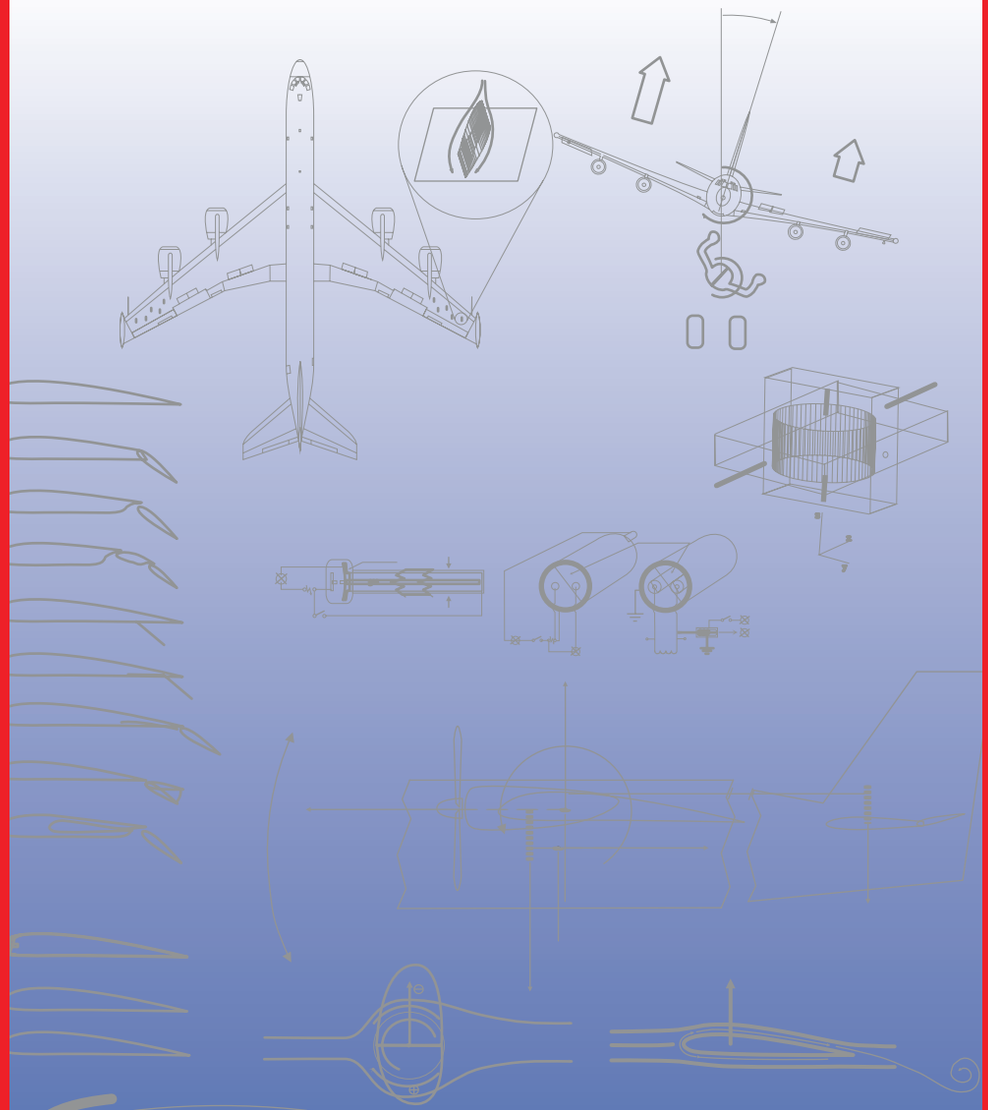

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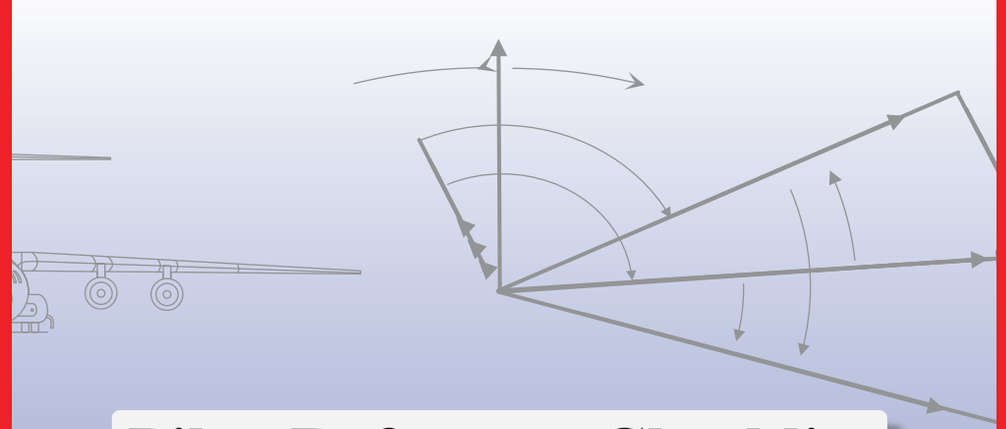

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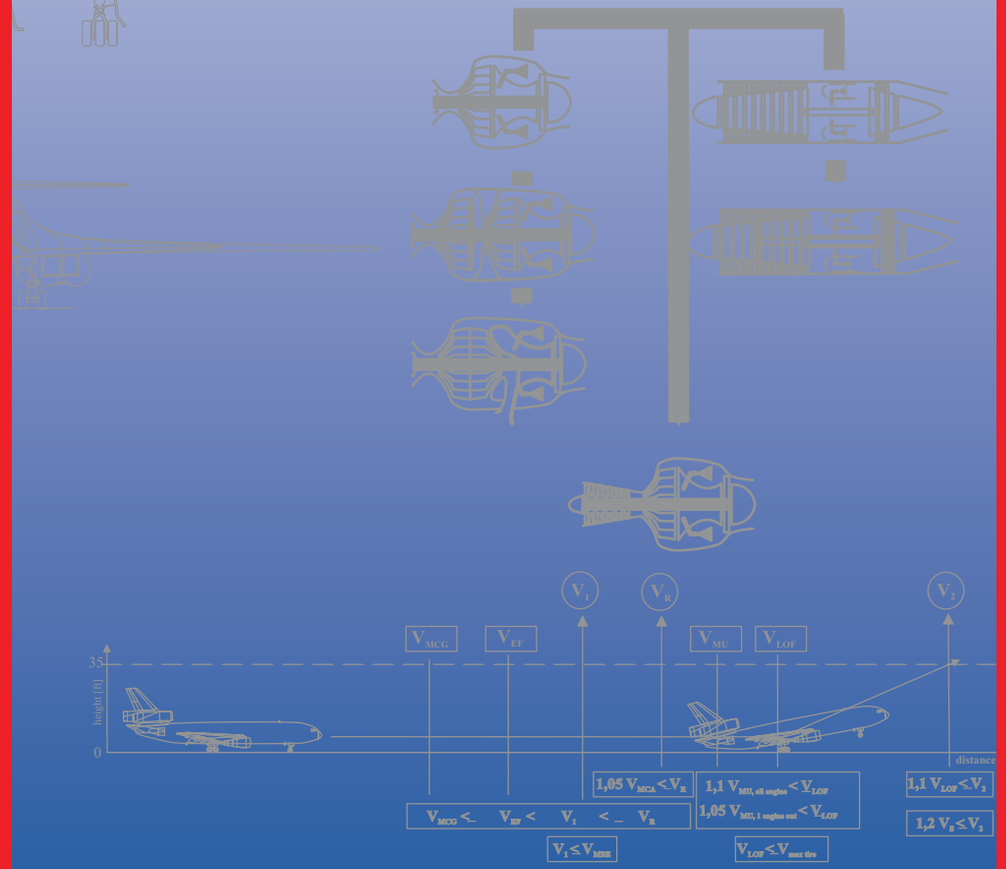
by
Michael Grossrubatscher



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Notes & Drafts:

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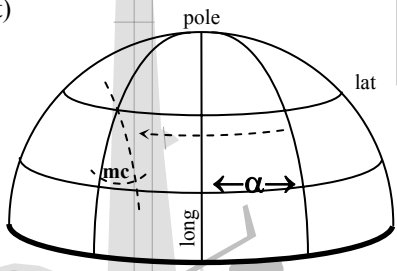
I. Navigation

λ = longitude (long), ρ = latitude (lat)



1. Distance between meridians

$$\alpha = \Delta\lambda \cdot \cos \rho \cdot 60 \qquad [\text{nm}]$$

2. Meridian convergence

$$mc = \Delta\lambda \cdot \sin \rho_m \quad (\rho_m = \text{middle latitude})$$

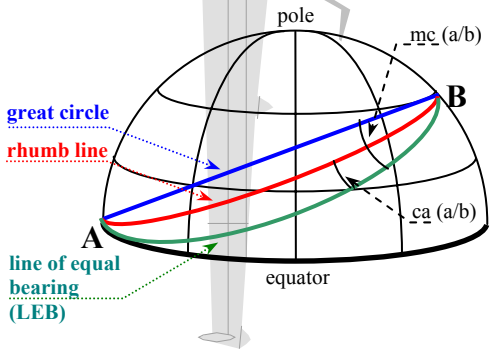
3. Dimensions

- equator & meridians: 360°· 60nm/° = 21600nm hence:
- on equator/meridian: 1°= 60 nm, 1´= 1 nm
- earth's diameter: ≈ 6300 km
- rotation: ≈ 15,04°/h eastbound

4. Conversion angle

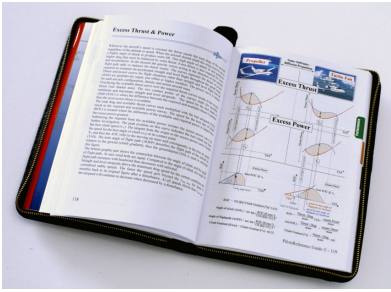
$$ca = \tfrac{1}{2} \cdot mc$$

- angle: great circle/rhumb line
- angle: rhumb line /LEB



great circle	shortest connection	VOR
rhumb line	Constant course	
LEB	constant bearing	ADF only

Notes & Drafts:



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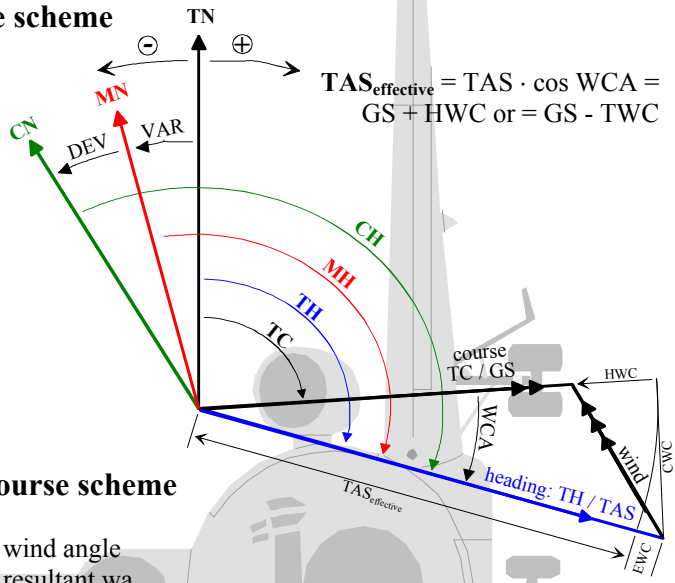
5. Basic course scheme



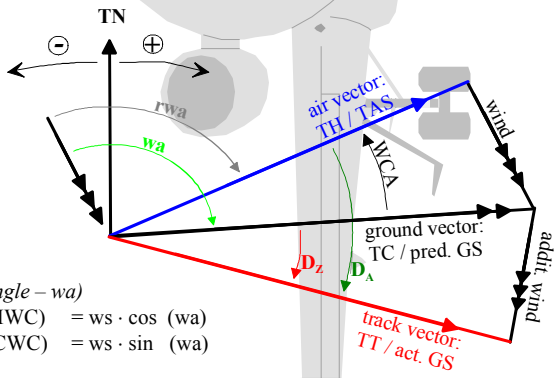
$TAS_{effective}$ = TAS · cos WCA =
GS + HWC or = GS - TWC

TC	
	±WCA
TH	
	-(±Var)
MH	
	-(±Dev)
CH	

6. Advanced course scheme

- wa = wind angle
- rwa = resultant wa
- addit. wind = additional wind
- D_A = drift angle
- D_Z = addit. Drift

	from	*to*
WCA	**course**	**heading**
D_A	**heading**	**track**
D_Z	**course**	**track**



7. Wind components

(Wind speed – ws; Wind angle – wa)

- Headwind component (HWC) = ws · cos (wa)
- Crosswind component (CWC) = ws · sin (wa)

8. 1:60 Rule

(Lateral deviation from desired track - VOR vs. GPS)

$$\text{Lateral deviation } [\text{nm}] = \frac{\text{Distance to fix} \cdot \text{lateral deviation } [°]}{60}$$

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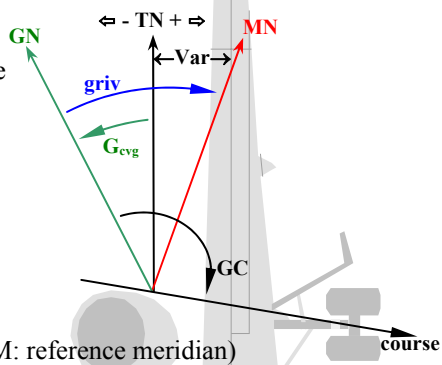
9. Grid nav course scheme

- G_{cvg} = grid convergence
- griv = grivation
- Var = variation
- GC = grid course



⇒ $G_{cvg} = \Delta\lambda \cdot cc$

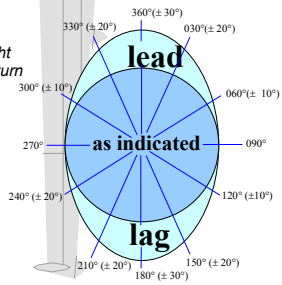
- $\Delta\lambda$: (LM: local meridian, ref. M: reference meridian)
  LM west of ref. M → $-\Delta\lambda$ (negative prefixed)
  LM east ref. M → $+\Delta\lambda$ (positive prefixed)

- constant of cone (cc)
  (always ± 1 for stereographic projection)
  cc = +1 in northern hemisphere
  cc = - 1 in southern hemisphere

10. Magnetic compass

- 6mT: compass erratic line
- Acceleration error:
  Acceleration north, deceleration south on easterly/westerly headings
- *Turn error (magnetic compass indication):*

- *inner circle shows compass indication in straight & level flight*
- *outer circle shows compass indication within standard rate turn*
- *compass leads in northern half in the direction of the turn*
- *compass lags in southern half in the direction of the turn*
- *see lead/lag: values depicted in brackets*



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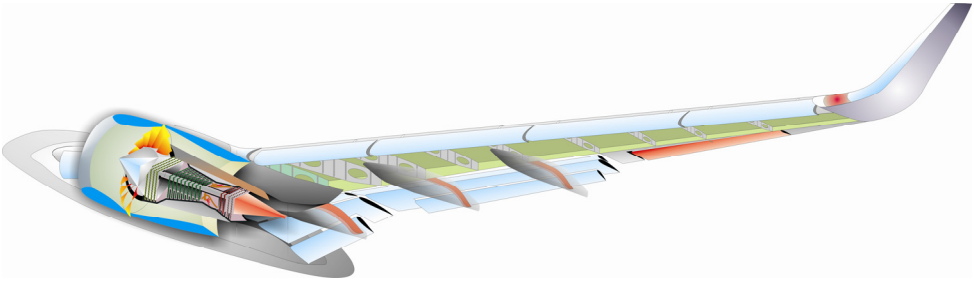
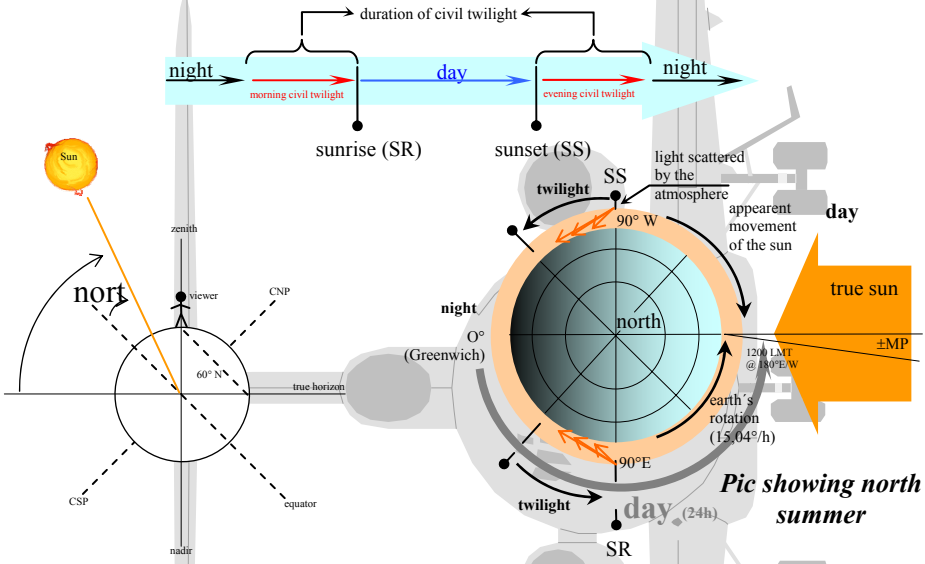


11. Time definitions

- UTC: universal time coordinated (artificial time)
- ST: standard time (time defined by state borders)
- LMT: local mean time (time defined by the sun)
- UT: LMT @ Greenwhich = LMT – east (+ west) longitude (15,04°/h)
- DST: daylight saving time (check relevant AIP if applicable)



12. Height of the sun / meridian passage

Height in ° Lat: $h = (90-\rho) \pm dec$; (ρ = Lat of viewer position, dec = declination of the sun - see actual air almanac)

- ➢ Dec of sun and lat of viewers position in same hemisphere: add dec
- ➢ Dec of sun and lat of viewers position in contrary hemisphere: subtract dec
- Equation of time: LMT ± MP = true sun (sun in zenith)

data from air almanac 1990:

Date	*Declination*	*MP [min]*
01.jan	23,0°S	+ 04
01.feb	17,1°S	+ 14
01.mar	7,6°S	+ 12
01.apr	4,5°N	+ 04
01.mai	15,1°N	- 03
01.jun	22,1°N	- 02

Date	*Declination*	*MP [min]*
01.jul	23,1°N	+ 04
01.aug	18,0°N	+ 06
01.sep	8,3°N	00
01.okt	3,2°S	- 10
01.nov	14,4°S	- 16
01.dec	21,8°S	- 11

Notes & Drafts:

13. Useful bearing / interceptions definitions

bearing (european)	*formula*	*american*	*GPS/FMS*
QDM	MH + RB	magnetic bearing to	BRG
QDR	QDM ± 180°	magnetic bearing from	BRG_{FROM}
QUJ	QDM ± Var	true bearing to	
QTE	QDR ± Var	true bearing from	LOP
desired QDM	see interceptions	desired track	DTK
intercept heading	see interceptions	course to steer	CTS

interception	*direction*		*enroute intercept angle (I∠)*	*correct to*	*CTS*
inbound	BRG > DTK	→ right / plus	BRG-DTK + 30° (max 90°)	DTK	DTK + I∠
	BRG < DTK	→ left / minus	DTK-BRG + 30° (max 90°)	DTK	DTK - I∠
outbound	$BRG_{from} > DTK_{from}$	→ left / minus	30 / 60 / max 90°	DTK_{FROM}	DTK - I∠
	$BRG_{from} < DTK_{from}$	→ right / plus	30 / 60 / max 90°	DTK_{FROM}	DTK + I∠

14. Frequencies / modulations / range / disturbancies

Range	*Freq. [Hz]*	*Systems*
LF	30k.....300k	ADF
MF	300k.....3000k	ADF
HF	3M.....30M	HF COM
VHF	30M.....300M	COM/VOR
UHF	300M.....3000M	GS/Tx/DME/RADAR/GPS
SHF	3G.....30G	PAR/ASDE

Modulation (AM)	
A_0	CW
A_1	CW, broken
A_2	CW + tone
A_3	voice
A_9	tone + voice

- Wave length: $\lambda = c/f$
- theoretical range of VHF and higher frequencies (optical range):

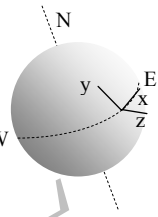
  range = 1,23 ·√ (height [ft]); [nm]

  (This formula takes the curvature of the earth into account only. Practically, the range is in most cases limited by the transmitter's power and/or by obstacles/mountains)

- Freq´s in the LF/MF/HF range can be disturbed by:
  - Statics (convective weather, high solar activity in high latitudes), air density differences (shoreline effect), reflection (mountain effect), interference (fading, twilight effect)

Notes & Drafts:

15. Gyros / AHRS / INS corrections



- *precession leads initial movement by 90°*

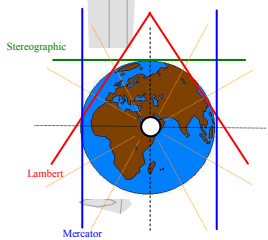
- True precession: see system's manual
- Apparent precession:
  - Earth rate precession (ERP)
  - Earth transport precession (ETP)

precession	***correction***		
	geographic east	geographic north	vector to center of the earth
	x-axis	y-axis	z-axis
ERP	*none*	$\varpi_E \cdot \cos \rho$	$\varpi_E \cdot \sin \rho$
ETP	v_N/R	v_E/R	$(v_N/R) \cdot \tan \rho$

- v_N: a/c speed vector northbound
- v_E: a/c speed vector eastbound
- R : earth's radius plus inflight height
- ρ : geo. latitude
- ϖ_E: earth's rotation (15,04°/h)

16. Chart projections

projection	***projection center***	***chart's straight line***	***used for lat: (N/S)***
stereographic	earth's center, adj. pole	stereodrome	50°...90°, Wx charts
Lambert	earth's center	lambodrome ≈ **great circle**	20°...70°
Mercator	earth's center	**rhumb line**	0°...40°



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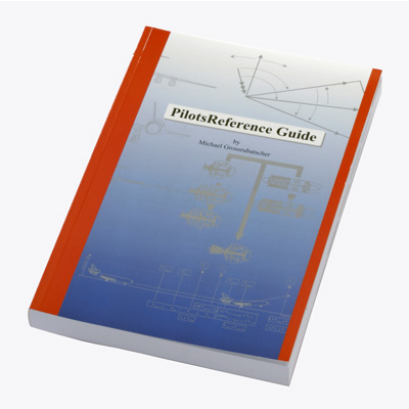

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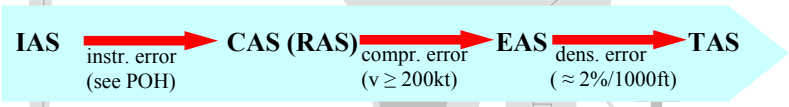
II. Performance

1. General

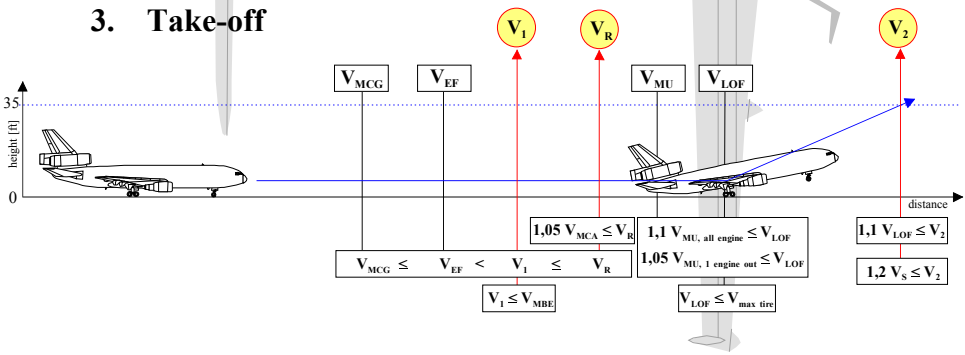
- Maximum altitude: max. alt. for 30° bank in level flight
- Aerodynamic ceiling: convergence of high and low speed buffet
- Service ceiling: $ROC_{all\ engines}$ =100ft/min, ROC_{SE} =50ft/min
- Max operating alt: max cabin alt (FL80) + $\Delta\ p_{max}$
- Absolute alt: rate of climb (ROC) = 0ft/min
-
- $SR = \frac{NAM}{m_{fuel}} = \frac{TAS}{FF}$; $SC = \frac{1}{SR}$
- ROC [ft/min] =GS[kt] · Climb Gradient [%] · 1,013
- Climb Gradient [ft/nm] = Climb Gradient [%] · 60,75

$$ROC = \frac{\text{Thrust - Drag}}{\text{mass}} \cdot TAS;\ \text{Climb Gradient [\%]} = \frac{\text{Excess Thrust}}{\text{mass}} \cdot 100$$

2. Speeds



3. Take-off

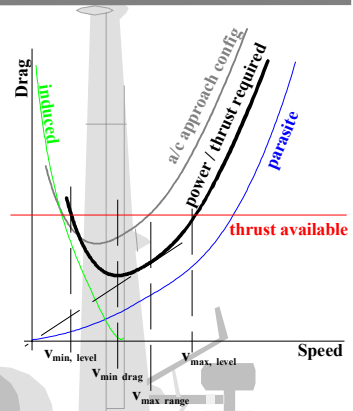


Notes & Drafts:

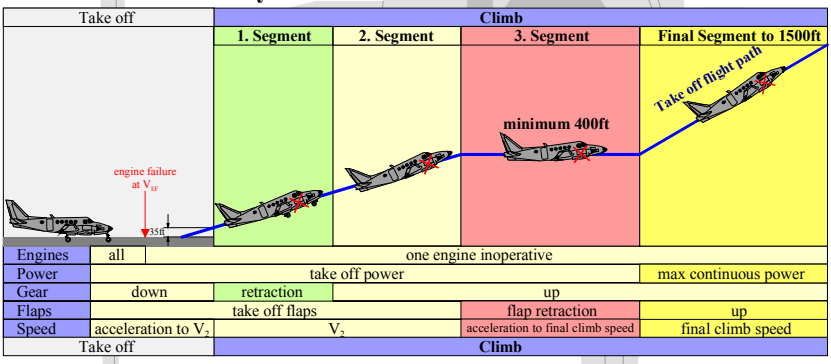
- **Take off distance , Drag curve**

TOD/TOM:
all engines
single engine
abort case
MTOM

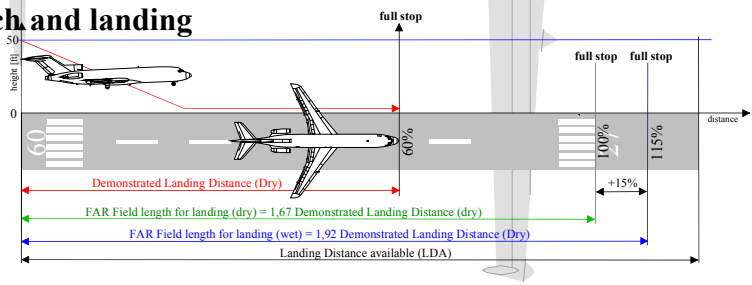
lowest mass or longest distance



- **Take Off Field definitions**
  - **TODA = RWY + clearway**
  - **TORA = RWY**
  - **ASDA = RWY + stopway**
  - **LDA = RWY**
  - **Useable clearway = max ½ RWY**



4. Approach and landing



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III. Weight & Balance

1. Definitions (JAR-OPS 1.605...1.625)

- Empty mass (EM): naked aircraft
- Empty mass wet (EM wet): naked aircraft plus liquids (oil, etc)
- Basic mass (BM): EM wet + extra equipment
- Dry operating mass (DOM): BM + crew + crew bags + pantry
- Operating mass (OM): DOM + take off fuel (TOF)
- Take off mass (TOM): OM + traffic load (TL)

⇒

EM wet + equip.	=	BM
BM + crew + crew bags + pantry	=	DOM
DOM + TOF	=	OM
OM + TL	=	TOM

2. Center of gravity (CG)

$$CG = \frac{\sum_i (m_i \cdot st_i)}{m_{total}} \quad [st]$$

3. Shift equation

$$\frac{m_{shift}}{m_{total}} = \frac{\Delta CG}{\Delta st}$$

4. Lowest of A/B/C method

Actual:	*Maximum masses:*		
DOM	max zero fuel mass	max t/o mass	max ldg mass
+TOF	+ TOF		+ trip fuel (TF)
= OM	= A (lowest)	= B	= C
	- OM		
	= allowable TL		
	- act. TL		
	= underload		

Calculation in blue on lowest value (of A,B or C)

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IV. Flight Planning

1. Nautical air miles (NAM)

- WCA/GS calculation → $time_{leg}$
- $NAM_{leg} = TAS_{leg} \cdot time_{leg}$ = still air distance range

2. Overhead/overhead flight planning

$\sum_{leg} NAM_{leg} + add_{climb} + add_{enroute\ climb} - sub_{descent} = TF$

3. VFR reserves

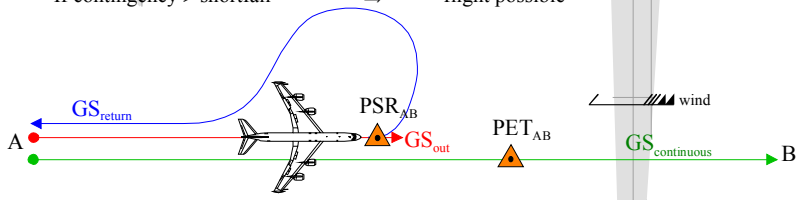
FAA: VFR day → 30 minutes res. ; VFR night →45 minutes res.

4. IFR reserves

Rules to apply	*Trip (TF) plus →*	*Reserve* (+ fuel for all predictable delays)		
		Contingency	*Alternate*	*Holding*
EUOPS piston	Cruise power set	5% of TF	Opt. Power	45 min
EUOPS turbine	Cruise power set	5% of TF	Opt. Power	30 min
FAA	Cruise power set	None	Opt. Power	45 min

5. Long range (reclearance procedure)

- Point of safe return: $PSR_{ab\text{-}x} = \frac{GS_{return}}{GS_{return} + GS_{out}} \cdot Endurance_{rest}$ [time]
- Point of equal time: $PET_{ab\text{-}x} = \frac{GS_{return}}{GS_{return} + GS_{continous}} \cdot Dist_{ab}$ [dist.]
- First decision point: $FDP = \frac{shortfall}{contingency} \cdot FT$ [time]
- If contingency > shortfall ⇒ flight possible



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V. Meteorology

1. General

PA / QNE alt
(1013,25hPa / 29,92 inHg)

± 120 ft/° dev. ISA

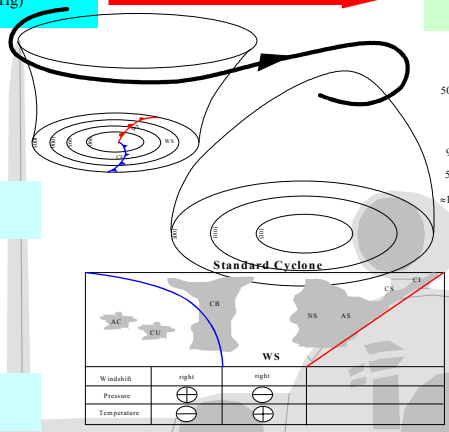
DA (service ceiling)
relevant for a/c performance calculations

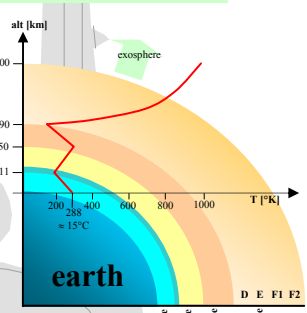
± 30 ft/ΔhPa dev. 1013hPa

QNH

± 1/273 per ° dev. ISA

True alt
relevant for terrain clearance





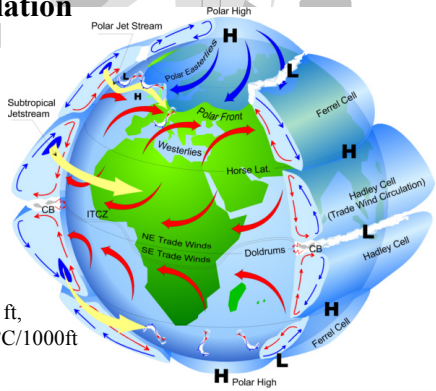
2. Mist / haze / brôme /cloud levels

Visibility	*relative humidity*	*phenomenon*
1..5km	< 80%	haze (hz)
1....5 km	> 80%	brôme (br)
Vis < 1 km	rh = 100%	fog (fg)

level	*clouds*	*height*
high	CI, CS, CC	6000 ft / 12 km / -56°C
middle	AC, AS, NS	6500 ft / 7 km / -35°C
low	ST, SC, CU, CB	7000 ft / 2 km / 0°C

3. Topographic / global circulation

pressure	*flight level*	*analysis*
850 hPa	50	temperature
700 hPa	100	humidity
500 hPa	180	wind
300 hPa	300	jet



4. ISA / adiabatic gradients

- ISA sea level: 15°C, 1013,25hPA
- ISA lapse rate: -2°C/1000 ft
- relative humidity: 0% (ISA)
- adiabatic lapse rate: dry ≅ -3°C/1000 ft,
  Saturated ≈ 1..2°C/1000ft

Notes & Drafts:

VI. Aerodynamics

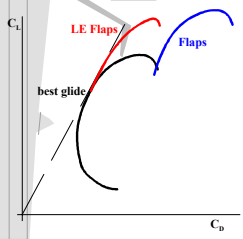
(β = bank angle, n = load factor, g = 9,81 ms^{-2})

1. Formulas

- Standard turn: $\beta = \frac{TAS}{10} + 7$ [°]
- Load factor: $n = \frac{1}{\cos \beta}$ [1]
- Stall speed increase: $v_{s,n>1} = v_s \cdot \sqrt{(n)}$ [kt]
- Radius of turn: (metric input!) $R_{turn} = \frac{v^2}{g \cdot \tan \beta}$ [m]
- Rate of rotation (metric input!) $RR = \frac{\tan \beta}{2 \cdot \pi \cdot v} \cdot 360 \cdot g$ [$°s^{-1}$]
- Slipping turn: inclinometer ball outbound / descent tendency
- Skidding turn: inclinometer ball inbound / climb tendency
- Level off radius (metric input!) $R_{level\ off} = \frac{v^2}{g \cdot (n-1)}$ [m]
- Stall speed with flaps $v_{s0} = vs \cdot \sqrt{\left(\frac{c_{L,max,clean}}{c_{L,max,flaps}}\right)}$ [kt]
- Sonic speed $M = \frac{TAS}{\alpha}$ [1]; $\alpha = 39 \cdot \sqrt{T}$ [kt]; (T in°K!)
- SAT/TAT conversion $SAT = TAT - \frac{IAS}{10}$ (appr. 200 kt < IAS)

2. Lift / Drag

$L = c_L \cdot A \cdot ½ v^2 \cdot \rho$; $D = c_D \cdot A \cdot ½ v^2 \cdot \rho$



3. Limit loads (JAA/FAA part 25, SF = 1,5)

- Clean: limit +2,5 / -1,0; ultimate +3,75 / -1,5 [g]
- Flaps: limit +2,0 / -0,0; ultimate +3,00 / -0,0 [g]

4. v/n diagram vertical gust speed conversion:

- v_B = ± 66 $ft \cdot s^{-1}$ = ± 20 $m \cdot s^{-1}$ = ± 4000 $ft \cdot min^{-1}$
- v_C = ± 50 $ft \cdot s^{-1}$ = ± 15 $m \cdot s^{-1}$ = ± 3000 $ft \cdot min^{-1}$
- v_D = ± 25 $ft \cdot s^{-1}$ = ± 7,6 $m \cdot s^{-1}$ = ± 1500 $ft \cdot min^{-1}$

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VII. Hypoxia / Supplemental Oxygen

1. Hypoxia

breathing	*first deficiencies*	*death*
air	10000 ft	22000 ft
100% oxygen	38000 ft	43000 ft
pressure (O_2)	45000 ft	50000 ft

2. Time of useful consciousness (TUC)

Altitude	*TUC*
25000 ft	5 min
27000 ft	3 min
30000 ft	90 sec

Altitude	*TUC*
35000 ft	45 sec
40000 ft	20 sec
43000 ft	15 sec

3. Oxygen requirements (FAA/EUOPS check EUOPS 1.385, 1.770...1.775)

EUOPS	
Cabin	*oxygen for*
Unpressurized	All occupants above F100
Pressurized	All until descent to F100 made

FAA: part 91 (cabin pressures)	
above	*oxygen for*
12500 ft MSL	for min. Crew (after 30 min)
14000 ft MSL	for min. Crew, always
15000 ft MSL	for each occupant, always

EUOPS: each commander shall ensure that:	
above	*oxygen for*
13000 ft	All flight crew req. for safe flight
10000 ft	as above if longer than 30 min

FAA: pressurized cabin a/c (part 91)	
above	*oxygen for*
FL 250	10 min. + emerg. oxygen
FL 350 single hand	mask on, auto sup. if cp>14000 ft
FL 350 multicrew	masks off, if quick donning avail.
FL 410	One CM mask on

quick donning masks shall be available in a/c certified for flights above FL 250

HUM PEERF

Notes & Drafts:

PilotsReference Image CD©
EAN 0094922913722

VIII. Further Regulations

1. IFR planning minima (JAA, commercial only)

Airport	*predicted weather at ETA ± 1h*	
T/O alternate	sufficient for intended type of approach	
destination	sufficient for intended type of approach	
enroute / dest. alt	intended approach	pred. Wx sufficient for
	CAT II / III	CAT I
	CAT I	non precision approach
	non precision approach	non prec. + 200ft/1000m
	circling approach	circling approach

2. Life vests (private/commercial: check EUOPS 1.825)

- 50nm over water and/or APP/DEP over water
- SE a/c additionally when out of glide distance to reach land

3. Dinghies (commercial: check EUOPS 1.830)

- 400nm over water or 120min whichever is less (check ETOPS if applicable)