Lagrange Points Are the Next Frontier of Superintelligence

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Abstract

The exponential scaling of Artificial General Intelligence (AGI) approaches the fundamental thermodynamic and power-density limits of terrestrial infrastructure. This paper proposes a multi-tiered extra-planetary architecture: the **Lagrange Compute Systems (LCS)**. We outline a phased deployment strategy, initiating with Earth-Moon Trojan points (L_4/L_5) to facilitate latency-sensitive inference, followed by Sun-Earth Trojan points (L_4/L_5) for high-throughput foundation model training. By leveraging the Coriolis-stabilized potential wells of these regions, the LCS framework circumvents the prohibitive station-keeping requirements associated with unstable collinear points (L_1, L_2). This architecture offers a viable pathway for the sustainable expansion of computational capacity beyond the thermal dissipation constraints of the planetary surface.

Project Page: https://github.com/yifanzhang-pro/lagrange-superintelligence

1 Introduction

Empirical scaling laws in deep learning establish a robust power-law relationship between computational expenditure and model proficiency. As computational demands enter the yottaflop regime, terrestrial data centers face fundamental physical constraints: localized power grid saturation and the thermodynamic limits of atmospheric heat dissipation.

To mitigate these constraints, we propose the Lagrange Compute Systems (LCS) architecture. Orbital selection is critical; Low Earth Orbit (LEO) is suboptimal due to thermal cycling, atmospheric drag, and Kessler syndrome risks, while collinear Lagrange points (L_1, L_2) function as unstable saddle points requiring continuous active maintenance. Conversely, the Trojan points (L_4/L_5) offer inherent structural stability via effective potential maxima. This paper delineates a dual-phase roadmap: the *Cislunar Tier* for interactive tasks and the *Heliocentric Tier* for asynchronous, large-scale model training.

2 Background: Orbital Mechanics and Stability

In the Circular Restricted Three-Body Problem (CR3BP), five equilibrium points exist. For the deployment of high-mass computational infrastructure, these locations are categorized by their dynamic stability:

- **Unstable Collinear Points (L_1, L_2, L_3):** Functioning as saddle points in the effective potential landscape, these regions require constant active station-keeping. Perturbations result in exponential divergence, imposing a propellant penalty proportional to the infrastructure mass. This renders them inefficient for multi-megaton computational arrays.
- **Stable Trojan Points (L_4, L_5):** Situated at the vertices of equilateral triangles relative to the massive bodies, these points are dynamically stable (given mass ratios $\mu < 0.0385$). Objects in these regions undergo stable libration, permitting the assembly of massive, modular swarms with minimal active control.

3 Phase I: The Earth-Moon LCS Tier

The Earth-Moon L_4 and L_5 points serve as the primary staging grounds for the first-generation LCS, balancing latency with orbital stability.

3.1 Latency and Connectivity

The Earth-Moon system exhibits a one-way light time (OWLT) of ≈ 1.28 seconds. Utilizing high-bandwidth optical cross-links, this tier functions as a low-latency extension of terrestrial networks for:

- **Latency-Tolerant Inference:** Hosting agentic models where a Round-Trip Time (RTT) of ≈ 2.56s is permissible, thereby offloading high-energy workloads from the terrestrial thermal budget.
- **Tele-operation:** Enabling near-real-time robotic control for the maintenance and modular expansion of the compute fabric.

3.2 Orbital Dynamics

The Trojan points provide *passive safety*. Unlike the L_1 point, where guidance failure results in rapid departure from the Lissajous orbit, the L_4/L_5 potential wells ensure that hardware remains trapped within stable libration orbits during power or propulsion contingencies.

Algorithm 1 LCS Libration Stabilization (Earth-Moon)

Require: State vector $\mathbf{x}$, Solar Perturbation $\vec{F}_{\text{sun}}$
Ensure: Control vector $\vec{u}$ maintains bounded libration

```
1: F_net ← ∇U_moon(r) + ∇U_earth(r)
2: if ||δx|| > ε_threshold then
3:     u ← −K(F_net + F_sun)          ▷ Corrective maneuver
4: else
5:     u ← 0                          ▷ Passive drift
6: end if
```

$$\vec{F}_{\text{net}} \leftarrow \nabla U_{\text{moon}}(\vec{r}) + \nabla U_{\text{earth}}(\vec{r})$$
$$\textbf{if } ||\delta\mathbf{x}|| > \epsilon_{\text{threshold}} \textbf{ then } \vec{u} \leftarrow -K(\vec{F}_{\text{net}} + \vec{F}_{\text{sun}}) \quad \triangleright \text{ Corrective maneuver}$$
$$\textbf{else } \vec{u} \leftarrow 0 \quad \triangleright \text{ Passive drift} \quad \textbf{end if}$$

4 Phase II: The Sun-Earth LCS Tier

As the demand for foundational model training scales, the architecture expands to the Sun-Earth L_4/L_5 points.

4.1 The Energy-Latency Tradeoff

The $\approx$ 8-minute OWLT at 1 AU necessitates a transition to asynchronous workloads. This redefines the distributed training paradigm; utilizing solar radiation pressure for momentum management allows for operational lifespans exceeding 50 years without significant propellant resupply.

4.2 Energy Abundance

Deployment at Sun-Earth L_4 ensures the array remains permanently outside Earth's umbra, providing a 100% solar duty cycle.

$$P_{\text{in}} = \eta \cdot A_{\text{array}} \cdot S_0 \tag{4.1}$$

With a solar constant $S_0 \approx 1361\,\text{W/m}^2$, energy harvesting is maximized and consistent compared to eclipsed geocentric orbits.

5 Deep Space Thermal Management

Thermal rejection is the governing constraint for high-density computation in vacuum. Radiative cooling is defined by the Stefan-Boltzmann law:

$$\dot{Q}_{\text{out}} = \epsilon\sigma A_{\text{rad}}(T^4_{\text{radiator}} - T^4_{\text{background}}) \tag{5.1}$$

By utilizing sun-shielded Multi-Layer Insulation (MLI) and V-groove radiators, the LCS leverages the Cosmic Microwave Background ($T_{\text{CMB}} \approx 2.7K$) as a heat sink. This facilitates the achievement of cryogenic operating temperatures, enabling superconducting compute fabrics and minimizing internal resistive losses.

6 Conclusion

The migration of large-scale AI infrastructure to Lagrange Compute Systems (LCS) represents a necessary evolution in response to terrestrial thermodynamic limits. This tiered architecture, utilizing the Earth-Moon system for inference and the Sun-Earth system for high-throughput training, provides a scalable, stable, and energetically abundant framework for the future of AGI.