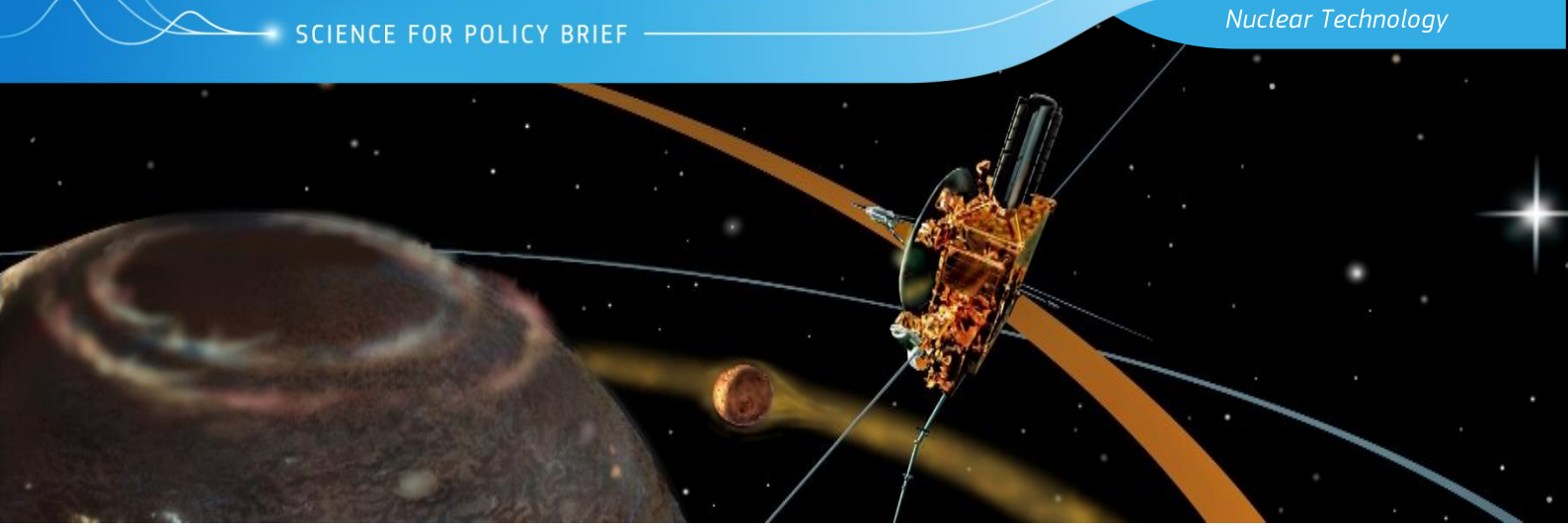
European Commission

SCIENCE FOR POLICY BRIEF

Nuclear Technology



Nuclear power in space

HIGHLIGHTS

→ Nuclear devices such as long-lasting batteries, fission power systems for lunar settlements or nuclear space propulsion are key technologies and can be game changers for human activity in space.

→ The EU has the capacity to step up its development and to benefit from large synergies with European nuclear research and industrial infrastructure.

→ The US, China and Russia are bringing forward ambitious research and development initiatives aiming to obtain critical geostrategic competitive advantages in space for research, defence and industry.

The geopolitics of space that once brought humanity together under the International Space Station (ISS) is overshadowed by ongoing international conflicts and systemic competition. In this context, could the European Union leverage its knowledge and expertise in nuclear technology to have a say in the future of space?

Long-lasting radioisotope batteries

Radioisotope Heater Units (RHUs) and **Radioisotope Thermoelectric Generators** (RTGs) are small nuclear devices harnessing the effects of radioactive decay to provide heat and electricity for decades. They are used to control temperature and supply electric power for space probes, such as *Ulysses*, developed by *ESA* in collaboration with *NASA*, or the *Curiosity rover*, currently exploring the surface of Mars.

ESA is actively contributing to their further advancement in a *dedicated programme* with the participation of the JRC.

Powering human settlements in space

NASA is preparing a **fission surface power system** to be ready by 2030 for a *demonstration on the Moon*. It will generate the electricity and heat needed to support life on the dark side of the Moon and throughout the lunar night that lasts about 14 days. China has recently *presented* a reactor concept for its development while similar *efforts* are starting to take shape within the EU. Although mining in a very low gravity environment is still an unresolved technical challenge, considering future in situ resource utilisation, the thorium and uranium available on the lunar surface could be used as fuel for this type of power systems.

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INTERESTING – Technological advances of recent years are allowing the development of new nuclear reactor designs for space in which the fuel is enriched to less than 20%. The High-Assay Low-Enriched Uranium (HALEU) enables further synergies between civil (e.g. Small Modular Reactors) and space applications.

Avoiding asteroid impacts

Ion thrusters use electricity to create the thrust needed by a spacecraft for manoeuvring. This electricity can come from solar panels or **nuclear fission micro-reactors**. However, beyond Jupiter's orbit, solar radiation is no longer powerful enough. A nuclear-powered spacecraft could be sent to intercept and deflect an asteroid on a potential collision course with Earth while it is still far away. It would act as a gravity tractor to deviate the object slowly from its course, saving life on Earth as a result. Russia has published its intention to design an electric-propulsion cargo spacecraft called *Zeus*, which a nuclear reactor will power.

INTERESTING – Micro-reactors could also be used to power large antennae in space emitting lots of electromagnetic radiation aimed at overwhelming the radio signals sent and received by hostile artificial satellites.

Speeding up crewed missions to Mars

Nuclear thermal propulsion (NTP) is being developed to make it possible to travel to Mars in around six months, three less than with chemical propulsion. *NASA* wants to *test a prototype* in 2026. Their objective is to make space propulsion more efficient and reduce the crew's exposure to cosmic radiation and zero gravity. Chemical systems have a high thrust-to-weight ratio, ion thrusters have high efficiency, and NTP systems have higher thrust than electric and are smaller than chemical systems.

Considering the accumulation of space debris around Earth's orbit and the increasing geopolitical tensions in space, a compact satellite with sufficient thrust to improve its manoeuvrability and ability to avoid collisions, becoming unpredictable to attacks, might entail a critical strategic advantage. However, the nature of NTP makes its operation within Earth's atmosphere or in its vicinity potentially unsafe.

MORE INFORMATION

Deep dive in nuclear power for space exploration
Nuclear Technology Set to Propel and Power Future Space Missions
Nuclear Energy for Space Exploration
Foresight on synergies between civil, defence and space industries

CONTACT INFORMATION

Jorge.TANARRO-COLODRON@ec.europa.eu
Daniel.FREIS@ec.europa.eu

Nuclear Safety in Space

Nuclear safety is an essential design criterion of space nuclear power systems and an indispensable requirement for deployment.

Nuclear power sources are designed to contain their inventory under all possible circumstances, including the most extreme accident scenarios like launchpad explosions or re-entry accidents where several thousand degrees can be reached. This was the case when, in 1968, the spacecraft Nimbus-B exploded at an altitude of 30 km, and its nuclear battery dropped into the pacific ocean. The radioactive fuel was recovered wholly intact and later re-used in Nimbus-3.

One of the pending milestones for the actual deployment of European nuclear power devices in space is the creation of a European Nuclear Safety Framework for Space. This will include a formalized Launch Safety Approval Process, which is currently being developed, empowering the French Guiana Space Centre in Kourou with the capacity to launch nuclear power sources under the highest safety standards.

Closely linked to safety are questions of sustainability, e.g. how to handle and dispose of the radioactive materials used on the Moon, requiring further expert consideration and scientific study.

Figure: Intact nuclear fuel capsule from Nimbus-B on Pacific Ocean floor.

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