

Fast Rides

Uses of Fusion for
Space Propulsion Systems

Basic Idea of a Rocket

- $F = m (d/dt) p$
- Rocket equation: $v_f = u \ln(M_i/M_f)$
(non-relativistic)
- So, higher exhaust velocity is better

$$V_{rms} \sim 10^3 \text{ m/s (N}_2 \text{ @ 1000K)}$$

$$V_{fus} \sim .086 C \text{ (He}_4 \text{ @ 3.5 MeV)}$$

$$C = 3 \times 10^8 \text{ m/s}$$

3 types of nuclear rockets

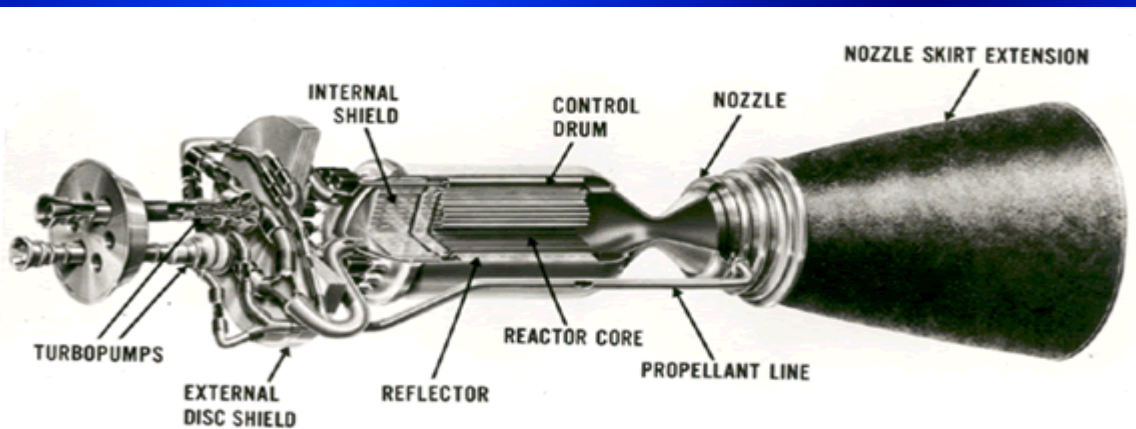
- Nuclear electric, NEP --- Generate electricity to run another drive, e.g. ion, photonic (Sanger, others).
- Nuclear thermal, NTP --- heat a secondary reaction mass.
- Direct nuclear thrust --- use the fusion products as reaction mass.

Nuclear Thermal Projects

- Feynman: 1940's (\$1 patent)
- NERVA: 1956 – 1971
- GSCR: 1960's
- Still viewed by some as engine for Mars transport (Boeing-NASA study 1990)

Project NERVA/Rover

- 1956 --- 1971
- USA (Los Alamos and other locations)
- 250,000 lbs. thrust (best)
- Never launched in space; lab work only.
- Several projects under ROVER.



<http://www.sti.nasa.gov/Pubs/Bulletin/04julypub/hist.html>

Courtesy of NASA.

Project PROMETHEUS

- NASA 2003 --- designs for the new Space Exploration Vision
- Fission NTP, NEP engines.
- Uncertainty over how much longer it will stay around.

Nuclear thrust rockets

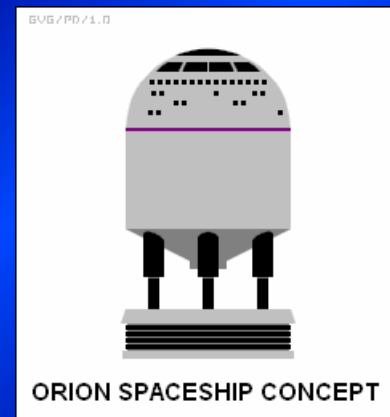
- Fusion reaction directly contributes to thrust.
- Origin in Project ORION
- Project Daedalus --- 1970's, UK
- Bussard ramjet
- Mixed with plasma rocket (along lines of VASIMR)

Project Orion

- Nuclear explosion pulse drive
- Read: blow bombs up behind the ship. Try not to blow the ship up, too. 1 per sec.
- Plumbbob test – 1957.
- High exhaust v with large force
- Pusher plates \rightarrow continual 1-g accel!
- Conventional explosion scale test success.

ORION (con't)

- Plans for 4000-ton, 1 year round-trip to Pluto.
- Problem: needed no-fission nukes.
- Killed by atmospheric test-ban treaty, radiation concerns.



Courtesy of Greg Goebel.

Project Daedalus

- Refinement of Project Orion in a sense
- D-T pellets to be inertially confined and detonated by an electron beam; explosion channeled by magnetic field.
- Designed for interstellar travel (Bernard's Star)
- 50,000 tons!



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www.thespace.com/space/future/fusion.php

Bussard Ramjet

- Interstellar space is filled with hydrogen at low density
- Idea: Collect hydrogen (large magnetic scoop) and use for your fuel --- don't need to bring fuel with you (higher efficiency!)
- Scoop is thousands of square km large (effective)
- Theoretically able to accelerate well up to significant fraction of C .

Bussard Ramjet (con't)

- Possibility of collecting interstellar antimatter as well.
- Drag and particles a concern.



Courtesy of NASA.

<http://www.thespacesite.com/space/images/bussard.jpg>

Sources

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