Defence Technology & Systems Course
DTS 5121 - Air Systems
AF 06 : Aircraft Performance

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Training Programme

1 : Of Thrust, Power and Weight
or what factors affect aircraft performance?

2 : Cruise Performance - Range and Endurance
or how fast and how long can the aircraft fly?

3 : Takeoff and Landing Performance
or how much runway do we need?

4 : Climb and Turn Performance
or how nimble is the aircraft?
References


Some common terms and conversion factors

Aircraft engine data (especially US engines) don’t use SI units!

a) knots (kt) – unit of speed = 0.5151 m/s

b) pound (lb or lbf) – unit of force = 4.448 N

c) pound mass (lb or lbm) – unit of mass = 0.454 kg

d) horsepower (hp) - unit of power = 0.7457 kW

e) nautical mile (nm) – unit of distance
   = 1’ of latitude at equator = 6080 ft   =  1853 m

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The basic idea of thrust production

\[
\text{Thrust} \sim \frac{d}{dt}(\text{mass flow} \times \text{exhaust velocity})
\]
How does a turbojet work?
World’s first jet engines

Hans von Ohain’s HS3B

Frank Whittle’s W1

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Example: Engine upgrade A4S to A4S-1
J65-W-20 turbojet
Replacement engine F404-GE-100D turbofan
F404-GE-400 cutaway diagram
Question: How does a turbofan work?

[Diagram of a turbofan engine with labels for various components: Secondary air stream, Duct fan, Outer nozzle, Fuel Injector, Turbine, Hot gases, Inlet, Primary air stream, Compressor, Combustion chamber, Nozzle.]
F404-GE-100D specifications

- Maximum thrust: 11,000 lbs.  48.9 kN
- Weight: 1,820 lbs  826 kg
- Length: 89 inches  226 cm
- Inlet diameter: 31 inches  79 cm
- Max diameter: 35 inches  89 cm
- Airflow: 142 lbs/sec  64 kg/sec
- Pressure ratio: 25-to-1
- Bypass ratio* 0.34

* Bypass ratio = (mass of air through fan) / (mass of air through core)
## Comparison: J65-W-20 and F404-GE-100D

<table>
<thead>
<tr>
<th></th>
<th>J65-W-20</th>
<th>F404-GE-100D</th>
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<tbody>
<tr>
<td>Max thrust (T) kN</td>
<td>37.4</td>
<td>48.9</td>
</tr>
<tr>
<td>Engine weight (W/g) k</td>
<td>1251</td>
<td>826</td>
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<tr>
<td>Engine T/W *</td>
<td></td>
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<tr>
<td>TSFC (kg/hr)/N **</td>
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* Not to be confused with the aircraft thrust to weight ratio

** TSFC is the thrust specific fuel consumption
TSFC is defined as fuel-flow rate per unit of thrust produced (N or lbf)
Fuel-flow rate is measured in units of mass of fuel flow per hour (kg/hr or lbm/hr)
Warning! TSFC is not non dimensional!

\[
\frac{(\text{lbm/ hr})}{\text{lb}} = \frac{\text{kg/hr}}{\text{N}}
\]

\[
\frac{4.448 \text{ N}}{\text{kg/hr}} = \frac{\text{lbm/ hr}}{\text{lbf}}
\]
The payoff

- 30% less take-off time
- 15% higher dash speed
- 35% faster acceleration
- 40% increased rate of climb (ROC)
- Max speed at sea level: 610 knots (1130 km/h)
- Max cruise speed at 30 kft (10 km): 446 knots (826 km/h)

Comments?

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Were there problems in airframe/engine integration?
Exercise: F16A and F16D

Question: What's the difference?