In-Pile Steady State Extreme Temperature Experiment (INSET)

NETS 2021

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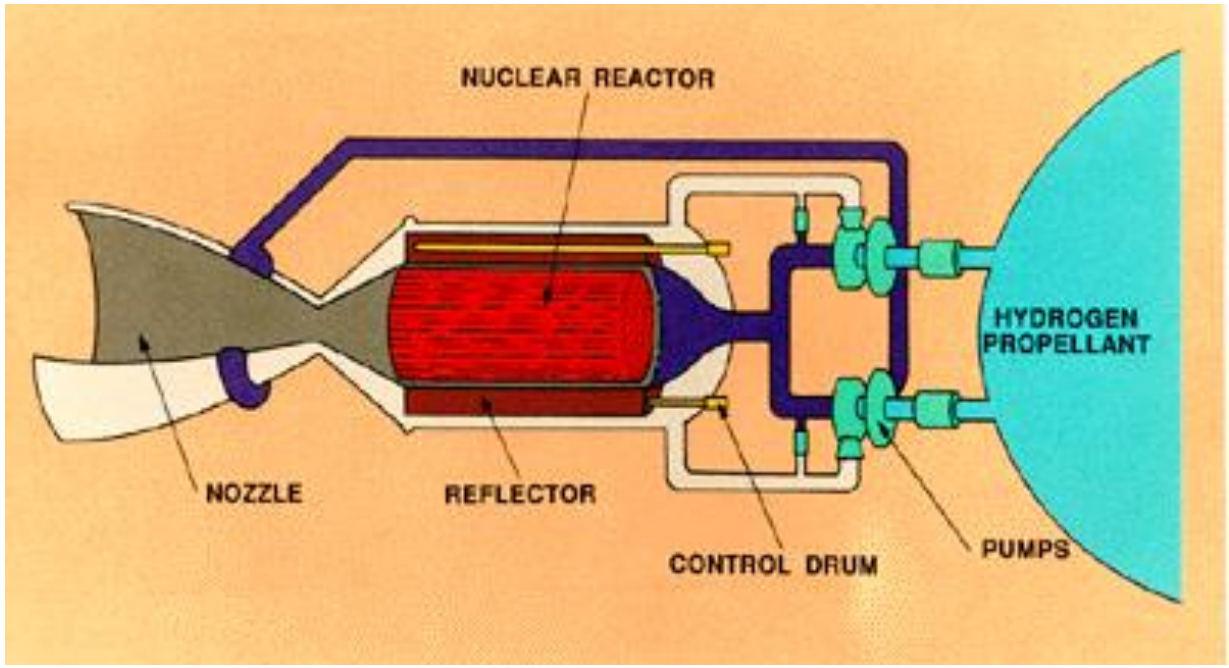
NTP Environment

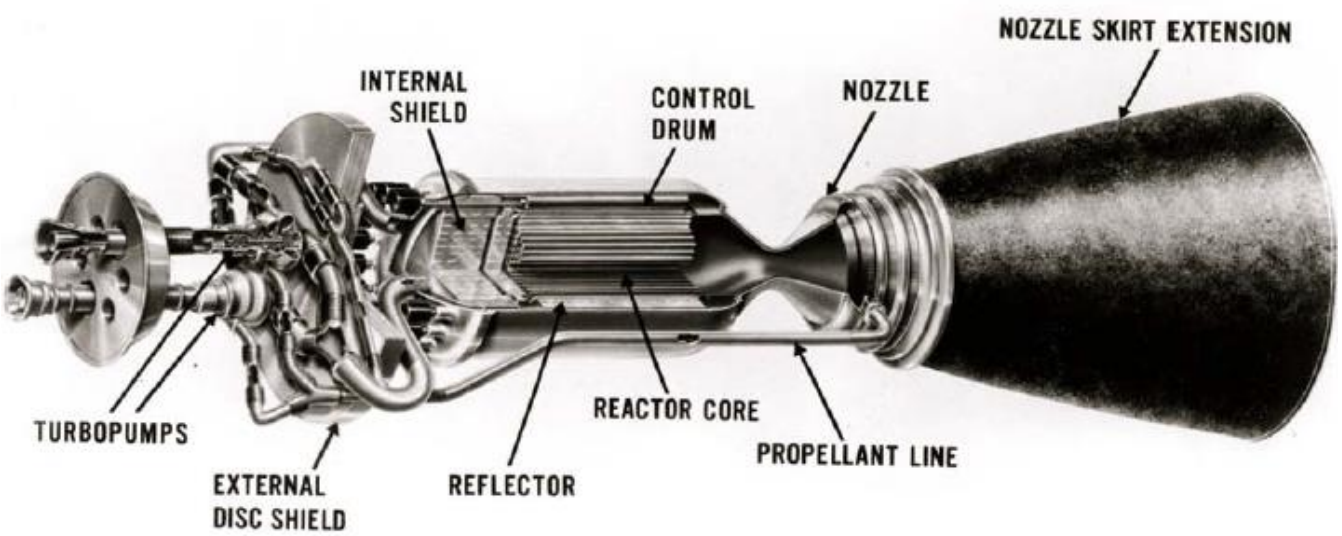


- Temperature < 2700 K
- Fluence < 10^{17} n/cm^2
- Hydrogen < 120 kg/s (10s kg/s)

Image: http://www.zamandayolculuk.com/nuclearthermal.htm [1], [2]

NTP Experimental History

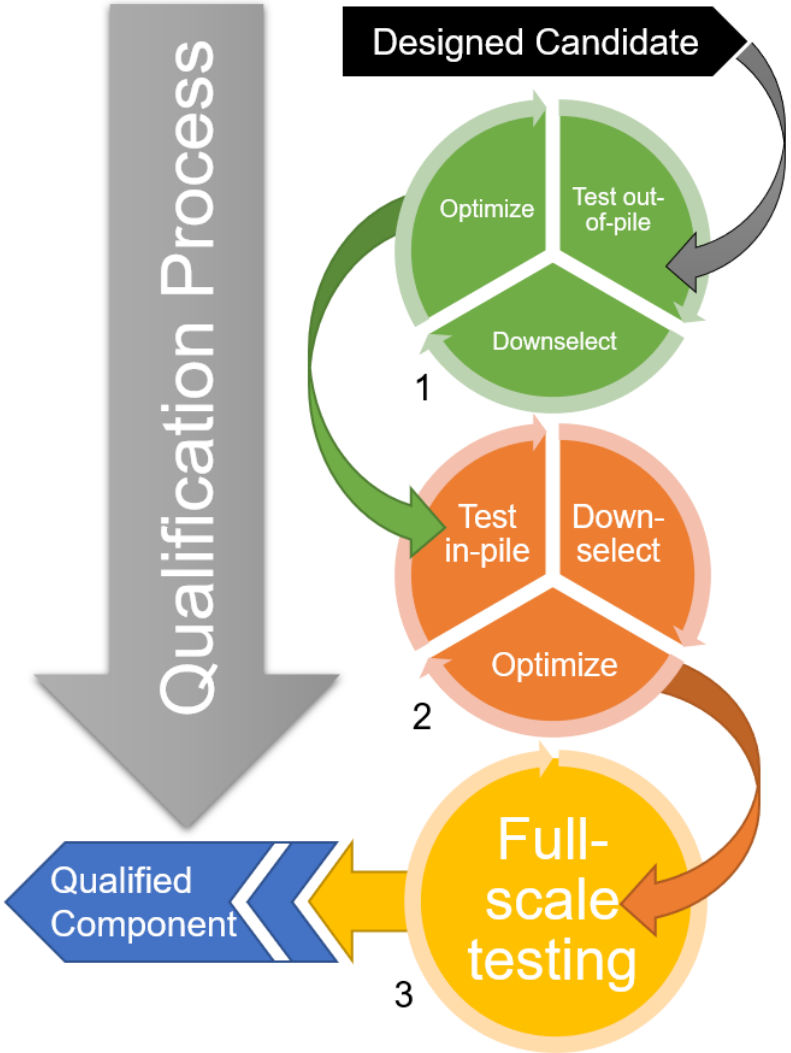
- Rover Program (1950s-1970s)
  - KIWI
  - NERVA
  - PHOEBUS
  - RIFT



- Space NTP Program (1980s-1990s)
- Space Nuclear Propulsion Project (Present)

Image: [1] [1], [3], [4]

INSET Motivation & Testing Strategy



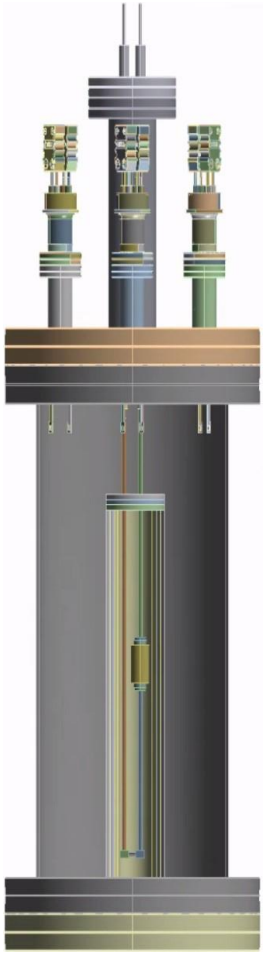
In-Pile **S**teady State **E**xtreme **T**emperature Experiment

- Cost effective
  - Prototyping
- Separate effects

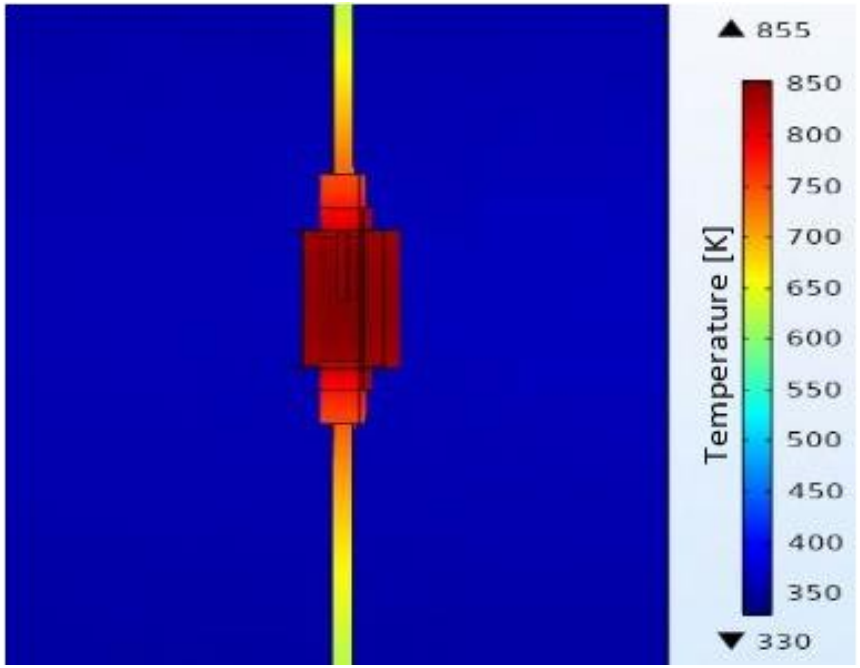
Image: [5]

INSET Design

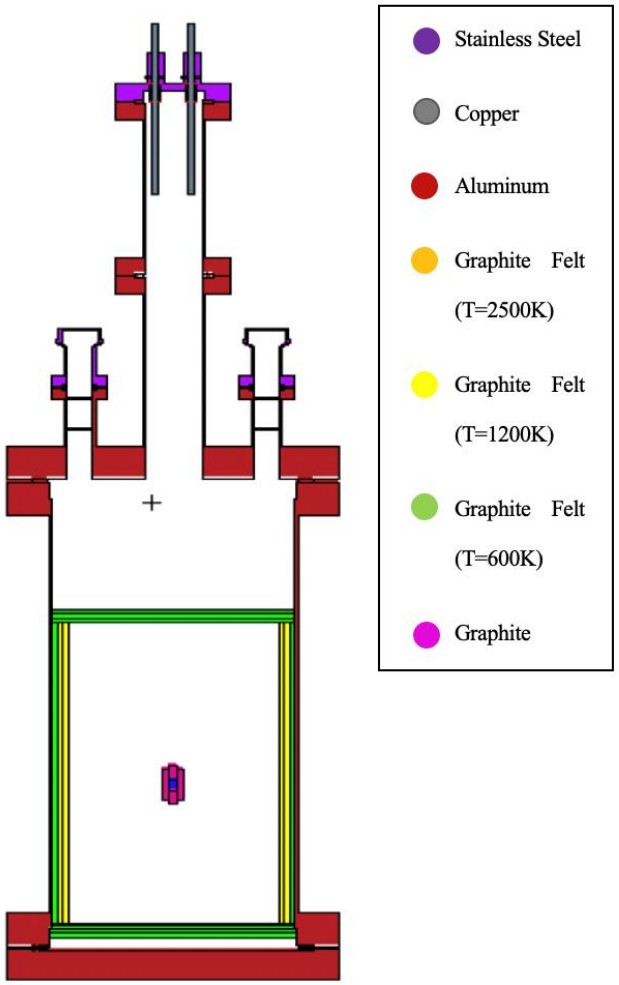
- Activation mitigation
- High temperature circuit
- DC heater
- Thermocouples
- Vacuum
- Instrumentation flexibility
- Cost inexpensive
- Reactor compatibility



INSET Predictability



Thermal



Neutronic

Images: [5]

OSURR and INSET Experiment

- OSURR
  - NSUF reactor
  - 9.5 inch dry tube
  - 10^{12} n/cm^2/s
    - 74% thermal
  - 450 kW

[6]

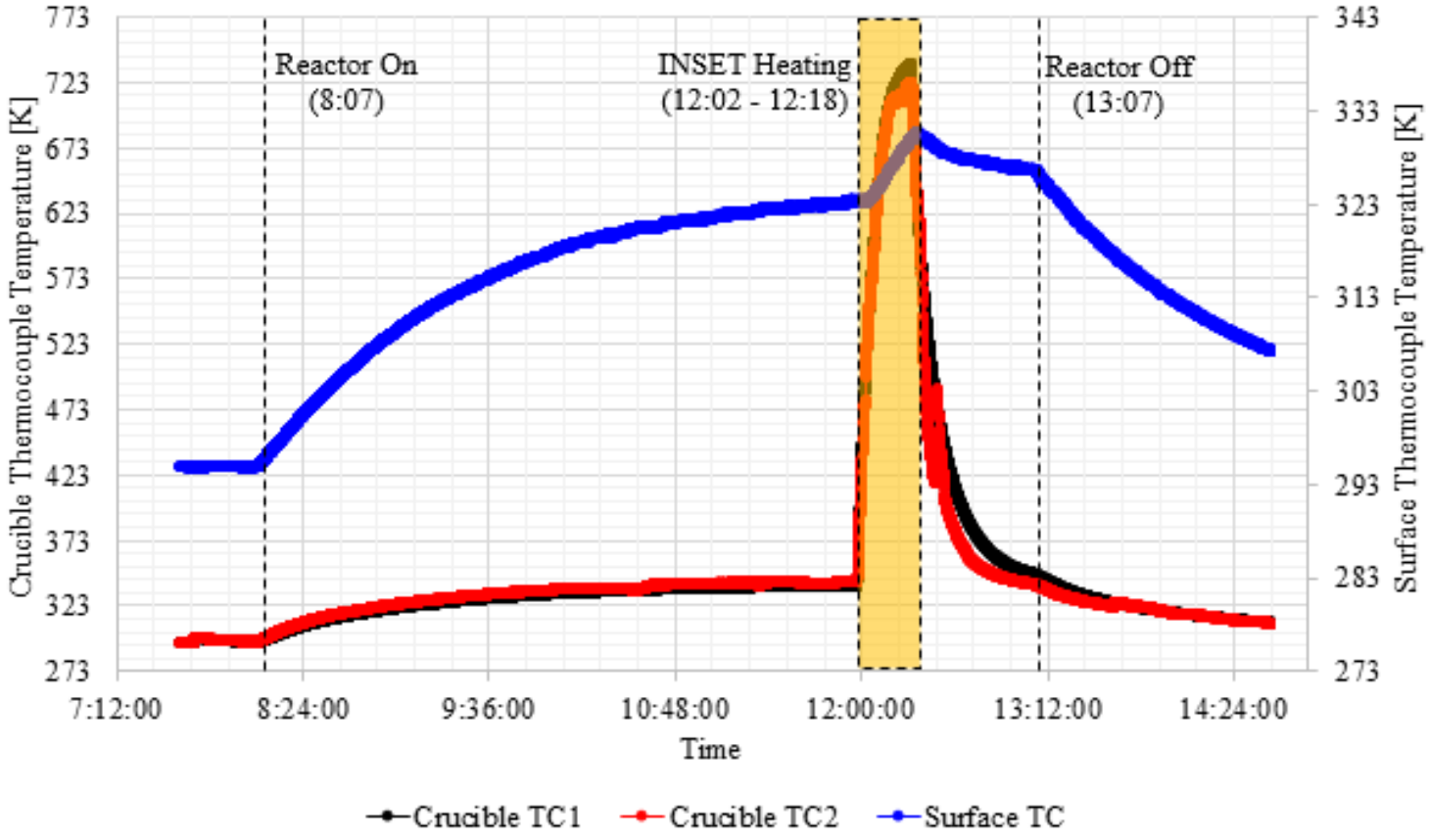
OSURR Nov 2019 INSET Experiment

Nov 2019

Cermet cladding investigation

- Temperature: < 1070 K centerline
  15 minutes
- Fluence: 10^{17} n/cm^2
  7 hours

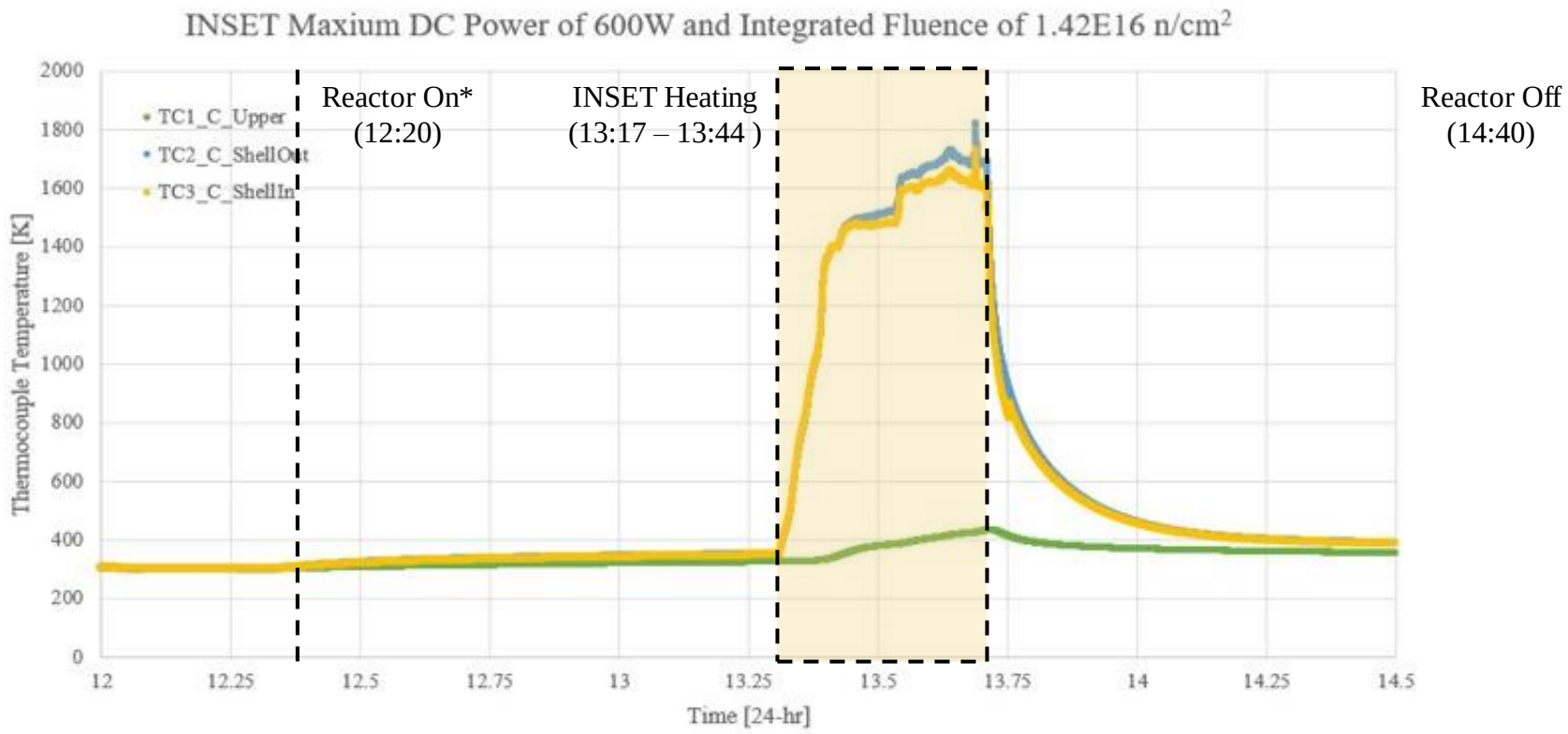
Results of OSURR Nov 2019



Using 40 W DC

[5]

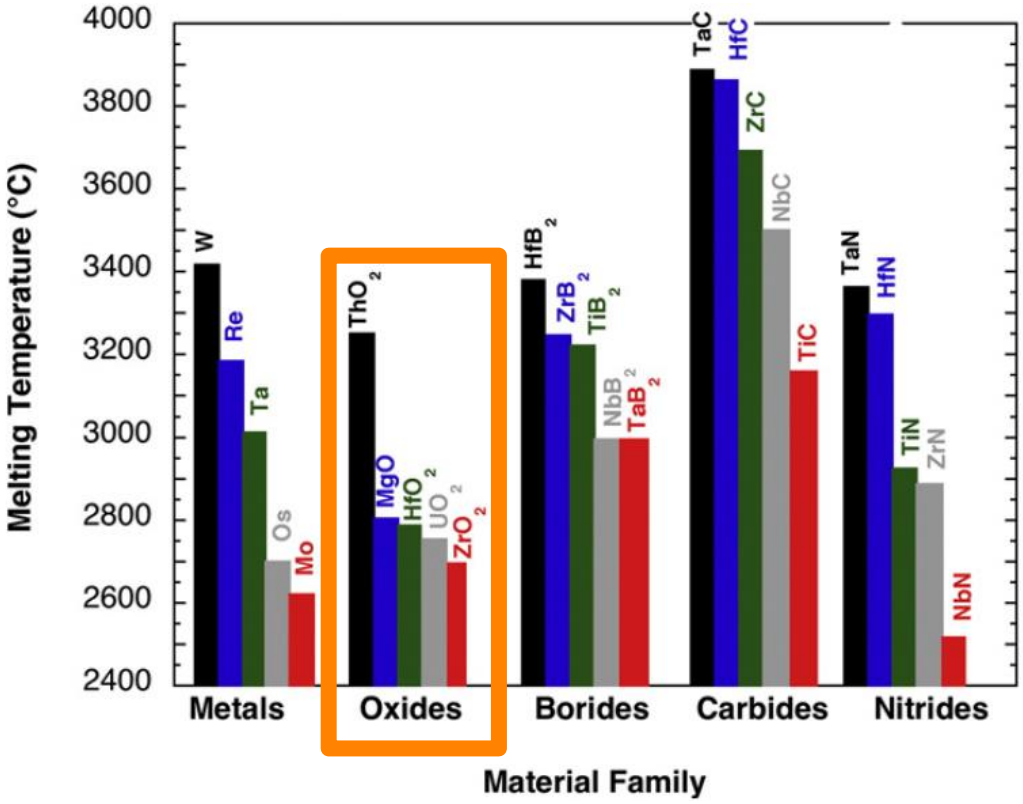
Latest INSET Results (March 2021)



* Reactor was re-started at this point. Earlier in the day the reactor was shut down to investigate performance.

Future Work

- Instrumentation tests
  - May 2021
- Higher temperature
- Hydrogen



Graph: [7]

Conclusions

- INSET has been proven to sustain 1800 K both in-pile and out-of-pile
  - 2700 K capability expected Q3 2021

- INSET serves as a high temperature, steady state, in-pile (or out-of-pile) testbed for NTP candidate materials and instrumentation
  - Down select candidates for more efficient integrated testing

Questions

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References

[1] S. Borowski, D. Mccurdy, and T. Packard, "Nuclear Thermal Propulsion (NTP): A Proven Growth Technology for Human NEO / Mars Exploration Missions," IEEE Aerospace Conference, 2012. E-18081.

[2] D. Koenig, "Experience Gained from the Space Nuclear Rocket Program (ROVER)," Los Alamos National Laboratory, 1986. LA-10062-H.

[3] J. Finseth, "Overview of Rover Engine Test," NASA Marshall Space Flight Center, 1991. NASA-CR-184270.

[4] J. Reuter, J. Sheehy, and A. Calomino, "Nuclear Technology Portfolio Briefing," NASA, 2020.

[5] T. Steiner, E. Hutchins, and R. Howard, “Steady-State In-Pile Nuclear Thermal Propulsion Experimental Testbed Initial Demonstration at The Ohio State University Research Reactor,” Nuclear Technology. 2021.

[6] National Science User Facilities. Department of Energy. 2021. https://nsuf.inl.gov/Page/reactors

[7] W. Fahrenholtz and G. Hilmas, “Ultra-high temperature ceramics: Materials for extreme environments,” Scripta Materialia 129 94–99. 2016.