The Utter Kaos designed by Joe Bridi is one of the greatest flying airplanes ever. When balanced properly it will track through any maneuver straight and true and it is very stable and easy to fly.

Balancing Act

By Jim Hamilton

Have you ever given much thought to the balance of an airplane and how it flies? Balance is an important factor in anything that flies. With airplanes it is important because balance affects not only how it flies but its performance as well.

There are several aspects that need to be understood about aircraft balance. First being, why does an airplane to be balanced? The answer is simple it *will fly better!*

The first thing to understand is the three axis that an airplane flies about. The three axis are the lateral (pitch), longitudinal (roll) and the vertical axis (yaw). These are three imaginary lines that the airplane pivots on. Second thing to understand is the three main movements around the axis, this means pitch, roll and yaw. The third understanding is the flight control that move the airplanes around the axis and that would be the elevator for pitch, the rudder for yaw, and ailerons for roll. A simple way to visualize this is to simply take you left hand pointing up and place the palm of your right hand on top you middle finger on your left hand (Like you are giving the time out hand sign). You can pivot your right hand atop your middle finger and see how an airplane rolls, pitches and yaws around a central point.

When in proper balance the airplane can sit on a central point and is balanced equally on all three axis. To further understand the three axis of flight is to imagine 3 straight lines passing through the plane. The longitudinal axis is a straight line that goes from the nose to the tail; the lateral axis is a straight line that goes from wing tip to wing tip and the vertical axis which is a line that extends from the top of the plane to its bottom. Having a basic understanding of the three axis of flight will help when it comes time to balance an airplane.

A majority of the time we balance airplanes within the recommended center of gravity limits. We use the recommendation from plans or guides given from the designer or manufacturer. When we do this we are checking the lateral balance of the plane (nose to tail). Lateral balance affects the pitch axis of the plane in which we control pitch using the elevator. If the airplane is nose heavy, we add weight to the tail, likewise if the airplane is tail heavy we add weight to the nose. Not always is it needed to add weight to achieve the proper balance, sometimes we can shift installed components (servos, receivers, battery pack, etc, etc.) to help balance an airplane, as opposed to adding weight, it can be a better option.

To understand weight and balance, the best way is to visualize a see-saw. The long board that the kids sit on represents the axis. The see-saw moves about a center point, and if two kids of equal weight are sitting at an equal distance from the center then the see-saw will be balanced. However, if two kids of different weight sit at the same distance then the see-saw does not balance. To balance two kids on a see-saw of different weights, you can have the heavier kid move toward the center and therefore balance the see-saw. This concept is called weight shifting. By reducing the distance from the balance point (moving the fat kid forward, I hope none finds that offensive!) and moving the heavier kid toward the center you are making the force of the heavier kid's weight less in terms of balance. This comes out to a simple equation: Weight x Arm = Moment. Weight is the actual weight of the kid, Arm is the distance from the center (balance point) and moment is the resultant force that is acting on the arm.

Like I said before, most of the time we concern ourselves with balance on the Center of Gravity (C.G). Balance on the C.G. affects the pitch airplane meaning up and down. If an airplane is nose heavy it will have a tendency to descend requiring nose up trim. If the plane is tail heavy it will have a tendency to climb requiring nose down trim. Small amounts of trim are acceptable, but excessive amounts can cause very bad flight qualities. When an airplane is excessively nose heavy it requires more control input to climb, fly straight and level and may cause problems when taking off and landing. When the plane is excessively tail heavy it likewise it will need more control input as well, but it produces more adverse qualities than the nose heavy condition. What I am talking about is stability, in a tail heavy condition the airplane will appear to be more sensitive in pitch. This may be desired for some airplanes; because the airplane is tail heavy it will be much more sensitive to stalls and spins and recovery from them may be very touchy (Anyone who has ever flown a plane that is real tail heavy knows what I am talking about, snap rolls and spins happen on their own!). This makes the airplane less stable. As a rule of thumb, it is better to have the plane more toward the nose heavy side than tail heavy.

When it comes to balancing an airplane, I started using a very simple method that does not require any major calculations, tools or wind tunnel testing. All you need is a string (Strong enough to hold the airplane), a hook to hang from the ceiling, a simple bubble level and of course some weights.

The first thing to do is to have a string suspended from the ceiling. I used a small hook that I drilled into my workshop's ceiling. Now if you don't or can't do that, then you can also attach the string to a beam from the ceiling or you can use a 2x4 piece of wood and some saw benches.

The next step is to find and mark the C.G. on your airplane. I was able to use the location found on the set of plans for my plane. For ARFs with no plans the instruction book will also have the C.G. location. If neither of those are available then you can calculate the C.G. yourself. In general, a good balance point for a straight wing airplane (meaning non-swept back) is located about 25-33% of the wings chord (wing's width). So if the wing has a 12" chord (width) the C.G. would be approximately 4" from the leading edge of the wing using 30% of its chord. This formula will normally get you in the ballpark range for C.G. minor adjustments can be made later. I placed masking tape on the fuselage and marked the location of the C.G. If you don't want to use tape, a dry erase marker works well and wipes off easily afterwards.

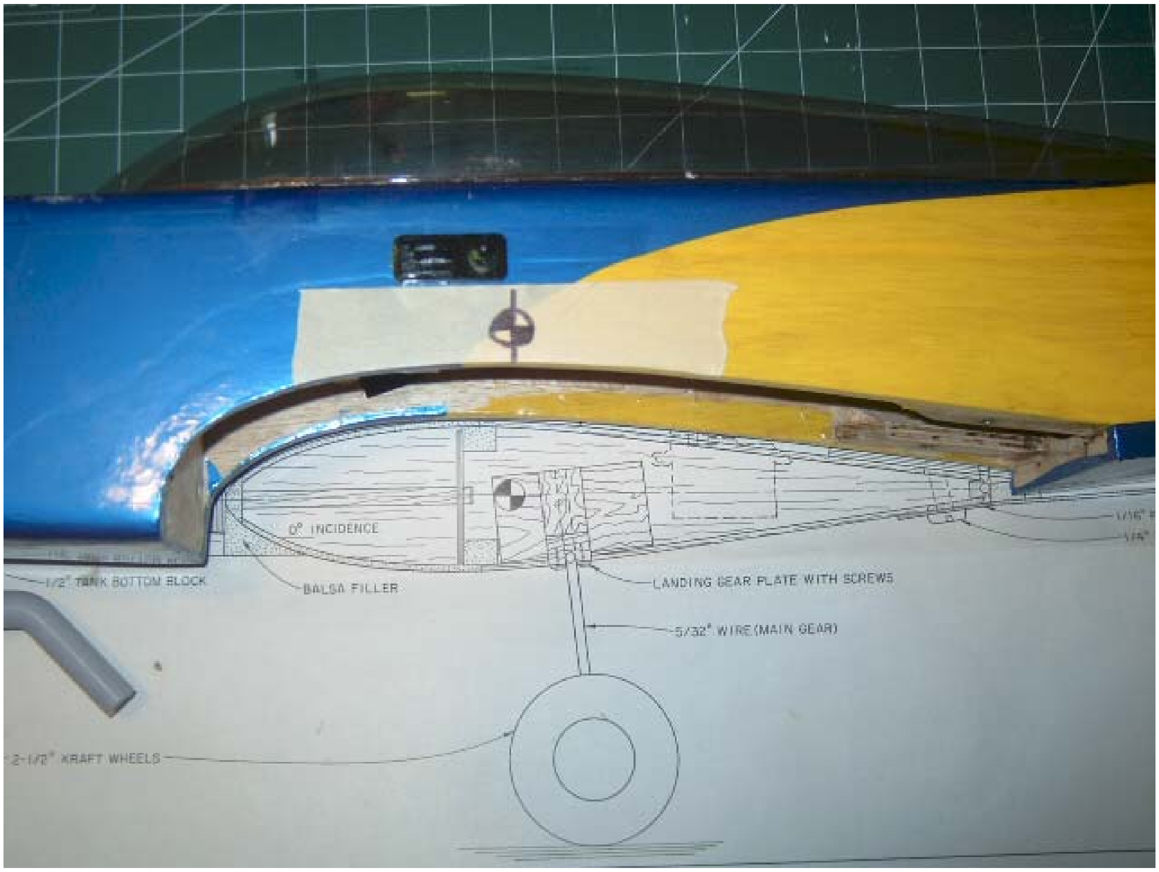
I ran the string around the fuselage and then mounted the wing. Then I ran the string back to the top of the hook and made a simple knot. I used a zip-tie at the top of the fuselage to keep the string steady and prevent any slipping. I used a support stand for the airplane when doing this, it made it easy to attach the string and when I was ready to "hang the plane all I had to do is take away the stand and the airplane was now suspended.

When the airplane was suspended from the string on its C.G., it was hanging very nose low with the left wing higher than the right. When I did the first couple of test flights on this airplane a few days earlier, it needed nose up trim and left aileron trim. While hanging on its C.G. now I could see why these trim inputs were required. Now if the airplane is built straight and true with no warps in the wing and the controls neutral, the trim inputs would indicate balance issues. I could see this plain as day when I had this plane suspended. The fix was very simple; I got some fishing weights and place them on the plane to balance it level. When it comes to weights there are many different ways you can add weight. Lead is a good choice because it is very soft and it has weight. In this case I used fishing weights, but also they make stick on weights and some people use lead shot as well which works very well it tight areas. For balancing the wing I used a cardboard rocket tube and added the lead weight until it balanced. I then put some glue into both ends of the tube to secure the weights inside it. Underneath the wing I made a small slit in the covering and glued the tube inside the wing securely. Keep in mind that the glue will add a little weight. I checked the balance of the wing, with the bubble level it was centered straight and level. For the pitch balance I used the same method using the fishing weights, once I had the airplane balanced where I wanted, I glued the weight to a discreet area on the tail and wing (cosmetics are important too!). I re-checked the balance once again and it was exactly where I wanted it to be, slightly nose down and wings level. When I say slightly nose down, that is the way most airplanes should balance. To what extent really depends on the model but in general for most airplanes this is about 3-10 degrees nose down. In other words *slightly* nose down from level.

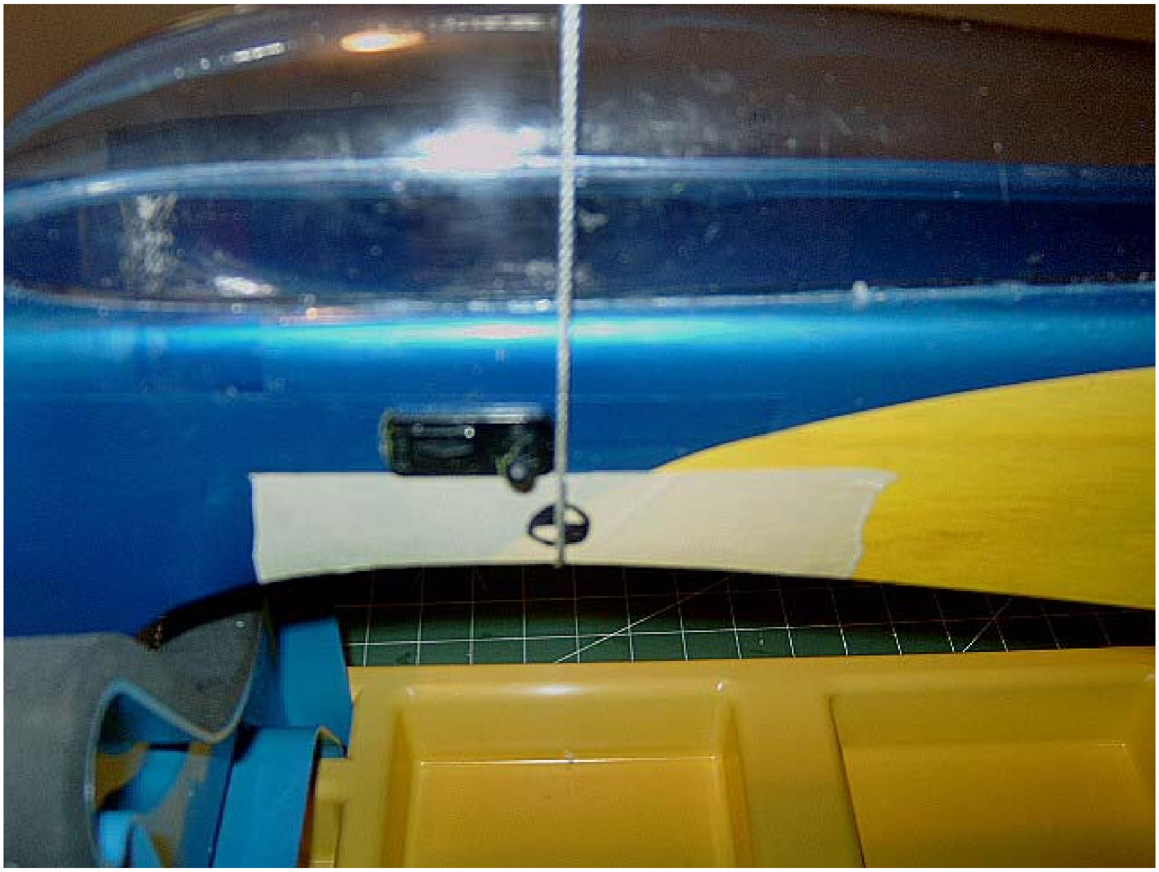
Although I hate adding weight to a plane in some cases it is needed, but in this case I could not see a way that was feasible to shift any weight inside the plane. In this case I only added a total of four to six ounces of weight overall. For a sixty size airplane the added weight was not very significant. The airplane did perform better, and that to me was more important than a small weight gain.

When I flew the airplane afterwards the trim inputs were pretty much centered and the airplane flew much better, which really made me happier because on the first couple of flights I was really impressed by the way it flew. Now with it balanced on both pitch and roll, it was even more of a delight to fly. Loops were effortlessly straight and the rolls were axial with little input. Inverted and knife edge flight was easier as well, with out the nose up trim and left aileron trim from before, the airplane required a lot less input to achieve straight flight when knife edge or inverted.

Whether you fly R/C, Control Line, Free-Flight or full scale aircraft balance is very important with regards to flight performance. Keep in mind as well that a properly balanced airplane will fly better too. This important for the fun factor in flying, if an airplane is out of balance it can be difficult to fly (possibly causing excessive nervousness and heart attacks). If you fly for fun an out of balance airplane can drive you nuts, and if you fly competitively an out of balance airplane may degrade its performance. The method I use to balance an airplane is not time consuming and it is very simple way to improve the flight characters of your plane. Just as important it is *very accurate* as well. This method can be used to balance any type of model airplane with just minor modifications and planning. This method can be adapted to balance airplanes of different sizes, designs and different wing mounting (high wing, low wing, rubber band / bolt on, separate wing panels, etc, etc.). The basic idea is to simply suspend the model from its center of gravity. A much larger and complex discussion could be made on balance, aerodynamics and flight performance but this method simplifies the process into a common practice that is easily done, simply put ,as many men much wiser than me have said “a balanced airplane flies better”.



Here is where I marked the C.G. on the airplane. From the plans it shows 4 ¼” from the leading edge of the wing.



I ran the sting under the wing saddle with the string centered on the C.G. location.

With the wing attached and the airplane suspended from this view you can see that this plane is nose heavy.

From this view is can also be determined the right side is heavier than the left.

On the left wing, I used a cardboard tube and put lead weights inside until the wing balanced level. I used this method in a similar fashion to balance the airplane on the fuselage.

I used a very simple bubble level to check the wing balance while I was adding weight and after I glued the weight in place. Like wise I did this for the fuselage as well, using double sided tape and place it centered on the C.G. and straight along the length of the side.