Shepherded Gyroscopic Mass Streams: A Modular Dynamic-Support Architecture for Cislunar Orbital Infrastructure

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Abstract

Dynamic-support structures use high-velocity mass streams to generate forces far exceeding the static strength of their materials, potentially enabling orbital infrastructure from conventional steels and composites. The Launch Loop (Lofstrom, 1985) is the most developed such concept, but its continuous segmented rotor requires extremely fast centralized control and presents a cascading-failure mode capable of releasing terajoule-scale energy.

This paper proposes an alternative architecture: the Shepherded Gyroscopic Mass Stream (SGMS). In SGMS, discrete 2 kg steel-composite balls, each spinning at up to 50,000 rpm and carrying integrated Halbach permanent-magnet arrays, travel at 10–15 km/s along trajectories maintained by co-moving and stationary shepherd stations in cislunar or interplanetary space. Because the stream is discretized, failures are inherently localized: a single-ball loss releases energy only at the unit scale, with no direct propagation mechanism between neighboring masses. Gyroscopic angular momentum provides passive attitude stability on timescales of months to years, allowing shepherd corrections to replace the sub-microsecond global control demands associated with continuous-rotor architectures, while local station interactions remain millisecond-scale.

The SGMS framework also permits incremental deployment. A 100-ball proof-of-concept segment could be established within months of initial lunar electromagnetic launch, using lunar-sourced mass, gravitational slingshot velocity gain, and shepherd-mediated trajectory correction. More broadly, the architecture shifts dynamic support from a monolithic continuously coupled rotor to a packetized, failure-tolerant stream that is more compatible with staged deployment and bounded-risk testing. Within the regime analyzed here, no immediate first-principles physical inconsistency has been identified. However, several key subsystem claims—especially payload coupling at operational velocity and shepherd deflection geometry—remain unvalidated and require experimental demonstration.

1. Introduction

1.1 The Infrastructure Bottleneck

Space development is bottlenecked by infrastructure economics. Chemical rockets deliver payload to low Earth orbit at $2,000–$15,000 per kilogram, with global annual throughput on the order of 1,000 tonnes. Large-scale orbital construction requires mass throughputs orders of magnitude higher and costs orders of magnitude lower. No incremental improvement to rocket propulsion closes this gap.

Dynamic-support structures offer a categorically different approach. A high-velocity mass stream exerts forces that can support loads far exceeding the static strength of the stream material—the principle that makes a garden hose rigid under flow. This allows construction from ordinary steels and composites, because the structure never bears its full load statically. The concept enables orbital rings, tethered platforms, and electromagnetic launch systems from materials available today.

1.2 The Launch Loop and Its Architectural Limits

The Launch Loop (Lofstrom, 1985, updated 2009) uses a continuous or near-continuous segmented iron rotor (~3 kg/m, ~5 cm diameter) circulating at 14 km/s inside an evacuated sheath, with magnetic deflection at ground stations supporting a 2,000 km horizontal track at 80 km altitude. Payloads ride the track on maglev carriages, accelerated to orbital velocity by eddy-current coupling. Throughput estimates reach 80 vehicles/hour at 5 tonnes each using commercially available iron and steel.

The continuous-rotor architecture has three structural vulnerabilities:

Centralized fragility. The near-continuous rotor demands servo-controlled electromagnets at ~10 m intervals with sub-microsecond timing precision. A single controller failure can initiate exponentially growing oscillations.

Cascading failure. A rotor fracture propagates at the speed of sound in the material, releasing gigajoule-to-terajoule energy across the full 2,000 km footprint. The system has no internal mechanism to isolate a local failure.

Atmospheric dependence. Operation at 80 km altitude requires an evacuated sheath along the full track length in a region where residual atmospheric density is non-negligible.

These are architectural constraints of the design, not engineering details amenable to incremental optimization. This paper proposes an alternative architecture that trades these vulnerabilities for a different set of challenges.

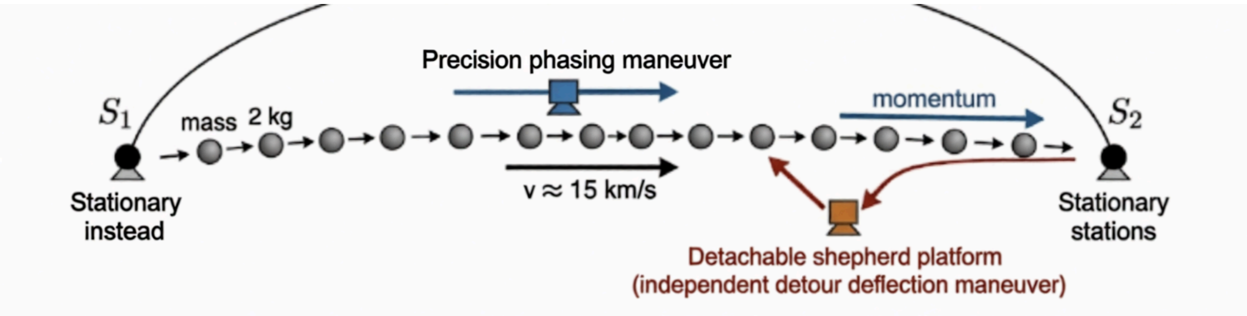
1.3 The Shepherded Gyroscopic Mass Stream

The SGMS departs from the Launch Loop in three ways: the rotor is replaced by discrete, independent spinning balls; the operating environment moves to free space (cislunar or interplanetary); and structural coherence is maintained by shepherd stations and shared orbital mechanics rather than a physical sheath.

Each ball is a 2 kg steel-composite sphere approximately 9 cm in diameter (average density ~5,000 kg/m^3), spinning at up to 50,000 rpm. The entire body rotates as a monolithic unit with no internal bearings. The spin provides gyroscopic attitude stabilization (angular momentum ~8.75 $kg \cdot m^2/s$), Halbach-array field generation ($\mu \approx 60$ $A \cdot m^2$) for close-range magnetic interactions, and flywheel energy storage.

Shepherd stations—independently powered platforms, both co-moving and stationary—perform stream phasing, failure isolation, and payload interface. Shepherds are detachable and repositionable via gravitational assists, eliminating dependence on fixed ground infrastructure.

Inter-ball magnetic forces are negligible at operational spacings (~2.2×10^{-16} N at 5 km). The stream is not a magnetically bound structure. Coherence derives from shared orbital trajectories and active shepherd management. The Halbach arrays serve local functions at close range ($d < 1$ m, where forces reach ~0.002 N): payload coupling, station interface, and magnetic signature sensing. The absence of inter-ball binding is what makes failure isolation absolute.



1.4 Two Distinct Timescales

A potential source of confusion must be addressed at the outset. The SGMS involves two fundamentally different control timescales, and conflating them would misrepresent the architecture:

Attitude drift timescale (months to years). Gyroscopic precession under ambient magnetic torques is extremely slow. In Earth's magnetotail shadow at lunar distance (B ~ 0.1 nT), a ball drifts 90° in ~73 years. Under nominal interplanetary magnetic field exposure (B ~ 5 nT), drift to 90° takes ~530 days. Shepherd attitude corrections are needed on timescales of months—not sub-microsecond, not even sub-second.

Station interaction timescale (sub-millisecond). When a ball passes through a shepherd station's interaction zone (~10 m at 15 km/s), the coupling window is ~0.67 ms. Payload acceleration, failure deflection, and close-range magnetic sensing all operate within this window. This is millisecond-class timing—vastly more relaxed than the baseline's sub-microsecond global servo, but not "seconds."

The architectural advantage is that the slow timescale governs the hard problem (maintaining stream coherence over megameter distances), while the fast timescale governs a local, well-bounded problem (individual station-ball interaction) that is amenable to conventional pulsed-electromagnet engineering.

1.5 Velocity Frame and Orbit Class

The 10–15 km/s stream velocity quoted throughout this paper refers to heliocentric translational speed—the velocity of the balls in the solar reference frame as they traverse cislunar or interplanetary space on high-eccentricity Earth-centered or heliocentric trajectories. This is not circular orbital velocity at any single altitude. For reference, circular velocity at lunar distance is ~1.02 km/s (Earth-centered) and lunar surface escape is ~2.4 km/s. The stream operates on trajectories that are hyperbolic with respect to the Moon and highly eccentric or escape-class with respect to Earth.

Reaching operational velocity from lunar-escape speed (~2.4 km/s) requires active energy input. Gravitational slingshots around the Moon and Earth provide partial velocity augmentation (~0.5–1 km/s per pass under favorable geometry), but purely passive flybys are insufficient to reach the full 10–15 km/s range. The balance is provided by shepherd electromagnetic boosts at periapsis—pulsed magnetic impulses delivered as balls pass through shepherd stations positioned along the flyby trajectory. This is propellant-free acceleration using the stream's own electromagnetic infrastructure and externally supplied electrical power (solar). The bootstrap sequence is detailed in Section 6.

1.6 Scope and Claims

This paper makes the following specific, bounded claims:

(1) Gyroscopic stabilization: A 2 kg, 0.046 m radius ball spinning at 50,000 rpm resists attitude perturbations with precession drift times of ~73 years (magnetotail, 0.1 nT) to ~530 days (IMF, 5 nT), establishing cislunar space as the required operating environment and shepherd attitude correction on timescales of months.

(2) Failure isolation: Single-ball failure energy is ~225 MJ (2 kg, 15 km/s)—less than 0.0002% of continuous-rotor cascade energy. No propagation mechanism exists between discrete units. A failed ball remains a severe hypervelocity hazard as an individual object, but systemic cascade is eliminated.

(3) Environmental survivability: LEO transit reference: total drag ~6 × 10^{-7} N, radiation ~10 krad/year (trapped belts), debris collision ~3 × 10^{-6} per ball per year. Cislunar primary environment: drag ~5 × 10^{-11} N (solar wind), radiation character shifts to GCR/SEP-dominated (requiring separate assessment), debris density far lower than LEO but not negligible in popular transit corridors.

(4) Material feasibility: All components constructible from existing steels, carbon-fiber composites, and NdFeB Halbach arrays. Rim speed (239 m/s) is well within flywheel burst margins.

(5) Bootstrap timeline: 100-ball segment operational within 6–9 months of first lunar electromagnetic launch, using gravity assists supplemented by shepherd electromagnetic boosts.

No claim of overall system feasibility is made. No first-principles physical impossibility has been identified in the bounded regime analyzed here, but several crucial subsystems—particularly payload electromagnetic coupling at 10–15 km/s relative velocity and shepherd deflection interaction geometry—remain unvalidated hypotheses requiring experimental demonstration.

2. System Architecture

2.1 Ball Design

The reference ball is a monolithic steel-composite sphere: 2 kg total mass, 0.046 m radius (~9 cm diameter), average density ~5,000 kg/m³. The interior is a high-strength steel core providing mass and structural integrity; the outer shell integrates a Halbach permanent-magnet array (NdFeB elements, ~30% of total volume) producing an effective magnetic dipole moment $\mu \approx 60$ A·m² with surface field ~0.5 T.

The entire ball rotates as a single body at up to 50,000 rpm ($\omega = 5{,}236$ rad/s). No internal bearings, slip rings, or articulated components exist. In vacuum, there is no atmospheric drag to oppose spin; spin decay occurs only through residual magnetic torques, which are quantified in Section 3.

Derived parameters:

Parameter	Value	Unit
Mass (m)	2	kg
Radius (r)	0.046	m
Diameter	~9.1	cm
Average density	~5,000	kg/m³
Moment of inertia ($I = 2/5\, mr^2$)	0.0017	kg·m²
Angular velocity (ω at 50,000 rpm)	5,236	rad/s
Angular momentum ($L = I\omega$)	8.75	kg·m²/s

Translational velocity (heliocentric)	10–15	km/s
Translational KE (at 15 km/s)	225	MJ
Rotational KE ($\frac{1}{2} I\omega^2$)	22.9	kJ
Rim speed (ωr)	239	m/s
Magnetic dipole moment (μ)	60	$A\cdot m^2$

The rim speed of 239 m/s provides substantial margin below the burst threshold of carbon-fiber composite flywheels (demonstrated >1,000 m/s). Translational kinetic energy (~225 MJ) exceeds rotational energy (~23 kJ) by four orders of magnitude, confirming that spin is an attitude-control and field-generation mechanism.

2.2 Shepherd Stations

Co-moving shepherds share the stream's trajectory and travel alongside ball groups. They perform fine-grained phasing corrections, monitor ball health via magnetic signature analysis, and serve as payload interface points. Co-moving shepherds interact with balls at low relative velocity, enabling extended electromagnetic coupling windows.

Stationary shepherds occupy fixed orbital positions (Earth-Moon L1/L2, stable high orbits) and provide coarse trajectory correction and failure isolation. Detecting anomalous balls via magnetic signature, they deliver pulsed electromagnetic impulses for deflection. At a passage time of ~0.67 ms (10 m range at 15 km/s), deflection to Δv = 50–100 m/s requires impulse of 100–200 $N\cdot s$ and peak forces of ~225 kN. These forces are within demonstrated pulsed-magnet capability, but the detailed coupling geometry (effective current loop, field gradient, interaction length) requires finite-element or experimental verification—this is identified as an open challenge in Section 9.

Both types are detachable. In a stream disruption, shepherds maneuver independently using gravitational assists for repositioning. No single station failure disables the system.

2.3 Stream Geometry

The baseline operational unit is a stream segment between two shepherd stations. A segment functions independently; no closed-loop geometry is required. Multiple segments can form linear links, branching networks, or closed loops as the system grows. The first useful system is two stations and a stream of balls between them.

2.4 Mass Augmentation

Manufactured balls can be supplemented by magnetically separated iron from lunar regolith or captured asteroidal fragments, serving as bulk momentum carriers in less-critical stream segments. However, the baseline 20–200 tonne system requires only manufactured balls.

3. Stability Analysis

3.1 Gyroscopic Precession

For the reference ball ($I = 0.0017$ kg·m², $\omega = 5{,}236$ rad/s, $\mu = 60$ A·m²), precession rate under magnetic torque $\tau = \mu B$ is:

$$\Omega p = \tau / (I\omega) = \mu B / (I\omega)$$

Environment	B	τ (N·m)	Ωp (rad/s)	$t_{90°}$
Magnetotail (lunar dist.)	0.1 nT	6.0×10^{-9}	6.8×10^{-10}	~73 years
IMF nominal (1 AU)	5 nT	3.0×10^{-7}	3.4×10^{-8}	~530 days
IMF elevated	10 nT	6.0×10^{-7}	6.8×10^{-8}	~265 days
LEO (unsuitable)	30 μT	1.8×10^{-3}	2.0×10^{-4}	~2.1 hours

In the magnetotail shadow at lunar distance, gyroscopic stability is effectively indefinite. Under full interplanetary magnetic field exposure, balls require shepherd attitude correction on timescales of months. In both cases, the relevant control timescale is many orders of magnitude longer than the baseline Launch Loop's sub-microsecond servo requirement. LEO is unsuitable for primary operations due to the strong geomagnetic field; this is a hard boundary condition of the architecture.

Gyroscopic precession acts as a low-pass filter on perturbations: high-frequency disturbances (magnetic jitter, thermal transients) are averaged out by the angular momentum, while only sustained torques produce measurable drift. This is a genuine passive-stability advantage that no continuous-rotor design possesses.

3.2 Inter-Ball Magnetic Forces

Axial force between aligned dipoles: $F(d) = (3\mu_0/2\pi)(\mu^2/d^4)$. With $\mu = 60$ A·m²:

Distance	Force	Context
1 m	0.0022 N	Close-range coupling
10 m	1.4×10^{-5} N	Shepherd sensing limit
100 m	1.4×10^{-9} N	< solar wind drag
5,000 m	2.2×10^{-16} N	Negligible

The stream has no passive magnetic coherence at operational spacings. Coherence is kinetic (shared trajectories) and active (shepherd management). Close-range forces (~0.002 N at 1 m) are sufficient for sensing and Lorentz/eddy-current augmented payload coupling but not for structural binding. This decoupling is the mechanism that prevents failure cascade.

4. Environmental Survivability

The SGMS operates primarily in cislunar or interplanetary space. LEO values are provided as worst-case transit references for phases when balls pass through low orbit during bootstrap or trajectory maneuvers.

4.1 Drag

Environment	Total Drag per Ball
LEO 600 km (transit reference)	~6×10^{-7} N
Solar wind (primary cislunar/interplanetary)	~5×10^{-11} N

In the primary operating environment, drag is negligible on all relevant timescales.

4.2 Radiation

The radiation environment changes character between LEO and cislunar/interplanetary space. In LEO, trapped Van Allen belt radiation dominates (~10 krad/year shielded at 600 km, yielding >100-year electronic lifetimes at 1 Mrad tolerance). Beyond the belts, exposure shifts to galactic cosmic ray (GCR) and solar energetic particle (SEP) environments, which are lower flux but higher per-particle energy and more penetrating. The monolithic steel-composite ball design provides substantial passive shielding; permanent magnets are effectively immune to radiation at these dose levels. A full GCR/SEP dose assessment for cislunar operations is warranted but is not expected to be limiting given the minimal electronics in the baseline ball design.

4.3 Debris

LEO debris collision probability: ~3×10^{-6} per ball per year at 600 km. For 10,000 balls, ~0.03 events/year (~1 loss per 33 years). In cislunar space, present-day man-made object density is far lower than crowded LEO bands, but the term “negligible” should be used cautiously: popular cislunar transit corridors are expected to grow in traffic density, and conjunction-risk practices are being extended to the cislunar domain. The modular architecture converts each loss into a single-ball replacement event rather than system failure.

5. Failure Modes and Isolation

5.1 Energy Comparison

Parameter	Launch Loop	SGMS (single ball)
Failure unit	km-scale rotor section	2 kg ball
Energy per event	GJ–TJ (propagating)	~225 MJ (isolated)
Propagation	Mechanical, at sound speed	None
Affected footprint	2,000 km ground track	Single object trajectory
System fraction at risk	Up to 100%	<0.01% (1 of 10,000+)

A single-ball failure releases less than 0.0002% of the energy in a continuous-rotor cascade. No physical mechanism exists for failure propagation between discrete balls separated by kilometers of vacuum. However, it must be noted that a 225 MJ object at 15 km/s remains a severe hypervelocity hazard as an individual object—the improvement is in systemic containment (no cascade, no propagation, graceful degradation), not in the harmlessness of any single failure.

5.2 Shepherd Deflection

Shepherd stations deflect failed balls onto escape trajectories via pulsed electromagnetic impulse (Δv 50–100 m/s, impulse 100–200 N·s, peak force ~225 kN over ~0.67 ms). This is within demonstrated pulsed-magnet force levels but constitutes a plausibility estimate, not a validated protocol. The interaction geometry—effective current loop, field gradient, coupling length—requires finite-element modeling or experimental measurement before the deflection protocol can be considered a closed safety case. This is identified as a priority open challenge.

6. Bootstrap Sequence and Economics

6.1 Lunar Electromagnetic Launch

Seed mass is launched from the lunar surface using electromagnetic mass drivers. O'Neill/NASA studies (1975–1977 Ames Summer Studies) demonstrated throughput of 1–10 payloads/second for 1–10 kg buckets at lunar escape velocity (~2.4 km/s). For 2 kg SGMS balls at conservative 1 ball/minute cadence, 100 balls require ~1.7 hours of firing time. The lunar environment (vacuum, low gravity, solar power) is ideal for electromagnetic launch.

6.2 Velocity Augmentation

Initial launch velocity is ~2.4 km/s (lunar escape). Operational velocity is 10–15 km/s heliocentric. This gap is bridged by a combination of gravitational assists and shepherd electromagnetic boosts. Gravitational slingshots around the Moon and Earth provide partial velocity augmentation under favorable geometry. NASA trajectory analyses indicate that lunar flybys can raise escape energy meaningfully but are insufficient alone to reach the full operational velocity range from lunar-escape conditions. The balance is provided by shepherd electromagnetic impulses at periapsis—pulsed magnetic boosts delivered as balls pass through shepherd stations during flyby trajectories. This is propellant-free acceleration using externally supplied solar-electric power.

Balls are launched in parallel batches; each assist loop takes 3–14 days. Shepherd capture and phasing begins after the first 10–20 units reach target velocity.

6.3 Timeline and Economics

Phase	Duration
Launches + initial captures	1–2 weeks
Velocity build (assists + shepherd boosts)	3–6 months
Shepherd phasing + verification	1–2 months
Total to 100-ball segment	6–9 months

Full-scale seed mass: 20–200 tonnes (10,000–100,000 balls at 2 kg). Launched entirely from the Moon, this avoids $40 million–$3 billion in Earth-to-orbit costs at current pricing ($2,000–$15,000/kg). The lunar mass-driver is a one-time infrastructure investment serving all subsequent stream operations.

7. Applications

The following applications are physically compatible with the SGMS architecture. Each requires explicit force-balance and energy-replenishment analysis not fully developed in this paper; they are described here to indicate the design space, not to claim operational readiness.

7.1 Dynamic Structural Anchoring

A high-velocity mass stream provides dynamic forces that can anchor larger structures—tethers, orbital rings, habitats—via momentum exchange at shepherd stations. A 10,000-ball stream at 15 km/s carries aggregate momentum of $\sim 3 \times 10^8$ kg·m/s. Load transfer from attached structures into the stream must be modeled as an explicit free-body problem: what reaction closes the force balance, and how is momentum depleted by anchoring loads replenished? If balls decelerate while supporting external loads, the stream requires reboost (shepherd electromagnetic impulses, gravitational assists, or additional ball injection) to maintain operational velocity. The replenishment budget is a critical design parameter not yet quantified.

7.2 Payload Acceleration

Payload vehicles can couple to passing balls via close-range eddy-current and Lorentz forces. At kilometer-scale inter-ball spacing and 15 km/s, individual balls pass a given point roughly every

0.33 seconds, producing sparse pulsed interactions rather than a smooth continuous drive. Effective acceleration requires either local densification (grouping balls into packets at shepherd stations for quasi-continuous coupling) or payload-side buffering (accumulating impulse over many pulses). The phrase "distributed linear induction motor" is appropriate only with explicit duty-cycle and densification provisions. Energy extracted from the stream for payload acceleration decelerates the balls and must be replenished.

7.3 Inductive Power Transfer

Each spinning ball is a rotating Halbach magnet—a brushless AC source. Receiving coils near the stream path experience alternating flux during ball passage. Power transfer rate depends on coupling distance, ball passage frequency, and spin rate. At operational spacings the duty cycle is low (0.67 ms interaction per ~0.33 s interval), limiting average power unless local densification is employed. Energy extracted for power transfer decelerates balls and requires replenishment.

7.4 Future Directions (Speculative)

Magneto-inertial fusion via coordinated ball-stream compression, atmospheric constituent scooping, and extension to solar-system-scale dynamic structures remain far-future extrapolations requiring separate analysis entirely beyond the present scope.

8. Comparison with Launch Loop

The SGMS trades one vulnerability set for another. It plausibly improves failure containment and incremental deployability; it introduces new challenges in cislunar astrodynamics, multi-body coordination, and station interaction timing that the Launch Loop avoids by operating within a physical sheath.

Parameter	Launch Loop	SGMS
Rotor type	Continuous segmented tube	Discrete 2 kg spinning balls
Environment	80 km, evacuated sheath	Cislunar/interplanetary, free space
Attitude control	Sub-μs servo (global)	Gyro passive (months–decades drift)
Station interaction	Continuous coupling	~0.67 ms pulsed windows
Failure energy	GJ–TJ (cascade)	~225 MJ (isolated)
Failure propagation	Mechanical, full system	None
Sheath	Required (2,000 km)	Not required
Deployment	Full build before use	Incremental segments
Seed mass source	Earth surface	Lunar EM launch
Time to first use	Years (full construction)	6–9 months (100-ball segment)

New challenges	Sheath integrity, thermal	Astrodynamics, coordination, pulsed coupling

9. Open Challenges

Intellectual honesty requires these be stated as clearly as the advantages:

Stream phasing at scale. Maintaining coherent spacing among thousands of balls over megameter trajectories requires distributed control without precedent. The computational and communications architecture is the primary systems-engineering challenge.

Payload coupling at operational velocity. Electromagnetic coupling between balls and payloads at 10–15 km/s relative velocity has not been experimentally demonstrated. The 0.67 ms interaction window, sparse duty cycle, and close-range force of ~0.002 N at 1 m raise questions about achievable energy transfer rates that only experiment can resolve.

Shepherd deflection geometry. The 225 kN peak force estimate is order-of-magnitude plausible but relies on simplified dipole models. Finite-element or experimental verification of the pulsed coupling geometry is required before the deflection protocol constitutes a safety case.

Energy replenishment. Every useful application (anchoring, payload acceleration, power transfer) extracts energy from the stream and decelerates balls. The paper describes the output side of this budget but not the replenishment side. Closing the energy balance—showing that shepherd reboost, gravitational assists, and new ball injection can sustain operations—is essential for any claim of long-term viability.

Lunar coilgun development. Electromagnetic launch from the lunar surface is studied (O'Neill heritage) but unbuilt. A coilgun launching 2 kg projectiles at 2.4+ km/s with targeting accuracy sufficient for gravitational capture is a significant engineering project.

Spin maintenance. Residual magnetic torques produce spin-down. Under nominal IMF (5 nT), torque is ~2.4×10^{-6} N·m. The spin-decay rate and re-spin protocol (electromagnetic boost at shepherd stations) need quantification.

Space traffic management. Thousands of hypervelocity objects in cislunar space present unprecedented coordination challenges. Regulatory acceptance requires demonstrated controllability.

10. Conclusion

The Shepherded Gyroscopic Mass Stream is a distinct architecture from the Launch Loop, sharing only the principle of dynamic support through high-velocity mass streams. It trades the Launch Loop's continuous-rotor vulnerabilities (centralized control, cascading failure, atmospheric sheath) for a different set of challenges (cislunar astrodynamics, pulsed-interaction coupling, distributed multi-body coordination).

The trade appears favorable on paper: passive gyroscopic stability replacing sub-microsecond servos, absolute failure isolation replacing cascade risk, incremental lunar-sourced deployment replacing monolithic Earth-launched construction, and multifunctional infrastructure potential (anchoring, transport, power transfer) from a single mass stream—all using existing materials.

No first-principles physical impossibility has been identified in the bounded regime analyzed here. However, several crucial subsystems remain unvalidated hypotheses. Payload coupling at 10–15 km/s, shepherd deflection interaction geometry, and energy-balance closure for sustained operations are open problems that require experimental demonstration, not further analytical elaboration.

If these challenges prove tractable, the SGMS offers a pathway from a single lunar coilgun shot to incrementally growing orbital infrastructure—built from steel, composites, and permanent magnets available today.

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