WHITE PAPER — ESA OSIP

Modulated Momentum Propeller (PHD-MMP): Closed-Loop Momentum Modulation for Non-Expulsive Spacecraft Propulsion Author: Stefan Y. A. Tubman, Independent Inventor, Sweden **Submitted to:** ESA Open Space Innovation Platform (OSIP) — Discovery & Preparation / Kick-Starter Call **Date:** 2026

1. Executive Summary

The **Modulated Momentum Propeller (PHD-MMP)** is a novel propulsion architecture exploring whether **structured, time-varying internal momentum fields** inside a sealed chamber can generate **measurable net external force without propellant expulsion**.

The concept investigates asymmetric oscillatory pressure fields, controlled vortex dynamics, and closed-loop momentum cycles to determine whether any physically plausible configuration can yield thrust suitable for spacecraft mobility.

This proposal seeks **ESA OSIP support** to conduct an **early-stage feasibility investigation**, combining:

- High-fidelity CFD and multiphysics modelling (in collaboration with RISE Research Institutes of Sweden)
- Analytical evaluation of momentum-modulation regimes
- Design and fabrication of a **Phase-I Hardware Demonstrator (PHD)**
- Diagnostic testing and thrust-measurement experiments

The objective is to determine whether the MMP architecture exhibits any **non-zero net force** under realistic physical conditions and to establish the scientific basis for potential follow-on maturation within ESA's Discovery & Preparation or GSTP frameworks.

2. Problem Statement

Spacecraft propulsion remains fundamentally constrained by **propellant mass**. Even high-efficiency electric propulsion systems require consumables, limiting:

- mission duration
- maneuverability
- operational flexibility
- small-satellite capability

A propulsion mechanism capable of generating thrust **without expelling mass** would represent a disruptive capability for:

- long-duration missions
- CubeSats and micro-platforms

- in-orbit servicing and inspection
- distributed space systems
- deep-space operations with minimal resupply

No existing architecture provides such capability within established engineering frameworks. PHD-MMP explores whether **structured internal momentum modulation** can yield **non-zero net force** while remaining consistent with physical constraints.

3. Proposed Innovation

MMP introduces a **non-expulsive, internally circulating momentum-modulation mechanism**. A sealed chamber containing a working medium (e.g., Neon, Argon, SF_6, plasma, or particle suspensions) is driven through **asymmetric oscillatory cycles** that shape vortex structures and pressure distributions.

Key innovative elements:

- Closed-loop momentum exchange rather than propellant expulsion
- Dynamic vortex shaping to create asymmetric internal momentum distributions
- Medium-agnostic architecture (gas, plasma, or particle suspensions)
- Potential micro-propulsion capability for station-keeping and fine maneuvering
- Scalable geometry from CubeSats to larger platforms
- Hardware demonstrator enabling direct thrust-stand measurements

This concept aligns strongly with **OSIP's mandate** to explore **high-risk, high-gain, non-incremental ideas** with potential long-term impact on European space capability.

4. Technical Approach (Phase I Feasibility Study)

The proposed OSIP-supported activity integrates modelling, analysis, and hardware prototyping to determine whether PHD-MMP can produce measurable net thrust.

4.1 Modelling & Simulation (RISE + partners)

- Develop chamber geometries and boundary conditions
- Simulate oscillatory pressure fields and vortex formation
- Model momentum-transfer cycles across multiple working media
- Evaluate nonlinear coupling between modulation frequency, medium density, and force output
- Identify parameter regimes with potential for asymmetric momentum exchange

4.2 Phase-I Hardware Demonstrator (PHD)

- Design and fabricate a benchtop sealed-chamber prototype

- Integrate high-speed actuators, pressure drivers, and flow-modulation elements
- Implement optical and pressure-sensor diagnostics
- Mount PHD on a micro-Newton thrust stand
- Conduct controlled test campaigns across modulation regimes

4.3 Performance Estimation & Analysis

- Quantify net force generation from simulation and hardware tests
- Identify scaling laws and sensitivity parameters
- Compare predicted and measured performance to micro-propulsion requirements
- Assess physical constraints, failure modes, and non-viable configurations

4.4 Feasibility Assessment

- Determine whether any parameter regime yields non-zero net thrust
- Evaluate physical plausibility within known fluid-dynamic and momentum-conservation frameworks
- Provide a go/no-go recommendation for further ESA maturation (Discovery, GSTP, or co-funding pathways)

5. Why ESA OSIP

The MMP concept is **high-risk, exploratory, and scientifically unconventional**, making it ideally suited for **ESA OSIP Discovery & Preparation** or **Kick-Starter** mechanisms, which explicitly support:

- disruptive early-stage ideas
- non-incremental innovation
- feasibility studies for unconventional concepts
- scientific de-risking prior to larger ESA programmes

If feasible, MMP could enable:

- propellant-independent spacecraft mobility
- long-duration missions without consumables
- new maneuvering capabilities for small satellites
- enhanced European competitiveness in advanced propulsion research

OSIP provides the ideal environment to evaluate such a concept through **rapid, flexible, early-stage support**.

6. Proposed Phase-I Deliverables (OSIP-Aligned)

- High-fidelity CFD/multiphysics simulation package

- Parameter-sensitivity and scaling-law analysis
- Phase-I Hardware Demonstrator (PHD)
- Thrust-measurement dataset and diagnostic logs
- Performance envelope and thrust-projection curves
- Feasibility report with go/no-go recommendation
- Roadmap for potential follow-on ESA maturation

7. Request to ESA OSIP

This submission requests **OSIP Discovery / Kick-Starter support** to conduct a **feasibility-focused Phase I investigation** of the Modulated Momentum Propeller.

Specifically, OSIP support is sought for:

- early-stage modelling and analysis
- hardware demonstrator fabrication
- diagnostic testing and thrust-stand measurements
- scientific and technical de-risking
- preparation of a follow-on roadmap for ESA programmes

The activity is structured to deliver a **clear, evidence-based feasibility assessment**, enabling ESA to determine whether further maturation under Discovery, GSTP, or co-funding mechanisms is justified.

8. Contact Information

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