On the 'Wing... #148

Basic control systems for tailless sailplanes

Perhaps the most frequently asked questions we receive involve control systems for tailless planforms — which control surfaces are needed, where those control surfaces should be located, how large they should be, and how much deflection is required.

Because of advancements in radio control technology, it is now very easy to set up control surface deflections based on separate "rates." That is, the pilot may switch between two or more deflection parameters with the toggling of a single switch. A great percentage of pilots have come to prefer the "exponential" rate, in which control inputs near neutral have very little effect on the control surface deflection, but control surface inputs nearer the extremes have a very large effect. Some modern transmitters allow the operator to tailor the exponential curve to suit there own preferences.

Additionally, combining inputs from two functions into a single actuating system (as is required for V-tails or elevons), or separating a single function into two or more separate actuating systems (as is required for a "six flap" system where there is an aileron, elevator, and elevon on one wing panel), is now possible.

Because of the above mentioned capabilities, this month's column will be limited to needed control surfaces, their location and size.

For the most part, needed control surfaces are based on the type of aircraft, just as for conventional tailed aircraft. It is possible, for example, to design, construct and successfully fly anything from a very simple rudder only "plank" to a "six-flap" equipped swept wing with adjustable winglets.

In general, the control surface chord should be between 20 and 25% of the local chord. There are, however, specific situations where the local control surface chord is substantially larger or smaller. The outer area of the elevator of Jim Marske's Pioneer II-D, for example, is about one half of the expected lower limit. Because the elevator area is concentrated in an area well behind the CG, and the torque rod must be at 90 degrees to the interior drive tube, there is a jog in the trailing edge of the elevator itself. See Figure 1.

Control surface location is very dependent upon the specific planform. There are, however, some relatively simple rules which can usually be applied:

1. Ailerons should be outboard, so the roll force which they exert is maximized.

2. The elevator should be placed as far as possible from the CG so the pitch force exerted by the control surface is maximized.

3. The rudder should be placed as far as possible from the CG so the yaw force exerted by the control surface is maximized.

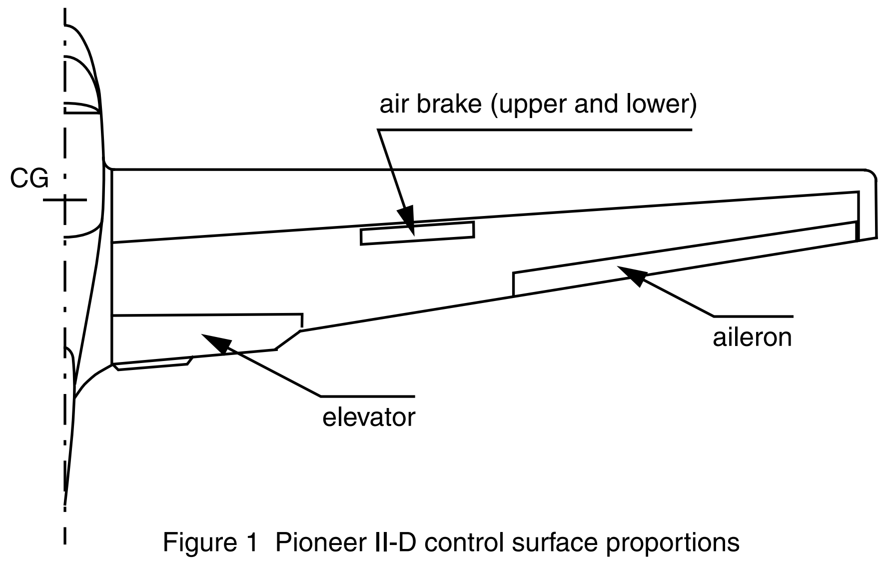

Figure 1 Pioneer II-D control surface proportions

4. Flaps, if used, should be placed in a location such that there is not an undue pitching moment generated.

Control systems for “plank” planforms

Figure 2a: We’ll start with the most simple control system, rudder only. Many modelers are unaware that very early radio control systems provided only one channel, and that single channel wwas devoted to rudder control alone.“Advancements” allowed rudder, elevator, and engine control to be obtained from that single channel, a relay, and complicated mechanical devices. In those early days the rudder was driven by a rubber band powered mechanical system, and deflection was neutral or full right or full left. Still, countless rudder-only models were flown successfully. The advent of proportional control made rudder-only control smoother, but also allowed the option of additional control surfaces, like elevator. Rudder control is sufficient for what appear to be coordinated turns if dihedral is adequate but not excessive. Any sweep of the rudder hinge line can affect the model in pitch. If the hinge line is swept back, the nose of the model will tend to pitch up. The greater the sweep angle of the rudder hinge line, the greater this effect. Additionally, the model must be trimmed for what we now consider excessive pitch stability. Flaps of about 5% of the wing area, if carefully placed, can be used for dethermalizing and landing control.

Figure 2b: Nearly all of us will feel some form of pitch control is necessary. The most simple elevator setup is one in which the elevator halves are inboard and connected by a torque rod extending through the fuselage. This is not a very efficient placement from an aerodynamic standpoint, but seems to work well enough that its popularity remains very high. The elevator area should be about 5% of the wing area.

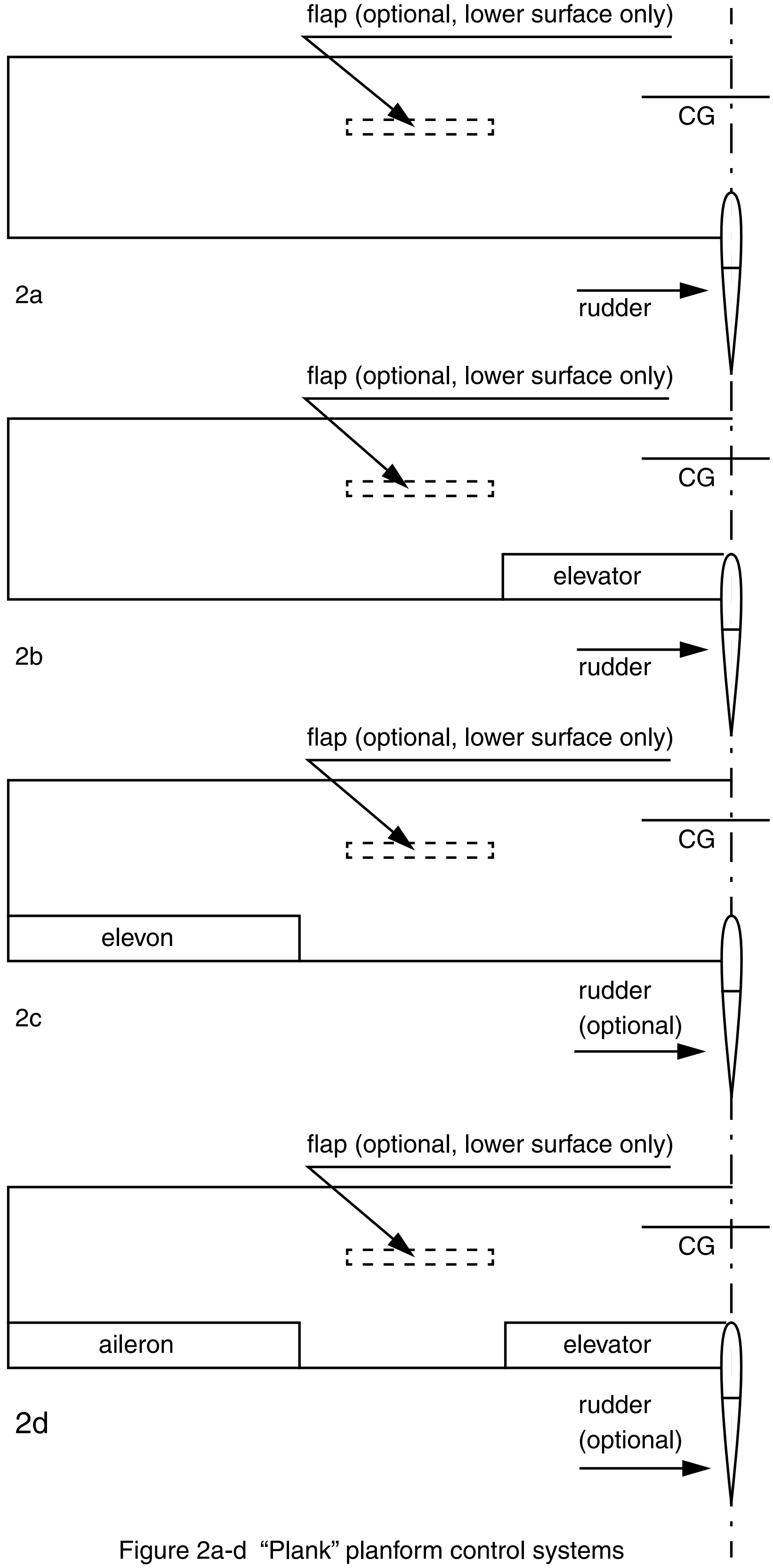

Figure 2a-d “Plank” planform control systems

Figure 2c: Moving the pitch control surfaces outboard raises aerodynamic efficiency, as during conditions when the wing is called on to produce maximum lift, the lift is derived from the center portion of the wing. The outer portion of the wing, with elevator deflected upward, has aerodynamic washout. Since the usual setup is to have separate servos for the two elevators, it is a very easy jump to use the transmitter in V-tail mode or combine channels to turn the elevators into elevons. (An elevon is a combination aileron and elevator, and should therefore be around 6% or 7.5% of the wing area.) Some experimentation may be needed when setting up the aileron function, as any differential will adversely affect pitch unless the centroid of the aileron is very close to the CG. Rudder control for this layout is an option which needs to be carefully weighed. If the aspect ratio is high, some form of yaw control is desirable. If you're flying on the slope and/or using a lower aspect ratio, the rudder is not necessary.

Figure 2d: This control system layout utilizes separate ailerons and elevator functions, and is similar to that used on the Pioneer II-D. As in the previous layout, 2c, aileron differential can adversely affect pitch control. 2:1 differential is used on the Pioneer, but the ailerons are very close to the CG because of wing taper, and the pitching moment imparted is negligible. The combination of separate rudder, elevator and aileron functions does have the advantage of producing flight control characteristics very close to those of a conventional tailed aircraft. The ailerons should cover the outer 40% to 50% of the wing span.

Control systems for wings with sweep back

Figure 3a: The most simple control system for swept wing planforms uses elevons which cover the outer 50% of the wing span. Separate control of yaw is not usually a consideration for swept wings because the sweep of the wing provides some amount of directional stability. If yaw control is determined to be needed, it can be achieved through moveable portions of the winglets, or through a rudder attached to a single central fin. As is the case with "plank" planforms which use ailerons, the use of differential can cause problems with pitch stability.

Figure 3b: Placing the elevator inboard seems at first to be an ingenious method of obtaining greater lift through downward deflection, and negative lift through upward deflection. The major difficulty which prevents this planform from succeeding is the placement of the elevator in relation to the CG. (Remember, there must be some lever arm.) This planform requires a large sweep angle, and increasing sweep is usually detrimental to subsonic performance, but it provides a good area for experimentation.

Figure 3c: The most common placement for the elevons is outboard, with the flaps inboard. If the wing sweep and the flap size and location are carefully coordinated, it is possible to slow the aircraft to a near standstill while maintaining pitch control without excessive elevator deflection. Flaps in this case can cover 20% to 40% of the span, always close to the centerline.

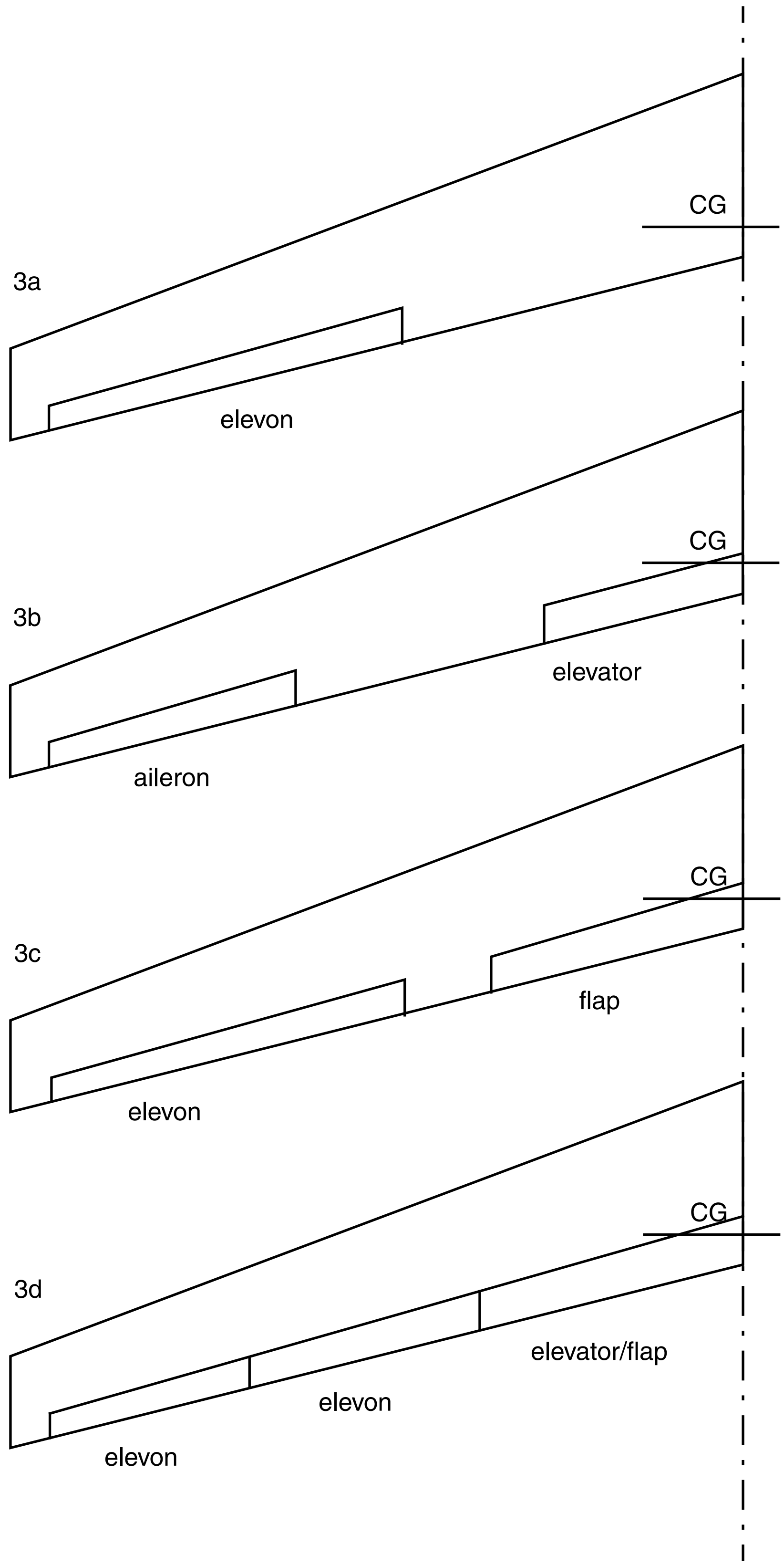

Figure 3a-d Swept wing planform control systems

Figure 3d: This is the “six flap” control system which has proven to be very popular in the German F3B environment. The span of each surface should be one third of the wing span. As most modern swept wings are built with three panels per side, each with a different twist parameter, the control surface is the same size as the corresponding wing panel. With several control surfaces across the semi-span, the lift distribution can be tailored for specific flight parameters — high speed, racing turns, thermal flight, and air brakes. If desired, a close approximation to the elliptical lift distribution can be maintained throughout all flight regimes.

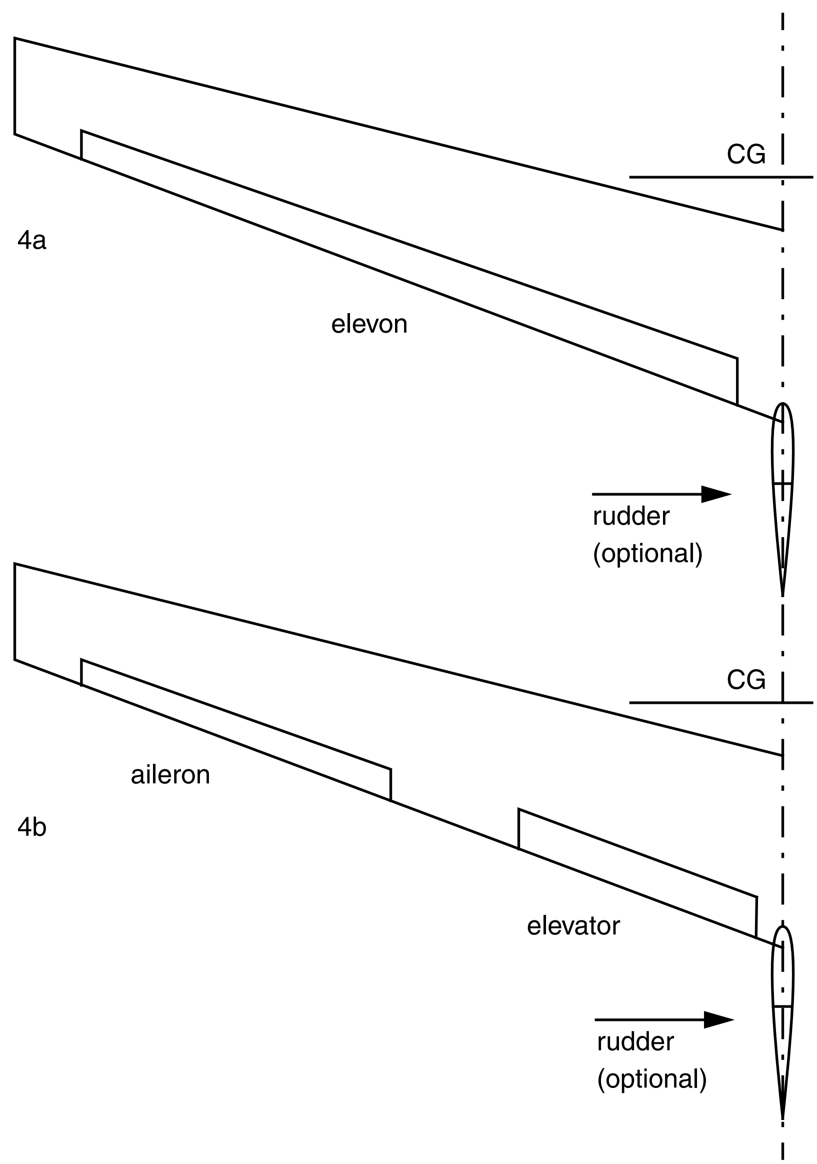

Figure 4a-b Control systems for swept forward wings

Control systems for wings with sweep forward

Figure 4a: This is the most simple control system for a swept forward wing. Larry Renger's "Toucan" originally used a similar control system layout. While very easy to set up and use, its inefficiency inhibits performance. In elevator mode, a portion of the surface is well behind the CG, but a major portion is closer to the CG and may in fact be in front of it if the sweep angle is large. Additionally, the aileron is nearly full span so there is an area which is well outboard, but closer to the centerline the deflection creates quite a bit of drag and generates very little roll moment.

Figure 4b: This is an ideal control surface layout for a forward swept wing, and is the recommended setup for the "Toucan." Because of the forward sweep, there is a large arm for the elevator to act upon. The ailerons are well outboard, and are therefore capable of generating large roll forces, but they are close to the CG as measured along the centerline. Aileron differential can thus be used without fear of untoward motions in pitch. A similar control surface layout was to be used on the Akaflieg Berlin B 11, a high aspect ratio sailplane with 18 degrees of forward sweep.

Conclusion

While we often tend to choose planforms based solely on aesthetic considerations, it is best kept in mind that truly successful aircraft are a synthesis of stability, control, performance and structure. Hopefully we've been able to describe the most common control surface layouts and relate them to the relevant tailless planforms in a cohesive way. The resources list provided below should provide a number of starting points for further investigation.

Resources

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