Propulsion Systems
Major US Airline Year 2000 Operating Costs

Cost per ASM = 9.75 ¢

- Aircraft Fuel: 13%
- Engine Maint. Material & OSR: 2%
- Engine Ownership: 3%
- Airframe Ownership: 10%
- Airframe Maint. Material & OSR: 2%
- Landing fees and other rents: 5%
- Passenger service: 3%
- Selling expenses: 9%
- Other: 13%
- Salaries: 40%

"Other" includes contracted services, asset write-downs, other non-recurring items
Airplane Operating Cost Comparison

Three Class Seating
3000 nm Trip

Seats = Constant

Increasing Seats

Current State-of-Art

GOAL
Typical Engine-Related Airline Cost Breakdown

- Initial Cost (List): 33%
- Fuel Cost: 54%
- Maintenance Cost: 13%

777-200ER/PW4090
$0.75/gal Fuel Price
Thrust Sizing Requirements

- Number of Engines
- Aircraft Max Take Off Gross Weight
- Take Off Field Length
- Time to Climb
- Cruise Altitude and Mach Number
- Lift to Drag of Wing
- Aircraft Potential Growth
Basic engine relationships

\[
\text{Thrust} = \frac{(\text{Velocity of exhaust} - \text{velocity of aircraft})}{\text{Mass}}
\]

Overall engine efficiency = $\eta_{\text{thermal}} \times \eta_{\text{propulsive}}$
Overall Engine Efficiency Includes Two Processes: Energy Conversion and Thrust Production

\[ \eta_{\text{overall}} = \eta_{\text{thermal}} \times \eta_{\text{propulsive}} \]
Thermal efficiency measures the process of converting chemical energy of the fuel into energy available for propulsion

- Function of overall pressure ratio and component efficiencies -

Current engines at 40:1
overall pressure ratio

Future engines at 60:1
overall pressure ratio
Propulsive efficiency measures the process of converting energy available for propulsion into useful propulsive power.

\[ \eta_{\text{propulsive}} \rightarrow 100\% \text{ as } V_{\text{exhaust}} \rightarrow V_{\text{o}} \]
Lower specific thrust is fundamental to improving fuel economy

![Diagram showing the relationship between specific thrust, fuel economy, engine efficiency, drag/thrust, and weight/thrust. Increasing bypass ratio is indicated by an arrow.]
Commercial Turbofan

- Fan
- Low pressure Compressor
  - Fan air bypassing the jet engine
- Combustors
- High pressure compressor
- Twin spool shaft to turn the fan and the compressors
- 2-stage high pressure turbine to turn outer shaft

Air Inlet

Thrust