# BRONZE LECTURES

## PRINCIPLES OF FLIGHT

## PART TWO

Stability

Flight Envelopes

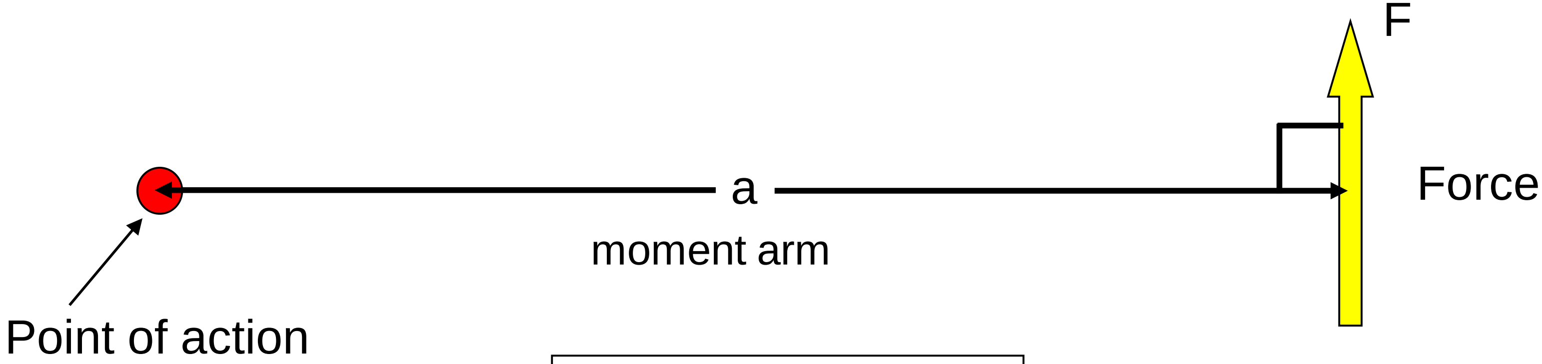
Polar Curves

Exam ?s

Slides available as advertised

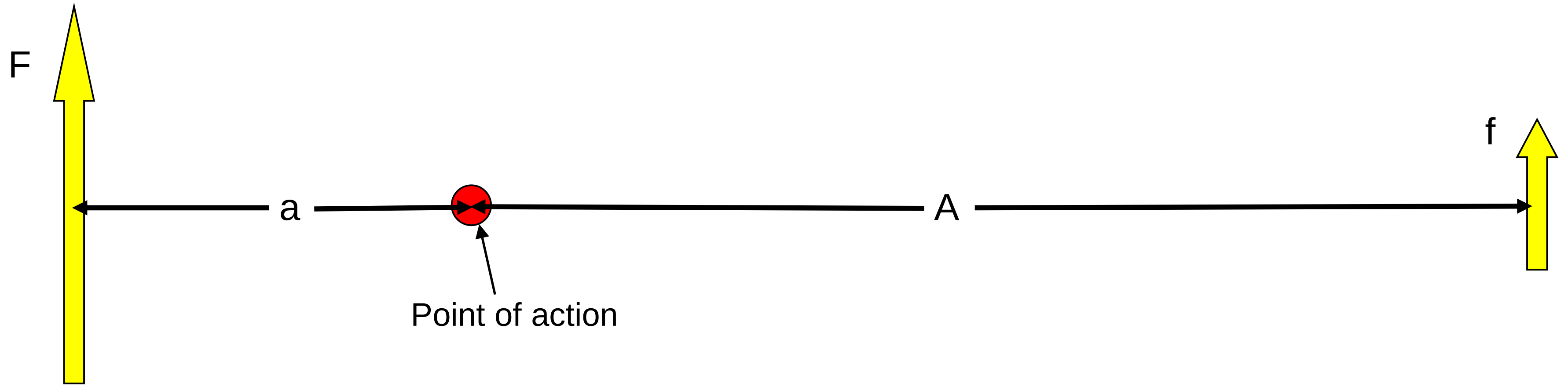
and on bayriver.co.uk (click on ‘gliding’)

# MOMENTS




MOMENT = a x F

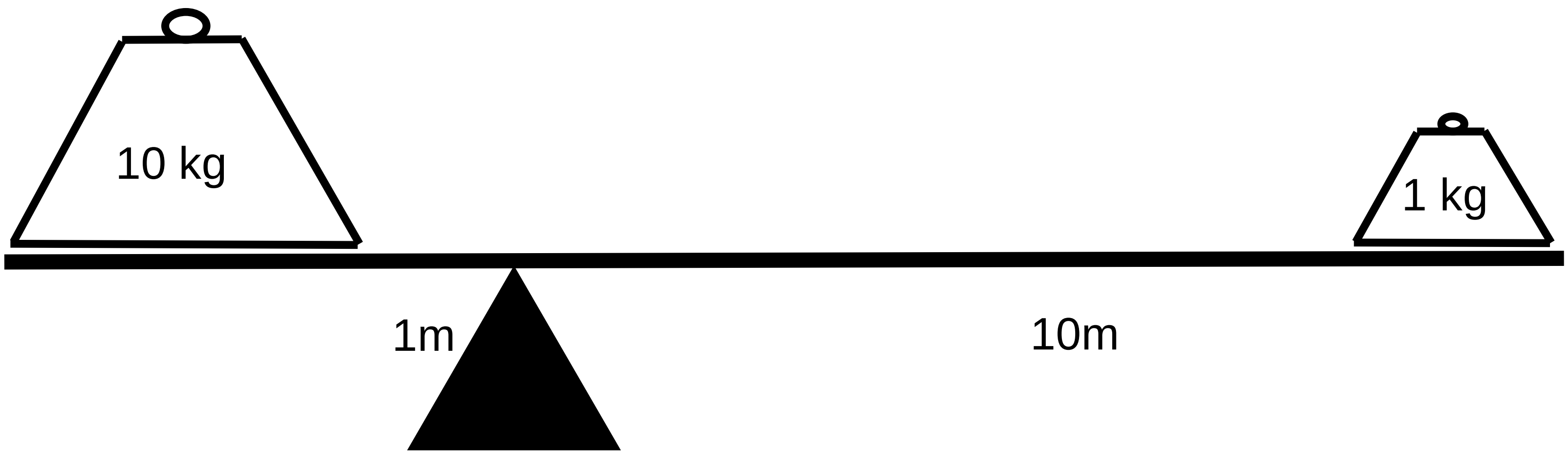
The MOMENT of a force about a point is the magnitude of the force multiplied by the distance from the point perpendicular to the line of action of the force.



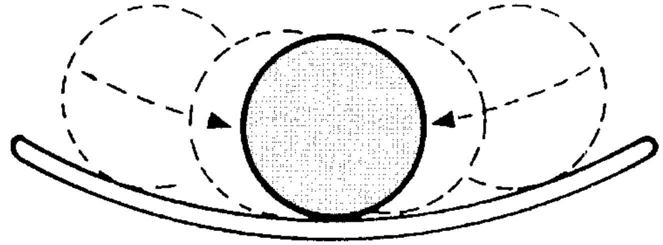

If F x a = f x A then the forces 'balance'

(If the sum of the moments is zero the object is in equilibrium)

# EXAMPLE



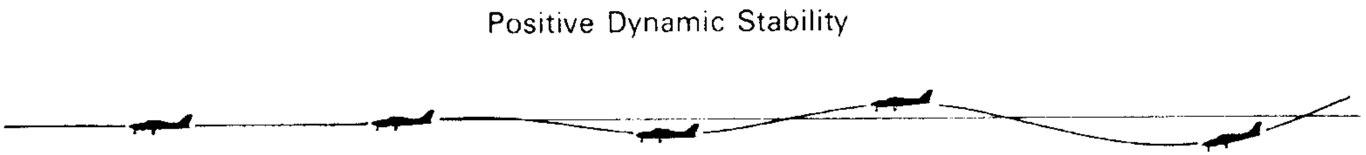

In balance



*Stability. A ball inside a bowl would return to its original position if disturbed.*

# STATIC & DYNAMIC STABILITY

- Previous diagrams relate to Static Stability
- The following diagrams relate to Dynamic Stability



# STATIC & DYNAMIC STABILITY

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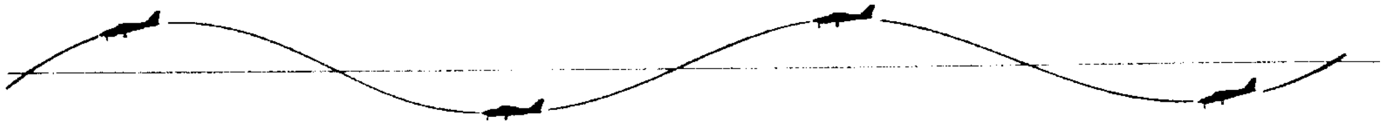
Neutral Dynamic Stability



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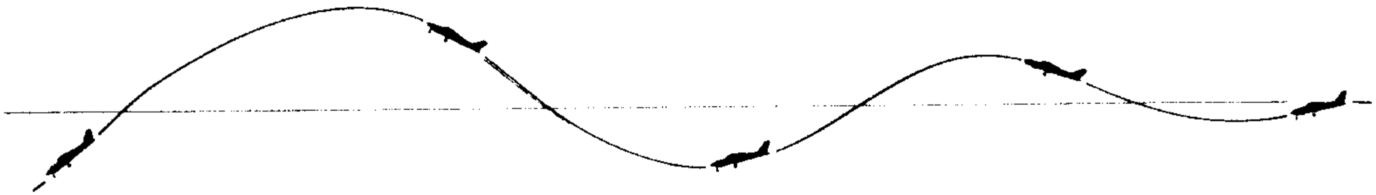
Dynamic Instability



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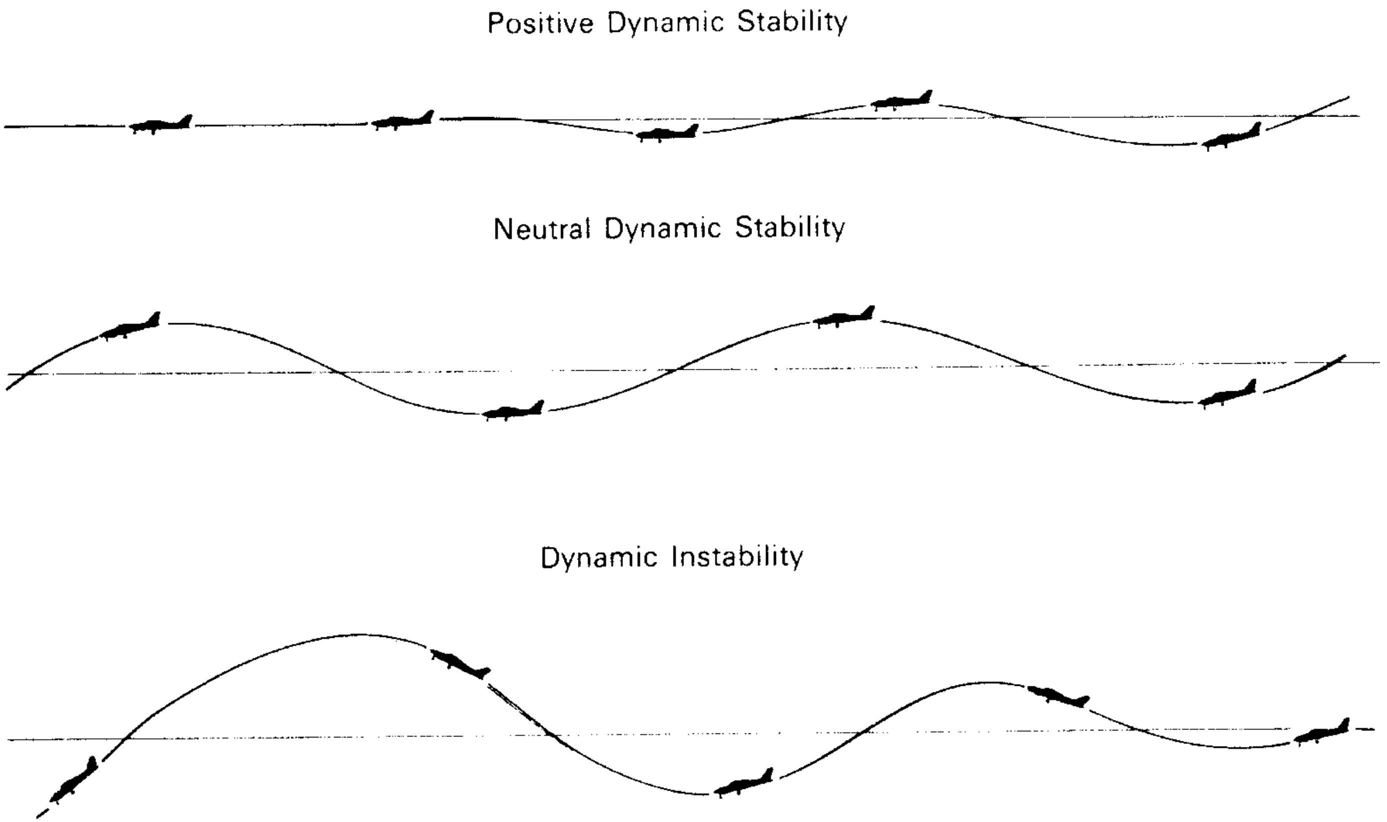
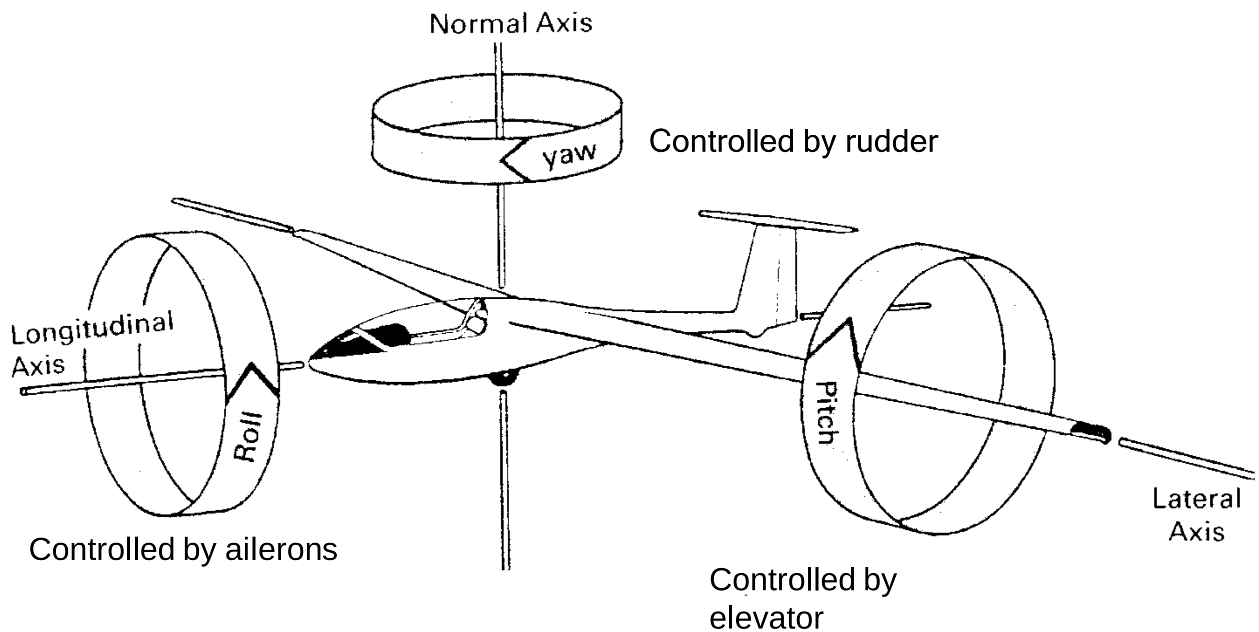



Normal Axis
yaw
Controlled by rudder
Longitudinal Axis
Roll
Pitch
Lateral Axis
Controlled by ailerons
Controlled by elevator

# STABILITY

| Axis of Rotation | Movement | Control | Stability |
|---|---|---|---|
| Longitudinal | roll | ailerons | lateral |
| Lateral | pitch | elevator | longitudinal |
| Normal | yaw | rudder | directional |

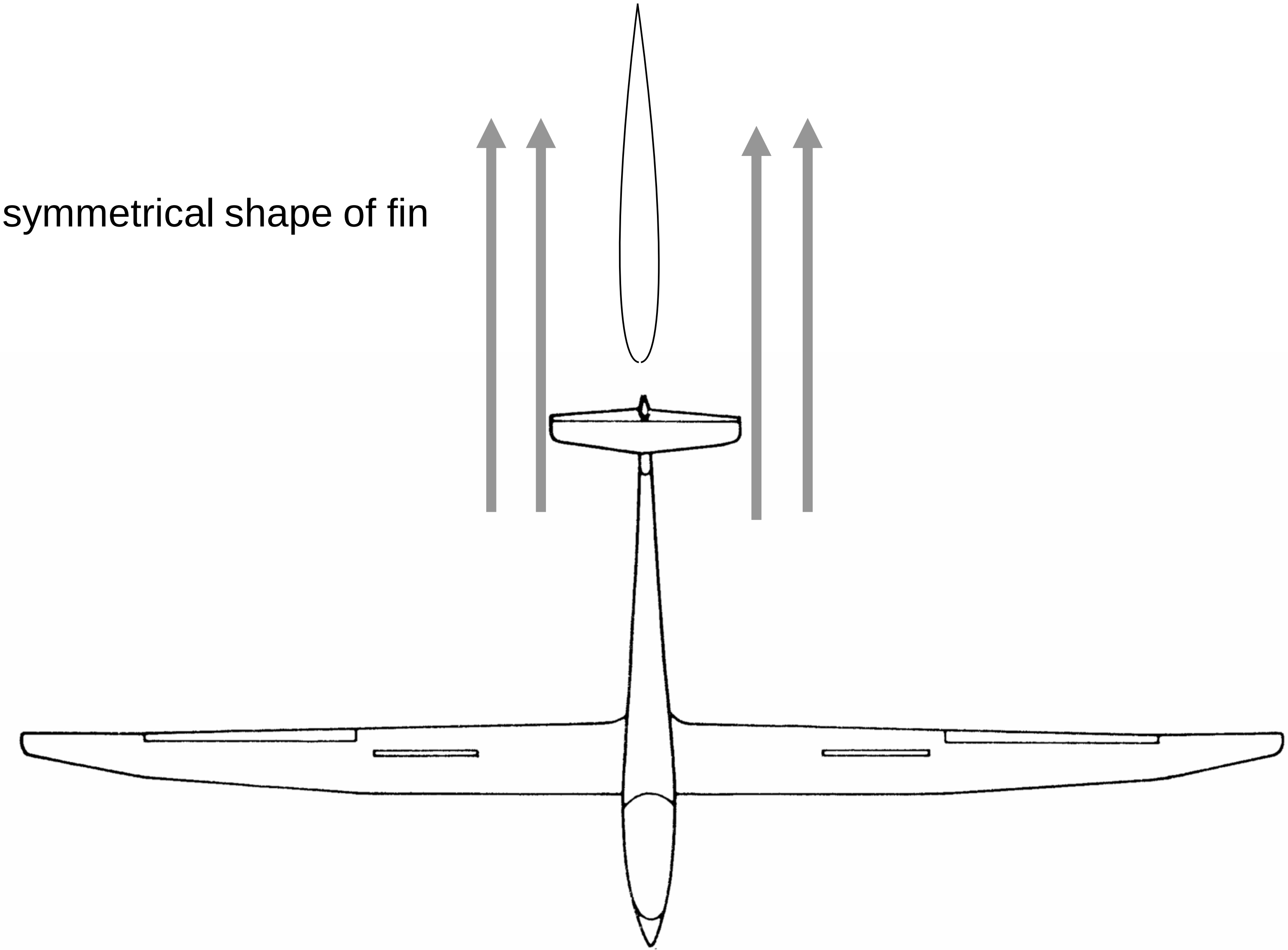
Beware confusing terminology

easiest to talk about

- roll stability
- pitch stability
- yaw stability (or directional stability)
- but BGA use lateral/longitudinal in exam

# DIRECTIONAL STABILITY (YAW)

Note symmetrical shape of fin



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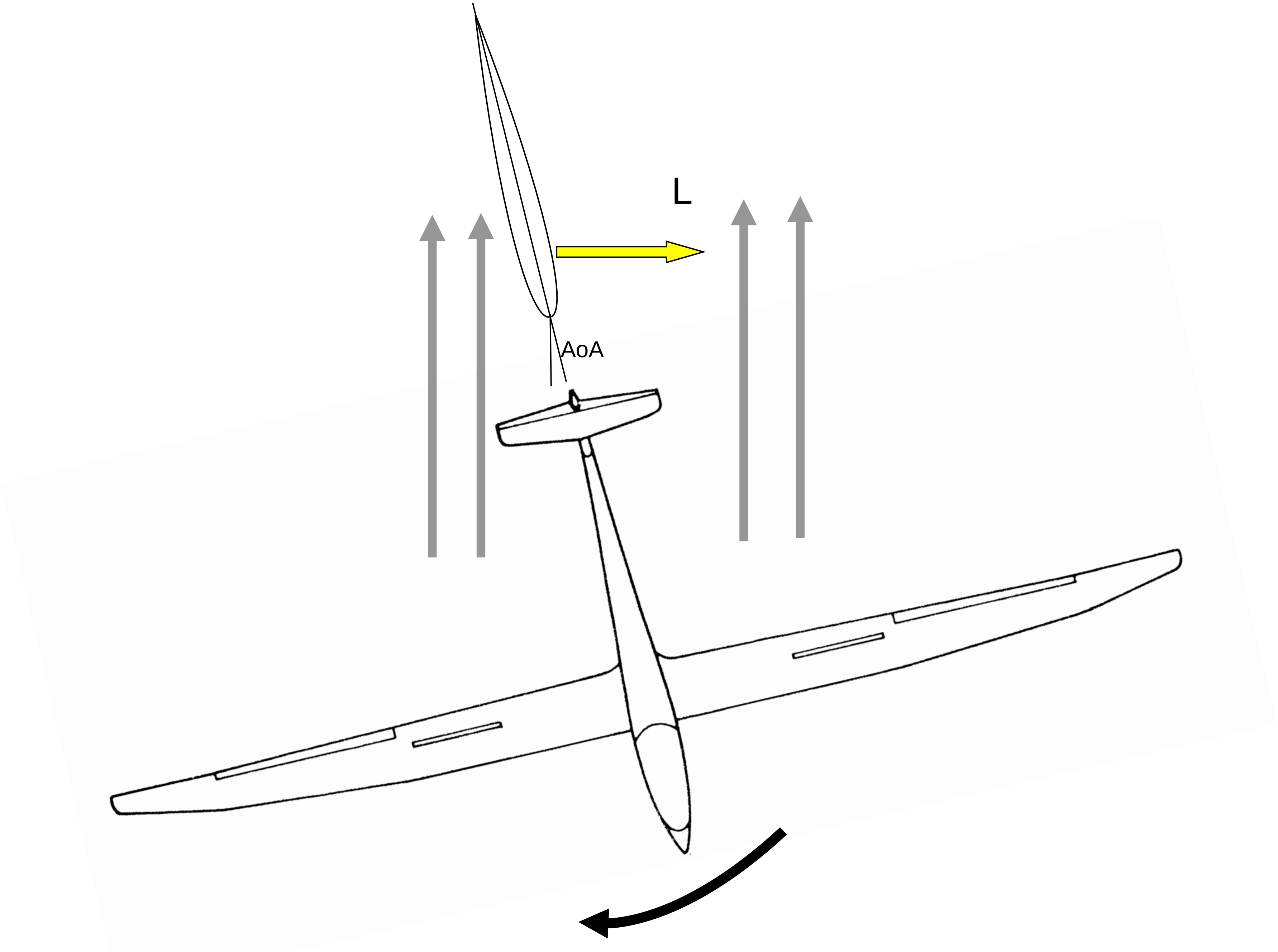

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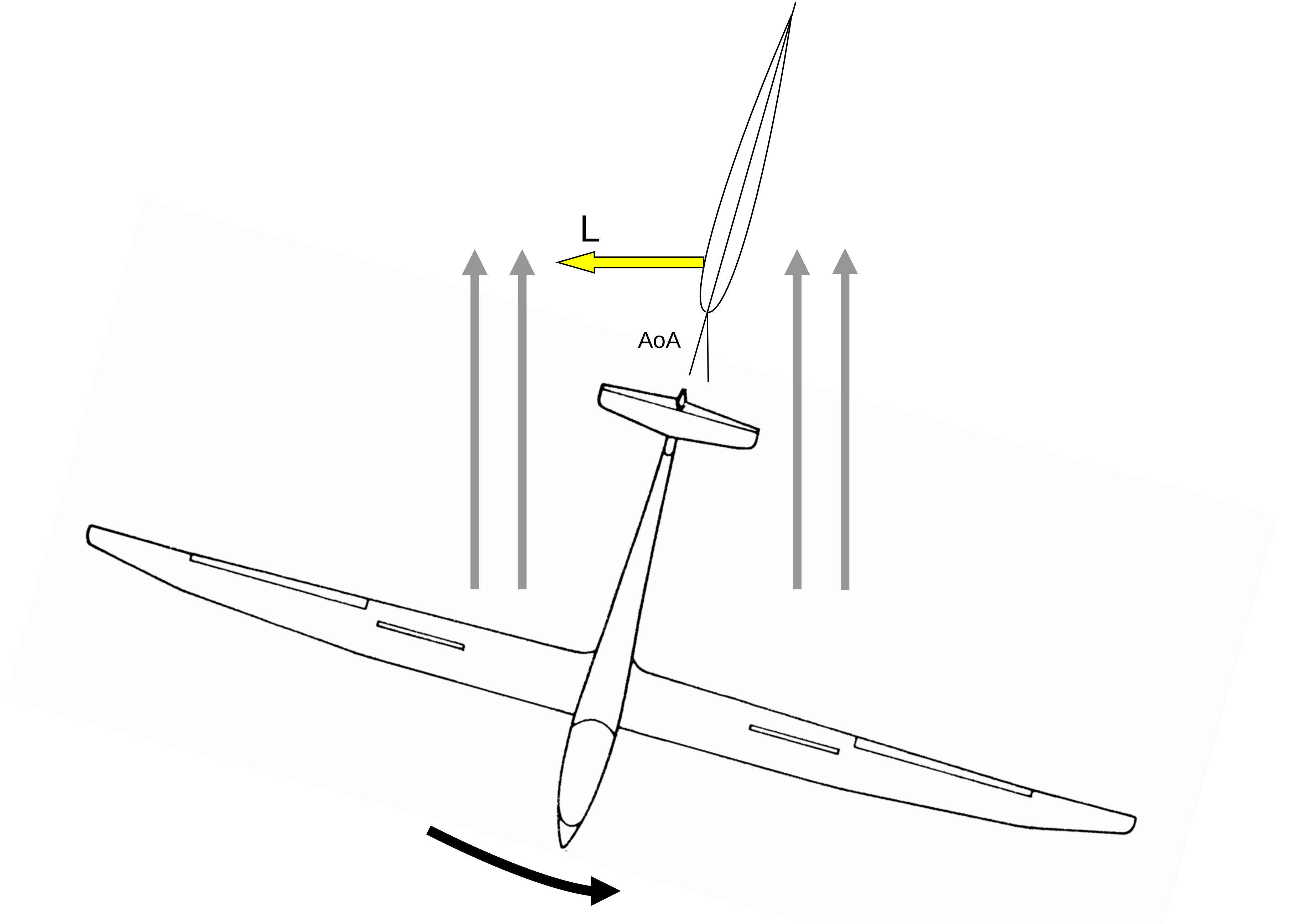
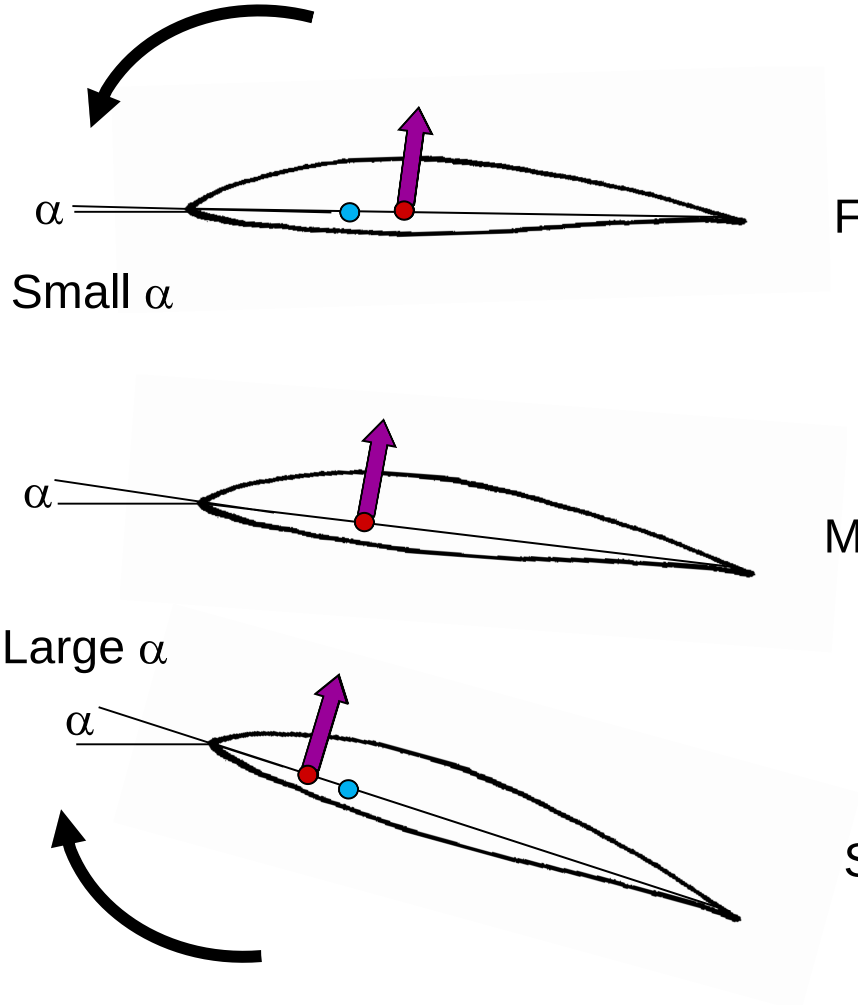


# PITCH STABILITY

(Note some of this depends on position of C of G)

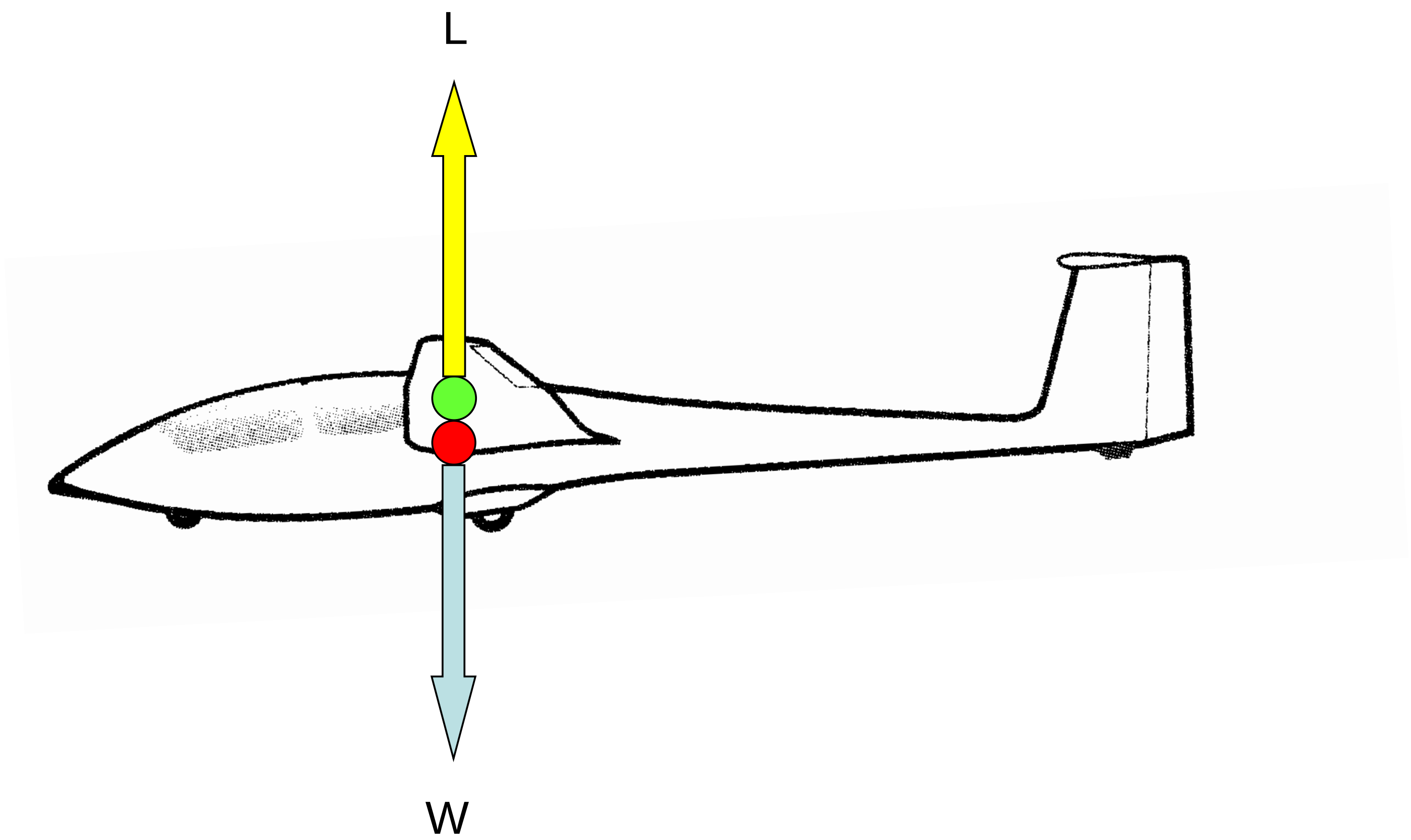
# REVISION OF MOVEMENT OF C of P




Fast CofP moves back Pitch down

Medium speed

Slow CofP moves forward Pitch up



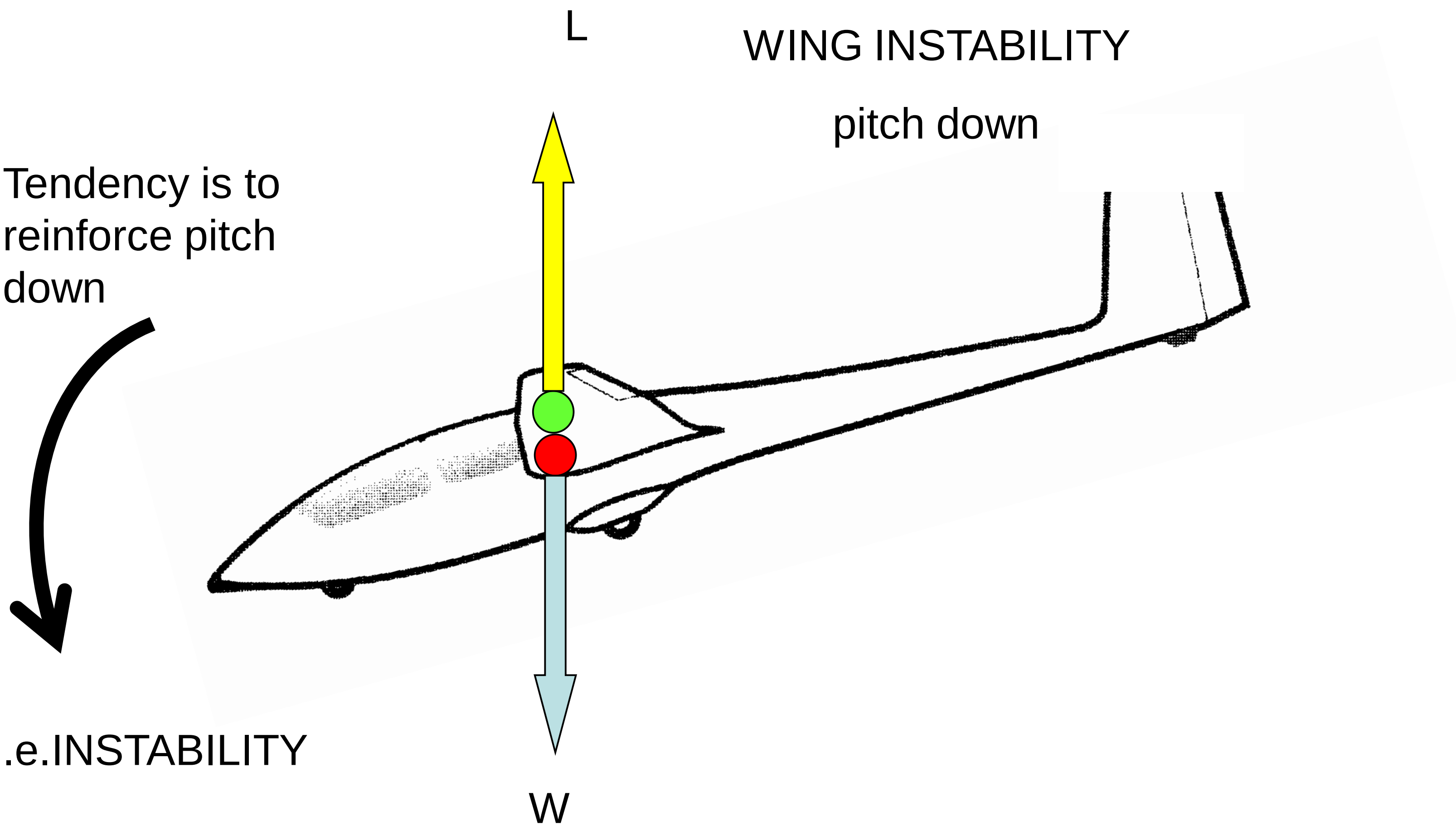

Centre of Gravity

Centre of Pressure

# WING INSTABILITY

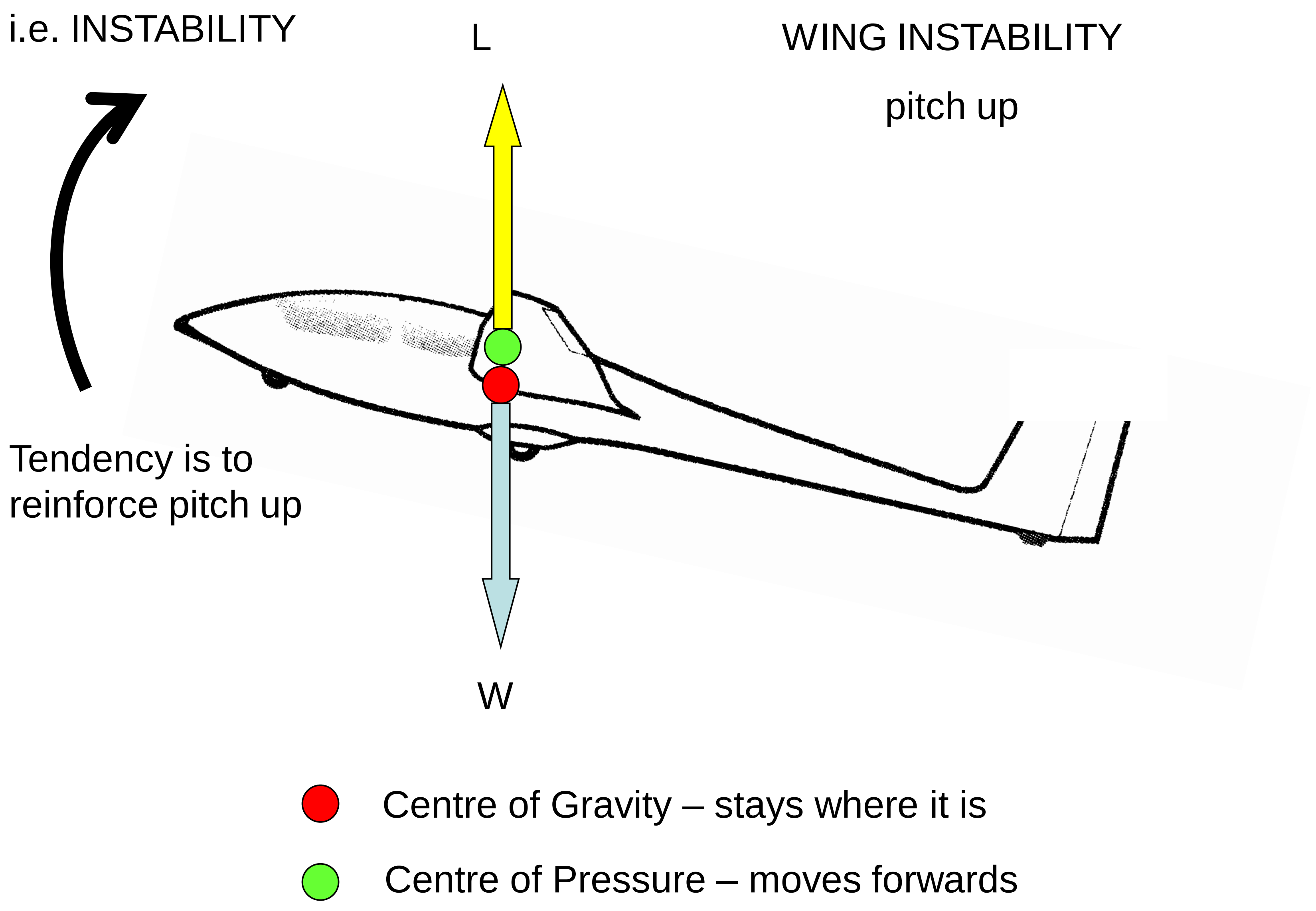
pitch down

Tendency is to reinforce pitch down

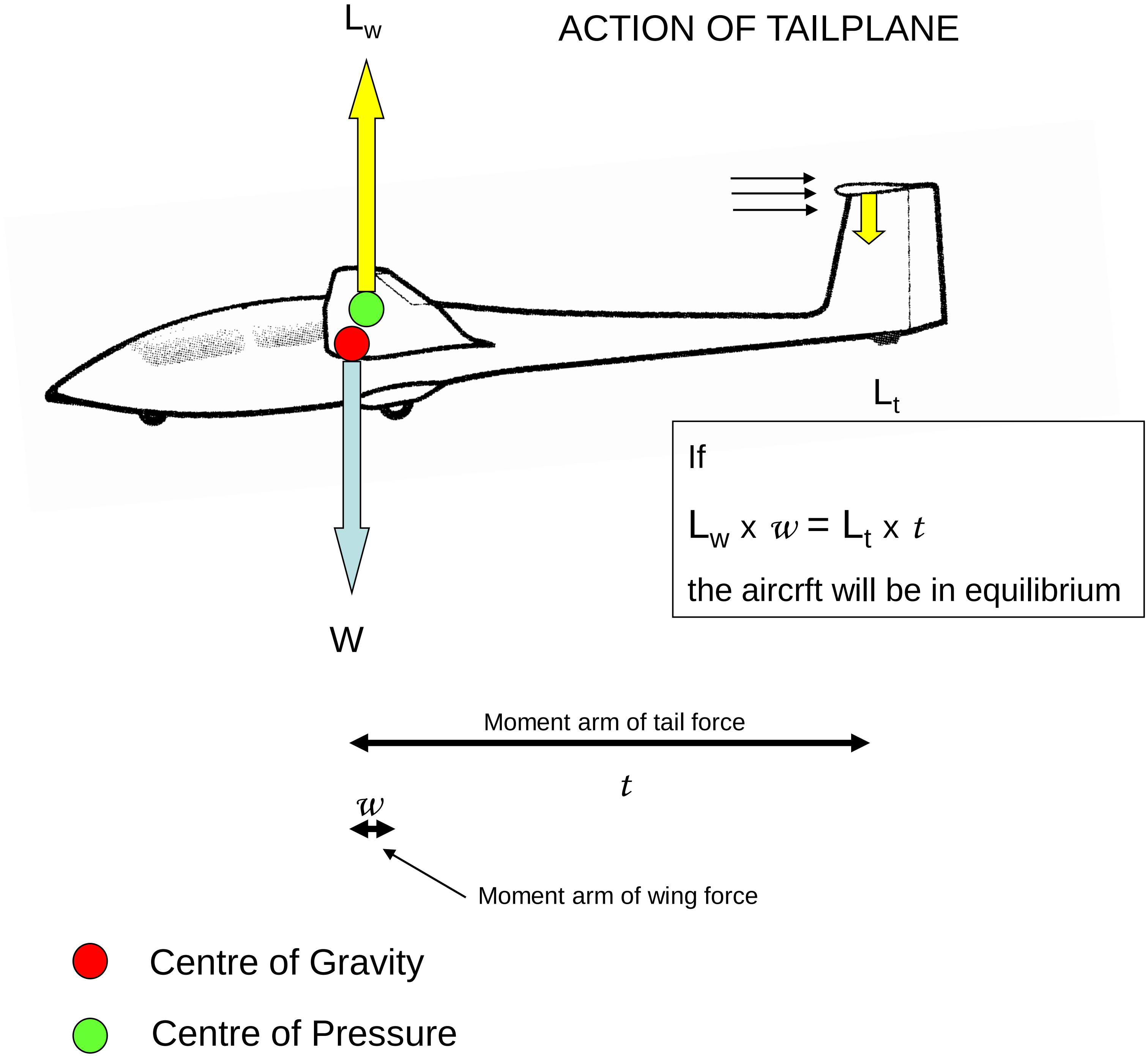



i.e.INSTABILITY

- Centre of Gravity – stays where it is !
- Centre of Pressure – moves backwards


i.e. INSTABILITY
L
WING INSTABILITY
pitch up
Tendency is to
reinforce pitch up
W
Centre of Gravity – stays where it is
Centre of Pressure – moves forwards

# ACTION OF TAILPLANE

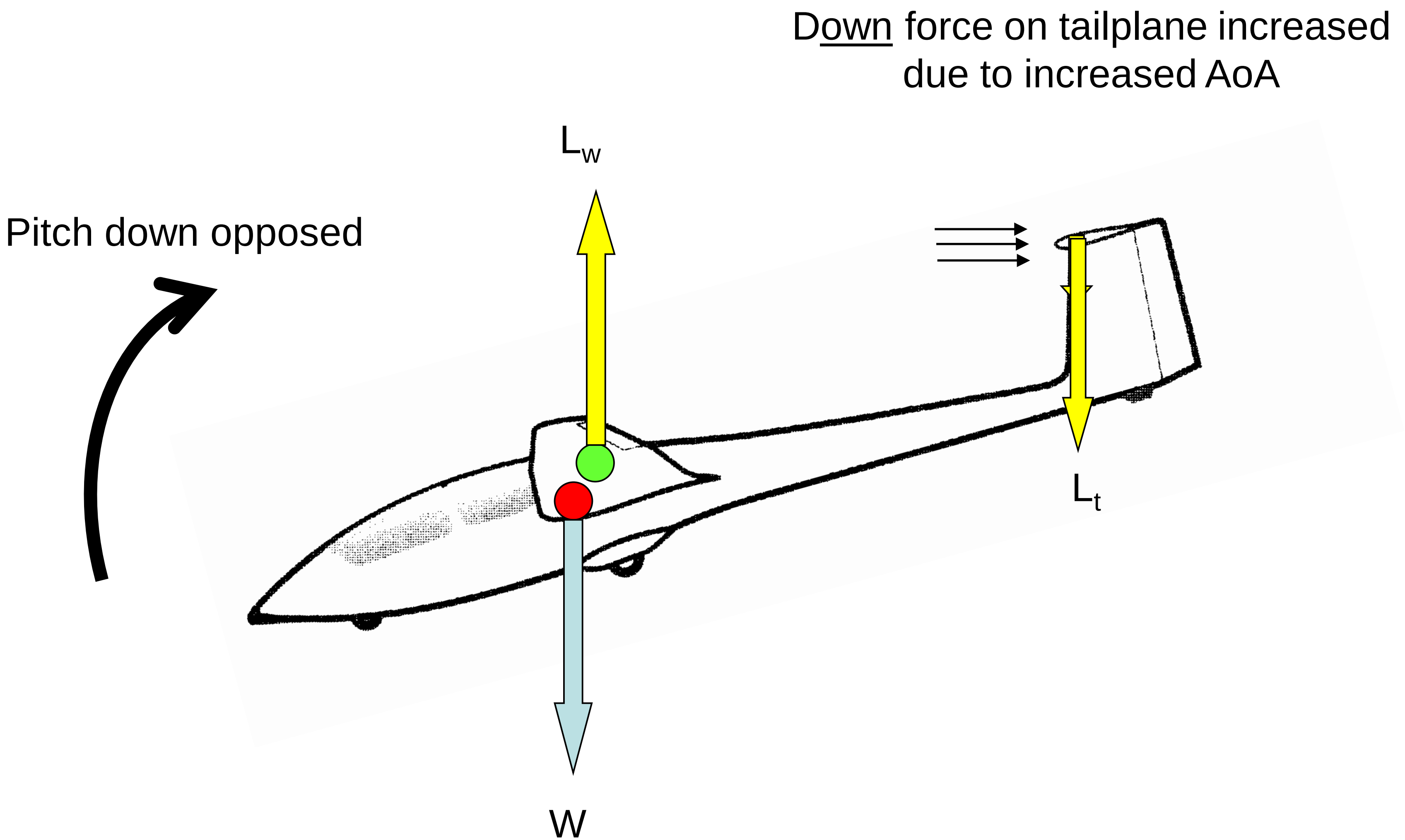



If

$L_w \times w = L_t \times t$

the aircrft will be in equilibrium

PITCH DOWN



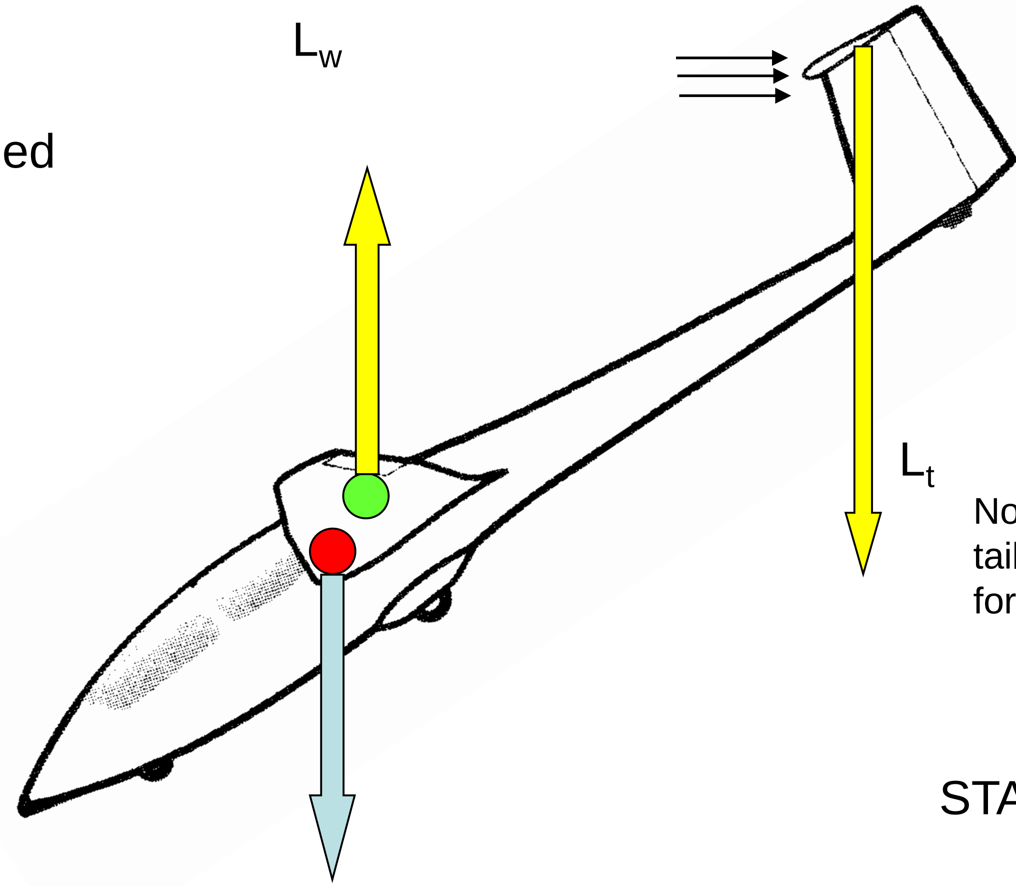

Centre of Gravity

Centre of Pressure

PITCH DOWN

Down force on tailplane increased due to increased AoA

Pitch down opposed



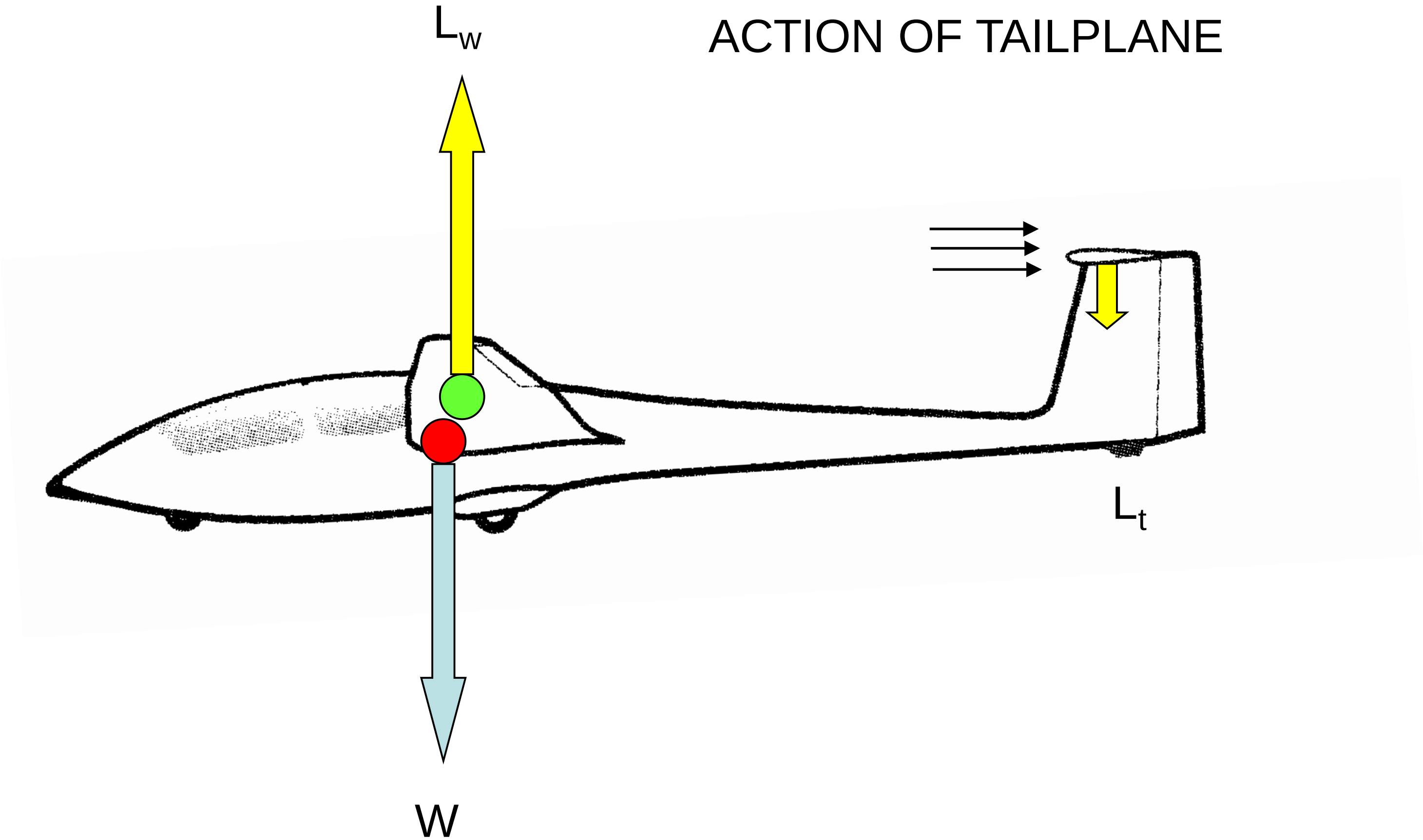

Note: The bigger the $\alpha$ of the tail the bigger the restoring force

STABILITY

Centre of Gravity

Centre of Pressure

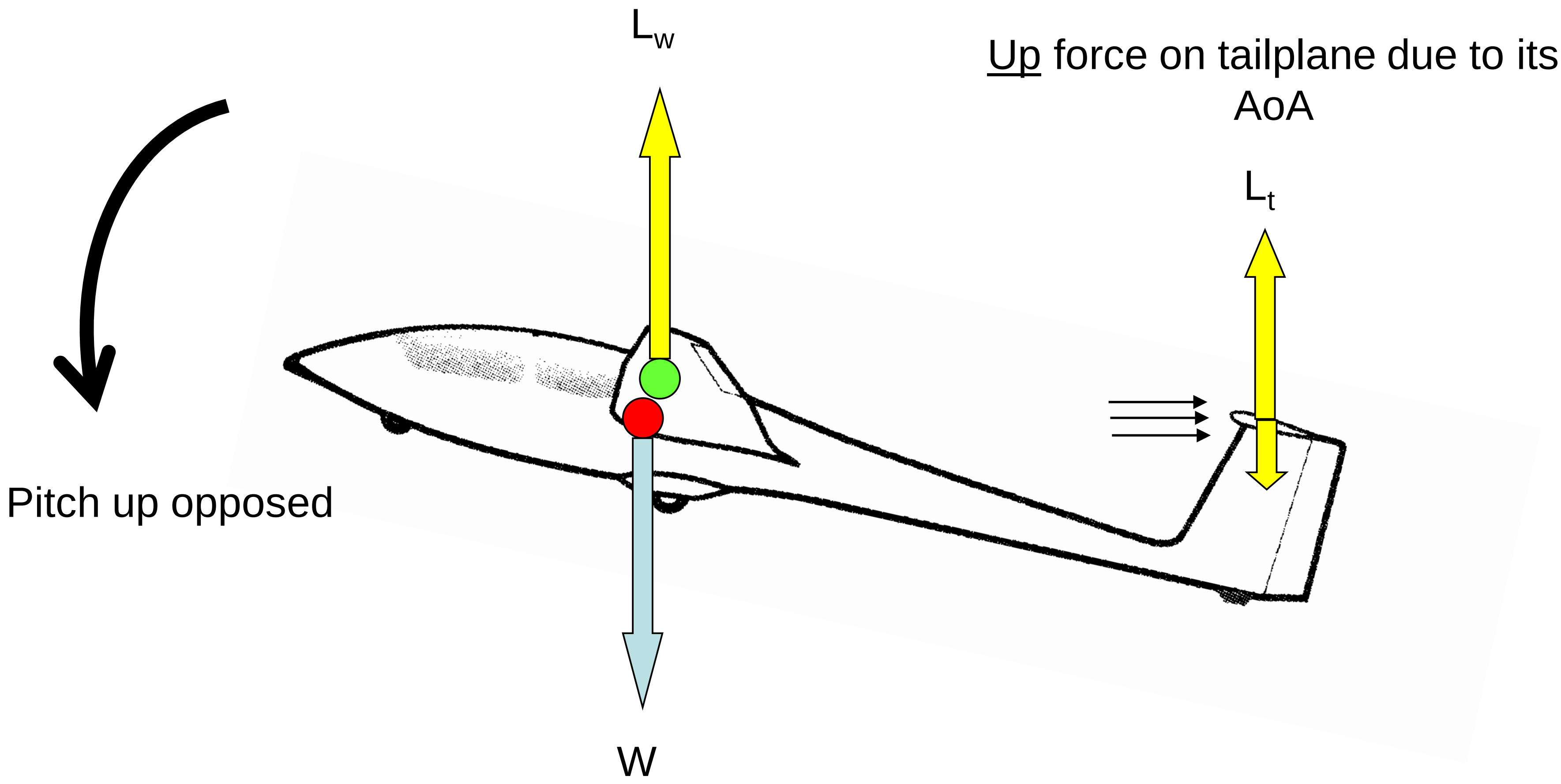
# ACTION OF TAILPLANE




Centre of Gravity

Centre of Pressure

# PITCH UP

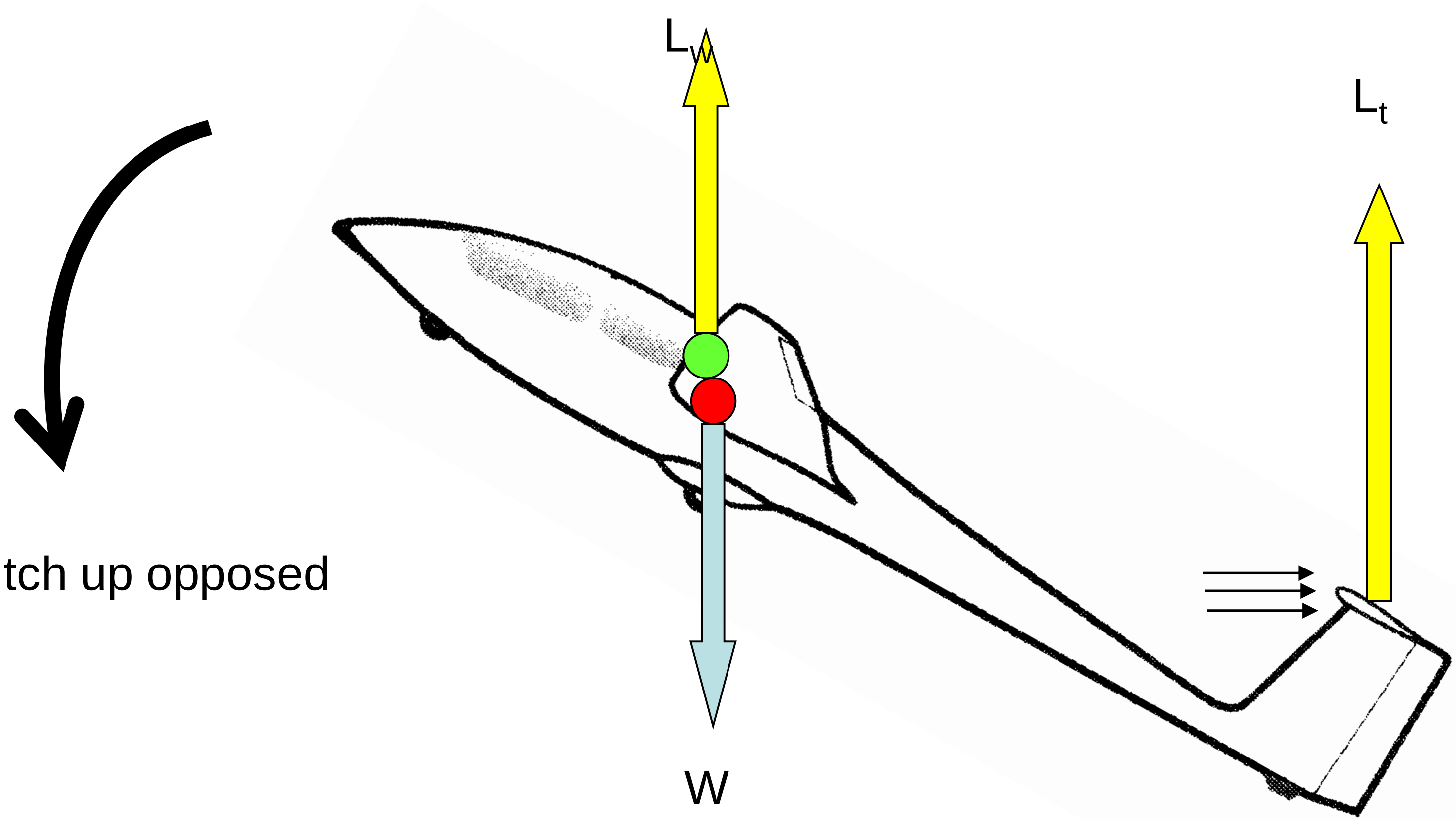



Centre of Gravity

Centre of Pressure

PITCH UP

Up force on tailplane due to its AoA




The bigger the α of the tail the bigger the restoring force

Pitch up opposed

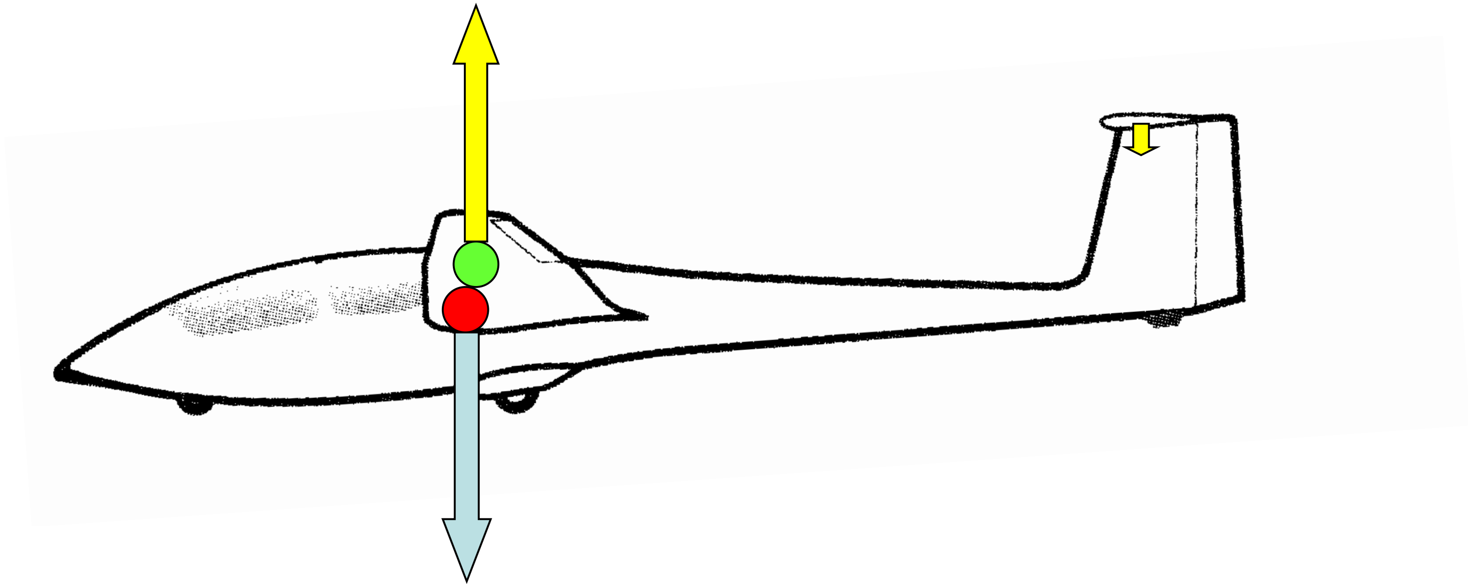
STABILITY

Centre of Gravity (red dot)

Centre of Pressure (green dot)

# ACTION OF TAILPLANE

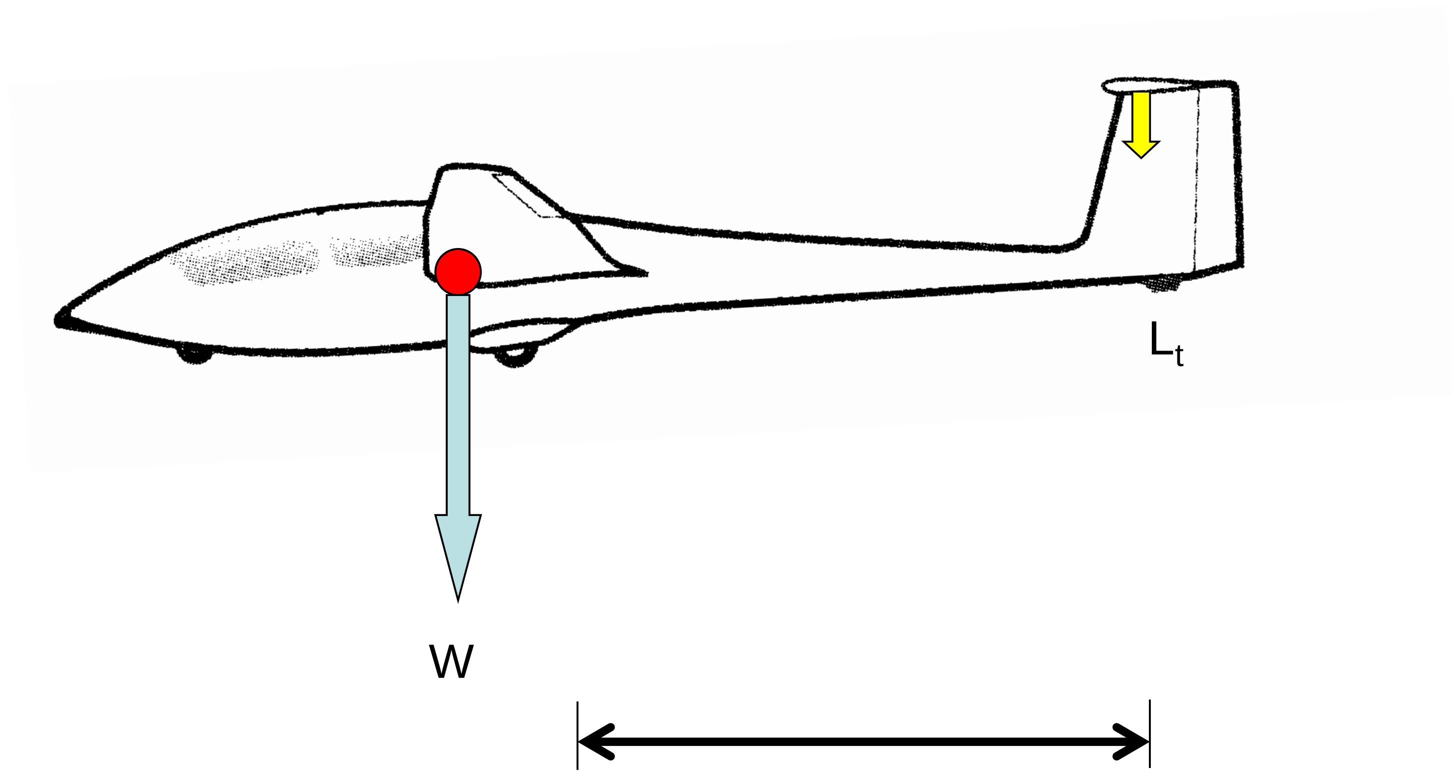
Aircraft are normally designed so that there is a slight down force on the tail during normal flight.  i.e. the tail has a slight negative AoA.



This is so that during a pitch-up the tailplane will continue to have a lower AoA than the main wing which will stall before the tail so still allowing use of the elevator to lower the nose for recovery.

POSITION OF C of G
(too far back)

**Wrong !!!**



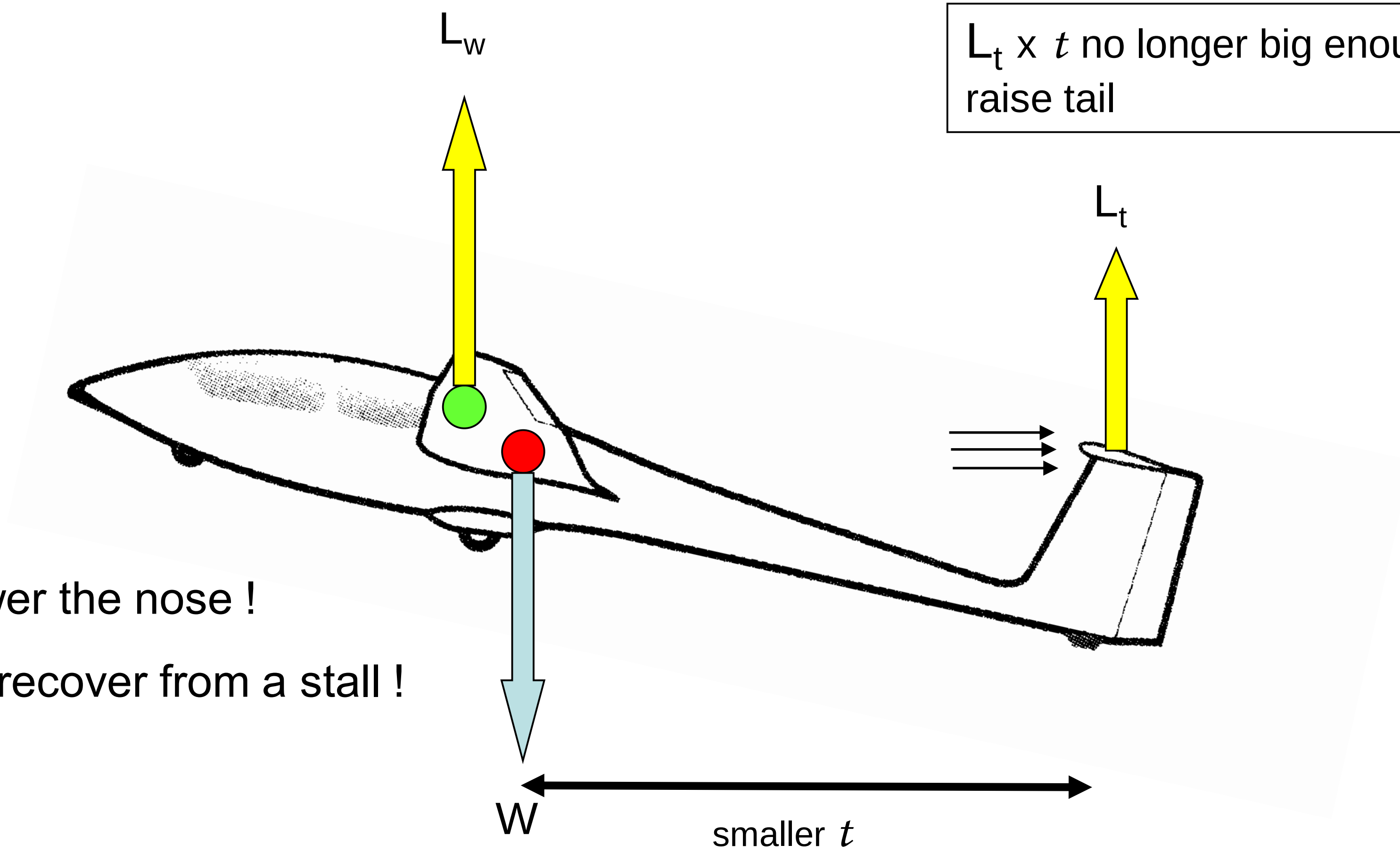

Since this distance has been decreased, the tail has less restoring moment

Centre of Gravity

Centre of Pressure

# PITCH UP

$L_t$ x $t$ no longer big enough to raise tail




Can’t lower the nose !

So can’t recover from a stall !

NOT GOOD !

Centre of Gravity

Centre of Pressure

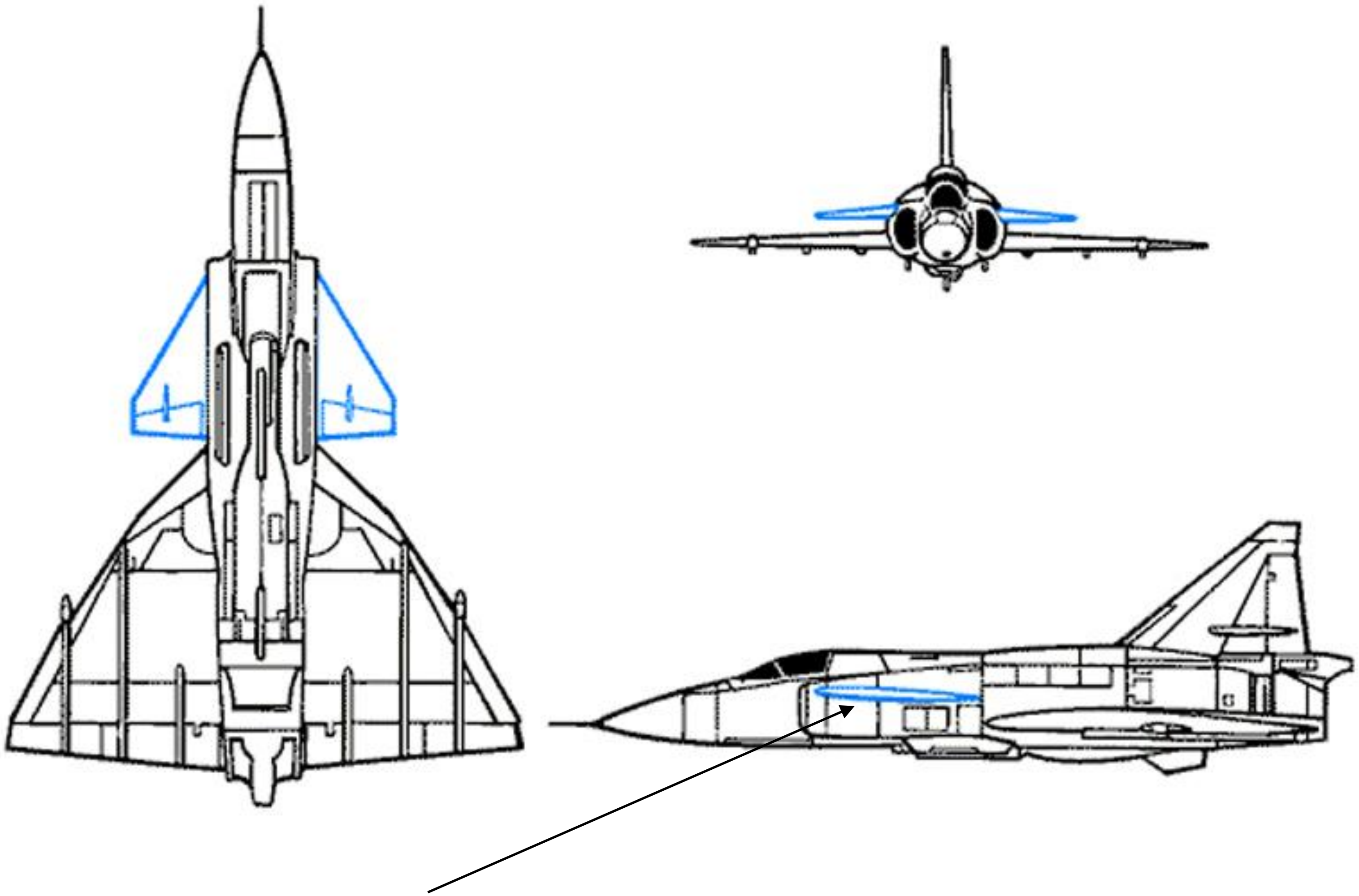
# PITCH STABILITY

- Mainplane is inherently unstable
  - As glider pitches up, C of P moves forward and the upsetting moment is increased
  - As glider pitches down, C of P moves backwards and the upsetting moment is also increased

- Therefore use tailplane
  - But note canards (elevators at the front -Wright Bros, Saab Viggen, Eurofighter, LongEZ), which essentially give longitudinal **instability** (but are ‘stall proof’)

- With a tail plane more deviation in pitch means more restoring moment
  - = **STABLE** (until tail stalls)
  - **Pitch stability is not an absolute**
  - The degree of stability depends on the moment/position of the CofG

Saab Viggen



Canard reaches stall angle before main wing. Therefore stalls before main wing – nose goes down – stops main wing stalling.

# STICK FIXED AND STICK FREE STABILITY

- Is what it says
  - a) Hold the stick stationary and see what kind of stability you have (=stick fixed stability)
  - b) Let go of the stick and see what kind of stability you have (=stick free stability)
    - The elevator tends to ‘follow’ the airflow effectively reducing the AoA and therefore the amount of lift and pitch restoring moment
    - So even if the glider is stable stick fixed it might be unstable stick free
- It so happens that
  - a) is related to the amount of stick *movement* needed
    - The more stable stick fixed, the greater the movement needed for control
  - and b) is related to the amount of stick *force* needed
    - The more stable stick free, the greater the forces needed for control
- Read a book if you want to know any more !!!

# IMPORTANCE OF C of G POSITION

- If it is too far back the tail may not be able to provide sufficient moment to lower the nose and the glider may be uncontrollable.  You may not be able to recover from a stall or spin.
  - Always ensure the pilot weight comfortably exceeds the minimum placarded weight.  IF NOT -  USE WEIGHTS
  - (OR DIE)
  - In 2-seaters watch the underweight pilot in the front seat (children)
- If it is too far forward you may not be able to pull out from a dive or round-out on landing
  - BEWARE overweight pilots
  - In 2-seaters watch the heavy pilot in the front seat
- Always check for installed ballast and tail ballast before getting in to fly

# IMPORTANCE OF C of G POSITION

Design-wise the C of G needs to be close to the C of P

- So that the (moment of the) tailplane lift does not need to be large (and tail drag can be kept low)
- Also so that a range of pilot weights can more easily be accommodated

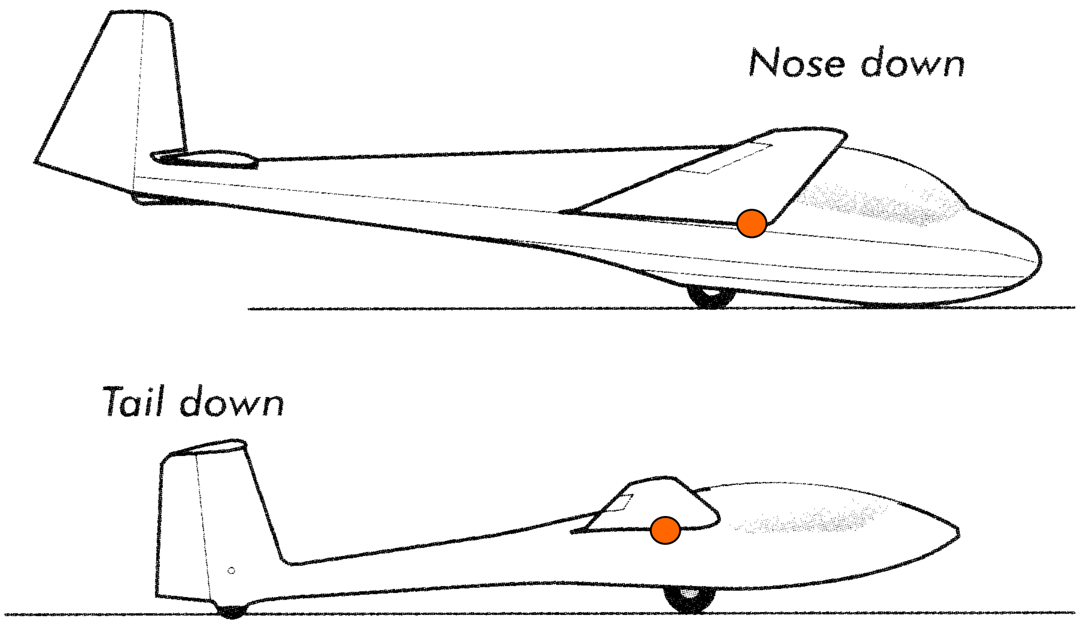
ICING: if the leading edge of the tailplane should suffer icing, there may not be enough lift for control (freezing level, cloud flying)

# Novice Pilots

- As stated above pitch stability is not an absolute
- An aircraft can be more stable - or less stable depending on the C of G position
- The placard represents the acceptable limits FOR A TEST PILOT
- Novice pilots should fly with the C of G WELL WITHIN the limits (i.e. as close to the median as is practicable)

And while we are talking about the C of G:-

Its position in relation to the main wheel will determine whether the glider sits on its nose or its tail when on the ground.




This affects the handling on takeoff and landing

Nose down types may be harder to keep straight when taking off in a cross wind. Also beware PIOs

Nose up types may ‘balloon’ on landing and are also susceptible to weathercocking in x-winds/ groundlooping because of C of G effects

Etc. etc. KNOW YOUR GLIDER / GET A BRIEFING

# TRIMMIMG

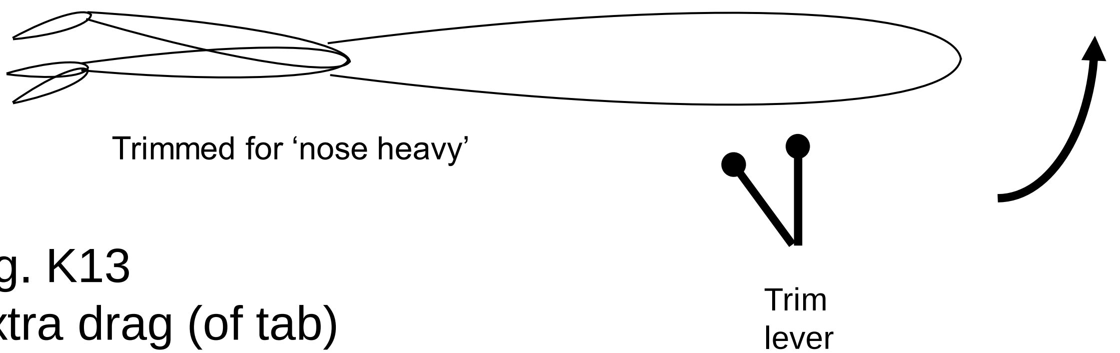
The glider will only be in perfect equilibrium for one speed/ AoA/ CofP/ CofG/ weight combination - when the tail force is exactly right

At any other constant speed (or weight) the elevator will have to be deflected to provide the additional appropriate tail force

If the glider is stable in pitch this means a pressure will have to be held on the stick – which is no fun, as any experienced pilot knows

Trimmers are provided to eliminate this pressure

Elevator trim tab (works opposite to direction of elevator movement)




- –e.g. K13
- –Extra drag (of tab)

Spring trims (moves ‘neutral’ position of stick)

- –e.g. K21/23
- –No extra drag

# TAIL BALLAST

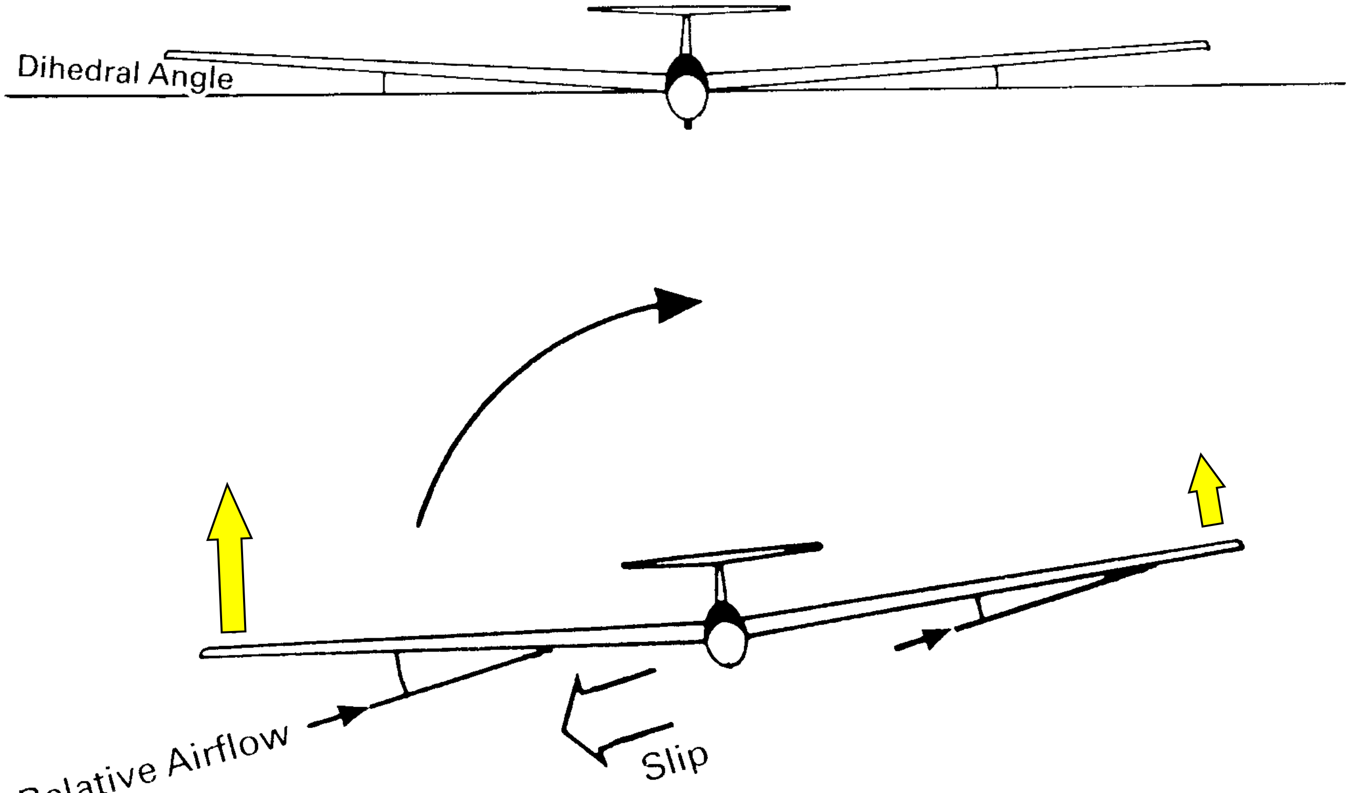
- Affects position of C of G
- Affects trim
- Affects drag on tail plane
- Make sure you observe the Pilots Operating Manual and any Placarded weight limits
- Used to REDUCE trim drag (but beware!)

# USE OF AIRBRAKES

- May cause pitch change
  - But depends on type – need to check

# ROLL STABILITY

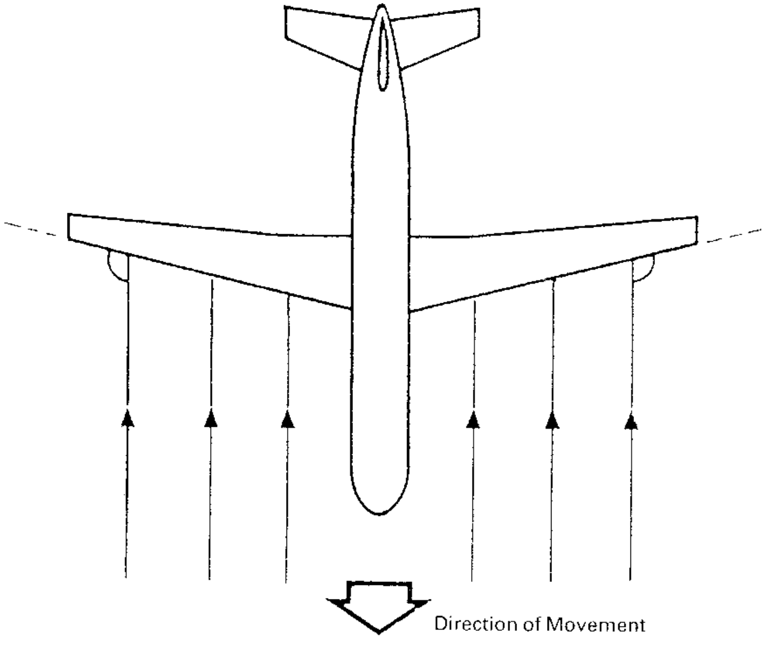
## Use of Dihedral



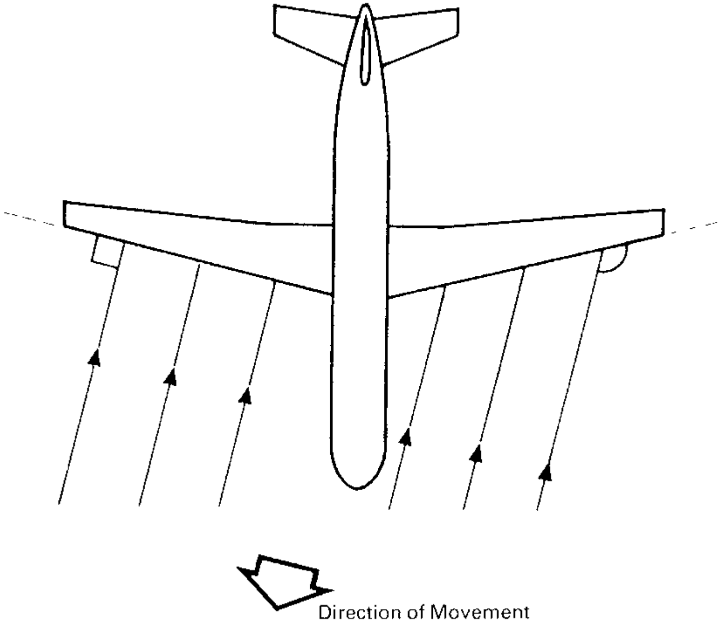
# ROLL STABILITY

Sweep back

When airflow meets wings symetrically an equal amount of lift is produced on each wing




When airflow meets wings asymetrically more lift is produce on one side tending to roll the aircraft level



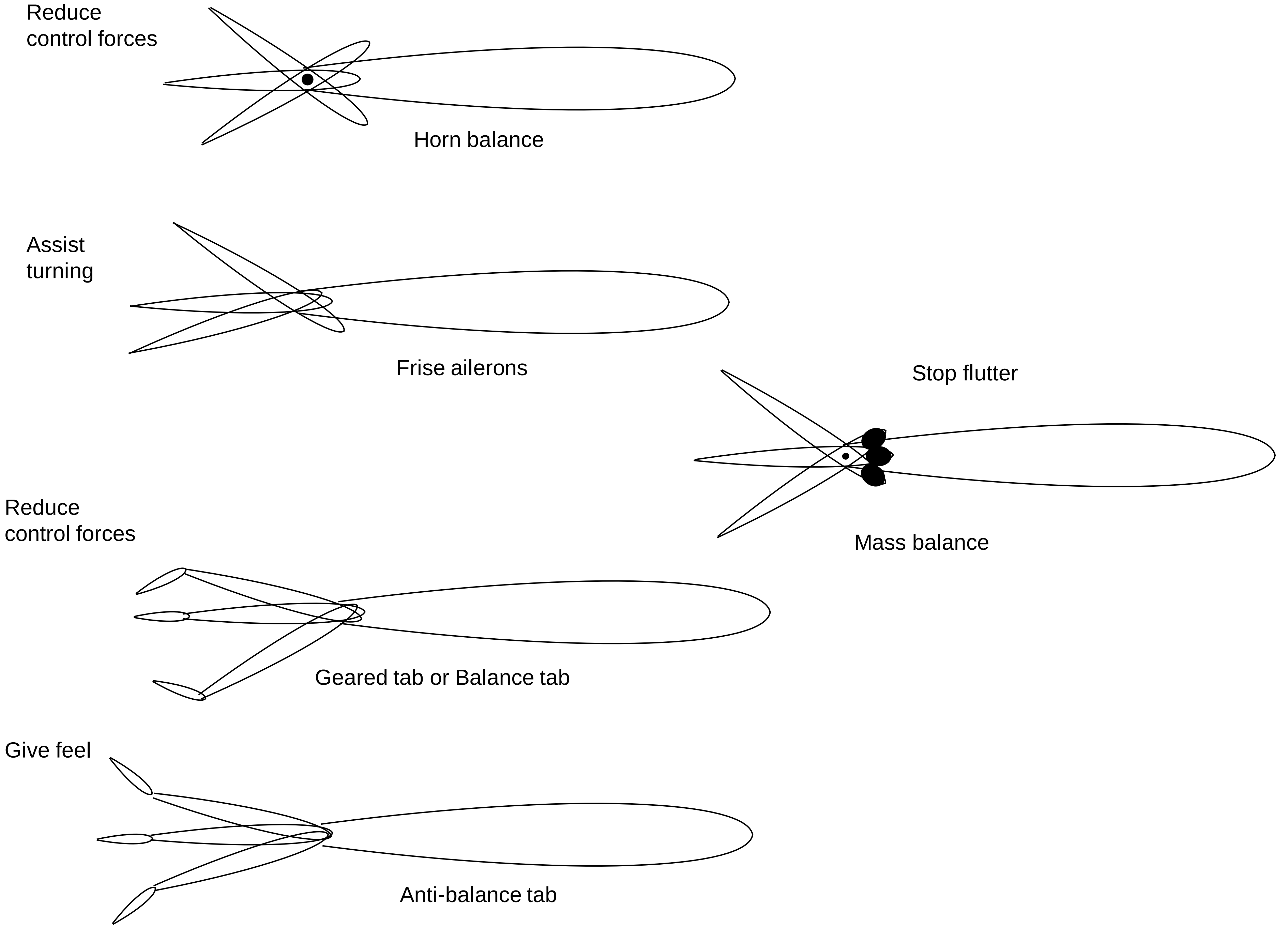
# ROLL STABILITY

- Sweep **forward***, as in the K7 and K13 leads to instability
  - therefore it is counteracted with exaggerated dihedral
- ‘Pendulum’ stability exists with very high wing aircraft (e.g. T21)
- Anhedral, as in the Harrier (which we used to have!), leads to instability
  - and is counteracted with lots of sweep back
    - But what the heck !!!
- Sweepback may lead to Dutch Roll
  - which again is countered with anhedral
- <u>Gliders</u> -generally speaking-are UNSTABLE in roll
  - i.e. they diverge into a spiral dive
- Use of <u>Airbrakes</u> tends to increase roll stability
    - (see Part 1 of these lectures)
    - *Sweep forward in K13, Bocian etc is a design feature to get the back seat pilot close to the C of G so that their weight doesn’t have much effect (and the machine can be flown solo from the front) – but still give the back seat pilot a view.

# STABILITY & CONTROL

- The more stable an aircraft is the more force/movement you must apply to the controls to make it deviate from its existing path.
- You need just enough stability but not too much (Goldilocks)
- Too much stability will make it feel ‘heavy’ to fly
  - although what a novice pilot may feel is ‘nice’ an experienced pilot may consider too heavy and what an experienced pilot thinks is ‘nice’ a novice may find ‘twitchy’
- If you have neutral stability or instability the aircraft will be hard, dangerous or impossible to fly
    - Similarly if it is much too stable (any axis)
- Aerobatic aircraft tend towards neutral stability
  - otherwise they wouldn’t be able to carry out the extreme manoeuvres
- Modern jet fighters are likely to be quite unstable
  - for this very reason
  - but they need a computer between the pilot and the controls (fly by wire)

# SOME CONTROL FEATURES



# CONTROLS

- Reducing control forces
  - Horn balance
  - Geared tab (or Balance tab)
    - Move in opposite direction to control surface
- Making turning easier
  - Frise ailerons
  - Differential ailerons
  - (Nimbus 3 uses spoilers as well)
- Providing ‘feel’
  - Springs in the control circuit
    - No drag but force not related to speed
  - Anti-balance tabs
    - Moves in same direction as control surface
    - Proportional force but extra drag
- Avoiding flutter
  - Mass balancing

# THE FLIGHT ENVELOPE

See separate presentation ⇒

# WINCH LAUNCHING

and the flight envelope

See separate presentation on winch launching.

# GLIDER AIRFRAMES AND MAINTENANCE

Flight/Pilot Operating/Maintenance Manuals
Care of GRP
- UV light
- Moisture
- Washing & polishing
  - A/bs, static ports

Rigging & DI (book)
Post flight reporting
Main spar loads
Tyres/wheel brake
Electrical (fuses, circ brkrs etc)
- protection, action if blown
- V x A = W

Bonding of metal parts

# THE POLAR CURVE

Separate presentation ⇨

# WHAT'S IN THE EXAM ?

Multi-guess !