

Weighing the Future: Strategic Options for U.S. Space Nuclear Leadership

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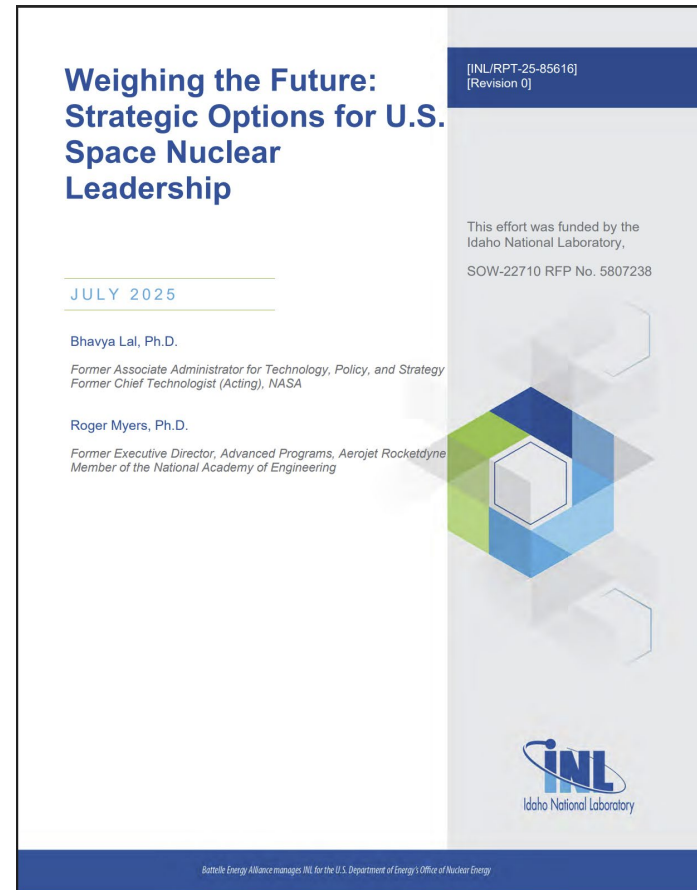
Idaho National Laboratory

Approach

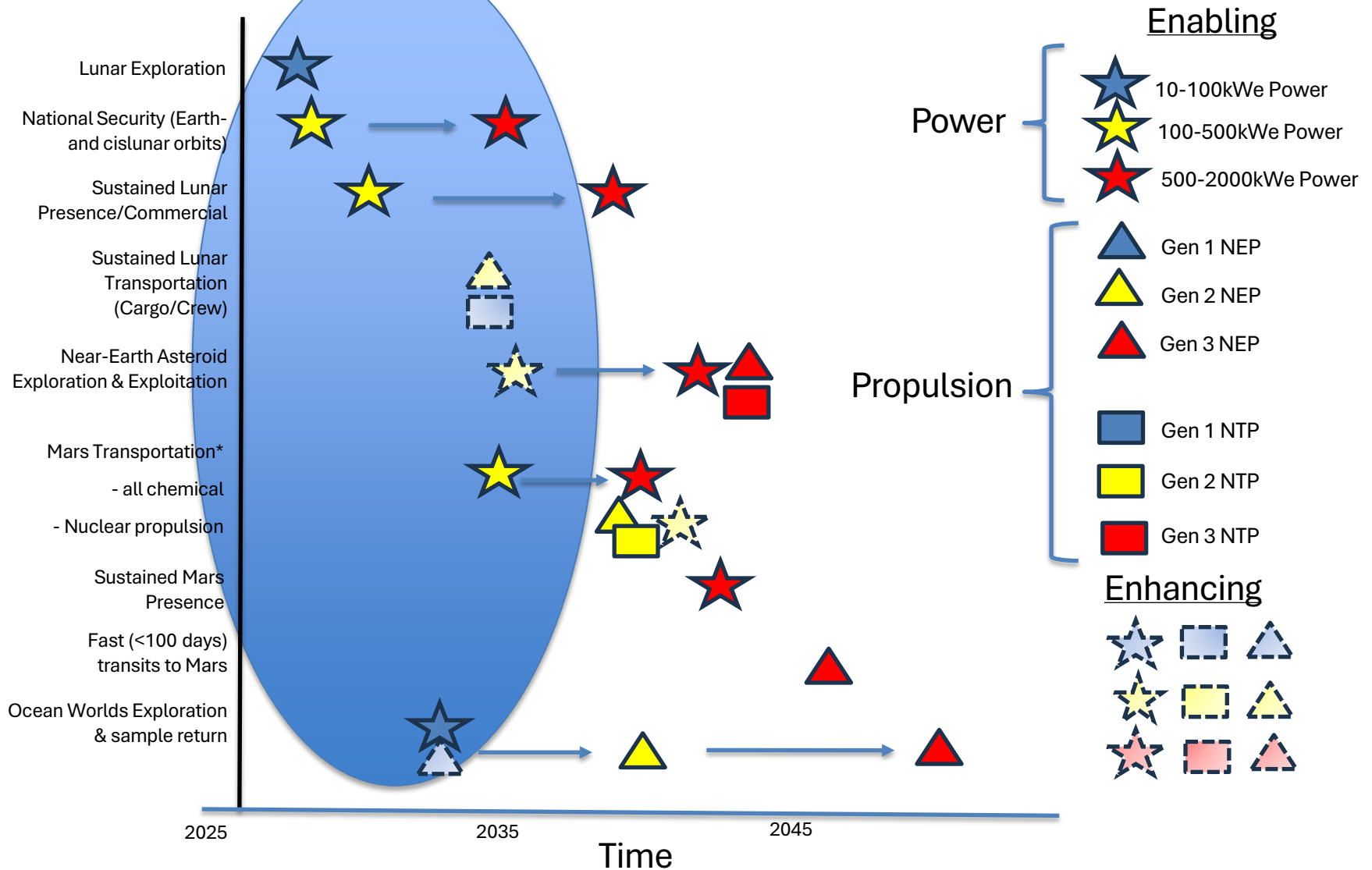
Between Jan 31, 2025 and May 5, 2025

- Reviewed articles, journal papers and historical documents
- Reviewed prior space nuclear and other national programs
- **Conducted >100 interviews with experts and policymakers**

Synthesis of these inputs with extensive debate formed our strategy

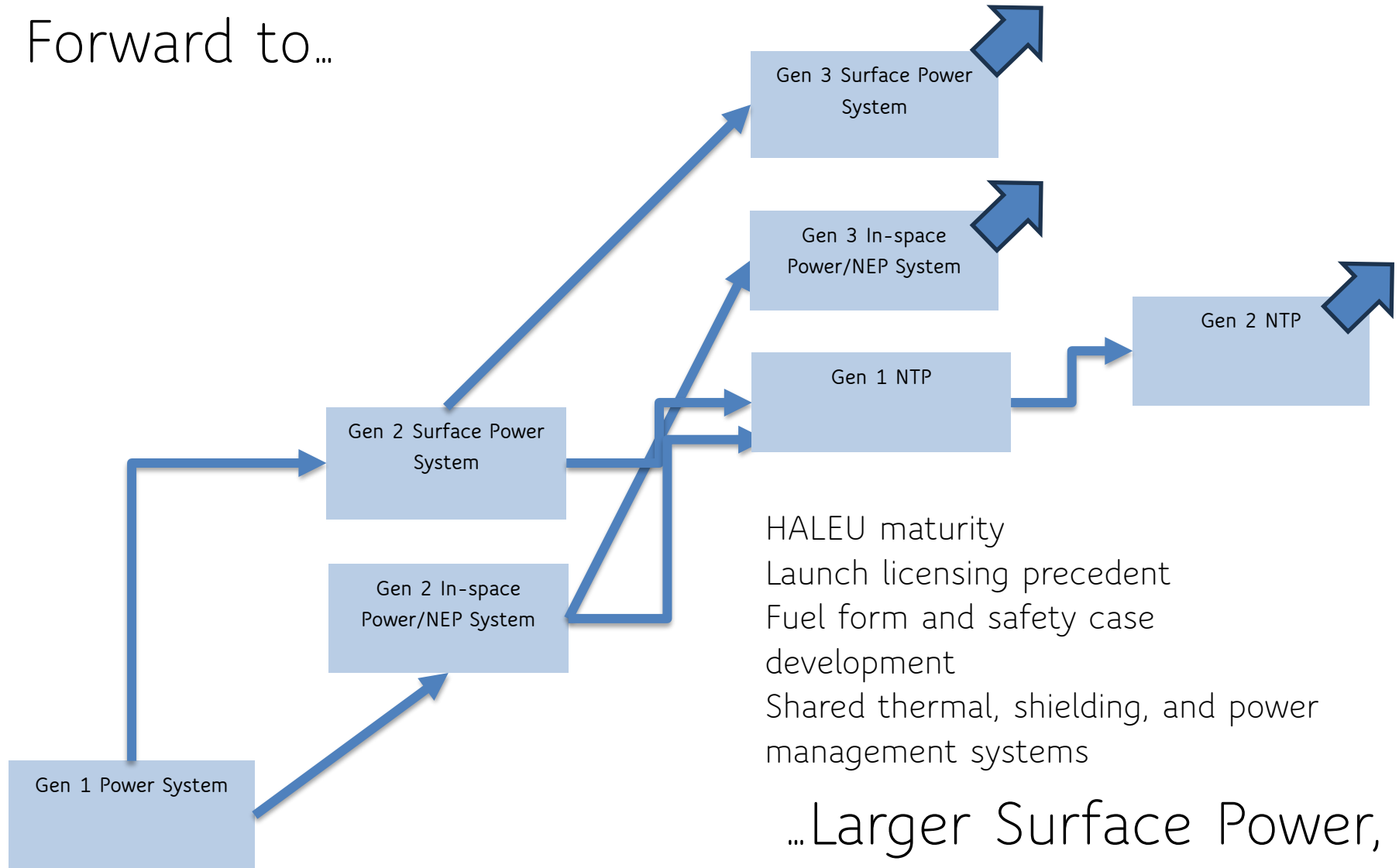


Why Power First



*NASA has not selected the propulsion option for initial Mars missions. Nuclear power is required for the all-chemical option to produce Earth-return propellant. If nuclear propulsion is selected then in-situ propellant production is not required (but is enhancing).

Strategic Sequencing: A Gen 1 Power Demo Feeds Forward to...



Selecting Among Options: Balance of Ambition Risk and Realism

Option	Demonstration	Scale***	Lead Organizations	Rough Cost to Govt.	Risk Profile
Go Big or Go Home*	Power or NEP flight demo by 2030 <i>Ground test by 2028</i>	100–500 kWe class	NASA or DoD with DOE as partner	~\$3B over 5 years	High
Chessmaster's Gambit	Two power demos - in-space or surface - by 2030 <i>Ground test by 2028</i>	10-100 kW class	Industry, NASA/DoD, DOE, FAA	~\$2B over 5 years	Medium
(Potential) Light the Path**	Commercial RPS demo by 2028	<1 kWe class	Industry, NASA/DoD, DOE, FAA	~\$100M (illustrative)	Low

*Should be pursued only if political, budgetary, and leadership conditions are aligned.

** Could proceed in parallel with either major Option. Requires further assessment.

*** Actual power levels may be driven by lift and lunar lander capacity and other architectural constraints.

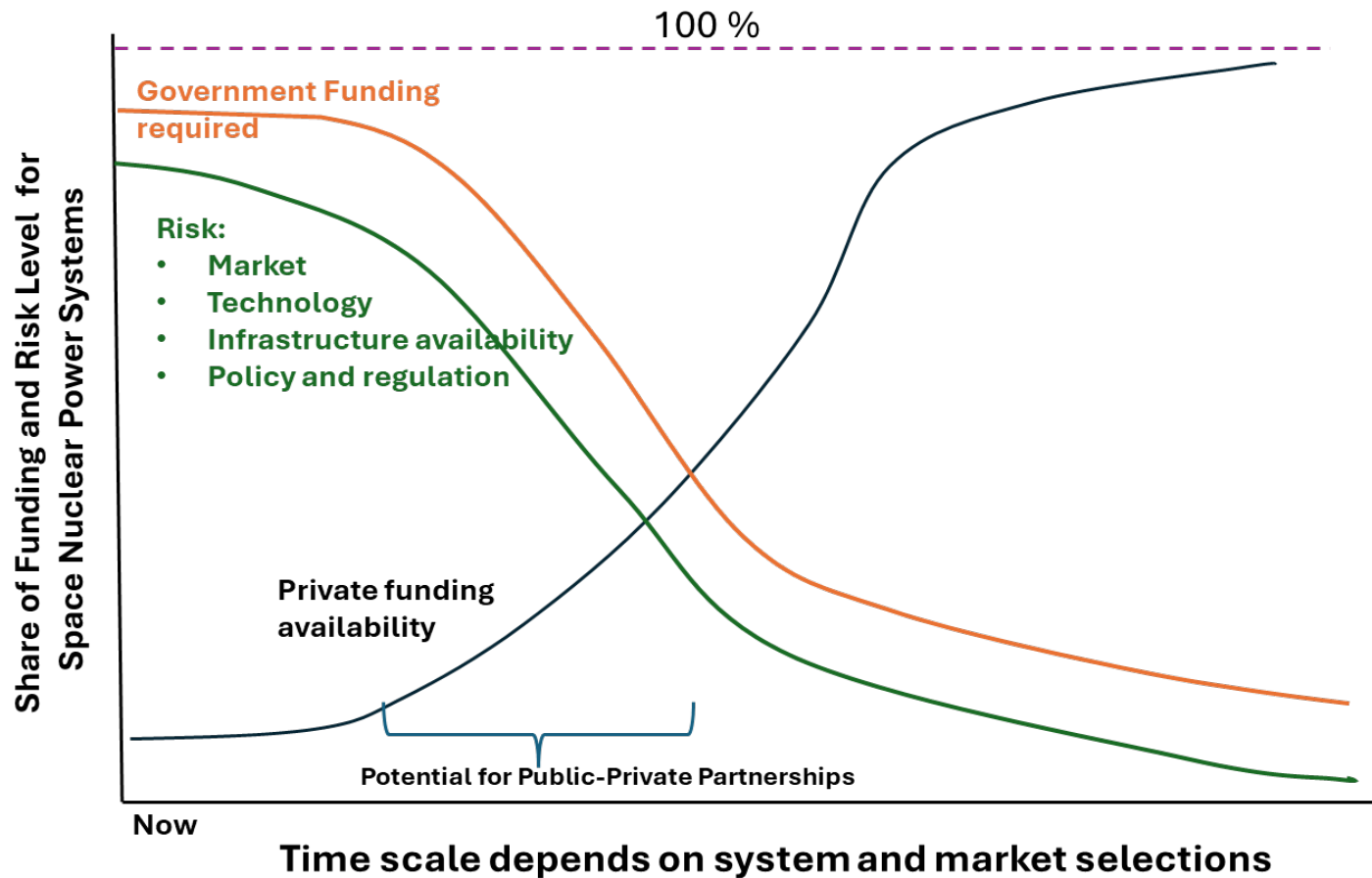
Option	Demonstration Goal	Power Scale (kWe) ***	Lead/Executing Entities	Execution Model	Target First Flight	Rough Public-Funding Estimate
1A/B/C “Go Big or Go Home”*	NEP flight demo	100-500	NASA or DOD + DOE	Government crash program	~2030	~\$3B (five-year total)
1D “Anchor Power”*	Power-only (in-space or surface) demo	100- 500	NASA or DOD + DOE	Government crash program	~2030	-
1E “Hybrid Manhattan”	Flagship + Fixed-Price	100-500 (NEP) + 10-100 (power)	NASA/DOD + Industry/DOD or Industry/NASA + DOE	Crash program and private programs run concurrently	~2030	Addl funding but not additive (pillars are similar)
2A “Chessmaster’s Gambit” (Lunar Surface)	Lunar surface demo	10-100	Industry/NASA + DOE	Fixed-price, tech agnostic, milestone partnership	~2030	~\$1B
2B “Chessmaster’s Gambit” (In-Space)	In-space demo	10-100	Industry/DOD + DOE	Fixed-price, tech agnostic, milestone partnership	~2030	~\$1B
3 “Light the Path”**	Commercial RPS demo	< 1	Industry/NASA/DOD + DOE	Fixed-price, tech agnostic, milestone partnership	2028	~\$100 M (illustrative)

**Only pursued if political, budgetary, and leadership conditions are aligned.*

*** Could proceed in parallel with either major option. Requires further assessment.*

**** Power levels will be driven by launch vehicle, lander capacity, and other architectural constraints*

Even *with* Commercial Leadership, Government Essential...



Four Non-Negotiable Pillars

“Without top-down centralized coordination, either demo will stall
[under bureaucratic friction and fragmented authority]”

Section 5



WHITE HOUSE LEVEL
COORDINATION



TECHNOLOGY
MATURATION



INFRASTRUCTURE
BUILD AND ACCESS



REGULATORY
REFORM

Strong Reception

<https://www.thespacereview.com/article/5065/1>

Signals of Influence

- NASA's August 2025 direction on a 100 kW lunar reactor by 2030 closely resembled the pathways we analyzed.
- DOE, DOD, OSTP, OMB, and National Space Council staff circulated the report in internal discussions.
- Companies, both large and small, told us that the framework helped shape their thinking as they prepared proposals.
- Media attention (>45 references in both the trade press (e.g., Space News) and mainstream (NYT, NPR, WSJ) increased awareness among Hill staff and senior officials who might not otherwise see technical reports.

Possible Reasons the Report Resonated

- We Reframed the Entire Debate
- We Gave Three Real Choices
- We Built It *With* the Community, Not *For* It
- We Briefed Early, Often, and Quietly
- We Had a Sponsor That Trusted Us Completely
- We Told Hard Truths Without Fear
- We Hit the Goldilocks Zone
- We Paired the Right Authors
- We Borrowed Playbooks That Worked
- Timing Was on Our Side
- Our Networks Opened Doors

NEW DEVELOPMENT AFTER REPORT COMPLETED - NASA MEMO

NASA advances lunar nuclear plan with commercial focus

On Aug. 29, NASA released a draft Announcement for Partnership Proposals (AFPP) for its Fission Surface Power initiative to gather industry input for the final version. The AFPP is designed to implement a policy directive signed July 31 by Acting Administrator Sean Duffy that seeks to accelerate work on nuclear power systems for the moon.



NASA Memo July 31, 2025

Goals

Field an **operational** lunar fission surface power system by **Q1 FY30**, delivering **≥ 100 kWe** to enable lunar-night survival and high-power surface operations, with applicability to Mars. Move quickly given China-Russia reactor plans.

Approach

Name an empowered ESDMD Program Executive within 30 days and issue an industry **RFP within 60 days**. Make two awards with option to down-select at PDR. Use a **closed Brayton** system, assume a heavy-class lander up to **15MT**, pay by **milestones** with **$\geq 25\%$** after delivery, and cap the NASA team at **15 FTE with 10%** overhead using a minimum-viable structure. Align tech work to the RFP and streamline decisions.

Funding

FY26 PBR proposes **\$350M in FY26** under a new Mars Technology program that includes FSP, ramping to **\$500M starting FY27**, with **additional funding** expected as Artemis shifts to commercial services.

National Aeronautics and Space Administration
Mary W. Jackson NASA Headquarters
Washington, DC 20546-0001



July 31, 2025

TO: Officials-in-Charge of Headquarters Offices
Directors, NASA Centers

FROM: Acting Administrator

SUBJECT: Directive on Fission Surface Power (FSP) Development

Executive Summary

- Fission surface power (FSP) is both an essential and sustainable segment of the lunar and Mars power architectures for future human space exploration missions.
- The FSP project leverages innovation in commercial microreactor technologies specifically referenced in the White House's 23 May 2025 Executive Order 14299 "Deploying Advanced Nuclear Reactor Technologies for National Security".
- To properly advance this critical technology to be able to support a future lunar economy, high power energy generation on Mars, and to strengthen our national security in space, it is imperative the agency move quickly.

Background:

- Since March 2024, China and Russia have announced on at least three occasions a joint effort to place a reactor on the Moon by the mid-2030s. The first country to do so could potentially declare a keep-out zone which would significantly inhibit the United States from establishing a planned Artemis presence if not there first.
- FSP directly addresses the top two technology shortfalls listed in NASA's 2024 Civil Space Shortfall Ranking document: #1 to enable systems to survive and operate through the lunar night; and #2 to provide a source of high-power energy generation for the Moon and Mars surfaces.
- Industry has provided data-driven feedback to NASA that surface power needs are at least 100kWe for long-term human operations including in-situ resource utilization.
- Since 2000, the Agency has invested over \$200M towards FSP technologies ranging from 1kWe to 200kWe with no significant advancement towards flight system readiness. The most recent effort was in 2023 with the completion of three \$5M industry study contracts, known as FSP Phase 1, focusing on a 40kWe concept. Cost estimates, schedules, and initial concept designs were received.
- The President's Budget Request (PBR) for FY2026 includes \$350M in FY26 for a new Mars Technology program that will accelerate the development of high priority technologies for Mars, (i.e. FSP). This funding ramps up to \$500M starting in FY27.
- Significant additional funds will be available as NASA transitions to commercial services for Artemis IV and beyond.

Even Newer Developments



A confidential manifesto lays out Isaacman's sweeping new vision for NASA

The former, and possibly future, nominee for the space agency said he did not intend for the document's public release.

“The agency should redirect talent and resources to nuclear electric propulsion. This is the logical evolution for power, efficiency and exploration at scale with dual use potential. NASA needs a mini-Manhattan Project to get America underway on nuclear power in space.”

Reforming NASA: A path to Mars and beyond
Op-Ed in The Hill
by Jared Isaacman and Newt Gingrich

“Another major section ... lays out a nuclear electric propulsion strategy — technology that Isaacman views as essential for traveling to Mars and around the solar system.” Politico



QUESTIONS

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Lessons for NASA

Empowered Leadership

- Model: Naval Reactors (Rickover) – End-to-end authority, lifetime tenure, and institutional continuity ensured safety and delivery.
- Lesson: A single empowered program office, with real authority and continuity, is essential. Without it, leadership churn will kill the program before the hardware flies.

Parallel Bets to Hedge Risk

- Models: Manhattan Project (1940s), Operation Warp Speed (2020) – Multiple enrichment methods, multiple vaccine platforms pursued in parallel.
- Lesson: Don't bet on a single technology. Fund at least two viable pathways so one success de-risks the field and sustains momentum.

Design for Fleet-Scale and Commercialization

- Model – Falcon 9, Shippingport: Falcon 9 succeeded because it was designed for reuse and rate production. Shippingport (1958) similarly mattered because it seeded a standardized fleet of reactors, not because it stood alone.
- Program must avoid “Battlestar Galactica” designs. From the start, systems should be modular, repeatable, and built for dozens of deployments across civil, commercial, and defense missions.
- Commercial adoption strategies should be designed in: the 2030 reactor should lead directly to industry-owned fleets powering a long-term lunar economy.

Deliver Early Wins to Lock in Momentum

- Models: COTS (2000s) – Both secured survival by showing near-term, tangible results, not paper studies.
- Lesson: Field a small but real reactor demo within 3–4 years. Early, visible success builds credibility, sustains bipartisan support, and pulls industry in – without relying on artificial political hooks.

Lessons for NASA (cont.)

Integrate Regulators Early

- Model - Operation Warp Speed (2020): Vaccine development was accelerated because FDA regulators sat inside the program office from day one, shaping milestones and approving trials in real time.
- FSP should follow the same model: bring regulators, launch safety, and mission authorization experts into the program office now. This affects design, reduces uncertainty, prevents late surprises, and ensures the system can be fielded on schedule.

Own the Public Narrative

- Model - Apollo (1960s): Apollo sustained funding because it captured imagination and framed exploration as a national mission, not just a technical program.
- FSP must be positioned the same way: not as a niche reactor project, but as the infrastructure that opens the solar system.
- Every milestone should be communicated as a step toward human expansion, national leadership, and long-term prosperity (and the America first narrative in this Administration)

Bottom Line: Ensure empowered leadership, parallel bets, designs built for fleets not one-offs, early wins to build credibility, regulators embedded from day one, and a public narrative that frames FSP as America's bridge to the solar system

The Duffy memo identifies a **high summit goal** for the program: fielding a 100+ kWe Brayton cycle space reactor. There are multiple paths to reach this summit, each with distinct risks, timelines, and tradeoffs:

- **The Sheer Rock Face (Direct Assault)**
 - Attempt to climb straight up the face by developing the full 100 kWe Brayton system from the start.
 - This is the fastest route if successful, but the most dangerous: the climb is steep, **costly**, and prone to failure if any single element falters.
- **The Long Ridge (Extended Ascent)**
 - Approach the summit by following a longer ridge route, accepting schedule extensions to reduce technical and programmatic risk.
 - This buys time for incremental maturation of key subsystems, but risks losing momentum, political support, and alignment with strategic windows.
 - **This route may not meet the Duffy deadline**
- **The Stepped Path (Incremental Staging)**
 - Climb in stages, stopping at intermediate ledges by building smaller systems first (e.g., modular reactors in the 40 kWe class) that can be daisy-chained toward higher power levels.
 - This provides early wins, operational experience, and scalable building blocks (**relevant for commercial developers**), though it may delay arrival at the true summit.
- **Bottom Line:** The 100 kWe Brayton summit is achievable, but the path chosen will determine not only whether we arrive, but whether the team—and the program—survives the climb.

Lessons for NASA (cont.)

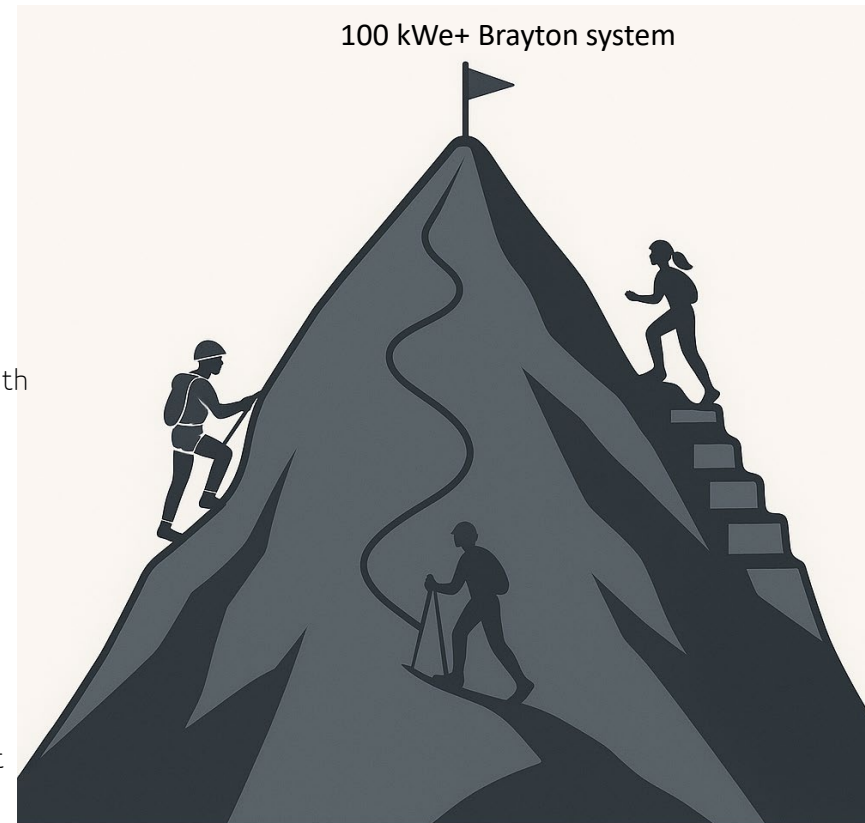


Diagram drawn by ChatGPT using instructions on the left

Some Questions (Imp ones in red)

Timeline and Authorities

- How and how quickly can NASA obtain its own indemnification authority—or must it work through DOE's existing framework?
- What changes are needed in the launch approval pathway under NSPM-20 to support a 2028-2030 flight demonstration?
- How will roles and responsibilities across DOE, NRC, DoD, FAA, and other organizations be formalized?
- How will the program secure sustained A-suite and White House commitment, especially when setbacks occur? Does program leadership have direct access to the NASA Administrator and the White House?

Workforce and Agency Roles

- How do NASA workforce and internal cost caps affect program execution? Which activities will NASA perform internally, and which will require DOE, NRC, national labs, or other agencies?

System Design and Commercial Approach (will affect how RFP is written)

- How will the design ensure a long-term commercial market for reactors on the Moon and beyond, consistent with NASA's vision for a cislunar economy?
- What does "success" look like in 2030—what metrics prove this program delivered?
- Will NASA sign power purchase agreements (PPAs) with vendors? What form will demand take?
- How will the system architecture ensure extensibility to Mars surface use or nuclear electric propulsion?
- What level of industry cost-share will be required, and what rights will vendors receive in return (ownership, on-surface operations, post-demo commercialization)?
- Beyond the first demo, what is the strategy for moving from a one-off reactor to a scalable fleet serving multiple missions (NASA, DoD, commercial)?
- Who are the committed customers beyond NASA, and how will their requirements be integrated into the program so this isn't another technology demo without follow-on demand?

More Questions (Imp ones in red)

Technology Maturation and Infrastructure

- How must current maturation plans evolve to credibly achieve goals such as a 100 kWe Brayton system?
- What infrastructure investments need to begin now to support this timeline?

Budget and International Participation

- What funding profile for FY 2026–2027 will NASA guarantee, and how will budget stability be communicated to vendors?
- Are there specific program elements (fuel supply, power conversion, testing) where international participation could accelerate progress?
- How will program health be reported to Congress and OMB in a way that preserves schedule flexibility when challenges arise?

Legal and International Issues

- Are there permitting, treaty, or other legal issues that need to be resolved early in the design process?
- What will be the technical basis for safety zones, and how will they be determined?
- How will NASA address questions on unresolved issues—such as decommissioning or commercial operation—before formal policy exists?

Strategic Posture and Continuity

- What are the top 3 risks (technical, political, financial) to a 2028–2030 demo, and what is the mitigation strategy for each?
- How will the program explicitly frame its geopolitical rationale, including deterring foreign exclusion zones and demonstrating U.S. leadership?
- Who provides oversight and operational responsibility after launch (e.g., DOC per the newest EO)? If a vendor fails mid-mission, who assumes responsibility and gains access to proprietary design data?
- If the first flight fails, what is the backup plan to sustain momentum and funding?
- How will the program proactively communicate benefits to Congress and the public, and pre-empt opposition to “nuclear in space”?