Energy Management and the Pitch/Power controversy.

Ed Williams

presented at

SMXgig '97, Santa Maria Ca

Does pitch or power control altitude/airspeed?

- Control of airspeed and altitude is a basic piloting skill.

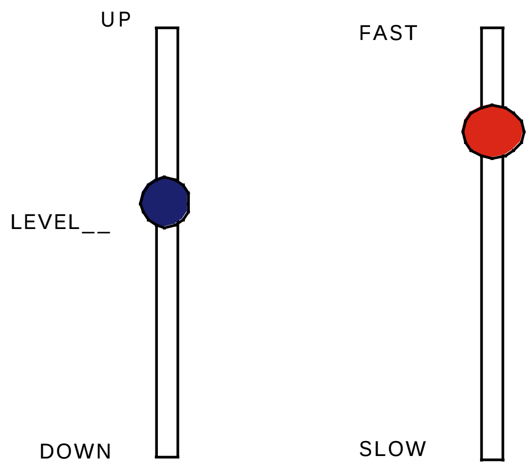
- Loss of control can have serious consequences.

- Nevertheless, the subject is always good for an argument.
  It isn't that simple.

- I'll discuss the issue in the context of energy management.

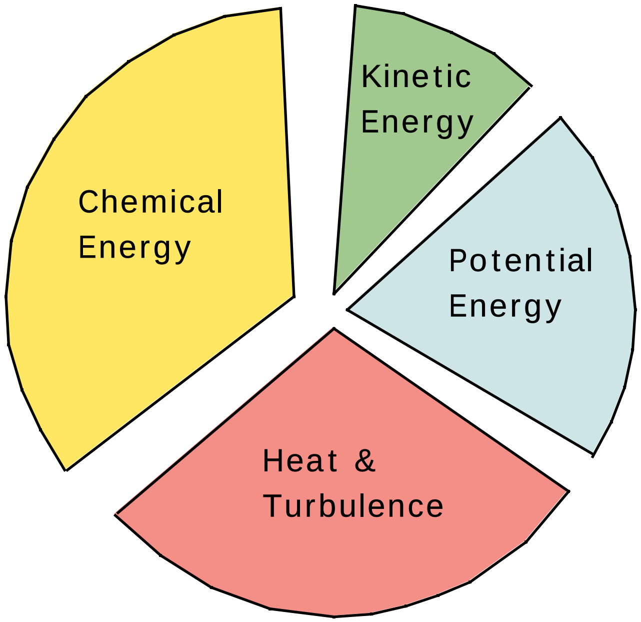
- The talk was motivated by a new book by a fellow physicist:
  John S. Denker- "*See How It Flies*"

An ideal airplane would have "speed" and "altitude" controls.



* Real airplanes have a throttle, yoke and trim
* Learning what they do is in Flying 101.
* There more than first meets the eye...

Energy is neither created nor destroyed- only changed in form.



Mechanical energy:

Kinetic Energy: $(1/2)\ M\ v^2$ - energy of motion

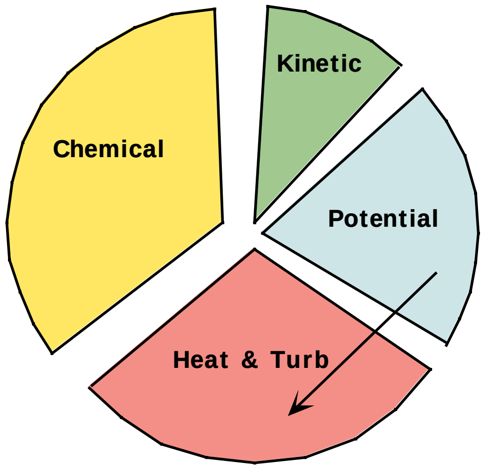
Potential Energy: Mgh - energy stored in altitude

Chemical Energy: - fuel in the tanks

Heat and turbulence- out the exhaust and left in the wake

Burning fuel or creating a wake is irreversible.

In different flight regimes, energy is converted in different ways.



Glide

In a constant airspeed, power-off glide, potential energy (altitude) is dissipated by drag. Kinetic and chemical energy are constant.

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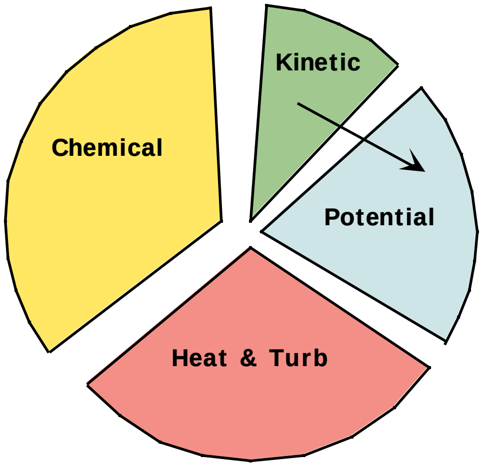


Zoom

In a zoom, we trade airspeed (kinetic energy) for altitude (potential energy).

Done quickly, the contributions from the engine (chemical) and from drag (heat & turbulent) can be neglected.

The change in $(1/2)\ M\ v^2$ equals the change in Mgh. Since the mass of the airplane is constant, it doesn't enter. A 747 will zoom the same as a C150!

One knot of airspeed at 100 knots is worth nine feet of altitude.

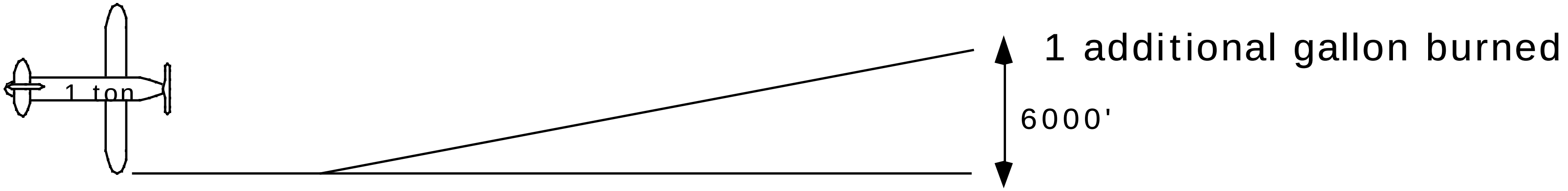
Maintaining 100+-5 knots, we can allow altitude excursions of +-45 feet.
Maintaining 200+-5 knots, we can allow altitude excursions of +-90 feet.

Fuel is chemical energy.

* One gallon of AVGAS contains about 41,500 foot-tons of energy.

* ~75% of that energy ends up as waste heat.
~20% of the remaining is dissipated by the prop.

* About 6000-6500 ft-tons/gallon remain to do useful work.



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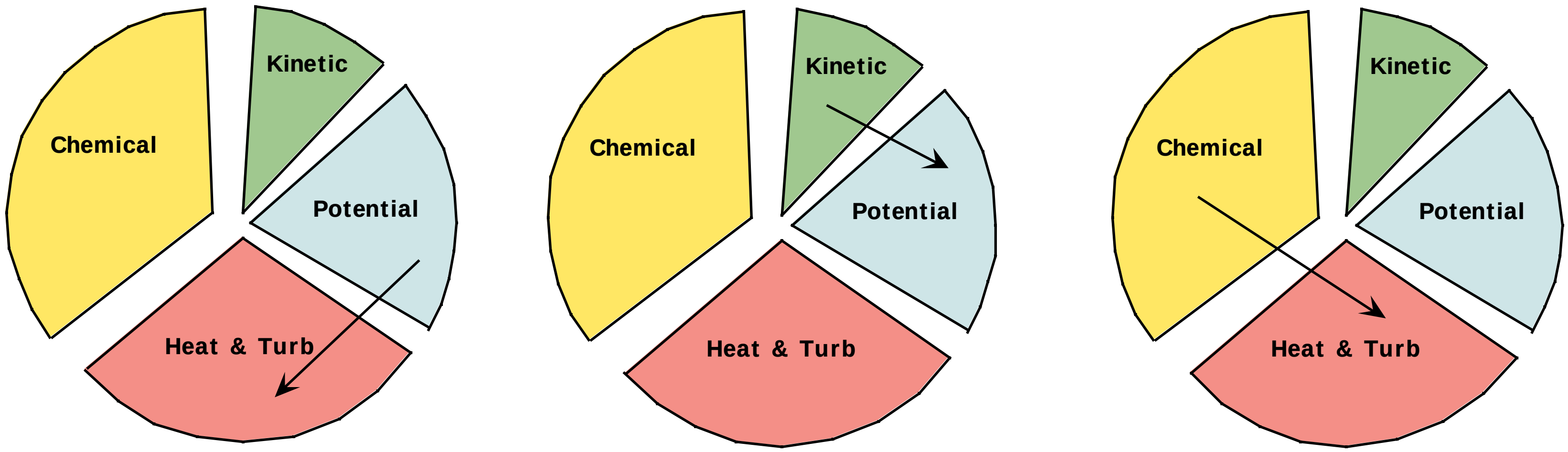
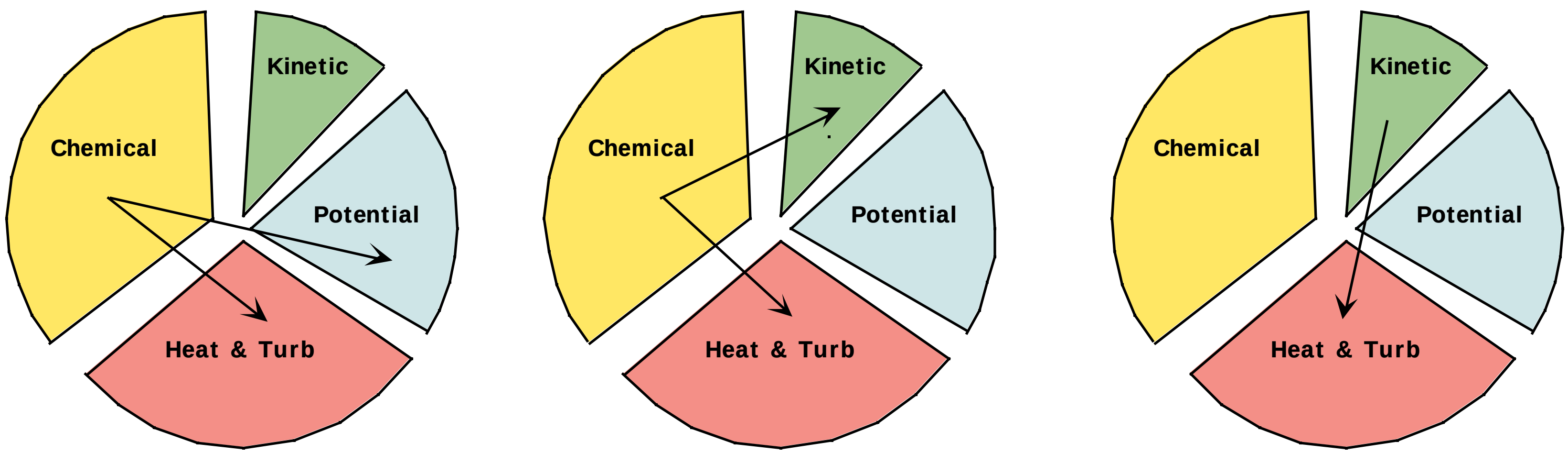


Glide ***Zoom*** ***Cruise***



Steady Climb ***Takeoff Roll*** ***Landing Flare***

E. A. Williams 4/26/97

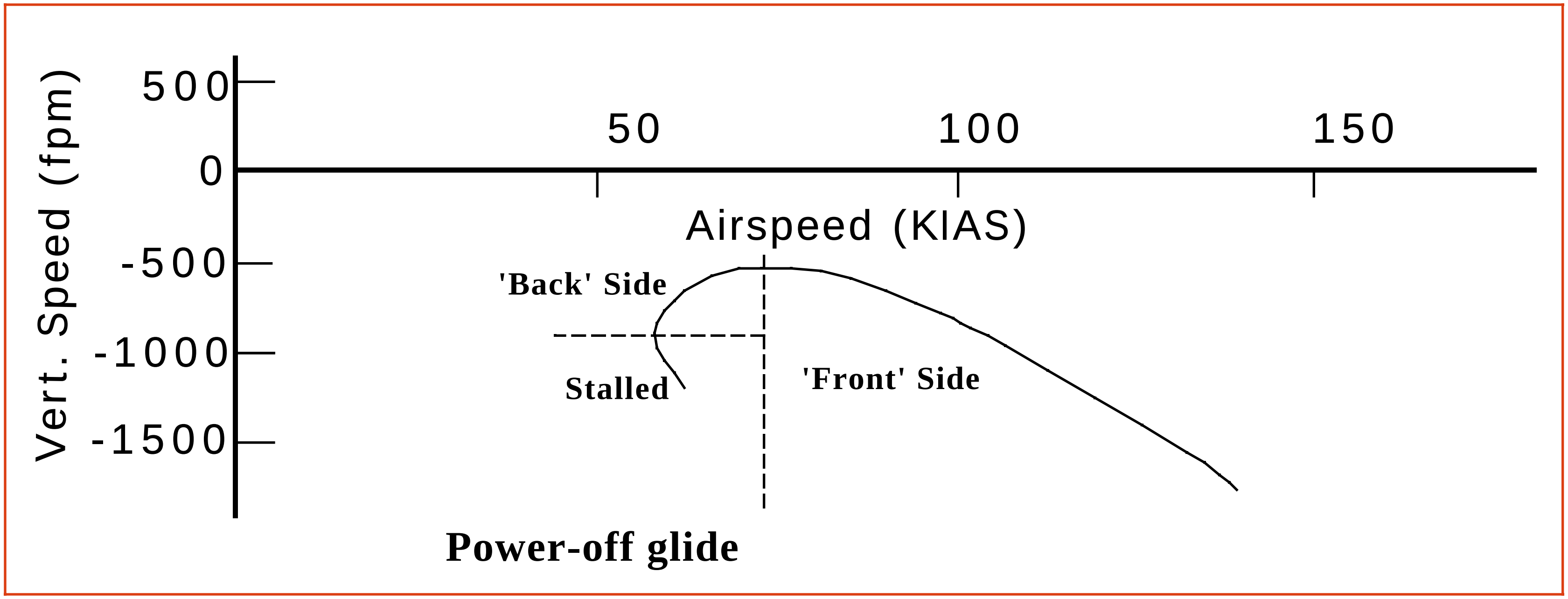
Power is the rate of energy usage

* Altitude (feet) measures potential energy--
  ROC (feet/min) measures the corresponding power.

	Energy	Power
Potential	Altitude	ROC
Chemical	Fuel quantity	Fuel flow
Kinetic	Airspeed	

* The throttle controls power. With more power, you can
  (i) overcome more drag
  (ii) climb faster/descend slower
  (iii) accelerate

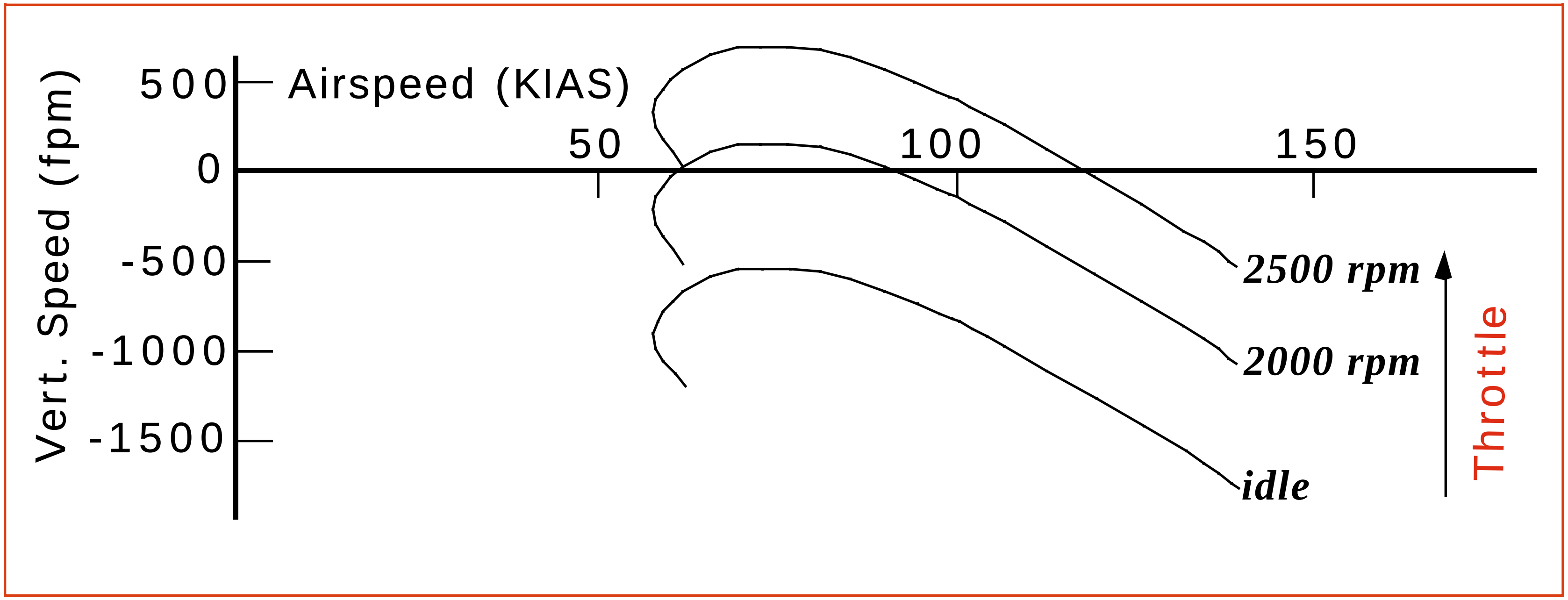
Airplane drag dissipates power according to IAS.



* On the 'front' side, parasite drag dominates, on the 'back', induced drag.

* The 'power required' curve may be more familiar. It's the negative of this, with HP as the vertical axis. (1 HP = 16 ft-tons/min)

At fixed airspeed, additional power feeds ROC.



* Reduction of power by ~500RPM/5" MP => 500 ft/min descent

What does the throttle do, then?

* The throttle controls power.
  (i) Adding power makes you climb faster/descend slower
  (ii) More power is required to fly faster or slower than V_y.
  (iii) More power is required to accelerate on any given flight-path.
* A trimmed airplane maintains airspeed with power changes. Adding power doesn't make you speed up. It makes you climb. In fact most airplanes *slow* on addition of power.
* Not on takeoff, or with altitude hold!

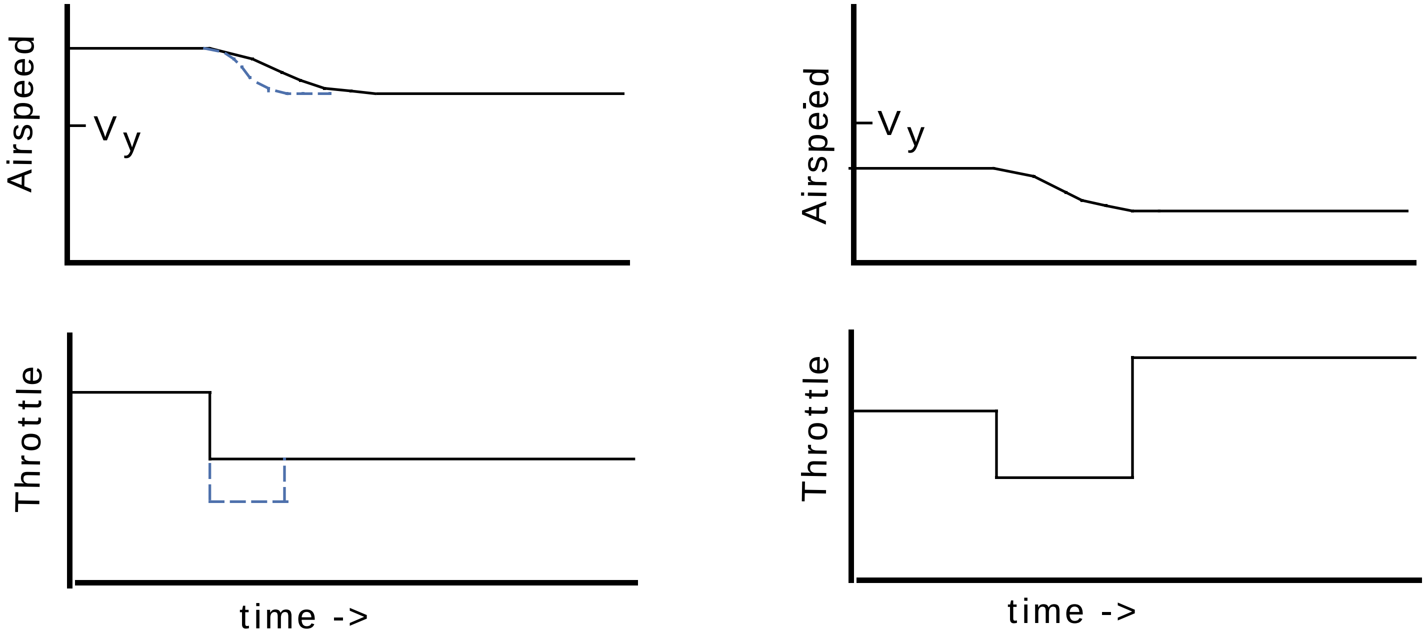
Managing your energy budget...

* Normally: chemical energy >> potential energy >> kinetic energy

High and fast	too much energy	reduce power/add drag
Low and slow	too little energy	add power
High and slow Low and fast	?? OK ??	correct airspeed with pitch and check again

Changing airspeed

while staying on altitude or glideslope...



- To reduce airspeed, we must lose energy => reduce power
- Trade excess airspeed for altitude using pitch.
- Reset power for the new operating point on the power curve.

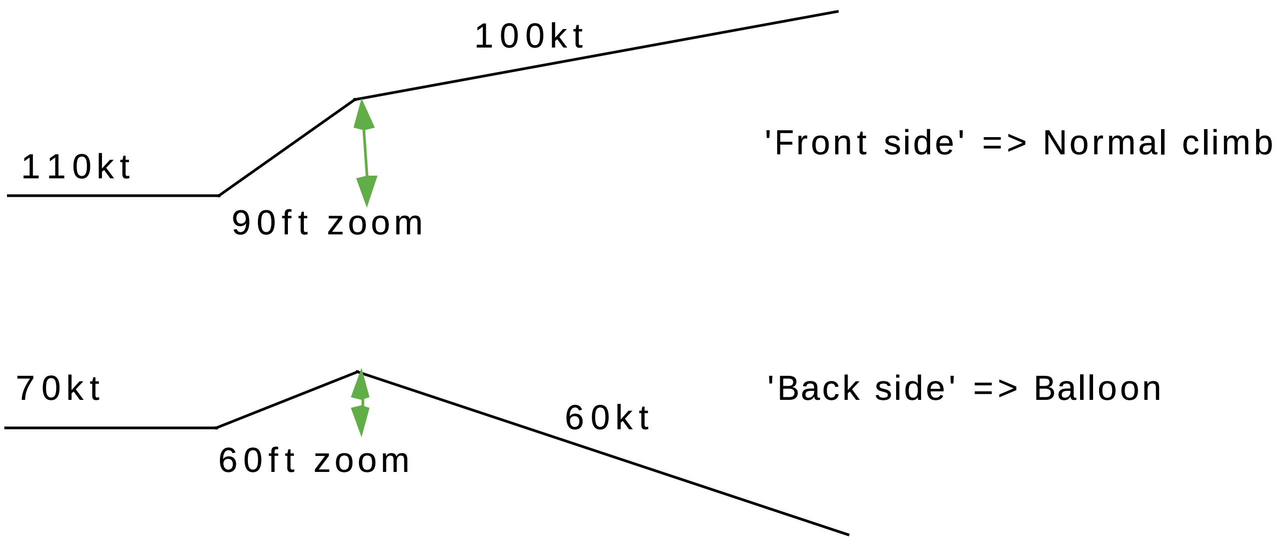
What is the effect of the yoke?

* Pulling on the yoke => increases AOA => decreases airspeed

* The change in airspeed causes:

  a) A short-term zoom

  b) A change in operating point on the power curve.



But in cruise I control altitude with pitch...

* We all do. So does an autopilot. It's very convenient.

* It works because (if):
  you accept airspeed changes
  you are on the 'front' side of the power curve

* Altitude low => raise pitch => short-term zoom + long term climb => back on altitude

* It *doesn't* work on the back side (<Vy).

  Altitude low => raise pitch => short-term zoom + long term descent => low *and* slow => raise pitch => stall/spin

In summary:

* The yoke directly controls airspeed, and, through "zoom" gives short-term, fine control of altitude.

  The *elevator* doesn't necessarily make you go up!!!

  Q's Is my airspeed OK? Do I want/need to exchange airspeed for altitude?

* The throttle controls your chemical energy supply.

  Q's Do I want more or less energy? Am I gaining/losing energy at the right rate?