SNS COLLEGE OF TECHNOLOGY

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DEPARTMENT OF AEROSPACE ENGINEERING

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DAY:45 TOPIC: **TWO CONTROL AIRPLANE**

Definition of TWO–CONTROL AIRPLANE

An airplane with no rudder in which control is achieved by means of ailerons and elevators only

Why a V tail?

Throughout the history of aviation there have been a number of very successful aircraft that employed V tails. They run the gamut from gliders to ultra-lights to midget racers to mainstream piston and jet aircraft~ and mainly fly just like their conventional-tail counterparts. In recent years, however, the Beech Bonanza received some negative press and was the subject of some FAA action based on a growing (but sparse) history of in-flight break-ups. We'll come back to this in a minute.

Aerodynamica**l**y, the V tail provides the same stabilizing forces in both the pitch and yaw axes that the conventional tail does. This is because the V tail has projected area in both directions. The "top view" of the tail represents the equivalent area of a flat horizontal tail, and the "side view" of the tail represents half the equivalent projected area of a vertical tail (this is because each side of the V tail provides an independent contribution to yaw stability.) V tails can be a**l**-flying (stabilator style) or comprised of a fixed and moveable portion. Because each moveable surface contributes forces to both the pitch and yaw axes, they are ca**l**ed "ruddervators", a combination of the words rudder and elevator.

When the ruddervators move in unison (both up or both down together) their opposing yaw forces cancel out, and the result is a pure pitch input. When they move in opposition, their

opposing pitch forces cancel out, and the result is a pure yaw input. Motions in between create a combination of pitch and yaw effects. Because the pitch and yaw controls in the cockpit are independent (the yoke or stick for pitch and the rudder pedals for yaw), a mechanical device called a "mixer" combines their inputs into the proper action for each ruddervator. This process is transparent to the pilot, who experiences control forces and aircraft responses the same as a conventional tail aircraft.

One interesting difference is that the V tail aircraft must have a trim tab on each ruddervator. The trim tabs move in unison to provide pitch trim; they can also move differentially to provide yaw trim (or any combination of the two.) This is something most small aircraft don't have (and mostly don't need, unless they are twins.) However, the trim tabs represent some additional complexity, and to be intuitive will also need a "mixer" device.

The V tail offers some advantages over the conventional tail. First, there is one less surface to construct, and one less surface hanging out in the breeze. In theory the V tail aircraft will have less drag, and hence a higher cruise speed, than an otherwise identical conventional tail aircraft. This is indeed the case. The V tail Bonanza was always about 5 knots faster than its Debonair sibling, all else being equal.

A second and probably more important benefit relates to how the vertical and horizontal tail surfaces interact during high angle-of-attack maneuvers like stalls and spins. Rudder effectiveness is decreased because some portion of the rudder is blanked out by the wake from the stabilizer/elevator/fuselage combo. This effect can be annoying or deadly, depending on the configuration of the aircraft. In some cases, the effect is strong enough to render the rudder ineffective at stopping a developed spin. NACA (forerunner to NASA) studies in the '40's showed the V tail to be more resistant to spins, and more effective at neutralizing them.

It is interesting to carefully study the evolution of the aircraft as it relates to the evolution of these problems. The original Bonanza was certified to 2400 pounds gross weight--an honest 4-seater with some capacity to spare, and a nimble, stable and swift craft. Our family owned a 1952 C model, and we probably have over 100 hours in it as teen-agers. We never experienced the "boogie". What we did know, and could easily demonstrate, was the tremendous ease with which it would accelerate past its 220 mph redline if you pointed it even a little downhill. Beech realized that the airplane had tremendous growth potential, and embarked on a steady series of upgrades to the power-plant and structure to accommodate steadily increasing gross weights and speeds. At some point, they realized that it needed additional tail area to regain stability that had been steadily eroding with its trek towards (ultimately) 3400 pounds. You can see what they did if you carefully study the tail of an early model and one of the heavier, later models. The fixed portion of each side of the tail is anchored to the fuselage with two spars. On the early models, the leading edge that is riveted on the forward spar overhangs forward about 5 inches, and is otherwise unsupported. On later models, Beech increased the tail area by increasing this unsupported overhang to about 12 inches. The fix Beech implemented after the FAA action was to rivet an aluminum "boot" onto the fuselage at the leading edge of this overhang. This boot wraps around and cages the leading edge, giving it some additional rigidity.

In fairness to Beech, it should be observed that this very clean airplane had the ability to achieve tremendous speed with only a little inattention on the pilot's part. We suspect most of the in-flight breakups occurred at speeds above the redline... Note also that the V tail Bonanza enjoyed a total production run approaching 10,000 aircraft over nearly 50 years, and enjoyed a very good reputation until near the end of its run.

So how do we avoid these problems?

First, we deliberately made the tail "larger" than is common practice, to provide an excess of stability that eliminates the chance of "boogie" or dutch roll. Note that the stabilizing effectiveness of the tail is a combination of its area and its moment (distance) from the wing. A short tail moment requires a larger tail area to achieve the same stability as a long tail moment and a smaller tail area. However, the long moment wins on several important counts:

The wing provides lift by pushing air down in a rather elegant way that minimizes drag. As air passes around the wing, its direction is rotated slightly so that it leaves the trailing edge with a downward motion component. This rotation force tends to pitch the nose

down, and must be counteracted by a down force on the tail. In stable level flight, the tail is providing a significant down force that looks just like additional weight to the rest of the airplane--weight that must be made up by additional lift from the wing (with corresponding additional drag). But the tail has the same properties as a lever--use a longer moment, and the pitch force of the wing can be counteracted by a smaller down force on the tail. So the longer moment solution has less drag for two reasons--less area than its short-tail counterpart, and less down force.

Second, the tail is providing lift (albeit negative) just like the wing. The drag associated with creating this lift can be reduced by giving the tail a long span and a high aspect ratio. This also provides additional stability because it better matches the change in tail lift to the change in wing lift as the angle of attack changes--there is less trim change with changing speed or load.

Third, we decided to provide the same trim mechanism that Mooney uses (among others)--the entire tail tilts up or down slightly to account for changes in speed or load. This eliminates the dual trim tabs, with their attendant complexity and drag (and potential as a source for flutter).

Fourth, both the Wind walker and Cosman LSA tails are built like a Mack truck. They have two internal spars made from carbon fiber and epoxy, and are attached to the fuselage with a really burley 4130 steel weldment.

If you had reservations, we hope you feel better about V tails now. We think we have a good solution for what we're trying to do, one that is efficient and aesthetic, that provides a distinctive alternative to the current offerings