## 16.512, Rocket Propulsion Prof. Manuel Martinez-Sanchez Lecture 1: Introduction

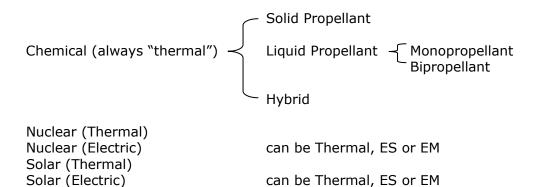
# Types of Rockets (Engines)

## - Depending on gas acceleration mechanism/force on vehicle mechanism.

"Thermal"	Gas pushes directly on walls by P (pressure) forces Nozzle accelerates gas by P forces (most large rockets, chem, nuclear, some electric)
Electrostatic	Ions accelerated by $\vec{E}$ field (a) Electrostatic force (push) on electrodes (Ion engines) (b) Force (push) on magnetic coils through gas $\vec{j}$ (Hall thrusters)
Electromagnetic	Gas accelerated by $\vec{j} \times \vec{B}$ forces Force (push) on coils or conductors (MPD thrusters, PPT's)

16.512 concentrates on Thermal

## - Depending on energy source:



16.512 deals mostly with Chemical.

## - Depending on Thrust level (per unit mass)

- High thrust ( $\geq 1g$ ) for launch, fast space maneuvering (16.512)
- Low thrust  $(10^{-5} 10^{-2} g)$  for efficient in-space maneuvers (16.522)

#### Performance Measures

<u>Specific Impulse</u>	$Isp = \frac{F}{\dot{m}g}$	$\left( \text{or } c = \frac{F}{\dot{m}} \right)$
	(sec)	(m/sec)

Dominant for chem. Rockets, range 200-500 sec Trade-off vs. mass for EP, range 500-6000 sec

Thermal Efficiency

η<sub>th</sub> = <u>Jet kinetic power</u> Thermal input power

(Thermal Rockets) Also for electrical thrusters

$$\eta = \frac{Power \ to \ jet}{Input \ electrical \ power}$$

$$\sim 30-80 \ \%$$

 $\eta_{\text{th}}$ 

Very close to 100% in chem. (non-issue) important in solar thermal (60-80%) electrothermal, etc.

Thrust/weight F/W

Very large ~ (20-100) for Chem. Medium (5-20) for Nuclear Very low (~10<sup>-3</sup>) for (Solar, EP, power limited)

Others (design selection factors)

- "Life", most meaningful in total impulse capacity
- Re-start capability
- Throttleability
- Dispersion
- Cost

#### **Rocket Selection Guide (by mission)**

- 1) <u>Non-Space missions</u> Atmospheric/Ionospheric Sounding Tactical Missile Medium-Long Range Missiles
- 2) Launch to space

Rocket Type Solid Propellant, 1-4 stages Solid Prop., 1-2 stages Solid or Liquid Prop., 2-3 stages (very high acceleration)

Solid, liquid or combinations, 2-4 stages (2-4g) Possible: hybrid, 2-4 stages

- 3) <u>Impulsive  $\Delta V$  in space</u> (time-critical maneuvers, energy change from elliptic orbits, plane change from elliptic orbits, non-fuel-limited situations...)  $\Delta V \leq 1000$  m/s
- 4) Low-Thrust ΔV in space (Mass-limited missions ΔV ≥ 2000 m/s non time-critical missions, small, continuous orbit corrections near-circular orbits...)

Small Solid Prop. (Apogee kick, etc) Bi-propellant (storable) liquids, Monopropellant (storable) liquids, Future: Nuclear thermal

Solar-electric systems: Arcjets (a bit faster, less Isp) Hall, Ion (slower, higher Isp) PPT (precision maneuvers) Nuclear-electric systems Direct solar-thermal