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

\[ V_{rms} \sim 10^3 \text{ m/s (N2 @ 1000K)} \]
\[ V_{fus} \sim 0.086 \text{ C (He4 @ 3.5 MeV)} \]
\[ C = 3 \times 10^8 \text{ m/s} \]
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 -> 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.

http://www.vectorsite.net/tarokt_2.html
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!

Courtesy of Adrian Mann. Used with permission.
www.thespacesite.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
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