

Servo Arm Geometry

Geometry and force/connection relationships are going to be a big part of this phase of the project. It's important that you understand how your mechanical connections will interact with the parts they link.

For the control rod ends, we will utilize ball links that are bolted to the servo arms. We use the ball links because they are simple to use and are very reliable. Because the connection is offset to the rotational center of the servo arm, any force will tend to create a twisting motion on the servo arm. If the servo arm were to twist, that in turn would put a side load on the control rod. In order to tame the twist and ensure a very solid connection, aluminum servo arms are necessary when using ball links.

The heavy-duty plastic servo arms sold by some of the aftermarket companies will work fine when used with a clevis that is supported on both sides of the arm but will twist when used in an offset environment like a ball link bolted to one side of the arm. I used S.W.B. arms on this project. The arms come pre-tapped to accept 4-40 bolts.

The wings and horizontal stabs will have the servos mounted in the bottom of them, vertically, nearly flush with the outer skin. There will be a short control rod linked from the servo arm to a mild steel bolt that will act as the control horn.

Before we sheeted the wings, we prepared the foam cores for the servo installations by inlaying ply mounts or "servo rails" under the skins. Geometrically this arrangement is not perfect because the movement of the control horn and the servo arm arc on differing airplanes.

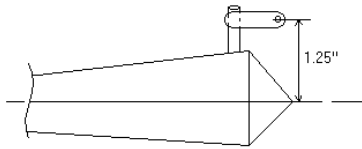
The force applied perpendicular to the hinge line given a specific rotational torque value changes in a nonlinear fashion as the servo rotates. A servo on its side is much better from a geometry perspective because both the control horn and the servo arm travel the same rotational path thus remaining constant as the surface is deflected. But, for simplicity, reliability, and easy service access most Scale Aerobatics aircraft are built the way we are doing it, so let's take a look at what we have to work with.

Before you get too worried about changes in force values during rotation, remember that the load on the surface being deflected is dynamic and changes with a number of factors including surface area, air speed, and of course degrees of deflection. In general, applied loads will increase as deflection increases so let's focus on that assumption.

As a basic starting point, the longitudinal centerline of the servo should be 90 degrees to the hinge line, *not* parallel to the aircraft's centerline. (For the stabilizers, they will be both.) We will be using S.W.B. aluminum arms that are 1.25 inches ("L" in diagram 2) to achieve 45 degrees of elevator surface deflection at 100% travel. The idea is to strive for a control horn length of 1.25 inches measured from the center of the hinge line (the beveled point) to the center of the control-rod connection point. (Diagram 1). We want to create a 1-to-1 ratio so that we get all the deflection we need without compromising (or reducing) the applied force (mechanical advantage) generated by the servo.

You can increase the mechanical advantage from your servo by utilizing a control horn that is longer than the servo arm but you will lose deflection degrees. You can also increase the surface throw by using a servo arm that is longer than the control horn but this ratio decreases the servo's mechanical advantage so it is not recommended. The

whole thing works kind of like gears on a bike. I find that a 1-to-1 ratio is just right when 45 degrees of deflection is desired.



Control horn should be measured from the center of the hinge line to the center of the control horn clevis. The height of the clevis should be equal to or greater than the servo arm length.

Diagram 1

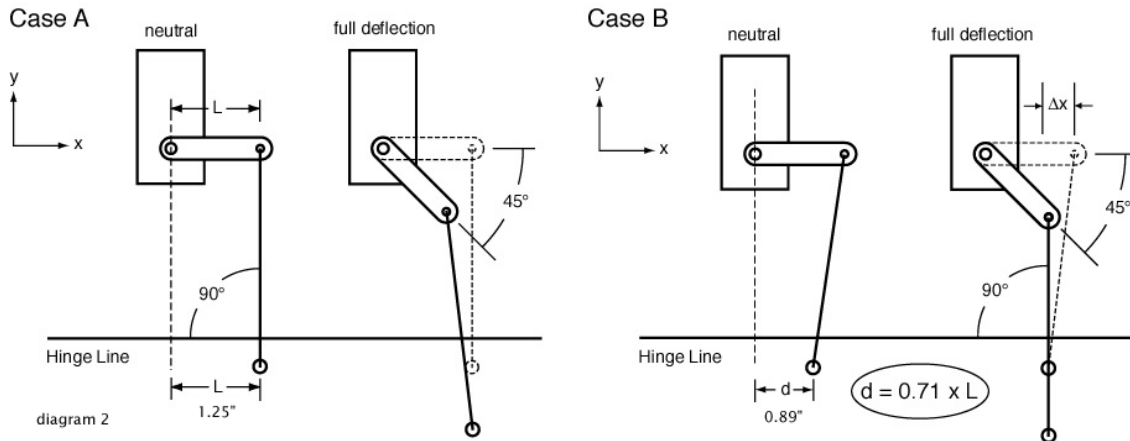
The servo rails mounted in the wings are approximately 2-1/2 inches, so positioning the servo in relation to the control horn is just a matter of mapping them out before the servo bays are cut. Since the movement of the servo arm is on a different plane from the control horn, let's take a look at how we can arrange them to get the best end result.

You can see in diagram 2, case A, that when the servo arm is centered at 90 degrees or parallel to the hinge line the control rod is positioned 90 degrees to the hinge line. As the servo arm travels in an arc the x displacement decreases causing the control rod to change its angle with respect to the hinge line. At 100% travel the arm has moved approximately 45 degrees.

The movement up until this point is fairly linear along the y axis but past 45 degrees the slope degenerates in a very nonlinear manner. Mechanical force also decreases as the x axis distance decreases and the control rod moves farther from 90 degrees. What we have is a situation where the mechanical force from the servo arm actually decreases as the arm travels to full deflection but the required applied force is increasing from flight loads as the surface is deflected further into the air stream.

In Case B, the control rod is 90 degrees to the hinge line at the point where the servo arm has reached full deflection of 45 degrees. In this case, the force is greatest at full deflection where flight loads are likely to be the greatest and the deflection travel is closer to a fully linear motion.

None of this is truly critical but it makes sense to arrange the positions of the components to get the best advantage possible. In Case B, with a 1-1/4-inch servo arm, we found the best location for the control horn is 0.89 inches from the centerline of the servo ("d" in diagram 2). For a sophisticated software program that will allow you to design your own linkage systems, take a look at the Linkage Design program from Envision Design at <http://members.cox.net/evdesign/>.



Courtesy of Erik Richard

Using the template that you made for the wing cores, find the locations of the stress-bearing plates, and if you embedded servo rails under the skins as we suggested during the sheeting portion of the construction phase, you'll need to locate them with the original templates as well.

When determining a location, the dowel should just touch the beveled leading edge stock. Find the location for the bay in reference to the dowel position as described above and mark it all out on the wing panels. We used a Dremel tool with a small router attachment for cutting the servo bays. Mask off the area around the servo bay to protect the wood. We cut the bays freehand but if you want to be more accurate with the edges of the bays, you can pin some 1/4-square balsa sticks in the appropriate positions to act as a cutting fence.



Decide how far you would like your servos to be recessed into the wing panel. We recessed the JR DS8411 servos to 3/8-inches deep. Make the initial cut to the depth of the desired servo recess according to the outside dimension of your servo. The remaining depth should be cut only between the servo rails to finalize the servo bay. If all was done correctly the servo lead tunnels in the flyingfoam.com wings should be accessible.

