Feasibility of a Matter/Anti-Matter Propulsion System for Generating Relativistic Speeds in Space

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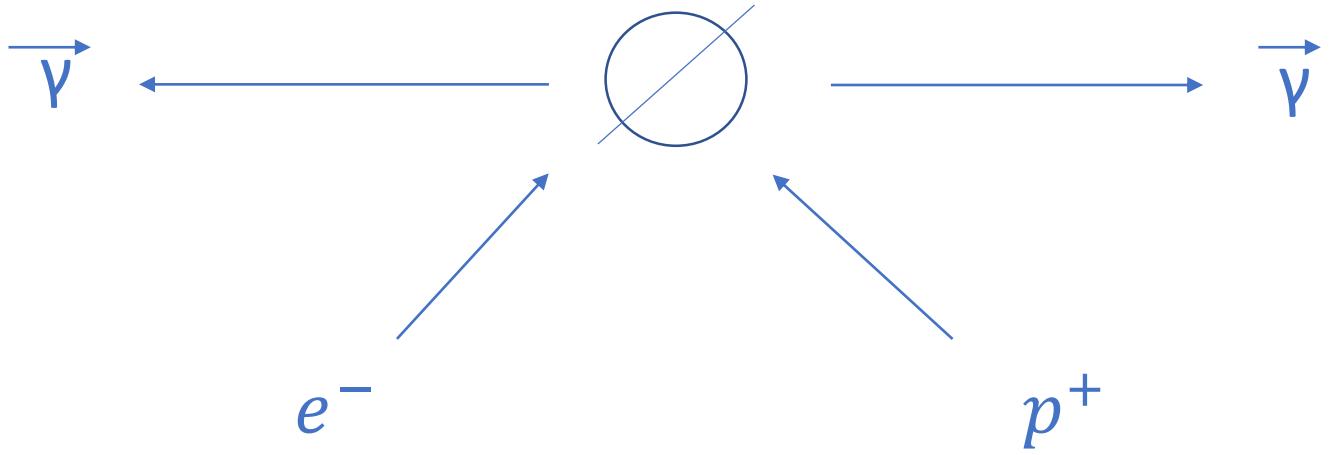
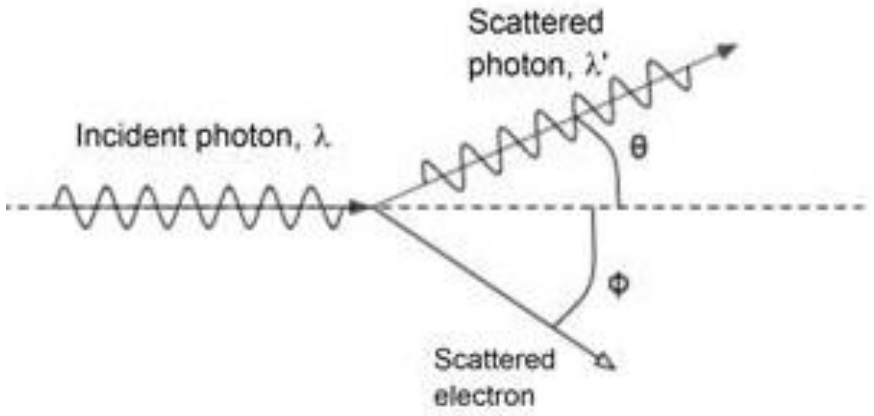
Matter/Anti-Matter Annihilation

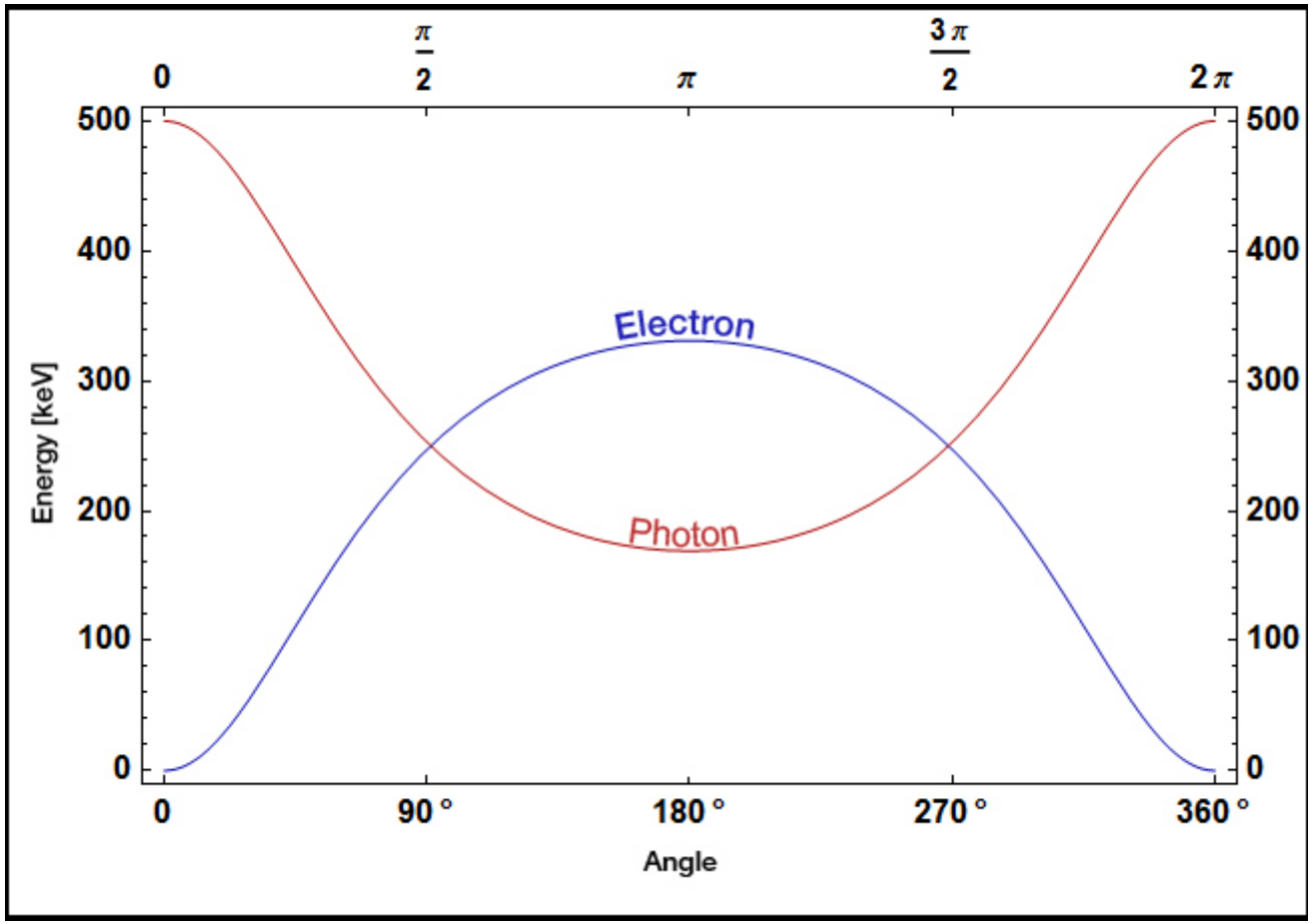


$\overrightarrow{\gamma}$ = 511 keV

Compton Effect

High-energy photons generate a physical recoil of electrons, depending on the angle of interaction





500 keV gamma ray after scattering

Matter/Anti-Matter Annihilation has been theorized as a propulsion energy for space travel

D. Smith & J. Webb, “The anti-matter photon drive, a relativistic propulsion system,” AIAA Paper 2001-3231 (2001).

C. Deutsch & N. Tahir, “Fusion reactions and matter-antimatter annihilation for space propulsion,” Cambridge University Press (2006).

The Problem (2007):

"Unfortunately, current state of the art technology is lacking in the areas of positron production and storage techniques for these concepts to be realized any time in the near future."

J. Webb, et al., "Project Hyperion, exotic propulsion research at Embry-Riddle Aeronautical University," 43rd AIAA/ASME/SAE/ASEE Joint Propulsion Conference, July 2007.

The Solution (2020):

Adequate generation of matter/anti-matter pairs, and storage of matter/anti-matter pairs, have now been demonstrated in the laboratory

Generation of Matter/Anti-Matter Pairs

- Hui Chen and others at Lawrence Livermore National Laboratory have demonstrated that large numbers of electron and positron pairs can be generated by a petawatt laser striking a gold substrate, and the resulting charged particles can be separated magnetically

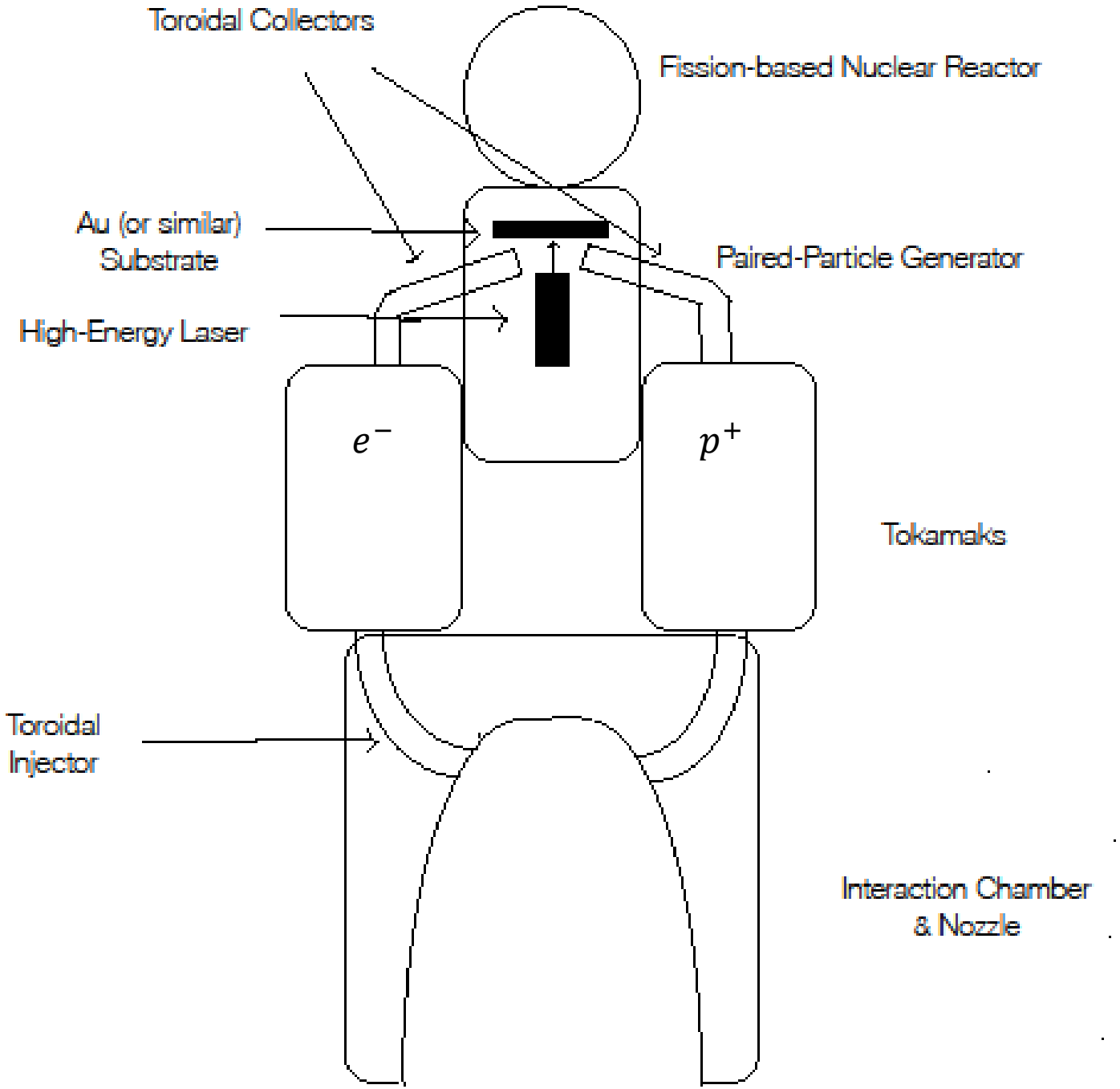
- **Lawrence Livermore Laboratory News**, “Billions of particles of anti-matter created in laboratory,” November 17, 2008.

Storage of Matter/Anti-Matter Pairs

- Eve Stenson and others at Max Planck Institute for Plasma Physics have demonstrated that large numbers of electrons and positrons can be stored in a dipole stellarator

- **Max Planck Institute for Plasmaphysick**, “The PAX/APEX experiment for production of a pair plasma,” June 6, 2016.

System Concept:

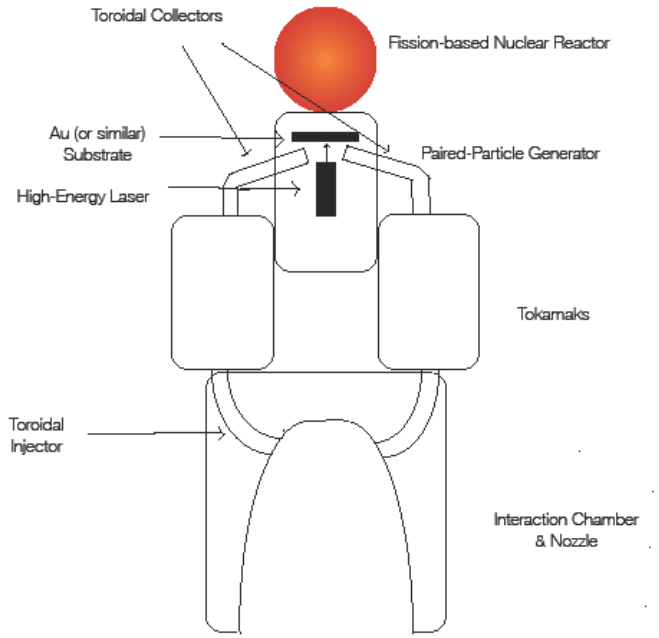


Primary System Components

- Nuclear Reactor (energy source)
- Paired-Particle Generator (paired-particle source, separator)
- Twin Tokamaks (storage)
- Annihilation Chamber (gamma-ray generation, thrust generation)

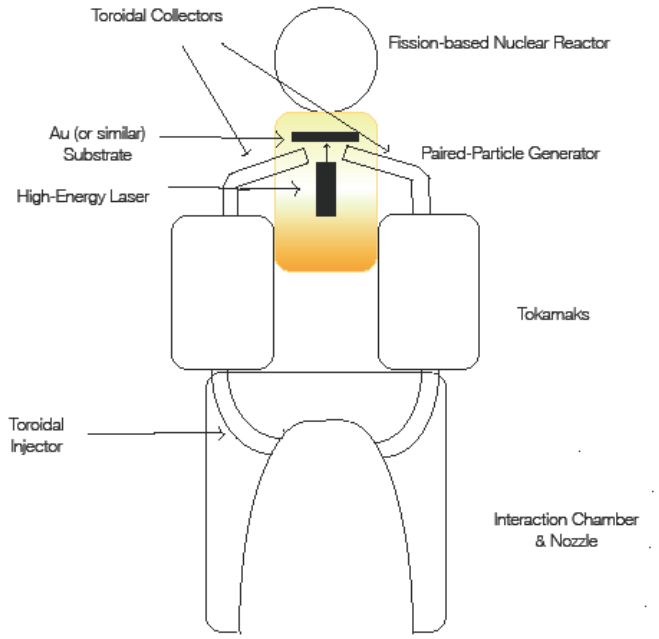
Nuclear Reactor

- Fission-based nuclear reactor
- Sized to meet the electrical requirements of the propulsion system and any payload



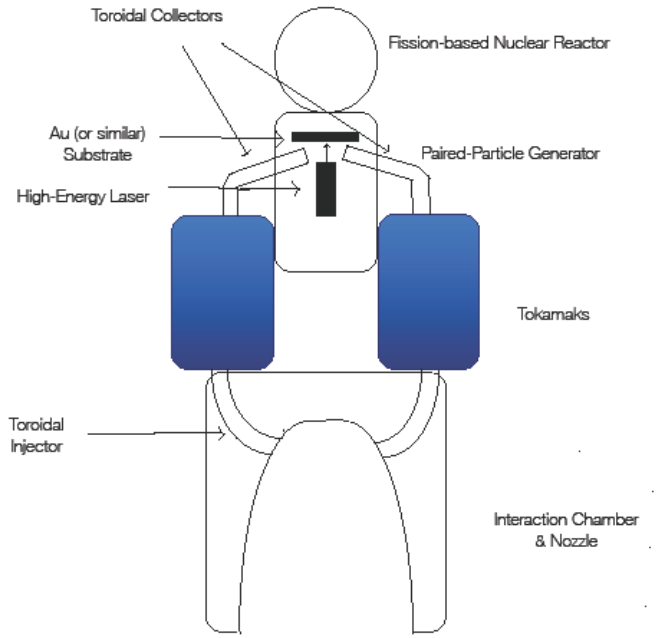
Paired-Particle Generator

- Petawatt Laser
- Au (or other) Substrate
- Separation Electromagnetic System



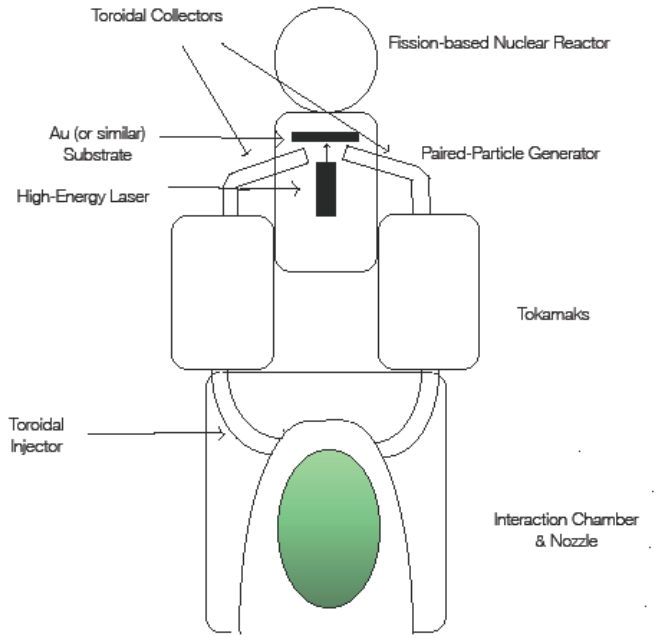
Twin Tokamaks

- One for electrons & one for positrons
- Similar to tokamaks used for fusion experiments
- Separation of paired particles from vessel, using toroidal magnetic fields
- Electromagnetic system to control and direct separate paired-particle beams



Annihilation Chamber

- Locus of electron/positron annihilation
- Shaped like chemical-rocket engines (a/k/a “nozzles”)
- “Exhaust” is gamma rays (therefore theoretical speed limit = *c*)



Theoretical Speed Calculation (1)

1. When an electron and positron interact & annihilate, they release two 511keV gamma rays.

2. The average Compton Effect electron recoil of each gamma ray is approximately 200 keV.

3. Assuming that the twin tokamaks can release 6 x 10^{18} pairs of electrons & positrons per second, 1.2 x 10^{19}gamma rays would be generated per second. (By comparison, the TRIUMF cyclotron ejects 6 x 10^{14} particles per second.)

Theoretical Speed Calculation (2)

4. 200 keV = 3.2 x 10^{-14} kg•m/sec/sec

5. 6 x 10^{18} particle pairs per second x 3.2 x 10^{-14} kg•m/sec/sec x 2 (because each annihilation results in 2 511-keV gamma rays) = potential thrust energy of approximately 380,000 kg•m/sec/sec

6. Assuming that the weight of the vehicle is 200,000 pounds (90,909 kg), the acceleration of the vehicle would be approximately 4.2 m/sec/sec

Theoretical Speed Calculation (3)

7. After a two-hour burn (7200 seconds), the vehicle would achieve a speed of approximately 67,000 mph.

8. After a 24-hour burn, the vehicle would achieve a speed of 812,000 mph. At that speed, a trip to Mars would take approximately 171 hours (excluding any necessary time to decelerate).

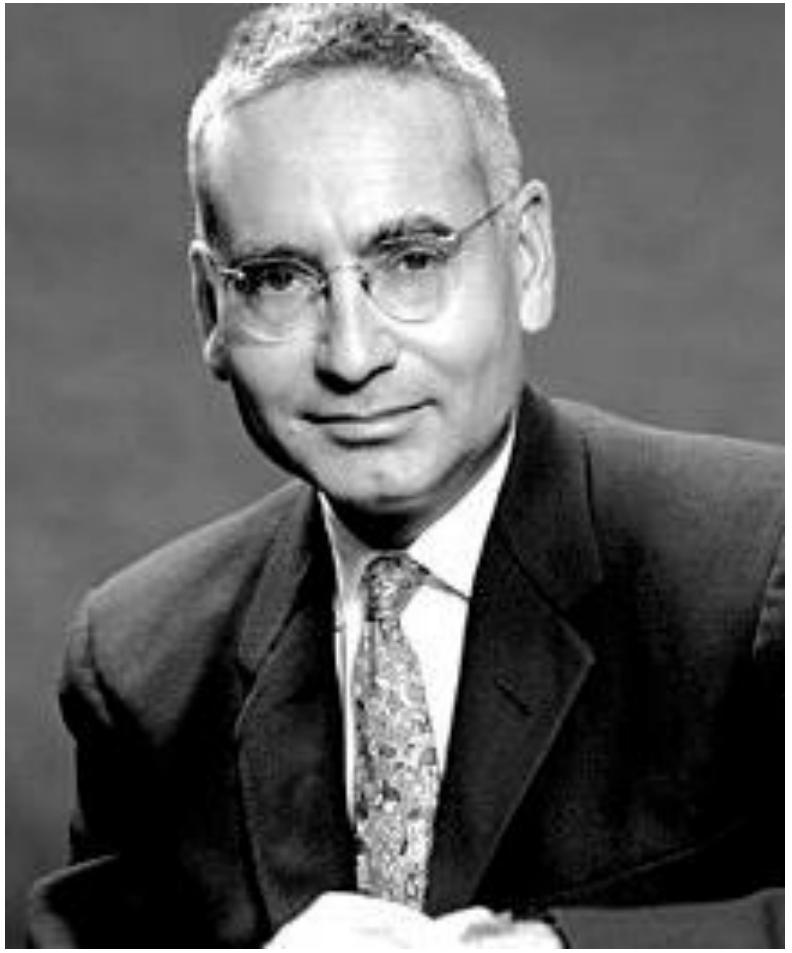
9. After a one-week burn, the vehicle would reach a speed of approximately 5,683,000 mph. That is .8% of the speed of light, putting this system within the realm of relativistic speed.

Significance of this Technology

It is likely that, within one generation, humans will be able to send unmanned probes *and* manned spacecraft to the outer planets and nearby star systems.

Next Steps (1)

- A. Weinberg, Director, Oak Ridge National Laboratory 1948-73
- Author, “Impact of Large-Scale Science on the United States,” **Science**, 134:3473 (July 21, 1961)
- Coined the phrase, “Big Science”



Next Steps (2) – U.S.

Component Research & Development

- A. Paired-Particle Generator designed for this purpose, with potential output optimized & determined (Lawrence Livermore National Laboratory)
- B. Twin Tokamaks designed for this purpose, with potential storage capacity & output optimized & determined (Fermilab National Accelerator Laboratory & National Magnetic Laboratory)
- C. Annihilation Chamber designed for this purpose, with potential thrust optimized & determined (Los Alamos National Laboratory, Redstone Arsenal)
- D. Fission reactor designed for this purpose, based on energy needs of the system (Oak Ridge National Laboratory)

System Design & Testing

- Based on the results of Phase I, system design can begin (NASA – Washington, Houston, Kennedy Space Center, Jet Propulsion Laboratory)
- Artemis Project for lunar base already under way

Next Steps (3) -- International

Models?

- U.S. Space Shuttle Program
- International Space Station
- European Space Agency

Difficulties

- Decisionmaking
- Budgetary Fragmentation

Opportunities

- Component Research & Development

Q & A

Thank You!

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