
8.7 Tail Feathers

The construction of the Hornet tail feathers is exactly like that of the Composite Seat – foam core, Kevlar and epoxy wet lay-up. Construction of the tail feathers is such that no extra bracing will be required. The horizontal stabilizers are cantilever mounted over two pieces of 4130 steel tubing, and secured by six screws that pass through the top surface of the tail feathers, through the tubes, and protrude out the bottom with self-locking nuts holding everything together. The total surface area for both horizontal stabilizers is about 8 sq/ft.

The drawings for the tail feathers are not complete. The design will be finalized in the future when Hornet 03-001 has been built and flown for some time. Therefore, the drawings provided for the tail feathers are for reference only. I strongly suggest that you NOT build these. As with any aircraft, aerodynamic shapes such as tail feathers require flight-testing to be fully proven and developed. This tail assembly has not flown and is not proven.
HORIZONTAL STABILIZER MOUNT BLOCK

DIMENSIONS AND TOLERANCES
UNLESS OTHERWISE SPECIFIED
LINEAR X, X, X ±0.01
ANGULAR X, X, X ±0.5°
ALL DIMENSIONS ARE IN INCHES

MATERIAL: GALOLITE, GRADE XX
HEAT TREAT:...

DRAWN: D. SHOEBRIDGE
APPROVED:...

REV
D. SHOEBRIDGE
SCALE 1:1
SIZE B

Printed on Monday, February 09, 2004

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GLUE IN PLACE BOTH CONTROL HORNS APPROXIMATELY AS SHOWN AFTER EPOXY IS CURED. APPLY PATCH AS SHOWN AFTER EPOXY IS CURED. APPLY MIXTURE OF 30% CLOTH AND 70% EPOXY TO SURFACE OF HORN. APPLY MIXTURE TO A CORNERED EDGE OF HORN. APPLY STRAIGHT EPOXY (NO FILLER) AS SHOWN TO BOTH CONTROL HORNS.
<table>
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<th>PIN</th>
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<tr>
<td>PART GROUP</td>
<td>Horiz. Stab. Reinforcement Block</td>
</tr>
<tr>
<td>PART</td>
<td>70 - Bracing, Supports, Frames, and Brackets</td>
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</table>

### Dimensions and Tolerances

**UNLESS OTHERWISE SPECIFIED**

- **LINEAR**
  - X, X: ±0.01
  - X, XX: ±0.005

- **ANGULAR**
  - X: ±0.5°
  - X, XX: ±0.1°

**ALL DIMENSIONS ARE IN INCHES**

---

**DO NOT SCALE DRAWING**

- **MATERIAL**
  - GAROLITE, GRADE XX

- **CREATED WITH**
  - SolidWorks

- **REV.**
  - D. SHOEBRIDGE

- **DATE**
  - PRINTED ON MONDAY, FEBRUARY 09, 2004

---

**FINISH**

- DETAIL

**SHEET**

- 1 OF 1

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<td>1</td>
<td>65-00002</td>
<td>HORIZONTAL STABILIZER</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>51-00015</td>
<td>LAMINATE &amp; EPOXY SKIN</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>50-00002</td>
<td>HORIZONTAL STABILIZER REINFORCEMENT BLOCK</td>
</tr>
</tbody>
</table>

NOTES:
1. ALL GASKET BLOCKS ARE GUARDED IN PLACE USING STRUCTURAL EPOXY.
2. ALL GASKET BLOCKS SHOULD BE CENTERED ON FOAM CORE CENTERLINE.
3. ALL HOLE PLUGS AND HOLE COVER GASKET BLOCKS SHOULD BE HOLE PLUGS IN THE GASKET BLOCKS CAN BE DRILLED CLEAR AFTER EPOXY HAS HAD TIME TO CUR.
8.8 Fuel Tank

One of the simplest, and yet, one of the most time-consuming designs on the Hornet has been the fuel tank. The reason for this is that I wanted to have an aerodynamic shape to the tank, and I wanted to try and minimize the CG swing of the Hornet as fuel was burned off. Also, in an effort to find a simple and cheap way to manufacture the tank, the design kept changing. I have changed the fuel tank design so many times over the course of a year that, frankly, I'm tired of looking at it. I had been focusing on one specific method of fabrication for the fuel tank - Kevlar over foam. I figured that the foam could then be melted out after the wet-lay-up process, leaving a Kevlar shell. Other past ideas have been to vacuum or blow mold the tank as needed, which is a very expensive option in low quantities. I also played with the idea of making the fuel tank out of welded aluminum. Here again, too complicated and expensive.

To simplify the installation of a fuel tank on the Hornet, a purchased fuel tank will be used, specifically a GT400 fuel tank. The GT400 fuel tank is also the same tank that is used on the GyroBee. Like the GyroBee, a similar method will be used to mount the fuel tank to the Hornet, but with one major difference; the Hornet will use a Kevlar over foam frame design. The frame that is used to hold the fuel tank on the GyroBee is made of individual aluminum pieces and then bolted together. There are several reasons for using Kevlar for mounting the fuel tank; 1) Kevlar is stronger than aluminum and will not fatigue, 2) there are fewer parts to deal with, 3) Kevlar has natural vibration dampening characteristics, and 4) because of the location of the Kevlar components, it will provide a great deal of added strength to the engine mount support and tail boom. The location of the fuel tank has not changed, and will be located directly underneath the engine mounts, just aft of the mast. The fuel tank will be held in-place in the exact same manner as the GyroBee – 2 bungee cords.
NOTES: UNLESS OTHERWISE SPECIFIED
1. THIS PART CAN BE FABRICATED USING 2 DIFFERENT PIECES OF STYROFOAM.
8.9 Engine and Propeller

The standard power plant package for the Hornet is a 40 hp Rotax 447 (2.58:1 ratio “B” gear box), swinging a ground adjustable, 2 bladed, Powerfin propeller, up to 64 inches in diameter. The Hornet, designed from the GyroBee, is designed to fly well on comparatively low power. Use of a Rotax is not mandatory, as other manufacturers make perfectly suitable engines in the 40-45 hp range that would do just as well, assuming the use of a reduction drive that would let you swing an efficient 60-64 inch prop! Unless you are very heavy or routinely fly from high elevation fields, the Rotax 447 should do just fine. If you have an altitude or weight problem, a larger engine will be required. A larger engine may not require any additional bracing or supports, but until a complete series of tests have been performed, installation of an engine greater than a Rotax 503 should not be attempted! Keep in mind that because of the increased airspeed that a larger engine will give, you may have to register the Hornet as an “Experimental”. In this case, you would be required to receive training and obtain a pilot certificate of some kind, usually a Private Pilot certificate, but at the very least, a Student Pilot Certificate. Contact a gyro rated Certified Flight Instructor for more details. You can find a list of CFI's at www.pra.org.
8.10 Rotor Blades

With the GyroBee, keeping the CE above the thrust line is done by using inefficient (draggy) rotor blades. This drag pulls back on the top of the rotor mast, keeping the CE from falling too low. Amplifying this much needed force is done through the use of a taller than average mast. However, relying on the drag of the rotor to always be there is not a sure bet, regardless of the type, brand, or configuration of gyro.

The biggest difference between the Hornet and the Bee family is the selection of rotor blades that can be used. Because of the CLT configuration of the Hornet, rotor drag is not nearly as critical, as is the case with the GyroBee and HoneyBee. Therefore, any properly sized rotor system can be used on the Hornet. Like that of the GyroBee and HoneyBee, it is recommended that a disc loading of about 1.0 pound per square foot (PSF) be used. A low disc loading such as this will cause the Hornet to be a “floater”. This not only improves your chance of finding a suitable spot to land in the event of a power failure, it also means that you can fly your approach at a significantly lower airspeed and that you can execute a no-roll landing much more easily, even without a stiff breeze to help.

Besides the necessary stabilizing affect, it is important to remember that the higher drag rotor blades used on the GyroBee and HoneyBee, limit their top speed to the FAA mandated 63 mph (55 KTS). Anything faster than that, and the aircraft will have to be registered as an “Experimental”. Except for the stabilizing affect, the same goes for the Hornet. Efficient rotor blades, having less drag, will cause the Hornet to fly faster than 63 mph. On the Hornet, even though high drag rotor blades are not required to maintain stability, they will keep the maximum airspeed at or below the part 103 limits.

9. Final Assembly Sequence

9.1 DXF Files

What is a DXF file? A DXF file is a vector graphic file, sometimes referred to as a “medium file format”. DXF files can be imported and exported by many different CAD packages. But most importantly, they can be imported into manufacturing programs and equipment. For sheet metal parts, DXF files can be loaded into water-jet cutting machines and the machine will automatically cut the part profile and all of the holes. DXF files are generally 2D in nature, which makes them small, so they will fit on a 3.5” floppy disk.

Several people have asked me in the past if I would send them DXF files of the flat parts for the Hornet. In short, the answer’s no! However, I will make them available for download. However, the only you will have access to them is through this document. Below are a series of URL’s pointing to a specific area of my website. As I’ve stated at the beginning of this document, these are for reference only, and I make no claims to the completeness and accuracy of the DXF file. There are discrepancies between the material callouts in the drawings and the material callouts of the DXF files. Once I have built my Hornet and confirmed the material deviations, I will make everything match.
Below you will find the Internet path to the DXF files and a list of all of the parts that are in each of the DXF files. Except for the 6061-T6 aluminum plate, these parts are probably thicker than they need to be. If the Hornet is within a few pounds of the Part 103 weight limit, substituting the material of the steel sheet parts below can provide some weight savings. Example: Instead of using .065" material, use .050". Instead of using .090" thick, use .075" thick. Instead of using .120" thick, use .100", or even .090" thick. Since there are so few parts that actually use .120" thick material, there really will not be much of a savings, and probably isn’t worth the effort to change. The formed steel shackles for the landing gear are going to see high shock loads. Therefore, it might be a bad idea to change to a thinner material on those parts.

Changing material thickness to save weight is the easiest method that can be done. Another option is to cut large holes in the parts to get ride of unneeded material. However, the only part that this can be done to is the Nose Block – on the upper and lower plates. All of the other parts are either too small or already have lightening holes in them. In the future, I may do a bit of redesign on the flat sheet parts, but I feel that I would only save a pound or two.

The simplest way to download the DXF files is to first go to http://www.geocities.com/donshoebridge/ftp. There you will see the DXF files. Right click on each of the files that you would like to download and click on either “Save Link Target As…”, or “Save Target As…”

9.1.1 Aluminum Plate .120 Thick 6061-T6

http://www.geocities.com/donshoebridge/ftp/120Thick6061-T6Plate.DXF - This file contains the following parts; 69-00001, 69-00002, 67-00011, 69-00004, and 69-00005,

9.1.2 Misc. Steel Plate .065 Thick

http://www.geocities.com/donshoebridge/ftp/065ThickMiscSteel.DXF - This file contains the following parts; 70-00013, 70-00018, 70-00022, 70-00026, 70-00029, and the side plates for 68-00001.

9.1.3 Steel Plate .090 Thick 4130

http://www.geocities.com/donshoebridge/ftp/090Thick4130Plate.DXF - This file contains the following parts; 67-00008 (upper and lower plates), 11-00001 (steering tab), 27-00001, and 69-00003.

9.1.4 Steel Plate .120 Thick 4130

http://www.geocities.com/donshoebridge/ftp/120Thick4130Plate.DXF - This file contains the following parts; 67-00007, 67-00009 (steering tabs), and 56-00002 (pivot tangs).
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