V-Tails for Aeromodels

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Yet Another Attempt to Explain Them

Watching the RCSE forum during November 1998 I felt, that the discussion on V-tails is not always governed by facts and knowledge, but feelings and sometimes even by irritation. I think, some theory of V-tails should be compiled and written down for aeromodellers such that we can answer most of the questions by ourselves. V-tails are almost never used with full scale airplanes but not all of the reasons for this are also valid for aeromodels. As a consequence V-tails are not treated appropriately in standard literature.
This article contains well known and also some not so well known facts on V-tails and theoretical explanations for them; I don't claim anything to be "new". I also list some occasionally to be heard statements, which are simply not true.

If something is wrong or missing: Please let me know (info@fmsg-alling.de), or, if you think that this article is a valuable contribution to make V-tails clearer for aeromodellers.

Introduction

Almost always designing a V-tail means converting a standard tail into a V-tail; the reasons are clear: Calculations yield specifications of a standard tail or an existing model is really to be converted (the photo above documents the end of the **2nd** life of this glider;-). The task is to find a V-tail, which behaves "exactly like its corresponding" standard- or T-tail - we will see, that this is not possible. We can design the V-tail to have the same behaviour in many respects, we might get some advantages, but we have to pay a price.

Conversion standard or T→V - here is the first question. It is not only of interest where we **arrive** when we have converted the tail (how the V-tail performs compared with the standard tail), but also where we **come from**: Was the "old" glider ok, or, as often with beginner's models, a bit overstable? Could it be, that an ill designed V-tail made a fine plane of a not so fine standard plane, compensating one fault by another? As far as I have learned, there mostly was one of 3 cases (ok-ok, simplified): A V-tail improved a plane a bit, or no change was visible, or the plane became unusable (e.g. I have heard of gliders where the new V-tail often caused a sudden stall). I almost never heard of a plane, which became only a bit worse by getting an ill designed V-tail.
In other words: Isolate the V-tail questions as far as ever possible from the other questions on gliders or the universe in general. At first find your personal best possible glider with a standard tail (PBPGS), which cannot be improved by changes of the stabilizer area or similar. This PBPGS is

the starting point of our attempt to make it even better by using a V-tail (PBPGV;-). The improvements are not necessarily of aerodynamic nature, but there are some other reasons to try it (simplicity, weight, steadiness, optics...).

For the nomenclature which I shall use in this article see Fig.1. All angles at aerofoils (α, β) are measured against the zero lift direction. To specify the dihedral of the V-tail I prefer the angle ν, measured from horizontal to the surface instead of the "opening angle" φ; converting one into the other is easy: ν=(180°-φ)/2. For the aspect ratio I use a small "AR". Other abbreviations: S: area, L: lift, R: roll, P: pitch, Y: yaw.
Indices: V: V-tail, H: Horizontal stabilizer (of a standard or a T-tail), S: Vertical (Side) stabilizer.

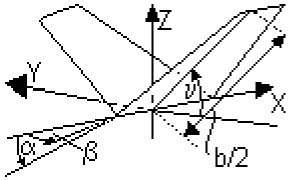

Fig.1: Symbols used in this article

Rules of Thumb

Once I spoke with a comrade, who had a perfectly flying electric plane with a V-tail. Of course I asked him, how he had designed it and he just answered "They all use 110° or so"; he surely meant the "opening angle". "...?" He scratched is head and said: "As I remember - hmmm - we took 10%", probably meaning, that the V-tail's area was approximately 10% of the wing's area.
First rule: Simply use the diagonales of the two rectangles defined by the standard tail. Another keyword of this rule is "projected area". This rule seems to get the name "old wives tale"; most grandmas know nice and wise stories, but possibly not in the field of V-tails. I have heard of model gliders flying well with grandma's rule, others became uncontrollable - see above. The basis of this rule is the (true) fact, that the vertical component of the V-tail's lift is only cos(ν) times the total lift. Perhaps grandma did not see, that this rule lets the V-tail replace **2** vertical stabilizers when applied consequently. There are some modifications of this rule, mainly reducing ν. Grandma simply knits too small V-tails.

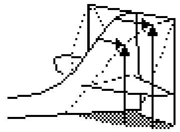
Fig.2: Grandma's rule

Thumb rule Nr.2: Use the standard tail's total area and make a V-tail of it. The angle ν is a matter of experience: Values from 32° to 40° and even more are to be heard. This is a quite simple and useable rule. The statement: "If the V-tail must yield the same stabilizing and control characteristics, it must have the same surface" sounds convincing, but it it is not at all an explanation what really happens. But this rule accidentially hits the truth much better than grandma's, and if some simplifying assumptions are made this rule can even be derived from the following extended explanation.

An Estimate

If you just want to see how your V-tail should look like: This is a rough estimate for the dihedral angle and the required area of your V-tail, compared against a "corresponding" standard tail:

- At first find the dihedral angle ν out of the areas of the vetical stabilizer and the horizontal stabilizer of your standard tail according to the dihedral formula or see the left part of Fig.3: The numbers near the curves indicate for which aspect ratio of the fin they were calculated - the aspect ratio of the V-tail is assumed to be near 4 or 5.
- Then get the area of the V-tail out of ν and the horizontal stabilizer's area using the famous "$\cos^2$-formula" or the right part of Fig.3. Use for your V-tail the about same aspect ratio as for your standard tail's horizontal stabilizer (4..5).
- Get an idea how large your control surfaces should be: Use higher relative chord length than usual for "normal" control surfaces (how about 30% instead of 25%?).

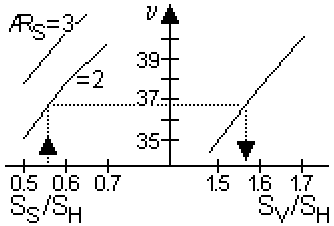

Fig.3: Find the dihedral angle (ν) and the area of the V-tail out of the dimensions of the standard tail

It makes no sense to use a V-tail at a glider with extreme high aspect ratio.

If you want to know "why", read the text from here to the end. If you want to know more read also the corresponding paragraphs of the details page, where referenced.

The NACA report 823

This is the only publication I have seen which contains results of wind tunnel measurements with V-tails. It helped me to learn something on V-tails in spite of many puzzles and problems:

- Results, which should be symmetrical aren't; this gave me some hints on the accuracy to be expected or that there may still be some hidden secrets which weren't explained by the authors.
- The effects of combined pitch and yaw stabilisation and control are not covered as desirable.
- The tested models were isolated tails and fictive fighter aeroplanes, not gliders. Some results might be inaccurate because the influence of the fuselage is to great.
- As usual sometimes the results are not easy to be separated from the "noise".
- The Reynolds numbers were of course greater than to be expected with model gliders, but as I do not discuss performance issues I think this should not be harmful.

I shall often refer to this report, but it should not be necessary for you to read it. I promise to be very cautious when I interpret measurement results, as amateurs, interpreting wind tunnel results, often look like greenhorns trying a weather forecast...

Deriving the Main Parameters of a V-tail

Its Role as a Horizontal Stabilizer

The first and most important point on our wishlist is: The V-tail must replace the horizontal stabilizer as close as possible. This means 3 requirements:

- It must fulfill the momentum equation, especially when the plane is flying near the limits of its speed range, including enough reserve for static stability and control even in extreme situations. This requirement yields a specification how much vertical lift the tail must be able to produce in order to avoid tuck down or a sudden stall.
- Ensure static stability: When the angle of attack does not correspond to the current speed (e.g. caused by an accidential pitch) the stabilizer must yield additional lift to correct the deviation without intervention by the pilot. The amount of the static stability to be provided depends much on the pilot's skill and taste. The tail's contribution to determine the static stability is its "response" to changes of the angle of incidence: How much additional lift is yielded by a specified change in α?
- It must damp pitch oscillations. The main contribution of the tail for damping is also its response in changes to α. Note, that the requirements for damping decrease when we can save some weight in the V-tail.

For the following discussion it is assumed that the tail boom length remains unchanged.

We have to find out, how much maximum lift a V-tail can deliver compared to a standard stabilizer, and how it responds to changes of the angle of attack. Or, better:
How must the V-tail be designed to deliver at least the same maximum lift and the same response as its standard counterpart?

The lift, generated by a stabilizer, can be calculated approximately using the well known formula:
$L = C_{L\alpha} \cdot \alpha \cdot q \cdot S$. The term $C_{L\alpha}$, called "lift gradient", defines the response of the stabilizer to changes in the angle of attack; its slope mainly depends on the shape of the stabilizer (no, not on the aerofoil characteristics). Aeorfoil theory yields the value $2 \cdot \pi / 57.3 \approx 0.11$ for $C_{L\alpha}$ in the case of an infinitely long wing (a rather good approximation for something which cannot exist;-). Aeromodellers use the simple correction formula $C_{L\alpha\,(AR<\infty)} = C_{L\alpha\,(AR=\infty)} \cdot (AR/(2+AR))$ to get a useable approximation for the lift gradient of the finite stabilizer; commonly used stability calculations employ it. If your V-tail has a significantly different aspect ratio as the original stabilizer you should account for this - see below.

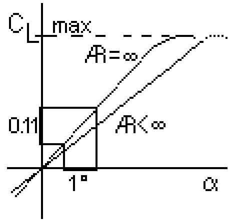

Fig.4: Lift/attack diagram for infinite and finite wings with a symmetric aerofoil

The maximum possible value for $C_L = C_{L\alpha} \cdot \alpha$ defines the maximum possible lift which the stabilizer can yield; it is mainly influenced by the properties of the aerofoil. In fact, as Prandtl showed, the maximum lift can be reached even with aspect ratios as low as 4.

I do not want to dive too much into details here as this effect is common to all wings, standard-, T- and V-tails.

For a conventional stabilizer the major corrections are done (others are fine tune and not discussed here), but with a V-tail we must account for some other effects.

As grandma already knows, the lift generated by a V-tail is not directed upwards or downwards as desired. As the V-tail is symmetrical, the sideward directed forces compensate each other during pitch. The vertical component of the lift is only cos(ν) times the total lift. As a consequence the V-Tail must be 1/cos(ν) larger to compensate this effect.

Next: Grandma oversaw, that the angle of attack, which is seen at the V-tail (the section angle of attack), becomes smaller with increasing ν. Don't worry, Grandma, this is not easy to see. The NACA report contains an explanation of this topic using pictures with planes and angles in 3D-space. I prefer an analysis employing vector algebra, it is presented in the details page. Both explanations yield the same result: The section angle of attack at the V-tail, α_v, is only approximately cos(ν) times the angle of attack, α, which the stabilizer sees. This means, that the response of the V-tail to changes in the angle of attack is reduced by cos(ν), but the maximum possible lift is **not** reduced, only a greater angle of attack for the whole aeroplane, α, is needed. When the standard tail already stalls, the V-tail still yields lift (Sounds good? See below).
What does this mean? The V-tail's response is again reduced by the factor cos(ν). To get the same response on a changing α the V-tail must be enlarged by another factor 1/cos(ν). But now the V-tail can produce more vertical lift than its conventional counterpart (we shall consider it later once more).

Here is a graphic of Mark Drela, which explains all this geometrically: vtail1.pdf (courtesy of Prof. Mark Drela, MIT). Note, that Mark uses δ instead of ν - 'ν' is not standard.

There are also some second order effects in the stabilizer role of the V-tail:

Fig.5 shows a scheme of lifting and trailing vortices at a V-tail which must produce lift upward. It is closely comparable to the situation of a "normal" wing except near the centre of the V-tail: If not disturbed too much by the fuselage, the tilted lifting vortices cause a stronger acceleration and consequently a stronger deceleration of the flow at the upper side of the V-tail near the centre. The stronger deceleration means a stronger adverse

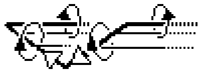

Fig.5: Circulation around a V-tail,

pressure gradient and an increased danger of flow separation (the contrary is the case at the lower side, but this region is disturbed by the fuselage). This effect has often been made responsible for sudden stalls but it should also occur with standard tails during combined pitch and yaw - so this effect, should it be relevant, is common to all tails.

acting as a horizontal stalilisator

At positive angles of attack, the V-tail is appearently swept back (forward for negative α); the sweep angle is $\alpha \cdot \sin(\nu)$; it should never exeed $15° \cdot \sin(40°) \approx 10°$ and can therefore be neglected. Additionally many V-tails intensionally are swept back. This may decrease the above mentioned danger of flow separation on the upper side and it may also be done to increase the length of the tailboom; sometimes perhaps the optical appearence might play an impotant role.

The flow around a V-tail does **not** see an apperantly thicker aerofoil than with a standard tail. Aerofoil thickness is a matter of displacement: The streamlines are displaced in a plane perpendicular to the wing, independently of the wing's orientation in space.

Any wing which generates lift does also induce additional flow velocities: It increases the flow velocity at the side where the lift is directed to. Resulting effects on two adjacent wings (interferrence) are sometimes called "biplane effect"; I do not like this term very much, but it is a short and convenient. It is discussed in more detail with the slip/pitch-momentum.
When a wing of a V-tail flies with a positive angle of attack (yielding lift upward) it induces an additional flow velocitiy at its upper side; the other wing of the V-tail "benefits from this additional flow" and yields more lift. The influence of the 2nd wing on the first one is similar. As a result the V-tail should deliver more lift upward than expected so far. The contrary is the fact when the (local) angle of attack is negative: The induced stream should decrease the lift downward of the V-tail. As pointed out in the details page for the slip case, the effect is quadratic - that means it is very small for small angles α_V, but its absolute value increases rapidly with a large angle α_V, such that one could expect a behaviour sketched in the diagram in Fig.5a (dark line).

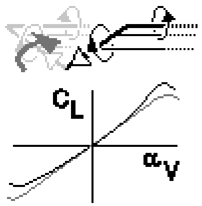

Fig.5a: The "biplane effect" at a V-tail acting as horizontal stalilisator

Confused? Me too. I think, we could set up a tabular compilation of effects and how to compensate them.

Flow property	**Effect on *vertical***		Compensation	Remarks
	lift gradient (response)	maximum possible lift		
Induced flow caused by	decreased	none (for	Common aspect	Only to be considered when the aspect ratios of the standard stabilizer

the limited aspect ratio		AR>4)	ratio correction formula	and V-tail are significantly different.
Lifting force is directed diagonally	decreased	decreased	increase area by $1/\cos(\nu)$	...as already heard from grandma.
The effective angle of attack (pitch) is reduced	decreased	none	increase area by $1/\cos(\nu)$	As a V-tail stalls later than its standard counterpart it can produce more vertical lift (about 15%), but see "Combined...".
Second order effects: Increased adverse pressure gradient (for $\alpha>0$), slight sweep	$\alpha>0$: small	$\alpha>0$: small	-	On the upper side, for $\alpha>0$, these effects and also the inbound flow due to the limited aspect ratio partially compensate each other. On the lower side, for $\alpha>0$, the effects have the same sign and might slightly decrease response and maximum lift of the V-tail.
	$\alpha<0$: small, if any	$\alpha<0$: small, if any	-	
Induced flow velocity ("biplane effect")	small	small	-	Increases maximum possible lift up ($\alpha>0$) and decreases maximum possible lift down ($\alpha<0$).

Our first estimate (the famous "$\cos^2$-formula"):

$$\mathbf{S_V=S_H/\cos^2(\nu)} \cdot C_{H\to V}$$
$$C_{H\to V}= (AR_H/(2+AR_H)) / (AR_V/(2+AR_V))$$

Usually the aspect ratios etc. of the original horizontal stabilizer and the V-tail are (nearly) equal, such that $C_{H\to V} \approx 1$ and may be omitted.

Stall Characteristics

As the section angle of attack at a V-tail is by $\cos(\nu)$ smaller than the one of a standard tail (ok-ok ...when the same aerofoil and aspect ratio are used), the V-tail should stall "later": The stall angle of a V-tail should be by $1/\cos(\nu)$ greater than the one of a standard tail.

The NACA Experiment

In this report some condensed results are published, which confirm the stabilizing properties of the V-tail (the "$\cos^2$-formula") over more than the interesting range of ν.
Also more detailed comparisons of a standard tail and a V-tail (ν=40°) are presented, regarding the lift behaviour over the full range of the angle of attack. I have difficulties with this diagram, because even the results for the standard tail are *not symmetrical*: Stall occurs at -16° (C_L=-0.8) and at

+12° (C_L<0.7) and the authors did not explain this; of course it would be possible just to offset the lift curve to make it symmetrical (stall at ±14° and about ±0.73) but this is pure speculation. I "corrected" the V-tail lift curve accordingly (just a guess, not more!) and found stall angles for the V-tail of about -16° and +18°. The diagram makes me assume, that the V-tail can produce more lift up than down, what could be interpreted as a confirmation of the "biplane effect". But the lift curve for the V-tail (out of the stall regions) looks nearly perfectly linear, not allowing to speculate over a - quadratic - overlaying biplane effect; on the other hand the stall at positive α (lift up) is much sharper than for negative α. This diagram poses more questions than it gives answers.

The V-Tail's Role as a Vertical Stabilizer

The requirements for the vertival stabilizer usually are weaker. For a symmetric glider there is no momentum equation to be fulfilled: When the glider does not slip, the vertical stabilizer needs not yield a lateral force. For asymmetric propeller planes (even single engine planes are asymmetric) there is a momentum equation, but the values are not so high as for the horizontal stabilizer. But this shall not be discussed here as it is a matter of all tails.

Important design parameters for a glider V-tail are slip stabilisation, yaw damping and rudder control. Commonly used methods for amateurs to find the correct vertical stabilizer area and shape are "experience", "statistic" and "we'll see". But this is not so important for a V-tail article, because I just give hints how to convert a standard vetical stabilizer into a V-tail.

Of course, most of the effects described for pitch stabilisation have their counterparts when the V-tail does not produce vertical lift but sideward directed forces. I shall not derive the main compensation formulae again as long as they just correspond to geometrical properties of the V-tail:
The aspect ratio of a V-tail is always much greater than the one of a vertical stabilizer (some extreme gliders have fins with a remarkably high aspect ratio, but it makes absolutely no sense to mount a V-tail on such an aeroplane). So, at a first glance the V-tail should have a much better performance as vertical stabilizer than the "original" - it hasn't, see below; but the correction factor $(AR_S/(2+AR_S)) / (AR_V/(2+AR_V))$ should not be neglected. Grandma's compensation factor for the diagonally directed lifting forces is $1/\sin(\nu)$ and the compensation factor for the reduced section angle of attack is also $1/\sin(\nu)$.

Again, here is a graphic of Mark Drela, which explains this geometrically: vtail2.pdf (courtesy of Prof. Mark Drela, MIT).

Obviously for a slipping V-tail the one side of the tail produces lift up and leeward, the other side down and leeward. The lift changes near the centre from up to down. Fig.6 shows a circulation scheme for this case. It contains a change of the orientation of the circulation near the centre of the V-tail, acompanied by a strong induced vortex downstream. What does this mean? Simply a lot of induced drag and decreased efficiency; the centre of the V-tail doesn't contribute to the

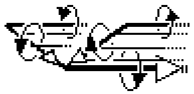

Fig.6: Circulation around a

stabilisation. In other words: The V-tail, acting as a vertical stabilizer, is about as lousy as its conventional counterpart (this is **not** the "biplane effect"). Another correction factor is to be introduced: The V-tail is viewed to be only 0.7 times as effective as it would be without this effect; the fixed correction factor $1/0.7 \approx 1.4$ - ignoring the shape of the V-tail - is in common use. For more information see the details page.

slipping V-tail

Here is the compilation of effects of the flow around a V-tail acting as a vertical stabilizer:

Flow property or geometric property	**Effect on *lateral***		**Compensation**	**Remarks**
	lift gradient (response)	maximum possible force		
Induced flow caused by the limited aspect ratio	decreased	small	Common aspect ratio correction formula	V-tails have a much greater aspect ratio than standard fins ($>2.5 \cdot AR_S$), but the lift reversal near the centre spoils this advantage. Both corrections together yield a factor close to 1 for usual configurations. (see below)
Lift reversal near the centre of the V-tail	decreased	decreased	increase area by, say, $1/0.7 \approx 1.4$	
Lifting force is directed diagonally	decreased	decreased	increase area by $1/\sin(\nu)$	(grandma's)
The slip angle is reduced	decreased	none	increase area by $1/\sin(\nu)$	For a V-tail it is not easy to distinguish between the angle of attack and the slip angle (I am sure, you know what is meant:-)

Our second estimate:

$$\mathbf{S_V = S_S / \sin^2(\nu) \cdot C_{S \to V}}$$
$$C_{S \to V} = (AR_S/(2+AR_S)) \,/\, (AR_V/(2+AR_V)) \cdot 1.4$$

Usual configurations yield $0.9 < C_{S \to V} < 1.2$,
see the table to the right: It lists values of $C_{S \to V}$ for some usual aspect ratios of standard fins and V-tails.

$AR_V \rightarrow$ $AR_S \downarrow$	**4**	**5**	**6**	**8**
2	1.1	1.0	1.0	0.9
3		1.2	1.1	1.1
4			1.2	1.2

Stall Characteristics

At the V-tail the section angle is sin(ν) times smaller than the corresponding angle at the standard fin and rudder. Therefore the V-tail should stall at larger slip angles. Of course the stall angle depends on the aerofoil and the shape, mainly the aspect ratio of the two wings; for a rough estimate it may be allowed to use the fin's AR_S and half the V-tail's AR_V (because of the lift reversal near the centre); the geometric shapes for both, a ½ V-tail and a standard fin, are comparably bad and no correction for this may be necessary. The (very rough) estimate for the stall angle of the V-tail may look as follows:

$\beta_{V\ stall}/\beta_{S\ stall} \approx (\beta_{xV}\cdot(1+2/AR_V)/\sin(\nu)) / (\beta_{xS}\cdot(1+1/AR_S))$,

β_{xV} being the stall angle of the V-tail's aerofoil and β_{xS} being the stall angle of the standard tail's aerofoil. The stall angle of the V-tail is of course furtherly influenced by the fact that the V-tail really slips but this is not so distinct and is ignored in this simple estimate.

The NACA Experiment

The condensed results indicated values for the yaw response close to the ones expected by the theory ("$\sin^2$-formula") as long as the dihedral angle ν was <50°. The V-tail in the experiment had exactly twice the aspect ratio and twice the area of the fin; the shape of the fin is exactly one half of the V-tail and the aerofoils were identical. Therefore I dare to compare the fin's measured stall angle (end of the linear sector) of ±14° to the stall angle of the V-tail of ±23°: The ratio should be 1/sin(40°)≈1.55, and it is about 1.6, a very fine result. Additionally the curves in the NACA report are nearly perfectly symmetrical.

Once More the 2nd Rule of Thumb

We derived 2 equations with 2 "ugly" factors, $C_{H\rightarrow V}$ and $C_{S\rightarrow V}$. Estimates for standard configurations allow us to set $C_{H\rightarrow V}=1$ and $C_{S\rightarrow V}\approx1$. This simplifies our equations to

$S_V=S_H/\cos^2(\nu)$ and $S_V\approx S_S/\sin^2(\nu)$.

A bit of algebra? Yes? It was already done in the NACA report and several times later! The two simplified equations may be written

$S_V\cdot\cos^2(\nu)=S_H$ and $S_V\cdot\sin^2(\nu)\approx S_S$ and added to $S_V\cdot(\cos^2(\nu)+\sin^2(\nu))\approx S_H+S_S$.

Now, using Pythagoras' theorem (yes, I mean $a^2+b^2=c^2$, in this case $\sin^2+\cos^2=1$;-), we get

$\mathbf{S_V\approx S_H+S_S}$. Äha!

NOTE: The simple rule of thumb is surprising good; it was derived here under only few, "allowable" assumptions; it already accounts for the interferrence between the two halves of the V-tail and is insofar "complete". (I have read the statement: "Yes, this rule may be nice, but there is also the biplane effect..." - this is not correct, as the mutual interferrence **is** already taken care of here.)

The Equivalent Dihedral Angle ν

The 2 formulas above, shuffled again, yield also:

$$\nu = \arctan\left(\mathrm{sqrt}\left((S_S \cdot C_{S\rightarrow V}) / S_H\right)\right)$$

I left $C_{S\rightarrow V}$ in the equation for those who don't dare to set it =1 and want to look it up in the table above.

Control Characteristics

I think it is common knowledge how the control flaps of a V-tail are to be used for pitch and yaw control. Fig.7 shows the necessary control flap deflections and the usual control force arrows. Both control flaps are used for both control directions; this lets one assume, that for combined control input, pitch and rudder, one of the flaps may be deflected by a too large angle.
Another trivial, but sometimes overseen point is, that both V-tail flaps have the same relative chord length (about 25%), whereas the elevators and the rudder of a standard tail mostly are very different ones (25% vs. up to 40%); there must be some conversion for rudder deflections to V-tail flap deflections. For more information on control flaps in general see the details page.

Fig.7a: Controlling pitch with a V-tail

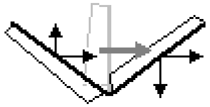

Fig.7b: Controlling yaw with a V-tail or a standard rudder

Please note: In the following discussion I often set a flap deflection equivalent to a change in the angle of attack of about 40% to 60% of the deflection angle. So a rudder deflection of 10° may be seen equivalent to a slip angle of about 4° to 6°, depending on the effectiveness of the control flap (see also the details page). This is of course a simplification, but may be seen valid for this article.

Often V-tails are tapered by a factor 0.6 or even more extreme, but the control flaps have a constant absolute depth over the whole span. I do not know any good reason for this as it restricts the control range of the V-tail (and other tails).

Pitch Control

When you pull up - that is: deflect the stabilizer's control flaps upward - the angle of attack at the tail surface is decreased. This causes additional lift downwards at the tail. For a V-tail this resulting lift is decreased by cos(ν) because it is directed diagonally (grandma), but the effective change in the section angle, α_V, is **not** reduced. As we have increased the V-tail by $1/\cos^2(\nu)$, compared with the standard horizontal stabilizer, and use control flaps with a comparable relative chord length, the flap deflection for pitch control at the - corrected - V-tail is about $1/\cos(\nu)\cdot C_{H\rightarrow V}$ times (factor

1.2..1.3) more effective than the one of a standard stabilizer. This means you need smaller control deflections for pitch control than with a standard horizontal stabilizer. This is not surprising, the NACA experiment and common experience confirm it.
According to the "biplane effect" strong control flaps deflection should produce more lift up (pitch down) than lift down (pitch up), but I think it is nearly impossible to confirm this in practice.

Rudder Control

V-tails are said to have poor rudder response. Let us have a closer look on this. Let me set up the ratio between the rudder force of a V-tail (nominator) and the one of a standard fin/rudder (denominator):
At first some items of the V-tail: The rudder deflection causes an additional angle of attack and additional lift. As the lift is directed diagonally its effectiveness as a side force is decreased by $\sin(\nu)$ as grandma already knew (put $\sin(\nu)$ into the nominator). The interferrence between the V-tail wings near the centre decreases the effectiveness of the rudder deflection by 0.7 (...into the nominator). If we corrected the surface of the V-tail by $1/\sin^2(\nu)$, as outlined above, the side force of the rudder deflection at the V-tail is increased ($\sin^2(\nu)$ into the denominator).
Let the V-tail have a control flap with a relative chord length of 25% yielding a factor of ≈0.5 to convert a flap deflection into a change of the angle of attack (0.5 into the nominator). We also correct the side force because of the aspect ratio of the V-tail: AR_V into the nominator and (AR_V +2) into the denominator.
The relative chord length of a standard rudder is usually much larger, up to 40%, so a factor of 0.65 is placed in the denominator to convert the rudder deflection into a change of the slip angle. The fin's aspect ratio is covered by AR_S in the denominator and (AR_S+2) in the nominator. The shape of the standard fin and rudder is not ideal an I personally guess another factor of 0.9 to account for this (denominator).
All this put together looks like

$$\frac{F_{VS}(\eta_V)}{F_S(\eta_S)} = \frac{\sin(\nu)\cdot 0.7 \cdot 0.5 \cdot AR_V \cdot (AR_S+2)}{\sin^2(\nu) \cdot 0.65 \cdot (AR_V+2) \cdot AR_S \cdot 0.9}$$

Note that some of the numbers in this expression cannot be determined exactly by the aeromodeller, but are rough estimates.

An example (V-tail: ν=35°, AR_V=4, control flaps: 25%; standard fin and rudder: AR_S=2, rudder: 40%) yields about 1.4 for this ratio. This means, the maximum rudder deflection of the standard tail, divided by 1.4 must be yielded by the maximum allowed rudder deflection of the V-tail. Rudder deflections at a standard tail are sometimes very large (up to about 30°) and the above estimate yields, that a control flap at the V-tail must be deflected by 30°/1.4≈21°; this should work.
To be honest: This estimate is weak and is often not confirmed by experience; once I had to replace a V-tail by another one with nearly the same measures except the control flaps (30% instead of 25%) and this improved the V-tail's rudder effectiveness remarkably. Other pilots report similar observations.

The following should be clearly visible: The V-tail's advantage in effectiveness for pitch control does not exist for yaw control. Maybe a pilot, who isn't familiar with V-tails, might interpret this as "poor rudder response", not as "improved elevator response".

The estimate is in general the "0.7·sin-formula" plus some corrections for different shapes and rudders; in the NACA experiment the "0.7·sin-formula" is approximately confirmed for dihedral angles ν up to about 40°.

Combined, Pitch and Yaw Stabilisation and Control

Thermal Gliding

During thermalling a V-tail is used with a bank angle of, say, 30°..45°. So its "outer" wing is directed nearly up-down and therefore acts like a standard vertical stabilizer and the "inner" wing acts like a standard pitch stabilizer... Nobody would ever think such complicated of a standard tail (which would be converted into an almost impossible to understand 1½ V-tails;-). No, it is much simpler.

When the aeromodel flies a horizontal circle with a radius r_c (the idealized form of thermalling) its flight path consists of two orthogonal curves:

- a sideward curve (sideward relative to the aeroplane) with a radius of $r_s = r_c/\cos(\omega)$ (ω being the bank angle), and
- an upward curve with a radius of $r_u = r_c \cdot \sin(\omega)$.

Thus the zero lift directions of the vertical and horizontal stabilizers must be shifted a bit outward and downward, depending on ω, r_c and the length of the tailboom.
Of course there exists an ideal bank angle for a given combination of mass, airspeed and r_c, but for the aeromodel's pilot it is difficult to see, if the model flies with this angle. Therefore an aeromodel is slipping for most of the time during thermalling and its aibility to stabilize for slip and roll is most important for its useability in this flight regime. The well known yaw/roll effect, caused by the lower flow speed at the inner wing, furtherly destabilizes the aeromodel by increasing its tendency to roll "into" the curve.

All this has nothing to do with the type of the glider's tail.

The V-tail just increases a tiny bit the glider's desirable tendency to roll "out" when it slips into the curve, as discussed later (slip/roll momentum). The vertical and side trim have the same sign for the outer wing of the V-tail, but as these trim deflections are small this overlay should never limit the glider's maneuverability in this flight regime. Note, that during stable thermalling the tail should not produce much more pitch- and yaw

momentums than during straight flight.
If your PBPGS is well suited for thermalling the corresponding PBPGV should do it comparably well.

Stall Characteristics

The tail must always yield enough pitch momentum for any situation to compensate the movement of the centre of lift: During low speed flight it must produce lift up to avoid sudden stall and during high speed flight it must push down to avoid tuck down.
What happens when in such an extreme situation an additional sideward force (yaw stabilisation) is required? The main topic to be regarded is stall at the horizontal stabilizer. Friction effects near the junctions of the wings with each other or with the fuselage may increase the stall danger. Also at large slip angles the fuselage may lower the effectiveness of the leeward part of the horizontal stabilizer.

For a standard tail, especially an X-tail, where significant parts of the fin are located below the horizontal stabilizer, the mutual influence between the fin and the horizontal stabilizer is restricted to the inner edges at the junctions; therefore the horizontal stabilizer can yield nearly its full vertical lift over a wide range of slip angle. When the horizontal stabilizer acts as an endplate for the fin (T-tail) there may be regions with increased danger of stall (see the details page). A voluminous fuselage may of course also influence the horizontal stabilizer's effectivity especially during slip.
The dashed line in Fig.8 indicates the maximum vertical lift for a standard tail over a varying slip angle. The sketch is to be read as follows: At a slip angle of 0° (no slip) a standard tail can be used with some maximum angle of attack, which depends on its aerofoil and the shape of the stabilizer. All other values are related to this angle; so for zero slip a standard tail can have a maximum angle of attack of "1". The slip angle is also related to this angle, so the number "0.5" means the slip angle is 0.5 times the stall angle of the standard stabilizer. Fig.8 indicates, that a standard tail can be used with nearly its full maximum angle of attack over the interesting range of slip. When the vertical stabilizer stalls the horizontal stabilizer is influenced such that it also stalls earlier (at smaller angles of attack). Note: Fig.8 is just a sketch indicating trends, not a diagram yielding exact values! For simplicity a symmetric aerofoil (with the same positive and negative stall angles) is assumed.

The section angle of attack at a V-tail is $\alpha_V \approx \cos(\nu)\cdot\alpha + \sin(\nu)\cdot\beta$ and it must not reach the stall angle.

To see, which maximum angle of attack is possible for the V-tail we plot the ratio

$$\frac{\alpha_{V\,max}}{\alpha_{max}} = \frac{1}{\cos(\nu)} - \frac{\beta}{\alpha_{max}} \cdot \frac{\sin(\nu)}{\cos(\nu)}$$

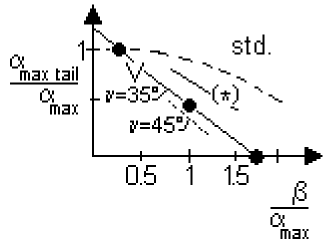

Fig.8: Maximum pitch

This compares directly the V-tail's aibility to avoid sudden stall or tuck down when the aeroplane slips with the corresponding aibility of a standard tail (it is assumed that the V-tail is designed according to the rules listed above, such that a given angle of attack yields the same vertical lift for both tails). When the angle of attack at the tail reaches the one indicated in Fig.8 (solid line), one of the two wings of the V-tail stalls.

momentum during varying slip

Assume the stall angle is 10° (e.g. N0009, AR=4). Then the stall behaviour of a V-tail ($\nu=35°$) looks about:

- $\beta=0°$ (no slip): The V-tail can yield more vertical lift as a standard tail as already seen above.
- $\beta\approx3°$: This advantage of the V-tail has already vanished, the V-tail can yield not more vertical lift than the standard tail.
- $\beta\approx10°$: The V-tail stalls already at a pitch angle of 5°!
- $\beta\approx15°..20°$: The V-tail stalls only because of the slip and is not able to yield pitch stabilisation at all!

When the tail yields lift up **and** slips stall occurs at first at the windward wing; the other wing sees a much smaller section angle of attack (... - sin(ν)) and should not stall immediately; but now the V-tail acts strongly asymmetrically (see below: " Parasitic Pitch Momentum") and gives the pilot a too short time to "do something").

All this sounds **dramatically**: The V-tail has limited aibility to fulfill the momentum equation; this makes it unsuitable for applications where this might be critical:

- Models with highly cambered aerofoils, suffering under a high degree of movement of the centre of lift (if not operated in a narrow speed range): Increase the V-tail's area by, say, another 10% and make it a bit flatter (ν about 15% (5°) smaller); this might improve your V-tail to perform near the line with the asterisc (see Fig.8). Or use a standard tail.
  Flaps at the wings should be used with even more caution than when standard tails are used (never deflect them downward during high speed and such stuff:-).
- Models requiring a strong yaw stabilisation, e.g. gliders with wings of extreme aspect ratio, resulting in large fins or V-tails with great dihedral ($\nu\approx45°$ or so). Slip angles are often very large and the trends indicated in Fig.8 are even worse for large ν. Simply do not use a V-tail.
- Aerobatic models (not just slope rockers) need control and stability under most extreme conditions. Do not use a V-tail.

The NACA Experiment

The measurements at an angle of attack of 9° showed both, stall at the standard fin and also stall at the V-tail at a slip angle of 15° to 20°. Stall at a standard fin obviously did not affect the pitch momentum; stall at the V-tail during slip is appears to be related to a strong pitch up momentum ($\alpha>0$), driving the aeroplane into complete stall. To be honest: I could not fully understand the relations between slip and pitch at the V-tail as they appear in this publication; stall behaviour of the complete model possibly was influenced too much by the fusealge etc. (no, I should not try to make a weather forecast...;-) such that the relationship between slip, stall at the V-tail and pitch were not as clearly visible as desirable. Unfortunately no measurements were published for the case of $\alpha<0$.

Combined Pitch and Yaw Control

A V-tail suffers similar problems when control for both, pitch and yaw, or a control under an extreme flight situation as described above is needed. Examples:

- As control flap deflections are added at one wing flap deflections may increase over a reasonabel limit of, say, 20° and the effectivity of the flap decreases strongly. To lower this effect you could increase the relative chord length of the control flaps to, say, 30%, see below, but it is still possible that the aeromodel does not respond correctly to extreme control commands.
- During (very) low speed flight the V-tail must yield lift up; assume the plane slips a bit to the left, such that the left wing of the V-tail is operated close to its stall angle. In this case the V-tail is not longer able to realize a strong left rudder command.

The R/C V-Tail-Mixer

A V-tail mixer, some electronics or a bit of software in the R/C transmitter, generates two outputs, V_l and V_r, out of the two inputs, Y and P, according to:
$V_l = c_Y \cdot Y + c_P \cdot P$ and $V_r = -c_Y \cdot Y + c_P \cdot P$.
Additional functions may be desirable:

- Compensation of asymmetry or other inaccuracies in the links,
- servo reverse and such stuff,
- compensation of the slip/pitch effect, see below, and
- an intensionally added pitch up on yaw input: I am not a friend of this but other pilots like it and say, it makes thermalling more comfortable.
- Modern mixers have a limiting capability, protecting the servo from running beyond its end positions.

The factors c_Y and c_P are adjustable and finding good values for the first flight is described here:
Assume that the servos, links and rudder horns are installed such that everything works symmetrically, as linearly as possible (or with exactly the disortions which you want) and the full servo deflection causes a control flap deflection of exactly the reasonable maximum (20°). All this should be done **before** you enter the mixer menu of your R/C transmitter.

As the V-tail's vertical control is about 20% more effective than the one of a standard tail (see above), we may use c_P=0.8 (or 80% on other scales). For a new aeromodel we do not know enough on it's yaw control effectiveness we start with c_Y=1 (100%).

When you use control flaps with a relative depth of more than 25% you may use accordingly smaller values; for a relative depth of 30% the effectiveness of the control flap increases by about 20% and you may start with c_P=0.7 and c_Y=0.8.

Side Effects

The following table shows how a V-tail reacts on events ("input"). Most of the reactions are already reviewed, because they are intended. Others were not treated until here, because they are not intended and consequently are side effects.

"Input"	**Response on**			**Remarks**
	pitch	**yaw**	**roll**	
$\alpha<0$	intended: $L_V<0$, see above	-	-	Fulfill the momentum equation
$\alpha>0$	intended: $L_V>0$, see above	-	-	
α	intended: L_V∈ (nose down), see above	-	-	Yield static stability
α↓	intended: L_V↓ (nose up), see above	-	-	
$\beta\neq0$	nose up, parasitical	intended, see above	parasitical	The pitch momentum is surprising
β or β↓	nose up∈ in both cases(!), parasitical	intended, see above	parasitical	

∈ means "increasing", ↓ means "decreasing". Again: Any control flap deflection may be set equivalent to a corresponding pitch or slip angle; control flaps "up" is comparable to α and so on. This simplification is "allowable" for the following discussions.

Parasitic Roll Momentum

A slipping V-tail produces a momentum around the roll axis; the same is the case when rudder is applied. See once more Fig.7b. In order to compare the V-tail's roll momentum with the roll momentum of a standard tail I split it up into 2 parts: The one caused by the sideward directed components of the V-tail's lifting forces, $R_{V\beta side}$, and the one caused by the vertically directed components of the V-tail's lifting forces, $R_{V\beta vert}$. Note that $R_{V\beta side}$ has a counterpart at the standard fin, $R_{S\beta}$.

The side force of the standard fin or the sideward directed components of the V-tail's lifting forces cause a momentum around the roll axis. Where is the roll axis located? It mostly is assumed to go through the lower end of the standard tail (tailboom) or through a point near the centre of the V-tail respectively, but this is not necessarily correct. The roll axis (at least when regarding the slip/roll effect) should be parallel to the flight path and therefore varies. The details page contains an approximative formula for $R_{V\beta side}$. $R_{S\beta}$ and $R_{V\beta side}$ have about the same, small magnitude and are wurscht for most aeromodellers.

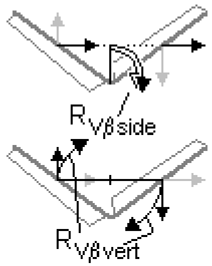

Fig.9: Roll momentum of a V-tail

The two vertically directed components of the lifting forces of the V-tail (they are directed diagonally) cause an additional roll momentum, $R_{V\beta vert}$, which has no counterpart at a standard fin. This roll momentum is independant of where we assume the roll axis of the aeroplane to be located (as long as it is in the XZ-plane). In the details page is an approximative formula for it; $R_{V\beta vert}$ is much stronger than $R_{S\beta}$ and $R_{V\beta side}$.

The parasitic roll momentum is sometimes said to have the "wrong" orientation: A plane slipping to the left rolls to the right and vice versa. I think, this should be seen differently for slip/roll and rudder/roll: The roll momentum caused by slip doesn't have the "wrong" orientation. Note that a dihedral at the (main) wing causes a slip/roll momentum of the same orientation as a V-tail and of a much larger magnitude and it is intended. A plane with an inward orientation of the slip/roll momentum is unstable and dangerous. The contrary may be the case for the rudder/roll momentum; it should be directed "into" the curve or, better, vanish.

The NACA Experiment

The slip/roll momentum was tested for configurations with a standard tail, a V-tail and without a tail. The roll momentum caused by wings and fuselage (without tail) had the greatest magnitude. The results somehow confirm a greater rudder/roll momentum of the V-tail than of a standard tail.

Compensation

Many parts of an aeroplane cause a slip/roll momentum, sometimes with much greater amounts than the tail, regardless of its type. At a first glance I might recommend for compensation of the V-tail's higher roll momentum: Don't bother about it.
In some cases it is of course of interest, to let this parasitic momentum not become too large, but: how large is "too large"? I never heard of a tolerable upper limit. Very skilled pilots might want to have an aeromodel with no or a very small slip/roll momentum and might look for a compensation:

Compensating the slip/roll momentum is easy: Just decrease the dihedral of the (main) wing by, say, 1° (each side). Compensation of the rudder/roll momentum is impossible with a usual V-tail, you can only use the ailerons, but I doubt that you will really suffer under the rudder/roll momentum.

Another, very elegant method to compensate the effect is, to let $R_{V\beta vert}$ have the contrary sign as $R_{V\beta side}$ by using an inverted V-tail. What does happen? With an inverted V-tail the total slip/roll momentum has a smaller magnitude and goes "into" the slip direction (dangerous!), but it can easily be compensated by increasing the dihedral of the (main) wing. The rudder/roll momentum is also smaller and directed "inward", but this may be intended. Examples for configurations with these interesting V-tails are the fascinating Aerosonde project, the the AVS project, or the fs 28 Avispa aeroplane (or simply the cover of Althaus' 1st book). I am not sure, that all these aeroplanes employ an inverted V-tail to compensate the parasitic roll momentum, as it is also an elegant way to combine a pushing propeller with a "tailed" configuration.

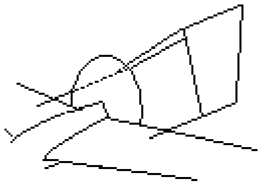

Fig.10: Inverted V-tail

Of course the inverted V-tail has disadvantages: It requires 2 tailbooms or a very high gear, is more difficulty to build and surely suffers under non-perfect landings more than other tails. The few samples I have seen so far all employ (nearly) rectangular shapes for the inverted V-tail and I am looking for some even more elegant versions (Fig.10 sketches a tapered, swept forward V-tail).

Please note: Several effects have reverse signs for inverted V-tails (e.g. the slip/pitch momentum becomes a pitch down momentum), but I do not mention this in the corresponding discussions.

Parasitic Pitch Momentum

A slipping V-tail or a V-tail with the control flaps deflected to yield yaw control can produce an undesired pitch up momentum. To be honest: I myself never observed any pitch up and also comrades didn't, even when I asked them to try it and to carefully watch the aeromodel; but I did not want to ignore it because it was simply Joe Wurts who reproted this effect in a discussion forum. Also the NACA experiment shows a very strong slip/pitch and rudder/pitch effect:

Fig.11 is a very simplified part of one of the measurement results and the following is clearly visible:

A model was tested with a standard tail, a V-tail and without any tail. The V-tail was designed according to the rules which are also outlined above, such that the slip/yaw momentum was somehow equal for the standard and the V-tail, as intended. The pitch momentum was measured for different slip and rudder angles. For the configuration without a tail a reasonable slip/pitch momentum was measured (dotted line). It is obviously caused by the wing and the fuselage (no weather forecast please...) and I think it is a good idea, to correct all other pitch measurements accordingly. The slip/pitch momentum curve for the standard tail (dashed line) is in general parallel to the corresponding curve for the non tail configuration. The offset is not of interest here (decalage) and it may be concluded, that a standard tail does not contribute to the slip/pitch momentum.

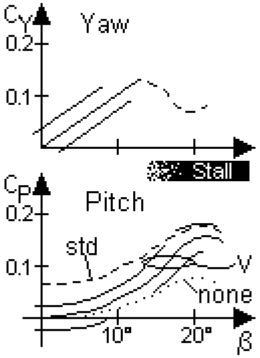

Fig.11: From the NACA

The curves for the V-tail (for 3 different rudder angles) are steeper and after correction they indicate an additional slip/pitch momentum with the following basic properties:

- It is very small for small slip angles, and
- it increases more than linearly between about 10° and 20° slip angle.
- It is nearly symmetric: The pitch is nose up for both slip directions ($\beta<0$ and $\beta>0$).
- The maximum amount of this (parasitic) effect is considerable, even after correction by the momentum of the non tail configuration.

Also control flap deflection for yaw control do not only cause a yaw momentum but an additional pitch momentum. Rudder at the V-tail of 10°(20°) causes an additional yaw momentum ΔC_Y of 0.02(0.03) and an additional pitch momentum ΔC_P of 0.02(0.03). These effects are clearly to be seen for an angle of attack of 0° (but not for about 9°) and it means that the model pitched more than it yawed when rudder was applied and I do not want to believe it (regardles of the weather tomorrow;-).

A V-tail is obviously not the only reason for an aeroplane to pitch when it slips or when rudder is applied. Of course friction effects are named as reasons, particularly when the fuselage is voluminous. It is surely possible that different reasons for a pitch momentum cancel out each other or add up in many cases.
Some explanations for the slip/pitch momentum of a V-tail are given:

- Asymmetric pressure distribution over the V-tail's span, which causes the leeward wing to yield more lift down than the other one to produce lift up - in short words: The leeward wing has higher pressure on its upper side which propagates also onto the upper side of the windward wing's upper side, such yielding more lift down (the windward wing acts as an end plate for the leeward wing). I do not think that this explanation is correct, as it contains only the 1st half of the story - a similar effect acts reversely: The lower pressure at the upper side of the windward wing is propagated onto the leeward wing, thus cancelling the pitch effect of the higher pressure there.
- Asymmetry in the control flap linkage, causing an unintended differentiation: This may of course be the case, but I think, a sensitive pilot, who observes this effect and is willing to investigate it, will at first very thoroughly check the links and will report this effect only when he is absolutely sure, that the links are symmetrical.
  Differentiaton in the V-tail's rudder may of course yield pitch (up or down), and an aeromodeller, who perhaps observes a pitch with his brand new glider will at first believe, that his rudder is differentiated and will "correct" this and unintensionally perform a compensation of the real pitch effect.

As you can see I'm not very happy with both explanations and here are 2 more "theories":

- The one is disappointing simple: **Stall** or, similarly, separation effects at largely deflected control flaps. Suppose, the V-tail yields lift up (during low speed flight) and slips so much that the windward wing sees a section angle of attack $\alpha_v = \alpha\cdot\cos(\nu)+\beta\cdot\sin(\nu)$ close to its stall angle and leaves the linear range of its lift curve; the leeward wing, seeing $\alpha_v = \alpha\cdot\cos(\nu)-\beta\cdot\sin(\nu)$, remains in the linear part of the lift curve and therefore yields more lift down than the windward wing, which yields lift up. Strong deflections of control flaps cause similar friction and separation effects.
  There are some problems with this explanation:
  (1) A pilot, who sees this pitch up will ½ sec later see his aeromodel stall.
  (2) With this explanation the effect should not be visible when the tail doesn't yield lift up or down; the measurements in the NACA report however do not confirm this, as the slip/pitch and the rudder/pitch effects are comparably distinct at angles of attack of 0°, much more than near 9°.
  (3) The effect should yield a pitch **down** during high speed flight and result in a tuck down - I am sure that this was not observed because tuck down happens rather quickly. Unfortunately the NACA report doesn't contain data for this case.
  (4) This would not be an explanation for the rudder/pitch effect when the aeroplane does not slip.
  There is a close relation between stall at a V-tail and a pitch momentum, but I think, this alone cannot be the whole story.
- I tried another explanation which is a derivation of the "biplane effect":

  The two wings of a slipping V-tail (or a V-tail with a large rudder deflection) influence each other such that the flow velocity at the leeward wing is higher than at the windward wing. Thus the downward directed vertical force of the leeward wing is stronger than the upward directed force of the windward wing and causes the aeroplane to pitch up. I provided some mathematics on this in the details page.
  This effect is quadratic, not linear, and this means, that it is **very small** for small slip angles and moderate rudder deflections. But for greater slip angles or large rudder deflections it increases reasonably.
  As the mutual interferrence of the wings is restricted to the parts near the centre of the V-tail the slip/pitch effect decreases with an increasing aspect ratio of the V-tail.

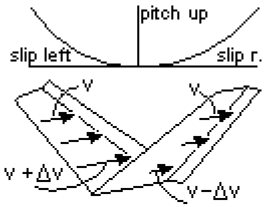

Fig.12: The slip/pitch momentum

This effect is not necessarily to be compensated as many pilots simply don't realize it; others obviously like this effect and even intensify it by introducing an additional differentiation (it might be comfortable during thermalling). If you want to compensate the ruder/pitch momentum you should not simply use linear differentiation, as this would overcompensate small rudder deflections or would not be sufficient for large rudder deflections. Some computer controlled R/C transmitters allow to derive an appropriate curve from the rudder input to be mixed with the V-tail outputs. Another method is of course to use a differentiating link like in Fig.13; a drawback is, that it is not so adjustable as a software solution.

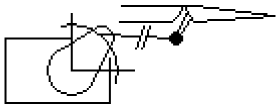
Fig.13: Compensating the slip/pitch momentum by using an appropriate link

Etc.

The Drag of a V-tail

Drag reduction is a strong motivation for aeromodellers to try a V-tail. When the V-tail is designed according to the rules layed out here, the wet surface is nearly the same as the one of a standard tail; therefore friction drag reduction will be minor, although a V-tail may be designed for slightly larger Reynolds numbers. There is no chance to save induced drag because of the better aspect ratio of a V-tail compared against the standard fin (because of the lift reversal near the centre during slip and rudder deflection).
A V-tail has a lower interferrence drag than any other tail. In Dubs' book I found the statement that the interferrence drag of a V-tail is "only" 4.5% of the V-tail's drag, compared to about 7% or more for other tails - perhaps for small and comparably slow aeromodels the savings may be greater because the relative amount of the friction drag is greater than for full size aeroplanes. This may of course be interesting for extreme racers or contest aeromodels.
Under normal conditions the control flap deflections for a V-tail are not greater than with a T- or standard tail and therefore the drag, caused by the control flaps, is not greater for a V-tail than with others.
All this may sound disappointing for those who tried a V-tail on order to save drag - a V-tail doesn't look better than a T-tail. I think, there are other possibilities to save much more drag.

Questions, Which Are Not Discussed Appropriately Here

Spin Recovery

Bad spin recovery is said to be one of the most critical properties of V-tails and some name it as the main reason why V-tails are not used in full scale aeroplanes. I found only few publications regarding this topic; some state, that spinning is very dangerous with V-tails, others don't (Hubert "Skip" Smith wrote: "The V-tail also shares honors with the T-tail in having good spin recovery characteristics").
I have not enough experience with spinning (I prefer spinning during high start when the glider still hangs on the line;-) and I'm not sure who is right. Spin recovery depends on similar design properties as static stability; the more statically stable the aeroplane is, the easier it is to recover from spinning. It should not be a V-tail property (just to heat up the discussion:-)

The V-tail in the Wake of the Main Wing

No part of any tail should be located in the wake of the main wing during any "normal" flight regime. An aeroplane should be designed such that this condition is fulfilled. When the aeroplane shall get a V-tail, an appropriate tailboom is to be used (ok-ok, simplification) that it is located high

enough such that it will not be hit by the wing's wake.
Recover from stall should function safely independantly weather the tail is "in" the separation wake or not. I cannot understand drawings with some ideas of a wake of separated flow, what happens inside this region and a statement, that a T-tail is in this awful bubble (Be sure: Sometimes it is and sometimes it isn't). Stall recovery is an important handling property and it must be independant of the type of the tail.

Control Flaps Linkages

Rudder horns and quicklinks on the upper side of the V-tail, outside the fuselage, are **out**.
Inside the fuselage or the tube, which is used as a tailboom, is not much space for 2 linkages. The rudder horns are short, possibly the control flaps are deeper than usual, therefore any slip in the linkages has greater influence than with standard tails. Use high quality links and servos! I think, an all moving V-tail is almost impossible to be built with the needed precision.
The load on the linkages should not be greater than the one at standard tails. I didn't care about this because **my** linkages are always destroyed during several very special "landings".

Other

Other people do know much better than I how to mount a V-tail onto the fuselage and how to set up the correct decalage.

More topics? Let me know (info)!

Comparison V-Tail / T-Tail / Standard Tail

I feel, this discussion will never end; too many personal preferrences are involved.

Topic	Std Tail	T-tail	V-tail	Remarks
Weight	normal	heavy	lighter	A good reason to try V-tails with aeromodels
Damage Resistance	normal	poor	better	For landing in high grass a V-tail is the best choice for an aeromodel
Drag	normal	better	better	The V-tail's drag advantage is not so good as often said
Static stability	normal	same	limited	The V-tail, when designed according to the rules outlined here, will yield the same static pitch stability

				as the other tails. But its aibility to avoid sudden stall or tuck down is limited when the aeroplane slips, so it is not suited for large gliders with high aspect ratios or when a highly cambered aerofoil is used at the main wing.
Maneuverability / control characteristics	best	good	works	The V-tail has some unique minor side effects; I would never choose it for an aerobatic aeroplane. See the details page for some remarks on a "clean", slipping T-tail.
Complexity	simple	high	simplest	A V-tail consists of only two surfaces. The mixer problem is solved with most current R/C transmitters. For full scale aeroplanes the (mechanical) mixer is a severe drawback.

I do like V-tails because of their insensitivity against my very personal way to land in high grass and because of their better appearance. Weight and simplicity are also important. I have learned, that V-tails do not have advantages in aerodynamics or flight mechanics.

Appendices

References

- NACA report No.823: "Experimental Verification of a Simplified Vee-Tail Theory and Analysis of Available Data on Complete Models with Vee-Tails" by Paul E. Purser and John P. Campbell, reprinted in an early SOARTECH
- "Theorie zum V-Leitwerk", yes, from me, in "MFI - Modellflug international"; it was published in 1987/88, so you won't ever get a copy of it; don't worry, this article is a good (extended and corrected:-) replacement.
- Dieter Althaus: "Profilpolaren für den Modellflug", Neckar-Verlag VS-Villingen, 1980, 3-7883-0158-9
- Fritz Dubs: "Aerodynamik der reinen Unterschallströmung", Birkhäuser Verlag, 3-7643-1872-4
- Hubert "Skip" Smith: "The Illustrated Guide to Aerodynamics", TAB Books Inc., 0-8306-2390-6
- Aerosonde is a robotic aeroplane for meterological applications. I became attentive on this project reading an article in a GPS-magazine on the first atlanitic crossing of this aeroplane.
- fs 28 Avispa is an experimental motor aeroplane (2 seats) of the Akademische Fliegergruppe Stuttgart e.V. (1972). It combined modern construction principles for gliders with an unusual design of a pushing propeller.
- Thomas Kutscheid: "Das Geheimnis des V-Leitwerkes", Magazine "Aufwind" 4/2001 pp46-50, www.aufwind-magazin.de

A word on

AZTEC and other panel programmes:

AZTEC is a free 3D vortex lattice code; I tried it out to calculate some numbers of the slip/pitch effect, but I did not succeed. The programme delivered pitch *down* instead of pitch up when the V-tail was assumed to slip. Nevertheless I think, AZTEC is a useable tool for calculation of "nearly" 2D problems. It seems that the programme is not longer available in the internet (Nov. 2000).
I tried also few other programmes, as they were available for me without spending lots of money (and without using software in an illegal manner). All codes had difficulties with the biplane effect.
Make a simple experiment: Design a trivial biplane; it should consist of two identical wings, arranged exactly one above the other and in parallel. With an angle of attack $\alpha>0$ the upper wing should yield more lift than the lower wing (this **is** the biplane effect). The simpler panel codes do not compute this: The results are identical lift for both wings. Of course I have no idea about the reason.

Footnotes

"Äha": Bavarian dialect. No literal translation; meaning: a mild form of "Surprise!", pronunciation: ['ɛha].
"Wurscht": Bavarian dialect; literal translation: "sausage", but used as an adjective; meaning: "not of interest", "unimportant". Pronunciation: [vurʃt]. The 'r' is not as usual in English, it should be formed with the - preferably wet - throat;-). Try it!

Legal Information

Author: Helmut Stettmaier, FMSG-Alling e.V.

Changes

November 12th 2001: Added few thoughts on the biplane effect: It not only may affect the V-tail's response to slipping but of course also during pitch stabilisation, what was not mentioned till now. Consequently my short discussion of the corresponding part of the NACA report No.823 was modified (more puzzles than before). Few more comments on AZTEC and other simple panel codes were added. Also minor typos and the Aerosonde-link were corrected.

November 2000: Clarifications (also in the details page) regarding AZTEC.

November, 16th 1999: Some clarifications due to discussions and questions added
Thank you, Jens Henkner (Technische Universität München), for your help!