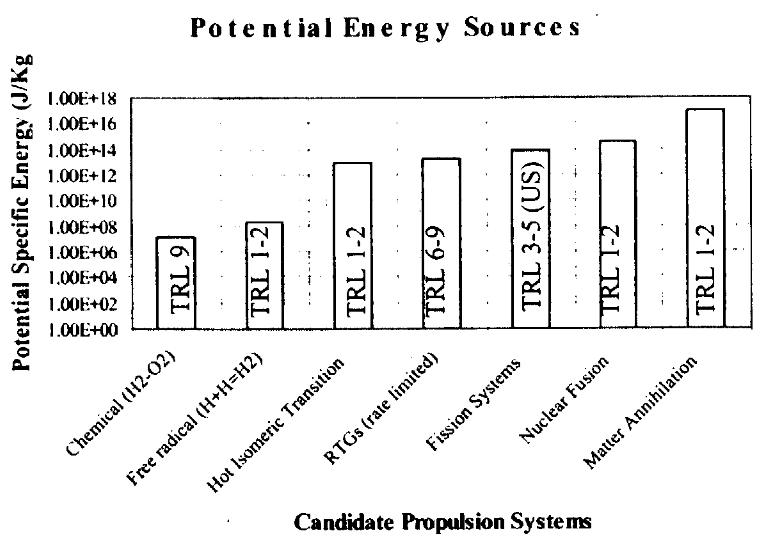
Simulated Atomic Fission Engine
(S.A.F.E.)

Marshall Space Flight Center
Propulsion Research Center / TD40

1999

Why Space Fission Propulsion?



- Chemical propulsion systems use chemical reactions to energize the propellant. Fission propulsion systems use fission reactions to energize the propellant. In both cases propellant remains non-radioactive.

- The theoretical energy density of fission systems is seven orders of magnitude greater than that of chemical systems.

- Space fission systems have relatively high TRL level.

- Near-term space fission systems enhance or enable advanced science and exploration missions. Advanced space fission propulsion systems enable rapid, affordable access to any point in the solar system.

- Fissioning 1 Kg of uranium provides as much energy as the kinetic energy in 5 million pounds of propellant exhausted with an Isp of 850 s (order of magnitude more energy than shuttle main tank).

History of Fission System Development

• Solid-Core Nuclear Rocket Program	• SNAP-50 / SPUR	• Advanced Liquid Metal Cooled Reactor
• Medium-Power Reactor Experiment (MPRE)	• High-Temperature Gas-Cooled Electric Power Reactor (710 Reactor)	• Advanced Space Nuclear Power Program (SPR)
• Thermionic Tech. Program (1963-1973)	• SPAR / SP-100	• Multi-Megawatt Program
• Space Nuclear Thermal Rocket Program	• Flight Topaz	• Thermionic Fuel Element Veri. Pro.
• SP-100	• DOE 40 kWe Thermionic Reactor Prog	• Air Force Bimodal Study

Partial list of major US Space Fission Programs that Have Failed to Result in Flight of a System

- **Fission systems have been operated by the government, universities, industry, and utilities for over 50 years. Dozens of countries now operate fission systems at the power levels of interest for space applications.**

- **Technology, fuels, and components required for space fission systems have been developed over the last 45 years.**

- **The only US flight of a fission system was over 3 decades ago. All US space fission programs (propulsion, power, and bi-modal) since have failed to result in a flight.**

- **From a public perception standpoint, "If it doesn't fly, it doesn't matter!"**

New Approach to Space Fission Propulsion System Development

1st Generation System

- Focus on demonstration of an advanced propulsion system
- Focus on safety, cost, schedule
- Innovative use of existing nuclear technology
- Nuclear portion adequate for numerous missions of interest

2nd Generation Systems
(Manned exploration inner solar system, advanced unmanned exploration)

- High thrust, high efficiency systems
- High thrust nuclear thermal systems
- Development of fuels and other nuclear components required

3rd Generation Systems
(Rapid travel throughout solar system)

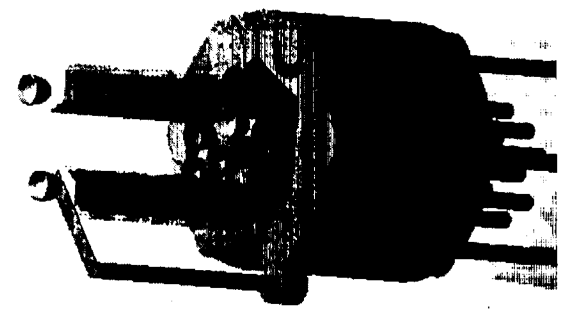
- Flowing-fuel systems
- Pulse fission systems
- Extensive development / high payoff

Most previous (failed) programs attempted to develop second or third generation systems without gaining experience from fielding a **<u>relevant</u>** first-generation system.

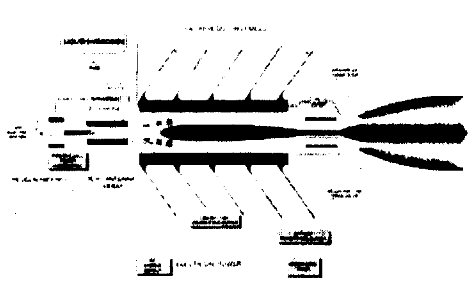
Propulsion Flight Demonstrator Schematic
Flight Configuration

Fission-based Propellant Energy Source

- Non-radioactive at launch
- Radiation resistant
- Operates close or far from sun
- Numerous propulsion modes
- Extremely high energy density

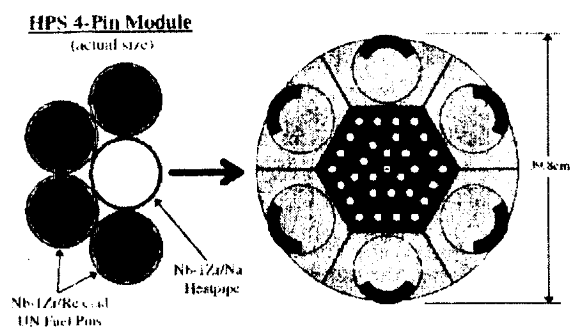


VASIMR Thruster



Isp > 3000 - 30,000 s
Thrust > 0.1 N

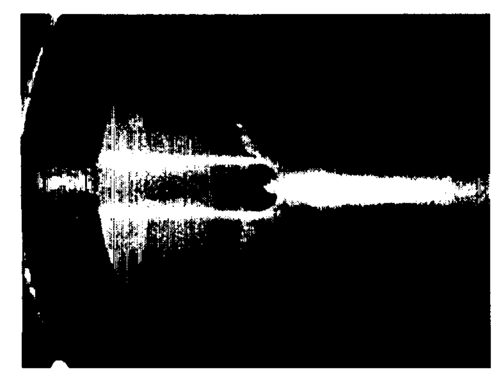
Direct Thermal Propulsion



The system shown (HPS7N) consists of 30 independent modules (12 '4-pin' and 18 '5-pin'). It is surrounded radially by a Nb-1Zr baffle, a beryllium-oxide (BeO) neutron reflector and 6 boron-carbide (B₄C) lined control drums.

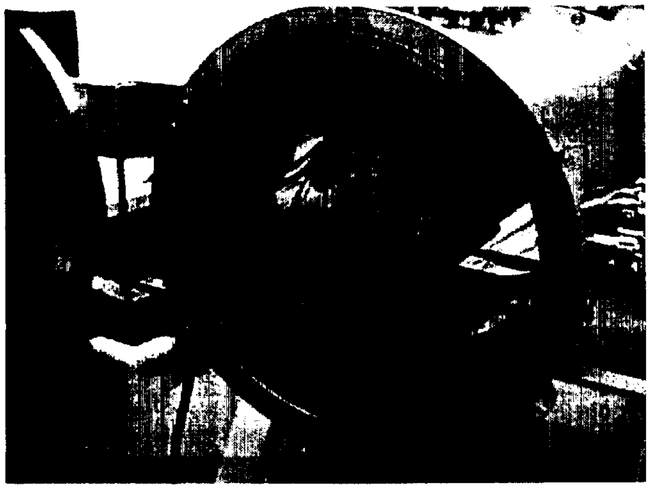
Isp > 500 s; Thrust > 400 N

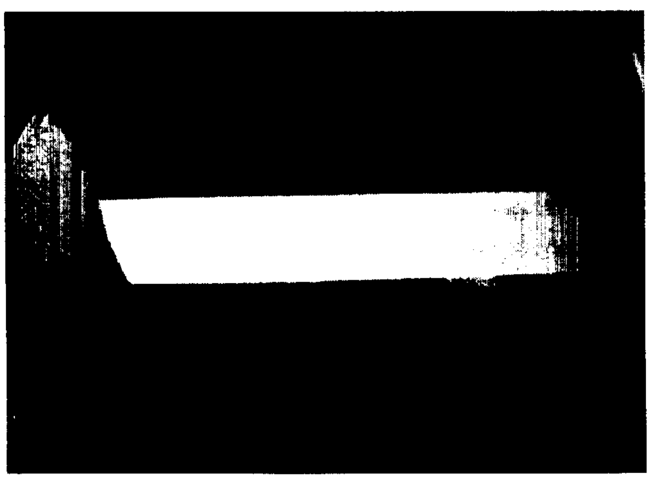
MPD (or other) Thruster

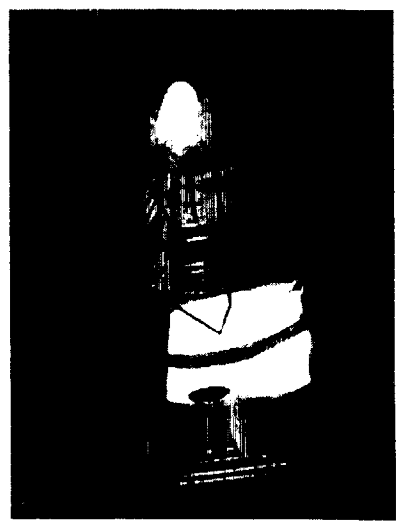


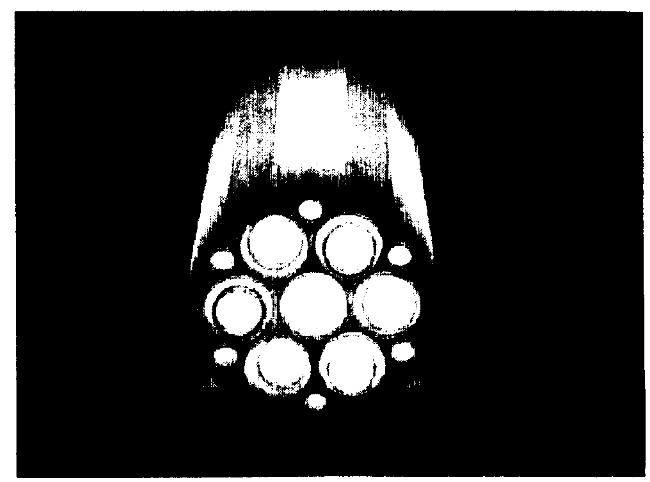
Isp > 1500 s
Thrust > 0.1 N

Ongoing Propellant Energy Source Tests









FY99 tests demonstrate feasibility of propulsion module. FY00 tests will demonstrate full-core thermal-hydraulic performance.

First Generation Propulsion System Status

- Fission propellant energy source feasibility studies and preliminary concept already developed.

- Design of propellant energy source enables 100% safety (in-space fueling), enables extensive testing of actual flight unit, and enables flight system development through non-nuclear testing. <u>All core components operate within the existing nuclear database,</u> even for multi-year missions.

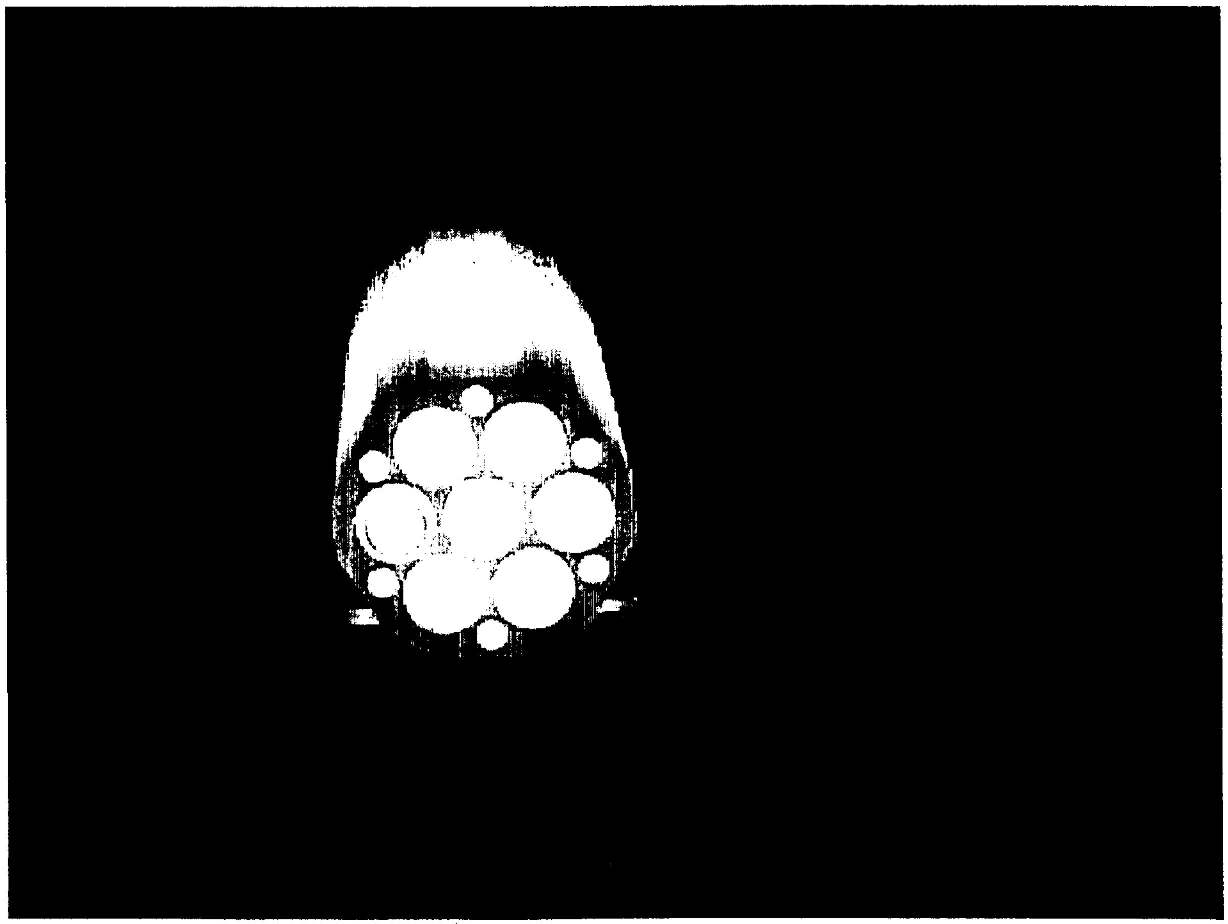
- High temperature module operation demonstrated (>1750 K tungsten fuel pin simulator, >1450 K isothermal heatpipe).

- Direct thermal propulsion tests initiated 10/99.

- Full core (unfueled) will be delivered from LANL in FY00 - full core testing will begin shortly thereafter.

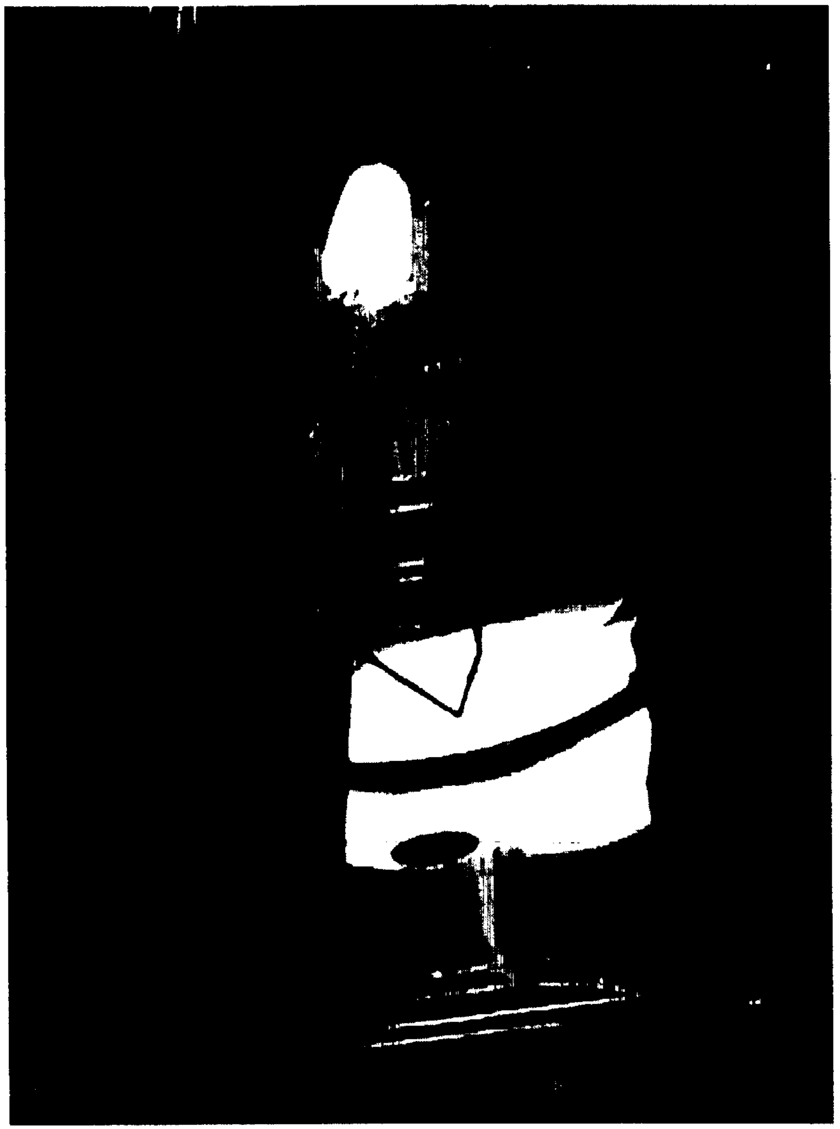
- Ground demonstration of in-space fueling mechanism planned for FY00.

Tungsten Fuel Pin Simulator Tests



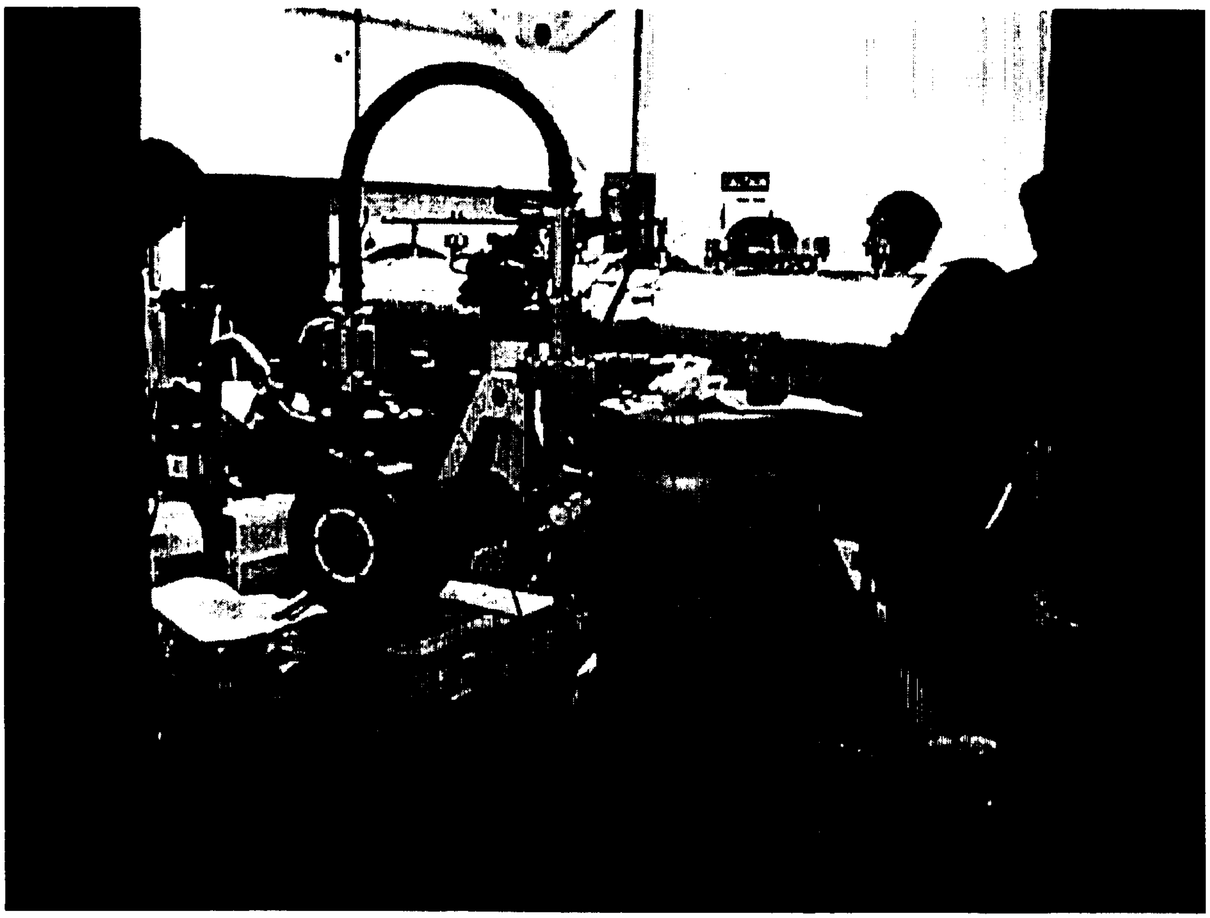
- $T > 1750$ K
- Provided Power vs Temperature Data
- Demonstrated High Temperature Test Capability

Full Module Test (High Efficiency Mode)



- Tungsten temperature >1750 K.
- Heatpipe (isothermal) >1450 K.
- Three heatpipe restarts as of 9/99.
- Fast start of heatpipe - room temperature to > 1400 K in 55 minutes.

First Generation Propulsion Flight Demonstrator Status



- 10/99: Test facility reconfigured to allow resistance heated testing of direct nuclear thermal propulsion mode and high efficiency mode simultaneously.