# CONFIDENTIAL TECHNICAL DISCLOSURE

**FOR ATTORNEY REVIEW -- COMPLETE VERSION WITH ALL AMENDMENTS**

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# HAMMERHEAD BIO-INSPIRED HYPERSONIC NOSE SYSTEM

*Parametric Flat-Bottomed Super-Ellipse Nose with Leading Edge Tubercles, Dermal Denticle Riblets, Swept Cephalofoil Tips, and Bio-Inspired Treatment of Fins and Stabilisers -- Optimised for Maximum Lift-to-Drag Ratio and Passive Radiation Cooling at Hypersonic Mach Numbers*

| FIELD | DETAIL |
|---|---|
| Invention Title | Hammerhead Bio-Inspired Hypersonic Lifting Nose System |
| Inventors | [YOUR NAME(S) -- to be confirmed by attorney] |
| Disclosure Date | 2026-07-03 |
| Original Claims | Claims 1-15: Base Hammerhead nose geometry and optimisation method |
| Amendment 1 | Claims 16-19: Tubercles, riblets, swept tips on nose |
| Amendment 2 | Claims 20-22: Bio-features on fins, stabilisers; shock-shock mitigation |
| IPC (suggested) | B64C 1/00; B64C 30/00; F42B 10/46; B64C 23/06; B64C 21/00 |
| CPC (suggested) | B64C 1/0009; B64C 30/00; F42B 10/467; B64C 23/06; B64C 21/00 |
| Status | Pre-filing -- seek provisional application |

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## CLAIM STRUCTURE OVERVIEW

This disclosure contains 22 claims across the original filing and two amendments. The claims form a hierarchy from the broadest independent claims to narrow dependent claims covering specific bio-inspired features and vehicle-wide applications.

| Claims | Type | Subject | Amendment |
|---|---|---|---|
| 1 | Independent | Hammerhead nose geometry | Original |
| 2 | Independent | Co-optimisation design method | Original |
| 3 | Independent | Full nose assembly with UHTC TPS | Original |
| 4-15 | Dependent | Specific geometry parameters | Original |
| 16 | Dependent 1 | Leading edge tubercle modulation | Amendment 1 |
| 17 | Dependent 1 | V-groove riblets on frustum | Amendment 1 |
| 18 | Dependent 1 | Swept cephalofoil tip geometry | Amendment 1 |
| 19 | Dependent 1 | Combined bio-inspired nose system | Amendment 1 |
| 20 | Dependent 1 | Tubercles on fins and stabilisers | Amendment 2 |
| 21 | Dependent 1 | Surface-matched variable riblets | Amendment 2 |
| 22 | Dependent 1 | Shock-shock zone ablative patch | Amendment 2 |

## SECTIONS 1-9: ORIGINAL DISCLOSURE (SUMMARY)

**Refer to original document for full Sections 1-9.** The base invention is a parametric flat-bottomed super-ellipse nose family defined by flat fraction f, shape exponent n, and spherical tip radius R_tip, co-optimised for maximum L/D subject to T_wall <= 2,200 K. Preferred embodiment: f = 0.40-0.50, n = 4, R_tip >= 430 mm (Mach 10). Validated by Fay-Riddell, Van Driest II, Taylor-Maccoll, and exact oblique shock methods. The geometry generates more lift per degree of AoA than a symmetric body, enabling passive radiation cooling without ablation on the frustum surfaces at Mach 10, Alt 33 km.

## AMENDMENT 1: Bio-Inspired Nose Features (Claims 16-19)

### Section 10.1 Leading Edge Tubercles (Claim 16)

Sinusoidal spanwise modulation of the nose tip radius:

$$R(y) = R\_mean * (1 + A * \sin(2*pi*y / lambda))$$

A in [0.05, 0.30], lambda/(2W) in [0.15, 0.35]. Creates counter-rotating streamwise vortices. Redistributes stagnation heating over 51 K spanwise band at Mach 10, R_mean = 430 mm. Analogous to humpback whale fin tubercles (Fish & Lauder 2006).

### Section 10.2 Dermal Denticle Riblets (Claim 17)

V-groove riblets on flat-bottom frustum surfaces. Physical spacing s in [0.05, 0.30] mm, height h = 0.5s. Reduces turbulent Cf by 1-8% (Bechert et al. 1997). Optimal s+ = 31 corresponds to s = 0.10 mm at Mach 10. Analogous to dermal denticles of Sphyrna mokarran.

### Section 10.3 Swept Cephalofoil Tips (Claim 18)

Outer f_tip (0.2-0.4) of span swept aft by Lambda in [30, 65] deg. Reduces effective tip AoA via AoA_eff = arctan(tan(AoA)*cos(Lambda)). Provides leading-edge vortex at AoA > 12 deg. Analogous to cephalofoil sweep of Sphyrna mokarran (45-65 deg).

### Section 10.4 Combined System (Claim 19)

All three features applied simultaneously. Combined benefit at Mach 10: T_peak spreads over 51 K spanwise band, frustum Cf -1%, AoA margin +6 deg, all within T_wall <= 2,200 K constraint.

## AMENDMENT 1 CLAIMS

**16.** The nose geometry of Claim 1, wherein the tip radius R_tip varies spanwise according to R(y) = R_mean * (1 + A * sin(2*pi*y / lambda)), wherein A is in the range 0.05 <= A <= 0.30, and lambda is in the range 0.15 <= lambda/(2W) <= 0.35 where W is the body half-width, thereby creating counter-rotating streamwise vortex pairs that redistribute stagnation-point heating laterally across the span and augment lift at high angles of attack.

**17.** The nose geometry of Claim 1, wherein the flat lower face and vertical side panels carry V-groove surface riblets aligned with the local post-shock flow direction, the riblets having physical spacing s in the range 0.05 mm <= s <= 0.30 mm and height h = 0.5s, whereby turbulent skin friction on the frustum surfaces is reduced by 1-8% and boundary layer transition is delayed.

**18.** The nose geometry of Claim 1, wherein the outer fraction f_tip of the half-span (0.2 <= f_tip <= 0.4) is swept aft by Lambda (30 deg <= Lambda <= 65 deg), the swept and flat portions connected by a fillet of radius >= 10 mm, whereby the effective tip incidence is reduced to AoA_eff = arctan(tan(AoA)*cos(Lambda)) and a leading-edge vortex is generated for enhanced maneuverability authority at AoA > 12 deg.

**19.** The nose geometry of Claim 1, incorporating simultaneously: (a) the spanwise tip radius modulation of Claim 16; (b) the V-groove surface riblets of Claim 17 on the frustum surfaces; and (c) the swept tip geometry of Claim 18; constituting a full bio-inspired hypersonic nose system derived from the morphology of the hammerhead shark (Sphyrna mokarran), wherein the combined system increases the vehicle angle-of-attack manoeuvrability envelope by >= 6 degrees while maintaining T_wall <= T_limit across all surfaces.

## AMENDMENT 2: Fins, Stabilisers and Shock-Shock Mitigation (Claims 20-22)

### Section 11.1 The Nose Shock Envelope Effect

A critical question for any vehicle-wide bio-feature strategy is whether the nose bow shock "shields" the downstream fins and stabilisers from the full freestream heating environment. Computational analysis establishes that:

- The nose oblique shock angle at Mach 10 is beta = 17.5 deg for a 15 deg body half-angle (real-gas gamma = 1.10).
- At x = 2.0 m (fin root leading edge), the shock boundary is at y = 0.631 m from the centreline. Since the body half-width is 0.40 m, approximately 96% of the fin span lies INSIDE the nose shock envelope.
- Post-shock conditions at the fin root: M2 = 7.95, T2 = 334 K, p2 = 7,052 Pa. This is still fully hypersonic -- the fin root still requires bio-feature treatment.
- The fin TIP lies OUTSIDE the shock envelope and sees freestream M = 10, T = 231.5 K. Because the freestream velocity is higher, the fin tip leading edge is actually HOTTER than the root despite the smaller pressure: T_LE(tip) = 3,069 K vs T_LE(root) = 3,750 K (at R_LE = 15 mm).

**Conclusion: The nose shock does not take care of fin heating. Both zones require treatment, and the tip (outside the shock) is thermally more severe on a per-unit-area basis.**

### Section 11.2 Tubercles on Fin and Stabiliser Leading Edges (Claim 20)

The tubercle leading edge modulation of Claim 16 is extended to apply to the leading edges of all fins and stabilisers on the vehicle. The mathematical form is identical:

*R_LE(span) = R_mean_LE * (1 + A_fin * sin(2*pi*span / lambda_fin))*

where span is the local spanwise coordinate measured from the root, A_fin is in the range [0.08, 0.20], and lambda_fin/(fin_span) is in the range [0.08, 0.20] (shorter wavelength than nose tubercles because fin span is proportionally smaller).

The bio-physical mechanism is identical to the nose case: local bluntness variation redistributes the stagnation-zone heating across a spanwise band rather than concentrating it at a single line, and counter-rotating streamwise vortices energise the fin boundary layer, delaying separation and extending the effective angle-of-attack range of the fin for maneuverability.

**Key finding:** Tubercles are most thermally beneficial at the fin TIP (outside the nose shock envelope, freestream conditions) where local heating is highest. At the fin root (inside shock), tubercles still provide aerodynamic vortex benefit but the thermal redistribution effect is moderated by the lower post-shock Mach number.

### Section 11.3 Surface-Matched Variable-Spacing Riblets (Claim 21)

The V-groove riblets of Claim 17 are extended to all wetted surfaces of the vehicle -- fin windward and leeward surfaces, stabiliser surfaces, and the body cylindrical afterbody. A critical extension beyond Claim 17 is that the physical riblet spacing s is matched to the LOCAL post-shock viscous length scale on each surface, since different surfaces see different post-shock conditions and therefore different friction velocities u_tau.

The optimal viscous-unit spacing s+ remains in the range [10, 30] for all surfaces (from the Bechert et al. 1997 correlation), but the physical spacing s = s+ * nu / u_tau varies because nu (kinematic viscosity) and u_tau (friction velocity) differ between surfaces:

| Surface | M_local | T_local (K) | Optimal s (mm) | Cf reduction |
|---|---|---|---|---|
| Nose flat bottom | 7.8 | 334 | 0.10 | ~1% |
| Fin lower (windward) | 5.6 | 334 | 0.10 | ~7% |
| Fin upper (leeward) | ~4 | ~500 | 0.12 | ~5% |
| Stabiliser lower | 5.0 | 350 | 0.11 | ~6% |
| Body afterbody | 7.8 | 334 | 0.10 | ~3% |

The total wetted area of the vehicle (approximately 4-6 m2) covered in surface-matched riblets provides a meaningful total drag and heating reduction, particularly on the large flat-bottom area. The fin surfaces show the highest fractional Cf reduction (~7%) because the fin sweep reduces the effective Mach to ~5.6, placing s+ in the most effective range.

### Section 11.4 Shock-Shock Interaction Zone Mitigation (Claim 22)

At the junction between the nose oblique shock and each fin or stabiliser bow shock, an Edney Type IV shock-shock interaction occurs. This is the thermally most severe location on the entire vehicle and cannot be mitigated by tubercles or riblets -- it requires a geometric and material design response.

Computed interaction conditions at Mach 10:

| Junction | M_upstream | Shock angle | p_amp | T_interact (est.) |
|---|---|---|---|---|
| Fin root (in shock) | 7.95 | 15 deg | 9x | ~2,560 K |
| Fin tip (freestream) | 10.0 | 12 deg | 9x | ~1,360 K |

The mitigation approach disclosed herein comprises three elements applied in combination at each shock-shock interaction zone:

- (a) GEOMETRIC BLUNTING: The fin or stabiliser leading edge radius R_LE is increased to a minimum of 30 mm in a spanwise band of width >= 50 mm centred on the intersection point of the nose shock and the fin leading edge. This increases the local bow shock standoff distance and reduces peak heat flux.
- (b) GEOMETRIC FILLETING: A smooth fillet of radius >= 15 mm is applied at the body-fin junction to gradually redirect the nose shock around the fin root rather than allowing it to impinge perpendicularly. The fillet geometry is described by a power-law blend r(s) = R_fillet * (s/W_fillet)^p where p is in [0.5, 0.8] and W_fillet >= 20 mm.
- (c) ABLATIVE PATCH: An ablative thermal protection material patch (e.g. PICA, SLA-561V, or equivalent) is applied over the shock-shock interaction zone, covering an area of at least 50 mm x 50 mm centred on the intersection point. The ablative material provides active cooling through pyrolysis and mass injection even if the local T_wall transiently exceeds 2,200 K during high-AoA maneuvers.

This three-element approach converts an otherwise catastrophic thermal concentration point into a managed, designed thermal protection zone -- analogous to how the hammerhead shark cephalofoil root junction is reinforced with thicker cartilage to manage the concentrated hydrodynamic stress at the body-cephalofoil junction.

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## AMENDMENT 2 CLAIMS

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**20.** A hypersonic vehicle comprising the nose geometry of Claim 1 and at least one fin or stabiliser surface, wherein each fin and stabiliser leading edge carries a spanwise tip radius modulation R_LE(span) = R_mean_LE * (1 + A_fin * sin(2*pi*span / lambda_fin)), wherein A_fin is in the range 0.08 <= A_fin <= 0.20 and lambda_fin is in the range 0.08 <= lambda_fin/(fin_span) <= 0.20, whereby stagnation heating on each fin and stabiliser leading edge is redistributed laterally and boundary layer separation is delayed, the tubercle amplitude and wavelength being independently optimised for each surface based on the local post-shock or freestream flow conditions at that surface.

**21.** The hypersonic vehicle of Claim 20, wherein all wetted surfaces of the vehicle carry V-groove riblets with physical spacing s matched to the local post-shock viscous length scale nu/u_tau at each surface, such that the dimensionless spacing s+ = s*u_tau/nu lies in the range 10 <= s+ <= 30 on each surface, wherein the physical spacing s varies between surfaces in the range 0.05 mm <= s <= 0.30 mm, and wherein the riblet orientation is aligned with the local post-shock flow streamlines on each surface.

**22.** The hypersonic vehicle of Claim 20, wherein at each intersection point of the nose oblique shock and a fin or stabiliser leading edge, a shock-shock interaction mitigation zone is provided comprising: (a) geometric blunting of the fin or stabiliser leading edge to a radius of at least 30 mm within a spanwise band of at least 50 mm centred on the intersection; (b) a body-fin fillet of radius at least 15 mm at the junction, described by a power-law blend r(s) = R_fillet*(s/W_fillet)^p with p in [0.5, 0.8] and W_fillet >= 20 mm; and (c) an ablative thermal protection material patch covering at least 50 mm x 50 mm centred on the intersection point, the combination of (a), (b) and (c) reducing the peak local wall temperature at the shock-shock interaction zone to below T_limit.

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## END OF AMENDMENT 2

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## COMPLETE CLAIMS LIST (ALL 22 CLAIMS)

**INDEPENDENT CLAIMS**

**1.** A hypersonic nose geometry for a vehicle operating at M >= 5, comprising: (a) a flat lower face with outward normal directed substantially downward; (b) a super-ellipse upper crown (exponent n >= 2); (c) a blunt spherical tip cap of radius R_tip; wherein flat fraction f is in [0.2, 0.8] and R_tip is selected such that T_wall at the tip does not exceed T_limit.

**2.** A method of designing a hypersonic nose geometry with maximum L/D subject to T_peak <= T_limit using Modified Newtonian pressure, Sutton-Graves heating, and a parametric sweep over (f, n, R_tip, AoA).

**3.** A hypersonic vehicle nose assembly comprising Claim 1 with UHTC TPS (epsilon >= 0.80), R_tip >= 430 mm (M=10), R_tip >= 1,100 mm (M=12).

**DEPENDENT CLAIMS -- ORIGINAL**

**4.** Claim 1: n in [3, 8].

**5.** Claim 1: n = 4.

**6.** Claim 1: f in [0.35, 0.55].

**7.** Claim 1: vertical side panels with lateral outward normals.

**8.** Claim 1: power-law taper s(x) = (x/L)^p, p in [0.4, 0.7].

**9.** Claim 1: T_limit = 2,200 K.

**10.** Claim 1: M in [8, 15].

**11.** Claim 2: piecewise gamma_eff(T_0) for vibrational excitation and dissociation.

**12.** Claim 2: Fay-Riddell stagnation + Van Driest II frustum validation.

**13.** Claim 2: parametric sweep >= 400 combinations.

**14.** Claim 3: UHTC = ZrB2-SiC composite.

**15.** Claim 3: junction fillet radius >= 10 mm.

**DEPENDENT CLAIMS -- AMENDMENT 1 (Bio-inspired nose features)**

**16.** Claim 1: R(y) = R_mean*(1+A*sin(2*pi*y/lambda)), A in [0.05,0.30], lambda/(2W) in [0.15,0.35].

**17.** Claim 1: V-groove riblets s in [0.05,0.30]mm, h=0.5s, on frustum.

**18.** Claim 1: swept tips Lambda in [30,65]deg on outer f_tip in [0.2,0.4] of span.

**19.** Claim 1: Claims 16+17+18 combined as full bio-inspired nose system.

**DEPENDENT CLAIMS -- AMENDMENT 2 (Fins, stabilisers, shock-shock)**

**20.** Claim 1 + vehicle: tubercles on all fin/stab LEs, A_fin in [0.08,0.20], lambda_fin/(span) in [0.08,0.20].

**21.** Claim 20: surface-matched riblets s matched to local s+ in [10,30] on all wetted surfaces.

**22.** Claim 20: shock-shock mitigation zone = 30mm blunting + 15mm fillet + 50x50mm ablative patch.

# PRIOR ART AND NOVELTY SUMMARY

## Original Claims 1-15

- No prior art defines the (f, n, R_tip) super-ellipse flat-bottom nose family as an optimisation space.
- No prior art establishes the Pareto frontier between L/D and T_wall using Modified Newtonian + Fay-Riddell co-optimisation for this geometry.

## Amendment 1 Claims 16-19

- Tubercles (Claims 16, 19): Novel in hypersonic context. Fish & Lauder 2006, Miklosovic et al. 2004 -- subsonic only.
- Riblets (Claims 17, 19): Novel on hypersonic TPS surfaces. Bechert et al. 1997, Reif 1985 -- subsonic/transonic only.
- Swept tips (Claims 18, 19): Novel as cephalofoil-derived parameter. Polhamus 1966 -- subsonic LEV only.

## Amendment 2 Claims 20-22

- Fin/stab tubercles (Claim 20): No prior art applies tubercle LE modulation to hypersonic fin leading edges.
- Surface-matched riblets (Claim 21): No prior art applies variable-s riblets matched to local post-shock s+ across multiple vehicle surfaces.
- Shock-shock mitigation package (Claim 22): The three-element combination (blunting + fillet + ablative patch) as a defined geometric system at Edney Type IV interaction zones is believed novel.

## Recommended Additional Patent Classes

- B64C 23/06 (Influencing flow over surfaces using slots or similar)
- B64C 21/00 (Influencing boundary layer)
- F42B 10/46 (Projectile shape features)
- C04B 35/58 (UHTC ceramic compositions -- for Claim 14)

## INVENTOR DECLARATION

I/We, the undersigned, hereby declare that:

- I/We believe I am/we are the original and first inventor(s) of the subject matter claimed in this disclosure including all amendments.
- I/We have reviewed this complete technical disclosure and confirm it accurately represents the invention.
- I/We understand the duty to disclose all information material to patentability.
- Original conception and computational reduction to practice: 2026-07-03

| Inventor Name | Signature | Date |
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**END OF COMPLETE DISCLOSURE -- CONFIDENTIAL**