Introduction to Aerospace Engineering

Lecture slides

Intro to Aerospace Engineering

AE112-9-10 Cockpit & Systems

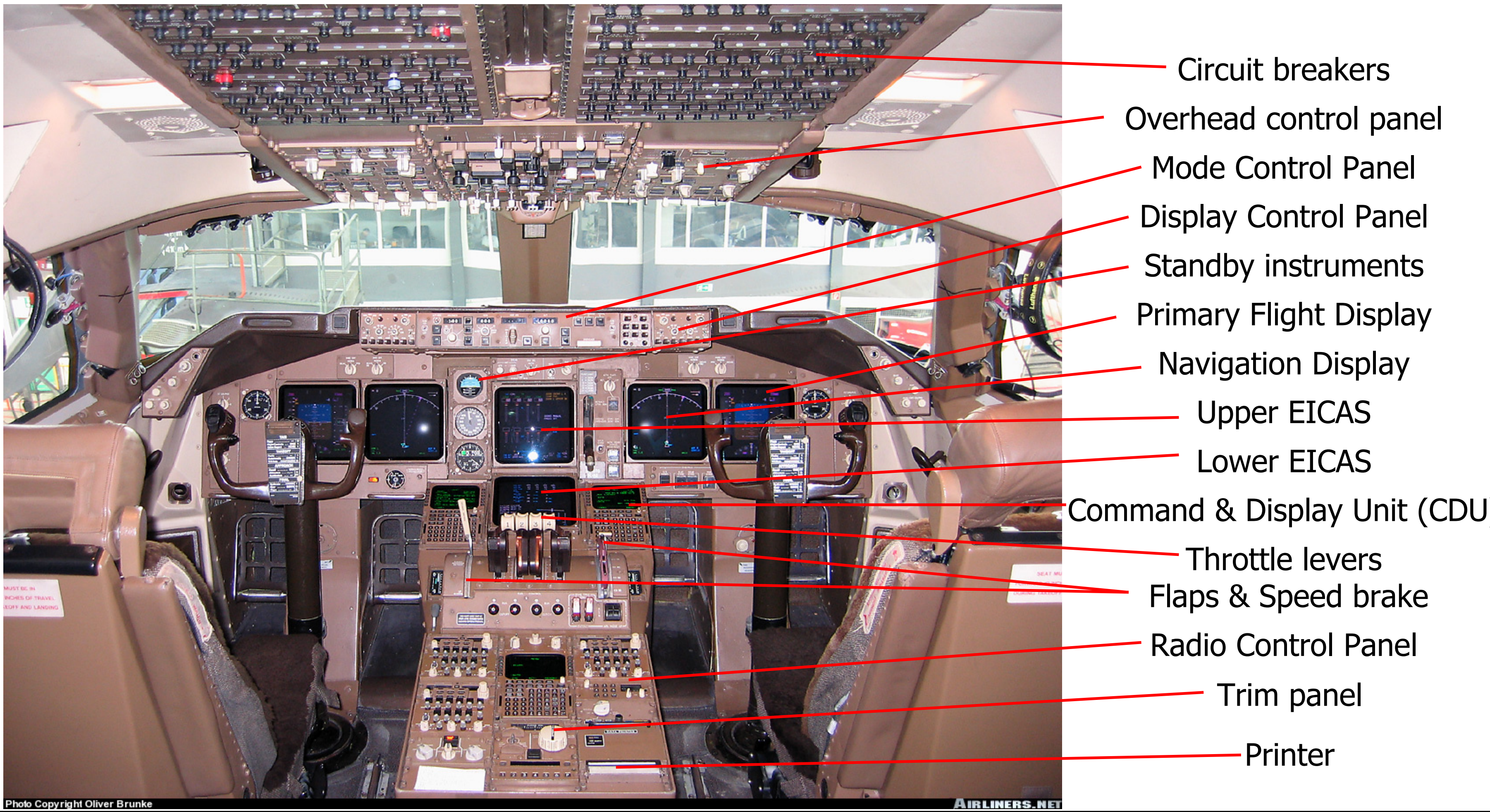
Prof.dr.ir. Jacco Hoekstra

Boeing 727 cockpit

Airbus A320

Airbus was first to introduce glass cockpit together with fly-by-wire on A320

Boeing 747-400



A380 cockpit

Point & Click device

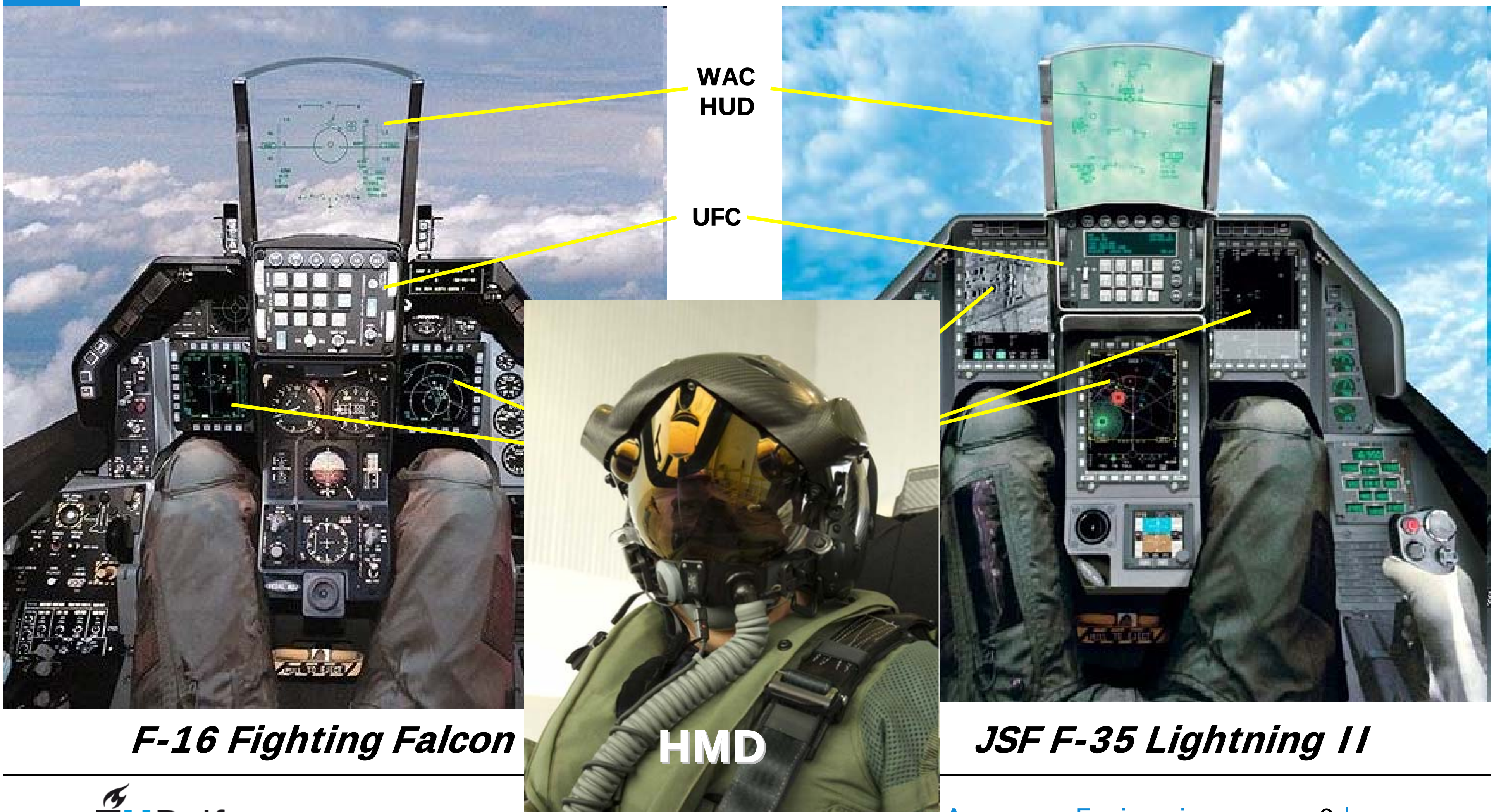
Electronic Flight Bag

Check out: http://www.gillesvidal.com/blogpano/cockpit1.htm

Classic GA cockpit: Cessna 172 Skyhawk

Glass in GA aircraft: Diamond DA-42 Twin Star

Modern fighter cockpits: HOTAS, MFDs & HMD



F-16 Fighting Falcon ***JSF F-35 Lightning II***

1.

Instrumentation

'This instrument has a 10 feet accuracy'

What's our speed? Which speed?

Primary Flight Display (PFD)

Units for speed, altitude & vertical speed

Note:
1 nm = 1852 m
1 mile = 1609 m

1 kts ≠ 1 mph
1 kts = 1.15 mph

- Circumference earth is 40000 km
- 1 nm = 1 minute = 40000 /360 /60 = 1852 m
- 1 kts = 1 nm/hr = 1852 m/ 3600 s = 0.51444… m/s
- M = V/a with speed of sound $a = \sqrt{\gamma R T}$ For air: $\gamma = 1.40$
- 1 ft = 0.3048
- 1 ft/min = 0.3048 m / 60 s =0,00508

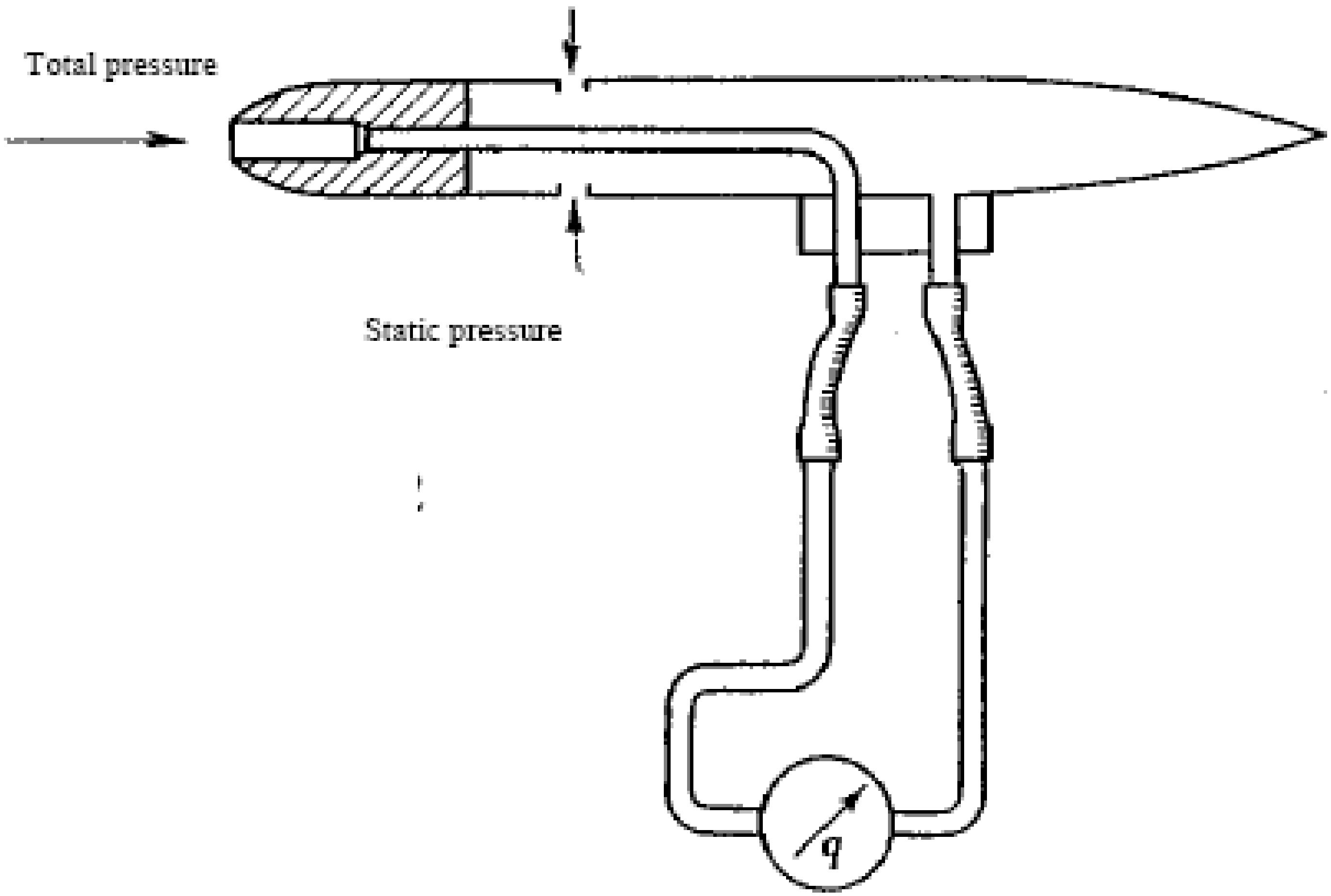
*E.g. 400 kts = 400*0.514444 = 206 m/s ; = 400*1.852 = 741 km/hr*

How do we measure speed?

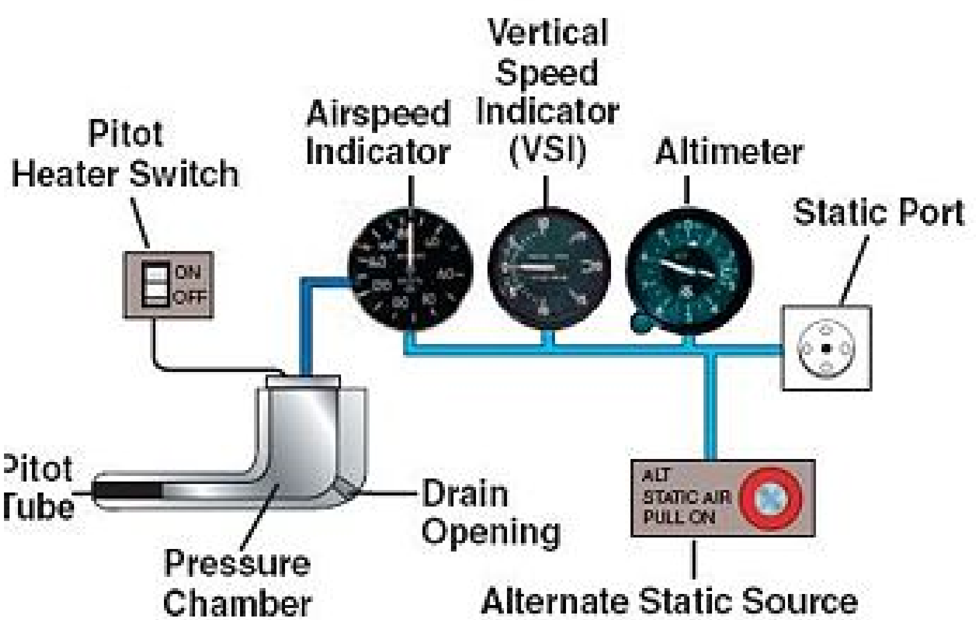
Primary Flight Display (PFD)

First of all: forget the wind!

Airspeed: Pitot Tube



Air data computer ADC
Airspeed, VS and altitude



DADC

Equivalent airspeed: no ISA required

- Equivalent airspeed is quickest way to get dynamic pressure

$$\tfrac{1}{2}\,\rho_0 V_{EAS}^{\;2} = \tfrac{1}{2}\,\rho V_{TAS}^{\;2}$$

So:

$$C_L \;\tfrac{1}{2}\,\rho_0 V_{EAS}^{\;2}\; S = C_L \;\tfrac{1}{2}\,\rho V_{TAS}^{\;2}\; S$$

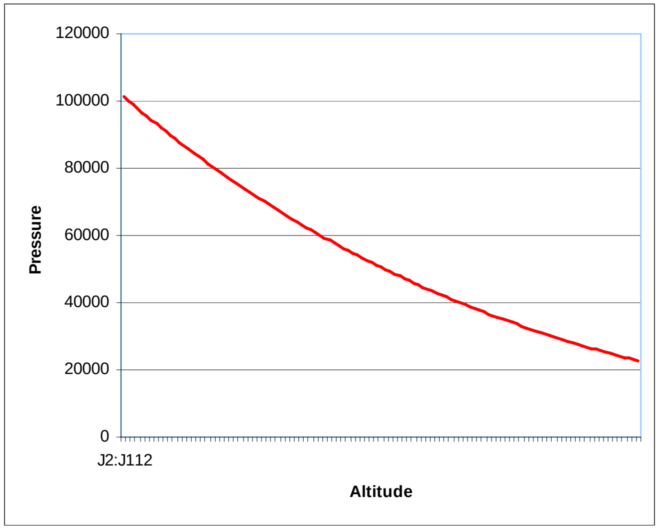
- If we assume no instrument errors and no compressibility effect (low Mach number), then EAS = CAS = IAS

Static pressure, dynamic pressure, total pressure

- Speed from difference static & total pressure
- Altitude from difference between static pressure and reference as set by pilot (QNH setting) based on definition in standard atmosphere
- V/S as change in p_{st}

Use: $$p_{tot} = p_{st} + p_{dyn}$$
$$= p_{st} + \tfrac{1}{2}\rho V^2$$

And ISA with QNH setting



What's our speed? Which speed?

- Ground speed: true airspeed + drift due tot wind

IAS = Indicated Airspeed

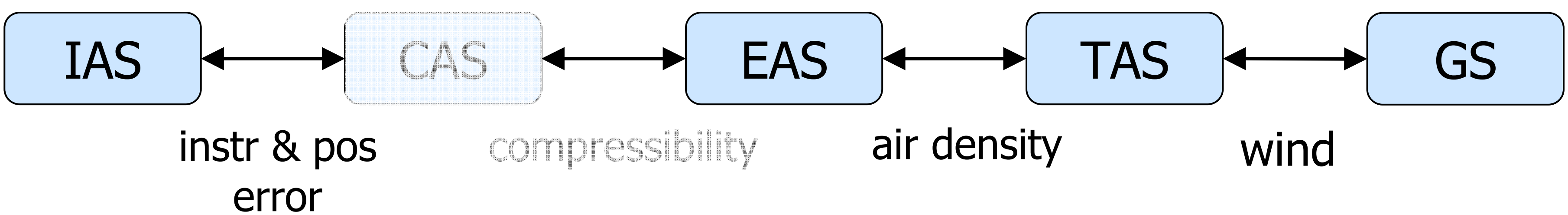
CAS = Callibrated airsp

EAS is often used in specifications because it specifies a certain dynamic pressure!

EAS = Equivalent airspeed
TAS = True airspeed
GS = Ground speed
M = Mach number= V_{TAS}/a

$$\tfrac{1}{2}\,\rho_0 V_{EAS}^{\,2} = \tfrac{1}{2}\,\rho V_{TAS}^{\,2}$$

$$EAS = TAS \times \sqrt{\frac{actual\ air\ density}{standard\ air\ density}}.$$



Homework assignment

- Complete the following tables (Hint: use Excel or other program):

altitude	TAS	EAS	Mach
0 (SL)	250 kts		
3000 ft	250 kts		
FL100 / 10000 ft	250 kts		
FL200 / 20000 ft	250 kts		
FL300 / 30000 ft	250 kts		
FL400 / 40000 ft	250 kts		

altitude	TAS	EAS	Mach
0 (SL)		365 kts	
3000 ft		365 kts	
FL100 / 10000 ft		365 kts	
FL200 / 20000 ft		365 kts	
FL300 / 30000 ft		365 kts	
FL400 / 40000 ft		365 kts	

altitude	TAS	EAS	Mach
0 (SL)			0.92
3000 ft			0.92
FL100 / 10000 ft			0.92
FL200 / 20000 ft			0.92
FL300 / 30000 ft			0.92
FL400 / 40000 ft			0.92

- Airbus gives the following maximum operating speeds (Vmo/Mmo):
  A330: 360kias/M0.86
  A340: 330kias/M0.86

  What would this mean?

Answer homework

altitude	TAS	EAS	Mach	rho	T	a	h[m]
0 (SL)	250	250	0.38	1.225	288.15	340	0
3000 ft	250	239	0.38	1.121	282.21	337	914
10000 ft	250	215	0.39	0.9045	268.34	328	3048
20000 ft	250	181	0.41	0.6452	247.88	316	6096
30000 ft	250	153	0.42	0.458	228.71	303	9144
40000 ft	250	124	0.44	0.3013	216.65	295	12192

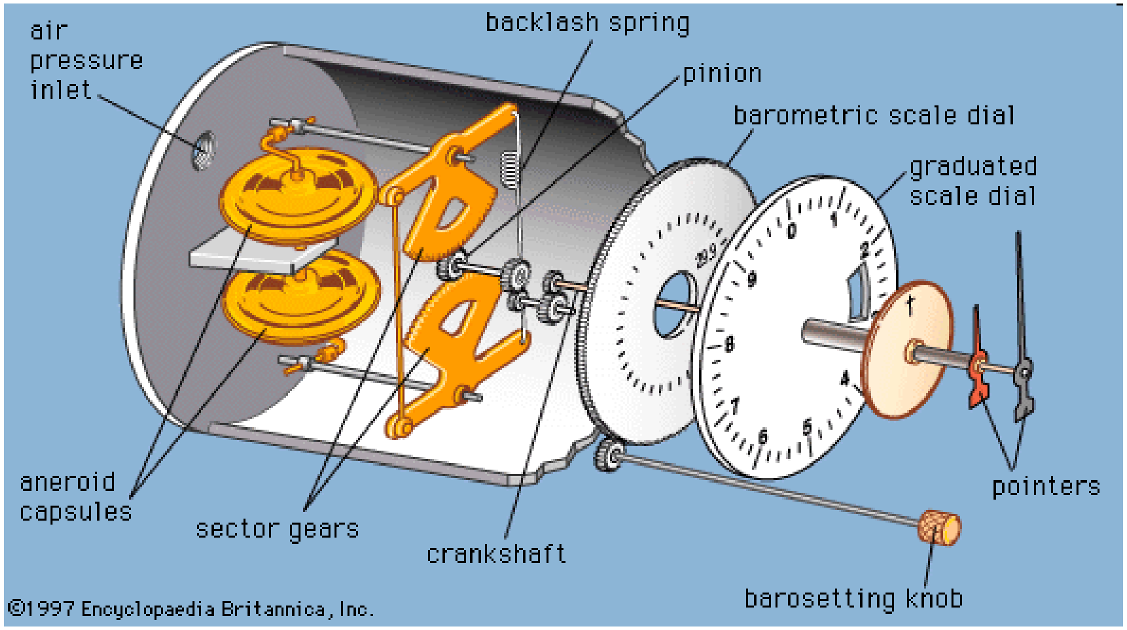
altitude	TAS	EAS	Mach	rho	T	a	h[m]
0 (SL)	365	365	0.55	1.225	288.15	340	0
3000 ft	382	365	0.58	1.121	282.21	337	914
FL100 / 10000 ft	425	365	0.67	0.9045	268.34	328	3048
FL200 / 20000 ft	503	365	0.82	0.6452	247.88	316	6096
FL100 / 30000 ft	597	365	1.01	0.458	228.71	303	9144
FL100 / 40000 ft	736	365	1.28	0.3013	216.65	295	12192

altitude	TAS	EAS	Mach	rho	T	a	h[m]
0 (SL)	609	609	0.92	1.225	288.15	340	0
3000 ft	602	576	0.92	1.121	282.21	337	914
FL100 / 10000 ft	587	505	0.92	0.9045	268.34	328	3048
FL200 / 20000 ft	564	410	0.92	0.6452	247.88	316	6096
FL100 / 30000 ft	542	331	0.92	0.458	228.71	303	9144
FL100 / 40000 ft	528	262	0.92	0.3013	216.65	295	12192

At low altitude the IAS is limiting at high altitude the Mach number
As a result the speed margin between minimum and maximum speeds will become less

Altitude

- Pressure altitude is not real altitude
- Adjust for pressure at sea level: QNH
- Above transition altitude: 4500 ft -> FL045
  Assume at sea level: 1013,25 mbar (=29,92 inch Hg)



- Flight levels are used above a so-called 'transition altitude'
- Flight levels use a 100 ft unit
- FL085 means 8500 ft above the 1013.25 hPa pressure

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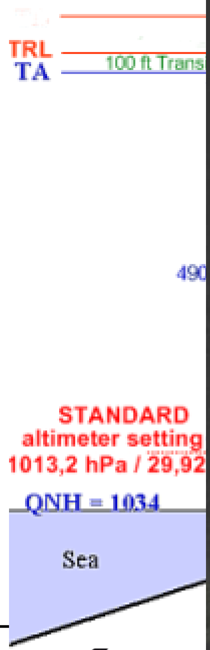


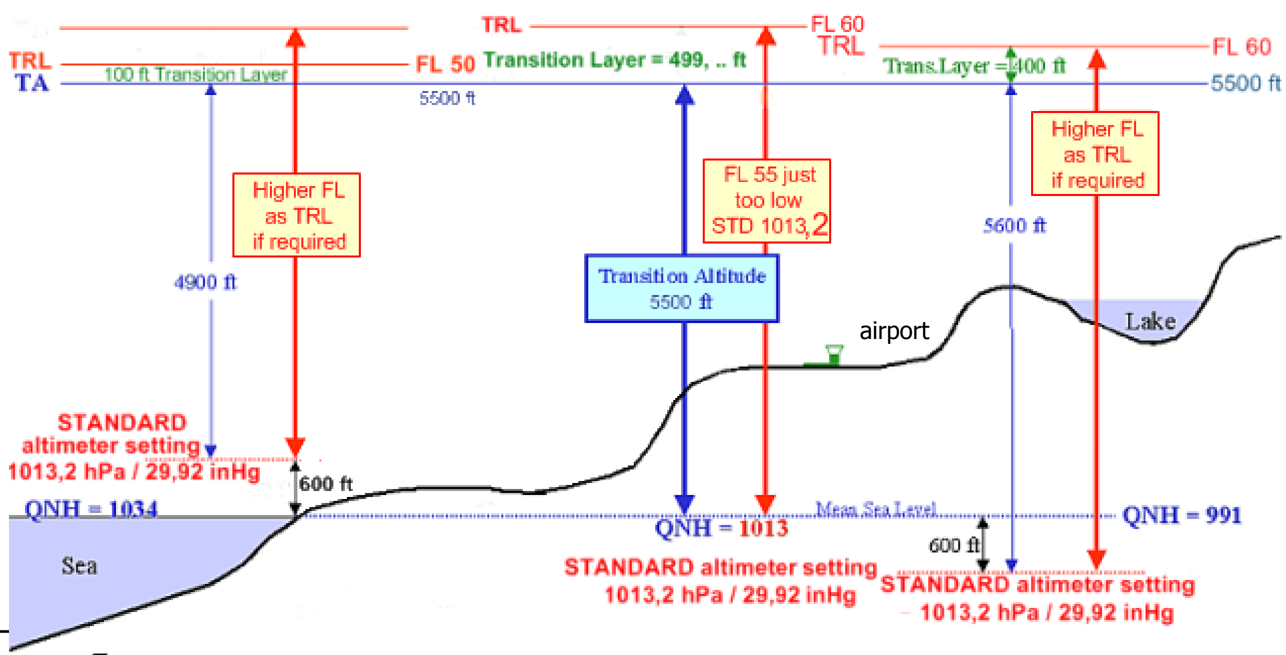
TRL
TA
100 ft Trans
490
STANDARD
altimeter setting
1013,2 hPa / 29,92
QNH = 1034
Sea

SPD
LNAV
VNAV PTH
.850
37000
110.10/120°
DME 162
A/P
320
300
277
260
240
220
10
20
37200
37000
36800
REF
30/130
BARO
213
airport
.847
109H
MAG
R
STD
994 HPA

1015
QNH

Altitude

- Pressure altitude is not real altitude
- Adjust for pressure at sea level: QNH
- Above transition altitude: 4500 ft -> FL045 (relative to p_0 = 1013,25 hPa = 1 atm)



Altitude

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Table for determining transition level

QNH (in millibars)	Transition altitude (in feet)				
	3,000	4,000	5,000	6,000	18,000
1032-1050	FL25	FL35	FL45	FL55	FL175
1014-1032	FL30	FL40	FL50	FL60	FL180
996-1013	FL35	FL45	FL55	FL65	FL185
978-995	FL40	FL50	FL60	FL70	FL190
960-977	FL45	FL55	FL65	FL75	FL195
943-959	FL50	FL60	FL70	FL80	FL200