Nuclear power returns to space: The strategic revolution shaping the next era of exploration

European

For more than half a century, **space nuclear power and propulsion** have remained a promising but difficult-to-mature field. Their potential has long been recognised: **faster deep-space transit, greater mission flexibility, high-power spacecraft operations** and **energy generation independent of sunlight**. Yet this potential has rarely translated into sustained flight programmes. Most efforts have remained limited to **studies, ground testing or isolated demonstrations**, constrained by political sensitivity, unstable funding, regulatory complexity, industrial readiness and limited near-term mission demand.

What is changing today is **not the maturity of the technology itself**, which remains at an early stage. The real shift is the emergence of a **more structured policy framework**, particularly in the United States, aimed at moving space nuclear systems from **fragmented research efforts** towards **coordinated development**.

Why a framework matters for an early-stage technology

For a technology of this scale and sensitivity, **engineering progress alone is not enough**. Public agencies, industry, laboratories and investors need a clearer signal that the technology is being considered for **future programmes**, rather than treated as an isolated R&D topic. A credible framework can reduce uncertainty by clarifying **government priorities, mission needs, agency responsibilities, funding routes, safety requirements** and **potential procurement mechanisms**.

This history helps explain the significance of the current policy shift, happening particularly in the U.S. Space nuclear power is not starting from zero. NASA notes that, despite **more than $20 billion invested over six decades**, the United States has flown only **one space reactor, SNAP-10A, in 1965**. More recently, NASA and DARPA's **DRACO programme** sought to demonstrate nuclear thermal propulsion, but the programme was closed out in 2025 before reaching flight. NASA's TechPort records the project as closed out in April 2025, following a DARPA stop-work memo to Lockheed Martin. The issue was therefore not that the technology "failed", but that previous initiatives lacked the **continuity, institutional demand, regulatory pathway and industrial base** needed to move from research to operational use.

WHAT IS HAPPENING IN THE UNITED STATES

On 14 April 2026, the U.S. Office of Science and Technology Policy released **National Science and Technology Memorandum 3**, or **NSTM-3**, establishing the **National**

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Initiative for American Space Nuclear Power. This memorandum is an **executive-branch policy instrument** designed to guide federal agencies, align responsibilities and translate political priorities into coordinated government action.

Its novelty lies in the **operational layer** it adds to a field that has long been discussed but rarely structured around concrete implementation. The United States had already issued a **National Strategy for Space Nuclear Power and Propulsion** in 2020. NSTM-3 goes further by setting **near-term objectives**, assigning agency roles, encouraging design competitions, calling for industrial-base assessments, preparing regulatory pathways and linking technology development to **specific mission needs**.

The memorandum gives **NASA, the Department of Energy and defence stakeholders** defined responsibilities. NASA is tasked with initiating a **mid-power space reactor programme**, including a lunar fission surface power variant ready for launch by 2030 and a potential **nuclear-electric propulsion demonstration**. Defence stakeholders are directed to assess operational use cases and pursue a mission-enabling in-space reactor by 2031, subject to funding. The Department of Energy is expected to support reactor development, assess the readiness of the **US nuclear reactor industrial base**, address fuel and infrastructure constraints, and provide nuclear safety and technical expertise.

By identifying missions, assigning responsibilities, encouraging private-sector participation and preparing launch and regulatory processes, the US government is creating a **clearer development pathway** for a technology that remains early-stage. Space nuclear power and propulsion are being framed less as **distant research concepts** and more as potential enablers of future **exploration, commercial and national security architectures**.

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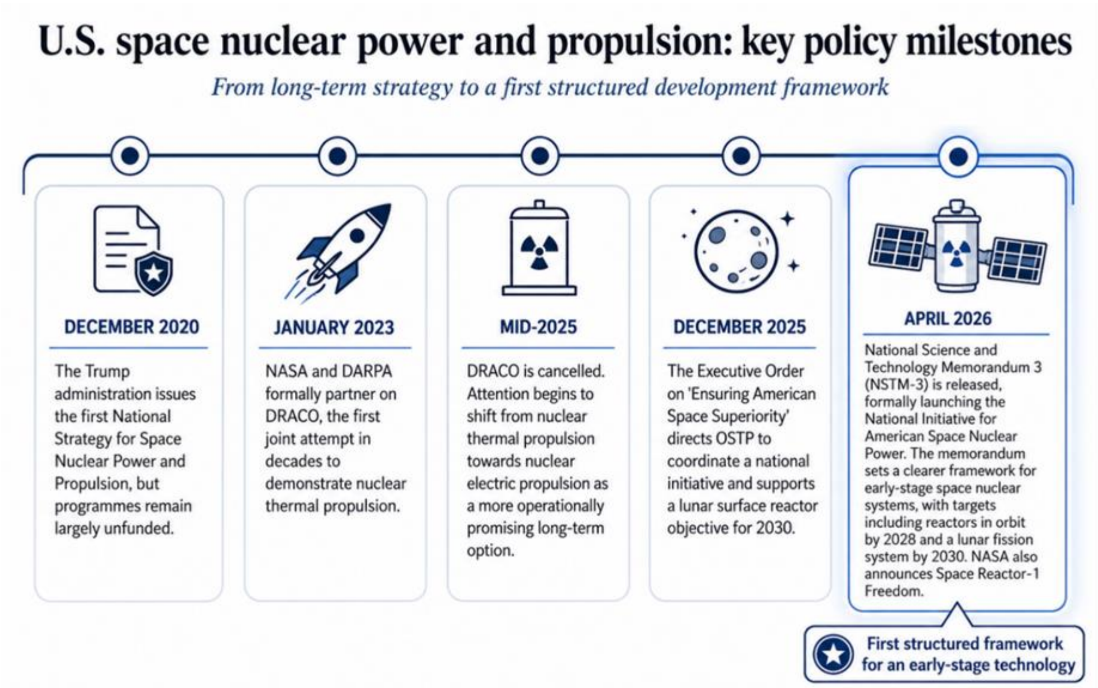

THE EXAMPLE OF SR-1 FREEDOM

NASA's Space Reactor-1 Freedom, announced in March 2026 and targeted for launch in late 2028, is the **first concrete mission attached to the new US policy framework**. It is not meant to represent a mature operational capability, but to test whether space nuclear power can move from research and demonstration towards a structured flight pathway.

- **Objective:** demonstrate a 20 kWe fission power system coupled with electric propulsion on a deep-space mission, while generating practical experience on launch approval, in-space operations and nuclear safety procedures.
- **Institutional and industrial role**: SR-1 is a NASA-led mission, with the Department of Energy contributing nuclear expertise on reactor design, fuel, infrastructure, testing and safety. Through NSTM-3, the mission also supports a broader effort to involve industry through competitive and milestone-based development approaches.
- **Next milestone:** the mission is expected to inform Lunar Reactor-1, a fission surface-power system planned around 2030. This shows that the US objective is not only propulsion, but also the use of nuclear power as enabling infrastructure for lunar surface operations, high-power spacecraft and future deep-space logistics.

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"Nuclear power in space will give us the sustained electricity, heating and propulsion essential to a permanent robotic and eventually human presence on the Moon, on Mars, and beyond."

MICHAEL KRATSIOS, U.S. OSTP DIRECTOR, APRIL 2026

THE EUROPEAN PICTURE

Europe has technical building blocks, but no equivalent policy framework

Europe is not absent from the space nuclear propulsion debate. Over the past years, ESA and European industrial and research actors have **developed important technical and analytical building blocks**, particularly through feasibility studies and technology roadmaps. However, these efforts have **not yet translated into a consolidated European policy framework** comparable to the one now emerging in the United States.

Figure 2 : Key milestones linked to nuclear propulsion in the Europe

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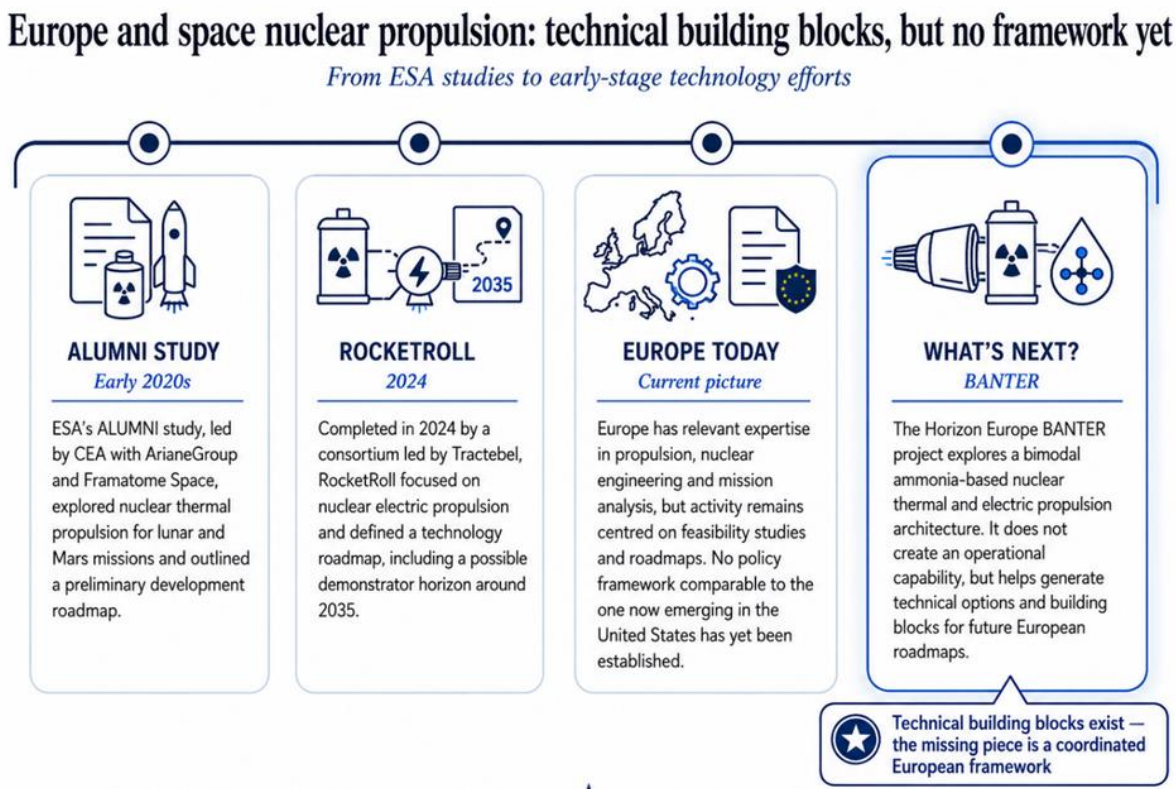

These studies show that Europe has **relevant expertise in nuclear engineering, propulsion, mission analysis and space transportation**. They also highlight the gap between technical potential and operational readiness. Unlike the United States, Europe does not yet connect mission demand, industrial development, regulatory preparation, safety authorisation, funding continuity and demonstration timelines. If space nuclear power and propulsion become relevant for deep-space logistics, lunar infrastructure, high-power spacecraft or outer Solar System missions, Europe will need to decide **what level of autonomy** it wants, which missions would justify investment, and which actors should be involved in building such a capability.

BANTER AS ONE EUROPEAN EARLY-STAGE TECHNOLOGY EFFORT

Within this broader context**, BANTER, the Bimodal Ammonia Nuclear Thermal/Electric Rocket project**, represents one **European research effort** exploring a novel propulsion architecture. Funded under the European Union's Horizon Europe EIC Pathfinder programme, BANTER brings together the University of Stuttgart, Centrum Výzkumu Řež, the University of Pisa and Novaspace.

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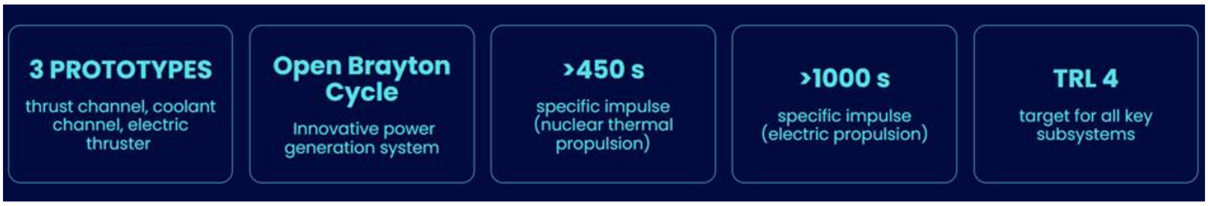
THE INNOVATION: AMMONIA, BIMODALITY, AND THE BANTER ARCHITECTURE

The defining feature of BANTER is the **use of ammonia (NH_3)** as a common propellant for both propulsion modes, nuclear thermal and nuclear electric, within a single integrated system. This **bimodal design** represents a meaningful departure from conventional approaches to nuclear propulsion, which typically treat the two modes as separate subsystems with separate propellant stores. Ammonia's appeal as a propellant is not immediately obvious. Liquid hydrogen remains the canonical choice for nuclear thermal propulsion because of its low molecular weight, which maximises specific impulse. But hydrogen brings severe storage challenges: it must be kept at cryogenic temperatures approaching absolute zero, and it tends to boil off during long missions. Ammonia, by contrast, **stores easily at moderate pressures** and **remains stable** across the temperature ranges encountered during transit. It is also significantly denser, which reduces tank volume and structural mass.

Figure 3 : Main features of the BANTER project



WHY THIS COULD MATTER FOR EUROPEAN AUTONOMY AND COMPETITIVENESS

The relevance of these developments goes beyond exploration missions alone. A mature space nuclear capability could, in principle, **support more flexible deep-space transport**, **cargo missions** beyond Earth orbit, **lunar surface operations**, **high-power spacecraft** platforms, **outer Solar System science** and **future in-space logistics**. It could also create opportunities for European spacecraft primes, propulsion companies, nuclear engineering firms, materials suppliers, testing facilities and mission operators. The potential user base would likely include space agencies planning exploration or science missions, spacecraft manufacturers developing high-power platforms, future logistics or transport service providers, and possibly defence or security actors interested in resilient cislunar operations. However, **these applications remain conditional**. They depend on cost, safety, political acceptability, regulatory feasibility,

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mission demand and the ability to demonstrate clear advantages over chemical propulsion, solar electric propulsion or other alternatives.

This is where early-stage projects such as BANTER can contribute. They do not close Europe's capability gap on their own, but they **help generate technical options** and assess whether new architectures could be relevant for future roadmaps. In particular, BANTER's ammonia-based approach could also be relevant in the longer term if in-situ resource utilisation becomes part of lunar or Martian infrastructure strategies, as ammonia may be compatible with future concepts for producing propellant from local resources.

Looking ahead

The next decade will be decisive because the first **credible frameworks for space nuclear development** are beginning to emerge. The United States is now linking **policy direction, mission timelines, industrial mobilisation and regulatory preparation**. SR-1 Freedom, targeted for launch in 2028, will be an important test case not only for the technology itself, but also for the ability to **launch, operate and govern space nuclear systems** within a structured national programme.

This is not only a **US-European issue**. Other countries are also exploring space nuclear power and propulsion, although most initiatives remain at **very early stages of maturity**. Russia has long signalled interest in nuclear electric propulsion through concepts such as **TEM/Zeus**, while China is reported to be pursuing institute-led nuclear thermal propulsion work and nuclear electric propulsion-related developments. However, available information suggests that these activities remain largely within **R&D, roadmap or early development phases**, with limited public transparency and no demonstrated operational capability. This broader landscape reinforces the main point: the field is active internationally, but still immature.

For Europe, the question is therefore not whether it should simply replicate the US approach. It is whether it can define its **own pathway** in a field where several major space powers are positioning themselves early. Europe will need to answer strategic questions: which missions would genuinely require nuclear power or propulsion, who the first institutional or commercial users could be, what level of **European autonomy** is desirable, what safety and regulatory framework would be acceptable, and what funding would be needed to move from **studies to demonstrators**.

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The central issue is no longer only whether nuclear propulsion can work in principle. It is whether the right **institutional, industrial, financial and regulatory conditions** can be created to make it usable. Countries and organisations that define **missions, standards, safety rules and industrial roles** early will be better positioned if space nuclear systems become an enabling layer for future deep-space exploration, lunar infrastructure, in-space logistics or high-power spacecraft operations.

For now, nuclear propulsion remains an **early-stage strategic technology**, but one that is entering a more structured policy phase. The question is not simply who will build the technology, but who will create the conditions for it to become a **credible capability**.

BANTER (Bimodal Ammonia Nuclear Thermal/Electric Rocket) has received funding from the European Union's Horizon Europe programme under the EIC Pathfinder scheme, pursuant to Grant Agreement No. 101186520, concluded with the European Commission on 25 October 2024. Learn more at banterspace.eu.

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