The Nuclear Cryogenic Propulsion Stage

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Nuclear Thermal Propulsion (NTP) development efforts in the United States have demonstrated the technical viability and performance potential of NTP systems. For example, Project Rover (1955 – 1973) completed 22 high power rocket reactor tests. Peak performances included operating at an average hydrogen exhaust temperature of 2550 K and a peak fuel power density of 5200 MW/m^3 (Pewee test), operating at a thrust of 930 kN (Phoebus-2A test), and operating for 62.7 minutes in a single burn (NRX-A6 test).[1] Results from Project Rover indicated that an NTP system with a high thrust-to-weight ratio and a specific impulse greater than 900 s would be feasible. Excellent results were also obtained by the former Soviet Union.

Although historical programs had promising results, many factors would affect the development of a 21st century nuclear thermal rocket (NTR). Test facilities built in the US during Project Rover no longer exist. However, advances in analytical techniques, the ability to utilize or adapt existing facilities and infrastructure, and the ability to develop a limited number of new test facilities may enable affordable development, qualification, and utilization of a Nuclear Cryogenic Propulsion Stage (NCPS). Bead-loaded graphite fuel was utilized throughout the Rover/NERVA program, and coated graphite composite fuel (tested in the Nuclear Furnace) and cermet fuel both show potential for even higher performance than that demonstrated in the Rover/NERVA engine tests. A schematic of a potential NCPS engine is shown in Figure 1.

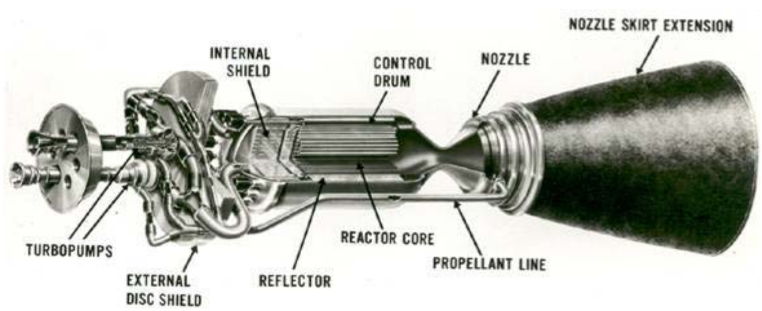

FIGURE 1: Schematic of an NCPS engine.

NASA's NCPS project was initiated in October, 2011, with the goal of assessing the affordability and viability of an NCPS. FY 2014 activities are focused on fabrication and test (non-nuclear) of both coated graphite composite fuel elements and cermet fuel elements. Additional activities include developing a pre-conceptual design of the NCPS stage and evaluating affordable strategies for NCPS development, qualification, and utilization. NCPS stage designs are focused on supporting human Mars missions. The NCPS is being designed to readily integrate with the Space Launch System (SLS). A wide range of strategies for enabling affordable NCPS development, qualification, and utilization should be considered. These include multiple test and demonstration strategies (both ground and in-space), multiple potential test sites, and multiple engine designs.

Two potential NCPS fuels are currently under consideration - coated graphite composite fuel and tungsten cermet fuel. During 2014 a representative, partial length (~16") coated graphite composite fuel element with prototypic depleted uranium loading is being fabricated at Oak Ridge National Laboratory (ORNL). In addition, a representative, partial length (~16") cermet fuel element with prototypic depleted uranium loading is being fabricated at Marshall Space Flight Center (MSFC). During the development process small samples (~3" length) will be tested in the Compact Fuel Element Environmental Tester (CFEET) at high temperature (~2800 K) in a hydrogen environment to help ensure that basic fuel design and manufacturing process are adequate and have been performed correctly. Once designs and processes have been developed, longer fuel element segments will be fabricated and tested in the Nuclear Thermal Rocket Element Environmental Simulator (NTREE) at high temperature (~2800 K) and in flowing hydrogen. A picture of CFEET is shown in Figure 2, and a picture of NTREES is shown in Figure 3.

Figure 2. CFEET

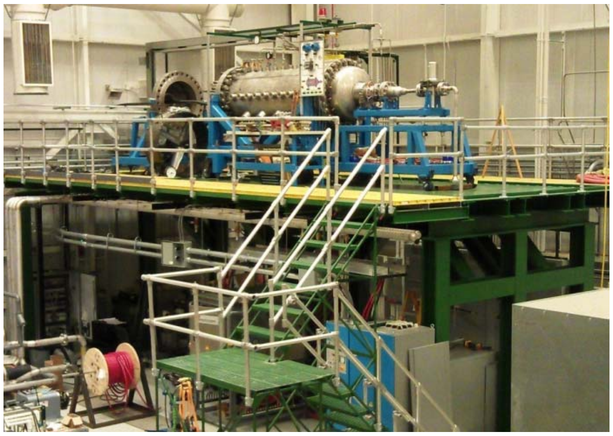

Figure 3. NTREES

References

[1] Koenig D. R. (1986) *Experience Gained from the Space Nuclear Rocket Program (Rover),* LA-10062-H, Los Alamos National Laboratory, Los Alamos, NM