Formulas / ATPL theory summary

(Rob Groothuis)

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Index ATPL

Handy formulas/guidelines general

****PUSH THE HEAD AND PULL THE TAIL**** → intercepting NDB QDR/QDM

$glidepath \cdot height \cdot (ft) = \frac{glidepath \cdot angle}{60} \times$ *distance (ft)* ≈ ***(300 ft/nm)***

rate of descent (ft/min):
GS x 5 = 3° glide path

climb gradient = $\frac{rate \cdot of \cdot c\lim b \times 6000}{TAS \times 6080}$

glide path in ° = $\frac{...\%}{100}$ x 60

angle of bank in rate 1 turn = $\frac{TAS}{10}$ + 7 (approximation)

radius of turn (NM) = $\frac{TAS}{rate \times 60 \times \pi}$

radius of turn (m) = $\frac{V^2 (m/s)}{10 \times \tan \cdot bankangle}$

"n" (load factor) = $\frac{1}{\cos \cdot bankangle}$

$\sqrt{load \cdot factor}$ = V_{Stall} increasing factor

IAS → (position/instrument error) → **RAS/CAS** → (compressibility) → **EAS** → (density) → **TAS**

EAS = $\sqrt{relative \cdot density}$ x TAS (example: relative density = ¼ at 40000 ft)

VOR's variation at station / NDB's variation at aircraft.

relative bearing + true heading = true bearing

QDR + var. = QTE (QDR = magnetic from station / QTE = true from station)

QDM ± 180° = QDR (radial) / **QDM = "bearings on the RMI"** (QDR = magnetic to)

LSS (kt) = $38{,}94\sqrt{T(°K)}$ [273°K = 0°C]

LSS = 661 kt (at sea level at ISA temp.= 288 k)
LSS = 573 kt (ISA tropopause temp.= 216,5 k)

$mach \cdot no. = \frac{TAS}{LSS}$

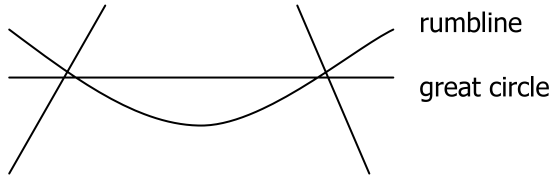
ATPL formulas – General navigation

departure (E/W) in NM = Δ longitude (in minutes) x cosine latitude

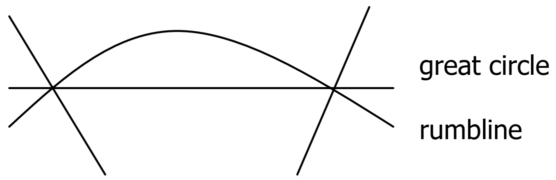
(earth) convergency = Δ longitude x sine mean latitude

conversion angle = ½ x convergency

<u>northern hemisphere</u>



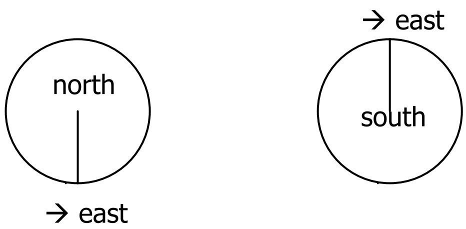
<u>southern hemisphere</u>



Mercator projection; scale = scale x or ÷ cosine Δ latitude (x from equator / ÷ to equator)

simple conic / Lamberts projection
(chart) convergency = Δ longitude x sine latitude (or parallel of origin / constant of the cone)

Polar stereographic
(chart) convergency = Δ longitude



(grid navigation) convergence = Δ longitude from datum meridian

(grid navigation) grivation = variation + convergence

$$glidepath \cdot height = \frac{glidepath \cdot angle}{60} \times \text{ distance (ft)} \approx \text{(300 ft/nm)}$$

rate of descent (ft/min) ≈ GS (NM) x 5 (at 3° glide slope)

glide path in ° = $\frac{...\%}{100}$ x 60

$$mach \cdot no. = \frac{TAS}{LSS}$$

$LSS \equiv 38{,}94\sqrt{T(°K)}$ [273°K = 0°C]

time to $PNR / PSR \cdot (radius \cdot of \cdot action) = \frac{E \times H}{(O+H)}$ / E= safe endurance, H=GS home, O=GS out.

distance to $CP = \frac{D \times H}{(O+H)}$ / D=distance between airfields → point of equal time, moving into the wind.

ISA → 15°C / 1013,25 mb / 1225 Gr/M^3 = International Standard Atmosphere

1,98 °C/1000ft lapse rate above MSL up to tropopause of 36000ft; remains constant at -56,5°C up to 66000ft then increases by 0,3 °C /1000ft up to 105000ft.

VOR's variation at station / NDB's variation at aircraft.

relative bearing + true heading = true bearing

QDR + var. = QTE (QDR = magnetic from station / QTE = true from station)

QDM ± 180° = QDR (radial) / QDM = "bearings on the RMI"

NDB's → plotting more than 2° longitudinal difference, convergency should be taken into account.

C + Dev. = M + Var. = T → from magnetic to true to plot is algebraic sum, from true (plotline) to QDM/QDR is algebraic sum (VARIATION).

NDB bearing → move aircraft meridian to NDB and take aircraft position variation.

$$\frac{relative \cdot height(ft)}{depression \cdot angle} = \frac{range(NM)}{9,4}$$

ATPL formulas – Meteorology

DALR = 3 °C/1000ft
SALR = 1,8 °C/1000ft in temperate climates (not constant)
S.L - 1013mb – 27 ft/mb // 18000 ft – 500mb – 48 ft/mb

[approximation]→ 4% height difference in true from indicated altitude for every 10°C air mass diff. from ISA.

wet bulb temperature → tells roughly how moist the air is and lies between DEW point and OAT
Falls with 1,8 °C/1000ft.

temperature rise föhn effect = (Lee cloud base – windward cloud base) x 1,2

by day (free stream to surface in NH)			by night	
	deg. backed	***free stream***	***deg. backed***	***free stream***
over land	30	50%	40	30%
over sea	10	70%	10	70%

ATPL formulas – Instrumentation

latitude nut wander = 15 x sine latitude (NH= +) in °/hour

earth rotation wander = 15 x sine latitude (NH= -) in °/hour

$$transport \cdot wander \equiv \frac{E/W \cdot GS \times \tan .lat}{60}$$ (NH= E= - / W= +)

total drift = real wander + earth rotation + lat. nut wander + transport wander

rate 1 turn = 180°/min (3°/S)
rate 2 turn = 360°/min (6°/S)
rate 3 turn = 540°/min (9°/S)

angle of bank required for rate 1 turn = $\frac{TAS}{10} + 7$

radius of the turn (NM) = $\frac{TAS}{rate \times 60\pi}$

ATPL formulas – Communications VFR / IFR

speed of light = 300000 Km/s

wave length $\lambda = \frac{C}{f}$ (C=speed of light in m/s / f=frequency in Hertz)

max skip distance (NM) = $1{,}43\sqrt{H}$ (of ionosphere in Km)

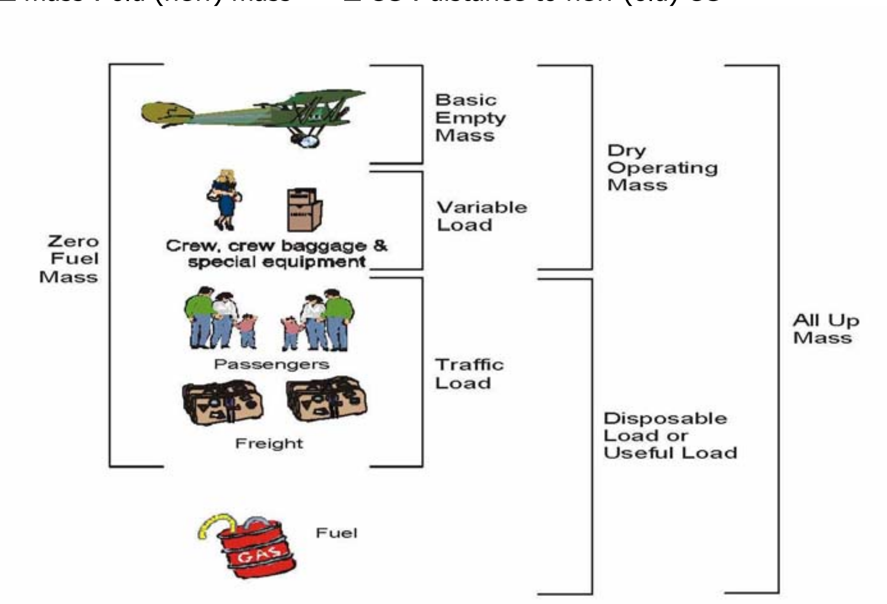
maximum (theoretical) range (NM) = $1{,}25\sqrt{H1} + 1{,}25\sqrt{H2}$ (feet)

ATPL formulas – Mass and balance

1 M = 3,28 ft / 1 ft = 0,304 M / USG or IG = 8 pints or 4 quarts
1 IG = 1,2 USG / 1 USG = 3,785 L / 1 Kg = 2,2 Lbs

$$\frac{mass \cdot change}{total \cdot old \cdot mass} = \frac{change \cdot of \cdot CG}{dis\tan ce \cdot from \cdot mass \cdot to \cdot new \cdot possition}$$

Δ mass : old (new) mass = Δ CG : distance to new (old) CG



maximum permissible traffic load = MTOM – DOM – fuel on board

MTOM = maximum take of mass / MZFM = maximum zero fuel mass

MTOM	MZFM	MLM
MTOM DOM - fuel (total) -	MZFM DOM - -----	MLM DOM - fuel (div+res) -
maximum traffic load	maximum traffic load	maximum traffic load

maximum fuel load in MTOM => fuel = traffic load
maximum fuel load in MLM => fuel = traffic load (+ sector fuel)

ATPL formulas – Flight planning

best range jet = 1,32 x V_{IMD} (indicated minimum drag speed)

SFC = fuel flow : thrust

SAR (jet) = TAS : (SFC x drag)

Best SAR (specific air range) is that altitude where 90% rpm gives 1,32 x V_{IMD} without accelerating.

PSR or PNR → last point on a route at which it is possible to return to destination with sensible fuel reserves.

time to point of no return = $\frac{E \times H}{(O+H)}$ E = safe endurance / H = groundspeed home / O = GS out

the greatest distance to PNR/PSR is obtained in still air conditions.

ETP (equal time point) or CP (critical point) = for quickest way home determination.

distance to CP = $\frac{D \times H}{(O+H)}$ D = total track distance / H = groundspeed home / O = GS out

for engine failure calculations → take the less engine speed in formula!!

ATPL formulas - Radio navigation

speed of light = 300000 Km/s = 162000 NM/s

wave length $\lambda = \frac{C}{f}$ (C=speed of light in m/s / f=frequency in Hertz)

max skip distance (NM) = $1{,}43\sqrt{H}$ (of ionosphere in Km)

skip distances are increased at night as the ionosphere weakens and refract less.

maximum (theoretical) range (NM) = $1{,}25\sqrt{H1} + 1{,}25\sqrt{H2}$ (ft)

NDB maximum (theoretical) range = $3\sqrt{power}$ in watts

****PUSH THE HEAD AND PULL THE TAIL**** → intercepting NDB QDR/QDM.

cloud height above aircraft (ft) = range (ft) x (scanner tilt – ½ beam width) : 60

PRP = pulse recurrence period = time it takes to send and receive one pulse.
PRF = pulse repetition frequency = number of pulses per second.

PRP = $\frac{1}{PRF}$

low PRF is needed for long range radars. Maximum range is controlled by PRF and power.

maximum theoretical range (m) = $\frac{C}{2 \times PRF}$ (C=300.000.000 m/s) minimum theoretical range (m) = $\frac{C \times pulse \cdot length}{2}$ (C=300.000.000 m/s)

beamwidth = 70 x wave length : antenna diameter

$glidepath \cdot height = \frac{glidepath \cdot angle}{60} \times$ *distance (ft) ≈ (300 ft/nm)*

glide path in ° = $\frac{...\%}{100}$ x 60

rate of descent (ft/min) ≈ 5 x GS (NM) (at 3° glide slope!!) → (x $\frac{3,5}{3}$ for 3,5° glide slope)

ATPL formulas - Principles of flight

IAS → (position/instrument error) → **RAS/CAS** → (compressibility) → **EAS** → (density) → **TAS.**

A x V = constant (A= area / V= speed)

P + ½.φ.V^2 = constant

Q = ½.φ.V^2 = dynamic pressure

Q and lift/drag are proportional to EAS^2 // EAS is slightly less than IAS.

EAS = TAS only at ISA mean sea level density.

EAS = $\sqrt{relativedensity}$ x TAS (example: relative density = ¼ at 40000 ft)

work done = force x distance // power required = force x speed

lift = C_L. ½.φ.V^2.S // C_L = lift coefficient

total drag = C_D. ½.φ.V^2.S // C_D = drag coefficient

$\sqrt{load \cdot factor}$ = V_{Stall} increasing factor.

radius of turn (NM) = $\frac{TAS}{rate.x.60.\pi}$

angle of bank in rate 1 turn = $\frac{TAS}{10}$ + 7 (approximation)

radius of turn (m) = $\frac{V^2 (m/s)}{10 \times \tan \cdot bankangle}$

speed of sound (kt) = 38,94 $\sqrt{T}$ (Kelvin)

Mach no. (M) = $\frac{TAS(kt)}{LSS(kt)}$ (M is ratio and has no units)

"n" (load factor) = $\frac{1}{\cos \cdot bankangle}$

ATPL formulas - Aviation law / Operational procedures

ATS comprises 3 services;

1. Air Traffic Services; Area Control Service / Approach Control Service / Aerodrome Control Service
2. Flight Information Service
3. Allerting Service

Controlled airspace;
Class A: most airways, important control zones and control areas (IFR only).
Class B: upper airspace → IFR and VFR permitted (controlled).
Class C: IFR + VFR (controlled) → IFR is separated from IFR and VFR, VFR is separated from IFR and receive traffic information about other VFR.
Class D: IFR + VFR (controlled) → IFR is separated from IFR and receive traffic information in respect of VFR flights. VFR receive traffic information on all other flights.
Class E: IFR + VFR permitted; IFR with air traffic control service and are separated from other IFR. All flights receive traffic information as far as practicable (no control zones).
Class F: IFR + VFR permitted; IFR flights receive air traffic advisory service and all flights receive flight information service if requested.
Class G: IFR + VFR permitted and receive flight information service if requested.

air traffic control service: IFR→ A, B, C, D and E / VFR→ B, C and D + all aerodrome traffic at controlled aerodromes.

aerodrome reference codes (first element);
1=< 800M / 2=800-1200M / 3=1200-1800M / 4=>1800M

braking action: 0,4=good(5) / 0,39-0,36=medium to good(4) / 0,35-0,3=medium(3) / 0,29-0,26=medium to poor(2) / <0,25=poor(1)

MSA = 1000 ft clearance within 25NM.

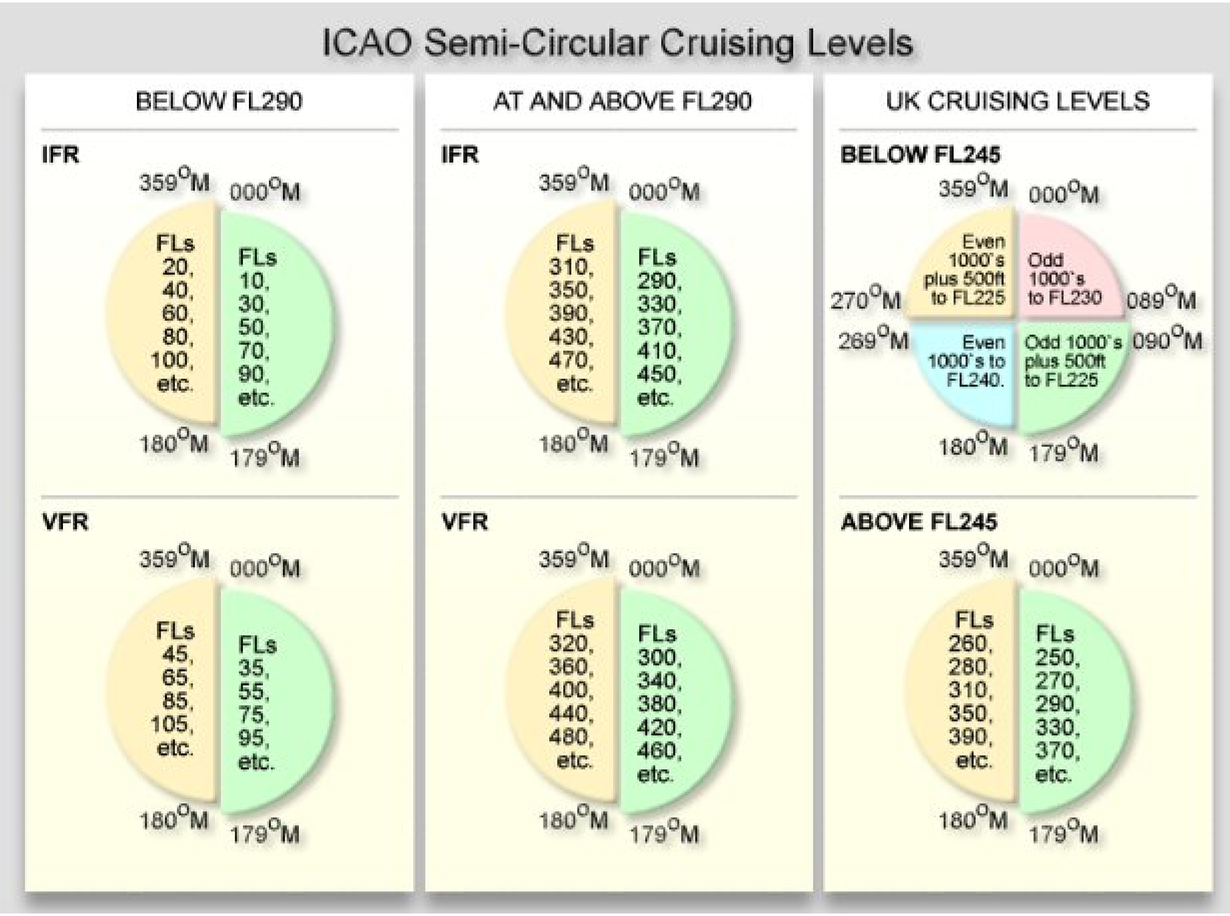
speed categories are calculated as 1,3 x stall speed in landing configuration.
A= < 91kt / B= 91-121kt / C=121-141kt / D=141-166kt / E=166-211kt

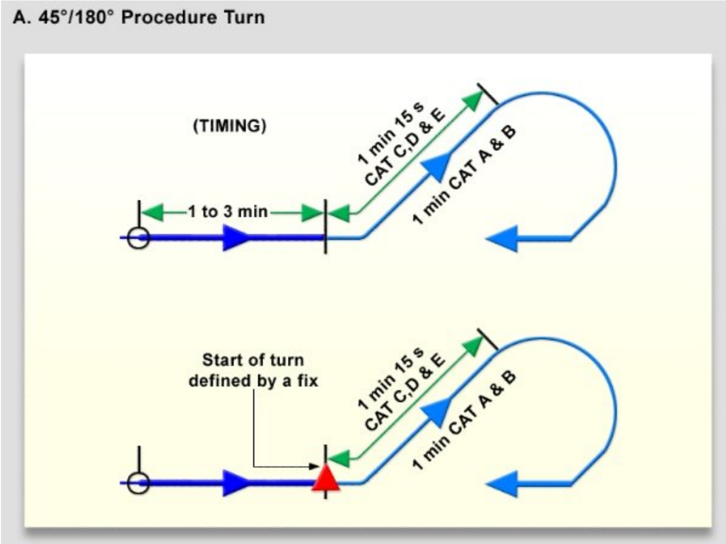
approach segment → arrival / initial / intermediate / final / missed approach.

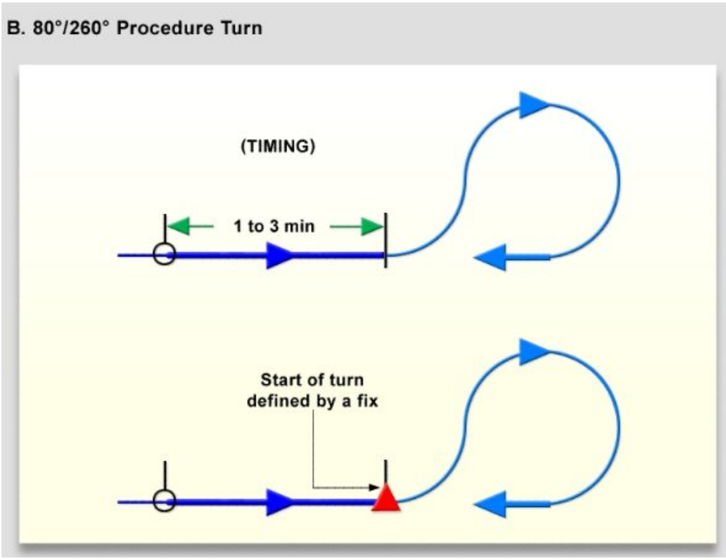
Arival → ends at IAF.
Procedures are used to direct the aircraft. 45°/180° procedure turn // 80°/260° procedure turn // base turns // race track procedure.
Initial → IAF to IF (intermediate fix).
Intermediate → obstacle clearance reduces from 1000ft to 500ft in the primary area.
Final approach → begins at FAF and ends at MAPt (missed approach point).
Missed approach → must be initiated if the visual references are not obtained by the time the aircraft reaches the MAPt.

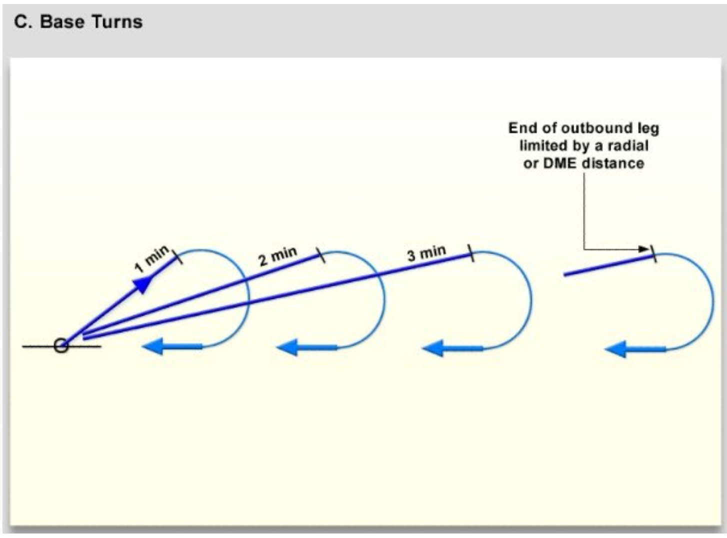
Airspace Class	F&G only at below 900m (3000ft) AMSL or 300m (1000ft) above terrain, whichever is the higher	All other classes and conditions
Distance from Cloud	Clear of cloud and in sight of the surface	1500m horizontally 300m (1000ft) vertically
Flight Visibility	5km*	8km at and above 3050m (10,000ft)AMSL 5km below 3050m (10,000ft) AMSL

CLASS	TYPE OF FLIGHT	SEPARATION PROVIDED	SERVICE PROVIDED	SPEED LIMITATION	RADIO COMMS REQUIREMENT	SUBJECT TO AN ATC CLEARANCE
A	IFR only	All Aircraft	Air Traffic Control Service	Not Applicable	Continuous Two-Way	Yes
B	IFR	All Aircraft	Air Traffic Control Service	Not Applicable	Continuous Two-Way	Yes
	VFR	All Aircraft	Air Traffic Control Service	Not Applicable	Continuous Two-Way	Yes
C	IFR	IFR from IFR IFR from VFR	Air Traffic Control Service	Not Applicable	Continuous Two-Way	Yes
	VFR	VFR from IFR	1) Air Traffic Control Service separation from IFR; 2) VFR/VFR traffic information (and traffic avoidance advice on request)	250 kt IAS below 3,050 m (10,000 ft) AMSL	Continuous Two-Way	Yes
D	IFR	IFR from IFR	Air Traffic Control Service, traffic information about VFR flights (and traffic avoidance advice on request)	250 kt IAS below 3,050 m (10,000 ft) AMSL	Continuous Two-Way	Yes
	VFR	Nil	IFR / VFR and VFR / VFR traffic information (and traffic avoidance advice on request)	250 kt IAS below 3,050 m (10,000 ft) AMSL	Continuous Two-Way	Yes
E	IFR	IFR from IFR	Air Traffic Control service and, as far as practical, traffic information about VFR flights	250 kt IAS below 3,050 m (10,000 ft) AMSL	Continuous Two-Way	Yes
	VFR	Nil	Traffic information as far as practical	250 kt IAS below 3,050 m (10,000 ft) AMSL	No	No
F	IFR	IFR from IFR as far as practical	Air Traffic Advisory Service; Flight Information Service	250 kt IAS below 3,050 m (10,000 ft) AMSL	Continuous Two-Way	No
	VFR	Nil	Flight Information Service	250 kt IAS below 3,050 m (10,000 ft) AMSL	No	No
G	IFR	Nil	Flight Information Service	250 kt IAS below 3,050 m (10,000 ft) AMSL	Continuous Two-Way	No
	VFR	Nil	Flight Information Service	250 kt IAS below 3,050 m (10,000 ft) AMSL	No	No

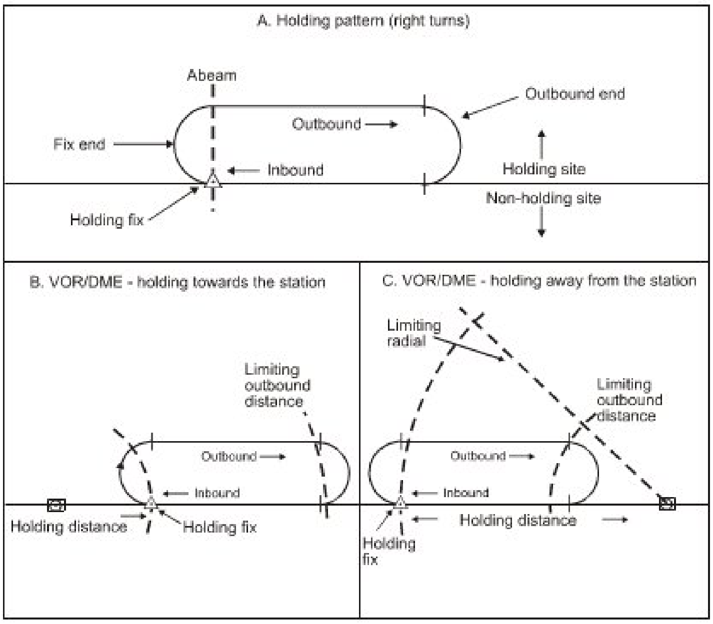



A. 45°/180° Procedure Turn
(TIMING)
1 to 3 min
1 min 15 s
CAT C,D & E
1 min CAT A & B
Start of turn
defined by a fix
1 min 15 s
CAT C,D & E
1 min CAT A & B

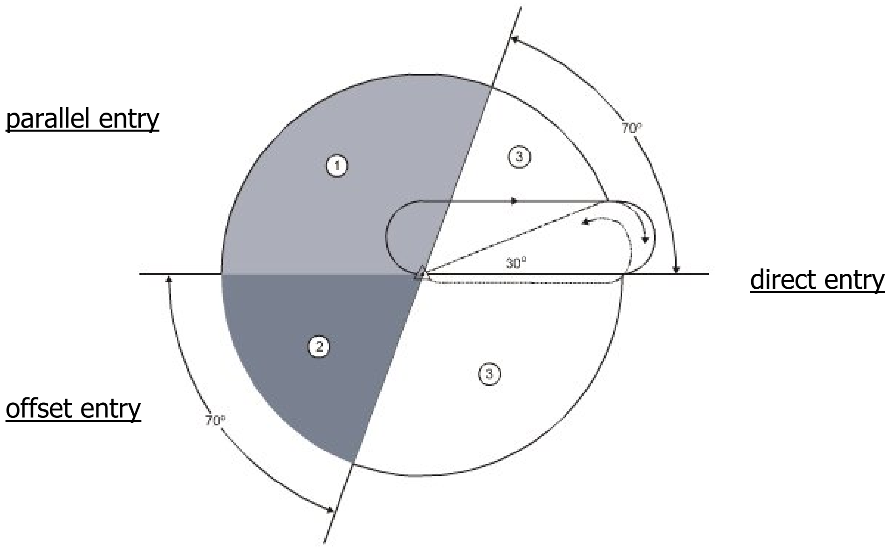

B. 80°/260° Procedure Turn
(TIMING)
1 to 3 min
Start of turn
defined by a fix


C. Base Turns
End of outbound leg
limited by a radial
or DME distance
1 min
2 min
3 min

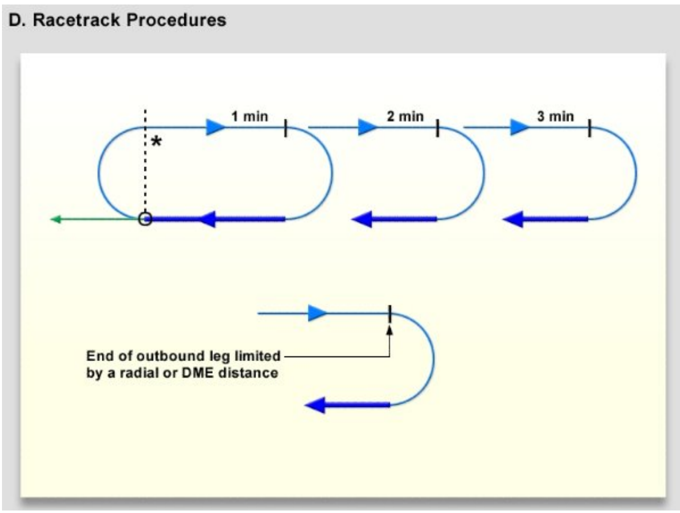
Shape and terminology associated with right turns holding pattern



Entry sectors



5° zone flexibility either side of the boundaries



landing categories

category	aircraft minima; DH / RVR
I	200 ft on barometric altimeter / RVR > 550 m
II	100 ft on radio altimeter / RVR 300 m
III A	0 ft on radio altimeter / RVR 200 m
III B	0 ft on radio altimeter / RVR 75 m
III C	0 ft on radio altimeter / RVR 0 m

jets must be able to land in 60% and turboprops in 70% of the LDA.

contaminated runway = > 25% of surface area is covered by;
>3mm of water or equivalent deep slush/snow.
compressed snow to solid mass.
ice incl. wet ice.

runway is considered wet → < 3mm water without significant areas of standing water.

class B aircraft → must be able to land in 70% of LDA, slope is taken into account.

net performance is worse than gross (Gross= 50:50 chance of better/worse).

NAT-OTS → eastbound Z-A, bottom to top (red eye) 01:00 to 08:00 hours
westbound A-Z, top to bottom 11:30 to 18:00 hours

heavy>136000kg / medium= 7000kg – 136000kg / light<7000kg.

thrust ≠ power → power = thrust x speed

V_{IMD} = where profile drag = induced drag → alpha = constant = 4°

TODA = TORA + clearway. Some runways have an overrun called "stopway".

ASDA = EDA (emergency distance available) = TORA + stopway.

balanced field : TODA = ASDA.

IAS → (position/instrument error) → **RAS/CAS** → (compressibility) → **EAS** → (density) → **TAS.**

V_R > 1,05 V_{MCA} (one engine out). V_{MC} is highest where the air is cold and dense (asymmetric thrust is greatest).

V1 = decision speed.
V2 = safety speed = target speed to be attained at the screen height (35ft/15ft) with OEI.
V3 = all engines speed at the screen (between V2 and V4).
V4 = all engine initial climb speed (V2 + 10kt).

class A jets must land in 60% of LDA, Turbo props and class B in 70%.

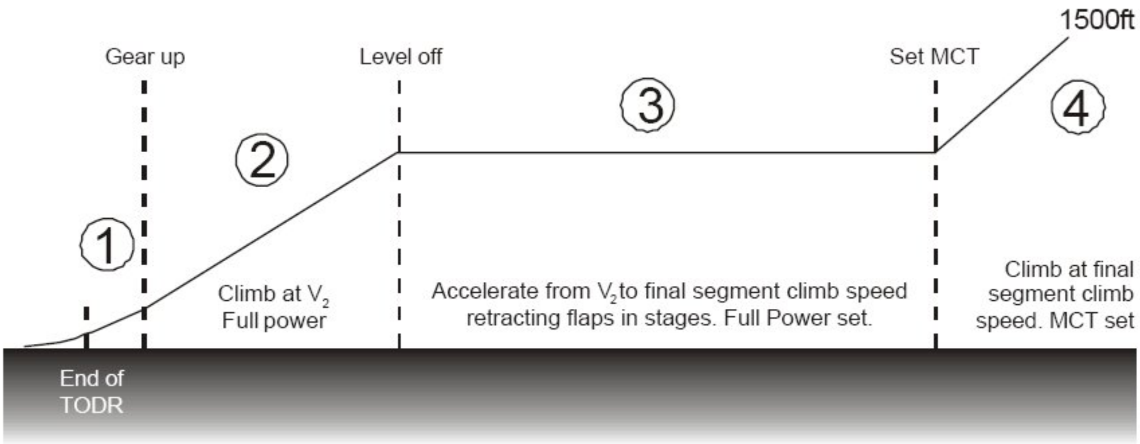
LDA x 60% = Gross LDR.

hydroplaning speed (kt) = $9\sqrt{P(psi)}$ (bar x 14,5 = psi).

braking coefficient	braking action	snowtam
0,4 >	good	5
0,39 – 0,36	medium to good	4
0,35 – 0,30	medium	3
0,29 – 0,26	medium to poor	2
0,25 <	poor	1

climb gradient = $\frac{rate \cdot of \cdot c\lim b \times 6000}{TAS \times 6080}$

The first segment lasts from 35ft to the point where the gear is retracted, the second segment lasts until flap retraction height at which point the aircraft is levelled and an accelerating third segment is flown whilst the flaps are retracted.



Net Take-off Flight Path

F = force (lbs) / A = area (sq in – in^2) / P = pressure (psi) → bar x 14,5 = psi

P = $\frac{F}{A}$

V = I x R // P = I^2 x R // P = V x I

hydroplaning speed (kt) = $9\sqrt{P(psi)}$ (bar x 14,5 = psi)

F (Hz) = rpm x pole pairs x 60

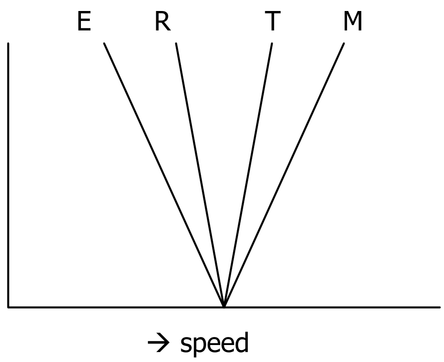
force = mass x acceleration // momentum = mass x velocity // work = force x distance

Power = $\frac{work}{time}$

the ratio of air to fuel which ensures complete combustion = 15:1 by weight.

manifold pressure is absolute pressure / boost pressure is relative to ISA pressure at sea level.

<u>speed diagram (with increasing altitude)</u>



E = EAS
R = RAS / CAS
T = TAS
M = mach number

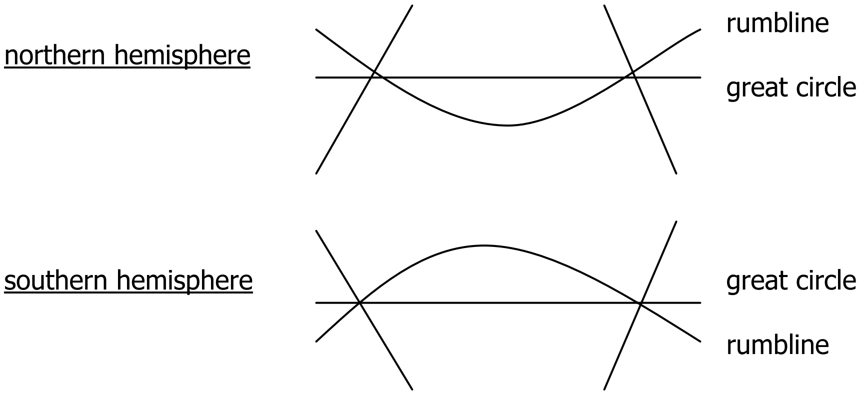
RAS/CAS is derived from ½ rho V^2

General navigation (ATPL)

departure (E/W) in NM = Δ longitude (in minutes) x cosine latitude

(earth) convergency = Δ longitude x sine mean latitude

conversion angle = ½ x convergency



Mercator projection; scale = scale x or ÷ cosine Δ latitude (x from equator / ÷ to equator)

simple conic / Lamberts projection
(chart) convergency = Δ longitude x sine latitude (or parallel of origin / constant of the cone)

Polar stereographic
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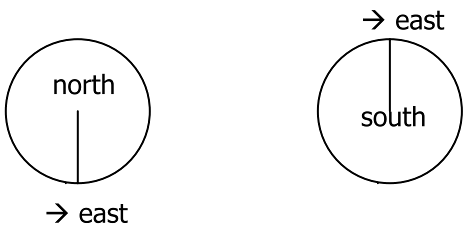

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glide path in ° = $\frac{...\%}{100}$ x 60

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distance to $CP = \frac{D \times H}{(O + H)}$ / D=distance between airfields → point of equal time, moving into the wind.

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QDM ± 180° = QDR (radial) / QDM = "bearings on the RMI"

NDB's → plotting more than 2° longitudinal difference, convergency should be taken into account.

C + Dev. = M + Var. = T → from magnetic to true to plot is algebraic sum, from true (plotline) to QDM/QDR is algebraic sum (VARIATION).

NDB bearing → move aircraft meridian to NDB and take aircraft position variation.

$$\frac{relative \cdot height(ft)}{depression \cdot angle} = \frac{range(NM)}{9,4}$$

true bearing = relative bearing + true heading

concave = hol // convex = bol

<u>Mercators projection</u> → light inside wire model of earth → developed cylinder, scale expands from equator.
scale = scale x or ÷ cosine lat. (from equator=x and to equator=÷)
RL are straight, GC concave to equator.

- not above/below 70° N/S.
- radio bearing connot be plotted; GC = concave.
- long distances connot be measured.
- shapes / angles are OK over small areas.

<u>simple conic projection</u> → parallel of origin; convergency correct.
(sine of parallel of origine = "N" = constant of the cone = convergency factor).

<u>Lamberts projection</u> → 2 standard parallels (scale correct).
1 parallel of origin (convergency correct).

- maximum spread of latitude 24°.
- parallel of origin is slightly closer to the pole from midway.

GC are nearly straight (slightly curved, concave to parallel of origin).
RL are nearly straight (slightly curved, concave to the pole).
scale within 1% constant // coverage 80°N to 80°S.

<u>Transverse mercator</u> → cylindrical projection with a meridian as its GC of tangency (central meridian).
convergency correct at central meridian and along the equator. usable within 350NM of central meridian.

<u>Oblique mercator</u> → GC of tangency is neither equator nor meridian (false equator of the projection).
for particular routes (one offs).

<u>Polar stereographic</u> → touches at pole. scale and convergency is correct at pole.
scale expand away from pole.
GC assumed right, actual curved concave to the pole.
RL concave to the pole.

before INS, GPS or Loran → ignoring compasses and flying gyro heading. maps were overlaid with a grid of lines indicating <u>gyro north.</u>
datum meridian = meridian where true north equals grid north.
convergency = difference between grid track and true track.

QFE = zero reading at airfield datum.
QNH = airfield elevation reading when on the airfield.
QFF = pressure observed at airfield datum reduced to sea level using ambient conditions.
QNE = height indicated at touchdown with 1013,2 mb setting. Used when QFE or QNH are outside the range of the subscale → high airfields.

density altitude = that altitude in ISA to which the actual density corresponds.

IAS → (position/instrument error) → **RAS/CAS** → (compressibility) → **EAS** → (density) → **TAS.**

If TAS > 300 kt → apply extra compressibility factor (always negative).

fluxgate detector (for remote reading compass) → not free to rotate.

Compass deviation;

P = longitudinal deviation component (magnetic force).
Q = lateral deviation component (magnetic force).
B = deviation coefficient (angle) due to P component (longitudinal).
C = deviation coefficient (angle) due to Q component (lateral).
A = fixed mis-allignment coefficient (independent of heading).

total deviation = A + B(sine heading) + C(cosine heading)

track made good = required track +/- track error angle.

drift = angle between track made good and heading.

bearing = direction from one point to another.

relative bearing is FROM fore/aft axis.

QUJ = true bearing to station.
QTE = true bearing from station.
QDR = magnetic bearing from station (radial).
QDM = magnetic bearing to station.

T I M E

plane of the elliptic = at 23,5° to the equator.
earth orbit is elliptical with the sun at one focus.
plane of the elliptic is approximately 66,5°.
solstice = sun highest/lowest point summer/winter.
23,5° S =tropic of Capricorn (21st of December) // 23,5° N = tropic of Cancer (21st of June).
equinoxes = 0°, day and night are equal length (spring and autumn).
aphelion = sun is furthest from the earth // perihelion = sun is closest to the earth.
sidereal = sterrentijd.

a transit = time taken between when the sun appears to pass overhead our meridian of longitude and the next transit is called a day.

length of a day→ varies not because the speed of rotation varying, or because of the tilt of the axis, but because the orbit is not symmetrical.

apparent solar day = the earth must turn trough more (or less) than 360° to get the sun overhead again.

mean solar day = an average of these long and short days (basis of our measurement of time).

the equation of time = difference between apparent and mean solar day.

mean sun= fictious body. mean day is the time between 2 successive transits of the mean sun = constant.

civil year = orbit around the mean sun = 365,24 days.

leap year = extra day (29th February) every 4 years (except whole century years unless it is devisable by 400).

time conversion = longitude west → Greenwich best
= longitude east → Greenwich least

a solar day is just under 365,25 days, the sidereal year just over // celestial body = hemellichaam

sidereal time (sterrentijd) and the first point of aries are also used to define the position of the sun, moon, planets and stars.

sub point = point on the earth immediately beneath a celestial body. can be defined using a system similar to lat and long. lat=declination and long=hour angle.

equinoctial = equivalent of equator (hemel equator).

hour angle is measured westward from 0° to 360°, with 3 different datums (**G**reenwich, **L**ocal and **S**idereal).
GHA / LHA / SHA (west from meridian to celestial body).
first point of aries = fixed datum in space.

LMT → is used to list the times of sunrise, sunset and twilight (schemering).

morning civil twilight = starts when the sun is 6° below the horizon and ends at sunrise.

evening civil twilight = starts at sunset and ends when the sun is 6° below the horizon.

66,6° N/S = sun does not rise in winter of the hemisphere.

64,5° N/S = sun does not set in summer of the hemisphere.

60,5° N/S = sun does not go as far as 6° below (in summer), there is continuous twilight between sunset and sunrise.

water vapour in atmosphere → mean quantity 1% (vary from 0 to 4%). Highest level low down troposphere, areas of high temperatures.

CO_2 absorbs long wave radiation from the earth.

O_3 (ozone) layer mainly in upper troposphere and lower stratosphere. plays major part in absorbing harmful ultra violet radiation from the sun.

rate of change of pressure with height is not linear (warm/cold).

ΔT in atmosphere only affects rate of pressure/density fall.

warm air mass = hogere hoogte druk // cold air mass = lagere hoogte druk.

S.L - 1013mb – 27 ft/mb // 18000 ft – 500mb – 48 ft/mb

in stratosphere temperature rises again due to ozone layer absorbs radiant energy from sun in the ultra violet band.

ozone layer = 18-30 KM

troposphere-(t-pause)-stratosphere-(s-pause)-mesosphere-(m-pause)-thermosphere-(t-pause)
18km 50km 80km 150km

75% of atmosphere by weight lies below tropopause.

tropopause; poles → 7,6 km / -45°C
mid latitude → 12,2 km / -55°C
equator → 16,8 km / -75°C

standard atmosphere temperature drop = 1,98 °C/1000ft to 11km at -56,5°C

QFF = pressure displayed on surface isobar charts.
= station pressure adjusted down to MSL using actual station temperature.

QNE = touchdown height indicated on altimeter if 1013mb is set.
= pressure altitude at touchdown point (used at high airfields).

[approximation]→ 4% height difference in true from indicated altitude for every 10°C air mass difference from ISA.

1 cal = 1 gram of water heated 1 k (specific heat)

long wave radiation → transfers a lot of heat out to the troposphere (from 100 units, 42 units) , 12 units by convection, latent heat 46 units.

wet bulb temperature → tells roughly how moist the air is and lies between DEW point and OAT
falls with 1,8 °C/1000ft.

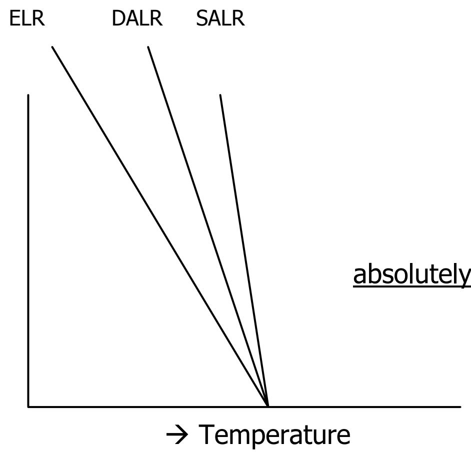
at 100% RH; DP, wet bulb and OAT are the same.

ELR = environmental lapse rate // adiabatic = no energy loss or gain

DALR = 3 °C/1000ft

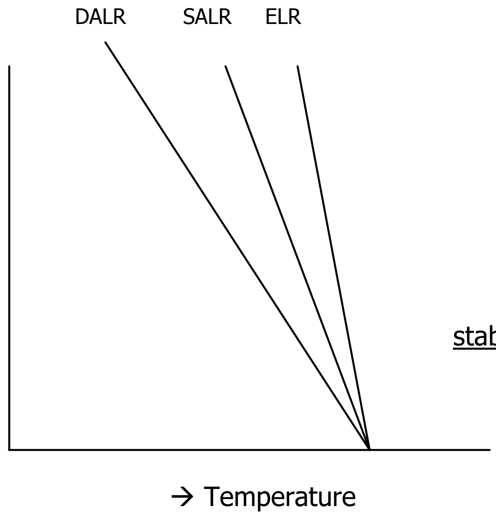
SALR = 1,8 °C/1000ft in temperate climates (not constant)

ELR>DALR and SALR



absolutely unstable air mass

ELR<SALR (and DALR)



stable air mass

when ELR is in between DALR and SALR, air mass is conditionally unstable.
* stable if rising air is dry.
* unstable if rising air is saturated.

triggers → some form of push or trigger is needed to get convection going.

→ orographic, thermal, frontal, non frontal convergence, turbulence.

inversions; at fronts / surface cooling at night / subsidence inversion / valley inversion.

pressure gradient force (PGF) = force that acts on a parcel of air at right angles to the isobars. the closer together, the stronger the PGF.

geostrophic force (GF) = (coriolis effect) → object not on the earth surface, seen by an air based observer, appear to turn right in the northern hemisphere and left in the SH.

geostrophic force = 2 x ῳ x ῄ x v Sine lat. (ῳ = earth rate of rotation)

geostrophic wind = steady state wind, free stream along the isobars. PGF=GF but opposed directed.

for the same isobar spacing, wind speeds are higher near the equator.

gradient wind = modified wind around pressure systems (curved isobars).

for gradient wind compared to the geostrophic wind → low round low, high round high.

inside 15° lat., the geostrophic wind scale does not work, so tropical winds are calculated, not measured. these winds are called cyclostrophic winds.

surface winds are measured 10M above the ground.

laminar boundary layer = 1000ft to 1500ft thick (by convention).

turbulent boundary layer = 2000ft thick (by convention).

wind change in boundary layer → N.H. direction change from 250° to 240° is said to be backing.
S.H. direction change from 10° to 20° is said to be veering.

by day (free stream to surface in NH)			by night	
	deg. backed	***free stream***	***deg. backed***	***free stream***
over land	30	50%	40	30%
over sea	10	70%	10	70%

isallobars = lines that join places with equal rate of change of pressure.

isallobaric effect → acknowledges that air flows into a low and out of a high across the isobars (correction needed when pressure is changing).

temperature rise föhn effect = (lee cloud base – windward cloud base) x 1,2

katabatic wind = flow down the sides of hills and mountains at night or very cold days with no strong gradient wind to hide the effect (Bora in Rhone valley).

anabatic wind = blow up the sides of hills and mountains on hot days during the day. air heated by conduction tend to convect straight up rather than follow the slope of the mountain anabatic winds only show when there is a gentle gradient wind flowing onto the slope which is than enhanced by the anabatic effect.

sea breeze = right angle to beach → land unless either 15 kt, after 15:00 LMT or "fully developed" is stated → then along the beach, low pressure (land) on the left (NH!).

thermal component / thermal wind vector → direct result of mean temperature differences in air mass aloft.

the high level wind is the vector sum of the low level wind and the thermal component (thermal wind vector).

contour charts = height of particular pressure level / isohypes = contour lines.

thickness charts = vertical extend between 2 pressure levels (show more clearly the distribution of temperature in the atmosphere as variations in mean sea level pressure are removed.

isopleths = lines of equal thickness.

cold pool = isopleths indicating cold air and also forming closed circles.

jet stream = a strong narrow current of air on a nearly horizontal axis in the upper troposphere or lower stratosphere exceeding 60 kt, characterised by strong lateral and vertical windshear (CAT).

jets will be found in the warmer air at or just below the warm air tropopause, but on surface charts will APPEAR to be on the cold side of the deviding line (due to slope cold/warm).

westerly and easterly waves → distributed by large landmasses or high mountains.
- in SH no really significant land blocks south of 30° except the Andes range in Chile and the southern Alps in New Zealand.
- in NH → Rocky mountains in North America and the Himalayan in Asia.

so big westerly waves only in the NH.

easterly upper flow is generally light and significant waves are rare. the one known instance occurs over Africa at around latitude 15° - 20° north in July to September → reaching jet speeds having been accelerated by the monsoon season in north India.

can affect surface pressure over West Africa, producing a series of large line squalls of CB drifting out toward the Caribbean.

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cloud base > 6500 ft a.g.l. = "medium" (alto) → temperate latitudes.
> 16500 ft a.g.l. = "high" (cirro) → temperate latitudes.

single cell CB
- development phase 15-20 min (→ total 2 hours travelling with 10000 ft wind, 700 mb).
- developing, mature and dying stage.
- general upward movement of 3000-4000 ft/min.
- tops have been measured rising with 5000 ft/min.
- active period < 1 hour (mature stage 30-40 min).

super cell thunderstorm → conditions; warm air below, cold dry air aloft with strong upper winds (usually between sub-tropical and polar air).

jet stream CAT → maximum CAT at a jet stream is found level with or just below the height of the jet core, in the warm air but on the cold side of the jet.

microburst = extreme form of windshear generated by the slug of descending air from a thunderstorm cell. downdrafts 3000-4000 ft/min possible. floating in opposite directions when hitting the ground with 50 kt vector change in service wind over a few km. last only minutes.

gust front = cold downdraft wind in front of thunderstorm. produce roll cloud up to 6000 ft / 24-32 km ahead of the storm.

LLWAS = low level wind shear alert system (anemometers surrounding the airfield or doppler radar, directly measuring wind vectors).

<u>wind shear at inversions and at the boundary layer</u> →
* free windstream of 40 kt, turbulence in the boundary layer and 20 kt groundwind + 40° heading difference.
* a vector difference between surface and free stream wind of 40 kt.
* a temperature inversion of > 10° in the first 1000 ft a.g.l. → completely isolating surface wind from free stream wind.
* presence of a turbulence inversion.

standing waves (+mountain waves, lee waves) → maximum turbulence is at the height of the ridge and one wavelength down (5-10 NM).

wake turbulence clearance → 2 minutes or 4NM for heavy behind heavy.

no icing above 0°C or below -45°C, clear ice near 0°C, rime near -25°C.
0°C → highest proportion of dangerous clear ice in cloud.

radiation fog → surface cools at night due to long wave radiation and the cold surface cools the air in contact by conduction.
advection fog → when a warm moist air mass moves over a cold surface. high wind can lift advection fog to low stratus or clear it all together by mixing.
arctic smoke → the reverse mechanism from advection fog. cold air passes over a warm surface. normally this triggers convection so a marked temperature inversion has to be present.

air masses → classification by their source region; polar/arctic/tropical and track classification; continental and maritime.

(PM) polar maritime → cool, moist, conditionally unstable air (convective cloud, showers and good visibility) → west-north/west.
(AM) arctic maritime → north.
(PC) polar continental → only in winter present for in summer the surface temperatures in the source region rises to 20-25°C and it becomes an area of mean low pressure.
(TM) tropical maritime → source is warm, moist, and stable. Azores high → south-west.
(TC) tropical continental→ comes from Turkey and eastern Mediterranean in summer where it is stable and hot but not particular dry. → summer air mass but summer extends to the autumn in practice.

cold fronts and cold occlusions move at roughly the speed directly taken from the geostrophic wind scale. warm fronts and warm occlusions move slower at approximately 2/3 of the speed.

thermal equator = line of maximum surface temperatures ≈ equatorial trough ≈ ITCZ.

transitional zones → circulation patterns and the weather moving with the thermal equator producing zones that have one type of weather in the summer and another in winter.

0°C at equator ≈ 16000 ft.

doldrums = exist at the ITCZ only when it is near the geographical equator = band of light and variable winds.

ITCZ ≈ between 30 NM and 300 NM wide → when moving, worst weather on the trailing side.

TRS = tropical revolving storm (sea water >26°C) → 64 kt sustained wind or more.

* polar climate → 65° - 90° lat. = polar high with dry, stable descending air cold settled conditions often displaced by travelling depressions. surface is icecap or tundra.
* disturbed temperate climate → 40° - 65° lat. = weather is dominated by travelling depressions with occasional high pressure systems. precipitation is high with mostly westerly winds.
* temperate transitional climate→ 35° - 40° lat. = a boundary zone which experiences the disturbed temperate climate in winter and the drier subtropical conditions in summer (mediterranean climate).
* arid subtropical climate → 20° - 35° lat. = continuous subtropical highs. generally fine weather. dessert regions predominate in these areas.
* tropical transitional climate → 10° - 20° lat. = mainly influenced by dry trade winds but in the summer of the hemisphere the belt of equatorial rain produces a distinct wet season (Savannah climate).
* equatorial zone → 10°S / 10°N lat. = influenced by the weather at the ITCZ, which moves north and south with the season. heavy rain and thunderstorms can occur throughout the year.

boreal climate zone → (dry climate zone) anomalous weather zone that occur only in the large landmasses of the NH → cool moist summers and very cold winters.

monsoon climate → on the sea borders of the major continental blocks. example; SW and NE monsoons of S/E Asia.

FIT = front inter tropical (French charts) = ITCZ.

the effect of thermal changes over the landmasses in winter and summer leads to the general statement that westerly jets are at their fastest leaving landmasses on the westside of the major oceans. the effect is most marked for sub-tropical jets in the winter of the hemisphere and for polar front jets in the summer.
jets slow and stabilize when running over large areas of open water.

AFTN = aeronautical fixed telecommunications network → via fax and telex.
MOTNE = (Europe) meteorological operational telecommunications network Europe.

MIST = meteorological information standard terminal → full meteorological service for national and international flights at most airports.

WAFS = world area forecast system (Bracknell, Frankfurt and Paris).

ICAO 3 weather domains - LL (FL100-250), ML (FL250-450), HL (FL450-600).

sigmet = validity is 4 hours, volcanic ash warnings may be valid for up to 12 hours.

general warnings = fog, normally for visibility < 600 M.
strong winds > 33 kt or gusts 42 kt.

ASDAR = aircraft to satellite data relay (automatic aireps to WAFC Washington and Bracknell).

0000 vis < 50 M / 9999 > 10 KM → windshear in Metar when below 1600 ft.

few = 1/8 , 2/8
scattered = 3/8 , 4/8
broken = 5/8 , 6/8 , 7/8
overcast = 8/8

MSLPC = mean sea level pressure chart → general weather and the movement of weather systems.

high level significant weather chart → 3 hours before and after valid.

a satellite at 36000 km altitude will revolve around the earth once every 24 hours. if placed at launch over the equator, orbiting in the same direction as the earth's rotation, it will appear stationary. this is known as a geostationary orbit.

low orbit polar satellites that orbit from the North Pole to the South Pole at about 900 KM altitude giving bands of detailed imagery.

there is a ring of geostationary satellites around the equator. european meteorological images come from meteostat, a geostationary satellite at the equator on the Greenwich meridian and from polar orbit satellites.

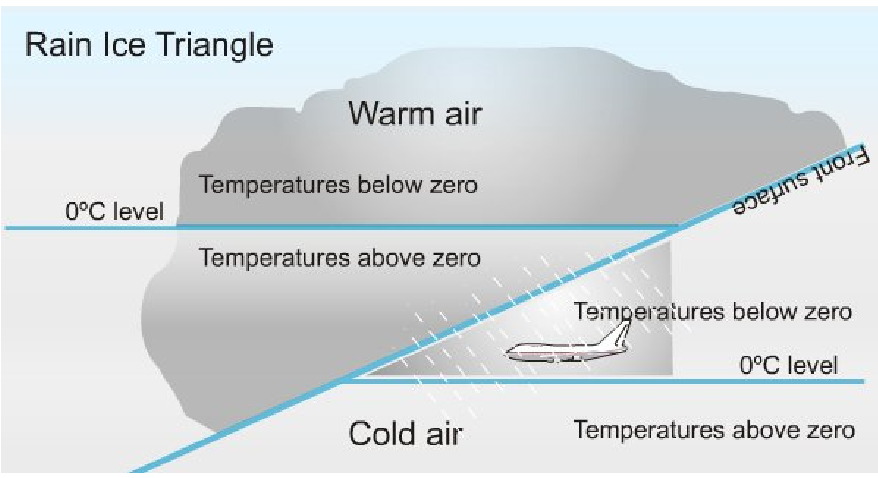
airborne weather radar = basic radar displays areas of greatest signal returns (greatest concentration of raindrops) → green, yellow and red on EFIS display. doppler radar on EFIS will add magenta indicating turbulence.

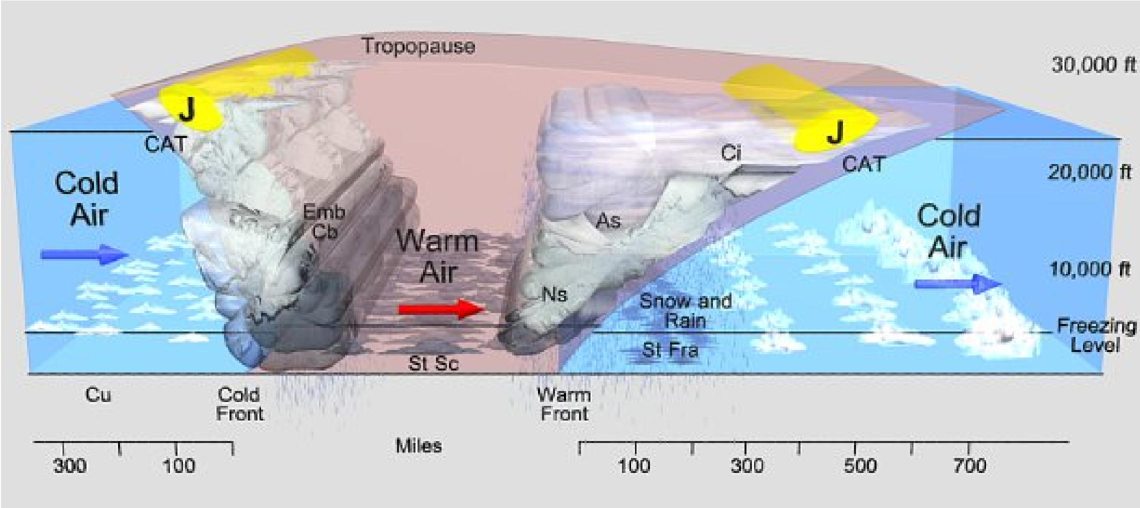
turbulence light=0-0,5G / moderate=0,5-1G / severe=>1G

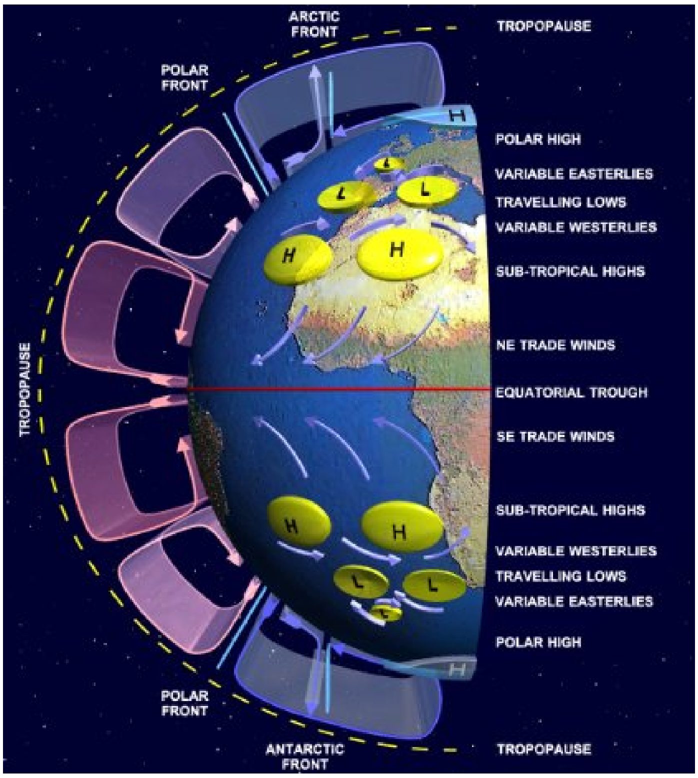
Weather chart symbols

	Thunderstorm		Rain
	Tropical cyclone		Snow
	Severe line squall		Widespread blowing snow
	Hail		Shower
	Moderate turbulence		Severe sand or dust haze
	Severe turbulence		Widespread sandstorm or duststorm
	Marked mountain waves		Widespread haze
	Light aircraft icing		Widespread mist
	Moderate aircraft icing		Widespread fog
	Severe aircraft icing		Freezing fog
	Freezing precipitation		Widespread smoke
	Drizzle		Volcanic eruption

	Cold front at the surface
	Warm front at the surface
	Occluded front at the surface
	Quasi-stationary front at the surface
	Axis of trough
	Axis of ridge
	Convergence line
	Inter-tropical convergence zone




Tropopause
30,000 ft
J
J
CAT
CAT
Ci
20,000 ft
Cold
Air
Emb
Cb
Warm
Air
As
Cold
Air
10,000 ft
Ns
Snow and
Rain
Freezing
Level
St Fra
St Sc
Cu
Cold
Front
Warm
Front
Miles
300
100
100
300
500
700


ARCTIC
FRONT
TROPOPAUSE
POLAR
FRONT
POLAR HIGH
VARIABLE EASTERLIES
TRAVELLING LOWS
VARIABLE WESTERLIES
SUB-TROPICAL HIGHS
NE TRADE WINDS
EQUATORIAL TROUGH
SE TRADE WINDS
SUB-TROPICAL HIGHS
VARIABLE WESTERLIES
TRAVELLING LOWS
VARIABLE EASTERLIES
POLAR HIGH
TROPOPAUSE
POLAR
FRONT
ANTARCTIC
FRONT
TROPOPAUSE


Polar
Disturbed Temperature
Temperate Transitional
Arid Sub-Tropical
Tropical Transitional
Tropical
Tropical Transitional
Arid Sub-Tropical
Temperate Transitional
Disturbed Temperature
Polar

Instrumentation

configuration error = position error.
manoeuvre error = rolling / pitching / yawing and random gusts.

TAT = SAT + kinetic heating (RAM rise).

K = recovery factor → measured TAT to true TAT   (SAT= OAT= COAT).

total head thermometer → also Rosemount probe.

angle of attack sensor = vane sensor or pressure sensor.

accelerometer = load factor sensor.

ASI → only calibrated to ISA MSL density.
static blockage of ASI → over reads.

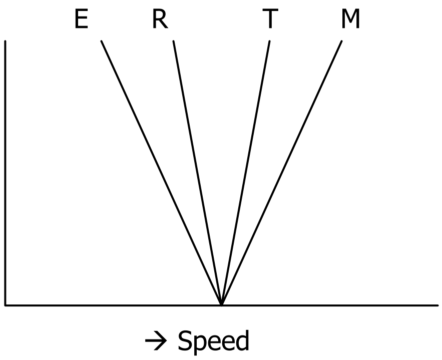
altimeter → calibrated to ISA temperature/pressure/density for all heights (non linear linkage).

hysteresis error = capsule in altimeter is not perfectly elastic so will distort differently for large increases / decreases in altitude.

sensitive altimeter = increasing sensitivity by having a stack of 2 or more capsules.

mach meter = ASI + altimeter interacting in the same case (ratio arm → ranging arm → indicator).
only instrument and pressure error (very small so indicated can be taken to be true).
density and temperature errors are self compensated.

speed diagram (with increasing altitude)



E = EAS
R = RAS / CAS
T = TAS
M = mach number

RAS/CAS is derived from ½ rho V^2

ADC = air data computer. feed→ pitot / static / TAT→ output to servo driven instruments.

gyroscopes → planes of freedom → space gyro = 3 planes of freedom (= 2° of freedom).
gimbal = gyro frame, at least 1 gimbal for every axis (cardanische ring).
degrees of freedom = planes of freedom – 1 (axis of rotation).

tied gyros = external influence controlling the direction of the spin axis.
- directional gyro = axis tied to the horizontal.
- artificial horizon = axis tied to the earth's gravity.

rate gyro = rate of turn indicator → freedom of movement in plane of rotation and one more plane 90° to the first.

azimuth = hoek met meridiaanvlak.
drift = when spin axis turns in earth horizontal plane.
topple = when axis tilts in any earth vertical plane.

real wander = spin axis moves away from its initial defined orientation in space.
apparent wander = orientation in space has changed while the gyro's orientation has not.
transport wander = If gyro is aligned to north on one part of the earth and then moved to another.

latitude nut wander = 15 x sine latitude (NH= +) in °/hour

earth rotation wander = 15 x sine latitude (NH= -) in °/hour

$$transport \cdot wander \equiv \frac{E/W \cdot GS \times Tan \cdot Latitude}{60}$$ (NH= E= - / W= +)

total drift = real wander + earth rotation + latitude nut wander + transport wander.

turn indicator=
- one degree of freedom (2 planes of freedom) thus one gimbal.
- rate gyro.
- spring force produces a secondary precession equal to and in the same direction as the yaw.
- looping error (when rapidly pitched nose up).
- are calibrated to show rates of turns correctly in balanced turns for rate 1, 2 and 3 at specific angle of bank and and TAS.
- gyro turns away from pilot → reason= this way at balanced turn the gyro precesses in opposite roll→ axis approximately horizontal thus more sensitive to turn rates.
- errors→ vacuum leak= under reading / feed failure= no reading.

rate 1 turn = 180°/min (3°/S)
rate 2 turn = 360°/min (6°/S)
rate 3 turn = 540°/min (9°/S)

angle of bank required for rate 1 turn = $\frac{TAS}{10} + 7$

radius of the turn (NM) = $\frac{TAS}{rate \times 60\pi}$

turn coordinator is a development of the turn indicator. the gimbal is raised at the front by 30°, thus instrument is sensitive to both roll and yaw → only indicates rate 1 turns accurately. unfortunately can easily be confused with the artificial horizon→ therefore warning "no pitch information".

RLG = ring laser gyro = relatively new technology, mainly present in IRS (inertial reference system).
RLG → "dither" is there to correct a specific problem.

rate integrating gyro (RI) → where extreme accuracy is required (gimbal gain). one degree of freedom, 2 planes of freedom. sensitive to "cross coupling".

in a strap down IRS, 3 RLG are mounted at right angles to each other and the whole set is fixed to the aircraft frame.
the system measures all rotations about the 3 axis giving a very accurate readout of aircraft attitude with reference to a space datum.

aclinic line = magnetic equator (no (in)cline) / isoclinic = lines joining points of equal dip.
DIP = angle between earths horizontal and resultant force.

aperiodic = fully damped system.

acceleration error = due to dip, CG in pendulous suspension system is not exact underneath the pivot.

in NH an E/W acceleration produces an apparent turn to north (in SH the other way around).

turning errors are a function of dip so zero on aclinic line and significant up to 35° N/S.
turns through the near pole; LAG // through the far pole; LEAD.

compass deviation;

P = longitudinal deviation component (magnetic force).
Q = lateral deviation component (magnetic force).
B = deviation coefficient (angle) due to P component (longitudinal).
C = deviation coefficient (angle) due to Q component (lateral).
A = fixed misalignment coefficient (independent of heading).
Total deviation = A + B(sine heading) + C(cosine heading).

compass card = deviation table.

fluxgate detector = measuring of earth magnetic field (not free to rotate).

selsyn system = "self synchronising" system.

G4F = single display system (gyro corrected continuously by selsyn transmission system).

G4B = remote repeater system (adds a master control unit to the gyro unit). Has the ability to feed headings to other remote systems like AP.

Com + Dev = Mag + Var = True

INS = inertial navigation system (=IRU or IRS).

acceleration → (first integration) → speed → (second integration) → distance.
inertial accelerometers detect linear acceleration (E and I bar system).

1e stable platform system → the platform the accelerometers are mounted on are kept level and aligned to north and measure acceleration relative to the platform.

2e wander angle system → only keeping it level and detecting how far it is out of alignment to north.

3e strapped down system → not worrying about either level or north alignment. just detecting how far out of alignment and out of level at initialisation and than monitor any changes.
alignment takes approximately 5 to 10 minutes dependent upon latitude.

gyro compassing = aligning of the stable platform with true north (takes about 15 minutes).

INS cockpit equipment = MSU (mode selector unit) // CDU (control display unit).

IRS (inertial reference system) uses 3 accelerometers and 3 ring laser gyros.

bounded errors do not increase with time, unbounded do.

both strapped down and stable platform systems suffer from Schuler errors.
the Schuler cycle is a damped 84,4 minutes.

power failure → if power is lost, alignment is lost and the NAV function will not work again.
older stand alone INS units → no more than 3 NM/hr drift typically allowed.

FDF (primary flight display) = EADI (electronic attitude director indicator).

ND (navigation display) = EHSI (electronic horizontal situation indicator) // SG = symbol generator.

EFIS colour coding
- green =active or selected mode, changing conditions.
- white = present situation and scales.
- magenta = command information, weather radar turbulence.
- cyan (blauw) = non active and background information.
- yellow = caution.
- red = warning.
- black = off.

ECAM = electronic centralised aircraft monitoring (airbus EICAS).
E/W = engine warning system.

APFDS → auto pilot flight director system. consists of auto pilot, FD system, auto throttle and yaw damper.

function of the outer loop is to control, inner loop to stabilize.
stability functions are yaw damper, pitch attitude and roll attitude
system gain is higher at low speed.

CMD = full auto pilot control // CWS = control wheel steering (outer loop control).

EPR = engine pressure ratio = designation of engine power output.
N1 = fan speed as a percentage (B737).

<u>auto land;</u> fail active system = allows the approach to continue after a single failure.
fail passive = 2 systems total.

CAT III = full auto lands → glide slope signal is disconnected at 45ft radio height.
CAT II/III use DH based on radio height.

<u>warnings or level A alerts</u> = require immediate crew action.

<u>caution or level B alerts</u> = require immediate crew alertness and possible future actions.

<u>advisory or level C alerts</u> = require crew alertness only.

radio altimeter; active from 2500ft down to ground level.
transmit a 30° cone down.
SHF between 4200MHz and 4400MHz described as FM.
the difference between transmitting and returning, the beat frequency, is measured.
accuracy = 1ft or ±3% (the greater of them).

TAWS → terrain awareness warning system.

GPWS mode 1; active 2450ft radio to 50ft and when barometric descent> 3x radio height ("sink rate" / "pull up" warning).
mode 2; triggered by reducing radio altitude and warns of raising ground ("terrain" warning).
mode 3; warns of barometric height loss after TOGA (flaps and gear not in approach configuration) ("don't sink" warning).
mode 4; warns of closeness to the ground without the appropriate gear/flap selection ("to low terrain" warning when at high speed and "to low flaps" at lower speeds).
mode 5; deviation below glide slope ("glide slope" warning).
mode 6; height and bank angles call outs designed to increase situational awareness (not required by JAR OPS).
mode 7; provides wind shear alerts and warnings (not required by JAR OPS).

stall warning = alpha sensor (vane or based on pressure).

TCAS = ACAS (airborne collision avoidance system).

TA = traffic advisory "traffic traffic" // RA = resolution advisory.
RA = crew response is to follow the instructions smoothly and promptly. pilot must inform ATC of deviations from clearances ASAP.

TCAS inputs → mode S replies / ADC for FL / IRS for attitude / flap position / radio altimeter.

(D)FDR = flight data recorder // CVR = cockpit voice recorder.

TGT= turbine gas / EGT= exhaust gas / TIT= turbine inlet / TET= turbine entry / JPT= jet pipe (700/1000°C).

thermo couples; dissimilar metals can create an electrical potential at their junction which is proportional to the temperature. (thermo EMF) → high temperatures.
galvanometer = millimetric voltmeter.
optical or radiation pyrometers → really high temperature measurement.

* direct tachometers = need to be near the cockpit.
* DC tachogenerator = output a voltage that varies with engine speed (wear and sparks).
* single phase tachogenerator = rectified to DC (no wear and sparks).
* three phase tachogenerator = frequency output that varies with speed.
* induction tachometer = suitable for high speeds (use a phonic wheel) digital output.

synchroscope = 1 master engine as reference.

pressure gauges = elastic pressure sensing elements are used.

MAP = manifold air pressure is an indication of the torque generated by the engine.
MAP measuring device = pressure bellows and fixed aneroid bellows working together.

EPR = engine pressure ratio.

FADEC = full authority digital engine control system.

capacitance systems = indicate fuel mass, not volume (=advantage).

fuel gauges always read zero after failure.

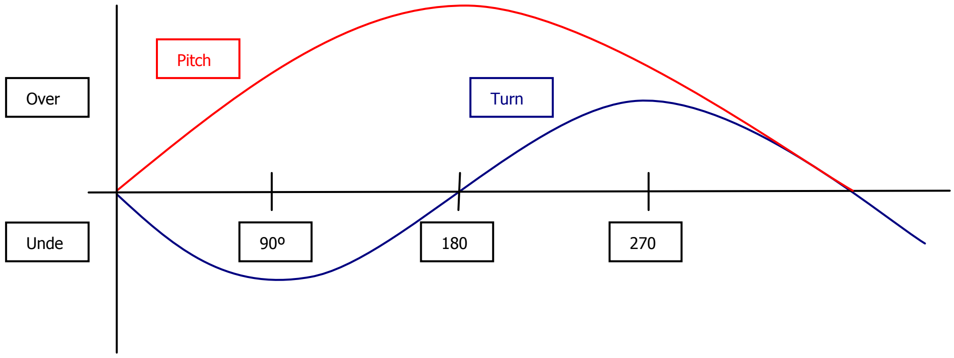
venturi flow indicator = accuracy ±2%.

variable orifice flow indicator → measuring volume but can be directed to mass flow using temperature sensitive resistors to compensate for density changes.

turbine volume flow indicators → turbine blades are built with magnetic inserts. the blades pass an induction coil in the casing. do not cope well with the large rate and temperature ranges on modern aircraft, these use a mass flow indicator.

mass flow indicator → meet massa traagheid van de vloeistof → speed x mass, so true mass can be indicated
- stator torque.
- rotor torque.

<u>attitude indicator (artificial horizon) turning errors</u>



speed of light = 300000 km/s

wave length $\lambda = \frac{C}{f}$ (C=speed of light in m/s / f=frequency in Hertz)

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surface attenuation → increases at higher frequencies.

ionospheric attenuation → increases as frequency decreases.

space waves = line of sight waves.

maximum (theoretical) range (NM) = $1{,}25\sqrt{H1} + 1{,}25\sqrt{H2}$ (ft)

surface waves → caused by diffraction and ground conductivity slowing the wave. are longest at low frequencies.

sky waves → refract from ionosphere → only reliable in HF band but present as interference in MF and LF.

D/E/F1/F2 layer → winter/day.

E/F layer → winter/summer day.

ionosphere is weaker at night (+ summer day more dense than winter day).

max skip distance (NM) = $1{,}43\sqrt{H}$ (of ionosphere in km)

atmospheric and surface attenuation = greatest at HF.

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ACAR = VHF data link between operator and aircraft.

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Mass and balance

1 M = 3,28 ft / 1 ft = 0,304 M / USG or IG = 8 pints or 4 quarts
1 IG = 1,2 USG / 1 USG = 3,785 L / 1 Kg = 2,2 Lbs

CG is usually in front of CP (centre of pressure).

CG moves forward → increases stability, fuel consumpsion and Vs (danger; making rotation and flare difficult).

CG optimum = near the aft limit.

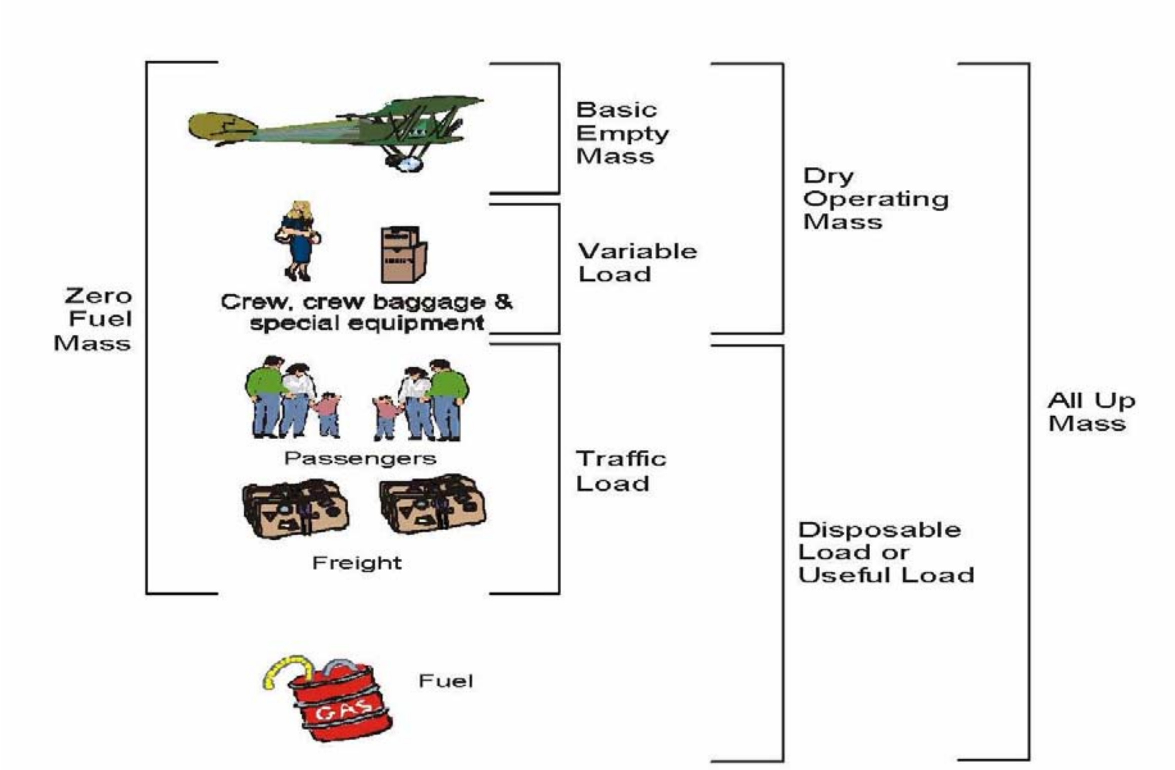
CG aft of the safe range → stability is decreased, aerodynamically unstable and will probably crash.

Vs (stallspeed) is proportional to the square root of the weight.

$$\frac{mass \cdot change}{old \cdot total \cdot mass} = \frac{change \cdot of \cdot CG}{distance \cdot from \cdot mass \cdot to \cdot new \cdot position}$$

Δ mass : old (new) mass = Δ CG : distance to new (old) CG

MAC = mean aerodynamic cord (CG is often expressed as a percentage of length from leading edge).



disposable load = bruikbare lading.

distribution load intensity = Kg/m^2 / floor running load = Kg/inch.

maximum permissible traffic load = MTOM – DOM – fuel on board
MTOM = maximum take of mass / MZFM = maximum zero fuel mass

MTOM	MZFM	MLM
MTOM DOM - fuel (total) -	MZFM DOM - -----	MLM DOM - fuel (div+res) -
maximum traffic load	maximum traffic load	maximum traffic load

maximum fuel load in MTOM => fuel = traffic load
maximum fuel load in MLM => fuel = traffic load (+ sector fuel)

transoceanic and polar flights → must meet specific MNPS.

MNPS = minimum navigation performance specification.

NAT OTS = north atlantic organised track system.
operating twice during 24 hour period - west bound system 11:30 to 18:00 UTC.
- east bound system 01:00 to 08:00 UTC.
crossing 30°W meridian; boundary between Shanwick and Gander oceanic control areas.

NAT → westbound tracks begins with A as the most northerly and continue vertically down B, C, D…… and so on depending on how many tracks are needed to accommodate the forcast traffic.

east bound tracks begins with Z as the most southerly and continue vertically upward with Y, X, W..etc.

MNPS separation → vertical 4000 ft (same direction) // 2000 ft (opposite direction).

RVSM → reduced vertical separation minima. possible for aircraft suitably equipped and approved (2000 ft / 1000 ft).

lateral separation = 1° = 60NM.

MSA = minimum sector altitude / minimum safe altitude → 1000 ft clearance within 25NM.

NAM = nautical air miles / GNM = ground nautical miles / SAR = specific air range (NAM per unit of fuel).

jet engines are most efficient around 90%.

best range jet = 1,32 x V_{IMD} (indicated minimum drag speed)

SFC = fuel flow : thrust

SAR (jet) = TAS : (SFC x drag)

best SAR (specific air range) is that altitude where 90% rpm gives 1,32 x V_{IMD} without accelerating.

best endurance altitude is above best range.

LRC (long range cruise) = 4% faster than still air best range speed and gives 99% of the range.

cost index in FMS = 00/200 → 00 = maximum range / 200 = minimum time.

aim to cruise within 2000 ft of the FMS optimum altitude.

optimum altitude increases as fuel burns off.

lower buffet boundary limit = 10% above Vs.
upper buffet boundary limit = onset of mach related buffet (M_{MO}).

ETOPS = extended time operations.

PSR or PNR → last point on a route at which it is possible to return to destination with sensible fuel reserves.

time to point of no return = $\frac{E \times H}{(O + H)}$ E = safe endurance / H = groundspeed home / O = GS out

the greatest distance to PNR/PSR is obtained in still air conditions.

ETP (equal time point) or CP (critical point) = for quickest way home determination.

distance to CP = $\frac{D \times H}{(O + H)}$ D = total track distance / H = groundspeed home / O = GS out

for engine failure calculations → take the less engine speed in formula!!

ACL = actual cruising level // CPA = closest point of approach.

accidents = 70% human errors.

72 beats/min (mean), adult at rest // 5 l/min of blood is pumped // breathing = approximately 16/min.

blood pressure normal = 100/60, maximum = 160/100.

21% oxygen in air (160 mmHg) // 14,5% oxygen in lungs (100 mmHg)

hyperventilation → increase in breathing→ reduction in CO_2→ change of acid balance (blood more alkaline)→ reduction of artery diameter→ lack of oxygen.

body unaided can cope with → +7 to +8G and -3G (z direction).

Boyle Marriott's law → volume of gas varies inversely with its pressure.

Henry's law → amount of gas dissolved in a liquid is proportional to the pressure over the liquid.

Dalton's law → total pressure of a gas is equal to the sum of the partial pressures.

atmosphere → 78% nitrogen, 21% oxygen, 0,9% argon, 0,03% carbon dioxide.

"grey out" → +3G(z) → also "tunnel vision".

rods = low lights, no colour // cones = sharp colour vision (photopic vision).

6/6 vision = you can see at 6m, what normal people can see at 6m.

- parallax = head movement cause distant objects to move relative to each other.

- perspective = converging parallels such as railway lines.

- relative size = distant objects are smaller.

- relative motion = closer moving objects move faster in angular terms.

- overlapping contours = objects in front of others must be closer.

- aerial perspective = scattering of light make distant objects appear blue.

colour blindness = 7% of all men / 0,1% of all woman.

night vision → pupil dilates / chemical within the rods→ vitamin A helps, probably B and C.

NIHL = noise induced hearing loss / high levels of noise → temporarily NIHL
unlikely at levels < 90dB / at 120dB discomfort / at 140dB pain / > 160dB drum maybe ruptured.
prolonged > 90dB can cause permanent damage.

sensory threshold = just noticeable difference (j.n.d.) = difference threshold.

somatographic illusion = pitch to be sensed under acceleration.

somatogyric illusion = "the leans", level flight seams banking.

vertigo = spatial disorientation (flicker vertigo is caused by flickering lights).

<u>vibration</u> 1-4 Hz → interference with breathing.
4-10 Hz → chest and abdominal (buikpijn).
8-12 Hz → back ache.
10-20 Hz → head aches, eye strain, pain in throat, speech disturbance and muscular tension.

BMI = body mass index = $\frac{weight(kg)}{(lenght \cdot in \cdot M)^2}$

5 stages of sleep → stage 1, 2, 3, 4 and paradoxical or REM sleep (rapid eye movement).

sleeping cycle = 90 minutes long, ± 4 to 5 REM stages.

EEG = electroencephalogram = measurement of brain activity.

paradoxic (REM) sleep increases during the night (4 to 5 cycles).

circadian = dagelijkse ritme.

westbound trans oceanic flights are easier to cope with than eastbound (red eye) flights.

the brain can only deal with one decision at a time.

cognitive illusions = misinterpretations of sensory inputs.

70% of the information we process enters via the visual channel.

perception is a highly subjective process.

bottom-up processing uses sensory information to start building a mental model.

top-down processing uses previous knowledge to modify the mental model.

expectancy or perceptual set = to some extend we perceive what we expect to perceive.

visual constancy = process of recognizing familiar objects even in unfamiliar conditions.

the sensory store; iconic memory stores visual information for ≈ 0,5 seconds.
ecoic memory stores auditory information for ≈ 8 seconds.

working memory; stores information for ≈ 15 – 30 seconds (= focus of consciousness)
contains the information you are consciously thinking about now.

maximum number of items that can be held in working memory = 7

long term memory; episodic memory (autobiographical memory, what you did on your holiday).
semantic memory (general knowledge, such as the meaning of words).
procedural memory (motor memory) information which cannot be described consciously.

working memory = short term memory ≈ 15 – 30 seconds.

eye should be at the design point throughout the flight.

situational awareness = maintaining an accurate mental model (requires conscious effort to maintain).

multi crew fundamental elements = cooperation and communication.

groupthink = danger of adopting false consensus (eensgezindheid).

homeostasis → physiological balance (interplay between the sympathic and parasympatic nervous system).
→ ANS system = autonomic nervous system (involuntary activities, like heartbeat).

fight or flight reflex → part of general adoption syndrome →
1. alarm reaction.
2. resistance.
3. exhaustion.

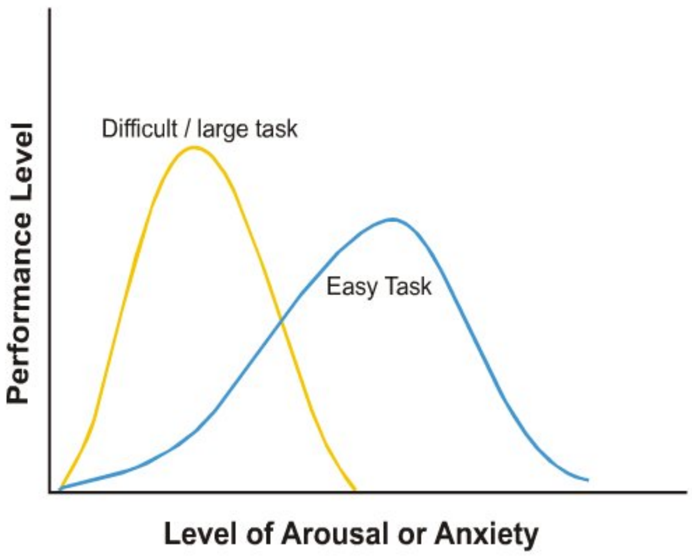
underload = complete absence of stress (undesirable).

stress = a heightened state of arousal caused by stressors in the environment.

stressors = any event or situation that induces stress.

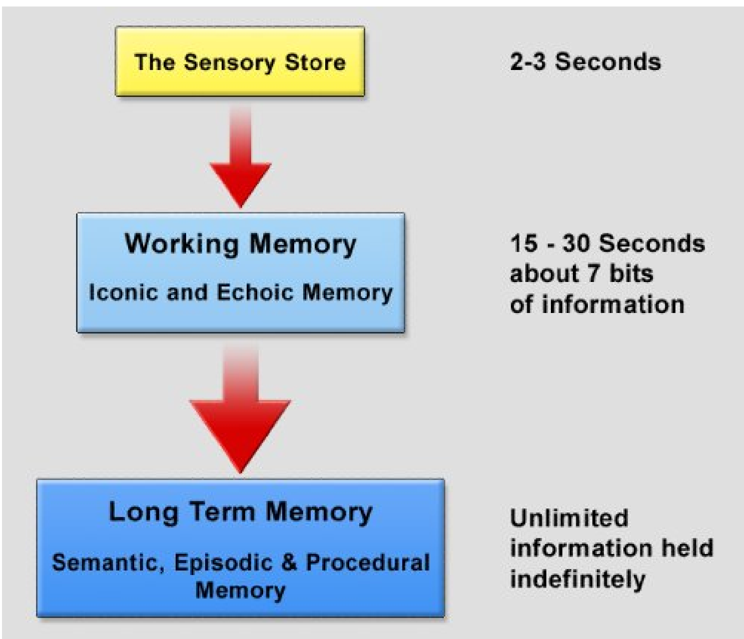
psychosomatic illness = physical illness stemming from psychological causes.

automation complacency = crew tend to become passive monitors of the system and fail to actively question its performance.

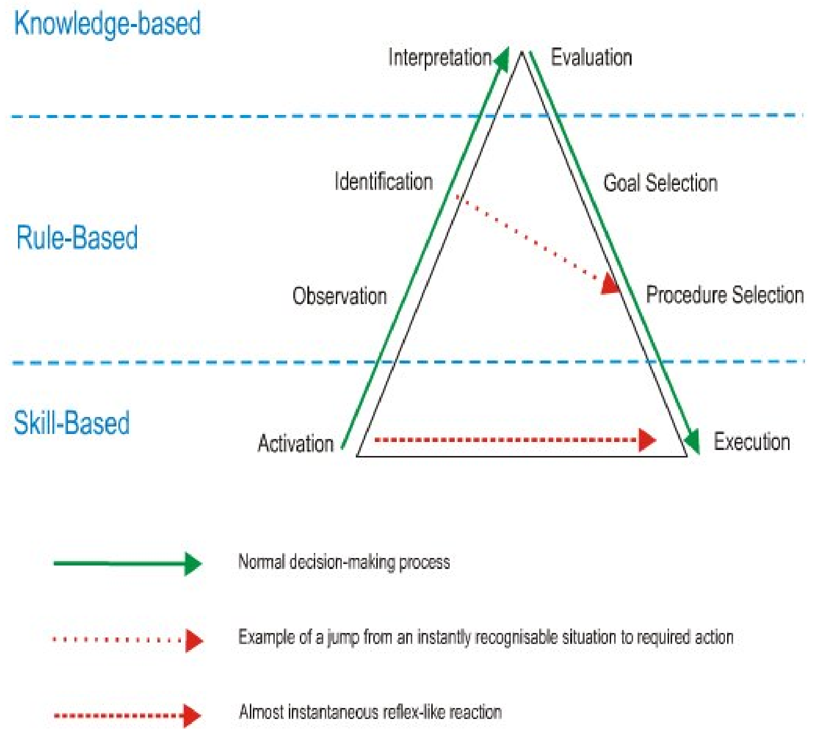


A certain level of arousal is a positive influence on performance. An extremely aroused/anxious pilot will perform significantly less well than an optimally aroused pilot.

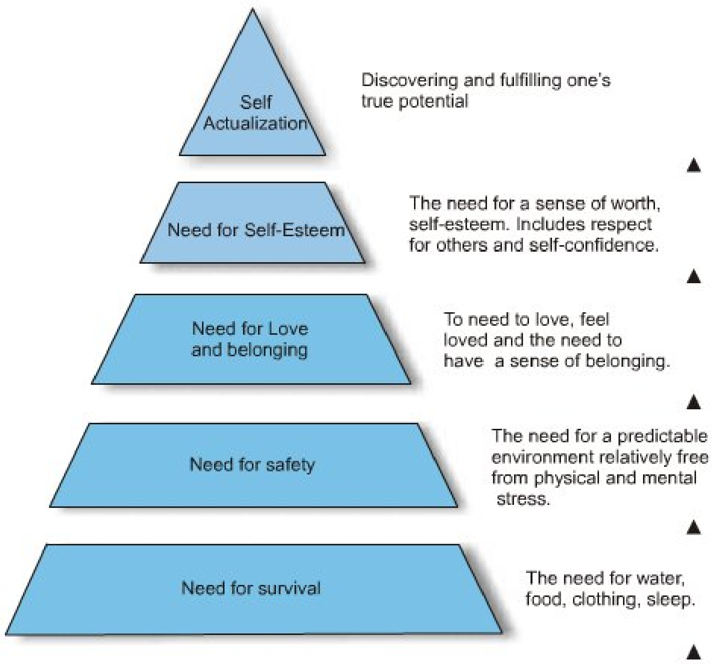
Memory



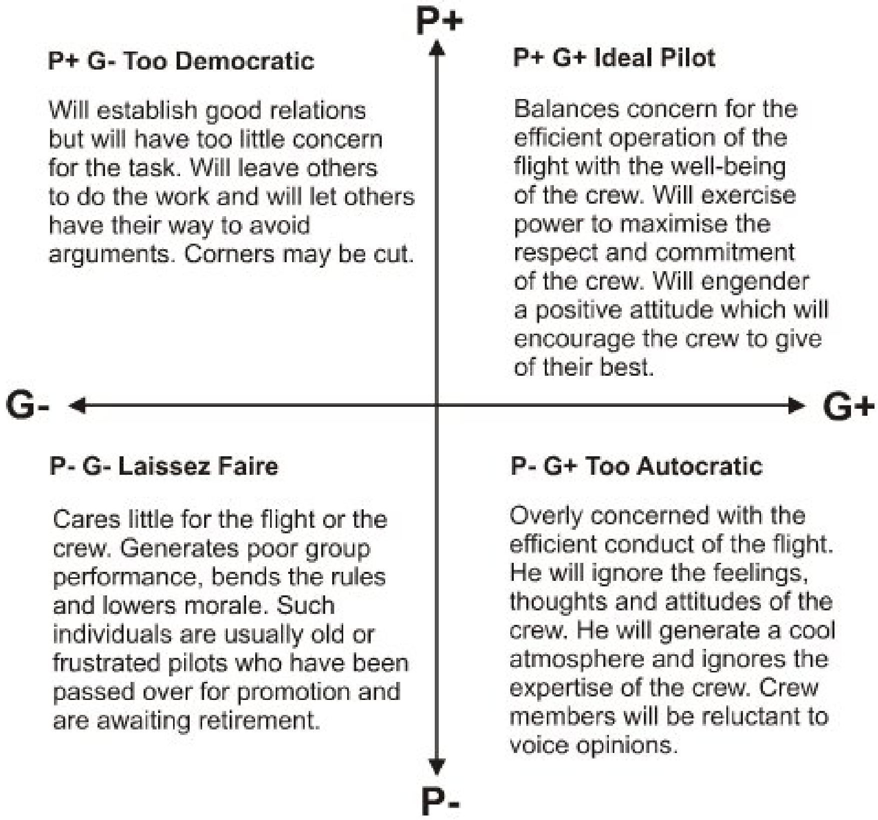
Decision making



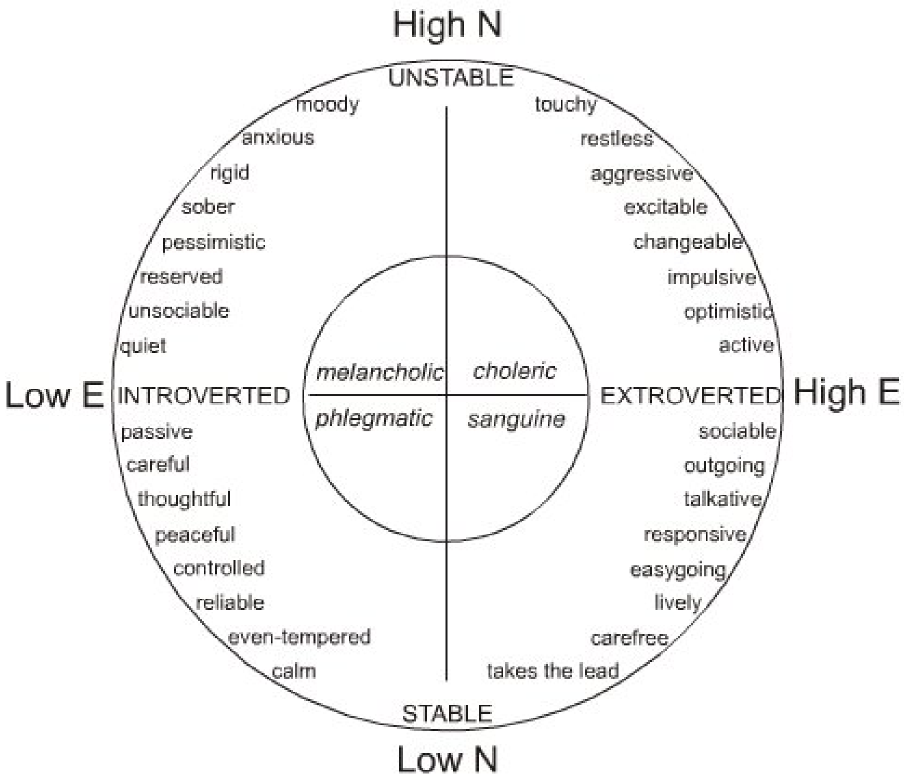
Hierarchie of needs



A person (P+) and goal (G+) oriented person is the ideal pilot.



A stable extrovert person is the ideal pilot.



high frequencies have short wave lengths.

speed of light = 300000 Km/s = 162000 NM/s

wave length $\lambda = \frac{C}{f}$ (C=speed of light in m/s / f=frequency in Hertz)

max skip distance (NM) = $1{,}43\sqrt{H}$ (of ionosphere in Km)

skip distances are increased at night as the ionosphere weakens and refract less.

maximum (theoretical) range (NM) = $1{,}25\sqrt{H1} + 1{,}25\sqrt{H2}$ (feet)

NDB maximum (theoretical) range = $3\sqrt{power}$ in watts

VLF = 3 KHz – 30 KHz / LF = 30 KHz – 300 KHz / MF = 300 kHz – 3 MHz

HF = 3 MHz – 30 MHz / VHF = 30 MHz – 300 MHz / UHF = 300 MHz – 3 GHz

SHF = 3 GHz – 30 GHz / EHF = 30 GHz – 300 GHz

emission classification 3 letter code (ICAO): 1e = waveform, 2e = modulation, 3e = type of information J3E=HF comm. / A3E=VHF comm. / A8W=ILS / A9W=VOR / PON=DME / NON=NDB carrier wave / A1A=NDB ident / A2A=alternative NDB ident.

ideal aerial size is half or a quarter of the wave length.

sky waves refract from the ionosphere (breking) caused by a change of speed. ionosphere is more dense in summer and during the day. sky waves are only reliable in HF band.

ACARS (AC communications addressing and reporting system) = data link between operator and AC (VHF).

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suns up, frequencies up suns down, frequencies down. Night typically half that of day.

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QUJ = true to station.
QTE = true from station.
QDR = magnetic from station.
QDM = magnetic to station.

****PUSH THE HEAD AND PULL THE TAIL**** → intercepting NDB QDR/QDM.

HF frequency classification

lowest usable HF	maximum usable frequency	optimum frequency
Static & Ionospheric attenuation	Best combination – use highest frequency that works	End of skip distance – a bit temperamental

radio spectrum classification

	VLF	LF	MF	HF	VHF	UHF	SHF	EHF
	Very	Low	Med	High	Very	Ultra	Super	Extra
Freq	3-30K	30-300K	300K-3M	3M-30M	30M-300M	300M-3G	3G-30G	30G-300G
Wavelength	100km-10km	10Km-1Km	1Km-100m	100m-10m	10m-1m	1m-10cm	10cm-1cm	1cm-1mm
	Myria	Kilo	Hecto	Deca	Metric	Deci	Centi	Milli
Space Waves								
Sky Waves								
Surface Waves	4000nm	1000nm	300nm	100nm				
Ionos Duct								
Atmos. Attn								
Surface Attn								
Ionos Attn								
Static								
Uses		Loran NDB 190k	NDB 1750k	Comms 2850K-22M	Comms 118M-137M	Glideslope GPS 1.5G(L1)C/A+P 1.2G(L2)P SSR DME	Radio alt. 4.3G MLS ATC/Wx Radar 9-10G	

radio emission classification

X3E (Comms)	A**X**W	**X**0N	A**X**A
J HF SSB Sup Carr	8 ILS	P DME	1 NDB Ident
A VHF DSB	9 VOR	N NDB Carrier	2 Alt NDB Ident

landing categories

category	aircraft minima; DH / RVR
I	200 ft on barometric altimeter / RVR > 550 m
II	100 ft on radio altimeter / RVR 300 m
III A	0 ft on radio altimeter / RVR 200 m
III B	0 ft on radio altimeter / RVR 75 m
III C	0 ft on radio altimeter / RVR 0 m

$$glidepath \cdot height = \frac{glidepath \cdot angle}{60} \times \text{ distance (ft)} \approx \text{(300 ft/nm)}$$

rate of descent (ft/min) ≈ GS (NM) x 5 (at 3° glide slope)

glide path in ° = $\frac{...\%}{100}$ x 60

system errors → FM immune filters reduce localiser interference.

radar bands are UHF, SHF with some EHF. Pulse radar uses a single aerial to both transmit and receive. continuous wave radar has no minimum range limitation (radio altimeter).

PRP = pulse recurrence period = time it takes to send and receive one pulse.
PRF = pulse repetition frequency = number of pulses per second.

PRP = $\frac{1}{PRF}$

low PRF is needed for long range radars. maximum range is controlled by PRF and power.

maximum theoretical range (m) = $\frac{C}{2 \times PRF}$ (C=300.000.000 m/s)

minimum theoretical range (m) = $\frac{C \times pulse \cdot length}{2}$ (C=300.000.000 m/s)

beamwidth = 70 x wave length : antenna diameter

airborn weather radar: 9 GHz – 10 GHz in the SHF band. conical beam is used for cloud.

cloud height above aircraft (ft) = range (ft) x (scanner tilt – ½ beam width) : 60

doppler = self contained on board navigation system that computes GS and drift of the aircraft (old).

loran = hyperbolic navigation systems show difference of distance or differential distance.
hyperbolic navigation systems need chains of beacons.
loran operates on frequencies around 100 KHz.
ground aerials often > 1300 ft.

GPS = USA // glonass = former soviet union.

GPS → 24 satellites, 21 operational and 3 spares - 6 circular orbital planes at 55° to the equator - each orbital plane, 3 or 4 satellites at 20200 km, once/12 hours – at least 4 satellites will always be in line of sight – mask angle 5° above horizon.
2 frequencies UHF described as L1 and L2. P code (precise//C/A code (coarse acquisition).
L1= C/A + P // L2= P only.

RNP = required navigation performance (maintaining accuracy 95% of the time).

RNP5 = ± 5 NM, 95% of the time // RNP0,01/15 = 0,01 NM / 15 ft (CAT II approach).

RNAV = area navigation = integrating several different systems.

FMS databases are updated every 28 days.

IAS → (position/instrument error) → **RAS/CAS** → (compressibility) → **EAS** → (density) → **TAS.**

A x V = constant (A= area / V= speed)

$P + ½.φ.V^2$ = constant

$Q = ½.φ.V^2$ = dynamic pressure

Q and lift/drag are proportional to EAS^2 // EAS is slightly less than IAS.

EAS = TAS only at ISA mean sea level density.

EAS = $\sqrt{relative \cdot density}$ x TAS   (example: relative density = ¼ at 40000 ft)

work done = force x distance // power required = force x speed

airflow → streamline flow → vortex flow → disturbed flow.

stagnation point → pressure equals total head pressure // RAF = relative air flow.

Lift = $C_L. ½.φ.V^2.S$ // C_L = lift coefficient

swept wings give less lift at high angles of attack.

positive pressures do not occur on the lower airfoil surface until alphas of 12° - 15°.

C_P on a cambered airfoil moves. on a symmetrical airfoil it remains near 20% - 25% MAC.

turbulent boundary layer is thick (20x laminair layer), draggy and high energy. laminair boundary layer is thin slippery and low energy.

profile drag = zero lift drag = parasite drag (skin friction / form drag / interference drag).

induced drag = lift depending drag or lift induced drag (vortex drag).

total drag = $C_D. ½.φ.V^2.S$ // C_D = drag coefficient

from 1 to 2 G means drag goes up by a factor of 4.

best ratio of EAS over drag = 1,32 x V_{IMD} (best range speed for jet aircraft)

V_{IMP} = minimum fuel consumption (prop AC).

V_{IMD} = minimum fuel consumption (jet AC).
= best angle in prop AC.

speed unstable regime =< V_{IMD} (drag rises as speed falls).

V1 = decision speed (is chosen for best scheduled field performance).

V2 < V_{IMD} and is in the speed unstable regime.

$V_{X\ (jet)} = V_{IMD}$ // $V_{X\ (prop)} = V_{minimum\ control}$ (= 1,1 x V_{stall}) // power = TAS x (thrust or drag)

V_Y EAS decreases with height / service ceiling jet < 500 ft/min, propeller < 100 ft/min.

stalling speed in manoeuvre increases by the square root of the load factor. load factors increase rapidly from 30° up.

$\sqrt{load \cdot factor}$ = V_{Stall} increasing factor. less weight will give you better turn performance. turn radius is greater at height. maximum rate speed is higher than minimum radius speed.

radius of turn (NM) = $\dfrac{TAS}{rate.x.60.\pi}$

angle of bank in rate 1 turn = $\dfrac{TAS}{10}$ + 7 (approximation)

radius of turn (m) = $\dfrac{V^2(m/s)}{10 \times \tan \cdot bankangle}$

washout = progressive reduction of wing incidence to the tip.
boundary layer control = uses vortex generators (sucking or blowing at the tip to keep the boundary layer attached to a higher alpha).

differential ailerons = upgoing at greater angle than downgoing aileron.
frise ailerons = nose of the aileron sticks down below the wing when the aileron deflects upwards.
→ equalising drag.

for any given EAS → aerodynamic damping decreases as height increases.

static stability describes the first response of the AC of being displaced in attitude or speed.
dynamic stability describes what happens after that, in the long term.

longitudinal dihedral = difference in incidence between wing and tail.

stick free stability is always worse than stick fixed.

speed of sound (kt) = 38,94 $\sqrt{T}$ (Kelvin)

LSS = 661 kt (at sea level at ISA temp.= 288 k)
LSS = 573 kt (ISA tropopause temp.= 216,5 k)

mach no. (M) = $\dfrac{TAS(kt)}{LSS(kt)}$ (M is ratio and has no units)

M_{FS} = free stream mach no. // M_L = local mach no.

mach wave → at Mach 1.0 , individual pressure waves pile up into a single pressure wave just ahead of the aircraft. mach waves that form near the aircraft, on wings and other parts of the structure, are more intense and are called shockwaves.

M_{det} = detachment mach no. ($M_{free\ stream}$ at which the shockwaves attaches!?)

transonic regime (from $M_{critical}$ to $M_{detached}$) → aircraft flies subsonic at high mach nos. → some local flows become supersonic.

M 0,89 → range where lift changes abruptly with changes in flow.

M 0,89 to M 0,98 → range where CP moves aft.

M 1,4 (=M_{det}) → C_L is down to 70% of its low speed value as there is no up wash ahead of the leading edge and there is an energy loss through the bow shockwave. → C_P is at about 50% MAC.

transonic flight → C_L is rising in the subsonic regime; increasing Reynolds number/effect of compressibility/ change in upwash.

M_{CDR} = mach critical drag rise.

propeller slip = difference between geometric pitch and effective pitch.

CSU = constant speed unit (if rpm falls, CSU moves to finer pitch, if rises to coarser pitch)

CSU will select (at constant power): coarse pitch at high speed and fine pitch at low speed.

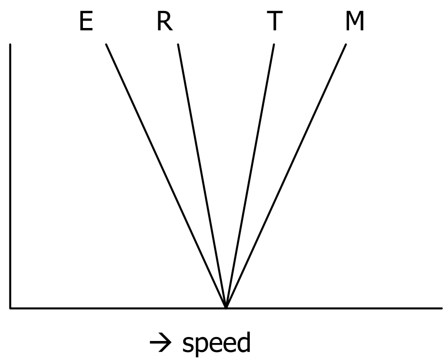
full propeller operating range → feather stop (+85°) – feathering – flight coarse pitch stop (+50°) – flight range – flight fine pitch stop (+14°) – taxi – ground fine pitch stop (-1°) – reverse - reverse pitch stop (-15°).

alpha range = flight range between flight fine and flight coarse pitch stop.
beta range = (for ground manoeuvring) direct adjustment of propeller pitch.

FI = fatique index (100 = fatique life has been used up). increasing aircraft AUM by 1% can increase fatique life consumption by 5%.

"n" (load factor) = $\frac{1}{\cos \cdot bankangle}$

speed diagram (with increasing altitude)



E = EAS
R = RAS / CAS
T = TAS
M = mach number

RAS/CAS is derived from ½ rho V^2

Aviation law

light signals

	to an a/c on the ground	to an a/c in the air
Green	Go (cleared take off)	Go (cleared to land)
Red	Stop	Stop (ie circle and give way)
Flashing Red	Get clear of landing area.	Stay clear of landing area (ie do not land)
Flashing White	Go to start	Go to start (ie land here but await signals)
Flashing Green	Cleared to taxi	Come back and await signals
Red pyrotechnic		Belay previous instructions - do not land for the moment.

ICAO annexes

annex	subject
1	Personnel Licensing (Getting a license is my Number 1 priority)
2	Rules of the Air (2 Sets of Rules, VFR and IFR)
3	Meteorological Services (3ºC/1000ft DALR)
4	Aeronautical Charts (4 Cardinal Points)
5	Dimensional Units (CRP 5)
6	Operation of Aircraft (DC6)
7	Nationality and Registration Marks (The League of Seven Nations)
8	Airworthiness (Looks like a propeller)
9	Facilitation (NEIN in German – Immigration)
10	Aeronautical Communications (100 for the Operator)
11	Air Traffic Control Services (1 to 1 Personal Services)
12	Search & Rescue (The one before Accident Investigation)
13	Accident Investigation (Unlucky for some)
14	Aerodromes (14 Aerodromes around Heathrow)
15	Aeronautical Information Services (Looks like IS)
16	Environmental Protection (16 Age of Consent, use protection)
17	Security (17ft security fence required)
18	Dangerous Goods (At 18 you can drink but it's DANGEROUS to drive)

holding speeds

	normal	turbulent
≤ FL140	170kts (A&B)/230kts	170kts (A&B)/280kts
≤ FL200	240kts	280kts
≤ FL340	265kts	280kts

intenational conventions

	Warsaw (1926)	Tokyo (1963) Hague (1970)	Montreal (1971)	Rome (1933/38/52)
Subject	Liability	Hijacking/ Jurisdiction	Non-Hijacking	Ground Damage
Withdrawal		Inform ICAO	6 Months notice to contracting states	

separation

type	description
Vertical	During ascent or descent 15 mins whilst vertical separation does not exist, down to 10 where navaids permit, or 5minutes if less than 10 minutes of an actual timed position report.
Lateral	**VOR/RNAV** 15° more than 15nm from facility.
	NDB 30° more than 15nm from facility.
	DR 45° more than 15nm from intersect
Longitudinal	**DME** (On track) 20nm or 10nm where front a/c is 20kt+ faster. Also 10nm when climbing or descending through level.
	Timing - 15mins, down to 10mins if navaids permit, down to 5 mins if front a/c is +20kts, to 3mins if +40kts.
	Mach number 10-5mins. Each minute less than 10 requires an additional .01M from leading a/c starting at 0.02M up to 0.06M.RNAV 80nm.
	RNP RNAV 80nm (RNP 20) verified every hour, 50nm (RNP 50) verified every ½ hour. Otherwise 80nm when same on-track waypoint.
	Radar Separation – 5nm standard, 3nm when conditions allow (UK 40nm from radar head) and 2.5nm on localiser/approach (5nm on localiser for wake turbulence).
Wake Turbulence 2mins UNLESS	**Departure** Lighter AND from intermediate part of runway (3min)
	Arrival LIGHT behind heavier (3min), 4/5/6 & 5nm
Departure	1, 2, 5mins. 1 if tracks diverge by 45° or more. On same track, 2 if speed difference of 40kts, 5 otherwise. <1 minute if taking off in different directions. 5 mins max between departing and arriving traffic

supplemental oxygen requirements

	over 10,000ft	over 13,000ft	over 14,000ft	over 15,000ft	minimum	
Pressurised					≤25kft	>25kft
Flight Deck	After 30 mins	Entire time			30min	2hr
Cabin Crew	After 30 mins	Entire time			30 min	
10% Pax	After 30 mins					
30% Pax			Entire time			
100% Pax				Entire time	10 min	
Unpressurised						
Flight Deck	Entire time					
Cabin Crew	After 30 mins	Entire time				
10% Pax	After 30 mins					
100% Pax		Entire time				

safety equipment requirements

pax seats	fire extinguishers (of which BCF)	crash axe	megaphone /deck	first aid kits	
7-30	1	1			
31-60	2 (1)				
61-200	3 (2)		1+1≥100	<100	1
201-300	4 (2)	2		<200	2
301-400	5 (2)			<300	3
401-500	6 (2)			<400	4
501-600	7 (2)				
>601	8 (2)				
	Plus 1 BCF in Cockpit				

reporting requirements

subject	reporting
Unlawful Interference	ASAP
Nav Irregularity/Met eg. VA, Radiation	ASAP
Accident	Quickest available means
Emergency which endangers safety & thereby violates local regs or procs	Local authority without delay, if required by state to appropriate authority then to state of origin in writing within 10 days.
Flight Incidents which (may) endanger safe ops	Authority within 72 hours
Technical defects and excess of tech limitations	Recorded in tech log
Air Traffic Incidents endangerment by other flying device/ATC etc.	ICAO PANS RAC
Birdstrike	ASAP ATC

licensing requirements

	total hours	PIC hours	XC hours	night hours	Instr. hours
ATPL (21-59) 500 MPA Transport Category a/c	1500 100 sim 25 Proc trainer	250 PIC/P1s 100 PIC	200 100 PIC/P1s	100 PIC/P2	75 30 ground
CPL (18- 5yrs	150		20 300nm flight	5 5 FSTOL as PIC	10 5 Ground
PPL (17-					
IR (A) for C/PPL			50 PIC 10 in Airplanes		

SARP's = standards and recommended practises.
PANS = procedures for air navigation services.

JAR 23 and 25 → covers the regulations applying to small and large aircraft respectively.

ICAO assembly is convened once every 3 years. they appoint the counsil for a 3 year term (permanent body composed of 33 contracting states).

ATS comprises 3 services;

4. air traffic services; Area Control Service / Approach Control Service / Aerodrome Control Service
5. Flight Information Service
6. Allerting Service

controlled airspace;
Class A: most airways, important control zones and control areas (IFR only).
Class B: upper airspace → IFR and VFR permitted (controlled).
Class C: IFR + VFR (controlled) → IFR is separated from IFR and VFR, VFR is separated from IFR and receive traffic information about other VFR.
Class D: IFR + VFR (controlled) → IFR is separated from IFR and receive traffic information in respect of VFR flights. VFR receive traffic information on all other flights.
Class E: IFR + VFR permitted; IFR with air traffic control service and are separated from other IFR. All flights receive traffic information as far as practicable (no control zones).
Class F: IFR + VFR permitted; IFR flights receive air traffic advisory service and all flights receive flight information service if requested.
Class G: IFR + VFR permitted and receive flight information service if requested.

air traffic control service: IFR→ A, B, C, D and E / VFR→ B, C and D + all aerodrome traffic at controlled aerodromes.

aerodrome reference codes (first element);
1=< 800M / 2=800-1200M / 3=1200-1800M / 4=>1800M

width of runways = 18 – 45M (precision approach runway not less than 30M at 1 or 2 type).

braking action: 0,4=good(5) / 0,39-0,36=medium to good(4) / 0,35-0,3=medium(3) / 0,29-0,26=medium to poor(2) / <0,25=poor(1)

AIRAC = aeronautical information regulation and control (part1 and 2).
AIC = aeronautical information circulars. issued monthly, contain information not suitable for AIP/NOTAM.

MSA = 1000 ft clearance within 25NM (mountainous areas 2000ft).

speed categories are calculated as 1,3 x stall speed in landing configuration.
A= < 91kt / B= 91-121kt / C=121-141kt / D=141-166kt / E=166-211kt

approach segment → arrival / initial / intermediate / final / missed approach.

<u>arival</u> → ends at IAF.
procedures are used to direct the aircraft. 45°/180° procedure turn // 80°/260° procedure turn // base turns // race track procedure.
<u>initial</u> → IAF to IF (intermediate fix).
<u>intermediate</u> → obstacle clearance reduces from 1000ft to 500ft in the primary area.
<u>final approach</u> → begins at FAF and ends at MAPt (missed approach point).
<u>missed approach</u> → must be initiated if the visual references are not obtained by the time the aircraft reaches the MAPt.

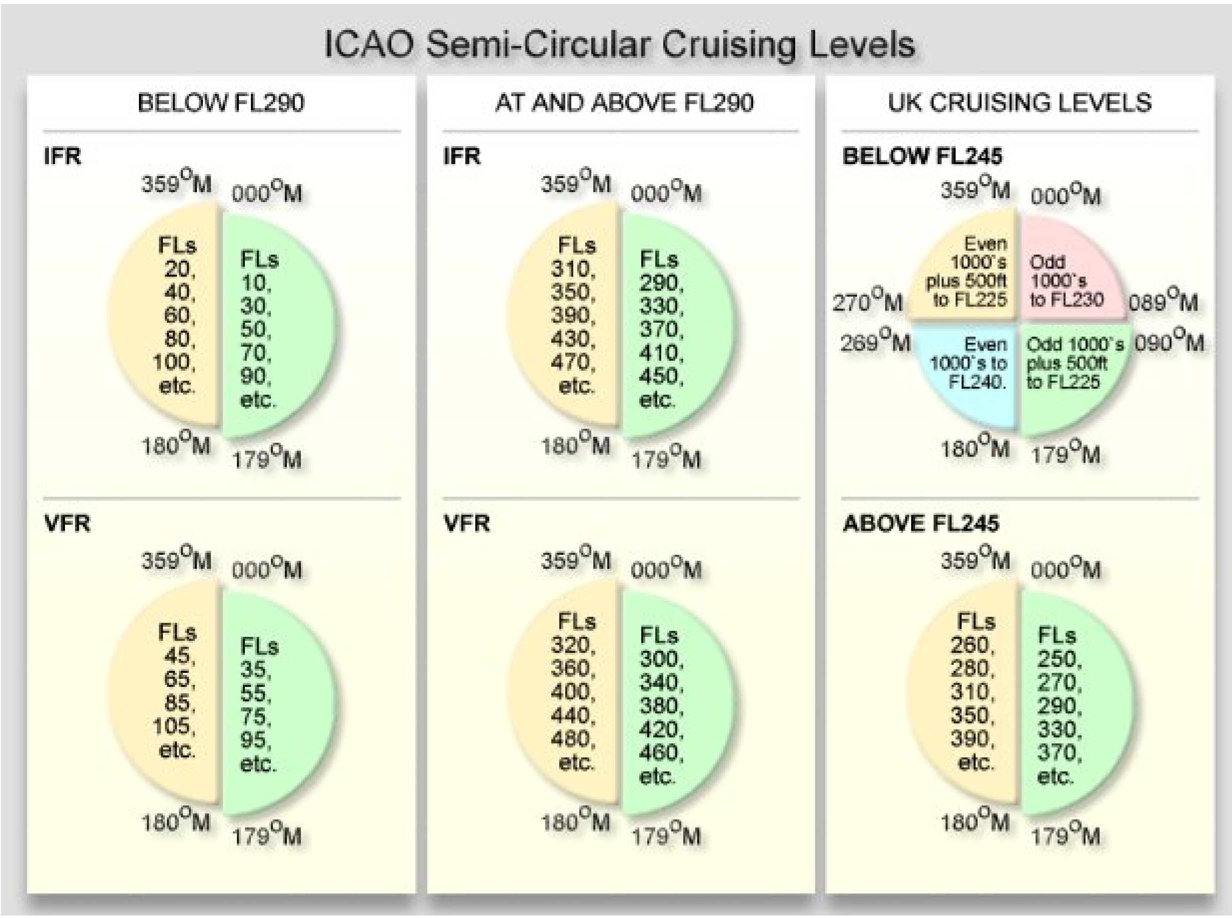
a circling approach is a visual manoeuvre.

all turns in holding procedures are calculated for angle of bank of 25° or 3°/s (=rate 1).
if not specified, right turns.

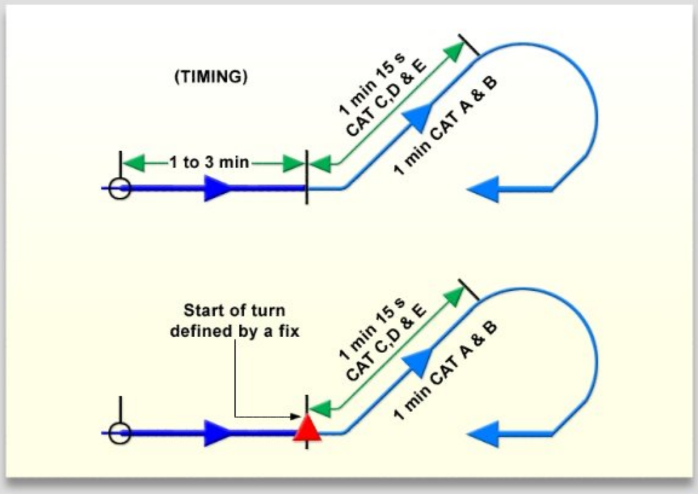
Airspace Class	F&G only at below 900m (3000ft) AMSL or 300m (1000ft) above terrain, whichever is the higher	All other classes and conditions
Distance from Cloud	Clear of cloud and in sight of the surface	1500m horizontally 300m (1000ft) vertically
Flight Visibility	5km*	8km at and above 3050m (10,000ft)AMSL 5km below 3050m (10,000ft) AMSL

Runway Lighting	**RVR = Reported Met. Visibilty multiplied by:**	
	Day	**Night**
HI Approach and Runway Lighting	1.5	2.0
Any other lighting	1.0	1.5
No lighting	1.0	Not Applicable

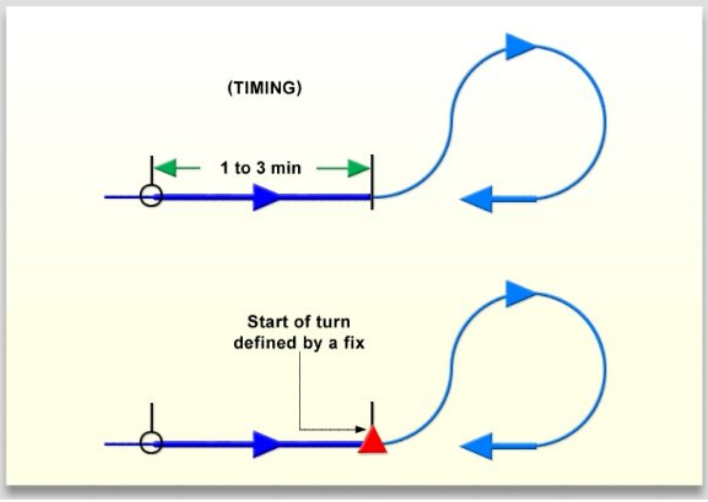
CLASS	TYPE OF FLIGHT	SEPARATION PROVIDED	SERVICE PROVIDED	SPEED LIMITATION	RADIO COMMS REQUIREMENT	SUBJECT TO AN ATC CLEARANCE
A	IFR only	All Aircraft	Air Traffic Control Service	Not Applicable	Continuous Two-Way	Yes
B	IFR	All Aircraft	Air Traffic Control Service	Not Applicable	Continuous Two-Way	Yes
	VFR	All Aircraft	Air Traffic Control Service	Not Applicable	Continuous Two-Way	Yes
C	IFR	IFR from IFR IFR from VFR	Air Traffic Control Service	Not Applicable	Continuous Two-Way	Yes
	VFR	VFR from IFR	1) Air Traffic Control Service separation from IFR; 2) VFR/VFR traffic information (and traffic avoidance advice on request)	250 kt IAS below 3,050 m (10,000 ft) AMSL	Continuous Two-Way	Yes
D	IFR	IFR from IFR	Air Traffic Control Service, traffic information about VFR flights (and traffic avoidance advice on request)	250 kt IAS below 3,050 m (10,000 ft) AMSL	Continuous Two-Way	Yes
	VFR	Nil	IFR / VFR and VFR / VFR traffic information (and traffic avoidance advice on request)	250 kt IAS below 3,050 m (10,000 ft) AMSL	Continuous Two-Way	Yes
E	IFR	IFR from IFR	Air Traffic Control service and, as far as practical, traffic information about VFR flights	250 kt IAS below 3,050 m (10,000 ft) AMSL	Continuous Two-Way	Yes
	VFR	Nil	Traffic information as far as practical	250 kt IAS below 3,050 m (10,000 ft) AMSL	No	No
F	IFR	IFR from IFR as far as practical	Air Traffic Advisory Service; Flight Information Service	250 kt IAS below 3,050 m (10,000 ft) AMSL	Continuous Two-Way	No
	VFR	Nil	Flight Information Service	250 kt IAS below 3,050 m (10,000 ft) AMSL	No	No
G	IFR	Nil	Flight Information Service	250 kt IAS below 3,050 m (10,000 ft) AMSL	Continuous Two-Way	No
	VFR	Nil	Flight Information Service	250 kt IAS below 3,050 m (10,000 ft) AMSL	No	No



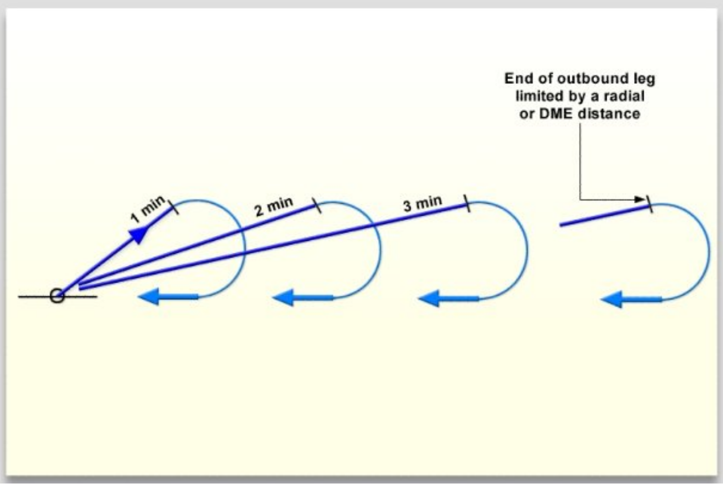
A. 45°/180° Procedure Turn



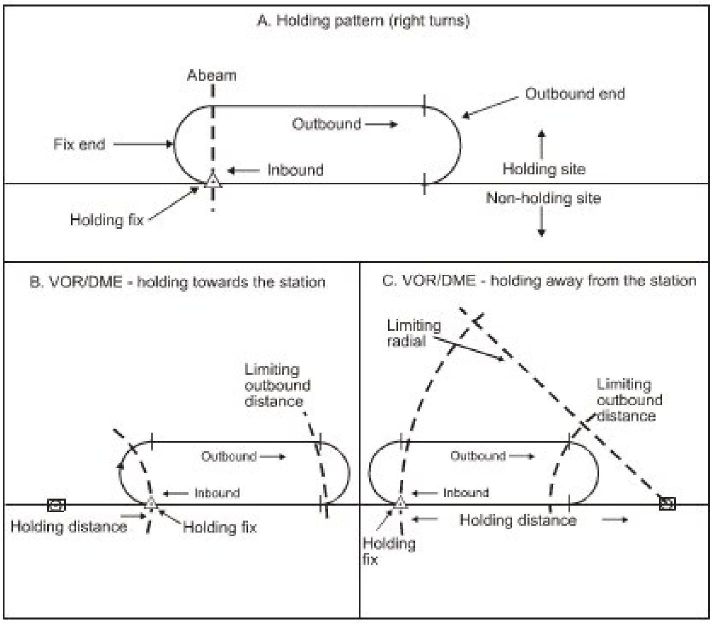
B. 80°/260° Procedure Turn



C. Base Turns

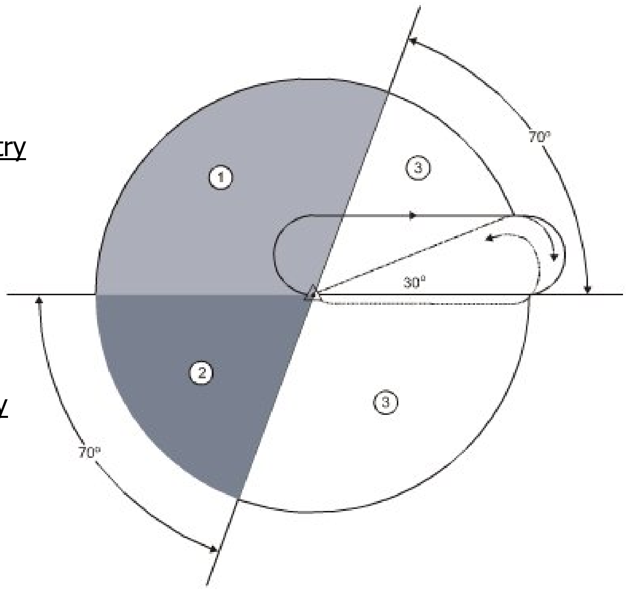


Shape and terminology associated with right turns holding pattern



Entry sectors

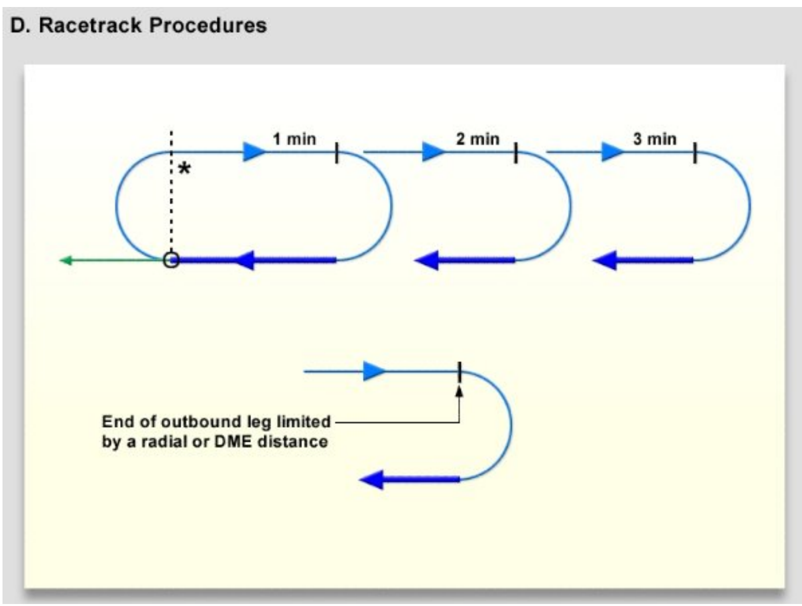
parallel entry



direct entry

offset entry

5° zone flexibility either side of the boundaries



Aeroplane Catagory	VAT
A	Less than 91kt
B	From 91kt to 120kt
C	From 121kt to 140kt
D	From 141kt to 165kt
E	From 166kt to 210kt

Category I RVR Minima				
Decision Height (ft)	Airport Lighting Facilities			
	Full	Intermediate	Basic	None
200	550m	700m	800m	1000m
201 to 250	600m	700m	800m	1000m
251 to 300	650m	800m	900m	1200m
301 & Above	800m	900m	1000m	1200m

Category II Minimum RVR		
Decision Height	Category A, B & C Aircraft	Category D Aircraft
100 ft – 120 ft	300 m	300 m
121 ft – 140 ft	400 m	400 m
above 140 ft	450 m	450 m

Cat III Minima			
Approach Category	Decision Height	Roll Out Control & Redundancy	RVR
IIIA	Less than 100ft	Not Required	200m
IIIB		Fail Passive	150m
IIIB	Less than 50ft	Fail Passive	125m
IIIB		Fail Operational	75m

Type of Approach	MDH
ILS LLZ (Localiser) only	250 ft
SRA to 0.5 nm	250 ft
VOR / DME	250 ft
VOR	300 ft
SRA to 1.0 nm	300 ft
NDB	300 ft
VDF	300 ft

recency is 3 take off's and landings in the last 90 days.

flight preparation documents are kept for 3 months.

RVR is always better than meteorological visibility.

CAT I	RVR=550 M	/	DH=200 ft	(barometric altimeter)
CAT II	RVR=300 M	/	DH=100 ft	(radio altimeter)
CAT III B	RVR=75 M	/	DH<50 ft	(radio altimeter)

jets must be able to land in 60% and turboprops in 70% of the LDA.

contaminated runway = > 25% of surface area is covered by;
>3mm of water or equivalent deep slush/snow.
compressed snow to solid mass.
ice incl. wet ice.

runway is considered wet → < 3mm water without significant areas of standing water.

wet runways need an additional 115% factor.

class B aircraft → must be able to land in 70% of LDA, slope is taken into account.

net performance is worse than gross (Gross= 50:50 chance of better/worse).

NAT-OTS →	eastbound Z-A, bottom to top (red eye)	01:00 to 08:00 hours
	westbound A-Z, top to bottom	11:30 to 18:00 hours

heavy>136000kg / medium= 7000kg – 136000kg / light<7000kg gross performance is the estimated fleet average.

class A aircraft → all jets and turboprops with more than 9 pax. seats or MTOM >5700kg (B-737). JAR 25

class B aircraft → small prop. driven aircraft, piston or turbo with < 9 pax. seats and MTOM <5700kg. JAR 23

class C aircraft → large piston aircraft > 9 pax. seats or MTOM > 5700kg (not many still flying commercially).

jet thrust reduces with altitude. on hot days jet thrust reduces with temperature.

most jet engines are flat rated below ISA +15°, and at low temperatures, thrust does not vary with temp.

most jets indicate thrust with EPR, B-737 uses rpm of the first stage fan (N1).

thrust ≠ power → power = thrust x speed

propeller thrust reduces with forward speed.

V_{IMD} = where profile drag = induced drag → alpha = constant = 4°.

TODA = TORA + clearway. Some runways have an overrun called "stopway".

ASDA = EDA (emergency distance available) = TORA + stopway.

balanced field : TODA = ASDA.

max. TODA = 1,5 x TORA (JAR OPS).

IAS → (position/instrument error) → **RAS/CAS** → (compressibility) → **EAS** → (density) → **TAS.**

screen height at the end of the runway is 15, 35 or 50ft heigh.

jet engine thrust reduces initially with speed because of intake momentum drag, but picks up as the ram effect builds up and assists mass flow.

V_R > 1,05 V_{MCA} (one engine out). V_{MC} is highest where the air is cold and dense (asymmetric thrust is greatest).

a range of decision speeds exist at weights below the OEI field length limited TOM.

the engine out take off calculation uses gross, 50:50, performance.

wet runways have V_{EF} 10kt lower and a 15ft screen height.

V2 = safety speed = target speed to be attained at the screen height (35ft/15ft) with OEI.

all engines case → the margin between net and gross = 1,15 (JAR 25), net being the greater of them.

V3 = all engines speed at the screen (between V2 and V4).

V_X on a jet is close to V_{IMD} (on piston aircraft close to stalling speed).

V_X is unchanged with altitude.

V4 = all engine initial climb speed (V2 + 10kt).

best range on a jet is 1,32 V_{IMD} / Best range on prop AC is $V_{IMD.}$

LRC (long range cruise) is 4% faster than still air best range speed and gives 99% of the range.

class A jets must land in 60% of LDA, Turbo props and class B in 70%.

LDA x 60% = Gross LDR.

class B (multi) aircraft need to clear obstacles by 50ft using net performance (net=0,77xgross).

class A aircraft need to clear obstacles by 35ft using net performance, 50ft in a turn.
(net=grossx0,8-twin // or 0,9-3 engines // or 1,0-4 engines).

the NTOFP (net take of flight path) ends at 1500ft.

increased V2 procedure can improve MTOM when WAT limited but not field length limited.
increased V2 procedure can improve climb gradients when obstacle limited but not field length limited.

reduced thrust take of = assumed temperature procedure = variable thrust procedure.

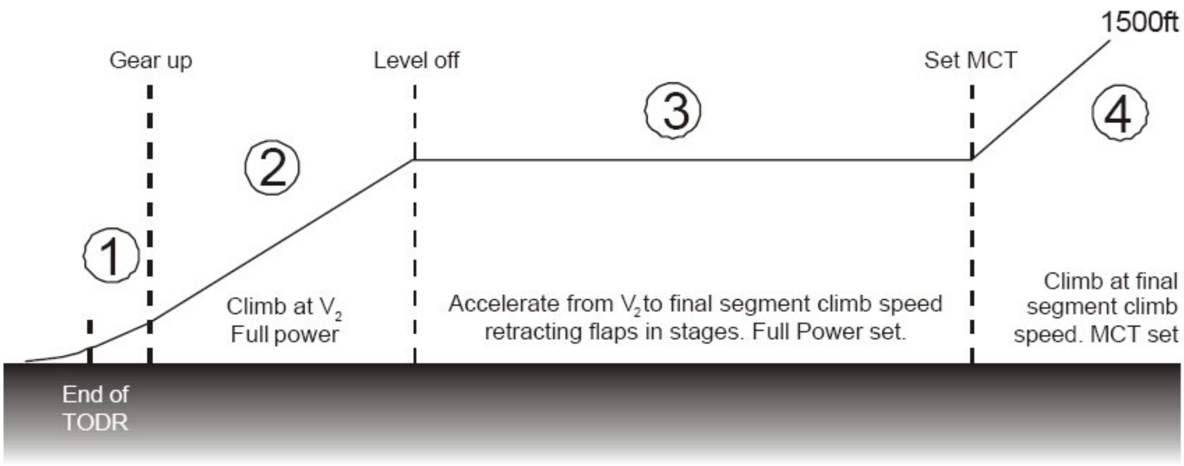
hydroplaning speed (kt) = $9\sqrt{P(psi)}$ (bar x 14,5 = psi).

braking coefficient	braking action	snowtam
0,4 >	good	5
0,39 – 0,36	medium to good	4
0,35 – 0,30	medium	3
0,29 – 0,26	medium to poor	2
0,25 <	poor	1

climb gradient = $\dfrac{rate \cdot of \cdot climb \times 6000}{TAS \times 6080}$

PMC = performance management control.

The first segment lasts from 35ft to the point where the gear is retracted, the second segment lasts until flap retraction height at which point the aircraft is levelled and an accelerating third segment is flown whilst the flaps are retracted.



Net Take-off Flight Path

F = force (lbs) / A = area (sq in – in^2) / P = pressure (psi) → bar x 14,5 = psi

P = $\frac{F}{A}$

V = I x R // P = I^2 x R // P = V x I

hydroplaning speed (kt) = $9\sqrt{P(psi)}$ (bar x 14,5 = psi).

RMS (root mean square) voltage = 0,707 x peak voltage

F (Hz) = rpm x pole pairs x 60

typical 3 phase aircraft AC supply = 115 V (RMS) / 400Hz.

TRU = transformer rectifier unit → 115V AC to 28V DC.

alternators are STAR wound and can produce 2 voltages.

CIVIL = in **C**apaciters the current **I** leads the **V**oltage which leads the current **I** in inductors **L**.

J3E = HF comms // A3E = VHF comms // A8W = ILS // A9W = VOR // PON = DME
NON = NDB carrier wave // A1A = NDB ident // A2A = alternative NDB ident

sky waves refract from the ionosphere // space waves are line of sight waves.

force = mass x acceleration // momentum = mass x velocity // work = force x distance

power = $\frac{work}{time}$

the ratio of air to fuel which ensures complete combustion = 15:1 by weight.

manifold pressure is absolute pressure / boost pressure is relative to ISA pressure at sea level.