Nuclear and Emerging Technologies for Space
Sponsored by Oak Ridge National Laboratory, April 26th-30th, 2021.
Available online at https://nets2021.ornl.gov

Safeguards And Proliferation Protections (SAPPs): A Way to Protect & Defend U.S. HEU-Fueled Space Power & Propulsion Reactors

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Abstract. This presentation highlights a way to protect the consideration of High-Enriched Uranium (HEU) for U.S. space reactors by means of protective functions that Safeguards And Proliferation Protections (SAPPs), proposed herein, can provide – pending comprehensive analysis of the important factors, and their pros & cons, for each specific space reactor application being seriously considered for development & use. Efforts to prescribe High Assay Low-Enriched Uranium (HALEU) for U.S. space reactors have advanced recently; largely driven – justifiably – by proliferation concerns. There are, however, valid arguments for retaining HEU as an option for U.S. space reactors. They include: 1) Reactor system and space vehicle size and mass, and associated trip times, are less for HEU-fueled systems; 2) Launch, nuclear, and astronaut safety are generally easier to ensure for HEU-fueled systems; and 3) Schedule (particularly development schedule), together with fuel availability and system lifetime/reliability, are currently more certain for HEU. Potential diversion of HEU, as a result of a launch or reentry accident away from U.S. territory, is a low probability event. And, future launches involving on-board reactors, particularly to the Moon or Mars, are likely to be rare events receiving global attention. Based on the above, it is important to retain HEU as an option for consideration by mission managers and system designers - if possible. SAPPs, akin to Permissive Action Links (PALs) for U.S. nuclear weapons, can serve to provide safeguards protection against HEU diversion/proliferation, should temporary loss of physical control of an HEU-fueled space reactor occur. This would allow U.S. HEU-fueled space reactor systems to be considered as a normal matter of course, while the benefits and risks of HALEU & HEU are seriously assessed & weighed for the application at hand. This process can proceed so long as SAPPs can be functionally established judiciously, designed creatively, and incorporated carefully, as needed, throughout mission/system development. Generic functions of SAPPs, for example, might be to: 1) Ensure the system will only function when properly called upon; 2) Ensure the system will not function, unless expected/specified actions and/or external environmental conditions are satisfied; 3) Ensure unimpeded access to the reactor internals/fuel is precluded unless specified external actions occur, as/when expected; 4) Ensure unimpeded access to the reactor internals/fuel is precluded if unexpected/unspecified external actions/conditions occur; and 5) Ensure the system and its fuel is protected against potential diversion. The specifics of such SAPPs would require protection against disclosure, since such knowledge would serve as a cookbook for their defeat. The objective here is to stimulate further discussions on all these topics among policy makers, system designers, mission managers, PALs designers, and program managers in appropriate settings.

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Purpose

To retain HEU as a viable option for consideration by mission managers & system designers, pending comprehensive assessment of key factors, and their pros & cons, associated with the design, development, validation, and use of HALEU vs HEU fuel for each specific application of a U.S. space reactor being seriously considered for development and use.

[Note: SAPPs serve as a concept, akin to Permissive Action Links (PALs); offering a measure of safeguards protection for U.S. HEU-fueled space reactors -- allowing consideration of HEU-fueled systems to proceed, while assessment of HALEU vs HEU is conducted & ultimate decision is made. See attached revised LT Abstract for generic functions of SAPPs]

Background

- SP-100 {the Program recognized that safeguard protections, akin to PALs, (e.g., SAPPs) would have to be integrated before freezing the system design for flight hardware build}
- Since ~2016, focus has shifted from HEU to HALEU, largely driven – justifiably – by proliferation concerns {exception was HEU-fueled Kilopower concept & KRUSTY test in 2018}
- NSPM-20, Aug 2019 {tiered launch approval; with HEU-fueled reactor systems requiring White House approval}
- ANS Aerospace Nuclear Science & Technology Division (ANSTD) position paper on HALEU vs HEU fuel initiated in 2019-2020 {currently on hold}
- Dr Susan Voss' NETS-2020 paper, "U.S. Policy on the Use of Highly Enriched Uranium in Space Nuclear Power" {to date, no policy prohibitions on HEU use in US or other nations}
- U.S. National Space Policy & Space Policy Directive #6, Re: Space Nuclear Power & Propulsion, issued Dec 2019 {set a high bar for use of HEU, but no prohibition}
- NASEM consensus report, "Space Nuclear Propulsion for Human Mars Exploration" issued Feb 2021 {recommended comprehensive assessment of HALEU vs HEU when decision to proceed in earnest is made, and identified factors and example factor characteristics (i.e., a partial list of subfactors) for subsequent assessment and appropriate weighting}

Identification & Characterization of Factors (beyond feasibility) Important for Assessing HALEU vs HEU

- Performance {Reactor & System/Vehicle Size, Mass (includes shielding mass), Trip times, or Transit Speed (for propulsion applications), Lifetime, etc}
- Safety {Nuclear & Launch Safety, Astronaut Safety (for crewed missions), etc}
- Cost {Fuel, Technology Development, Testing, Physical Security, etc}
- Schedule {Technology Development, Testing, etc}
- Availability of Fuel {a function of time and state of manufacturing}
- Proliferation/Diversion {Risk (i.e., Probability & Consequences), Political/International Influence, Design and/or Operational Mitigations (e.g. Pingers, PALs/SAPPs), etc}
- Participation by Interested Parties {non-Cat I licensees could not participate in manufacture, development, or testing of HEU-fueled systems}

"For informed decision-making, it is important to fully understand & document the basis for selecting HALEU or HEU fuel for each specific space reactor application at the outset"