



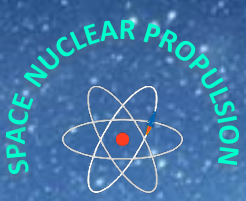
# **Recent Activities to Mature Nuclear Thermal Propulsion Technologies**

**AIAA Science and Technology (SciTech) Forum**

**Orlando, FL**

**10 January 2024**

**NASA George C. Marshall Space Flight Center  
Space Nuclear Propulsion (SNP) Project  
Dr. Kurt Polzin, SNP Project Chief Engineer**



# Activities



- **Government Technology Maturation**
- **Reactor Design and Development Contract Efforts**
- **Demonstration Rocket for Agile Cislunar Operation (DRACO)**
- **Evaluation and Planning for Future Test Facilities**

# Government Technology Maturation

- **Problem Statement – Develop and prove out a robust nuclear fuel element that could operate at extremely high temperatures ( $\geq 2700$  K propellant temps) AND in a hot, reactive  $H_2$  environment**

- **Fuel Development**

- Cermet (ceramic-metallic composite fuel) – Rover/NERVA history
- Cermec (ceramic-ceramic composite fuel)
- Solid-Solution Carbide – Soviet TOPAZ history

**Fuel development crawl-walk-run approach**

- Particle and Coating Development
- Fuel Wafer and Element Fabrication
- Moderator Development
- Tubing and Insulator
- Non-nuclear test and evaluation
- In-Reactor irradiation testing

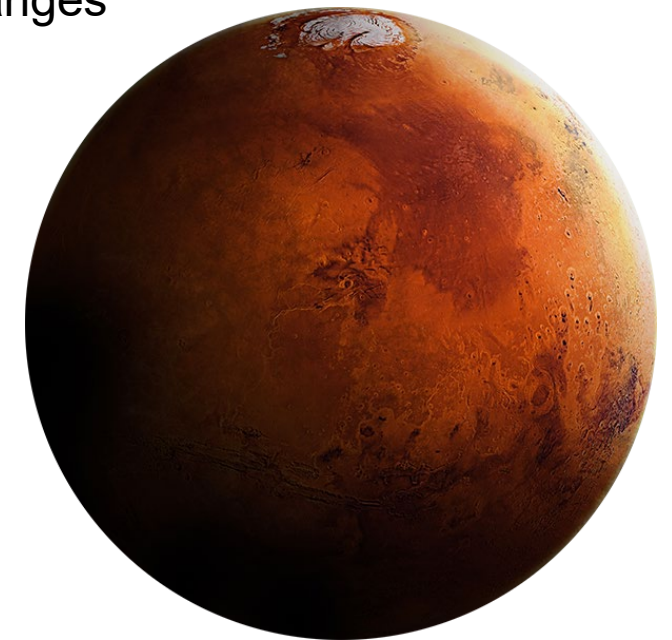


- **Three Phase 1 contracts announced in July 2021 to develop NTP reactor and engine designs**
  - **Ultra-Safe Nuclear Technologies (USNC-Tech)**
  - **General Atomics (GA)**
  - **BWX Technologies (BWXT)**
  
- **Two Phase 1 Extension contracts awarded in mid-2023 to continue design refinement and mature critical technologies through manufacturing demonstrations and testing**
  - **Ultra-Safe Nuclear Technologies (USNC-Tech)**
  - **General Atomics (GA)**
  
  - **BWXT is part of the DRACO team – Not continued on a SNP Phase 1 Extension contract**

# Reactor Design Requirements and Targets

## - Approx Needs for an Opposition-Class Human Mars Mission -

- **Reactor Temperature:**
  - Hydrogen outlet temperature Goal  $\geq 2850$  K, Threshold  $\geq 2700$  K
    - Corresponds to specific impulse ( $I_{sp}$ ) = 900 sec
    - A fuel temperature of approximately 2900 K or greater needed to achieve the required hydrogen outlet temperature
- **Thrust:**
  - 12,500 lb<sub>f</sub> with extensibility to 25,000 lb<sub>f</sub> without major design changes
- **Mass of reactor components:**
  - Goal  $\leq 2000$  kg, Threshold  $\leq 3500$  kg
- **Lifetime cumulative burn duration:**
  - Threshold  $\geq 2$  hours
- **Number of restarts:**
  - Goal  $\geq 8$ , Threshold  $\geq 5$
- **Desired Attributes:**
  - Use of high assay low-enriched uranium (i.e.,  $< 20\%$  enrichment)
  - Extensibility to  $\geq 1000$  sec  $I_{sp}$



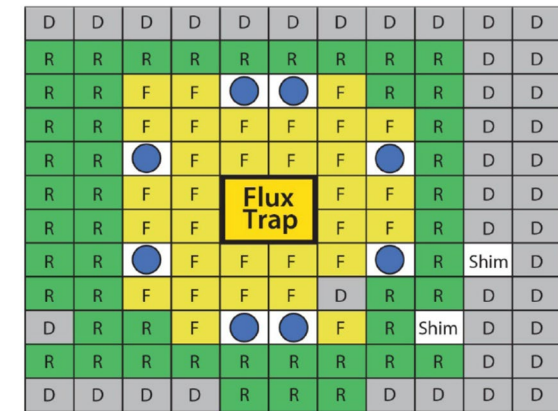
- **In-orbit flight demonstration of a nuclear thermal rocket engine in 2027**
- **Foundational Principle – DRACO will launch without there having been an integrated ground test of the engine system**
- **Partnership between DARPA and NASA**
- **Other Government Participants**
  - U.S. Space Force
  - DOE/NNSA
- **Prime Contractor: Lockheed Martin**
- **Reactor Subcontractor: BWX Technologies (BWXT)**



- **Problem Statement – What upgraded or new test facilities are needed to further mature NTP systems and reduce risk to the level where it has sufficient, demonstrated performance and lifetime for human and robotic science missions**

- **In-Reactor irradiation testing**

- **Desire: Investigate NTP fuel elements at prototypic irradiation conditions**
- **Problem: No reactor to properly replicate in-core NTP conditions**
- **Solution: Subscale Maturation of Advanced Reactor Technologies (SMART)<sup>1</sup>**
  - **Demonstrate fuel before investment in full-up reactor/engine build**
  - **Full length operation with post-irradiation evaluation/margin assessment**



Legend: D: plug, R: Be reflector, Flux trap (experiment), F: fuel, ● control rod

- **Full Engine Test**

- **Support integrated reactor/engine development testing to develop understanding of integrated system issues and con-ops**
- **Measure performance, capture/scrub exhaust to ensure no release of nuclear products**



<sup>1</sup> Options for Subscale Maturation of Advanced Reactor Technologies Testing for Nuclear Thermal Propulsion, D.E. Burns et al., US DOE OSTI Technical Report INL/RPT-22-65557-Rev000, 2022. DOI: [10.2172/1844192](https://doi.org/10.2172/1844192)

