TITLE:- STABILITY IN THE SHADOWS: MODELING DRIFT OF AUTONOMOUS NODES IN LAGRANGIAN ORBITS

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Abstract:- This Paper Investigates the dynamics of Orbital Drift of Autonomous Nodes operating near Lagrangian Points (L1 - L5). These are Gravitational Equilibrium zones used by DysonNode Satellites for Orbital Positioning. Even with stabilization protocols, gradual displacement due to micro-gravity , solar pressure, and quantum curvature instabilities leads to drift — Threating Long-term System Autonomy.

Introduction:- Lagrangian Points allow Stable orbital positioning with minimal fuel. But nodes placed there are not fully static – they undergo liberation, Chaotic drift, and Non-linear due to;

- ★ *3 Body Gravitational Instabilities*
- ★ *Solar Wind + Radiation pressure*
- ★ *Momentum Build-up via micro-thrusts*
- ★ *Curved Space Warping due to nearby mass activity.*

What are lagrangian Points ? :- They are points in a two-body gravitational System (e.g., Sun- Earth) where a Third Body can Remain in relative equilibrium.

Points	*Type*	*Stability*
L1, L2, L3	*Collinear*	*Unstable (Require Connections)*
L4 / L5	*Triangular*	*Conditionally Stable (But Susceptible to Perturbations)*

Drift Dynamics near L1 - L5:- Lagrangian Zones are not flat- they're dynamic potential Wells.

★ *L1 - L3 - > Unstable equilibrium Nodes placed here drift Rapidly without Corrections.*

★ *L4 / L5 L - > Stable but can drift under Small Perturbations (e.g., mass loss, radiation).*

Drift Grows Exponentially if left Uncontrolled;

$$\delta r(t) \propto e^{\lambda t}$$

Mathematical Orbit Perturbations Model:- *Use Hill- Clohessy - Wiltshire equations for Small Oscillations;*

$$\begin{cases} \ddot{x} - 2n\dot{y} - 3n^2x = 0 \\ \ddot{y} + 2n\dot{x} = 0 \\ \ddot{z} + n^2z = 0 \end{cases}$$

Where., x,y,z = Position from equilibrium

n = Mean Motion of Central Body

Drift from Solar Radiation Pressure:- *Solar Photons import tiny but Cumulative force;*

$$F = P_{solar} * A * (1 - P) / c$$

Where., A = Area facing the Sun

P = Reflectivity Coefficient

c = Speed of Light

Drift Momentum Metric:- *Define Node Drift Index (NDI);*

$$NDI(t) = \sqrt{(x(t) - x0)^2 + (y(t) - y0)^2}$$

If NDI (t) > R_{safe}, trigger fallback

Set., R_{safe} = 10000 Km

$\lambda = 1.4 * 10^{-5}\ 1/second$

Fallback Conditions:-

Conditions	*Trigger*
NDI > R_{safe}	*Auto thrust Vector Correction*
Rate of drift d(NDI) / dt > 3 km/sec	*Shutdown Non-linear*
Positional Sensor error > 2%	*Switch to Redundant Inertial Navigation*

Dyson Node Inertial fallback delay:- Node Control Lag↣ Drift not Corrected Instantly.

Even 1 - 2 second fallback delay at 1 AU - > Micro-Oscillations grow Chaotic over time.

Autonomous Correction Algorithms:- Our Model Includes;

★ *Predictive Correction using Velocity Curve.*

★ *AI Controlled micro-thruster burst in opposite Direction.*

★ *Fuel Less Corrections using Solar Sail orientation.*

Curvature Feedback Model (SOLIS Original):- We Integrate Curvature – based drift feedback;

Let;

$$\mathcal{K} = Local\,Curvature$$

Then define;

$$\delta_{drift} \propto \nabla\, \mathcal{K} * \hat{r}$$

That is., If Spacetime Curvature Changes near the node ,Drift Direction aligns with Curvature Gradient.

Simulation Parameters: -

parameter	*Value*
Inertial drift velocity	*0.01 m/ s*
Time Window	*6000 Orbital Cycles*
Correction Latency	*0.2 Second*
Radiation Pressure	$9\ \mu N/m^2$

Fallback Protocols:- If Drift exceeds Critical boundary;

- ★ *Switch to Station keeping emergency mode*
- ★ *Cut off Non-Critical Sensors*
- ★ *Focus only on Orientation And thrust Correction*

Real world parallels:- ★ SOHO< JWST, Gaia all perform Constant Corrections around L1/L2.

★ L5 Mission (Planned) will need AI Stablizations like SOLIS Nodes.

★ The model could literally guide future lagrangian Stabilizers.

Theoretical Hypothesis:- "A dyson node is not in orbit – it's surfing the fabric of Curvature. It's drift is not Random, it is Spacetime's whisper of Imbalance".

— > I propose drift is practically geometric – based not only on Mass and Informational Entropy Gradients in Curved geometry.

Conclusion: - Lagrangian drift is Inevitable – but not uncontrollable. With Real time modeling Curvature based predictions, and predictive Correction, SOLIS Nodes can maintain for decades without failure.

— > This scenario Proves., Autonomy is not about staying balance while drifting inside chaos.

References:-

1. ***Roy, A. E.***
   "Orbital Motion,"
   Institute of Physics Publishing, 2004.

2. ***Farquhar, R.W., Muhonen, D.P., Church, L.C.***
   "The Trajectory Design of the ISEE-3 Mission,"
   AIAA/AAS Astrodynamics Conference, 1977.

3. ***NASA Goddard Space Flight Center,***
   "Lagrange Points: Gateway to Space Exploration,"
   https://solarsystem.nasa.gov

4. ***Koon, W.S., Lo, M.W., Marsden, J.E., Ross, S.D.***
   "Dynamical Systems, the Three-Body Problem and Space Mission Design,"
   California Institute of Technology, 2000.

5. ***Szebehely, V. and Giacaglia, G.E.O.***
   "Stability of L4 and L5 in the Elliptic Restricted Problem of Three Bodies,"
   The Astronomical Journal, 1964.

6. ***ESA Gaia Mission Documentation,***
   "Orbit Maintenance at L2: Station-Keeping for Billion-Star Mapping,"
   https://www.esa.int

7. ***F.W. Dyson, A.S. Eddington, and C. Davidson,***
"A Determination of the Deflection of Light by the Sun's Gravitational Field,"
Philosophical Transactions of the Royal Society, 1920. (Included due to curvature linkage)

8. ***Szebehely, V.***
"Theory of Orbits: The Restricted Problem of Three Bodies,"
Academic Press, 1967.

9. ***Project SOLIS — Heet Trivedi (2025)***
"Curvature-Based Autonomous Drift Correction Algorithms in Lagrangian-Equilibrium Nodes,"
Self-Published Research Archive, 2025.