



VICTORIA FLYING CLUB

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Flight for Range and Endurance

- Review Straight and Level Flight
- Definition and Motivation
- Flight for **Range**
 - Diagrams, Maximum Range (Experimental)
- Flight for **Endurance**
 - Diagrams, Maximum Endurance (Experimental)
- Summary and Questions
- Pre-Flight Briefing



Review Straight and Level Flight

- *Attitude plus power equals performance!*
- Mentally perform a power reduction from the cruise power setting while maintaining straight and level flight.
- What effect does the power reduction have on the airspeed and the fuel consumption?
- What effect does the power reduction have on the estimated time of arrival?



Definition and Motivation

- Airspeed and fuel flow can be traded off
- **Range** – achievable **distance** per **fuel** unit (air versus ground range): **destinations, alternates**
- **Endurance** – achievable **time** per **fuel** unit: **holding or orbiting** procedures, cockpit **management / decision making, economy**
- **Maximum range** – *best* achievable **distance**
- **Maximum endurance** – *best* achievable **time**



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CRUISE PERFORMANCE

CONDITIONS:

2550 Pounds

Recommended Lean Mixture

Pressure Altitude Feet	RPM	20°C BELOW STANDARD TEMP			STANDARD TEMPERATURE			20°C ABOVE STANDARD TEMP		
		% MCP	KTAS	GPH	% MCP	KTAS	GPH	% MCP	KTAS	GPH
2000	2550	83	117	11.1	77	118	10.5	72	117	9.9
	2500	78	115	10.6	73	115	9.9	68	115	9.4
	2400	69	111	9.6	64	110	9.0	60	109	8.5
	2300	61	105	8.6	57	104	8.1	53	102	7.7
	2200	53	99	7.7	50	97	7.3	47	95	6.9
	2100	47	92	6.9	44	90	6.6	42	89	6.3
4000	2800	83	120	11.1	77	120	10.4	72	119	9.8
	2550	79	118	10.6	73	117	9.9	68	117	9.4
	2500	74	115	10.1	69	115	9.5	64	114	8.9
	2400	65	110	9.1	61	109	8.5	57	107	8.1
	2300	58	104	8.2	54	102	7.7	51	101	7.3
	2200	51	98	7.4	48	96	7.0	45	94	6.7
	2100	45	91	6.6	42	89	6.4	40	87	6.1
6000	2850	83	122	11.1	77	122	10.4	72	121	9.8
	2800	78	120	10.6	73	119	9.9	68	118	9.4
	2500	70	115	9.6	65	114	9.0	60	112	8.5
	2400	62	109	8.6	57	108	8.2	54	106	7.7
	2300	54	103	7.8	51	101	7.4	48	99	7.0
	2200	48	96	7.1	45	94	6.7	43	92	6.4

Cruise Performance POH Section 5

- Consider **conditions**
- Select pressure **altitude**
- Select **temperature**
- Select **power** setting
- Interpolate as required
- Determine **airspeed** and **fuel flow**

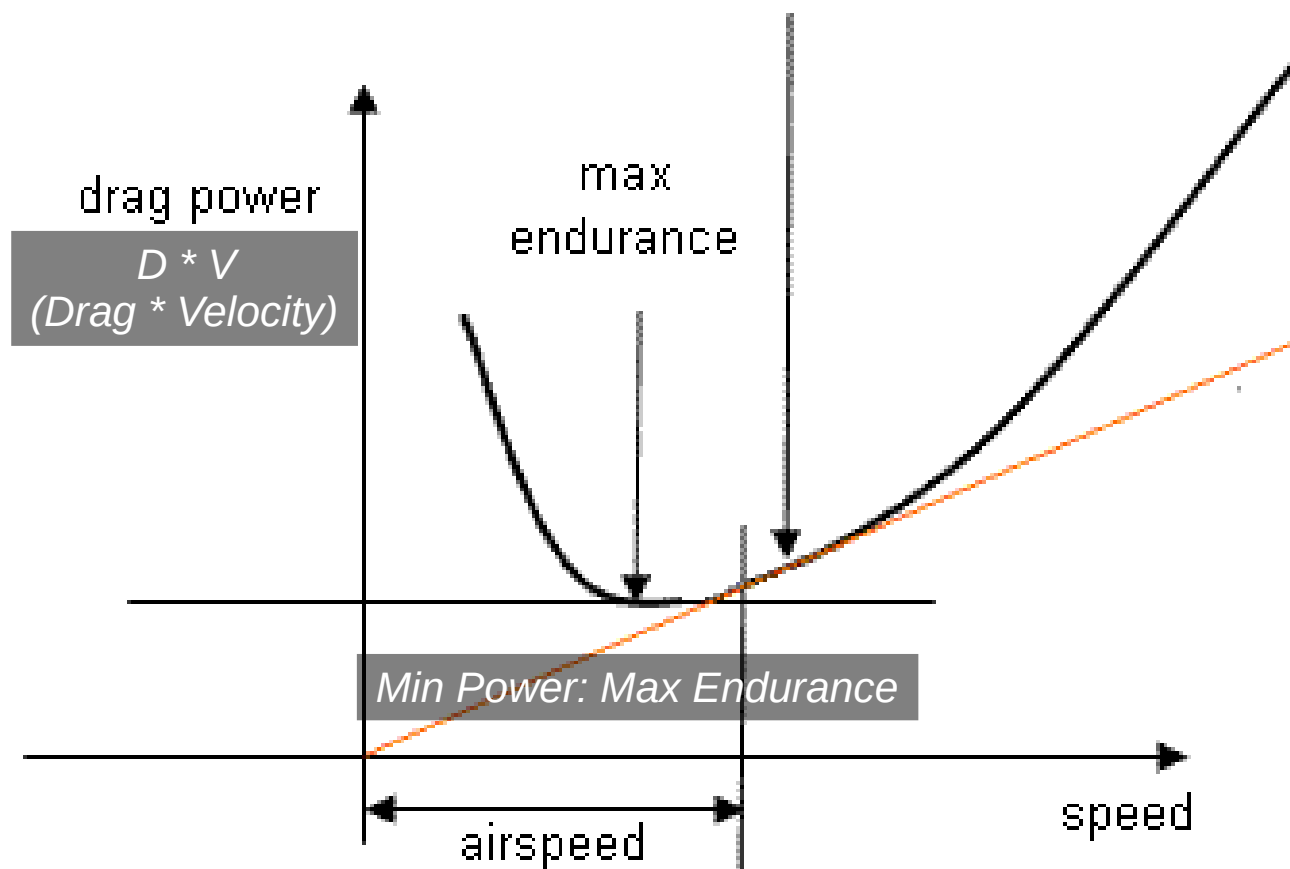


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Flight for Endurance

Power Required

still-air max
range speed

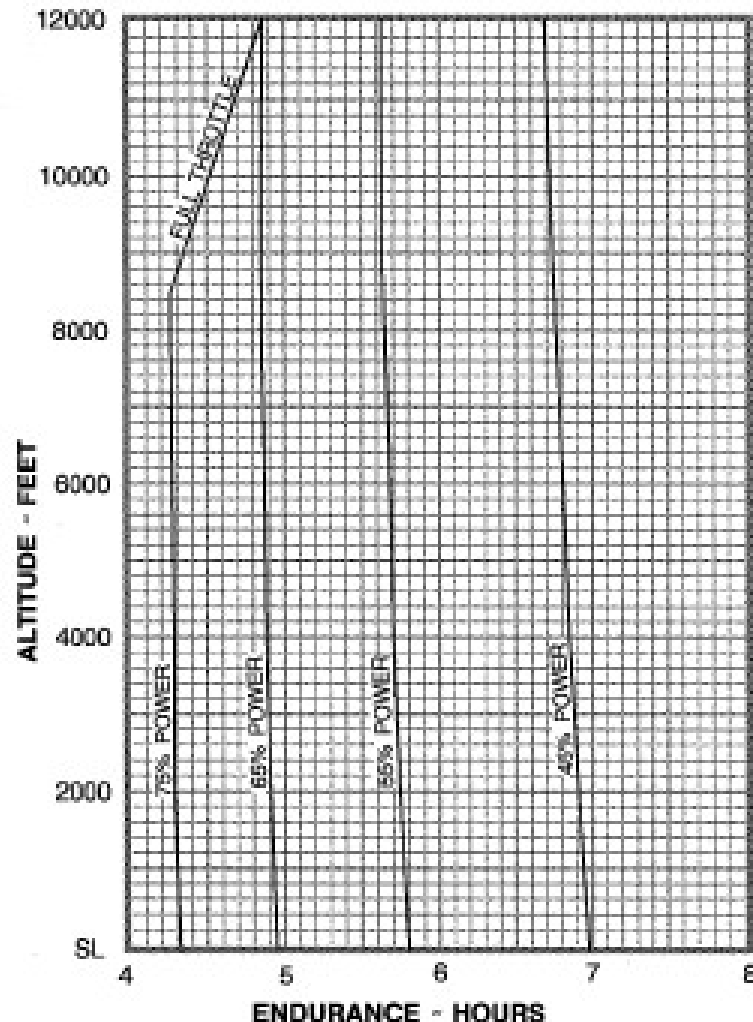




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ENDURANCE PROFILE 45 MINUTES RESERVE 53 GALLONS USABLE FUEL

CONDITIONS:
2550 Pounds
Recommended Lean Mixture for Cruise At All Altitudes
Standard Temperature



NOTE:

1. This chart allows for the fuel used for engine start, taxi, takeoff and climb, and the time during climb.

Endurance Profile POH Section 5

- Consider **conditions**
- Select pressure **altitude**
- Select **power** setting
- Determine **endurance**
- **Endurance** decreases *slightly* for given % of power available
- Specific fuel consumption (**SFC**) increases *slightly* with altitude for power-rated engines (piston-propeller)



Flight for Maximum Endurance (Experimental)

- Reduce **power** in **100 RPM** steps maintaining **level flight** with *stable* **airspeed** steps and **trim**
- *Unstable* decreasing airspeed indicates slow flight range – more power required
- Accelerate to **cruise airspeed** and then decrease **power** to *slightly* higher than last *stable* setting to compensate for turbulence and possible required turns
- Lean **mixture** as recommended
- Notice reduced control responses due to reduced airflow



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Leaning



- Slowly turn **mixture** knob out / *anticlockwise* until a drop in RPM can be observed
- Turn the **mixture** knob back in / *clockwise* until the RPM has increased again (**2-3 turns**)
- Check **fuel flow** and **exhaust gas temperature** (**50°F** below peak EGT)

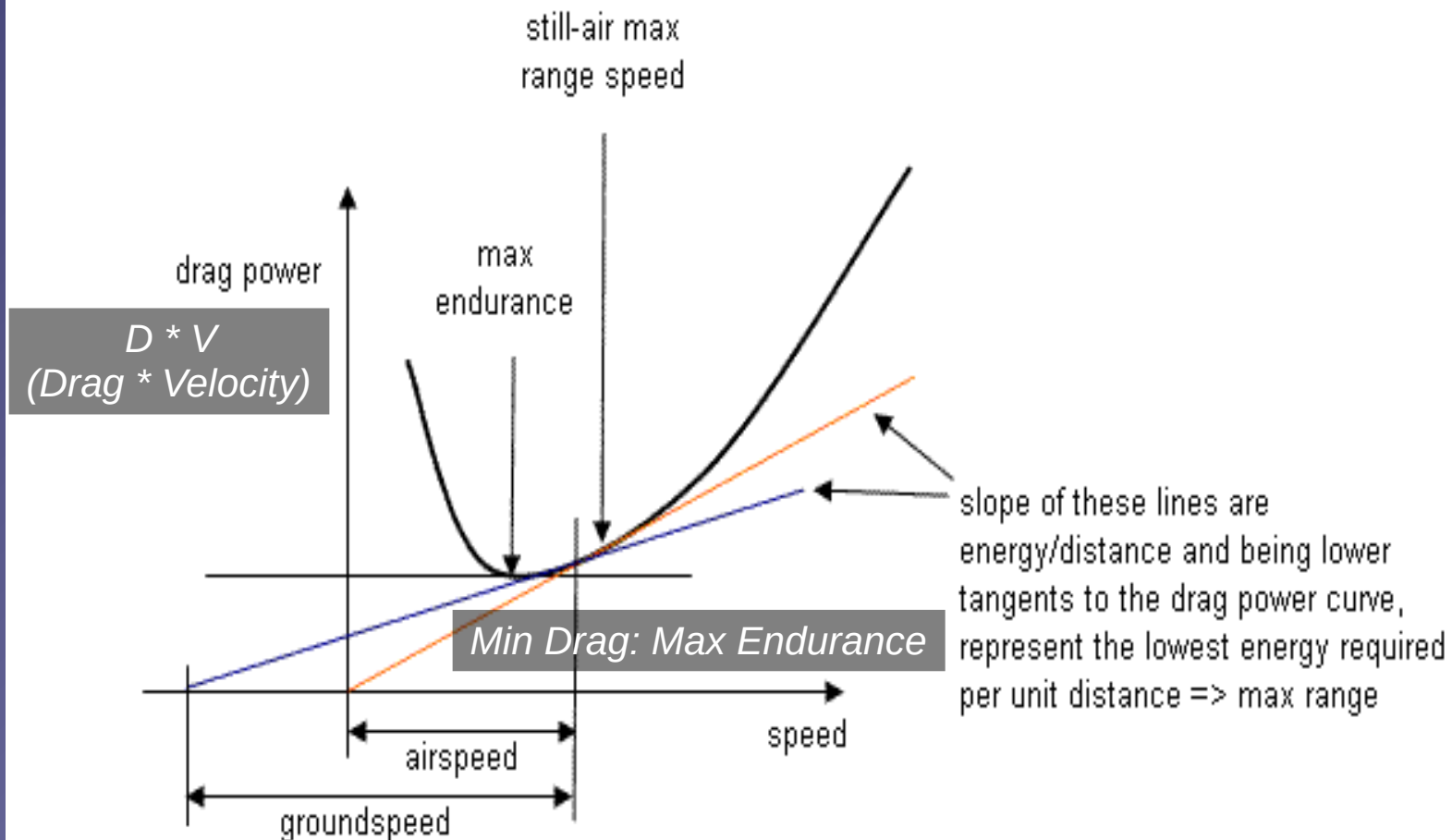


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Flight for Range

Power Required

Optimize both power and speed

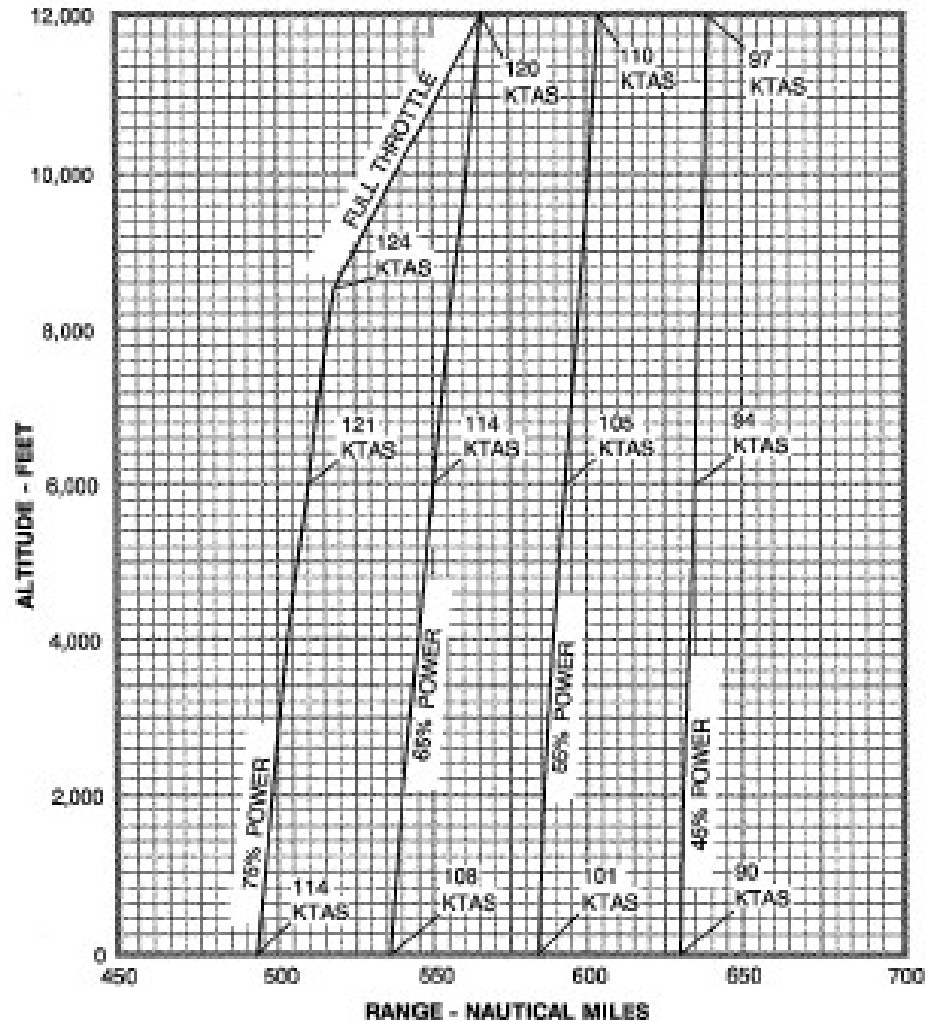




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RANGE PROFILE 45 MINUTES RESERVE 53 GALLONS USABLE FUEL

CONDITIONS:
2550 Pounds
Recommended Lean Mixture for Cruise At All Altitudes
Standard Temperature
Zero Wind



NOTES:

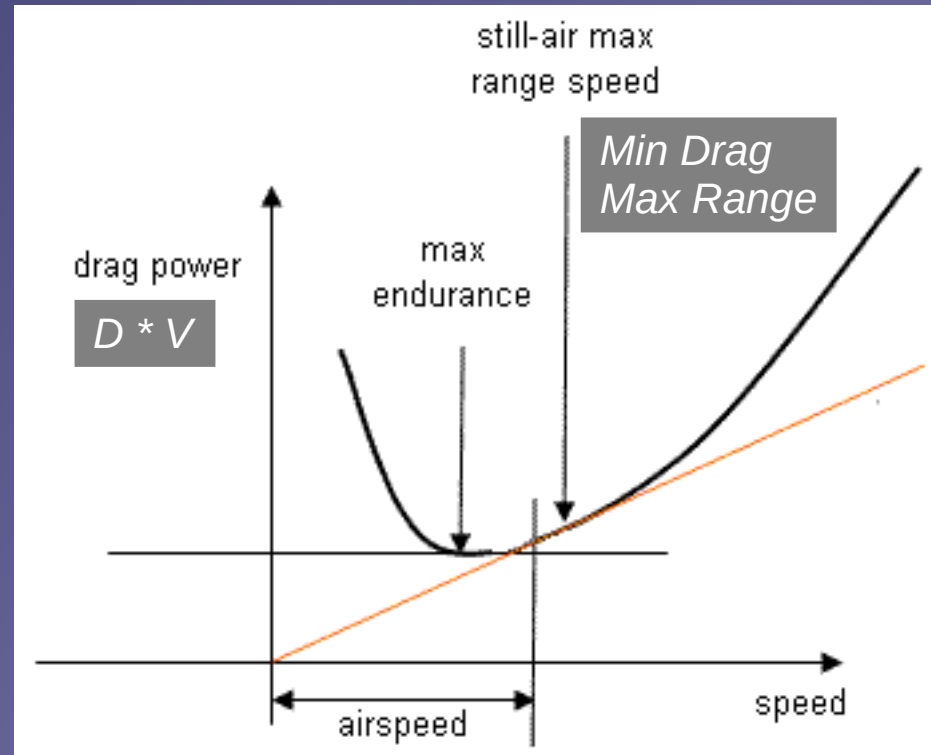
1. This chart allows for the fuel used for engine start, taxi, takeoff and climb, and the distance during climb.

Range Profile POH Section 5

- Consider **conditions**
- Select pressure **altitude**
- Select **power** setting
- Determine **range**
- **Range** increases with increasing altitude
- True airspeed (**TAS**) increases with increasing altitude



Flight for Maximum Range



- Increase **power** in **100 RPM** steps until a *non-linear* increase in **airspeed** can be observed
- Maintain **level** flight, **trim** and lean **mixture** as recommended (rich of peak)



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Range and Endurance – Instruments



- **Control:** Attitude, Power → **Performance:** Airspeed, Altitude
- Mixture → Exhaust Gas Temperature, Fuel Flow



Factors Affecting Range and Endurance

- **Endurance:** fuel available, power setting, flap setting (**configuration**), **weight**, center of gravity, **air density** (altitude, temperature, humidity), contamination, mixture, **turbulence**
- **Range:** fuel available, power setting, flap setting (**configuration**), **weight**, center of gravity, **air density** (altitude, temperature, humidity), contamination, mixture, **wind** (air versus ground range)



Summary / Quiz

- Define range, maximum range, endurance and maximum endurance.
- Give examples for when flight for range or endurance is preferable.
- What are the main factors that influence range and endurance and how do they affect them?
- Mentally configure the airplane for best range and endurance and state all required actions, respectively.



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Pre-Flight Briefing

- Exercise
- Training Area
- Departure and Arrival Procedures
- Weather Briefing / NOTAMs
- Aircraft and Documents
- Time and Fuel Requirements
- Safety Considerations and Responsibilities



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Additional Materials

- Additional materials for Flight for Range and Endurance
- Flight Instructor Guide – Exercise 10, Lesson Plan 4



Specific Fuel Consumption

- Jet (thrust specific fuel consumption):
 - $TSFC = \text{Fuel Consumption} / \text{Unit of Thrust}$
 - $\text{Fuel Flow} = TSFC * \text{Thrust}$
- Propeller (brake specific fuel consumption):
 - $BSFC = \text{Fuel Consumption} / \text{Unit of Power}$
 - $\text{Fuel Flow} = BSFC * \text{Power}$



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Maximum Endurance

Propeller Aeroplanes

Minimum Fuel Flow gives Maximum Endurance

$$\text{Fuel Flow} = \text{SFC} \times \text{Total Power}$$

minimum at V_{MP}

Piston - minimum at
low altitudes

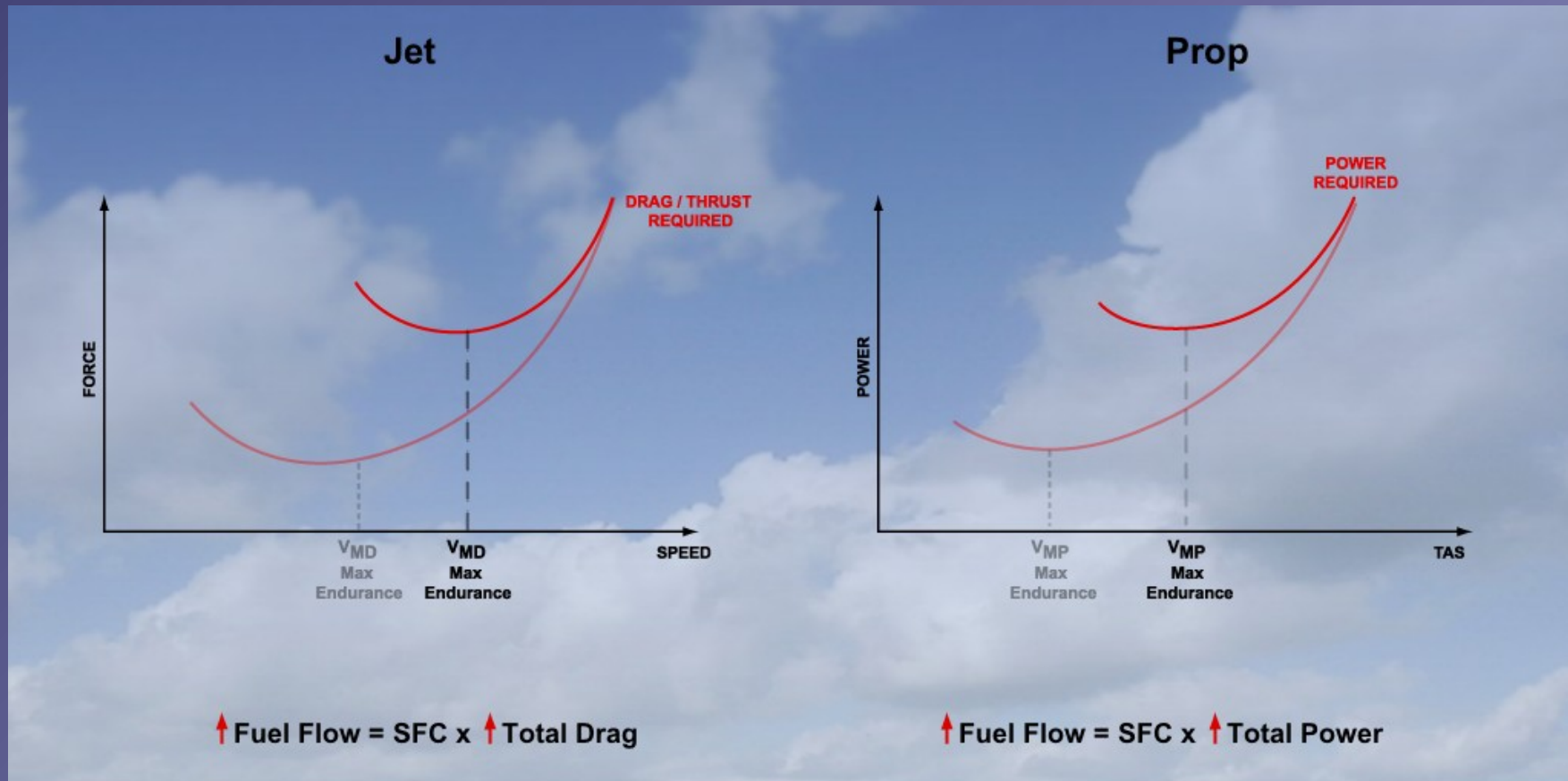
Turbo-prop - minimum at
middle altitudes

Endurance - Propeller Aeroplane

For maximum endurance, a propeller aeroplane must fly at V_{MP} and operate either at low or middle altitudes.



Weight and Endurance

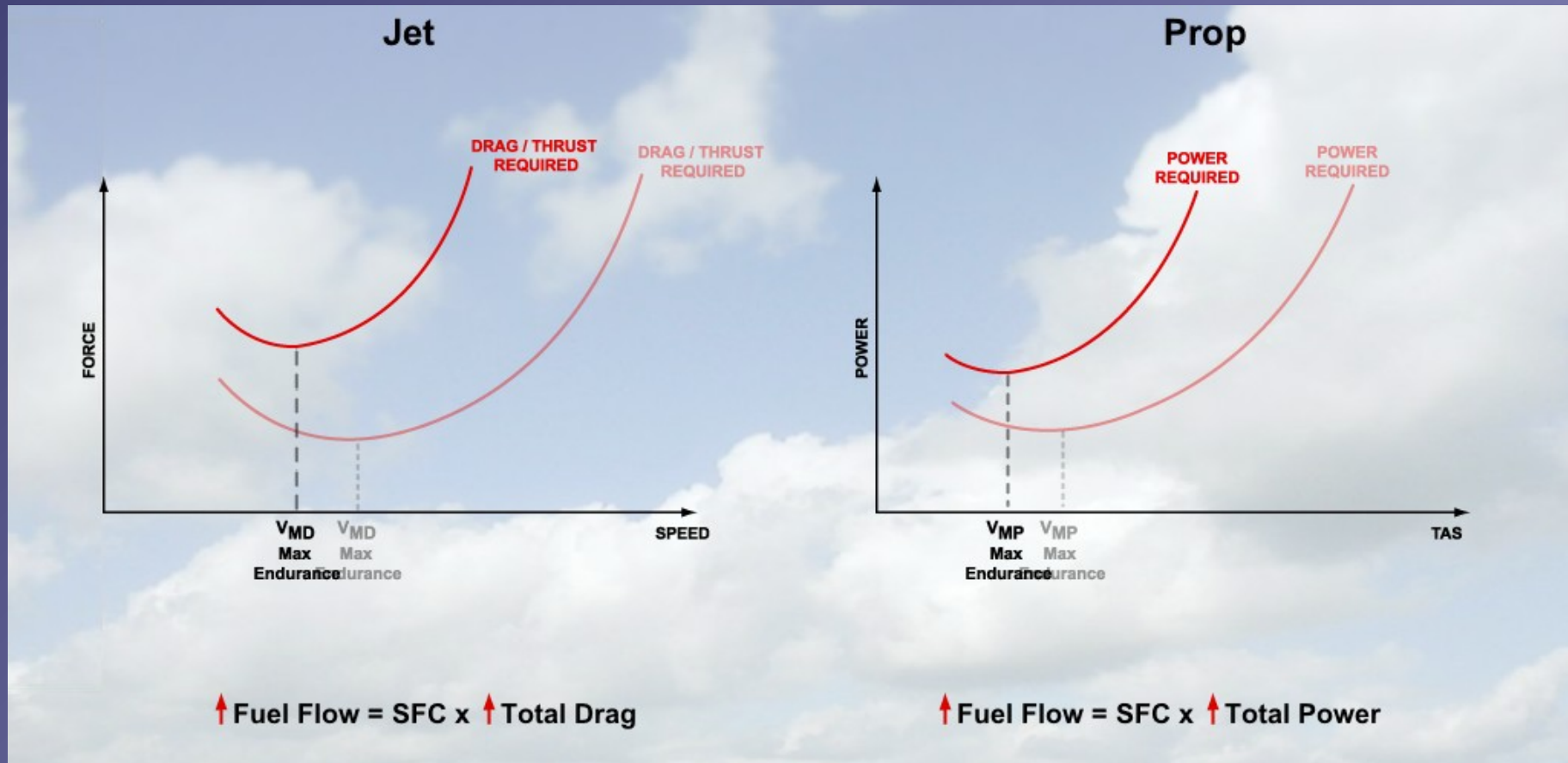


Factors Affecting Endurance - Weight

Increasing weight will increase the drag and power required and therefore increase the fuel flow and decrease endurance. The speed for maximum endurance increases.



Configuration and Endurance



Factors Affecting Endurance - Configuration

Deploying flaps and undercarriage will increase the drag and power required and therefore increase the fuel flow and decrease endurance.

The speed for maximum endurance decreases.



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Altitude and Endurance



Factors Affecting Endurance - Wind and Altitude

Wind has no effect on the endurance of the aeroplane.

Jet aeroplanes reach maximum endurance above the tropopause.

Turbo-propeller aeroplanes reach maximum endurance at about 10,000 ft.

Piston engine aeroplanes reach maximum endurance at mean sea level (MSL).



Specific Range

- Specific Air Range
 - *Air Range = Air Distance / Unit of Fuel*
 - *SAR = TAS / Fuel Flow*
 - Jet: *SAR = TAS / TSFC * Thrust Required*
 - Propeller: *SAR = TAS / BSFC * Power Required*
- Specific Ground Range
 - *Ground Range = Ground Distance / Unit of Fuel*
 - *SGR = GS / Fuel Flow*
 - Jet: *SGR = GS / TSFC * Thrust Required*
 - Propeller: *SGR = GS / BSFC * Power Required*
- Maximum Specific Range
 - *Maximize **TAS** or **GS** while minimizing **SFC***



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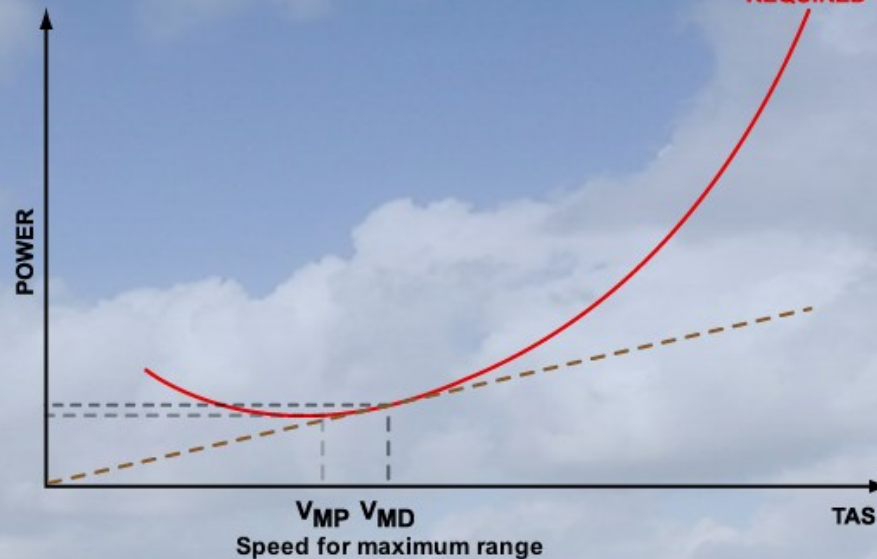
Maximum Air Range

PROPELLER

$$\text{SPECIFIC AIR RANGE (SR)} \uparrow = \frac{\text{TAS} \uparrow}{\text{SFC} \times \text{TOTAL POWER} \uparrow}$$

Maximum ratio at V_{MD}

POWER
REQUIRED



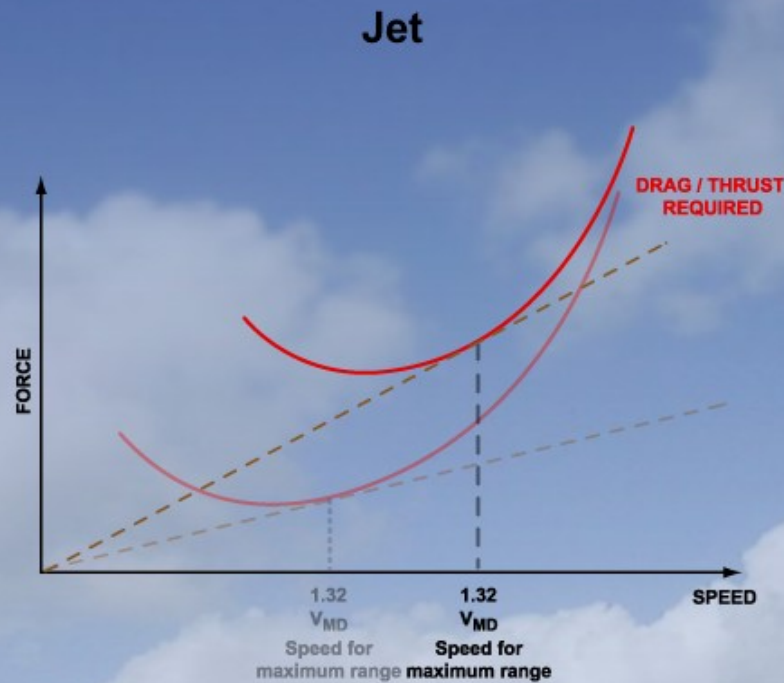
Range - Propeller Aeroplane

For maximum range, a propeller aeroplane must fly at V_{MD} and as high as possible.

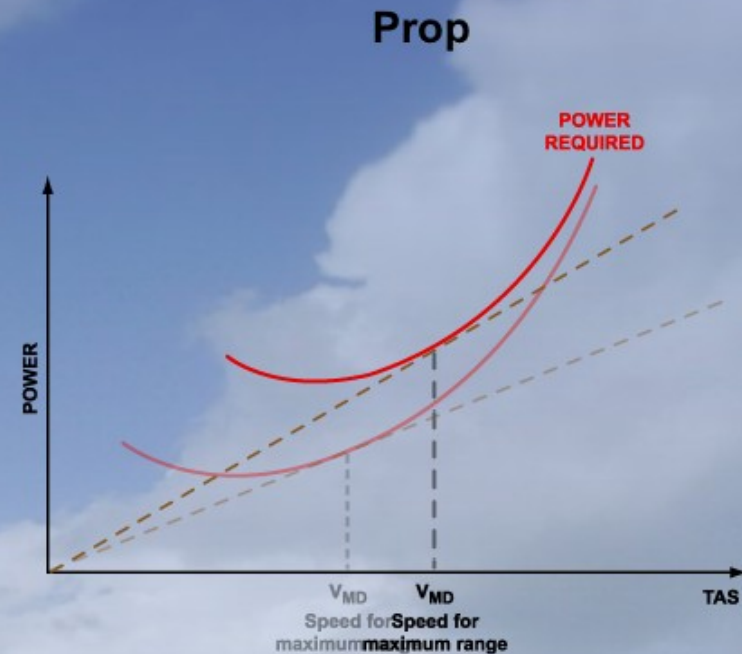


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Weight and Range



$$\text{SPECIFIC AIR RANGE} \downarrow = \frac{\text{TAS}}{\text{SFC} \times \text{Total Drag}} \uparrow$$



$$\text{SPECIFIC AIR RANGE} \downarrow = \frac{\text{TAS}}{\text{SFC} \times \text{Total Power}} \uparrow$$

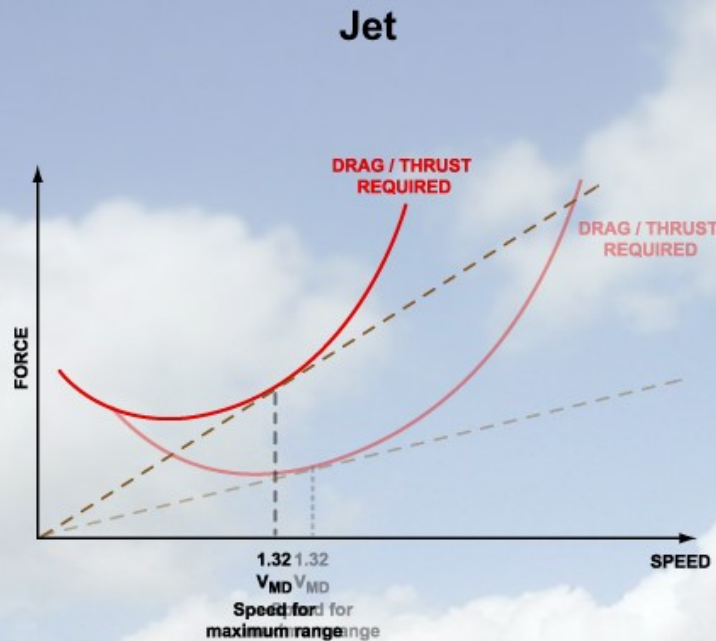
Factors Affecting Range - Weight

Increasing weight will increase the drag and power required and therefore increase the fuel flow and decrease range. The speed for maximum range increases.

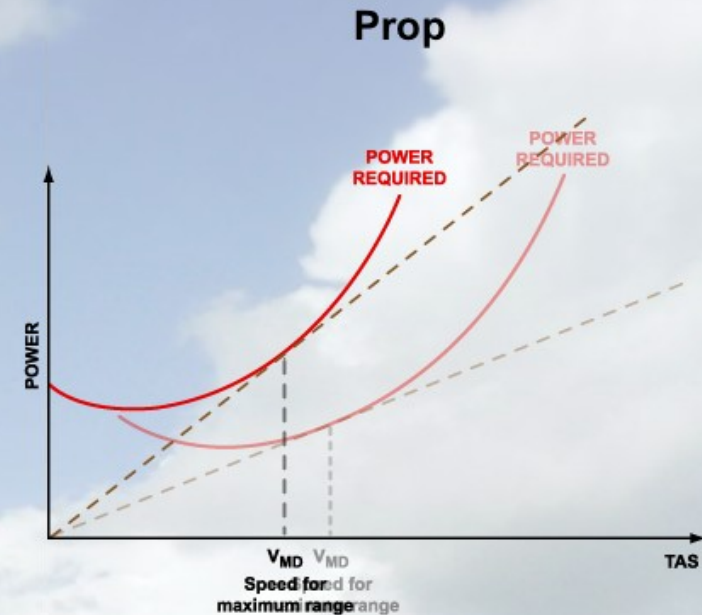


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Configuration and Range



$$\text{SPECIFIC AIR RANGE} \downarrow = \frac{\text{TAS}}{\text{SFC} \times \text{Total Drag}} \uparrow$$



$$\text{SPECIFIC AIR RANGE} \downarrow = \frac{\text{TAS}}{\text{SFC} \times \text{Total Power}} \uparrow$$

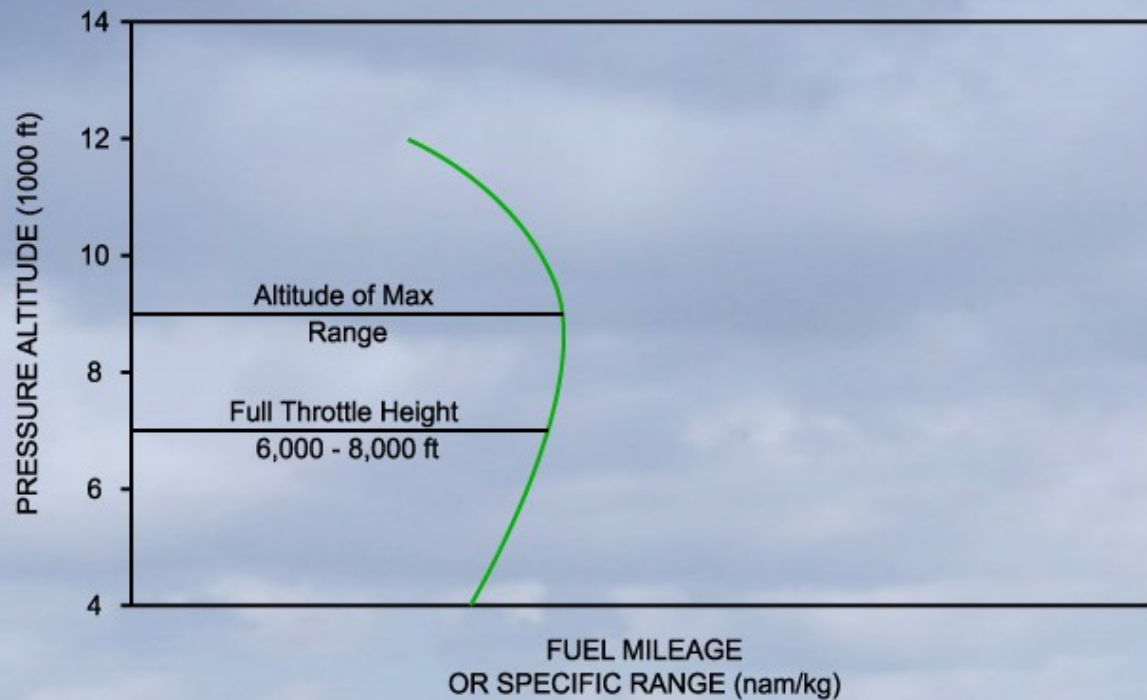
Factors Affecting Range - Configuration

Deploying the flaps and undercarriage will increase the drag and power required and therefore increase the fuel flow and decrease range.



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Altitude and Range



$$\uparrow \text{SPECIFIC AIR RANGE} = \frac{\text{TAS} \uparrow}{\cancel{\text{SFC}} \times \text{Total Power} \uparrow}$$

Factors Affecting Range - Altitude - Propeller Aeroplane

Piston Engine propeller aeroplanes specific range increases with altitude till just above full throttle height (6,000 - 8,000 ft).