# A System-Level Review of a Fusion-Powered Space Propulsion System

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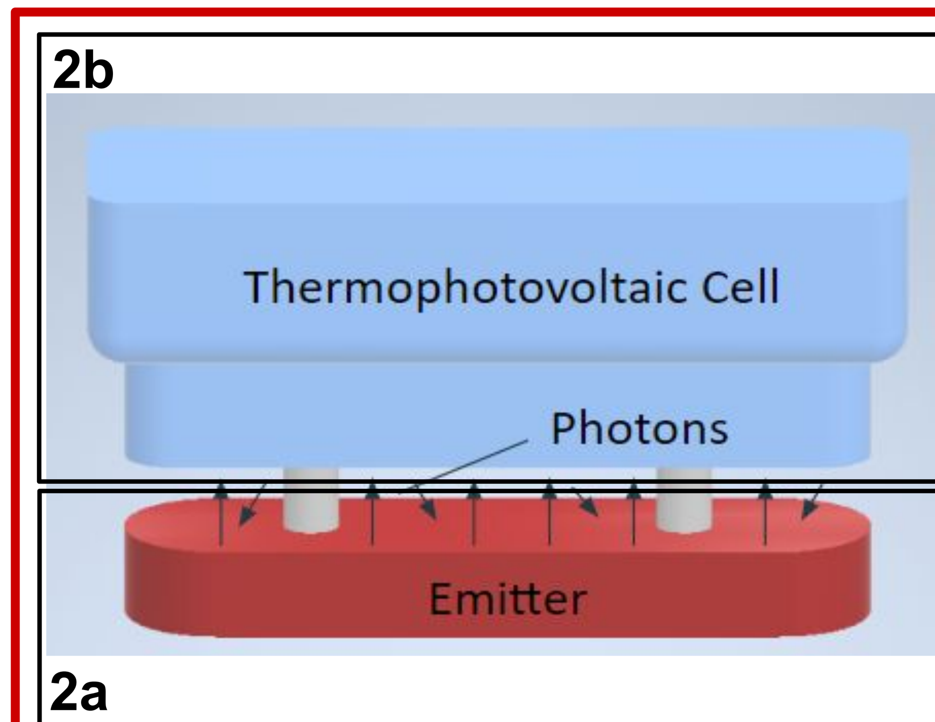
References & Acknowledgements

## Introduction

- A barrier to future space exploration is the lack of sufficiently robust power and propulsion technologies for interplanetary travel.
- Nuclear fusion provides one solution to these issues by generating large amounts of power from relatively low-mass fuel. The lower craft mass that results from this greatly reduces the cost of long-distance travel in space.
- Such a fusion-powered propulsion system will require several auxiliary subsystems and technologies, namely:
  - Thrust conversion
  - Power generation
  - Structural design
  - Thermal and radiation shielding
- Outlined are components of relevant subsystem technologies

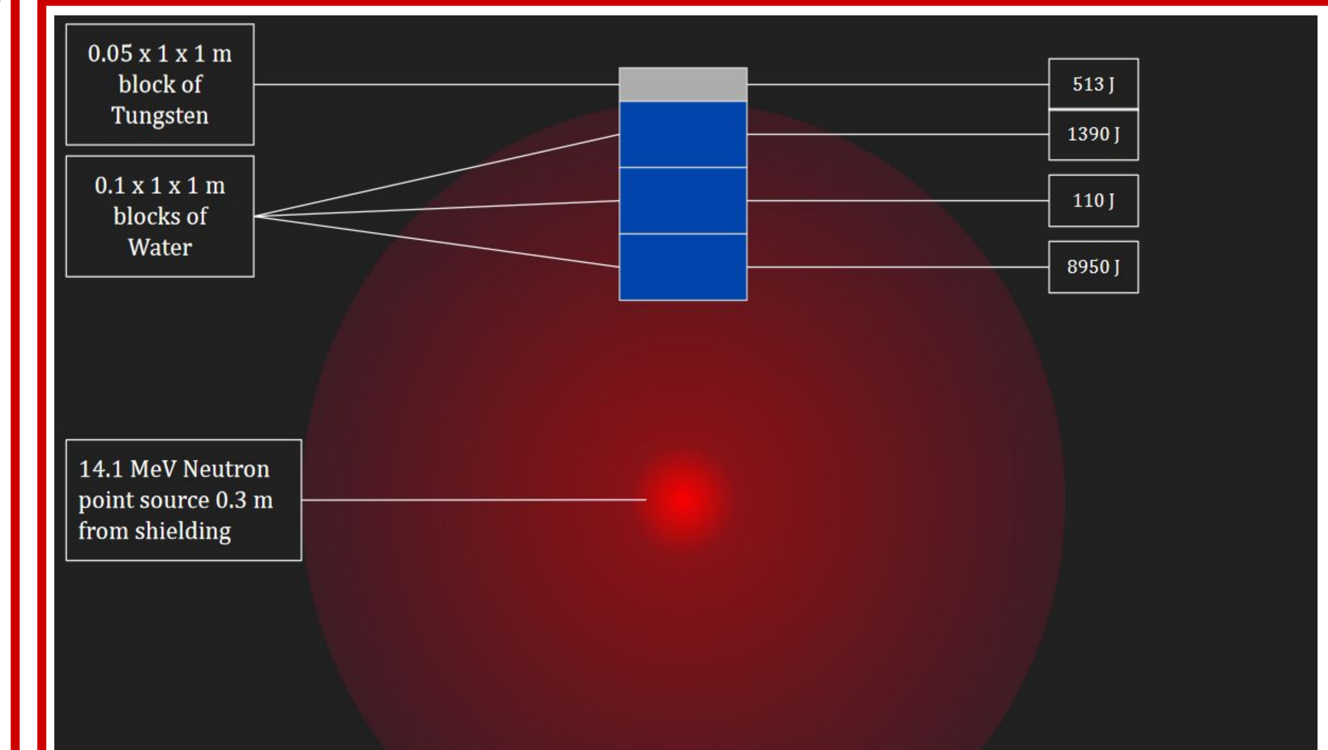



## WASTE ENERGY CONVERSION

Preliminary model of bremsstrahlung power capture system. This system utilizes bremsstrahlung radiation, a byproduct of $p^{11}B$ fusion reactions.

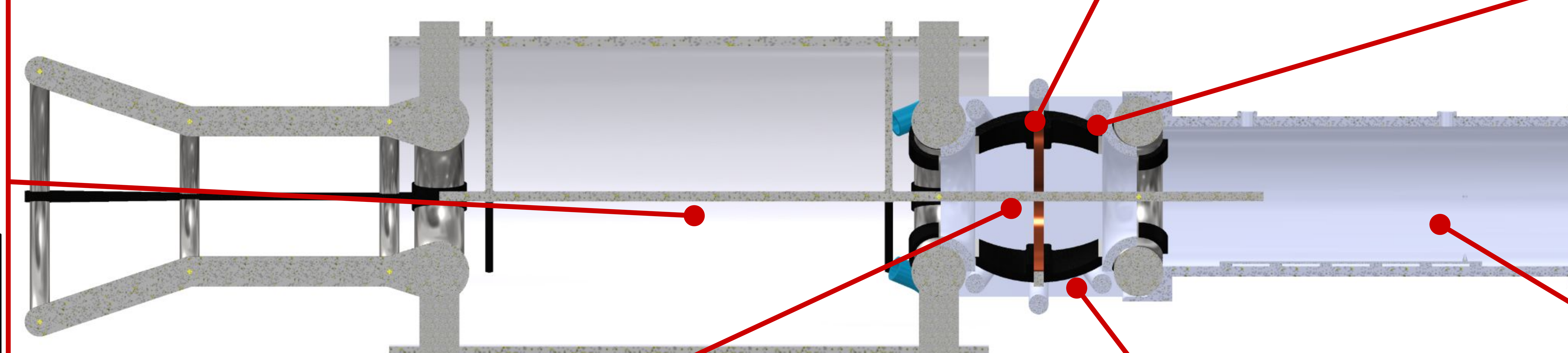
2a) Bremsstrahlung radiation directly heats a tungsten emitter, exciting the electrons and releasing energy in the form of photons radiated outward.

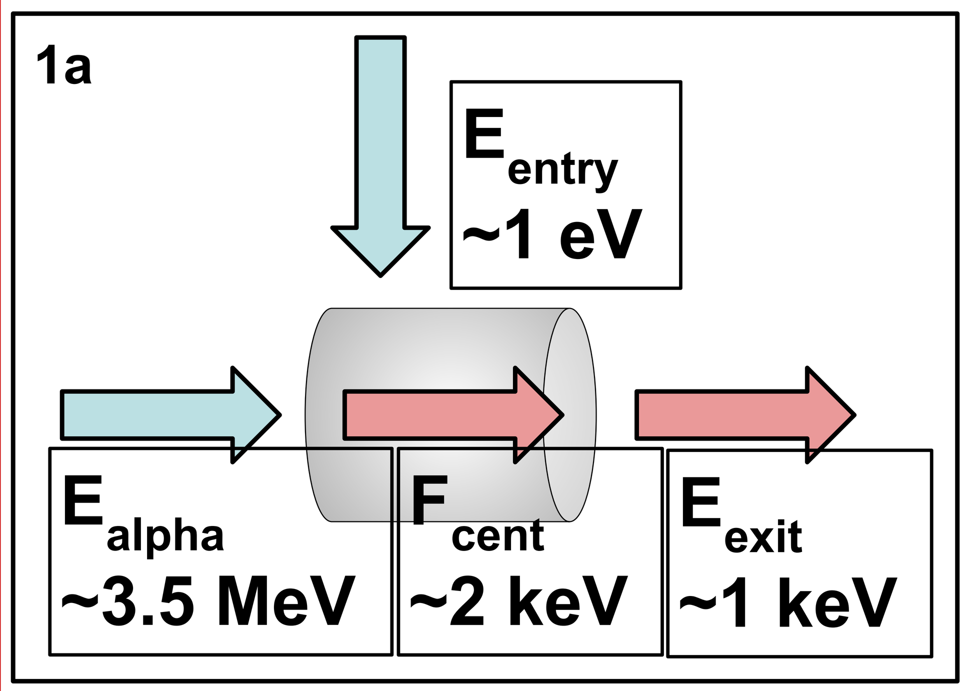
2b) A thermophotovoltaic cell then absorbs these released photons, directly converting their energy into power, and reflects back the unabsorbed photons for recycled use.

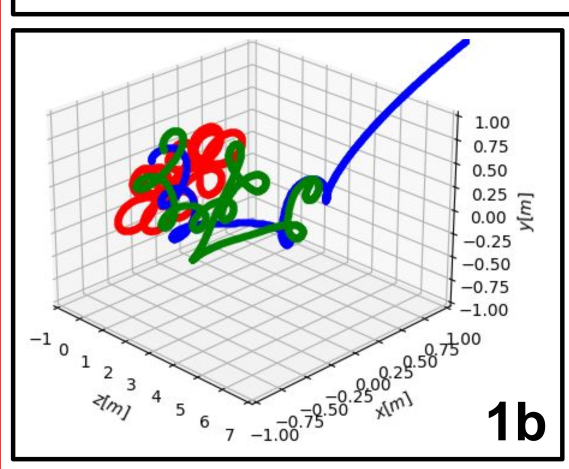


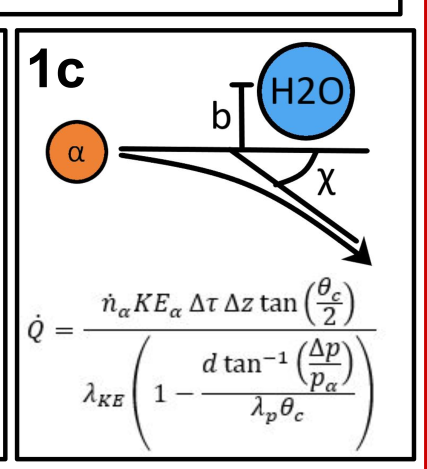

## RADIATION ANALYSIS

4) Cross-section of a potential neutron shielding configuration for the superconducting coils with values of energy absorbed within each "block."






## PRODUCT-THRUST CONVERSION

1a) Diagram of energy transfers in the mixing chamber. Alphas must be cooled to reach an exit energy of ~1 keV. Propellant particles must reach high enough energies to overcome a centrifugal force on their exit.

1b) Trajectories of example particles in the mixing chamber. Red and green particles are magnetically confined. The blue particle is in the loss cone.

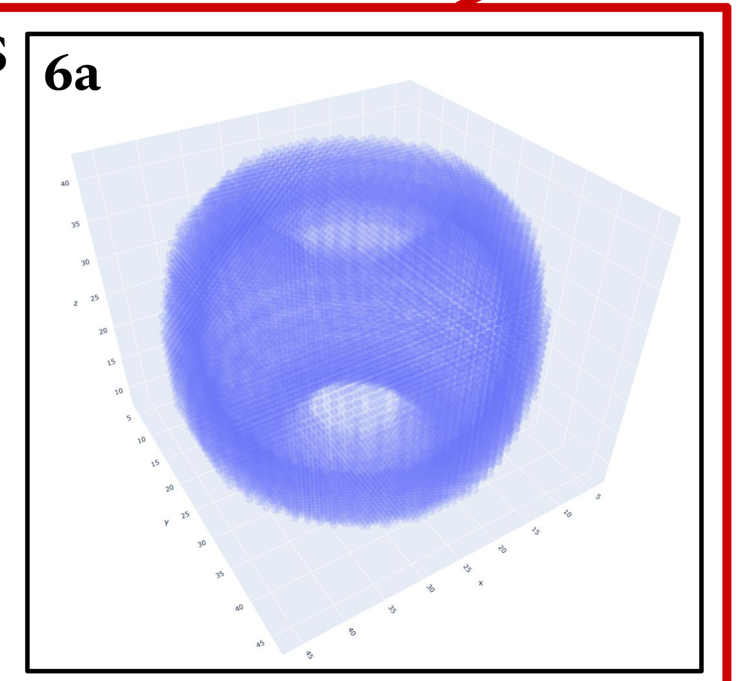
1c) Energy is transferred to the propellant through 'Coulomb Collision.' Also shown is the rate of heat transfer to the propellant, obtained from this interaction.

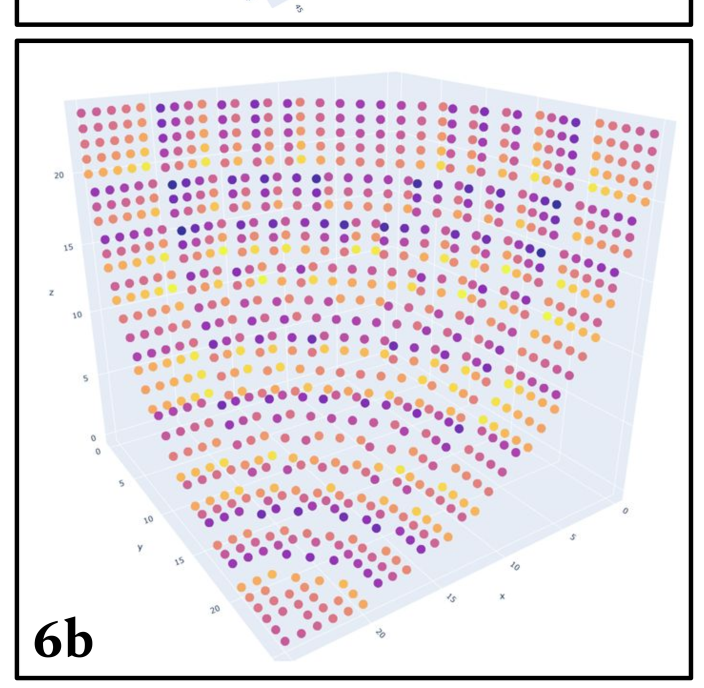
## THERMAL ANALYSIS

An expanded, irradiated region can be modeled via a toroidal shell in three-dimensions.

6a) The plasma geometry, with octahedral symmetry.

6b) An energy gradient dependent on the total radiative output of the burning plasma and the corresponding angle of incidence with the modelled region.

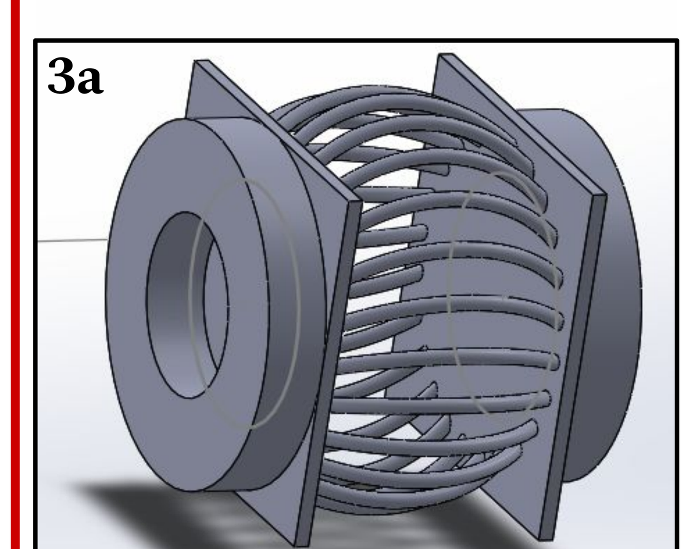


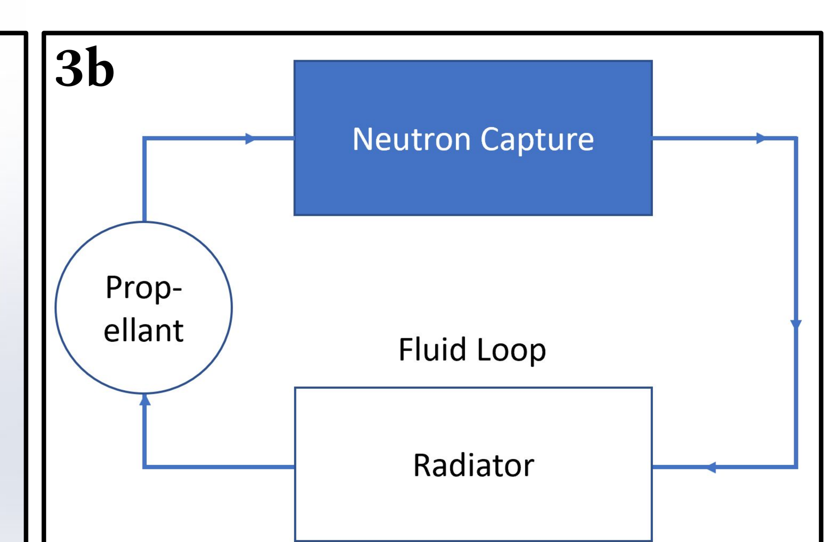




## STRUCTURAL ANALYSIS

3a) Preliminary CAD model of the neutron power system. The system utilizes neutron radiation, a byproduct from D-T fusion reactions, to generate electrical power.

3b) A high-temperature fluid loop is directly heated through the radiation and goes through a power cycle, where the waste heat is expelled into propellant pre-heating and a radiator. Heat pipes that arc across the reactor chamber assist the heating fluid through the cycle.




## DIRECT ENERGY CONVERSION (DEC)

Axial-radial view of the present iteration of the Direct Energy Conversion scheme.

5a) The positive beam passes through a sequence of electrodes with a fixed varying voltage to modulate the continuous wave into a longitudinal wave.

5b) The modulated beam continues to a similar circuit with weaker voltages and a π/2 phase lag. Therefore, the modulated "bunches" induce a voltage in the second LRC circuit. This driven voltage is captured and transferred externally by the damping device (Cockroft-Walton generator shown).