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A comparison of pulsed and steady-state reactor operation for a fusion rocket

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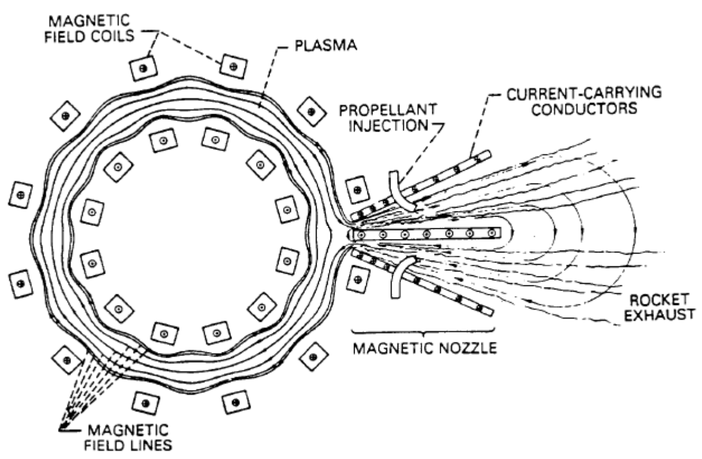
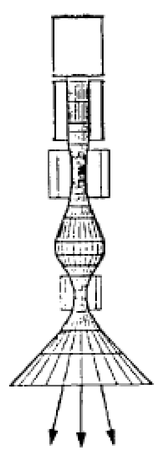
Overview

Nuclear fusion has been proposed as a propulsion source for high energy space exploration missions to increase our ability to explore the solar system. Various methods of achieving fusion are being researched so a space fusion program would have to decide on the optimal reactor type to use in creating a rocket. Tokamaks, which are one of the most popular terrestrial research setups, would likely be to massive for a space mission so other options must be considered.

One of the major design decisions is whether to use a steady-state or a pulsed reactor. Steady-state concepts include the tandem mirror and field reversed configuration concepts which utilize magnetic confinement systems. Pulsed concepts include inertial confinement fusion concepts, and systems which use a combination of magnetic and inertial confinement, such as magnetized target fusion and magneto-kinetic fusion.

The difference in operational mode leads to system level concerns such as safety, reliability and vehicle integration. Safety concerns make it desirable to minimize the recirculation power since that would have to be dissipated in an emergency. Vehicle integration includes minimizing the system mass and methods of creating a rocket from the reactor.





Impact

In order for humanity to explore and expand beyond Earth, high-energy propulsion systems, such as fusion rockets, are needed. The development of these systems would drastically reduce the travel times required for inter-planetary missions. This would allow for routine trips to Mars and increased exploration of the outer planets that would be difficult to accomplish with chemical rockets. Fusion propulsion would also allow for larger payloads proportional to the total system and the reactor could be used to provide electrical power to the vehicle. Interstellar exploration would also become possible, although even a mission to a close star would be a long term endeavor requiring multiple decades to perform.

Key Findings

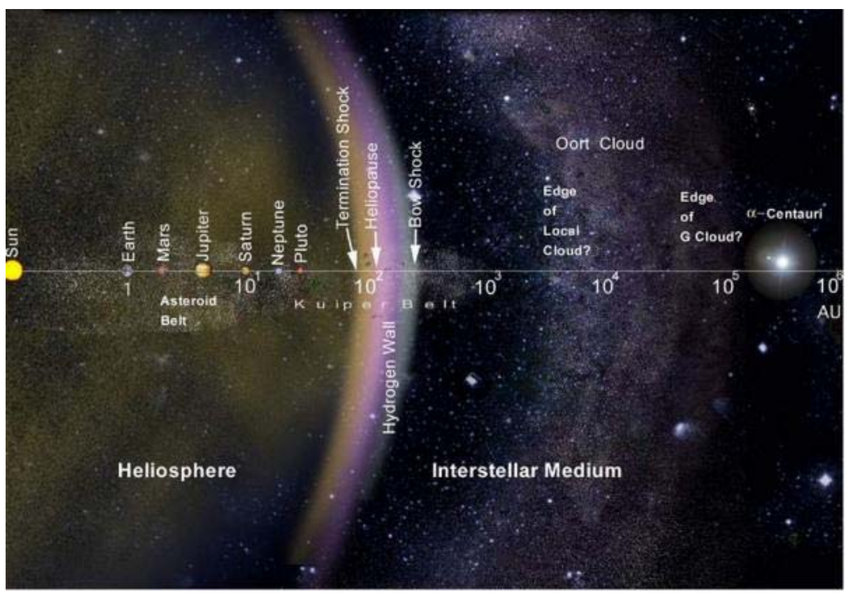
Minimizing the recirculation power is difficult for steady-state systems which rely on magnetic containment of the plasma and therefore require large amounts of power to maintain strong magnetic containment fields. Pulsed systems, such as inertial confinement, do not rely on external magnetic fields but do require storing the energy to ignite the next pulse.

Designing a reliable pulsed system is more challenging than a steady-state system because of the effects of cyclic fatigue which requires an additional safety margin to accommodate.

Both pulsed and steady-state systems have components with large masses; large capacitor banks are required to store the energy needed for ignition in a pulsed system and the magnetic fields used to contain the plasma in steady-state systems require large magnets and supporting structure.

Toroidal reactor geometries, which are popular in steady-state research, can be utilized for a rocket by adding divertors to channel the exhaust into the nozzle, but linear geometries are simpler since the rocket can be created by adding a magnetic nozzle at the end of the reactor.

The final decision on whether to use a pulsed or steady-state system will depend primarily on which fusion concept develops soonest, since both pulsed and steady-state systems could be used successfully.



Explanation

The development of fusion propulsion would benefit the American Astronomical Society's interests since it would allow for greater utilization of space. Larger and more power intensive science missions could be performed, which would expand our understanding of the universe.

Acknowledgements

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