A Path Toward a Governance Framework for Nuclear Thermal Launch Vehicles

Executive Summary

Nuclear thermal propulsion has long been studied for in-space applications, but recent technical and regulatory analysis suggests that use of nuclear thermal systems during launch, if carefully designed for public safety and sufficient performance, may be feasible under existing legal and regulatory frameworks. This paper proposes that nuclear thermal launch vehicles (NTLVs) can be governed as a straightforward extension of current launch, nuclear safety, and space liability regulation, rather than as a novel class of activity.

Using the United States regulatory system as a reference model, it is shown that existing authorities already cover most of the safety, licensing, and liability questions raised by NTLVs. Early, transparent application of these authorities can create governance precedents that other states may later adapt. The primary governance challenge is coordination of regulatory responsibility across agencies.

The purpose of this paper is not to advocate for a specific vehicle or operator, but to outline a governance approach that minimizes regulatory fragmentation, reduces uncertainty, and supports responsible innovation.

1. Introduction: From Feasibility to Governance

The feasibility of nuclear thermal propulsion is no longer speculative. Open literature, historical programs, and recent feasibility studies indicate that nuclear thermal systems capable of operating without measurably radioactive exhaust are technically plausible, with superior operational – and thus economic – details compared to traditional chemical rockets. As feasibility thresholds are crossed, the central question shifts from whether such systems could exist to how they should be governed.

As shown in the following sections, NTLVs do not require a fundamentally new governance regime. Instead, they fit within existing legal structures governing civil aviation and launch licensing, nuclear materials safety, environmental (particularly radiological) protection, international space law, and liability. The challenge is to make this fit explicit, so that regulators, operators, and the public share a common understanding of how responsibility is allocated.

2. Defining the Activity: What Is a Nuclear Thermal Launch Vehicle?

For governance purposes, and the purposes of this paper, we propose this definition for a NTLV:

> A reusable launch vehicle that employs nuclear thermal propulsion during portions of ascent to orbit, the exhaust of which has no more than trace-level radioactive emissions (total per launch, comparable to other licensed industrial or launch-related sources), and does not allow its nuclear system to be at criticality while on orbit (even momentarily, though decay heat may exist) except as separately licensed.

That definition, particularly the clause about the exhaust and specifying “reusable”, deliberately excludes many nuclear thermal propulsion systems that may be acceptable for use in deep space but are unacceptable for use in a launch vehicle.

It is expected that specific implementing regulations will go into more detail, such as providing numerical limits on radioactivity of the exhaust and possibly applying further limits on when the nuclear engine may achieve criticality. The United States regulatory model, used as a reference case below, already does this as of the date of this paper.

Ground storage and maintenance of the nuclear system is expected to occur at licensed facilities. NTLVs, being launch vehicles, will also need to be licensed as launch vehicles. As they are reusable, which means they reenter the Earth’s atmosphere so as to return to a location they can be launched from again, they will also need to be licensed as reentry vehicles, if licensed under regulations that license reentry and launch vehicles separately.

3. United States Regulatory Model (Reference Case)

3.1 Allocation of Authority

Under existing U.S. law, regulatory responsibility can be coherently divided:

- **Federal Aviation Administration (FAA)**: Licensing of launch and reentry operations, public safety during flight, range safety, and environmental review. The governing regulations as of the date of this paper, 14 CFR 450, include provisions that require evaluating and addressing the risk of radiation-related hazards from a launch vehicle, for those launch vehicles that have a risk of radiation-related hazards.
- **Nuclear Regulatory Commission (NRC)**: Licensing of nuclear materials, ground facilities, storage, and handling of the nuclear propulsion system when not under FAA flight jurisdiction. If a NTLV is stored in one of a set of shielded hangars between launches, the NRC can license that hangar complex as a “non-power research reactor”.

This division mirrors established practice for other dual-domain technologies and does not require new statutory authority.

3.2 Treatment of Nuclear Propulsion During Ascent

Current regulations do not explicitly prohibit nuclear thermal propulsion during ascent. Nuclear propulsion, if used consistently with the NTLV definition above, can be evaluated under the same public safety frameworks applied to other propulsion systems, with additional scrutiny of radiological risk.

This approach aligns with existing precedent. Propulsion method alone does not trigger categorical exclusion or prohibition. Risk to the public does.

3.3 Relationship to SPD-6 and NSPM-20

Space Policy Directive–6 (SPD-6) governs nuclear power systems used in space (“on interplanetary missions” and “in…orbits”) but is silent on nuclear propulsion used exclusively during launch (prior to entering orbit). Private discussions with SPD-6’s authors confirmed that this scenario was not considered. Under U.S. administrative law, the absence of explicit authorization does not, by itself, constitute a prohibition; accordingly, this omission does not in itself preclude NTLVs. However, it is an opportunity for clarification.

Radiological risk thresholds can be aligned with *National Security Presidential Memorandum–20* (NSPM-20). For example, having no greater than a 1-in-1,000,000 probability of any member of the public receiving a total effective dose (as defined in 10 CFR 835.2) from one mission (one launch of a NTLV) exceeding 25 millirem will more than satisfy NSPM-20's relevant thresholds (3.a.ii-iv, and 4.b.ii or 4.c depending on whether the nuclear fuel is or is not low-enriched uranium). This provides continuity with existing U.S. nuclear space policy.

SPD-6 and NSPM-20 are not the final word on this matter. That final word is the licensing regulations as administered by the FAA and NRC; see 3.1 and 3.2 above. SPD-6 and NSPM-20 deserve special mention because implementation of said regulations to govern nuclear material on space missions often refers to SPD-6 and NSPM-20, as of the date of this paper.

4. Risk, Liability, and Transboundary Considerations

4.1 Launch and Reentry Accidents

Existing launch accident liability regimes already address damage to third parties, environmental contamination, and international claims under the Liability Convention. The presence of nuclear materials affects consequence magnitude, not legal structure. Existing frameworks can incorporate additional damage categories (e.g., radiological cleanup) without conceptual change.

4.2 Unintended Deorbit or Overflight

Unintentional reentry into foreign territory is a known risk for space objects. NTLVs extend this risk profile but do not create a new category of transboundary harm. The existing space law principles of state responsibility and liability remain applicable.

4.3 Airspace Sovereignty

NTLVs do not modify states' right to deny overflight or landing permissions: they have no more right to land in states that do not want them than any other launch vehicle has. Governance does not require universal acceptance; it requires clear rules for those who choose to participate.

5. Governance as Process, Not Just Compliance

A key governance insight is that regulation must be visible as a process, not merely satisfied as a checklist. This includes documentation of interagency consultation, public explanations of how existing rules are being applied or clarified, and transparent articulation of which authorities are responsible for determining magnitude and applicability of which risks. When regulators and operators collaborate to clarify rules, such as explicitly codifying treatment of nuclear propulsion during ascent, this constitutes governance, not regulatory capture.

6. International Propagation and Adaptation

The U.S. model described here is not prescriptive for other states, but it is copyable. Other bodies likely to observe and adapt such precedents include UNCOPUOS (via working groups and guidelines) and OECD (through policy reports), and national space and nuclear regulators.

Importantly, governance propagation often occurs quietly through professional networks rather than formal treaties. Early clarity reduces the risk of divergent national interpretations.

The *UN Principles Relevant to the Use of Nuclear Power Sources in Outer Space* adopted by the General Assembly articulate internationally recognized expectations for the safe use of nuclear systems associated with space activities, including thorough safety assessments, notification of re-entry risks, and state responsibility for damage. These principles emphasize transparency, protection of the public and environment, and adherence to international law, norms that dovetail with the governance approach outlined above and that other states or multilateral bodies could adapt for emerging applications such as NTLVs.

However, the Principles are focused on nuclear power sources for onboard electrical power. They were not drafted with NTLVs in mind, and would require clarification or revision for application to NTLVs. For example, concepts such as an “operating orbit” (Principles 2(d) and 2(e)) presume exclusively on-orbit operation, whereas a launch vehicle’s operational profile begins at Earth’s surface. Similarly, provisions addressing re-entry following malfunction (Principle 5) do not clearly map to routine atmospheric descent and landing. In addition, Principle 2(c) specifies the use of highly enriched uranium, whereas contemporary regulatory practice in some states (such as the U.S. model) favors high-assay low-enriched uranium for new civil nuclear applications, which include NTLVs. These gaps reflect differences in activity scope rather than deficiencies in the underlying safety norms.

7. Why Early Governance Clarity Matters

The analysis underlying this paper is not proprietary. Other analysts can come to the same conclusions. As feasibility thresholds are crossed, multiple actors may develop NTLVs.

Early governance clarity reduces incentives for regulatory arbitrage, prevents fragmented or reactionary rulemaking, and supports public trust. The question is not whether NTLVs will ever be explored, but whether they will emerge within a coherent and responsible governance framework.

8. Conclusion

NTLVs can be governed through existing legal and regulatory structures with modest clarification and coordination. Treating them as an extension of current regimes rather than an unprecedented exception offers the best path toward safety, legitimacy, and international consistency.

We realize that a call to no action is an unusual call to action, but that is what we recommend: treat NTLVs as the launch vehicles they are, not as a new class in need of separate regulation.

References and Supporting Analysis

Technical and regulatory feasibility analysis, including engagement with U.S. regulators, is documented in publicly available studies such as *A Path Toward Nuclear Thermal Spaceplanes* (https://doi.org/10.5281/zenodo.18226586).

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