Request for Information

DARPA-SN-25-21

Nuclear Thermal Rocket Propulsion

Defense Advanced Research Projects Agency

Tactical Technology Office

Responses due 20 January 2025 by 4:00 PM Eastern Time (ET).

This Request for Information (RFI) from the Defense Advanced Research Projects Agency (DARPA)'s Tactical Technology Office (TTO) seeks to identify sources capable of providing innovative and revolutionary solutions for space qualified nuclear thermal rocket propulsion engine design, development, modeling and simulation, engine integration, autonomous engine and reactor control, engine instrumentation, and engine system integration. Engine system integration includes consideration of the required safety analysis needed to obtain nuclear launch authorization from the Department of Defense (DoD).

DARPA, in partnership with National Aeronautics and Space Administration (NASA), is currently developing a space qualified nuclear thermal rocket engine (NTRE) under the Demonstration Rocket for Agile Cislunar Operations (DRACO) program. The DRACO NTRE consists of a first-of-a-kind, compact, ultra-high temperature, high-assay low-enriched uranium (HALEU) fueled, flow-through nuclear reactor; engine control electronics; autonomous control software for the reactor and engine; and interfaces (structural, thermal, etc.) to enable integration into a spacecraft for demonstration in a nuclear safe orbit.

The DRACO demonstration will use pressure-fed gaseous helium as a propellant to reduce system complexity; however, the DRACO reactor is designed for operation with liquid hydrogen propellant to allow extensibility to future operational systems. The DRACO NTRE will include features that ensure the system remains sub-critical across a broad range of environments and handling conditions until it reaches a nuclear safe orbit. DARPA intends for this RFI to leverage the current DRACO reactor design and development effort.

To enhance transition to future missions, the integrated engine must be usable by a wide range of spacecraft providers. For example, if proprietary algorithms are identified for reactor control, interface definitions or application programming interfaces (API) must be provided to enable an outside party to control the DRACO NTRE.

Responses to this RFI may be used to inform and explore future programs that will seek to build and test space qualified NTREs that are available for use by a wide range of U.S. spacecraft manufacturers. The Government will comply with data rights assertions for responses to this RFI.

BACKGROUND

DoD Applications

The dramatic improvement in propulsion efficiency offered by nuclear thermal propulsion potentially enables development of a true space logistics network and supports the emerging

U.S. Space Force evolution to a truly responsive capability.

"Military history is replete with examples of combat forces employing maneuver warfare to move quickly, sidestep defenses, achieve surprise, reorient quickly in the battlespace, and hold centers of gravity at risk to achieve victory. As in domains of human endeavor on Earth, the advantage in space will go to the force capable of sustaining maneuver on a scale previously unknown to a domain dominated thus far by Keplerian and Newtonian thinking.

"The current paradigm of positional space operations (PSO) must naturally give way to dynamic space operations (DSO), where spaceborne combat forces are no longer static and predictable. Moreover, a dynamic and dominant force in space will only be as effective as its ability to sustain space maneuver—particularly in the face of an adversary. Only then can that force maintain initiative, achieve surprise, and outmaneuver an adversary in the space domain to achieve victory.

"Traditional Earth-facing military missions now require space-facing, in-domain military missions to expand reach, keep watch, deter adversaries, project effects, and protect national and international interests. Keplerian "positional" thinking that treats powered movement across orbits as a rare and costly event is no longer adequate. The force capable of sustaining maneuver will gain and maintain the advantage over time; indeed, competitors such as China are already demonstrating many of the technologies required to sustain maneuver and act dynamically in space."

Reference:
Dynamic Space Operations: The New Sustained Maneuver Imperative,
John Shaw, Daniel Bourque, and Marcus Shaw,
Aether: A Journal of Strategic Airpower and Spacepower, Winter 2023

NASA Applications

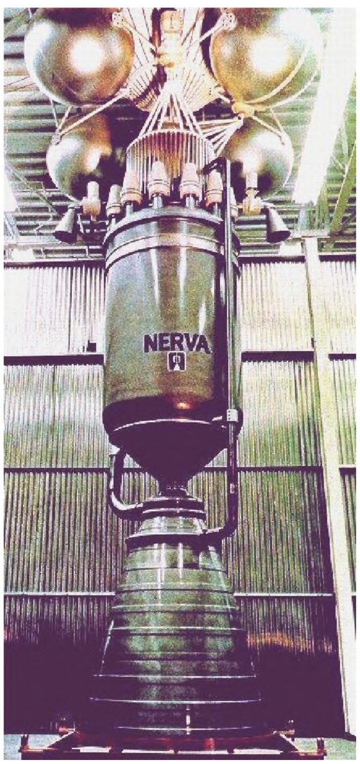
The human exploration of Mars is a daunting undertaking. Safely transporting astronauts to and from Mars will require advances in many areas to develop spacecraft that are up to the challenge. Propulsion systems are one such area. Advanced nuclear propulsion systems (alone or in combination with chemical propulsion systems) have the potential to substantially reduce trip time compared to fully non-nuclear approaches. Shorter trip time reduces risks associated with space radiation, zero gravity, launch and orbital assembly requirements, and many other aspects of long-duration space missions.

In addition to potential crewed missions to Mars, nuclear thermal propulsion offers potentially game-changing capabilities for deep space science missions, such as cutting years off transit times for planetary exploration, and widening launch windows based on orbital alignment.

Technical Background

A nuclear thermal propulsion (NTP) system is conceptually similar to a chemical propulsion system, where the combustion chamber has been replaced by a nuclear reactor to heat the propellant. Figure 1 depicts the basic components of an NTP system, which consists of the NTRE and a propellant storage and management subsystem. The NTRE includes a reactor subsystem consisting of the core, control drums and their actuators, reflector, shield, and pressure shell. The remainder of the NTRE consists of propellant feed (including associated valves and pipes), the nozzle, and the engine control system (including sensors and actuators). The propellant storage and feed components are part of the propellant storage and management subsystem – and while not part of this RFI, these components have physical and functional interfaces to the NTRE.

The propellant is directly heated by the nuclear reactor and then accelerates out the nozzle to generate thrust. This is in contrast to generating heat with combustion, as is the case in a chemical rocket. The control drums, which absorb neutrons, are situated around the outer annulus of the reactor core within the reflector. The drums are used to turn the reactor "on" and "off" and to increase or decrease reactor power. The turbopumps and/or pressure regulation are used to control the mass flow rate and pressure of the propellant.



NERVA Nuclear Thermal Rocket Prototype

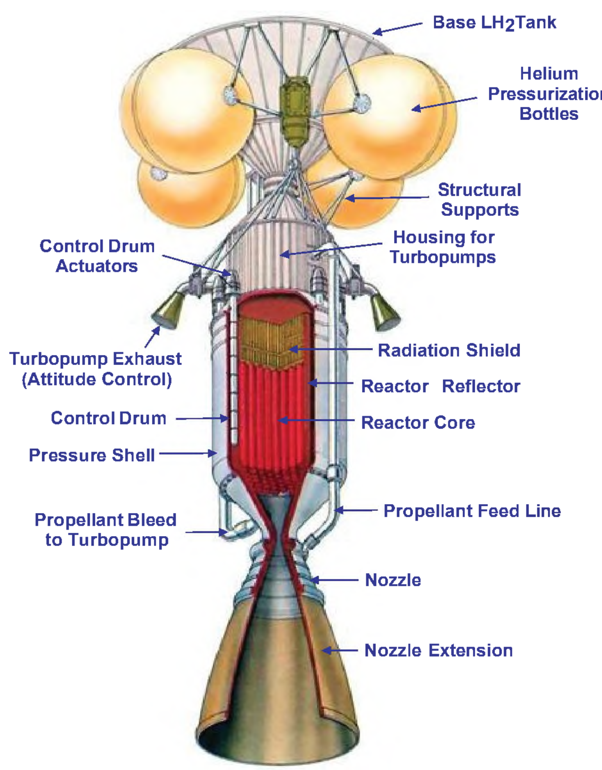


FIGURE 1: Photo of a nuclear thermal propulsion (NTP) system from the Rover/Nuclear Engine for Rocket Vehicle Applications programs (left) and a cutaway schematic with labels (right). SOURCE: M. Houts, et al., "NASA's Nuclear Thermal Propulsion Project," NASA Marshall Space Flight Center, 2018, ntrs.nasa.gov/citations/20180006514.

Although the Rover/Nuclear Engine for Rocket Vehicle Applications (NERVA) programs demonstrated proof of concept for an NTP system, the programs were cancelled before program goals were achieved due to a shift in funding priorities. Consequently, no complete NTP system has been assembled and tested in its flight configuration or flown in space. Other NTP programs have been carried out since Rover/NERVA, but none have built any additional reactors or engines.

The Argonne National Laboratory (ANL) and General Electric GE-710 programs, which developed concepts for fast-spectrum ceramic-metal (cermet) fuels for nuclear-powered aircraft and NTP concepts that utilized highly enriched uranium (HEU) cermet fuels, such as tungsten uranium dioxide (WUO_2), were manufactured and tested. The Space Nuclear Thermal Propulsion (SNTP) program was primarily a fuel development effort for the particle bed reactor that tested the use of coated HEU particles for NTP, and it identified many challenges. The SNTP program also conducted moderator block experiments using polyethylene moderator material, and it produced hardware for nonnuclear component engine testing. Ground testing of complete SNTP reactors was planned, but not implemented, before program termination.

Source: *National Academies of Sciences, Engineering, and Medicine. 2021. Space Nuclear Propulsion for Human Mars Exploration. Washington, DC: The National Academies Press. https://doi.org/10.17226/25977.*

ELIGIBILITY

DARPA invites white paper submissions from all those engaged in related research activities and appreciates responses from all capable and qualified sources, including, but not limited to, universities, university-affiliated research centers (UARCS), not for profit research centers, Federally Funded Research and Development Centers (FFRDCs), private or public companies, individuals, and Government-sponsored research laboratories.

REQUESTED INFORMATION

DARPA is interested in responses that provide information and insights into the responders' experience and capabilities related to the following key challenges.

- **Space qualified NTRE design, development, modeling, and simulation leveraging the existing DRACO reactor development effort**
- **Modeling, simulation, design, development, and implementation of autonomous engine and reactor control during startup, full thrust, and cooldown operations on orbit**
- **Engine instrumentation sufficient to control the reactor and engine, collect data required to validate current reactor and NTRE performance models, and collect diagnostic data sufficient to detect and diagnose potential anomalies or failures during on-orbit performance**
- **Nuclear safety and space system and launch safety for all phases of the mission to include reactor transport from the manufacturing facility, launch site integration, launch vehicle mate, launch, on-orbit operations, and post-mission disposal**
- **Space systems engineering and system integration, including development of a non-proprietary interface with a host spacecraft**
- **Approaches and facilities for space qualification testing of a NTRE and associated components and subsystems**

SUBMISSION FORMAT

This announcement contains all information required to submit a response. No additional forms, kits, or other materials are needed.

Submissions of white papers in response to the RFI should be concise. Responders should submit a single integrated response addressing the areas described above. DARPA will only review responses submitted in a Microsoft Word (.doc or .docx) file or unprotected Adobe Acrobat (.pdf) file. Each response is limited to not more than 10 pages using 12- point font and 1-inch margins on 8.5-inch by 11-inch paper. Effective responses that can be provided in fewer than 5 pages are encouraged.

Cover Sheet (1 page, not included in page count): Provide the following information:

a. Response Title
b. Technical point of contact name, organization, telephone number and email address
c. Indicate classification level (Unclassified, Unclassified/CUI, Secret Collateral)

Technical Description (no more than 10 pages). Graphics within the technical descriptions are encouraged to the extent that they aid in succinctly describing the concepts.

Bibliography/References (no more than 2 pages, not included in page count)

Graphic Overview Slide (1 page, optional, not included in page count): If desired, include a single PowerPoint slide that graphically depicts the main ideas of the response. The contact information should include the respondent's technical and/or administrative points of contact (names, addresses, phone numbers, fax numbers, and e-mail addresses) to enable potential clarification discussions.

All technical and administrative correspondence and questions regarding this announcement and how to respond to this RFI should be sent to DARPA-SN-25-21@darpa.mil . E-mails pertaining to this RFI that are sent directly to individual DARPA program managers will not receive a response. No telephone inquiries will be accepted.

DISCLAIMERS AND IMPORTANT NOTES

This is an RFI issued solely for information and program planning purposes; this RFI does not constitute a formal solicitation for proposals or proposal abstracts. In accordance with FAR 15.201(e), responses to this notice are not offers and cannot be accepted by the Government to form a binding contract. Submission of a response is strictly voluntary and is not required to propose to subsequent Broad Agency Announcements (if any) or research solicitations (if any) on this topic. No solicitation exists; therefore, do not request a copy of the solicitation. If a solicitation is released, it will be synopsized on the SAM.gov website. It is the responsibility of any potential offerors/bidders to monitor this site for the release of any solicitation or synopsis.

DARPA will not provide reimbursement for costs incurred in responding to this RFI or participating in any subsequent workshop pertaining to this RFI.

If a response is classified, it should be coordinated with DARPA prior to submission. Responders wishing to provide a classified response should send an e-mail to the Special Notice (SN) mailbox as soon as possible with the subject line "Classified Coordination Requested" to allow time for proper coordination. NO CLASSIFIED INFORMATION SHOULD BE INCLUDED IN THE RFI RESPONSE SENT TO DARPA-SN-25-21@darpa.mil.

To the maximum extent possible, please submit non-proprietary information. If proprietary information is submitted, it must be appropriately and specifically marked. It is the submitter's responsibility to clearly define to the Government what is considered proprietary data. Any proprietary information should clearly be labeled as "Proprietary." DARPA will not publicly disclose proprietary information obtained as a result of the RFI.

To the full extent that it is protected pursuant to the Freedom of Information Act and other laws and regulations, information identified by a respondent as "Proprietary" will be appropriately controlled. Submissions may be reviewed by Government personnel and support contractors bound by appropriate non-disclosure agreements. Responses to this RFI will not be returned.

Respondents are advised that DARPA is under no obligation to acknowledge receipt of the information received or provide feedback to respondents with respect to any information submitted under this RFI. Responses to this RFI do not bind DARPA to any further actions.

POINT OF CONTACT

DARPA/TTO
DARPA-SN-25-21@darpa.mil