Chapter 1

Air law: Review of the basics

1. General provisions

Introduction:
- Federal government has final authority through Aeronautics Acts
- Canadian aviation regulations (CAR) under authority of Aeronautics Acts
- Transport Canada & representatives are government authority → The minister
- Canadian aviation regulations advisory council (CARAC) makes recommendations for CAR

Interpretation:
- Listing of standard air regulations terms

Inspection of aircraft/documents:
- Pilot's license holder/registered owner need to produce documentation if requested for inspection
- Allowed to request: Peace officer, immigration officer, minister

Return of documents:
- If Canadian aviation document is suspended/canceled → Person should return it after effective date

Record keeping:
- Backup of computer info shall be kept and protected against loss, destruction & tempering
- Info requested by minister should be produced promptly → Print on paper

Principal:
- Air operator: Employed/contracted as operations manager, chief pilot, person responsible for maintenance control system, person that exercise control over air operator as owner, accountable executive appointed by air operator

Accountable executive:
- Apply to flight training unit operator certificate, approved maintenance organization, air operator cert
- Applicant shall: Appoint individual as AE to be responsible for Operations/activities,
  Meeting requirements of regulations,
  Notify minister the name of person appointed,
  Submit signed agreement to accept responsibilities within 30 days,
  AE must have control of financial & human resources necessary for activities & ops,
- AE is still responsible even with MCP, operation manager, maintenance manager
- If AE is holder of more than one cert, only one AE shall be appointed to be responsible for ops & activities

Safety management system (SMS):
- Applies to Approved maintenance organization & Air operator certificate
- Include: Safety policy
  Setting goals for improvement of aviation safety & measure the attainment of goal
  Identifying hazards to aviation safety & for evaluating & managing risks
  Ensure personnel are trained & competent to perform duties
  Internal reporting & analyzing of hazards, incidents, accidents, taking action to prevent reoccurrence
  Doc containing safety management system processes & process to make personnel aware
  Quality assurance program
  Process for conducting periodic review/audit of safety management system
- Correspond to size, nature, complexity of operations, activities, hazards, risks associated

Aircraft marks:

- Cannot operate aircraft in Canada unless its marks are visible & displayed
- Aircraft registered in foreign state: Marks have to be displayed according to laws of that foreign state
- Written authorization permitting aircraft without marking from Minister (Air show, exhibition etc)

Certificate of registration on board:

- Cannot operate in Canada other than foreign registered aircraft unless cert. is carried on board

Transfer of legal custody & control:

- Certificate of registration is canceled when transferring legal custody & control
- Notify Minister of transfer in writing for not later than 7 days after transfer
- Owner has legal custody & control of Canadian aircraft when owner has complete responsibility for operation & maintenance of aircraft

Operation of a leased aircraft by non-registered owner:

- Lessor & lessee each hold Canadian operator certificate issued in respect to aircraft type to be operated
- Lessee is qualified to be registered owner of Canadian aircraft
- Maintenance control system & maintenance schedule approved by Minister
- Crew members of aircraft are employed by lessee
- Registered owner informs Minister in writing no later than 7 days after term of lease commences

operator leasing aircraft to another operator without getting new C of R

⇒ TC authorization permitting operation must be carried on board

2. Aerodromes and airports

Aerodrome:

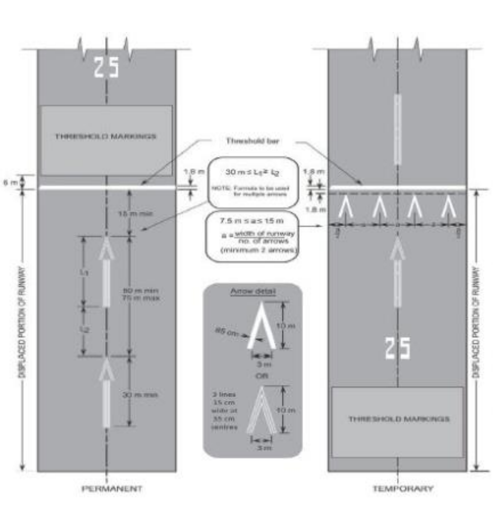
- Any area of land/water that is designed for arrival, department, movement & servicing of aircraft
- Known as registered aerodrome in CFS

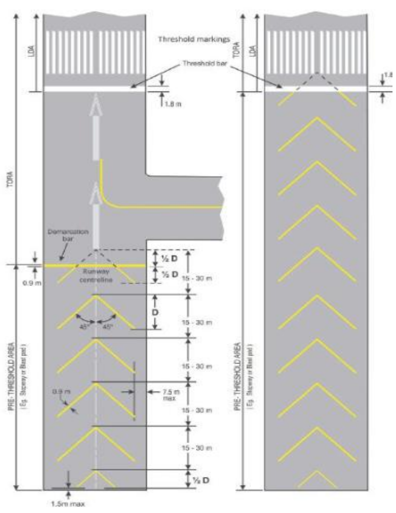
Airport:

- Certified aerodrome
- Inspected & maintained to TC requirements
- Current status is advertised in Canada Flight Supplement (CFS), Canada Air Pilot (CAP), NOTAM & voice

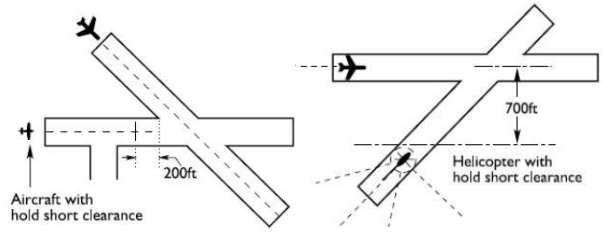
Makers and markings:

- Maneuvering area: For taxiing, takeoff & landing → Runway & taxiway
- Apron: Loading of cargo, passengers, refurling, parking
- Movement area: Maneuvering area + apron
  Prohibited to walk, stand, drive/park vehicle & cause obstruction to aircraft without permission from ATC/FSS/operator of airport
  Animal to run within boundaries of airport is not allowed
- Runways & numbering: Magnetic bearing (Southern domestic) to the nearest 10°, last zero is omitted
  → Indicating what direction it is pointing to
  Displayed at approach end of each runway with reciprocal at other end
  Left (L), Right (R), Centre (C)
- Runway markers: Takeoff & landing area boundaries of aerodromes without prepared runways
  → Indicated by conical/gable-type markers (Orange & white for airport, orange for other)
  Highway-type cones also ok, evergreen tree in winter
  Not more than 90m (300ft) apart along each side of runway
  → No boundary markers are required if movement area is delineated from surrounding
- Runway markings: Displaced threshold: Line across runway with arrowheads pointing
  Can be used for taxing & takeoff roll / landing rollout from opposite
  Has not met standard obstacle clearance requirements for IFR
  → Land before this mark at pilot's discretion only
  Temporary threshold: Install flags/cones/wing bar lights to indicate
  NOTAM/voice advisory describes markers, expected duration, length of close portion, remaining usable runway
  Paved area: Marked with yellow chevrons when length > 60m
  Not available for taxiing, initial takeoff roll/landing rollout
  May also be used on blast pads (Prevent jet blast to damage runway)
  Pre-threshold areas & stopways: Paved but non-loading bearing
  → Design to stop if overrunning
  Provide room to stop if abandon T/O

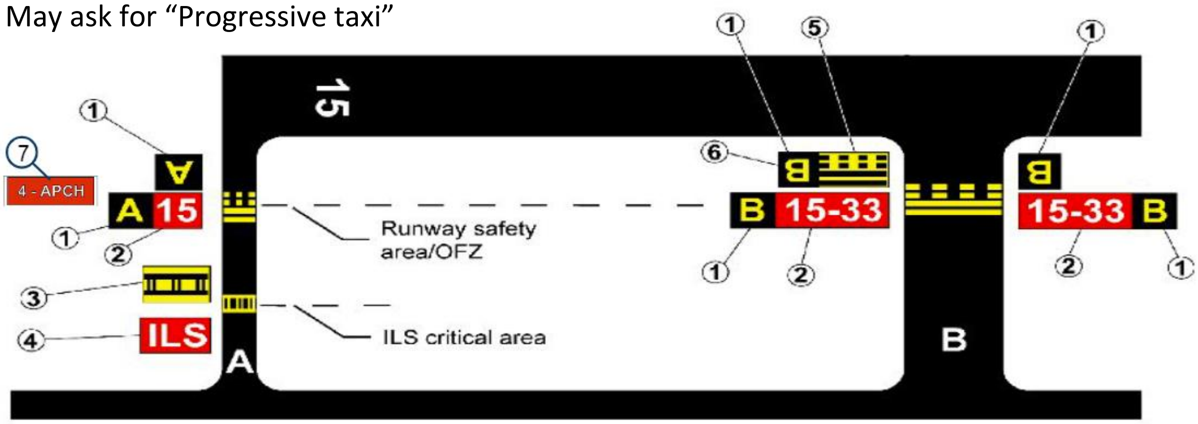


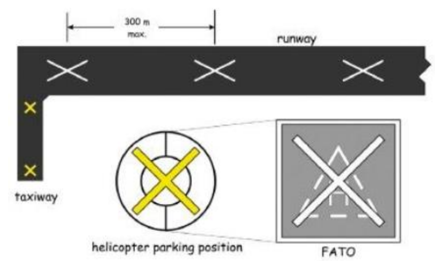


- Taxiways: Yellow line down centre, lettered for identification



- Holding short:
  Aircraft: Hold 200ft from edge of runway if no hold short line
  Hold 200ft from edge of intersecting runway during sequential & simultaneous ops. at controlled
  Helicopter: Hold 700ft from operations at controlled airport
  Taxiway with crossing runway: Must hold short (Yellow solid & dashed line) unless have a clearance
  → Hold on the solid line side
  After landing: Cross solid line & hold on solid line side
  May ask for "Progressive taxi"





- Closed markings: White crosses on runway & yellow crosses at end of taxiway, night with red lights
  Movement area: Marker boards, cones/red flags, flag/marker near centre of area,
  red flags if portion is small enough for aircraft to bypass
  Wind socks must be removed

Windsock:
- Dry standard wind direction indicator: Horizonal = 15kt, 5° = 10kt, 30° = 6kt
- Runway > 1200m (4000ft) requires windsock at each end
  → Near touchdown zone & 60m outward from edge of runway & clear of obstacle free zone
- If wind direction is available via radio/smoke/air/water, windsock is not required

Blue taxiway Lighted windsock
Parking area lights

Aerodrome lighting:
- Night operation runway: 2 parallel rows of white lights/retro-refelctive markers visiable at least 2 miles
- Each lines of lights/markers: At least 420m (1377ft) in length and not more than 60m (200ft) apart,
  Contains no fewer than 8 lights/markers
- Runway threshold: Green, red when viewed from the back
- Taxiway: Blue
- Aircraft radio control aerodrome lighting (ARCAL): Keying microphone & remain on 15mins
  Should key sequence to ensure full 15mins cycle
  Type J: 5 times within 5sec
  Type K: 7 times intiatilly to turn on max intensity
  Adjust by keying 7/5/3 for high, medium, low

Standard circuit:
- 1000ft AGL & left turns unless specifiy

Overflying aerodrome:
- Shall not fly over at height less than 2000ft unless authorized/for purpose of takeoff & landing
- Cross aerodrome & join circuit at least 500ft above circuit alt.

Canada flight supplement:
- Contains info on all registered & certified aerodromes in Canada
- Updated every 56 days
- Canada water aerodrome supplement available annually

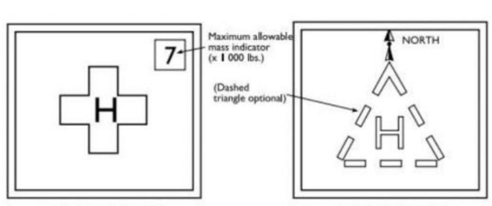
Prohibitions:
- Do not tow plane onto active maneuvering area at night without wingtip, tail & anti-collision lights on
Tow vehicle should be illuminated
- Do not park/leave plane on active area at night unless wingtip, tail & anti-collision lights on
Or illuminated by lanterns suspended from wingtip, tail & nose
- Do not operate/cause obstruction on surface of water area of aerodrome that should be clear of obstacle
- Do not display marker/marking/light/signal that will cause person to believe it is an aerodrome
- Do not display near aerodrome with marker etc that causes glare/confusion/prevent visual perception
- Do not remove/deface/extinguish/interfere with marker etc for purpose of air navigation
- Do not discharge firearm within/into aerodrome without permission
- Do not allow animals to be unrestrained within boundaries of aerodrome

Fire prevention:
- No person shall smoke/display open flame when on apron, aircraft loading bridge, gallery/balcony that is contiguous to or that overhangs apron, where likely to create fire hazard that could endanger others
- Exceptions: Operator may authorize maintenance/servicing operations to use open flame/spark
May permit smoking in enclosed building/shelter located on apron

Runway surface condition:
- Provided when: Frost, snow, slush, ice on runway
Snow banks, drifts, windows on/adjacent to runway
Sand, aggregate materials, anti-icing, de-icing chemicals are applied to runway
Cleared runway width falls below published width
Runway lights are obscured/partially obscured by contaminants
Significant change in RSC including a return to bare & dry condition
As per required minimum inspection frequency

Canadian runway friction index:
- Reported when: Ice, frost, wet ice, slush over ice on runway
Sand, aggregate materials, anti-icing, de-icing chemicals are applied to runway
Chemical solution on ice on runway
Compacted snow on runway
Dry snow not exceeding depth of 2.5cm (1 in) on runway

Heliports markings:



3. Personnel licensing and training

Flight crew permit/license/rating:

- No person shall act as flight crew member unless: Have personal documents with you
  Have accurate & current medical

Flying foreign registered aircraft:

- Pilot have Canadian license/Equivalent to a foreign validation license issued under the laws of that state
- Pilot has Canadian license & aircraft is registered in contracting state

Recency requirements:

- Act as PIC/co-pilot within 5 years, otherwise complete flight review & PSTAR within 12 months before flight
- Complete at least 1 of following every 24 months: Flight review with instructor
  Attend safety seminar by TC
  Participate in TC approved recurrent training program
  Complete self-paced study program
  Complete training program/PPC
  Complete requirement for issuance/renewal of license permit/rating & complete written exam
- Complete 5 takeoffs & landings every 6 months to carry passengers
  Day: Takeoff/Landings can be done during day/night
  Night: Takeoff/Landings only at night
- Complete 3 takeoffs & landings every 3 months to act as flight crew in commercial operations in aircraft of that type/category/class/flight sim
- IFR: Proficiency check in aircraft/flight training device within 24 months
  After 1st 12 months, complete 6hrs of IFR including 6 approaches to minimum in past 6 months

Personal log:

- Date of flight, Type of aircraft & registration mark, Flight crew position
- Flights conditions (Day, night, VFR, IFR), Place of departure & place of arrival
- All of the intermediate takeoffs & landings, Flight time

Copilot flight time:

- Air operators may have programs of supervisions to allow co-pilots to credit flight time as PIC
- 100% count towards issuance of a higher license for ATPL requirements

Min 15 dual instrument time,
Max 5 ground

Privileges:

- Commercial pilot license: Exercise privileges of PPL, VFR OTT & Night rating
  PIC of single pilot aeroplane
  SIC of aeroplane requiring 2 pilots
  Fly for commercial air service as PIC (If min flight crew is 1 pilot)
  Co-pilot of an aeroplane
- ATPL: With Group 1 IFR → PIC/co-pilot of aeroplane requiring 2 pilots
  IFR lapses → CPL privileges
- Second officers: Act as second officer in any aircraft that rating applied to
  Act as second officer for purpose of training/competency check
  Act as flight engineer
  SO that supervises other SO may conduct training & competency check

Medical requirements: Expires on 1st day of 13th month (Last day can fly = "Last day")

- CPL: Category 1

  Valid for 12 months (6 months if 40yo older with passengers in single-pilot aircraft/60yo or older)

  ECG/EKG at 1st medical, every 2 years between 30-40yo, every year after 40yo

  Audiogram on 1st medical & on 55th birthday

  May exercise PPL privileges until end of validity (60 months)

Prohibitions against using privileges:

- Should not fly when: Suffering from illness, injury, disability

  Taking drugs

  Receiving medical treatment

  Involved in aircraft accident

  30 weeks or more pregnant/within 6 weeks of giving birth

Permission to continue:

- When renewing medical: Write "fit" & stamped, signed, dated
- Medical can be renewed in booklet as many times as needed until the booklet expires

Requirement to hold flight training unit operating certificate:

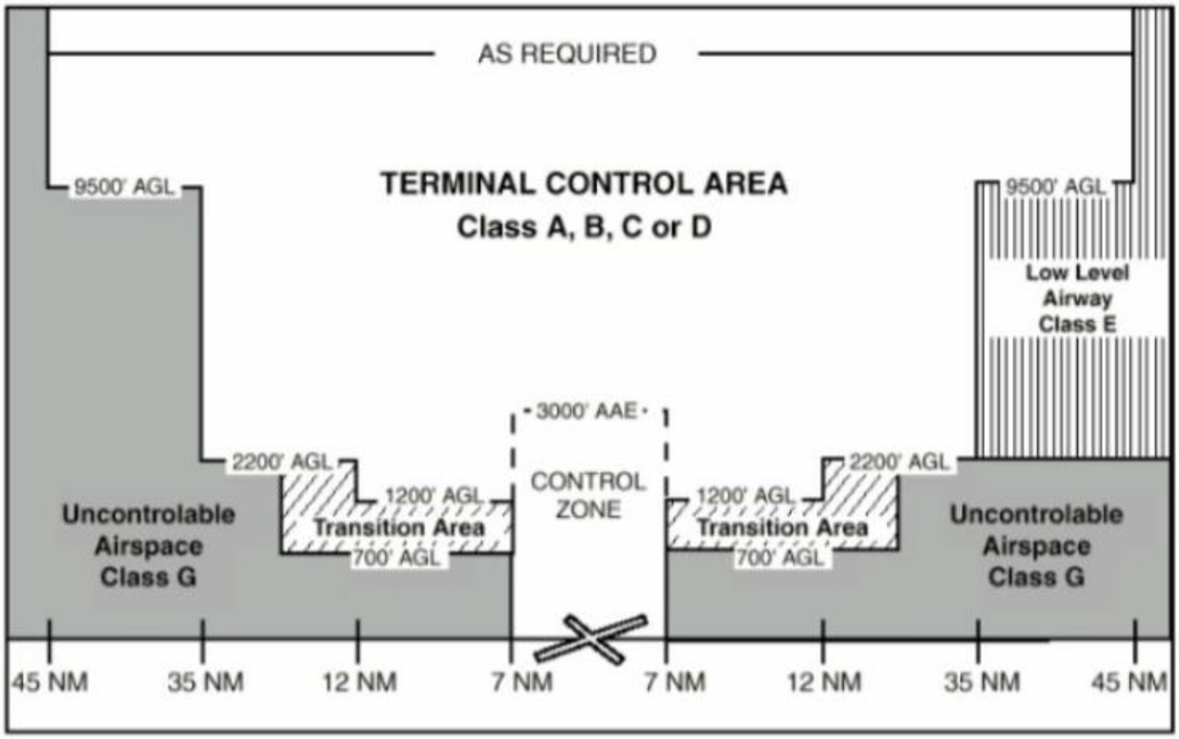
- Holds flight training unit operator certificate
- May operate without FTU operator certificate: Person holds air operator certificate

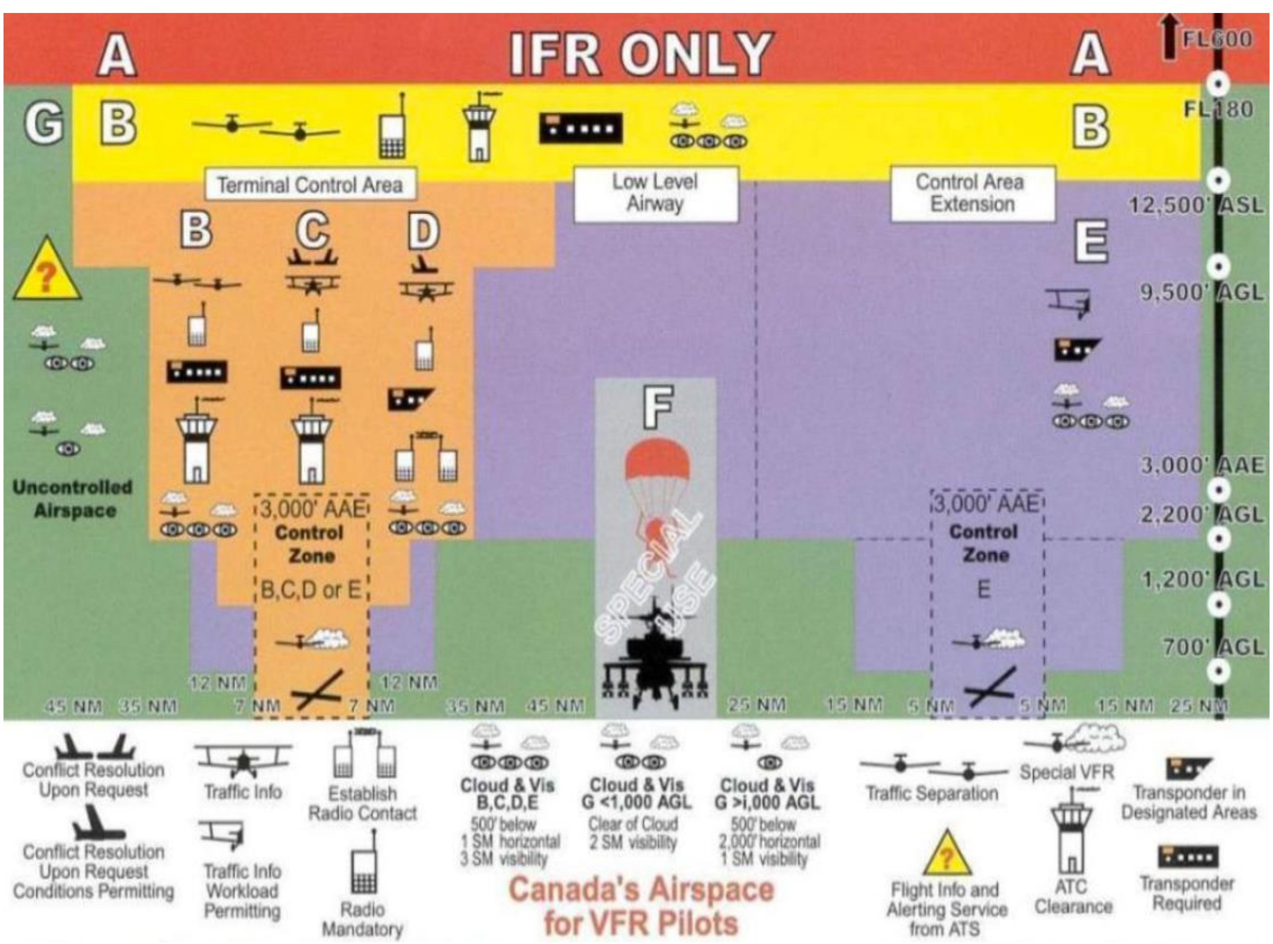
  Training is other than toward RPP, PPL, CPL, Instructor rat.
- Class 1/2/3 instructor without FTU OC can provide training to owner of aircraft/members of owner family

4. Airspace structure

Airspace classification:

- Airspace dimensions & VHF frequency for high density airport in Canada are shown on VTA & CFS
- 7 classes in Canadian domestic airspace





Class A (Controlled high level airspace): Maybe VFR 601.06(1)

- IFR only
- Require radio & ATC clearance, Mode C transponder, IFR certified & with sensitive pressure altimeter
- Southern Control Area (SCA) in Southern Domestic Airspace (SDA): 18000ft ASL to FL600 NOT FL180!!
  Northern Control Area (NCA) in Northern Domestic Airspace (NDA): FL230 to FL600
  Arctic Control Area (ACA) in Northern Domestic Airspace (NDA): FL270 to FL600
- Pilot is IFR rated

Class B:
- IFR, VFR
- Require radio & ATC clearance, Mode C transponder, Appropriate nav equipment
- Provide ATC service to IFR & Controlled VFR (Similar to flight following)
- All low level controlled airspace 12501-17999ft
- Hatched pattern on LO chart (Instrument)
  Dark blue line on VNC

Class C:
- IFR, VFR
- Require radio & ATC clearance, Mode C transponder
  NORDO/No TXPDR at ATC discretion for Day VFR

- Traffic separation for IFR
  Traffic info & conflict resolution upon request for VFR
- PIC has responsibility to avoid aircraft, maintain terrain & obstruction clearance & remain in VFR, communicate to ATC any concerns related to pilot responsibilities
- If ATC services are not operating, Class C reverts to Class E

Class D:

CZ: 3/5/7NM & 3000ft AAE
Military CZ: 10NM & 6000ft AAE

- IFR, VFR
- Require radio & establishment of two-way communication
  NORDO/No TXPDR at ATC discretion for Day VFR
- Transponder: May need, See charts/CFS
- Clearance for IFR
  No clearance needed for VFR
- Traffic separation for IFR
  Traffic info for VFR
- Class D control zone = Towered airport

Class E:
- IFR, VFR
- VFR controlled airspace weather min apply in both airspace & control zone
- If towered airport C/D closes, become a Class E controlled so follow MF procedures
- Controlled airspace: No special requirements for VFR
  IFR needs a clearance & are provided with separation
  Low level airways (2200ft AGL to 12500ft ASL for Class B or up to 17999ft ASL),
  control area extensions, transition areas,
  control zones established without an operating control tower

- Control zone: VFR must follow Mandatory Frequency procedures
  Get traffic advisory from FSS at least 5mins prior to entering

- E7000: Starts at 7000ft AGL unless ASL is stated

Class F:
- IFR is not permitted unless obtained permission from user agency, has Altitude Reservation, or conducting Contact/Visual Approach
- Restricted: Prior permission/approval only
- Advisory: VFR may fly through but keep alert, non-participating aircraft should not enter
- Unless specified, monitor 126.7MHz in Class F
- Class F restricted area may be created in NOTAM and not appear on charts
- **A**erobatic, **H**ang gliders, **S**oaring, Flight **T**raining, **P**arachute, **M**ilitary, **F**light Test Area

Class G:
- Uncontrolled airspace with no restrictions for IFR & VFR, no traffic separation
- 99% of Canadian Airspace
- Broadcast on 126.7MHz
- Green on LO chart (IFR map)
- Extends to 17999ft ASL unless specified in SDA
- Low level air routes start at surface & are designed by 2 letters and a number (E.g. AR34)
- L-Routes: RNAV routes   up to but not including 18000ft ASL

Transponder airspace:
- Class A, B & C require transponder as specified in Designated airspace handbook
- Class D & E may require as specified in DAH
- All Class E extending from 10000ft ASL to 12500ft ASL within radar coverage
- If Mode C fails: Proceed to next aerodrome of intended landing
  ATC may authorize aircraft to operate without transponder
  to allow aircraft to proceed to maintenance facility

Controlled airspace:
- ATC service is provided and within which some/all aircraft maybe subject to ATC
- IFR requires clearance to enter/operator within all classes of controlled airspace
- Types: High level airspace 18000ft ASL and above/ Low level airspace that is Class B, C, D or E

Control zone:
- Extends upwards vertically from surface of earth up to and including 3000ft AGL unless specified

Control area extension:
- Provide additional controlled airspace to handle IFR traffic
- Surrounds & overlies core control zone, Usually circular with defined radius
- IFR traffic is controlled by Area Control Center (ACC)
- Extends upwards from 2200ft AGL to 17999ft ASL

X terminal
X centre

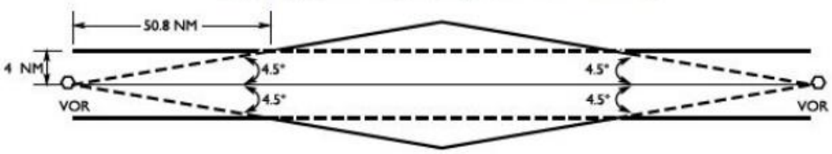
Special VFR:
- Must have two-way communication & pilot must request SVFR
- Grant permission for VFR aircraft to proceed into Control Zone when weather is below VFR
- Pilot must: Remain clear of cloud, maintain visual contact with ground
  Aeroplanes requires 1SM minimum visibility, Helicopter requires ½ SM minimum visibility
- ATC for Control zone must authorize SVFR
- Aeroplane: SVFR to arrive/depart for day, only arrival for night
- Helicopter: SVFR to arrive/depart for both day & night

Low level airways:

- Controlled low level airspace extending upward from 2200ft AFL up to 17999ft ASL
- VHF/UHF airways: 4NM width on each side of airway centerline out to 50.8NM
  Then width increase between points where lines diverging 4.5° on each side of centerline where they meet similar lines projected from adjacent facility
- Victor airway based on VOR/VORTAC & NDB = Boundary of LF/MF airway
- LF/MF airway: 4.34NM width on each side the centerline out to 49.66NM
  2 letters & a number
  Then width increase between points where lines diverging 5° on each side of centerline where they meet similar lines projected from adjacent facility
- T-route: Low-level controlled fixed RNAV route
  10NM on each side of centerline
  Airspace & protection areas do not splay (do not spread wide)
  Not shown on VNC but can be found on LO chart
  If T-routes are there = Class E airspace
- If see airway centerline & no boundary between aircraft's position and centerline & above 2200AGL → Class E

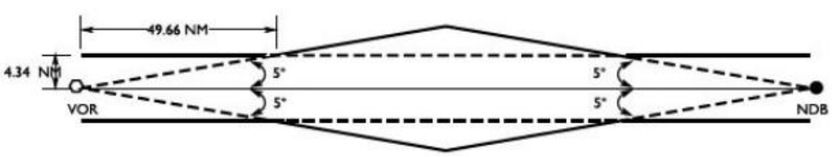
Fixed RNAV Route

VHF/UHF Airway Dimensions

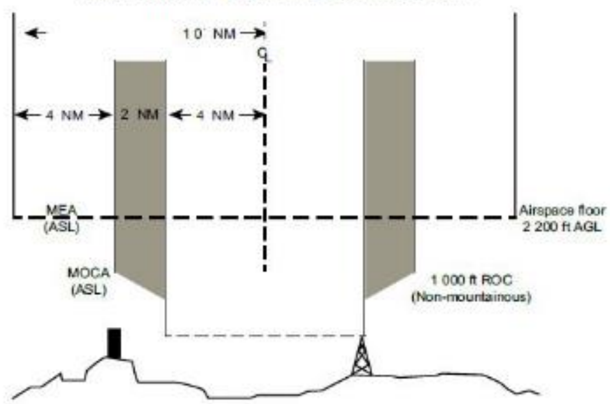


VHF/UHF Airway
Based on VOR and NDB

LF/MF Airway Dimensions



Fixed RNAV Route Cross Section



5. Forest fire flight restrictions and hazards to aviation

Flight restrictions:

- Forest fire: Standing timber, grass & any other vegetation/buildings are building
- Fire control authority: Official of gov forestry service/fire control agency
- No person shall operate aircraft over that area/area within 5NM at altitude < 3000ft AGL

Forest fire NOTAM:

- Restrict aircraft that are not involved with forest fire ops with more restriction than normal
- Includes location & dimension of the area, airspace in which forest fire ops are being conducted

Forest fire exceptions:

- Involved with surveillance & enforcement of Aviation Legislations
- With permission of fire control authority

Projections of directed bright light source at an aircraft:

- No person shall project bright light source to create hazard to aviation safety/cause damage & injury
- Person who want to project: Submit written request to Minister for authorization & obtain the approval
- No PIC shall operate aircraft into beam from directed light unless authorized by Minister

6. Operating and flight rules

Reckless aircraft operation:
- No one is permitted to operate aircraft in a way that would endanger person/property

Flight crew member's and fitness:
- Operator of aircraft shall not require person to act as flight crew member/carry out preflight duty if: Has reason to believe the person is noy fit for duty/Suffering from fatigue

Alcohol/drugs and flight crew:
- No person shall act as crewmember within 12hrs after consuming alcoholic beverage/under influence while using any drugs that impairs person's faculties
- AIM: Best to allow 24hrs between last drink & takeoff
  Remain in fluid of inner ear after trace of alcohol in blood have disappeared
  ∴ Difficulty in balance experienced in hangover
- 0.05% of alcohol can also reduce piloting skills
- Effect of alcohol & hypoxia is additive → 6000ft ASL (1830m) 1 drink = 2 drinks at sea level
- Body metabolizes alcohol at fixed rate ∴ Coffee, medication & oxygen will not alter this rate

Alcohol and passengers:
- No person shall consume alcohol on board an aircraft unless:
  Served by operator of aircraft (Not to person if believe they may present hazard to aircraft)
- Passengers may be refused boarding if deemed they may present hazard to flight
- Intoxicate person may be served alcohol if have medical release & attendant is with them

Compliance with instructions:
- Passenger on board shall comply with instructions given by any crew member
- Crew member on board during flight time shall comply with instructions of PIC
- Pilot's word is law

Smoking:
- No person shall smoke on board during takeoff/landing or when directed not to smoke by PIC
- No person shall smoke/ tamper with/disable smoke detector installed in aircraft lavatory

Aircraft operating limitations:
- No person shall operate aircraft unless it is operated in accordance with operating limitations set out in Aircraft flight manual or the mounted placards

Portable electronic devices:
- No operator of aircraft shall permit use of PED on board where the device may impair functioning of aircraft's system or equipment
- No person shall use PED on board except with permission of operator of aircraft

Fueling and passengers:
- Private operator: Aircraft can be refueled with passengers embarking/disembarking
- Commercial operator:
  Must be approved in COM & passengers must be secured on board & as per operations manual
  Not refuel when engine is running unless they are secured on board and follow procedures in CARs

Starting engines on the ground:

- No person shall start engine of aircraft unless either one of:
  Pilot’s seat is occupied by person who is competent to control aircraft
  Precautions have been taken to prevent aircraft from moving
  Seaplane: Aircraft is in location from which any movement of aircraft will not endanger person/property
- No person shall leave engine of aircraft running unless either one of:
  Pilot’s seat is occupied by person who is competent to control aircraft
  When no person is on board, precautions are taken to prevent aircraft from moving & not unattended

Aircraft icing:

- No person shall conduct/attempt to conduct takeoff with frost, ice, snow adhering to critical surface
- Critical surface: Wings, Control surfaces, Rotors, Propellers, Horizontal & vertical stabilizers,
  Other stabilizing surface, Aircraft with rear mounted jet engine the upper area of fuselage

Overflight of built-up areas:

- No person shall over fly unless aircraft is operated at altitude from which in the event of engine failure, it would be possible to land without creating hazard to person/property
- No person shall conduct takeoff, approach, or landing within built-up area of city/town unless it is conducted at airport, heliport or military aerodrome

Minimum altitudes and distances:

- Built-up area: 1000ft above highest obstacle with horizontal radius of 2000ft
  Helicopters 1000ft above highest obstacle within horizontal radius of 500ft
- Non built-up area: 500ft from any person, vessel, vehicle, structure
- National parks: Over flight shall not be conducted below 2000ft AGL

Permissible low altitude flight:

- May be operated lower than rules if:
  During police operation, To save a human life, Fire-fighting/Air ambulance operations,
  For purpose of flight inspection, An aerial application, Helicopters: External load operations

Right-of-way:

- Based on ability to maneuver
- Have nothing to do with how expensive the airplane, the size, IFR or VFR
- Converging aircraft: Has other on its right shall give way
  Airplane/Helicopter → Aircraft with towing/Airships → Gliders → Balloons
  Cannot pass over/under/cross ahead of others unless won’t create risk of collision
- Approaching head-on: Alter heading to right
- Overtaking: Aircraft being overtaken has right-of-way
  PIC of overtaking whether climbing/descending/level flight should alter heading to right
  Pass on right hand side
- Landing: Aircraft that is landing/about to land has right-of-way
  Low altitude aircraft has right-of-way
- On water: Legally still aircraft & subject to Aeronautics Act
  Rules should be adhered to are those that apply to watercraft

Collision avoidance:

- No person shall operate aircraft in proximity to another aircraft as to create risk of collision
- Pilots of aircraft are responsible for taking any action as is necessary to avoid collision

Towing:
- No person shall operate aeroplane that is towing an object unless it is equipped with tow hook & release control system that meets applicable standards of airworthiness

Formation flight:
- No person shall operate except by pre-arrangement between PIC of each aircraft, flight is conducted within control zone, the PIC & appropriate ATC unit

Dropping objects in flight:
- No person shall create hazard to person/property on surface by dropping object from aircraft in flight

Entering or leaving aircraft in flight:
- No PIC of aircraft shall permit person to enter/leave aircraft during flight unless: Special permission for air shows/Person leaves for purpose of making parachute descent

Parachute descents:
- Not allowed:
  Will drop into/operate in either controlled airspace/air route
  Over/into built-up area/open-air assembly of persons

Aerobatic maneuvers:
- Not allowed:
  Over built-up area/open-air assembly of persons
  In controlled airspace unless in accordance with special flight operations certificate
  When visibility < 3miles
  Below 2000ft AGL except in accordance with special flight operations certificate

Aerobatic maneuvers with passengers:
- Not allowed unless PIC has:
  At least 10hrs dual flight instruction/20hrs conducting aerobatic maneuvers
  At least 1hr of conducting aerobatic maneuvers in preceding 6 months

Fuel dumping:
- No person shall jettison fuel in flight unless:
  Necessary to do so in order to ensure aviation safety
  All appropriate measures are taken to minimize danger to human life/environment

ATC compliance:
- Instructions/clearances
- On known traffic only
- Pilot is not relieved of responsibility for traffic avoidance

ATC clearances:
- Authorization for aircraft to proceed with certain action
- If received & accepted by PIC then need to comply with all clearances except in emergencies
- May deviate for collision avoidance/TCAS/GPWS alerts, notify ATC asap
- VFR: Read back when requested by ATC
- Read back all hold short clearances

Pilot must acknowledge & comply with ATC instructions & VFR clearance
Read back VFR clearance when requested by ATC

ATC instructions:

- Directive, PIC must acknowledge & comply with provided safety is not jeopardized

Airspeed limitations:

- No person shall operate aircraft below 10000ft ASL at IAS > 250kt
- No person shall operate aircraft below 3000ft AGL within 10NM of controlled airport at IAS >200kt unless authorized by ATC

Cruising altitudes:

- Depends on: Magnetic track in SDA/True track in NDA,
  VFR: >3000ft AGL/IFR
- RVSM: Reduced vertical separation minima → designated RVSM airspace
- VFR cruising altitudes: 180° - 359° → Even thousands + 500ft
  000° - 179° → Odd thousands + 500ft

ALTITUDES OR FLIGHT LEVELS	AIRCRAFT TRACK	
	000° – 179°	180° – 359°
ABOVE FLIGHT LEVEL 290: FLY 4 000 FT INTERVALS	BEGINNING AT FLIGHT LEVEL 290 (FL 290, 330, 370, 410, 450)	BEGINNING AT FLIGHT LEVEL 310 (FL 310, 350, 390, 430, 470)
RVSM	FL 290, 310, 330, 350, 370, 390, 410	FL 300, 320, 340, 360, 380, 400
AT OR ABOVE 18 000 ASL BUT BELOW FL 290: FLY 2 000 FT INTERVALS	ODD FLIGHT LEVELS (FL 190, 210, 230, etc.)	EVEN FLIGHT LEVELS (FL 180, 200, 220, etc.)
BELOW 18 000 ASL: (FLY CORRESPONDING FLIGHT LEVELS IN STANDARD PRESSURE REGION) FLY 2 000 FT INTERVALS	IFR and CVFR	IFR and CVFR
	ODD THOUSANDS ASL (1 000, 3 000, 5 000, etc.)	EVEN THOUSANDS ASL (2 000, 4 000, 6 000, etc.)
	VFR	VFR
	ODD THOUSANDS plus 500 FT ASL (3 500, 5 500, 7 500, etc.)	EVEN THOUSANDS plus 500 FT ASL (4 500, 6 500, 8 500, etc.)

Altimeter setting procedures:

- Standard pressure region: NDA & all airspace at/above FL180 ASL
  Set to 29.92in of Mg
  Must reset altimeter before entering/leaving
  Climb SPR to SPR: Prior to desired flight level
  Climb ASR to SPR: After through FL180
  Descend from SPR: En route altimeter setting before passing through FL180
- Altimeter setting region: SDA up to 17999ft ASL
  Set to current altimeter setting/elevation of airport before take off
  Cruise: Nearest station/current setting of destination during landing

Landing or takeoff at night:

- Aerodrome/Helipad is lighted in accordance with aerodrome lighting requirements

Unmanned air vehicles:

- In accordance with rules for Remotely piloted aircraft system (RPAS)

Refusal to transport:

- Shall not transport if person may present risk to safety of aircraft, persons, property

Flight time & air time:

- Flight time: Aircraft is first moved under its own power for purpose of flight
  Aircraft comes to rest at end of flight
- Air time: Wheels become airborne to wheels touch ground again
- Flight time in pilot logbook & airtime in journey logbook

Sterile flight deck:

- During critical phases of flight including taxi, takeoff & landing, when below 10000ft
- Avoid: Eating, engage non-essential conversation within cockpit & with cabin
- Read publication not related/required for safe operation of aircraft

7. Altimeter setting procedures

Flight levels vs Altitudes:

- Standard pressure region with standard pressure → Use flight level in lieu of altitude
- Expressed in hundreds of feet

Altimeter setting regions:

- Departure: Current altimeter setting/elevation of aerodrome (+/-50fts for IFR)
- Enroute: Current altimeter setting of nearest station along flight
  Nearest station of route if stations are separated >150NM
- Arrival: Current aerodrome altimeter setting

Altimeter setting validity:

- Current up to 90mins from observation time
- Caution if older than 60mins/pressure falling rapidly
- 0.01 inches of mercury = 10ft correction
- Authorized remote altimeter setting → Apply altitude correction as indicated on CAP charts

Standard pressure region:

- Set to 29.92 inches of Mercury/1013.2 mb
- At/Above 18000ft ASL in SDA and in all of NDA
- Departure: Current altimeter setting/elevation of aerodrome
- Enroute: PRIOR to reaching flight level then set to 29.92/1013.2
  If desired level > FL180, change setting at 18000ft ASL
- Arrival: BEFORE descent then set to current altimeter setting
  UNLESS a hold is conducted/expected
  If cruising level > FL180, change setting at 18000ft ASL

Standard pressure region transition:

- Make change while in STANDARD PRESSURE REGION, after entering/before leaving
- Into Altimeter setting region: Obtain altimeter setting as far as practical before transition point

8. Operating and emergency equipment

Prohibition:
- No person shall operate aircraft unless required operational & emergency equipment is carried on board

Equipment standards:
- Required equipment must be functional
- Meet standards in Airworthiness Manual

Requirements for power-driven:
- Checklist, Timepiece, Hand-held fire extinguisher, First aid kit
- Necessary current aeronautical charts & publications covering route of proposed & probable diversionary route (VFR, VFR OTT, Night VFR, IFR)
- Night: Flashlight is readily available to each crew member

Survival equipment flights over land:
- Not required for balloon/glider/ultralight, aircraft with VHF radio within 25NM of home base,
  Multi-engine aircraft south of 66° 30' north, in IFR in controlled airspace/air routes
- Other: Sufficient for each person on board given geographical area, season, climatic variations
  → Start fire, provide shelter, provide/purifying water, visually signaling device
- Suggested min equipment for each geographical area: AIM Survival advisory information

Float and land planes – life preservers/flotation devices:
- Takeoff/landing on water in aircraft or operate aircraft over water beyond point where aircraft can reach shore in event of engine failure → Life preserver, individual/personal flotation device for each person
- Life preservers: Not more than 50NM from shore unless life preserver for each person on board
  Life jackets must be stored on board to be easily accessible

Life rafts:
- SE/ME plane: Beyond 100NM from suitable emergency landing site/
  Cannot be reached within 30mins at cruising speed specified in flight plan/itinerary
  → Whichever distance is lesser
- ME plane that capable of maintaining flight with any engine failed: 200NM and 60mins
- Transport category: 400NM and 120mins
- SE/ME that is unable to maintain flight with any engine failed helicopter: 25NM and 15 mins
- ME helicopter: 50NM and 30mins

) If > 50 NM then must be life preserver
< 50NM then life preserver / individual / personal
flotation device

9. Flight planning

Pre-flight:

- PIC: Familiar with available info that is appropriate to intended flight
  Has final authority as operation of aircraft
  Ensure aircraft is in condition for safe flight

Weather:

- PIC: Familiar with available weather info that is appropriate for intended flight

Flight plan/itinerary: IFR must file flight plan/itinerary

- Flight plan/itinerary: Beyond 25NM from departure aerodrome
  Operate within or into ADIZ (Air defense identification zone)
- Flight plan: Fly from Canada to foreign state
- Main reason: Search and rescue
- IFR may file IFR itinerary if: Conducted in part/whole outside controlled airspace
  Facilities are inadequate to permit the communication of flight plan
- Flight plan: Filed with Flight information center (FIC)/Flight service station (FSS) via telephone, in person, NavCanada website, radio on Flight information service en route (FISE) frequency
  → Up to 24hrs in advance, at least 30mins before departure
- Responsible person: Flight itinerary is filed with FIC/FSS or responsible person
  → Anyone who agrees to notify SAR in case aircraft becomes overdue
  PIC should ensure responsible person knows what to do if late/no-show
- Overdue aircraft: Flight plan: within 1hr of overdue time
  Flight itinerary: Exceed SAR time specified in flight itinerary
  24hrs of ETA in other cases

Contents:

Aircraft ident	Registration letters Company designator followed by flight number
Flight rules	I: IFR V: VFR Y: IFR first then VFR Z: VFR first then IFR
Type of flight (2 letters in total, 1st can be blanked)	C: Controlled VFR D: Defense VFR E: Defense flight itinerary F: Flight itinerary S: Scheduled air service N: Non-scheduled air transport ops G: General aviation M: Military X: Other than preceding categories
Number & type of aircraft	Number of aircraft Type of aircraft indicated by manufacturer's designator If no designator/formation forming: ZZZZ
Wake turbulence category	H: Heavy, maximum certificated takeoff mass >= 136000kg (300000lb) M: Medium, maximum certificated takeoff mass 7001-13599kg (15500-300000lb) L: Light, maximum certificated takeoff mass <= 7000kg (15500lb)

Equipment codes	COM, NAV, Radar (SSR) 1st suffixes: COM/NAV, oblique stroke, suffix to denote SSR → (../C) S: Standard equipment (VHF RTF, VOR, ILS) G: IFR GPS receiver must be TSO C-129 approved VFR not mandatory for TSO C-129 approved
Departure aerodrome	Canada: Point of departure, stopover, destination, alternate (3/4 letters as in CFS) ICAO: 4 characters location indicators Water/private/personal land VFR aerodrome: No location indicator → ZZZZ
Time	Coordinated universal time
Airspeed	True airspeed for 1st/whole cruising portion of flight IFR: Updated in flight if TAS changes >5% of filed or +/- 0.01 Mach Knots: N0100 for 100kt Mach number: M082 for Mach 0.82
Cruising level	Planned cruising level for 1st/whole portion of route Flight level: F085 for 8500ft Altitude in hundreds of feet: A045 for 4500ft Uncontrolled VFR: VFR
Route	CKK7 DCT CYWG A045 (0045) CYWG DCT CKK7 Steinbach South direct Winnipeg at 4500ft and landing. Stop for 45mins. Winnipeg direct Steinbach South. CKK7 DCT CYWG DCT CKK7 Steinbach South direct Winnipeg (over flying & not landing) then direct Steinbach South.
Destination	4 letters location indicator of destination aerodrome
Total estimated elapsed time (EET)	Total time from initial takeoff to last landing (IFR: Ends at initial approach fix) Includes stopover times
Search And Rescue (SAR) time	If left bank: Defaulted to 1hr for SAR Flight plan: 1hr after last ETA Flight itinerary: If unspecified 24hrs after last ETA
Alternate aerodrome	VFR: Do not need to file alternate airport IFR: At least 1 alternate is required, 2nd alternate is optional
Other information	Dangerous/hazardous cargo on board Reason for special handling If departure aerodrome has no air/ground com with ATS, phone number may be used if aircraft becomes overdue En route locations at which instrument approaches & overshoots are requested Other reasons for special handling by ATS Indicate any COM, data, surveillance applications/capabilities not specified above
Endurance time	Fuel endurance including all reserves SAR can get "radius of action" based on TAS, wind speed & endurance
Persons on board	Total number of persons on board

Emergency radios	CROSS OUT if not available: U for COM on 243.0MHz (UHF) V for COM 121.5MHz (VHF) E for Emergency locator transmitter (ELT) ELT: Categories should be entered in ELT box A/AD: Automatic ejectable/automatic deployable F/AF: Fixed/Automatic fixed AP: Automatic portable P: Personnel W/S: Water-activated/Survival
Survival equipment	CROSS OUT if not available: P for polar D for desert M for maritime J for jungle
Survival equipment: Life jackers	CROSS OUT if not available: L for life jackets with lights F for life jackets with fluorescein U/V to indicate radio capability of jackets (UHF/VHF)
Survival equipment: Dinghies	CROSS OUT if not available: D/C for dinghies Insert number of dinghies carried, total capacity in persons Cross OUT C if dinghies are not covered Insert color of dinghies if carried
Aircraft color and markings	Insert color of aircraft and significant markings
Remarks	CROSS OUT N if no remarks Indicate any other survival equipment carried & remarks Indicate if aircraft is equipped with ballistic parachute
Wheels/skis/floats	Check appropriate box for wheels, skis, floats, amphibian
Arrival report	Indicate what FSS, FIC or ATC unit you plan to close flight plan with
Aircraft owner	Indicate aircraft owner, person, company to be notified if SAR is initiated
Pilot name and license	Name of PIC & license number

Arrival report requirements:

- Close flight plan/itinerary as soon as possible but not later than:
  1hr after last reported ETA for flight plan
  24hr after last reported ETA for itinerary
- After SAR time has passed then will start searching, but may also start as early as 5mins after expiry time

Arrival report contents:

- As specified in CFS
- Arriving airport is served by tower: They will close flight plan automatically (But best to confirm)
- Controlled airport not served by tower/uncontrolled airport: Must be made to FSS as soon as practicable
  → Accomplish by radio (If FSS frequency within range)/by phone call to FIC

Overdue aircraft report:

- If suspect aircraft is missing: Notify ATC, FSS, CARS, Rescue coordination center
  Provide all available info concerning the overdue aircraft

Changes in flight plan:

- VFR: PIC intends to make change to route/duration/destination aerodrome of flight
  Notify ATC, FSS, community aerodrome radio station, responsible person

Fuel requirements & reserve:

- VFR fixed wing day: To destination aerodrome & then to fly 30mins at normal cruising speed
- VFR fixed wing night: To destination aerodrome & then to fly 45mins at normal cruising speed
- IFR fixed wing prop: To fly to & execute approach & missed approach at destination aerodrome, to fly to & land at alternate aerodrome and then to fly for period of 45mins
- IFR turbo-jet: To fly to & execute approach & missed approach at destination aerodrome, to fly to & land at alternate aerodrome and then to fly for period of 30mins
- Day/Night VFR Helicopter: To destination aerodrome then to fly 20mins at normal cruising speed
- Commercial night VFR Helicopter: 30mins at normal cruising speed

Fuel definitions:

- Reserve fuel: Extra fuel carried for unforeseeable, basically what cannot be planned for
- Contingency fuel: Extra fuel carried for foreseeable, what can be planned for
  → Weather, traffic, extra taxing, unfamiliar with area,
  flying around water when no flotation devices are carried
- Required fuel = Climb + cruise + reserve (If given then includes taxi & contingency)
- Used fuel = Burnt off during taxi + climb + cruise

Diversions from flight plan:

- SAR in Canada: Visual search extend to max of 15NM on either side of planned route, starting from aircraft's last known position & extending to destination
- ∴ Critical to adhere to filed routes and advise ATC of route changes/deviations

10. Pre-flight and fuel requirement

Carry-on baggage/cargo:
- Stowed in bin, compartment, rack
- Restrained to prevent shifting
- Must not block exit/emergency exit
- Stowed in passenger compartment must be packaged/covered to avoid possible injury

Crew member instruction:
- Each crew member is instructed: Duties that he/she is to perform
  Location & use of normal/emergency exits and all emergency equipment

Passenger briefing:
- Location and means of operation of emergency and normal exits
- Location and means of operation of safety belts, shoulder harnesses, restraint devices
- Positioning of seats and securing seat backs and chair tables
- Stowage of carry-on baggage
- Prohibition against smoking

VFR fuel requirements:
- Fixed wing Day: To destination aerodrome then fly 30mins at cruising speed
- Fixed wing Night: To destination aerodrome then fly 45mins at cruising speed

IFR fuel requirements:
- Propeller-driven: Fly and execute an approach and missed approach at destination,
  To fly to and land at alternate aerodrome and then to fly 45mins at cruising speed
- Turbo-jet powered: Fly and execute an approach and missed approach at destination,
  To fly to and land at alternate aerodrome and then to fly 30mins at cruising speed

No alternate IFR fuel requirements:
- Propeller-driven: Fly and execute an approach and missed approach at destination,
  Then to fly 45mins at cruising speed
- Turbo-jet powered: Fly and execute an approach and missed approach at destination,
  Then to fly 30mins at cruising speed

Definition:
- Reserve: Extra fuel for unforeseeable that cannot be planned for
- Contingency: Foreseeable → Possible delay from taxiing and takeoff, weather, air traffic routing etc

Exam:
- Required: Climb, cruise, reserve (Taxi and contingency if given)
- Used: Taxi, climb, cruise
- Turboprop’s jet fuel: 7lb/U.S. gal

Chapter 2

Air law: VFR Procedures

1. Operations in the vicinity of an aerodrome

General:
- Procedures for Mandatory Frequency (MF) areas
- Procedures for Aerodrome Traffic Frequency (ATF) areas
- All mandatory & aerodrome traffic frequencies in use at selected aerodromes as given in CFS
- All non-standard procedures as given in CFS

MF areas:
- Established at aerodrome if traffic volume & mix of aircraft traffic is such that there would be a safety benefit derived from implementing MF procedures
- May or may not be a ground station in operation at aerodrome that MF area has established
- MF ground station: Flight Service Station (FSS), Remote Communication Outlet (RCO),
  Community Aerodrome Radio Station (CARS),
  Approach UNICOM (Universal Communications) → Will have designator UNICOM (AU)
- Operations: VFR & IFR → Only when equipped with working two-way radio unless have prior permission
  PIC → Maintain listening watch on MF's frequency
- MF extends 5NM & 3000ft Above aerodrome elevation (AAE), with specific dimensions in CFS

MF with ground station:
- Almost always located at controlled airports
- Types: Ground station onsite (FSS, CARS, UNICOM)
  Remote Aerodrome Advisory Services (RAAS) provided remotely by FSS
- M: Mandatory
- Heavy lines: FSS onsite
- Light lines: Operate remotely via RAAS with controlling location in brackets

MF without ground station:
- No control zone/box to indicate FSS/RAAS

General MF procedures:
- Radio call should be directed to ground station with MF if it is in operation, otherwise to location name
  → FSS on location/RAAS: RADIO
  Uncontrolled: TRAFFIC
- NORDO may operate at MF when ground station is in operation & have prior notice and permission

Entering MF maneuvering area:
- PIC shall report intentions before entering maneuvering area
- Request aerodrome traffic advisory from MF
- Announce intentions at uncontrolled MF before entering taxiway

MF departure procedures:
- Before moving onto runway: Report the departure intentions
- Before takeoff: Ascertain by radio communication & visual observation that
  no likelihood of collision with other aircraft/vehicle during takeoff
- After takeoff: Report departing from aerodrome traffic circuit, maintain listening watch on MF/ATF
  Fly runway heading until circuit altitude then can intercept en route leg

MF arrival procedures:

- Observe traffic circuit to avoid collision & conform to circuit formed by other aircraft
  → Nobody in circuit and wind is calm then can choose which runway
- Before entering MF area: At least 5mins before entering area
  Give position, altitude, ETA, intentions
- When joining circuit: Give position in circuit
  When on downwind leg, final approach
  When clear of surface on which aircraft has landed

MF reporting procedures for circuits:

- Joining downwind leg
- When on final approach with intentions
- When clear of surface on which aircraft has landed

Flying through MF area:

- Before entering MF area: At least 5mins before entering area
  Give position, altitude, intentions
- When clear of MF area

NODRO MF procedures:

- May operate if: Ground station is in operation at aerodrome
  Prior permission of intension to operate aircraft at aerodrome is given

ATF operations:

- Busy uncontrolled aerodromes
- Radius of 5NM and extends 3000ft AGL
- Crossover aerodrome at 500ft above circuit height if field inspection is required
- Descent on upwind side to cross midfield at circuit height/join straight in downwind at circuit height
- All turns should be left unless indicated in CFS
- NORDO is permitted but must use standard circuit procedures & complete 2 full legs of circuit, be Vigilant

Uncontrolled with no MF/ATF:

- Broadcast position & intention on 123.2MHz

Receive only VOR:

- Set VOR to listen
- Set communication ratio to the one with "R" and transmit

Noise operating criteria:

- Noise abatement procedures & noise control requirements specified in Canada Air Pilot/CFS

Noise restricted runways:

- No takeoff of subsonic turbojet plane with MTOW > 34000kg (74956 lb) at noise restricted runway unless:
- Certificate of noise compliance issued in respect of plane
- Foreign certificate of noise compliance issued by country of registration & validated by Minister

2. Visual flight rule (VFR)

Control zones/airspace:

- 3 miles visibility
- 1 mile horizontally & 500ft vertically from clouds
- 500ft AGL (in Control zone)

Special VFR:

- Aircraft other than helicopter within control zone:
  Equipped with radio, Has authorization from ATC,
  Visibility not less than 1SM, Clear of cloud, Maintain visual contact with ground at all times
- Day: Takeoff & landing
- Night: Landing only
- Build-up area: 1000ft above highest obstacle within 2000ft horizontal distance
- Other: 500ft from any person, vessel, vehicle, structure
- Pilot must ask for SVFR & get clearance/permission
- IFR aircraft may deny/delay permission to enter SVFR
- Pilot requesting SVFR is telling controller that visibility is poor to keep separation from other aircraft
- Only can be requested in control zone

Uncontrolled airspace:

- 1000ft AGL or above: 1 mile visibility (Day), 3 miles visibility (Night)
  2000ft horizontally & 500ft vertically from clouds
- Lower than 1000ft AGL: 2 miles visibility (Day), 3 miles visibility (Night)
  Clear of clouds

VFR over-the-top:

- Must have VFR OTT rating/IFR rating/CPL
- 1000ft vertically from cloud
- At least 5000ft if operate between two cloud layers
- Visibility at least 5 miles
- During day only and cruise portion
- Forecast destination weather: Scattered/few/clear of cloud
  Visibility of 5 miles or greater
  No precipitation, fog, thunderstorm, blowing snow
  → TAF: 1hr before till 2hrs after ETA
  If no TAF then use GFA: 1hr before till 3hrs after ETA

Circuits in low ceilings:

- Still need to be 500ft below cloud base
- If clouds are too low & not leaving you safe altitude to fly = Clouds are too low to be in circuit

3. Radio communication

Continuous listening watch:

- If equipped with radio, PIC shall ensure listening watch is maintained on appropriate frequency
- Communication is established with applicable unit for the airspace that the pilot is flying in
- ATC unit: Tower/Terminal
- FSS: Class E control zone
- MF, CARS

Communication failure (VFR):

- Troubleshoot: Check frequency, volume, headset plugs etc
- COM is required (Class B, C, D, MF areas):
  Squawk 7600
  Leave controlled airspace
  → Control zone: Land at airport/aerodrome for which the control zone is established
  Controlled airspace: By shortest route (Descend below floor/leave laterally),
  land at nearest & practicable uncontrolled airport/aerodrome
- COM is not required (Class E, G):
  Avoid entering controlled areas, divert to airport/aerodrome which clearance is not required
  Cellphone on board may receive ATC clearance/Advise FSS of arrival in Class E control zone
  If needed, enter controlled airspace with caution & follow communication failure procedures

Light signals:

	Air (Rock wing in day, flash landing light at night)	Ground
Steady green	Cleared to land	Cleared for takeoff
Flashing green	Return for landing	Cleared to taxi
Steady red/red flare	Give way to other aircraft, continue circling	Stop
Flashing red	Airport unsafe do not land	Taxi clear of landing area in use
Red pyrotechnical	Do not land for the time being, military airports only	
Flashing white		Return to starting point
Blinking runway lights		Get off runway now

Projectiles: Red & green stars = In vicinity of restricted area & alter course

4. Emergency communication/Security

Emergency radio:

- All communication radios must be able to transmit/receive on 121.5MHz

Interception: Not ARMED interception

- Receive interception signals from: Peace officer, officer of police authority/Canadian Force
  Any person authorized to do so by Minister
- If unidentified aircraft may be truly hostile, until proven to contrary
- Intercepted aircraft: Maintain steady course & under no circumstance take retaliatory action
  Otherwise may be construed as hostile intent
- Practice interceptions are not carried out on civil aircraft
- Guideline for interception: CFS in emergency section
- Communications can be established on 121.5MHz

Air defense identification zone (ADIZ): Surface to FL600

- Area for security & control of aircraft by authorities of CAN/USA from surface to unlimited altitude (UNL)
- Procedure to enter/operate in/fly through:
  Flight plan/itinerary before entering/takeoff in ADIZ → File with ATC, FSS, CARS
  Penetration of ADIZ must be within 20NM of proposed route and +/- 5mins of ETA → Notify if changes
  For VFR departs within ADIZ, after takeoff then communicate & report location, altitude, aerodrome

Emergency security control of air traffic plan (ESCAT):

- Provides for security & control of civil and military air traffic by NORAD Commander
- Ensure effective use & security control of airspace when air defense emergency occurs
- Only in effect during 9/11, 1st and only time they were in effect
- System is tested without prior notice occasionally
  → Acknowledge test & continue flying
- When implemented: Controlled airspace → Report as required by regulations
  Uncontrolled airspace → Report every 30mins and comply with instructions
  Required to land at nearest aerodrome
  Obtain approval before takeoff

FSS/ATC

5. Special flight operations

Aviation events:

- Obtain Special Flight Operations Certificate (SFOC) from nearest TC office
- SFOC: Name & address of certificate holder
  Number, date of issue, validity period of certificate
  General conditions identified in section 603.04
  Special conditions, registration of plane
  Name and qualifications of flight crew member
  Any other additional condition
- Required: Parachute descent in controlled airspace/air route/built-up area/open-air assembly of persons
  Conduct takeoff/landing other than balloon within built-up area other than airport etc
  Aerial application/inspection/photography at altitude & distances less than normal legal
  Helicopter while in Class B/C/D external load operations over built-up area
  Operation of Unmanned Air Vehicle (UAV)
  Operation of powered aircraft while person enter/leave aircraft in flight
  Aerobatics in controlled airspace/air route or below 2000ft AGL

6. Aircraft requirements

Flight authority:
- All aircraft must have a flight authority
- Most common: Certificate of Airworthiness
- Special certificate of airworthiness: Restricted, provisional, amateur-built, limited, owner maintained
- Flight permit: Experimental (No passengers), specific purpose

Flight manual:
- Flight manual that is accessible to flight crewmembers in flight on board

Markings and placards:
- Nationality & registration marks must be affixed to aircraft in proper manner, clear, visible
- All required markings & placards must be affixed to required part

Equipment standards/serviceability:
- No person shall takeoff unless:
  Meets applicable standards of airworthiness
  Serviceable & where required by operational circumstances is functioning

Approved MEL = compliance becomes mandatory

Minimum equipment list: Must be approved by Minister
- Mandatory for commuter & airline operations
- Minister may establish a Master minimum equipment list (MMEL) for those aircraft types
- Company may have own MEL
- MEL may depend on type of flight (Day/night/IFR)
  → List of items that are allowed to be inoperative

NOT WHAT TO BE OPERATIVE

Unserviceable and removed equipment: Even unserviceable can still takeoff
- With MEL & no takeoff unless:
  Aircraft is operated in accordance with any conditions/limitations specified in MEL
  Copy of MEL is carried on board
  If AD is in conflict with item listed in MEL → AD prevails
- Without MEL & equipment is required by:
  Standards of airworthiness that are applicable to day/night VFR or IFR
  Any equipment list published by manufacturer respecting aircraft equip that is required for intended flight
  Certificate: Air operator, private operator, special flight operator, flight training unit operating
  Airworthiness directive
- Final decision rests with PIC: If thinks aviation safety is affected then no takeoff

Deicing/anti-icing equipment:
- When icing conditions are reported/forecast: PIC should verify aircraft is adequately equipped to operate in those conditions

7. Transportation safety board

TSB:

- Responsible for investigating all aviation related accidents & occurrences
- Purpose is to prevent a recurrence but not to lay blame
- Operate on 24/7 standby
- Contact numbers in phone book, AIM, CFS, through local FIC & FSS

Aviation occurrences:

- Accidents or incident that is associated with operation of aircraft

Reportable aviation accident:

- Accident is event results from operation of aircraft with one ore more following items occurring:
  Person sustains serious injury/killed
  Aircraft sustains substantial damage (Structural failure, damage affecting strength/performance)
  Aircraft is missing/inaccessible
- Incident resulting directly from operation of aircraft >2250kg (5000lb):
  Engine fails/shut down
  Transmission gearbox malfunctions
  Smoke/fire occurs
  Difficulties in controlling aircraft are encountered
  Aircraft fails to remain on landing/takeoff area
  Aircraft lands with gear retracted/drags a wing tip, engine pod or other part of aircraft
  Crew member incapacitation that poses threat to safety
  Depressurization occurs that necessitates emergency descent
  Fuel shortage results in diversion/requires approach and landing priority
  Aircraft is refueled with incorrect type of fuel/contaminated fuel
  Collision/risk of collision/loss of separation
  Crew member declares emergency/requires priority handling
  Slung load is released unintentionally/as precaution
  Any dangerous goods are released in/from aircraft

In the event of an accident:

- School/company should have Emergency response plan (ERP) that is reviewed & followed
- Report accident as soon as possible and by quickest means of communication possible
- Procedures on how to report can be found in AIM or by contacting nearest FIC/FSS
- Removal of wreckage may be done only with authorization
  → Except survivors to be rescued, additional danger can be avoided, prevent further destruction by fire

8. Air traffic services/procedures

NavCanada:

- Responsible for: ATC, Flight information (FSS & FIC), Weather briefing,
  Electronic nav aids, Private not for profit company

Air traffic services:

- Provided by: Area control centres, Terminal control units, Control towers

Airport control service:

- Provided by airport control tower (TWR) to aircraft & vehicles on maneuvering area of airport and to aircraft operating in vicinity of airport

Area control service:

- Provided by Area Control Centers (ACC) to IFR & controlled VFR operating within specified control zones

Terminal control service:

- Provided by ACC to IFR & CVFR operating within specified control zones
- Terminal radar service: Additional service provided by IFR units to VFR aircraft within Class C airspace

Air traffic services:

- Alerting service, Altitude reservation service
- Aircraft movement information service (AMIS), ATC service

Advisory services:

- Flight info will be available to aircraft communicating with ATC prior to takeoff/during in flight
- Factors such as volume of traffic & frequency congestion may prevent controller from providing service
- VFR will be provided with info: Severe weather conditions along proposed route of flight,
  changes in serviceability of navigation aids,
  conditions of airports & associated facilities
- Flight information messages are intended as information only → Pilot makes final decision

Flight Information Centers:

- FICs provide weather briefings & flight planning services with flight service specialist
- 5 FIC locations across country 5 Flight Information Regions (FIR)
- **Flight Information Services En-route (FISE)**
- **Upon request**: Meteorological info, Aeronautical info, Relay of communications with ATC
- **En-route aircraft may submit to FIC**: PIREPs, IFR & VFR position reports, revised flight plan/itinerary info
- **Aeronautical broadcast service**: FISE: 123.275, 123.375, 123.475, 123.55
  SIGMET & urgent PIREP & info of fuel dumping: 126.7
- **VFR flight plan alerting service**
- **Flight regularity message service**

Flight Service Stations:

- Located at Class E control zones at some airports, call sign is "RADIO"
- Provide service 24hr a day to airports where they are located & to any number of Remote Communication Outlets (RCOs) assigned to them, check CFS for operating hours at particular location
- **Aerodrome Advisory Service (AAS)/Remote Aerodrome Advisory Service (RAAS)**

- **Initial aerodrome advisory communication with flight service specialist**
- **NOTAM, RSC, CRFI:** Included for 12hrs for domestic traffic & 24hrs for international traffic
- **Aerodrome lighting, Relays ATC clearances, VFR arrival report, Alert appropriate agency**
- **Vehicle Control Services (VCS), VDF Service**

FIC and FSS:
- **RAAS, VCS, Alerting service, Emergency assistance service, VDF service, NOTAM info service, Weather observation service**

Dial-up remote communication outlet:
- Direct connection to ATS unit through commercial telephone line
- Pilot activates system via aircraft radio transmitter by keying microphone 4 times on published DRCO freq
- Freq for DRCO are published in CFS

Airport Radio (APRT RDO)/Community Aerodrome Radio Station (CARS):
- Provided by observer-communicators that are certified to conduct aviation weather observations & radio communications to facilitate aircraft arrivals and departures
- **Emergency service, Communication service, Weather observation service, Flight plan/itinerary service, Monitoring of equipment/NAVAIDs**

Universal communications:
- Air-to-ground com operated by private agency at uncontrolled aerodromes (low traffic, no control tower)
- Use of info received from UNICOM station is entirely at discretion of pilot
- May call UNICOM to announce location & intentions

Automatic Terminal Information Service (ATIS):
- Wind, Altimeter setting, Ceiling, visibility, runway in use, NOTAMs

Radio communication procedures:
- Radio can be operated only by persons holding Restricted Radiotelephone Operator's Certificate
- Reciprocal agreement between Canada & USA: Can operate with pilot's & radio operator's license

Radar service:
- Clock system
- Relative to aircraft's track but not heading
- If altitude is not given then it is unknown

Wake turbulence separation:
- Caution anywhere behind and less than 1000ft below a larger aeroplane/heavy helicopter
- Non-radar departures: 2mins separation interval to any aircraft takes off into wake of heavy aircraft
  Wake turbulence advisories to light aircraft taking off behind medium aircraft
  If not comfortable then may request more time
- Radar departures: Heavy behind heavy: 4 miles
  Light behind heavy: 6 miles
  Medium behind heavy: 5 miles
  Light behind medium: 4 miles

Controlled circuit procedures:
- Join/depart as controller instructs at control towered airports

Uncontrolled aerodromes:
- Exchange traffic info when approaching/departing
- Some aircraft may have No Radio (NORDO)

Mandatory frequency: 2 types: Advisory & non-advisory
- Designated frequency at uncontrolled airport/Controlled airport where tower has closed
- Must report position, intentions and monitor while operating within MF area
- 1st call should be at least 5mins prior to entering
- Must have a radio
- 5NM radius up to 3000ft AAE
- Specific dimensions & listed as MF in CFS
- Class C/D towered airport closes then become Class E MF area

Aerodrome Traffic Frequency (ATF):
- Busy uncontrolled airports, Listed in CFS
- 5NM radius up to 3000ft AAE
- Usually have ground station with UNICOM, If no ground station then ATF is 123.2MHz

VFR En route:
- Monitor 126.7MHz unless required to be on another frequency
- Uncontrolled airspace: Report location on 126.7MHz (bcst)
  If reporting on another frequency then also broadcast on 126.7
- Position reports should be made all over NAVAIDs along route to nearest station
- VFR position report format: Identification, position, time over, altitude, VFR, Destination, Type of flight plan
- Encourage to make position reports on nearest FISE frequency with FIC where they are recorded
  → Way position are available in the event of SAR action (Purpose of VFR position report)
- 126.7MHz is also used for broadcasting SIGMETs/AIRMETs from nearest FIC

VFR holds:
- VFR flights may be asked to "ORBIT" over given location, VFR checkpoint/call-up point
- Aircraft should remain within 2NM of call-up/checkpoint
- VFR checkpoints & call-up points are published in CFS & VTA
- Left turns are recommended, inform ATC if not acceptable

Land and Hold Short Operations (LAHSO):
- Landing Distance Available measured from threshold/displaced threshold to 200ft short of nearest edge of runway being intersected must be published in CAP & CFS
- ATC shall broadcast LAHSO advisories including LDAs through ATIS/voice advisory
- Weather minima of 1000ft ceiling & visibility of 3 miles
- Criteria may be reduced by regional director, civil aviation with written agreement between ATC & operator
- Reported braking action must be not less than good
- Runway must be bare (No snow, slush, ice, frost, standing water)
- Winter: Only center 100ft of runway must be bare
- Tailwind <5kt for both dry & wet runway (ATC may approve <10kt for dry)
- Crosswind <25kt for dry, <15kt for wet
- Not during thunderstorms, turbulence, wind shear

- ATC includes specific directions: Clear to land Runway XX, hold short of Runway YY
- Pilots: Obligate to remain 200ft short of closest edge of runway being intersected
  Must advise ATC immediately of non-acceptance of clearance
- Helicopter: 700ft from centerline of other runway

Runway incursion prevention:
- If in doubt then ask
- Must read back hold short, otherwise just use callsign
- Look for sign & markings on pavement

Chapter 3

Air law: Aircraft

1. Documents

"A R O W J I L"

Certificate of airworthiness:

- Most common type of flight authority issued by TC
- Lists serial number, aircraft type, date of issue for aircraft
- Homebuilt aircraft requires special certificate of airworthiness
- Ferry flights/for testing purposes may be issued with temporary flight permits
- Validity: Aircraft must remain in airworthy condition, required equipment must be on board & functioning
  Periodic inspections must be carried out & entered in journey log
  PIC & owner responsibility → Mandatory Airworthiness directives (AD) must be done, signed the work be done by AME
  → Special maintenance outlines/items that are issued by Transport Canada
  Must be operated accordance with Aircraft operating manual & within Weight and Balance
- Expiration: Do not have expiry date, but will expire if mentioned conditions are not met
- Annual airworthiness information report: Submit to TC on annual basis
  Not required to go flying
  Way for TC to track hours of aircraft & fleet have both flown
  Failure to submit does not affect C of A, but may result in fine

Certificate of registration:

- Registration & serial number of aircraft, owner's name & address, aircraft's specific purpose (Private/commercial)
- CARs require aircraft operating in Canada be registered based on who has legal custody & control
- If airplane is leased, lessee/operator of aircraft is on C of R → Aircraft operator
- Valid as long as there is no change of owner, address, purpose
- Expires when have changes: Notified TC within 7 days, new C of R will be sent within 90 days
- Expires if aircraft is destroyed/permanently withdrawn from service or doc became illegible/destroyed
- Change of ownership: Buyer complete Application for registration (back of C of R) and submit to TC
  Interim C of R: Valid for 90 days
  Submit change of ownership card included
  Only proof of ownership is bill of sale

Pilot operating handbook:

- Includes normal, emergency, weight & balance, performance data, other handling procedures
- Must operated in accordance with POH to keep C of A in force
- Must reflect model year & exact type of aircraft
- Must be original/certified true copy

Weight and balance report:

- List current weight amendments, standard & optional equipment included to give Basic Empty Weight
- Expires if moderate/major repair changes the C of G/moment (Things being added/deleted etc)
- Make changes to POH if W&B changes

Journey log: NO 25NM requirement

- For all flights excepts: Aircraft not planned to land & shut down at location other than point of departure
  Aircraft is balloon & journey is available to PIC prior to & on completion of flight
- Begin new log: Enter enough entries related to old logs to maintain unbroken chronological record
- Old log must be kept for 1 year after last entry
- When to make entry: After every individual flight & asap in a permanent way (ink)
  Mistakes → Cross with single line, enter correct info below
  Accumulated daily flights if operator has approved daily flight sheet

Proof of insurance:

- Public liability/Third party liability insurance: Damage externally done by the aircraft
  All aircraft must carry proof of liability on board
- Passenger liability: Injuries done to passengers on board the aircraft
  Optional for private but mandatory commercial including Flight training units
- Hull insurance: Covers damage to aircraft itself, optional

Inspections:

- Based on accumulated Airtime
- Commercial: Every 25, 50, 100 or 200hrs depending on manufacturer's recommendations
- Annually: Private aircraft inspection, compass swing, ELT certification → Journey log entry
- Aircraft defects & rectifications should also be noted

Pilot license:

- Have it on when acting as flight crew member
- Includes: Pilot's name, address, citizenship
  Type of flying (private/commercial) and category (airplane, helicopter etc)
  Validity for class (single, multi, land, sea, high performance, non-high performance)
  Validity for aircraft types
  Ratings (instrument, instructor, type)
  Valid when accompanied by current medical certificate
- Passport style: Licenses, permits, competency records, medical certificates, photo identification
- Radio operator's license: Valid for life, administered by Industry Canada

2. Aircraft equipment requirements

Day VFR (CAATER):
- Magnetic compass
- Airspeed indicator
- Altimeter (Sensitive, 2 needles)
- Timepiece
- Engine Instruments (Tachometer, Oil pressure, Oil temp, Fuel gauges, MP gauge)
- Radio if in MF/Class B, C, D

VFR OTT (GPSTAR):
- Pitot heat & alternate static source
- Gyroscopic direction indicator/stabilized magnetic direction indicator
- Attitude indicator
- Turn & slip indicator/Turn coordinator
- Radio communication equipment for two-way communication on appropriate frequency
- Radio navigation equipment adequate to permit aircraft to be navigated safely
  NDA: Means of establishing direction that is not dependent on magnetic source

Night VFR (TGFILE):
- Turn & slip indicator/Turn coordinator
- Gyroscopic direction indicator/stabilized magnetic direction indicator
- Means of illuminating the instruments
- Adequate source of electrical energy
- Spare fuses (50%) of total unless breakers are used instead
- Position & anti-collision lights
- When carrying passengers: Landing lights
- Commercially: Attitude indicator, VSI, OAT gauge, Pitot heat (AVOP)

Position and anti-collision lights: Visible 2 miles away
- Navigation/position lights: Red on left, Green on right, White on tail
- Anti-collision light: Flashing white, red or both
- Night with passengers: Functioning landing light

Seat and safety belts:
- No person shall operate aircraft other than balloon unless it is equipped with seat & safety belt
- Latches must be metal to metal

Restraint system:
- Person is carried on stretcher/incubator or similar device
- Person is carried for purpose of parachuting from aircraft

Shoulder harness:
- Each front seat is to be equipped with safety belt that includes shoulder harness
- Exception includes small aircraft manufactured before July 18, 1978

Passenger seat belts/restraints:

- PIC shall ensure each person on board is briefed on seat belt operation & directs all persons on board:
  During movement of aircraft on surface, during takeoff & landing,
  Any time during flight that PIC considers it necessary that safety belts be fastened
- Passenger who is not an infant:
  Ensure passenger's safety belt/restraint system is properly adjusted & securely fastened
- If responsible for infant for which no child restraint system is required/provided:
  Hold infant securely in passenger's arm
- No passenger shall be responsible for more than one infant

Infant = less than 2 y/o

Crewmember seat belts:

- Pilot flying should have seat belt on at all times
- Other crew should wear during takeoff, landing, directed by PIC

Child restraint: Responsibility of PIC

- No operator of aircraft shall permit use of child restraint system on board unless:
  Person using the system is accompanied by parent/guardian who attends to safety of the person in flight
  Weight & height of person using the system are within range specified by manufacturer
  The system bears a legible label indicating the applicable design standards & date of manufacture

Flight control lock:

- No operator of aircraft shall permit use of flight control lock unless
  Flight control lock is incapable of becoming engaged when aircraft is being operated
  Unmistakable warning is provided to person operating the aircraft whenever flight control lock is engaged

Deicing/anti-icing:

- No takeoff unless: PIC thinks aircraft is adequately equipped to operate in icing conditions
  Current weather reports/pilot reports indicate icing conditions no longer exist

Oxygen equipment:

- No person shall operate unpressurized aircraft unless it is equipped with sufficient oxygen dispensing units & oxygen supply to comply with requirements set out

Unpressurized aircraft:

- All crew + 10% passenger: Entire period of flight > 30mins at cabin altitude 10000-13000ft ASL
- All persons: Entire period of flight at cabin altitude > 13000ft ASL
  Air transport & not less than one hour at cabin altitude > 13000ft ASL

Pressurized aircraft following emergency descent (Descent profiles for routes concerned must be considered):

- All crew + 10% passenger: Entire period of flight > 30mins at cabin altitude 10000-13000ft ASL
  Entire period of flight at cabin altitude > 13000ft ASL
  Air transport: Either one of above & not less than 30mins (a)
  Flight crew members & not less than 2hrs for aircraft that can operate exceeding FL250 (b)
- All passengers: Entire period of flight at cabin altitude > 13000ft ASL
  Air transport & entire > 13000ft ASL & not less than 10mins

(a): Constant ROD from max operating alt to 10000ft ASL in 10mins then 20mins at 10000ft ASL
(b): Constant ROD from max operating alt to 10000ft ASL in 10mins then 110mins at 10000ft ASL

Oxygen use:

- Cabin altitude 10000-13000ft ASL: Crew should wear O_2 mask and use it for any part of flight > 30mins
- Cabin altitude > 13000ft ASL: All persons shall wear O_2 mask and use it for duration of flight
- Pilots at controls of aircraft shall use O_2 mask:
  Not equipped with quick-donning mask is operated at/above FL250
  Equipped with quick-donning masks and is operated above FL410

Transponder:

- Except for balloon/glider, aircraft shall not operate in transponder airspace unless it is equipped with transponder & pressure-altitude reporting equipment (Mode C)
- May operate with unserviceable transponder if:
  Aircraft is operated in accordance with Minimum Equipment List
  If no MEL, aircraft is operated to next aerodrome of intended landing and to complete planned flight schedule/proceed to maintenance facility in accordance with ATC clearance
- ATC may authorize aircraft to operate within airspace where transponder is required if:
  ATC receives & approves the request prior to aircraft entering airspace
  It is not likely to affect aviation safety

ELT:

- Broadcasts distress signal in event of sudden deceleration
- Emits siren-like signal on 121.5, 243, 406 MHz, transmitted to SAR satellites which indicate search area
- Powered by non-water-activated batteries shall be maintained:
  12 months with operational test requirement, 24 months with applicable performance test requirement
- 406 ELT: New standard replacing 121.5/243 ELT, but all ELT transmits on 121.5/243 MHz so pilot can check
- Location: Orange plastic box about 12 inches long, located in tail
- A/AD: Automatic/Automatic Depoly, F/AF: Fixed/Automatic Fixed, AP: Automatic Portable, P: Personnel, W/S: Water-activated/Survival
- Testing: Old → 1st 5mins of every UTC hour, not exceed 5sec
  406 → Self-test function & check power output of 121.5MHz transmitter
- Requirement: >25NM from home base, except glider, balloon, airship, ultralight, gyroplane, large commercial jets
  New manufactured/registered as of Feb 1 2009 is required to have 406 ELT
- Instructions: OFF: Will not activate, ARM: Activate in event of accident, ON: Transmitting
  Toggle switch: On airplane instrument panel/On the unit itself
  In emergency then turn on and leave on
- Emergency instructions: Contains g-sensor, turns on automatically, but still should switch to ON manually
  Do not delay & do not turn it off
- Unserviceable: May operate aircraft for up to 30 days if:
  ELT is removed at 1st aerodrome at which repairs/removal can be accomplished
  ELT is promptly sent to maintenance facility
  Placard is displayed om cockpit stating ELT has been removed & date of removal
- Accidental: Always check on 121.5MHz at end of every flight
  Report to nearest ATS unit with location, time, duration

3. Aircraft maintenance requirements

General:

- Do not takeoff unless aircraft is maintained in accordance with:
  Any worthiness limitations applicable to aircraft
  The requirements of any Airworthiness Directives
  Equipment is functioning where required
- Owner's responsibility to ensure that maintenance is completely properly

Maintenance release:

- Do not takeoff in aircraft undergone maintenance unless it is certified by signing of maintenance release
- Test flight: Maintenance release is conditional on completion of test flight
  → Must be completed by qualified pilot
  No passengers are permitted other than flight crew members & necessary persons
  PIC shall enter results in journey log after test flight
  If results are satisfactory then the entry completes the release

Elementary work:

- Does not require maintenance release to be signed by an AME
- Elementary work performed must be detailed in technical record & signed by person who performed it
- Owner is responsible for authorizing person who may perform elementary work
- Example: Replace tires, clean & replace spark plugs, replace fuses, check tire pressure and refill etc
- Private plane: Pilot should get training but can do the work if feel comfortable
- Commercial plane: Person must be trained from qualified AME and supervised for 1st time

Maintenance schedule:

- Do not takeoff unless is maintained according to Maintenance Schedule that conforms to Aircraft equipment and maintenance standards
- Schedule depends on private and commercial

Abnormal occurrence:

- Before takeoff in aircraft that is subjected to abnormal occurrence, it must be inspected for damage by qualified person
- If inspection does not involve disassembly, it may be performed by PIC

Maintenance responsibility:

- Owner/operator of aircraft: Responsible for ensuring maintenance & AD compliance
- PIC: Determine if aircraft is safe for flight

Airworthiness directives:

- Owners are responsible for ensuring aircraft are not flown unless meet requirements of AD
- AD not complied with = Flight authority not in effect & aircraft not airworthy
- CAR recognizes foreign AD & equivalent notices
- If conflict between AD issued by TC and foreign aviation authority: AD issued by TC prevails

4. Technical maintenance records requirement

Required log:
- Journey log
- Separate technical record for: Airframe, engine (each), variable pitch propeller (each), modifications

General:
- Make entry accurately, legibly, permanent manner
- Enter person’s name & signature/employee number
- Note date of entry
- Carry over enough entries to ensure unbroken chronological order when starting new volume
- Retain every entry in journey log for period of not less than 1 year
- No person shall make single entry for series of flight unless: Same PIC throughout the series
  Approved daily flight record is used

Carrying on board:
- No person shall conduct takeoff unless journey log is on board the aircraft
- Flight training units may get exemptions if flight starts and ends at home base
- May not be required if aircraft does not shut down at location other than point of departure
- Air balloon may fly without journey log if it can be easily accessed before & after the flight

Transfer of records:
- Owner who transfers title must also deliver to that person all the technical records related
- When aircraft has been sold are travelled to new location, journey log & technical log should be sent via separate means

5. Commercial maintenance system

Person responsible for maintenance:

- Oversee maintenance related issues and liaise with TC
- Submit service difficulty reports to TC within required time & establish a filing and follow-up program
- Ensure quality of maintenance by complying with manufacturers recommendation/industry standard
- Control & preservation of technical records
- Ensure manual & technical reference publications are available & amended in timely manner
- Technical dispatch of aircraft returned from maintenance
- Establish maintenance evaluation program
- Control of parts & materials for performance of servicing & elementary work
- Ensure personnel is trained to perform elementary work & servicing duties is maintained
- Appoint & train alternate to their position during absence of more than 3 day period
- Appoint & train delegate to assist as required in above duties

Maintenance policy manual:

- How things will be done maintenance wise

Maintenance control manual:

- When and where all inspections are to be completed

Deferring jobs:

- Pilot needs to consult with maintenance staff before
- Initial in Deferred Maintenance List

Maintenance Schedule Approval (MSA) form:

- After certain amount of flying hours & scheduled by chronological time on certain parts of equipment

➔ Phase inspections

(ESTTFE) IAW: Initial airworthiness

Item	Task	Interval	Tolerance
Survival & emergency equipment	Overhaul IAW	12 months	15 days
Engine air filter	Replacement	On condition	N/A
Tachometer	Accuracy check	12 months	15 days
Fixed pitch propeller	Maintain IAW	5 years	30 days
Transponder	Test IAW	24 months	30 days
406 MHz ELT battery	Replacement	5 years	30 days

- Usually PRM complete all out of phase items that will come due before next 100hr inspection
- PRM will put note in logbook if there is limitation

6. Miscellaneous

Munitions:

- No person shall carry weapons, ammunition or other equipment designed for use in war, unless it is Canadian aircraft or Minister has authorized the carriage of such equipment

Flight training devices:

- Simulators & flight training devices must be certified annually by TC
- Certificates should be displayed in prominent location
- Student must record certificate number of device in PTR & logbook in order for time to be credited

Flight sim with cert = certified by TC

Flight sim for PPC : Have flight sim cert
Maintain in accordance with approved maintenance schedule

Chapter 4

Air law: Commercial Aviation

1. Commercial flight operations

Air taxi:
- Single-engined aircraft
- Multi-engined aircraft other than turbo-jet-powered airplane
  - ➔ MCTOW of 19000lb or less, seating of 9 or less excluding pilot seats
- Multi-engined helicopter certified for operation by one pilot and operated under VFR

Aerial work:
- Commercial air service other than Air transport/Flight training service
  - ➔ Aerial application, banner towing, forest fire, photography, mapping

Commuter:
- Multi-engined aeroplanes with MCTOW of 19000lb or less, seats of 10-19 excluding pilot seats
- Turbo-jet-powered aeroplanes with max zero fuel weight of 50000lb or less & Canadian type certificate has been issued authorizing the transport of not more than 19 passengers
- Multi-engined helicopters with seat of 10-19 excluding pilot seats unless certified for one pilot & VFR

Airline:
- Multi-engined aircraft with more than 19000lb
- 20 or more passengers

Flight training unit:
- Flight training only

Air Operators Certificate (AOC):
- Type of services
- Specific operations for aircraft performance, IFR procedure, weather minima, crew training

Company Operations Manual (COM):
- Specific approved operations
- Shall be amended by Air Operator when required and submit to Minister
- Include instructions & information necessary to enable personnel to perform duties safely

Aircraft Flight Manual (AFM):
- Also referred as POH
- Must be actual manual

Maintenance Control Manual (MCM):
- Maintenance and inspection schedule
- Procedures for snags
- AD search

Standard safety briefing:
- Use and position of exits, seat belts, seat position, ELT, fire extinguisher

Safety features card:
- Information in pictographic form at passenger’s seat

Individual safety briefing:

- Any info in standard safety briefing & safety feature card that passenger is not able to receive
- Most appropriate brace position in consideration of condition, injury, seat orientation etc
- Location to place service animal that accompanies the passenger
- Mobility restricted, visually impaired, comprehension restricted, hearing impairment, infant, minor

2. Flight and duty time limitations

Monitoring system:

- Air operator keep record of: All flight times, start & end times & duration of flight duty period, duty period and rest period, all time free from duty
- Include details of system in Company Operations Manual

Flight time limitations:

- Private: 1200hr in 12 months, 300hr in 90 days, 120hr in 30 days, single-pilot IFR 8hr in 24hr
- Commercial: 1000hr in 365 days, 300hr in 90 days, 112hr in 28 days, single-pilot IFR 8hr in 24hr

Flight duty period:

- Begins when earliest of following and ends at engine off/rotors stopped at end of flight
- Carries out any duties assigned by private/air operator or delegated by Minister before reporting for flight
- Reports for a flight/Reports for the first flight if more than one flight during flight duty period
- Reports for positioning
- Reports as flight crew member on standby

Flight duty time limitation and rest period:

- Private: 14hr in 24hr
  15hr in 24hr if total flight duty period in previous 30 days does not exceed 70hr
  Or rest period before flight is at least 24hr
- Air operator: Average flight duration less than 30mins, 30 to less than 50mins, 50mins or more

Item	Start Time of Flight Duty Period	1 to 11 Flights	12 to 17 Flights	18 or More Flights
		1 to 7 Flights	8 to 11 Flights	12 or More Flights
		1 to 4 Flights	5 or 6 Flights	7 or More Flights
1	24:00 to 03:59	9 hours	9 hours	9 hours
2	04:00 to 04:59	10 hours	9 hours	9 hours
3	05:00 to 05:59	11 hours	10 hours	9 hours
4	06:00 to 06:59	12 hours	11 hours	10 hours
5	07:00 to 12:59	13 hours	12 hours	11 hours
6	13:00 to 16:59	12.5 hours	11.5 hours	10.5 hours
7	17:00 to 21:59	12 hours	11 hours	10 hours
8	22:00 to 22:59	11 hours	10 hours	9 hours
9	23:00 to 23:59	10 hours	9 hours	9 hours

703 Air Taxi
704 commuter
705 Airlines

Day VFR:

Item	Start Time of Flight Duty Period	Maximum Flight Duty Period
1	24:00 to 03:59	9 hours
2	04:00 to 04:59	10 hours
3	05:00 to 05:59	11 hours
4	06:00 to 06:59	12 hours
5	07:00 to 12:59	13 hours
6	13:00 to 16:59	12.5 hours
7	17:00 to 21:59	12 hours
8	22:00 to 22:59	11 hours
9	23:00 to 23:59	10 hours

Minimum rest period:

- Not interrupted by air & private operator
- Not less than 8 consecutive hours of sleep in suitable accommodation
- Has time to travel to and from accommodation, personal hygiene and meal
- Time spent following flight duty is NOT counted as rest
- Air operator need to provide not less than 15mins per 6hrs of flight duty period
- End of flight duty period: Home base → 12 hours/ 11 hours + travel time
  10 hours in accommodation provided by air operator
  Away → 10 hours in suitable accommodation
  Notify rest period & duration in advance

Unforeseen operational circumstances:

- Private: Extend up to 3 hours if PIC & crew considers safe to do
  Due to unforeseen after beginning of flight duty period
  Next rest period is extended at least equal to length of extension
  PIC notifies private operator (Need to retain copy of noti for 5 years)
- Commercial: Occurs within 60mins of beginning of flight duty period could lead level of fatigue
  Reduce member's flight duty period
  Extend member's flight rest period
  Extend member's flight duty period by 1 hour for single-pilot
  2 hours if flight crew is not augmented
  3 hours if flight crew is augmented and only 1 flight
  2 hours if flight crew is augmented and 2/3 flights
  Augmented: Flight crew that comprises more than min number required
  Each can leave post and replaced by another for in-flight rest

Split flight duty period:

- Private: Flight duty period may extend by up to one half of length of rest period to max of 4 hours IF
  Operator provides flight crew with notice of extension before reporting for 1st flight/on standby
  Operator provides flight crew with rest period of at least 4 consecutive hours in accommodation
  Member's next minimum rest period is increased at least length of extension

3. Type rating

Blanket type rating:

- Entitles pilot to fly aircraft as described
- PPL: All single pilot non-high performance, single engine land aeroplanes

Individual type rating:

- For aircraft not included and indicated by Aircraft type designator
- Two pilots minimum flight crew (MFC), High performance aircraft,
  Each type of helicopter/2 seat gyroplane/powered balloon or airship, Medical restriction

High performance aeroplanes:

- MFC of 1 pilot with Vne>= 250kts and/or Vso>= 80kts
- Requirement: 200hrs total flight time in aeroplanes
  Ground & flight training acceptable to Minister on aeroplane type
  Perform qualifying flight under supervision of TC inspector within 12 months before applying

Minimum flight crew (MFC):

- All listed in CARs
- Two pilots MFC: PIC with ATPL & type rating, SIC at least CPL & type rating
  Both pilots: 250hrs total flight time in aeroplanes
  Ground & flight training
  IATRA of at least 70% or ATPL
  Pilot proficiency check within previous 12 months

SIC may log PIC hours
under approved ATPL training

4. Aerial work

Application:
- Commercial air service other than air transport or flight training4
- No passenger, only crew members

Operating instructions:
- Follow Company Operations Manual

VFR uncontrolled minima:
- May operate with vis < 2 miles & below 1000 AGL if: Authorized to do so in air operator certificate
  Complies with commercial air service standard

Night/VFR OTT/IFR:
- Not permitted if towing/carrying helicopter class B, C, D, external load/dispersing product/single-engined
- May operate if: Authorized to do so in air operator certificate
  Complies with commercial air service standard

Operating over water:
- Except takeoff/landing cannot go beyond point can be reached shore in event of engine failure

Briefing of non-crew member:
- Must be conducted for ground crew

Night and IMC flights:
- At least one landing light
- If multi-engined: 2 generators/alternators, each with separate engine
  2 independent sources of energy, vacuum and electric for instruments

Single-pilot IFR:
- Required: Autopilot, headset with bomb mic, chart holder with light
- 1000hrs total time, 100hrs multi-engines, 50hrs in IMC/sim, 50hrs on type

Shoulder harness:
- Front seats must have safety belt with shoulder harness

External load:
- Unless attachment device

Designation of PIC and SIC

Flight crew qualification:
- Hold license & ratings required by Air operator, complete PPC & ground & flight training program

PPC validity:
- Complete by TC, good to 1st day of 25th month, may extend for 60days, can renew within 90days of expiry date & have same renewal date

Training program:

- Company indoctrination, upgrading, aerial work, type, aircraft servicing & handling, emergency, surface contamination

Distribution of COM:

- Each crew member, ground operator, maintenance personnel must have own copy
- Or available in aircraft and keep up to date

Standard operating procedures:

- Required to be used in MFC of 2 or more
- Enable crew to operate within Aircraft flight manual
- Must be onboard

Operational flight plan:

- Must be prepared with procedures specified in COM

Carriage of persons:

- Not permitted unless person is essential during flight

  Permit parachute descents and the person is parachutist

Operation of aircraft in icing conditions:

- Not authorized if PIC think safety of flight might be affected

5. Air taxi operations

Application:
- Single-engine
- Multi-engine other than turbo-jet-powered aeroplane, MCTOW <= 19000 lbs, <=9 seats excluding pilots
- Any aircraft authorized by minister

Operating instructions and flight authorization:
- Follow Company Operations Manual

Single-engine aircraft with passengers:
- Not permitted for IFR/night VFR
- May operate if: Authorized to do so in air operator certificate
  Complies with commercial air service standard (eg Cessna Caravan)
- Not applicable to single-engine helicopters

Operating over water:
- Except takeoff/landing cannot go beyond point can be reached shore in event of engine failure

External load:
- Unless with type certificate/supplemental type certificate

Simulated emergency:
- Not permitted if flight characteristics may be affected

VFR obstacle clearance:

Not permitted

- Except takeoff/landing: At night, <1000 ft from highest obstacle within 3 miles horizontal distance
  Aeroplane at day, <300 ft AGL or horizontal distance of <300 ft from obstacle

VFR uncontrolled minima: NOT for above 1000 AGL
- May operate with vis < 2 miles & below 1000 AGL if: Authorized to do so in air operator certificate
  Complies with commercial air service standard

Weather conditions:
- Weather must be checked prior to flight & forecasted to be VFR along the route

VFR OTT:
- Only can do so when authorized in AOC & complies with commercial air service standards

Routes in uncontrolled:
- Night VFR/IFR in uncontrolled must be listed in list of approved routes
- Info includes: MEA, MOCA, Distance, Track, Nav aids

Weight & balance:
- Must be within aircraft flight manual, procedures must be specified in COM

NO IFR / Night VFR on route other than air route unless air operator establishes the route

Briefing of passengers:
- Individual safety briefing if special needs
- Briefing cards available to all passengers

Shoulder harness:
- Front seats must have safety belt with shoulder harness

Designation of PIC and SIC:
- Must have 2 pilots if passengers in IFR flight unless otherwise authorized in AOC

Flight crew qualification:

Maybe competency for flight instructor students ≠ Passengers

- Hold CPL/ATPL
- 3 takeoffs & landings within last 90 days
- PIC of multi/single IFR or night: PPC
- SIC of multi: PPC or competency
- PIC of single & NOT IFR/night: competency
- PIC with passengers: 5 hrs on type for single engine
  15 hrs on type and basic model for multi engine

PPC:
- Instrument flight proficiency if candidates conduct commercial IFR, flight test will also renew IR
- Conducted by TC/Company check pilot
- Flight planning, airplane inspection, taxiing, engine checks, takeoff & landing, airworks, normal & emergency procedure, precision & non-precision approach
- Operators may group similar aircraft as single type for PPC

Competency check:
- Single engine day VFR (Passengers & cargo), IFR (Cargo), Night VFR (Cargo)
- SIC on multi-engine under VFR/IFR of plane certified for two-pilot operation

Valid period: = Recurrent every 12 months
- Till 1st day of 13th month
- Renew within last 90 days and extend for 12 months
- May extend up to 60 days by Minister
- Retake initial training when more than 24 months since last PPC

Training program:
- Company indoctrination, upgrading, aerial work, type, aircraft servicing & handling, emergency, surface contamination, dangerous good, flight above 13000 ft

Distribution of COM:
- Each crew member, ground operator, maintenance personnel must have own copy
- Or available in aircraft and keep up to date

Standard operating procedures:
- Required to be used in MFC of 2 or more
- Enable crew to operate within Aircraft flight manual
- Must be onboard

Single-pilot IFR:

- Required: Autopilot, headset with bomb mic, chart holder with light
- 1000hrs total time, 100hrs multi-engines, 50hrs in IMC/sim, 50hrs on type

Air taxi refuelling procedures:

- Approved in COM, pilots supervise fueling & remain near main exit, exits are clear, engine not running unless propeller brake and brake is set, external power not connected/disconnected, not smoking, lightning discharge not within 8km, HF radio & weather radar not activated, camera not within 10 ft

Night and IMC:

- At least 1 functioning landing light
- For icing, mean of illumination or other means to detect formation of ice
- Multi-engine: 2 generators/alternators, each with own engine/rotor drivetrain
  2 independent sources of energy, at least 1 not battery, each can drive all flight instruments

Portable electronic devices:

- No operator shall permit if device may impair aircraft's system/equipment
- No person shall use except with permission
- Onus for determining whether electronic devices will cause interference is placed on operator

Operational flight plan:

- Must be prepared with procedures specified in COM

Operation of aircraft in icing conditions:

- Not authorized if PIC think safety of flight might be affected

6. Flight training units

Requirement to hold a flight training unit operating certificate:

- Complies with conditions & operations specifications set out in certificate

Eligibility to hold a flight training unit operating certificate:

- Person is Canadian, citizen/PR/corporation of USA or Mexico

Training without FTUOC:

- Person holds private operator registration document/air operator certificate
- Aircraft used for training is specified in air operator certificate
- Training is other than toward obtaining pilot permit
- Trainee is: Owner/member of family of owner of the aircraft being used
  Director of corporation that owns the aircraft used for training other than towards pilot permit
  Using aircraft at arm's length from flight instructor, training other than towards pilot permit

Notification requirement:

- Need to notify Minister legal name, trade name, address, base of operations, category of aircraft, name of flight instructor
- Notify with 10 days if there is change and upon service being discontinued

7. Private operator passenger transportation

Definition:
- Flying for business but not to sell seats like company car
- Usually operated by companies & private individual

Application:
- Large aeroplanes (>= 12500 lbs), Turbine-powered, Pressurized, Multi-engined

Certificate:
- No operation unless person is holder of private operator registration document:
  Large aeroplane, turbo-jet-powered aeroplane, turbine-powered pressurized aeropplane > 6 pax seats

Management system:
- Operations manager, chief pilot, maintenance manager, main & sub base of operation, registrations & nationalities of aircrafts, geographic area of operation

Certificate content:
- May allow to fly with special weather minima/navigation system

Authorizations:
- Operator's operation manuals need to set out processes, practices, procedures
- Submit to Minister within 10 days in there's change in manual

Operational control system:
- Procedures: Aircraft operating with W&B limit, names of persons onboard are recorded before each flight,
  Search & rescue authorities are notified in timely manner is aircraft is missing
- Self dispatch: Flight planning requirement, timing within flight crew should inform operator of
  departure & arrival, method of confirming aircraft has arrived safely at unattended
  aerodrome during VFR or an IFR flight plan has been canceled prior to landing
- Dispatch co-authority of pilot & dispatcher: Flight planning, flight following, method of confirming aircraft
  has arrived safely at unattended aerodrome during VFR
  or an IFR flight plan has been canceled prior to landing,
  Method to approve & record flight plan by PIC & dispatcher,
  Method to approve and record change of flight plan,
  Switch between flight plan and flight watch if separated,
  Mean at each location that PIC receive meteorological info,
  copy of flight plan, can contact dispatcher before takeoff

No alternate IFR:
- Cant conduct IFR without having alternate UNLESS: Person is authorized to do so in COM
  International/NDA, carry fuel reserve of 5% of fuel required

Designation of PIC and SIC:
- Operator shall record name of PIC & SIC for each flight
- Retain record at least 180 days

Special authorization:

- Takeoff minima, flights without IFR alternate, minimum performance capability of long-range nav systems, GPS approaches and types

VFR minima uncontrolled airspace:

- Below 1000ft AGL, vis at least 2 miles unless authorized

Takeoff minima:

- Reported RVR >= 1200 ft or Vis >= 0.25 mile if: Operator is authorized to do so under special authorization
  Aircraft operated at least by 2 crew members
  Flight plan specifies takeoff alternate aerodrome
  → Twin-engined, distance flown within 60mins at cruising
  Three or more engine, 120mins

Instrument approach procedures:

- Cant conduct instrument procedure using GNSS receiver UNLESS:
  Operator is authorized to do so
  Ground training: GNSS & theory of operation, operation of the model of GNSS, action to do for warnings
  In flight training: operation of the model of GNSS, action to do for warnings,
  use of GNSS for instrument approach & duties of each crew
- Cant conduct CAT II/CAT III instrument approach unless conducted with Manual of All Weather Operation

Navigation systems:

- Need authorization to use that navigation system

Training program:

- Hold of certificate needs to create ground and air training program for crew

AOM:

- Maintain Aircraft operations manual to provide guidance to crew
- Contain performance & limitation data if flight manual is not carried on board

8. Safety management system Part 1

How SMS works:
- Safety problem/hazard/concern → Report → Analyze and implement corrective measure → Evaluate corrective measure → if worked then document, if not then re-analyze & correct & evaluate

Culture:
- Positive corporate culture contributes towards safety & being responsible for safety
- Non punitive policy for reporting concerns should be implemented (Not be punished for voicing concern)
- Reports are taken seriously & subject to risk analysis → critical to maintenance of effective & trusted program
- Large number of reports can be indicator of healthy safety culture
- Absence of recurrent reports on particular topics after implemented measures is most important

Importance:
- Impact future operational safety
- Unknown unsafe condition may exist at time of occurrence
- Requires objective & in-depth risk analysis to identify & validate these conditions
- Using accident investigations to identify hazards is knee-jerk & costly
- Best to identify hazards & apply corrective measures before accidents

1:600 rule:
- Every 600 reported incidents with no injury/dagame
  → 30 incidents with property damage, 10 accidents with serious injuries, 1 major/fatal injury
- Analyze report of hazards help identify issue before they cause injury/significant damage

Risk analysis:
- Accept risk then monitor trend, re-assess if accident is later to be found
- Take action to eliminate, reduce, mitigate risk to acceptable level

Risk assessment:
- Probability x Severity = Risk
- Results: Negligible (1-3), Low (4-6), Moderate (8-10), High (12-16), Catastrophic (20-25)

9. Safety management system Part 2

SMS regulations:

- Must appoint accountable executive: Operations/activities, Meeting requirements of regulations, Notify minister the name of person appointed, Submit signed agreement to accept responsibilities within 30 days
- Application to certificate of: Airport, FTU operator, Manufacturer, Approved maintenance organization, Air operator, ATS operation
- Include: Safety policy
  - Setting goals for improvement of aviation safety & measure the attainment of goal
  - Identifying hazards to aviation safety & for evaluating & managing risks
  - Ensure personnel are trained & competent to perform duties
  - Internal reporting & analyzing of hazards, incidents, accidents, taking action to prevent reoccurrence
  - Doc containing safety management system processes & process to make personnel aware
  - Quality assurance program
  - Process for conducting periodic review/audit of safety management system
- Correspond to size, nature, complexity of operations, activities, hazards, risks associated

Key features:

- Systematic approach to management of safety
- Focus on hazard of business
- Management controls to all aspects of business process critical to safety
- Active monitoring & audit processes to validate control are in place to ensure safety
- Use of quality assurance principles including improvement & feedback mechanisms

Safety management plan:

- Four P's: Philosophy
  - Policy: One page statement regarding company's policy towards SMS & use of SMS protocols
    - Involve senior management & staff representatives in preparation of policy
    - Consistent with companies safety philosophy
    - Reflect actual company working environment
    - Recognized as one of key company policies
  - Procedure: Day to day activities that company use throughout organization
    - Staffed must be trained and capable of using procedures
    - Procedures must be checked occasionally to ensure they are effective
  - Practices: Actual things done by staff
    - Senior staff should be alert for practices that do not match with procedures
    - Why not follow procedure: Poor training, too complex, working conditions
- Non-punitive reporting: Employee must feel comfortable reporting hazards/occurrences
  - Main concept most accidents are human error & can be prevented
  - Not covered: Gross negligence, Criminal intent, Employees who knowingly fail to report an occurrence
- Roles/responsibilities: Roles may be shared by same position/positions may be shared
  - EXCEPT only one Accountable Executive
  - Key positions: Account Executive, SMS Manager/Coordinator, Employees
  - Roles relating to SMS should be assigned to department heads
  - Department manager: Manage day to day operations, Work with SMS manager to coordinate SMS activities in department, Use SMS manager as resource to identify hazards

SMS manager: Manage day to day activities, Reports to AE on performance of SMS, Provides support to department managers as required, Conducts corrective action follow up

- Communication: Safety critical: Simple & easy to view safety bulletins at start of shift
  Important/need to know: Not as time critical, can go through normal channels
  Nice to know: Training programs, bulletins boards, memos, newsletters
- Safety planning: Set goals that are realistic, measurable, achievable
- Performance measure: Is the system working, Number of hazards comparison, money saved/lost

Documentations:

- Set of written policies, processes, procedures, goals, requirements, roles, responsibilities, directions of how to do various tasks
- Records: Documentations of hazards, events, mitigation, follow up

Safety oversight:

- Hazard identification & risk management
- Hazard: Condition with potential of causing loss/injury
- Incident: Hazard causing something to happen without loss of hurt to property/persons
- Accident: Hazard causing injury/loss
- Risk: Chance of loss/injury measured in severity & probability

Training:

- Initial: Basic training (general staff), Intermediate training (senior staff), Advance training (SMS personnel)
- Recurrent: Knowledge verification, Intermediate training (senior staff), Advance training (SMS personnel)
- Indoctrination: Training for new hires

Quality assurance:

- Systematic monitoring & evaluation of various aspect of project
- Elements: Control, job management, defined & well managed processes, performance & integrity criteria, identification of records
- Competence: Knowledge, skills, experience, qualifications
- Soft elements: Personnel integrity, confidence, organizational culture, motivation, team spirit, quality relationships
- Audit: Scheduled: Only audit required
  Annual audit may be broken into smaller audits performed during slow time of year
  Specialty: Following a specific occurrence, Identify system deficiency & correct it

Emergency preparedness:

- Whom to notify initially
- Care of survivors
- Emergency call list
- Notification of next of kin
- Public relations handling
- Record keeping
- Accident scene protection/investigation
- Personnel briefing
- Useful forms for on-duty

10. CADORS

Civil aviation daily occurrence reporting system:

- TC collects aviation occurrence info through CADORS to prevent recurrence & improve safety
- Provide initial info on occurrences involving any Canadian-registered aircraft, any events occur at Canadian airports & sovereign airspace/international airspace for which Canada has accepted responsibility
- TC ensure accuracy & integrity of data contained with CADORS but info should be treated as preliminary, unsubstantiated and subject to change
- Transportation safety board of Canada is official source of aviation accident & incident data in Canada

When:

- Anything “unusual” is reported
- E.g. flight plan not being closed, student getting lost, major accident, taking off without clearance

Where:

- TC website

Chapter 5

Airframes, engines, aircraft systems

1. Airframes

Truss:

- Fuselage made up of steel/Al tubes: welded/bolted together in shape of truss
- Strength provided by tubes
- Covered by metal/fabric/composite materials
- Longerons: Lengthwise tube
- Struts: Spanwise & Diagonally for extra strength
- Add Bulkheads & Stringers: Streamline the shape
- Loads travel through internal frame of aircraft
- Citabria, Piper Cub, Kitfox

Semi-monocoque/stressed skin:

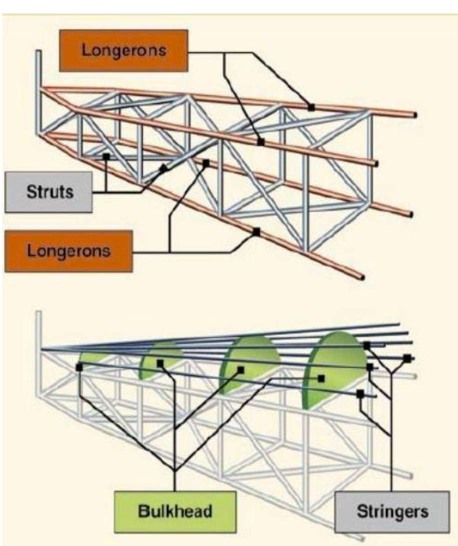
- Series of formers & bulkheads held together by stringers running lengthwise
- Wrapped tightly with a skin: stressed skin
- Pro: Can create pressurized vessel between 2 bulkheads

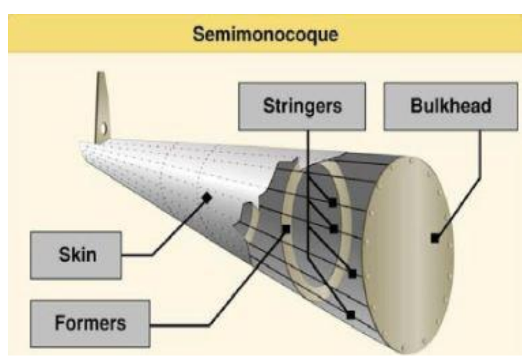
Monocoque:

- No stringer, also type of stressed skin
- Like soda can
- Luscombe 8 series

Composite:

- Smooth, compounded curved construction
- By fiberglass/carbon fiber/kevlar
- Pro: Stronger, lighter but no fatiguing problem as metal
- Con: Internal damage from impact but is not shown externally
  Heat deterioration (Like glue), but can be solved by UV blocker
  More expensive than Al
  Will not give warning of overstress ∴ may suddenly break
- Cirrus, Diamond

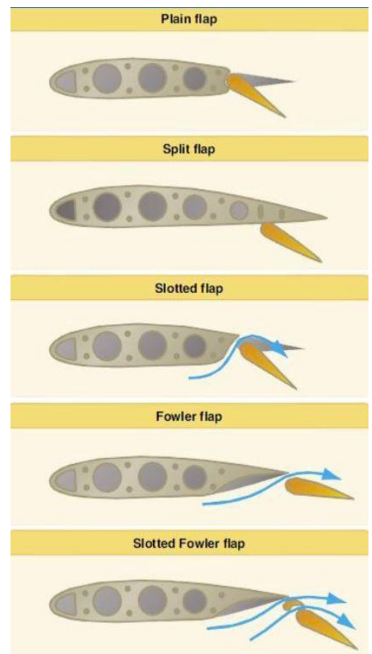




2. Landing Gear, Brakes, and Flaps

Tricycle gear:
- Pro: Won't nose over easily
    Better directional stability on ground
    Better visibility over nose while taxi
    Easier ground handling

Conventional gear:
- Pro: Increased propeller clearance
    Less parasite drag on landing gear
    Main gear takes most load ∴ suit rough/unimproved RW
    Less damage to plane if wheel gives out
- Con: Ground loop (∵ COG position relative to wheel's position)



Retractable gear:
- Folds/tuck up into wing/fuselage
  ∴ ↓ parasite drag, quiet (∵ streamlined)
- Electric motor, hydraulic pump, manually operated (as backup)
- Con: Complicated to maintain, Forget that it's up

Type of main gear:
- Spilt axle (Bungee cord/Oleo)
- Spring steel cantilever/Spring leaf (Steel flexes to absorb shock), Cessna
- Single strut (Oleo to absorb), Cherokee

Brakes:
- Hydraulic disc brakes, differential braking (right & left brake system)
  ∴ Greater control and tighter turn
- Use MIN. amount of break, DO NOT overuse/land with breaks ON
- Short final: Heels on floor, toes on rudder

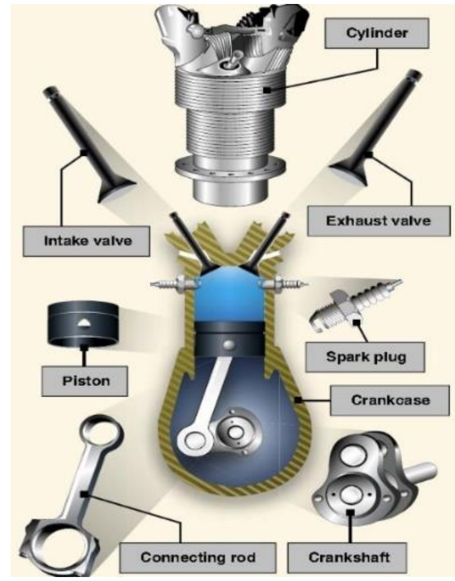
Flaps:
- ↑ lift & drag (∵ ↑ camber of wing, AOA, coefficient of lift, SOME types of wing area)
- Hydraulically, Electrically, Mechanically

Tires:
- Low pressure tires for soft/rough airstrips, Small tires may need to operate in pavement only

Flaperons:
- Flaps + Ailerons (Pilots have separate control)
- "Mixer" will combine separate input into single control surface
- Pro: ↓ weight (∵ less hinges)

Cowl flaps: control airflow in ALL phases of flight
- For high performing piston engine powered airplane: control amount of cooling air around engine
- TO/climb: Airspeed slow, power high ∴ need more cooling
- Cruise/descent: close/partially (∵ cause drag)

3. Piston Engines: Operation



Horizontally opposed engine (Boxer engine):

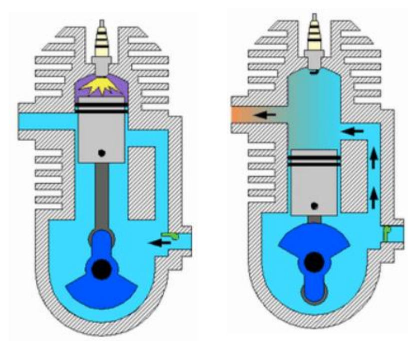
- Reciprocating, air cooled, four-stroke, piston engine
- Even no. of cylinders & small frontal area ∴ Low parasite drag

Radial engine:

- Reciprocating, air cooled, round-shaped
- Odd no. of cylinder (∵ Keep balance)
- Pro: Less problem in cooling
- Con: Large frontal area ∴ lots of parasite drag
  Expensive to maintain

Four-stroke cycle:

- No. of strokes to complete combustion for specific purpose
- Intake: Intake value opens, Exhaust valve closes
  Piston moves downward → creates vacuum → Pull fuel & air mixture through intake valve
- Compression: Both valves close
  Piston moves upward → compress fuel & air → ↑ total density → reach max. potency
- Power: Both valves close initially
  BEFORE reaching top dead center, spark plug fires → ignites compressed fuel-air mixture
  → burn & expand → piston moves downward → BEFORE reaching bottom dead center, exhaust valves open
  (Linear motion of piston → rotational motion by crankshaft through connecting rod)
- Exhaust: Exhaust valve opens, intake valve closes
  Piston moves upward → burned gasses out of cylinder
  Leading: Intake open before reaching top dead center
  Lagging: Exhaust remain opens
  ∴ ↑ engine performance



Two-stroke cycle:

- Compression: Inlet port opens, air-fuel mixture enters chamber,
  piston moves upwards compressing then spark plug ignites
- Power: Heated gas exerts pressure on piston, piston moves downwards,
  waste heat is exhausted

Cooling:

- Air cooled: By fins on crankcase & cylinders
  Baffles in cowling: force airflow past all cylinders & oil cooler
- Liquid cooled: Pro: Better control of temp
  Con: Heavier, complex (∵ water jacket, radiator, pumps, coolant)
  Piston-powered helicopter: use cooling fan
  ∴ Plane cooled by forward motion , helicopter by hovering

Magneto:

- Engine-driven electrical generator → Independent of battery/alternator
- Use permanent magnets & coil to produce high voltage → fire spark plugs
- 2 independent ignition system for 2 spark plugs per cylinder
  ∴ smoother & complete combustion, NO ignition redundancy if one magneto fails

- OFF: Grounding (Short circuit), wire: "P-lead"
- Right: Left grounded, vice versa, need to check whether one operates without the other
- Both: Removes ground from both
- No drop in RPM: 1. Broken P-lead
  Can be checked by idle RPM then ignition switch to OFF momentarily
  Broken: Continue to run, mags still live, Good: engine quit, then put back to both
  2. Improper magneto timing

Dual ignition:
- Adjust time to fire spark plug at right time
- Too early/late → engine power & life will be affected (e.g. rough running)
- Usually ~50RPM difference

Exhaust system:
- Reduce noise & take pollution away from cabin area
- Shroud around muffler: Provide cabin heat
- If leak in exhaust system → Carbon Monoxide poisoning
- Smell exhaust → turn OFF cabin heat

Peak power
= Full rich in climb

Ancillary controls:
- Mixture control:
  Rich: lots of fuel, Lean: reduced fuel
  Fuel/air by weight: 1:15 is chemically correct (Stoichiometric), 1:14 is best power mixture
  Lean correctly: Save fuel, ↑ efficiency of engine, ↓ chance of spark plug fouling
  Keeps combustion chamber clean ∴ ↓ possibility of pre-ignition

Too lean:	Too rich:
Rough engine running	Fuel wastage
Backfiring	Spark plug fouling
Overheating	Combustion chamber deposits
Sudden engine stoppage	Rough engine running
	Loss of power/outright engine failure

↓ Mixture burns slowly → cylinder to heat for longer

∴ Slightly richer mixture → keep engine cooler during high power
Idling for long → spark plug fouling

Carburetor heat:
- Without carb temp gauge: Full ON before reducing power
  Full OFF after applying power
  If partial use may form ice
- With carb temp gauge: OFF for takeoff/full power is needed
  Adjust carb heat lever to keep gauge out of yellow/red lines
- Air through carb heat is not filtered ∴ min use on ground & taxi with OFF so no dust enter engine

Turbocharger & Supercharger:

Produce less power in less dense air
Produce more power in colder air
MP drops during climb

- Climb and air becomes less dense ∴ ↓ in engine performance
- T & S: Compress & ↑ density of air (engine will think it is at a lower altitude)
- Turbocharger: Powered by engine exhaust → turns power turbine of turbocharger
  Pro: Lightweight, NOT take power directly from engine
  Con: Hot operating, expensive and maintenance intensive (∵ extreme temp change)

Supplies compressed to cylinder

More efficient than supercharger

Compress air PRIOR to entering carb/fuel injection

- Wastegate: Regulate amount of exhaust gas to turbine
  ∴ regulate speed of turbocharger
  Open: NOT turbocharged, gas ported overboard
  Closed: Turbocharged, direct through turbine
- Supercharger: Internally driven compressor powered directly by engine
  Come off crankshaft via a gear reduction system
  Pro: Reliable, less expensive
  Con: Takes power up to 16% from engine
  Compress air DOWNSTREAM of carb

Forced reduction

Effects of density altitude and humidity:

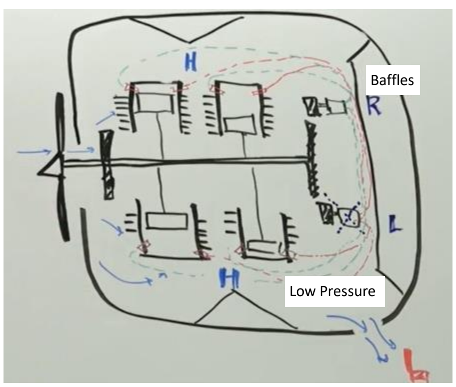
- Density altitude: Pressure Alt. corrected for temp (aircraft 'thinks' it is operating at)
- Airplanes: Change power output of engine, performance of propeller and lift created by wings
- Helicopter: Change rotor performance
- Hot/High/Humid = LOW air density (Thin air) = HIGH Density Alt.
- Cool/Low/Dry = HIGH air density (Thick air) = LOW Density Alt.

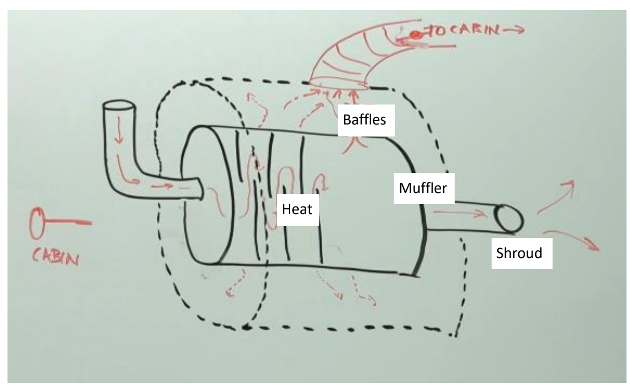
Take care of engine:

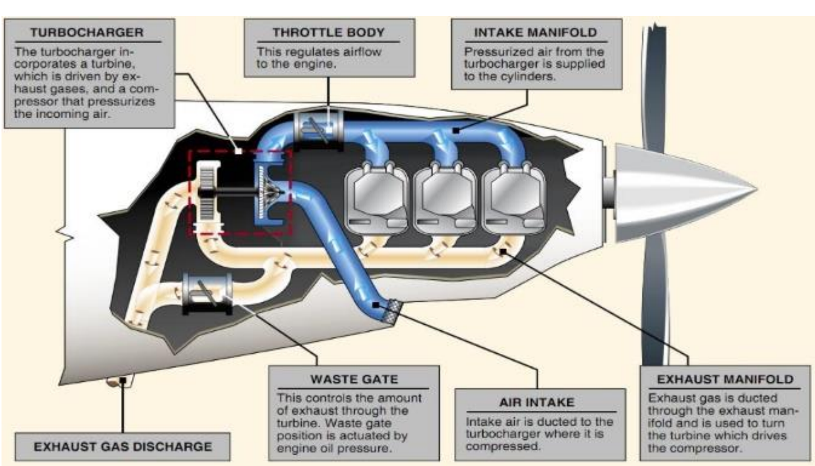
- Read Pilot Operating Handbook/Aircraft Flight Manual
- Avoid long climbs at low airspeed (∵ lots of heat with low amounts of cooling air)
- Avoid descents with large/quick power ↓ & high airspeed (∵ sudden/shock cooling, cracked cylinder)

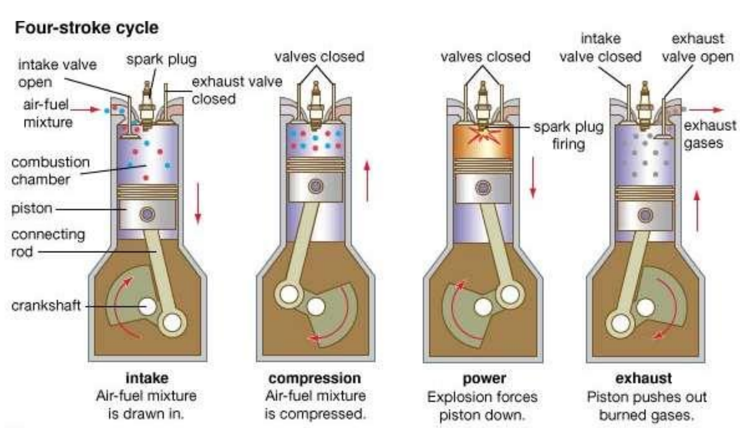
Limitations and operations:

- Winter operator below 0°C: Partially block engine intake to ↓ cooling airflow
- Allow proper warm up (Min. operating temp is green, oil temp is green)









4. Piston engines: Instruments

Engine Instruments:
- Part of VFR Req.: Oil pressure gauge, Oil temp gauge
- Optional: Cylinder head temp gauge
  Exhaust gas temp gauge
  Carb temp gauge
  Fuel flow/Pressure gauge
  Coolant temp gauge (for liquid cooled engine)

Cylinder head temperature:
- Measure temp of one of cylinders in Fahrenheit/Celsius
- Too high: overheating, will lower resistance of metals and risk pre-ignition
- Too low: may not vaporize fuel properly

Oil pressure:
- Measured in Pounds per Square Inch
- Register within 30sec of a start/60sec if cold, if not then shut down & investigate
- Too low: Engine damage
- Too high: Damaged seals → oil loss

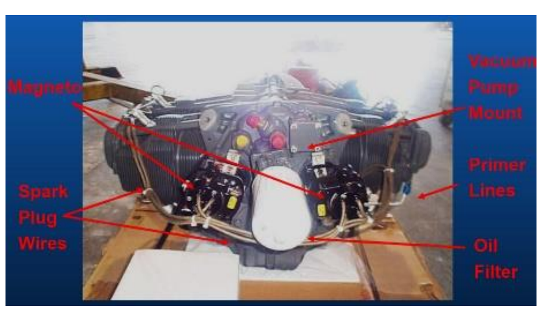
Oil temperature:
- Measure oil temp in Fahrenheit/Celsius (best in 180 – 220°F ∵ evaporate water in oil)
- Fast rising temp maybe due to not enough oil

Hand starting a piston engine airplane:
- Never be attempted without proper instruction from qualified person
- A qualified person must remain at controls of plane & prevent from moving forward
- Reduce engine thrust after starts

O-320:
- 320 = Cylinders combined to provide displacement of 320 cubic inches

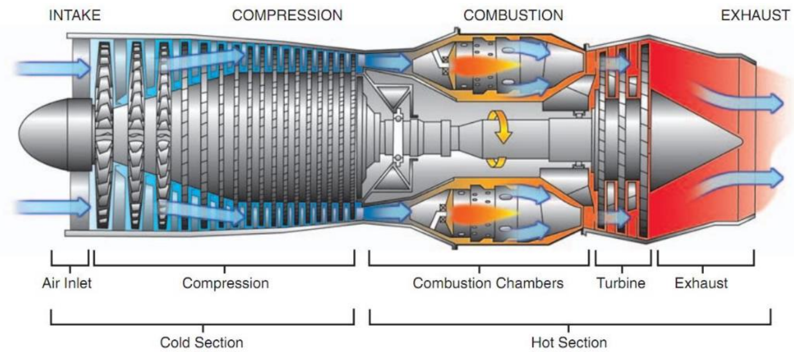
Vacuum pump:
- Power attitude indicators, heading indicators and inflate deice boots
- Mounted to back and driven off the engine ∴ engine fails → vacuum pump fails
- Not really reliable, may fail every 500hrs

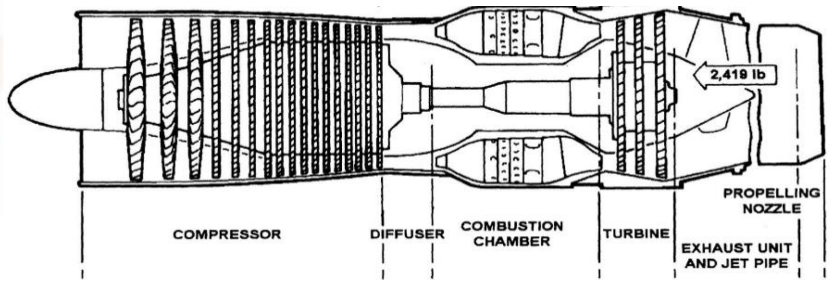
Brake horsepower (BHP):
- What is available after friction and other losses have been accounted for



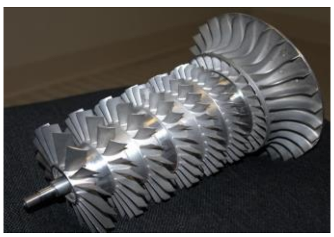
5. Turbine Engine

Turbojet:

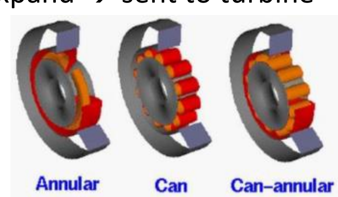




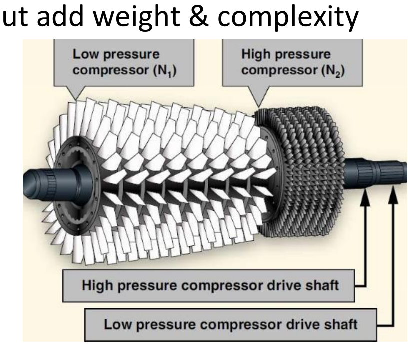
- Principle: Exit velocity > Freestream/entrance velocity → Thrust
  One smooth flow with rotating turbine & minimum moving part
- Engine inlet: Surrounding air are continuously brought into engine through intake/inlet
- Compressor: Rows of airfoils creating small jump in pressure, like electric fan needing energy to run
  Axial flow: Efficient but lots of stages
  Vanes arranged in row, airflow is parallel to axis of rotation
  Rotor add kinetic energy & stators convert it into pressure
  Set of vanes get smaller as air is compressed
  Rotor/stator pair → Stage, Set of rotors → Spool
  Centrifugal flow: Spin air outwards
  Found at end of set/stages of axial compressor
  Have diffuser to convert KE in flow of pressure



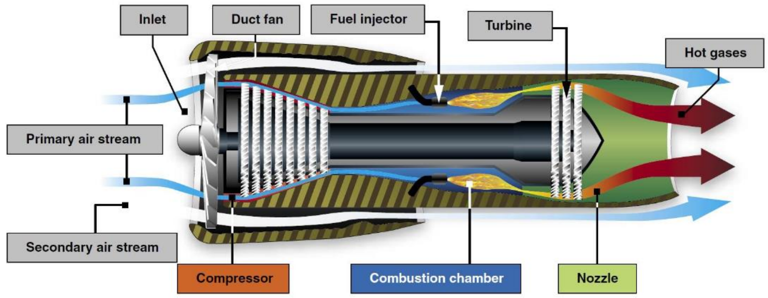
- Diffuser: At the end of cold section
  Slows down compressor delivery air to reduce flow loss in combustor
  Slower air → Stablize combustion flame
  Higher static pressure improves combustion efficiency
- Burner: Small amount of fuel mix with air and ignite
  Run very lean, 70-80% of air is not used in combustion
  Typically 100 pounds of air with 2 pounds of fuel
  Combustion at constant pressure, fuel-air mixture causes heating & expand → sent to turbine
  Types: Annular, Canister, Can-Annular

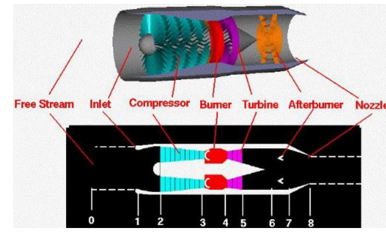


- Igniters: Ignite fuel from burner during startup
  May need to be placed ON to help prevent flameout in precipitation
- Turbine: Extract energy from flow of gas by blades spinning in flow
  Requires fewer stages than compressor
  Favorable pressure gradient & not susceptible to stalling → higher pressure change in 1 stage
- Afterburner: Add fuel between turbine stage → Improve power output but add weight & complexity
  Usually in military jets, will decrease efficiency
- Compressor shaft: Linking compressor & compressor turbine
  Can be "nested" → Multiple shaft speed
- Nozzles: Exhausted gas are vented
  Design can slightly aid in thrust & quieter



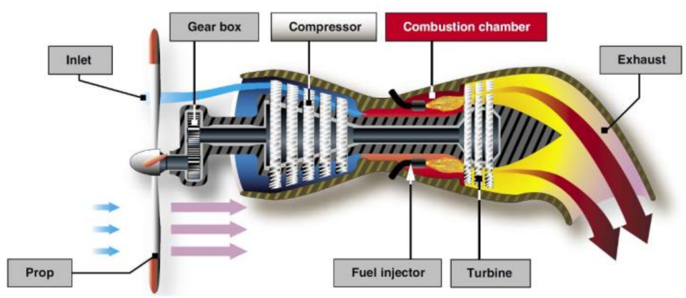
Turbofans:





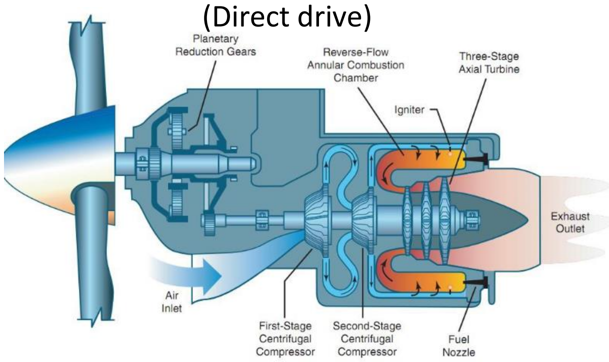
- Principle: Core engine is surrounded by fan in front & additional turbine in rear
  Fan & fan turbine composes of many blades & connected to additional shaft
- Incoming air captured by engine inlet then passes through fan, some into core & mix with fuel & combust
- Hot exhaust passes through core & fan turbines & out through nozzle
- 30-40% more fuel efficient than Turbojet & much quieter (Cushion effect to cool down & create sound barrier)
- Bypass rations: Air goes around engine to air goes through core
  Gives info about performance of turbofan engine
  Low bypass: BPR < 5:1, Higher fuel consumption but higher speed
  High bypass: BPR > 5:1, Fan generates 80% of thrust, lower fuel consumption & quieter
- Nozzles: Co-annular, allows air of different velocities & temperatures (Bypass & exhaust) to mix & exit more silently
- Engine pressure ratio: Ratio of Turbine outlet pressure to Compressor inlet pressure
  Used as parameter that corresponds to thrust

Turboprops:

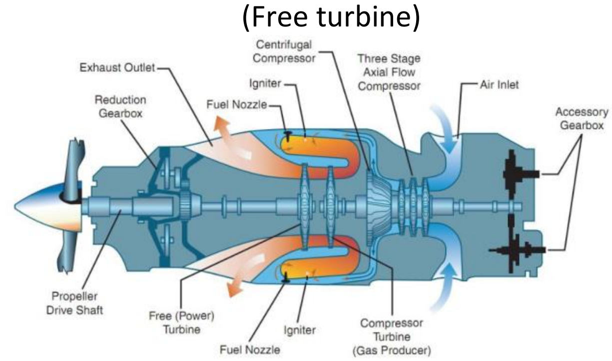


- Core engine, gearbox & propeller
- Exhaust is used to turn POWER turbine → Power turbine drives prop through gearbox & create thrust
- Single-shaft engine: Compress turbine & power turbine may be the same turbine
- Exhaust velocity is low because energy is extracted by power turbine → Produce little jet thrust
- Direct drive: Compressor turbine & power turbine are same turbine
  Compressor shaft & output shaft are same shaft and is connected to gear box
- Free turbine: Compressor shaft & power shaft rotate independently
  Most common is PT6A engine, seems to be mounted backward in cowling

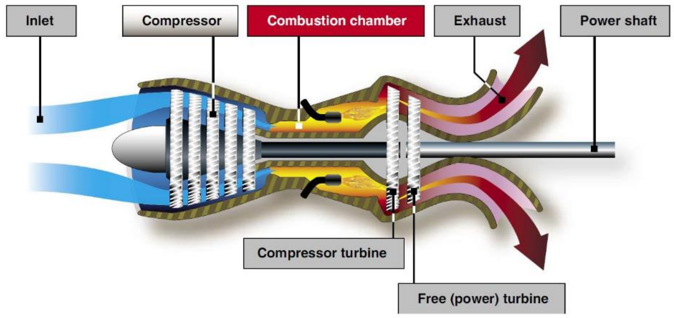
(Direct drive)



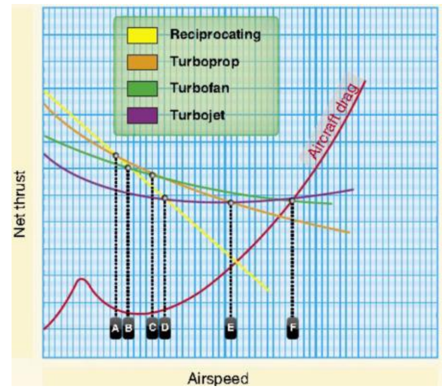
(Free turbine)



Turboshaft:



- Similar to free turbine turboprop, differing in function of turbine shaft
- Used to drive helicopter rotor system
- Driving compressor, electrical generator, pump, marine application



Turbojet vs Turbofan vs Turboprop:
- Turbojet is efficient in high speed but perform poorly & waste energy at low speed
- Turboprop is efficient at lower speed but fare poorly as speed increases
- Turbofan is best compromise

Compressor bleed air:
- Air from low speed compressor: Less PSI & lower temp, used for cabin pressurization
- Air from high speed compressor: Greater PSI & high temp, used for wing & engine inlet deicing

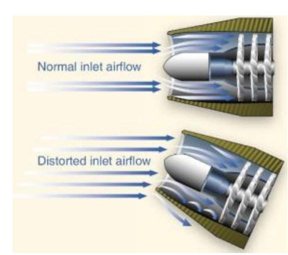
Auxiliary power unit:
- Hidden mini-turbine engine in tail
- Power up electrical system & provide pneumatic pressure to spin up compressors in main engine during start

Starting a turbine:
- Need to get up to 12% of normal compressor speed before introducing & igniting fuel
- Via starter/pneumatic start (Done through APU/GPU) → Spin up starter turbine then spin up compressor to light up/ignition speed

Hot start:
- If inject fuel into burner too early/before compressor get enough speed → Fuel will burn out of control
  Not enough pressure in engine to throw hot air out towards back through turbine engine
  → All fuel burn in burner area & melt down engine
- 500°F EGT after 20% N1 then OK, before then big trouble (Exact speed & EGT temp may vary)
- Fuel cutoff, igniters off, maintain N1 speed and airflow will cool things down

Hung start:
- Insufficient cooling air throughout engine, not necessarily because of improper propeller speed
- Due to hot, high, humid (High density altitude)

Compressor stall:



- Aerodynamic stall that aerofoils in compressor are loaded above lifting capacities
- Indicated by loud bang & strong vibration
- Reduce power & AOA, Increase airspeed
- Variable inlet guide vanes & variable stator blades will inhibit compressor stall

6. Diesel engine

Principle:

- Take in air, piston moves upwards & compress to 200bar
- Heavy fuel such as crude oil/petro will be injected into heated air due to high pressure
- High temp from compression will ignite fuel by auto-ignition without need of spark plug

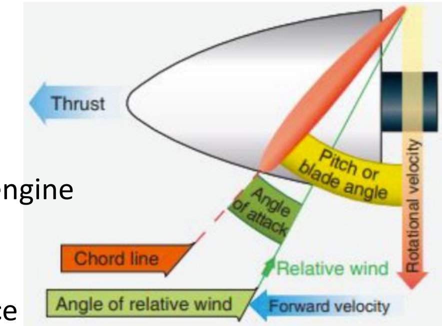
Mode of operation:

- Suction: Pure air get sucked in by piston moving downward
- Compression: Piston compresses air through work of crankshaft
- Power: Air at max compression at top-dead-centre & pressure and temp are high
  Injection pump injected heavy fuel into hot air, auto-ignition, piston get pressed downwards & power crankshaft
- Expulsion: Burned exhaust are ejected out of cylinder through second valve by piston sliding upward

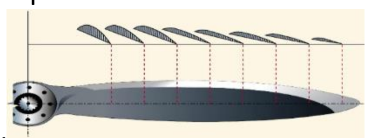
Pro & Con:

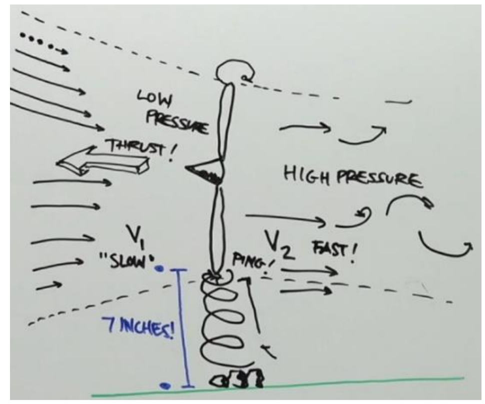
- Pro: Can use lower cost fuel like Jet A, 100LL being harder to find & more expensive
  More efficient up to 35%, more durable engine since it needs to handle higher compression ratio
- Con: Heavier weight, hard start in cold temp Lower fuel consumption

7. Propeller Basics



Propeller:
- Similar to airfoil which produces lift
- Convert engine power through torque of crankshaft into thrust
- With 2-6 blades, 3/more are used in constant-speed system and on multi-engine
- Multi-bladed: Tend to be shorter → greater ground & fuselage clearance
  Produce higher less objectionable sound frequency
  ↓ vibration, greater flywheel effect, ↑ takeoff performance
- Low pressure and slow wind in front of propeller
- Propeller tip to ground: Min. 7 inches





Propeller twist:
- Change in blade angle of incidence from hub to tip
  ∵ Since propeller speed varies across diameter
  ∴ Twisting produces more thrust from hub to tip

Geometric and effective pitch:
- Propeller efficiency: Ratio of thrust horsepower to brake horsepower
- Geometric pitch: Theoretical distance a propeller should advance in 1 rotation
- Effective pitch: Actual distance a propeller will advance in 1 revolution
- Propeller slip: Difference between effective pitch & geometric pitch

Effects of propeller:
- Torque: Propeller forcing plane to rotate in the opposite direction to propeller's rotation
  From pilot's perspective: Rotates clockwise → Tendency to roll to left
- Slipstream: Airfoil of propeller creates drag → Air rotate in direction of propeller's rotation & move aft
  Aircraft have vertical fin & rudder → Stick up & projects above centerline of slipstream
  Helical propwash strikes left side of tail → Push tail to right and nose to left
  Effect of propwash in cruise: Anticipated by aircraft designer
  Vertical fin & rudder: installed at slight angle align to airflow
  ∴ High airspeed low power: Left rudder, Low airspeed high power: Right rudder
- Gyroscopic effect: Spinning propeller = gyroscope
  Law of precession: Force exerted on spinning mass causes a reaction 90° along direction
  Pitch causes yaw, yaw causes pitch
  Primarily associated with conventional gear (taildragger)
  → Nose down pressure, raise tail wheel off, left yaw

- Asymmetric thrust/P-factor: Level flight: Propeller disc orientates in vertical plane to horizontal
  → Blades have same AOA, Thrust of entire prop is same
  Nose up: Blade pitch angle on right descending blade ↑
  Blade pitch angle on left ascending blade ↓
  Descending blade takes large "bite"/cut of air
  Higher AOA than upgoing blade → More thrust on right side
  ∴ Yaw to left and require right rudder
  Some aircraft with engine pointed right → Offset P-factor of des. blade
  Conventional gear (Taildragger): Affected with tail on ground, yaw left

Conventional gear : Torque, P-factor, Gyroscopic precession
⇒ left turning tendency

Fixed-pitch propellers:

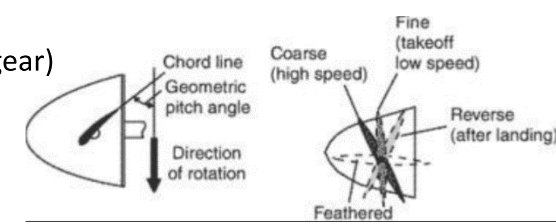
- One-piece props with single fixed blade angle (pitch)
- Climb prop: Smaller blade angle, Cruise prop: Larger blade angle
- Pitch is high enough for cruising but also low enough for takeoff and climb
- Economical & lightweight
- Max thrust near RPM providing max torque from engine (~2400RPM)
- Throttle controls both power & RPM
- Fixed throttle setting: ↑ / ↓ in airspeed, ↑ / ↓ in RPM at constant throttle setting
  ↑ / ↓ in throttle, ↑ / ↓ in RPM at constant airspeed

Variable-pitch propellers:

- Change pitch automatically/manually: Operate engine at most efficient setting
- More efficient than fixed-pitch propeller
- Constant speed: Most advanced
  Governor provides constant RPM: Control force acting on propeller to change blade angle
  Blade angle automatically ↑ / ↓ to maintain RPM as throttle is changed
  With throttle & RPM set, blade angle auto. changes as airspeed changes to maintain RPM
  Prop lever can change blade angle to ↑ / ↓ RPM

Coarse pitch:

- Travel forward a greater distance with each rotation
- Plane moves forward at greater speed for given RPM (Like high gear)
- Best for high speed cruise & high altitude flight
- AKA high pitch/low RPM/decreased RPM



Fine pitch:

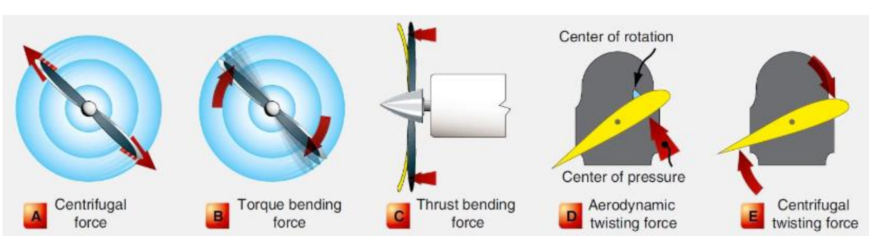
- Less torque/drag, revolve higher speed, engine can develop greater power (Like low gear)
- Best for takeoff & climb
- AKA low pitch/high RPM/increased RPM

Windmilling:

- Propeller: Lift component is responsible for generating thrust
  Drag component slows down the plane
- Propeller tip is limited to 600kt as speed of sound is approached
- Even for dead engine, still possible to have max RPM ∵ Force of windmilling propeller
- Fully feathered propeller produces least lift & drag → Prevent windmilling

Propeller care:

- Visually inspected before each flight, look & feel for surface damage & dents, nicks, scratches
- Imperfection should be dressed out by engineer before cracks
- Minor repairs should not impar propeller performance



Visual inspections:
- With spinner: External surface for damage, attachment part for normal tightness
- No spinner: Front & back surface of propeller hub, attachment onto engine shaft for normal tightness
- Once a year for one-piece fixed-pitch / Every 100hrs for other types: Inspect every inch
- Engineer: Remove spinner & have propeller installation bolts checked for tightness with torque wrench

Preventing damage:
- Avoid high RPM operation when stationary/taxiing over dirt, loose stones, puddles etc
- Do not use constant-speed propeller blades as handles to move plane on ground
- Pulling/pushing with propeller damages actuating components inside hub
- Use tow bar/area of airframe that is safe for push/pull

Roughness/vibration:
- Bent blades/out of track
- Improper mounting of pro on engine shaft
- Imbalance: one side of prop heavier than other
- Propeller is loosely mounted on engine shaft
- Blade angle between blades out of tolerance with respect to each other
- Spinner imbalance due to improper mounting, dirt, snow or ice inside shell

Cleaning the propeller:
- Clean cloth dampened with light oil to wipe prop, especially near salt water
  → removes and repels substances that cause corrosion & prevent water erosion
- Never scrape blades, use abrasive cleaners, or use water to clean prop and hub (May corrode)

Repainting propeller:
- Use non-reflective black for side of blades with face pilot
- Use bright colors for opposite side so spinning prop can be easily seen
- Should not be shiny ∵ Shiny disc is hypnotic & distracting

Checking blade check:
- Ability of one blade to follow the other in same plane of rotation
- Held to reasonable limits to prevent roughness

Propeller diameter:
- Function of engine & airframe limitations
- Larger (Smaller) propeller diameter for low (High) airspeed operations
- Constant-speed prop is larger than fixed-pitch due to variability of blade angles

Shape of propeller tips:
- Rounded, swept, square
- Meet blade vibration, resonance, special design conditions, noise requirements, flight performance

8. Propeller Systems and Operation

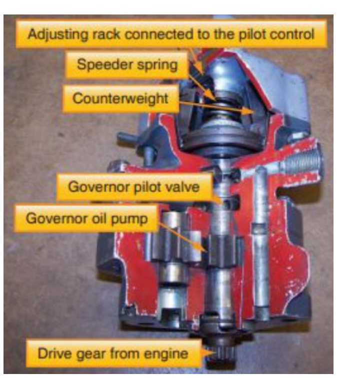
Propeller pitch definition:
- Coarse: High pitch angle, high angle of incidence, used for cruise
- Fine: Low pitch angle, low angle of incidence, used for takeoff & initial climb out
- Feather: Pitch angle used for eliminating propeller drag during engine failure (Multi-engine)
- Reversing: Negative pitch angle, used for decelerating during landing

Variable pitch propeller:
- Pitch is changed hydraulically in single-engine system using engine oil controlled by propeller governor
- Constant-speed non-feathering system (Single-engine): Pitch is increased with increased oil pressure
- Constant-speed full-feathering system (Multi-engine): Pitch is decreased with increased oil pressure

Constant-speed propeller system:
- Pilot can select propeller/engine RPM based on altitude & engine power, RPM will remain constant
- RPM is controlled by varying angle of incidence, pitch of propeller blade, throttle setting
- Governor will increase blade angle if pilot increases power
- Torque on engine required to spin propeller is increased from increased pitch
  → Reduce RPM, Increase speed

Propeller governor:
- Mounted on engine with gear and its supporting oil lines
- Engine gearing drives governor gear pump & flyweight assembly
- Gear pump changes engine oil pressure to provide quick & positive propeller pitch change
- Rotational speed of flyweight assembly varies directly with engine speed controlled by pilot valve
- Oil flow will be directed to/form propeller & allow oil flow back from/to propeller depends on pilot valve
- Prop lever is connected to governor control lever which is attached to threaded shaft
  → Lever moves then threaded shaft turns & move up/down to increase/decrease
  compression on speeder spring
- Cockpit control forward = governor control shaft screws down = increase compression on spring
  → Increase speed necessary for flyweight to move pilot valve which produce higher RPM (Finer pitch)
- Prop lever forward (back) = Finer (Courser) pitch

Flyweight:
- Change position of pilot valve with centrifugal force
- L-shaped flyweight are installed with lower legs projecting under bearing on pilot valve
- Increasing RPM: Engine RPM increases → Tops of flyweights are thrown outward by centrifugal force
  Lower legs pivot up & raise pilot valve against force of speeder spring
  Flyweight spin faster & further then causing pilot valve to be raised
  Oil flows to (from) propeller in constant-speed (full-feathering) system



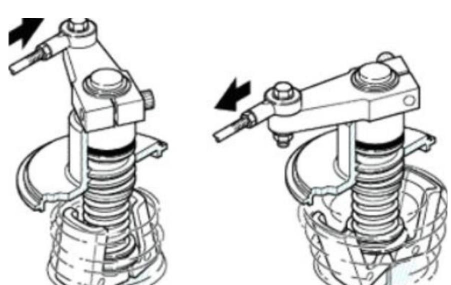
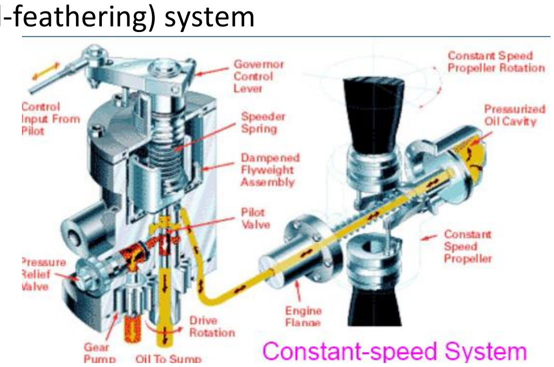


Fig. 8



On-speed condition:
- When RPM is constant
- Force of flyweight = Speeder spring load
- Positions pilot valve in constant RPM position with no oil flowing to/form propellers

Overspeed condition:
- As airspeed increases caused by plane descending/engine power increasing → Pitch of blade is too low
- RPM will increase and flyweight will move outward & speeder spring push pilot valve up
  → Oil flows to (from) propeller in constant-speed (full-feathering) system
- Pitch then increases & brings RPM to original setting

Underspeed condition:
- As airspeed decreases caused by plane climbing/engine power decreasing → Pitch of blade is too high
- RPM will decrease and flyweight will move inward & speeder spring hold pilot valve down
  → Oil flows from (to) propeller in constant-speed (full-feathering) system
- Pitch then decreases & brings RPM to original setting

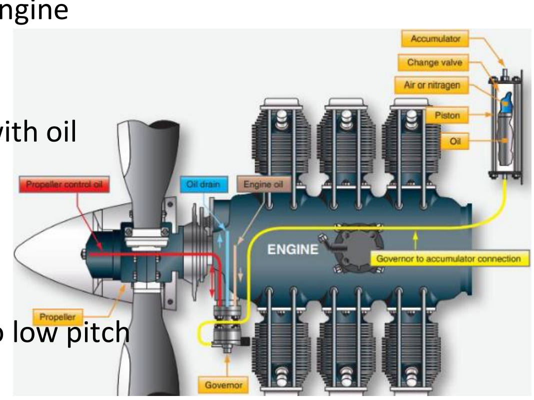
Loss of oil pressure:
- Single-engine: Prop will move towards fine pitch & act as fixed pitch
- Multi-engine: Prop will move to maximum coarse pitch due to springs & centrifugal counterweight force
  Pilot need to activate feathering/by autofeather system with turboprops

Constant-speed non-feathering system:
- Oil pressure supplied by governor acting on piston produces force that is opposed by Natural centrifugal twisting moment of blade

Constant-speed full-feathering system:
- Oil pressure supplied by governor acting on piston produces force that is opposed by Counterweight & large spring
- Usually in multi-engine only
- Turn to very high pitch (90° angle of incidence) & blades are almost parallel to air stream
- Eliminates asymmetric drag forces & yawing caused by dead engine

Feathering:
- Mechanical linkage overrides flyweight & speeder spring
- Cockpit control moves to feather → Governor lever & shaft are turned beyond normal low-RPM limit
- Threaded shaft backs out the shaft lift rod engages pilot valve spindle & lift pilot valve
- Oil flow out from propeller & moves blade to feather pitch position

Unfeathering accumulator:
- Permit feathered propeller to be unfeathered in flight for air-starting engine
- Governor provides external high-pressure oil outlet
- External outlet is connected to accumulator
- One side of accumulator is filled with compressor nitrogen and other with oil
- Check valve maintains oil pressure in accumulator when feathered
  → Allows oil to be stored under high pressure same as normal flight
- When move from feather to low pitch → Check valve is unseated
  & permit high pressure oil to flow to governor pilot valve
- Speed spring forces pilot valve down & oil flows to propeller & move to low pitch



No unfeathering accumulator:

- Pilot can move propeller control to high RPM (low pitch) & engage engine starter
- If engine is turning over fast enough to develop sufficient oil pressure, blades will be forced out of feather

Sitting on ramp:

- Single-engine: Propeller full flat/fine pitch driven by the spring
- Multi-engine: Propeller full coarse pitch due to spring/nitrogen charge
  Centrifugal latch pins prevent blades from completely feathering
- Free-turbine engine: Full feather position

Engine startup:

- Single-engine: Oil pressure comes up, blades remain flat position (Prop lever fully forward)
- Multi-engine: Oil pressure comes up, blades will be moved to low pitch mechanical stop
  Prop lever fully forward, RPM is controlled by power since RPM is below governor's range

Engine runup:

- Prop lever should be fully forward & blade will be in full fine pitch
- Governor is being asked for redline RPM (Normal runup 1700-2000 RPM)
- Propeller angle remains constant until prop control is moved back enough to request less RPM
  → Allow magnetos to be checked without governor keeping RPM constant
- Cycling: Pull prop lever back & allows governor to be tested & circulate fresh air
  → Loosen pressure on speed spring & overspeed condition
  Flyweight opening pilot valve, Oil flow towards (out) oil dome in single (multi) to increase pitch
  RPM will drop (increased blade pitch increases engine load)
  Full-feathering propeller: Pitch will continue increasing towards feather
  Should NOT be allowed below given RPM to avoid stress

Takeoff:

- Full throttle & monitor RPM, MP, fuel flow
- RPM should be very near redline shortly after roll since blades at fine pitch
- More airflows pass through blades & take load off engine then RPM will want to increase
  → Blades come off low-pitch stops to maintain selected RPM for takeoff

Making power change:

- Increase RPM first then MP
  → If MP first, combustible mixture is increased to each cylinder and want to spin propeller faster
  Cannot happen because blades take bigger bite of air/operates at high angle of incidence
  Cylinder stress increases as propeller keeps RPM from increasing
  Expanding gases push harder & unable to move piston faster → damage engine
- Decrease MP then RPM

When do blades meet stop:

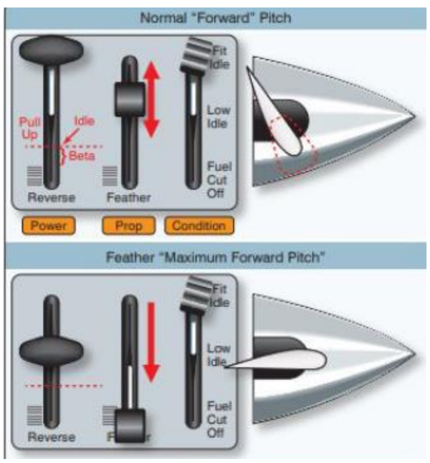
- Low power & low airspeed, approach to land: Engine cant maintain RPM & airflow is not enough
  to drive propeller so it meets low-pitch stops
- High airspeed descent, windmill effect: Propeller becomes unloaded & blades twist to coarse pitch
  Work like fixed-pitch & pull back prop level has no effect

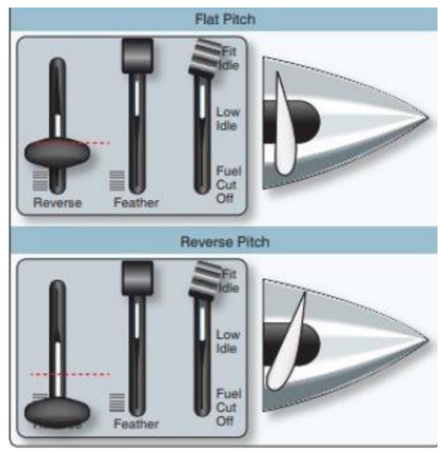
Multi-engine failure:

- Failed engine will have same RPM, MP, Oil temp & pressure (EGT will provide clue)
- Governor continues to send oil to propeller to decrease blade pitch to maintain RPM
- Governor is engine driven & windmilling propeller is enough to power governor

Turboprops:

- Fuel control unit & propeller governor are connected & operated together
- Power lever directs signal to fuel control for specific amount of power
- Fuel control unit & propeller governor establish correct combination of RPM, fuel flow & prop blade angle to provide proper power & thrust
- Alpha range: Propeller blade angle & fuel flow are governed automatically according to predetermined schedule
- Beta range: Ground handling range, blade angle is governed by governor but controlled by power lever
- Reverse thrust: Power lever moves below start position, pitch is reversed to provide deceleration
- Built in gates to prevent from selecting beta/reverse range in flight

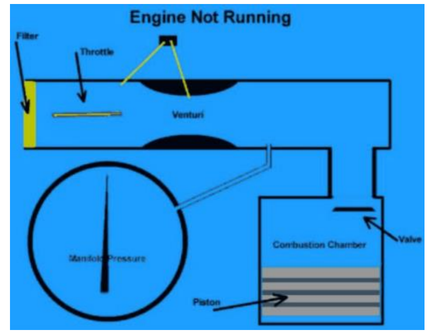




9. Manifold pressure

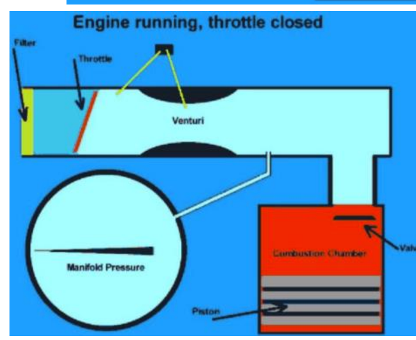
Principles:

- For constant-speed/variable-pitch propeller (controllable pitch)
- Propeller is by propeller control lever to maintain fixed RPM by changing pitch
  ∴ Tachometer is not accurate measure of engine output (Thrust) and need additional equipment
- Measure the pressure of fuel/air ratio that enters the intake manifold of engine (in Mg)
- Only measurement of engine output
- Throttle valve opens → More fuel/air mixture being sucked → High manifold pressure reading



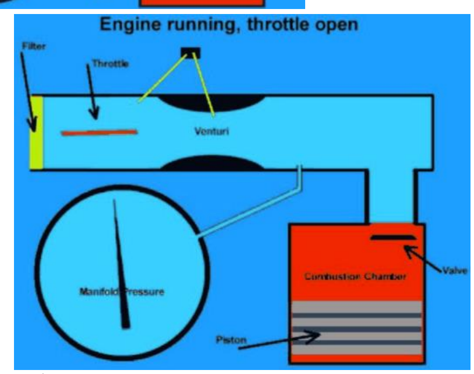
MP - Engine off:

- Static manifold pressure: 29.92in Mg (Standard atmosphere)
- Check gauge for accuracy:
  Set altimeter, subtract 1 per 1000ft ASL.
  MP gauge should show close to this



MP - Engine idle:

- Piston is trying to suck air into combustion chamber
  But partial vacuum is formed
  → Decrease in MP
- Most stress on intake pipe is encountered
  ∵ Greatest amount of suction



MP - Full throttle:

- Draw as much air as it is capable of mixing with fuel & burn
- Typically not always reach the static manifold pressure value
  ∵ Resistance of intake filter, throttle plate (more edge on), bend in ducting
- Possible to exceed ambient MP due to "Ram effect"
  with increased airspeed of aircraft
- When engine is running/windmilling: Suck air & measure as MP
  ∴ MP of dead engine may not drop as expected

Factors/Depends on:

- Ambient pressure, position of throttle plate, speed of pistons (vacuum pump)

Experiment:

- Keeping throttle constant & RPM ↓ : MP rises sharply towards ambient pressure
  ∵ Piston moving slower & pumping less air & creating less vacuum
- Keeping throttle constant & RPM ↑ : MP drops sharply

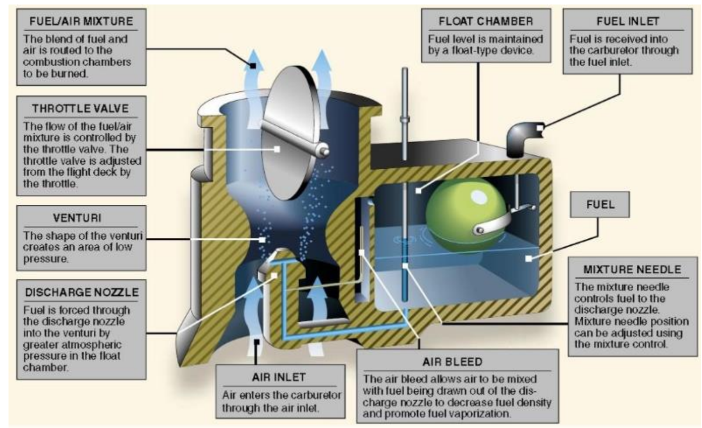
Induction system leak:

- More air will get into system → Leaner mixture setting unless at full throttle
- Detect: Engine roughness during ground idle, Whistling noise coming from engine during idle, Abnormally high MP for throttle position

10. Carburetor

Theory of operation:

- Mixing fuel & air: By vaporizing fuel into air in proper ratio
- Regulating amount of fuel/air mixture by WEIGHT that enters engine: With throttle setting
- Most are updraft float carburetor, mounted on the bottom of engine
- Route outside air from intake through duct into carb → fuel/air mixture is sucked up to engine
- Equip with small chamber containing fuel & float valve (maintains constant amount of fuel in chamber)
  ∴ constant & sufficient source of fuel



Venturi:

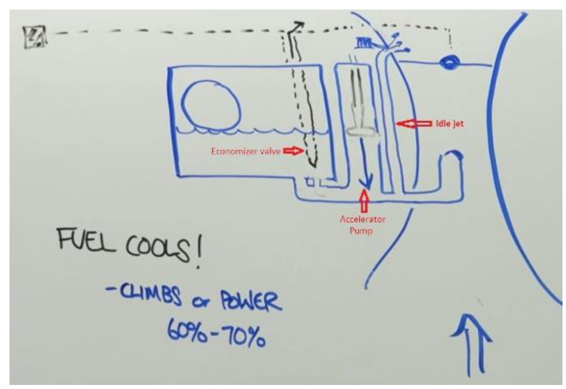
- Tubular structure: Diameter near middle ↓
  Diameter near intake manifold ↑
  ∴ create vacuum (Bernoulli Principle)
- Middle: Velocity of air ↑ , Pressure ↓
- Fuel intake port locates inside Venturi

Vaporized fuel:

- Metered amount of fuel is sucked into carb
- Fuel vaporizes into fine particles in intake airflow ∴ correct ratio of fuel/air cause correct burning

Accelerator pump, economizer valve, idle jet

- Accelerator pump: Provide additional amount of fuel for sudden engine acc.
  ∴ Prevent stumbling when develop max. horsepower
- Economizer valve: Small needle that allow more fuel to
  flow through at high power setting
- Idle jet: allow engine to idle when throttle is closed



Effect of air density changes on fuel/air ratio:

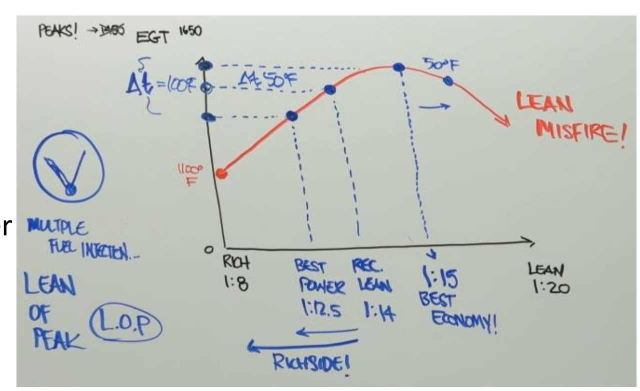
- Climb: Air density ↓ , Fuel/air ratio richer
- Descend: Air density ↑ , Fuel/air ratio leaner

Mixture control:

- Regulate fuel flow into carb to adjust fuel/air ratio
- Enrich: Lower engine temp, Lean: Increase engine temp
- How: Climb to given alt., lean mixture and the engine will start to run faster, keep lean and engine will run rough, then enrich by a bit (Or consult POH for recommended lean)
- Allow for proper temp, keep engine cylinders clean, prevent spark plug fouling & engine roughness, ↓ fuel wastage

Exhaust Gas Temperature Gauge:

- Red needle for peak EGT (aka Max. economy)
  White needle for measuring relatively
- Towards lean from full rich: EGT will rise until it peaks
  Then fall if mixture is leaned further



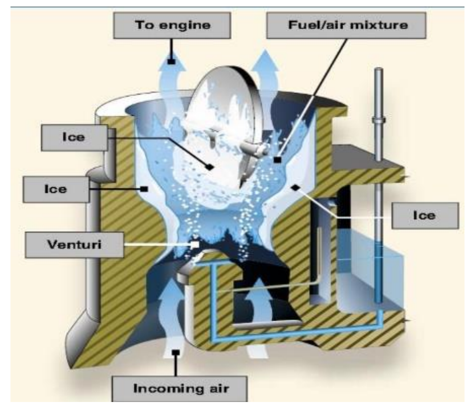
Induction icing: Air filter, induction tubing, throttle valve of fuel injected engine

- Buildup of ice in fuel induction system, affect all types of piston engined planes, helicopter & gyroplanes
- Air induction part becomes blocked with ice when visible moisture is in air
- AKA Impact ice, prevalent when Outside Air Temp is -4°C (25°F) in snow, sleet or supercooled liquid
- Can affect BOTH fuel injection & carburetor system, MAIN type of icing for turbocharged engine

Carburetor heat:

- Melt/Prevent carb ice (Pull on: Heated air enters, Carb now less dense, enrich mixture, ↓ engine output)
- Air comes from unfiltered section inside cowling, pass through heat box which warms intake air
- Can use when atmospheric conditions are conducive to carb icing
- Normal intake duct becomes blocked by impact ice: carb heat can act as alternate air source

Why carburetor/throttle icing: If not asking for severe then -5°C to +30°C



- Air passes through venturi: ↓ in air pressure, ↓ in air temp
- Fuel passing through venturi is vaporized ∴ takes heat from air
- Combine effects: Temp drop of 20°C -30°C
- Cause moisture in air/fuel to condense and freeze
- Most severe with high relative humidity & temp between -5°C to +15°C
- MOGAS has high volatility (cools more on vaporization)
  ∴ Easier to have carb ice than AVGAS
- Easier to occur when partially close throttle & low power setting
  ∵ Act like a venturi (air pass edge of throttle plate will speed up so reduce temp in that area)
- May use carb heat anytime the power setting is below certain RPM (e.g. 2100 RPM)

Detection & recovery: Engine roughness with application of carb heat

- First detected by gradual drop in RPM in fixed-pitch/drop in manifold pressure in constant-speed
- Apply carb heat: additional decrease in power, engine temp ↑, engine run rough as ice melts
- Ice is gone: RPM/Manifold pressure will restore & no engine roughness, turn OFF carb heat then
- If ice is persistent: Keep carb heat ON, need to LEAN mixture because of hot air (Less dense)

Throttle:

- Regulates amount of fuel/air mixture that enter engine ∴ control power of engine develops
- Fixed pitch propeller: Throttle directly controls RPM (Tachometer gives engine power output)

Manifold pressure:

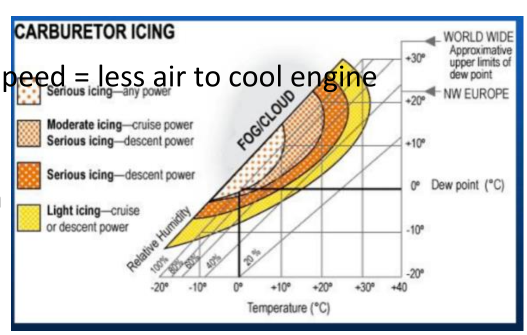
- Variable-pitch type propeller (Constant-speed/Full-feathering system): Throttle controls M.P.
- Propeller control: Regulate RPM of engine and propeller
- Setting power: Adjustment of both throttle & propeller control

High elevation:

- T/O from high elevation: Lean according to POH, otherwise spark plug fouling/engine failure

Long climb run richer:

- Help cool engine as extra fuel acts as coolant, ∵ climbing = slower airspeed = less air to cool engine



Fuel ice:

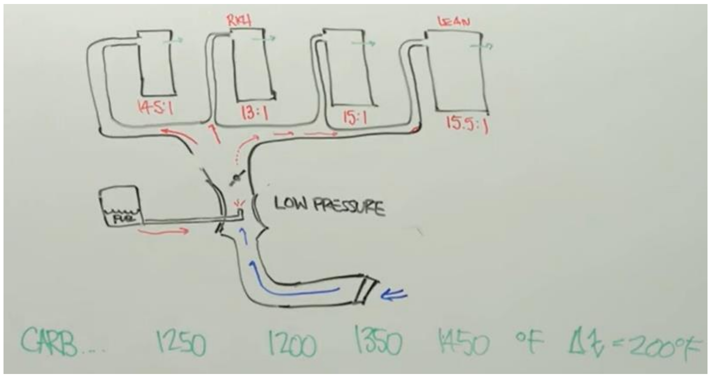
- Moisture content of air freezes as result of cooling by fuel vaporization
- Occur between +4°C to +27°C, whenever relative humdity > 50%

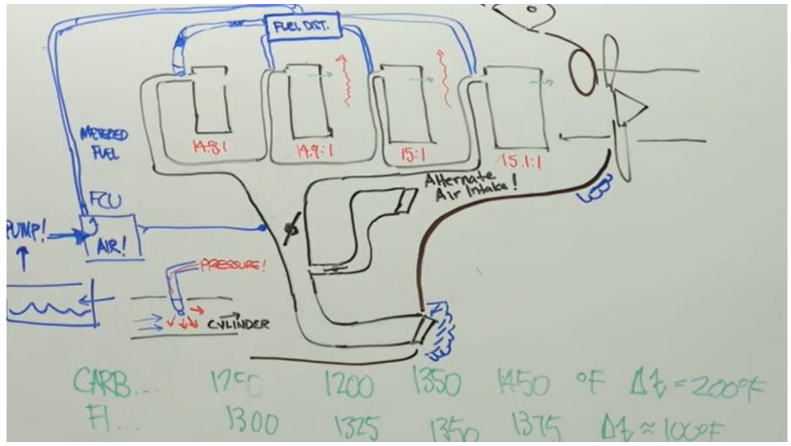
11. Fuel Injection

Principles of operation:

- Fuel is atomized by nozzles (Higher pressure than carburetor)
- Discharged into the air stream entering intake manifold
- In diesel engine: discharged into intake of cylinder
- Throttle: connected to fuel metering valve

  → automatically calibrated to send correct fuel/air mixture to engine





Pro: NOT efficient fuel delivery

- Uniform distribution of fuel to cylinders. Fuel is separately metered to each cylinder.
- More power since there is no need to heat carburetor heat
- Better cooling (∵ Eliminate lean/hot mixture to distant cylinders)
- NO carburetor icing (induction icing), but STILL impact & throttle icing
- Save fuel (∵ more regulated fuel flow)
- Faster & more accurate throttle response (∵ fuel directly injected into cylinder)
- Easier starting in cold weather

Con:

- Difficult to start a hot engine
- Vapour lock: Fuel evaporates and huge bubbles of air are left inside

  Open oil door & park into the wind in order to prevent

  High power setting + Electric fuel pump ON = NO fuel flow → Vapour lock

  Sol: Mixture lean, Full fuel, Fuel pump ON → cool fuel will cool down system

  Hard to restart if engine quits due to fuel starvation

Icing:

- STILL impact & throttle ice
- NO carburetor ice

Alternate air:

- Air filter becomes blocked: Alt. air should open automatically
- Suspect induction trouble: Manually open alt. air

12. Electrical system

Electrical system:
- Have battery combined with generator/alternator
- Battery: power for starter motor, acts as backup if generator/alternator fails
  Stores energy with limited amount only
- Either 12(older)/24(modern) volt

Generator VS Alternator:
- Provides power for lights, flaps, gear, avionics, de-icing etc and recharges the battery
- Alternator produce electrical power/current at LOW to HIGH RPM ∴ good for piston engine
- Generator produces electricity within small range of RPM (high) setting ∴ good for jet engine/turbine

Master switch:
- Linked master switch for alternator (Left) and battery (Right)
- Battery can be turned on independently
- Alternator can ONLY be turned on with battery, but also can be turned off independently
- Turn off battery = Turn off both side

Ammeter:
- Rate of flow being produced in electrical system
- Zero: No charge
  Positive: Alternator is providing power
  Negative: Battery is providing power, load exceeds alternator capacity
  Full-scale positive: Malfunction of voltage regulator

Load meter:
- Load imposed on electrical system by components that are running
- Alternator failed: Indicate zero

Voltage regulator:
- Control rate of charge to battery by stabilizing generator/alternator electrical output
- Generator/alternator voltage output: higher than battery voltage (14 volts for 12V battery)
  ∵ difference in voltage helps battery charged
- Will open during starting: Allow shot of prime from battery to alternator
  Make sure every electric is off before starting, otherwise will fry them all

Circuit breakers and fuses:
- Protect from over voltage/electrical shorts
- Check status as part of pre-flight check
- Circuit breakers: Trips and projects outward when overloaded
  Can be reset (ONCE ONLY) after pushing it back in
  Pops out again: Malfunction, DO NOT reset again
  Circuits should be checked and repairs prior to next flight
- Fuses: Do not trip
  Thin wire will break or burn out
  Need to be visually checked and replaced
  If fuse burn out again after replacement: checked and repaired

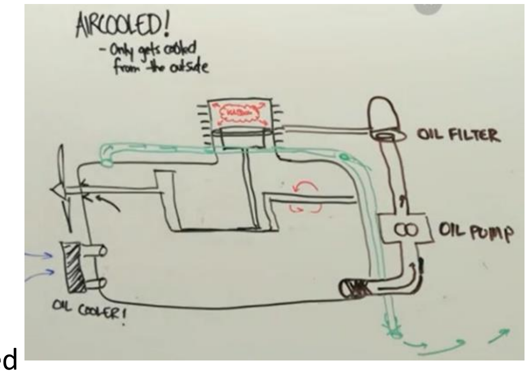
Bus bar:

- Takes current and branches it out to various electrical components
- Circuit breaker may have several subsystems
- May have multiple buses

Battery:

- Provide energy for starter motor during engine start
- Piston: Usually lead-acid type battery: Flooded cell/Sealed cell (Active Glass Matt, AGM)
- Transport: Nickel Cadmium battery
- Turbine: Mixture of NiCd and lead-acid
- If alternator fails, battery can provide power for limited time only, turn off unnecessary electrical items
- Light aircraft: around 10-35 amp hours

13. Lubricating systems



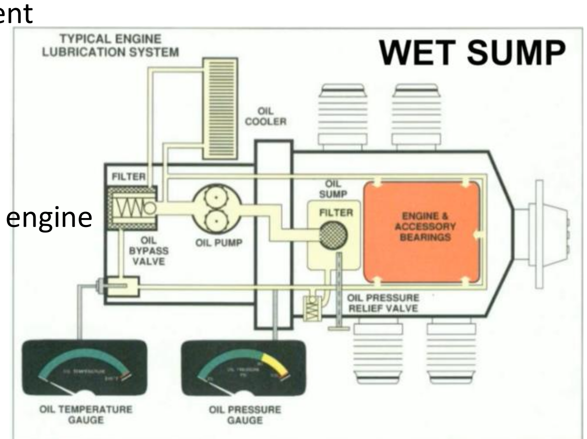
Purposes:
- Lubricating (Boundary & Hydrodynamic), Cooling, Sealing, Cleaning

Types of oils:
- Viscosity: resistance to flow
- Winter: Oil is cold, does not flow well ∴ Low viscosity oil should be used
- Eliminate need for changing oil: Use multi-grade oil (20W50, 15W50)
- Synthetic (Lower friction, Longer life)/Non synthetic (Better cleaning & sealing)
- Detergent (Ashless dispersant): Normal everyday use
  Contains additives: help keeping engine clean and sludge from forming
- Non-detergent (Mineral): Break in a new engine ∴ Usually for first 50hrs of engine's life
  No addictive potentially varnishing the sides of cylinders
  If not break in → high consumer of oil in the rest of life

Splash lubrication:
- Oil contains at bottom of crankcase → splash throughout engine via the turning crankshaft
- Not used in new aircraft

Forced feed lubrication:
- Oil is forced under pressure to engine parts, Pressure relief valve to regulate oil pressure to engine
- Dry sump lubrication: Separate tank of oil, forced into and through crankcase and back by pump
  Especially for radial engine
- Wet sump lubrication: Oil contained in bottom of crankcase, fed through engine by pump

Venting:
- Allow blow by gasses to escape crankcase without damaging seals/gaskets
- Oil overfills/expand too much when heated → spill out through vent
  ∴ May have small amount of oil along belly
- Investigate unusual streams/puddles



Oil filters:
- Fitted to force feed systems → clean oil and engine, Extend life of engine
- Oil filter located DOWNSTREAM of oil pump
- Mechanics will check for metallic particles at oil change
- Color & state of oil: provide engine's condition

Oil cooler:
- Cold temp: Oil in oil cooler becomes viscous and may plug up cooler → overheated engine
- Non-congealing oil cooler: Prevent overheating with bypass, allow viscous oil to flow and warm up other

Oil viscosity:
- Too low: Premature engine wear ∵ greater difficulty in maintain oil film between moving parts
  Not likely to cause overheating
- Too high: Overheating ∵ Slow flow through oil cooler and cause oil cooler to be bypassed
- Low (High) viscosity = Low (High) oil pressure
- ↑ oil temp + ↓ oil pressure = Oil leak

14. Fuel system and fuels

Types, colors, and properties:

- 80 (80/87): Red 100LL (Low lead): Blue 100/130 (High lead): Green
  Jet fuel: Clear MOGAS (Car gas): Yellow

Octane rating:

- 1st number: Octane rating at lean mixture, 2nd number: Octane rating at rich mixture
- If not available, use next higher one: Prevent detonation, but can cause spark plug fouling (Higher lead)
- Octane: Min. detonating qualities, it dilates & burns slowing producing intense heat
- Heptane: Max. detonating qualities, extremely explosive and burns rapidly
- Fuel mixture resists explosion → Higher compression within cylinder → More heat at combustion
  → Longer stroke from cylinder → more power from engine

Density and weight

- AVGAS at 15°C: 6lb/US gallon
- Jet fuel at 15°C: 7lb/US gallon
- Colder = Fuel density ↑ & heavier

Additives:

- Ethylene Dibromide: Cleaning agent to prevent spark plugs from oxidizing
- Anti-icing fuel additives: Delay formation of ice crystals
- Additives are effective as long as used as recommended
- Lead tetra-ethylene: Slow combustion & boost octane rating

Contamination & deterioration:

- Water (denser), dirt or unknown contaminate should be investigated & removed/drained from fuel
- Fuel gets stale: After 6 months should NOT be used without being tested
- Temp variation: Cause water to accumulate in fuel due to condensation

Fuel tank location:

- Made of flexible rubber bladder/sealed rigid metal tank
- Commonly located in wings, sometimes in belly/fuselage

Loose fuel cap:

- If loose: During the flight the tank will empty, depends on aircraft how fast and how much
  ∵ airflow over top of wing acts as vacuum → Low pressure → Sucks fuel out

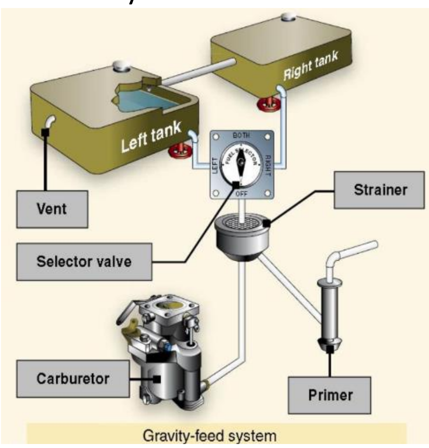
Venting and baffling:

- Allows air to enter tank as fuel is used, maintain constant pressure and avoid vacuum
- If vent is blocked: Fuel to engine gradually diminishing & fuel starvation
- If tank is overfilled: Fuel expands in hot weather and may overflow through vent
- Backup: Usually cap of right tank is like mushroom top: holes allow air to flow in
- Baffling: Used in rigid fuel tanks, like wall inside the tank
  → Prevent fuel from sloshing, more accurate fuel quantity reading

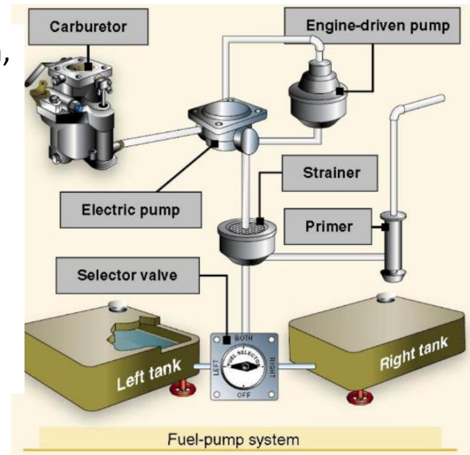
Fuel line filters and drains:

- At least one drain valve located at lowest point of tank
- Some locate at low points in plumbing system (engine sump/fuel strainer/cross-feed system drainer)
- Check during pre-flight for water/contaminates and drain them to eliminate
- Water will sink to bottom of strainer, if clear then only contains water

Fuel system:



- Usually set to both, simultaneously feed fuel to engine for take and landing



- Most do not have "BOTH"
- Usually switch every 30mins
- Running dry: Engine will quit and vapor lock and then hard to restart
- Engine failure: Change position of fuel selector
- Use electrical fuel boost pumps when start & change tank as backup to engine driven pump

Detonation: May due to overheat in steep climb

- When fuel burns explosively instead of evenly & slowly
  ∴ Loss of power, engine overheating, roughness, engine damage for prolonged period
- Caused by using fuel with too low octane rating/too lean mixture
- High cylinder head temp indicates detonation, Takes place in all cylinders

Pre-ignition:

- Areas of glowing hot carbon build up due to improper mixture → hot spot in cylinder
  ∴ Act like mini-spark plugs, ignite fuel/air mixture before spark plugs fire, very harmful to engine
- Only exist in 1/2 cylinders

Vapor lock:

- Common during hot temp, especially fuel injected airplanes
  ∵ Fuel in lines become vaporized & air working as blockage to fuel flow
- Trick: Get cool fuel through lines before attempt to start

Fuel heater:

- Cold temp/High alt.: Fuel may go gelling/thickening
- Usually in turbojet, turbofan, turboprop that use jet fuel ∵ more likely to congeal in cold

Fuel primer:

- To make engine starts easier during cold/plane parked for many hours
- Atomizes fuel and sprays directly to entrance of cylinder
- Use properly to avoid wear & tear on starter and excessive battery drain and flooding

Priming and over priming:

- Warm temp: 1-2 sprays, cold temp: up to 6 sprays, very cold: spray while engaging starter
- Weak, intermittent explosions, puffs of escaping black smoke (May have fire even) = Too much fuel
  ∴ Full throttle, mixture full lean, engage starter

Fuel management ground and air:
- Fuel should be checked before flight
- Never trust gauges until fuel amount & type has been checked and is correct
- Do NOT use MOGAS unless engine is modified

Fuel handling and fueling:
- Grounding: Attach ground wire between fuel pump or truck or drum to metal unpainted part of aircraft ∴ Neutralize static charge
- Bonding: Ability of components of aircraft to pass electrical charge between them
- Fuel nozzle should touch side of fuel filler hole (After contact then starts, stop before break contact)

Fueling from drums:
- Use proper filter/water separator with portable pump
- Do NOT pump fuel from bottom of drum or from a drum which has just been moved (∵ water & dirt)
- Chamois lined funnel should be used only in emergency ∵ ↑ possibility of generating charge of elect.
- Chamois: Leather cloth, may end up clogging fuel system filters & nozzles
- Use good quality chamois only: Reduction in flow = suspect water contamination
- NEVER wring chamois free of water: Nullifies water separation properties of chamois

Jet A-1:
- Kerosine grade
- For most turbine engined aircraft
- Flash point +38°C (100°F) & freeze point -47°C
- Widely available outside USA

Jet A:
- Kerosine grade
- Normally only available in USA
- Flash point +38°C (100°F) & freeze point -40°C
- Prist is included with different manufacturers & FBOs

Jet B:
- Naphtha & kerosine fractions
- More difficult to handle due to higher flammability
- Minimal demand & availability, usually in very cold climates
- Does not require Prist/FSII

Fuel system icing inhibitor (FSII)/Prist:
- Fuel may have dissolved water that does not appear in droplet form
- Fuel’s capacity to hold water decreases when flying higher & colder
- Prevent formation of ice in fuel lines
- Inhibit growth of bacteria & fungi in hot & humid conditions
- Usually for jet that fly in cold weather & does not have fuel tank heaters

15. Fuel Drum Etiquette

Tool box:

- Rubber gloves, bung wrench, approved filters, standpipe & collar, diaphragm & nylon valve repair kit, Grounding cables, screwdrivers & water paste

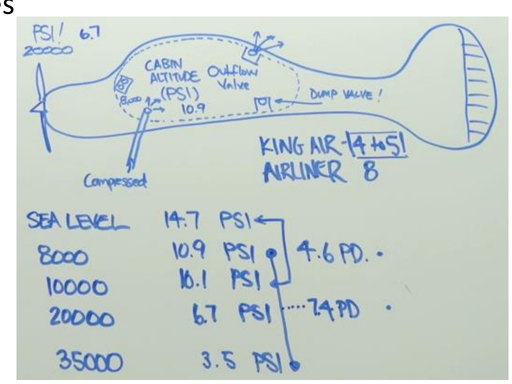
Basic:

- Ensure proper fuel regardless of what is printed outside
- Fill date: Company discourage using fuel more than 2 years old (May have fungus & thrive in water)
- Check for odour
- "X" is for contamination
- Improper sealing: Loose bung/vent, gaskets that are torn/missing/twisted
- Partly filled drum is more likely to contain moisture
- Store drums on side with bungs & vents at 3 & 9 oclock position (Can minimize breathing)
- Open drum: Stand on end, block it with high side at 12, bung at 3, vent at 9 (Prevent dirt reaches opening)
- Standpipe should not reach lowest point in drum so wont suck water
- Stand up drum before usage to allow contaminants time to settle out & avoid agitating
- Hot-refueled: Lots of ground crew, no passengers on board, pilot at controls, proper refueling procedure
- Locate drum after emptying
- Grounding: Dry winter air & blowing snow, dusty & sandy causes static, avoid nylon clothing
  Drum to ground, drum to pump, pump to aircraft, nozzle to aircraft, open cap, reverse order
- Fuel cache: Located clear of sandy, dusty, debris-strewn areas
- Kolor Kut: Water finding paste
- Filter: Pump should have clean & serviceable go-no-go filter & particle filter with intact o-ring
  → Bind up & prevent flow in presence of water (Increased pressure means blockage/contaminate)
  Rag/chamois do not stop water & not very effective in stopping dirt & debris
- First pump stroke: Squirt into container so dirt/water/debris will be flushed out of hose
- Foreign object damage: Dispose of plastic caps, metals rings, date tags etc

16. Other aircraft systems

Oxygen system:

- Allows for flight at higher alt. in non-pressurized aircraft
- Constant flow Rebreather bag: O_2 flows at constant rate to bag below mask
  Breathes combination of fresh O_2 & re-breathed air
  Simple but not very efficient ∵ Vented freely → have max. alt
  Used in commercial airplanes as drop down masks
- Constant flow Nasal cannula type: Breathes combination of fresh O_2 & re-breathed air
  Vented freely → have max. alt
  Higher alt. requires higher flow rates
- Demand oxygen type: O_2 flows into mask only when inhaled
  No rebreather bag ∴ more efficient
  Must be firmly attached to face

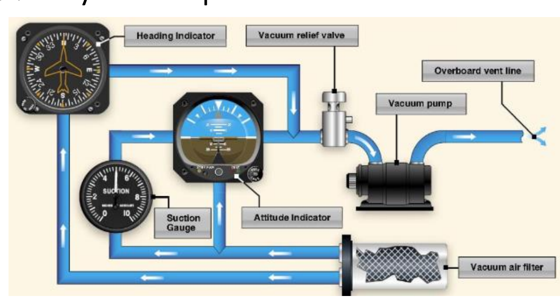


Pressurization system:

- Allow flying high w/o need of mask
- Airplane is airtight with sealed doors, windows and pressure bulkhead
  → Keep low pressure alt. within cabin when flying high
- Piston: Provided by turbocharger
- Turboprop/Turbojet/Turbofan: Engine bleed air from compressor section
  Air con is used to control cabin temp ∵ Compressed air is hot
- Differential pressure: Pressure difference in PSI from inside to outside of plane
  Outflow valve: regulate cabin pre., have "Altimeter" to set cabin pre.
  King Air: 4 PSI, Airbus: 8PSI
- Cabin altitude: Alt. that cabin is pressurized
  Usually set cabin alt. to 8000ft ∵ Easier to design pre. vessel with smaller differential

Vacuum system:

- Provides power to spin gyros in gyroscopic instruments (Attitude & Heading indicators)
- Engine driven vacuum pump: Most common, creates pressure difference in system
  Filtered air inlet allows outside air to rush into gyros, spins up to 13000RPM
  Need 4-6 inches of mercury pressure difference to operate
  Monitor vacuum pump using suction gauge
- Venturi driven: Old-styled, simple, cheap
  Does NOT work at slow airspeed/in icing condition ∴ Only for VFR plane
- Electric motors (Schematic): Reliable but expensive



De-icing/anti-icing system:

- De-icing: Remove ice from critical surfaces
  Rubber boots: Long inflatable tubes around leading edge
  After build up, boots inflate & breaks off ice
- Anti-icing: Prevent build up of ice from forming
  Fluids: Secrete fluid onto wing & prevent ice from forming
  Or coated with glycol solution before takeoff
  Heating devices: Heated propellers/Heated windshields

Environmental system:

- Cabin heat: Routing outside air through shroud that covers muffler then route into cabin
- Cabin air: Simple air scoop/door that deflects outside air into cabin

Aircraft control rigging:

- Cable (Most GA), pushrod, Fly by wire
- For 152, if elevator gets stuck, can use elevator trim to control ∵ separate system

Chapter 6

Theory of flight

1. Principles of flight

Bernoulli:

- 19^{th} century discovered internal pressure of fluid ↓ as velocity ↑ (Total energy is constant)
- Venturi: Constricted section of tube with smaller diameter in middle
- Equal amount of air has to be rushing through venturi as is entering original opening
  ∴ Need to travel faster, lower pressure than both ends
- Wing: Curve to speed up airflow over the wing ∴ Pressure ↓
- Bottom of the wing still has high pressure

Newton:

- The overall momentum of system should be conserved
- 1^{st} law: Body in motion tends to remain in motion
- 2^{nd} law: Force is required to alter body's state of motion
- 3^{rd} law: Apply force causes an equal and opposite reaction
- Wing: at an angle to airflow, forces the air down ∴ wing must rise

Lift:

- 2-D: Newton: Conservation of momentum in system, Bernoulli: Conservation of energy in fluid
- 3-D: Euler: Conservation of mass, Navier-Stokes: Consider viscosity and changes within fluid
- Is turning of fluid's flow (Bernoulli & Newton only show partly)

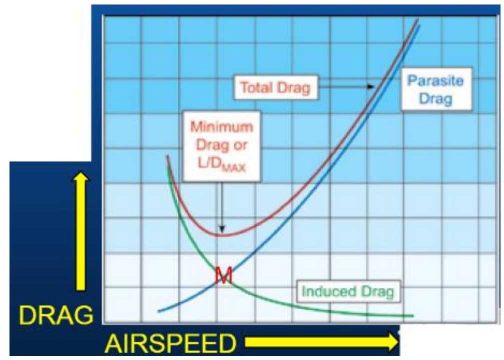
Angle of attack:

- Angle at which the relative wind meets the chord line of airfoil
- Slow down → requires higher AOA to generate enough lift
- Newton: Increase air that is forced down (downwash) by wing as it moves through air
- Bernoulli: Create large curve on upper surface, air go through top at higher AOA

2. Forces acting on an aircraft

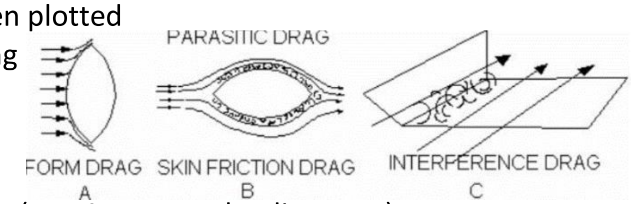
Lift:

- Component of aerodynamic force that is perpendicular to relative airflow
- Airfoil: Shape of wing
- Wing: Bottom is flat/nearly flat, Top is curved, Thicker at front edge, Taper to thin surface at trailing
- Molecules of air on top of airfoil travels faster than those in bottom → air turns in another direction
- Bernoulli: Pressure above wing is lower ∵ Air on top is moving faster
  ∴ Pressure difference → Net result is lift
- Newton: Wing generates lift by deflecting air downwards
- $L = \frac{C_L \cdot \rho \cdot V^2 \cdot S}{2}$
- C_L: Dependent on airfoil & AOA
  Determined experimentally then plotted
  P: Density of Air
  S: Total surface area of wing
  V: Velocity of wing



Induced drag: ↑ when AOA/weight/wing loading ↑

- Component of aerodynamic force that is parallel to relative flow, results from creation of lift
- Higher pressure air under wing flows around wing tips to lower pressure air above wing
  → Produce vortices at wing tips → Add to induced drag component
- Airspeed ↑ then ID ↓, Airspeed ↓ then ID ↑
- $D = \frac{C_D \cdot \rho \cdot V^2 \cdot S}{2}$
- C_D: Dependent on airfoil & AOA, Determined experimentally then plotted
  P: Density of Air, S: Total surface area of wing, V: Velocity of wing



Parasite drag:

- Caused by parts of aircraft which do NOT contribute to lift
- Unwanted resistance of air on object that is traveling through air (e.g. Antennae, landing gear)
- Form drag: Created by shape of the body as it resists motion through air
- Skin friction: Air flowing over body tends to cling to its surface
- Interference drag: Caused by effect of one part on another (e.g. where wing is attached to fuselage)

Lift and drag:

- Constant alt.: Control AOA: Elevators
  Power: Engine throttle for fixed pitch (& propeller pitch control for variable-pitch)
  Pitch + Power = Performance
- Lift to drag ratio: $L = AOA \times V^2$ (Not exact equation)
  Best lift/drag ratio (Point M) = Min. total drag = Best gliding speed for max. distance
  Parasite drag ↑ with speed, Induced drag ↓ with speed
  → Sum of 2 drags ↑ with speed

Thrust:

- Forced produced by engine: Forward motion of aircraft by pushing air backward which causes reaction
- Directed more or less parallel to longitudinal axis

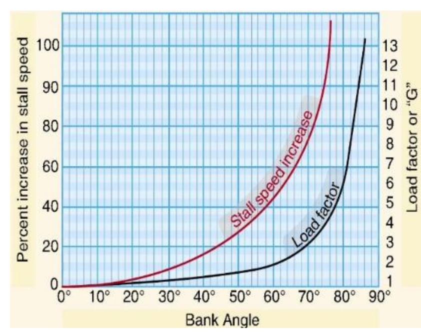
Weight:
- Force from center of mass of aircraft toward center of earth
- Centre of Gravity: Point which resultant of all weights of all parts can assume to pass through

Equilibrium:
- Steady motion, NOT as state of rest
- When thrust = drag → Speed is constant and equilibrium
- When lift = weight → Equilibrium in cruise and steady rate of climb/descent
- Climb: does NOT due to lift is greater comparing to level flight
  ∵ Increased thrust and nose up attitude have vertical component → acts upwards and aircraft climbs

Centre of pressure:
- Lift distributed along surface of airfoil acts upward & perpendicular to relative airflow
- Resultant of all lift forces can be considered to be at a single point → COP
- Can move depending upon AOA

Centripetal & Centrifugal force:
- Force to inside a turn & caused by horizontal component of lift, Force to outside a turn
- Turning is ACCELERATING

Load factor:
- Total load supported by wings divided by total weight of airplane
- Straight and level: 1G, ∵ weight supported by wing = weight of loaded aircraft
- In turn: Weight of aircraft ↑ due to addition centrifugal force
- Level to nose down: Upward centrifugal force which decreases to less than 1G
- Faster turn / Steeper bank: Greater centrifugal force
- Resultant load: Weight resolved with centrifugal force the load on wings
- 45°: 1.41G, 60°: 2G
- Sudden movement in steep bank angle: Load factor may exceed design limit



Forces in a turn:
- Do not overbank in circuit
- During turn: Lift always act 90°to wingspan, inclined away from vertical
  Vertical force of lift and weight is NOT in balance ∴ NOT in equilibrium
  Will descend unless AOA is ↑ to produce lift
  Vert. component of lift: Opposes weight, Horizontal component of lift: Makes aircraft turn

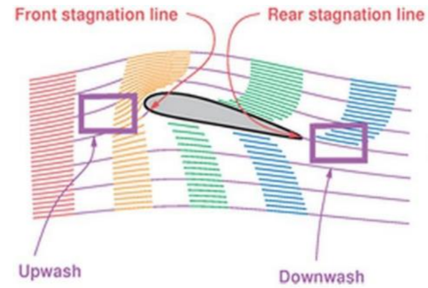
Effective rate and radius of turns:
- Higher airspeed → Larger radius, Lower airspeed → Smaller radius
- Higher angle of bank → Smaller radius, Lower angle of bank → Greater radius
- ↑ airspeed requires ↑ angle of bank to maintain constant rate of turn

Angle of attack and altitude:
- Max. coefficient of lift is CONSTANT regardless of altitude
  → determined simply by design of airfoil and AOA (Only variable) it is flown at

3. Aerofoils

Relative airflow:

- Airflow approaches the wing directly opposite the wing's direction of motion



Angle of attack:

- Angle between relative airflow and chord line
- Determine how much lift a wing is generating

Angle of incidence:

- Angle at which the wing is mounted to fuselage
- Angle between chord line & aircraft's longitudinal axis/horizontal datum line
- Improve flight visibility, enhance takeoff and landing, reduce drag in level flight

Pressure distribution:

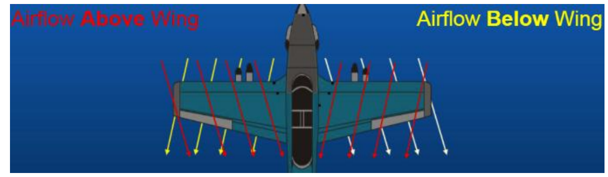
- Pressure along surface of airfoil is not constant → Diff pressure at points all over airfoil
- Centre of pressure: "Average" of these pressures, point where aerodynamic force exerts itself
- AOA ↑, COP moves forward
- After stall, COP moves rearward

Wake turbulence:

- Produced by differences in air pressure over top & bottom of wing/rotor of plane → Induced drag
- Plane encounter vortex will tend to roll & impose instant structural loads as high as 10Gs
- Starts with rotation & reaches peak intensity at lift-off ∵ Weight is sustained by wings & speed is low
- Seen from behind: Left wing vortex turns clockwise, right wing vortex turns counterclockwise
  Move downward & outward
- Form when nosewheel of aircraft lift off, stop when nosewheel touches down
- Rotation of vortex is around 80° per second, Spiraling motion around 1500ft per min
  Downward motion around 300-500ft per min
- Severity: Heavy, slow & clean configuration plane → Greatest intensity of vortex
  Worst: Behind plane either take off/landing (Wing is at high AOA) & at gross weight
- Size: Covers area about 2 wing spans in width & 1 wing span in depth
  Large heavy aircraft: Vortices settle below & behind plane at 400-500ft/min,
  less than 1000ft in 2mins, Level off at about 1000ft below flight path within 2mins
  Can trail generating aircraft by 10-16NM
- Dissipating time: Sink to ground & tend to move laterally outward at 5kt
  Crosswind can keep vortices (UPWIND vortex) directly over runway
  Strength remains constant for first 2mins and last up to 5mins
  Atmospheric turbulence: Break up quicker; Calm conditions: Last longer
- Quartering winds: Cause vortex to drift onto runway environment
- Avoidance: Crossing behind & below flight path of large heavy plane/ANY size of heli (size has less effect)
  Helicopters generate powerful vortices based more on weight
  Takeoff: Stay upwind & plan to airborne before rotation point of previous plane
  Landing: Touchdown before rotation point of plane taking off
  After touchdown point of plane landing
  ATC will give min 2mins between departure of heavy & light plane
  Light behind medium then gives advisory
  Solely pilot's responsibility to avoid wake turbulence, Ask for revised clearance

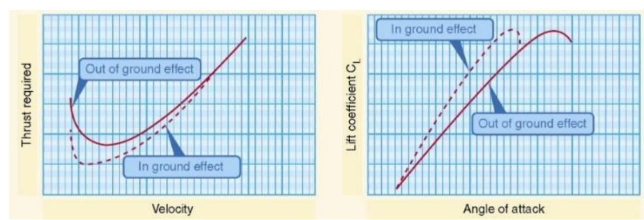
Downwash:
- Air passes over airfoil and it is directed downward
- “Turning” of air accounts for lift generated by wing

Wing tip vortices:
- Airflow top of wing: TOPIN, flow towards fuselage (Low pressure)
- Airflow below wing: Flow away from fuselage (High pressure)
- AOA ↑ / Camber ↑ , Strength of vortices ↑

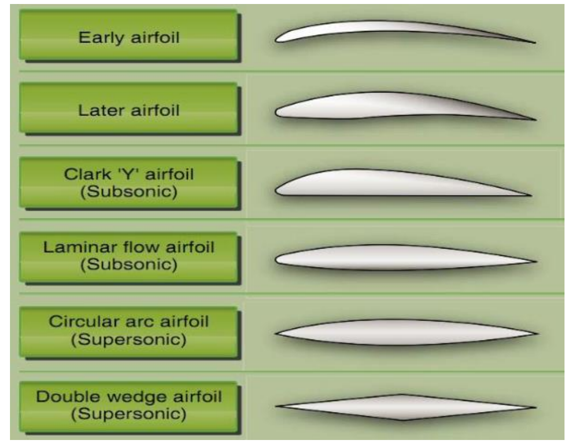


Stalling:
- When wing’s AOA exceeds its critical angle (around 15-18°)
- Stalled wing still generating lift but not enough to overcome weight
- Stall at same AOA ∵ determined by design of wing
  ∴ Regardless of speed, weight, COG etc

Ground effect:
- Formation of wingtip vortices ↓ when aircraft fly low to ground ∴ Induced drag ↓
- Closer airfoil to ground = greater performance gain from ground effect
- Downwash: Deflected more parallel to surface
- Reduction of drag + Greater lift at given AOA = Lift off at lower speed than normal
  → Useful during soft field takeoff
- Danger: Heavily loaded airplane cannot push through ground effect and start climb
  When altitude beyond wingspan, induced drag ↑ as vortices forming fully
  → Settle back to ground effect, try to pull plane then stall
  ∴ High density altitude will make this danger greater



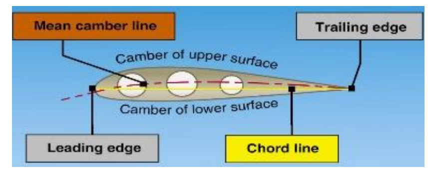
4. Design of the wing



Wing planform:
- Shape of wing when viewed from above
- Rectangular, delta (triangle shaped), tapered, elliptical

Span and chord:
- Chord: Imaginary line from leading edge to trailing edge
- Span: From wing tip to wing tip

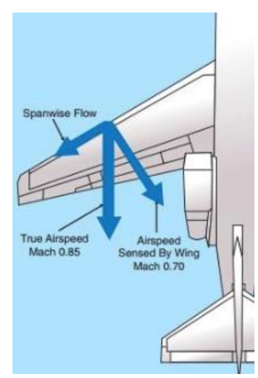
Aspect ratio:
- Span divided by chord
- High aspect ratio: Low induced drag, high parasite drag
- Low aspect ratio: High induced drag, low parasite drag



Camber:
- Positive camber: Top surface of wing is curved away from chord line more than bottom surface
- Negative camber: Bottom surface of wing is curved away from chord line more than lead surface
  → not used in main wing, but used on horizontal stabilizers
  ∵ generate down force, balance rotational tendency caused by wing
- Symmetrical: Same curvature on top as on bottom, usually for aerobatic aircraft
- Mean camber: Average camber of upper & lower surface of wing
- Greater camber, greater lift → Flaps increase camber & lift
  But also generate extra drag (induced & skin friction)
- A max camber exists to provide max lift, beyond that then will generate less lift

Laminar flow:
- When air meets the wing initially → smooth flowing air adheres to surface of wing
- Boundary layer: Point at which airflow meets and sticks to wing, extremely small
  Boundary layer that attaches to wing = Laminar airflow
- Turbulent layer: As approaching center of wing, loss speed due to skin friction → Thicker & turbulent
- Transition point: Where boundary layer changes from laminar to turbulent

Laminar flow wings:
- Improves boundary layer airflow by moving transition point further aft
- ↓ amount of drag produced by wing
- Normal wing: High lift & high drag, gentle stall, max camber at 35% of chord
- Laminar flow wing: Low lift & low drag, abrupt stall, max camber at 50% of chord



Sweepback: Allow higher airspeed
- Used in high speed aircraft & avoid to airflow to go supersonic
- Only component of airflow perpendicular to leading edge affect pressure distribution & formation of shock wave (Airflow struck at angle smaller than 90 °) → Tricks the wing into thinking it is going slow
- Pro: ↑ Critical mach number, force divergence mach number & mach number at which drag rise peaks
  → How fast the plane can fly prior to the shockwave is former
  ∴ Delays onset of compressibility effects
- Con: Tend to stall at wingtips, Requires slat, slots, flaps to offset low speed performance

Dihedral:

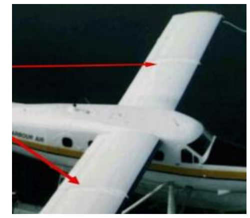
- Upward angle (V-shaped) from wing root to wing tip, ↑ lateral stability by preventing roll

Anhedral:

- Wing tips are lower than wing toot, A-shaped

Wash out:

- Wing that has been twisted, used to solve stall characteristics in tapered wing
- Angle of INCIDENCE at wing root is higher than that in wingtip
- During motion, AOA will be less at wing tips than that in wing root
  ∴ Tips will stall last, ↑ aileron control



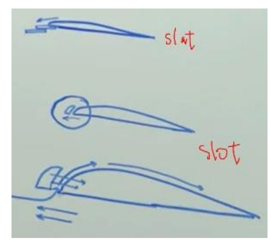
Stall strips and wing fences:

- Stall strips: Attached to leading edges near wing root, can replace wash out
  → allow root of wing to stall before wing tips by upsetting boundary layer
- Wing fences: If wing is stalled then will not spread due to being stopped by wing fences,
  Disrupt span-wise airflow   Prevent airflow from washing out at high AOA
  → Control airflow over top of wing, better handling at reduced speed, ↑ stall charact.

lessen vortices

Slats and slots:

- Slats: Small airfoils that open in front of wing to smooth airflow
  Increased camber & wing area provide extra lift → Like flaps but in leading edge
- Slots: Openings built into leading edge that allow high pressure air to pass through at high AOA, ↑ lift



Spoilers:

- Destroys lift by causing airflow to separate from top of wing
- Assist in braking by outing weight of aircraft on wheels & producing drag
- Sometimes used to assist aileron control → Spoilerons

Flaps:

- ↑ lift & drag by ↑ camber (↑ coefficient of lift) & wing area
- Steeper approach angle without increasing airspeed
- ↓ stall speed, ↑ forward visibility

Vortex generators:

- Placed along span around 10% aft of leading edge → Create tiny vortex over airfoil
- Energize the normally stagnant boundary layer of air on top of wing
- More resistant to flow separation ∴ Delay the turbulent, permits flight at lower speed/Higher AOA

Winglets: lessen vortices

- ↑ effective wingspan by ↓ induced drag caused by wing tip vortices
- Some planes: Install winglet = Aerodynamically adding 3ft to wing span
- Expensive, add weight, not available on all plane

Canards:

- Airfoil mounted in front of wing → produce lift upwards & stabilizers produce -ve lift
- Will not enter full stall ∵ Canard stalls first → nose drop to prevent main wing stall
- Some canards can be moved by flight controls and some are fixed

5. Load factor

Maximum weight:

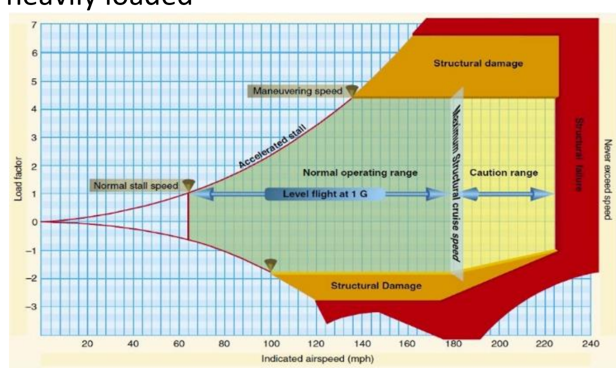
- Maneuvers/conditions are capable of imposing loads strong enough to overstress plane
  → ↑ load & stalling speed ∴ Must be loaded within weight limits

Load factor:

- Total load supported by wings divided by total weight of plane
- Straight & level: 1G
- Turn when maintain altitude: Weight ↑ due to addition of centrifugal force
- Bank angle determines total weight increase
- If load factor ↑, stall speed ↑
- Late turn to final in circuit with increased rudder & aileron and slow speed → cause spin
- V_s in turn = V_s x $\sqrt{(\text{Load factor})}$
- Negative load factor: abrupt change from level to nose down, upward centrifugal force
  → G load is less than 1G, planes are rated for low -ve G than +ve one

Maneuvering speed (V_a):

- Max speed at which full deflection of controls can be made without exceeding design limit
- Guarantees that plane will stall at limit load factor
- $V_a = V_s \times 1.9$
- If weight ↓, V_s ↓, ∴ V_a for lightly loaded plane is lower than heavily loaded
  → 20% decrease in weight = 10% decrease in V_a
- V_a ranges between 1.6-1.9 times the flaps-up power-off V_s
- ONLY based on positive G load



Gust load:

- Gusts: rapid & irregular upward/downward movement of air
  → Can cause high load factor
- Weight/Speed/Wing loading ↑, Gust loads ↑
  ∴ Plane should fly below V_a to prevent excessive load factor from gust load
- Airspeed will fluctuate 5-15kt in light turbulence & up to 25kt in severe

Type of manuevers:

- Limit load: Pilot must keep the load factor within
- Ultimate load: Designed & certified to withstand 1.5 times the limit
- Normal category: Max gross weight are permitted, certain meneuvers like spins may be prohibited
  → -1.52G to 3.8G
- Utility category: Speicifed manuvers may be performed in POH
  In both normal & utility category depending on weight & balance → -1.76 to 4.4G
- Aerobatic category: Speicifed manuvers may be performed in POH → -3G to 6G

Type of operation:

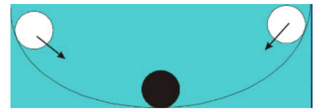
- Standard: Few restriction but cannot used for airline/commuter operations
- Restricted: One purpose only, no passengers, Restricted sign & no passenger placards must be installed
- Experimental: Testing/Homebuilt
  Passengers are allowed, large placards must be placed to show not yet certified

Be careful
stability VS Balance

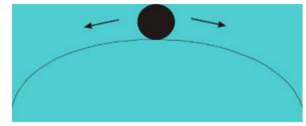
6. Stability

Ability to remain in position/attitude during flight & return to given position/attitude after disturbance

Positive:
- Ball in bowl: Always turn to original position following displacement/disturbance



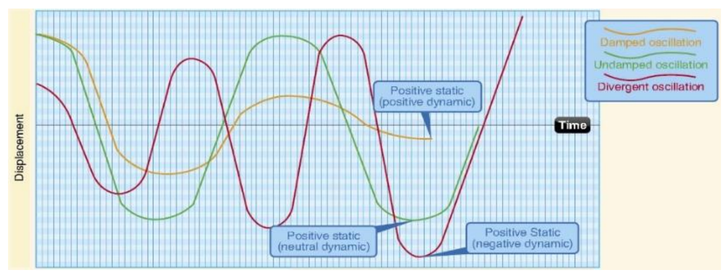
Neutral:
- Ball on flat surface: Remain in new position after displaced



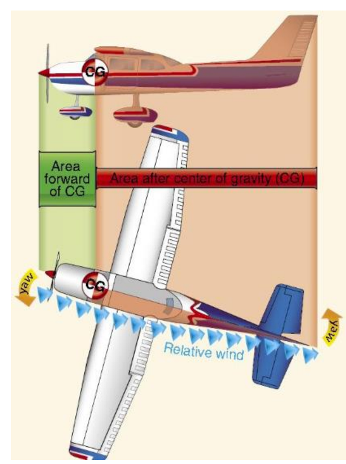
Negative:
- Ball on upside-down bowl: After displacement will move in that direction, sometimes accelerates

Static:
- Initial tendency to return its original position
- Pitch back towards cruise attitude after being pushed to nose up: Position static stability

Dynamic:
- Overall tendency to return its original position after series of oscillations



Longitudinal (Pitch) stability:
- Around lateral axis
- Affected by size & position of horizontal stabilizer & position of COG
- Nose heavy is more stable ∵ Want to recover its speed during stall
  ∴ COG is somewhat forward (Still well within envelop)



Lateral (Roll) stability:
- Around longitudinal axis
- Trainer: Positive roll stability, Aerobatic: Neutral/negative roll stability
- Achieved by: Dihedral, Sweepback, Keel effect, Proper distribution of weight

Directional (Yaw) stability:
- Around vertical axis
- Achieved by tail surfaces & fin & rudder, keel effect, sweepback

Inherent:
- Naturally stable due to features incorporated into design
- Trainers: Nice & stable, forgive student's fault
- Aerobatic & fighter: Neutral stability/unstable
  Being able to change direction quickly

Methods of achieving stability:
- Upward-inclined wings (Dihedral effects)
- Swept back wings

7. Flight control

Elevator:

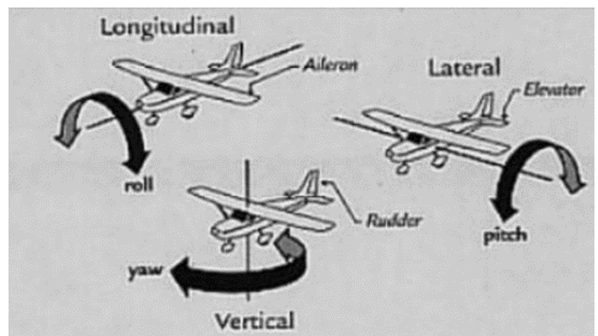
- Control pitch attitude, moves about lateral axis
- Horizontal stabilizer & elevators are hinged to rear of stabilizer on tail
- Pull up = Elevator moves up = Tail down and nose up
- Stabilator: Entire stabilizer moves in response to elevator control pressure, commonly on Piper

Ailerons:

- Control banked attitude to roll, moves about longitudinal axis
- Located close to wingtip at trailing edge
- Roll to right: Left aileron down & Right aileron up (View from behind)

Rudder:

- Control nose to yaw left or right, moves about vertical/normal axis
- Hinged to the aft end of vertical stabilizer
- Yaw to right: Rudder moves to right



Longitudinal axis:

- Extend lengthwise through fuselage, Roll by ailerons, X Axis

Lateral axis:

- Extends wingtip to wingtip, Pitch by elevator, Y Axis

Vertical (Normal) axis:

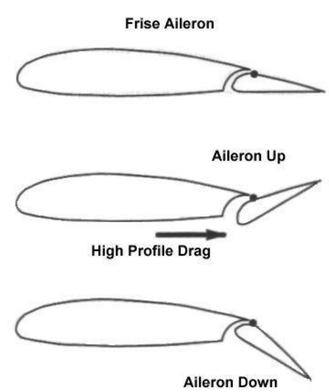
- Passes vertically through COG, Yaw by rudder, Z Axis

Aileron drag:

- Opposite-turning tendency generated when ailerons are deflected
- Created by greater drag of down going aileron "yanking" when start a turn
  ∴ Yaw into opposite direction to roll
- One type of adverse yaw, need to be corrected with rudder

Frise ailerons:

- Help ↓ aileron drag
- Hinge is offset: Leading edge of upgoing aileron moves into airflow below the wing & create drag
  → Equalizes drag created by lowered aileron on other wing, ↓ adverse yaw
- Form a slot: Air flow smoothly over aileron ∴ More effective at slow airspeed



Differential ailerons:

- Upgoing aileron moves higher (Displaced further than down going aileron)
  ∴ Create more drag then equalizes drag produced by down going aileron
- Modern uses combination of differential & frise type

Dynamically balance:
- Assist in moving controls
- Air strikes portion of control surface that extends opposite to direction of movement of control surface
- Used for elevators, rudders & ailerons which also ↓ aileron drag

Mass and static balance:
- Mass balance: Counteract flutter (Vibration) by positioning a weight ahead of hinge
  Mounted internally/externally on airplane's control surface
- Static balance: Reference to control surface's CG being within specified range without an airflow

Reduce pressure on flight control.

Trim tab: Need by autopilot. Assist pilot to move control

- Small airfoil attached to trailing edge of control surface
- Reduce pressure of pilot holding the control position
- All planes have elevator trim, some have rudder & aileron trim

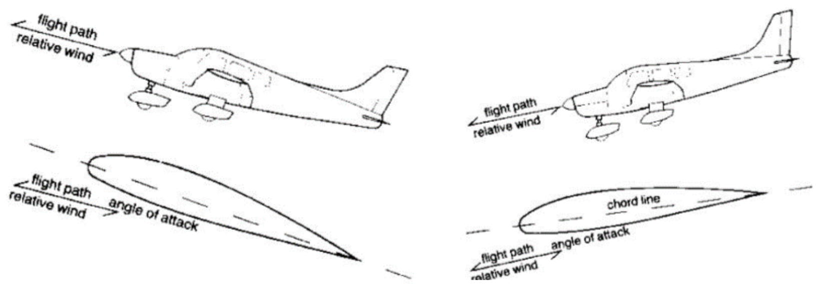
Balance tab:
- Coupled to control surface
- Tab automatically moved in opposite direction when control surface is moved
- Airflow striking tab counterbalances the air pressure against control surface ∴ Easier to more & hold

Servo tab:
- Used on larger aircraft
- Pilot directly moves the servo tab
  → Force of airflow on servo tab moves the control surface

Anti-servo tab:
- Usually on stabilator
- Moves as same direction as control surface is moving ∵ Large tail surface produces huge pitch change
- Offset part of the pitch of pilot's input

8. Relationship of speed to angle of attack

Relative airflow:
- Parallel to but opposite in direction to flight path
- Unrelated to attitude of aircraft, only related to direction of travel
- Taxiing: Motion combines with wind direction & speed ∵ Tethered to ground
- In flight: Only motion of plane through air produces relative airflow ∵ Moves with wind
- Climb: Relative wind come from slightly above plane
- Descent: Relative wind come from slightly below plane
- AOA ↑, Lift ↑, Induced drag ↑



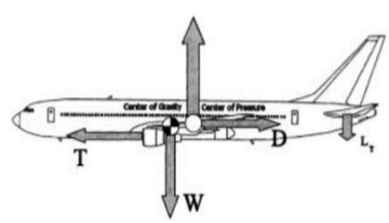
Critical AOA:
- Based on design of airfoil
- Stall at same angle (16°-18°)
- Contaminated wing stall at lower AOA

Constant altitude with slow speed:
- Lift ↓, AOA must be ↑ to maintain altitude
- Induced drag ↑ (∵ More downwash & greater vortex)

Constant altitude with high speed:
- Lift ↑, AOA must be ↓ to maintain altitude
- Induced drag ↓, Parasite drag ↑

Best glide:
- Power-off speed for best gliding distance
- Average airspeed for best lift/drag ratio
- Fly faster/slower: ↓ gliding distance in still air
- With headwind: Higher speed than glide speed → improve ground speed, sink rate ↑, glide range ↑
- With tailwind: Slower speed than glide speed → Sink rate ↓, glide range ↑

Sensors:
- Since critical AOA is constant, jet aircraft use it for wing's flying ability
- Vane sensor: Found on one of sides of aircraft's nose
  Sends AOA info to flight computer
- Pressure sensor: Install holes both above & below leading edge of wing
  Install 2 pressure ports into pitot/pitot-like tube
  ∴ Difference in pressure: Convert into AOA information



Force couples: Forces equal, parallel, opposite
- Lift (COP) vs Weight (COG), Thrust (Propulsion) vs Drag (Acts through COP, parallel to relative airflow)
- Thrust below drag: Nose down tendency when power ↓
- COP behind COG: Overall pitch stability of aircraft

Horizontal stabilizer:
- Symmetrical aerofoil installed in path of downwash from wings
  → Downward force to keep nose up

- COP behind COG: Push nose down
- Downwash creates upside down AOA: Push tail down and keep nose up

Speed vs AOA:

- Speed ↓ , COP moves forward
- Less downward force required on horizontal stabilizer
  ∴ AOA must ↑
- Speed ↑ , COP moves back
- More downward force required on horizontal stabilizer
  ∴ AOA must ↓

Mach buffet boundaries:

- Function of speed of airflow over wing (Not necessarily speed of aircraft)
- Big lift demand made on wing from too fast airspeed/too high AOA → High-speed buffet
  Large AOA can increase airflow velocity over upper surface of wing & cause shock wave
- Aircraft flying too slow for its weight & altitude necessitating a high AOA → Low-speed buffet
- AOA of wing has greatest effect on inducing Mach buffet in high/low-speed boundaries
- High altitude: Thinner air requires greater AOA to maintain level flight
- Heavy weight: Greater lift is required & therefore greater AOA
- G loading: Same effect as heavy weight, caused by turns/rough controls/turbulence & therefore greater AOA

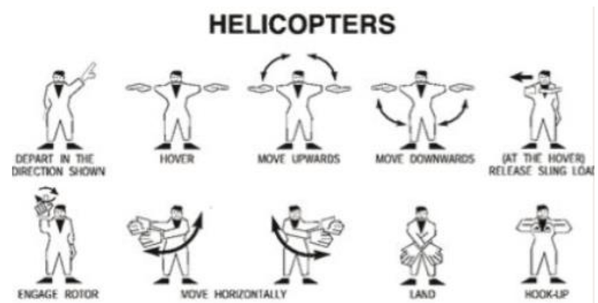
Chapter 7

Flights operations

1. General flight operation

Pilot-in-command responsibilities:

- Ensure aircraft is airworthy
- Know relevant air regulations
- Know forecast & reported weather
- Physically, mentally, medically & legally fit for flight
- Use proper communications procedures
- Know relevant numbers for the aircraft flown
- Have up to date charts on board aircraft
- Have required safety equipment on board aircraft
- Know how to operate all systems & controls of aircraft including emergency procedures
- Be familiar with NOTAMS that affect the flight
- Ensure passengers have been briefed on flight
- During flight be aware of active traffic
- Ensure proper ATC clearance have been granted
- Maintain awareness of & avoidance of restricted airspace



Aircraft defects/Minimum equipment list:

- Ensure all defected are repaired before operation
- Defects may be found in aircraft's log book (N/A to ultralight)
- If unsure it is airworthy, find a maintenance engineer (AME) (N/A to ultralight)

Winter operations:

- Clean aircraft concept: Takeoff is prohibited when frost, ice or snow is adhering to any critical surface
  ∵ Slightest accumulation of frost can seriously affect performance
- Cold soaking: From warm location to cold location (Climb) then back to warm location (Descent)
  → Condensation & ice may build-up on aircraft's skin
  ∵ Fuel cell in the wing may be very cold and outside temperature is hot
- In-flight airframe ice contamination: Ice accretions changes shape of wings, ↓ lift
  Ice on propellers results in vibrations, ↓ thrust
  Ice on windshield hinders vision
  Ultra-light: Stay out of cloud, out of precipitation when temp < 0°C
- Landing wheeled aircraft on snow surfaces: Do not land on surface with snow unless guarantee safety
  Should observe from air/call ahead
  Map/CFS: ltd win maint. → Call ahead
  No win maint. → Stay away in winter
- Whiteout: Unbroken snow cover + Beneath an overcast sky = Horizon is obscured
  Blowing snow may be additional cause
  ∴ Pilots lost depth perception & have difficulty in judging distance ∵ Loss of horizon & terrain
  If continue to fly then will become IFR ∴ Greater reliance on flight instruments

Thunderstorm avoidance:

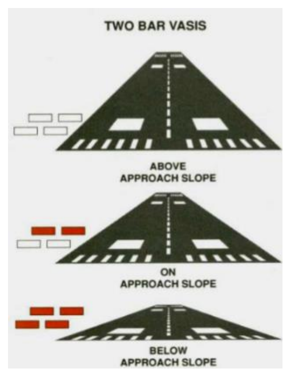
- Severe turbulence extends up to 20NM from storm
- No way to be sure of severity by just looking
- Lightning: Puncture skin of aircraft, damage electronic equipment, engine failures, permanent error in magnetic compass, Ultra-light may not be bonded electrically ∴ Maybe control malfunction
- Do not takeoff/land when thunderstorm is approaching & fly underneath thunderstorm

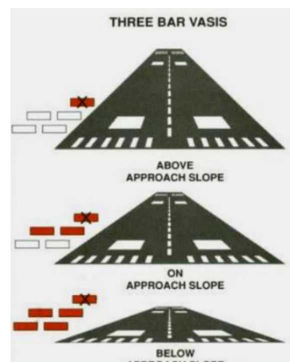
- Avoid area where storm covers 6/10 of that area
- Always review current weather reports

Mountain flying operations:
- Mountainous terrain causes rapidly changing & unpredictable weather conditions
- Downdraft occurs in shaded area (Cooler) of mountains
  ∴ Should fly on sunny side (Warmer) where updraft are likely
- Selected route should avoid topography that prevent safe forced landing
- Know how to do Maximum rate Minimum radius turn
- Aircraft's ceiling and performance figures in POH are based on Density altitudes

Wildlife conservation:
- Shall not fly at altitude less than 2000ft AGL when near herds of reindeer/caribou, parks, reserves and refuges
- Boundaries of these area and depicted on charts

Collision avoidance – use of landing lights:
- Keep constant lookout for aircraft, have passengers to help as well
- Use landing light frequently
- Strobe lights can also be used but not during taxiing & during flight in clouds
- If relative position of converging aircraft does not change → Avoid collision by changing alt/heading
- Ultra-light are not permitted to fly at night

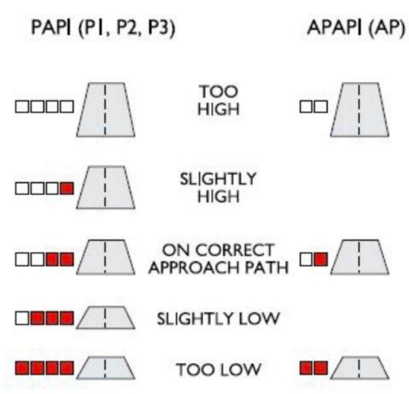




Canadian runway friction index:
- Measurement that indicate how slippery a runway is
- CRFI 1.0 = Max friction coefficient for bare & dry runway
- Ice covered runway will have CRFI 0.1-0.3
- CRFI is found in ATIS, NOTAMs and FSS

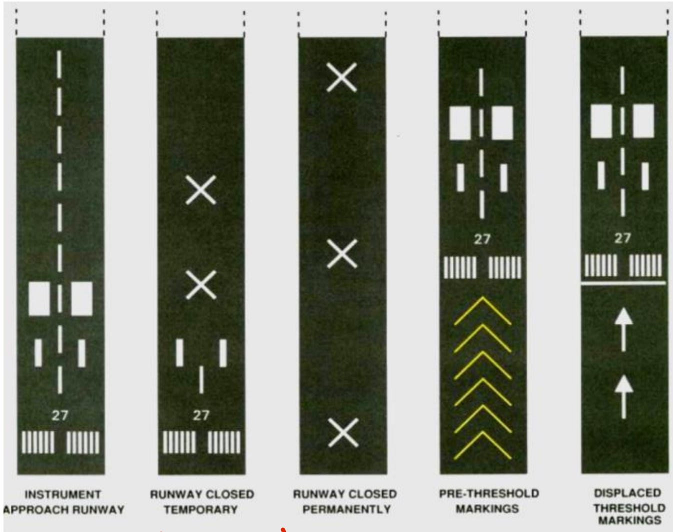
Runway numbering:
- Based on direction of runway, rounded off to nearest 10°
- Northern domestic airspace: True north, Southern domestic airspace: Magnetic north
- L: Left, R: right, C: center

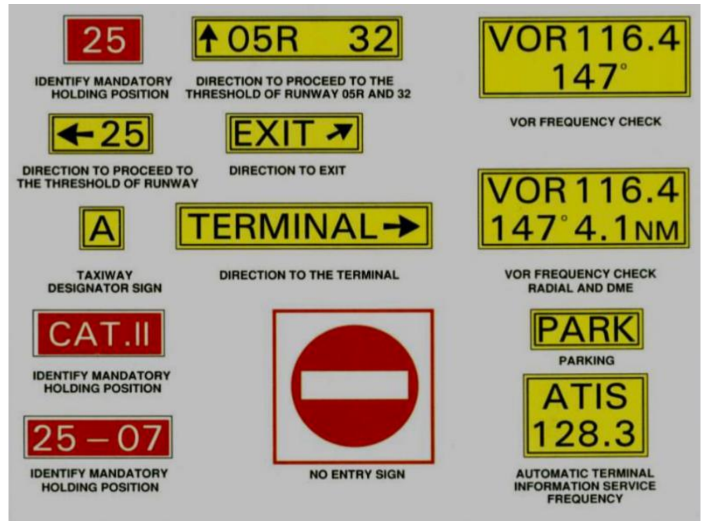
VASIS/PAPI:
- Visual Approach Slope Indicator System
- Precision Approach Path Indicator
- Lights on edge of runway, 1000ft from threshold indicates aircraft is descending on proper path (3°)
- 2-Bar VASIS: AKA V1 & V2, four light units on left side of runway grouped in 2 (Upwind & Downwind)
- 3-Bar VASIS: 2-bar VASIS with one light unit added to form additional upwind bar
  Small aircraft should ignore the additional bar
- PAPI: Abbreviated PAPI (2 lights) or PAPI (4 lights)
  Slowly replacing VASIS



Approach, runway, aerodrome markings and lighting:

- No takeoff or landing at night unless aerodrome has proper lighting requirements
- Min aerodrome lighting: 2 parallel rows of white light, spaced not more than 200ft
  Min length of 1400ft





(Stopway)

Pre-threshold markings: Yellow chevrons → Not load bearing, Do not taxi or takeoff
Design to collapse, For emergency such as aborting takeoff

Displaced threshold markings: White arrow → Load bearing, Can taxi & takeoff
For letting us know may have obstacles in front of runway

Obstruction markings and lightning:

- Towers are indicated on aviation charts by symbols
- Red lights of steady/flashing or white strobes
- Takes up to 2 years before new tower is on map ∴ Check NOTAMS/Flight planning section in CFS
- Avoid low flying & keep good lookout

Units of measurements and conversion:

- Use standard E6B slide type computer/electronic computer for conversion
- CFS also has conversion charts

Wheelbarrowing:

- Occurs when excess airspeed at touchdown with nose down attitude that concentrate weight on nose wheel /Taxiing too fast with surplus lift that keeps main gear off ground
- Prevent: Ensure proper airspeed, apply back pressure during flare
- Insufficient runway: Pitch up, full power, overshoot
- Sufficient runway: Close throttle, ease control aft of normal position

Porpoising:

- Aircraft bounces off main wheel then nose/tail wheel
- Can be eliminated by applying back pressure
- Insufficient runway then go around

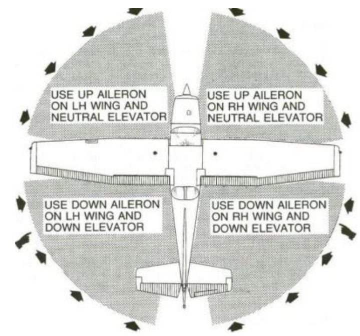
Hydroplaning:
- Wheels skim along surface of water on wet runway surface
- Function of water's depth, tire pressure & ground speed
- Landing distances can be increased by up to 700% when tires hydroplane

  Rotating tire: Hydroplane at $9 \times \sqrt{\text{(Tire PSI)}}$

  Non-rotating tire: Hydroplane at $7.7 \times \sqrt{\text{(Tire PSI)}}$

  ∴ If sense hydroplanes, release a bit brake pressure
- 10kt crosswind during hydroplaning can cause plane to drift off 200ft wide runway in 7sec
- Only occurs on hard surface runways

Taxiing:
- Keep power & braking to min
- During windy conditions need to move control to dive away and climb in wing
- Plan ahead for slope & surface conditions
- Never enter runway without making sure approach & base are clear
- Holding instruction while taxing must be acknowledged & read back



Effects of wind/wind shear:
- Hazardous for plane within 1000AGL during landing/takeoff
- Takeoff: If headwind then strong increase performance, If tailwind then sudden decrease performance
- Avoid wind shear by using PIREPs (Pilot Reports) or SIGMETs (Significant Meteorological Information)
- Study icing & turbulence FGA along with upper winds & frontal placements
- Recover: Full power, pitch attitude with max AOA
- Increase performance shear: Reduce power, then increase to higher setting before shear
- Decrease performance shear: Increase power, then decrease to lower setting before shear
- Susceptible: Large, heavy aircraft with slow speed

Radio/Electronic interference/Portable electronic devices:
- Prohibits use of portable electronic devices that may impair functioning of aircraft's system/equip.
- Prohibits use of portable electronic devices except with permission of operator of aircraft
- Requires air operators to establish procedure for the use of PED on board an aircraft that meets the Commercial Air Services Standards (CASS) & are specified in Company Operations Manual (COM)

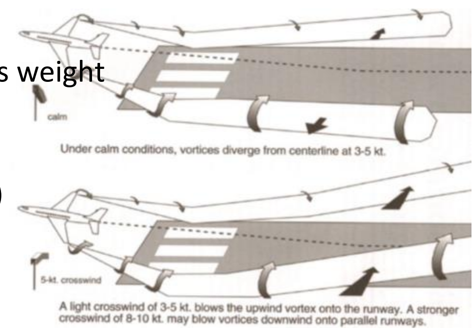
  → Company is responsible to determine if they interfere and responsible for the policy

Bird avoidance:
- Use of landing lights during both day & night improves visibility to pilots & birds
- Use especially during takeoff & landing
- 4lbs bird colliding at 130kt will hit plane with force equals to 2 tons
- Do not fly below birds ∵ Birds tend to dive
- Need to fill out bird/wildlife strike report for all encounters

2. Wake turbulence

Wake turbulence:
- Produced by differences in air pressure over top & bottom of wing/rotor of plane → Induced drag
- Plane encounter vortex will tend to roll & impose instant structural loads as high as 10Gs
- Starts with rotation & reaches peak intensity at lift-off ∵ Weight is sustained by wings & speed is low
- Seen from behind: Left wing vortex turns clockwise, right wing vortex turns counterclockwise
  Move downward & outward
- Form when nosewheel of aircraft lift off, stop when nosewheel touches down
- Rotation of vortex is around 80° per second, Spiraling motion around 1500ft per min
  Downward motion around 300-500ft per min

Identify the danger:
- Heavy, slow & clean configuration plane → Greatest intensity of vortex
- Worst: Behind plane either take off/landing (Wing is at high AOA) & at gross weight
- Dense air creates severe vortices (i.e. cold air)
- Vortices settle below & behind plane at 400-500ft/min
- Within 200fts above ground: Move outward at 2-5kt (Usually 5kt in TC AIM)
- Can drift with wind & move into touchdown zone/Linger over runway



Under calm conditions, vortices diverge from centerline at 3-5 kt.

A light crosswind of 3-5 kt. blows the upwind vortex onto the runway. A stronger crosswind of 8-10 kt. may blow vortices downwind onto parallel runways.

Avoidance:
- Rotate & climb above departing aircraft, wait few mins after an overshooting aircraft
- Approach above preceding aircraft & beyond touchdown point

Separation minima (Radar departure):
- When directly behind preceding & at less than 1000ft below
  Super heavy behind super heavy: 4 mi
  Heavy behind super heavy: 6 mi
  Medium behind super heavy: 7 mi
  Light behind super heavy: 8mi
  Heavy behind heavy: 4 mi
  Medium behind heavy: 5 mi
  Light behind heavy: 6 mi
  Light behind medium: 4 mi

Separation minima (Non-radar departure):
- 2 mins separation for any aircraft taking off into wake of heavy:
  Takeoff from the threshold of same runway
  Takeoff from threshold of parallel runway located less than 2500ft away
  Only wake turbulence advisories to light behind medium
- 3 mins separation for any aircraft taking off into wake of heavy/light into medium:
  Starts takeoff roll from intersection/point further along runway then preceding
  Following aircraft may require longer runway than preceding
- Up to 3 mins if projected flight path of following will cross preceding heavy

Pilot waiver:
- Controllers need to advise pilot if clearance is denied due to wake turbulence
- Pilot may consider waiving wake turbulence requirement but controllers cannot initiate waiver

If pilot think vortices from preceding will move / break up before takeoff roll & position before takeoff position of preceding

- Cannot be waived:
  Light/medium behind heavy & takeoff from intersection/further along runway in direction of takeoff
  Light/medium after heavy takeoff/make low or missed approach in OPPOSITE direction of takeoff
  Light/medium after heavy make low or missed approach in direction of takeoff
- Pilot-initiated waiver for VFR means pilot accepts responsibility for wake turbulence separation
  Controller will issue clearance with wake turbulence cautionary
- Controllers are responsible for ensuring wake turbulence minima for IFR departures

Categories:

	KG	LB
Light	<=7000	<=15500
Medium	7000-136000	15500-300000
Heavy	>=136000	>=300000

A380: Super heavy, 560000KG

	Idle blast area (ft)	Takeoff thrust area (ft)
Jumbo	600	1600
Medium	450	1200
Small	200	500

Size:
- Covers area about 2 wing spans in width & 1 wing span in depth
- Large heavy aircraft: Vortices settle below & behind plane at 400-500ft/min, less than 1000ft in 2mins
  Level off at about 1000ft below flight path within 2mins
- Can trail generating aircraft by 10-16NM

Dissipating time:
- Sink to ground & tend to move laterally outward at 5kt
- Crosswind can keep vortices directly over runway
- Strength remains constant for first 2mins and last up to 5mins
  Atmospheric turbulence: Break up quicker; Calm conditions: Last longer

Avoidance:
- Avoid crossing behind & below flight path of large heavy plane/ANY size of heli (size has less effect)
- Helicopters generate powerful vortices based more on weight
- Takeoff: Stay upwind & plan to airborne before rotation point of previous plane
- Landing: Touchdown before rotation point of plane taking off/after touchdown point of plane landing
- Solely pilot's responsibility to avoid wake turbulence ∴ Do not hesitate to ask for revised clearance

Light quartering tailwind & wake turbulence:
- Light quartering tailwind:
  Blow wake back onto glide slope
  Decay less quickly at point of flight path intersection
  Push & keep main part of vortex to centre of runway
  Move vortices into touchdown zone

3. Search and rescue

Service availability:

- Available continuously throughout Canada & Canadian coastal waters
- 3 Joint rescue coordination centers: Victoria, Trenton, Halifax
- Major SAR providers: Military, Provincial governments, CASARA, Canadian coast guard,
  Parks Canada, Trained volunteers

Request for assistance:

- When aircraft is known to be overdue: Operators/person concerned should notify nearest JRCC/ATS
- Do not delay the reporting a missing aircraft
- Once plane is reported missing, Missing aircraft notification (MANOT) will be sent to nearby ATS
- If MANOT is sent to pilot, maintain visual lookout & monitor 121.5MHz if possible

Aiding persons in distress:

- When observe aircraft, ship/vessel in distress then should keep in sight
- Report to ATS with: Time of observation, position of plane
  General description of scene, physical condition of survivor

Aircraft emergency assistance:

- Distress: Mayday, threatened by serious or imminent danger, requires immediate assistance
- Urgency: PanPan, concerning safety but not require immediate assistance

Action by pilot-in-command during an emergency condition:

- Precede the distress/urgency message with mayday/pan pan three times
- Includes: Registration, Nature of situation, Intention of PIC, Present position

VHF direction finding (VDF):

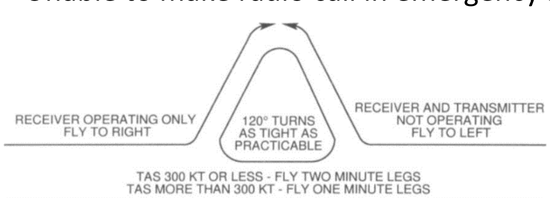
- At selected towers & FSS, will be listed in CFS under COM section
- Only VHF communication radio is required by aircraft
- Displays bearing from station for control/FSS
- Controllers will ask for "Transmit for bearing": PIC should slowly read back registration for 3-5secs

Transponder alerting:

- 7700: Alert ATS for emergency
- 7600: Communication failure
- 7500: Unlawful interference (Hijack)
- 7500 then 7700: Unlawful interference & desperate situation & request armed intervention

Radar alerting maneuvers:

- Unable to make radio call in emergency situation: 7700, Monitor emergency frequency
  Fly 2 triangle patterns & resume course & repeat every 5mins
  (Assume that you are within radar coverage)



Survival basic techniques:

- Even if no ELT, a search will commence based on flight plan, intended track & last position report
- Keep plane clear of snow and try to make it visible
- Average SAR time is 24hrs
- Build fire to stay warm & dry & provide signal
- Prepare greens to smudge when plane flies near
- 3 fires arranged in triangle is standard distress signal

  ∴ Worth checking smoke in unpopulated area

SAR and flight planning:

- SAR time is 60mins by default, on an itinerary then is 24hrs
- Estimated en-route time (EET): Total time of flight & total time of stops

  E.g. CYAV 0045 CYAV
- Flight plan/itinerary is primary source of information for SAR
- In Canada, visual search extend up to max of 15NM on either side of flight planned route from last know position to destination

  ∴ Critical to adhere filed route & advise ATC for route changes/deviations

4. Aircraft critical surface contamination

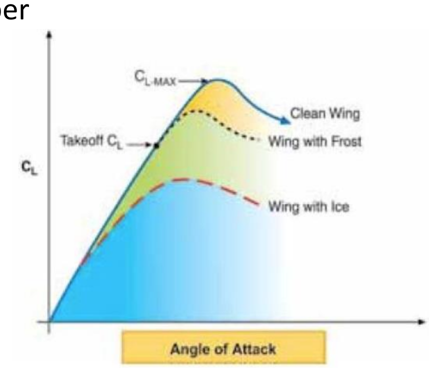
Effects of contamination on performance:
- Accumulation of frost, snow or ice on wings/lifting surface alters lifting characteristics of airfoil
- Even light layer spoils smooth flow of air over wing by separating the vital boundary layer air
- Stall speed ↑ & stall AOA ↓
- Few mm of ice will ↑ stall speed by as much as 20%
- Alter airflow over wings & might fail to generate lift
- Also add weight to aircraft but main concern is distortion of lift

wing covered in frost during takeoff
=> Decrease critical AOA
(NOT lift / drag)

Clean aircraft concept:
- Air regulation that does not allow pilots to takeoff when frost, ice/snow is adhering to any of the plane's critical surfaces
- If possible contamination then need to be inspected before takeoff by pilot/crew member who is trained in what to look for
- PIC has responsibility to ensure surface is free from contamination before flight

Critical surfaces:
- Surface that produces lift
- Wings, Control surfaces
- Propellers, Rotors
- Horizontal stabilizers, Vertical stabilizers/any other stabilizing surfaces
- For plane with rear mounted engines, the upper surface of fuselage

Frozen contaminants:
- Ice accumulation with thickness & roughness of medium to coarse grit sandpaper
  → ↓ lift by as much as 30% and ↑ drag by as much as 40%
- Contamination changes shape of airfoil & change flight characteristics
- Ice/frost can be removed with special de-icing solution or by putting plane in heated hanger
- Ensure aircraft is completely dry before taking outside, otherwise will freeze
- Warm aircraft taken outside may collect icing from falling snow



Cold soaking phenomenon:
- Ice can form even outside air temperature is well above 0°C (32°F)
- Fuel tank may have fuel with low temp & it lowers the wing skin temp to below freezing point
- Liquid water coming in contact with wing then will freeze to wing surfaces
- Can be caused by fueling with cold fuel
- Cause frost to form on upper & lower wing if high relative humidity
- During flight: Temp of plane & fuel in wing may be colder than ambient temp
  May conduct heat away from precipitation and form ice in wing areas above fuel tanks
  May form ice due to humidity in air even no precipitation

Practices for pilots to ensure clean aircraft:
- Only exception is takeoff with frost on underside of wing if aircraft manufacturer's instruction says ok
- Examine surface with eyes & hands (Visual & tactile inspection)
- Have aircraft de-iced & ensure de-icing fluid is used evenly on upper & lower section of all surfaces
- Use wing covers/hangers to protect plane when parked

Aircraft de-icing/anti-icing fluids:

- Type I: Various percentage of glycol mixed with water (more glycol, lower temp to freeze)
  Provide protection against water re-freezing but not against further contamination
  Remove existing ice, tend to be quite thin & run off aircraft quickly
- Type II: Anti-icing, more viscous than Type I and will stick to surface & absorb precipitation
  Design to stay on wings during ground ops. (Shear off when takeoff, V_r shear speed = 100kt)
  ∴ Little adverse effects on aircraft performance when in flight
- Type III: Longer hold over time than type I but shorter hold over time than Type II
  Flow off characteristics are designed for aircraft with V_r < 100kt
- Type IV: Meet standard of Type II, longer holdover time than type II
  Dyed green so not mistaken as ice & spray coverage can be better seen
  Typically have V_r > 100kt
- Holdover time: Amount of time that de-icing/anti-icing fluid provides beneficial effect
  Depends on water amount (mix ration), relative humidity, winds, temp, type of fluid
  Calculated from start of final application to when it is no longer effective
- Fluid failure: Exceeding holdover time, change in weather, jet blast etc

Preventative measures and de-icing procedures:

- Preventative measures: Hangar: Must cool aircraft if precipitation is present, fuel may hinder cooling
  Wing covers: Care to avoid damage & use of ladders, may freeze to wing
- Removal of surface contamination:
  Heated de-ice fluid: Type I fluid, works best when heated & many of these must be heated
  Blast/Melt that ice off
- Hand sprayers: Type I fluid but not heated, portable, be sure to cover all surfaces
- Manual means: Broom, rope, brushes, squeegees
  Be careful of antennas & sensors, safety first
- Hot air: Portable forced air heaters, use directly onto contamination
  Use caution when precipitation is still failing
- Water: When above 0°C
  Cold water: Float plane pilots use plane's bilge pump to spray river/lake water to remove frost from wings
  Hot water: Only where available, caution must be used as hot water refreeze fast
  ∴ Create ice on surface even at temp above 0°C
- Wait: For sun to rise: OAT ↑, Airplane's skin temp ↑/Bring plane inside

Operational considerations:

- One step (manually/type I fluid), Two steps (Type II or Type IV fluid to protect for additional time)
- Apply fluid symmetrically
- Avoid: Pitot/static/AOA sensors, Control surface cavities, Cockpit windows,
  Radome (Structural, weatherproof enclosure that protects a radar antenna), Intakes, Engines
- Maintain communication with ground crew & ask ATC about delays
- Taxi slowly with flaps/slats retracted, May need to deice again

Emerging technologies

- Considerations: Fluid costs/hazards
- Infrared heat systems
- Forced air: Alone/Augmented
- Ground ice detection system: Aid in detecting contamination

5. Aircraft de-icing & anti-icing fluids

Removing ice:
- Frozen contaminants are removed by using freezing point depressant fluid (FDP)
- De-icing & anti-icing fluid should not be used unless approved by manufacturer
- FDP is soluble in water & absorb/melt ice slowly
  → Can be sped up by using heater fluid & high-pressure spray equipment

De-icing & anti-icing:
- De-icing: Frost/ice/snow/slush is removed by use of heated aircraft de-icing fluid (ADF)
- Anti-icing: Aircraft anti-icing fluid (AAF) is applied to surface free of contamination in order to protect it
- Major airports have Central de-icing facility (CDF) to de-ice & anti-ice immediately prior to takeoff
- Small airports may require company personnel/pilot to de-ice using pressure sprayer
- Sites not having CDF may require operator to carry equipment on board aircraft/store in airport

Representative surface:
- Portion of aircraft that can be observed by flight crew from inside aircraft & is used to be judged whether the surface is contaminated → Then can reasonably expect other critical surface is in same condition
- Used as tool to gauge state of critical surface after using de-icing & anti-icing fluid
- Air operators that have established program in accordance with TC ground icing operation standard may have representative aircraft surface designated & approved for aircraft

Fluid description:
- De-icing: Ethylene glycol, diethylene glycol, propylene glycol based fluid with water, corrosion inhibitors, wetting agents, dye → remove contaminate & short period of anti-icing
- Anti-icing: Also contain polymeric thickeners → Prevent formation of unabsorbed frozen contamination
- Qualified fluid: Subjected to endurance time test & holdover guideline have been developed
- Must be used in accordance with Approved ground icing program

Type I:
- Orange/pink
- Primarily used to remove existing ice, typically heated
- Minimum 80% glycol, unthickened with low viscosity so run off aircraft quickly
- Reduce freezing point of water so turning ice into liquid
- Some protection against re-freezing but not much against further contamination
- Flash freeze over (Fluid failure) can occur in short time after HOT expires

Type II:
- Colorless/pale straw color
- More for anti-icing
- More viscous than Type I & will stick to surface
- Allow precipitation that falls to be absorbed & liquefied
- Sheer speed about 100kt

Type III:
- Longer HOT than Type I but shorter than Type II
- Used on low rotation

Type IV:
- Green
- Meet standard of Type II, longer HOT

Holdover time:
- Amount of time that de-icing/anti-icing fluid is providing beneficial effect
- From beginning of start of final application to time when fluid is no longer effective
- Use only high confidence level time (lesser time published in chart)

Aerodynamics:
- Fluid becomes more viscous when temp decreases & have negative effect on aerodynamics
- Amount of fluid that sheared off depends on speed reaching during takeoff & time to reach that speed
- Aerodynamic acceptance test: Coldest temp the fluid has acceptable aerodynamic characteristics
  High speed: Vr >100-110kt, acceleration to lift off > 23 sec
  Low speed: Vr > 60kt, acceleration to lift off > 16 sec

Freezing point:
- Temp of first ice crystal formation
- Concentration is increased from 0% by volume & freezing point decreases
  Will start to increase as concentration is increased towards 100%

Lowest operational use temperature:
- Fluid concentration-specific
- Higher of: Lowest temp at which fluid meets aerodynamic acceptance test for given aircraft type
  Actual freezing point of fluid plus freezing point buffer (10°C for Type I, 7°C for Type II/IV)

Fluid failure:
- Exceeding HOT, change in weather, Jet blast
- Must be cleaned periodically

Procedure for de-ice:
- CAP & CFS

6. Weight and balance – Definition

General:

- COG falls into specified limits ∴ Ensure controllability of plane in flight
- More weight = less performance capability
- Performance changes depending on how weight is distributed

Overloaded airplane:

- Higher takeoff speed, longer takeoff run
- Reduced rate of climb
- Decrease in range
- Decrease in cruising speed
- Reduction in plane maneuverability
- Higher stalling speed
- Higher approach & landing speed
- Longer landing roll/stopping distance

Standard airplane weight:

- Right out of assembly line

Standard empty weight:

- With all of standard equipment installed
- Usually includes unusable fuel, operating fluids & full engine oil

Basic empty weight:

- With all optional equipment installed
- Most plane includes full oil & unusable fuel
  Some may exclude, depends on POH and W&B report

Useful load:

- Difference between maximum (gross) takeoff weight & basic empty weight
- How much weight we can put in aircraft
- Includes usable fuel, pilot, crew, passenger, baggage & freight

Usable fuel:

- Fuel available for flight planning

Unusable fuel:

- Fuel remaining in tanks after runout test has been completed according to government regulations
- Due to shape of fuel tank in wing

Maximum takeoff weight:

- Maximum weight that aircraft is approved for start of takeoff run

Maximum gross weight:

- Maximum permissible weight of airplane

Maximum ramp weight:

- Maximum weight approved for ground maneuvering
- Allow extra pounds above maximum takeoff weight typically for fuel
  → For start, taxi and run-up

Fuel/oil weights:

- Need to memorize
- AVGAS: 6.0lb/US gal
- J.P.4: 6.7lb/US gal
- Jet A & A-1: 7.0lb/US gal
- OIL (65 grade): 7.5lb/US gal

Zero fuel weight:

- Weight of airplane, crew, passengers, baggage, oil & unusable fuel

Maximum zero fuel weight:

- Maximum weight of passengers, baggage & crew before the rest must be fuel
  ∵ Too much weight in fuselage will put too much stress in wings if loaded beyond this value

Balance principles:

- Sum of moments on left & right of pivot point/fulcrum must be equal
- Moment: Weight of object multiplied by distance (arm) from reference point
- Fulcrum of plane is located at Centre of lift/COP on wing
- Total weight of aircraft located at COG is counterbalanced by force provided by elevators
- If COG/Centre of lift changes position, elevator force must also change
- Weight of aircraft, fuel, pilot, passengers & baggage is distributed throughout plane (Like small arrow)
- Total weight can also be considered as being concentrated at one given point (Like big downward arrow)
  → The position through which all weights appear to act through is known as COG

Datum:

- Datum line: Arbitrarily selected line on plane set by manufacturer that horizontal distances are measured for W&B
- Can be nose of plane, fire wall, or any other convenient point
- Not as same as fulcrum

Arm:

- Distance from datum line to item

Moment:

- Multiply weight by arm and expressed in inch pounds
- Simplify by divided by 1000 (Used for C152 & C172)

Mean aerodynamic chord:

- COG range is expressed in inches from balance datum line
- Large commercial aircraft: Expressed as percentage of average chord of wing (AKA Mean aerodynamic chord)

7. Weight and balance – Calculation

Centre of gravity calculations:
- Determine COG position: Add up all weights & all moments
- Moment aft of datum: +ve number, Moment forward of datum: -ve number
- Typically only oil / baggage compartment in nose will be only -ve number
- Oil: 7.5lb/gallon, AVGAS: 6lb/gallon
- Sum of moments / Total weight = COG

Loading graph:
- Graphical method for determining moments during aircraft W&B calculation
- Automatically multiples weight & arm

Moment loading envelope:
- Check total weight & moment lies inside the envelop to see whether the plane is properly loaded

COG envelope:
- Check total weight & COG location inside the envelop to see whether it is in acceptable range

COG tables:
- Fairly lengthy, not common for small aircraft

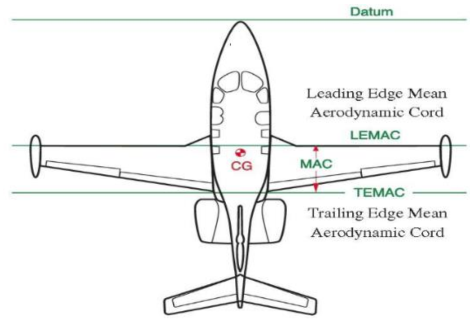
Load adjustment:
- Position of COG is influenced by manner of how loads are distributed
- Plane has a maximum allowance for a forward & rearward COG
- Operating plane with COG outside limits will change characteristics of plane & could be fatal

Aircraft balance:
- Balance point in middle: Fulcrum, downward forces of both sides should be equal
- Fulcrum of aircraft in flight is located at Centre of lift
- Most plane: COG is forward of Centre of lift ∴ Naturally want to nose down
- Elevator at aft end → Provide counterbalancing force to COG & level attitude
  When trim elevators: Correct amount of elevator balance force & relieves pilot from constant control
- Forward COG: Tail need to provide more down force, Trim nose up
  Flying at higher AOA → More drag
  Cruise slower which requires more fuel
  Stall speed increases
  Generally will be more stable
- Aft COG: Tail need to provide less down force, Trim nose down
  Light control forces, pilots may overstress the plane
  Flying at lower AOA → Less drag
  Cruise faster which requires less fuel
  Stall speed decreases
  Poor longitudinal stability
  However difficult to recover from stall

Rule of thumb:
- Pilot should calculate one W&B for takeoff and one for landing ∵ Fuel will be burnt during flight
  ∴ May be safe on takeoff but inacceptable COG during landing

Normal category:
- Expected to be operated under normal conditions
- Non-aerobatic & non-training operations
- +3.8G to -1.5G

Utility category:
- Expected to be operated under training conditions
- Stricter W&B limitations
- Around +4.4 to -1.7G
- Generally spins are approved only for utility category



Mean aerodynamic chord:
- For advanced aircraft
- Average chord and position for non-rectangular wing
- Leading edge mean aerodynamic chord: Imaginary leading edge would be placed at
- Trailing edge mean aerodynamic chord: Imaginary trailing edge would be placed at
- Most planes have acceptable COG range within 10-30% of MAC, usually located at 25% of MAC

8. Weight shift

$$\frac{w}{W} = \frac{d}{D}$$

w: weight to be moved
W: gross weight of aircraft
d: Distance that CG moves/must be moved
D: Distance between stations

9. Segmented weights of passengers

Definition:

- Actual weight: Weighing passenger prior to boarding a flight
  Volunteered weight: Ask passenger & add 4.5kg (10lb) to disclosed weight
  Add allowance for personal clothing & carry-on baggage
  Estimated weight: Reasonable estimate by operator
- Air operator segmented weight: Derived by air operator from statistically meaningful data
- Segmented weight: With predetermined degree of accuracy & reliability for passengers aged 12 or above
  Includes clothing & carry-on baggage
- Air operator standard weight: Applicable only to that operator & maybe used in lieu of published standard
- Published standard weight: Average passenger weight as published in TIC AIM RAC
  Includes clothing & carry-on baggage
  Can be used without actual weighing

Implementation:

- Only use segmented weight when actual weight, volunteered weight, estimated weight is not available
- Operator is prohibited from using standard weight for plane operating under Subpart 703 Air Taxi that also have certified passenger seating capacity of five or more passengers → Use actual/segmented weight
- Segmented weight is applicable only to 12 years or older for 703 Air Taxi operators only
  → 5.9kg (13lb) is added to average adult passenger weight
- Based on certificated seating capacity instead of passengers on board
- Personal clothing: 3.6kg (8lb) in summer & 6.4kg (14lb) in winter
- Infants: Weighted with accompanying adult
  If over 10% of adult passenger's weight, add at rate of 13.6kg (30lb) per infant
  If occupying separate seats then should be treated as children

Chapter 8

Aircraft performance

1. Aircraft performance

Effect of density altitude:

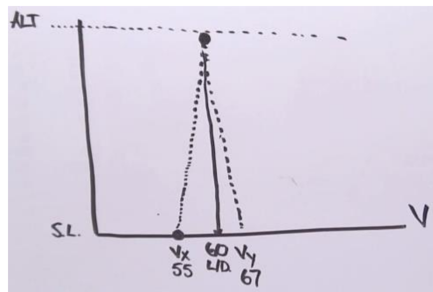
- Service ceiling, absolute ceiling & leaning setting are all given in terms of density altitudes
- Air density ↓ when: Temperature/Altitude/Humidity ↑ and barometric pressure ↓
  ∴ Engine with less power, propeller with less thrust, wing with less lift
  → Longer takeoff run, poorer climb performance, longer landing distance

Ground effect:

- Decrease in drag (induced drag) when close to fixed surface, pronounce if wing is close to ground
- May become airborne before it is ready to fly due to ground effect → Stalling/Settling back to ground
- Used for soft field takeoff: Get airborne asap, held just off surface as accelerates to proper speed

Best angle of climb (V_x):

- Most altitude gain for gain distance, best for takeoff over obstacles
- Higher altitude = Higher V_x
- Equal to L/D speed at absolute ceiling



Best rate of climb (V_y):

- Most altitude gained for given time
- Higher altitude = Lower V_y
- Equal to L/D speed at absolute ceiling

Maneuvering speed (V_a):

- Max speed at which it is safe to use full deflection of controls
- If speed < V_a: Wing stalls before sustaining damage
- If speed > V_a: Wing overloads, sustain structural damage
- Set at stall speed at load factor of capable of carrying without damage
- If weight ↑ , V_a ↑

Maximum normal operating (V_{NO}):

- Max continuous operating airspeed
- No turbulence or sudden attitude changes
- Top of green arc

Never exceed (V_{NE}):

- Do not go faster under any conditions
- Red line

Maximum flaps extended (V_{FE}):

- Do not extend full flaps over this speed
- Top of white arc
- Some flaps may be operated faster than this, consult AFM/POH

Gliding for range:

- Fly at AOA that gives best lift/drag ratio
- Speed is found in POH and corresponds to a specific AOA

Flying for range:

- Distance that can fly per unit of fuel
- Tailwind (Headwind): Glide distance ↑ (↓) because ground speed ↑ (↓)
- Increase (Decrease) speed when gliding into headwind (Tailwind) will ↑ distance traveled over ground

Flying for endurance:

- Time that we can stay in air with given amount of fuel
- Wind has no effect on endurance

Slow flight:

- Fly just above stalling speed, below speed for best endurance & best glide
- Controls feel sluggish (Aileron is not effective but rudder still ok due to slipstream)
- Nose high attitude, low airspeed with stall horn, require power to maintain altitude
- Recovery: Full power (Nose will pitch up and yaw left), Carb heat cold, Set for V_y attitude
  Flaps up, reach cruise speed, reduce power

Stall:

- Loss of lift & increase in drag when aircraft is flown greater than critical AOA
- Any increase in the AOA will result in decrease in lift
- Occur at any airspeed, attitude, power setting
- AOA that the wing stalls is determined by airfoil design
- Happens when airflow over wing has become turbulent & separates
- Recovery: Forward elevator/Release back pressure, Add power
  Smoothly pull out dive, pitch for climb attitude
- Power on stall: Directional control may be more difficult
  Nose raises higher, More pronounced pitch forward during stall
  Possible wing drop: Opposite rudder to wing dropping, may need full power
  Do not apply power if nose drops below horizon
- Secondary stall: Attempt to hasten completion of stall recovery before regaining sufficient speed
- Imminent stall: Approaching a stall but not allowed a complete stall
- Accelerated stall: Stall at higher speed with excessive maneuvering loads such as steep turns/pull ups
  Downward deflection of aileron increases AOA of that section → stall first
  ∴ Turn left = Downward right aileron stalls, right wing drop & roll to right
- Stalling speed: Weight & balance, power, flaps, angle of bank, aircraft condition, landing gear
  Lowest will be wings level, power on, full flaps & aft COG

Indicated vs True stall speed:

- Indicated stall speed always stays the same
- True stall speed will increase with altitude
- Both are same at sea level
- If density altitude ↑ , indicated airspeed is the same but true airspeed & landing distance ↑
- Only thing that changes indicated stall speed is load factor

Spins:

- Stall aggravated by yaw, follows corkscrew path in almost vertical downward direction
- One wing is stalled more than other
- Incipient spin: 4-6sec in light aircraft, approximately 2 turns
- Fully developed spin: Airspeed, vertical speed & rate of rotation are stabilized

Small aircraft loses approximately 500ft per each 3sec turn

- Recovery: Wings regain lift, usually recover in ¼ to ½ of a turn after anti-spin input is applied
- Low airspeed but not below stall, altimeter showing descent
- Gyros may topple ∵ too much rotation around too many axises
- Low wing in turn coordinator indicates direction of spin, position of ball is meaningless
- Factors: Power/flaps/Aft CG makes spin flatter, heavier increase spin's inertia

Spirals:

- Steep descending turn in which airspeed, rate of descent & wing loading increase rapidly
- Control sensitivity will be increased significantly
- If back pressure is applied before wings are level: Design load factor may be exceeded
- Recovery: Throttle to idle, wings level, ease out of dive
- Spin vs Spiral dive: Spin: Stalled, low speed, rotation about all axes
  Spiral dive: Not stalled, high speeds that are increasing

Bank and speed vs Rate and radius of turn:

- Same angle of bank: Faster (Slower) aircraft has smaller (greater) rate of turn & larger (smaller) radius
  ∴ Faster plane requires steeper bank angle to maintain standard rate turn

Effect of centre of gravity on performance:

- Shifting COG changes stalling speed, cruising speed, landing & takeoff performance & characteristics
- Tail heavy: Rearward COG, need less trim, less stable, fly faster due to less drag from less tail pressure on stabilizer & reduced AOA on main wing, lower stall speed
- Nose heavy: Forward COG, need more trim, more stable, fly slower due to more drag from more tail pressure on stabilizer & increased AOA on main wing

Use of flight manual:

- Actual flight manual for the aircraft must be used
- Ground school aircraft manuals are not legal for use in aircraft, only used for studying purposes

2. Use of performance charts

Performance chart:
- Allow us to figure out what our aircraft is & is not capable of
- Numbers are obtained by test pilots in brand new planes ∴ Actual numbers may vary
- Read the "Conditions section" and "Notes" sections before using chart
- Apply all corrections in the same order as appear, otherwise result in wrong answer

Takeoff distance chart:
- Pressure alt: Before using chart, reduce altimeter setting & field elevation/indicated alt to pressure alt
  Based on standard atmosphere, reduce prevailing conditions to pressure alt
  → common baseline alt ∴ Used to determine density alt, true alt, true airspeed
- Dry grass: Add 15% to GROUND ROLL only
- How: 1) Set altimeter to 29.92, the reading itself is pressure alt
  2) 1 inch of mercury = 1000ft of alt
  29.92 subtract current altimeter setting, multiply by 1000, add (+ve)/subtract(-ve) from elevation

Wind components:
- See the line of degree and circle of wind speed meets
  → Straight down for crosswind & straight left for headwind

Cruise charts:
- How fast to go during cruise & How much fuel it burns during cruise
- Appropriate brake horsepower setting

Fuel burn charts:
- Endurance chart: How long we can stay in the air
- Range chart: How far we can theoretically get (under zero wind)
- Climb performance chart: Subtract between value if not taking off from sea level

Landing charts:
- Dry glass: Add 45% to GROUND ROLL only

Effects of various runway surfaces on takeoff and landing run:
- Muddy, wet, soft, rough, snow, ice: Distance will increase
- Downslope: Illusion of being too low on approach ∴ Pilot tend to approach higher than normal
- Upslope: Illusion of being too high ∴ Pilot tend to approach lower than normal

Runway surface condition:
- Amount, position & type of snow on runways & taxiways, Can be found in NOTAMs and ATIS

Canadian runway friction index (Formally known as James brake index):
- How slippery the runway is, Helps to decide if there is enough braking effectiveness & crosswind control
- Can be found in NOTAMs or ATIS
- 1.0 is perfect runway, 0.0 is completely poor
- 0.8 would be very dry & bare runway suitable for landing, 0.1 would be wet ice with poor braking
- Given crosswind component requires a min CRFI value to ensure for directional control
- Greater crosswind component requires greater CRFI

3. CPL graphs (MAC, Take-off distances)

% MAC:

- Find arm and use chart/formula
- Weight & balance: %MAC and weight

Chase takeoff distance:

- Use of few graphs

4. CPL graphs (Others)

CRFI scale:

- Use lowest number to calculate

Demonstrated to be safe crosswind:

- V_{SO} * 0.2

Chapter 9

Pilot decision making and human factors

1. Visual illusions

Vision:

- Visual references provide most important sensory info
- Central (Foveal) vision: Identification of object & perception of colors
  IFR central vision allows pilot to acquire info from flight instruments
  VFR central vision allows pilot to acquire external info to make judgement
- Peripheral (Ambient) vision: Perception of movement (self & surrounding environment)
  Enables orientation independent from central vision
  Motion of surrounding environment produces perception of self-motion
- Illusions of motion: Caused by blowing snow, ripples in water, blowing grass
  Ignored by keeping eye moving & referencing known stationary objects nearby

Visual references:

- Comparative size, form, shape of known objects at different distances
- Nearby objects are perceived as moving faster than distant objects
- Interposition of known objects
- Varying texture/contrast of known objects at different distances
- Differences in illumination perspective of objects
- Flight attitude: Determined by pilot's visual reference to natural horizon, may reference to surface below
  Artificial means → Attitude indicator/flight instruments
- May become obscured by smoke, fog, haze, dust → Airport adjacent to large bodies of water
  Sparsely populated area

Aerial perspective illusions:

- Make you change slope of final approach
- Upsloping runway: Illusion of high-altitude approach → Tends to pitch nose down, undershoot
- Downsloping runway: Illusion of low-altitude approach → Tends to pitch nose up, overshoot/stall
- Upsloping terrain: Illusion of high-altitude approach → Tends to pitch nose down, land short/stall
- Downsloping terrain: Illusion of low-altitude approach → Tends to pitch nose up, land further down
- Narrow runway: Illusion of high-altitude approach → Tends to pitch nose down, too close to ground
- Wide runway: Illusion of low-altitude approach → Tends to pitch nose up, missed approach/stall
- Black hole approach: Approach at night/water/unlighted terrain to lighted runway & horizon is not visible
  May respond by lowering approach slope

Illusion:

- Autokinetic: Stationary object is moving in front of aircraft's path (∵ Staring light in dark background)
- False visual reference: Cause you to orient aircraft in relation to false horizon
  ∵ banked cloud/featureless terrain
- Rain on windscreen: YOU seem higher & farther away
- Vection illusion: Nearby aircraft make pilot feel as their plane is moving
- White out: Low visibility by snow, overcast cloud, fog → Featureless & no point of visual reference

1/2 NM forward = seems 200 lower than actual

2. Spatial orientation

Background:
- Natural ability to maintain our body orientation/posture in relation to surrounding at rest/during motion
  → Human are designed to maintain spatial orientation on ground
- In flight: Sensory stimuli (Visual, vestibular, proprioceptive) vary in magnitude, direction, frequency
  Difference will lead to sensory mismatch that produce illusions

Vestibular aspects:
- Inner ear contains vestibular system → Organ of equilibrium
- Semicircular canals: Three half-circular, interconnected tubes
  Corresponds to rolling, pitching, yawing → Detect angular acceleration
  Sense movement then indicate a turn for 20 seconds
  → Then send erroneous signal that turn has stopped even the turn continues
  Rolling out then will sense like turning in opposite direction
- Illusion: Leans → Caused by sudden return to level flight following gradual & prolonged turn (~2°/sec)
  Graveyard spin → Caused by intentionally/unintentionally enter a spin, may apply alternate rudder
  Graveyard spiral → Caused by returning level from prolonged turn, may apply alternate aileron
  Coriolis illusion → Caused by tilting head suddenly, feel like rolling in all direction

The otolith organs:
- Utricle: Detects changes in linear acceleration in horizontal plane
- Saccule: Detects gravity changes in vertical plane
- Somatogravic illusion: Inversion → Steep ascent then sudden level, illusion of inverted flight
  Head-up → Sudden forward linear acceleration during level, illusion of nose up
  Head-down → Sudden linear deceleration during level, illusion of nose down

Proprioceptive receptors:
- Sensors located in skin, muscles, tendons, joints
- Sensing relative position of body parts in relation to each other
- Cannot let you differentiate between straight & level and performing coordinated turn

Prevent spatial disorientation:
- Experience in demonstrator
- Don't attempt visual flight if may get trapped in deteriorating weather

Airsickness:
- Normal response characterized by unfamiliar motion & orientation clues
- Symptoms: Vertigo, loss of appetite, nausea, increased salivation & swallowing, drowsiness
- Development: May become completely incapacitated
  Fatigue, alcohol, drugs, medications increase individual susceptibility
- Prevention: Less likely to become airsick if attention is occupied
- Medication: Should not take anti-motion sickness medication → Drowsy/affect brain function
- Countering: Repetitive exposure to flying conditions that initially resulted in airsickness
- In flight: Open air vents, loosen clothing, supplemental oxygen, land asap

3. Aviation physiology

Hypoxia:
- Lack of sufficient oxygen for body to operate normally
- May be accompanied by feeling of well being → Euphoria
- Minor: Impair night vision & slow reaction time
- Serious: Interferes with reasoning, unusual fatigue, loss of consciousness
- Due to atmospheric pressure & partial pressure of oxygen both decline at higher altitude
- Tolerance: Increased by continual exposure to high altitude
  Vary with level of hemoglobin & oxygen carrying capacity of blood
  Decreased by fatigue, cold & poor physical conditioning
- Smoker: Increases carbon monoxide levels in blood & reduces lung capacity
- Do not fly > 10000ft ASL without supplemental oxygen/cabin pressurization
- Retina of eye is more sensitive to hypoxia → First symptom is decrease in night vision
  (Euphoria according to TC)

Hyperventilation:
- Breath at faster/deeper rate than body requires
- Rate of breathing: Controlled by amount of carbon dioxide in lungs & blood
- CO_2 is blown off & level in blood drops below normal
- Slight dizziness, feeling of coldness, sensation like tight band around head, pins & needles in hand and feet
- Person may feel they cannot get enough air → Continued hyperventilation may cause unconsciousness
- Occurs in association with anxiety, fear, during intense concentration on difficult task
- Recover: Slow rate of breathing to 10-12 breaths per minute, do not breathe deeply
  Keep respiratory rate slow until symptoms disappear & resume normal breathing pattern

Gas expansion/trapped gases:
- Dysbarism: Gases trapped in body that expand/contract in body
  Cause severe toothaches, ear, sinus pain, abdominal pain
  During descent/when descending too quickly
- Barotraumas: Physical damage caused by trapped gases
  Ears are most susceptible → Use Valsalva technique (Close mouth, hold nose, blow gently)
  Yawning, swallowing, chewing gum

Decompression:
- 18000ft ASL: Atmospheric pressure is halved
- 25000ft ASL with unpressurized cabin: Subject to "bends"
- Scuba diving: Atmospheric pressure underwater increases by 1atm for every 33ft (10m)
  Breathe pressurized air for more than few minutes supersaturate their tissues with nitrogen
  Nitrogen bubble formation may take place > 8000ft ASL
- Non-compression dives & < 8000ft ASL → 12hr
- Decompression stops are required on return to surface → 24hr
- Any divers & > 8000ft ASL → 24hr

Vision:
- Cones in eye require light to function properly ∴ Night pilots may experience reduced vision
- Use peripheral vision → Look at things off center
- Yellow/pink markers don't show up under cockpit's red lighting
- Flight light should have red filter → Red light does not cause eye to adjust as white light

Scanning:

- By segmenting windshield & examine each segment before moving to next
- Left to right/Middle then moving outwards
- Most dangerous: Growing larger
  Not moving horizontally/vertically is hardest to spot

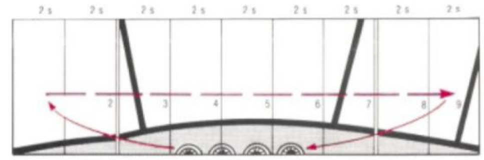


Figure 3. Side-to-side scanning method

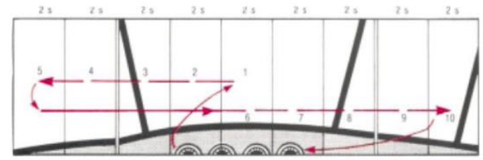


Figure 4. Front-to-side scanning method

Hearing:

- Noise level is extreme & hearing loss over time is common
- Use earplugs/noise canceling headphones

Orientation/disorientation:

- Disorientation: Preventable aviation accident involving VFR pilot → Continue fly into instrument condition
- Spatial disorientation: Become confused about sense of position/movement
- Vertigo: Sense/hallucination of spinning/rotating even after motion has stopped
- Somatogravic illusion: Accelerations = Illusion of climbing/nose up
  Decelerations = Illusion of descending/nose down
  Banks = Illusion of level flight
- Fluid in inner ear is moved when body is moved & sensed by brain → Give sense of equilibrium
- Vestibular illusions: In turn the fluid in inner ear incorrectly indicates turn has stopped
  Fluid indicates turn in opposite direction when returns to wing levels
- Visual illusions: Due to rain, fog, haze, slope of runway, terrain slope, lighting
- Should scan & trust all instruments

Airsickness:

- Open vents/windows, loosen clothing
- Do not take medication for airsickness → May cause drowsiness & impair judgment

Body rhythms/jet lag:

- Jet lag: Disturbance of circadian rhythm by moving through different time zones
  Insomnia, disruption of bodily function, irritability
  Body is accustomed to going to sleep & waking up
- Do not use drug, take 1 day per time zone change to get into new rhythm
- Least alert between 0300-0500 and 1500-1700

Sleep/fatigue: Our body CANNOT adjust to new sleep cycle in few days

- Stress, noise, eye strain, vibration, temp variation, heavy work load, poor diet, boredom
- Combat boredom: Keep busy, ground speed check, nav/fuel calculation, play "what if"

Anesthetics/blood donations:

- Local anesthetic for dental work: 24hr
- Spinal/general anesthetic /serious operations: Until aviation doctor says it is safe
- Blood donation: 48hr

Carbon monoxide:

- Product of fuel combustion → Colorless, odorless, tasteless gas
- Requires up to 48hr to dispose of CO
- Altitude increases → Susceptibility to CO poisoning increases
- Defect in cabin heat system may allow gas to enter cockpit of aircraft
- Symptom: Inability to concentrate, blurred thinking, dizziness & headache
- Solution: Turn off heater, open air ventilator, descend to lower altitude, use oxygen

Night vision:

- Hypoxia, CO poisoning, alcohol, drugs, fatigue & smoking will affect
- Should keep cockpit lights low, take 30mins to adjust to new light setting
- Blind spot in center of eye at night → View 10-15° to one side of object

Effect of smoking:

- May have 5-10% hemoglobin saturated with CO
- May become hypoxic at below 10000ft ASL

Time of useful consciousness:

- Amount of time to perform flying duties efficiently with inadequate oxygen supply
- Smoking can reduce tolerance by 3000-6000ft
- Reduce depression may reduce TCU up to 50%

Altitude	Conscious time
20,000	5 - 12 minutes
25,000	2 - 3 minutes
30,000	45 - 75 seconds
35,000	30 - 60 seconds
40,000	10 - 30 seconds
45,000	12 - 15 seconds
50,000+	12 or less seconds

Effect of G forces:

- Tolerance: Increase due to physical conditioning, continued exposure, weight lifting, constant short run
  Decrease due to smoking
- Positive: Stagnant hypoxia → Blood is unable to be pumped to head
- Negative: Redout → Blood gathers in head causing everything to have reddish tinge

More on hypoxia:

- Hypoxic hypoxia: Result of low oxygen levels in bloodstream, due to exposure to altitude
  8000ft some people notice slight increase in heart rate & speed of breathing
  10000ft all pilots will experience mild hypoxia
- Anaemic hypoxia: Result of heavy bleeding, cancers, anaemia
  May experience breathlessness, fatigue, chest pain
- Ischaemic/stagnant hypoxia: Result of inadequate blood flow/constriction of blood vessels
  e.g. fingers & toes exposed to cold
- Histotoxic hypoxia: Results of inability of cells of body to use oxygen available → High blood alcohol level

4. Pilot decision-making

Decision-making process:

- Gather, review, analyze, decide and do, evaluate

Factors that influence decision-making:

- Knowledge: Pay attention in ground school, listen to instructor, ask question, read & absorb info
- Situational awareness: Know what is going on around
- Skill: Practice until becoming automatic reactions & maintain at high level beyond flight
- Experience and training: Wrong experience may reinforce bad habits & inappropriate actions
- Reasoning: Reaching conclusion by careful thinking, help to avoid emergency & early sign of trouble
- Risk assessment: Potential risk of how serious the problem is depend on attitude, knowledge, skill
- Attitudes: Learn to recognize attitudes in ourselves

Loss of situational awareness:

- False assumption: Make assumption base on incorrect/ignored info
- Expectancy: Except for one thing but another thing happens
- Fixation: Focus on one item while something more important goes unnoticed
- Ignoring bad news: Such as bad weather report
- High concentration: Tendency to relax & make false assumptions after periods of high concentration
- Regression: People with experience are vulnerable to false assumption on a new type

Stress:

- Overload: Physical pressure such as extreme temp, noise, vibration, lack of oxygen
  Fatigue, lack of physical fitness, medications, death in family, fear
- Capacity to cope: Emergency situation may be hard to manage
- Arousal: Little then can alert us, too much then result in discomfort/panic
- Response: Omission, error, queuing, approximation, fixation, regression, tremor, escape
- Symptoms: Loss of sense of humour, anger, disturbed sleep, weight change, backaches, tense stomach
  Tendency to blame others, refusal to make time for friends, full of doubt, pessimistic
- Stress free: Maintain physical fitness, social support, recreation, self-assessment, emotional stress
- I'M SAFE: Illness, Medication, Stress, Alcohol, Fatigue, Emotion
- Acute vs chronic: Short period of time vs constant & may stop noticing its effect

Managing risk:

- Pilot: Habit of doing preflight inspection of themselves
- Aircraft: Weight & balance calculation, fuel consideration, takeoff & landing performance, limitation
  Walk-around to access, monitor engine & flight instruments during flight
- Environment: Weather, length, width, surface, obstacles, landing aids
- Operation: By purpose of each flight
- Situation: Set of circumstances present at given time

Hazardous attitudes:

- Anti-authority: Resent having to take instruction from anyone, may scorn rules & regulations
- Impulsivity: Not taking time to consider alternatives & select the best
- Invulnerability: Not feeling that accidents will happen to them
- Macho: Always trying to prove that they are better than anyone else
- Resignation: Not seeing themselves as making great deal of difference in what has happened

5. The pilot and the operating environment

Personal health and fitness:
- Pilot's license is valid as long as medical is able to be renewed → Physical fitness is important
- Refrain from smoking, watch diet, exercise regularly, protect eyesight & hearing from damage
- Do not fly when suffering fatigue/unfit to perform duties

Diet and nutrition:
- Balanced diet & 3 meals a day
- Overeating & obesity are detriments to pilots → Susceptible to hypoxia & health problem

Dehydration:
- Human body & lungs give off more water vapour at height of 5000ft
- Careful to avoid drinks with high caffeine/carbonated

Medications:
- Do not fly with drug that impairs pilot's faculties that may endanger safety
- Prescription drugs: Only take with approval of aviation doctor before flying
- Non-prescription drugs: Negative side effect → drowsiness, impaired judgement, blurred vision

Substance abuse:
- Impair pilot's ability to make sound decisions

Alcohol:
- Not act as crew member within 12hr after consuming alcoholic beverage
  → Best to allow 24hr (AIM recommends)
  Must not act as crew member if their ability is impaired regardless of time
- Alcohol may main in fluid of inner ear even after all traces of alcohol in blood have disappeared
- 1 ounce of alcohol takes at least 3hr to be metabolized by body
- 6000ft ASL: 1 drink is equivalent to 2 drinks at sea level

Pregnancy:
- Pilots having normal pregnancy with no complications can fly up to 30 weeks
- Fetus: Subject to increased g-forces & cosmic radiation,
  12-14 weeks may have risk of injury due to seat belt
- Lower tolerance to nausea, increased risk of anemia, general lack of energy

Heat/cold:
- Heat: Cause pilot severe discomfort & irritability, reduce tolerance to stress
- Cold: Stiff muscles, slow pulse, breathing that is shallow & slower,
  weakness & sleepiness, confusion, vertigo, loss of consciousness

Noise/vibration:
- Excess noise: Headaches, auditory fatigue, airsickness
- >80 dB: Damage ear & reduce ability to hear properly
  ∴ Wear earplugs & noise cancelling headphones

6. Aviation psychology

Decision-making process:

- Fly the aircraft
- Gather required info: Assemble all info & cross check instrument at same time
- Review info
- Analyze alternatives: Ask "what if"
- Decide & do
- Evaluate: Confirm whether best option has been chosen
- Start process over if necessary
- Purpose: Help minimize effect of human errors
- Pilot needs to identify personal attitudes hazardous to safe flight

Factors that influence decision-making:

- Knowledge, Situational awareness, Skill, Experience and training, Reasoning, Risk assessment, Attitudes

Hazardous attitudes:

- Anti-authority: Resent having to take instruction from anyone, may scorn rules & regulations
- Impulsivity: Not taking time to consider alternatives & select the best
- Invulnerability: Not feeling that accidents will happen to them
- Macho: Always trying to prove that they are better than anyone else
- Resignation: Not seeing themselves as making great deal of difference in what has happened

Stress:

- Acute stress: Short period of time, can be positive but may lead to exhaustion
  Heartbeat, breathing rate & blood sugar levels all increase
- Chronic stress: Constant & may stop noticing its effect
  Slowly drain mental & physical resources
  Sense of hopelessness/inability to cope

DECIDE:

- Decide, estimate, choose, identify, do, evaluate

7. Pilot-equipment relationship

Controls and displays – Errors in interpretation and control:

- Check & double check
- Expecting something to be a certain way does not mean it will happen

Standard operating procedures – Rationale/benefits:

- Ensure all pilots follow same procedure to operate a given aircraft
  → Avoid cockpit disagreement & improve crew coordination, ensure they understand each other
- Provided by air carrier, must be followed by all flight crew members and mandatory

Correct use of checklists and manuals:

- Checklist is accurate & should be followed to the letter
- Good operating practice to read each item out loud as checks are being done
- Do not memorize checklists and avoid using it
- Checklist: Enable aircraft to be operate in normal/abnormal/emergency conditions according to POH
  For prestart, pre-take-off, post-take-off, pre-landing
  Emergency: Fuel, hydraulic, electrical, mechanical system, engine inoperative procedures

Error in interpretation – Use of maps/charts:

- Be sure to understand map symbols using map legend

8. Interpersonal relations

Communications:

- Flight crew: Be professional, treat others as you would like to be treated
  Always follow rules & procedures, listening is key
- Maintenance personnel: Write specifically & accurately
  Talk to maintenance engineer, get to know aircraft & how it works
- Air traffic services: Ask them for alternative if not feeling comfortable about their instruction
  Ask them for clarification if unsure
- Passengers: Be consistent, explain actions, make safety absolute priority

Operating pressures:

- Family/relationship/peer/group: Do not being distracted/influenced by other pilots
  Make decisions based on own abilities & judgement
- Employer/self: Safety first
  Disreputable employer may push pilot to take risks & blame them for accident
  We may place greatest pressure on ourselves

9. Crew resource management

CRM:

- Effective use of resources available: Other crew/people, machinery, fuel, information
- Optimize interpersonal activities & man/machine interface
- Training: Communication, interpersonal interaction, critique, leadership/followership, situational awareness, problem solving, decision making, judgement, stress management

Communication:

- Process of exchanging ideas & info, keep aspect of working as crew
- Barriers: Language, personality, status, distance, noise

Skills:

- Ask the right question: Acquiring info, avoid conflicts
- State opinion: Passive behavior (Peace at all cost), Aggressive behavior (Winning at all cost), Assertive behavior (Consider wants, needs & disagreements of others)
- Resolving differences: Consider what's right & previous relevant experience
- Evaluating constructively: Captain's responsibility, reinforce good decision, discourage repetition of error
- Managing resources: Assess state of crew's readiness, other human resources, state of machine, all info
- Make decision
- Aviate, Navigate, Communicate

10. Night flying

Official night:

- Start at end of evening civil twilight & end at start morning civil twilight
- 6° below/above horizon & descending/ascending

Night rating requirements:

- 10hrs of night flying (5 of dual and 2 being X-C, 5 of solo with 10 takeoff & landing)
- 10 dual instrument (No more than 5 sim)
- Instrument at night cannot be counted towards both night & instrument
- Take passenger: 5 takeoff & landing in previous 6 months & serviceable landing light
  Aircraft category, class & type endorsed on license

Lights:

- Engine start: Anti-collision (Beacon)
- Taxi, takeoff, landing: Anti-collision (Beacon), Position (Nav), Landing/Taxi, Red cockpit
- Cruise: Anti-collision (Beacon, strobe), Position (Nav), Red cockpit, Map reading

CARs:

- 3SM in uncontrolled & controlled unless SVFR
- SVFR of departure only for helicopters
- 45mins reserve for VFR
- TGFILE: Turn coordinator, Gyroscopic heading indicator, Fuses (50%), Illumination, Lights, Electrical energy
- GPS if in NDA
- AVOP if commercial in turbine-powered pressurized/large aircraft: Attitude indicator, VSI, OAT, Pitot heat
  (Prevent icing of ASI system)

Night hazard:

- Wildlife
- Fog: Light wind + close temp & dew point spread, radiation fog
- Strong wind above: Low level jet may form over inversion
  Light wind on surface, howling wind at circuit altitude
- Electrical failure: Monitor ammeter & load meter
- Forced approach: Turn on landing light & point plane into wind
- Airport time & closure

Night vision:

- Requires about 30mins for rods to become adjusted to darkness
- Off-center viewing
- Smoking, CO, hypoxia & drugs adversely affect night vision
- Avoid bright light
- Red light preserves night vision but distorts colors

Two blind spots:

- Physiological blind spot: Oval-shaped area of blindness in each eye → Cant see image within that region
  Usually do not notice it because other eye will compensate
- Central blind spot: No rods in fovea → Look 15° off a faint light source
- Use off-center scanning technique

Lack of color vision:
- Rods in low light scenarios are unable to distinguish color

Reduced acuity:
- Central vision blindness at night
- High rod-to-optic nerve fiber ratio reduces acuity

Reduced depth perception:
- Rod vision & pupil dilation reduces depth perception

Night myopia:
- Short sightedness occurs during attempts to dark focus
- Periodically change your focus distance

Visual hypoxia:
- Retina is more sensitive to hypoxia, noticeable as low as 5000ft AGL
- Smokers are more susceptible due to buildup of CO in blood

Night blindness:
- Due to pigment deficiency in rods
- Induced within 60days on diet lacking vitamin A

Effects of aging:
- Pupil size decreases
- Range of eye focus & visual acuity is reduced
- Color discrimination becomes more difficult
- Longer to process visual info & read under dim light conditions
- Sensitivity to glare increases

Night illusion:
- Autokinesis (Objects appear to shift)
- False reference (Stars/lights near horizon)
- Venus & Sirius (False aircraft)
- Night myopia (Dilation, inability to focus)
- Somatogravic (Acceleration with pitch)

Night limitation:
- Blind spot (No rods & cones where the optic nerve is)
- Light to dark adaptation

Empty-field myopia:
- Tendency to focus 3-5ft away due to lack of stimulation
- Detection of object outside the restricted view is delayed
- Sky is featureless & visibility >10km
- Very dark night with no stimuli outside cockpit to focus on
- Hazy conditions when optical properties of atmosphere alter appearance of aircraft & terrain
- Bright light & glare in sunny conditions over cloud/flight course in direction of sun
- Flying over snow/desert with featureless ground and over large bodies of water

Pre-flight planning:

- Route study, Weather condition, Equipment, Alternate plan
- Taxi speed illusion → Speed is deceptive & depth perception is reduced
- Takeoff and climb: Takeoff into black-hole, somatogravic illusion
- Cruise: Ability to detect & monitor weather, terrain detection
- Approach and landing: Runway detection, effects of runway slope, runway dimensions,
  runway lighting, atmospheric conditions, black-hole approach
- Black-hole illusion: Airport near brightly lit city with few/no terrain features/light between you and airport
  Airport that is on coast/lake shore
  Airport in very sparsely settled areas

Preventative measures:

- Recognize normal human visual limitation
- Learn visual illusions at night & use CFS for more info
- Use instruments for approaches: ILS, DME readouts, altimeter
- Airport aids: VASIS, T-VASIS, PAPI
- Avoid visual long straight-in approaches
- Use radio nav and GPS
- Pay attention to alert devices: Radio, altimeter, GPWS
- Double check expectations & perceptions
- Adequate sleep & nutrition

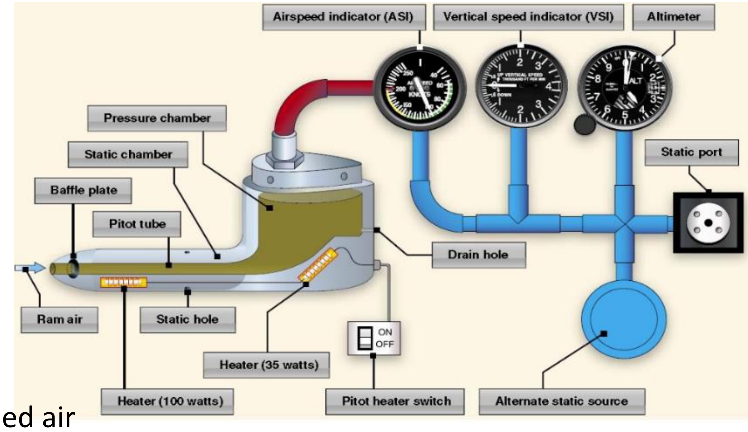
Chapter 10

Flight instruments

1. Pitot-static system

Pitot-static system:

- 3 instruments are connected to it: Altimeter, Vertical speed indicator, Airspeed indicator
- 2 main parts: Pitot & lines, Static port & lines
- Must be inspected every 24 months for IFR flights



Pitot tube:

- Connected only to airspeed indicator
- Atmospheric pressure in this tube is increased by dynamic pressure due to forward motion of plane through air
- Check to see pitot tube is not blocked & cover is taken off before flight
- Mounted lower & ahead of wing: Ensure undisturbed air
- Mounted further out the fuselage: Avoid interference of slipstream
- May have error when flying at high AOA ∵ Air is not forced into the pitot tube

Static pressure port:

- Connected to airspeed indicator, altimeter, vertical speed indicator
- Allow air pressure inside instruments to equalize with outside barometric pressure
- Check whether it is free of contaminants & not covered prior to flight & flush with fuselage
- Many ultralights do not have pitot static systems

Heated pitot tube:

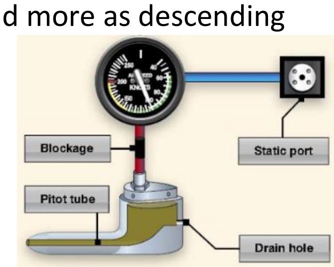
- Any aircraft used for IFR must have electrically heated pitot tube to prevent icing
- A switch in cockpit controls pitot heat
- N/A to ultralight

Alternate static source:

- Select internal static source if outside source becomes clogged with ice
- Some aircraft will come with an actual control labelled as Alternate static
- If not, one may pull the static line from the source (e.g. Located under the carpet on pilot side for 152)
- Extreme case: Break glass of vertical speed indicator
- Instruments relying on static pressure may operate differently:
  Altimeter may indicate a higher than actual altitude
  Vertical speed indicator will momentarily indicate climb then settle back to initial
  Airspeed indicator will indicate greater than normal airspeed
- IFR flight requires alternate static source
- Cabin pressure almost always lower than outside pressure
- N/A to ultralight

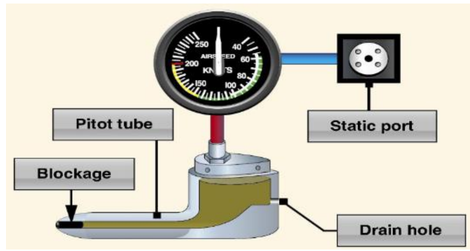
Blocked static port:

- Airspeed indictor: Under-read more and more as climbing, over-read more and more as descending
- Altimeter: Stop moving
- Vertical speed indicator: Reduce to 0 if climbing/descending and remain at 0



Completely blocked pitot:
- Affected airspeed indicator only
- During a climb: Airspeed will ↑ , During a descent: Airspeed will ↓
- Causes airspeed indicator to act like altimeter (Increase in climb & decrease in descent)

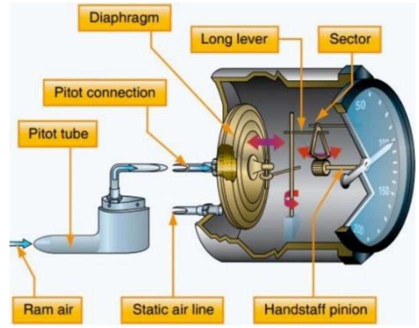
Partially blocked pitot tube:
- Drain hole is still open ∴ Allow dynamic pressure in pitot to slowly leak out
- Airspeed indicator will decrease to 0



Pitot and static port types:
- C-152 & C-172: Pitot & static port are separate
- PA-28 & DA-40: Pitot & static port are combined

Pressurized airplane pitot/static:
- If instrument static pressure line becomes disconnected inside pressurized cabin during cruising: Altimeter & airspeed indicator will both read low
- Altimeter would indicate cabin pressure altitude (lower than actual altitude of plane)

2. Airspeed indicator

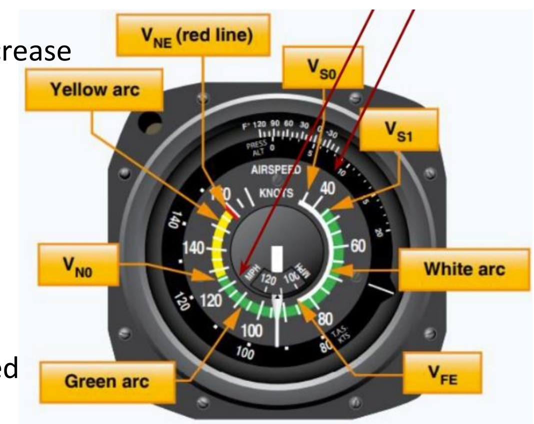


Principle of operations:

- Pitot tube measures dynamic & static pressure
- Air's velocity decreases to zero creating build-up in pressure in pitot tube
  → Fills the diaphragm & causing diaphragm to expand
- Static port fills interior of instrument surrounding diaphragm
  → Resist diaphragm expanding, equalizing static pressure leaving only dynamic pressure

Error and malfunctions:

- Speed directly off the dial: Indicated airspeed
- "I C E T"
- Positional error: Caused by position of pitot tube
  1. Travel through air turbulent eddies are created
     ∴ Give incorrect readings
     Sol: Single engine: Position as far as possible ahead of wing's leading edge
     Multi engine: Near nose of aircraft
  2. Angle at which pitot tube meets airflow
     Sol: Aligned to be most accurate during approach
     → IAS corrected for positional error = Calibrated airspeed
- Compressibility error: Introduced at higher airspeed (>250kt)
  → CAS corrected for compressibility error = Equivalent airspeed
  Pilots of C-152 & ultralight do not have to worry about this
- Density error: Caused by changes in altitude & temperature
  Sea level: IAS = TAS ∴ As altitude ↑, TAS > IAS
  Add 2% to IAS for every 1000ft of pressure altitude increase
- Pitot static system can malfunction if being blocked



Markings:

- Top of arc: Higher speed, Bottom of arc: lower speed
- White arc: Flap operating range
  V_{SO}: Bottom of white, power off, full flaps, stall speed
  V_{FE}: Top of white, maximum flap extension speed
  May be permitted to use partial flaps above this speed
- Green arc: Normal operating range
  V_S: Bottom of green, power off stalling speed with clean config (Gear & flaps up)
  V_{NO}: Top of green, maximum structural cruising speed
- Yellow arc: Caution speed range
  Operate at these speeds only in smooth air & do not make abrupt control movements
  V_{NO}: Bottom of yellow, maximum structural cruising speed
  V_{NE}: Top of yellow, red line
- Red arc: V_{NE}: Never exceed speed, maximum speed the plane can be operated
- Blue line: Used on multi-engine airplanes, Best single-engine rate of climb
  V_{YSE}: Speed to maintain in event of engine failure

Airspeed definitions:

- Indicated airspeed: Uncorrected speed directly read off indicator
  Stalling speed is always the same in terms of IAS
  ∵ Pitot tube & static port both lose same amount of pressure at same rate

Values stated in manual such as approach speeds should be used as stated in POH

- Calibrated airspeed: IAS corrected for instrument & installation (position) error in pitot static system
  CAS can be found in the chart appears in POH/AFM
- True airspeed: CAS corrected for air density error
  Actual speed of plane through air
  TAS stall > IAS stall when at high altitudes/high temperature

True airspeed indicator:

- Built-in adjustment scales allow pilot to adjust instrument for temperature & pressure
- Both IAS & TAS can be read off indicator

Ground speed:

- Actual speed that aircraft is travelling over the ground
- TAS then correcting for wind speed & direction at altitude
- Ground speed check: Timing how long it takes to fly a known distance

Technically advanced type airspeed indicator:

- Garmin & Avidyne systems: Tape type, left side of primary flight display
- Arcs & colour coding are the same as traditional, also provide V_X, V_Y, V_R
- Trend indicator: To see whether aircraft is accelerating/decelerating
- Provide TAS at bottom of tape, Ground speed is also given usually on multi flight display

Indicated stalling speed:

- During normal conditions of weight & environment, plane will stall near published IAS
- Stall IAS does not change with change in altitude
- Alt ↑, TAS stalling speed ↑ ∵ Aircraft need to fly faster to obtain same IAS & same amount of lift

Stall speed factors:

$V_{ref} = 1.3 \times V_{S0}$

- Bank angle: $V_{ST} = V_S \times \sqrt{\text{(Load factor)}}$
- Centre of gravity: Forward COG = Stall speed ↑
  Need to pull back to hold nose up → Up elevator increases download on horizontal stabilizer which acts like extra weight
  ∴ Need to fly at higher AOA for same airspeed as compared to rearward/aft loading
- Weight: Weight ↑, Stalling airspeed ↑
  Fly at higher AOA for same airspeed compared to when it is lightly loaded
  ∴ Wing will reach critical AOA sooner → higher stall speed
- Turbulence: Cause stall airspeed ↑ as gust may increase AOA suddenly
  Wind shear: ↓ speed of air over wing ∴ ↓ amount of lift
  E.g. sudden reduction in headwind/sudden increase in tailwind
  Rule of thumb: Add half of gust factor to approach speed
- Contamination: Frost, snow, ice, mud → ↑ stalling airspeed
  ∵ cause airflow over wing to separate sooner
  Roughness of medium/coarse sandpaper: ↓ lift by 30%, ↑ drag by 40%
- Power: ↓ stalling airspeed, Upward component of thrust changes relative airflow & ↓ AOA
  Extra airflow over root of wing → improves amount of lift
- Rapid change of airflow: Accelerated stall: From cruise to climb, relative airflow changes with attitude
  If pitch quickly, relative airflow cannot change as quickly & critical AOA will be exceed at high speed

Hot/high=Faster IAS:

- High temp & high elevation: ↑ landing roll ∵ TAS > IAS

Equivalent airspeed:

- CAS corrected for adiabatic compressible flow at altitude of flight
- Sea level: EAS = CAS, other altitude: EAS < CAS (Below CAS of 200kt/10000ft then negligible diff.)
- At mach number below onset of wave drag: Aerodynamic force & moments are proportional to square of EAS

3. Multi-engine airspeed and definitions

Minimum control speed (V_{MC}): NOT ↑ when weight ↑

- Retain control & maintain straight flight with max rudder deflection & not more than 5° of bank following failure of critical engine
- Travel air: 80mph IAS
- Determined with conditions: Engine developing max rated power at time of critical engine failure
  Min practical test weight with rearmost COG
  Landing gear retracted, flaps takeoff position
  Propeller of failed engine windmilling
- At speed low than V_{MC}: Plane will yaw & roll towards failed engine
  → Gain control by only reduce power in good engine/increase airspeed through change in attitude/both

Critical engine in light twin is eliminated
⇒ opposite rotation of propellers with clockwise on left & counter-clockwise on right

Decision speed (V_1):

- Committed to fly & cannot stop on remaining runway
- Below: Could stop on runway & abort takeoff
- Above: Continue & use V_2/V_{YSE} for climb
- N/A for light piston

Rotation speed (V_R):

- Speed to start flying & raise the nose
- Travel air: 85-90mph IAS

Takeoff safety speed (V_2):

- Can be safely flown on one engine
- N/A for light piston (Would use V_{YSE} instead)

Design flap speed (V_F):

- Max speed that flaps may be extended
- Travel air: 130mph IAS

Intentional one engine inoperative speed (V_{SSE}):

- Speed above V_{MC} & V_S is selected to provide marginal lateral & directional control when one engine is suddenly rendered inoperative (If not given in POH, use V_{MC} +10kt)
- Intentional failing of one engine below this speed is not recommended
- Travel air: 90mph IAS

Maneuvering speed (V_A):

- Max speed that full control will not overstress the plane
- Travel air: 160mph IAS

Flap extension speed (V_{FE}):

- Maximum speed at which flaps can be fully extended
- Travel air: 130mph IAS

Maximum speed with landing gear extended (V_{LE}):

- Maximum speed to fly with landing gear extended
- Travel air: 165mph IAS

Best angle of climb (V_X):

- Gives most altitude in least distance
- Use to clear obstacle
- Travel air: 83mph IAS

Best rate of climb (V_Y):

- Gives most altitude in shortest time
- Travel air: 103mph IAS

Single engine best-rate-of-climb speed (V_{YSE}):

- Most altitude in shortest time on single engine
- Indicated on ASI as blue line
- Travel air: 108mph IAS

Single engine angle-of-climb speed (V_{XSE}):

- Most altitude in least distance on single engine
- Travel air: 98mph IAS

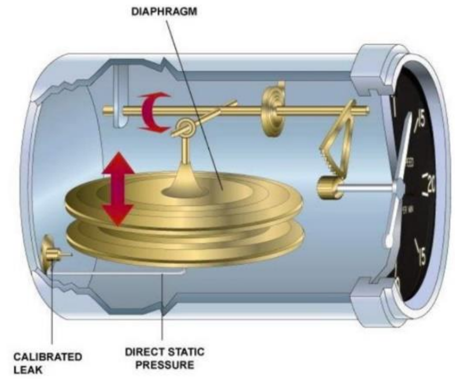
Stall speed – Clean configuration (V_S):

- Stalling speed with gear & flaps up
- Travel air: 85mph IAS

Stall speed – Landing configuration (V_{SO}):

- With gear & flaps down
- Travel air: 75mph IAS

4. Vertical speed indicator



Vertical speed indicator:
- Rate at which aircraft is ascending/descending
- Feet per minute
- Only connected to static port

Principle of operations:
- Contains small capillary tube that allows air to leak at slow & calibrated in/out of sealed case
- Pressure inside case is compared to pressure inside aneroid bellow (Experience pres. change instantly)
  → Pressure inside case & bellow will be same when stops climbing/descending → Read 0, level pointer
- Small change of pressure = Small rate of up/down
- Climb: Deflected upwards showing a climb in FPM

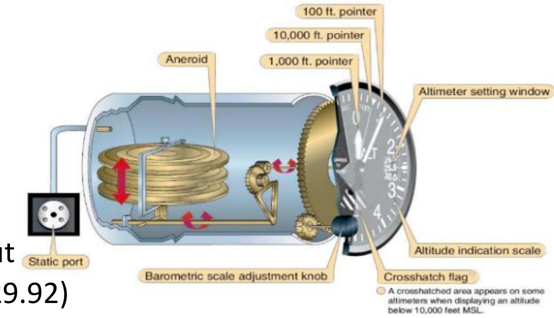
Error and malfunctions:
- Lag error: Takes 6-8 seconds for pressure differential to indicate climb/descent
- Do not depend on VSI when changing attitudes
- No delay/instantaneous VSI costs $40,000 ∴ Use lagging VSI

Reversal error:
- Sharp/sudden pitch change → Vertical speed indicator will temporarily show the opposite direction
- Pitch up will show descent/Pitch down will show climb
- Due to sudden pressure change around plane

Using the VSI:
- Small piston powered aircraft: Rate of climb < 1000FPM
- En-route/During approach to landing: 500FPM
- Straight & level: 0 FPM
- Check whether it show 0 on ground, otherwise ask mechanic to use adjusting screw to calibrate

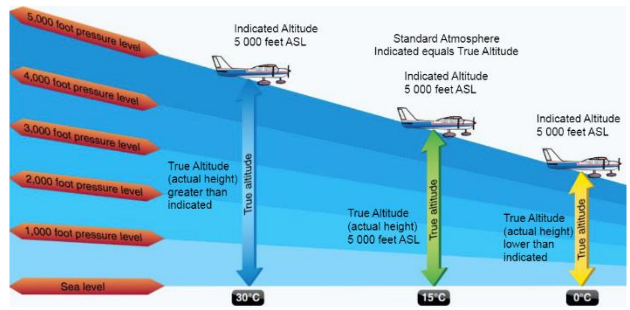
Glass cockpit VSI:
- Garmin: Tape that point to VSI speed in FPM
- Avidyne: Needle to show VSI

5. Altimeter



Principles of operation:

- Aneroid barometer that measures pressure of atmosphere
- Connected to static port, allow atmospheric pressure to move in & out
- Series of aneroid capsules that are filled with standard atmosphere (29.92)
  → Static pressure ↓ then aneroid capsule expands ∴ Indicate climb
- Altimeter is designed with standard atmosphere
  → Sea level, 29.92in of mercury, 15°C,
  Temp decreases 1.98°C & Pressure drops 1inch per 1000ft, Air is dry
  Nothing more than an engineering reference point



Marking:

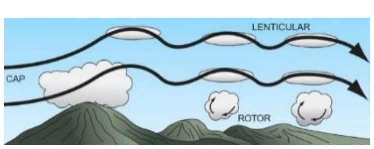
- Large: Hundreds, Small: Thousands, Smallest: Ten thousand
- Adjustable barometric scale: Kollsman window
- Three point altimeter, drum altimeter, G1000 altimeter

Kollsman window:

- Adjust altimeter for differences in atmospheric pressure by getting altimeter setting and set
- After setting altimeter setting, alt. should be within 50ft of field elevation
- Uncontrolled aerodromes: Set altimeter to elevation of aerodrome → gives us the altimeter setting

Altimeter errors:

- Altimeter setting changes as flying from one place to next ∴Must adjust, reflect local altimeter setting
  → Flying from high press. to low press. & no correct setting, Altimeter will read too high (Fly too low)
  Flying from low press. to high press. & no correct setting, Altimeter will read too low (Fly too high)
- Low pressure systems: From high press. area to low press. area is dangerous
  Northern hemisphere: Drift to right = Fly into low press. area
  ∵ Counterclockwise airflow around a low in N. hemi.
  ∴ Uncorrected altimeter will read too high
- Abnormally high pressure: Caused by extremely cold & dry air & produce press. > 31.00in Hg
  Highest setting is usually 31.00in Hg
  ATC will issue actual altimeter setting & confirm pilot sets to 31.00in Hg
  for operations below 18000ft ASL
  All IFR, CVFR, VFR below 18000ft ASL: set to 31.00in Hg even it's > 31.00
- Temperature: Pressure vary from place to place due to temperature variations
  Cold air is denser than warm air
  ∴ Given vertical depth: Pressure of cold air will change at greater rate than warm air
  For same change in pressure, warm air will have greater vertical depth than cold air
  Cold correction chart show how much indicated altitude can be out in cold conditions
- Mountain effect: Wind deflected around mountain will increase in speed (∵ Bernoulli's)
  ∴ Wind speed ↑ & local press. ↓, Altimeter read too high
- Mountain waves: Wind over mountain tops form waves of oscillating fast flowing air



Extend up to 700 miles downwind, cause severe downdraft & press. ↓ significantly
Severe nearest summit of mountain, up to 5000FPM
→ Drop in pressure can result in overreading by 3000ft
Downdraft can be smooth & pilot may not notice & altimeter will not register descent

Altitude terminology:

- Indicated altitude: Altitude we read on instrument, depends on accurately set altimeter setting
- Pressure altitude: Altitude when set to 29.92in Hg, based on standard atmosphere
  (29.92 – current altimeter setting) x 1000 + elevation
- True altitude: Exact height above mean sea level (e.g. heights on aeronautical charts)
  If 29.92in Hg & standard atmosphere conditions then TALT = PALT
  Indicated altitude corrects it for non-standard atmospheric pressure & temp
  Important to find out whether have enough obstacle clearance
  Error is greatest with large difference from standard temp along with high alt. AGL
- Absolute altitude: Actual height above earth's surface (AGL) with correct altimeter setting & non-standard variations in temp taken into account
  i.e. True altitude – height of terrain
- Density altitude: Pressure altitude corrected for nonstandard temp, affect actual performance
  Service ceilings & absolute ceilings are given in terms of density altitude
  Hot, High humidity, low pressure → High density altitude, Low actual density of air

Encoding altimeter:

- Allow ATC to know pressure altitude & position of transponder equipped aircraft
- Known as MODE C operation of transponder
- ATC radar detects transponder by series of pulses from encoding altimeter
- When pilot selects local altimeter setting in aircraft, pressure altitude readout to ATC will not be affected

6. Magnetic compass

Principles of operation:

- Only instrument in plane that pilot determines the direction of flight
- Magnets inside compass cause it to align with magnetic North Pole

Compass pivot:

- Like a paper cup being suspended upside down from its center on point of pencil
- Mounting the card on pivot then it can freely rotate
- Magnets are mounted on the inside lip near bottom of upside down cup (Prevent wobbling)

Compass construction:

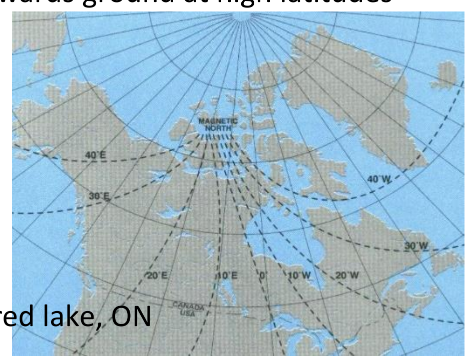
- Compass is enclosed in a casing filled with white kerosene to dampen out vibration/oscillations
- Lubber line: On glass face & show exact readings of compass

Compass operation:

- Case of compass & lubber line are fixed, Compass card within kerosene is free to move
- Magnets in compass will align with earth's magnetic field
- During turning: Card will rotate but casing & lubber line will stay fixed → New heading

Magnetic dip:

- Earth's magnetic lines of force are horizontal at equator, vertical towards the magnetic poles
- Needle will try to follow these lines of force & it will dip downwards/towards ground at high latitudes
  ∴ Compass becomes unreliable near magnetic pole
- A compass is balanced like pendulum to compensate for the dip
  → Centre of buoyancy is above COG



Variation:

- Magnetic north pole & true north pole are not located at same place
- Variation: Difference between true north pole & magnetic north
- Agonic line: Line of zero variation, right now in east of Kenora/west of red lake, ON
- Isogonic line: Lines of equal magnetic variation
- Variation values to the East of agonic line: Westerly variation, magnetic north is west of true north
  to the West of agonic line: Easterly variation, magnetic north is east of true north
- "East is least & West is best": Easterly variation → Subtract from true and get magnetic
  Westerly variation → Add to true and get magnetic
- Greatest compass error: Long east west cross-country

Deviation:
- Difference between compass indications when installed in aircraft compared to when outside aircraft
- Caused by influence of magnetic fields due to metal & electronic equipment
- Compass swinging: Park aircraft on a compass rose painted on level surface (Ramp/taxiway)
  Aligned with magnetic North marking on ground
  Turn on all electronic equipment & power up as normally operated
  Record deviation value in the compass reading from North
  Rotate the plane to the right every 30° and record the deviation until 360°
  Adjust the compass unless it is less than a few degrees
  Must be swung annually (During annual inspection)
  The check is noted in Journey Log Book & Compass correction card/Deviation card
- True → Variation → Magnetic → Deviation → Compass

Northly turning error:
- Caused by magnetic dip
- During turn: Friction, inertia, other forces cause inaccuracies
- "North lags and South leads": Turn from/to North: Initially rotate in opposite direction, lag by max 30°
  Turn from/to South: Initially rotate ahead of turn, lead by max 30°
- Greatest on headings of north/south and lease noticeable on headings within east/south quadrants
- Turns near east/west: Heading match compass ∵ Leading & lagging effects cancel each other out

Acceleration and deceleration errors:
- Caused by magnetic dip
- Only when flying on east/west headings
- Accelerating: Compass will register a turn to north, decelerating: Compass will register a turn to south
- "EWANDS": East and West headings, Acceleration North, Deceleration South

Check compass heading:
- On ground: Must be on level surface & away from any metal structures
- In flight: Only accurate when wings-level (no turn) and steady-state (Not accelerating/decelerating)
  ∴ Whether maintaining altitude/climbing/descending
  → Check it with wings level attitude & constant airspeed

Take care of compass:
- Avoid placing metal items like flight computers, rulers, clipboards, headsets, radios, speakers
- May introduce permanent change in indications of compass

7. Gyroscope

Principle of operation:

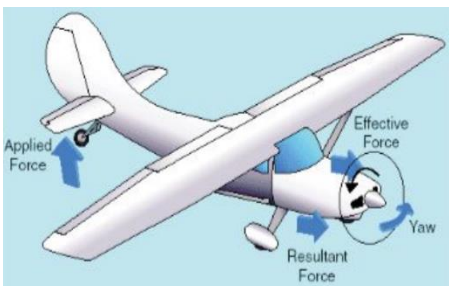
- Gyroscope: Rotor/spinning wheel rotating at high speed
  Typically mounted in universal mounting → Gimbal, axle can point in any direction
- Spinning object: Possess gyroscopic characteristics
  Outer rim has heavy mass, rotates at high speed on low friction bearings
  → Resists changes in direction

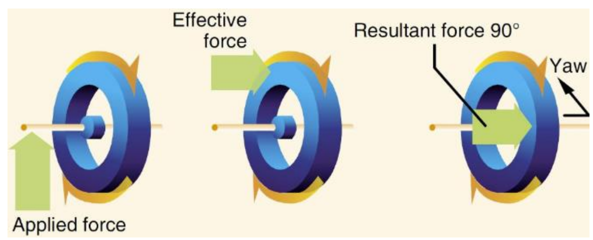
Rigidity in space:

- Once in motion then resist turning
- When gimballed (free to move in given direction): Instrument dial attached will remain rigid in space
  ∴ Stay in same position
- Once spin, housing holding the gyro turns around it → Panel moves around gyro & instrument face

Precession:

- Deflection of spinning wheel 90° to plane of rotation when deflective force is applied at rim
- Tail-dragger: When lifting tail, resulting force acts 90° from original force in plane of rotation



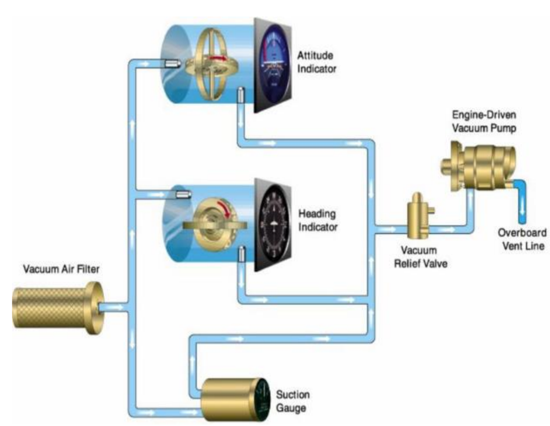


Vacuum driven:

- Require 4-6in Mg to operate
- Engine-driven vacuum system: Vacuum pump run by engine to create partial vacuum in system
  → Sucks air into system driving gyros
- Venturi-driven vacuum system: Venturi tube mounted on outside of aircraft
  → Airflow moving through constriction of venturi to create partial vacuum
- Typically power attitude indicator & directional gyro (or heading indicator)

Electrically driven:

- Powered by direct/alternating current provided by alternator/generator
- Typically power turn coordinator
  ∴ If attitude indicator fail, it becomes a backup/tiebreaker



8. Heading indicator

Principle of operations:

- Vacuum driven gyro instrument that indicates heading of aircraft
- Based on gyro spinning about horizontal axis
- Uses principle of rigidity in space
- Gyro inside instrument remains same place, aircraft & instrument case are turning about gyro

Errors:

- Friction forces cause it to precess
- Earth's rotation also causes precession (Apparent Precession, 0° at equator & 15° per hour at pole)

Reasons to use:

- Steadiness in turbulence & during other aircraft movements compare to magnetic compass
  E.g. Speed up/Slow down/Turn: Compass will have error but not the heading indicator
- Pilot need to readjust for apparent precession & frictional precession in timely fashion to be reliable

Setting the heading indicator:

- Not automatically synchronized with magnetic compass
- Pilot should set it to compass heading prior to takeoff
- Check against compass every 15mins during flight (Only in straight and level non-accelerated)
- Check heading indicator against runway number when lining up
- Will drift/precess by small amounts over time → Mechanical precession

Reading:

- North, east, south, west
- Numbered every 30°, Long marks every 10°, short marks every 5°

Limitations:

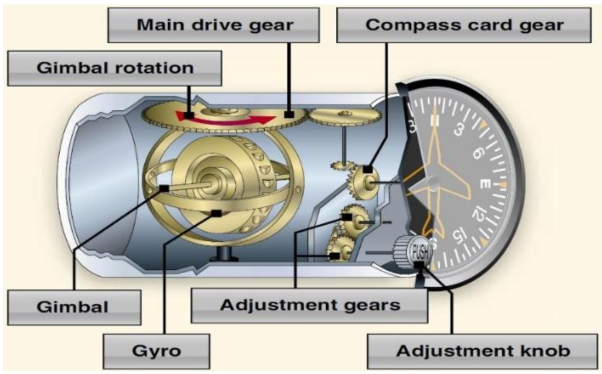
- Prone to tumbling
- Lose gyroscopic characteristics for maneuvers more than 55° of pitch/bank
  → Heading card will spin rapidly, cannot be used for navigation until reset

Glass type:

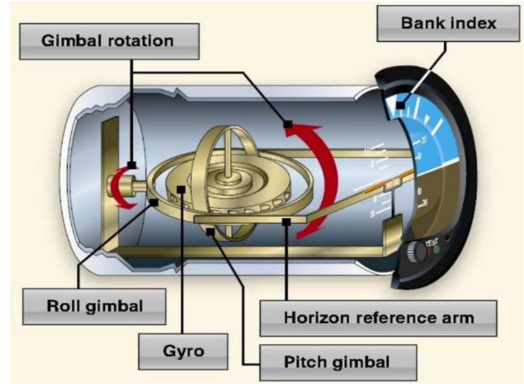
- Heading indicator is below attitude information on PFD
- Can set it to full 360° or 140° arc
- GPS, VOR, ADF, ILS can all be selected

Attitude and heading reference systems:

- Get information on pitch, bank, heading
- By lasers, accelerometers, magnetometers then feed to PFD
  ∴ No more tumbling
- If fail, have a traditional standby attitude indicator & compass



9. Attitude indicator



Principle of operations:

- Gyro instrument that is vacuum driven/electrically driven
- Provide an artificial horizon
- Based upon gimbal mounted gyro that spins about vertical axis
- Show rotation about longitudinal axis (AOB) & lateral axis (Pitch)
- Miniature wings: Attached to case remain parallel to wings of plane
- Horizon bar: Separates top (light) & bottom (dark)
- 1st three marks are 10° apart, next mark at 60° and 90°
- Align wings with horizon bar when on level ground
  → Wings above horizon bar = nose high
- Left turn: Blue portion of ball will roll to right
- Rigidity in space establishes reference plane which keeps gyro axis perpendicular to earth's surface

Errors/malfunctions:

- Acceleratings will indicate a climb
- Decelerating will indicate a descent
- Errors can be caused by bearing friction

Limitations:

- May tumble subject to pitch/bank maneuvers over 55°
  → Attitude card will spin rapidly ∴ Not for orientation

Power sources:

- Engine-driven vacuum
- Venturi-driven vacuum
- Electrically driven

10.Turn and bank indicator/turn coordinator

Purposes:

- Indicate rate of turn & quality of turn → Whether the turn is coordinated
- Turn coordinator: Identify both yaw & roll (Rate of yaw, Rate of roll)
- Turn & bank indicator: Identify only yaw (Rate of yaw = Rate of turn)
- Typically electrically powered

Turn and bank indicator:

- Turn needle: Linked to electrically driven gyroscope, shows direction of turn
- Doghouse: Mark on either side of center, represents Standard rate turn
  Moves through 3° of heading change per sec, 2mins to turn 360°
- Inclinometer: Glass level containing black ball, measure turn quality
  During straight & level/during turns: Should stay centered
  Moves by roll (Like inertia)

Turn coordinator:

- Miniature plane to show rate of turn
- Upper mark indicates level flight (Or no yaw) when wings align with them
- Lower marks indicate standard rate turn of 3°/sec

Turn quality:

- Centrifugal force: Outward & away from center of turn
- Coordinated turn: This force must be euqal to force of gravity acting on ball
  ∴ Ball will remain in middle

Skid:

- Not enough bank for rate of turn/Too much rudder
- Centrifugal force > Force of gravity
- Ball will go outside of inclinometer

Slip:

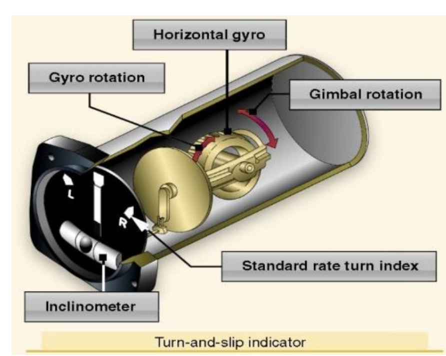
- Too much bank for rate of turn/Insufficient rudder
- Force of gravity > Centrifugal force
- Ball will go toward inside of inclinometer

Correcting for slips or skids:

- Step on the ball/Adjust AOB
- Slip: More rudder/Less bank
- Skid: Less rudder/More bank

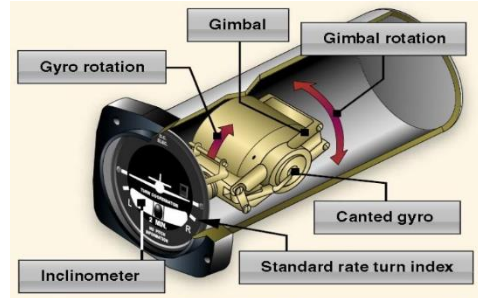
Principle of operations:

- Turn and bank indicator: Gyroscopic precession is used
  Spin axis of gyro is horizontal
  Gyros spins up & away from you
  Gimballed along plane perpendicular to spin axis
  Due to mounting
  → Only capable of responding to yaw



Turn-and-slip indicator

- Turn coordinator: Gyroscopic precession is used
  Gyro gimbal is angled/canted 30-35° to the horizontal
  → Capable of responding to yaw & roll
  Spin axis of gyro is horizontal
  Gyros spins up & away from you



Turn coordinator

Standard rate turn:
- Faster airspeed = Greater AOB to complete
- Rule of thumb: AOB = (KTAS/10) + 7

Taxiing:
- Turn and bank indicator: Needle indicates direction of turn, ball moves opposite direction of turn
- Turn coordinator: Little aeroplane bank in direction of turn, ball moves opposite direction of turn

11.Instrument flying

Control instruments:
- Attitude + Power = Performance
- Attitude indicator & Tachometer/Manifold pressure

Performance instruments:
- All others instruments, confirm the attitude and power

Classification of instruments:
- Pitch instruments: Attitude indicator, Altimeter, Vertical speed indicator
- Bank instruments: Attitude indicator, Turn coordinator, Heading indicator
- Power instruments: Tachometer, Airspeed indicator

Instrument scan:
- Continuous cross checking to make sure they are doing what they should doing
- Errors: Fixation, omission, over-emphasizing one instrument's indication

Instrument interpretation:
- Get the correct mental image of what is happening

Aircraft control:
- Apply correct attitudes & movements for situation
- Make change to control instruments, then monitor changes on performance instruments

Partial panel:
- Fly without all 6 of instruments → Normally without attitude & heading indicator
  ∵ Both run by vacuum system so likely to fail
- Need to modify normal scanning pattern to get all relevant information

Unusual attitudes:
- Unexpected rate/instrument indication contrary to what is expected → May end up with stall/spiral dive
- Causes: Improper scanning, inattentive, disorientation, turbulence, neglects cockpit duty, confused
- Prevention: Proper scanning, know your limits & be alert, aware of instrument limitations

Nose up approaching stall:
- Use Airspeed indicator & Turn coordinator as primary instrument, check trend of airspeed indicator
- Full power, nose down until ASI stops decreasing, level wings with TC, reduce to cruise power, check ins.
- Attitude indicator & Heading indicator may not be reliable because may have toppled
- Altimeter & Vertical speed indicator may not be reliable because have lag

Nose down spiral:
- Use Airspeed indicator & Turn coordinator as primary instrument, check trend of airspeed indicator
- Power off, level wing with TC, nose up until ASI stops increasing, increase to cruise power, check ins.
- Attitude indicator & Heading indicator may not be reliable because may have toppled
- Altimeter & Vertical speed indicator may not be reliable because have lag

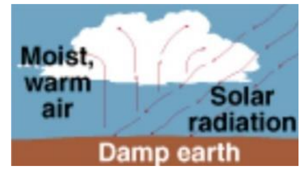
Chapter 11

Meteorology 1

1. The big picture

Sun:

- Energy from sun is root cause of all weather

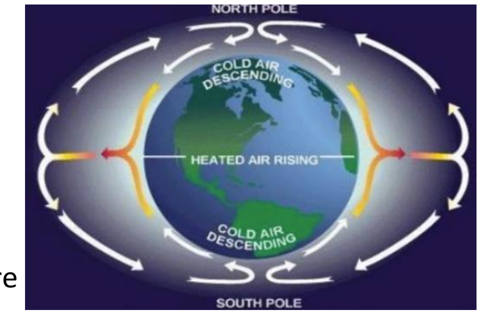


Radiation:

- Sun's rays strike earth then converts into heat energy

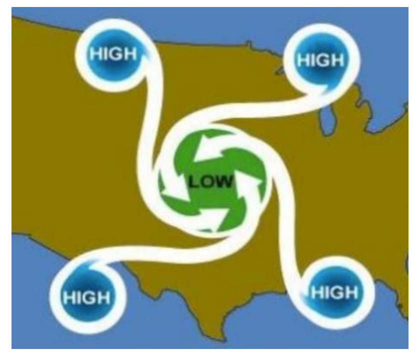
Uneven heating:

- Surface is heated unevenly ∵ Rotation of earth, land & oceans, seasons



Rising air:

- Rising air at equator ↓ air pressure, creating area of low pressure
  → Then travels towards pole then cool & sink forming area of high pressure



High to low:

- Area of high pressure always flow towards area of low pressure

Wind:

- Flowing air

Deflection:

- Wind does not flow directly to low
  ∵ Rotation of earth & terrain

Cold air to warm air:

- Wind moves cold air into warm air and vice versa

Fronts:

- Interacting areas of warm & cold air

Water vapour:

- Air is capable of carrying water vapour

Saturation:

- Air can only hold certain water vapour before it will try to get rid of it

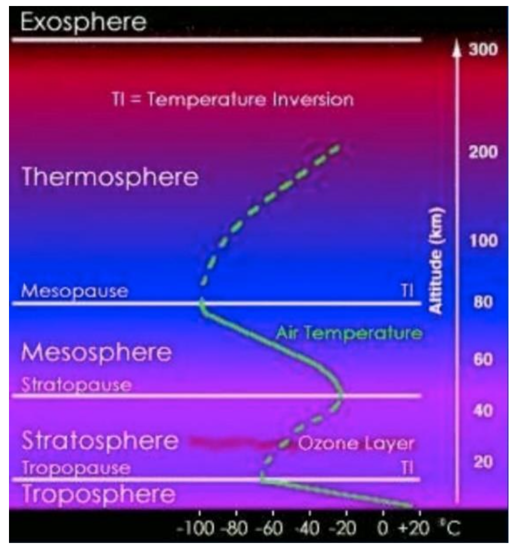
Clouds and precipitation:

- Form when water vapour is released

2. The earth's atmosphere

Composition/properties:
- 78% nitrogen, 21% oxygen
- 1% of argon, carbon dioxide, others gases & water vapour
- Water vapour: Responsible for fueling weather in atmosphere by transporting heat
- Properties: Capacity for expansion, mobility & compression

Vertical structure:
- Gaseous area surrounding planet is divided into several concentric spherical layers (Strata)
- Each strata is separated by narrow transition zones → "____pause"
- Move away from surface of earth then atmosphere gets thinner
- Atmospheric layers → Characterized by differences in chemical composition,
  Produce variation in temp & lapse rate



Troposphere:
- Means "Region of mixing" (Vigorous convective air currents occur)
- Closest layer, most weather takes place here
- Air is denser than higher layers
- Temp ↓ constantly with height, water vapour content also ↓
  → -1.98°C/1000ft (Standard lapse rate)
- >99% atmospheric water vapour is found here
  → Play major role in regulating air temp
  ∵ Absorbs both incoming solar energy & thermal radiation that is re-emitted by planet's surface

Tropopause:
- Boundary layer between troposphere & stratosphere
- Average temp: -56°C, remains relatively isothermal, sudden change in lapse rate
- Marks top of weather layer (except CBs), indicated by layer of haze
- Generally smooth flying conditions with little moisture
- Over poles the tropopause is nearest the earth: 8KM/25000ft
- Over equator: 18KM/54000ft
- Height is higher in summer than winter → Average height: 11KM/38000ft through globe

Stratosphere:
- 50000ft above tropopause, extends up to 50KM/180000fts
- Atmospheric pressures continues to decrease but air temp starts to increase to 0°C/273°K
  ∵ Ozone layer absorbs much of incoming solar radiation
- Does not permit convection ∵ temp increases → Weather is not able to punch through from tropopause
  ∴ Stabilizing effect on thunderstorms & other weather

Mesosphere:
- Layer from 50KM/180000ft to 80KM/275000ft
- Shift in lapse rate & temp decreases (Much more rapid & temp get much colder up to -100°C/173°)
- Concentrations of ozone & water layer here are negligible
- Higher altitude: Gases begin to form layers according to molecular mass

Thermosphere:

- Starts at 100KM
- Temp will increase up to 727-1227°C/1000-1500°K ∵ Intense solar radiation
- Where aurora/Northern lights are formed
- 100-200KM: Major components are still nitrogen & oxygen, gas molecules are widely separated

Exosphere:

- Starts at 500KM, up to 960-10000KM and relatively undefined
- 140-160KM: Enter realm of satellites, aerodynamic lift can no longer maintains height
- Transitional zone between Earth's atmosphere & interplanetary space
- Pressure is little more than vacuum

Standard atmosphere ICAO:

- Since atmosphere is constantly changing regarding temp, pressure & moisture content
  ∴ Need a baseline/ideal atmosphere for meteorologists & engineers
- Rarely exists in real life
- Condition: At sea level
  29.92in Hg/14.7lbs per sq inch/1013mb or hPa
  15°C/59°F
  1in HG drop per 1000ft increase
  1.98°C drop per 1000ft increase (Standard lapse rate)
  Dry air mass, no precipitation

ISA conditions:

- ISA +3 = 3°C warmer than standard

3. Atmospheric pressure

Pressure:
- Force per unit area exerted against surface by weight of air above that surface
- Number of air molecules ↑ , Greater force on that surface & pressure ↑

Pressure measurements:
- Aviation: Inches of mercury ("Hg)
- Meteorologists: Millibars (mb)
- 29.92in Hg = 1.0 atm = 101.325 kPa = 1013.25 mb

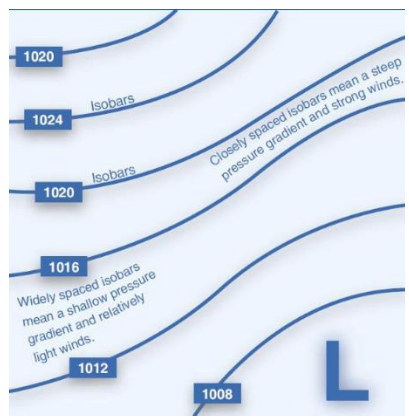
Station pressure:
- Actual weight of column of air extending upwards from station to outer limit of atmosphere

Mean sea level pressure (MSL):
- Station pressure reduced to sea level using average temp of past 12hrs
- Column of warm air exert less pressure than column of cold air

Isobars:
- Connecting areas of equal pressure (After correcting for MSL pressure)
- Isobars are shown as being 4mb apart
- Indicating whether pressure changes are gradual/dramatic over distance

Pressure gradient:
- Change in pressure over given distance

  → Closer isobars = Greater/Steep pressure gradient = Stronger wind
- Air flows from areas of high pressure to low pressure → Wind



Horizontal pressure differences:
- Due to atmospheric heating occurs differently at different times & places
- Warm air rises & create low pressure, cold air sinks & create high pressure

Pressure system:
- High pressure systems: Area where air is sinking

  Northern hemisphere: Rotating clockwise & gently outwards from center

  AKA Anticyclone

  Can be caused by drop in temp ∵ Density of air ↑ when temp drop so it sinks

  Suppress upward motion required to develop clouds & precipitation

  ∴ Fair weather (Fewer clouds, good visibility, light winds, poss. early morning fog)
- Low pressure systems: Area where air is rising

  Northern hemisphere: Rotating counterclockwise & strong inwards flow

  AKA cyclone

  Caused by convergence of air coming into region being forced to rise

  → Air expands & become less dense

  Favors development of clouds & precipitation

  ∴ Cloudly weather & precipitation, Lows tend to be quick moving (Faster in winter)

- Trough: Elongated area of low pressure
  Symbol is a long purple line
  Bring clouds, showers, wind shift (Convergence/squeezing → forces lifting of moist air behind line)
  Fronts always lie in troughs
- Ridges: Elongated area of high pressure with a low pressure on each side
  Fair weather is associated
  Rare to see the symbol (Sawtooth pattern) 
- Col: Neutral region between 2 highs & 2 lows
  Weather tend to be unsettled (Fog in winter, Showers & thunderstorm in summer)

Effect of temperature on pressure:

- Constant pressure: Warmer air will have higher/greater height than cooler air
  Warm air is less dense than cold air
  Moving same distance upwards/downwards in warm air results in smaller pressure change
- Same altimeter setting: During winter, it is closer to ground when flying circuit than summer

4. Meteorological aspects of altimetry

Altimeter setting: Based on standard temp & lapse rate

- Station pressure taken hourly then reduced to sea level pressure using ISA (15° and -1.98°/1000ft)
- Only accurate in vicinity of reporting station
- Expressed in inches of mercury in North America
- Turn altimeter sub-scale down = Indicate lower altitude
- Set in Kollsman window, need to re-calibrated if the indication vary >50ft from field elevation
- MSL pressure: Uses AVERAGE temp over past 12hrs instead of STANDARD temp (Station pressure)
- Necessary to adjust altimeter setting from one station to next, best within 100miles

Altimeter pointers moves when:

- Changes in air pressure: Aircraft changes altitude → Pressure within altimeter case changes
  ∴ Expands/contracts the aneroid barometer then rotate pointer through linkage
  Pressure ↓ = Indicated altitude ↑, Pressure ↑ = Indicated altitude ↓
- Strictly mechanical: When knob on altimeter is rotated
  Linkage allows pilot to change altimeter to field elevation/setting given by ATC/FSS
- Non-standard temperature: Should be compensated for min obstacle clearance/decision height for instru. when flying IFR during winter (less than/equal 0°C)

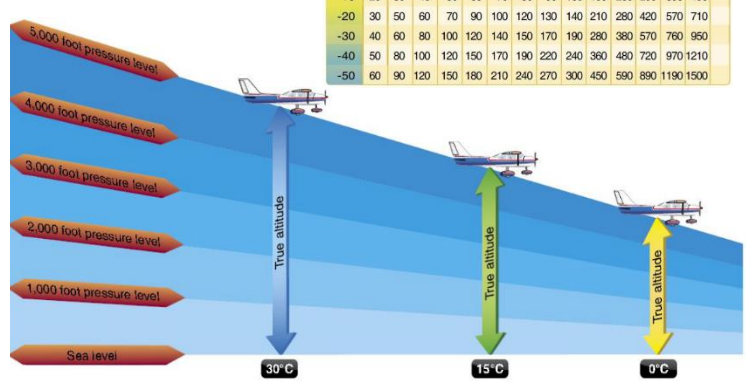
Flying from different pressure areas:

- From high to low, look out below (If no adjustment then will slowly descend)
- From low to high, too much sky (If no adjustment then will slowly ascend)

Reported Temp 0 °C	Height Above Airport in Feet 200	300	400	500	600	700	800	900	1000	1500	2000	3000	4000	5000
+10	10	10	10	10	20	20	20	20	20	30	40	60	80	90
0	20	20	30	30	40	40	50	50	60	90	120	170	230	280
-10	20	30	40	50	60	70	80	90	100	150	200	290	390	490
-20	30	50	60	70	90	100	120	130	140	210	280	420	570	710
-30	40	60	80	100	120	140	150	170	190	280	380	570	760	950
-40	50	80	100	120	150	170	190	220	240	360	480	720	970	1210
-50	60	90	120	150	180	210	240	270	300	450	590	890	1190	1500

Flying from different temperature areas:

- From hot to cold, you are being bold
  (If no adjustment then will slowly descend)



Pressure altitude:

- Altitude indicated when set to 29.92in Mg (ISA)
- (29.92 – Current altimeter) x 1000 + Elevation

Density altitude:

- Pressure altitude corrected for nonstandard temp
- The height that the aircraft thinks it is above sea level → Affects aircraft's performance (Best prediction)
  e.g. higher density altitude = poorer performance
- When temp > ISA → Density altitude > Pressure altitude
- When temp < ISA → Density altitude < Pressure altitude
- Performance chart in POH/AFM is based on density altitude
- Standard ISA then pressure altitude = density altitude

True altitude:

- Exact height above sea level
- When temp < 0°C then need to correct for obstacle clearances during IFR
- Rule of thumb: Multiply by 4ft per 1000ft for each 1°C temp varies from ISA
- Find PA, Set PA opposite to OAT(Based on indicated) in E6B, Subtract station from indicated to find AGL
  Find AGL in middle circle & read correction in outer circle, Add correction to station altitude
- Cold temp = Lower true altitude

5. Temperature

Temperature scale – Fahrenheit or Celsius:

- Metric: Freeze at 0° and boil at 100°
- Fahrenheit: Freeze at 32° and boil at 212°

Radiation heating:

- Incoming shortwave tangent radiation from sun's ray are absorbed by earth and warm it
- Warmth is re-radiated into atmosphere as infrared radiation which has longer wavelength
  → Terrestrial radiation
- Water vapour & carbon dioxide are effective at absorbing infrared radiation → Warm surrounding atm.
- Water vapour can be present throughout troposphere & warm area with greatest moisture
  ∴ Clouds are good at absorbing terrestrial radiation → Send it into space & back towards earth

Terrestrial radiation + Conduction = Heating:

- Atmosphere is heated from below → Bottom to top

Diurnal variation:

- Day time: Vertical currents begin as sunrises
  → Faster air aloft is brought down, lower surface air is carried aloft
  Surface wind to increase in speed, veer in direction & become gusty
- Night time: Earth gives off energy that it has received → Lead to cooling
  Surface wind decrease in speed & back in direction
  Do not occur over large lakes & oceans since nocturnal inversions do not develop over water

Seasonal variation:

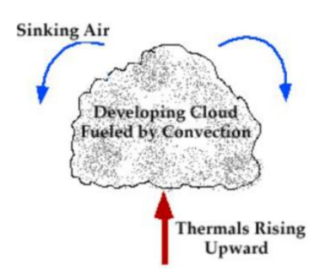
- Aixal tilt of earth → Angle of incoming solar rays strike the earth changes
- Shallow lighting angle = Less heating → Winter, Steeper lighting angle = More heating → Summer
- More hours of daylight in summer so more heating

Latitude:

- Equator: Sun is nearly overhead throughout entire year → Strong heating
- More northern/southern latitude: Sun is far from overhead → Energy being spread out

Topography:

- Land is quicker to soak up solar radiation than oceans/lakes
  → Land will heat up much quicker
- Land is quick to release the heat, lake/ocean will stay warmer for longer
- Vegetation & soil type can change amount of heating



Convection:

- Air near warm surface is heated & rises due to buoyancy, different materials convect differently
- Transport heat in vertical sense efficiently, greatest during summer afternoon

Advection:

- Air is carried from cold area of earth's surface to warm area by wind
  → Then warmed by surface from below ∴ Moves heat laterally

cloud is not form by condensation

Conduction:
- Layer of air that are in immediate contact with earth's surface area heated through conduction
- But air is poor conduction ∴ Conduction only responsible for heating in layers nearest the surface

Latent heat:
- Heat energy that is hidden in water vapour
- Water vapour will be carried in high level of atm. → Release heat & condense, warm surrounding air

Compression:
- Air sinks/subsides → Compressed by increasing air pressure of lower atm. ∴ Warm up air

Turbulent mixing:
- Turbulence caused by friction between air & ground creates eddies in up and down motion

Radiation cooling:
- Earth's surface continues to radiate heat after sunset
  → Ground is cooled down & air in contact is also cooled, may form fog
- Rarely has effect beyond first few thousand feet above ground

Advection cooling:
- Carries air from warm area to cooler area

Adiabatic cooling:
- Rising air will start to expand & lead to cooling, happen near mountains/fronts/area with convection
- Not saturated (no visible moisture): Dry adiabatic rate of -3°C/1000ft
- Saturated: -1.5°C/1000ft

Horizontal differences in temperature:
- Surface temp is warmest at equator ∵ Steep angle of sunlight
- Coolest at poles

Temperature variations with altitude:
- Air temp cools with height → Standard lapse rate: -1.98°C/1000ft
- Environmental lapse rate: Observed change in temp with increase of altitude & not a constant value

Inversions:
- Where temp of atm. ↑ with alt. ↑ & air is very stable (Act as barrier to vertical movement of air)
- Causes: Surface based inversion → Radiation cooling from surface on clear nights (Nocturnal radiation)
  Shallow cold front blowing in under warmer air
- Stability of atmosphere: Depends on ambient temperature lapse rate
- Low level temp inversion & high relatively humidity: Smooth air, poor visibility due to haze/fog/stratus
- Strong temp inversion: Wind shear during takeoff/landing

Isotherms:
- Joining places of equal temp on map

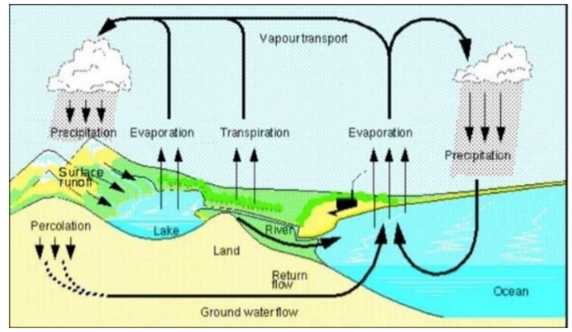
Isothermal layers:
- Temp remains same at different altitudes, very stable air

Chapter 12

Meteorology 2

1. Moisture

States of matter:
- Solid: Atoms & molecules in fixed position, constant shape
- Liquid: Weaker internal force Can hold together, not maintain constant shape
- Gas: Atoms behave randomly & gas expands to fill space
  Confined to atm. by Earth's gravity



Change of state:
- Add/take away from atm. from changing state
- Amount of water vapour that air can hold is controlled by temp
- Melting: Solid to liquid, absorbs heat
- Evaporation: Liquid to gas, absorbs heat
- Condensation: Gas to liquid, gives up heat (If temp = dew point, clouds/fog/dew are formed)
- Freezing: Liquid to solid, gives up heat
- Deposition: Gas to solid, gives up heat (Hoarfrost & snow)
- Sublimation: Solid to gas, absorbs heat (Dry ice, freeze drying)

Dew point: cool = Energy given off during condensation/deposition
- Temp of air must be cooled in order to reach 100% saturation
- Give measurement of how much water the atm. is holding (Higher DP = greater moisture content)
- Amount of water vapour that air can hold depends entirely upon temp (Warmer can hold more moisture)

Relative humidity: Air subsides: Temp ↑, relative humidity ↓
- Ratio of actual water vapour present in air to how much water vapour the air can potentially hold
- Saturated air: 100% relative humidity → Precipitation/fog
- Spread between dew point & current temp can show indication of relative humidity
  → Small spread: presence of lower clouds & potential of fog

Cloud formation:
- Clouds form when warm air rises → Expand & cool → Water vapour starts condensing as air rises

Dry adiabatic lapse rate:
- Adiabatic: Dry parcel of air (not yet experienced saturation) does not mix with surrounding air
  → Parcel rises through atm., surrounding pressure is lower so parcel expands
  Less energy per unit of volume → Air cools
- -3°C/1000ft, use for calculations of temp at altitude for dry air/Stratus (Subsiding air will warm at DALR)
- -2.5°C/1000ft, use for calculations of cloud base ($\because$ Decrease in dew point temp: -0.5°C/1000ft)

Saturated adiabatic lapse rate:
- Take into account that significant energy (latent heat) is released when water condenses
- When air cools to dew point & water starts condensing → Air parcel cools more slowly
- -1.5°C/1000ft, use for calculations of temp at altitude in saturated air

Calculation:
- Cloud base: Find dew point spread, 2.5°C/1000ft, Add to elevation
- Freezing level: Find new dew point (0.5°C/1000ft), 1.5°C/1000ft (3°C if -ve DP), Add to cloud base & AGL
- Layer cloud use 3, Convection cloud use 2.5

Precipitation:
- When water droplets grow sufficiently in size & weight to overcome lifting agents (Fronts/updrafts)
- Stronger updraft → Larger drops (∵ Collide with other drops & absorb then grow in size)

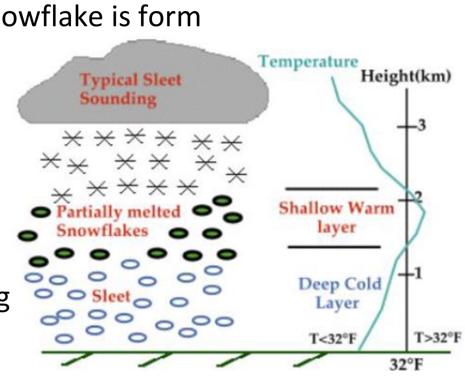
Convergent and cyclonic rainfall:
- Caused by convergence of two air masses (front)
- Warm front rainfall tends to be steady, Cold front rainfall tends to be showery

Orographic/Relief rainfall:
- Warm moist air is forced to rise over obstacle
  → Cool & allow condensation to take place then form clouds & precipitation
- Also can increase amount of cyclonic rainfall by retarding speed of depression's movement
- Cause air stream to converge & funnel through valleys
- Rainfall totals will increase where mountains are parallel to coast, rain shadow on leeward side

Convectional rainfall:
- Occur when ground surface is locally heated & adjacent air expands & rises
- Heating occurs daily in summer, air remains warmer than surrounding air then continues to rise
- Large cumulonimbus clouds are likely to form
  → Has effect of cooling air as it falls because some will evaporate as it falls
- Unstable conditions force air to rise in strong vertical updraft
- Updraft is maintained by energy released through latent heat as water vapour condenses then freezes
- Top of cloud is characterized by ice crystals & flattened by reaching temp at tropopause
- Ice crystal & frozen water droplets become large enough then fall
  → Create downdraft that reduces warm air supply to chimney and limit lifetime of storm
- Lightning: Ice crystal in upper cloud create +ve charge & ground retains -ve charge

Snow:
- Same conditions as rain but dew point temp are below freezing so vapour condense straight to solid
- Ice crystals will form if there are small particles present for them to form onto
  → Aggregate to form snowflakes, Heaviest when air temp is just below freezing

Sleet/ice pellets:
- Mixture of ice & snow formed when upper air temp is below freezing → Snowflake is form
- Lower air temp is just above freezing (2-4°C) → Partially melted into sleet
- If cold layer is thick enough → Precipitation will refreeze into ice pellets



Freezing rain:
- Water droplets form in upper air then fall and turn into ice
  after come into contact with object → Forming layer of ice
- Falling rice remains supercooled preventing it from freezing until contacting
  → Very small droplets may remain in liquid form until -40°C
- Commonly found at winter warm fronts

Hail:
- Frozen rain drops which are > 5mm in diameter, usually forms in CB & in summertime/cold front
- Circulate up & down in clouds for long time until large & heavy enough to form downdraft
- Occurs when supercooled water droplets freeze

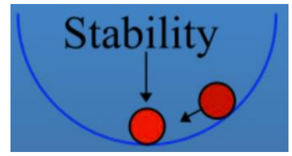
Dew/Frost:

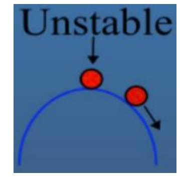
- Form under calm, clear, anticyclonic conditions → Allow earth to cool quickly, usually form 20ft AGL
- Dew point above freezing: Dew, Dew point below freezing: Frost through deposition

Ice pellets:

- Small translucent balls of ice smaller than hailstones
- Above-freezing air between 5000-10000ft AGL, sub-freezing air both above & under (Ahead of winter WF) → Melting of snowflake falling through warm layer & re-freeze to ice pellet in sub-freezing layer
- Winter warm front: When freezing rain freezes

2. Stability and instability





Definition:

- Stable air: Small change is resisted & system returns to its previous state
- Unstable air: Small change initiates a bigger change

  Lifting action in atm. → Stability ↓
- Stability: How a parcel of heated air would react within air surrounding it
- Adiabatic process: Like balloon filled with air at certain temp then how it reacts as it travels through air

Stable air:

- Smooth flying, Poor visibility
- Steady precipitation, Layer cloud (Stratus)
- Ultimate: Fog, Shallow lapse rate
- Inversion (Negative lapse rate), Warm air moving over cold air

Increasing stable conditions (Warmer air aloft):

- Surface cooling: → Radiation cooling: Calm clear night, air near surface cools quicker than air above

  Air aloft may re-absorb outgoing radiation, warm air in upper atm.

  ∴ Cooler air pools up near surface, Temp ↑ with height

  → Surface cold air advection: Cold air filters into region at surface

  Cause temp to drop faster at surface than high alt.

  Tend to enhance inversion
- Warming at higher alt.: → Radiation cooling: same as above

  → Warm advection aloft: Warm air moves into higher alt. & ↑ temp aloft

  → Subsidence inversions: Area of descending air (From high press./leeward side)

  Air warms as descending to lower alt.

  But rarely goes all the way to ground

  ∴ Layer (Few thou. ft) of air is warmer than air below it

Unstable air:

- Bumpy flying, Good visibility
- Showery precipitation, Cumulus cloud (Heap)
- Ultimate: Thunderstorm, Steep lapse rate
- High temperature/dew point spread

Increasing unstable conditions (Colder air aloft):

- Heating of surface: Radiation during daytime from sun will ↑ surface temp

  Variation horizontally in temp & density ∵ Amount of radiation absorbed differs

  ∴ Convection: Rising warm air replace cool dense air
- Surface warm air advection: Warm air moves into region at surface → ↑ temp faster than high alt.

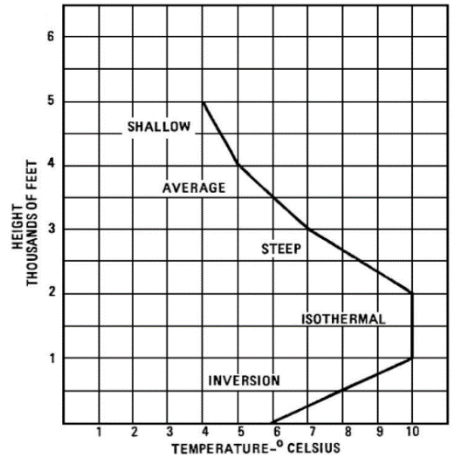
  ∴ Warm conditions at surface than at high alt.
- Air moving over warm surface: ∵ Cold convection, warm surface warms up the lowest layer of cold air

  ∴ Free to begin mixing with layers above
- Cooling of upper atm.: Cold advection aloft, Mixing of air,

  Large scale of rising air: Upper part (atm. weight ↓) of layer

  rises & cools more than bottom

Lapse rate:



- Steep lapse rate: Temp ↓ rapidly with alt. ∴ Instable
- Shallow lapse rate: Temp ↓ slowly with alt.
- Inversion: Temp ↑ with alt. ∴ Stable
- Isothermal layer: Temp does not change with alt. ∴ Stable

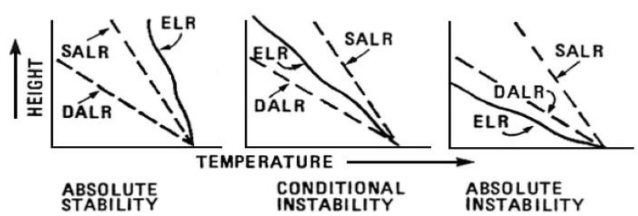
Way to cause surface heating:
- Radiation, Conduction, Advection, Convection

Way to cause surface cooling:
- Cold air advection, Radiation cooling

Lifting process that causes instability:
- Convection
- Convergence (Low pressure system): Excess air rises as pressure systems meet
- Mechanical turbulence: Surface friction
- Orographic lift: Air moving hills/mountains
- Frontal lift: Advancing air being pushed up by cold air on bottom
- Any lifting process can lead to cloud formation → Air cools, reaches saturation point, vapour condenses

Subsidence (High pressure system):
- When air sinks ∴ Compression & warming the air
- As it descends the cloud will disappear because liquid water droplets will evaporate

Absolute stability:



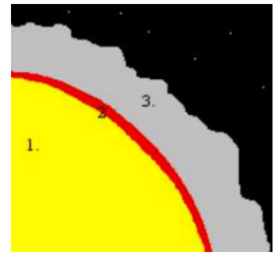
- Parcel of rising would always be cooler than air surrounding
- DALR & SALR > (Or steeper than) ELR

Conditional stability:
- Depends of whether the air is saturated or not
- DALR > (Or steeper than) ELR > (Or steeper than) SALR

Absolute instability:
- ELR > (Or steeper than) DALR & SALR

Potential instability:
- Depends on trigger mechanism such as lift
- Air is initially stable & unsaturated then becoming saturated ∴ Lapse rate changes & adds heat
- Resembles conditional instability
- ELR becomes steeper with altitude

3. The seasons



Sun:

- Statistic: Diameter 1.35 million km, Surface 6000K/10500°F,
  150 billion meters from earth, Light travels to earth in 8mins
- Visible layer: Photosphere, Chromosphere, Corona
- Solar wind: Outermost particles of solar corona moves fast & escape sun's gravity
  Interact with Earth's magnetic field & other particles in upper atm.
  ∴ Aurora Borealis/Northern Lights
- Sunspots: Sun's energy output operates in 11 year cycle
  Dark spots that are visible on surface of sun
  Not yet be able to prove that solar activity is related to climate
- Solar flares: Area above sunspot brightens & release huge amount of energy (UV, Radio, X-Ray etc)
  → Intensify solar wind & aurora, may interfere with radio & TV reception

Earth:

- Axis: Titled 23.5° with respect to Earth's orbital motion, Northmost (Southmost) = North (South) pole
- Equator: Encircles the widest point of Earth, equidistant from either pole at every point
- Rotation: Rotates along plane of equator, Looking over North Pole = Rotate counterclockwise

Seasons:

- Due to tilt of Earth
- Summer in Northern Hemisphere: Tilt toward the sun is maximum in late June
  → Also sun is further from Earth

Equinox:

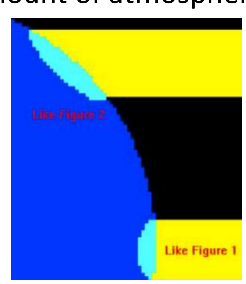
- When day & night are the same length, sun is directly over equator
- March 21 (Vernal equinox) & Sep 21 (Autumnal equinox)

Solstice:

- Either day/night are longest, sun is directly above 23.5°N/23.5°S latitude
- June 21 (Summer solstice, North Pole titled towards sun)
- Dec 20 (Winter solstice, South Pole titled towards sun)
- One of poles experience 24hrs of daylight and the other experiences 24hrs night

Seasonal temperature:

- Winter: Sunlight is spread out over larger area
  And sasses through atm. at lower angle → Pass through thicker amount of atmosphere

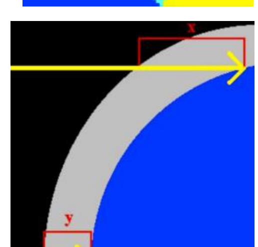


Light spread phenomena:

- Large shape is receiving less energy per square inch than smaller one is

Atmospheric scattering:

- Particles of gas & dust can scatter sunlight through atmosphere
- Equator: Subjected to less scattering



4. Clouds

Clouds:

- Visible aggregate of tiny water droplets/ice crystals that are suspended in atm.
- Type depends on stability & moisture content
- Saturated air is required for clouds & fog to form (From liquid to solid)
  → By lowering air temp to dew point temp (Rising air/lifting process)

  → By adding water vapour into air

  → By mixing warm moist air with cold air

Cloud coverage:

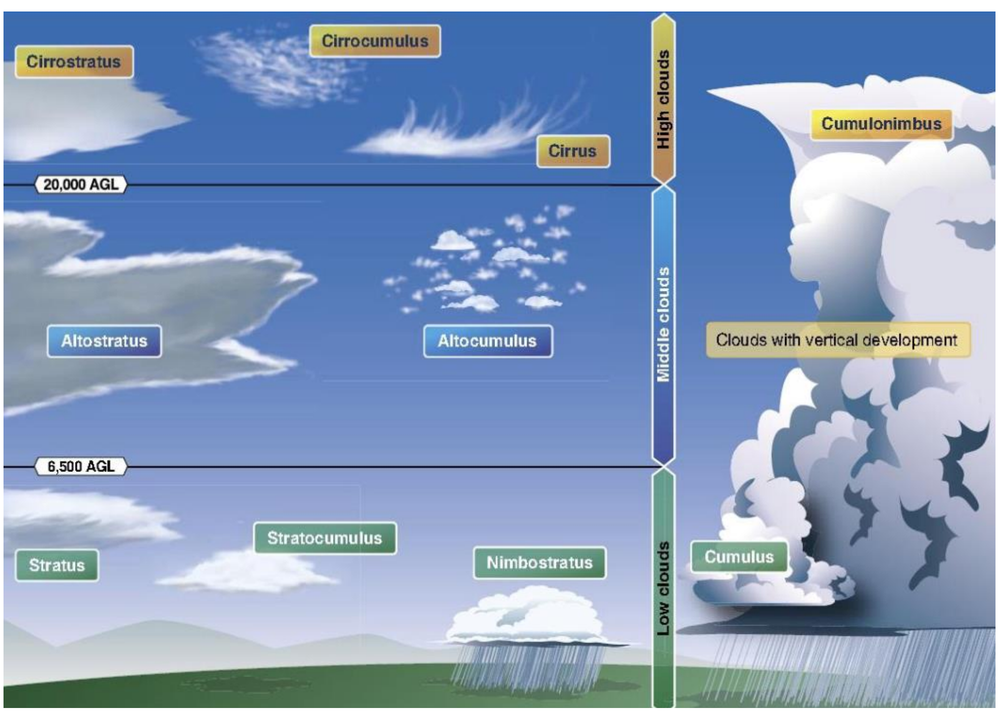
- Reported in oktas/eighths of celestial dome
- SKC: Clear sky
- FEW: 1/8 to 2/8 of sky covered
- SCT: Scattered, 3/8 to 4/8 of sky covered
- BKN: Broken, 5/8 to 7/8 of sky covered
- OVC: Overcast, 8/8 of sky covered

Ceilings:

- When sky is either BRK/OCV
- VFR pilots are not permitted to fly above it (Unless with VFR OTT rating)
- Defined by Vertical visibility (VV) on METAR & TAF
- Depicted on GFA with scalloped border

Cloud classification:

- 4 families based on height & vertical development
  → High clouds, Middle clouds, Low clouds, Clouds with vertical development
- Stratiform: Develop horizontally
- Cumuliform: Develop vertically
- Stratus: Associated with fog & low clouds with poor visibility
- Latin name, describes appx. alt. & appearance

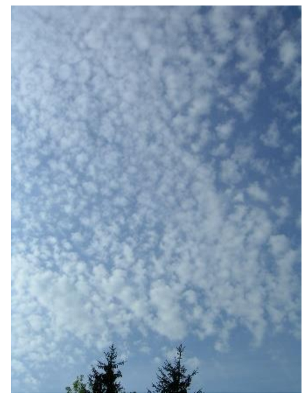


High clouds:

- 20000ft – 40000ft
- Cirrus (CI): High & wispy
  Occur in high pressure systems & fair weather
  Point in direction of air movement at their alt.
  Mainly composed of ice crystals
  Ragged windswept appearance of CI → Strong wind/jet streams
- Cirrostratus (CS): Sheet-like high-level clouds composed of ice crystals
  Tends to thicken as warm front approaches, ↑ ice crystals
- Cirrocumulus (CC): Rare
  White sheet with "pebbly" pattern
  High ice crystals

Cirrus (CI)

Cirrostratus (CS)



Cirrocumulus (CS)

Middle clouds:

- 6500ft – 20000ft
- Altocumulus (AC): Puffy "cotton ball" type
  Followed by thunderstorms as day progresses if on a warm & humid summer
  Icing in usually present in cloud above freezing level especially heavy on top of cloud
- Altostratus (AS): Layer cloud with no definite pattern
  Steely/bluish in color, can see the sun/moon dimly through (Like behind frosted glass)
  Can produce heavy precipitation but often cause light drizzle
- Altocumulus Castellanus (ACC): Created from instability associated with air flows having marked vertical shear & weak thermal stratification

Altocumulus (AC)

Altostratus (AS)

Altocumulus Castellanus (ACC)

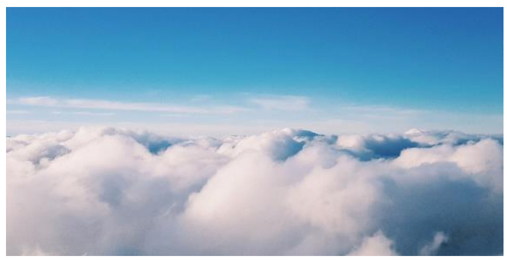
ST / SC = Drizzle, Freezing drizzle
Snow grains

Stratus (ST)

Low clouds:

- Surface to 6500ft
- Stratus (ST): No waves/pattern, "grey"
  Low layer cloud & smooth air
  Resembles fog but does not rest on ground
  Drizzle
- Nimbostratus (NS): Dark, low level clouds
  Primarily composed of water droplet (∵ the base lie below 6500ft)
  Light to moderate continuous precipitation
  "Nimbo" = Precipitation
- Stratocumulus (SC): Low, lumpy layer of clouds
  Varying precipitation from light to heavy shower
  Main producer of drizzle
- Stratus Fractus (SF): Stratus cloud that has been torn by wind into fragments
  May have drizzle
- Cumulus fractus: Stratocumulus torn by wind, Differentiated from Stratocumulus (More rounded tops)

Nimbostratus (NS)



Stratocumulus (SC)

Stratus Fractus (SF)

Clouds of vertical development:

- Have high portion of supercooled water while developing
- As cell ceases to grow, ice crystal will be found (Severe in CB, Horizontal extent of icing is minimal)
- Cumulus (CU): Fair weather, floating cotton/popcorn popping & lifetime of 5-40mins
  Presence of significant vertical currents at low levels without precipitation
  With proper conditions, may develop into TCU then CB
- Towering Cumulus (TCU): Growing cumulus cloud, on the way to becoming Cumulonimbus
- Cumulonimbus (CB): Larger & more vertically developed than fair weather cumulus
  With thunder & lighting
  Vigorous convective updrafts more than 50kt and contain greatest turbulence
  Top can reach up to 60000ft depends on height of troposphere & buoyancy of updraft
  "Nimbus" = Precipitation
- Altocumulus Castellanus (ACC)

Towering Cumulus (TCU)

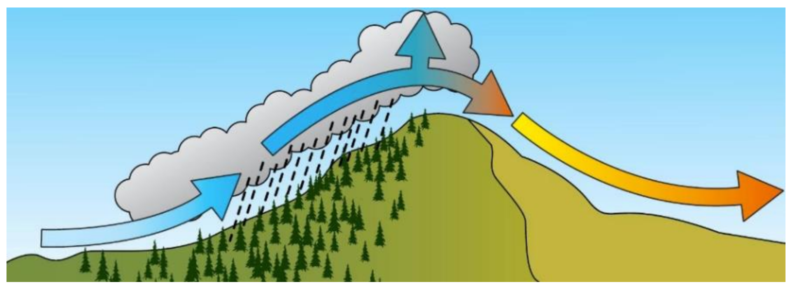
Cumulonimbus (CB)

Cumulonimbus (CB)

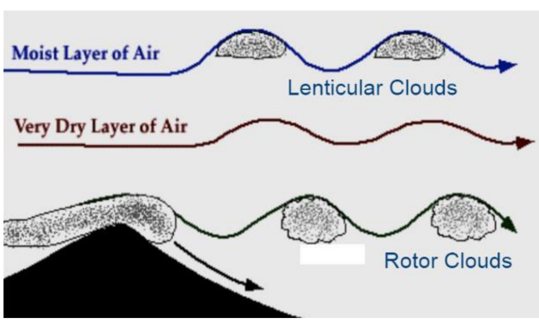
Others:

- Mammatus: Base of CB, Indicate atmosphere is extremely unstable, severe weather is imminent
  Funnel clouds may also be associated, steer well clear
- Orographic clouds: When air is forced to rise by earth's topography
- Mountain wave clouds: → Lenticular clouds forms in wave crest very high & hundreds of miles long
  → Rotor clouds form downwind & below each mountain wave crest, dissipating & forming at the same time ∵ Rotation of air
  A result of gradient wind shifting from surface to that altitude
  → Cap cloud lies over top of mountain & extend partially down leeward slope, indicates extremely strong downdraft
- Contrails: Form by water vapour contained in exhaust of jet engine
  Cold temp at high alt. turns vapour into ice crystals
  Resemble long thin line of cirrus cloud
- Roll cloud: Associated with thunderstorms
  May form near main cloud base in shear area where downdraft comes out

Mammatus



Orographic clouds



Mountain wave clouds

Lenticular & Rotor clouds

Cap cloud

Contrails

Roll cloud

5. Wind

Definition:

- Movement of air in atmosphere horizontally (Most common)
- Caused by horizontal pressure differences
- Air moves from higher pressure to lower pressure

Isobars and millibars:

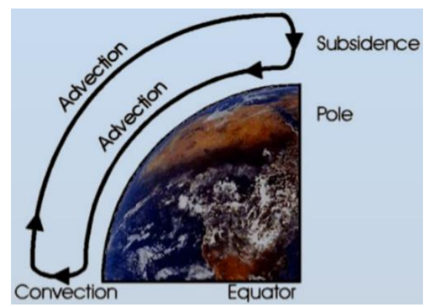
- Isobars: Imaginary lines joining points of equal MSL pressure
- Millibars: Pressure is measured in millibars & isobars are drawn at 4 millibar interval
- Standard sea level pressure: 1013mb

Pressure gradient:

- Rate of change of pressure over distance → Indicate by actual pattern of isobars
- Close together = Steep pressure gradient, strong winds
- Surface wind in high: Flow outward of isobar, Surface wind in low: Flow inward of isobar

Global circulation of air:

- Convection: Air rises at equator where it is heated, causing area of low pressure, travel up to hole
- Advection: Horizontal movement of air
- Subsidence: At poles air sinks again, forming area of high pressure, blow outwards towards equator

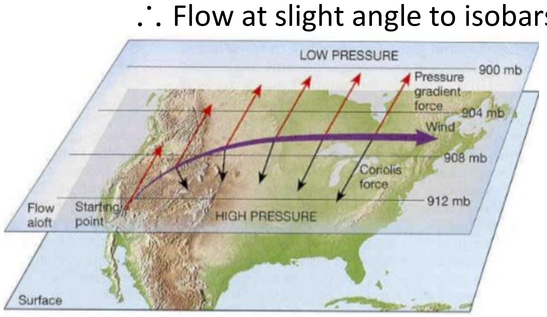


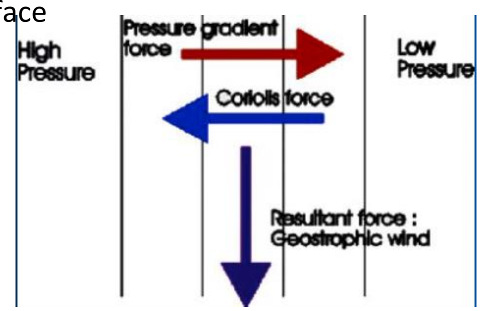
Deflection caused by earth's rotation:

- Due to Coriolis force and it is result of earth's rotation
- Northern hemisphere: Air moves from high to low pressure deflects to right
- If earth does not rotate: Air move at right angles to isobars & from high to low
- Coriolis force: Like a merry-go-round turning anticlockwise

Air in upper troposphere:

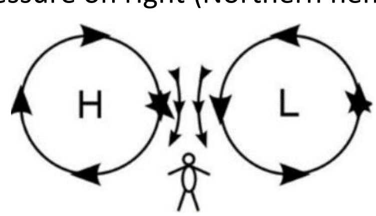
- Unaffected by friction
- Balance between Pressure gradient force & Coriolis force
- Resultant of Pressure gradient wind & Coriolis force is geostrophic wind blows parallel to isobars
  → 2000-3000ft above ground
- Lower than 2000ft: Slightly modified by friction from surface → Causes wind to slow down
  Reduction in Coriolis force causes wind to blow slightly left
  ∴ Flow at slight angle to isobars near surface





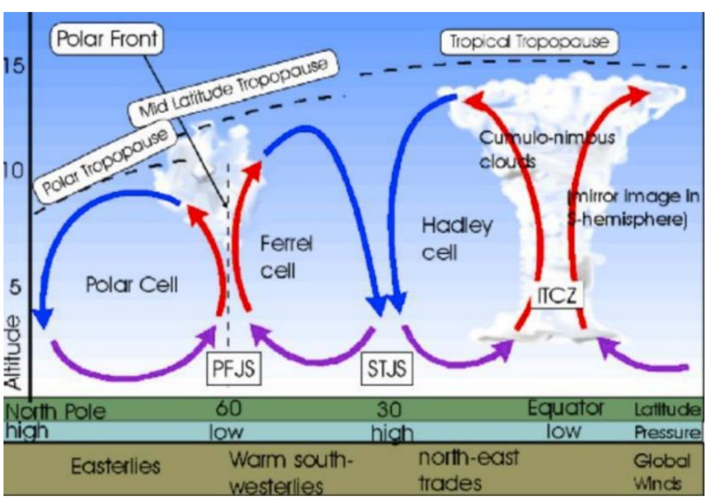
Buys Ballot:

- Stand with back into wind, Low pressure on left & High pressure on right (Northern hemisphere)



Tri-cellular model:

- Air crosses ocean & become warm & moist then head towards equator
  Doldrum: Gentle wind near surface of equator
  Air arrives at equator the InterTropical Convergence Zone & heated more
  → Two streams of air meeting (South & north) and forces air to rise → Form CB (Afternoon TS, Low press)
  Air rises then cool & moves aloft northwards
- Increasing air density & diversion by coriolis force cause air to slow down & subside → High press (Lat 30°)
  Clear skies & stable weather conditions
  Hadley cell is completed, some return back to equator (NE trade wind) & some continue to pole
  Form bottom of Farrel cell
- Air Pick up moisture across sea & meet cold polar air rushing southward at Lat 60° → Polar front
  Air being forced up causing low pressure & bring unstable condition which produce cyclonic rainfall
  Travel back towards equator along top of Farrel cell/Travel up to pole (Descend and form high press)
  Return to polar front as cold Easterlies
- Hadley cell: Air crosses warm oceans & become warm and moist at it heads towards equator
  Near surface of equator is an area with gentle winds called doldrums
  The air arrives equator (Inter-tropical convergence zone) and is heated even more
  Increasing warmth & 2 streams of air meeting (From south & from north) → Force air to rise
  ∴ Form high cumulonimbus cloud, afternoon thunderstorms & low pressure systems
  Rising air cools down & moves away from equator (Northwards)
  Increasing air density & diversion by Coriolis force causes air to slow down & subside
  Latitude of 30°: Clear sky, stable weather conditions, area of high pressure
  Some air returns back to equator as NE trade winds & some continues towards pole
- Ferrel cell: Air continues towards poles forms bottom of Ferrel cell
  Picks up moisture as it crosses sea & meets cold polar air rushing southward at latitude of 60°
  → Forming polar front
  Air is forced upwards causing area of low pressure
  ∴ Unstable conditions, cyclonic rainfall
- Polar cell: Rising air either travels back to equator along top of Ferrel cell
  Or towards poles → Being cooled down & descends forming area of high pressure
  Returns to polar front as cold Easterlies

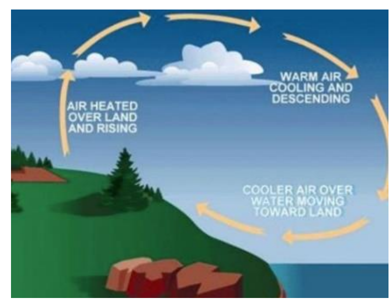


Veering and backing:
- Veering: Wind direction changing clockwise
- Backing: Wind direction changing anticlockwise
- Rule of thumb: Winds veer & increase during climb out
  Winds back & decrease during descent

Low level winds:
- At 3000ft: Wind parallels the isobars
- Surface of earth exerts frictional drag on air blowing just above it → Change wind's direction & speed
- Difference in terrain conditions directly affects how much friction
  → Calm ocean surface < Hills & forests < City & extremely rough terrain

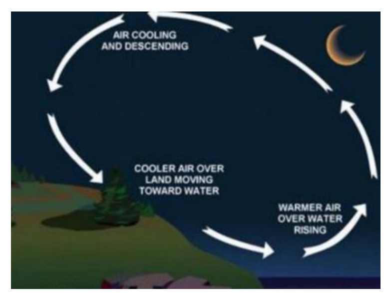
Gust/squall:
- Gust: Brief rapid change of wind direction/speed
- Squall: Prolonged change of wind direction/speed, last for a minute or more

Diurnal effects:
- Surface winds can be expected to be stronger & gustier during day than night
- Night: Nocturnal inversion develops, no link between upper & lower surface winds
  Surface winds tend to back & decrease at night
  ∴ Large difference between upper & lower winds
- Day: Vertical currents are formed that link upper & lower winds making them similar
  Surface winds tend to veer & increase



Sea breezes:
- Onshore breeze from sea during day
- Land heats up quickly but also let go of heat quickly
- Water takes while to heat up but retain heat better
- High pressure develops over water & low pressure develops over land

Land breeze: veer & increase due to reduced friction
- Offshore breeze towards sea during night
- High pressure develops over land & low pressure develops over water



Wind associated with mountain:
- Anabatic winds: Formed as sunward side of mountain slope heats up
  Warm air rises up slope creating upwards flow on mountain
  Turbulence can occur as portions of slope heat at different rate
- Katabatic winds: Flows down slope of mountain
  Happen in area that are shaded/snow covered
  More powerful at night when radiation cooling starts
  Seem to pulsate as cold air builds & suddenly release downstream
- Topographical effect: Air being blown horizontally confronts a mountain then being lifted up
  Rising air cools & cloud may form and precipitate if cools to saturation point

Wind shear:

- Sudden change in wind speed/direction in short distance resulting in a tearing/shearing effect
  → Exist in horizontal/vertical direction and occasionally in both
- Greater change in speed/direction → greater severity of shear
- Causes: Micro-bursts (Virga-possible indication), Jet-streams, Topography, Fast moving fronts
- 2 types: Speed shear → Wind blowing at different speed at different altitude creates turbulence
  Directional shear → Wind blowing in different directions at different altitudes creates turbulence
- Aircraft performance: Increased performance shear → Headwind increases/Tailwind decreases
  Temporarily increase IAS (Dynamic pressure changes)
  May cause aircraft to overshoot/float further down runway
  Slower ground speed, increase in gradient of climb, shorter landing distance
  Decreased performance shear → Headwind decreases/Tailwind increases
  Tend to sink & undershoot aiming point
  Higher ground speed, longer landing distance

TS, Waterdrome/ Strip protected by terrain, Enter/Exit JS

NOT WAKE TURB

Rossby waves:

- Result of temp variations & rotation of earth
- Blow from west to east
- Help to circulate differences in global temp
- Depending on season & circulation there can be 3-6 waves at given time
- Wind velocities found in upper tropospheric waves are not uniform
  → High winds are called jet streams

Jet streams:

- Very strong high altitude winds >60kt, Thousands miles long & hundreds mile wide
- Polar front jet stream: Between 40° and 60° in both hemispheres
  Division between Polar & Ferrel cells
  Moves south then brings cold air → Dry & stable conditions with high pressure
  Moves north then warmed → Give strong winds & heavy rainfall
  Stronger in winter & plunge far to south ∵ Large temp differences between cells
- Subtropical jet stream: Around 25° to 30° of latitude, boundary between Ferrel & Hadley cells
  Moves less than polar jet stream, lower wind velocities (∵ Less temp variations)
- Easterly equatorial jet stream: Form aloft at ITCZ
  More seasonal & associated with summer monsoons in India
  Gentle jet stream in terms of winds

6. Jet stream

Definition:

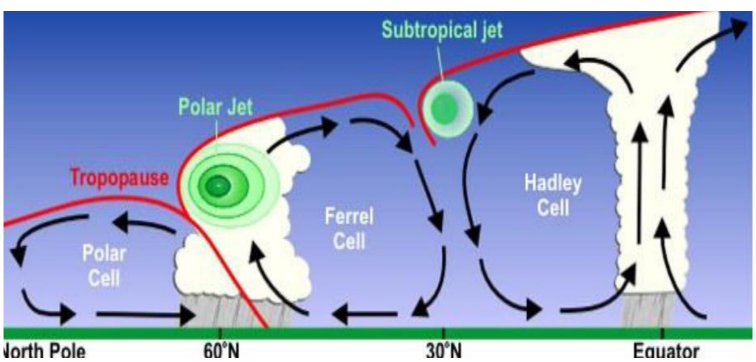
- Relatively horizontal, high speed, tubular shaped current of air in vicinity of tropopause
- Axis is centered on line of max wind speed, characterized by high wind speed & strong wind shear

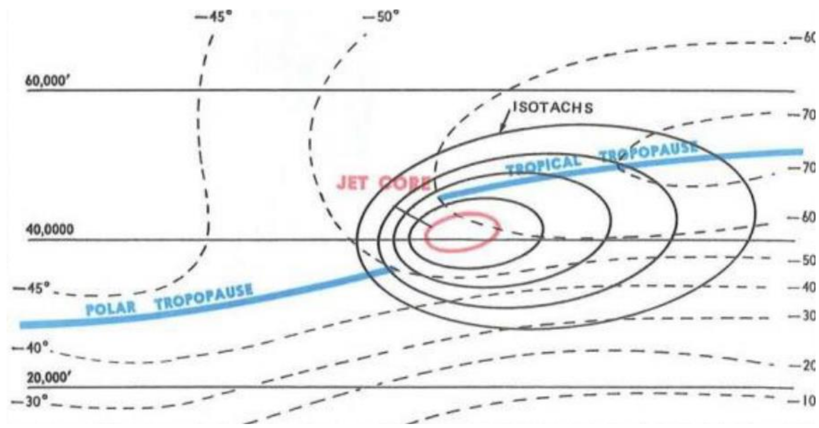
Characteristics:

- Width: Few hundred miles
- Depth: 2-6 miles
- Altitude: 10000-30000ft
- Ragged windswept appearance of cirrus cloud = Very strong wind/jet streams
- Wind speed of at least 60kts & may increase to more than 200kts
  Will drop abruptly above, below, to either side of jet core
  Located in warm air side of a front & about 2000-3000ft below warm air boundary in tropopause
- Polar jet stream: Most important in northern hemisphere
  Frontal type of jet stream & can enhance/change surface weather patterns

Jet stream development:

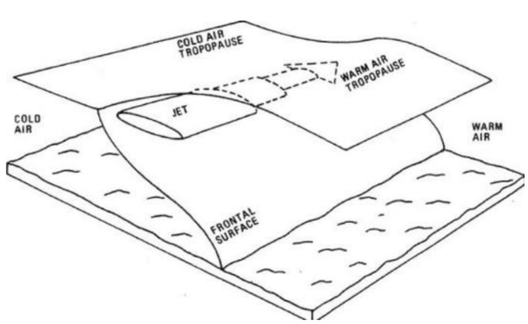
- Upper winds are controlled by temp structure of atmosphere below
- May have strong horizontal temp gradient exist through deep layer of atmosphere → Jet stream develops
- Major jet streams in northern hemisphere are located just below tropopause
- Frontal system has sharp temp contrast
  → Abrupt change in tropopause height
  → Cause tear between height of pressure surface in upper tropopause → Jet stream development

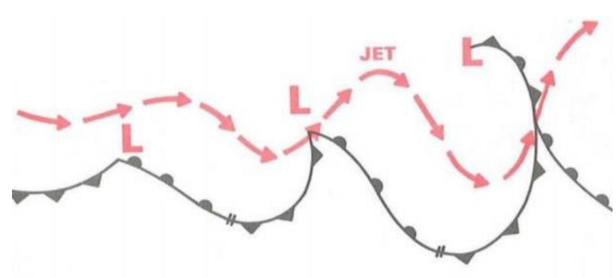




Position of jet core:

- Looking downwind/Towards east: Warm air tropopause on right & above core
  Cold air tropopause on left & same level/lower than core
- Always associated with cold front except subtropical jet
- Lie in warm air above & to north of frontal surface



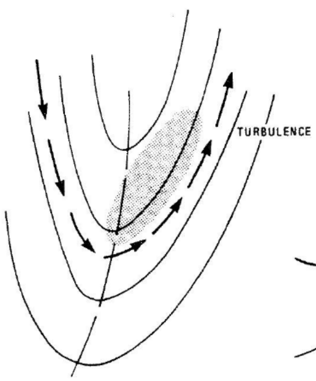


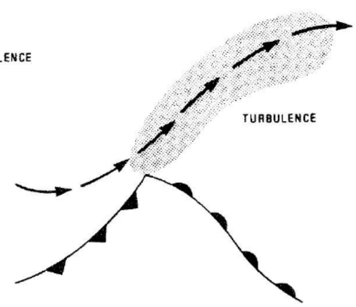
Seasonal height & speed variation:

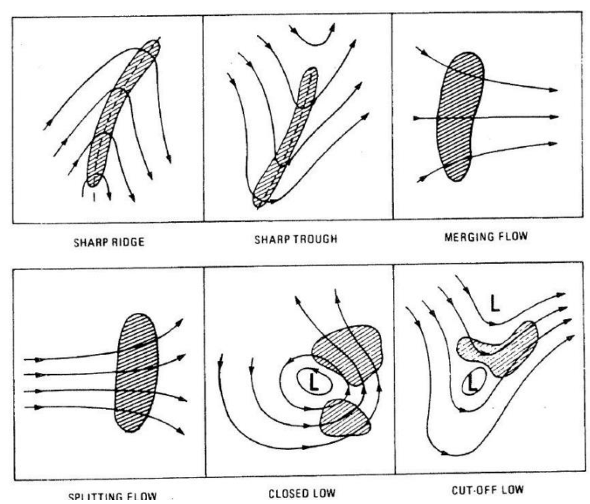
- Move south in terms of latitude in winter & do this along with associated front
  (Cold air will migrate southwards during cold weather)
- Speed is higher in winter than in summer
  (Temp contrast across air masses & corresponding front are sharper in winter)
- Altitude is lower in winter due to lowered pressure height
  (Colder air = more dense = lower height for given pressure value)

Jet stream turbulence:

- 30kts isotach spaced closer than 90NM in 250mb chart = Horizontal shear for Clear Air Turbulence
- Jet stream vertical shear varies from 5kts/1000fts up to 20kts/1000fts
- Not all jet streams have turbulence
- Common on cold air side due to sudden drop in wind speed
- Common above core (Between core & tropopause)
- Most likely in upper trough on poleward (low pressure) side of jet stream
  → Flying with tailwind & encounter JST then turn right in northern hemisphere to get away





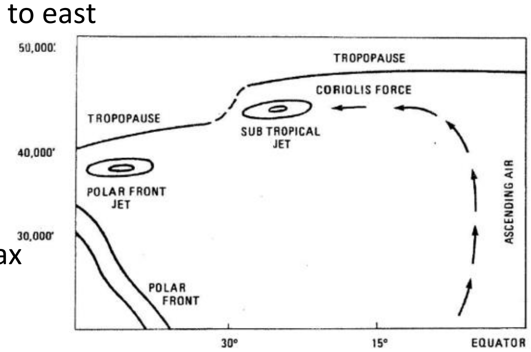


Jet stream vertical turbulence:

- Encounter JST while flying with crosswind (From north to south/South to north)
  → Observe OAT for a while: Temp rises then climb to get out of turbulence
  Temp falls then descend to get out of turbulence
  Temp constant then either climb/descend is fine

Subtropical jet stream:

- Not associated with frontal system
- Strong solar heating in equatorial regions produce ascending air → Turns poleward at high level
  → Coriolis force then turn winds to right & cause jet to flow from west to east
- If polar front moves south then polar JS may merge with subtropical JS



Low level nocturnal jet:

- Overnight cooling creates inversion & produce wind shear near top
- Max wind during midnight at 700-2000AGL
- Speed of 8kt at ground & 25-40kt at max & 15-30kt at 1000ft above max
- Prairies: Sheet of wind thousands of miles long, hundreds of feet thick
- CAT: 40kt or greater is common
  Sudden change in wind speed causes low-level wind shear
  Inversion dissipates in morning & shear plane and gusty wind move closer to ground

Chapter 13

Meteorology 3

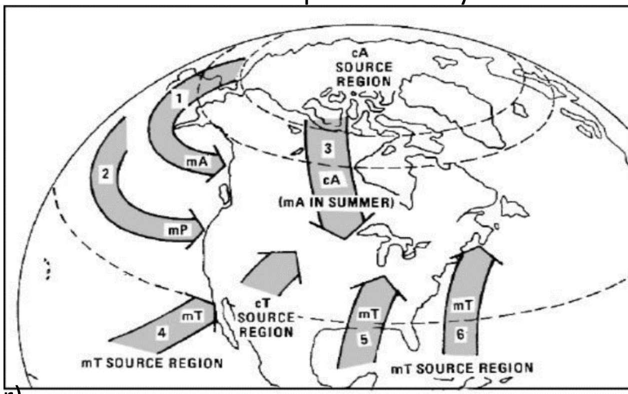
1. Air masses

Definition:

- Large body of air usually 1000miles or more across, similar properties of temp & moisture in horizontal
  → Any horizontal layer at any height will have uniform properties of mass (High pressure area is the best)
  Uniform temp throughout air mass & wind varies little with height

Source regions:

- Large flat areas → air is stagnant long enough to take on characteristics of surface below
- Always occur in area of high pressure → Slow moving highs are the best
- A week or two over uniform area of earth's surface will create air mass → Uniform temp & humidity



Factors affecting air mass weather:

- Moisture content
- Stability of mass
- Any cooling/heating processes present

Classification:

- Moisture: Continental (Dry), Maritime (Moist)
- Temperature: Arctic (Cold), Polar (Cool/Cold), Tropical (Warm)
- Canada: cA (Winter), mA & mP (Summer & Winter), mT (Summer)

Continental Arctic:

- Cold & dry, originates north of Arctic Circle
- Winter: cA plunges southward over Canada & USA
- Summer: Rare, ∵ Nearly 24hr of daylight to warm Arctic

Front between mP & mT
=> Polar

Maritime Arctic:

- Cold & moist, form farther to south of cA air
- Winter: Dominate weather in Canada particularly along coastal areas
- Summer: Bring convection & showers to interior of Canada
  May form over Canadian North that is far away from ocean
  → Due to lots of lakes in Northern Canada
  Thaw & pump air mass full of moisture and warmth, cause it become less stable
- Brings clear and pleasant weather to the North

Maritime Polar:

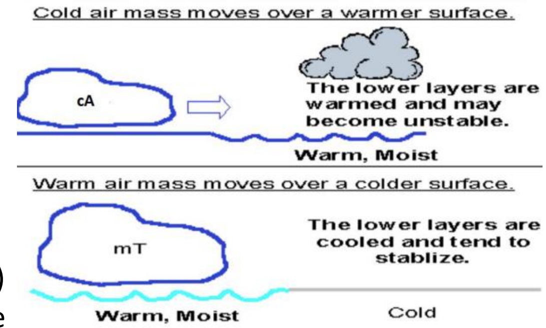
- Cool & moist, form over northern Atlantic & northern Pacific oceans
- Bring cloudy damp weather to Canada
- Most often influence Pacific northwest & Atlantic northeast
- Can form anytime of year & not as cold as cP

When cold Arctic moves quite far south over warm temp ocean

Maritime Tropical:

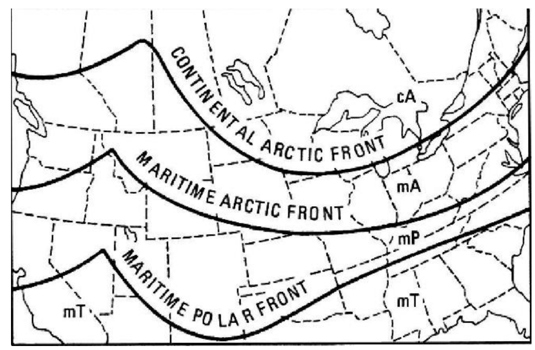
- Warm temp with lots of moisture
- Common across eastern Canada, originate over warm waters of southern Atlantic Ocean & Gulf of Mexico
- Can form year around but most prevalent across Canada during summer
- Responsible for hot humid day of summer

Modification:



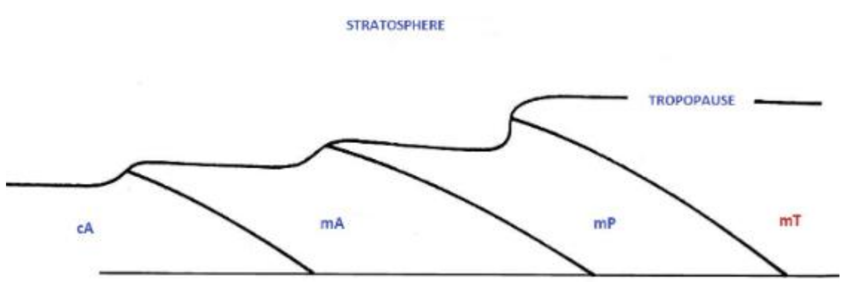
- May be great enough to create new type of air mass
- Depends on: Speed at which It is moving
  Moisture content of area over which it is passing
  Temp difference between air mass & new region
- Modified by warming from below (Solar radiation/Over warm surface)
  → Instability & convection mix in higher level in atm up to tropopause
  GFA: With additional script of "k" to show it is colder than surface below (cAk)
  Lead to instability of air mass → Form cumuliform, turbulence, good visibility, shower, TS
- Modified by cooling from below (Over cold surface)
  → Inversion resists mixing & lead to modification only in lowest levels of air mass
  GFA: With additional script of "w" to show it is warmer than surface below (cTw)

Air mass characteristics:
- Stable: Poor low-level visibility
  Layer type cloud
  Steady precipitation
  Steady winds which can change markedly with height
  Smooth flying conditions
- Unstable: Good visibility (Except in precipitation)
  Convective type cloud
  Showery precipitation
  Gusty winds
  Turbulence

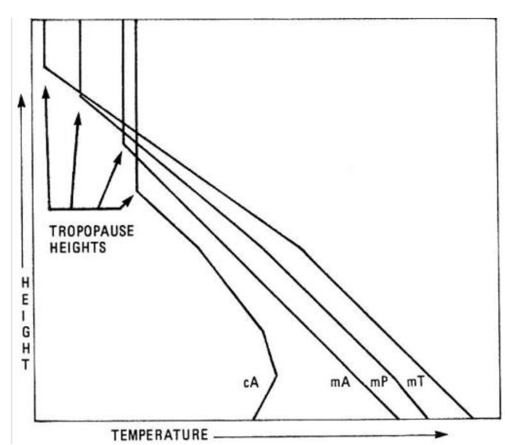


Frontal boundaries:
- When air masses collide → Boundaries between masses are known as fronts

Heights and temperature:
- Air mass is always topped by troposphere
- Warmer air mass causes higher level of tropopause
- At tropopause: Temp of warmest air mass (mT & mP) will be colder than cooler air mass (mA & cA)



From north pole to equator
(North to south from left to right)



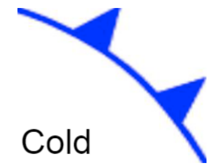
2. Fronts and frontal weather

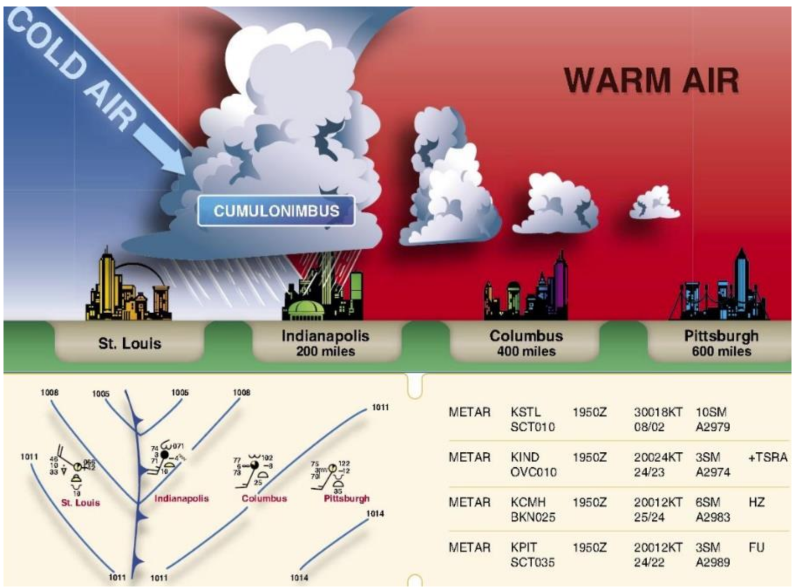
Introduction:

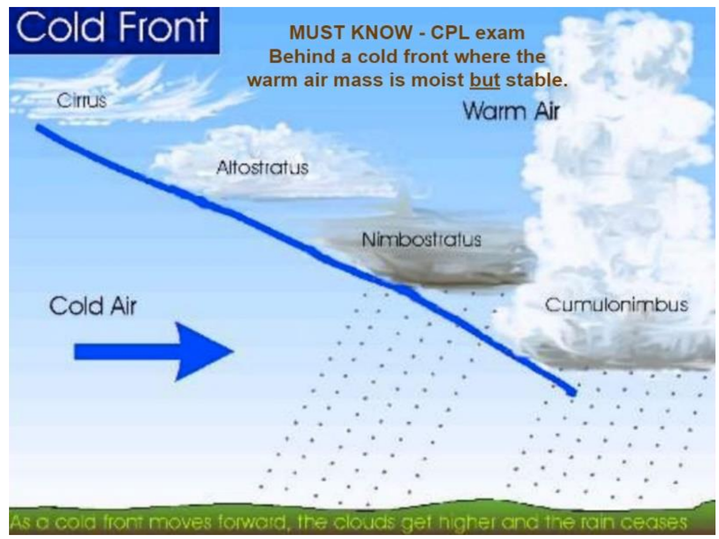
- Movement of front is dependent on motion of cold air that is perpendicular to it
- Name of front is determined by motions of cold air → Allow advancing air to be given its name
- Actual weather may exist many miles ahead/behind the marked position

Cold fronts:

- Leading edge of cold air mass aka transition zone where cold air mass is replacing warmer air mass
- Frontal lift: Forms when wedge of cold air forces its way under warmer air mass
- Typically have steep slope (1-1.5 of a degree is not uncommon)
- Tend to move faster than warm fronts due to cold air being more dense than warm air
  ➔ Fastest moving frontal/occlusion system





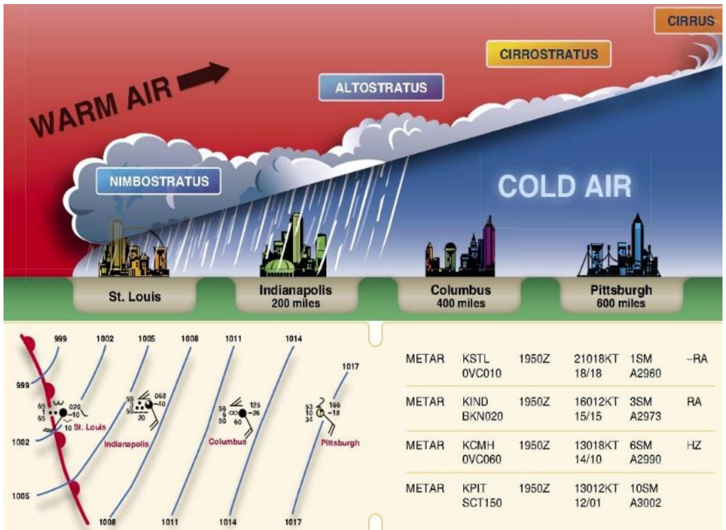


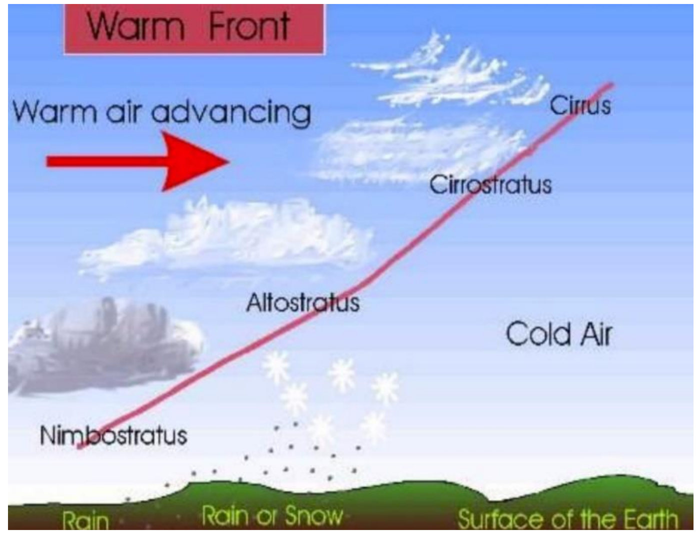
	Before	As it passes	After
Winds	South to southwest	Gusting, veer & increase	West to northwest
Temperature	Warm	Sharp drop	Steadily dropping
Dew point	High, remains steady	Sharp drop	Steadily lowering
Pressure	Falling steadily	Sharp rise	Steadily rising
Clouds	Increasing CU, TCU, CB Formed by expanding warm air as it's lifted by cold air	CB	Slow moving, warm air stable → NS, AS, CI Fast moving, warm air unstable →CU
Precipitation	Short period of showers	Heavy rain, thunder, lightning Sometimes hail	Showers when clearing
Visibility	Fair to poor in haze	Poor but improving	Good except for in the showers

SCT – BKN ceilings
CU clouds
Good VIS
Showery precip

Warm fronts:

- Retreating edge/trailing edge of cold air mass
- Much slower than cold front, warm air will override cold air & frontal lift causes it to rise
- Slope of warm front tends to be shallow (0.5 of a degree)

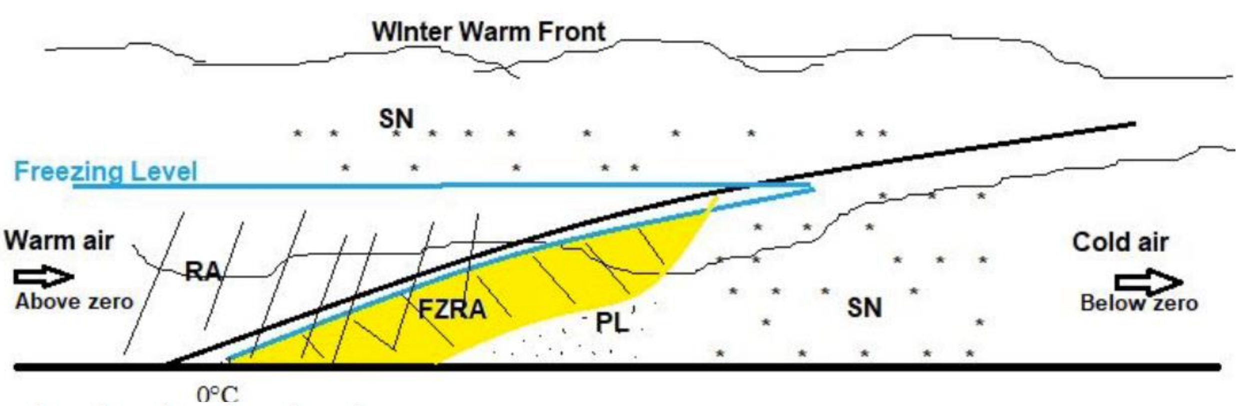


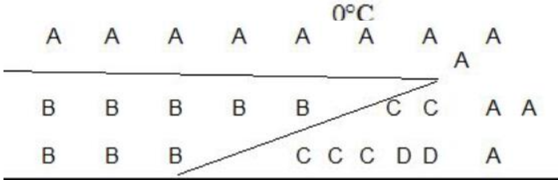


	Before	As it passes	After
Winds	South to southeast	Variable, veer	South to southwest
Temperature	Cool to cold with slow warming	Steadily rise	Rise then steady
Dew point	Steadily rise	Steady	Rise then steady
Pressure	Falling gradually	Steady	Slight rise then fall
Clouds	Approaching in order: CI, CS, AS, NS, ST and fog CB in summer when fast moving & warm air is unstable	ST NS if there is precipitation	Clearing with scattered SC Occasionally CB in summer
Precipitation	Light to moderate: Rain, snow, sleet, drizzle	Drizzle/none	Commonly none Sometimes light rain/showers
Visibility	Poor	Poor but improving	Fair in haze

Winter warm front:

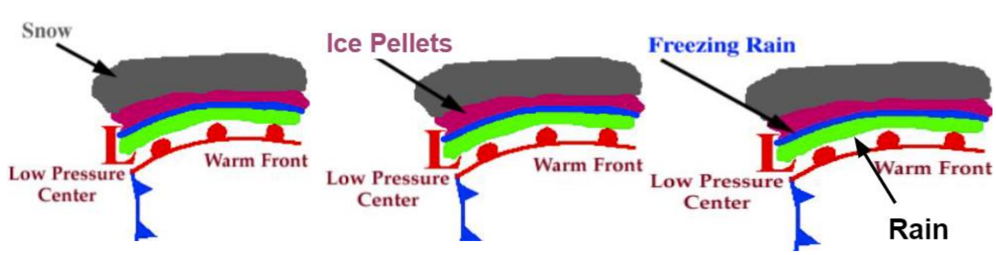
- With ice pellet = Have freezing rain at higher altitude





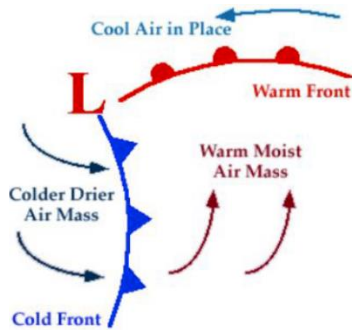
TC uses a diagram similar to above.

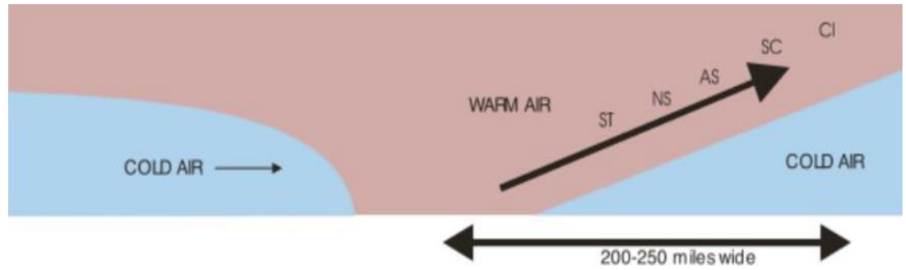
In this diagram (A) is snow, (D) is ice pellets, (C) is freezing rain, and (B) is rain.

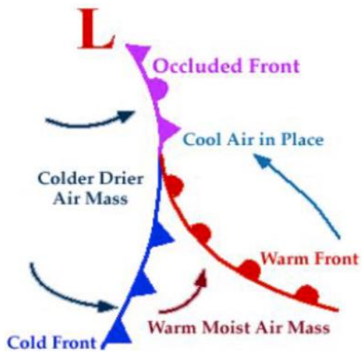


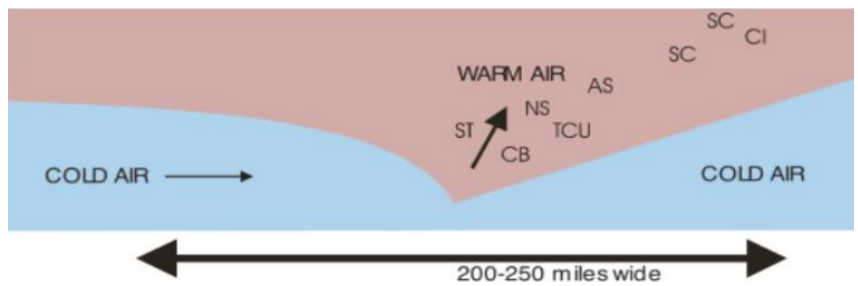
Occluded front:

- When cold front associated with a low "catches up" to warm front
  → Overtaking & undercutting warm front due to greater density of cold air



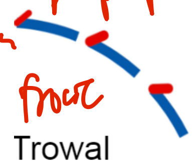




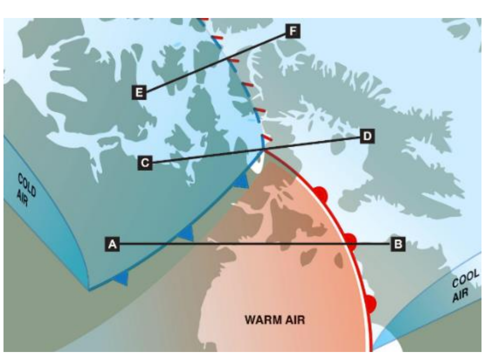


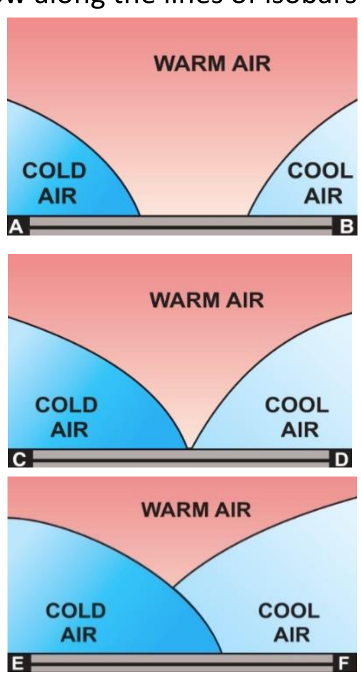
Trowal:

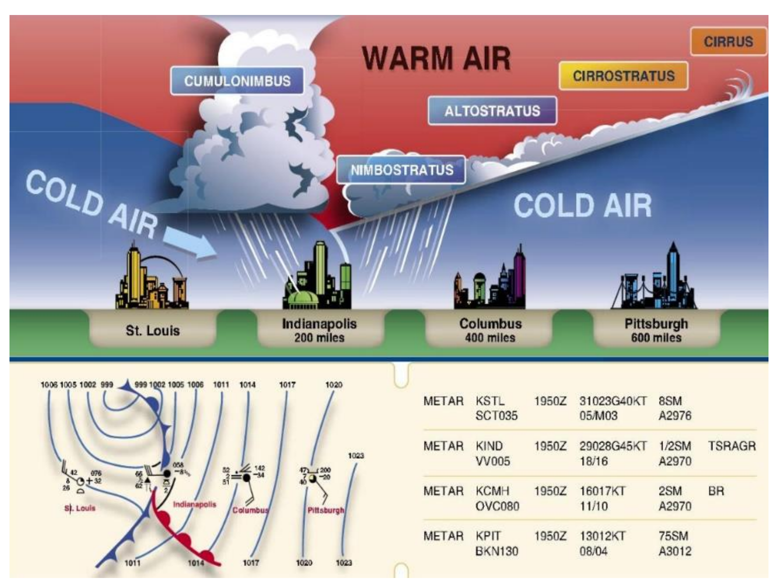
wide spread cloud & precipitation
possibly line of thunderstorm
forced up by occluded front



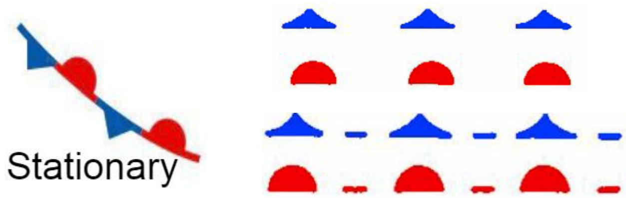
- TRough Of Warm Air Aloft
- Needs 3 air masses to form
  → Cold air mass, cool (partially mixed), warm air mass aloft
- Formation, Zipping up, Fully formed
- Clouds & precipitation depend on moisture content of warm air → Dry/showery/heavy precipitation
- Resemble both warm front & cold front conditions
  → Cloud pattern ahead of trowal is similar to warm front, trails is like a cold front
- Cumulus buildup, thunderstorms with stratiform cloud, continuous precipitation & widespread low ceiling
- Associated with low in northeast sector: Any/all of maximum precipitation, icing, convective activity
- Winter: Freezing rain & severe icing conditions (Rain aloft in occluded warm air falls through cold sector)
- Front revolves around Low along the lines of isobars







Stationary front: Like warm front but less intense weather



- Front that is not moving, neither air mass is replacing other
- Wind will blow parallel to front
- Clouds & prolonged precipitation
- Noticeable temp change/change in wind direction when crossing from one side to other
- Frontogenesis: Initial formation of a front, occurs when temp gradient becomes sharper
- Frontolysis: Dissipation of front, occurs if temp contrast between two air masses should decrease

  If one of air masses is modified/Weaken temp gradient along frontal zone due to wind field

  when temp & density differences between 2 air masses equalize

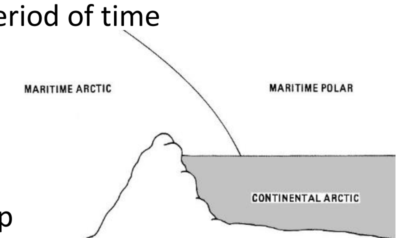
weather may below VFR when starts to rain

Upper front:
- Non-occlusion situation, when air is trapped on surface & frontal weather is pushed aloft
- Upper warm front: In winter where colder surface air stays on ground & warmer air moves overhead
- Indication: Winds will not shift/veer
  Temp will not change
  Precipitation is quite likely to fall & appropriate cloud types seen
- Higher altitude: Frontal passage weather is similar to normal frontal weather
- Occurs when advancing cold air meets even colder air

Frontal fog (Precipitation fog):
- Associated with weather at fronts particularly warm fronts
- Frontal precipitation falls into colder air ahead of below warm air
  → Cold air becomes saturated through evaporation

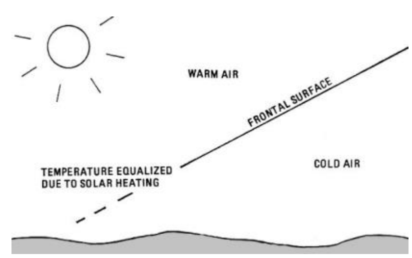
Fast moving cold front:
- Very steep front commonly forms in summer
- Cold & dense air moves ahead rapidly → Warm air ahead is forced to rise violently
- Surface friction along front may create protruding nose of cold air → Extremely unstable
- If warm air is moist & unstable: Line of thunderstorm → Squall line, narrow band of violent weather
- Wind veers with frontal passage, strong & gusty & turbulent for considerable period of time

Upper cold front:



- Maritime cold front crossed Rockies from Pacific
- Cold Continental Arctic Air lying stagnant across prairies
- Due to coldness & denseness of Continental Arctic air the front will ride over top
- Can occur anywhere that cold air is trapped on surface & can be either upper cold/warm fronts

Upper front at daytime:

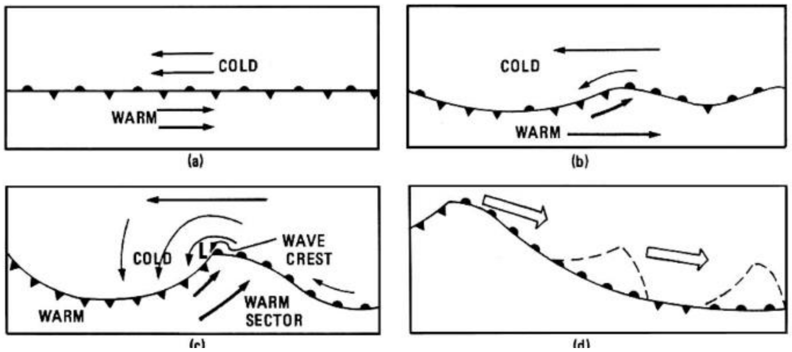


- Lower cold air being heated by daytime heating & no significant temp contrast
- At levels above this modification the front will remain
- Most commonly with warm fronts but also can occur with cold fronts

Level of front:
- Fronts in GFA are drawn to surface
- Fronts on SIGWX chart are also drawn according to surface position

Frontal waves:

- Wave-like turbulence that normally form on quasi-stationary fronts
- Initially winds on both side blow parallel to front
- Divergent flow at upper level/displacement of front will cause fall of pressure
- Wind flow will further change pressure & front location

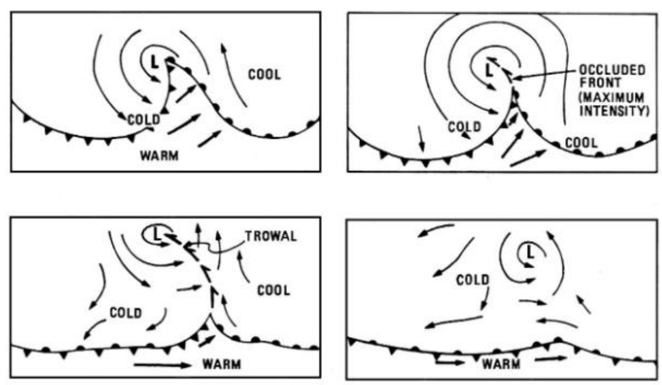


Stable front waves:

- May not develop further & move along front with associated weather at speed dependent of upper air flow
- Wind speed typically 15-20kts, up to 40-50kts
- Last for 2-3 days

Unstable front waves:

- Low pressure area continues deepen under certain atmospheric conditions
- Wind speed behind cold front starts to increase
- Cold front speeds up & starts to catch up warm front
- Unstable frontal waves lead to "Occlussion"



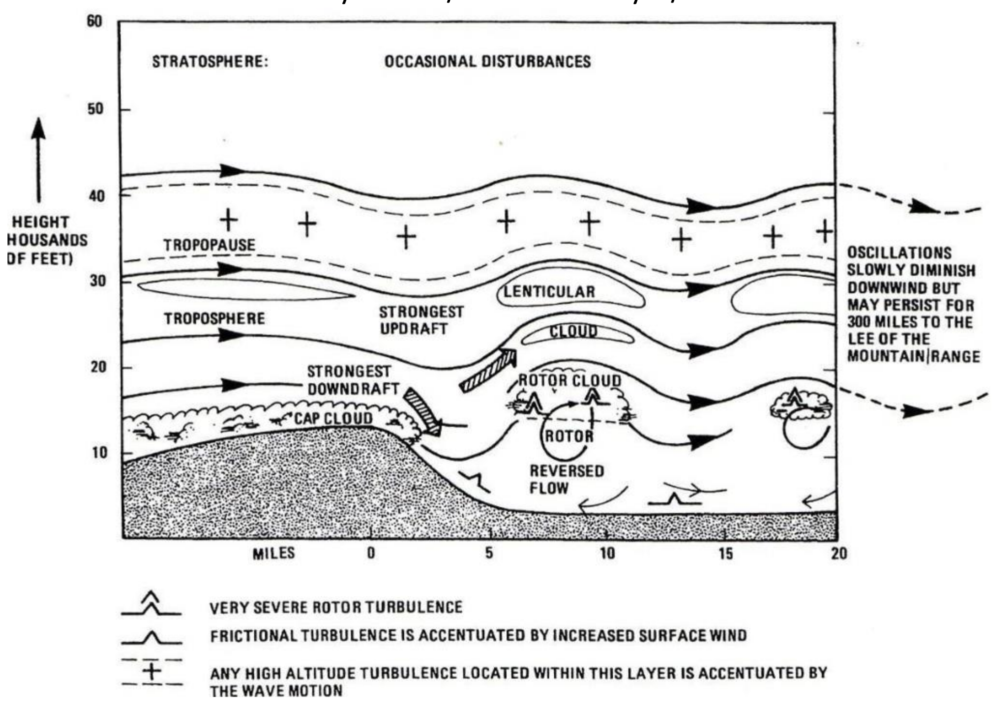
Chapter 14

Meteorology 4

1. Mountain waves, wind and turbulence

Formation:

- Winds are forced upward by impeding mountain range → Descends downward on lee side (downwind)
- Airflow may bounce up & down for some distance downstream of mountain range
- Most severe near mountain/mountain ridges and at about same height as top of summit
- Reach intensity of 5000FPM
- Significant horizontal & vertical shear may exist
- Condition required: Wind direction within 30° perpendicular to mountains
  Wind velocity on windward side >= 25kt
  Winds aloft increase with height
  Stable air mass layer aloft/Isothermal layer/Inversion near mountain top



Key components:

- Wavelength: Distance from crest to crest/trough to trough
  Proportional to wind speed & inversely proportional to atmospheric stability
  With moisture then will form lenticular clouds & mark crest of each wave
  Average wavelength is 8NM, total wave distance from mountaintop to dissipation is 100NM
  Factors: Stability → Greater atmospheric stability, shorter wavelength
  Wind speed → Greater wind speed, longer wavelength
  Lateral position of ridges → Ridge spacing can change mountain wave
  Ridges will need to be at least 5 miles apart
- Amplitude: Half the vertical distance from trough to crest
  Varies with height above ground → Small amplitudes near surface due to friction
  Larger amplitudes between 3000-6000ft above ridge
  Greater amplitude, shorter wavelength
  Factors: Stability → Lower stability, lower amplitude
  Mountain size → Larger mountains, greater amplitude
  Mountain shape → Ridges with width similar to wavelength produces great amplitude
  Sharp lee slopes → Greater amplitudes
  Drops of greater than 3000ft will produce largest amplitudes

Stable air will be smooth with little turb
but lot of vertical shear

Orographic clouds:

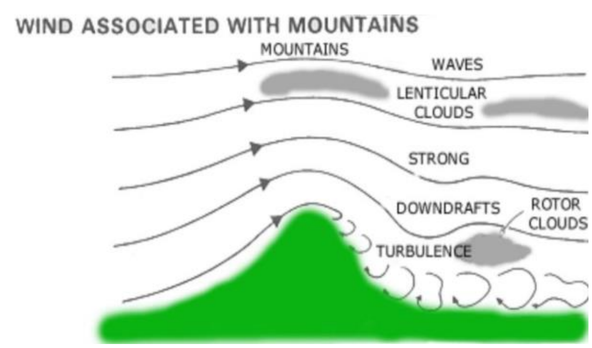
- Formed when air is forced to rise by earth's topography
  → Either prior to encounter ridge/soon after encounter ridge
- Must be sufficient moisture for clouds to form
  ∴ Lack of clouds does not always mean there is not turbulence

Lenticular clouds:

- 20000-40000ft, form in crests of waves & hundreds of miles long
- Air in mountain wave rises & cools then condenses out moisture to form leading edge
- Air flows over crest evaporates due to heat of compression & absorbs moisture
- Winds associated with mountain wave extend to tropopause make it difficult to avoid by fly over
- Wind speed tends to increase at crests
- Torn lenticular: Amount of shear develops between difference in wind speed at crests
- Breaking wave may also be shown
- ACSL: Alto-cumulus standing lenticular, CCSL: Cirro-cumulus standing lenticular

Roll/rotor clouds:

- Posses greatest amounts of turbulence
- Avoid flying through/between/below them
- Form downwind from each wave crest & within lower turbulent zone
- May dissipate & form at the same time due to rotation of air
- Does not tell us about intensity of turbulence
- Avoid: Diameter varies between 600ft to 2miles
  Center of rotation typically is near ridgeline
  2000-5000FPM vertical velocity
  Severe turbulence, 1st rotor is typically most intense
- If must pass through: Fly over, then fly around, never fly beneath



Cap cloud:

- Lie over top of mountain, extend partially down leeward slopes
- Indicate extremely strong downdraft

Mountain wave turbulence:

- Flying downwind: Higher ground speed, less time affected by vertical currents
  Hit turbulent areas faster ∴ Turbulence will be more violent
  Configure aircraft for turbulent air penetration
- Spaced wave: Smooth flying conditions seem to prevail
  See fluctuations in ASI & VSI
- Lee wave region & Low turbulence zone (Lower levels are going to be turbulent for all types of planes)

Altimeter effects when flying in mountain wave:

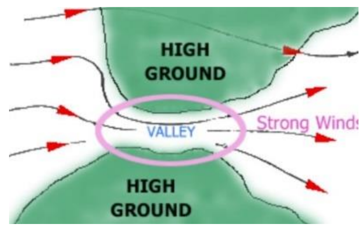
- Drop in pressure with increase in wind speed causes altimeter to read incorrectly
- May overread by as much as 3000ft
- If flying upwind on windy day: Actual ground separation on passing over crest of ridge may be small
- Error will be present until airflow returns to normal speed & some distance away from mountain

Winds in mountainous terrain:

- Anabatic winds: Formed as sunward side of mountain slope heats up
  Warm air rises up slope creating upwards flow on mountain
  Turbulence can occur as portions of slope heat at different rate

- Katabatic winds: Flows down slope of mountain
  Happen in area that are shaded/snow covered
  More powerful at night when radiation cooling starts
  Seem to pulsate as cold air builds & suddenly release downstream

- Glacier wind: Extreme type of Katabatic wind
  Caused by glaciers which can produce area of extreme cooling
  Can blow in > 80kt
- Funneling: Winds are deflected around large single mountain peaks
  Through valleys of mountain ranges
  → Speed ↑ due to local decrease in pressure
  Converge: Increase to combined speed
  Diverge: Less than original speed
  Winds meeting headland tend to curve around



Suggestion:

- Stay out of mountains when wind speed at peak > 20kt
- Fly at least 50% higher than mountain range
- Avoid rotor clouds in low level turbulence area
- Do not rely on altimeter indications
- Use appropriate airspeeds for turbulence penetration
- If caught in downdraft then speed up and get out of it instead of pitching for V_y
- Cross ridge from downwind side: Do at 45° & at least 3000ft above when strong winds are present

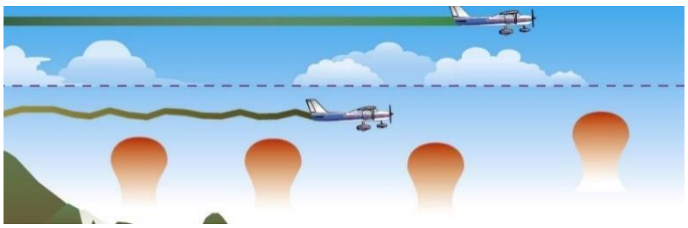
Severity of mountain wave:

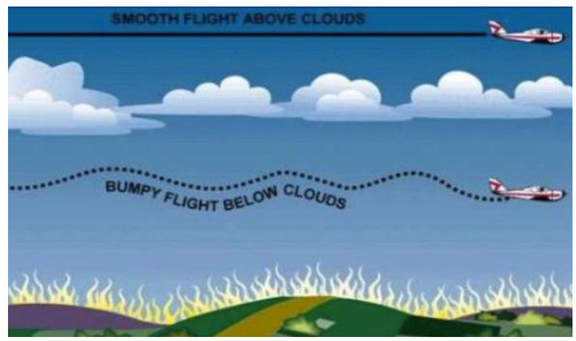
- Depends on strength of wind, angle to range, stability/instability of air
- Most severe: Strong airflows that blow at right angles to range & in stable air
- Jet stream nearly blowing perpendicular to mountian range increases severity of wave condition

2. Turbulence

Convective (Thermal) turbulence:

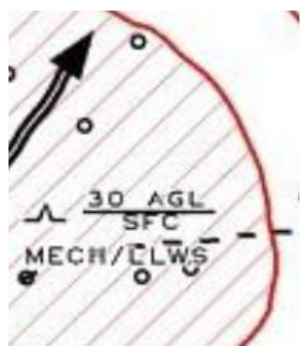
- Caused by unequal heating of earth's surface
- Darker areas such as soil, rocks, sand heat up faster than lighter area such as grass, water
- Cause downward currents during day over water
- Warm air rises & replaced by cooler sinking air
- Cells are hundreds of feet in diameter, rise at rate of few thousands FPM in unstable conditions
- Fair weather cumulus, towering cumulus, altocumulus castellanus, cumulonimbus
  → Indicate convective turbulence is happening
- Best to fly above cloud to avoid convective turbulence on early morning/late evening
- Expect to have turbulence in lower levels when cold air moves over warm surface
- GFA: TCU, ACC, CB imply significant convective turbulence
  "Do not only look at Ice Turb & Fzlvl chart for turbulence questions"

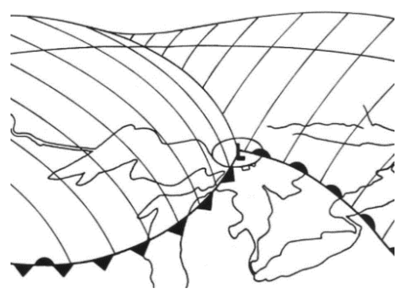




Mechanical turbulence:

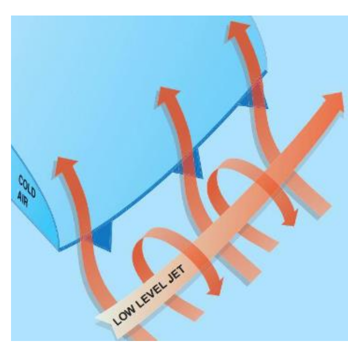
- Caused by friction between air and ground/When wind encounters trees and man-made objects
- Unstable air & rougher terrain → Stronger turbulence
- Vertical extent of mechanical turbulence in lower level is greatest when cold air moves over warm surface
- GFA: Show base with max height, only when turbulence is expected to be moderate/severe





Frontal turbulence and shear:

- Caused by friction that occurs between 2 opposing air masses
- More commonly associated with cold front but can occur at warm front too
- Frontal wind shear: Happens with fronts that have steep wind gradients
- Fronts with temp changes of 5 degrees or more may cause this to happen
- Another mechanism is front that moving high speed → 30 kt or more

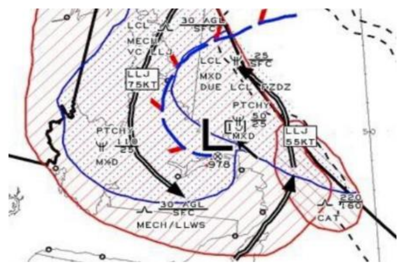
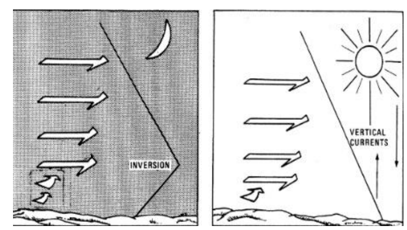


Orographic turbulence: Most likely to occur in valley bottom

- Caused by friction in air currents through mountainous regions as air moves up mountains/hills
- Approaching from windward side are helped by rising currents
- Approaching from leeward side encounter descending currents
- Cross ridges at 45° & at more than 2000ft → Can turn away from ridge quickly & turn back if required

Wind shear:

- Sudden change in wind speed/direction in short distance resulting in a tearing/shearing effect
  → Exist in horizontal/vertical direction and occasionally in both
- Greater change in speed/direction → greater severity of shear
- Causes: Micro-bursts (Virga-possible indication), Jet-streams, Topography, Fast moving fronts
- 2 types: Speed shear → Wind blowing at different speed at different altitude creates turbulence
  Directional shear → Wind blowing in different directions at different altitudes creates turbulence
- Aircraft performance: Increased performance shear → Headwind increases/Tailwind decreases
  Temporarily increase IAS (Dynamic pressure changes)
  Slower ground speed, increase in gradient of climb, shorter landing distance
  Decreased performance shear → Headwind decreases/Tailwind increases
  Tend to sink & undershoot aiming point, longer landing distance
- Pilot should monitor power and vertical velocity required to remain on the proper glide path

Low-level wind shear:

- Significant non-convective wind shear that affect aircraft operation within 1500ft AGL over aerodrome
- Causing rapid gain/more critically a loss of airspeed
- TAF/METAR: Labelled as "WS", Report height of top of shear layer (in hundreds of feet AGL)
  Forecasted wind speed & direction at that height
- Often depends on aircraft observations & radiosonde reports
- Guidelines: Wind speed change >25kt within 500ft AGL
  Wind speed change >40kt within 1000ft AGL
  Wind changing by 50kt within 1500ft AGL
  Pilot reporting loss/gain of IAS of 20kt or more within 1500ft AGL
- Causes:
  Low level jet: Associated with frontal system
  Powerful jet of cold/warm air(front) following a front can produce turbulence
  Found typically at 700-2000ft AGL
  Nocturnal inversion: Great speeds aloft than at surface → Hazardous during approach & departure
  Max wind 700-2000ft AGL
  Up to 8kt at ground, 25-40kt at max, drop to 15-30kt 1000ft above the max wind
  Extreme max speed in excess of 65kt with WS of 10kt per 100ft below it
  Microbursts: Gust front form thunderstorm passes the wind can shift 180° an increase in speed
  Strong shafts of rain can create downbursts of cold air → Strong gusts & wind shifts
  Last for few minutes and typically only about a mile wide

Virga: Rain that falls dragging cold dense air along with it, if fall into drier air below then will evaporate
Cold air continues downwards without rain → Strong downdraft
Funnel clouds: Associated with thunderstorm, severe wind shear
High level clear air turbulence: Associated with jet stream aloft
Greatest below & to left of jet core when facing downstream
Sharp temp gradient, mountain waves, wind profiles that vary significantly also can lead to areas of CAT

Reporting criteria:

- Light: Slight changes in attitude/altitude, <15kt airspeed fluctuation
- Moderate: Causes bump/jolt but aircraft remains in control
- Severe: Large abrupt change, momentarily out of control, >25kt airspeed fluctuation
- Extreme: Airplane is violently tossed, control impossible, may cause structural damage
- Light chop: Slight rapid & rhythmic bumps without changes in altitude/attitude

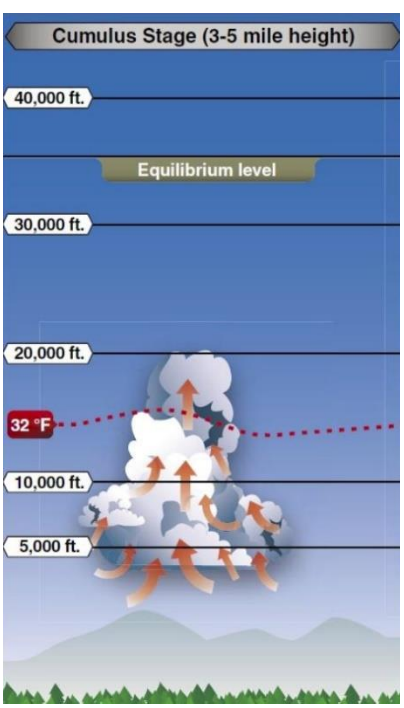
3. Thunderstorms

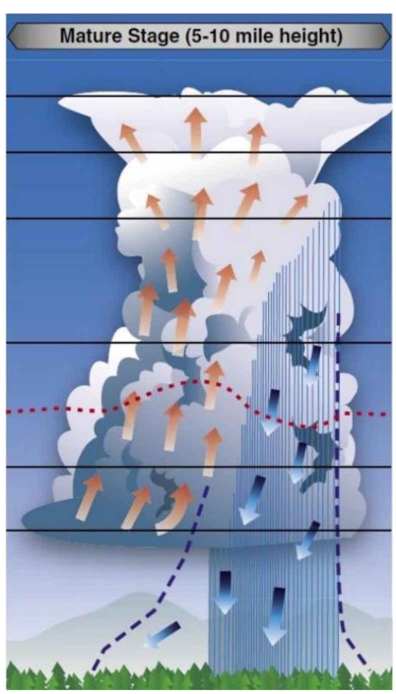
Requirement:

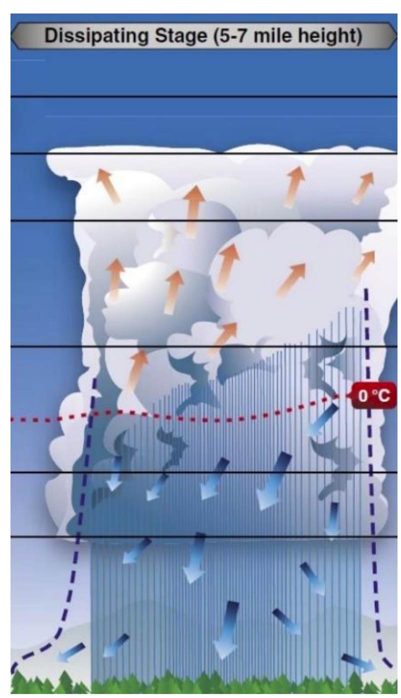
- High moisture content
- Steep lapse rate (Unstable air)
- Lifting agent
- Greatest in tropical regions

Development/structure:

- Cumulus stage: Warm, moist, unstable air is forced to rise
  Moisture cools into liquid drops of water due to cooler temp at high alt → Cumulus cloud
  Latent heat is released & warms air → Less dense than surrounding dry air
  Upward growth rate of clouds is 5-20m/s (10-45MPH)
  Updraft holds water droplets & ice crystals ∴ Rain is unable to fall
  Cloud typically extends above freezing level & usually no precipitation
- Mature stage: Warmed air continues to rise until existing air is warmer so air cannot rise anymore
  → Usually this cap is tropopause
  ∴ Air is forced to spread out as anvil shape
  Water droplets combine into larger & heavier droplets, freeze to ice particles
  → Fall & melt to rain
  May already reach height of 60000ft & updraft with 6000FPM
  Strong downdrafts tend to form in area of heaviest precipitation
  → Heavy rain cools & drags down air so downdraft up to 2000FPM
  Intense precipitation, turbulence (Due to opposite rushing air current), thunder, lightning
  Greatest turbulence due to opposite rushing air currents at middle level
  Updraft continue to dominate in inner portions, downdrafts on outside edge
  Last about 15mins but maybe an hour or more
- Dissipating stage: Heavy precipitation causes cloud to cool → Downdraft dominate base of cloud
  Downdraft push down out of TS → Hit ground & spread out causing microburst
  Lose energy & rainfall ceases due to cooling
  Cool air carried to ground by downdraft → Cut off inflow of TS
  ∴ Updraft disappears & TS will dissipate







Thunderstorms type:
- Embedded thunderstorms: Obscured by cloud decks
- Orographic: Form in mountainous areas, created as air is forced to move up steep slope
- Convection (Air mass TS): Rising hot air creates energy source that TS require
  Often seen on summer afternoon, even forest fire can trigger them
- Frontal (Steady-state TS): Created by frontal lift
  Fast moving cold fronts create most energetic storm, may develop in warm front
  Often form TS lines extending for hundreds of miles, embedded in cloud decks

Squall line:
- Fast moving line of TS
- Will be issued in SIGMET, should take extra fuel
- Found well ahead of fast moving cold front
- Leading edge of squall line: Updrafts & downdrafts are most severe
- If need to pass through line of TCU/CB → Penetrate less dark area

100-200NM ahead of fast moving cold front
warm air mass is unstable with high moisture
Tendency for cold front itself to become inactive

Lightning:
- Voltage potential/difference between 2 objects must exist
- Air has electrical resistance
- When potential/difference is large enough → Electrons flow to +ve charge forming lightning
- Probability of lightning strikes occurring to aircraft is greatest with temp -5°C to 5°C
- Lightning may strike aircraft flying in clear air in vicinity of TS
  → Puncture skin of aircraft, damage electronic equipment, engine failure, permanent error in compass
  Become blinded, temporarily lose hearing

Hail:
- Strong updrafts push water droplets up above freezing level
- Updraft dissipates & frozen droplets fall & collect more water
- Another updraft may push droplets up & refreeze at larger size
- Cycle may repeat many times until hail is too heavy for updraft to carry it aloft
- Alert for hail when radar echoes are well defined
- May be thrown outward from storm cloud for several miles

Flight near thunderstorm:
- Severe turbulence may extend up to 20NM from TS
- Frequency & severity of turbulence associated with areas of high water content → Increase radar return
- No flight path through area of strong radar echoes separated by 40NM/less can be considered free of turb
- Turbulence under TS should not be underestimated especially when relative humidity is low
- Virga: Rain that evaporates before reaching ground & related to microbursts

Engine water ingestion:
- Updraft velocity in TS approaches/exceeds terminal falling velocity of rain → High concentration of water
- May exceed quantity of water a turbine engine is capable of ingesting
- Result in flameout/structural failure of engine

Thunderstorm consideration:

- Avoid visually: At least 10 miles on downwind side & 3 miles on upwind side
- Using radar: Avoidance distance to 20 miles due to radar error
- Vivid & frequent lightning = severe activity in TS & any with top of 35000ft/higher
- Pressure: Falls rapidly ahead TS then rises abruptly after rain starts
- Do not land/takeoff when TS is approaching
- Do not attempt to fly under TS
- Avoid area where TS are covering 5/8 or more of sky
- Microburst: Rapid downburst that can occur within 10NM of TS
  1NM in diameter at 2000AGL with horiz. extent at surface of approx. 2-2.5NM
  Wind shear as high as 6000FPM & horiz. wind as much as 45kt at surface

2NM diameter
less than 5 mins
Under TS / within 10NM of one

- Clear top of TS by 1000ft per 10kts of wind speed at cloud top
- Initial downburst to dissipation seldom longer than 15mins with max intensity wind lasting 2-4mins
  → Microburst may concentrate into line structure & continue for an hour
- Avoid by at least 20NM from any TS & anvil of CB

If enter TS:

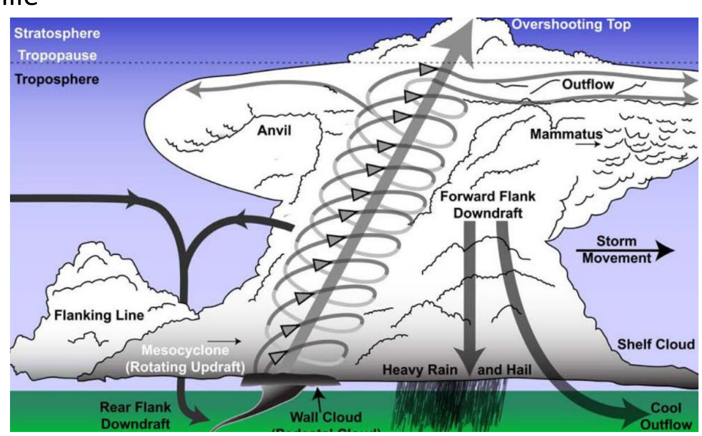
- Tighten seatbelt, plan course that will pass storm area with min time
- Carb & pitot heat on, set penetration airspeed, turn up cockpit light to highest
- Disengage autopilot, tilt airborne radar antenna up and down occasionally
- Penetrate at altitude below freezing level or above level of -15°C to avoid most critical icing areas
- Concentrate on instrument & maintain constant attitude

Hurricanes:

- Destructive cyclonic (extremely low pressure system) storms that originate in tropical waters
- Huge systems of organized thunderstorm
- Quite large, typically 100 miles or greater

Tornado/funnel cloud:

- Rotating funnel shape cloud linking ground to large TS/CB/TCU
- Mammatus clouds are signs
- Funnel cloud is not tornado until it touches down
- Wide variety of shapes & sizes, diameters of 30ft to 0.5 mile
- Last few minutes but also last for several hours
- Most likely in spring/summer in North America
- Average forward speed of 50km/h (30MPH)
- Path of destruction typically 3-4km (2-2.5SM)
- Wind speed within tornado 65-450km/h (40-280 MPH)



Waterspouts:

- Funnel cloud that makes contact with water
- Smaller diameter & weaker than tornadoes
- Can form over land & move across water

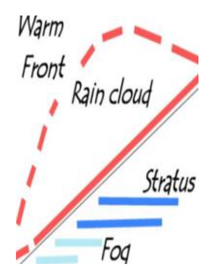
4. Surface based layers

Fog:
- Cloud that is in contact with ground → Commonly as stratus type
- Key ingredients: Moisture: High relative humidity (Maybe high temp as well)
  Condensation nuclei: Small particles upon which water vapour condenses (Dust, smoke)
  Very light surface wind: Set up mixing action, without wind then dew will appear
  Cooling process/Add moisture: Get condensation going
- Temperature & dew point spread < 3°C & dropping → Anticipate fog

Fog types:
- Radiation: Form by radiation cooling on clear nights with high relative humidity & light winds are present
  Patchy, few hundred feet thick
  Present shortly after sunrise
  As wind speed increases/sun rises warming up ground → Fog lifts & dissipates
  Tend to form in valleys & low lying areas
  Restricted to land area
- Advection: Form by advective cooling as result of horizontal movement
  of warm moist air over land/sea surface colder than itself
  Thickest when winds up to 15kt at night
  Common in coastal area/during winter warming periods & early spring thaws
  Dense covering wide area & last for several days, persist until wind direction changes/ > 15kt
  → Become low stratus cloud
  Leeward side of hill/mountain can have alternate aerodrome ∵ Subsidence heat dissipate fog
  Forms exclusively during the day with maritime air drifting over a cold inland area

Lighter easterly wind
moist air
over Prairies

- Upslope: Cloud resting on ground as result of light to moderate upslope wind
  Moist air cools down due to expansion as it moves up gradually rising terrain
  Leeward side of hill/mountain can have alternate aerodrome
- Frontal/Precipitation: Continuous precipitation ahead of warm front falls into colder air below
  → Rain evaporates & saturation occurs causing fog
  Happens at warm front/trowal
  Humid warm air meets very humid cold air



- Steam: Known as sea smoke when formed over ocean by water vapour being added to air
  Ideal when extremely cold dry air blows over body of open water
  Cold air mixes with warm moist air over water & cools until excess water vapour condenses
- Ice: When temp are significantly below zero
  Created by exhaust from engines/large industrial center on cold winter day

Mist or fog:
- Mist: Visibility meets/exceeds 5/8 of mile → 5/8 SM up to 6SM → BR
- Fog: Visibility < 5/8 SM → FG
  Shallow → MI
  Patches → BC
  Partial → PR

Haze/smoke:

- Haze: Consists of particles of dust, salt, water droplets that are minute & cannot be felt/seen
  Form on days with high temp & high humidity → Milky appearance
  Bluish against dark background & yellow/orange hue against bright background
- Smoke: Cause haze & reduce visibility to zero in stable air especially when flying into sun

Blowing obstructions to vision:

- Wind will lift fine & dry snow
- Reduced visibility to zero from surface to approximately 500ft, average 15-30ft above ground
- Vertical visibility in METAR: VFR ceiling

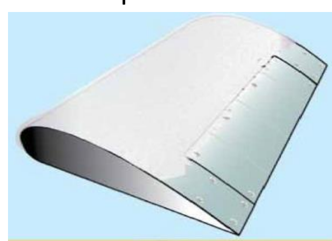
White out:

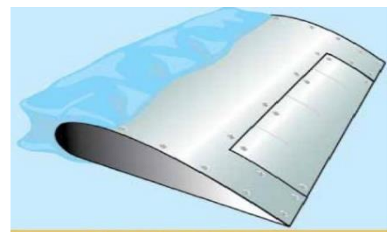
- Visibility & contrast are severely reduced by snow/sand
- Horizon disappears completely & no reference point

5. Aircraft icing

Airframe ice:

- Supercooled water droplets strike airframe that is < 0°C
- Tends to favour locations with decreased condensation nuclei levels & vertical currents
- Clear ice: Large supercooled water drops slowly freeze
  Smooth & transparent
  Most dangerous type of icing
  Large accumulations are shown by presence of upper & lower horns
  Caused by freezing rain & freezing drizzle
  Forms in cumuliform (heap, vertically developed) clouds with strong vertical currents
  → Tend to be worst near tops of these clouds
  Lenticulars will produce severe clear ice
  Heavy, may affect control surfaces, unlikely to flake off when building is great
  Likely to occure in CB & Cu in temp between 0°C to -25°C
- Rime ice: Instantaneous freezing of small supercooled water droplets
  Rough, milky, opaque
  Forms in layer-type clouds such as stratus
  Brittle, not very adhesive
  Results in light to moderate levels of icing
- Mixed ice: Combination of rime & clear ice


Rime Ice


Clear Ice Buildup with Horns

Ice accumulation:

- Airfoil shape: Thin airfoil collects ice more efficiently than thick one
  Thin stabilizer picks up ice quicker than main wings
- Speed of aircraft: Higher airspeed = Greater rates of ice accumulation
- Droplet size: Larger droplets require strong vertical currents to overcome gravity
  ∴ TCU, CB, ACC, orographically lifted clouds, leewave clouds
  More likely to strike the wing than small droplet
  Clouds with larger liquid content = Greater icing intensity
  → More suspect in warmer air masses

Icing intensity:

- Trace: Ice becomes perceptible
  Rate of accumulation is slightly greater than rate of sublimation
  Not hazardous unless > 1hr
- Light: May create problem if flight > 1hr
- Moderate: Rate of accumulation is quick enough that even short encounters will be potentially hazardous
  De-icing/Anti-icing equipment will be required & diversion may be necessary
- Severe: Rate of accumulation is fast enough to render De-icing/Anti-icing equipment useless
  Immediate diversion is necessary

What should be done when icing conditions are encountered:

- Make an immediate decision → Climb/descend/go back
- Activate de-icing equipment such as pitot heat

Effects of aircraft icing:

- Increase in drag: More power to sustain flight, caused by rough surfaces
- Decrease in power: Due to intake blockage
- Engine failure: Carb-icing/blocking of air intake
- Engine FOD (Foreign Object Damage) is likely for turbine engines
- Icing alters shape of wing: Increase in stall speed
- Decreasing AOA of stall & increasing stall speed: Stall can occur before warning system activates
- Deteriorating trim effectiveness: Less lift from horizontal tail requires more elevator which could run out
  Horizontal tail can also stall
- Asymmetric shuddering & vibrations due to one propeller/rotor blade shedding ice
- Control surfaces may freeze in place
- Wing flaps can be damaged if retract/extend in icing conditions
- Landing gear mechanism may freeze in place/damage by movement
- Fuel vents may become blocked & lead to starvation
- Pitot may be blocked leading to airspeed errors
- Completely obscured cockpit vision due to ice in windshield
- Reduction in radio reception & may cause antennas to vibrate and break off

Icing checklist:

- Get weather briefing from forecaster, ask & check for PIREPS
- De-ice aircraft before takeoff
- Is aircraft certified for flight through icing
- If anti-icing/de-icing devices begin to lose effectiveness then change route/altitude immediately
- With ice avoid abrupt maneuvers: Banking & ice increases stall speed, may bank only 5°
- Fly approach with extra power & airspeed
- File PIREP asap in air/on ground
- Clear ice in cumuliform clouds, worst at 0°C and -10°C
- Rime ice in stratiform clouds, worst at -10°C and -20°C
- Anti-ice & de-icing equipment is most effective at removing rime ice
- May takeoff: Without icing/icing in bottom of wing as a result of cold soaked fuel

De-ice equipment:

- Remove ice after it has formed
- De-icing boots on leading edge of wing: Inflate by vacuum pump, break off & shatter accumulated ice

Anti-ice equipment:

- Used to prevent ice from collecting on surface
- Electric heating: Used on propellers & windshields
- Jet: Use bleed air from engine to heat leading edge
- TKS: Weeping wing system pump fluid through mesh screen on leading edge of wing & tail

Frost:

- Form on aircraft when surface temp of aircraft: Below dew point & freezing
- Frost with roughness of medium/coarse sandpaper: Decrease 30% of wing lift & increase 40% of drag
- Cold soaked fuel: Fuel tank in wings changes temp of outer surface of wing
  Typically when airplane comes down from flight levels into warmer air below
  Warm moist air condenses & freezes when comes in contact with wings

Impact icing:

- May occur over intake air filter on both fuel injected & carburetor equipped aircraft → Engine failure
- Select carb heat on to bypass air filter → Lean mixture if carb heat is used continuously
- Use alternate air in fuel injected aircraft
- Ice may form on cowl intakes causing engine to overheat

CARs:

Canards

- Critical surface: Wings, control surfaces, rotors/propellers, horizontal/vertical stabilizers,
  Upper surface of fuselage in rear mounted engine, any stabilizing surface
- No person can takeoff in aircraft that has frost, ice/snow adhering to any of critical surface
- Takeoff may be permitted if frost on bottom of wing due to cold soaked fuel according to manufacturer
- Visual inspection before takeoff is mandatory by PIC/flight crew designated by PIC/trained person

How to avoid:

- Stay out of cloud & visible moisture when temp is below freezing
- Fly through front directly instead of at an angle
- Study GFA and plan route
- Be ware & avoid winter warm front particularly one with freezing rain
- Read PIREPs
- Carry extra fuel in case of diversion (More power is required to offset drag by icing/prolonged use of carb)
- Ensure contamination is completely removed from aircraft
- Change altitude to get out of icing layer but not to climb too steeply
- Advise ATC for immediate actions
- Turn back 180° & get out

Tail stall:

- Excess icing on tail: Sudden & violent pitching of nose down
- Recognition: Abnormal pitch forces when flaps are extended
  Buffet may be felt in control column instead of airframe
  Pilot induced oscillation may be early indication
- Recovery: Raise flaps to previous setting
  Pull back on yoke, reduce power if altitude permits
  Do not increase airspeed unless needed to avoid wing stall

Hoar frost-icing in clear air:

- Caused by cooling on clear & calm nights, DP colder than freezing
- Water vapor turns into ice crystals/frost through deposition which usually melt after sun rises
- May occur when cold airplane descends into warm & moist airmass

Aerodynamic heating:

- Rise in temp in aircraft skin caused by compression & friction as aircraft penetrates air
- Airspeed of 500-600kts is required to ensure no ice will collect
- Ineffective to remove ice once it has formed

Chapter 15

Weather reports and forecast

1. Aviation weather services

Flight information centers (FIC):

- Toll-free access to weather briefings & flight planning services
  → Aviation weather briefing service
- 5 FIC locations across country which service 5 flight information regions
- Flight information services en-route: Exchange on FISE freq. of info relevant to en-route phase of flight
  Meteorological info: SIGMET, AIRMET, PIREP, METAR, SPECI, TAF, Altimeter setting,
  Weather radar, lighting info & briefing update
  Aeronautical info: NOTAM, RSC, CRFTI, MANOT
  4 main FISE sequencies: 123.275, 123.375, 123.475, 123.55 MHz

Aviation weather briefing service (AWBS):

- Meteorological & aeronautical information to assist pilots in pre-flight planning
- Flight service specialist adapts meteorological information including satellite & radar imagery
  → Consultation & device on special weather problems, accept flight plan information during briefing

Flight service stations (FSS):

- Located at Class E control zones
- Aerodrome advisory service:
  Info relevant to arrival & departure at uncontrolled aerodrome & for transit through an MF area
  Provided on MF and also in conjunction with Vehicle control service
- During initial aerodrome advisory communications:
  Runway, wind direction & speed, air traffic that warrants attention,
  Vehicle traffic, wake turbulence cautionary, aerodrome conditions, weather conditions
  May updates the info when appropriate after initial advisory
- NOTAM, RSC & CRFI are included in advisories for 12hrs (domestic) 24hrs (international)
  Prior to the time limits can be received in pilot briefing/can be obtained on request

FIC & FSS:

- NOTAM information service: NOTAM, RSC, CRFI info by flight service specialist
- Weather observation service: Observation, recording and dissemination of surface weather info
- Callsign is "Radio"

Internet:

- Collaborative flight planning service (CFPS) of Nav Canada, replacing AWWS service

Automatic terminal information service:

- Continuous broadcasting of recording info for arriving & departing on a discrete VHF/UHF freq.
- Improve controller & flight service specialist effectiveness & relieve freq. congestion
- CAVOK: No cloud below 5000ft AGL/Highest min. sector altitude whichever is higher,
  Visibility 6SM or more, No precipitation, thunderstorms, CBs, shallow fog, low drifting snow
- ATIS freq. can be found in CFS

VOLEMT (HF) Broadcast:

- Flight weather info via HF shortwave radio, used for North Atlantic crossings, frequency in CFS

Unofficial weather information:

- Help to get the big picture, but should call a briefer before heading out to fly

2. Notice to airmen (NOTAM)

General:

- Noti. contains info concerning: Aeronautical facility/charts/info publications, service, procedure, hazard
- Issued when/where timely knowledge is essential
- Publish with sufficient notice time to take required action (At least 24hrs advance notice is desirable)
- Lead time is at discretion of originator but not exceeding 14days but no less than 6hrs
- Distributed by teletype on Aeronautical fixed telecommunication network/Voice advisory using radio

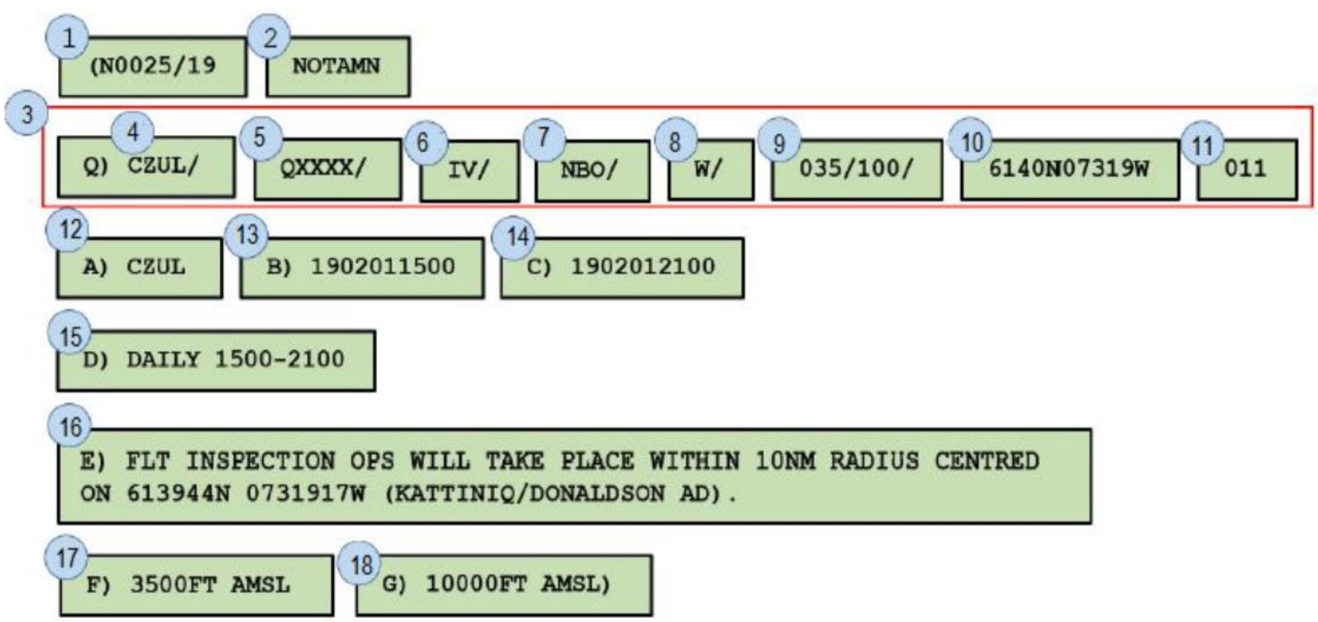
Criteria for issuing a NOTAM:

- Temporary nature & of short duration/permanent or temp. changes of long duration at short notice
- Establishment/withdrawal of electronic & other aids to air navigation & aerodromes
- Changes in freq., identification, orientation & location of electronic aids to navigation
- Interruptions in service/unreliability, return-to-normal operation of en route & terminal aids to nav.
- Establishment/withdrawal/significant change to designated airspace or air traffic procedures & services
- Presence/removal of hazards that could endanger air nav./aircraft operations
- Military exercises/maneuvers & airspace reservations
- Establishment/discontinuance/change in status of Advisory/Restricted areas
- Communication failures where no satisfactory alternative freq. is available
- Inaccuracies/omissions in publications that might endanger aircraft operations
- Significant changes in operations of runways & service abilities of associated approach/runway lighting system that could prohibit/limit aircraft operations
- Failure of measuring/indicating systems needed to supply current info on altimeter setting, surface wind, RVR & cloud height for the pilot about the land/takeoff
- Any other info of direct operational significance as recommended in Annex 15 to Convention on ICA

NOTAM format:

1. NOTAM continuity number:
   SNNNN/YY
   S: Series letter (18 in total → C to V), NNNN: 4-digit NOTAM number, YY: 2-digit for calender year
2. NOTAM types
   N: New, R: Replacing, C: Cancelling
3. Q line
   Qualifier line: Coded info, coordinates, radius of area of influence for filtering purposes
   Divided into 8 fields separated by stroke
4. FIR:
   ICAO location indicator of FIR that the info is located geographically (Canada has 3)
   If more than 1 FIR: ICAO nationality letters then followed by XX (e.g. CZXX)
5. International NOTAM (Q) code:
   Contains 5 letters, 1st: Code abbreviations for use in composition of NOTAMs
   2nd & 3rd: Identify subject being reported, 4th & 5th: Status of operation of it
6. Traffic type:
   I: IFR only, V: VFR only, IV: Both IFR & VFR
7. NOTAM purpose:
   NBO, BO, B, M, K
   N: Immediate attention, B: Operational significance, O: Flight operations, M: Miscellaneous, K: Checklist
8. NOTAM scope:
   A: Aerodrome info, E: En route info, W: Nav. warnings, AE: Aerodrome & en route, L: Checklist

9. Lower limit/upper limit:
   Indicates airspace expressed in flight level (FL), if no specific height then 000/999
10. Geographical coordinates:
    Represent the center of circle whose radius encompasses whole area of influence
11. Radius of area of influence:
    3 figures that rounded up to next whole nautical mile, measured from rounded center coordinates
12. Location indicator (Item A):
    Location indicator of aerodrome/FIR
    If no available ICAO location indicator, use ICAO nationality + “XX” & followed up in Item E by plain name
    E.g. Location indicator with 3 letters and 1 number → Shown as CXXX
13. Start time (Item B):
    10-figure group: Year, month, day, hours & minutes in UTC
    NOTAMR & NOTAMC: Actual date and time of the NOTAM origination
14. End time (Item C):
    Duration of info, PERM: Permanent nature, EST: Approximate duration
    No Item C in NOTAMC
15. Schedule (Item D):
    Event occurs at specific time during “in force” period indicated in Item B & C → Inserted under Item D
    E.g. DAILY 1500-2100
16. Text (Item E):
    English text with decoded NOTAM code, ICAO abbr., indicators, identifiers, designators, call signs, frequency, figures & plain language
17. Lower limit (Item F):
    Lower limit referring to nab. warnings & airspace restrictions
    GND: Ground, SFC: Surface
18. Upper limit (Item G):
    Upper limit referring to nab. warnings & airspace restrictions
    UNL: Unlimited



3. Aviation weather reports

Weather reports:

- Hourly, gives info about current conditions at a location
- Differ from a forecast in that forecast is predictive

Meteorological aerodrome reports (METAR):

- Info about actual conditions on UTC hour within 5NM radius of given aerodrome
- Wind knots, Cloud AGL, Visibility SM, Time UTC
- Correction code alpha (CCA) indicates 1st corrected METAR/AWOS
- METAR: Normal hourly report made on the hour, for a specific location, valid at time of observation
- SPECI: Special report, significant weather changes off the hour, maybe more than 1 SPECI within hour

1. 4-letter ICAO identifier: Can be found in CFS
2. Date and time of observation: Day of month at ZULU time   00000KT = Calm
3. Wind direction: Degree True & speed in knots, VRB → Variable direction if winds are 3kt or less
4. Visibility: Prevailing visibility near ground in statute miles, higher visibilities in mountainous regions
5. Runway visual range: Runway numbering with rage and upward/downward/no trend
   10-minute average RVR is reported when prevailing visibility <1 mile with RVR<6000ft
   RVR 4000VP6000: Visibility 4000ft varying to greater than 6000ft
6. Weather phenomena: Light (-), Moderate (No sign), Heavy (+)
   Precipitation → RA: Rain, DZ: Drizzle, SN: Snow, SG: Snow grains,
   PL: Ice pellets, GR: Hail, GS: Snow pellets, IC: Ice crystal
   Obscuration → BR: Mist (Visibility >= 5/8 mile), FU: Smoke, FG: Fog (Visibility < 5/8 mile),
   HZ: Haze, SA: Sand, DU: Dust, VA: Volcanic ash
   Other → PO: Dust/sand whirls, SQ: Squalls, SS: Sandstorm, DS: Duststorm,
   +FC: Tornado/waterspout, FC: Funnel cloud, TS: Thunderstorms
7. Sky cover: AGL, amounts are cumulative in METAR & TAF
   SKC: Sky clear (Partially obscured/is included with 1st layer),
   FEW: Few & <1-2 oktas, SCT: Scattered & 3-4 oktas, BKN: Broken & 5-7 oktas
   OVC: Overcast & 8 oktas, VV: Vertical visibility & sky obscured & considered as obscured ceiling,
   CLR: No cloud below 10000ft (AWOS)
   Ceiling: level of 1st cloud base that has coverage amount of 5-8 oktas (i.e. broken & overcast)
8. Temperature/dew point: M = negative temperature, 0.5 degrees are rounded up to next degree
9. Altimeter setting: A = inches of mercury, Q = Hectopascals (WS=wind shear within 1500ft AGL)
10. Remarks: SLP = Sea level pressure, put 9/10 in front then closest to 1000 is the right answer

Automated weather observation station (AWOS):   Does not report cloud opacity

- Computerized weather reporting, more accurate than human if "not affected by conditions"
- Indicated by the word AUTO in METAR
- Heavy rain/blowing snow can cause error, cloud height sensor tends to under-read during precipitation
- Reports are issued on the hour, may produces more SPECI than human
- Some can give automatic voice report via phone/VHF frequency
- Cloud layer are limited to 4, CLR when no layers are detected below a base of 25000ft (Some 10000ft)

Limited weather information system (LWIS):

- Not install METAR AUTO & SPECI AUTO but some info is required for IFR approaches
- Only hourly reports
- Wind speed & direction, temperature & dew point, altimeter setting

Pilot reports (PIREP):

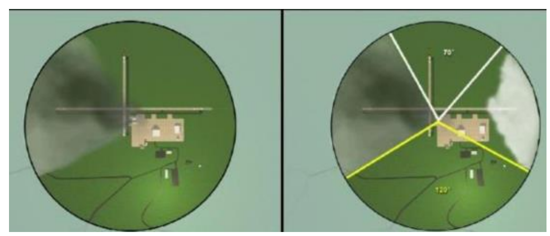
- Reports of weather conditions encountered by aircraft during flight
- Contact FSS/FIC to report significant observations of weather
- Can be both AGL/ASL, Usually ASL
- Wind direction by pilots in magnetic will be converted to degrees true in PIREP
- Location & time, Altitude, Aircraft type, Cloud (Base, amount, top), Temperature, Wind direction & speed, Turbulence, Icing, Remarks
- U/A: PIREP, UUA/UACN01: Urgent PIREP, OV: Over listed with an identifier, TM: Time, FL: Flight level/alt. in hundreds of feet, WX: Weather & visibility, TA: Temperature, TB: Turbulence, IC: Icing, RM: Remarks, SK: Sky conditions, WV: Wind velocity (in degree true)

Prevailing visibility:

- Max visibility value common to sectors comprising one-half/more of horizontal circle
- Determined by human observation

Runway visual range:

- Max horizontal distance as measured by automated visual landing distance system & reported by ATC/FSS for direction of takeoff & landing
- Light/marker can be seen from point above its centerline at height to average eye level of pilot in touchdown
- RVR sensor "A" located near runway threshold
- CAT II landing system: with second sensor "B" about mid-point of runway
- Measuring amount of light reaching a detector after being transmitted by projector



METAR = conditions

TAF = Future / Expecting

4. Aviation weather forecasts

Area Forecasts (FA):

- Text based, nearly impossible to read & decipher

Terminal Aerodrome Forecasts (TAF):

- Forecast for a specific aerodrome
- Gives expected weather within 5NM of runway complex depending local terrain
- Issued 4 times a day for either 12, 24, 30 hour period
- Type of forecast: TAF, AMD: Amended
- Station identifier & issue date: 4-letter ICAO standard format, issued on what day at what time UTC
- Validity period: Two 4-digit date/time groups → Start date & time of TAF, End date & time of TAF
  Valid from the moment it is issued, not start date & time
  Valid until amended/next scheduled TAF is issued/period of validity ends & no new TAF
- Forecast period: Covers period from what day what time until what day what time
  Max. period of validity for TAF is 30 hours
- Winds: Degrees True, VRB: Variable direction & less than 3kt, may also be used if can't forecast single °
- Wind shear: Low-level non-convective wind shear, Affect within 1500ft AGL will be included in TAF
- Visibility: P6SM: Greater than 6SM
- Sky cover: Clouds heights in AGL, Only cumulonimbus (CB) cloud will be specifically identified in forecast
  BRK, OVC, VV → VFR ceiling
- Changing weather: TEMPO: Temporarily, No longer than 1 hour in each instance
  Will not cover more than half of total time
  → Restricted to TS, FR prep. LLWS, ceiling, Vis less than IFR
  FM: From a certain time
  BECMG: Permanent but gradual change
  PROB: Probability, if higher than 50% then use BECMG, TEMPO, FM
  → for Thunderstorms, Freezing precipitation, LLWS, Low ceiling and Vis
- Remarks: Unique to Canadian TAFs

Upper winds and temperature forecast (FD, Wind aloft reports):

- Forecasts of wind direction & velocity & expected air temp at specific heights
- Prepared every 12 hours, spit out by computer and based on computer model
- Rare that these forecasts are spot on
- Wind direction in degrees True & speed in kt
- 9900: Light & variable wind at less than 5kt
- Field elevations above 1500ft ASL will not report a 3000ft ASL FD
- Temp is not reported on a 3000ft ASL FD
- Valid time: Info is good for use from AA to BB
- Altitudes: ASL
- Station identifier: Given with 4-letter ICAO identifiers
- Winds and temp: XXYYZZ → XX0 degrees at YY knots, Temp ZZ
  Wind direction between 51 to 86: Subtract 50 from direction, Add 100 to speed
  If all temp are below 0: Minus (-) sign will be omitted
  Wind veer: Clockwise, Wind back: Anti-clockwise

```
FD KWBC 151640
BASED ON 151200Z DATA
VALID 151800Z FOR  USE 1700-2100Z TEMPS NEG ABV 24000

FT   3000    6000    9000   12000   18000   24000   30000  34000  39000

ALA                  2420   2635-08 2535-18 2444-30 245945 246755 246862
AMA          2714   2725+00 2625-04 2531-15 2542-27 265842 256352 256762
DEN                 2321-04 2532-08 2434-19 2441-31 235347 236056 236262
HLC         1707-01 2113-03 2219-07 2330-17 2435-30 244145 244854 245561
MKC  0507   2006+03 2215-01 2322-06 2338-17 2348-29 236143 237252 238160
STL  2113   2325+07 2332+02 2339-04 2356-16 2373-27 239440 730649 731960
```

Airman’s meteorological advisory (AIRMET):

- Short term weather advisories that are designed to highlight but is not described in current GFA
- Will be issued if following unforeseen conditions appear:
  Instrument meteorological conditions, Freezing precipitation (Not severe enough to warrant SIGMET), Moderate icing/turbulence, Isolated thunderstorms, Forecasted & observed wind direction differs by more than 60°/sustained winds are to be greater than 30kt

Significant in-flight weather warning messages (SIGMET):

- Short term forecasts of serious weather for aircraft in flight:
  Severe thunderstorms, Squall line (line of CBs), Hail, Volcanic ash, Hurricanes, Tornadoes, Severe icing, Marked mountain waves, Widespread sand/dust storms, Low level wind shear
- Will be broadcast on 126.7, can get further info from nearest FISE freq.

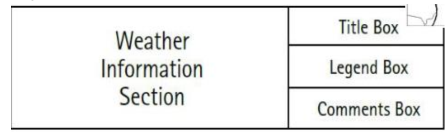
5. Graphic area forecast (GFA)

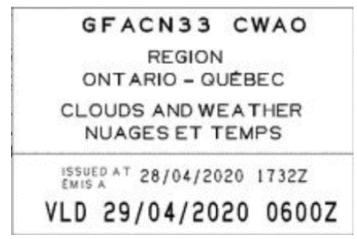
Introduction:
- 2 sets of charts: Clouds & weather, Icing & turbulence & freezing level (ICG TURB & FZLVL)
- Most probable meteorological conditions expected to occur below 400mb/24000ft
- For en route weather forecasting & pre-flight planning requirements of general aviation & regional carrier

Issue and valid times:
- Issued 4 times daily at appx. ½ hour before beginning of forecast period
- Every 6 hours, valid at 0000, 0600, 1200, 1800
- 3 Clouds and weather & 3 ICG TURB & FZLVL: Near-term, 6-hour, 12-hour forecast
- 12-hour clouds & weather chart: Includes IFR outlook for additional 12-hour period
  ∴ Each set of 6 contains a forecast for next 24 hours

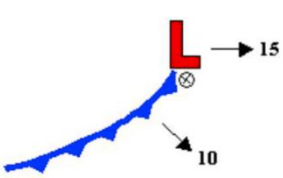
Units of measure:
- Wind speed: Knots
- All heights & cloud heights: Hundreds of feet ASL unless otherwise noted
- Horizontal visibility: Statute miles
- Time: UTC
- Nautical mile scale bar in legend

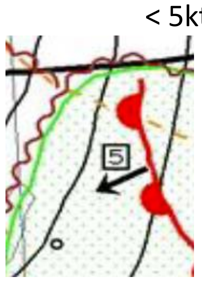
Layout:
- Title box: Chart name, issuing office 4-letter ID, chart type,
  date/time of issue, valid date/time of chart
- Legend box: Weather symbols & nautical mile scale bar
  TS: Thunderstorm, PL: Ice pellets
  FZRA: Freezing rain, FZDZ: Freezing drizzle
- Comments box: Formation/dissipation of fog
  Increasing/decreasing visibility etc
  12-hour clouds & weathers: Includes IFR outlook
  Valid for additional 12-hour
  ∴ It is valid for 24 hours
  IFR weather, cause etc
  IFR: Cigs <1000 ft **AND/OR** Visibility < 3SM
  MVFR: Cigs 1000-3000ft **AND/OR** Visibility 3-5SM
  VFR: Cigs >3000ft **AND** Visibility >5SM
- Weather information section: 2 types

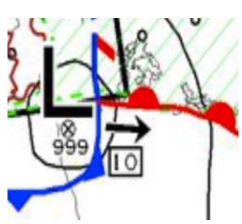


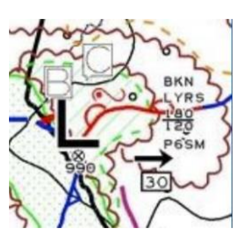


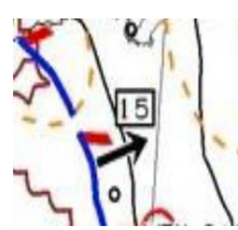
Clouds and weather chart:
- Forecast of cloud layers, surface-based phenomena, visibility, weather, obstructions to vision
- Lines joining points of equal surface pressure (isobars): Depicted 4mb intervals
- Relevant synoptic features that are responsible for depicted weather are shown with speed & direction
- Synoptic features: When speed >= 5kt then will be indicated by arrow & speed value
  < 5kt the letters QS (Quasi-stationary) are used





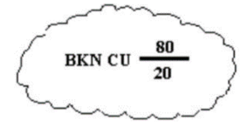


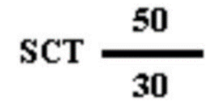




- Clouds: Bases & tops of clouds between surface and 24000ft ASL
  Tops of convective clous (TCU, ACC, CB) may extend above 24000ft ASL
  Cirrus clouds are not depicted on chart
  Cloud type will be indicated if considered significant (Especially CU, TCU, ACC, CB)
  Scalloped border encloses area of clouds for BKN/OVC → VFR ceilings
  No border: Unorganized clouds (SKC, FEW, SCT), P6SM
  Amount of cloud at each layer is based on that level only, not on summation amount
  → Bases and tops of each layer are indicated

SCT + SCT = ceilings





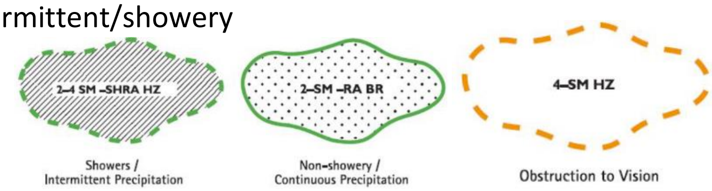
Abbreviation	Description	Spatial Coverage
ISOLD	Isolated	25% or less
OCNL	Occasional	26–50%
FRQ	Frequent	Greater than 50%

Convective clouds

Abbreviation	Description	Spatial Coverage
LCL	Local	25% or less
PTCHY	Patchy	26–50%
XTNSV	Extensive	Greater than 50%

Non convective clouds

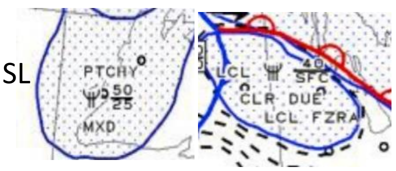
- Surface based layers: Described in abbr. plain English
  OBSCD: Obscured, VV: Vertical visibility in hundreds of feet AGL
- Visibility: Statute miles, P6SM: Greater than 6SM
- Weather and obstructions to vision: Only mentioned when visibility is forecast to =< 6SM
  Green dashed outer line, internal solid & slanted: Intermittent/showery
  Green solid outer line + dotted interior: Continuous
  Dashed orange line: Obstruction to vision



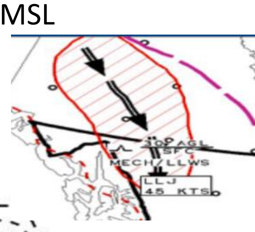
- Isobars: Joining parts of equal MSL pressure
  Drawn at 4 millibar intervals
- Surface winds: At least 20kt then are indicated by wind barbs & associated wind speed value
  Closer isobars = Higher pressure gradient = Stronger winds

Icing, turbulence and freezing level chart: be careful if ask for VFR flight

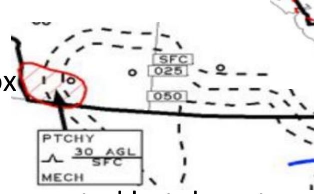
- Including type, intensity, bases & tops for each icing and turbulence area
- Surface synoptic features such as fronts & pressure centers are shown
- Icing: Moderate/severe icing, bases & tops of each layer is in hundreds of feet AMSL
  CLR: Clear, RIME, MXD: Mixed
  Light icing are described in Comments box
  If icing is expected only part of forecast period covered by the chart → Comments box



- Turbulence: Moderate/severe turbulence, bases & tops of each layer is in hundreds of feet AMSL
  MECH: Mechanical, LLWS: Low level wind shear, LEE WV: Lee/mountain waves,
  LLJ: Significant low level jet, CAT: In clear air



- Freezing level: Isotherms for freezing level are indicated by dashed lines
  Measured ASL with 2500ft intervals
  Above freezing layers aloft, temporal changes → Comments box



GFA amendments:

- Automatically amended by AIRMET when sth is not forecasted & occur/forecasted but do not occur
- Automatically amended by SEGMET even though it is not explicitly stated in SIGMET itself

GFA corrections:

- Re-issue if original GFA contains significant error, only erroneous chart is corrected and put in Comments
- Correction code: CCA, CCB, CCC etc

6. Weather maps and prognostic charts

Surface weather charts:

- Surface analysis charts & Surface prognostic charts
- Winds: Pennants (Triangle) = 50kt, Full feathers = 10kt, Half feathers = 5kt

Surface analysis charts:

- Actual info observed at specific time
  → Can see how weather has been developing
- Pressure patterns are drawn from surface to 3000ft AGL
- Weather visible from surface up to any level is included
- Can be a few hours old, based on obs. at 00Z, 06Z, 12Z, 18Z

Surface prognostic charts:

- Predict expected weather at surface
- Pressure patterns are drawn from surface to 3000ft AGL
- Issued 48 & 36 hours before standard validity times of 00Z & 12Z (Be sure to carefully read valid time box)

COLOUR	SYMBOL	DESCRIPTION
BLUE	H	High pressure centre
RED	L	Low pressure centre
BLUE		Cold front
BLUE		Cold front aloft
RED		Warm front
RED		Warm front aloft
RED / BLUE		Stationary front
PURPLE		Occluded front
BLUE		Cold frontogenesis
RED		Warm frontogenesis
RED / BLUE		Stationary frontogenesis
BLUE		Cold frontolysis
RED		Warm frontolysis
RED / BLUE		Stationary frontolysis
PURPLE		Occluded frontolysis
PURPLE		Squall line
PURPLE		Trough
BLUE / RED		Trowal

SYMBOL	DESCRIPTION OF SYMBOL	TRANSLATION
1.	green shading	continuous rain
2.	green hatching	intermittent rain
3.	green comma	drizzle
4.	green triangle with green period in centre	ice pellets
5.	green star	snow
6.	green curved line (used with comma or period	freezing rain (with period) freezing drizzle (with comma)
7.	green period over green inverted triangle	rain shower
8.	green star over green inverted triangle	snow shower
9.	green T with green lightning symbol	thunderstorm
10.	yellow shading	fog

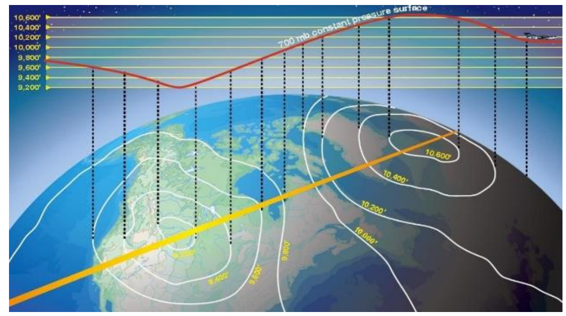
		C_H		
	TT	C_M	PPP	
VV	ww	N	PP	a
	T_dT_d	C_L	w	

C_H: High cloud type
C_M: Middle cloud type
C_L: Low cloud type
N: Cloud cover (portion of sky covered)
PPP: Atmospheric pressure (mb)
PP: Pressure change since last obs. (mb)
a: Graphical representation of pressure change
ww: Present weather when observation is taken
w: Past weather in past hour at time of observation
VV: Visibility code (vs. kilometers)
T_d T_d: Dew point (°C)
TT: Air temperature (°C)

Upper level charts (Constant pressure charts):

- Issued at 00Z & 12Z
- Analysis chart & Prognostic chart (SIG WX chart)
- Show reported wind speed & direction, temp, moisture, frontal systems, pressure systems
- Give picture of extent of weather system, cloud levels, thunderstorms
- Fronts are not included unless they extend up to pressure level of chart
- Based on levels of constant pressure since plane will be in standard pressure region with standard pressure value set on altimeter subscale → ∴ Looking at height of air for given pressure at given location
- Contour lines: Appx. height of pressure level, spaced 60m apart except at 250hPa where spacing is 120m
  Closer contour lines → Stronger wind, Far apart → Light wind
  250hPa chart: Analyze wind speed using dashed line for point with same wind speed
  → Isotachs, drawn at 30kt intervals starting at 60kt

Analysis chart:

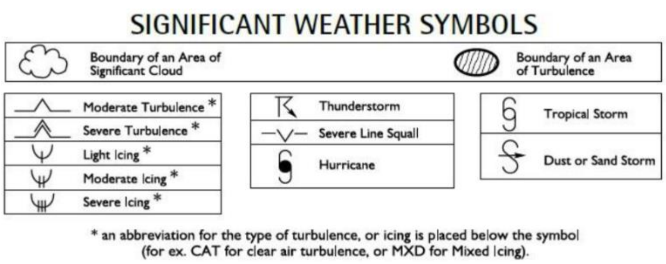


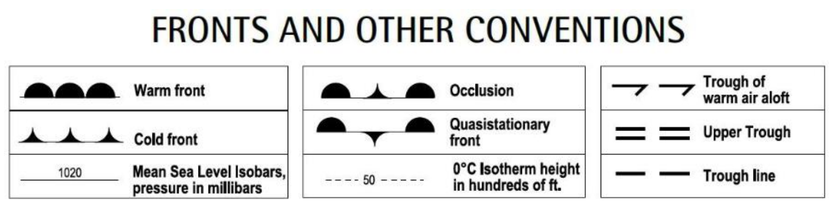
- Analyzed & created appx. 3hrs after getting actual upper wind data
- 250mb = 34000ft ASL = 1050 dM (decametres)
- 500mb= 18000ft ASL = 570 dM
- 700mb = 10000ft ASL = 300 dM
- 850mb = 5000ft ASL = 150 dM
- Actual height listed above would differ as air temp changes
  → Warm (Cold) then expand upwards (contract) & height would become greater
- Technically when flying through these columns at flight levels → True altitude will constantly change

Prognostic chart (SIG WX chart):

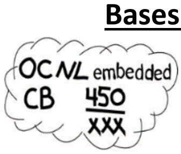
XX = Base below this chart

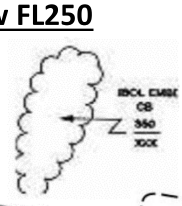
- Forecasted weather
- Significant weather prognostic charts (700-400mb) → (10000 – 24000 ASL
- Significant weather prognostic high level charts (FL250-FL630)



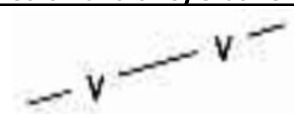


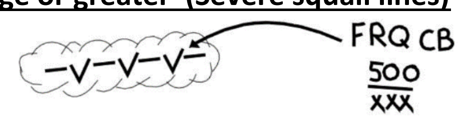
Bases below FL250



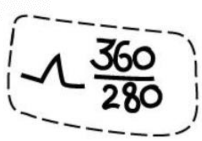


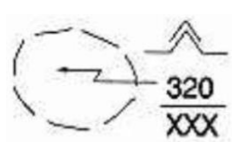
Lines of CBs of 5/8 coverage or greater (Severe squall lines)

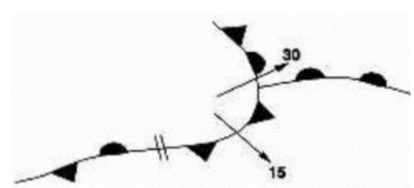




William







Typical storms

Moderate Turbulence

Severe Turbulence

Frontal system

7. Satellite imagery

Satellite imagery:

- Image resolutions available to public at less than 1KM
- Instant access to data covering vast area → Valuable to surface based observations
- Weather warning is issued in timely manner, ↑ Public safety
- Gather info about location & movements of icebergs, safer oil & gas field operations in Arctic
- Equipped with sensors, cameras, processor, storage for data, transmitter, receiver, solar power unit
- Weather satellite is placed in Geostationary orbit & Polar orbit

Geostationary satellites:

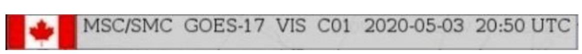
- Placed in orbit above equator at altitude of appx 36000KM → Motion matches pace of earth's rotation
- Observer: Satellite as motionless relative to star & space
- National Oceanic and Atmospheric Administration (NOAA)
  → Employs Geosynchronous Earth Orbit Satellite (GEOS) as one line of satellites for imagery
  GEOS West: 135° west longitude, observe west of Hawaii & North and South America
  GEOS East: 75° west longitude, observe North and South America & Atlantic Ocean
  GEOS South: 60° west longitude, observe North and South America
- 1 full disk image is produced every 30mins, also rapid scan to monitor every 1/5/10 mins
- Looping several images = build an animation showing evolution over time
- Con: Do not provide accurate info above latitudes of 60° ∵ Orbiting over equator

Polar orbiting satellites: Better level of detail in image

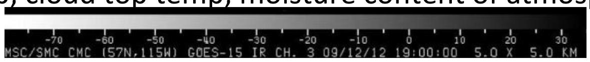
- Orbit earth at an altitude of appx. 850KM
- Complete 1 orbit every 105mins → Circle earth 14 times/day
- ∵ Earth rotates beneath them → Appear to move west by appx. 2 time zones per orbit
  ∴ Will not be above same point after 1 orbit
- 2 NOAA Polar Orbiting Environmental Satellites (POES) are orbiting, one on each side on planet
  → Images of given area every 6 hours with very high resolution images
- Con: Only every 6 hours ∴ Not ideally suited to monitor development of storms/fast moving systems

Image types:

- Visible image:
  Much like our eyes would see
  White Albedo style



  Objects can be seen ∵ reflect light incident upon them from sun
  → Can only be used during daylight hours
  Appearance of objects will change since angle of incident light will also change
  Clouds, Banks of fog & large cumuliform clouds would appear better defined
  Low sun angles: Cloud can take on 3D appearance
  Resolution is 2KM at Equator and deteriorates further North
- MSC: Meteorological service of Canada
- GOES-15: Geostationary operational environmental satellite – number
- IR: Infrared

- Infrared image:
  Measure temp and can be done in many different wavelengths
  Tell us surface temp, cloud top temp, moisture content of atmosphere
  White temp style 

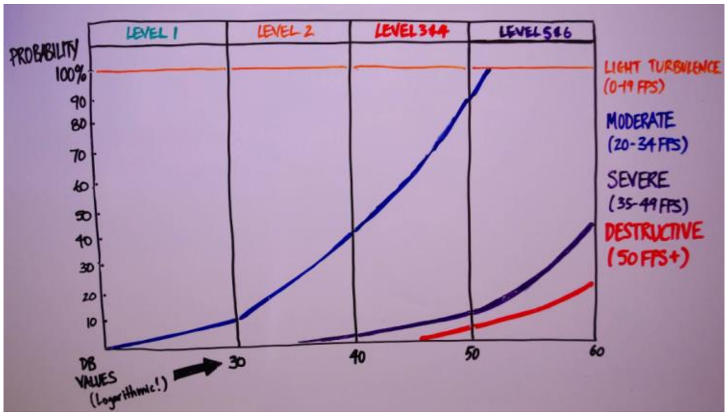
  Color temp style 

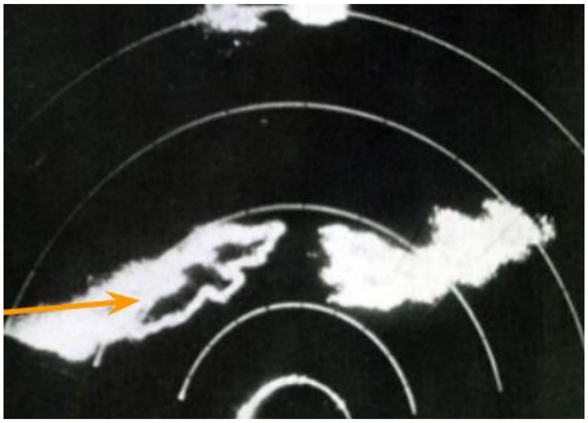
  All objects above -272°C will emit IR radiation, sensor detect & assign temp to each pixel
  Estimate temp of object by matching their shades to temp scale
  By correlation between altitude & temp ($\because$ Lapse rate) → Estimate height & types of cloud tops
  GEOS satellites can scan at multiple IR wavelengths and set time between scans
  Cold temp outbreaks/mountain terrain: Surface of earth can be as cold as cloud tops
  → Contaminate temp of cloud on image $\because$ Represents average of temp of cloud top & object underneath
  Fog/very low clouds: Quite shallow & difficult to pick out on IR image ($\because$ Same temp as ground below it)
  Temp inversion: Temp aloft is warmer than ground → Cloud can appear as dark objects
  Resolution of IR images is 4KM at Equator & deteriorates further North
- Water vapour imagery: Tell us where there is a lot of moisture in air
  Looped to show where moisture is headed
  High moisture content: Bright white, Relatively dry: Dark/Black

8. Airborne weather radar

General description:
- Used to find & avoid thunderstorm
- Radar transmits extremely narrow beam of energy from sweeping & tiltable antenna mounted in nose
  → Strike moisture-laden cloud, rainfall, solid objects an echo is received
  → Translated into visual indication of extent, range, azimuth of any thunderstorm/terrain in that range
- Ability of radar to see through weather is reduced proportionally as rate of rainfall increases

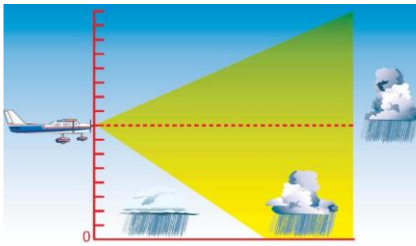
Rainfall gradient:
- Rate of rainfall change
- Turbulence is proportional to rate at which rainfall increases/decreases over specific distance
- Rainfall increases/decreases rapidly over short horizontal distance = High rainfall gradient & turbulence



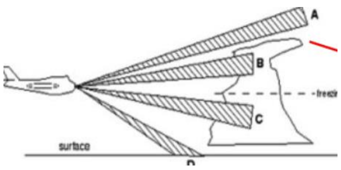


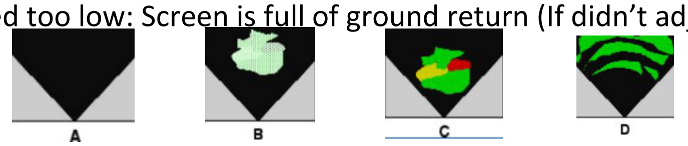
ISO – Echo contour:
- Circuit defines location & extent of each storm cell in thunderstorm by taking all radar echoes above a certain strength & cause them to black out → Leaving black hole in cloud indicating hard core of cell
- Edge of hole creates a contour line → Any point along = rainfall is the same iso
- Thin white ring = steep gradient = greatest turbulence
- Adjacent areas will also have turbulence

Reflectivity:
- Radar can see water best when in liquid form
- No echo: Water vapour, cloud, fog, ice crystals, small dry hail
- Rain has strong echo & to limited degree wet snow
- Dry snow is poor reflector
- Size of raindrop matters most in terms of reflectivity instead of number of drops
- Wet hail appears as giant raindrop → Highest reflectivity



Tilt control:
- Display on radar panel has control that allows pilot to tilt antenna up/down
- Radar antenna is stabilized in roll mode → Remain level to horizon as plane turns
- Proper antenna tilt can make difference between valuable & no info
- Aimed too high: Above freezing level & no return (If didn't adjust tilt during climb)
  May only have frozen (dry) precipitation
- Aimed properly: Max available data is displayed
- Aimed too low: Screen is full of ground return (If didn't adjust tilt during descend)

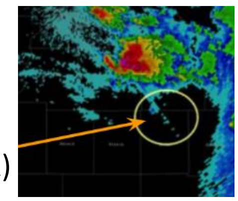
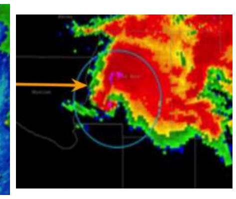




Mapping:
- Tilt radar for best ground mapping display
- Show lakes & mountains
- Fence post effect: Pick up grid effect from roads & fields all being at right angles in Central plains
- Tilt down until ground return is displayed then tilt up until ground return is at min but still present → Give pilot optimum setting for precipitation display
- Actual usage: Scan storm in vertical fashion to get more info

Attenuation:
- Large area of precipitation: Signal may bounce all over the place & become absorbed by moisture
- Display not accurately showing what lies within area of precipitation
- Green may be strongest part (Radiated signal has been absorbed & scattered by near precipitation)
- One cell "shadows" another cells → Radar shadow are severe & cause by a dense weather system

Hail on radar:
- 3 different characteristics scope patterns: Finger/protrusion (L)
  Hooks (indicating tornado)
  Scalloped edge on cloud outline (R)

- Echoes appear suddenly & along any edge of storm outline
- Change intensity & shape quickly
- Weak/fuzzy projection are not normally associated with hail
- Hail echoes show up better when gain is reduced slightly

Practical:
- Theoretical angle 8° high, sweeps 45° either side of 12 oclock
- Beam is stabilized (Stay at same angle with regard to earth regardless angle of aircraft)
- Many errors with stabilizing systems & angles on tilt controller are not always consistent/accurate
- Distance x 100 = Feet per degree

Threat ident procedure:
- Fundamental beam position
- PIC need to set up radar so bottom of beam is parallel to earth
- Anything radar shows will be at/above present altitude
- If beam is 8° & zero position is accurate, tilt it to +4° for TIP

Weather radar tilt calibration:
- Adjust tilt until bottom edge of beam is sweeping along ground on 20NM arc
- Divide altitude in thousands feet AGL by 2
- Increase tilt by number of degrees based on calculation (e.g. 12000AGL = 12/2 = 6)

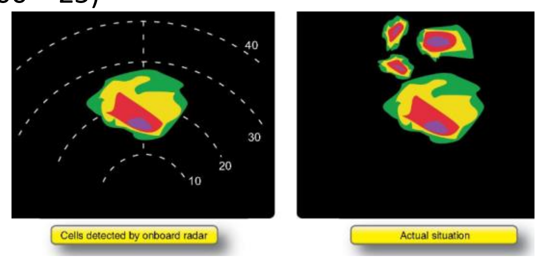
High elevation procedure:
- Start in TIP position (+4°)
- Note distance to echo of interest
- Raise tilt until echo become so weak that you can barely see it
- Multiply difference in tilt by distance in NM by 100
- Add result to current altitude
- Storms exceeding 30000ft should be avoided
- Radar top exceed freezing level by 10000ft or move → Damaging size hail will be encountered

Tilt up technique (TUT):

- Set tilt to +10°
- Returns at 30NM = Storm at least 30000ft above us, Returns at 20NM = Storm at least 20000ft above us
- Terminal area: Radar echoes above 20000ft is potential killer
- Any echo contours at 10° tilt is no go when operating below 15000ft
- Rules: Echo first appears at distance of 20NM/greater whether contouring or not must be avoided
  Any echo that contours must be avoided no matter how tall it is
  If gear is down & contouring echo appears within 5NM → Execute missed approach

Surface analysis procedure(SAP):

- Select 50/25/10 NM range as runway nears & set tilt to -4°
- Determine height of terrain in relation to aircraft
- 10000ft AGL: Ground should give return at 25NM (10000/4° = 2500/100 = 25)
- Any echo within 10NM arc should be noticed



Storm avoidance (Rules of thumb):

- Flying below freezing level: Avoid storm by min of 5NM
- Flying above freezing level: Avoid storm by min of 10NM
- Avoid any storm that is changing shape rapidly by min of 20NM
- Echo shown on radar, contoured or not, beyond 50-70NM indicates intense storm & dangerous
- All echoes: Warm weather (0°C/above) → min of 5NM
  If aircraft is not going to clear cloud top by more than 5000ft → min of 20NM
  Flying above 23000ft → min of 20NM
- Never fly near echo with radar top above 30000ft
- All weather with radar tops above 15000ft may be dangerous
- Assume all magenta radar returns are severe thunderstorms
- Never assume ATC/PIREP will provide warning
- Never continue flight toward radar shadow

9. Weather detection systems

Lightning detection (Spherics devices):

- Detect lightning produced by thunderstorm
- 360 degrees view & up to 200NM
- Stormscope, Strikefinder
- Pros: Less expensive than radar
  Simple to install & maintain
  No moving part
  Detects storms 360 degrees from aircraft
  Detect cell & storm hidden behind other storms
  Real-time info about electrical discharge
  Estimate data on azimuth & distance of electrical discharges
- Cons: Radar gives better detail & updates faster than lightning detectors
  Radar detects rain & turbulence due to severe downdrafts
  Lightning can occur many miles from active cell

Airborne radar:

- Transmit extremely narrow beam of energy from rotating/swiveling antenna mounted in nose of plane
- Echo is received when bean strikes moisture-laden clouds, rainfalls, solid objects
- Beam's energy bounces off target & return to radar transceiver where echoes are translated into visual indication of extent, range, azimuth of any thunderstorm/terrain in that range
- Not all beam is reflected & some energy can pass on through to be bounced off successive precipitation targets (If cell is strong → Hide other cells behind it & cause area in background to appear clear)

Data-link receivers:

- Receiving info from either satellite/ground based broadcast
- XM Weather: Satellite updated service
  METAR, TAF, Upper wind, Satellite & ground radar
  Cost $50/month & update every 2-5mins
- ADS-B: Ground-based system
  Includes all weather info but not as high res as XM weather
  No cost & update every 2-5mins

10. Ground based weather radar

Introduction:

- Radio Detection And Ranging
- Can detect targets that reflect its beam by day/night & under clear/overcast sky conditions
- Range is greater than searchlight since target does not have to be in direct line of sight to be detected
- Meteorologists use it to detect & locate precipitation and measure intensity
- Pilots: Ground based, Airborne weather radar unit, XM-Weather, ADS-B, Phone data

Ground based radar:

- Sweep sky slowly & at several levels
- Emit VHF waves/microwaves in form of short pulses
- Environment Canada: Pulses of 1-2 millionth of a second in length, separated in intervals 2000 times greater (Approx. 0.004 second)
- Strike target (Water, snowflakes, sleet, hail)
  → Reflected with intensity proportional to number, size, reflectivity (Wet snow reflect better than dry)
- Time for pulse to be reflected back from target to radar = Estimate its range

Plan Position Indicator (PPI):

- Simplest, oldest, fastest
- Radar is elevated at fixed angle & rotates 360 degrees around axis
- Radar beam get higher & higher as it moves away from emitter
- Usefulness decreases at greater range

Constant Altitude PPL (CAPPI):

- Beam scans sky both horizontally & vertically
- Beam is set at given elevation angle & perform rotation → Beam is elevated & perform another rotation
  → Repeat until all of sky has been painted by radar & will take 10mins → Volume scan
- All data is collected & analyzed by computer then display along given height across horiz. distance in radar
- Additional processing of volume scan can produce vertical slices/cross sections of atmosphere
  → Allow forecasters to identify internal structure of storms
- Pro: Easier to interpret
- Con: Still suffer radar beam increasing in altitude with distance
  Takes more time to produce an image since whole sky has to be scanned

Doppler radar:

- Able to sense reflectivity & radial velocity
- Radial velocity: Speed that objects are moving towards/away from radar
  Measured by Doppler Shift in beam that is reflected from target
- Able to detect presence of small targets such as dust & insect in air stream
  → Infer motion of surrounding air without presence of precipitation
- Forecasters can monitor conditions that leads to development of convective cells for Thundershower/Tornadoes, track progression of Gust Fronts, detect downburst, evaluate wind shear

Canadian radar imagery:

- Environment Canada: Doppler radar out to distance of 120KM
  From there computer algorithm that show CAPPI profile at average height of 1.5KM

Interpretation errors:

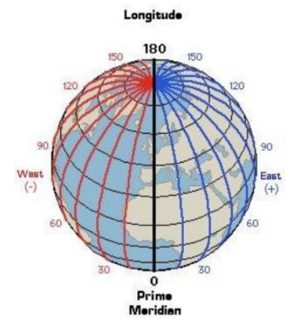
- Ground clutter: Beam may intersect ground & produce return signal if point radar low to ground
  Beam may miss precipitation near horizon at distant from radar if point above ground
  If some echoes on consecutive radar images never move → Ground clutter
- Blocking beams: Mountain/hills may block radar beams → Show shadow/no precipitation
- Anomalous propagation: Beam of radiation passes through atmosphere will curves downward
  Due to vertical variation in density of atmosphere (Less density = Travel faster)
  Extreme: Air near ground is cold & dense → radar beam is bent down to ground
  Produce strong echoes at large distances from radar
  AP echo can be unusual with sudden sharp changes in density
  Motions tend to be erratic/misleading
  Best point of comparison are surface observations & satellite data
- Attenuation: One storm in front of other will absorb radar's energy → Masking the other one
  Solution is to look at radar returns from stations immediately adjacent to it
- Overshooting beam: Precipitation forms below radar's beam elevation → Can be missed entirely
- Virga: Rain/precipitation falls from high level but evaporates before reaching ground → False returns
  Still can be downdrafts below Virga
- Electromagnetic interference: Wireless devices may interfere radar & lead to long spikes on radar returns
  Sun may have same effect
- Seasonal variations: Snow may act like stealth plane & radar may not be able to detect
  Environment Canada will change reflectivity
  Rain mode & snow → Under read intensity
  Snow mode & rain → Over read intensity

Chapter 16

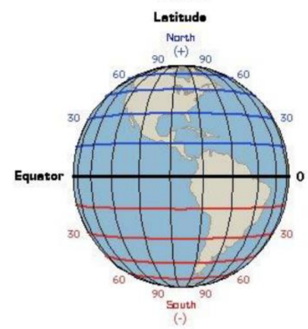
Navigation 1: Flight planning

1. Definitions

Meridian:
- Semi great circles that run north to south & join at earth's True Poles
  E.g. 30°W and 150°W are on same great circle
- Prime Meridian: 0° of longitude, passes through Greenwich, England
- International date line: 180° of longitude, opposite side to prime meridian
  Makes some political jogs in US & Russia to avoid date change
  The day officially changes from one to the next



Longitude:
- Degrees (°), Minutes (‘), Seconds (“)
- 60 minutes = 1 degree, 60 seconds = 1 minute
- Angular measures, earth rotate 15° in an hour (i.e. one time zone)
- Measured east or west of prime meridian



Latitude:
- Measured north or south of Equator
- 1 minute latitude = 1 NM, 60 minutes = 1 degree, 60 seconds = 1 minute

Equator:
- Line of latitude that is equidistant from poles (0° of latitude)
- Both a great circle and rhumb line
- Circumference: 24000 miles

Great circles:
- Circle on surface of sphere whose plane will cut the sphere into 2 equal pieces
- Shortest distance between 2 points on surface of earth
- Does not cross longitude at constant angle ∴ Heading must be changed frequently
- When using a VNC

Rhumb lines:
- Curved line on earth that cut all meridians at same angle
- All parallels of latitude are rhumb lines including equator
- Pro: Constant heading, Con: Not being the shortest distance between 2 points
- Straight line on Transverse Mercator Projection is rhumb line
- When using a VTA

Variation:
- Magnetic poles is not the same location as geographic poles
  ∴ Magnetic meridians do not coincide with True meridians
- Angle between magnetic meridians & true meridians: Magnetic variation/declination
- Compensating: True to Magnetic: Variation east, magnetic least
  Variation west, magnetic best

Isogonic lines:
- Dashed lines that represent same amount of magnetic variations
- Not always straight due to localized differences in earth's magnetic field

Agonic line:
- Line up between geographic pole & magnetic pole and give 0° magnetic variation
- 1 agonic line in each hemisphere (West of Thunder Bay in western hemisphere)
- East of agonic line: Westerly variation, West of agonic line: Easterly variation

Deviation:
- ∵ Magnetic fields associated with metal & radio in plane → Compass may not point North Magnetic Pole
- Angle that compass needle is deflected from magnetic meridian → Deviation
- Compasses can be fitted with correction magnets to correct deviation
  → Remaining deviations will be measured by turning plane to known compass heading (Swing compass)

Track:
- Direction of plane intends to travel over ground (e.g. straight line drawn on chart)
- Angle between this line & meridian measured clockwise through 360°
- Can be named true/magnetic/compass with reference to meridians from which they are measured
- Track make good: Actual path travelled by aircraft over ground

Heading:
- Direction of aircraft's nose in relation to true/magnetic north
- Nav log: True → Magnetic by variation → Compass by deviation
- Heading may differ from track due to wind strength & direction

Airspeed:
- Speed through air
- Indicated airspeed: Read from airspeed indicator
- True airspeed: Based on positional error, altitude & temperature, RPM

Ground speed:
- Speed relative to ground, Speed & direction of wind will alter ground speed
- Headwind: Lower ground speed, Tailwind: Higher ground speed

Bearing:
- Object's direction as measured clockwise from meridian

Drift:
- Wind blowing from left to right will cause aircraft to drift away from intended track
  ∴ Need to crab into the wind

Air position:
- Theoretical position at a given moment assuming not affected by wind ∴ No-wind position

Scale:
- Ratio of distance on map to actual distance on ground

Difference between latitude and longitude:
- Latitude is not longitude turned over 90°
- Longitudes converge at poles but latitude are parallels
- 1 minute of latitude = 1NM, 1 minute of longitude does not have constant length

2. Canada flight supplement

Canada flight supplement (CFS):

- Joint civil and military publication which contains all registered & certified Canadian aerodromes
- Also contains information on North Atlantic aerodromes
- Revised & reissued every 56 days and is available in French/English
- General: Tables, legends, associated information relevant to interpretation of supplement
- Aerodrome/facility directory: Data & sketches for Canada aerodromes & heliports, selected in N. Atlantic
- Planning: Information for flight planning, characteristics of airspace, chart updating, flight restriction, IFR routes, airway intersections, chart distributors, cruising altitude order, weather minima
- Radio navigation and communications: Data for radio nav. aids & communication facilities
- Military flight data and procedures: Procedures for flight in US, N. Atlantic & Alaska, air/ground communications & military training routes/areas
- Emergency: Emergency procedures & codes, light signals, ELT use, com. failure, intercept procedures

Reference:

- Aerodrome geometric center coordinates
- Location from community
- Variation
- Time zone factor with daylight saving time value
- Elevation ASL of highest point on landing surface
- Aeronautical charts on which the aerodrome and/or Nav aid can be found

REF	N54 06 W114 26 1.7SW 18°E UTC-7(6) Elev 2121′ A5015 E-15 E-16 LO1

Operator:

- Aerodrome operator
- Cert: Certified, with airport certificate, meets TC standards & inspected regularly
- Reg: Not subject to TC inspection, contact operator for current information
- Mil: Military, require prior permission for civilian aircraft
- PPR: Prior permission required
- PN: Prior notice required
- Landing fees

OPR	County of Barrhead 780-674-3331 Reg

Public facilities:

- A: Facilities available in terminal
- B: Facilities available on aerodrome
- C: Facilities exist within 5NM
- D: Facilities exist within 30NM
- 1: Telephone, 2: Food, 3: Taxi, 4: Medical facilities,
  5: Accommodations, 6: Car rental, 7: Public wifi, 8: Public internet access

PF	B-1 C-2,3,4,5

Flight planning:

- FIC: Flight information center, pre-flight & en-route flight planning services
- ACC: Area control center, provide weather information (hourly/special reports only)

FLT PLN	NOTAM FILE CYEG
FIC	Edmonton 866-WXBRIEF
ACC	Edmonton IFR 888-358-7526 or 780-890-8304/8305

Services:

- Fuel types/oil available is listed
- Servicing: 1: Storage available, 2: Servicing/minor repairs
  3: Major repairs, 4: Parking (extended term), 5: Tie-down facilities
  6: Plug-in facilities, 7: Pick-up/drop off only & no extended parking

SERVICES	
FUEL	100LL 780-674-2601/0827/2011/5313 JB (D), supply own pump, 888-778-8765

Runway data:

- Runway designation: Northern domestic airspce: Actual true bearing followed by “T”
  Southern domestic airspace: Actual magnetic bearing
- Length & width in feet
- Type of surface: Asphalt, grass, gravel
- RCR: Runway condition report

RWY DATA	Rwy 07/25 3500x100 asphalt
RCR	Opr Ltd maint

Lighting:

- TE: Threshold and runway end lighting
- ME: Medium intensity runway edge lights, variable 3 settings
- ARCAL: Aircraft radio control of aerodrome, remotely turn on lights by keying microphone
- Type K: variable intensity (3 settings)

LIGHTING	07-(TE ME), 25-(TE ME) ARCAL-123.2 type K

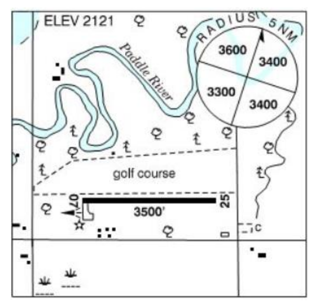
Communication:

- ATF: Aerodrom traffic frequency, radio is not mandatory but recommended
- 5NM 5200ASL: Specified ATF area

COMM	
ATF	tfc 123.2 5NM 5200 ASL

Obstacle clearnace circle:

- Highest obstacle altitude ASL + 1000ft then round up to next highest 100ft increment
- Guide for VFR pilots
- Radius is specified on outer ring of OCC
- Not designated A, B, C, D, E, F then is classified as G



Procedure:

- Special instructions regarding circuit (E.g. right hand circuits)
- If not specified, standard circuit altitude is 1000ft above elevation and left hand

PRO	Rgt hand circuits Rwy 10 (CAR 602.96).

3. Aeronautical charts

Published & produced by Nav Canada's Aeronautical Information Services
Distributed by Nav Canada's Aeronautical Publication Sales and Distribution Unit

VFR Navigation chart (VNC):

- VFR flights in low to medium altitudes
- Based on Lambert Conformal Conic Projection
- Lines on this map are great circles
- 1:500 000 or 1 inch to 8 statute miles
- 52 charts in total
- Validity: Updated when there are enough changes, on average every 2 years

VFR Terminal area chart (VTA):

- VFR flights at low altitudes
- Based on Transverse Mercator Projection
- Lines on this map are rhumb lines
- 1:250 000 or 1 inch to 4 statute miles
- 7 charts in total
- Validity: Updated when there are enough changes, on average every 2 years

Chart validity and updates:

- Check NAVCANADA website and look under Aeronautical information products to check whether the chart is valid & current and also see the next anticipated publishing date
- Check NOTAMs for new obstruction or airspace changes or revisions to charts
- Check CFS for Flight planning, previous NOTAM can be found in this section

Lo chart:

- IFR below 18000ft ASL
- Lambert conformal conic projection
- Scale varies from chart to chart
- Contains radio aids, airports and other points of interest to aviation but NO topographical features
- Valid for 56 days, date of validity are stated on the front
- 10 charts in total

Hi chart:

- IFR at 18000ft ASL and above
- Features same as Lo chart
- 6 charts in total

Canada flight supplement (CFS):

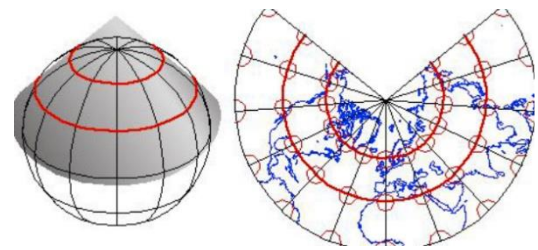
- Joint civil and military publication which contains all registered & certified Canadian aerodromes
- Also contains information on North Atlantic aerodromes
- Revised & reissued every 56 days and is available in French/English
- General: Tables, legends, associated information relevant to interpretation of supplement
- Aerodrome/facility directory: Data & sketches for Canada aerodromes & heliports, selected in N. Atlantic
- Planning: Information for flight planning, characteristics of airspace, chart updating, flight restriction, IFR routes, airway intersections, chart distributors, cruising altitude order, weather minima

- Radio navigation and communications: Data for radio nav. aids & communication facilities
- Military flight data and procedures: Procedures for flight in US, N. Atlantic & Alaska, air/ground communications & military training routes/areas
- Emergency: Emergency procedures & codes, light signals, ELT use, com. failure, intercept procedures

Canada Air Pilot (CAP):
- Relevant to IFR arrivals & departures
- Includes procedures of: Instrument approach, Standard instrument departure, Noise abatement
- Amended and reissued every 56 days
- 7 volumes in total

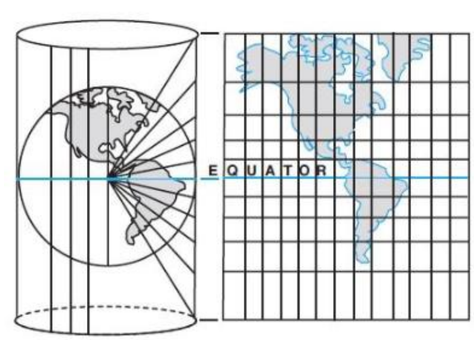
Water aerodrome supplement (WAS):
- Provides tabulated textual data & graphical info to support Canadian VFR charts
- Contains aerodrome/facilities directory of all water aerodromes shown on Canadian VFR charts
- Listed communication stations data, radio aids & other data supplemental to VFR charts
- Revised & reissued annually

Designated airspace handbook (DAH):
- Listed all airspace & classes in Canada
- Valid for 56 days

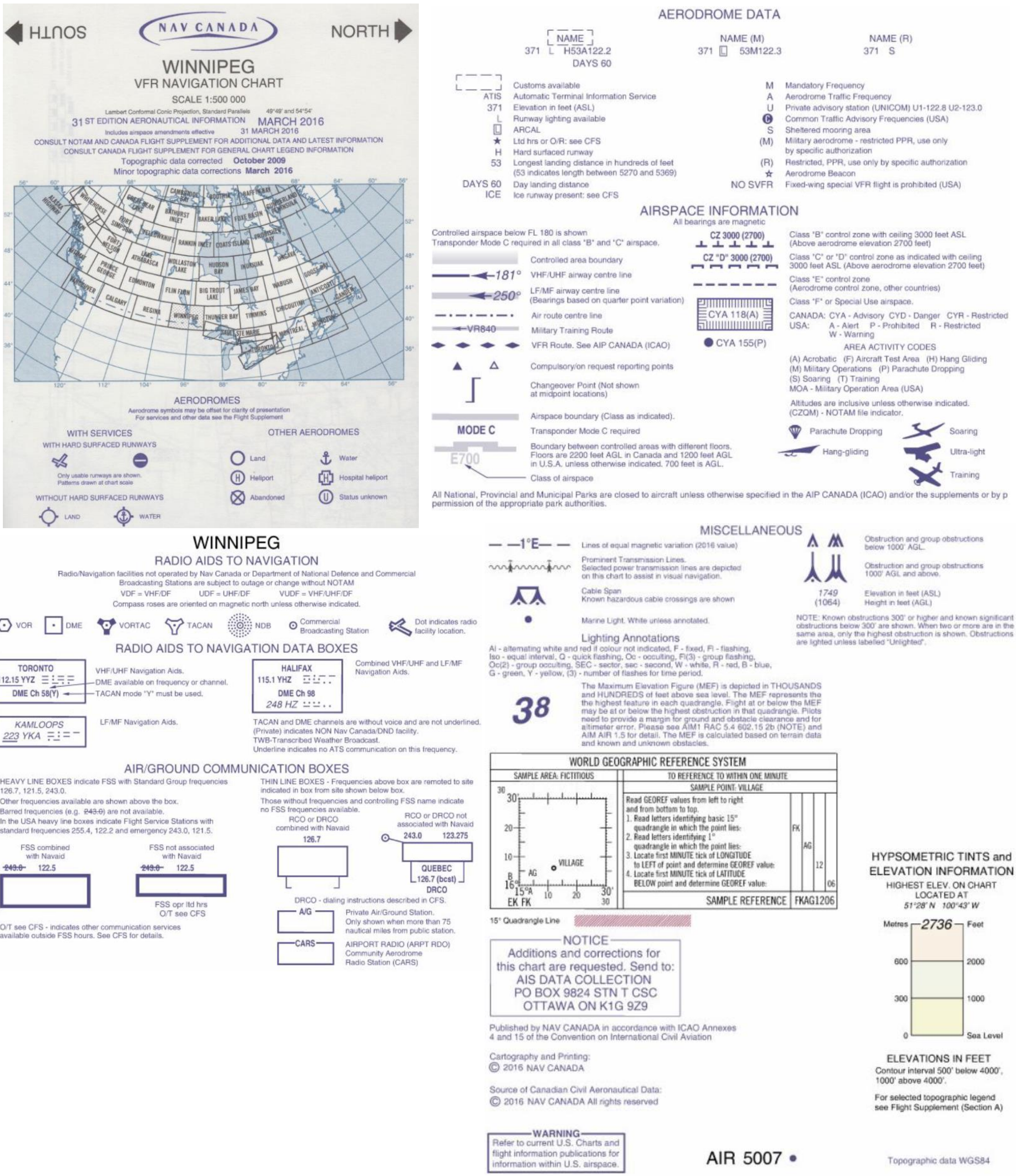


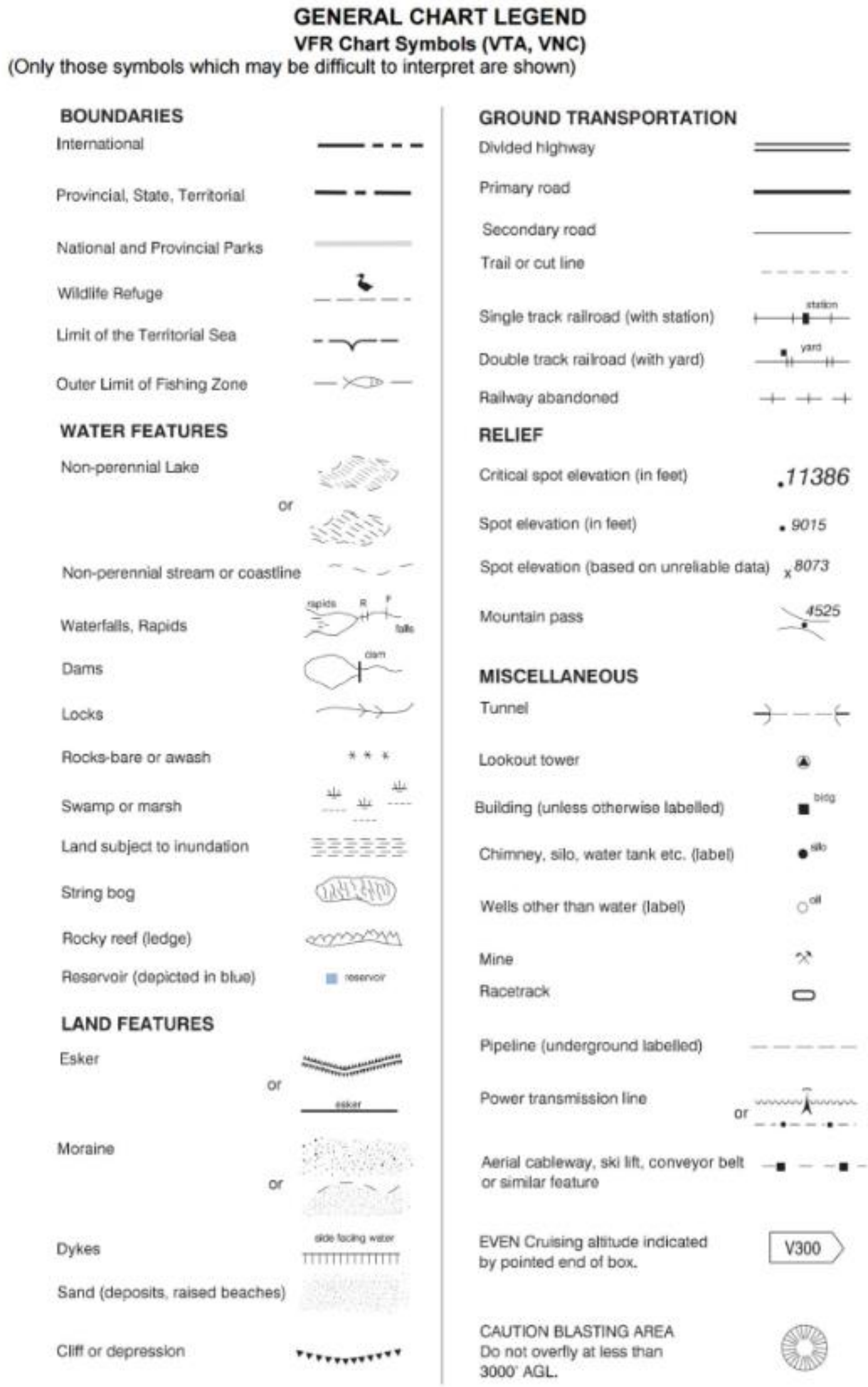
Lambert conformal conic projection:
- Like a cone being opened & unrolled
- Angles between meridians & paralles will be same on chart as on ground → conformal
- Scale is same along both meridians & parallels
- Meridians of longitude converge when getting nearer to pole
  → Curvature is almost unnoticeable
- Convergency: Angles that one meridian makes with another on Earth
  Varies with latitude, no convergence at equator
  Converge at angles equal to change of longitude between meridians at pole
- Parallels of latitude: Curves that concave towards nearest pole, curvature is considerable
- Distances are uniform, maximum distortion is not more than ½ of 1%
- Straight line drawn between 2 points is an arc of great circle
  → Will not have same bearing when measured on 2 different meridians
- Flights up to 300 miles: Use the meridian nearest to center & need to change heading at regular intervals

Mercator projection:
- Based on cylinder that has its point of tangency at equator
- Like a light at center of globe then cast shadow of meridians & parallels on a cylinder
- Shadows of northerly parallels of latitude → Straight & parallel lines, Cast wider apart than actual
- Shadows of meridians → Straight & parallel lines, Same distance apart at poles as in equator
  ∴ Extreme exaggeration of meridians in northerly area
- Straight line between 2 points is rhumb line
- No constant scale of distance
- Exaggerated in high latitudes

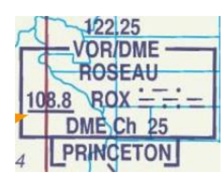


4. Map legends





Double simplex radio stations:



- Receive and transmit on separate channels
- Princeton radio is RCO FSS and can be reached on 122.1
- Listening must be done on NAV radio tuned to 112.4 (Need to tell them)
- Without underline (left one) then has ATS communication and with (right one) then no ATS

Maximum elevation figure:

- Show in thousands and hundreds (ASL) of the highest feature in quadrangle
- All obstructions 300ft or higher AGL/deemed by TC will be charted
- New obstructions will be NOTAMed then inserted in CFS and then next edition of chart

AERODROME SKETCH AND VFR TERMINAL PROCEDURES CHART (VTPC) LEGEND

All distances in nautical miles. Runway dimensions in feet. Elevations in feet above sea level. Bearings are magnetic except when labelled G for Grid or T for True. ALL AERODROME SKETCHES ARE ORIENTED ON TRUE NORTH. (If symbols not found, consult VFR chart symbols). Text or symbols will be depicted as white on black where they coincide with buildings or other areas depicted with solid black

AERODROME SURFACES

Turnaround bay

Hard surface runway

Under construction, closed or abandoned surface

Sand, gravel, turf, etc., runway

Ski, ultra-light, glider strip (activity labelled) — Ski strip

Displaced runway threshold — or

Taxiway, apron or holding bay

Taxiway designator — A

LIGHTS

Aerodrome beacon (rotating or strobe)

Hazard beacon

Obstruction light

Obstructions (heights ASL unless otherwise noted) — 3600 — lighted — group

Landing direction indicator — lighted

Wind direction indicator — lighted

Lighting annotations: F-fixed, Fl-flashing, Occ-occulting, R-red, G-green, Bl-blue
Lights are white unless otherwise annotated

APPROACH LIGHTING

Refer to Section A Lighting

RADIO AIDS

NDB		TACAN	
VOR		VORTAC	
VOR/DME		Radio aid (labelled)	

COMMUNICATIONS-CLASS "C" AIRSPACE

125 — Ceiling in hundreds of feet ASL
ADVSY — Calling agency
125.4 238.3 — Frequencies
30 — Floor in hundreds of feet ASL

AIRSPACE

Class "B" control zone

Class "C" or "D" control zone

Class "E" control zone

Floor Separation

Helicopter routes

Fixed wing VFR routes — or — direction

AIRSPACE (Cont'd)

Class "F" airspace
CYA - Advisory CYD - Danger CYR - Restricted

Advisory Area Activity Codes
(A) Acrobatic
(F) Aircraft Test Area
(H) Hang Gliding
(M) Military Operations
(P) Parachuting
(S) Soaring
(T) Training

CYA 125(A)
to 5000

Altitudes are inclusive unless otherwise indicated
e.g. (above 5000' to 10,000')
(5000' to below 10,000')

MISCELLANEOUS

Unidirectional arrester cable

Bidirectional arrester cable

Arresting barrier

Cliff or depression

Transmission line

Cable span

Trees

Fence

Noise Sensitive Area

Built-up areas

Cemetery — C

Instrument Approach Waypoint

VFR call-up point prior to entry of the specified class of airspace. — NAME

VFR checkpoint prior to CZ entry, within a CZ, or prior to entry of special use airspace. — NAME

NOTE: When cleared to orbit the aircraft should remain within 2NM of the Call-up/Checkpoint in the direction of the arrow. It is recommended that all turns be made to the left.

Heliport (Where FATO & TLOF are embedded or coincidental)

Hospital heliport (Where FATO & TLOF are embedded or coincidental)

FATO (Where TLOF is not coincidental)

Heliport parking pad

Soaring

Hang gliding

Ultra-light aircraft operations

Training

Parachuting

Land Aerodrome

Water Aerodrome

Aerodrome Status Unknown

Abandoned Aerodrome

LEGEND

AERODROMES

AERODROMES

LAND — WATER

Civil

Joint Civil-Military

Military

Aerodromes in black have an instrument approach procedure available.

Aerodrome symbols may be offset for clarity of presentation.

Land aerodrome name shown only when different than associated NAVAID.

Water aerodrome name shown only when different than adjacent land aerodrome or NAVAID.

AERODROME DATA

562 ★ L H57

562 Elevation given in feet above sea level.

L Runway lighting available.

L ARCAL

★ Ltd hrs or O/R: see CFS

H Hard surface runway.

57 Length of longest landing distance available given to nearest 100 feet with 70 feet as the dividing point. i.e. 5680 is 5700 and shown as 57

Water aerodrome data not shown.

RADIO AIDS TO NAVIGATION AND COMMUNICATION BOXES

RADIO AIDS TO NAVIGATION

Radio/Navigation Facilities not operated by NAV CANADA or Department of National Defense are subject to outages or changes without NOTAM.

VHF/UHF Aids are displayed in BLACK. LF/MF Aids are displayed in GREEN.

COMPASS ROSE. Oriented to Magnetic North except in the Northern Domestic Airspace where VHF/UHF aids may be oriented on True or Grid North. Smaller sizes are used in congested areas.

VOR — VOR/DME — VORTAC — TACAN

Symbols may be displaced for sake of clarity, however the compass roses are correctly positioned.

DME — LF/MF NDB

AIR/GROUND COMMUNICATION BOXES

~~243.0~~ 239.8 (also shown in GREEN) — HEAVY LINE BOXES indicate FSS with Standard Group frequencies 126.7, 121.5, 243.0 Low altitude discrete frequencies available are shown above the box. Barred frequencies (e.g. ~~243.0~~) are not available.

FSS opr ltd hrs

* O/T see CFS * indicates other communication services available outside FSS hours. See CFS for details.

122.5 126.7 (also shown in GREEN) QUEBEC 126.7 (bcst) — Remote Communications Outlet (RCO) or Dial-up Remote Communications Outlet (DRCO) associated with a Navigation Aid. Low altitude discrete frequencies above Thin Line Box are remoted to site indicated in box from FSS shown below box.

FIC/FSS will selectively activate the 126.7 MHz RCO transceiver when required to provide aeronautical broadcasting service (SEE CFS)

126.7 THUNDER BAY DRCO — RCO or DRCO not associated with a Navigation Aid.

DRCO dialing instructions described in CFS.

RADIO AIDS TO NAVIGATION DATA BOXES

NAME Ch 102 115.5 YWG N49 55.7 W97 14.3 248 WG N49 54.0 W97 21.0 — Combined VHF/UHF and LF/MF aids co-located with FSS. DME available on frequency or channel. Underline indicates no ATS communication on this frequency.

NAME Ch 98 115.1 YHZ N44 55.4 W63 24.1 — VHF/UHF aids co-located with FSS. Navaid coordinates

NAME Ch 82 UOD N49 55.7 W97 14.3 DME 113.5 — UHF aids. TACAN and DME channels are without voice and not underlined.

NAME 110.75 PLL Ch 44(Y) — DME aids. TACAN mode "Y" must be used if indicated.

NAME 248 NAM N49 55.7 W97 14.3 (Private) Unmonitored — LF/MF aids. Underline indicates no ATS communication on this frequency. Non NAV CANADA / DND facility.

Subject to unscheduled outages without NOTAM.

PAL — PeripherAL Station. Remote site for extended range communications (PAL).

CARS — Community Aerodrome Radio Station (CARS).

A/G — Private air/ground station (A/G).

U.S.A. (including ALASKA)

122.1R 122.6 123.6 TWB — HEAVY LINE BOXES indicate Flight Service Stations (FSS). Frequencies 122.2 255.4 and emerg 121.5 and 243.0 are normally available at all FSS's and are not shown above boxes. All other freqs available at FSS's are shown.

Transcribed Weather Broadcast

Frequencies positioned above thin line NAVAID boxes are remoted to the NAVAID site. Other frequencies at the controlling FSS named are available, however altitude and terrain may determine their reception.

CHADRON CDR — Name and identifier for FSS not associated with NAVAID.

122.1R WASHINGTON — THIN LINE BOX without frequencies and Controlling FSS name indicates no FSS frequencies available.

Controlling FSS Name.

AIRSPACE AND ROUTE INFORMATION

AIRWAYS AND ROUTES

VHF/UHF data is displayed in BLACK. LF/MF data is displayed in GREEN.

Some VHF/UHF airways/air routes are based on LF/MF facilities and a serviceable ADF is required at the MEA on the LF/MF portions. Centre lines and bearings on these portions are displayed in green.

V487 VHF/UHF airway centre line and identification.

REPORTING POINTS

Compulsory

On request

A circle over a radio aid, intersection or waypoint denotes RNAV Fly-over.

Arrow points to aids forming intersection if not otherwise obvious.

B22 LF/MF airway centre line and identification.

AR4 Uncontrolled air route and identification.

EVEN altitude direction indicated by pointed end of box.

Commonly used track or transition.

L601 276T Uncontrolled low level fixed RNAV route.

T701 273 Controlled low level fixed RNAV route.

Reference bearings are calculated at each waypoint or NAVAID in degrees TRUE in Northern Domestic Airspace and degrees magnetic in the Southern Domestic Airspace.

089 Radial from a VHF/UHF radio aid.

089 Bearing inbound to an LF/MF radio aid.

276 276T Southern Domestic LF/MF outbound bearings are calculated at the NAVAID on quarter point variation. Northern Domestic Airspace LF/MF outbound bearings are calculated at the NAVAID and are true tracks.

YPE 117.2 Facility Locator used with radial line in the formation of an intersection if not otherwise obvious.

HU 296 Facility Locator used with bearing line in the formation of an intersection if not otherwise obvious.

X X Mileage breakdown point.

Denotes DME fix. (Distance same as route mileage).

23 Denotes DME fix. (Encircled mileage shown when not otherwise obvious).

77 96 Total mileage between radio aids and/or compulsory reporting points.

BOUNDARIES

FIR (Flight Information Region).

T Area of True Tracks.

Air Defence Identification Zone.

Control Area (CTA) Separation.

Observed Coordinated Universal Time Zone (UTC).

International Boundary.

A Altimeter Setting Region.

CZ 3000 (2700) Class "B" control zone with ceiling 3000 feet ASL. (Above aerodrome elevation 2700 feet).

CZ "D" 3000 (2700) Class "C" or "D" control zone as indicated with ceiling 3000 feet ASL. (Above aerodrome elevation 2700 feet).

Class "E" control zone 3000' AAE, unless specified.(AAE above aerodrome elevation)

NOTE: CZ data will not be depicted on LO charts when fully contained within a Terminal Area Chart.

Boundary of Terminal Area Chart.

SPECIAL-USE AIRSPACE

CYA - Advisory Area Activity Code:
- (A) Acrobatic;
- (F) Aircraft Test Area;
- (H) Hang Gliding;
- (M) Military Operations;
- (P) Parachuting;
- (S) Soaring;
- (T) Training.

CYR - Restricted.

CYD - Danger.

Altitudes are from the surface up to and including altitude shown unless otherwise indicated.

(CZQM) - NOTAM file indicator.

U.S.A. (including ALASKA)

P- Prohibited. R- Restricted. W- Warning.

MOA- Military Operations Area. (In Green).

48 48 Mileage between other reporting points, radio aids and/or mileage breakdown points.

2600 2600 MEA (Minimum Enroute Altitude).

*2300 *2300 MOCA (Minimum Obstruction Clearance Altitude). MOCA omitted when same as MEA.

MRA 6000 MRA (Minimum Reception Altitude). MRA omitted when same as MEA.

Change in MEA or MOCA at an intersection or mileage breakdown point.

15 25 15 25 Changeover point with mileage to radio aids. (Not shown at midpoint locations).

U.S.A. (including ALASKA)

X MCA (Minimum Crossing Altitude).

R MRA (Minimum Reception Altitude).

MAA 15500 MAA (Maximum Authorized Altitude).

MISCELLANEOUS

This product is based on NAD83 coordinates.

5°W Isogonal (2014)

(250 kt) Holding pattern with airspeed indicates maximum assessed speed for hold or shuttle

Distances are in nautical miles and tracks are magnetic except in the Northern Domestic Airspace where tracks are true e.g. (258T).

All altitudes are ASL unless otherwise noted MOCA's (or MEA's when MOCA omitted) meet obstacle clearance requirements under ISA (International Standard Atmosphere) conditions.

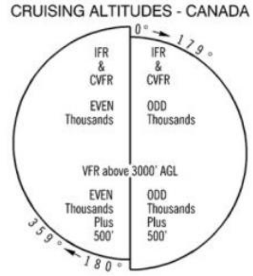
Open areas (white) indicate controlled airspace.

Shaded areas (green) indicate uncontrolled airspace.

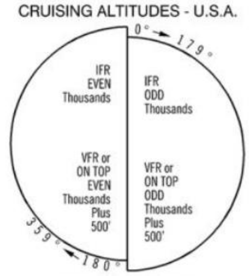
Controlled airspace above 12500 ASL in Canada.

5⁷ Area Minimum Altitude (AMA)

CRUISING ALTITUDES - CANADA



CRUISING ALTITUDES - U.S.A.



VFR above 3000' AGL
IFR-Outside controlled airspace
IFR within controlled airspace as assigned by ATC
All courses are magnetic.

5. Time and longitude

Time zones and relations to longitude:

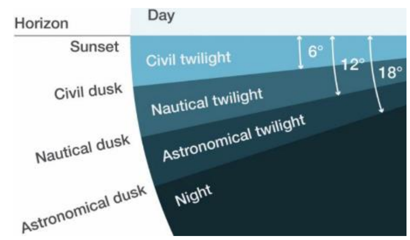
- Mean solar day: Interval between 2 successive passes on pass over a given meridian of longitude
  → Traverse 360° of longitude per day
- 1 hours = 15° longitude, 1 minute = 15' longitude, 1 second = 15" longitude
- Define time as particular distance that sun travels across the sky

Local mean time:

- Specific time at particular meridian
- Time zone: Width is 15° of longitude
- Pacific: UTC-8, Mountain: UTC-7, Central: UTC-6, Eastern: UTC-5, Atlantic: UTC-4, Newfoundland: UTC-3.5

Conversion of UTC to local and vice versa:

- Local mean time at Prime meridian in Greenwich, England
- Daylight saving time: Advance 1 hour in spring and brought back 1 hour in fall



Twilight:

- Between day and night when there is light outside but the sun is below horizon
- Occurs when earth's upper atmosphere scatters & reflects sunlight & illuminates lower atmosphere
- Sun's elevation: Angle that geometric center of sun makes with horizon
- Length of twilight depends of latitude
  → Equatorial & tropical regions have shorter lengths of twilight than higher latitude

Civil twilight:

- Begins when center of sun's disc is 6° below horizon and is ascending, ends at sunrise appx. 25mins later
- Begins when center of sun's disc is 6° below horizon and is descending, ends at sunset appx. 25mins later
- Brightest form of twilight, enough natural sunlight, only brightest objects can be observed with naked eye
- Night: Time between the end of evening civil twilight and beginning of morning civil twilight
- Day: Time between beginning of morning civil twilight and end of evening civil twilight

Nautical twilight:

- When geometrical center of sun is 6°-12° below horizon
- Less bright than civil twilight and artificial light is generally required for outdoor activities

Astronomical twilight:

- When the sun is 12°-18° below horizon

Twilight charts:

- AST: 60W, EST: 75W, CST: 90W, MST: 105W, PST: 120W
- **Add 4mins for each degree west of standard meridian**
- **Subtract 4mins for each degree east of standard meridian**

6. Pilot navigation

Use of aeronautical charts:

- Use current chart, hold map either north up/along track, highlight track with marker & circle info.

Measurement of distance:

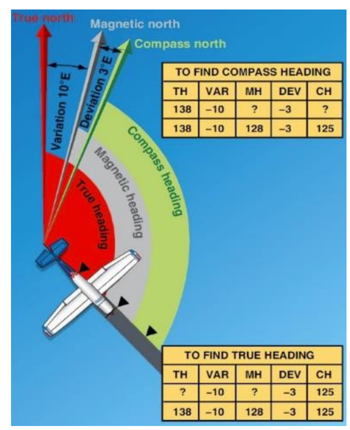
- 1 minute of latitude = 1 NM
- Measure from the center of aerodrome symbol
- Measure along Victor airway: Measure from center dot of VOR (Small white dot on aerodrome symbol)

Measurement of track:

- Number of degrees between direction of flight & true north as measured clockwise from longitude line
- Read true course in degrees at top of protractor from where longitude line touches

Methods of departing:

- Overhead departure: Climb to cruise altitude while circling over departure aerodrome
  Cross over aerodrome & set appropriate heading
- Set heading point method: A point other than the airport used to depart on cross country
  ∵ Cannot always predict traffic and active runway
  → Give time & distance we may need to get completely organized
  Should be along track within 15 miles of departure
- Direct method: Turn into heading and goes, assume this for written exam
- Checkpoints & pinpoints: Circle/make log of prominent landmarks that help to pinpoint
  Set up checkpoints for ground speed checks
  Note distance between checkpoints & also remaining distance to destination



Ground speed checks and ETA revisions:

- Measure distance between 2 prominent checkpoints before takeoff
- In flight: Use stopwatch to get time between 2 points, use minute and second
  → Divide distance by time to get revised ground speed
- Use ground speed to calculate remaining time

Variation and deviation:

- Variation: Difference between true north and magnetic north
  Found by looking for isogonal lines on map
  Apply variation to true track then gives magnetic track
- Deviation: Compass error caused by aircraft, found on compass card & journey logbook
  Apply deviation to magnetic track gives compass track

True track and magnetic track:

- True track: Line measured on map in relation to true north
- Magnetic track: Line measured on map corrected for variation in relation to magnetic north

True/magnetic/compass heading:

- Nav log: Start with true track, apply forecasted wind (Weatherman gives degrees true),
  Apply variation for magnetic, apply deviation for compass
- When using airway/Lo chart/Hi chart: Need to convert wind to magnetic

Determining drift with 10° drift lines:

- Draw 2 lines from both point of departure and destination at 10° angle on either side of track
- 1 in 60 rule: 1° off course and fly for 60NM, it will be 1NM off course
- Opening angle: Between off-course position from departure (Distance off course/Distance flown x 60)
- Closing angle: Between off-course position from destination (Distance off course/Distance remaining x 60)
- Visual alteration method: Identify off-course position & note number of degrees that drifted
  → Fly yourself to position back on track using a prominent landmark on track
  Then apply correction into the wind by same amount of drift error

  Best to follow road in winter
- Double track error method: Note off-course position and time flown
  Double the drift angle and steer this amount towards track for same time
  Adjust originally-flown heading by amount of drift angle experienced
  "Only can be used when off-course position is before mid-point of track"

  Be careful of "regain" track
- Opening and closing angles method: Add opening & closing angle, steer towards the track
  "Can be used anywhere along the track"

Diversion to an alternate:

- Draw selected route while in flight use a pencil and edge of hand as straight edge
- Magnetic course can be determined by laying pencil on map
  → Move to VOR compass rose when keeping parallel to new course
- Calculate distance by minute of latitude or by 10 mile tics along original track
- Determine how far all the possible diversion aerodromes & select most appropriate
  I.e. Easiest course to follow such as including major visual reference

Return to departure point (Reciprocal track):

- Apply wind correction in opposite direction, 2 minute rate 1 turn = 60 seconds to complete 180°

Low level navigation:

- Watch out for: Power lines, towers, hills, mountains
- Mark position fixes and times frequently, Keep finger on map, fly & trust a constant heading

Deduced (Dead) reckoning:

- Based on time, distance and direction only, Primary navigational method used in early days

In-flight log and mental calculations:

- Have a form to write down time when passing checkpoints & anything important to note
- Distance in NM divided by 3 then multiplied by 2 will give minutes to fly distance at 90kt ground speed

Procedures when lost:

- Climb for better visibility & radio range
- Draw circle of uncertainty from last known position (By aircraft's speed & think about how far it travelled)
- Read map carefully and identify prominent landmarks, Use radio aids, cross track 2 VORs, NDBs, Use GPS
- Contact local FIC/FSS or tower for a DF steer, If serious then contact FSS/any other ATC
- Last resort is precautionary landing

Fuel requirements:

- VFR fixed wing day (night): To destination and fly for 30 (45) mins at normal cruising speed
- IFR fixed wing (Turbo-jet): Fly and execute an approach and a missed approach at destination, to fly & land at alternate, and then to fly for 45 (30) mins

7. 1 in 60 rule

- 1 in 60 rule: 1° off course and fly for 60NM, it will be 1NM off course
- Opening angle = Distance off course / Distance flown * 60
- Closing angle = Distance off course / Distance remaining * 60

8. Triangle of velocity

Pilotage:

- Flying to destination by “hedge-hopping” or “sightseeing”
- Fly from point to point using towns, roads & other landmarks

Ground position or fix:

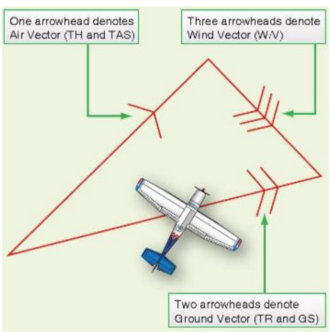
- The point on surface or earth that is directly underneath the aircraft by map reading

Air position:

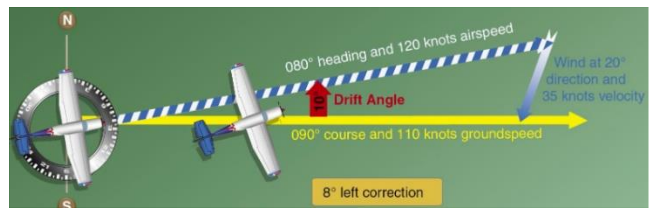
- Imaginary position
- Location of aircraft would be after period of time based ONLY heading & true airspeed
- Would be the same position as if assuming calm/no wind condition

Solving for a course with winds:

- Wind triangle: Graphical representation of relationship between aircraft motion & wind



Use extensively in dead reckoning navigation
Air vector: True airspeed, true heading
Wind vector: Wind speed, wind direction
Wind direction is drawn 180° different from the convention
Ground vector: True track, ground speed
Resultant of algebraically adding air vector & wind vector



- E6B
- Electronic flight computer: CX-2, CX-3

9. LO Chart definition and terms

Introduction:

- Start from surface & extend up to but not include 18000ft ASL
- Radio aids, airways & air route, airspace, aerodromes, intersections, important altitude
- No terrain except major bodies of water
- Scales varies

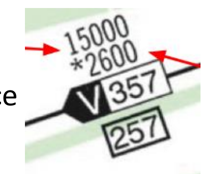
EVEN altitude as indicated by pointed end of box

Airspace:

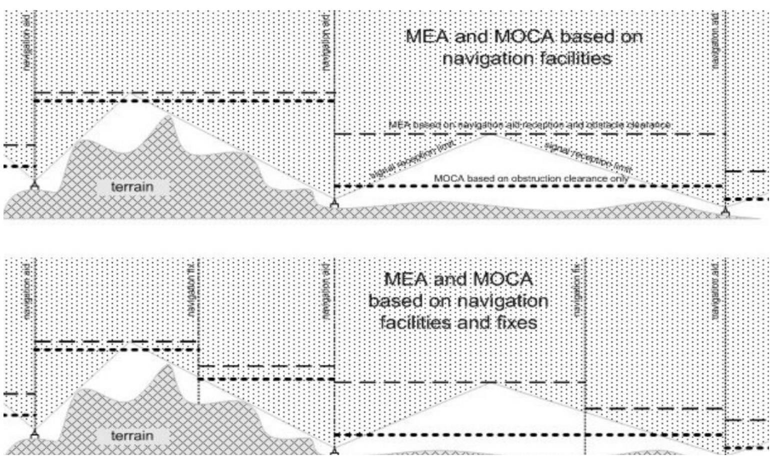
- Uncontrolled: Green
- Controlled: White, Will not tell type but at least Class E
  Low-level airways, control zones, terminal control areas, transition areas, control area extension
- Class B: White hatches, above 12500 and ends at 17999

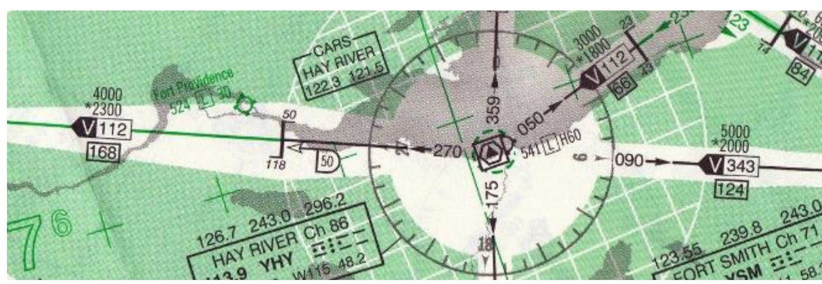
Minimum altitude:

- Minimum enroute altitude: ASL on airways/air routes to ensure acceptable nav signal coverage
  Also meet Obstacle clearance requirements under ISA conditions
  MEA of low-level airway maybe higher than obstacle clearance



- Minimum obstacle clearance altitude: ASL on airways/air routes that meet IFR obstacle clearance
  If MOCA is lower than MEA then will be published
  If same then only MEA
  Cross specific fix at which change in MEA takes place, at higher MEA
  Lowest safe altitude to use during emergency
  Min of 1000ft above all obstacle
  ➔ Cold weather should fly higher because of ISA deviation of alt.

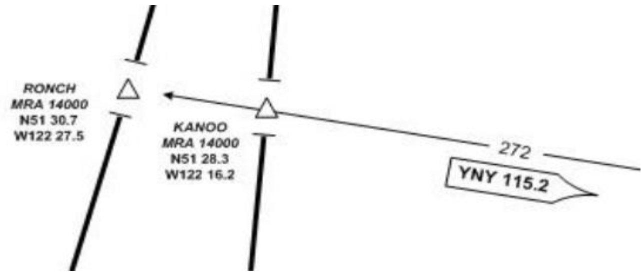




- Area minimum altitude: Provides 1000fts clearance in any given quadrangle
  Southern: Area of 2 degrees latitude by 4 degrees longitude
  Northern: Area of 2 degrees latitude by 8 degrees longitude
  1000fts rule may change in designated mountainous regions

- Minimum reception altitude: On airways, assure receiving signal from nav aids like NDB/VOR
  Greater distance between nav aids = Higher MRA
  Only provide reception guidance instead of obstacle clearance

omitted then same as MEA



Precaution in mountainous region:

- Designated mountainous region: Special rules concerning min IFR altitude to ensure obstacle clearance
- If IFR within DMR but no min alt for IFR is published: 2000fts above obs within 5NM in regions 1 & 5
  1500fts above obs within 5NM in regions 2,3 & 4
- If published: Fly in accordance
  1000fts above published if large variation in temp/pressure
- Otherwise: IFR at least 1000fts above highest obstacle within 5NM

MOCA (More):

- 1000ft ObsClear: Airways & air route outside DMR
  Certain airways & air route within DMR for arrival/departure stage
  Safe altitude 100NM outside of DMR
  All min sector altitude
  Instrument approach transition (Including DME arcs)
  Radar vectoring areas except when in certain DMR
  AMA outside DMR as shown on En route & Terminal area chart
- 1500ft ObsClear: Airways & air route within DMR 2,3,4
  Safe altitude 100NM within DMR 2,3,4
- 2000ft ObsClear: Airways & air route within DMR ~~2,3,4~~ 1/5
  Safe altitude 100NM within DMR ~~2,3,4~~ 1/5
  Certain radar vectoring areas within DMR
  AMA within DMR as shown on En route & Terminal area chart

May need to use average between NAVAIDS

112
VLR

285
CYWG

CYWG → VLR
Fly 283°M

Remember to Apply wind for heading calculation

Chapter 17

Navigation 2: Practical navigation

1. Navigation computer

Only E6B can calculate True Altitude:

- Rule of thumb:
  Multiply by 4ft per 1000ft for each 1°C the temperature varies from ISA
  → Calculate outside temperature if it is ISA based on the given indicated altitude (-2°C/1000ft)
  (Actual OAT – Theoretical OAT) * 4 * AGL / 1000 + Indicated altitude
- E6B: Set PA & OAT (OAT is based on Indicated altitude -1.98°C/1000ft if not given) in left window
  Find calibrated altitude in inner circle (Indicated – Elevation)

Fuel weight:

- CX-3 uses Jet B (6.68lb/gal)
- Tc uses Jet A (7lb/gal)

Turboprop : Jet A

2. Pre-flight preparation

Factors affecting choice of route:

- Analyze all navigation information available & select route
- Most direct route is not always best one: May involve over water that cannot be crossed by gliding
  May cross restricted/dangerous area/unfavorable terrain
- Cruising Altitude Order starts at 3000ft AGL
- Route for long cross country may depends on weather

Map preparation:

- Draw selected route on appropriate & current aeronautical chart
- Don't black anything vital out with line, make details easily distinguishable
- Draw out drift lines → 10° on either side of required track line for opening & closing angle track correction
- Mark off at equal internals → 10 mile intervals, easier to evaluate distance, ground speed, flight time

Meteorological information:

- Get weather info from FIC → 866-WXBRIEF / 800-WXBRIEF
- Internet: flightplanning.navcanada.ca
- Weather channel
- NavCanada forecasts don't go out beyond about 24hrs

NOTAM:

- Obtain from FIC, FSS, AIP update
- Info about airport construction, air shows, runway conditions, tower lights, new rules

Selection of checkpoints:

- Prominent landmark (roads, rivers, cities), VOR/NDB radial or bearing
- RNAV/GOS waypoint
- Smaller aircraft with slow speed: Checkpoints should be within 50NM
- For 90kt aircraft: Checkpoint every 30-40mins

Fuel requirements:

- Day VFR: 30mins at normal cruise
- Night VFR: 45mins at normal cruise
- Personal fuel limit depends on experience, aircraft familiarity, weather, knowledge of flight path

Weight and balance:

- Calculate W&B for intended flight, for both takeoff & landing
- Weight will change throughout flight as aircraft burns off fuel

Use of CFS:

- Study info that it contains & know how to properly use it

Documents required onboard:

- AROWJIL: Certificate of Airworthiness, Certificate of Registration, Owner's manual, Weight and Balance,
  Journey log book, Insurance, Personal licenses (License, Medical, Radio Operators Certificate)

Flight plan/itinerary:

- File before the flight
- Leave itinerary with a responsible person who know what to do
- Close after the flight

Flight log form:

- Flight time is logged in logbook and is engine start to engine stop

Aircraft serviceability:

- All aircraft must have annual inspection
- Commercially registered aircraft must follow manufacturer’s recommendations as found in POH
  May also have approved MEL in place
- Pilot finds problem: Snag/defect aircraft by writing problem in log book before next flight
  → Remains grounded until the pilot is deferred/rectified by AME

3. Filling in a VFR navigation log

See video

Chapter 18

Navigation 3: Radio navigation

1. Radio theory

Electromagnetic spectrum:

- Navigation & communication in aviation rely heavily on use of radio waves
- Radio waves have low energy, long wavelengths, low frequency comparing to UV, visible etc

Low frequency/Medium frequency (LF/MF):

- 30-3000 KHz
- Non-directional beacons, commercial radio stations, marker beacons
- NDBs: 190-415 & 510-535 KHz
- AM radio: 550-1750 KHz

High frequency (HF):

- 3000-30000 KHz (3-30 MHz)
- Long range air & ground communications:
  Oceanic crossings & operations in high North
  Range depends on conditions in ionosphere
  Sun up frequency up, sun down frequency down
- Northern Canada: VHF communications cannot be established ∴ Use 5680 KHz
- HF is utilized on Transatlantic flight

Very high frequency (VHF):

- 30-300 MHz
- Used extensively in aviation for navigational aids & communications
- TV: 50.00-88.00 MHz, FM Radio: 88.1-107.9 MHz
- ILS: 108.10-111.95 MHz
- VOR (United States): 108.00-117.95 MHz
- VOR (Canada): 112.00-117.95 MHz
- Aviation voice communications: 118.00-137.00 MHz

Ultra high frequency (UHF):

- 300-3000 MHz
- Used by military & government, some DME is also found in this range

Ground waves:

- Follow along surface of earth
- Able to diffract/bend around obstacles & follow curvature of earth
- Surface attenuation: Part of wave coming into contact with surface of earth & getting slowed down
  → Downward tilt in wave

Sky waves:

- Radio waves sent up towards space & reflected back to earth from ionosphere
  → Allow sky wave to travel very long distance (Beyond where ground waves stop)
- Skip zone: Area between ground & sky waves touches back down at earth's surface
  Signal will be erratic/non-existent
- Travels further at night than during day
- May be affected by solar activity & other electromagnetic disturbances
- LF, MF, HF utilize both ground & sky waves for propagation

Line-of-sight:

- VHF & UHF will penetrate ionosphere & do not bounce/bend
- VHF is free of atmospheric & precipitation static

HF single sideband (SSB):

- AM signal: Carrier & 2 sidebands (Upper & lower)
- SSB: HF radio transmission in which only 1 sideband is allowed to be transmitted
  Other sideband & carrier are suppressed
- Once signal gets to receiver the carrier can be re-inserted
- Why:
  Eliminate carrier & emit only 1 sideband → Transmitter's available power is used to greater advantage
  Lower power requirements allow SSB messages to be transmitted over several thousand miles
  Compress speech into narrower bandwidth → Conserves spectrum space

2. Emergency locator transmitter

Emergency locator transmitter (ELT):

- Broadcast distress signal in event of sudden deceleration which is likely to happen in event of accident
- Loud siren like signal on 121.5 & 243 MHz
- 406 MHz: Coded signal of ELT so serial number can be matched & SAR can tell whose ELT is it
  Transmit to SAR satellites which will calculate & indicate search area

406 MHz ELTs:

- New standard for ELTs & replacing older 121.5/243 MHz
- Transmit signal of 5 watts (121.5 MHz only transmits 25 milliwatts)
- GPS enabled: Transmit data every 50 seconds includes serial number, latitude & longitude of unit
  → Linked via database to specifically registered aircraft

Location of ELT:

- Orange/yellow plastic box about 12 inches long, Usually in tail

Types of ELT:

- A/AD: Automatic ejectable/automatic deployable
- F/AF: Fixed/Automatic fixed
- AP: Automatic portable
- P: Personnel
- W/S: Water-activated/Survival

Testing 121.5MHz ELT:

- Only during 1st 5mins of any UTC hour, Not exceeding 5 sec
- If accidentally triggered then the sheer power of it will wash-over other frequencies on aircraft's radio
- Check 121.5MHz before shutdown

Testing 406MHz ELT:

- ELT & cockpit remote: Tested in accordance with manufacturer's instructions
- Beacons: Self-test function, also checks power output of 121.5MHz transmitter
- More than 50 sec: Alert being directed to Joint Rescue Coordination Center & treat as real emergency

ELT requirements:

- Required if operate >25NM from home base
- Except: Gliders, balloons, airships, ultra-lights, gyroplanes, large commercial jets

ELT operating instructions:

- OFF: Will not activate, ARM: Will activate in event of accident, ON: Transmitting
- Contains G-sensor that detects & automatically activates transmitter
- Switch ON position asap, don't turn to OFF
- Portable: Antenna should be vertical to ensure optimum radiation of signal
  Place transmitter on piece of metal will provide reflectivity to extend transmission range

Unserviceable ELT:

- May operate up to 30days if:
  ELT is removed at 1st aerodrome at which repairs/removal can be accomplished
  ELT is promptly sent to maintenance facility
  Placard is displayed in cockpit stating ELT has been removed & date of removal

406 & 121.5 ELT maintenance:

- Non-water-activated batteries:
  12 months with applicable operational test requirement (Conducted by operator, self test on ELT)
  24 months with applicable performance test requirement (Conducted by avionics technician)
- Water-activated batteries:
  Not exceeding 5 years
- Shall be maintained at interval recommended by manufacturer

Accidental ELT transmissions:

- Check at end of every flight
- Report accidental activations asap to nearest ATS unit:
  Location of transmission, time, duration

3. ADF

Serviceable : Morse code identifier
Bearing pointer is pointing & steady

Introduction:

- Automatic direction finder: Common in 1940s, slowly phrasing out now
- Non-directional beacon: Physical ground station that emits signal
  ADF LF/MF receiver receives NDB signal
  Accuracy of at least +/-5° for approach & +/-10° for en route
- Frequency range: 190-415, 510-535 KHz
  Groundwave component that follow curvature of earth → Low alt reception & distance
  May receive AM radio as well
- Types of NDB: L: Less than 50 watts
  M: At least 50 watts and up to 2000 watts
  H: At least 2000 watts

Limitation:

- Night effect: Radio waves are reflected by ionosphere & return to earth 30-60 miles from station
  Ionosphere changes in terms of height above earth as sun rises/sets
  → Direction of NDB appears to change as reflection angle changes & ADF point will fluctuate
  Greatest effect within 1hr of sunrise/sunset & distance > 30miles from station
  Greater distance from station = greater night effect
  Minimize effect: Average needle's fluctuation, Fly higher alt, Select station with lower freq
  Below 350kHz has little night effect
- Mountains: Reflect radio waves & produce terrain effect
  Magnetic deposits that cause indefinite indication
  Should only use strong station with definite directional indication/not obstructed by mountain
- Shorelines: Refract/bend low freq radio waves as passing from land to water
  Little/no effect if radio waves reach aircraft at angles > 30°
- Electrical storm: ADF needle points to source of lightning because it sends out radio waves
  Should note the flash & not use them
  Cause greatest error associated with reception of NDB
- Precipitation static: Pointer capabilities may be impaired as NDB's are susceptible than VOR's to static
  Ice & sleet on antennae produces error reading on ADF needle & reduce signal
  Can be lessened by reducing airspeed
- Bank error: Loop antenna that rotate to sense direction of signal is mounted parallel to normal axis
  → Error when aircraft is in banked attitude
- Ore deposits
- Fading effect

Advantages:

- Low installation cost of NDB & can provide instrument approach
- Low degree of maintenance
- Provide nav in terminal & en-route on low-level airways & airways that do not have VOR coverage
- Greater range than VOR

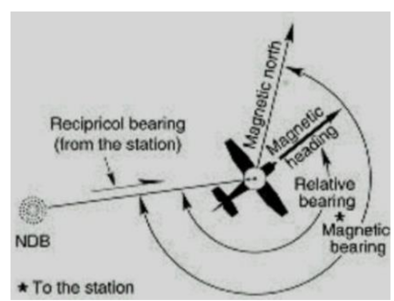
Receiver:
- Listen for 2/3-unit identification in Morse code
- LF/MF freq transmits signal with 1020Hz to provide continuous identification except during voice comm
- If no audible Morse → Under maintenance/calibration & should not be used
- Signal is received, amplified & converted to audible
- RF oscillator provides carrier wave & is used by airborne equipment to calculate bearing to station
- Low frequency oscillator provides identification signal of station to be identified

Tuning the ADF:
- Turn to Receive mode (Use this mode for continuous listening if no ADF function)
- Select frequency & adjust volume until background noise is heard then identify station
- Switch to ADF mode & pointer on bearing indicator will show bearing to station relative to nose of plane
- Loop switch to check operation of indicator: Close then pointer will move away from bearing of station
  Release then pointer will return to bearing of station
  Sluggish/no return = Malfunctioning equipment/weak signal

Control box – digital readout type:
- Frequency tuned is displayed as readout rather than tuning/turning into frequency band
- ADF mode: Determines bearing to station & display on RMI, uses sense & loop antennas
- ANT mode: Reception of radio using sense antenna, recommended for tuning
- TEST mode: Perform ADF system self-test, needle moves at least 90°/RMI to position 315°

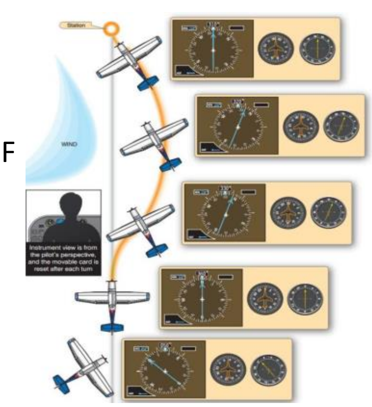
Antenna:
- ADF receives signal on both loop and sense antenna
- Several coils are spaced at various angles inside antenna
- Loop antenna: Common because it is small flat antenna without moving parts
  Sense direction of station by strength of signal on each coil
  Cannot determine whether bearing is TO/FROM station
- Sense antenna: Provide bearing TO/FROM station & voice reception when ADF function is not required

Terms:
- Relative bearing: Pointer point bearing to NDB/station relative to nose of aircraft
- Magnetic heading: Determine direction
- Bearing to station: Track to get to beacon
- Bearing from station: Number of degrees from station
- RB + MH = BTS
- BTS +/- 180 = BFS

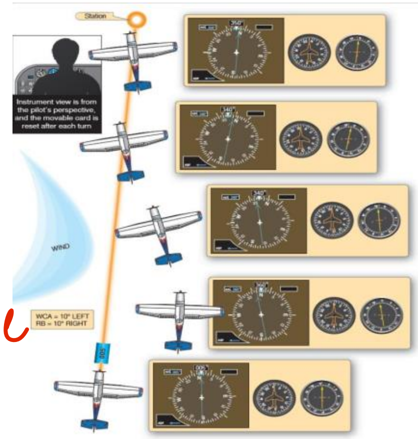


ADF operation monitoring:
- ADF audio should be monitored because no system failure/OFF warning flags
- Monitor if for enroute/critical phrase of approach & check NOTAM

Homing:
- Fly to station by keeping bearing indicator needle on 0° when using fixed-card ADF
- Tune desired frequency & identify station, Set knob to ADF & note RB
- Turn toward RB until bearing indicator is 0°, Continue flight by remaining RB of 0°
- Need to constantly change MH to hold aircraft on RB of 0° →



Tracking to NDB/Station passage:



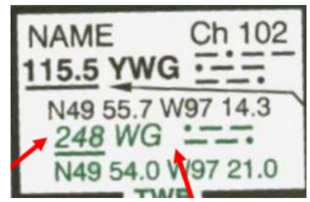
- Track directly to station by correcting for winds
- RB may not be zero due to wind (NOT flying needle pointing straight ahead)
- Require pilot to identify by using both bearing indicator & heading indicator
- Sensitivity increases near NDB
- Needle swings rapidly from directly ahead to directly behind when overflying

↳ Swing > 90° & stays there

Position fix by ADF:

- Tune and identify two stations
- Set to ADF mode & note MH on heading indicator
- Continue to fly heading & record RB from each station
- Add RB of each station to MH and get MB (BTS)
- Correct MB for variation to get true bearing
- Plot reciprocal & aircraft is located at intersection

Map indication:



- Green on map
- Frequency & morse code

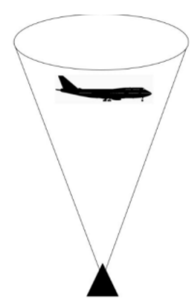
Time check & distance to station:

- Find BFS
- Turn 90 degrees from bearing to station
- Note time taken to cross given number of degrees bearing change time in seconds
- Time to station in minutes = Time in seconds / no of bearing changed
- Distance to station = (True airspeed * Time to station) / 60

Types of ADF:

- Fixed card: Nose of airplane is always oriented to 0 on bearing indicator regardless of actual MH (SHOW RB)
- Movable card: Pilot can rotate azimuth card so corresponds with MH (SHOW BTS)

Cone of confusion/silence:



- Area of ambiguity directly above station where bearing info is unrealiable
- Needle may swing left/right/centre regardless of heading

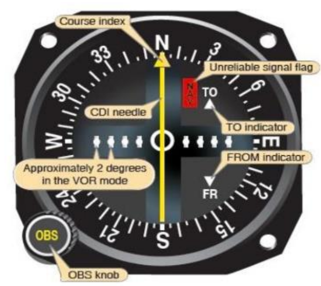
4. VHF omni directional range

VOR navigation:
- Ground based stations, around 450 VORs in Canada
- Maintained by NavCanada
- Each one broadcasts unique Morse code identification

VOR chart reference:
- Black on aviation charts

Advantages:
- VORs in Canada operate in VHF: 112.00-117.95 MHz
  → Precipitation static & other annoying interference that caused by storms/various weather are not issue
- Accuracy: Tracking accuracy of +/- 1° is possible when flying VOR radial

Disadvantages:
- Transmitted by line-of-sight
  → Obstacles block VOR signals & restrict distance over which they are received at given altitude
  Sudden scalloping fluctuation of cockpit indicators normally for short time intervals
- May receive erroneous indications due to reception of 2 VOR stations operating on same frequency
  → 160 available frequencies with 450 VORs ∴ Space the station as far as possible



Reception distance:
- NM = 1.25 * $\sqrt{\text{Altitude AGL}}$

Airways:
- Airway system in Canada is partially based on VORs
- Consists of ground stations that transmit track guidance signals that are used for navigation by aircraft

How VOR works:
- VOR receiver receives an azimuth signal sent from station → Radial of the VOR
- 360 useable radials oriented to magnetic north in SDA

VOR receiver:
- Modern aircraft with 1 control unit as both VOR receiver & VHF communication transceiver → NAVCOM

Navigation indicator/VOR head:
- Provide aircraft's position relative to radial
- Omni bearing selector: Rotate azimuth ring which displays selected VOR radial at top of indicator
  Show reciprocal of selected radial at bottom
  Flying reciprocal heading to bearing selected → Reverse sensing
- To/from/off flags: Indicate whether track with take pilot to/from station
  Out of station range & cannot receive reliable/usable signal → Displays off
- Track bar/course deviation indicator: Aircraft heading agrees/close to radial selected
  → TB/CDI shows position relative to track selected (To left/right)
  10° spread from center to either side for VOR signal, 2.5° in LOC mode
  RNAV's CDI → Indicates distance off track

- Track arrow: Area around VOR station is divided into halves/envelopes
  Fly to left (right) of track → Needle swings to right (left) **also depends on TO/FROM**
- Reference line: Perpendicular to track arrow & intersecting it at station
  → Divide into to (lower) & from (upper) envelope
- Finding position from station: Adjust OBS until track bar is centered with a FROM flag
- Tracking to a station: Adjust OBS until track bar is centered with a TO flag

Area of ambiguity:

- Opposing reference signals actuate TO FROM indicator cancel each other → OFF indication
- Area widens with increasing distance from station
- Greater distance = Longer TO/FROM flag will indicate OFF as aircraft moves between envelopes

Heading has no effect:

- Pilot receives same indicator no matter heading as long as aircraft remains on that radial
  → Can circle continuously while remaining on the same radial from VOR

Position fix:

- Without DME then need to use 2 VOR stations
- VOR gives only direction but not distance from station
- Tune to Number 1 VOR to one of desired stations for Center From flag
- Repeats procedure with other VOR station
- Draw line outbound from VORs along radials → Intersection is the aircraft's position

Test a VOR:

- VOR test (VOT): Test frequency is in CFS
  Spin OBS to 360 the CDI must center +/- 4° with a FROM flag
  Spin OBS to 180 the CDI must center +/- 4° with a TO flag
  "180 TO as in Cessna 182"
  Check for full scale deflection both ways by checking 10° from both sides of 360/180°
- Cessna radio: Tune to any VOR within range
  Hold test toggle switch down
  Spin OBS to 360 the CDI must center +/- 4° with a FROM flag
  Spin OBS to 180 the CDI must center +/- 4° with a TO flag
  "180 TO as in Cessna 182"
  Check for full scale deflection both ways by checking 10° from both sides of 360/180°
- Checkpoint: Taxi up beside VOR test sign
  Follow directions
  Should indicate within +/- 4°
  DME should be within 0.5NM of posted distance

- Dual VORs: Tune in 2 VOR receivers to same station
  Select same radial on indicators
  Must indicate +/- 4°
- Landmark: Airborne geographical for a VOR test
  Fly over landmark on a known & published radial
  Note the indicated radial on VOR
  Reading should be within +/- 6° of published value

Station passage:

- Needle will become more sensitive
- Heading control will become more critical
- Over station, CDE swings to full deflection then gradually comes back to center
- TO FROM indicator will change, the TO indication to a FROM indication
- Consider station passage: 1^{st} complete reversal of TO FROM indicator

Time and distance to station:

- Time to station (minute) = Time to cross radials (second) / radials crossed (degrees)
- Distance to station (NM) = TAS x Time to station (minutes) / 60

5. Radio magnetic indicator

Definition:

- Advanced form of VOR/ADF that provides heading info
- Can point up to 2 stations simultaneously (NDB and/or VOR)
- Usually to use with either NDB/VOR station by a switch
- Both a bearing indicator & heading indicator
- Side of pointer with arrow → Head, other side → tail

Slaved gyro: Slaved to operate like heading indicator not requiring it to be set to compass)

- Heading indicator is connected to remotely located magnetic compass (Flux valve)
  → Automatically being fed with directional signals
- Always show direction of aircraft in relation to magnetic north & no need to reset every 15mins
- Also have free mode to allow pilot to manually adjust heading
  CAN be manually slaved

Bearing indicator:

- Head of needle always display BTS no matter using VOR/NDB

Tracking with RMI:

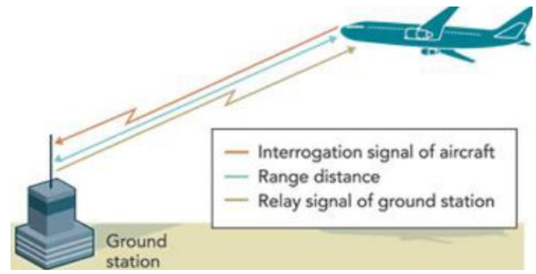
- Heading is indicated on azimuth card
- Magnetic bearing is shown by pointer
- Heading to compensate for wind drift does not influence magnetic bearing if aircraft remains on bearing

6. Distance measuring equipment

Introduction: Provide slant range

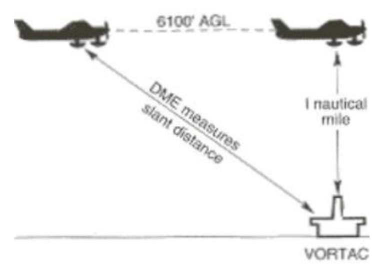
- Provide distance to station in nautical miles & ground speed in some systems
- Receivers can get info from VORTAC, TACAN, DME installation
- Operates in UHF (Line of sight) but the frequency may be paired with VOR/ILS/LOC frequency
- Modern aircraft: Automatically tunes DME when selected proper VOR/ILS frequency
- Inherent error: +/- 0.5NM or 3% of distance, whichever is greater

Basic principles:



- Transmit & receive paired pulses from ground station
- Transmitter in aircraft sends out narrow pulses at 1000MHz
- Signal received at ground & trigger 2nd transmission of different freq
- Reply pulses are sensed by timing circuit in aircraft's receiver
  → Measure elapsed time between transmission & reception
- Circuits within radio convert measurement to electric signal & operate distance & ground speed indicator

DME components:



- Transceiver: Sends interrogating signal to ground station
- Internal computer: Measure time interval elapsed until response
- Antenna: For transmission & reception, mounted underside of aircraft
- Digital readout of frequency, DME, ground speed

Slant range:

- Distance to station is slant range in NM
- Distance from the station to the aircraft compared to the ground or horizontal distance from the station
- Greatest error: High altitude/closest to station ⇒ DME most accurate when low & far

Ground speed:

- Only accurate if plane flying TO/FROM DME
- DME system measures speed by comparing time lapse between series of pulses
- If not flying to/from DME → Speed of closure to/departure from DME
- After turning DME receiver to ground speed will have delay in readout
  → Must be long enough to compare time lapse between several pulse signals

Frequency hold:

- Radios are selected by primary VHF nav radio
- Pilot selects VOR freq & DME freq is held
- DME hold function will retain freq of original VORTAC on DME, Pilot can switch VOR to another freq

Finding position:

- With DME: Use radial of VORTAC & distance info from 1 station
- Without DME: Radials from 2 stations
- Can use DME to establish intersections & holding patterns
- Many airports have instrument approach procedures based on VOR & DME equipment
  → Usually with lower minimum than when only VOR is used

7. Global navigation satellite system

Principles of operation:

- Global positioning system: Navigation system based on earth orbiting satellites
- Initially with 24 orbiting satellites but up to 32 have been operational at one time
- Constantly moving around earth, making 2 complete orbits around Earth in under 24hrs
- GPS satellites are referred to NAVSTAR satellites
- 1st GPS satellite in Feb 1978, weighs 2000lbs & 17ft across with solar panels extended
- GPS position based on measuring time & obtaining triangulation between satellites to get position
- 3 satellites in view to get 2-D position, 4 satellites to determine 3D position

Advantages:

- Point to point navigation, Not affected by weather, Unlimited range, Accurate, Economical

Availability and accuracy:

- Accurate as little as 1 meter, 6 meters horizontally & 8 meters vertically for 95% of time
- 24 hours 7 days a week
- ILS signals are monitored and if there is malfunction then must shut down within 6 seconds

Coordinate checks:

- Always verify coordinates of waypoint are set accurately
- Verify lat/long from CFS/map when accepting nav info from GPS

Errors are cancelled by triangulation by taking reading on at least 4 satellites for 3D

General: Show Track To Station

- GPS was developed by United States Department of Defense (DOD)
- Operating from 11900NM orbit on 6 different orbital paths, Transmits signals on 1227.6 & 1575.42 MHz
- Automatically select signals from 4 or more satellites to calculate 3-D position, ground speed, track, time
  → Allows quicker warning of off-course deviations, making for smoother operation
- Global coverage with no signal inaccuracies associated with propagation in earth's atmosphere
- Line-of-sight where there is: Mountainous terrain, man-made structures, poorly located antenna
- Precise timing is key to GPS nav: Each GPS satellite has 4 atomic clocks
  Accurate to 1 nanosecond/1 billionth of a second
- Satellite broadcasts this time & use it along with data from receivers to calculate satellite's position
- Master control station in Colorado Springs can send up corrections if errors are detected

Differential GPS: Ground based GPS/GNSS station in known position to augment satellites

- Locating receiver on ground at precisely surveyed position
- Able to calculate errors in satellite signals → Linked to aircraft in form of correction, reduce position error
- Wide area augmentation system (WASS): Satellite based augmentation system (SBAS)
  Network of ground-based reference stations create correction signal, sent to WAAS geostationary satellites
  Device receive correction signal from satellite, improve accuracy
- Local area augmentation system (LASS):
  Grounded based augmentation system (GBAS)
  All-weather aircraft landing system based on real-time differential correction of GPS signal
  Local reference receivers in airport send data to central location at airport
  Data is used to formulate correction message then transmitted to users via VHF data link
  Receiver on aircraft use info to correct GPS signal, provide standard ILS-style display for precision approach

Receiver Autonomous Integrity Monitoring (RAIM):

- GPS receiver TSO C-129, requires at least 5 satellites

Baro-aiding:

- Only 4 satellites are required for RAIM to function
- Allows GPS to use your static system to provide vertical reference
- Less likely to experience outages
- Some require manual entry of altimeter setting

Advanced RAIM, Fault Detection and Exclusion (FDE):

- Requires at least 6 satellites
- Position solutions are compared with different satellite combination → Faulty satellite can be excluded

IFR operations:

- Only GPS of TSO C-129 is approved as primary navaid for IFR operations
- Must be approved for IFR before use in IFR conditions
- Consult aircraft flight manual supplement (AFMS) → Required document and must be TC approved
- Handheld GPS are not approved for IFR operations

GPS approaches:

- GPS is approved for non-precision approaches & overlays
- Overlaid approaches use GPS to replace use of VOR, VOR/DME, NDB, NDB/DME
  when GNSS is included in approach title
- GPS can identify navadis & DME when waypoint is taken from current database
- WAAS technology allows precision approaches with vertical guidance to be flown with approved GPS

Tips:

- GPS displays track over ground ∴ Heading indicator and track are not the same → Wind correction angle
- Be careful to enter correct waypoint & correct type of waypoint
- Keep situational awareness using map & other radio navigation aids

8. Other radio and radar aids

VHF direction finding (DF steers):

- Provide directional assistance to pilot who may not be sure of their location
- Information about aircraft's location is obtained by tower/FSS using radio signal transmitted by aircraft
- Heading indicators should not be reset without advising the DF operator once service is being provided
- Info on airports that have VDF is found in CFS & VNC → Replacing has been replaced by radar
- Transmit for bearing of at least 5 seconds, controller will know where you are from station,
  repeat process as aircraft comes closer to station

Primary surveillance radar (PSR):

- Displays reflected radio signals from contacts like aircraft/weather without requiring any info from aircraft
- Reflects returns in green

Secondary surveillance radar (SSR):

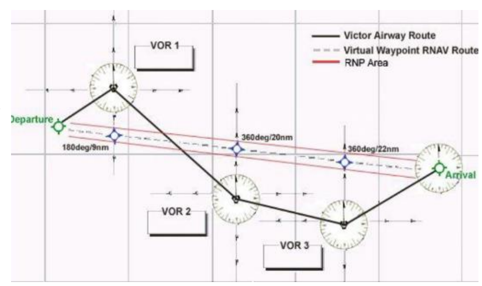
- Requires reply from transponder → Interrogation to determine aircraft's range
- Significantly improved range over PSR
- Does not determine position of aircraft without a transponder
- Does not locate weather

Area navigation (RNAV):

- Permits aircraft operation on any desired course within coverage of station-referenced navigation
- No airways required
- More lateral freedom & more complete use of available airspace
- Pros: Route structure can be organized between any departure & arrival point to reduce flight distance
  Aircraft can be flown into terminal areas on pre-programmed paths → Expedite traffic flow
  Instrument approach can be used at certain airports without local instrument landing aids at airport
- CDI for RNAV shows distance off track in nautical miles

VOR/DME:

- Track-line computer (TLC) based on azimuth & distance info from VORTAC
- As known as RHO-THETA system
- Phantom station can be created by setting
  distance (RHO) & bearing (THETA) of waypoint from convenient
  VOR/DME in appropriate windows of waypoint selector
  ∴ Make up an RNAV route



Inertial navigation systems (INS):

- Completely self-contained & independent of ground based navigation aids such as external nav info
- After being supplied with initial position info: Capable of updating with accurate info
  → Track, distance, course error, ETA, ground speed, wind
  Guidance & steering info
- Core consists of inertial platform, interior accelerometers, computer
- Senses movement of aircraft over the ground using 2 gyroscopes
  → Maintain orientation in space while accelerometers sense all direction changes & rate of movement
  Info from accelerometers & gyroscope is sent to computer ∴ Correct track for drift, rotation of earth etc
- Accuracy depends on accuracy of initial position info programmed into system ∴ Alignment before flight

- Accuracy decays with time at 1-2NM per hour
- Position updates can be accomplished in flight: Ground based references with manual input
  Automatic update using multiple DME or VOR inputs

Flight management system:

- Integrated system uses navigation, atmospheric, fuel flow data from several sensors
  → Provide a centralized control system for flight planning & fuel management
- Use navigation data to calculate & update a best computed position
- Referred to multi-sensor RNAV
- Navigation computer unit: Nav base with regional/worldwide library of navaid, waypoint, airport, airway
- Sensor input: External DME, VOR, Air data computer (ADC), fuel flow sensors
- One/more long range sensors are incorporated: INS, IRS, GPS/GNSS
- Most FMS are approved for en route IFR in most classes of RNAV airspace

Tactical air navigation (TACAN):

- Used primarily by military for en route, non-precision approaches
- Works like VOR/DME
- Provides azimuth in form of radials, slant distance in NM from ground station
- Operates in UHF range with frequencies identified by channel number (126 channels) → Published in CFS
- Only DME info is being received from TACAN for normal pilots
  → Apparent radial info obtained through VOR receiver can only be false signals
- With military equipment then can receive: Range, radial speed, bearing

Radar altimeter:

- Dependable accurate height above ground level → Absolute altitude
- Receiver transmitter: Broadcasts pulsed tone directly downward and translate time to AGL
- Antenna: Can be placed on either flat or curved area under fuselage
  Designed specifically for each system → Changing unit involves changing antenna
- Indicators: Pilot can select Decision height (DH) to about 2500ft AGL → Warning when descends to DH

Precision approach radar (PAR):

- Military only, aircraft can be talked down to runway by controller with 2 radar screens (Horiz. & vertical)
- Precision approach (Similar to ILS) with minimum of 200ft
- Few are left in world

Flight director system:

- Combines horizontal situation indicator (HSI) & attitude director indicator (ADI)
- Can be used with/without autopilot
- Command bars/cross hairs are placed over top of attitude indicator
- It can: Intercept radial inbound to VOR/ILS
  Give pitch commands for missed approach, guidance on procedure turns
  Calculates crab angle to correct for wind, when to roll into and out of bank
- When not using the FD: Called using raw data

Altitude warning:

- Warn pilot of a 200ft deviation with a horn & light

Airborne collision avoidance systems:

- ACAS: Airborne collision avoidance system (ICAO usually use)
- TCAS: Traffic alert and collision avoidance system (FAA usually use)
- Both is exactly the same system
- Receive SSR equipped aircraft's transponder & computer calculates if there is chance of collision
- Displays for TCAS is over top of VSI & has voice prompts

9. Surveillance

Procedural surveillance (Dependent):
- Method of providing ATC services without use of radar
- Pilots report position using voice channel, Relies on pilot/aircraft navigation capability
- Slow, cumbersome & exposed to human error

Primary radar surveillance (Dependent):
- Radar measures position of aircraft, allows smaller separation standards
- Used in busy terminal areas

Secondary radar surveillance (Co-operative):
- Radar measures position of aircraft, transponder to downlink altitude
- Addition of safety alerts, more accurate

Transponder:
- Airborne system: Controller, receiver/transmitter, small L-band antenna mounted underside of plane
- Ground equipment: Transmitter/receiver, rotating directional antenna
- Ground equipment sends out special interrogation signal
  → Airborne transponder picks up signal & sends back strong pulsed signal in reply
  Reply signal is computed to distance & direction, if using Mode C then includes pressure altitude
- Pressure altitude is provided by internal pressure altimeter which is independent of aircraft altimeter

Phraseology and use:
- Mode A: Identification (Position information only)
- Mode C: Identification & altitude information (Position & aircraft pressure altitude)
- Mode S: Unique signature, altitude, limited data
  Able to handle 16 million separate code, help reducing loads placed on heavily used VHF channel
  Data link capability, integral component of all TCAS II/ACAS II installations
  No requirement to replace Mode A/C with Mode S until impossible to maintain
  Airworthiness approval must be obtained by Canadian aircraft operators which install Mode S
- Squawk, Squawk ident, Squawk standby, Stop squawk
- Off, Stby, On, Alt

Transponder codes:
- 1000: IFR below 18000ft ASL
- 1200: VFR at/below 12500ft ASL
- 1400: VFR above 12500ft ASL (Not assigned by ATC)
- 2000: IFR at/above 18000ft ASL
- 7500: Unlawful interference (Hijack), 7500 then 7700 means desperate & request armed intervention
- 7600: Communication failure
- 7700: Emergency
- Do not change code when leaving controlled airspace unless being told so
- ATC can follow registration/type using code

ADS-B:
- Determines aircraft's position via satellite navigation & periodically broadcasts to ground/satellite stations
  → Enable all suitably equipped aircraft to be tracked without need for radar stations

- Level of accuracy is dependent on the on-board certified WAAS-GNSS sensor
- Can be received by ATC ground as replacement for SSR/by aircraft to provide situational awareness
- Automatic: No interrogation required, Dependent: Depends on aircraft to provide data
  Surveillance: Allows ATC to monitor your activity, Broadcast: For anyone to pick up
- Pros: Inflight weather service, Collision avoidance, Replace radar & ATC in non-radar environment,
  Surface surveillance runway incursion avoidance, Improved visual runway capacities,
  Enhances pilot situational awareness, Collaborative decision making,
  Reduces costs, Lessens harmful effects on environment
- Principle of operation: Aircraft determines its position using GPS
  Mode S transponder then broadcasts position along with identity, altitude, velocity
  Ground station can receive broadcasts & relay into to ATC for precise tracking

Space-based ADS-B:

- Surveillance coverage to all airspace
- No ground station except those required to collect return signals and route to ATC units
- Based on 66 Low Earth Orbit (LEO) satellites
- Deliver to Navcanada with position, speed, heading within one second

ADS-B system:

- Universal access transceiver (UAT): 978 MHz, data link for GA in US,
  Costs generally lower & receives free weather info, can observe others
  Not for use at/above 18000ft
  Also supports FIS-B and TIS-B
- 1090 ES: Uses mode S extended squitter transponder, usually just required software update
  Limited bandwidth in crowded spectrum → No weather info but still can send out info
  Outside US/Class A then required
- Requirement: WAAS GPS receiver to supply position data to transponder/transceiver
  Mode S extended squitter transponder
  If in US & below 18000ft MSL: Combine Mode C/Mode S with Universal access transceiver

ADS-B functions:

- ADS-B out: Transmit only, not receiving anything
  Broadcast location, pressure altitude, ground track & speed, ICAO identifier etc
  Commercial uses 1090 ES & GA uses 987MHz UAT
  Broadcast twice every second automatically without interrogation
  Required from Jan 1 2020 in US
- ADS-B in: Receives transmissions from ADS-B out equipped aircraft within radio range
  Line-of-sight to ADS-B out sources & requires screen to display traffic info
  1090 ES ADS-B does not receive weather
  978MHz UAT ADS-B in can show aircraft, terrain, weather etc

FIS-B:

- Constant broadcast, provide text weather & graphical weather & airspace status
- ADS-B by Navcanada does not include provision for FIS-B as ADS-B 1090ES cannot accommodate this info

TIS-B:

- Broadcast from ground stations only in response to ADS-B out aircraft
- Provides custom traffic report from ground stations to aircraft with ADS-B out on 1090ES
- Covers 30NM in diameter and 3000ft high
- Aircraft with ADS-B in can see this report & other aircraft if they are equipped with ADS-B out

ADS-B in US:

- Mandated in 2020 & have ground-based ADS-B system across country
- 1090ES above 18000ft & ground-based 978UAT below 18000ft
- Provides TIS-B & FIS-B

Airspace	Altitude
Class A	All
Class B	From surface to 10,000 feet MSL, including the airspace from portions of Class B that extend beyond the Mode C airspace up to 10,000 feet MSL (e.g. SEA, CLE, PHX)
Class C	From surface up to 4,000 feet MSL including the airspace above the horizontal boundary up to 10,000 feet MSL
Class E	Above 10,000 feet MSL over the 48 states and DC, excluding airspace at and below 2,500 feet AGL
	Over the Gulf of Mexico at and above 3,000 feet MSL within 12 nautical miles of the coastline of the United States
Mode C	Airspace within a 30 NM radius of any airport listed in Appendix D, Section 1 of Part 91 (e.g. SEA, CLE, PHX) from the surface up to 10,000 feet MSL

Multiateration (MLAT):

- Based on time difference of arrival (TDOA)
  → Calculate difference in transponder response time at multiple ground receivers
  Compares results to determine position
- 3 receiving units are required to obtain horizontal position
- Increase air traffic service situational awareness of aircraft & vehicles on ground
  → Safely manage ground movements including in low visibility operations

10. Fixed card ADF intercepts

Find BTS & BFS
Find MH for inbound/outbound
Determine intercept heading
Over desired track the RB will change
Turn to inbound/outbound heading & maintain RB of 180/360

The procedure to intercept an inbound/outbound track of an NDB.

1. Test the ADF instrument (Assumption: its works)
2. Calculate the intercept Heading*
   a. Normally the Intercept angles are 30° or 45°
   b. When close to the track we could use 90° intercept angle
   c. When intercepting a track immediately after crossing a station we would use 15° intercept angle.
3. Fly the intercept heading
4. As we move towards the desired Track (to be intercepted) the bearing pointer starts to move.
5. Once over the desired track (to be intercepted) the bearing pointer makes an angle (Head of the bearing pointer when flying inbound and Tail of the bearing pointer when flying outbound) equal to the intercept angle.
6. Now we fly the desired Magnetic heading (Inbound/Outbound) and keep the bearing indicator pointing straight at the nose of the aircraft, if flying inbound or keep the bearing indicator pointing at the tail of the aircraft if flying outbound.

* Explained in the next slide

11. VOR intercept

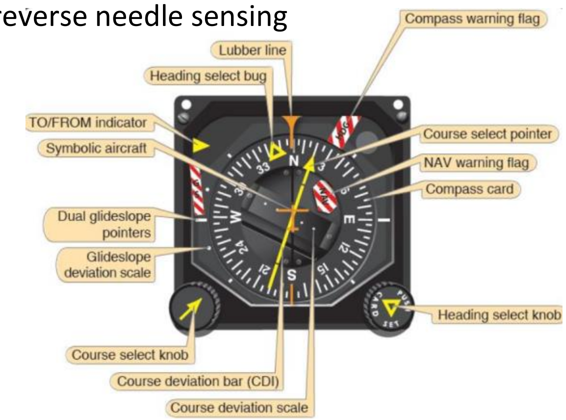
The procedure to intercept a VOR radial.

1. Test the VOR instrument
2. Calculate the intercept Heading*
   a. Normally the Intercept angles are 30° or 45°
   b. When close to the station we could use up to 90° angle to intercept radials inbound
3. Set desired radial course on the VOR and fly the intercept heading
4. As we close in to the desired radial CDI starts to move (towards the center)
5. Once over the desired radial, CDI is centered
6. Now we fly the desired Magnetic heading (Inbound/Outbound) and keep the CDI centered.

12. Horizontal situation indicator

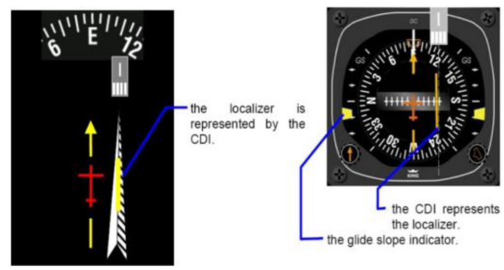
Introduction:

- Combines heading indicator with VOR/Omni display & eliminates reverse needle sensing
- Heading info is from manual pilot adjustment/slaved gyroscope
- Heading bug: Visual reminder of what heading to be flown
  Track heading in autopilot heading mode
  Adjust using heading select knob at lower right
- Course selector: Used for RNAV, GPS, VOR, ILS
  Adjust using course select knob at lower left
- Course deviation indicator: Displaced to left = Fly left
  VOR mode: 1 dot = 2° course error
- To/From indicator: Same side of station as selected OBS → From
  Heading does not matter



HSI on ILS:

- Arrow-head always must be set to Front Course
- CDI represents localizer
- CDI moves towards centre as approaching extended runway centre line
- No To/From flag
- 1 dot on localizer = 0.5° (if 5 dots per side)
- 1 dot on glide slope = 0.1° (if 5 dots per side)
- Rotating arrow-head has no effect on position of CDI in relation to arrow because localizer freq is used



Tips to track:

- Best to position end of CDI needle under lubber line
  → Prevent overshooting
- Passing outer marker: Hold lubber line between CDI & course pointer
- No difference whether localizer tracks inbound/outbound (No reverse sensing)
  (If OBS is still set for front course → At bottom of instrument when inbound i.e. self reversing)

解題方法:

- 根據 OBS 畫十字
- 根據 TO/FROM flag 決定哪兩個 quadrant (箭嘴同一邊嘅 flag=TO)
- 根據 CDI 決定 track 在東南西北(不要用左右)
- 根據 heading 畫出飛機
- 060° radial inbound = Heading/track 240°
- 睇 TO/FROM 判斷 inbound/outbound 不需理會 radial
- 060° radial outbound = Heading/track 060°
- 畫好飛機位置再用 dot 判斷 radial(不用理會左定右 deflection)

同 outbound track of 300° 唔同!!

用 inbound / outbound 判斷 From / To
Inbound = To , Outbound = From
再用 Radial / Bearing