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IV. Rocket Propulsion Systems

A. Overview

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for AE 4451 Jet and Rocket Propulsion

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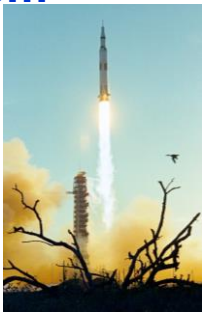
Rocket Propulsion System

Definition: device that provides thrust to a vehicle by accelerating some stored matter (the **propellant**) and exhausting it

– in rocket propulsion (unlike air-breathing engines), the propulsion system carries all its own propellant

Saturn V, Apollo 8



NASA

Bussard Ramjet

ScienceSource

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Rocket: Performance Parameters

- **Thrust**
  - important when there are minimum (or maximum) allowable accelerations, e.g., launch in gravity field
- **Impulse** $\int F(t)dt$
  - measure of time integrated performance (to change momentum of vehicle)
- **Other important issues**
  - structural weight, size/shape, complexity, reliability, hazards, throttling, reuse,…

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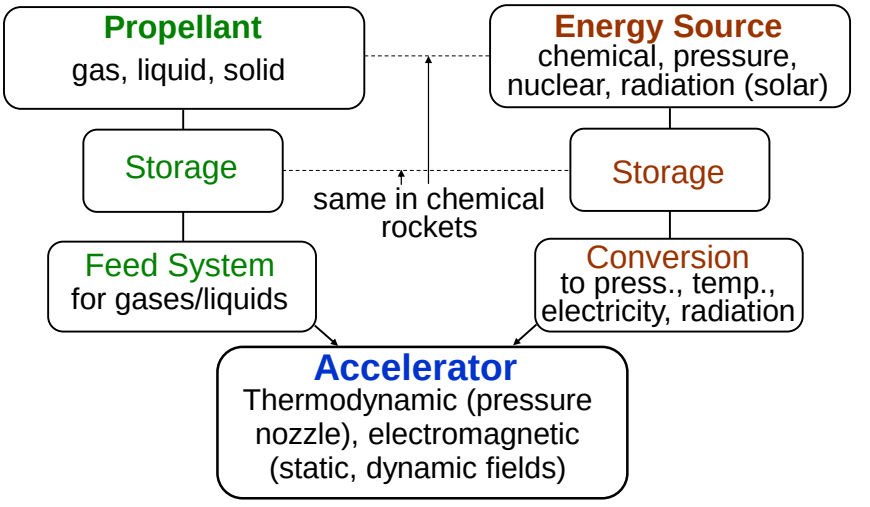
Rocket Propulsion Elements



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Examples: Pressure Rocket

- Cold Gas Thruster
  ⇒cold gas (N_2, N_2O,…) stored at high pressure with thrust provided by acceleration through nozzle

Vacco.com

  - Propellant=Energy source (thermal energy)
  - Feed system: piping from storage to nozzle
  - Energy conversion: none
  - Accelerator: nozzle (thermal to kinetic energy)

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Examples: Chemical Rocket

- Bipropellant: LH2-LOX (H_2/O_2)
  ⇒react pressurized H_2 and O_2 in combustion chamber, nozzle exhaust
  - Propellant=Energy source (chemical energy)
  - Storage: liquid (cryogenic) tanks

RS-25 (SSME) *NASA*

  - Feed system: liquid pumps and piping
  - Energy conversion: chemical to thermal energy (combustion)
  - Accelerator: nozzle

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Examples: Electrical Rocket

- Ion Engine

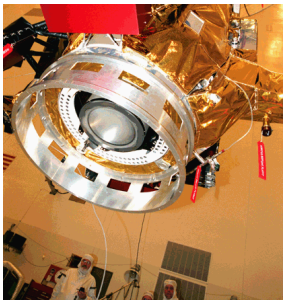
  ⇒ionize neutral gas (Xe); ions accelerated by E field; ions recombined with e^-

  – Propellant: neutral gas

  – Energy source: e.g., nuclear or solar

  – Energy conversion: nuclear/ solar to electrical

  – Accelerator: high voltage electrostatic field



Deep Space 1 NASA

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Applications

- Space Propulsion
  - launch: from “planetary” body to orbit
  - orbit Insertion: from launch orbit to mission orbit
  - maneuvering: maintain or change orbit or trajectory
  - attitude Control: orientation of vehicle
- Aircraft Propulsion
  - high thrust/acceleration (sustained or boosters)
  - high speed flight (> ramjet/scramjet capability)

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Chemical Rockets

- Common Applications
  - usual choice for high thrust rockets, e.g, launch, orbit change, aircraft propulsion
  - also used for maneuvering and attitude control
- Propellants
  - monopropellants: exothermic decomposition of single species (liquid)
    - N_2H_4, H_2O_2, N_2O, …
  - bipropellants
    - RP-1/O_2, H_2/O_2, $CH_3(NH)NH_2$/N_2O_4
  - …

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Chemical Rockets (continued)

- Propellant Storage
  - Gas rockets: fuel/oxidizer stored as gases – requires large storage volumes
  - Liquid rockets: stored as liquids – more complex but high impulse
  - Solid rockets: propellant is solid – lower impulse but simpler
  - Hybrid rockets: usually solid fuel+liquid oxidizer
- Motors vs. Engines
  - Motor = propellant stored inside comb. chamber
  - Engine = storage outside combustion chamber

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Other Rockets: Applications

- Pressure (cold gas)
  - attitude control + maneuvering: reduced thrust as pressure used up, rendevous
- Electrical
  - resistojet thrusters
  - arcjet thrusters - maneuvering + attitude control
  - ion engines/Hall thrusters - space propulsion
- Future (?) systems
  - nuclear thermal: like chemical rockets with nuclear-based heat addition, high thrust
  - magnetoplasmadynamic and other electrodynamic devices, high impulse

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Non-Rocket Propulsion for Space Applic.

- Combined Cycles: typically combine air-breathing with rocket cycles for single-stage to orbit (SSTO)
- Solar sails: use momentum from solar radiation
- Magnetic sails: use magnetic fields
- Tethers: conducting material moving through EM fields can produce currents/voltages or passing current through tether can produce forces
- (Gravity assist: sling shot effect)
- Warp drive, Cannae Drive …..