The Possible, the Impossible, and the Undecidable in Interstellar Propulsion

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Abstract

This paper synthesizes two complementary research programs: (i) constructive engineering of an interstellar "railway" based entirely on general relativity and quantum field theory, and (ii) formal undecidability results arising when resource allocation and replication dynamics are encoded into computational problems. Together, they frame interstellar propulsion as both a solvable engineering challenge and an intrinsically uncomputable problem class. We review key mechanisms—self-replicating waystations, pellet-beam propulsion, magsail braking, dust survival—alongside limits imposed by quantum energy inequalities, computational undecidability, and entropy constraints. The result is a curated anthology of concepts, mapping the boundary between the possible, the impossible, and the undecidable in interstellar transport.

Keywords: Interstellar propulsion, undecidability, self-replication, pellet beams, magsails, quantum energy inequalities.

1 Introduction: Between Physics and Computation

Interstellar transport is a natural frontier for both physics and engineering. Recent proposals such as Breakthrough Starshot [3], fusion concepts [5], and pellet-beam propulsion [4] demonstrate credible, though costly, extrapolations of known physics. Yet every constructive design eventually collides with two limits:

1. **Physics-bound constraints**, including quantum energy inequalities (QEIs), entropy laws, and dust-impact survival.

2. **Computation-bound constraints**, arising when resource allocation, replication, and scheduling are encoded in ways that reduce to undecidable problems.

This work builds directly on our companion studies: Paper IV (*Bootstrapping an Interstellar Railway* [1]) develops a constructive program for self-expanding infrastructure. Paper V (*Interstellar Transport as an Undecidable Resource-Allocation Problem* [2]) formalizes the computational limits. Here we synthesize the two into a speculative but rigorous anthology.

2 Constructive Program: The Interstellar Railway

The core engineering architecture is the "interstellar railway." A single 1-ton seed probe self-replicates across the void, constructing waystations spaced ~ 2 ly apart. Each station serves dual roles:

- Accelerating pellet beams (gram to kilogram scale) to relativistic speeds.

- Acting as magnetic or photonic braking mirrors for inbound payloads.

Figure 1: Mock schematic: self-replicating waystations extend an "interstellar railway" from the Solar System to the target.

The falsifiable thresholds (ISRU throughput, pellet collimation, dust survival, braking distance) are testable within near-term space engineering, placing the program firmly in the realm of physics, not speculation [1].

3 Formal Program: Undecidability in Resource Allocation

Beyond engineering lies computation. When replication, error correction, and energy distribution are modeled precisely, they can encode classical undecidable problems (e.g., tiling or halting). Paper V showed that:

- Determining optimal waystation spacing under stochastic replication errors is equivalent to an undecidable scheduling problem.

- The question of whether a seed probe will eventually fill space with viable stations is formally undecidable.
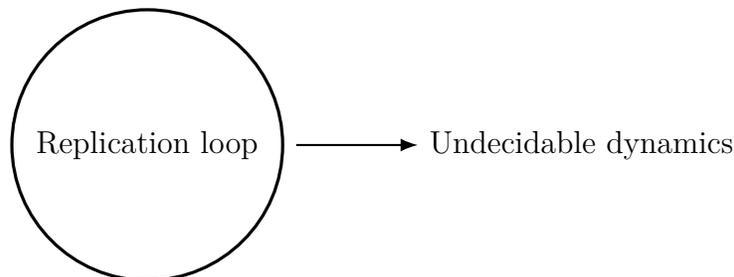

Figure 2: Mock schematic: replication dynamics can encode undecidable problems, implying intrinsic limits to predictability.

Thus interstellar propulsion is not merely an engineering challenge, but also a computational one with Gödel/Turing boundaries [2].

4 Anthology Synthesis: Between the Possible and the Undecidable

The juxtaposition of constructive engineering and undecidability yields a three-way classification:

1. **Possible:** Pellet-beam propulsion, magsail braking, ISRU replication—demonstrably consistent with GR+QFT.

2. **Impossible:** Macroscopic warp drives, traversable wormholes—ruled out by QEIs and entropy laws.

3. **Undecidable:** Long-term viability of replication under noisy environments—cannot be guaranteed even in principle.
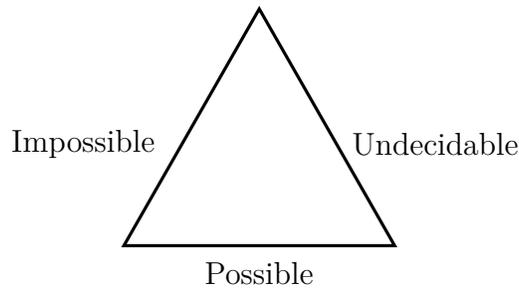
Impossible Undecidable

Possible

Figure 3: Conceptual map: interstellar transport sits at the intersection of the possible, impossible, and undecidable.

This framing transforms interstellar propulsion from an engineering exercise into a new kind of science: one that lives at the boundary between physics and computation.

5 Conclusion: A Dyson-Style Outlook

Like Dysons classic speculative reviews, this work is not a blueprint but a map. It shows where physics permits engineering, where laws forbid it, and where undecidability prevents even prediction. Future work should:

- Pursue near-term falsifiable tests (pellet collimation, ISRU throughput).

- Formalize undecidability links using computational complexity theory.

- Explore hybrid programs where constructive and formal approaches inform each other.

In this way, interstellar propulsion becomes both a physical frontier and a conceptual one—an experiment in stretching the limits of science itself.

Acknowledgments

References

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