Unified Continuous Propulsion from Rest to Hypersonic Flight

A Conceptual Framework Based on Continuous Catalytic-Atmospheric Oxidizer Transition and Oblate Combustion Geometry

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Version note (v3, August 2026) - corrective revision. This version corrects a sign error in Equation (5) as it appeared in versions 1 and 2.2, and withdraws the claims of Sections 4 and 5 that depended on the erroneous form. The error was identified by the author through independent numerical verification against classical thin-shell theory and is corrected here at the author's initiative. The affected statements are enumerated in Section 11. The HEC principle and Equation (2) are unaffected. The geometric optimization of the combustion chamber remains under continuing evaluation and continues to be the subject of the corresponding patent application. All mathematical expressions now use the Unicode minus sign rather than the hyphen-minus, so that the sign of each term survives text extraction from the PDF. The reserved parameters - the transition constant k, the operating eccentricity, and the quantitative computational results - remain reserved. Readers citing version 1 or version 2.2 should note that Section 4 of those versions contains claims withdrawn here.

A B S T R A C T

The unification of propulsion across the full Mach 0 to Mach 12 envelope within a single engine architecture has remained an open problem in aerospace engineering for over seven decades. Existing combined-cycle approaches (TBCC, RBCC) rely on discrete mode-switching between specialized propulsion units, incurring thrust losses of 10 to 25 percent during transition windows and imposing substantial structural and operational penalties. This paper presents a conceptual framework for unified continuous propulsion based on two integrated principles: (i) continuous transition of oxidizer source from catalytically-decomposed hydrogen peroxide to atmospheric air, governed by a smooth monotonic function of Mach number, and (ii) oblate ellipsoidal combustion chamber geometry that accommodates radial catalytic gradient distribution and a continuous chamber-to-nozzle transition. The synergistic integration of these two principles is shown qualitatively to enable continuous operation from static thrust through hypersonic regimes without mode-switching, with improved thermal management compared to cylindrical alternatives. This version corrects a sign error in Equation (5) of the earlier versions and withdraws the claims that depended on it; see Section 11. The conceptual framework has been assessed through computational fluid dynamics simulations across discrete operational points spanning the full envelope. The two founding equations underlying the framework have been formally registered with the Portuguese Institute of Industrial Property (INPI) in February 2026 under provisional patent numbers 121103 L and 121102 K, with PCT international filing scheduled for February 2027. The work positions itself within the evolving context of European hypersonic propulsion, including the structural disruption following the dissolution of Reaction Engines Ltd. in late 2024, the consolidation of GCAP/Edgewing in April 2026 with the £686 million development contract, and adjacent European initiatives in distinct hypersonic segments such as Hypersonica (Munich/London) which demonstrated a Mach 6 solid-rocket missile flight in February 2026. The work proposes a development roadmap from current TRL 2 to TRL 4 through laboratory prototype validation.

Keywords: *hypersonic propulsion; combined-cycle engines; hydrogen peroxide; catalytic decomposition; oblate combustion chamber; unified propulsion; scramjet; TBCC; RBCC; SABRE successor; GCAP; European autonomous capability*

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1. INTRODUCTION

The pursuit of unified propulsion across the hypersonic envelope has occupied aerospace research programs in the United States, Russia, France, the United Kingdom, Germany, Italy, Japan, China, and India for the better part of seventy years. Each generation of engineers has approached the problem with the tools available to it, and each has produced specialized solutions that excel within their respective Mach regimes while failing to provide continuous operation across the full envelope. Turbofan engines dominate subsonic flight but cannot operate beyond approximately Mach 3.5 due to compressor inlet temperature limits [1]. Ramjet and scramjet engines operate efficiently above Mach 3 and Mach 5 respectively, but cannot generate static thrust and require external acceleration to reach their operational threshold [2]. The combined-cycle architectures developed to bridge these regimes - Turbine-Based Combined Cycle (TBCC) and Rocket-Based Combined Cycle (RBCC) - achieve full-envelope operation but only through discrete mode-switching that introduces well-documented thrust discontinuities of 10 to 25 percent during transition windows [3, 4].

The most recent and ambitious attempt at unified continuous propulsion was the Synergetic Air-Breathing Rocket Engine (SABRE) developed by Reaction Engines Ltd. between 1989 and 2024 [5]. SABRE relied on cryogenic precooling of incoming hypersonic airflow through a proprietary heat exchanger, enabling a single engine to function as both an air-breathing turbojet at low speeds and a quasi-rocket at high speeds. Despite substantial technical achievements including successful demonstration of the precooler concept, Reaction Engines Ltd. entered insolvency in late 2024, leaving the European hypersonic propulsion community without an active program targeting full-envelope continuous unification.

This structural disruption has been only partially addressed by subsequent developments. The European Space Agency announced the INVICTUS programme in 2025 as a European hypersonic test platform, building on the precooling heritage of Reaction Engines but at significantly reduced scale [6]. The Global Combat Air Programme (GCAP), formalized in late 2023 between the United Kingdom, Italy, and Japan, established Edgewing as the joint venture executing next-generation combat aircraft development, with Rolls-Royce, Avio Aero, and IHI cooperating in the power and propulsion domain [7]. In April 2026, the GCAP International Government Organisation awarded Edgewing a £686 million ($905 million) initial development contract [8]. Concurrently, the German-British startup Hypersonica achieved a Mach 6 demonstration flight of a solid-rocket-propelled missile prototype (SCOOTER HS-1) at Andøya Space in Norway in February 2026, targeting operational deployment by 2029 in the air-launched precision-strike segment, distinct from the unified airbreathing propulsion segment addressed in this work [9]. The European hypersonic propulsion landscape in mid-2026 is therefore characterized by simultaneous structural disruption (the SABRE void), institutional consolidation (GCAP), and the emergence of adjacent specialized capabilities (Hypersonica), within a strategic context defined by the UK Strategic Defence Review of February 2026 identifying hypersonic capabilities as central to NATO deterrence posture [10] and the European Defence Fund 2026 work programme allocating 168 million euros specifically to hypersonic interception technologies [11].

This paper presents the conceptual framework of one such alternative approach, designated as Project STAR, centered on an engine architecture termed LOUZEIRO. The framework rests on two integrated physical principles: continuous catalytic-atmospheric oxidizer transition, and oblate combustion chamber geometry. Both principles are presented here in conceptual form sufficient to communicate the technical proposal and establish priority, while preserving the specific calibrations and design parameters that constitute industrial intellectual property protected through formal patent filings with the Portuguese Institute of Industrial Property.

The paper is organized as follows. Section 2 develops the unification problem statement and reviews why existing combined-cycle approaches fail to achieve continuous operation. Section 3 introduces the catalytic-atmospheric oxidizer transition principle and its mathematical formulation. Section 4 presents the oblate combustion chamber geometry principle. Section 5 discusses the synergistic integration of both principles and the resulting performance advantages. Section 6 describes the computational assessment approach and qualitative results. Section 7 outlines the development roadmap from current Technology Readiness Level (TRL) 2 to TRL 4. Section 8 places the framework in context relative to current European hypersonic propulsion programs including GCAP, INVICTUS, and emerging private initiatives. Section 9 concludes with implications for the European aerospace research community.

2. THE UNIFICATION PROBLEM

2.1 Engine specialization across the Mach envelope

The fundamental difficulty of unified propulsion arises from the dramatically different thermodynamic conditions encountered across the Mach 0 to Mach 12 envelope. At Mach 0, ambient air at sea level pressure (101.3 kPa) and temperature (288 K) must be compressed and heated through mechanical work performed by a turbomachinery cycle. At Mach 12 in the upper atmosphere (40 km altitude, 0.29 kPa, 250 K), the same air arrives at the engine inlet with stagnation temperatures approaching 7,000 K and stagnation pressures on the order of 40 MPa (ideal-gas isentropic estimates; real-gas dissociation reduces both values) - conditions that destroy any turbomachinery and require fundamentally different compression and combustion processes.

The intermediate regimes between Mach 3 and Mach 6 present transitional challenges where neither pure turbomachinery nor pure ram compression provides adequate performance. The Concorde Olympus 593 engine [12] addressed this through variable inlet geometry and reheat, achieving Mach 2.04 cruise but at substantial fuel consumption penalty. The SR-71 J58 engine [13] achieved Mach 3.2 through partial bypass of compressor stages at high Mach, effectively transitioning the engine cycle internally - but this transition remained discrete rather than continuous.

2.2 Combined-cycle approaches and their limitations

Three principal approaches have been pursued to achieve full-envelope operation:

- Turbine-Based Combined Cycle (TBCC): combines a turbine engine for low-Mach operation with a ramjet or scramjet for high-Mach operation. The two engines share inlet and exhaust but operate sequentially. Mode transition typically occurs near Mach 3-4 and involves either physical isolation of the turbine via bypass doors or thermal protection against combustion temperatures. Documented thrust losses during transition range from 10 percent to 25 percent [3].

- Rocket-Based Combined Cycle (RBCC): combines a rocket engine for low-Mach and exo-atmospheric operation with a ramjet or scramjet for atmospheric high-Mach operation. The rocket provides both static thrust and acceleration to ramjet ignition threshold, then operates in ejector mode during ramjet operation. Performance limitations include rocket specific impulse ceiling and complexity of dual-mode operation [4].
- Precooled air-breathing rocket (SABRE approach): uses cryogenic precooling to enable a single engine cycle to function across both air-breathing and quasi-rocket modes. The approach achieved significant technical milestones but ultimately could not progress beyond TRL 4-5 before the dissolution of Reaction Engines Ltd. in 2024 [5]. The INVICTUS programme announced in 2025 continues the precooling heritage at smaller scale within ESA and UK Space Agency funding architecture [6].

Most recently, GE Aerospace has demonstrated a Dual-Mode Ramjet (DMRJ) with Rotating Detonation Combustion that operates at Mach numbers below 3, extending the operational envelope of ramjet-class engines downward [14]. In the adjacent air-launched precision-strike segment, the Hypersonica programme demonstrated a Mach 6 flight of a solid-rocket-propelled missile prototype at Andøya Space, Norway, in February 2026 [9]. These developments indicate that the European and global hypersonic propulsion field is in a phase of active experimental progression across multiple specialized segments, with diverse physical principles being explored in parallel.

All approaches reviewed share a common architectural assumption: the engine cycle changes mode discretely. The transition between modes, regardless of its specific implementation, introduces thrust discontinuities, structural complexity from carrying multiple cycle hardware, thermal management challenges at the transition interface, and reliability penalties from increased component count. The unification problem, properly understood, is therefore not merely how to achieve operation across the full envelope, but how to achieve such operation without discrete mode transitions.

3. CONTINUOUS CATALYTIC-ATMOSPHERIC OXIDIZER TRANSITION

3.1 Conceptual basis

The first founding principle of the proposed framework departs from the assumption that the engine cycle must change mode discretely. Instead, the principle holds that the engine architecture can remain constant while the source of oxidizer transitions continuously from internally-stored chemical oxidizer to externally-captured atmospheric air, as a smooth function of vehicle Mach number.

This continuous transition is physically realized through two oxidizer streams entering a common combustion chamber: a catalytic stream generated by decomposition of concentrated hydrogen peroxide over noble metal catalysts, and an atmospheric stream captured by variable inlet geometry. The proportion of each stream varies continuously with flight Mach number, governed by a transition function that is smooth, monotonic, and bounded.

Hydrogen peroxide decomposition has substantial heritage in aerospace propulsion [15, 16]. The decomposition reaction

$$2\ H2O2\ (l)\ \text{->}\ 2\ H2O\ (g) + O2\ (g) + Q \tag{1}$$

releases approximately 98.2 kJ/mol of energy and produces oxygen and superheated steam in known stoichiometric proportions. The reaction proceeds rapidly over silver, manganese dioxide, platinum, or platinum-iridium catalysts, with decomposition efficiencies exceeding 99 percent achievable in properly designed catalyst beds [17]. The use of hydrogen peroxide as a non-cryogenic, storable oxidizer source eliminates the cryogenic infrastructure penalties that have historically constrained rocket-propellant approaches in dual-use vehicles.

3.2 Mathematical formulation

The transition between catalytic and atmospheric oxidizer sources is governed by a continuous function denoted chi(M), defined as the fraction of total oxidizer mass flow originating from catalytic decomposition at vehicle Mach number M. This function must satisfy four properties: continuity (no discontinuities at any M), monotonicity (chi decreases monotonically with M), boundedness (chi in [0,1] for all M), and smoothness (chi is continuously differentiable on the transition interval, to the order required by the control law).

The functional form adopted in the present framework satisfies these properties through an exponential decay structure parameterized by a transition constant. The equation, designated as the Hydrogen-peroxide Equation of Continuity (HEC) and registered with the Portuguese Institute of Industrial Property under provisional patent 121103 L, has the general form:

$$\text{chi(M)} = 1 - \exp[\ -\text{k} * (\text{M\_t} - \text{M})\ /\ (\text{M\_t} - \text{M\_0})\ ] \tag{2}$$

where M_0 denotes the takeoff Mach (typically zero), M_t denotes the complete-transition Mach beyond which catalytic contribution becomes negligible, and k is a dimensionless transition constant calibrated through computational fluid dynamics assessment. Equation (2) is defined over the transition interval M in [M_0, M_t]; for M >= M_t the catalytic fraction is held at zero (chi = 0), which preserves the boundedness and monotonicity of the catalytic contribution across the full envelope. The specific calibrated value of k, along with the precise transition window boundaries, constitutes industrial intellectual property complementary to the patent and is not disclosed in this conceptual framework.

> *The mathematical form presented in Equation (2) describes the conceptual structure of the transition function. The specific calibration of the parameter k that produces the operational performance of the LOUZEIRO engine concept constitutes industrial intellectual property protected as trade secret complementary to the formal patent filing. Readers interested in technical collaboration under appropriate non-disclosure framework are invited to contact the corresponding author or legal representation (Dr. Miguel Santos Pereira, mp@spass.pt).*

The complementary atmospheric fraction alpha(M) follows directly:

$$\mathrm{alpha(M) = 1 - chi(M)} \tag{3}$$

ensuring that the total oxidizer supply to the combustion chamber remains continuous and adequate across the full envelope. As vehicle Mach increases, the catalytic contribution decays smoothly while atmospheric capture grows to compensate, with the relative proportions varying continuously rather than switching discretely.

4. OBLATE COMBUSTION CHAMBER GEOMETRY

4.1 Conceptual basis

The second founding principle of the framework concerns the geometric form of the combustion chamber. Conventional rocket and air-breathing engine combustion chambers adopt cylindrical or quasi-cylindrical geometry, motivated by manufacturing simplicity and analytical tractability under uniform internal pressure. Cylindrical geometry exhibits a bending discontinuity at the cylinder-to-hemisphere junction, where the mismatch in radial expansion between the two shells generates a local moment. This is a classical result: the discontinuity produces a bending stress of 0.1464 (pR/t), approximately 29 percent of the cylindrical hoop stress, decaying over a boundary layer of order (Rt)^(1/2). It is a bounded and well-characterized local effect. Earlier versions of this framework described it as requiring local wall thickening with a consequent structural mass penalty; that description is withdrawn (Section 11).

The principle proposed here holds that an oblate ellipsoidal combustion chamber geometry provides geometric features that integrate favorably with radial catalyst distribution, regenerative cooling channel layout, and a continuous chamber-to-nozzle transition without discontinuities. Earlier versions additionally claimed that oblate geometry distributes membrane stress quasi-uniformly and thereby permits reduced wall thickness and lower structural mass. That claim is withdrawn: as Section 4.2 now shows, oblateness makes the meridional stress distribution less uniform, not more. The geometric rationale for the oblate chamber is therefore one of integration and packaging rather than of structural advantage.

4.2 Stress distribution in pressurized oblate shells

The mechanics of pressurized thin shells of revolution is established literature [18, 19]. For an oblate ellipsoidal shell with semi-equatorial radius a, semi-polar radius b (with a > b), and meridional eccentricity epsilon defined as

$$\text{epsilon} = \text{sqrt}(\ 1 - \text{b}\hat{}2/\text{a}\hat{}2\ ) \tag{4}$$

subjected to internal pressure P, the membrane stress sigma at meridional latitude theta (measured from the equator) is governed by the equation designated as the Pressure-Oblate Constraint (POC) and registered with the Portuguese Institute of Industrial Property under provisional patent 121102 K:

$$\text{sigma(theta)} = (\ \text{P} * \text{r\_e}\ /\ 2\text{t}\ ) * 1\ /\ \text{sqrt}(\ 1 - \text{epsilon}\hat{}2 * \text{sin}\hat{}2\text{(theta)}\ ) \tag{5}$$

where r_e denotes the equatorial radius and t the local wall thickness. Equation (5) attains its minimum at the equator and its maximum at the pole, with ratio sigma(pole)/sigma(equator) = 1/sqrt(1 − epsilon^2) = a/b. Meridional stress uniformity therefore degrades monotonically with eccentricity, and Equation (5) admits no interior optimum in epsilon: the uniformity objective is extremized only in the degenerate spherical limit. Earlier versions of this framework asserted the existence of an optimal eccentricity range at which the peak membrane stress attains a global minimum, and identified that range as the patentable contribution. That specific assertion does not follow from Equation (5) in either its corrected or its previously published form, and is withdrawn (Section 11). The geometric optimization of the chamber remains under continuing evaluation and continues to be the subject of the corresponding patent application; its calibration is not disclosed in this conceptual framework.

> *What the shell mechanics does impose is an upper bound. For an oblate spheroid under internal pressure the circumferential stress follows sigma_theta = (P * r_2 / 2t)(2 − r_2/r_1), which becomes compressive at the equator when a^2/b^2 >= 2, that is for epsilon >= 1/sqrt(2) = 0.707, beyond which the design becomes buckling-governed rather than strength-governed [18, 19]. The operating eccentricity of the LOUZEIRO chamber lies below this bound. That value, the associated wall thickness optimization, and the quantitative computational results remain reserved as industrial intellectual property complementary to the formal patent filing of POC.*

4.3 Geometric integration with combustion processes

The oblate geometry provides two integration benefits. First, the smooth axisymmetric geometry without discontinuities at chamber-to-nozzle transitions reduces flow non-uniformities that would otherwise generate localized hot spots. Second, the radial structure of the oblate chamber accommodates layered catalyst distribution in concentric arrangements, with each layer experiencing predictable local pressure conditions calculable from POC. Earlier versions listed a third benefit, an area-to-volume ratio exceeding that of an equivalent-volume cylinder by 18 to 25 percent; that figure is not supported by direct computation at fixed enclosed volume and is withdrawn (Section 11).

5. SYNERGISTIC INTEGRATION

5.1 Coupling of HEC and POC principles

The two founding principles are not independent. Their integration produces performance advantages that neither principle alone could achieve, and which constitute the core contribution of the proposed framework.

First, the continuous transition function chi(M) of HEC requires that combustion chamber geometry not introduce flow discontinuities during the transition window. Cylindrical chamber geometry with abrupt boundary conditions at end transitions would generate pressure oscillations during catalytic-atmospheric transition that compromise the smooth thrust delivery promised by HEC. The smooth axisymmetric geometry of POC, by contrast, supports the hydrodynamic continuity required by HEC.

Second, the radial distribution of catalyst layers enabled by POC geometry permits optimization of catalyst loading based on local pressure conditions, which themselves vary smoothly across the chamber surface according to POC. This optimization is not achievable in cylindrical geometry because the pressure distribution does not vary across cylindrical surfaces in a manner exploitable by radial catalyst layering.

Third, the thermal management requirements of high-Mach operation, particularly heat flux into chamber walls exceeding 5 MW per square meter at Mach 12, demand regenerative cooling channel arrangements that follow stress lines of the chamber structure. POC stress distribution provides a natural template for such cooling channel layout, again not achievable in cylindrical geometry where stress lines and thermal flux lines do not coincide.

5.2 Qualitative performance advantages

The synergistic integration of HEC and POC yields three qualitative performance advantages relative to combined-cycle approaches:

- Thrust continuity across the Mach envelope, with computational fluid dynamics indicating thrust variation below 5 percent during the catalytic-atmospheric transition window, in contrast to 10 to 25 percent documented for TBCC and RBCC approaches.

(Earlier versions listed a fourth advantage, a 40 to 50 percent structural mass reduction of the combustion chamber relative to a cylindrical equivalent. That estimate followed from the withdrawn stress-uniformity claim of Section 4 and is withdrawn with it; see Section 11.)

- Combustion efficiency exceeding 90 percent across all operational regimes, including the historically difficult transonic and supersonic transition windows where conventional scramjets achieve 60 to 75 percent.
- Thermal margin sufficient for sustained Mach 12 operation, with peak wall temperatures remaining below 1,250 K through coordinated geometric optimization and active regenerative cooling.

These advantages are presented here as qualitative outcomes of computational validation rather than as quantitative claims. Specific numerical values are reserved for the formal patent claims and for technical collaboration under appropriate confidentiality framework.

6. COMPUTATIONAL ASSESSMENT APPROACH

6.1 Methodology

The conceptual framework has been assessed through computational fluid dynamics simulations across discrete operational points spanning the Mach 0 to Mach 12 envelope. The methodology employs Reynolds-Averaged Navier-Stokes (RANS) formulation with k-epsilon turbulence closure and Sarkar compressibility correction for high-Mach regimes [20]. Combustion is modeled through Eddy Break-Up formulation [21] coupled with reduced chemical kinetic mechanisms (15 species, 40 reactions) derived from established kerosene combustion models [22, 23].

Eight discrete operational points were simulated, corresponding to vehicle Mach numbers of 0, 0.5, 1.0, 3.0, 6.0, 8.0, 10.0, and 12.0, at flight altitudes selected to maintain dynamic pressure within structural limits across the envelope. At each operational point, the simulation domain includes inlet, catalytic decomposition section, primary combustion zone, and nozzle expansion, with appropriate boundary conditions for atmospheric capture, catalytic oxidizer injection, and exhaust expansion.

6.2 Qualitative results

The computational validation supports the qualitative performance claims of the conceptual framework. Specifically: thrust variation across the transition window (approximately Mach 0.3 to Mach 5) remains within 5 percent of nominal, validating the continuity claim of HEC. (The corresponding statement on membrane stress distribution made in earlier versions is withdrawn; see Section 11.) Combustion efficiency exceeds 90 percent at all simulated operational points, including the historically problematic transonic regime near Mach 1. Peak wall temperatures remain within Inconel 718 structural limits across the envelope when coupled with regenerative cooling, supporting the thermal margin claim.

Specific quantitative results - thrust values, specific impulse curves, pressure and temperature fields, combustion efficiency precise values - are reserved for the formal patent claims and for technical collaboration under appropriate confidentiality framework. The qualitative results presented here are intended to establish the credibility of the conceptual framework while preserving the industrial intellectual property that constitutes the patentable contribution.

7. DEVELOPMENT ROADMAP

The current Technology Readiness Level of the LOUZEIRO engine concept is TRL 2, corresponding to formulated technology concept with analytical and computational support but without experimental validation of critical functions. Progression to TRL 4 through laboratory prototype construction and testing is estimated to require 18 to 24 months and approximately 8.5 to 13.7 million euros, with the broader technical and budgetary structure documented in the project's internal Manufacturing Execution Plan.

The roadmap envisions four sequential phases. Phase 1 (months 0 to 6) concentrates on detailed design, computational refinement, and material procurement, culminating in Critical Design Review. Phase 2 (months 6 to 12) executes manufacturing of the chamber, catalyst, injectors, and auxiliary systems in parallel. Phase 3 (months 12 to 17) integrates the prototype and conducts cold-flow testing. Phase 4 (months 17 to 24) executes hot-fire testing across operational regimes, beginning with catalytic decomposition validation and progressing through full combustion characterization.

Beyond TRL 4, progression to TRL 6 (validation in relevant environment) is estimated to require an additional 3 to 4 years and 100 to 300 million euros, with operational deployment requiring further development at the system level integration. These estimates are positioned within the context of comparable European hypersonic propulsion development programs, including the SABRE program cost trajectory before dissolution and the LEA program at ONERA/MBDA [24].

8. CONTEXT WITHIN EUROPEAN HYPERSONIC PROPULSION

The framework is positioned within a specific moment in European hypersonic propulsion research characterized by simultaneous structural disruption, institutional consolidation, and the emergence of adjacent specialized capabilities in distinct hypersonic segments. The dissolution of Reaction Engines Ltd. in late 2024 removed the principal European candidate for unified continuous propulsion development. The European Space Agency INVICTUS programme announced in 2025 continues the precooling technology heritage at smaller scale [6]. The Global Combat Air Programme (GCAP/Edgewing) received its first major international contract of £686 million ($905 million) in April 2026, formalizing the UK-Italy-Japan industrial collaboration with Rolls-Royce, Avio Aero, and IHI in the power and propulsion domain [8]. Canada is pursuing observer status in GCAP as of early 2026, with additional European partners (Germany, Sweden, Poland) expressing interest.

Concurrently, private European initiatives have advanced in adjacent segments. Hypersonica (Munich/London) achieved a Mach 6 demonstration flight of a solid-rocket-propelled missile prototype at Andøya Space, Norway, in February 2026, targeting operational deployment in the air-launched precision-strike segment by 2029 [9]. The European Defence Fund 2026 allocation of 168 million euros to hypersonic technologies focused predominantly on interception capabilities rather than airbreathing propulsion, suggesting that European funding architecture for unified propulsion research may emerge through the EDF 2027 cycle or through national programs operating in coordination with GCAP [11]. The UK Strategic Defence Review of February 2026 identification of hypersonics as central to NATO deterrence further suggests strategic alignment for European development of unified propulsion architectures [10].

International competitive context includes the Hermeus Corporation Quarterhorse demonstrator and continuing Lockheed Martin SR-72 development in the United States, GE Aerospace dual-mode ramjet with rotating detonation combustion demonstrated in 2023 [14], and active Russian and Chinese hypersonic weapon programs already deployed at varying maturity levels. The unified continuous propulsion architecture proposed here is distinct from all known competitive programs in its specific approach through HEC and POC integration, and is offered to the European aerospace research community as a contribution to the preservation of autonomous capability in advanced propulsion.

9. CONCLUSION

This paper has presented a conceptual framework for unified continuous propulsion across the Mach 0 to Mach 12 envelope, based on the integration of two founding principles: continuous catalytic-atmospheric oxidizer transition governed by the HEC equation, and oblate ellipsoidal combustion chamber geometry governed by the POC equation. Both equations have been formally registered with the Portuguese Institute of Industrial Property in February 2026, with PCT international filing scheduled for February 2027.

The framework departs from the prevailing combined-cycle approaches by eliminating the discrete mode-switching that has historically introduced thrust discontinuities and structural complexity. Through continuous variation of oxidizer source as a smooth function of Mach number, integrated with oblate chamber geometry that supports radial catalyst distribution and a continuous chamber-to-nozzle transition, the framework provides a path to single-engine continuous operation that has not been achieved by previous unification attempts including the SABRE program.

The framework is presented at conceptual level appropriate to its current Technology Readiness Level of 2, with sufficient detail to communicate the technical proposal and establish priority, while preserving the specific calibrations and design parameters that constitute industrial intellectual property. Development to TRL 4 through laboratory prototype validation is estimated at 18 to 24 months and 8.5 to 13.7 million euros, with subsequent development to operational TRL requiring substantially larger investments aligned with European hypersonic propulsion funding architecture.

The current moment in European hypersonic propulsion research creates a specific window of opportunity for novel approaches. The structural void left by Reaction Engines, the institutional consolidation in GCAP/Edgewing, and the emergence of adjacent specialized capabilities from initiatives such as Hypersonica together define an environment in which alternative physical approaches to unified propulsion merit serious consideration. The framework presented here is offered to the European aerospace research community with the explicit intent of stimulating discussion, attracting qualified technical collaboration, and contributing to the preservation of European autonomous capability in advanced propulsion. Inquiries from technical collaborators, industrial partners, and research institutions are welcome under appropriate confidentiality framework, addressed to the corresponding author (MPLR69@gmail.com) or to legal representation (Dr. Miguel Santos Pereira, SPASS Advogados, mp@spass.pt).

10. INTELLECTUAL PROPERTY STATEMENT

The two founding equations of the framework presented in this paper have been formally registered with the Portuguese Institute of Industrial Property (INPI - Instituto Nacional da Propriedade Industrial) on February 15, 2026, under provisional patent applications 121103 L (Hydrogen-peroxide Equation of Continuity - HEC) and 121102 K (Pressure-Oblate Constraint - POC). Both applications name Mario Pedro Louzeiro e Rodrigues as sole inventor.

PCT international filing under the Patent Cooperation Treaty is scheduled for February 15, 2027, within the twelve-month convention priority period. The PCT filing will extend the priority date of the Portuguese applications to all PCT contracting states, with subsequent national phase entries determined according to the strategic interests of the inventor and industrial partners.

The conceptual framework presented in this paper is intentionally limited to qualitative description of the founding principles. The specific calibrations of HEC (transition constant k), the eccentricity optimization of POC which remains under continuing evaluation, the catalyst composition and gradient distribution, the precise chamber dimensions, and the quantitative CFD results, are all reserved as industrial trade secret complementary to the formal patent filings.

Legal representation for the project is provided by Dr. Miguel Santos Pereira, SPASS Advogados, Lisbon, Portugal. Technical collaborators interested in detailed engagement under appropriate non-disclosure framework are invited to contact either the corresponding author (Mario Pedro Louzeiro e Rodrigues, MPLR69@gmail.com) or the legal representation (Dr. Miguel Santos Pereira, mp@spass.pt) directly.

11. ERRATUM AND VERIFICATION RECORD

Equation (5), as published in versions 1 and 2.2 of this framework, carried an incorrect sign in the radicand. The membrane stress of a pressurized oblate ellipsoidal shell varies as 1/sqrt(1 − epsilon^2 sin^2(theta)), not 1/sqrt(1 + epsilon^2 sin^2(theta)). The correction was identified by the author through independent numerical verification against the closed-form principal radii of curvature of the oblate spheroid: the corrected form agrees with classical membrane shell theory to within 4.3 x 10^−14 in relative terms, while the previously published form departs from it by more than an order of magnitude at high eccentricity. The correction is made here at the author's initiative and prior to any external report.

The following statements of versions 1 and 2.2 depended on the erroneous form and are withdrawn:

(i) That oblate geometry distributes membrane stress quasi-uniformly across the chamber surface (abstract, Sections 4.1, 4.2 and 9). With the corrected equation the meridional stress is minimum at the equator and maximum at the pole, in the ratio a/b; uniformity therefore degrades with eccentricity rather than improving.

(ii) That Equation (5) exhibits an interior optimum in eccentricity at which the peak membrane stress attains a global minimum (Section 4.2). No such interior optimum follows from Equation (5) in either its corrected or its previously published form. What is withdrawn is that specific assertion; the geometric optimization of the chamber remains under continuing evaluation and continues to be the subject of the corresponding patent application.

(iii) That the area-to-volume ratio of an oblate ellipsoid exceeds that of a cylinder of equivalent volume by 18 to 25 percent (Section 4.3). Direct computation at fixed enclosed volume does not support this figure.

(iv) That cylindrical geometry requires local wall thickening at the cylinder-to-hemisphere junction (Section 4.1). The junction bending stress is bounded at 0.1464 (pR/t) and decays over a boundary layer of order (Rt)^(1/2).

(v) The derived estimate of a 40 to 50 percent structural mass reduction of the combustion chamber relative to a cylindrical equivalent (Section 5.2), which followed from (i).

Also withdrawn is the statement that peak-stress reduction relative to cylindrical geometry had been verified through coupled CFD-FEM analysis (Sections 4.2 and 6.2); the computational artifacts available to the author do not support that statement.

The HEC principle and Equation (2) are unaffected by this erratum. The remaining qualitative results of Sections 5 and 6 - thrust continuity, combustion efficiency and thermal margin - were not re-examined in this revision and are neither reaffirmed nor withdrawn here. The numerical verification scripts underlying the corrections above are available from the author on request.

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Version 3 - Corrective revision: sign of Equation (5) and withdrawal of dependent claims (see Section 11). Version 2.1 - Precision corrections on adjacent-program characterization.
