Vertical and Horizontal Tail Sizing

Aerospace Design

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Vertical and Horizontal Tail Sizing

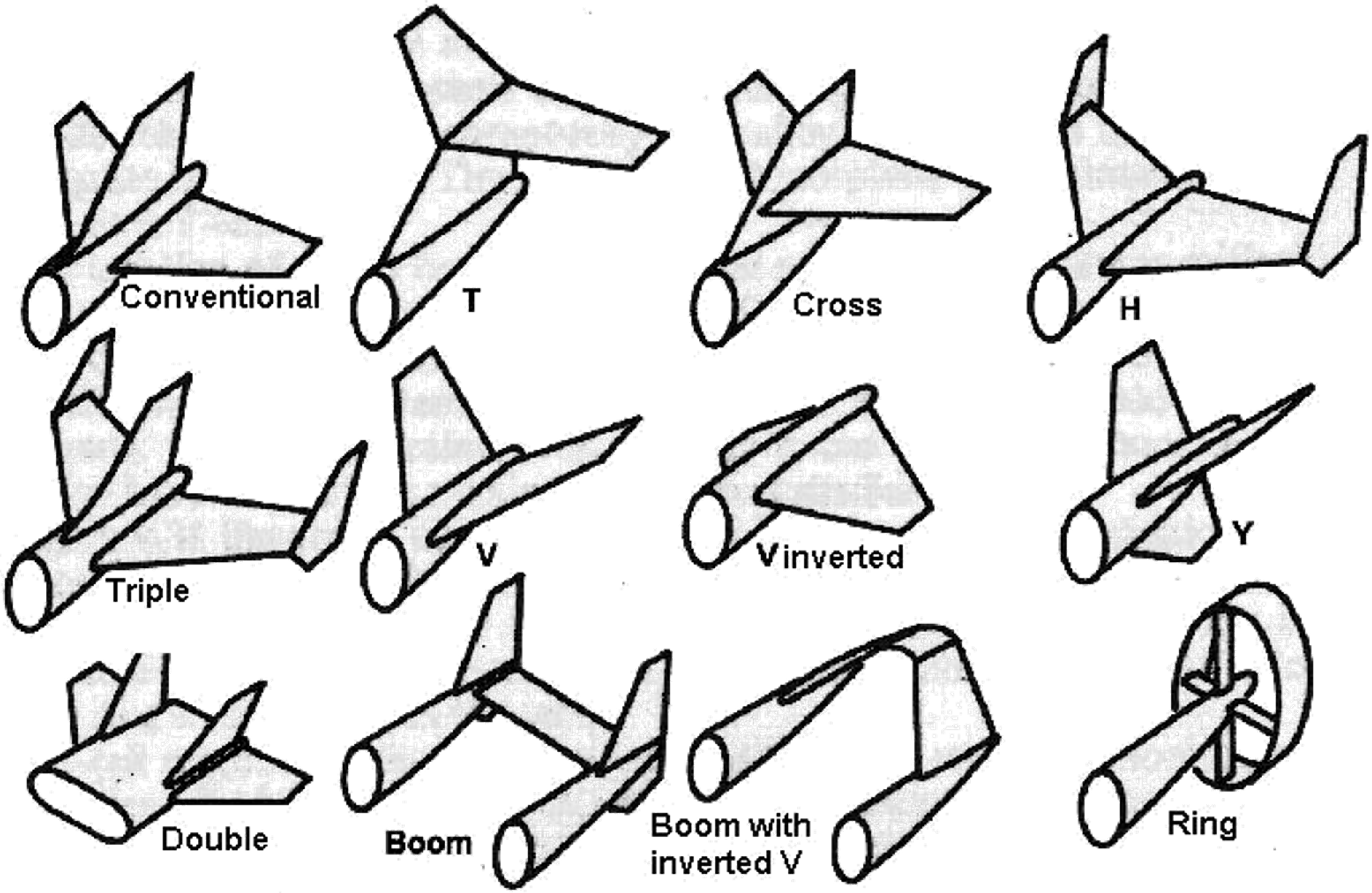
- ***Aft tails*** and ***canards*** (control or lifting canards)
- ***Empirical relations***, based on ***historical data***, which relate the tail area and location to the wing area, chord and span are used to size the tail
- The selection of the tail ***airfoil section*** will be based on the same procedure that was used for the main wing airfoil selection
- ***Symmetric airfoils*** (or with a very small negative camber) are chosen due to their low base drag coefficient (C_{D_0})
- The ***tail planform*** is also based on historical data
- The design of the ***control surfaces*** will be done latter in the design process when the ***static stability and control*** are studied
- The horizontal and vertical tail 3D lift characteristics and drag will be quantitatively estimated, with the same procedures used for the design of the main wing

Tail Design Requirements

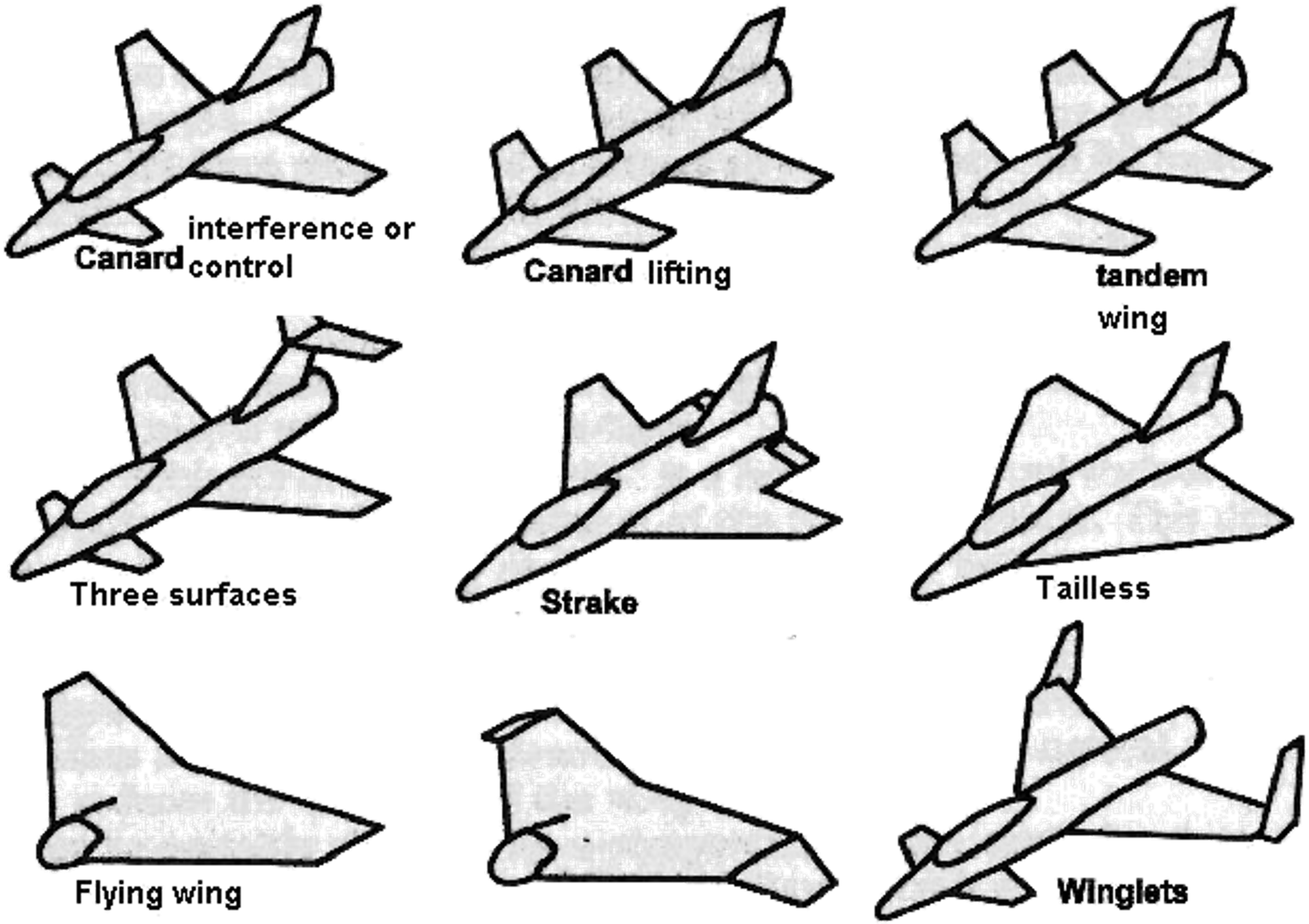
- Tail Tasks

- ***Stabilize the aircraft*** (make the moments around the cg zero)
- ***Correct rolling and yaw moments*** caused by ***propeller wake***
- Provide ***control*** in case of ***engine failure***
- Provide ***control*** of ***cross winds***
- ***Control and manoeuver the aircraft in pitch*** (horizontal stabilizer) and in ***yaw*** (vertical stabilizer/fin)
- Other factors that affect tail configuration and location are: ***weight***, ***spin recovery***, ***survivability***, ***combat stealth*** and ***manoeuverability***

Tail Configurations



Tail Configurations



Conventional tail

- Surfaces on the aircraft centerline and minimum weight

T-tail

- Horizontal tail acts as winglet of the vertical tail, increasing the efficiency of the vertical tail and reducing its dimensions
- For low angles of attack the horizontal stabilizer is far from the wake of the wing (less affected by downwash)
- Since the vertical tail must carry the loads from horizontal tail, its structure is heavier than in the conventional configuration
- The horizontal stabilizer should be placed out of the separated wing wake at high angles of attack, in order to maintain control effectiveness – in these cases, the trailing edge of the elevator may be designed to be affected by the separated wing wake flow, so that a buffeting on the pitch control is produced, warning the pilot of an imminent stall

Cross-tail

- Compromise between the two previous, less weight than T-tail, horizontal stabilizer still far from the wake of the wing, but it does not act no longer as the vertical stabilizer winglet, not increasing its efficiency

H-tail

- Airflow around vertical stabilizers not disturbed by the fuselage and they work as winglets of the horizontal stabilizer, increasing its efficiency and allowing for a reduction in its size
- Allows for high manoeuvrability, or for a reduction in overall tail height reduction, increasing also the survivability. It has a weight larger than the conventional tail configuration

Twin tail

- Used to increase the manoeuvrability while positioning the vertical stabilizers away from the aircraft centerline and from the fuselage wake at high angles of attack

Tail Configurations

V-tail

- Less wetted area (and friction drag)
- Since the surfaces act as horizontal and vertical stabilizers simultaneously, the controls (rudders and elevators) are coupled, increasing control complexity and inducing a high yaw-roll coupling – particularly an adverse yaw-roll effect, *i.e.*, yawing the aircraft to one side to induce a turn will generate a roll moment that will oppose the turn

Inverted V-tail

- Solves the previous problem, allowing for coordinated turns and reducing spiral tendency. However an increased ground clearance is necessary

Y-tail

- The presence of a vertical stabilizer reduces the control complexity of a V-tail. The wetted area is higher with relation to the V tail, but lower than in a conventional tail. (*Ex:* F4 uses an inverted Y tail to keep the horizontal stabilizers away from the wing wake at high angles of attack)

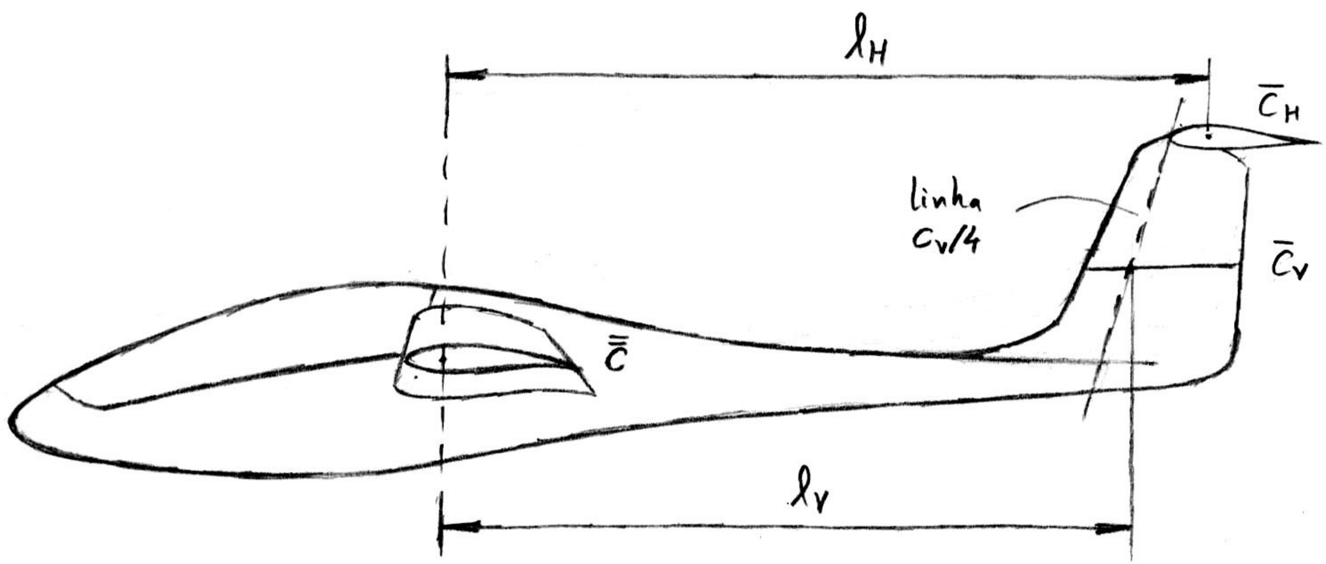
Canard

- Is a an horizontal stabilizer located in front of the main wing, producing positive lift to stabilize the aircraft – zeroing the pitching moment around the C.G. in levelled flight and increasing the pitching down moment while increasing the angle of attack
- When used for control, ***control-canard***, may produce very little lift or positively interfere with the main wing – upwash outboard the canard due to the tip vortices
- Can also be used to produce a considerable amount of lift, ***lifting-canard***, 15 % to 25 % of total lift (in this design the wing is affected by the canard downwash)
- The C_{L_α} is usually lower than the one of the main wing and is also usually designed to stall at lower angles of attack than the main wing, so that the pitch down moment increases with increasing angle of attack
- Besides producing positive lift to stabilize the aircraft, the canard design also decreases the overall drag, by decreasing the lift distribution per area and then decreasing the induced drag (this effect is also noted in positive g manoeuvers)

- Volume coefficients

$$V_H = \frac{S_H l_H}{S_w \bar{c}_w} \qquad V_V = \frac{S_V l_V}{S_w b_w} \qquad V_C = \frac{S_C l_C}{S_w \bar{c}_w}$$

- C.G. is assumed to be at ¼ of mean aerodynamic chord and usually geometric chords are used to simplify the process



- Historical Data

	Typical Values	
	V_H	V_V
Glider	0,50	0,02
"Homebuilt"	0,50	0,04
General Aviation – Single Engine	0,70	0,04
General Aviation – Twin Engine	0,80	0,07
Agriculture aircraft	0,50	0,04
Twin turboprop	0,90	0,08
Hydroplane	0,70	0,06
Training jet	0,70	0,06
Fighter	0,40	0,07
Military transport/Bomber	1,00	0,08
Civilian transport	1,00	0,09

Tail and Canard Sizing

- ***T-tail:*** reduce the volume coefficients by 5 % (increased efficiency of this configuration) with relation to the conventional tail
- ***H-tail:*** reduce the horizontal tail volume coefficient by 5 % and each vertical stabilizer will have half of the vertical tail area of a conventional configuration
- ***V-tail:*** the total area must equal the sum of the vertical and horizontal tail areas of a conventional tail and the angle between the two tails is given by

$$\arctan\left(\sqrt{S_V/S_H}\right)$$

TABLE 6.3: Coefficient scaling for different tail types.

Type	Equivalent C_{VT}	Equivalent C_{HT}
T-Tail	0.95	—
H-Tail	0.50	0.95
V-Tail	1.00	1.00

TABLE 6.4: Typical lengths, l_{VT}, l_{HT}, and l_C.

Type	$l_{Tail}/l_{Fuselage}$
Front-Mounted Prop.	0.60
Wing-Mounted Engines	0.50–0.55
Fuselage-Mounted Engines	0.45–0.50
Canard	0.30–0.50

- Aspect ratio and taper

	Horizontal Stabilizer		Vertical Stabilizer	
	A	λ	A	λ
Fighter	3,0 a 4,0	0,2 a 0,4	0,6 a 1,4	0,2 a 0,4
Glider	6,0 a 10,0	0,3 a 0,5	1,5 a 2,0	0,4 a 0,6
Other	3,0 a 5,0	0,3 a 0,6	1,3 a 2,0	0,3 a 0,6
T tail	-	-	0,7 a 1,2	0,6 a 1,0

- Horizontal tail sweep angle
- The leading edge sweep of an aft horizontal stabilizer is usually set higher than the one on the wing, giving an higher critical Mach number for the stabilizer with comparison to the wing, delaying loss of elevator effectiveness due to shock wave formation
- If the sweep is chosen to be the same as the main wing, than the previous effect may be accomplished by choosing an airfoil for the stabilizer with a smaller value of $(t/c)_{max}$ - but of course without reducing to much the stall angle of attack, to maintain control effectiveness

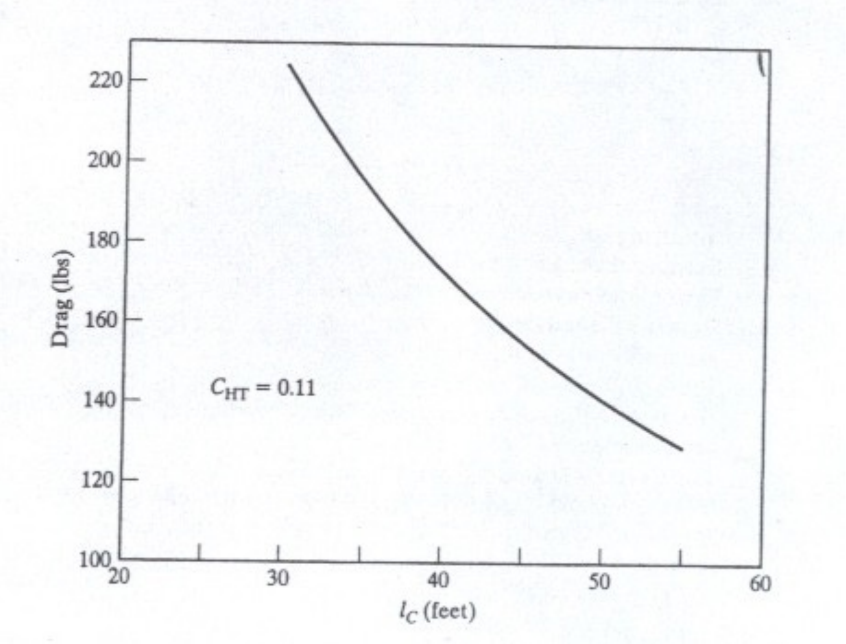
- Vertical tail sweep angle
- Usually between 35 deg and 55 deg. For supersonic aircraft higher sweep angles may be used if the leading edge Mach number is intended to be subsonic
- To maximize the stability and control a higher C_{L_α} is desired. This is achieved by increasing AR, decreasing leading edge sweep and by adopting T, or H-tail configurations where the stabilizers work as winglets, increasing efficiency

Tail and Canard Drag

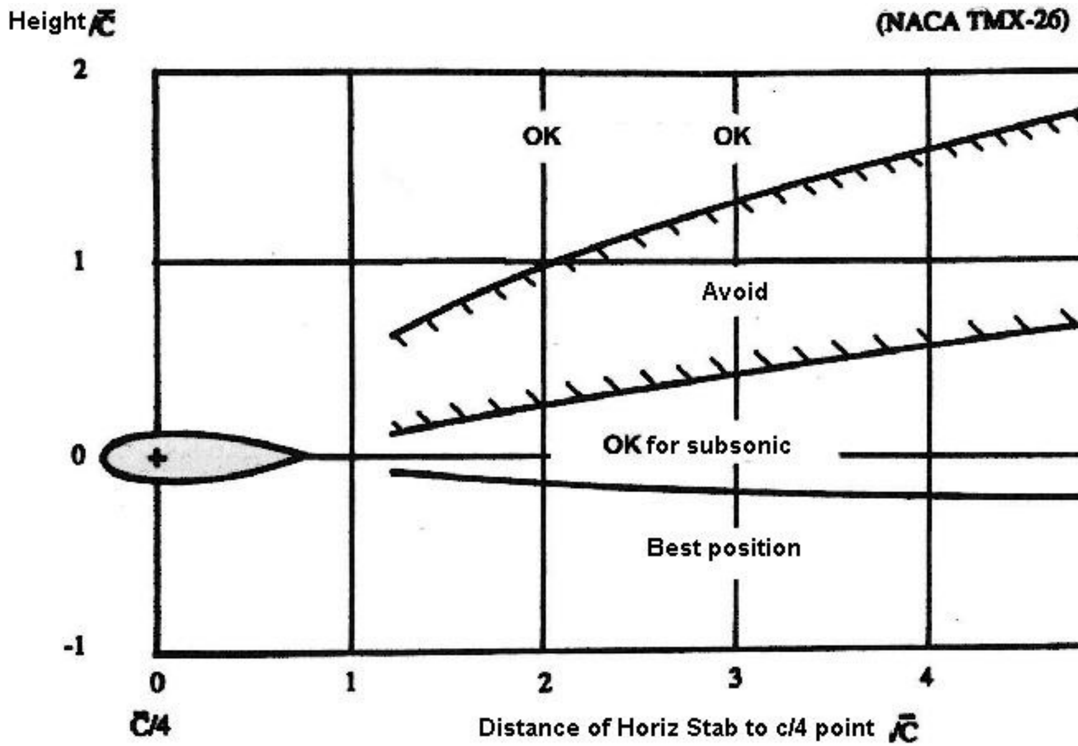
- C_{D_0} is calculated using the same procedure applied to the main wing: C_f is estimated as if a flat plate was considered and then it is multiplied by F (form factor) – calculated in the same manner as for the wing, but increased by 10 % to account for hinge gaps – and Q (interference factor)

TABLE 6.6: Values of interference factor, Q, for different tail arrangements.

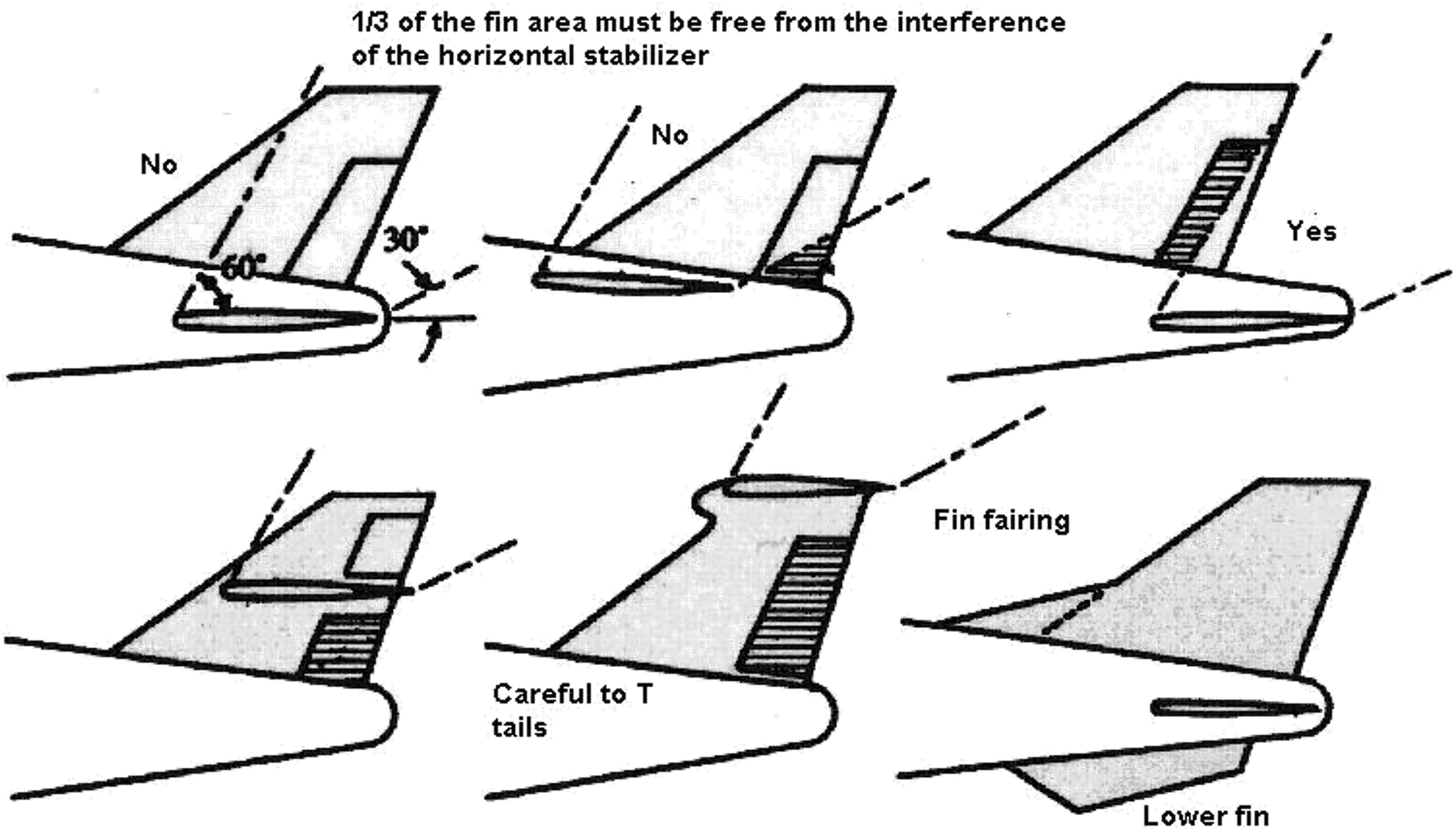
	Q
Conventional Tail	1.05
V-Tail	1.03
H-Tail	1.08



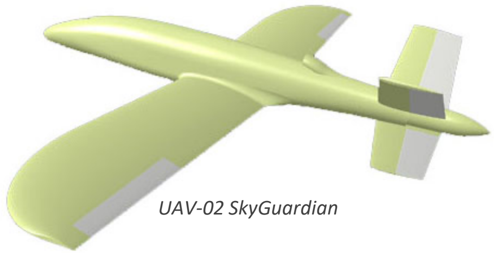
Horizontal Tail Positioning



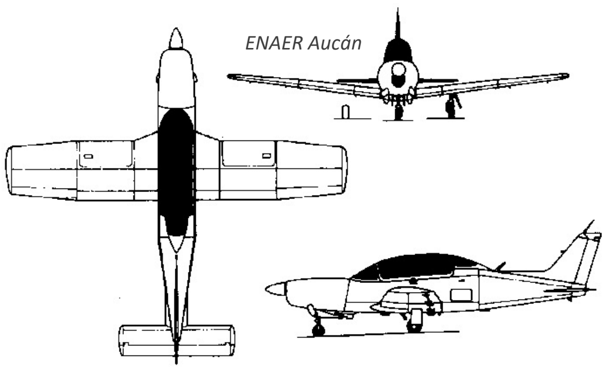
Spin Recovery



Example of Configurations

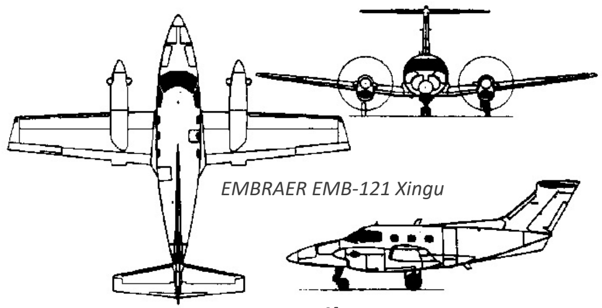


Y-tail

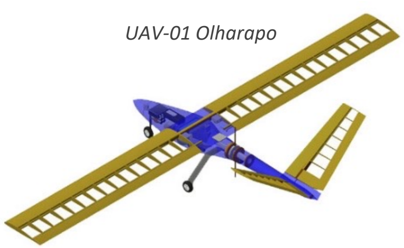


Conventional tail

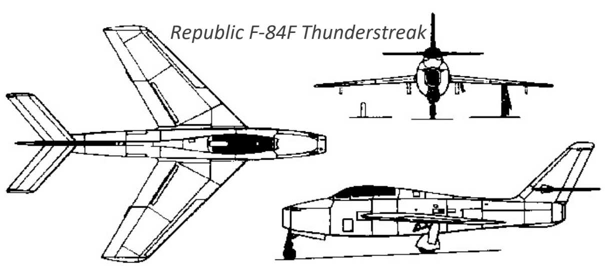
Inverted V-tail



T-tail

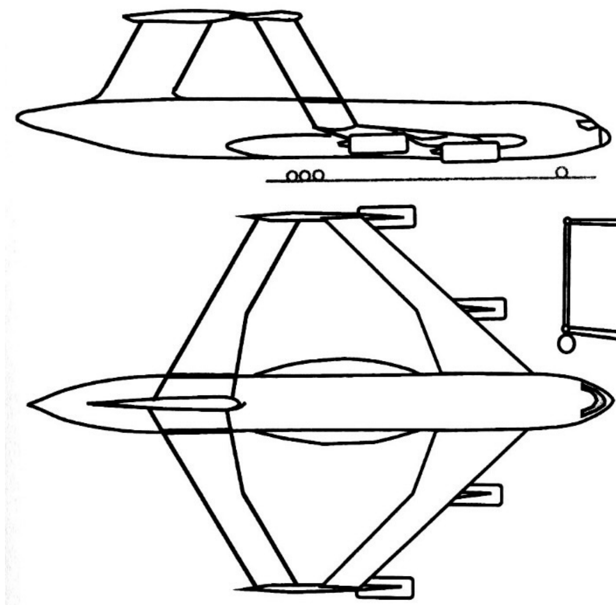
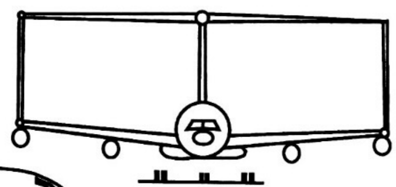
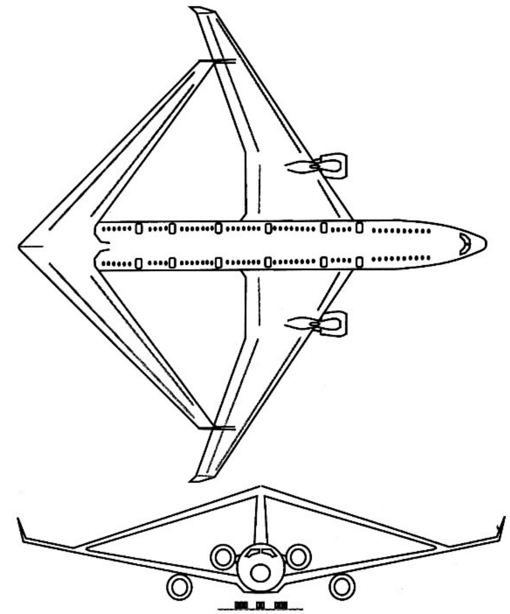


V-tail



Cross tail

Example of Novel Configurations

Joined Wing

- C.G. travel range larger
- Span reduction
- Induced drag reduction
- Structural Issues - buckling