

Future Space Propulsion

by Deuce =^.=.

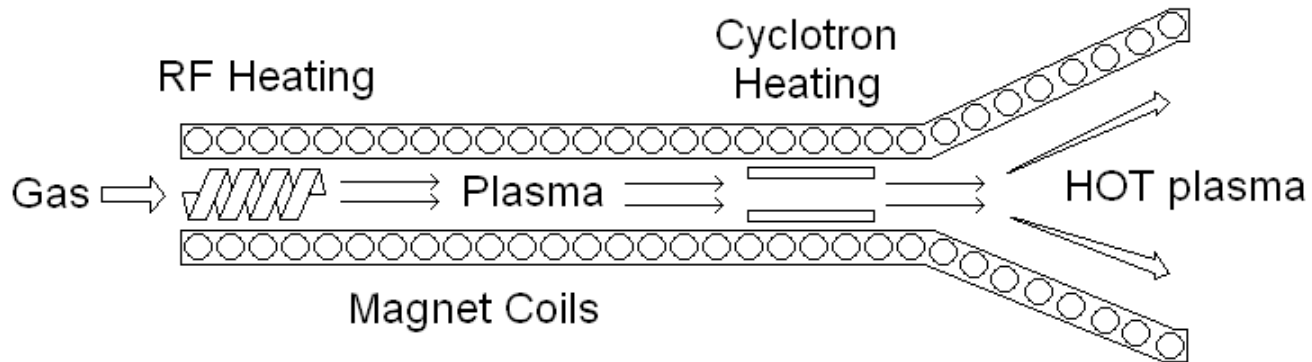
Isp and Delta-V: The Problem

- Direct travel in-system takes 10-30 km/s delta-V.
This is hard to do!
- Fast travel in-system takes >100 km/s delta-V.
This is even harder!
- Chemical rockets (Isp 350-450): ≤ 10 km/s
- Electric thrusters (Isp 3000-6000): ≤ 100 km/s
- Theoretical limit is much higher. How can we do it?

Fission Drives

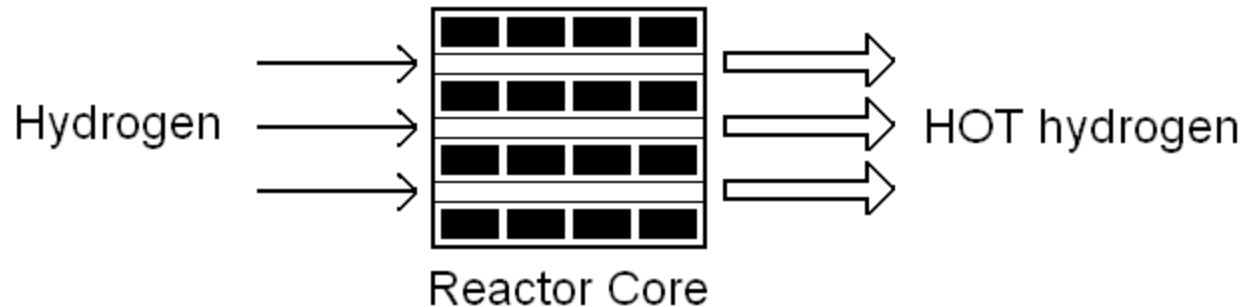
- Well-studied.
- Many approaches:
 - Nuclear-electric
 - Nuclear-thermal
 - Kinetic
- Best possible performance:
 - Specific energy $1e+12$ to $1e+14$ J/kg.
 - Isp of 100,000 to 1M, delta-V 1% to 10% C.

Nuclear-Electric: VASIMR



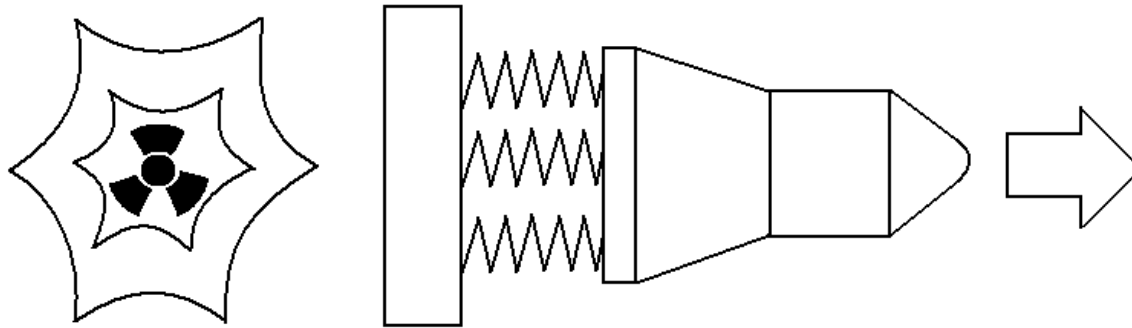
- Electric drive optimized for high-Isp, long lifetime.
- Magnetic tube guides plasma.
- Radio waves excite plasma (no contact).
- Can be adjusted for lower-Isp/high-thrust mode or high-Isp/low-thrust mode.
- Best test results: Isp 30,000 (delta-V 1000 km/s)

Nuclear-Thermal: NERVA



- Reactor core runs hot.
- Working fluid (hydrogen gas) pumped through core, heats up.
- Low Isp, very high thrust.
- Best test results: Isp 600 (delta-V 20 km/s)

Nuclear Pulse - Orion

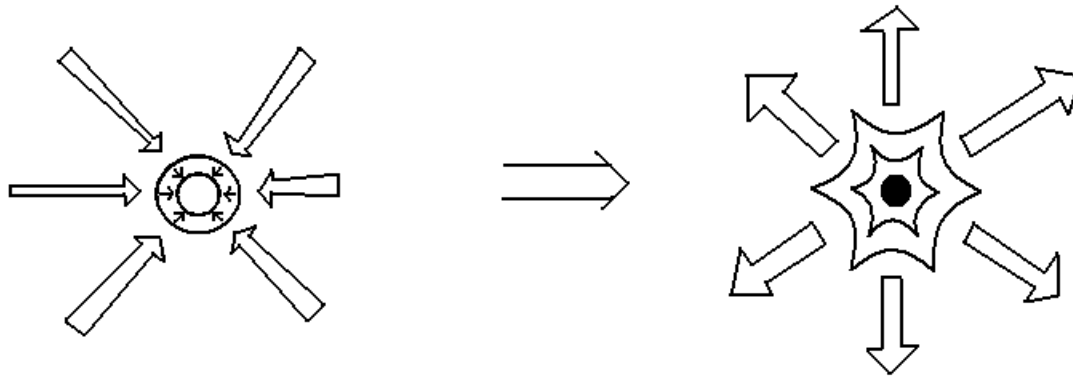


- Huge craft, huge shock plate.
- Tac-nukes thrown below the plate, detonated.
- Shock plate absorbs blast, lifting the ship.
- Very high thrust, very high Isp. Exact values unknown.
- Tests used chemical explosives only.

Fusion Drives

- Many theoretical studies, few experiments.
- Approaches:
 - Inertial confinement (ICF)
 - Magnetic confinement (MCF)
- Best possible performance:
 - Specific energy $1e+14$ to $1e+15$ J/kg.
 - Isp of 1M to 3M, delta-V 10%-30% C.

Inertial Confinement Fusion

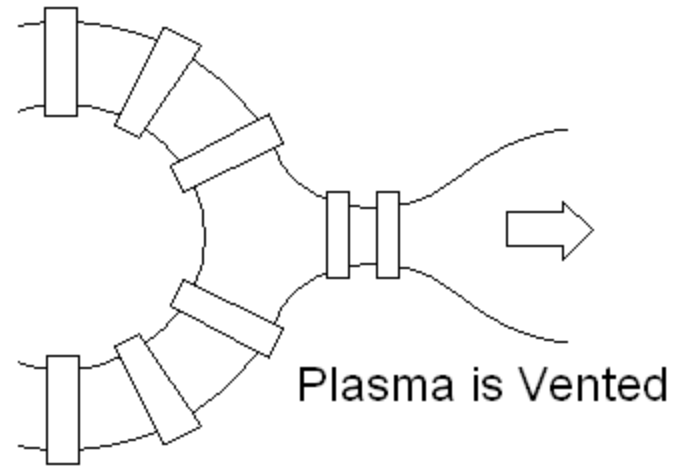


- Lasers or particle beams zap fuel pellets.
- Pellet fuses, explodes.
- Magnetic nozzle channels plasma fireball.
- Examples: Daedalus study, Longshot study.

Magnetic Confinement Fusion



Magnetic Bottle

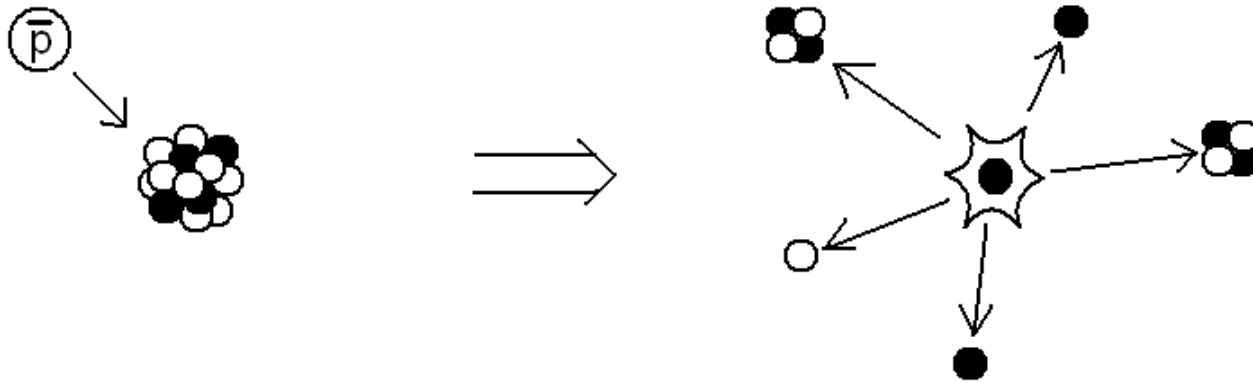


- Magnetic field holds plasma.
- Keep it dense enough long enough for fusion to heat it up.
- Divert hot plasma to exhaust nozzle.
- Example: Discovery II study.

Antimatter Drives

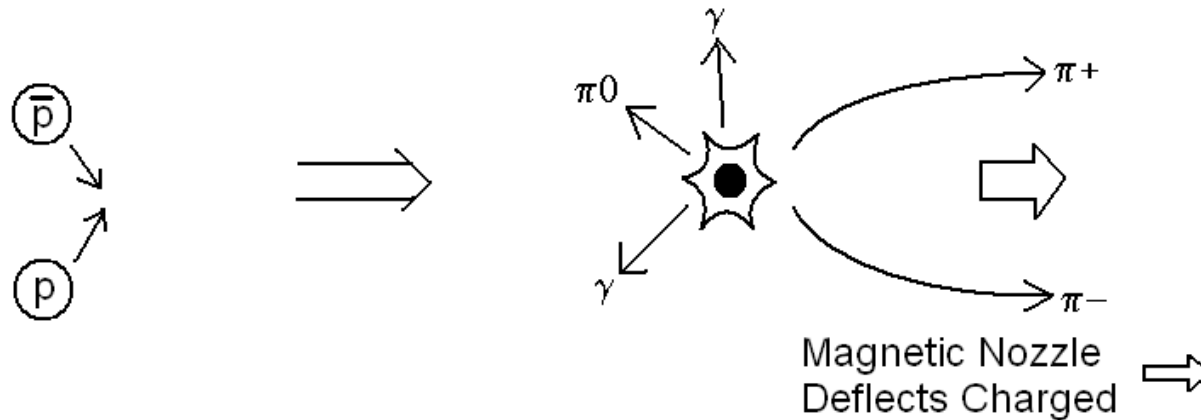
- Some theoretical studies.
- Have to make the fuel from nothing!
- Approaches:
 - Antimatter-catalyzed fission or fusion.
 - Directly use antimatter annihilation products.
- Best possible performance:
 - Specific energy of mix is $1e+17$ J/kg.
 - Isp of 30M, delta-V of up to $3x$ C.

Antimatter Catalyzed Reactions



- Antiproton annihilates inside a heavy nucleus, releasing energy.
- Energy release shatters the nucleus.
- Neutrons can fission other heavy atoms.
- Heat from shattering and fission can ignite a fusion fuel pellet.
- Example: AIMStar study.

Beamed Core Antimatter Drive



- Antiproton annihilation produces a lot of crud!
 - Gamma rays, mesons, etc.
- Charged pions can be deflected by a magnetic nozzle.
- Requires prohibitively large amounts of antimatter, but best known drive.

Looking Forward

- These drives need new engineering, but not new physics – they can be built.
- Other options (sailcraft, launchers) less flexible, more capital investment. Self-propelled drives still have a niche!
- With delta- V like this, future of space travel is bright!