N93-26968

SPACE NUCLEAR THERMAL PROPULSION

SNTP

US AIR FORCE
Phillips Laboratory
Grumman, Babcock & Wilcox
Brookhaven & Sandia National Labs

Air Force Facility

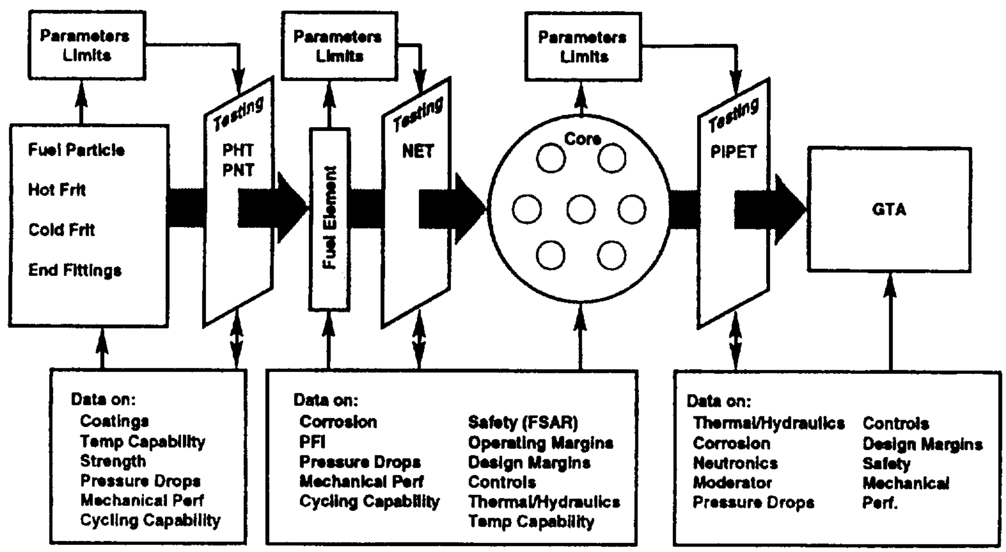
David F. Beck
PIPET Project Manager
Sandia National Laboratories

The Space Nuclear Thermal Propulsion (SNTP) program is an initiative within the U.S. Air Force to acquire and validate advanced technologies that could be used to sustain superior capabilities in the area of space nuclear propulsion. The SNTP program has a specific objective of demonstrating the feasibility of the particle bed reactor (PBR) concept.

SNTP

The term PIPET refers to a project within the SNTP program responsible for the design, development, construction and operation of a test reactor facility, including all support systems, that is intended to resolve program technology issues and test goals.

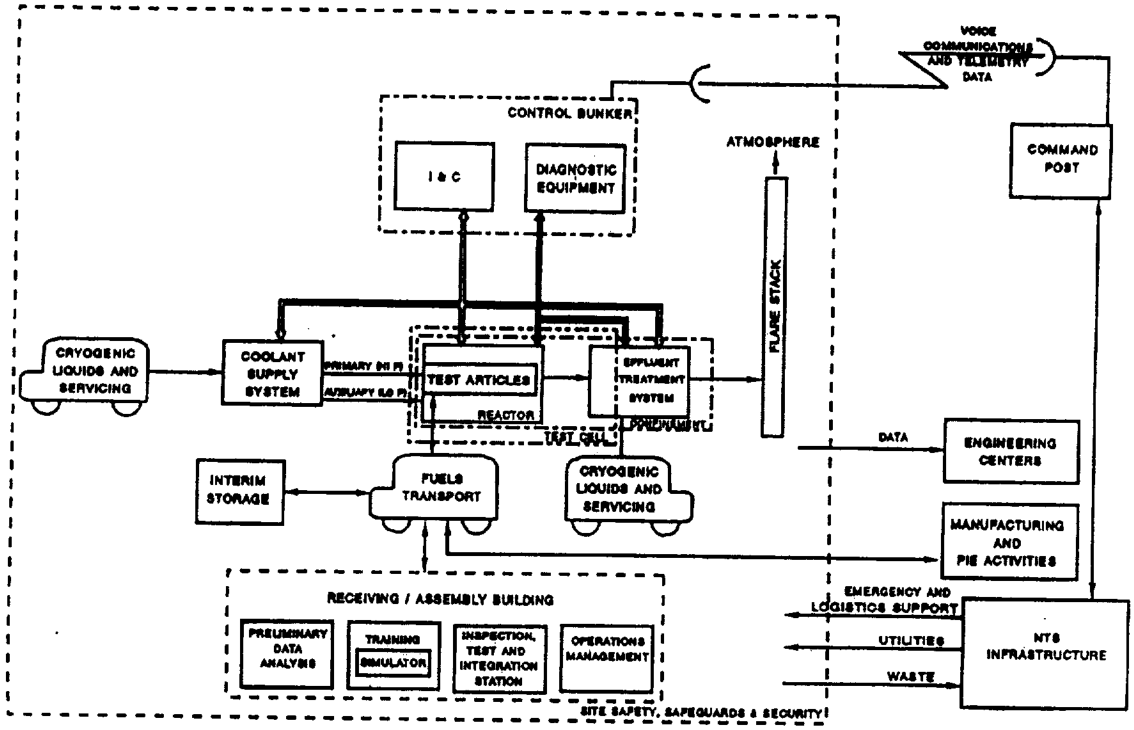
Experiment Data Flow



The PIPET project will provide the necessary capability to complete the final steps in the SNTP program nuclear test plan.

No known reactor facility in the world is capable of providing prototypical test conditions for SNTP PBR fuel or fuel elements. Although certain nuclear tests (pre-PIPET) within the current SNTP program may probe the design envelope of the fuel and fuel element, the best that can be accomplished is very short run times and very low flow conditions for sub-sized or nonstandard fuel element designs (e.g., PNT and NET). The high-power densities that make the PBR so attractive will never be tested to prototypical design conditions until the PIPET element-test reactor is built.

No operational reactor facility in the U.S. is capable of testing a flight-like NTP reactor core or engine under power (some limited capability exists in the CIS, but even this does not include any cryogenic hydrogen support and is not currently configured for propulsion type testing). No facility in the world is capable of providing nuclear test support for NTP reactors or engines under the current and rightful concern for protecting the environment and public health. The investment in building a high power density fuel element test reactor can be leveraged into a facility that can also provide test support in meeting certain NTP ground test requirements.



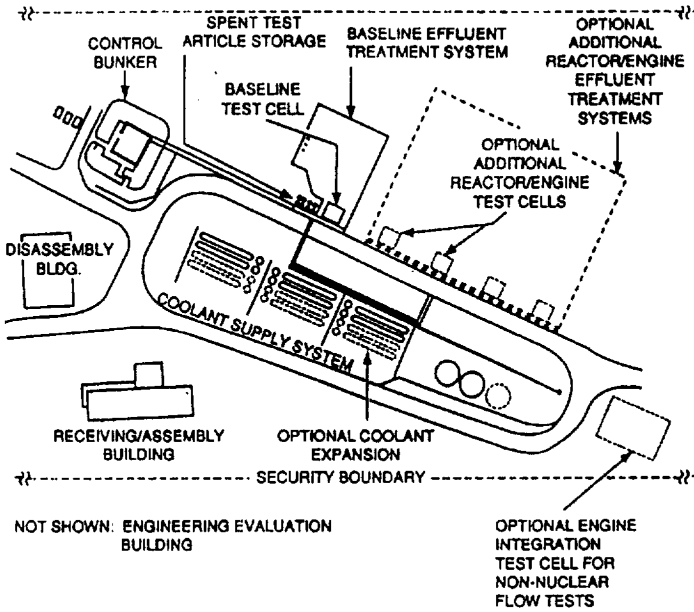
PIPET TEST REACTOR SYSTEM

The PIPET system includes:

1) Major interfaces with the host site for utilities & logistics support.

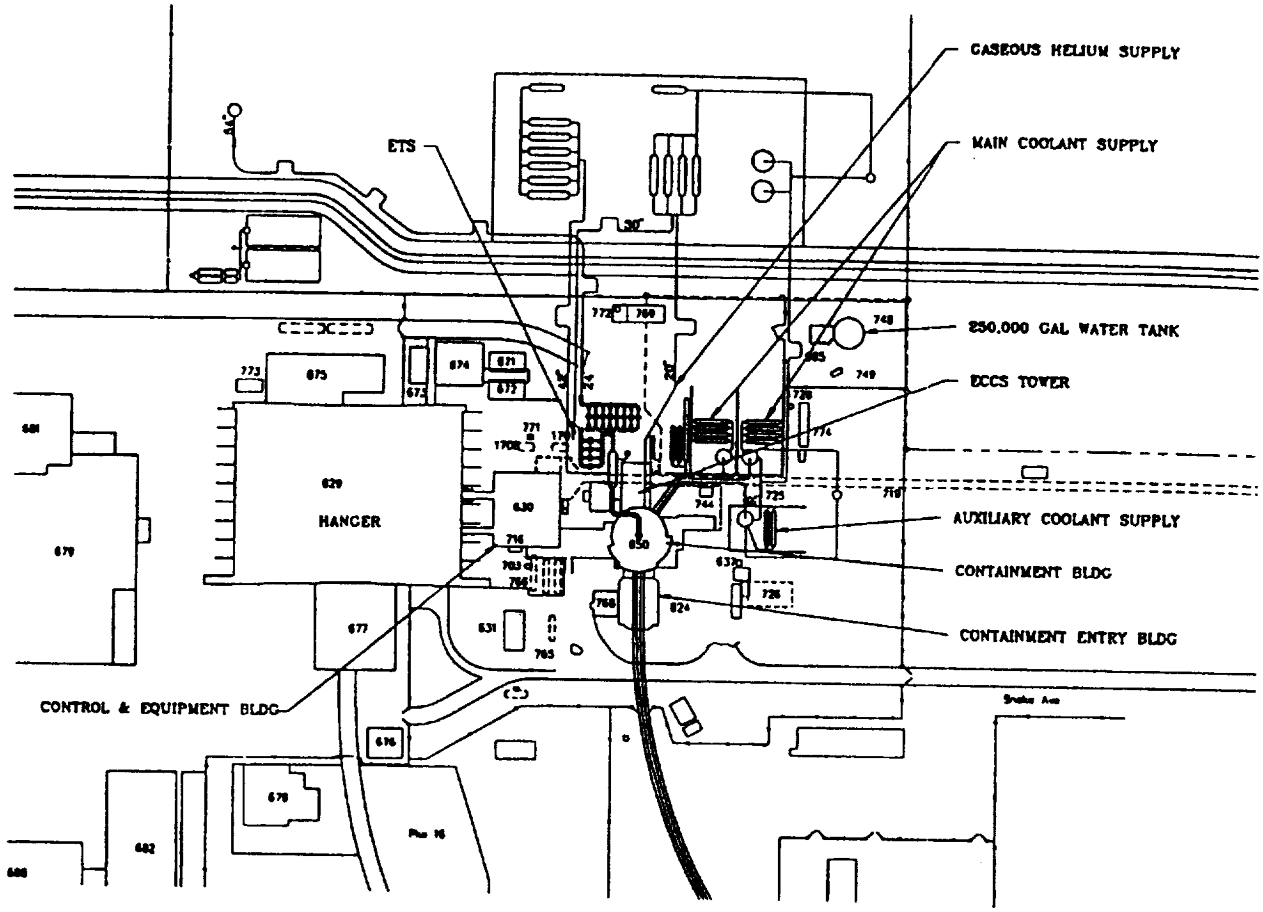
2) Facilities including a control bunker, a receiving and assembly building, temporary dry storage areas for irradiated materials, a disassembly building, and test cell(s).

3) A reactor coolant supply system consisting of a cryogenic hydrogen supply and hydrogen effluent treatment system.

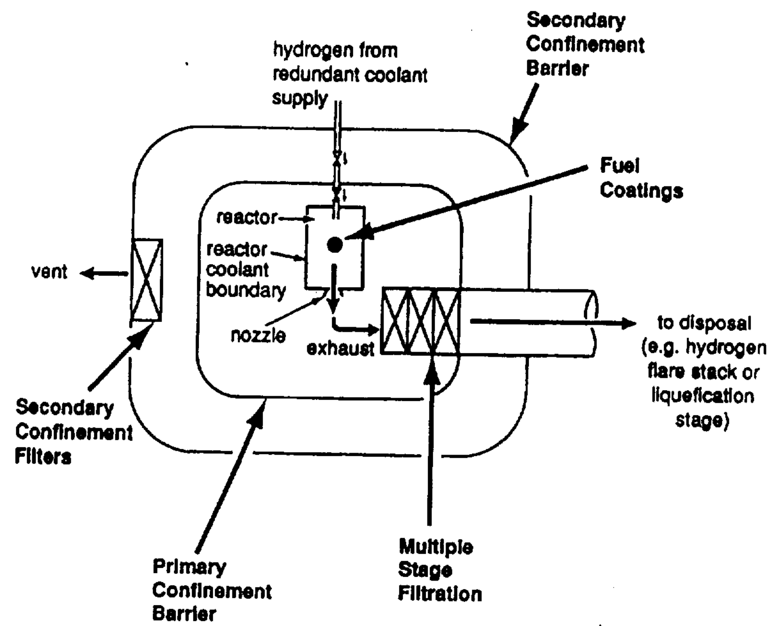


SNTP Baseline Facility Conceptual Site Plan Illustrating Laydown Space for Optional Expansions

One location for the PIPET test station supported by the SNTP program Environmental Impact Statement is a "green-field" location on the Nevada Test Site (NTS). This would involve essentially all new construction, with designs developed to meet program requirements.

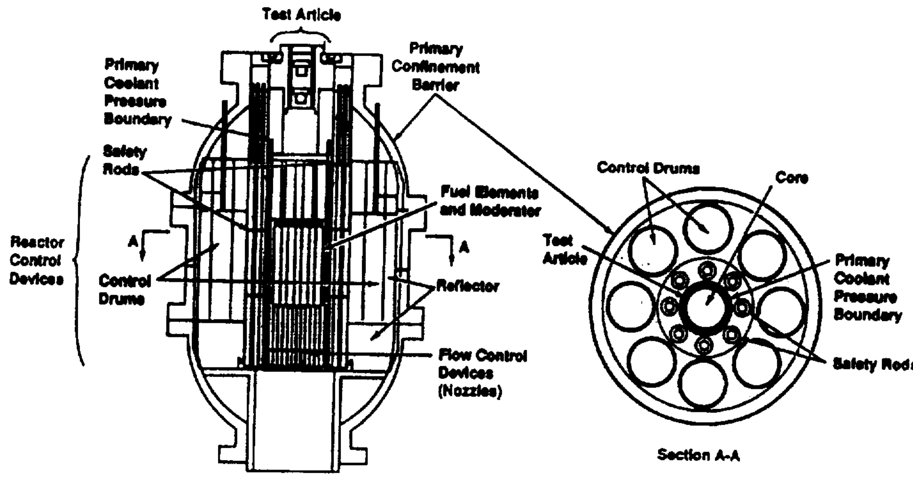


The second alternative site for the PIPET facility is a location within Test Area North (TAN) of the Idaho National Engineering Laboratory (INEL). This would involve renovation, adaptation and use of existing structures such as the Contained Test Facility (CTF) and TAN 607 Hot Shop Complex.



Depiction of the Use of Multiple Physical Barriers and Single-Failure Criteria in Preventing the Unmitigated Release of Fission Products

The Space Nuclear Thermal Propulsion program is committed to achieving the highest practicable levels of safety both in program activities and in the ultimate safety both in program activities and in the ultimate product of the program. Safety considerations will include: protection of the health and safety of the public; protection of the health and safety of all employees where program activities are done; protection of the environment and lands from contamination or damage as a result of program activities; and protection of the property and facilities used in the program. Unmitigated release of fission products is prevented by use of concepts such as 'defense in depth.' This includes administrative, physical, and operational controls and measures. Physical controls for ground testing on NTP concepts involve multiple barriers including fuel coatings, primary confinement systems, and secondary confinement systems. Physical barriers to be employed that will prevent the unmitigated release of fission products are diagrammed above. As implemented for the SNTP program, the primary confinement barrier around the reactor looks much like a reactor vessel in a conventional power plant design, but is functionally much different. The mechanical structure used to support and direct flow through the multiple stage filtration system also serves as the balance of the primary confinement barrier. The secondary barrier includes the test cell structures, which may serve multiple functional needs (for example, weather protection and shielding).



Simplified Drawing of the Test Bed Preliminary Design

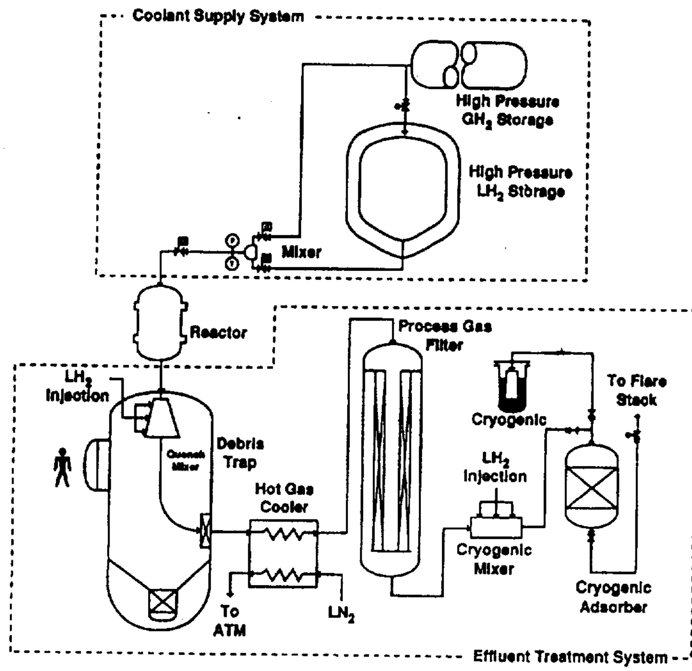
The test reactor by design contains two major subsystems — a test bed and a test article.

The test bed nominally provides:

1. A primary fission product confinement barrier.
2. Interfaces between the test article and other programmatic equipment (for example, coolant supply, effluent treatment, and instrumentation and controls).
3. An experiment volume in which the test article (fueled portion of the reactor) is tested.
4. Independent reactivity systems to bring the overall reactor system to the desired preoperational reactivity state; control startup, shutdown, and operational transients; and provide scram capability.

Test articles are designed for ease of removal to enable rapid test turnaround, ease of reconfiguration, and minimal worker exposures. Reactivity controls within the test bed are designed for ease of removal, so that test articles containing their own reactivity control mechanisms can take advantage of the confinement and programmatic equipment interfaces without having to relay on other design features. Test article design options can thus be seen to include:

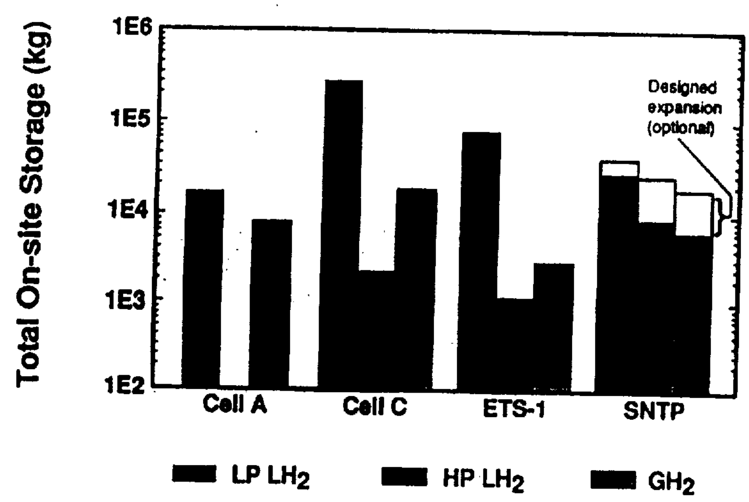
1. A hybrid core design where a previously qualified test article design has a single fuel element replaced with a new design.
2. A new test article that makes use of all the inherent features found in the test bed.
3. A new test article with integral reactivity control systems, only making use of the confinement barrier and subsystem interfaces of the test bed.
4. Replacement of the entire test bed/test article assembly with a new reactor design.



Simplified Line Diagram Of The Baseline Reactor Coolant System

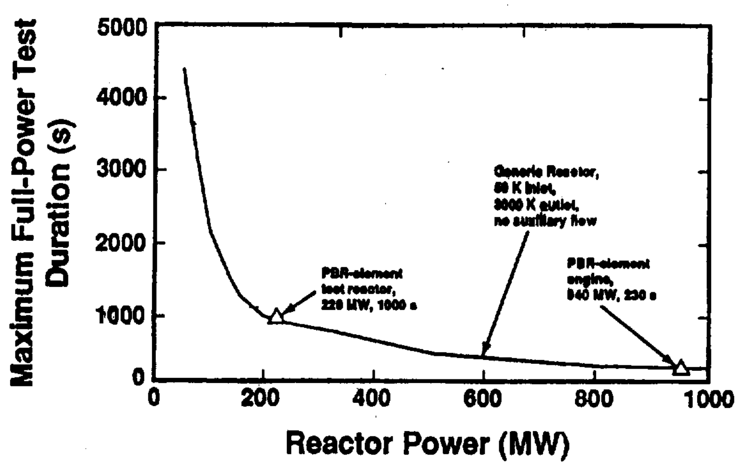
A primary coolant system has been designed that meets the safety and performance requirements of the SNTP program for use in the development, demonstration, and qualification of NTP fuel elements, reactors, and engines. (Integrated stage qualification, including high-altitude simulation, is not a requirement for the current program.) The functional requirements of the reactor coolant system design includes:

1. Provide an adequate, redundant, highly reliable supply of cryogenic hydrogen at required pressures, temperatures, and flow rates (hydrogen supply - coolant supply system).
2. Interface with the primary heat source (test reactor or engine).
3. Cool the hot primary flow to temperatures compatible with structural and heat exchanger materials. Catch any core debris material resulting from failures (planned or unplanned) and maintain it in a coolable, subcritical configuration. Allow access for remote/robotic retrieval of core debris. Provide initial, coarse-filtering to prevent downstream heat exchanger plugging and act as a getter for plate out of fission products with boiling points above the cooldown temperature (debris trap).
4. Provide additional cooling of exhaust flow to temperatures compatible with downstream particulate filters (hot gas cooler).
5. Filter out particulates entrained in the exhaust flow (process gas filter).
6. Retain any fission products still in volatile form (for example, krypton and xenon) for a sufficient time to allow for decay (cryogenic mixer/adsorber stage).
7. Dispose of cleaned effluent (flare stack).



NTP Facility Baseline Hydrogen Storage Capacities

The PIPET facility includes an initial, baseline coolant supply capacity designed to envelope the minimum test duration requirements of the SNTP program. Optional supply system expansions are planned that will provide capability to meet maximum test duration requirements. The figure above provides a comparison between the planned SNTP program PIPET test facility on-site hydrogen storage capacities against the test-cell hydrogen installations of the ROVER/NERVA Program.



Baseline Facility Test Durations

The planned baseline reactor coolant supply system, although designed to meet several operating point requirements, is best represented by an extensive set of operating envelopes that are a function of mass flow rates, temperatures and pressures. However, to illustrate the system performance, a generic NTP reactor was used to generate a test duration envelope as a function of reactor power. This curve is, roughly speaking, a line of constant energy. Also shown are operating points for two conceptual PBR test article designs.

SUMMARY

- A nuclear test facility has been designed that meets SNTP facility requirements including:
  - safety and environmental policies
  - minimum impact on waste streams
  - provisions for appropriate safeguards and security
  - meets minimum SNTP performance levels
  - supports expansion to maximum SNTP performance levels
- The design approach taken to meet SNTP requirements has resulted in a nuclear test facility that should encompass a wide range of NTP test requirements that may be generated within other programs. The SNTP PIPET project is actively working with DOE and NASA to assess this possibility.

Additional information concerning these facilities can be found in:

Allen, G.C. et al. (1992), "Ground Test Facilities for Evaluating Nuclear Thermal Propulsion Engines and Fuel Elements," in Proceedings of the 1992 Nuclear Technologies for Space Exploration, Jackson, WY, 16-19 August 1992, pp 514-523.

Beck, D.F. et al (1993), "Test Facilities for Evaluating Nuclear Thermal Propulsion Systems," to be presented at the Tenth Symposium on Space Nuclear Power and Propulsion, Albuquerque, NM, January 1993.

Shipers, L.R., and Allen, G.C. (1992), "Handling Effluent From Nuclear Thermal Propulsion System Ground Tests," presented at the Third Specialist Conference on Nuclear Power Engineering in Space Nuclear Rocket Engines, Semipalatinsk-21, Republic Kazakhstan, September.

Shipers, L.R., and Brockmann, J.E. (1993), "Effluent Treatment Options for Nuclear Thermal Propulsion System Ground Tests," to be presented at the Tenth Symposium on Space Nuclear Power and Propulsion, Albuquerque, NM, January 1993.