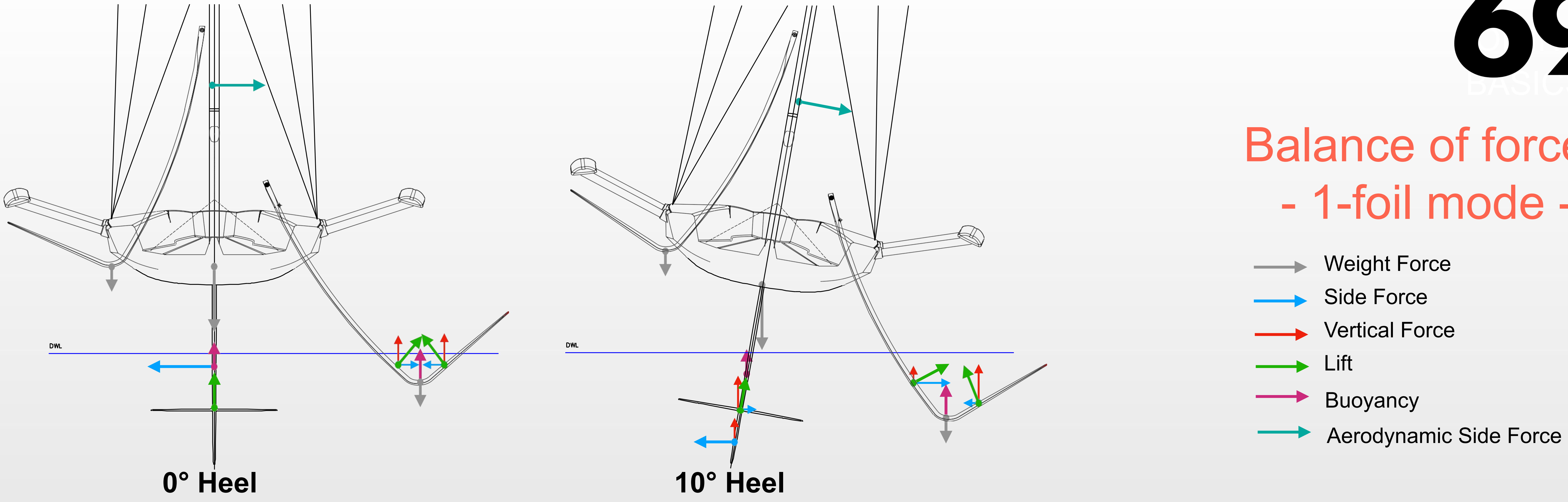

69F
#69FSAILING
FOILING BASICS

Overview

1. Balance of forces - 1 foil mode
2. Righting Moment
3. Why the daggerboard
4. Balance of forces - 2 foil mode
5. Lift and angle of attack
6. Flight Control
7. Ventilation vs. Cavitation
8. Fence and Ventilation

Balance of forces
- 1-foil mode -



Side Force

- Hydrodynamic force generated from the foils' strut has a leeward side force component
- Hydrodynamic force generated from the foils tip has a windward side force component
- Hydrodynamic force generated from the daggerboard has a windward side force component

Hydrodynamic Vertical Force

- Vector sum of the lift generated by the tip and strut
- Vertical force generated by rudder foil

Weight Force

- Sum of the weight of every item onboard

Heel Angle effect

- Introduces a leeward horizontal force component in the rudder foil
- Horizontal component of foil's strut lift become bigger (increases leeway)
- Vertical component of foil's tip lift force becomes bigger (reduced side force to windward)

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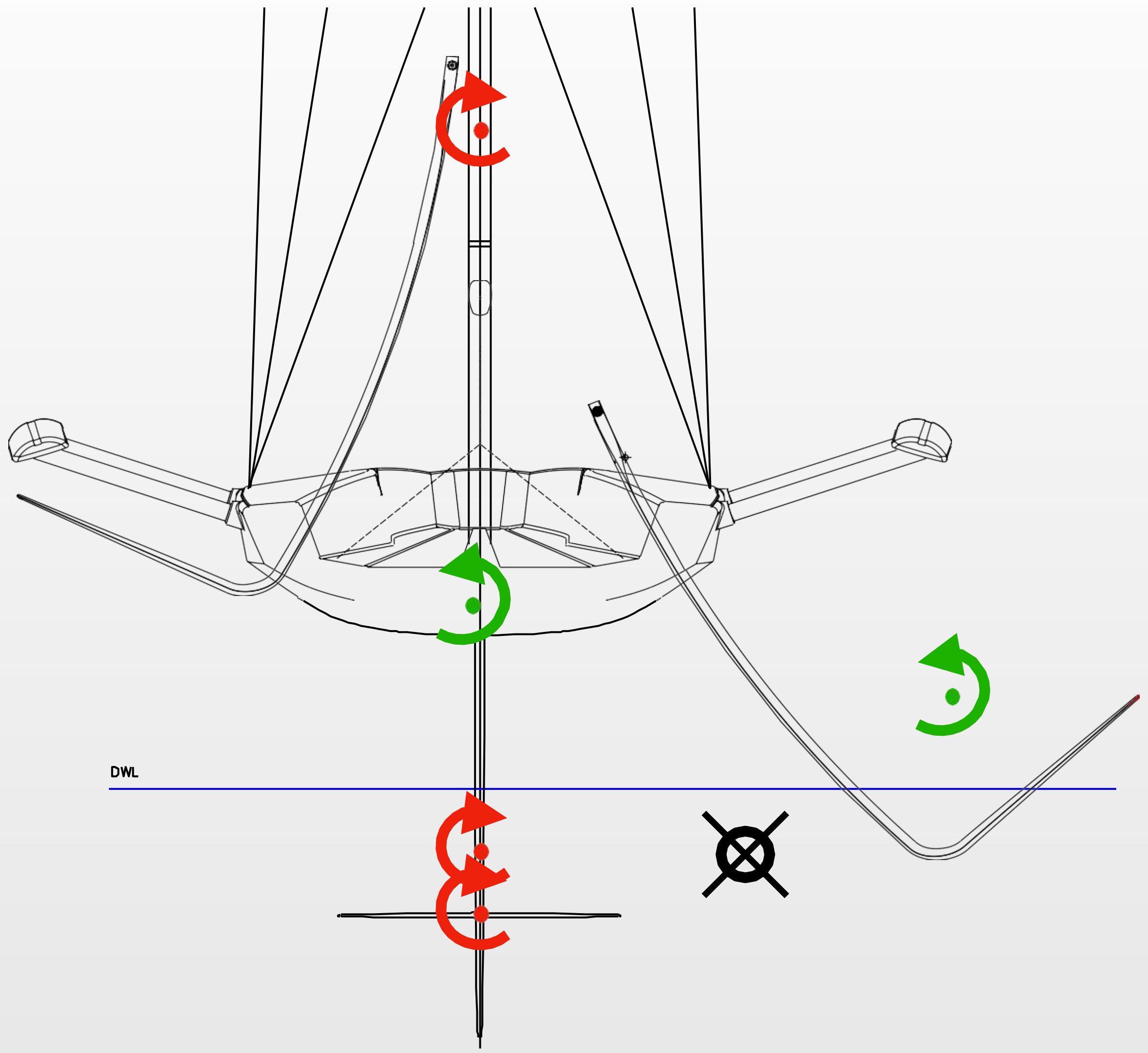
Righting Moment

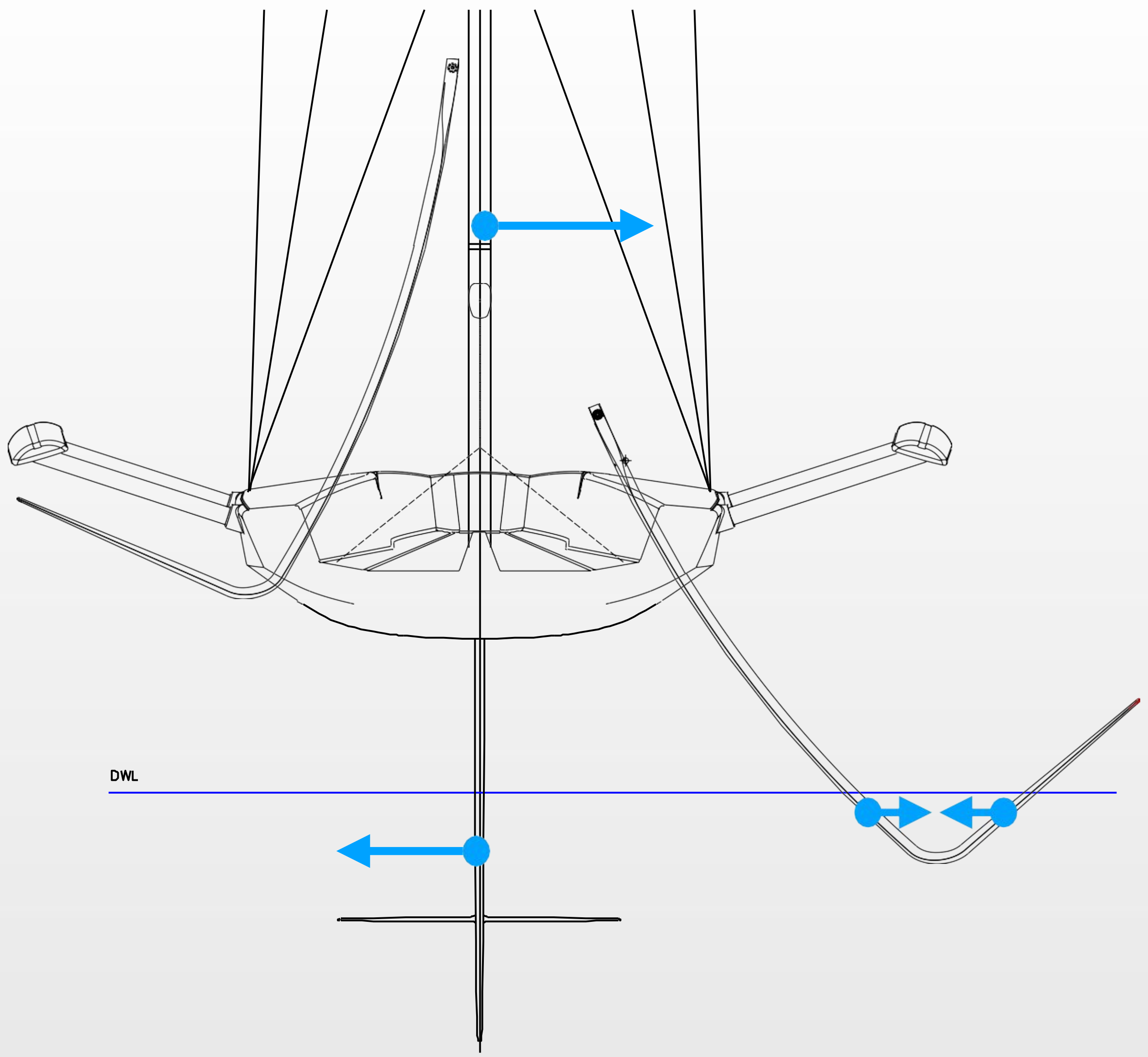


Righting Moment
Heeling Moment Moments

Reference Point

	Force	Lever
Righting Moment	Foil vertical force	Horizontal distance from center of the area in planform of the main foil plus the rudder
	Boat Weight + Crew Weight	
Heeling Moment	Rudder foil lift	
	Aerodynamic side force	Vertical distance from center of the area in front view of the main foil plus the rudder
	Rudder strut + daggerboard side force	

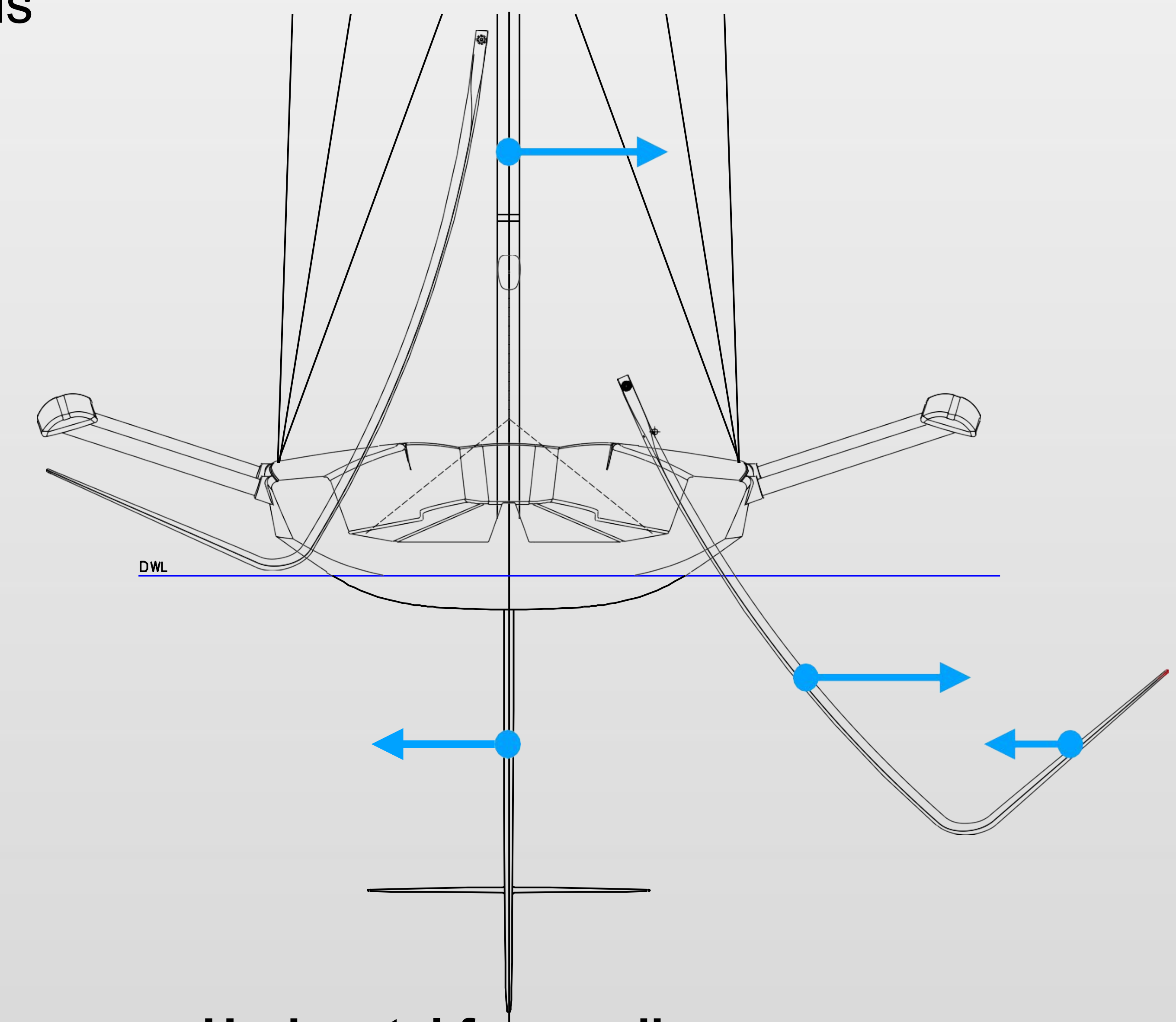
Why the daggerboard?



Horizontal forces diagram (foiling)

- To balance out the side force generated by the foil strut and sails and reduce leeway
- To increase foil efficiency: removing the daggerboard would increase the leeway and as a result would increase the angle of attack of the flow on the tip and decrease it on the strut. This would create imbalance between the two.
- To bring the boat upright after a capsize.

- When the boat is in displacement mode, the leeward force component generated by the strut outbalances the windward one generated by the tip because of the difference in wetted surface area. This is why just before take off the boat tends to bear away.



Horizontal forces diagram (displacement)

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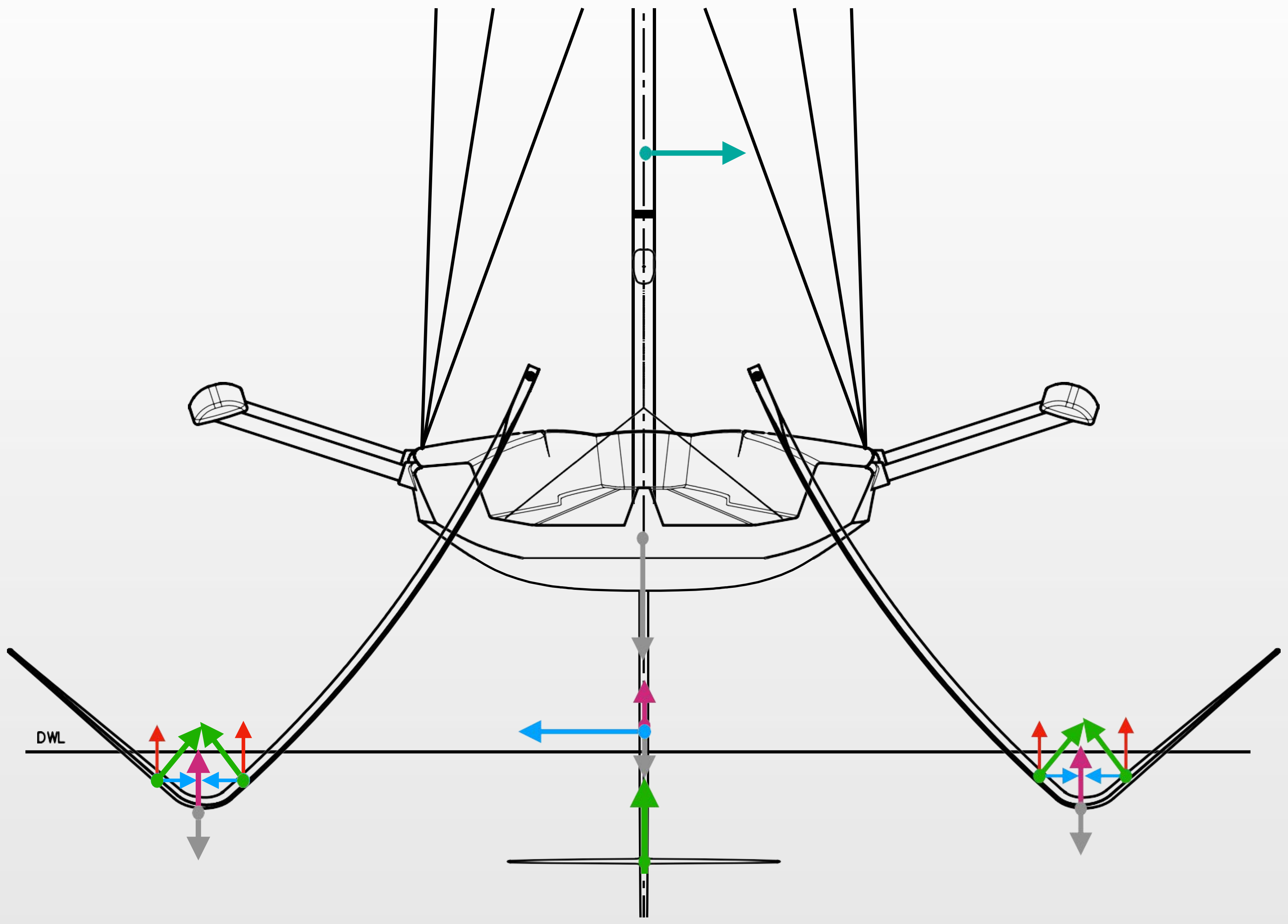
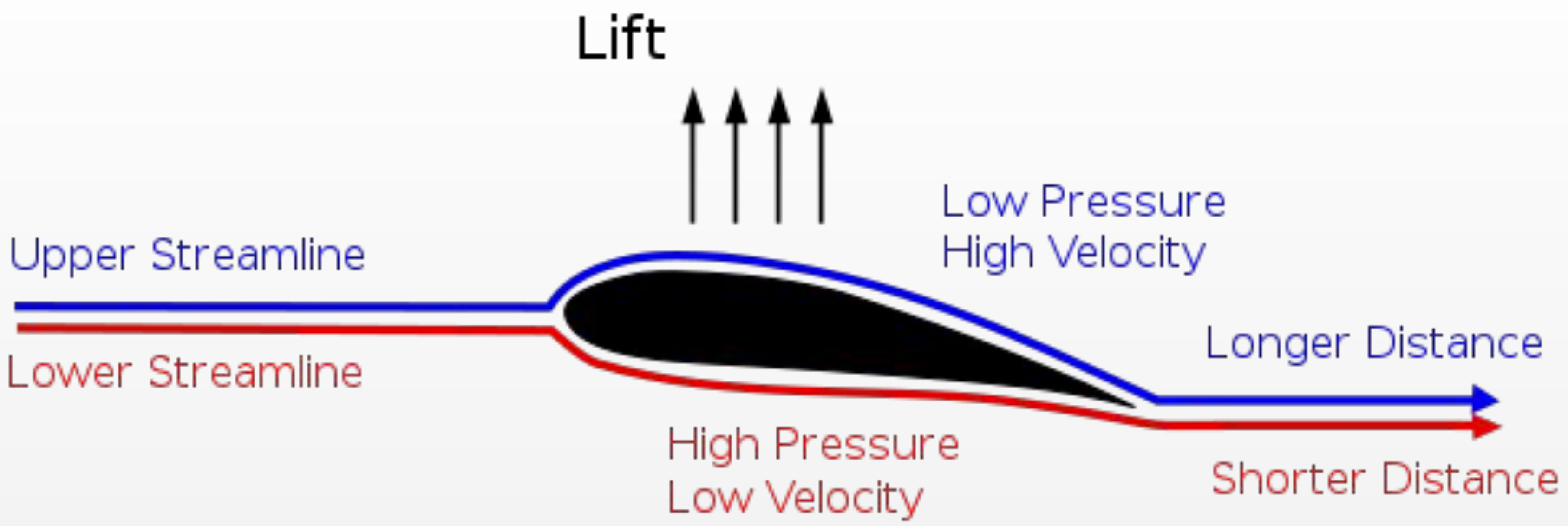
Balance of forces
- 2-foil mode -



- Weight Force
- Side Force
- Vertical Force
- Lift
- Buoyancy
- Aerodynamic Side Force

- As compared to the 1-foil mode, having two foils deployed will results in a larger vertical force generated by the main foils which will need to be compensated by a larger lift in the rudder foil
- The 2-foil mode allows the boat to take off at lower speeds, which is why it is normally used in TWS<10knt
- The drag of the second foil is compensated by the additional lift generated
- The windward foil has the effect of introducing an additional heeling moment. Therefore, the whole crew weight is moved to the racks even with light wind to compensate
- Generally, the windward foil would be set so as to generate less lift than the leeward one and both foils would be set at smaller angle of attacks as if we were sailing with just the leeward one in the water

Lift and angle of attack



- Lift results from the pressure differential that is created between the top and bottom surfaces of a foil moving through a fluid

$$\mathbf{\mathit{Lift} = 0.5 \times C_L \times \rho \times S \times V^2}$$

S = wetted surface area

V = speed

ρ = fluid density (salt water =1025kg/m3)

C_L = Lift coefficient (mainly dependant on section and angle of attack)

- Every time speed is doubled, the lift is increased exponentially (power of 2)
- Lift is proportional to the wetted area of the foil (double the wetted area will result in double the lift assuming the section is constant)
- The bigger the angle of attack, the larger the lift that is produced. If the AoA is increased too much the flow will become separated on the top surface of the foil, the foil will stall and lift will drop to zero
- On the 69F the rudder foil contributes to approx. 20% of the total lift

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Flight Control

In general, we can use the notions of lift and angle of attack to make boats fly and control the flight height in the following ways depending on the foil type:

- **Non self-levelling** (e.g. T-shaped, L-shaped) can be controlled with:
  - Rake system: active system which changes AoA by “rotating” the whole appendage about a fixed point on the hull
  - Flap: angle of trailing edge area can be changed relative to the angle of the rest of the foil
- **Self levelling foils** (e.g. V-Shaped) work by increasing/decreasing wetted surface area. This can be done:
  - Actively: changing angle of attack of foils
  - Passively: for instance when sailing through a wave

In the case of the 69F, which has V-shaped, self-levelling foils, the flight height will directly determine the amount of foil area that is submerged and therefore the amount of lift produced.

Self levelling foils are generally safer because the lift drop is gradual as the flight height increases making it harder to pitchpole for example.

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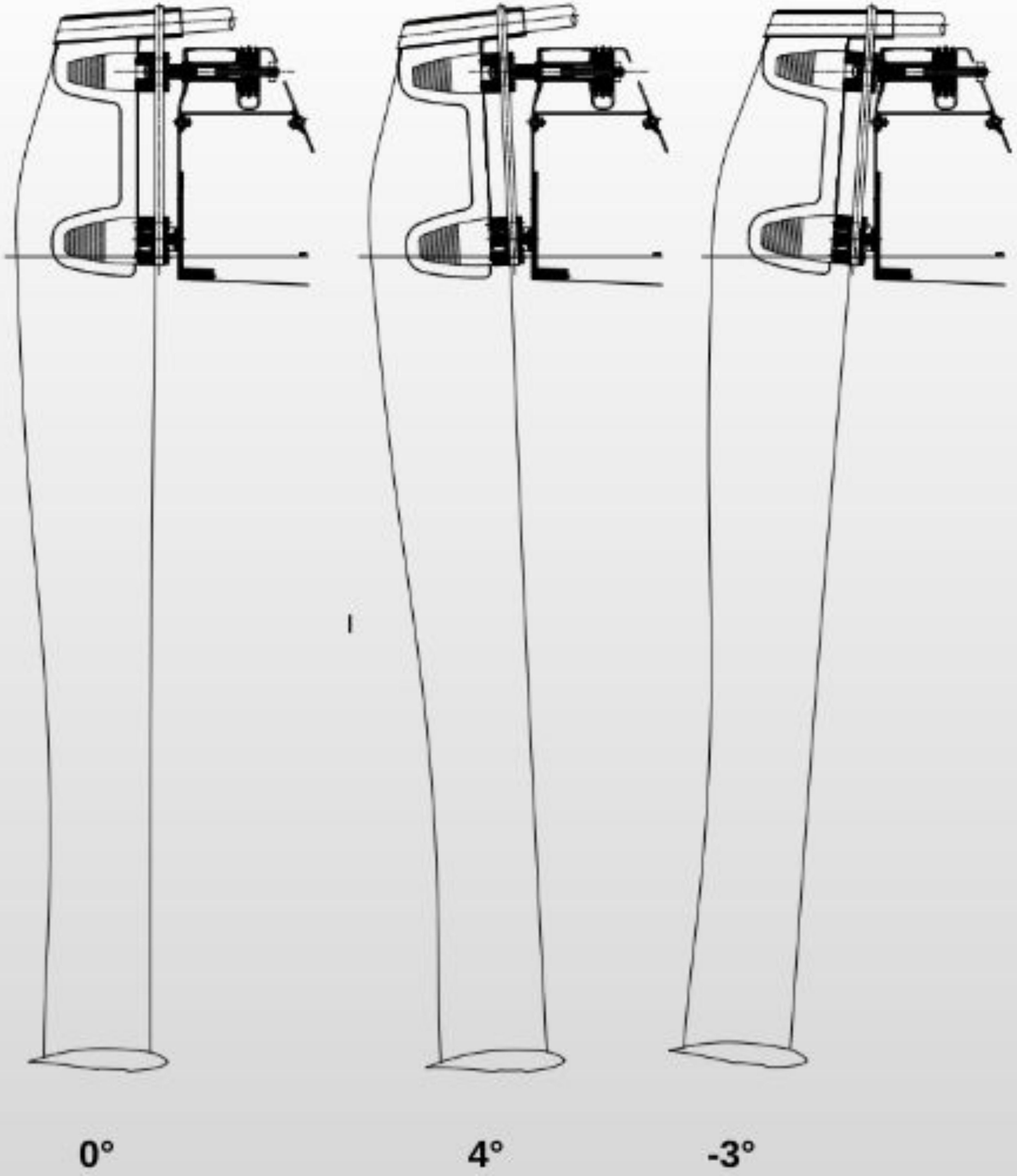
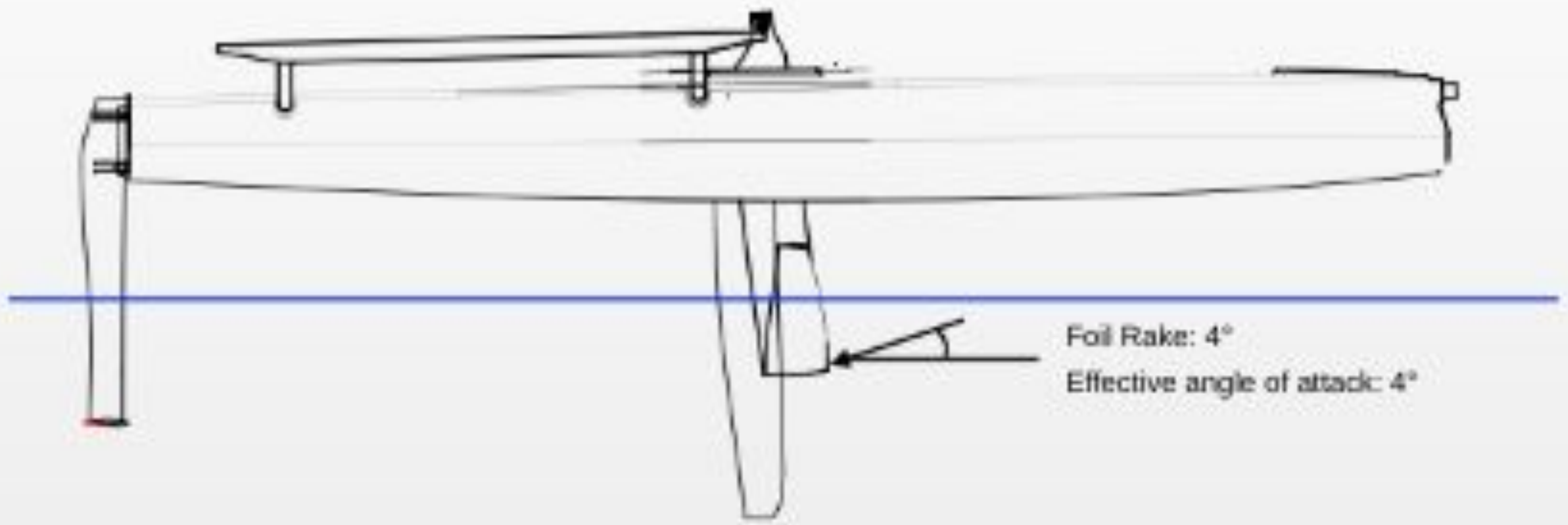
Flight Control



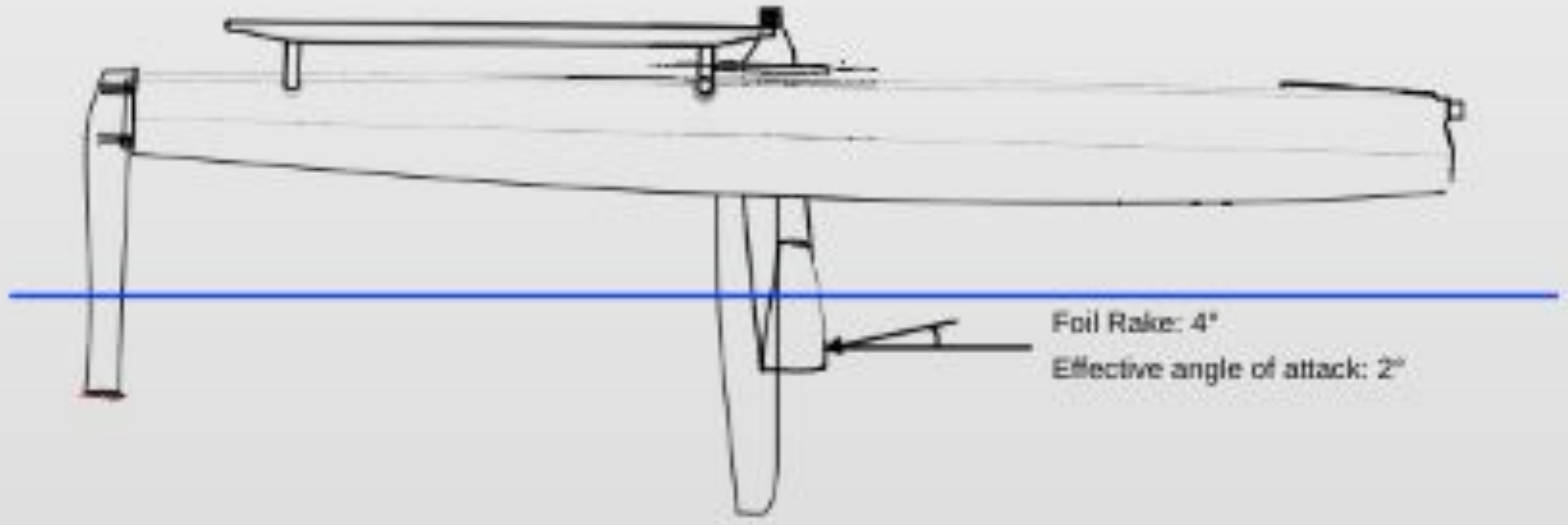
The 69F has a 7° range on the rudder (from -3° to +4°)

Change in AoA is achieved by moving the rudder head fwd and aft while the whole rudder pivots about the bottom bearing.

Flight Control



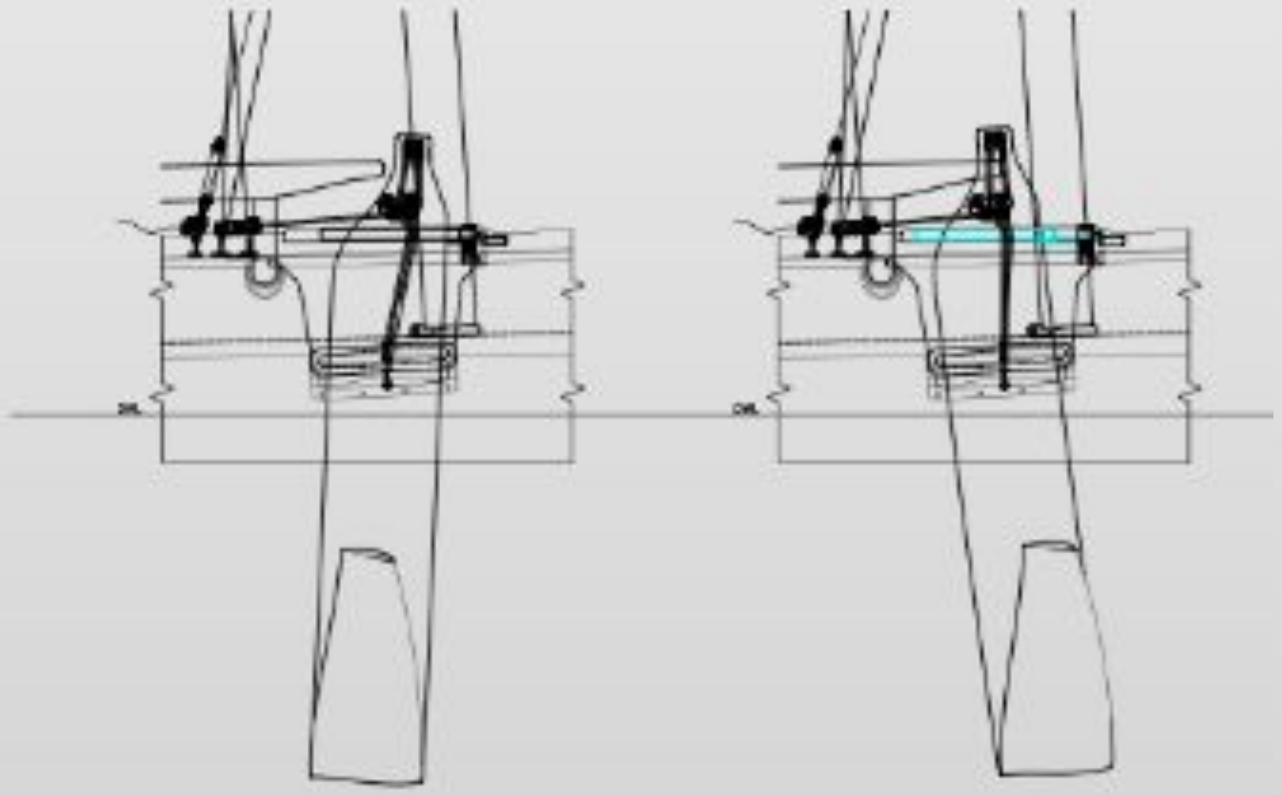
0° trim



2° trim by the bow

The 69F main foils have a 12° range (from -4° to +8°)

Such angles are relative to the trim of the boat. For instance, trim by the bow of 2° will reduce the actual angle of attack of the flow on the foils by 2°.



Rake angle is changed by sliding the top bearing fwd and aft making the whole foil pivot about the bottom bearing which is fixed.

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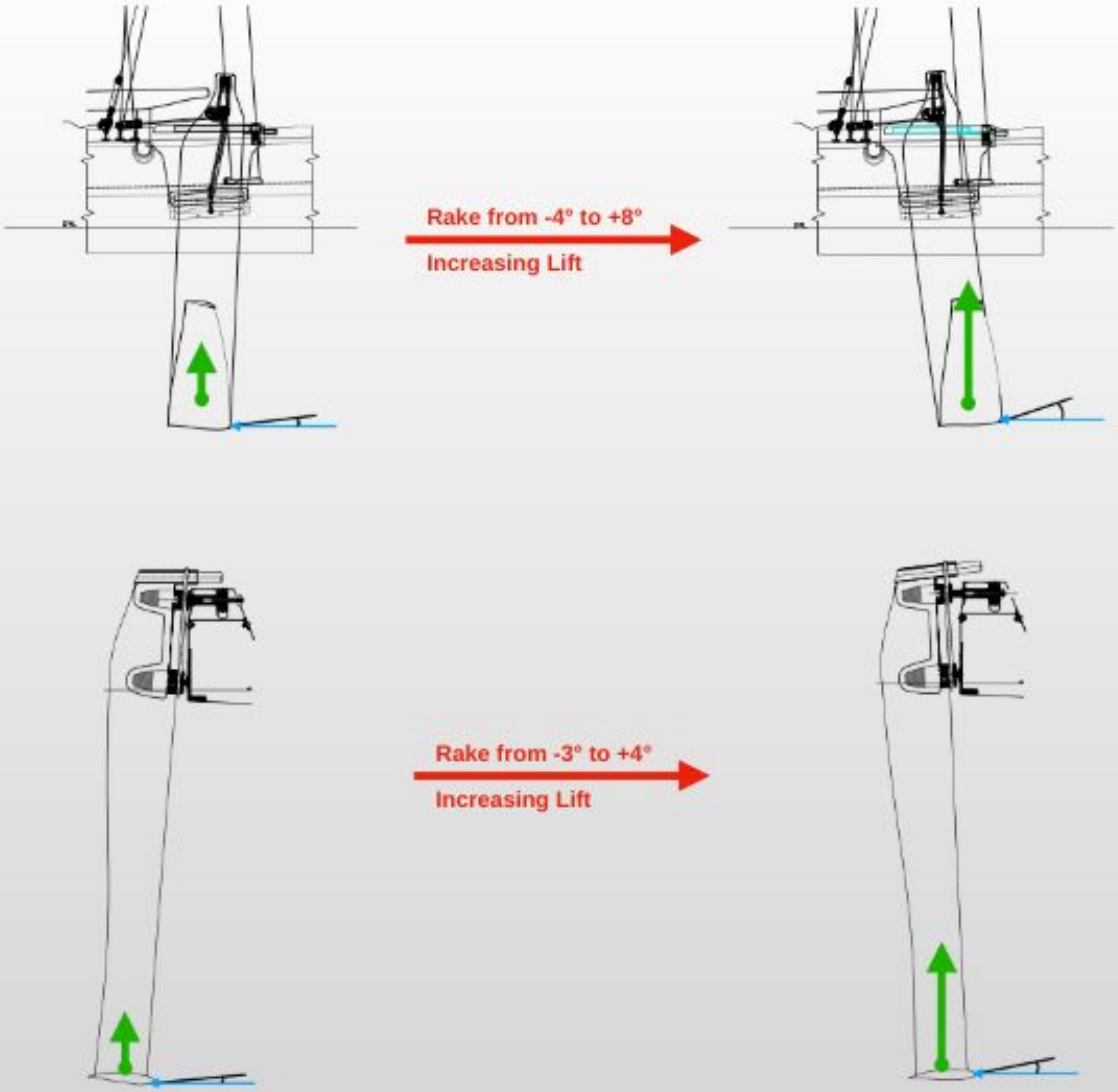
Flight Control



The 69F main foils have a 12° range (from -4° to +8°)

Ventilation vs. Cavitation

- **Ventilation**: occurs when part of the foil pierces the surface and air is sucked down the lifting surface because of the pressure differential between the atmosphere and the flow accelerated over the foil. This happens on foils but can also occur on rudders struts.
- **Cavitation**: occurs when the flow velocity is such that the local pressure of the fluid drops below the vapour pressure value and vapour-filled cavities start to form. Cavitation can occur when the velocity of the fluid is extremely high and/or the foil section is generating lots of of lift.

The term cavitation is often misused to describe ventilation. Just to give a reference, cavitation occurs on propeller blades or on foils generally when boats start sailing at speeds >40 knots so it is not something that is really experienced on normal boats.

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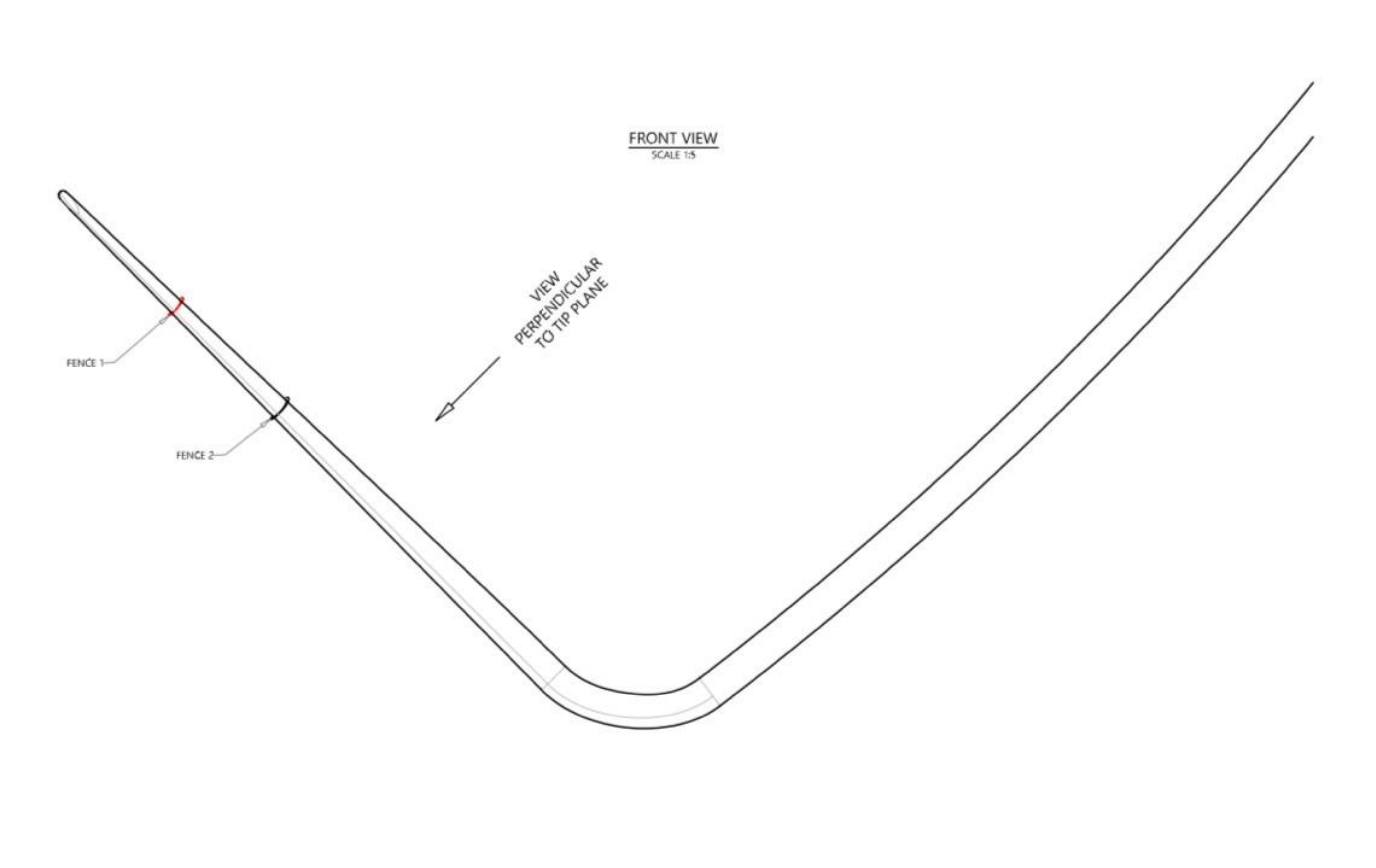
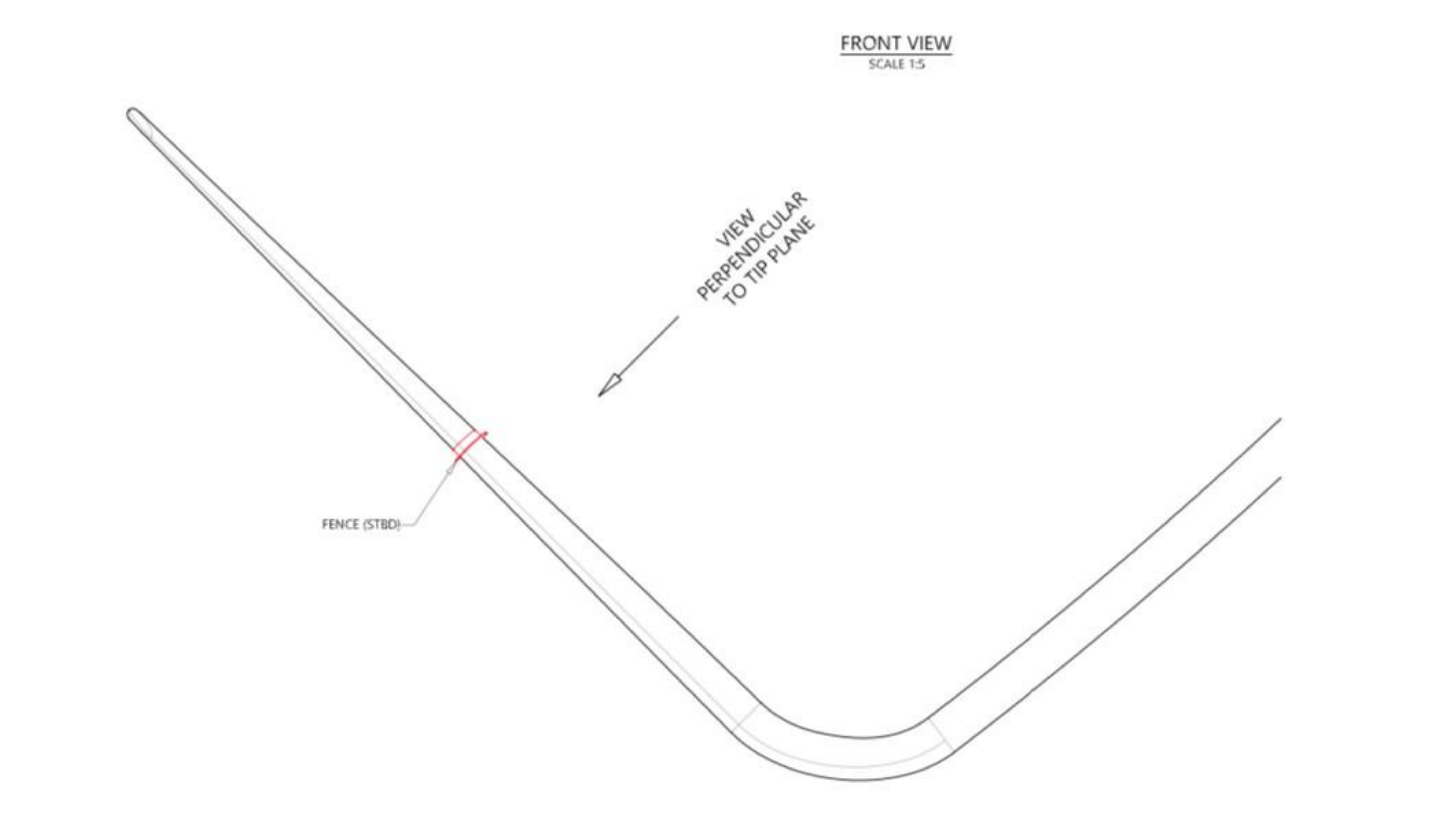


Fence and ventilation

Ventilation example from the early days of 69F

(Fence 420mm from tip)

Fence and ventilation



Ventilation example from the early days of 69F

(Fence 530mm from tip)