NASA is interested in the development of nuclear thermal rocket (NTR) propulsion systems, subsystems, and components for use in future robotic science missions, as well as for human exploration missions to the Moon, Mars, and near-Earth asteroids. Besides providing high thrust and high specific impulse (Isp) primary propulsion, the basic NTR can also be configured for electrical power generation, bipropellant operation, ascent/descent and hybrid propulsion system applications.

In-Space Primary Propulsion

The high thrust and high Isp (~875–1000 s) NTR uses a fission reactor with U-235 fuel as its source of thermal energy production. During the various short primary propulsion maneuvers, large quantities of thermal power (100s of MW) are produced within the NTR and removed using LH2 propellant that is pumped through the engine’s reactor core. The superheated hydrogen gas is then exhausted out the engine’s nozzle to generate thrust.

Electrical Power Generation

The “Bimodal” NTR (BNTR) option produces both high thrust propulsion and electrical power for spacecraft operations (e.g., active refrigeration of cryogenic propellants, crew life support and high data rate Earth communications). During the “power generation phase,” the BNTR operates in an “idle mode” at greatly reduced power (~150 kW). Energy generated within the reactor is removed using a “closed” gas loop (He-Xe) and then routed to an efficient (~20%) dynamic power conversion system (e.g., Brayton turbine-alternator-compressor unit) to generate low-to-moderate levels (~10s to 100s of kW) of electricity.

Bipropellant Operation

In the “LOX-augmented” NTR (LANTR) option, gaseous oxygen is injected into the hot hydrogen exhaust downstream of the nozzle’s sonic throat. Here it undergoes “supersonic combustion” providing LANTR with an “after-burner” nozzle feature allowing a variable thrust and Isp capability that depends on the operating oxygen-to-hydrogen mixture ratio. Transition to LANTR operation provides a number of engine, vehicle and mission benefits that include thrust augmentation for small engines, reduced gravity losses, shortened burns, and increased bulk...
propellant density leading to smaller tanks and reduced stage sizes.

**Ascent and Descent Propulsion**

With its high thrust, power generation, and bipropellant (LH2 and LOX) operational capability, bimodal LANTR propulsion could allow interesting sample return missions from the frozen “water-ice” worlds of the outer Solar System. Samples can be collected and returned using LH2 and LOX propellants produced from in situ ice for ascent and return propulsion maneuvers.

**Hybrid Propulsion Operation**

In the “hybrid” BNTEP system, the electrical power output of the BNTR is increased to support the addition of electrical propulsion (EP) thrusters. The benefits of the BNTEP concept includes high thrust for quick departure and capture maneuvers, as well as sustained operations at higher Isp values (1000s of seconds) resulting in reduced propellant consumption and potential spacecraft mass reductions on both nearer term robotic and future human exploration missions.

Key technologies and concepts being investigated include:

- High temperature (~2500 – 3000 K), low-to-moderate burn-up carbon- and ceramic-metallic (cermet)-based nuclear fuels for NTR / BNTR propulsion
- Improved chemical vapor deposition (CVD) and coating techniques for carbon-based fuels that prevent cracking, fuel erosion via H₂ attack and fission product release
- Innovative concepts for non-nuclear, hot H₂ and He-Xe, simulation tests of BNTR fuel element designs
- Concepts for LANTR propulsion that differ from the “afterburner” nozzle concept discussed above
- Noninvasive, radiation hardened instruments for measuring temperature, pressure, propellant flow rate at H₂ temperatures in the ~2500–3000 K temperature range
- Concepts for autonomous connection and leak monitoring of “tank-to-tank” propellant lines

Supporting technologies and concepts include:

- Lightweight, high pressure turbopumps providing ~2.5–7 kg/s of LH2 propellant for 5–15 klbf NTR / BNTR engines
- Lightweight, high heat flux regeneratively-cooled nozzles
- Lightweight, high heat flux LOX “afterburner” nozzles and supersonic injectors for LANTR operation
- High temperature (~1300 K), long life, high reliability Brayton rotating units
- Lightweight, high temperature radiators for BNTR operation
- Lightweight, low power LH2 refrigeration system to eliminate propellant boiloff
- High strength metal alloys and/or composites for structures and LH2 and LOX tanks
- Radiation tolerant systems and materials

For long duration robotic science and future human exploration missions, increased safety and reliability are of extreme importance. It is also highly desirable that key technologies have applicability to a wide range of missions. For example, high temperature, high burn-up UO2 in tungsten metal “cermet” fuel can potentially be used for both NTR, BNTR, nuclear electric propulsion (NEP) and planetary surface power system applications. Lastly, technologies that can easily and efficiently be scaled in size (e.g., thrust level and electrical power output) and can be used in a host of applications (high degree of commonality) are highly desirable.