# Overview: Conventional Aerospace Propulsion Systems

- Main requirement of propulsion system
  - **produce thrust** to:
    - accelerate some body
    - maintain velocity but overcome drag, gravity,...


- **Jet engines**
  - accelerate and exhaust propellant to provide thrust to *vehicle*





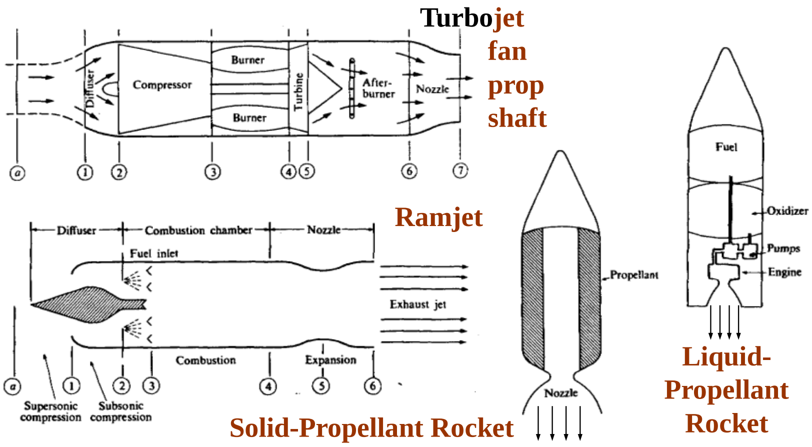


# Engine Design - Goals

- Meet **required thrust** throughout flight envelope
  - aircraft: takeoff, climb, cruise, ...
  - spacecraft: launch, orbit transfer, planetary mission,...
- **High efficiency**
  - minimize amount of fuel (energy input) required to provide delivered thrust (energy output)
  - low weight (less thrust to accel. engine alone)
- Constraints
  - **materials limitations** (max. temperature, stress,...)
  - **low emissions**: NOx, soot, toxics, signature,....
  - other: size, lifetime, manufacturability, maintainability

# Conventional "Jet" Propulsion Systems

- Propulsion from exhaust of accelerated propellant




Figures adapted from Hill and Petersen, *Mechanics and Thermodynamics of Propulsion*, Addison Wesley



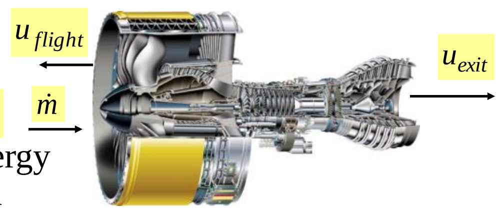




# Airbreathing Engine Design: Exit Velocity

- Propellant exit velocity or kinetic energy obtained by converting thermal energy in nozzle
- Can improve efficiency of "airbreathing" engine (significant fraction of propellant is ambient fluid) by using **lots of "air"** with **low velocity increase**

$$\tau/A \approx \dot{m}\left(u_{exit} - u_{flight}\right)$$




- Reduces kinetic energy lost in exhaust fluid
- Less important at high Mach numbers

GP7000 figure from www.pratt-whitney.com

# Engine Design: Pressure

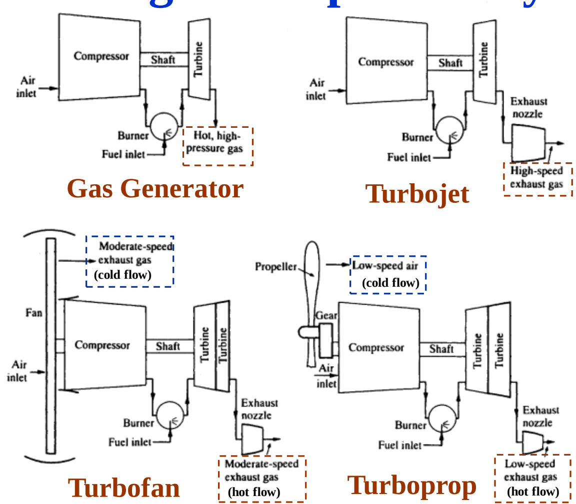
- Generally more efficient to work at high pressure in combustion chamber
  - higher pressure produces higher thrust for same amount of fuel/propellant
- Jet (including rocket) engines use expansion of flow through nozzle or turbine
  - pressure is driving force in the expansion
- Combustion can also be more efficient at high p







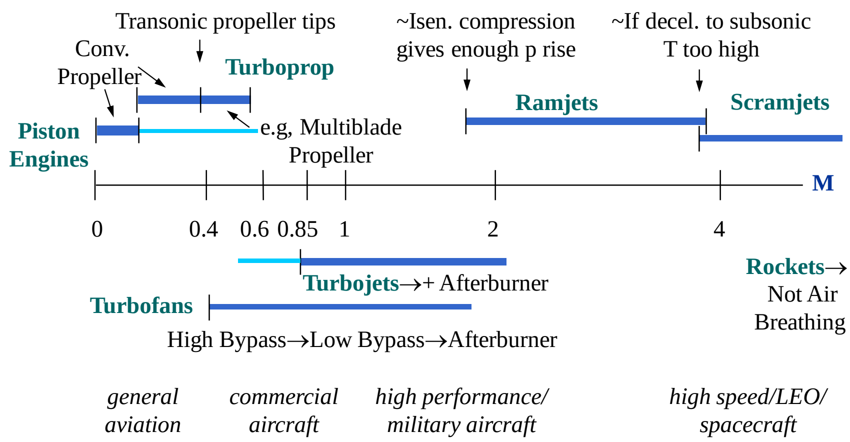
# Turbine Engine Propulsion Systems




Figures adapted from Hill and Petersen, *Mechanics and Thermodynamics of Propulsion*, Addison Wesley

# "Optimal" Operating Ranges

- Flight Mach number effects engine choice










# Analysis Methods

- We will first learn certain analysis methods and concepts in order to understand operation and design of propulsion systems
- To model **thrust**
  - need **mass and momentum conservation** laws
- To model **energy and property** (p,T,..) changes
  - need **thermodynamics** (*energy conservation*=1st Law, 2nd Law, and *state equations*)
  - need **chemical thermodynamics** for **combustion**
- To model overall engine **performance**
  - need **thermodynamic cycle analysis**