RESTART OF THE U.S. SPACE NUCLEAR REACTOR POWER PROGRAM

V.C. Truscello
Manager, SP-100 Project
Building 169-515
Jet Propulsion Laboratory
California Institute of Technology
4300 Oak Grove Drive
Pasadena, California
U.S.A. 91109

After a ten year hiatus, the U.S. space nuclear reactor program is once again in high gear. In February, 1983, the Defense Advanced Research Project Agency (DARPA), Department of Energy - Office of Nuclear Energy (DOE), and National Aeronautics and Space Administration - Office of Aeronautics and Space Technology (NASA) signed an agreement to jointly sponsor a space nuclear reactor power system program known as SP-100.

The program office is housed in the Washington, D.C. area while the field laboratories implementing the program are housed at the Jet Propulsion Laboratory in Pasadena, California, Los Alamos National Laboratory in Los Alamos, New Mexico, and the Lewis Research Center in Cleveland, Ohio. Overall management of the project office is at JPL.

The restart of the space nuclear program is attributable to the maturing of space technology and space missions. The U.S. flew its only nuclear reactor power system back in 1965, a thermoelectric system powered by a thermal reactor, while launching over 20 smaller isotope powered devices since the early 1960's. Since the premature phase-out of the nuclear reactor program in 1973 (the isotope powered space program continues), due to a lack of specific missions to utilize the device's capabilities, space utilization has increased dramatically. Requirements today are more demanding in terms of power level, weight, maneuverability and hardenability. A light weight, high-powered nuclear power system can enable or significantly enhance military and civil satellite missions. Man's increasing presence in space such as in the space stations over the next decade cries for power systems that are more rugged, durable and higher performing than the leading candidate - solar photovoltaics. Not only has space technology matured, but power technology has also made significant strides since the late 1960's. The U.S. program to develop commercial reactor power plants has vastly improved the state of technology for compact, light weight, fast spectrum reactors. Although much of the technology base is at reactor core temperatures below 900K, the experience in designing and operating such liquid metal cooled systems will greatly contribute to the higher temperature (up to 1500K) versions that will be necessary to meet future mission requirements. Even the achievements in power conversion technology have been impressive. Although the leading candidate for space reactor power in the late 1960's was in-core thermionics, today due to other related advancements, both thermoelectric devices with their long successful history in isotope space systems (RTGs) and high efficiency Stirling engines based on developments for terrestrial energy systems are formidable contenders for space reactor systems.

Along with power conversion technology improvements, advanced heat transport techniques in the form of heat pipes have been demonstrated both on earth and in space.

The above legacy, as a result of advancements in technology in support of other applications, provides the SP-100 Program a strong spring-board for rapid development and deployment of high performance nuclear reactor systems.

The overall program approach can be summarized as follows. Over the period March 1983 to July 1985 the program is in a technology assessment and advancement phase, conducting those activities that will enable a specific power system concept to be selected for development and ground testing during the next phase which could begin as early as 1986. During the critical first three years (1983-1986), the objectives of the program are to (1) define missions which need nuclear power and to determine their specific characteristics and needs as a basis for design. (2) perform conceptual design studies of three attractive but different power plant approaches and define the critical technological issues for the concept and (3) conduct experiments and analyses to address the identified issues and resolve them in sufficient depth to satisfy ourselves they will not affect the technical feasibility of the concept.

To gain assurance that the overall design will evolve into a system that is safe and which can eventually receive launch approval, an intensive nuclear safety program is being conducted in parallel with the other activities. Safety cannot be an afterthought introduced into the design once it meets all the other requirements. It must be an active ingredient in both the formative and detailed development stages. An important operating philosophy which has been imposed on this program is that the nuclear power source will not be activated until it resides in an orbit sufficiently high that its eventual reentry is delayed to a point in time when the radioactivity level of the reactor core will pose no danger to the general population no matter where it reenters.

Now, what is the present status of the program? The program has already completed one of its major milestones, a nine month effort by a number of industrial contractors to produce a careful evaluation of potential candidates. Quite a large array of concepts were possible and investigated. After much deliberation, three concepts were selected in January 1984 for further study. These concepts are (1) a fast flux liquid metal cooled reactor coupled to a thermoelectric power converter, (2) a fast flux in-core thermionic reactor/power conversion system, and (3) a low temperature fast flux liquid metal cooled reactor coupled to a

Stirling engine conversion system. Since January, the system contractors have continued the task of evolving and improving on the earlier conceptual designs. Many of the design and configuration issues identified in the early studies are being investigated in more detail in an attempt to optimize the design. A number of specific technology issues are being studied in some detail by both the industry team and participating laboratories. By 1985 the following critical tasks will be completed:

(1) Design/fabrication and test of a 25 kWe free piston Stirling engine capable of operating at space conditions. This will be augmented with a 10,000 hour life test of a 3kW unit;

(2) Design/fabrication and test in a reactor environment of thermionic diodes to demonstrate the potential for 7 year life. Critical issues are fuel/clad swelling at elevated temperatures (1700-1800K), and neutron irradiation degradation of the electrical insulators;

(3) Design/fabrication and test of a thermoelectric module to demonstrate light weight compactness and fabricability. A critical issue is thermal stresses at interface bonds. This will be augmented with the development of high-temperature thermoelectric materials with a figure of merit in excess of $1.0 \times 10^{-3}K^{-1}$;

(4) Demonstrate reactor construction material compatibility. An important feasibility issue with regard to using refractory metals in a reactor deal with the material transport fluid/cladding/fuel chemical interactions. Temperatures in the 1300-1700K aggravate this problem. Fuel pin experiments will be conducted within a fast spectrum reactor. Bench test of capsules containing various combination of materials will also be conducted;

(5) Determine the creep strength, ductility and weldability of refractory alloys before and after irradiation. MoRe, ASTAR-811C, WRe and NbZr will be characterized. The data base for these materials will be improved wherever it is found wanting;

(6) Reestablish the ability to fabricate UN fuel elements. Establish the capability to fabricate refractory metal fuel pins;

(7) Fabricate and life test refractory metal heat pipes using lithium operating at 1500K. Transient characterization for start-up and shut-down will also be performed.

If all goes as expected, by July of 1985, the program should be in a strong position to make an intelligent decision as to the viability of these concepts for space reactor power and which systems should be selected for the next phase of development - the ground test engineering experiment. To support that decision, an extensive effort is being conducted to estimate the costs and schedule of the ground demonstration phase. Whereas the present phase is in the order of 60 million dollars over three years, the next phase could be from one to two orders of magnitude higher. A thorough understanding of these costs is mandatory. Appropriate test and evaluation strategy must be developed to help minimize these costs.