Position Statement #40

Space Nuclear Power and Propulsion Systems

DARPA

The American Nuclear Society (ANS) supports and advocates for the research, development, and use of nuclear power and propulsion systems for space-related science, exploration, commercial applications, and national security. Space nuclear systems (SNS) can provide electricity, heat, and propulsion for missions whose requirements are beyond the capabilities of solar power, fuel cells, and conventional chemical means. Nuclear-based systems include, but are not limited to, radioisotope power systems (RPS), fission-based nuclear systems for power or propulsion, and systems based on nuclear fusion or other advanced nuclear technologies.

ANS recommends the following actions related to SNS:

1. Flexible and innovative funding mechanisms for government-purposed SNS. These mechanisms could include public-private partnerships, contracts for commercial services, and milestone-based technology development awards. The goals of these mechanisms should be to open competition for commercial-system providers, to develop technologies for government and commercial use, and to ensure efficient use of federal dollars.

2. Indemnification and/or insurance policy covering SNS accident liability. Only limited liability and indemnification mechanisms are currently available for SNS applications, hindering the ability of the commercial nuclear sector to contribute to U.S. goals in space. An expanded indemnification policy can ensure financial responsibility with the use of SNS.

3. Further international policy development and international cooperation in the development of SNS. Existing international policies pertaining to use of SNS were developed before the advent of modern SNS technologies and commercial applications. American leadership in international safety and other norms, such as inclusion of nuclear in the Artemis Accords, can facilitate global adoption of SNS for peaceful applications.

4. Broadening the application of government policies to be inclusive of all types of SNS. With the current rapid increase in space activities, SNS applications will continue to grow in type, application, and end user. Existing government space policies (e.g., Space Policy Directive-6 [SPD-6][1, a] and National Security Presidential Memorandum 20 [NSPM-20][2,b]) are not broadly applicable to the range of technologies. For example, SPD-6 provides specific guidance for end of life of fission reactor systems in Earth orbit but not of other systems (e.g., radioisotope power systems).

Background

The U.S. pioneered the development and use of the radioisotope thermoelectric generator (RTG), a type of RPS, and has been designing, launching, and safely deploying RTGs to space since 1961. These RPS systems (including radioisotope heater units [RHUs]) have supported various science and defense platforms in Earth orbit, as well as planetary orbiters, landers, rovers, crewed Apollo missions, and even interstellar probes. RPS provide safe, long-lived, and reliable power solutions for spaceflight platforms,

a. SPD-6 establishes high-level goals, principles, roles, and responsibilities and a supporting road map that demonstrate the U.S. commitment to using space nuclear power and propulsion systems effectively and responsibly.

b. NSPM-20 provides specific guidance for government and nongovernment launches of spacecraft containing space nuclear systems based on the type of radioactive material being launched.

and their power output can individually deliver tens to hundreds of Watts electric (We) or Watts thermal (Wt) power.

Nuclear fission reactors can safely provide power from thousands to millions of We — an essential for consideration of permanent lunar and Martian habitats or larger power/propulsion systems for crewed or robotic missions. Nuclear fission reactors can be used in several applications for spaceflight. For example, a reactor on a spacecraft could provide electrical power to electric/ion propulsion devices, a concept known as nuclear electric propulsion (NEP). Additionally, nuclear reactors are attractive for supporting the high energy demands of eventual surface habitats on the moon and Mars, also known as fission surface power (FSP). Fission-based nuclear reactors also provide unique opportunities for improved direct propulsion systems through concepts where reactor cores superheat coolant that is ultimately used for spacecraft propellant, referred to as nuclear thermal propulsion (NTP). Significant technology development efforts for NTP systems were pursued between the 1950s and 1970s, and while many successful designs were built and tested terrestrially, no U.S. NTP systems were ever flown. Various NEP and FSP initiatives have taken place over the past decades, providing valuable studies, technology innovations, and design considerations.

As of 2023, the U.S. has publicly supported 28 spaceflight missions with 47 individual RTG units (in the tens to hundreds of We per RTG). Also, 10 spaceflight missions have required RHUs representing hundreds of individual units in total (approximately 1 Wt per RHU). One fission reactor power system — SNAP-10A — was also successfully launched and operated (~500 We) and remains in a safe parking orbit around Earth.[3]

Some notable spaceflight activities made possible by nuclear technologies include the following:

- The Transit Satellite System, which was a partially RPS-powered naval satellite constellation and a precursor to the modern Global Positioning System (GPS).
- All the Apollo missions, which used science platforms supported by RPS and enabled prolonged data collection and transmission capabilities from the lunar surface.
- Numerous RPS-supported spaceflight missions that have enhanced our understanding of the outer planets and their moons (e.g., topology, geology, atmospheres, and imagery).
- Martian landers and rovers that have provided a significant and sustained ability to perform exhaustive science made possible by RPS.
- Voyager 1 and 2 — the farthest spacecraft from Earth — which now nearly 50 years after their 1977 launch explore regions of interstellar space while still deriving onboard power from an RPS.

While the history of space nuclear activities is rich with success, there has been a resurgence of federal and commercial interest in spaceflight nuclear technologies and policies in the 2020s. For example, recent U.S. presidential executive orders and strategic policies have provided guidance on how to navigate the launch approval process for spacecraft carrying nuclear systems[1] along with providing safe operating and disposition guidance[2] for orbital payloads including nuclear systems. In addition, various interagency memoranda of understanding have recently been established for coordination of national nuclear space initiatives.[4,5] Federal space nuclear technology investments have increased in recent years between the National Aeronautics and Space Administration and the U.S. Department of Energy's various FSP, NTP, and NEP programs to develop advanced technologies while also continuing to improve existing RPS capabilities for science and exploration needs. The U.S. Department of Defense has rising interest in space nuclear technologies to maintain technological superiority and international positioning in potentially contested regions of Earth orbit and cislunar space. U.S. industry has also seen a recent increase in established nuclear companies and nuclear start-ups rapidly innovating in the field of space nuclear technologies. While the U.S. federal government is providing regulatory, policy, and financial incentives to build space nuclear infrastructure, industry is also stepping up to support these initiatives, which is setting the stage for an exciting renaissance of space nuclear technology development.

Since 1961, the advantages of safe, reliable, efficient, and long-lived nuclear power systems to support science, exploration, and national security platforms in inhospitable and remote regions of space has been an obvious solution to many of the complicated operational scenarios that spaceflight presents. Not only do these same complications persist today, but as humans look to significantly expand into space, a larger energy demand will follow, and there are limited engineering solutions available outside of nuclear technologies to fulfill this need. As such, ANS supports policies, programs, and initiatives that support rational approaches to advancing the space nuclear sector. ANS embraces these enabling technologies as safe engineering solutions for our sustained presence in space.

References

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American Nuclear Society

708-352-6611

askanything@ans.org

ans.org