D-^{3}He Fusion: Physics, Engineering, and Applications

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Overview:

This poster explains why D-^{3}He fusion fuel is not more popular than D-T fuel (physics), *and why it should be* (engineering and safety)!

D-^{3}He Fuel Burns Less Easily than D-T Fuel, So It Faces Larger Physics Obstacles, Making It a Second Generation Fuel in Many People's Minds

First generation:

$D + T \rightarrow n$ (14.07 MeV) + ^4He (3.52 MeV)

$D + D \rightarrow n$ (2.45 MeV) + ^3He (0.82 MeV) {50%}

$\rightarrow p$ (3.02 MeV) + T (1.01 MeV) {50%}

Second generation:

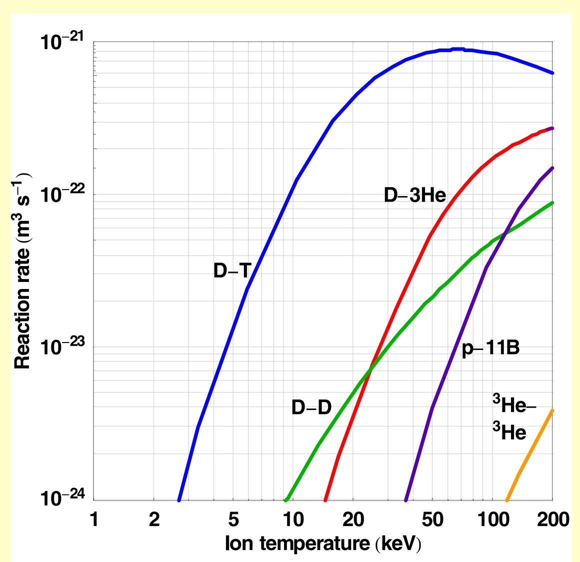
$D + {}^3He \rightarrow p$ (14.68 MeV) + ^4He (3.67 MeV)

Third generation:

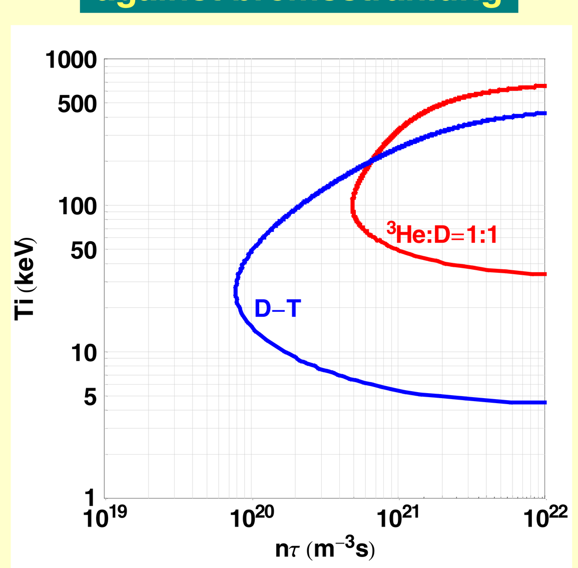
$^3He + {}^3He \rightarrow 2\,p + {}^4He$ (12.86 MeV)

$p + {}^{11}B \rightarrow 3\ {}^4He$ (8.68 MeV)

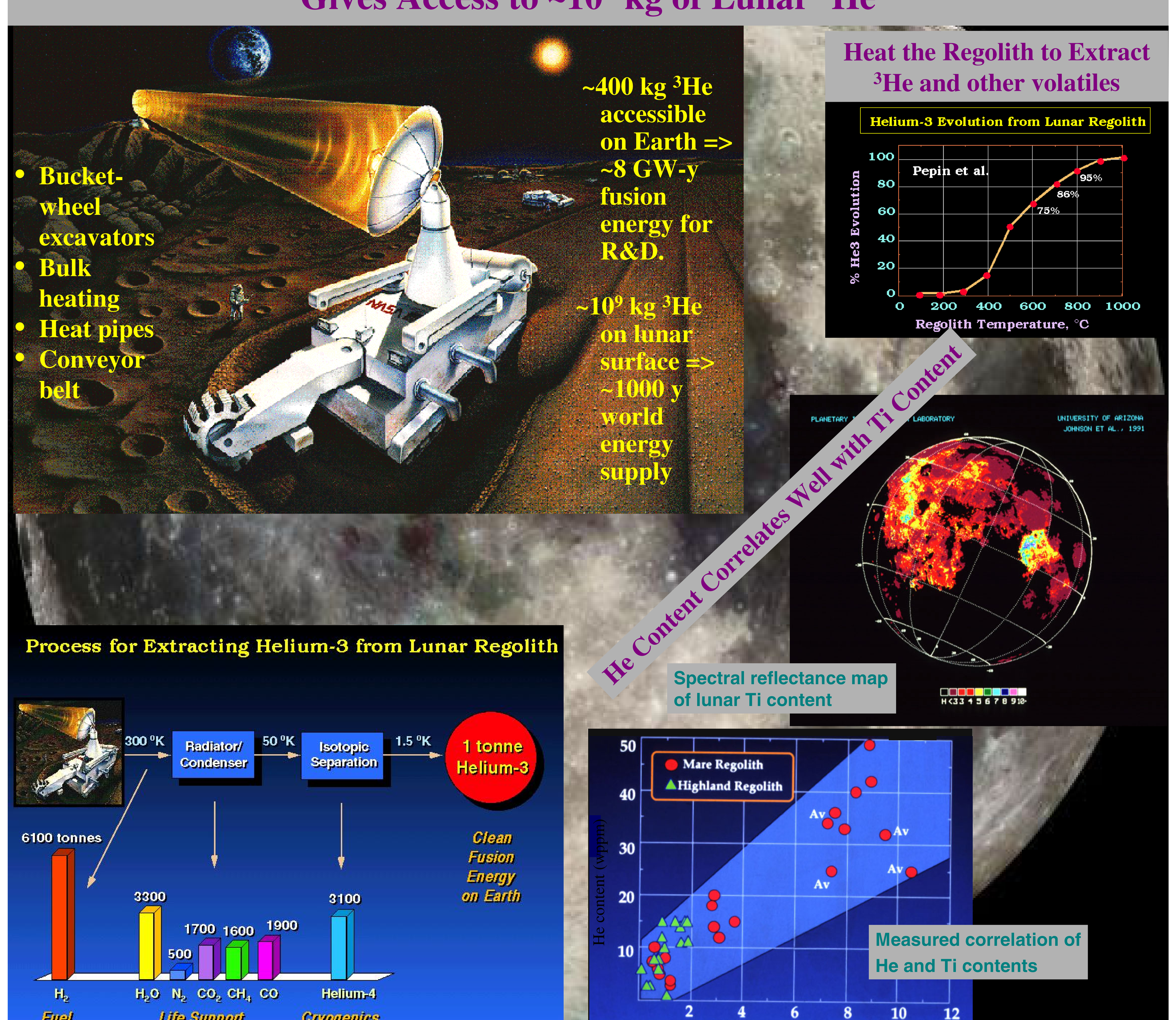
Fusion cross sections averaged over a Maxwellian distribution



Ignition contours against bremsstrahlung



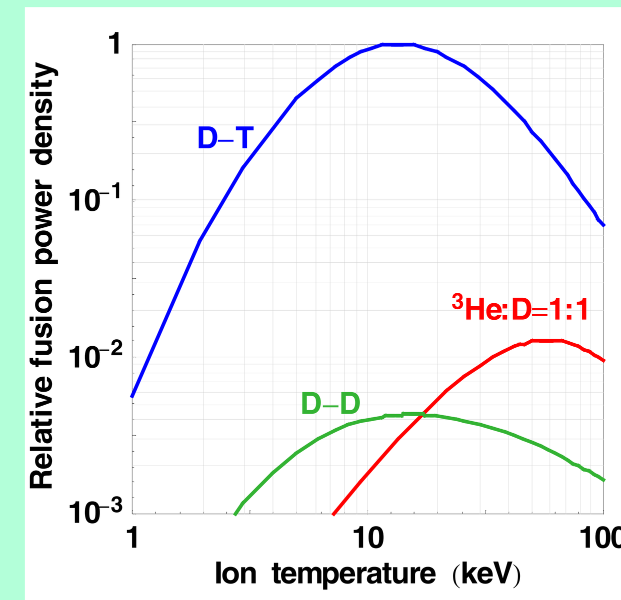
^{3}He Resources Are an Issue: Earth Contains ^{3}He Sufficient Only for an Engineering Test Program, but Well-Developed Terrestrial Technology Gives Access to ~10^9 kg of Lunar ^{3}He

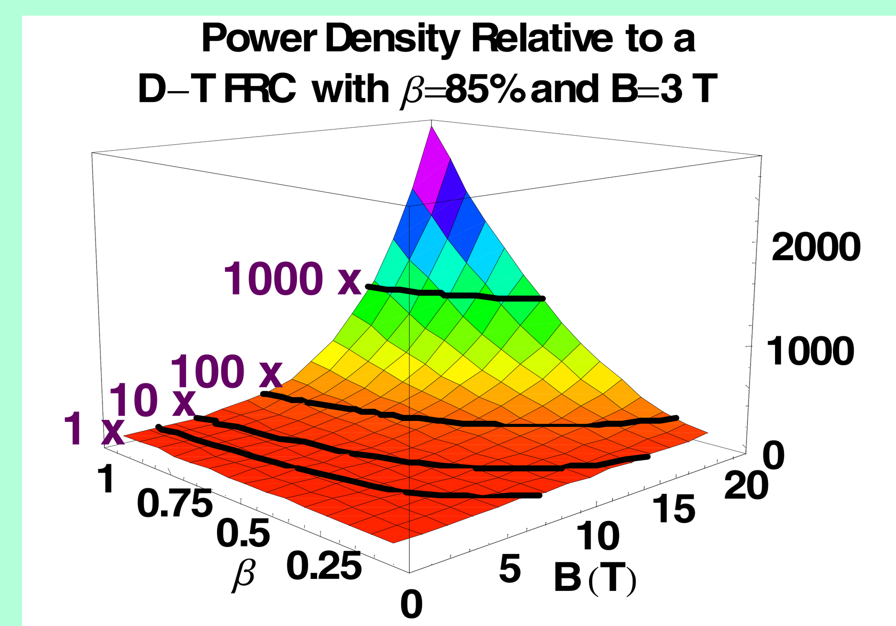


D-^{3}He Fuel Leads to Lower Fusion Power Density, but This Can Be Overcome by Higher Magnetic Fields and "Beta"

- D-T fueled innovative concepts become limited by neutron wall loads or surface heat loads well before they reach β or B-field limits.
  - β = plasma pressure/ magnetic-field pressure
  - β measures how effectively the B-field is used.
  - D-T fueled FRC's (β ~85%) optimize at B ≤ 3 T.
- D-^{3}He needs a factor of ~80 above D-T fusion power densities.
  - Superconducting magnets can reach at least 20 T.
  - Fusion power density scales as $\beta^2 B^4$.
  - Potential power-density improvement by increasing β and B-field appears at right.

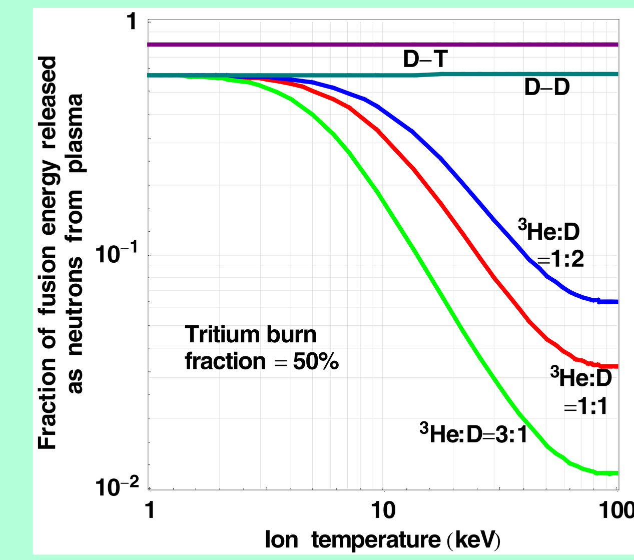
Power density





D-^{3}He Fuel Lowers Neutron Production and Gives Easier Engineering and Safety

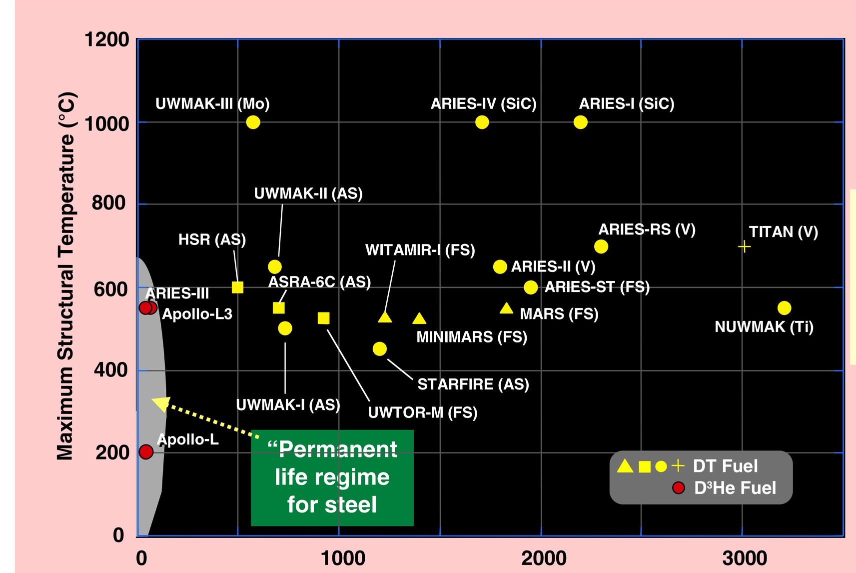
Neutron power fraction



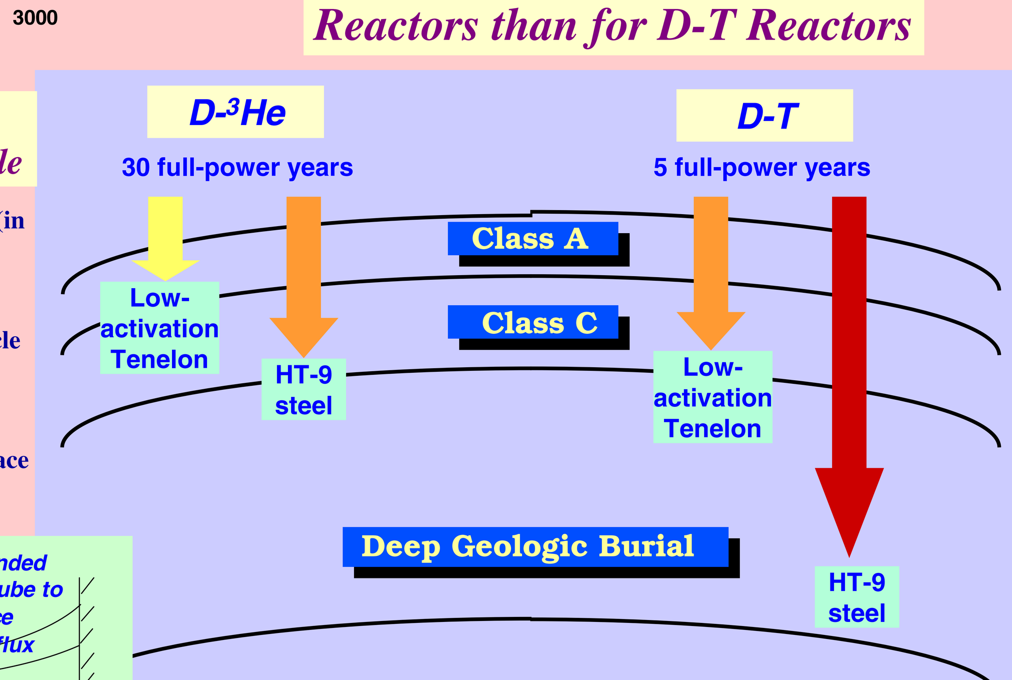
- Reduced neutron flux allows
  - Smaller radiation shields,
  - Smaller magnets,
  - Permanent first wall and shield, and
  - Easier maintenance.
- Increased charged-particle flux allows direct energy conversion of fusion energy to electricity.
- Smaller neutron flux reduces activation of materials and radiation damage to them.

D-^{3}He Fuel Eases Engineering Difficulties

The Low Radiation Damage in D-^{3}He Reactors Allows Permanent First Walls and Shields to be Designed

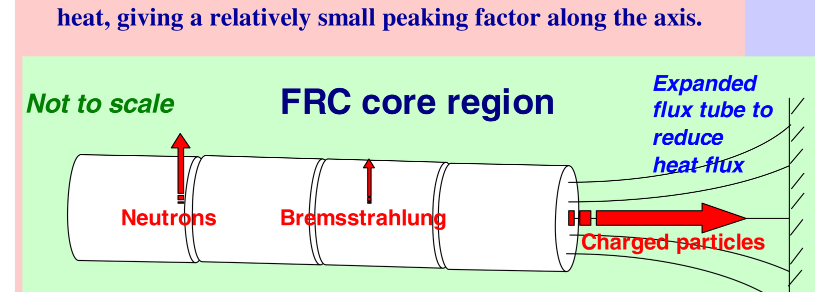


Radioactive Waste Disposal is Much Easier for D-^{3}He Reactors than for D-T Reactors



High Heat Fluxes in D-^{3}He Reactors Stem from High Power Density, but Are Manageable

- Charged-particle power transports from internal plasmoid (in an FRC or spheromak) to edge region and then out ends of fusion core.
- Expanded flux tube in end chamber reduces heat and particle fluxes, so charged-particle transport power only slightly impacts the first wall.
- Mainly bremsstrahlung power contributes to first-wall surface heat, giving a relatively small peaking factor along the axis.

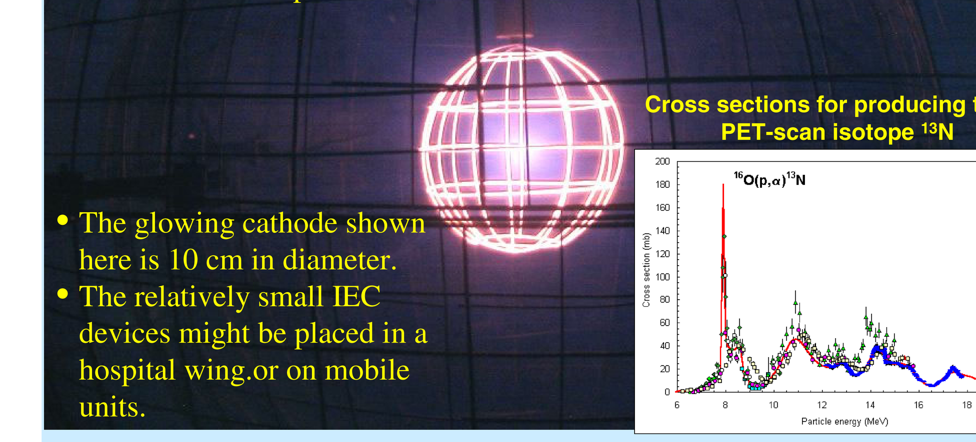


D-^{3}He May Find Many Uses. Some of Them, Discussed Here, Are:

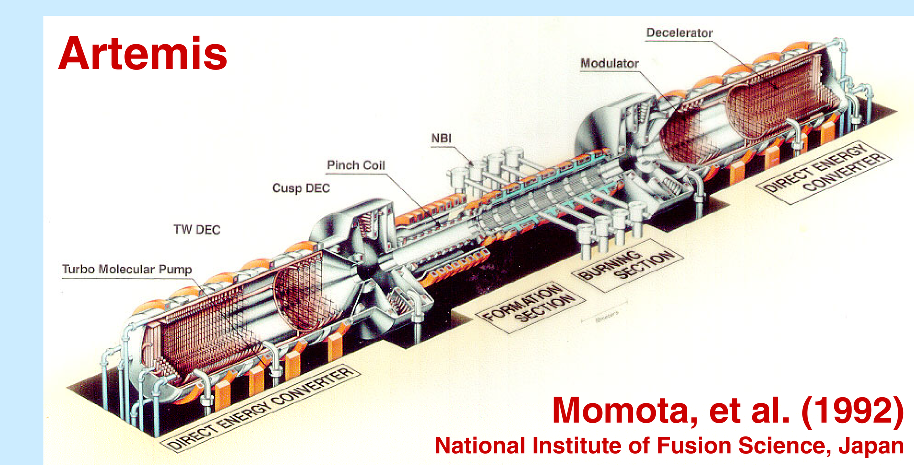
- Radioisotope production
- Electricity production
  - Potentially proliferation-proof
- Space propulsion

Radioisotope Production

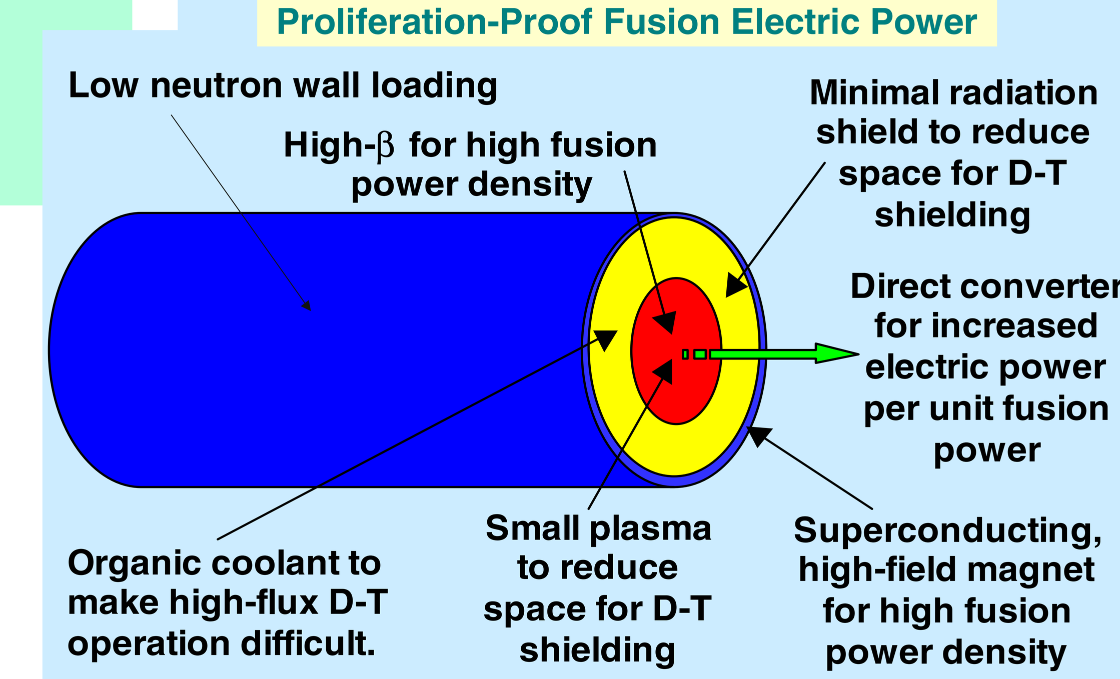
- In inertial-electrostatic confinement (IEC) fusion, high voltages on spherically symmetric, semi-transparent grids radially accelerate ions.
- UW experiments have achieved 160 kV accelerating potentials, more than sufficient for D-^{3}He fusion.
- UW presently holds the world record for steady-state production of 14.7 MeV D-^{3}He protons.
- The glowing cathode shown here is 10 cm in diameter.
- The relatively small IEC devices might be placed in a hospital wing or on mobile units.



Commercial Fusion Electric Power

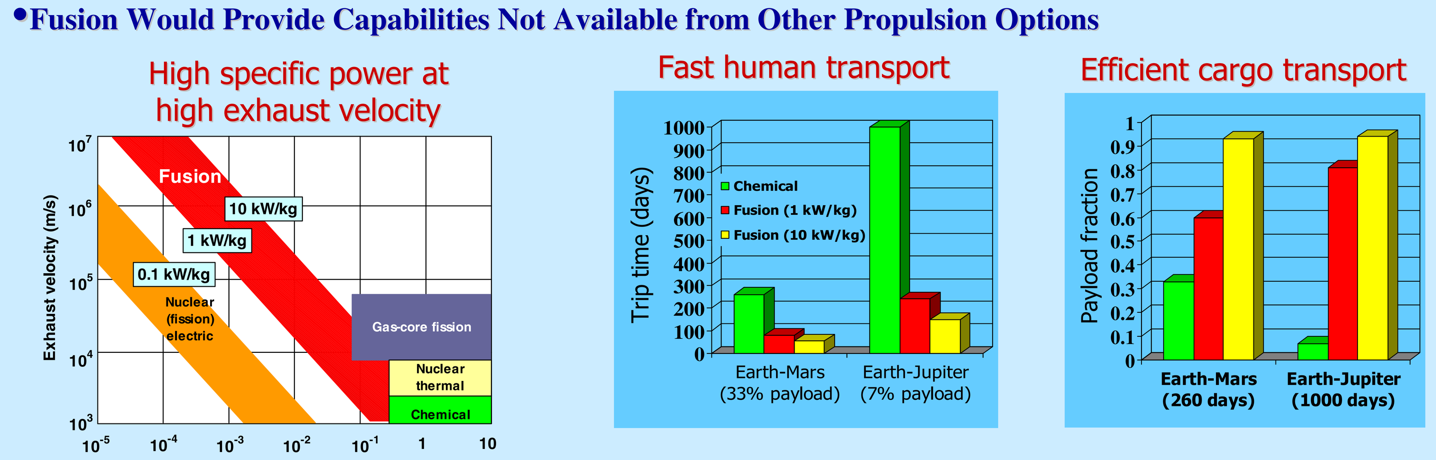


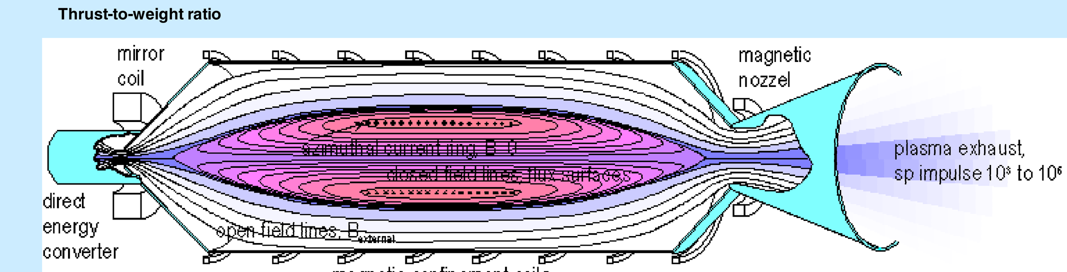
Proliferation-Proof Fusion Electric Power



Efficient Long-Range Space Propulsion

- Fusion Would Provide Capabilities Not Available from Other Propulsion Options





- Rocket design from Univ. of Washington web page for the Star Thrust Experiment (STX): www.aa.washington.edu/AERP/RPPL/STX.html