Space Nuclear Operations Deep Dives

• Follow on activities to work reported in NASA/CR-2020-220569 which was presented as a full paper in this conference and was included in the NETS 2020 Special Issue of Nuclear Technology

• Choose specific missions and activities to evaluate the operational complexities of reactors in more detailed and specific scenarios
  • #1: Provide electrical and thermal power to a Lunar ISRU outpost
    • Full report available @ NTRS (ntrs.nasa.gov) report number NASA/CR–2020–5009307
  • #2: Nuclear thermal propulsion to and return Mars for both cargo and crewed missions
    • Full report available @ NTRS (ntrs.nasa.gov) report number NASA/CR–2021–0000387
Lunar/ISRU Operations Deep Dive: Objective & Scenario

- Objective: evaluate the operational complexities of reactors providing electrical and thermal power to a growing Lunar ISRU outpost.
- Describe: reactor considerations for a growing presence, notional only, none are designed
  - First, an ISRU demonstration project (100 to 200 kW, batteries, solar panels, or a radioisotope thermoelectric generator – no reactor needed at this low power level)
  - Second, an ISRU pilot plant project (10 kW, Kilopower-like, HEU or HALEU metal fuel, simple, self-regulating, Stirling engines power conversion, autonomous control monitored from Earth, remaining on lander, minimal setup, no maintenance, etc.)
  - Third, a small-scale initial ISRU production plant (50 to 100 kW, Kilopower-like, HEU or HALEU metal or ceramic fuel, simple, self-regulating, Stirling engines power conversion, autonomous control monitored from Earth, deployed from or remaining on lander, minimal maintenance, human habitat, etc.)
  - Fourth, followed by a full-scale ISRU commercial operation (500 to 2,000 kW, HEU or HALEU fuel, pumped liquid metal primary loop, gas secondary loop core, Brayton cycle power conversion, control monitored locally and from Earth, deployed from lander, human rating is required, maintenance as needed and possible, etc.)
Lunar/ISRU Operations Deep Dive: Key Conclusions

- Full radiation fields surrounding these reactors will have to be analyzed during the design of the system and be mapped once the reactors are on the surface and operating.

- For any reactor system that may need to be human rated, it is important to consider not only the planned maintenance, but also any projected emergency maintenance.

- Wide array of maintenance scenarios for these reactors may exist, from no planned maintenance on the pilot plant reactor to complicated maintenance scenarios, both planned and unplanned.

- Lunar surface impacts are expected to be minimal:
  - Very low potential for nuclear accidents to spread contamination over a wider area.
  - Probability of accidents causing interference with other Lunar activities should be minimized.

- Post-operational decommissioning and disposal needs to be considered:
  - Aim to not interfere with other planned activities.
  - Exclusion areas should be established.
  - Initial pilot plant reactor exclusion area for the can be quite small.
• Reactor **system setup and startup** will need to be fully considered during the system design process
  - Inherent simplicity of self-regulating reactors during the lunar ISRU outpost establishment provides reactor and mission designers understanding and confidence to move to larger and complicated systems

• **Restart** of reactors following shutdowns also needs consideration
  - Crucial if reactor providing life support and other critical functions
  - Consider how fast a reactor may need to be restarted should it experience an operational anomaly

• Reactors will need to utilize considerable amounts of **autonomous control**

• Astronauts involved on these missions need to be **able to SCRAM** the reactors locally

• Having one local crew member constantly monitoring a reactor control board is **impractical**

• Since there will be a time delay between the Earth-based mission control room, those who are monitoring the mission health will only be able to send **simple commands** to reactors