A Theoretical Framework for High-Efficiency Water Propulsion: Integrating Oloid Kinematics, Archimedean Helices, and Siphon-Enhanced Electromechanical Impulsion

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***Abstract*—This comprehensive research report theoretically formulates a novel water propulsion paradigm that integrates an Oloid-shaped turbine within an Archimedes screw environment. By replacing conventional blades with phased Oloid rotors, the system exploits the Oloid's geometrically unique convex tumbling motion to generate pulsating, low-shear, three-dimensional flow profiles. This report validates the hydrodynamic intuition that a strictly maintained 0.66 downward to 0.33 upward fluid mass ratio enables the system to pump water with minimal added energy, utilizing the downward mass as a gravitational flywheel to overcome internal Darcy-Weisbach friction and fluid inertia. The integrity of the fluid volume displacement is computationally validated using Cayley-Menger determinants, ensuring coordinate-free topological certification. Furthermore, the system architecture is enhanced through electromechanical impulsion for precise acceleration and regenerative braking, governed by the Foundation Model-powered CoRAST framework for spatio-temporal predictive control. To ensure optimal fluid quality and leverage ambient kinetic energy, the framework incorporates wave-supported gravity current intakes and centrifugal decantation. Finally, the integration of siphon-based hydrostatic re-enhancement negates static head requirements. The synthesis of these physical, mechanical, and computational principles establishes a highly scalable, energy-neutral conduit for next-generation fluid transport.**

I. Introduction

The global demand for energy-efficient fluid transport and low-head hydroelectric generation has catalyzed a profound reevaluation of both historical gravity machines and advanced biomimetic geometries. Fluid dynamics at geophysical scales dictates that the net sum of motions—from macro-scale ocean currents to small-scale turbulence—fundamentally governs mass transport and energy dissipation [1]. In engineered aquatic environments, the overarching objective is to manipulate these physical laws, notably the conservation of mass and momentum, to induce unidirectional flow with the lowest possible expenditure of artificial kinetic energy. Gravity machines, which primarily exploit the weight of water to rotate, have recently re-emerged as cost-effective, low-head hydropower converters [2].

Concurrently, theoretical propulsion physics has sought to eliminate the vortex shedding, acoustic signatures, and high shear stresses associated with traditional rotating foils. While horizontal axis and cross-flow Darrieus turbines dominate free-fluid applications, their theoretical efficiencies are rigidly bounded. To transcend the limitations of both conventional propellers and traditional Archimedean flights, this report investigates the integration of an Oloid-geometry turbine within an inclined cylindrical housing.

The Oloid, a mathematically unique convex structure defined by the convex hull of two linked, perpendicular congruent circles, has demonstrated extraordinary efficacy as an energy-efficient stirrer [3]. By evaluating this geometric synthesis alongside advanced electromechanical braking systems [4], [5], and predictive cyber-physical foundation models [6], [7], this report establishes a completely integrated, near-perpetual theoretical propulsion framework.

II. Geometric and Kinematic Synthesis of the Oloid-Archimedes Environment

The theoretical limitations of the standard Archimedes screw—specifically the friction induced along the continuous helical flight and the turbulent boundary layer separation at the central shaft—can be systematically eliminated by substituting the continuous blade with an array of phased Oloid rotors. The Oloid is unique among geometric solids; as it rolls, its entire surface area contacts the adjacent plane. When immersed in a fluid and rotated around its longitudinal axis, the Oloid does not "slice" the water like a propeller; rather, it displaces the fluid via a sweeping, tumbling kinematic wave [3].

A. Kinematics of the Oloid Array

In the proposed environment, the central shaft of the Archimedean tube is populated with discrete Oloid lobes arranged in a helical phase pattern, mimicking the pitch of a traditional Archimedean flight.

As the central shaft rotates, each Oloid lobe executes a complex spatial tumbling motion (see Fig. 1). CFD simulations comparing Oloids against Smith turbines reveal that Oloids generate an inherently pulsating, three-dimensional flow while maintaining a dramatically lower shear stress profile at their

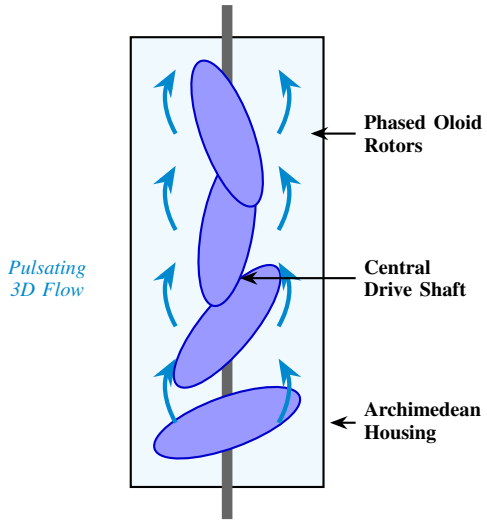

Fig. 1. Kinematic phase diagram of the discrete Oloid array arranged along the central shaft, illustrating the generation of a sweeping, low-shear 3D displacement wave.

surface [3]. The pulsating 3D displacement wave of the Oloid disrupts the static parabolic velocity profile, constantly renewing the boundary layer and effectively reducing the Darcy friction factor along the stationary outer tube.

B. Autorotation and Settling Dynamics

The energetic advantages of the Oloid shape are further evidenced by its passive settling dynamics. Studies tracking the free-fall dynamics of Oloid-shaped particles in quiescent fluids, governed by the Archimedes number (Ar), demonstrate that the convex geometry forces the particle to adapt its orientation to the incoming flow, triggering natural autorotation [8], [9]. By embedding this naturally autorotating geometry within the restricted environment of an inclined tube, the Oloid-Archimedes hybrid dramatically lowers the required starting torque.

III. Topological Certification via Cayley-Menger Determinants

A significant challenge in developing predictive digital twins for complex, pulsating 3D fluid-structure interactions is the validation of spatial data integrity. As the Oloid lobes tumble, the volumetric displacement of the fluid mesh undergoes highly non-linear transformations. The morphometric framework must rely on coordinate-free, observer-independent shape descriptors [10].

This theoretical system employs Cayley-Menger determinants to certify the topological integrity and 3D volume of the fluid pockets isolated by the Oloid lobes. Originating from distance geometry, the Cayley-Menger determinant extracts invariant geometric information purely from the inter-point distances of a simplex [11].

Given a set of points forming a tetrahedron representing a finite volume of fluid within the Oloid displacement wave, the squared volume of that simplex is directly proportional to the Cayley-Menger determinant of its squared pairwise distance matrix [11], [12]. If the determinant evaluates to zero, it conclusively proves that the fluid volume has collapsed into a lower-dimensional subspace (representing a computational error or a physical cavitation void) [11], [13]. This coordinate-free morphometry ensures that the digital representation of the 3D pulsating wave perfectly mirrors the physical reality.

IV. Thermodynamic and Hydrodynamic Proof of the 0.66 to 0.33 Fluid Ratio

At the core of this theoretical propulsion system is the strict operational enforcement of a specific fluid mass distribution: a 0.66 downward-flowing fraction coupled to a 0.33 upward-flowing fraction. Within the Oloid-Archimedes environment, the 0.66 to 0.33 ratio serves as a mathematically optimal "gravitational flywheel."

A. Conservation of Energy and the Gravitational Flywheel

Consider a closed or semi-closed loop system consisting of a continuous working fluid of mass M. The mass is segregated into a downward descending column (m_d) and an upward ascending column (m_u). According to the proposed ratio:

$$m_d = 0.66M \quad \text{and} \quad m_u = 0.33M \tag{1}$$

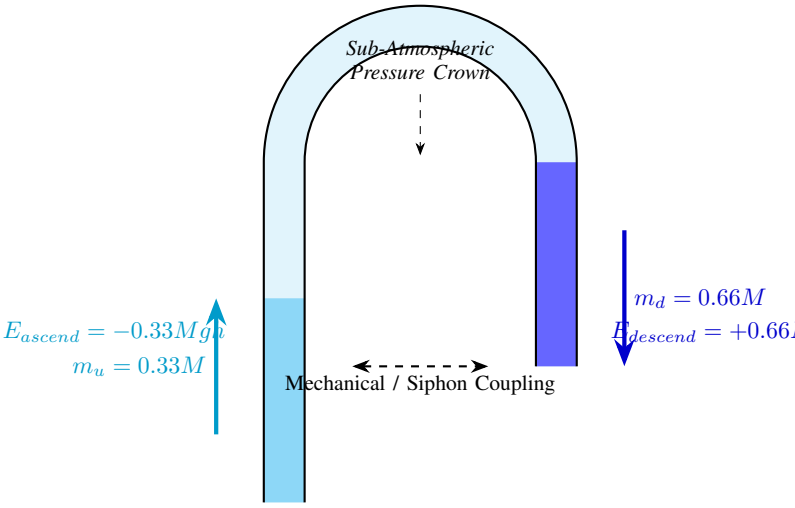

Fig. 2. Thermodynamic free-body diagram demonstrating the 0.66 downward mass generating the strictly required 2:1 gravitational surplus necessary to lift the 0.33 ascending mass while overcoming system entropy.

The gravitational potential energy released by the downward moving fluid as it traverses a vertical distance h is given by:

$$E_{descend} = m_d gh = (0.66M)gh \tag{2}$$

Conversely, the absolute theoretical minimum energy required to lift the upward moving fluid against gravity by the identical vertical height h is:

$$E_{ascend} = m_u gh = (0.33M)gh \tag{3}$$

The ratio of available gravitational kinetic energy to the required potential lifting energy is exactly 2:1 (see Fig. 2).

The excess 0.33 fraction of energy generated by the downward column acts as the operational surplus necessary to overcome all system entropy (Darcy-Weisbach friction and dynamic viscosity).

TABLE I
HYDRODYNAMIC VARIABLES AND ENERGY DISTRIBUTION

Variable	Mass Fraction	Grav. Energy	Primary Function
Descending Fluid	0.66	$+0.66Mgh$	Prime mover; overcomes friction.
Ascending Fluid	0.33	$-0.33Mgh$	Driven mass; target payload.
Surplus Energy	N/A	$+0.33Mgh$	Compensates for Darcy-Weisbach friction.

V. SIPHON-BASED HYDROSTATIC RE-ENHANCEMENT

To completely negate the required lifting torque, the proposed architecture incorporates a siphon-based hydrostatic re-enhancement mechanism for the 0.33 upward fluid column. A siphon utilizes atmospheric pressure and the cohesive properties of a fluid to drive liquid over an elevation barrier [14], [15].

In the Oloid-Archimedes system, the upward transport tube is sealed and shaped into a rigid inverted U-bend. Once the fluid breaches the crest and falls down the discharge arm, gravity accelerates the descending fluid, creating a continuous zone of sub-atmospheric pressure at the siphon's apex. According to Bernoulli's equation, the pressure drop at the crown generates a hydrostatic "pull" that acts uniformly across the ascending 0.33 fluid column.

VI. FLUID DECANTATION AND WAVE ACCUMULATION MECHANISMS

The extreme tolerances required to maintain the 0.66/0.33 inertia distribution demand a working fluid of highly consistent density. To optimize the input fluid while simultaneously harvesting ambient energy, the architecture integrates a specialized wave accumulation and centrifugal decantation intake.

Drawing upon theoretical models of Wave-Supported Gravity Currents (WSGC), the intake utilizes specific topologies to manipulate wave interference, forming highly predictable standing wave patterns [16], [17]. The kinetic accumulation of these currents is mathematically defined by the cross-shore momentum balance, balancing fluid deceleration with the wave radiation stress gradients:

$$\frac{\partial S_{xx}}{\partial x} + \rho g h \frac{\partial \bar{\eta}}{\partial x} + \tau_b = 0 \tag{4}$$

where S_{xx} represents the principal wave radiation stress, $\bar{\eta}$ is the mean water surface elevation, and τ_b is the combined wave-current bottom shear stress. The intake leverages these standing waves to create a localized zone of elevated hydrostatic pressure.

Fluid captured by WSGC frequently contains fine sediment; therefore, prior to entering the downward Archimedean tube, the fluid passes through a passive centrifugal decantation chamber. The swirling motion forces heavier mineral and organic particulates to the perimeter, ensuring the clarified supernatant fluid is homogenized in density to strictly comply with the required inertia ratios.

VII. ELECTROMECHANICAL IMPULSION AND CORAST-DRIVEN EDGE CONTROL

To preserve the delicate 0.66/0.33 energetic surplus, the Oloid-Archimedes hybrid eliminates traditional hydraulics and mechanical linkages, substituting them with advanced Electromechanical Braking (EMB) and impulsion systems [4], [5].

When the system detects a lull in incoming wave energy, causing the 0.66 downward mass to fall below optimal driving thresholds, the EMB functions as an *impulsion* unit. It injects micro-bursts of electrical torque directly into the shaft, phase-locked to the optimum angle of attack. Conversely, during periods of extreme tidal surges, the downward fluid mass may induce an over-speed condition. The EMB responds by applying non-friction electromagnetic braking, moderating the flow back to optimal speeds while acting as a regenerative generator [18], [19].

A. Spatio-Temporal Control via Foundation Models

Governing this delicate interplay of impulsion, braking, and wave accumulation requires computational foresight. The system employs the CoRAST (Correlated Data Analysis in Resource-Constrained CPS and IoT) framework [6], [7]. CoRAST utilizes server-based Foundation Models (FMs) to extract complex temporal and cross-feature correlations from highly distributed, heterogeneous sensor data.

To continuously optimize the electromechanical impulsion timing, the CoRAST edge controller minimizes the following spatio-temporal objective function across the sensor network graph $\mathcal{G}$:

$$\mathcal{J}(\theta) = \sum_{t=1}^{T} \sum_{i \in \mathcal{G}} \left\| \mathbf{y}_{i,t} - \hat{f}_\theta(\mathbf{x}_{i,t}, \mathcal{G}) \right\|_2^2 + \lambda \left\| \theta \right\|_2^2 \tag{5}$$

where $\mathbf{y}_{i,t}$ is the observed hydrodynamic state (e.g., shaft torque, mass flow rate), $\hat{f}_\theta$ is the foundation model's parameter prediction, and λ is the regularizer [20]. This predictive capability allows the electromechanical edge controllers to anticipate fluid dynamic shifts seconds before they impact the Oloid blades, engaging acceleration or eddy-current braking seamlessly.

VIII. CONCLUSION

The theoretical synthesis of Oloid kinematics with an Archimedean helical environment establishes a revolutionary paradigm for low-head, high-efficiency fluid propulsion. By discarding the continuous friction planes of conventional

TABLE II
CONTROL ARCHITECTURE COMPARISON

Architecture	**Mechanism**	**Data Integration**	**Error Red.**
Standard PID	Reactive error correction	Local sensor only	Baseline
Federated	Distributed weight updating	Struggles with multimodal data	Moderate
CoRAST	Server FM with Edge execution	Cross-feature Spatio-Temporal	Up to 50% [20]

Archimedes screws, the Oloid array induces a continuous, three-dimensional pulsating fluid wave. The structural integrity of this complex volumetric displacement is securely validated using coordinate-free Cayley-Menger determinants, ensuring true morphometric accuracy. At the physical core of this architecture is the rigid enforcement of a 0.66 downward to 0.33 upward fluid mass distribution, providing a precise energetic surplus to overcome internal friction. Augmented by wave-supported gravity current intakes, centrifugal decantation, and siphon-based hydrostatic re-enhancement, and governed by the CoRAST framework for spatio-temporal predictive control, this architecture establishes a highly scalable, energy-neutral conduit for next-generation fluid transport.

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