

## Canadair Regional Jet systems

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- EICAS (engine-indicating and crew-alerting system)
- Electrical (AC and DC!)
- Fire Protection
- Fuel
- APU
- Engines
- Hydraulics
- Landing Gear
- Brakes
- Flight Controls
- Pneumatics
- Air Conditioning
- Pressurization
- Ice - Rain Protection
- Oxygen
- Flight Instruments
- Communications
- Navigation
- Autoflight

Red = we'll talk about it

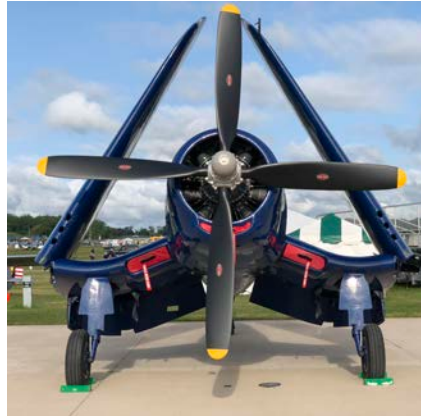
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## Radial Engines

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2,000 HP Corsair



3

## Turboprop Engines

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A turbine engine that spins a propeller: *turboprop*.

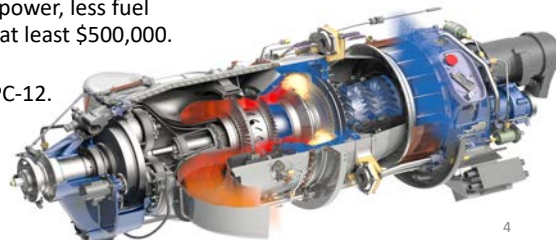
Popular examples: [Pratt & Whitney PT6](#) (free turbine); [Garrett/Honeywell TPE331](#) (direct drive through transmission). PT6 uses more fuel; the Garrett is more challenging to maintain. New contender: [GE Advanced Turboprop](#) (below), based on the Czech Walter design.

Advantages: Lightweight, reliable, and powerful.

Disadvantage: For moderate horsepower, less fuel efficient than piston engines. Cost at least \$500,000.

Airframes: Beech King Air, Pilatus PC-12.

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4



## Turbofan ("jet") Engines

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- Powerful, reliable, fuel-efficient (Boeing/Airbus size)
- Normally aspirated
- Low noise and vibration
- model planes to A380 with one gap: 4-seaters
- Cost \$100,000+
- Birds, gravel? Parachute for single engine!

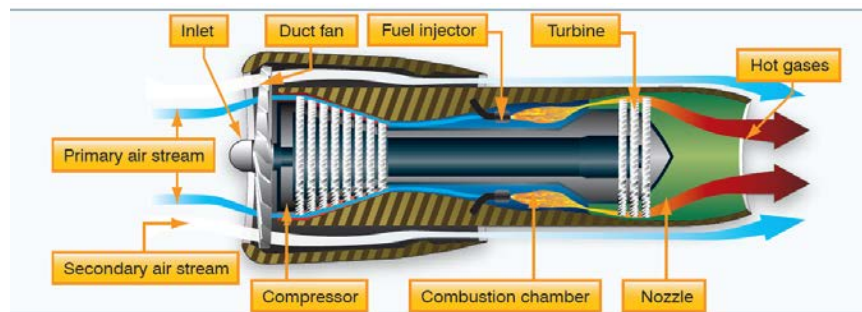


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## Compress and Burn Smoothly

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## Reciprocating (Piston) Engine

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- Lycoming and Continental produce designs unchanged since the 1950s (or earlier!)
- In your basic Cessna or Piper:
  - 4-Cylinder
  - Horizontally Opposed
  - Normally Aspirated
  - Direct Drive
  - Air/oil-cooled
  - Carburetor
  - 160-180 HP



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## Reciprocating Engine Variations

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- Fuel-injection: most new airplanes
- Turbocharger: high-altitude power (one oil system!)
- Horizontally opposed = less vibration; go to 6 cylinders for more/smooth power (310-350 HP common)
- Rotax: high RPM, water-cooled, transmission drives prop at a lower speed

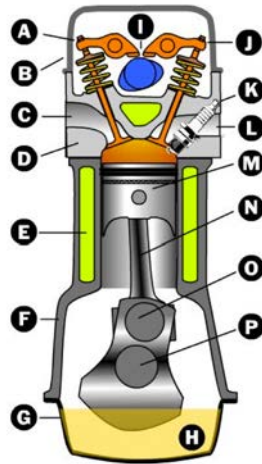
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# One cylinder within a reciprocating internal combustion engine

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- |  |   |
|--|---|
| <b>A</b> Intake Valve, Rocker Arm & Spring | <b>I</b> Camshaft                           |
| <b>B</b> Valve Cover                       | <b>J</b> Exhaust Valve, Rocker Arm & Spring |
| <b>C</b> Intake port                       | <b>K</b> Spark Plug                         |
| <b>D</b> Head                              | <b>L</b> Exhaust Port                       |
| <b>E</b> Coolant                           | <b>M</b> Piston                             |
| <b>F</b> Engine Block                      | <b>N</b> Connecting Rod                     |
| <b>G</b> Oil Pan                           | <b>O</b> Rod Bearing                        |
| <b>H</b> Oil Sump                          | <b>P</b> Crankshaft                         |

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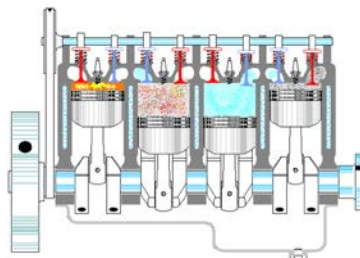
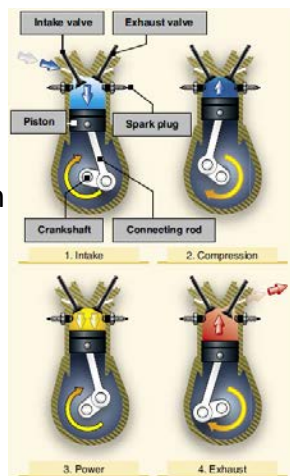


# The Reciprocating Internal Combustion Engine: 4-stroke cycle

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## 4-Stroke Cycle:

- Intake
- Compression
- Combustion
- Exhaust



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## How are Engines Cooled?

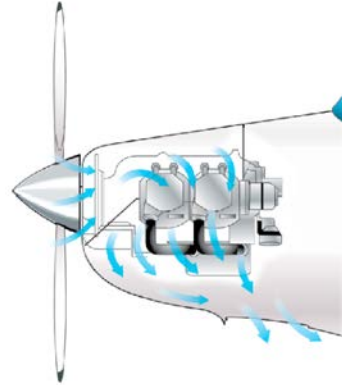
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Air-cooled

Oil circulation also cools engine

To help cooling

- Lower nose in climb
- Increase airspeed



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## The Mixture Control

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- Adjust to compensate for density changes as aircraft flies at different altitudes and temperatures
- Decreased air density  $\rightarrow$  lean mixture



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## Fuel/Air Mixture

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- Ratio of air to fuel based on weight
- Too Lean
  - Engine will run rough
  - Cylinder Head and Oil Temps too high
- Extra Rich
  - Provides added cooling to engine
  - In some cases can cause roughness also (fouled spark plugs)

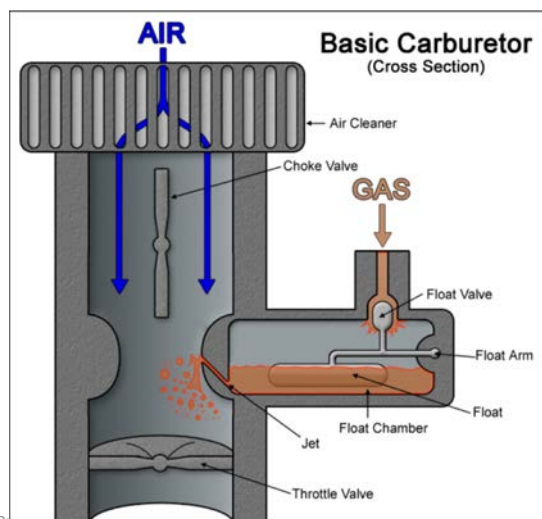
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## The Carburetor

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- Mixes fuel and air in something close to an appropriate ratio (nowhere near as precise as a 1980s automobile!)



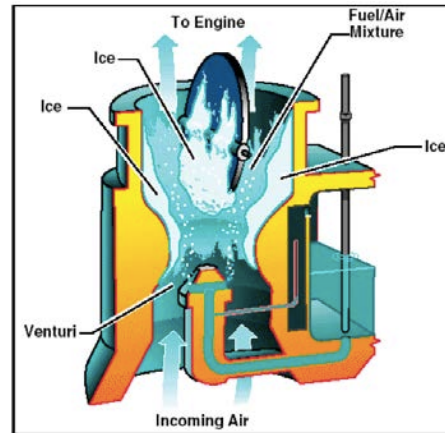
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Blower/Wikipedia/Phd/fic

## Carburetor Icing

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- Conditions for carburetor ice formation
  - Outside air temp 20-70 degrees F
  - High humidity
- Carb. ice detected by loss of RPM
- Carb. Heat used to eliminate ice
- Carb. Heat enriches mixture
- Carb. Heat *reduces* performance



Source: public domain

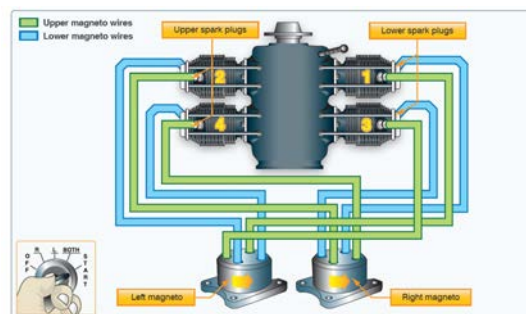
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## Ignition System

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- Independent of electrical system
- Magnetos generate electricity for spark
- Each cylinder has two spark plugs
- Each plug within a cylinder is driven by a different mag
- Engine will run on single magneto, but not with as much power.
- No Battery? No Problem!



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## Abnormal Combustion

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- Pre-Ignition: slow burn before the spark
  - Hot spot inside cylinder
- Detonation—explosive burn before the spark
  - Can be caused by wrong fuel grade or too lean mixture
  - Indicated by
    - High Cylinder Head Temperatures
    - High Oil Temperatures
    - “Knocking” sound
  - Corrective actions
    - Lower nose in climb
    - Increase airspeed
    - Enrich mixture

Read: PHAK 7-18-19

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## Aviation Fuel

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- 100LL (low lead) – blue
- Old days: 100/130 (green); 80/87 (red). (LEAN/RICH)
- Future: UL94, G100UL, 91/96UL
- Jet Fuel (tan/straw): hazardous to pistons
- Clear “fuel” in the sump?



Mixture of jet fuel and 100LL may still look blue/legit.

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# Propellers

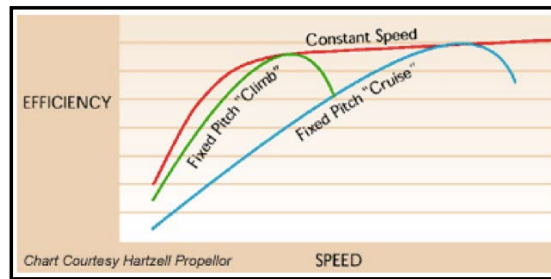
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## Fixed Pitch Propeller

- Non-adjustable

## Constant Speed Propeller

- Blade angle changes to maintain selected RPM



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Source: public domain

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# Constant Speed Propellers

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## Three control levers

- Throttle
- Propeller – engine RPM via blade angle
- Mixture

Avoid high power, low RPM




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See: PHAK 7-6, AFH 11-5

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The image shows a modern glass cockpit instrument panel. It features several key instruments:
 

- Altitude Indicator:** Shows current altitude and target altitude.
- Airspeed Indicator:** Shows airspeed in knots.
- Turn Indicator:** Shows the aircraft's heading and turn rate.
- Horizontal Situation Indicator (HSI):** Shows the aircraft's position relative to a course.
- Vertical Speed Indicator (VSI):** Shows the rate of climb or descent.
- Slip/skid Indicator:** Shows the aircraft's lateral deviation from the intended path.
- Turn Rate Indicator:** Shows the rate of turn in degrees per second.
- Turn Rate Trend Vector:** Shows the trend of the turn rate.

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## FLIGHT INSTRUMENTS

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## “Steam-Gauge” Flight Instruments

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Standard 1950s Six Pack:

- Airspeed Indicator (ASI)
- Attitude Indicator (AI)
- Altimeter
- Turn Coordinator
- Directional Gyroscope (DG)
- Vertical Speed Indicator (VSI)



The image shows a classic 'Steam-Gauge' flight instrument panel with six analog gauges:
 

- Airspeed Indicator (ASI):** Top left gauge showing airspeed in knots.
- Attitude Indicator (AI):** Top center gauge showing pitch and roll.
- Altimeter:** Top right gauge showing altitude in feet.
- Turn Coordinator:** Bottom left gauge showing turn rate and slip/skid.
- Directional Gyroscope (DG):** Bottom center gauge showing heading.
- Vertical Speed Indicator (VSI):** Bottom right gauge showing rate of climb or descent.

Electric!

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## Pitot Static System

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The diagram illustrates the components of a Pitot Static System. On the left, a ram air inlet passes through a pitot tube into a pressure chamber. A static chamber is also connected to the system. The pressure chamber contains a heater (100 watts) and a pitot heater switch. The static chamber contains a heater (35 watts). A drain hole is located at the bottom of the pressure chamber. The system is connected to three instruments: an Airspeed Indicator (ASI), a Vertical Speed Indicator (VSI), and an Altimeter. A static port is also shown. An alternate static source is connected to the static chamber.

Bug in pitot? Tape on static? See PHAK 8-10

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## Airspeed Indicator (ASI)

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Standard color coded markings

- White arc – flaps
- Green arc – normal
- Yellow arc – smooth air
- Red line – never exceed speed

The image shows a typical Airspeed Indicator (ASI) gauge. The scale is marked in knots, ranging from 0 to 240. The markings are color-coded: a red line at approximately 250 knots (Never Exceed Speed), a yellow arc from 100 to 160 knots (Smooth Air), a green arc from 160 to 200 knots (Normal), and a white arc from 0 to 40 knots (Flaps). The needle is currently pointing to approximately 100 knots.

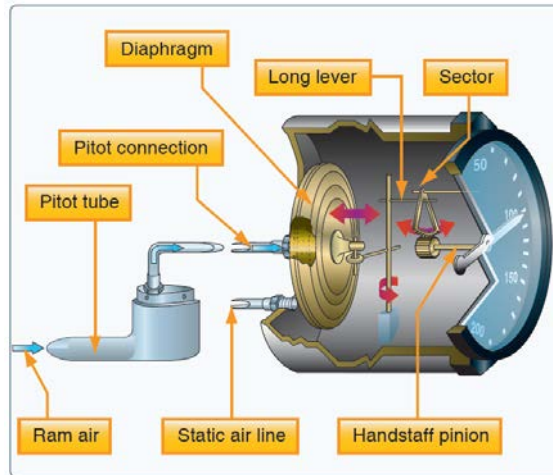
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## ASI: Under the hood

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## ASI and V-speeds

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- $V_{S0}$  – Stall speed in landing configuration
  - Lower limit of white arc
- $V_{S1}$  – Stall speed in specified configuration (clean)
  - Lower limit of green arc
- $V_{FE}$  – Max flap extension speed
  - Upper limit of white arc
- $V_{NO}$  – Max structural cruising speed
  - Boundary between yellow and green arc
- $V_{NE}$  – Never exceed speed
  - Red radial line
- $V_A$  – Maneuvering speed
  - **Not indicated on ASI**



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## The SR20 needs this

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## Altimeter

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- Pressure sensing from static port
- Hundreds, thousands, ten thousands hand
- Kollsman Window to adjust for nonstandard prevailing pressure
- (10,180')



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## Our Previously Wonderful Standard Atmosphere

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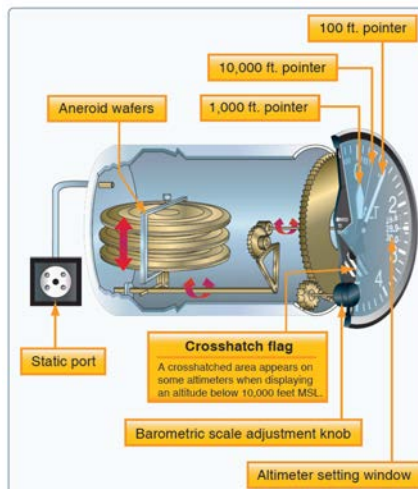
Altitude (ft)	Pressure (inHg)	Temperature	
		(°C)	(°F)
0	29.92	15.0	59.0
1,000	28.86	13.0	55.4
2,000	27.82	11.0	51.9
3,000	26.82	9.1	48.3
4,000	25.84	7.1	44.7
5,000	24.89	5.1	41.2
6,000	23.98	3.1	37.6
7,000	23.09	1.1	34.0
8,000	22.22	-0.9	30.5
9,000	21.38	-2.8	26.9
10,000	20.57	-4.8	23.3
11,000	19.79	-6.8	19.8
12,000	19.02	-8.8	16.2
13,000	18.29	-10.8	12.6
14,000	17.57	-12.7	9.1
15,000	16.88	-14.7	5.5
16,000	16.21	-16.7	1.9
17,000	15.56	-18.7	-1.6
18,000	14.94	-20.7	-5.2
19,000	14.33	-22.6	-8.8
20,000	13.74	-24.6	-12.3

29



## Altimeter: Under the hood

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## Altitude Definitions

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- True – actual height above sea level
- Indicated – what is shown on altimeter
- Absolute – height above the ground
- Pressure – height above standard datum plane (29.92" Hg), read from altimeter set to 29.92"
- Density – pressure alt. corrected for non standard temperature

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## Altitudes

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- Pressure Alt. = Density Alt.
  - At standard temperature
- Pressure Alt. = True Alt.
  - Standard atmospheric conditions
    - 15 deg C, 29.92 inches of Mercury

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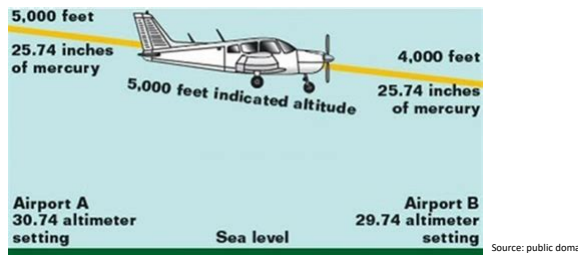




# High to Low Look Out Below

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- Turn knob 1" higher in Kollsman Window and the altimeter will read 1000' higher
- Inadvertently do this flying from high pressure to low pressure weather.



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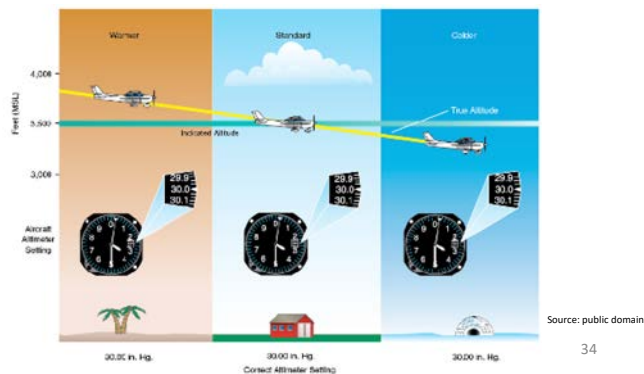
33



# High to Low (Temp) Look Out Below

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- True altitude < indicated when pressure is lower than Kollsman Window setting
- Same situation if air is colder than standard



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## Vertical Speed Indicator (VSI)

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- Indicates rate of climb or descent in hundreds of feet per minute
- Slight lag unless it is an "IVSI," more common in helicopters



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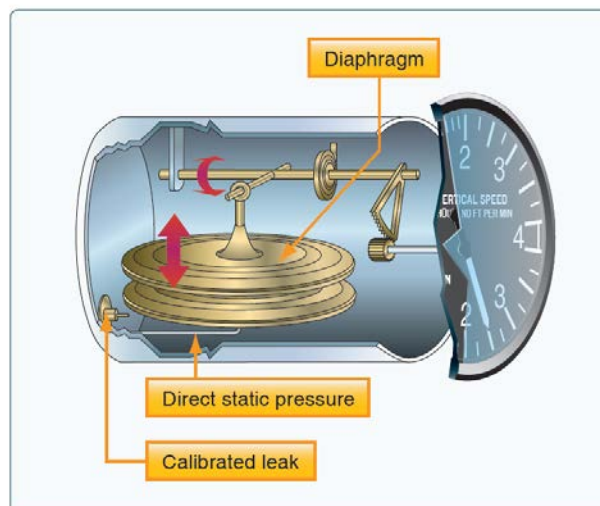
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## VSI: Under the hood

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## Gyroscopes: Main Properties

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- Rigidity in space
  - Gyroscopes resist attempts to reorient themselves
- Gyroscopic precession
  - A deflective force applied to a spinning gyroscope acts as if applied 90 degrees in the direction of rotation

PHAK 8-15

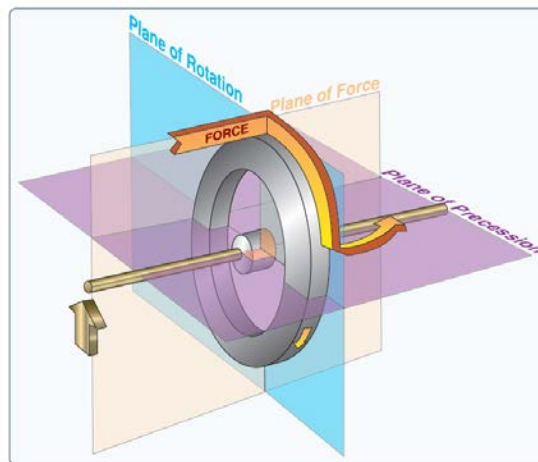
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## Gyroscopes: Precession

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**Figure 8-19.** Precession of a gyroscope resulting from an applied deflective force.

38



# Turn Coordinator

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- Gyroscopic Instrument
- Angled to indicate both initial rate of roll and rate of yaw
- Ball indicates “quality” (coordination) of turn



FIGURE 5.—Turn Coordinator.

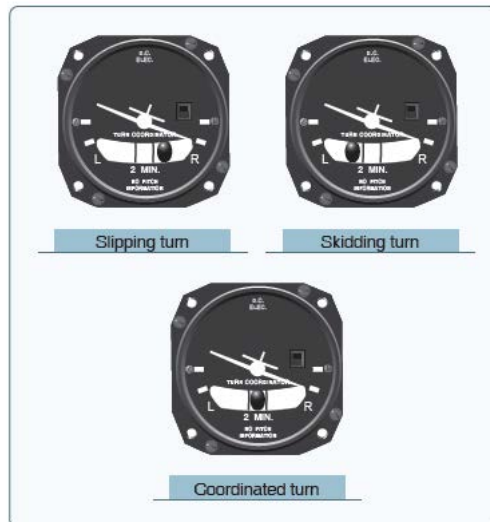
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PHAK 8-16



# Turn Coordinator Turning

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# Attitude Indicator (AI)

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- Gyroscopic
- Indicates pitch and bank
- Set reference “airplane” in level flight only

Archaic: “Artificial Horizon”



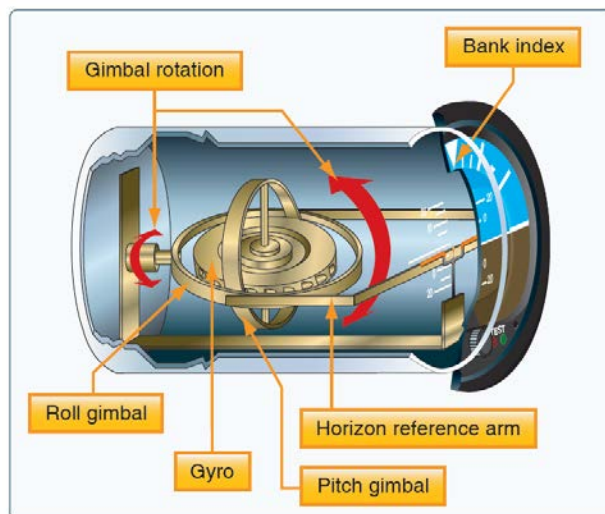
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# AI: Under the hood

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# AI for the pilot

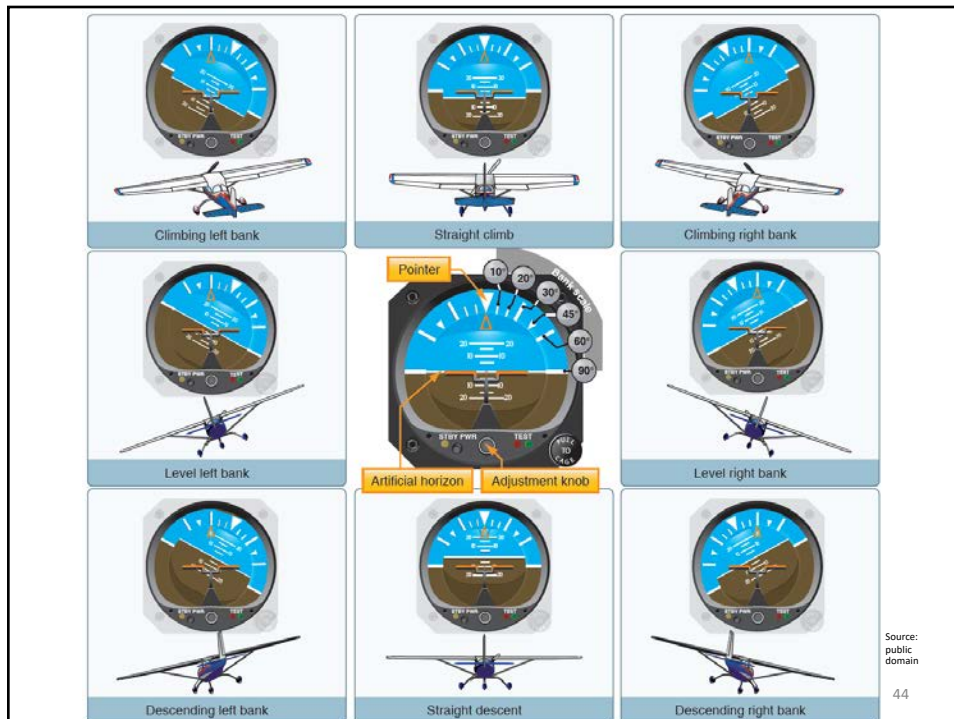
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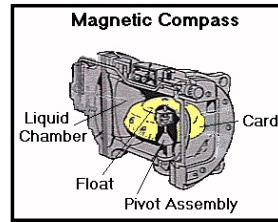
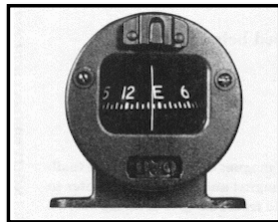
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# Magnetic Compass

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- Aligns itself with magnetic north pole
- Accurate when straight and level
- Full of errors! (read PHAK 8-24)



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# Magnetic Variation

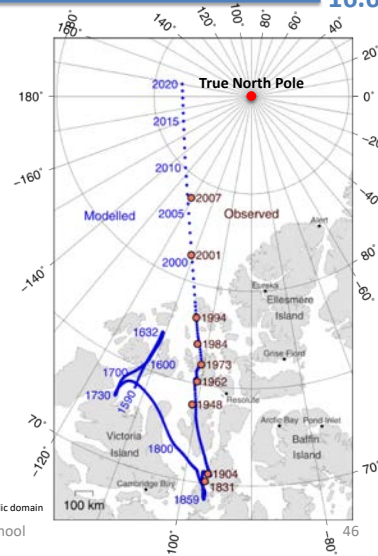
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- True North Pole
  - Earth’s rotation axis, where line of longitude meet
- Magnetic North Pole
  - compass points here
  - Moves over time



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# Local Magnetic Variation

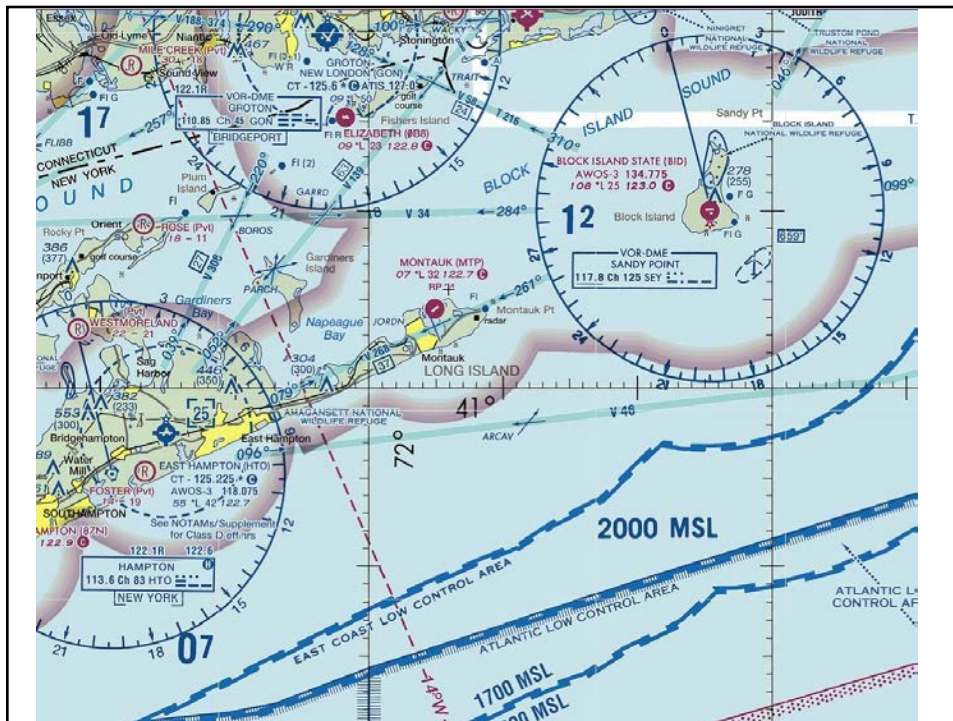
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- True north != magnetic north
- VORs in magnetic
- Isogonic lines
- “east is least; west is best”: true + W variation = mag



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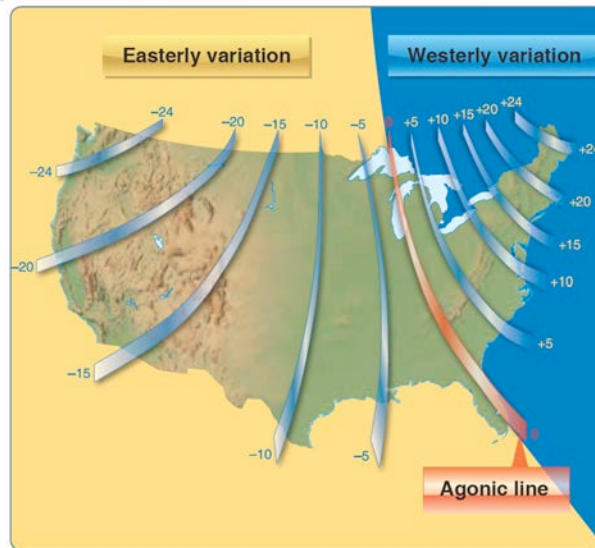
47





## National Magnetic Variation

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49

## Magnetic Deviation

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Compass error due to stuff in the plane.

Read PHAK 8-24 for the rest:

- dip-related
- acceleration-related



Ask New Age passengers to leave the healing magnets at home.

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# Heading Indicator or “DG”

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- Directional Gyroscope
- Does not seek north
- Pilot periodically aligns to Magnetic Compass



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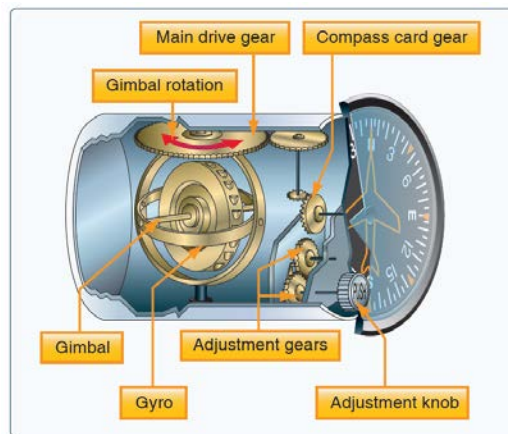
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# HI/DG: Under the hood

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## HSI: Horizontal Situation Indicator

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- Looks similar to Heading Indicator
- Normally “slaved” to compass
- Combines navigation and heading information



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## TAA: Technologically Advanced Aircraft

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“glass” (LCD) cockpit popular since 2003 in light aircraft

Pioneered by Cirrus with Avidyne (MIT spin-off). Adopted industry-wide by 2007, mostly with Garmin.

Aftermarket electronic flight instruments are widely available as retrofits for aircraft built 1930-2000.



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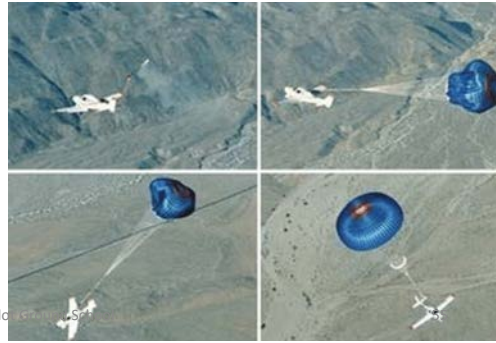
## Ballistic Airframe Parachute

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Pioneered on ultralights.

1999: Cirrus SR20 first certified airplane to include.

Today: most experimental and some certified aircraft, including Cirrus Jet(!)



## Summary

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- Piston engines can have quirks; turbines will just quit
- Six pack: Airspeed (pitot), Attitude (gyro), Altitude (static), Turn/Ball (gyro), DG/HSI (gyro), VSI (static)
- Altimeter measures percentage of atmosphere above/below
- Compass full of errors except when straight and level
- Aircraft manufacturers are really systems integrators.
- **Study: pitot-static failures**
- **Study: compass errors**



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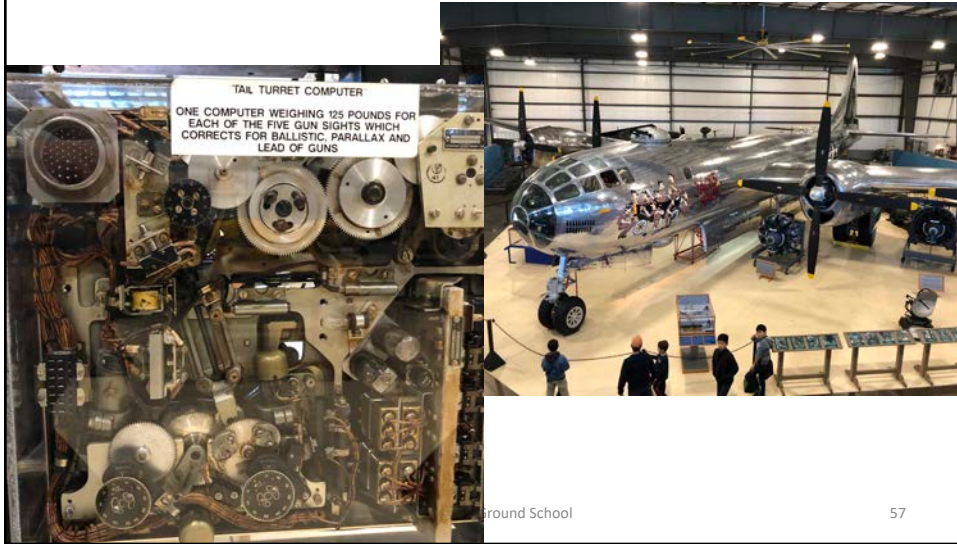
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# Questions?

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