

Bootstrapping an Interstellar Railway: Self-Replicating Waystations for Relativistic Payload Transport

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Abstract

We propose a fully physical architecture for interstellar transport, relying only on general relativity and quantum field theory. A single 1-ton seed probe self-replicates using in-situ resources to construct a chain of pellet-beam accelerators and magnetic braking stations across 1020 light years. This “interstellar railway” enables the reliable delivery of 1,000-kg scientific payloads at $0.20.3c$, with self-expansion and error-corrected manufacturing sustaining the infrastructure. We detail seed architecture, replication fidelity, pellet-beam dynamics, braking strategies, dust mitigation, navigation, power budgets, and reliability engineering. A decision framework compares this concept against single-shot laser sails [1] and fusion micro-explosives [3], identifying parameter ranges where a railway dominates. We conclude with falsifiable criteria: ISRU throughput, replication error rates, pellet collimation, dust survival probability, and braking distance.

Keywords: Interstellar propulsion, Self-replication, Pellet beams, Magsails, Relativistic transport, In-situ resource utilization.

1 Waystation Topology and Pellet Beams

Stations are spaced ~ 2 ly apart, following early pellet-beam concepts [2]. Each accelerates pellets (gram to kilogram scale) to $\sim 0.3c$ using electromagnetic mass drivers. Payloads couple via:

- Magnetic scoops for charged pellets.
- Ablative catchers for neutral pellets.

Pointing tolerance: $< 10^{-9}$ rad over multi-year flight. Off-axis tolerance: $< 10^3$ km at capture.

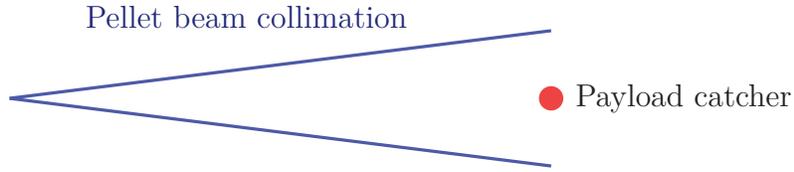


Figure 1: Mock illustration of pellet-beam collimation from a waystation to a payload catcher 2 ly away. Beam divergence must remain below 10^3 km at capture.

2 Braking Strategies

At destination, payload decelerates without onboard propellant:

- Magsail coupling to ISM and stellar wind (cross-section $\sim 10^6$ km²) [1, 4].
- Photon braking using staged reflectors built by earlier seeds.
- Pellet deceleration: final stations send counter-streams for drag.

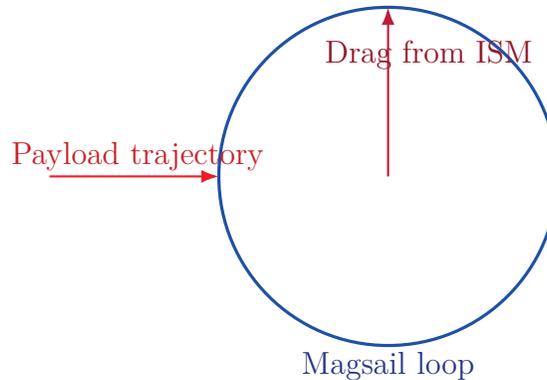


Figure 2: Mock magsail braking: payload couples magnetically to ISM/stellar wind plasma, producing drag over ≤ 5 ly.

3 Dust and Meteoroid Mitigation

At 0.3c, micron dust grains deposit MeVGeV energies per impact. Dust hazards to relativistic spacecraft have been analyzed in detail in [5]. Shield stack:

- Sacrificial foils (graphite).
- Plasma pre-ionization + magnetic deflection.
- Forward wafer swarm as shepherds.

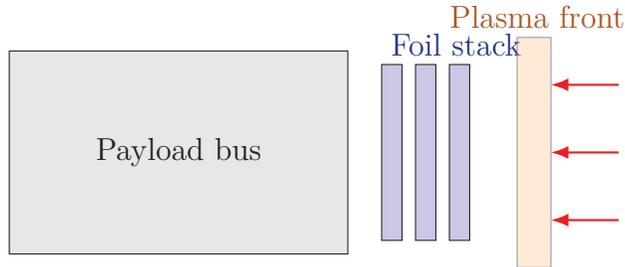


Figure 3: Mock shield topology: sacrificial foils + plasma deflection + shepherd wafers protect against relativistic dust impacts.

4 Falsifiability and Predictions

A crucial feature of the interstellar railway concept is that it rests on testable engineering and physical assumptions rather than speculative physics. We identify five falsifiable criteria that can confirm or rule out feasibility within GR+QFT:

- ISRU throughput $\gtrsim 10$ tons/yr per station.
- Manufacturing fidelity $\leq 1\%$ replication error per generation.
- Pellet collimation $< 10^3$ km divergence over 2 ly, consistent with prior beam studies [2].
- Dust shielding with survival probability $\geq 90\%$ over 20 ly.
- Braking distance ≤ 5 ly at $0.20.3c$.

5 Conclusion

We presented a railway-like interstellar propulsion concept based only on established physics. By bootstrapping a chain of self-replicating stations, 1,000-kg payloads can be accelerated and decelerated at relativistic speeds. The architecture distributes infrastructure, reduces single-point failure, and is falsifiable through near-term ISRU, manufacturing, and beam-pointing demonstrations. If thresholds are met, interstellar transport of ton-scale payloads becomes a realistic mid-term goal, extending earlier visionary concepts of relativistic transport [1].

Acknowledgments

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