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ADVANCED NUCLEAR THERMAL PROPULSION CONCEPTS

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In 1989, a Presidential directive created the Space Exploration Initiative (SEI) which had a goal of placing mankind on Mars in the early 21st century. The SEI was effectively terminated in 1992 with the election of a new administration. Although the initiative did not exist long enough to allow substantial technology development, it did provide a venue, for the first time in 20 years, to comprehensively evaluate advanced propulsion concepts which could enable fast, manned transits to Mars. As part of the SEI based investigations, scientists from NASA, DoE National Laboratories, universities, and industry met regularly and proceeded to examine a variety of innovative ideas. Most of the effort was directed toward developing a solid-core, nuclear thermal rocket and examining a high-power nuclear electric propulsion system. In addition, however, an Innovative Concepts commitee was formed and charged with evaluating concepts that offered a much higher performance but were less technologically mature. The commitee considered several concepts and eventually recommended that further work be performed in the areas of 1) gas core fission rockets, 2) inertial confinement fusion systems, 3) antimatter based rockets, and 4) gas core fission electric systems. Following the commitee's recommendations, some computational modeling work has been performed at Los Alamos in certain of these areas and critical issues have been identified.

The gas core fission rocket offers the potential of delivering high thrust with an Isp between 2000 to 5000 s. The underlying principle is that a localized accretion of uranium plasma can be maintained in a rocket chamber by fluid dynamic forces. By utilizing no solid materials in the rocket volume, exhaust gas tempertures can be raised to the several electron volt level to produce high Isp. Some of the obvious problems are:

1) efficient containment of the expensive uranium fuel;
2) thermal flux loads at the first wall;
3)thermal balance of the entire system ;
4) nozzle cooling and erosion problems; and
5) possible requirement of a magnetic nozzle.

Currently, some calculations of criticality and flow fields are being performed for the counter-flow toroidal rocket concept, shown in Fig. 1. This concept offers potential advantages over the previous, spherical gas core concept by reducing the Kelvin-Helmholtz mixing at the uranium/hydrogen interface. In addition, the cylindrical geometry may allow magetic fields to be used to enhance the uranium confiement. Currently, cold flow experiments are being developed to demonstrate the toroid formation process and to determine loss rates of a heavy "fuel" gas.

One of the envisioned problems with the gas core fission reactor, in general, is the low thrust to weight ratio of the engines. This ratio is dependent on the density of uranium which is decreasing with increasing Isp. One concept which may alleviate the critical mass obstacle is to utilize the toroidal geometry and flow characteristics of the fission rocket but to power the system with positron annihilations instead of fission reactions. In addition to the aforementioned issues, this concept would also require evaluation of energy deposition by the annihilation photons, positron storage and production concepts, and positron delivery optics. Preliminary calculations of the photon deposition profiles are currently underway as part of a concept feasibility study.

The concept of using gas or plasma core reactors for propulsion may also be applied to nuclear electric propulsion (NEP) systems. The primary drawback of NEP systems is the large mass associated with the entire power/propulsion assembly. As shown in Fig. 2, a major issue to make the NEP system more competitive with thermal systems is the need for a high efficiency conversion process that has low weight and that produces power compatible with electric thruster requirements. In this context, Los Alamos is hosting a University of Florida student who is planning a series of experiments to demonstrate the feasibility of using a Recoil Enhanced MHD technique to increase fluid conductivity in order to efficiently produce power without moving parts.

In conclusion, the current environment for advanced propulsion research is not strongly supportive. Several advanced concepts exist, however, where small scale experiments and evaluations can demonstrate feasibility. If some of the identified issues can be resolved by university research in the next few years, a higher performance prpulsion system might be made available to the country for future manned missions to even farther planets. Now is exactly the time to pursue these proof-of-concept studies in the Laboratory environment.

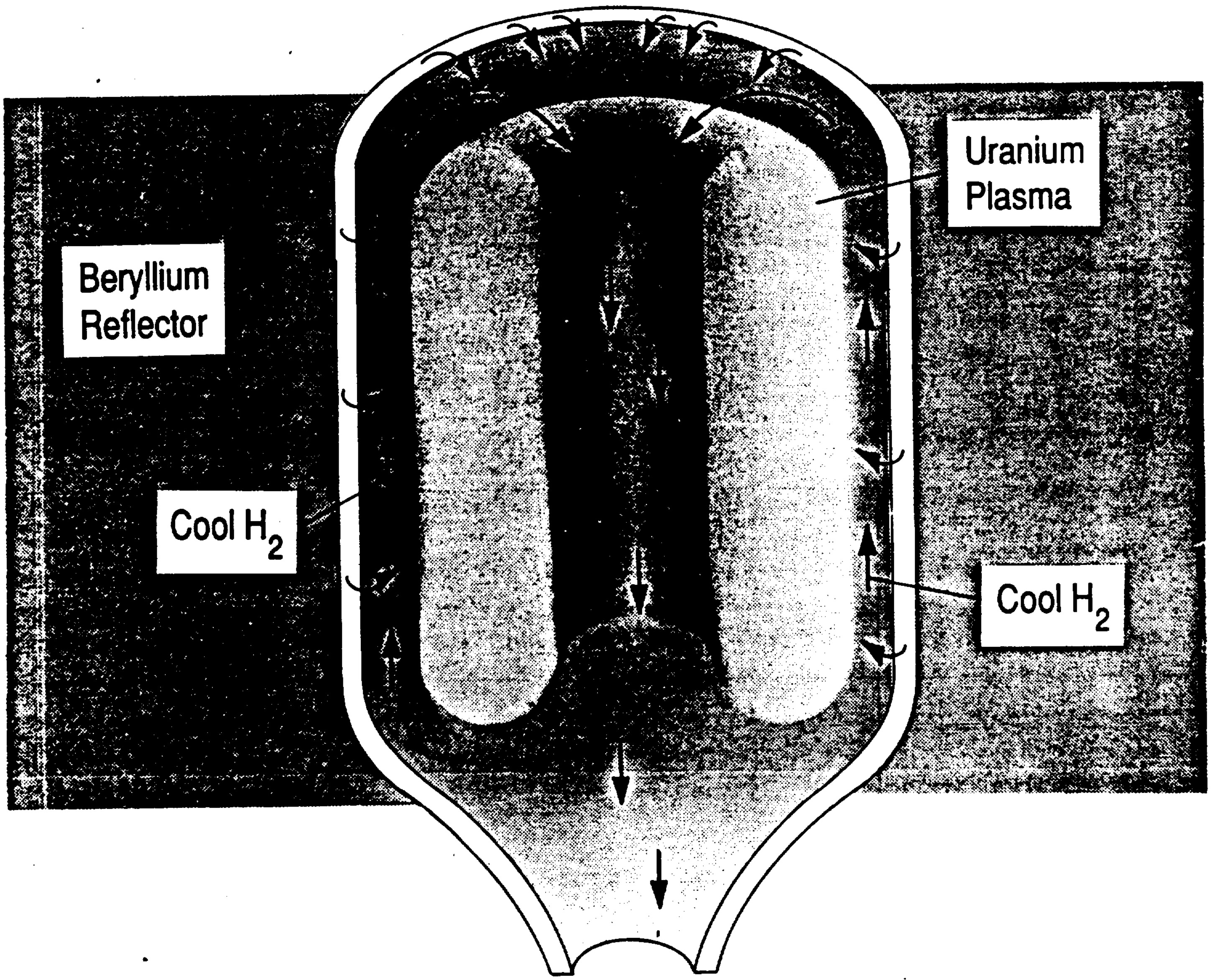
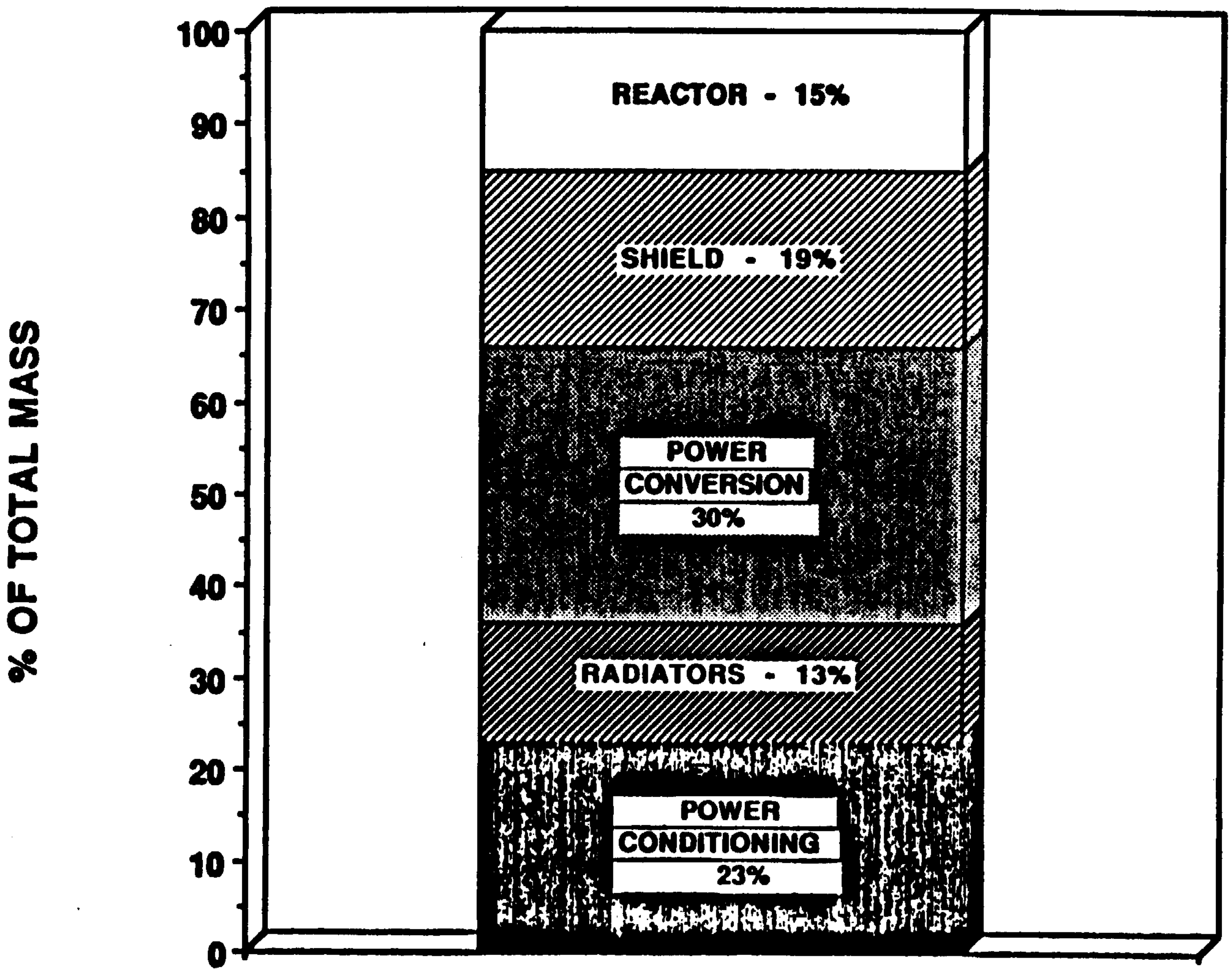


Figure 1. Conceptual Representation of the Counter-Flow Toroidal Gas Core Rocket

Figure 2. NEP SYSTEM MASS BREAKDOWN



Source: SP-100 Derivative Baseline

Courtesy of the NASA Electric Propulsion Workshop

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