ICE YACHT 2026 · PRELIMINARY ENGINEERING STUDY

Rebuilding a 1999 record-attempt ice yacht as a verified 3-D vehicle — and simulating it properly for the first time

A quarter-century-old paper design for a 240 km/h single-seat ice yacht existed only as three dimensioned 2-D views and a set of hand-calculated force balances. This study rebuilds it as a parametric 3-D model, checks that a real pilot fits inside it, and puts the complete vehicle through full 3-D viscous computational fluid dynamics — the first time this concept has been simulated as a whole.

The headline finding is not a faster vehicle. It is a *trustworthy* one: a lower predicted speed than the original claimed, arrived at with methods, checks and stated uncertainty the original did not have — and a safety margin problem the original had no way to see.

2-D → 3-D
from three orthographic views to a parametric solid model, surface-faired and dimensionally verified

618,030
cell 3-D viscous CFD mesh of the complete vehicle — hull, sail, beams, fin, runners

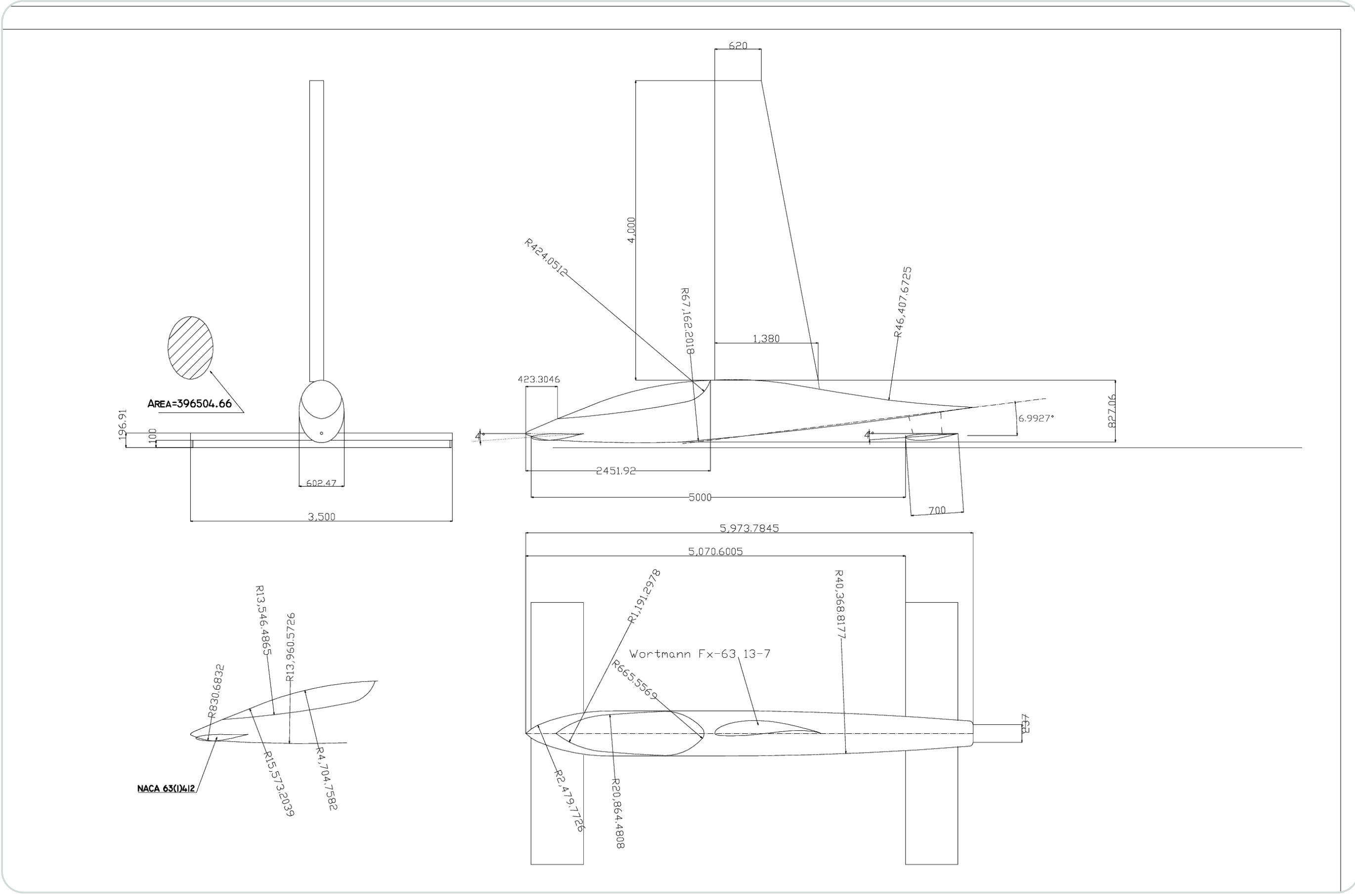
176 cm
pilot accommodated, verified in 3-D with seat, controls, harness and sight line

2 ×
independent reviews of the geometry and flow results, the second performed blind

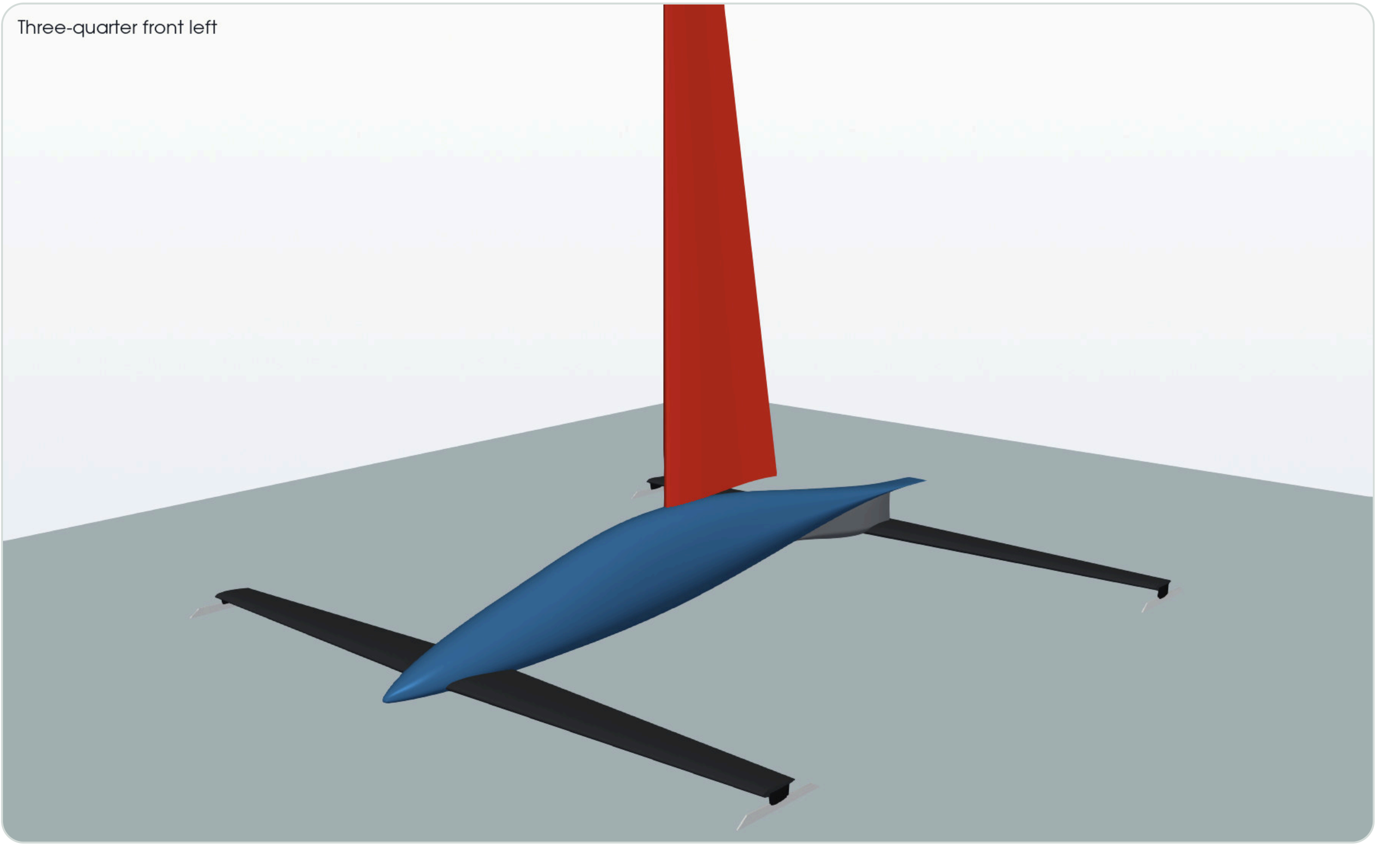
Above: conceptual visualisation. The vehicle's proportions and layout follow the engineering model; the carbon finish and setting are presentational.

What changed: from a drawing to a vehicle

The original design survives as a dimensioned general-arrangement drawing. Everything about its three-dimensional form — how surfaces meet, whether a pilot fits, how air actually moves around it — had to be reconstructed and then built as a real solid model.

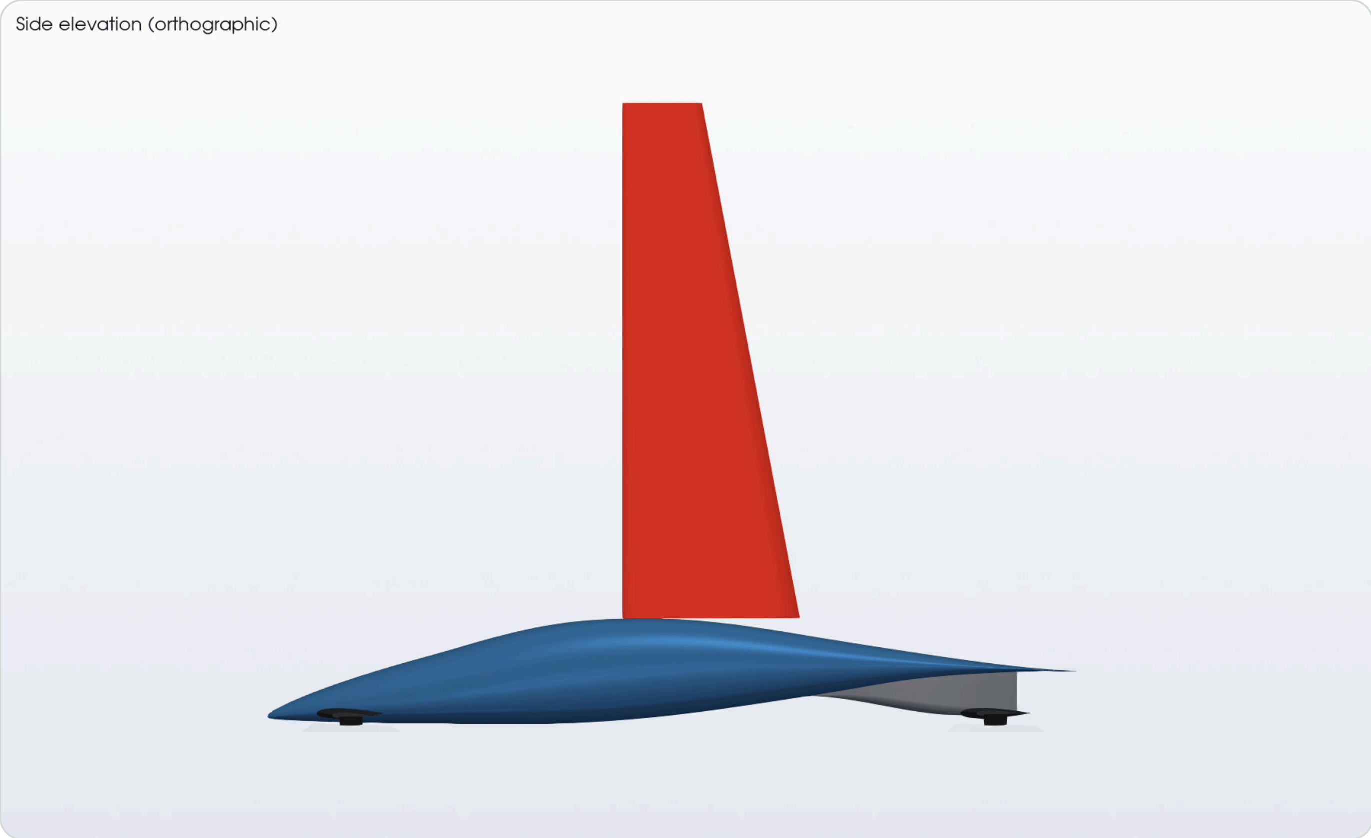


Before The original drawing, restored from the source document: three orthographic views, section callouts and dimensions. Complete as a specification, silent on three-dimensional form.

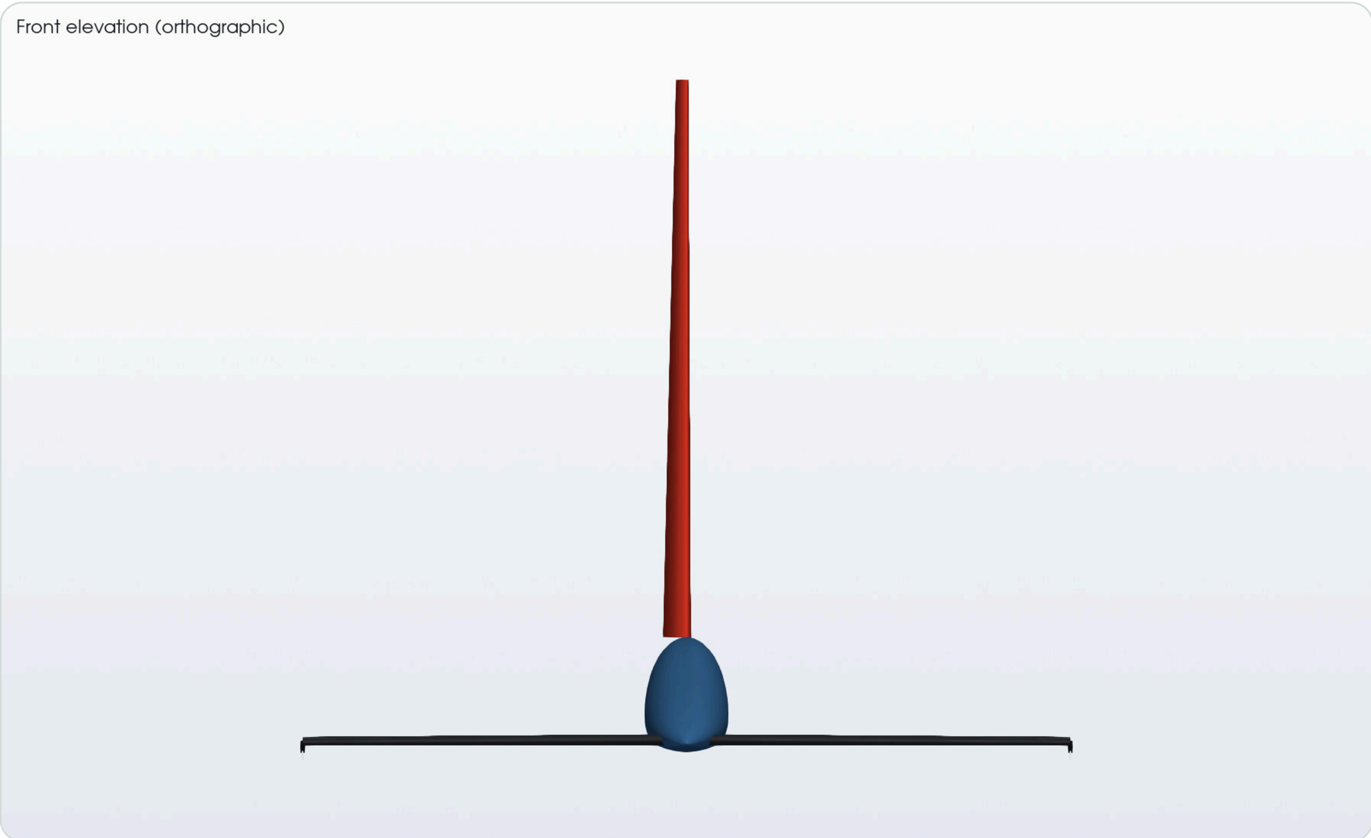


After The 2026 parametric model: a single faired hull, rigid sail, two full-span crossbeams, four runners and a new ventral fin. Every dimension is scripted and rebuildable from source.

The vehicle, orthographically



Side



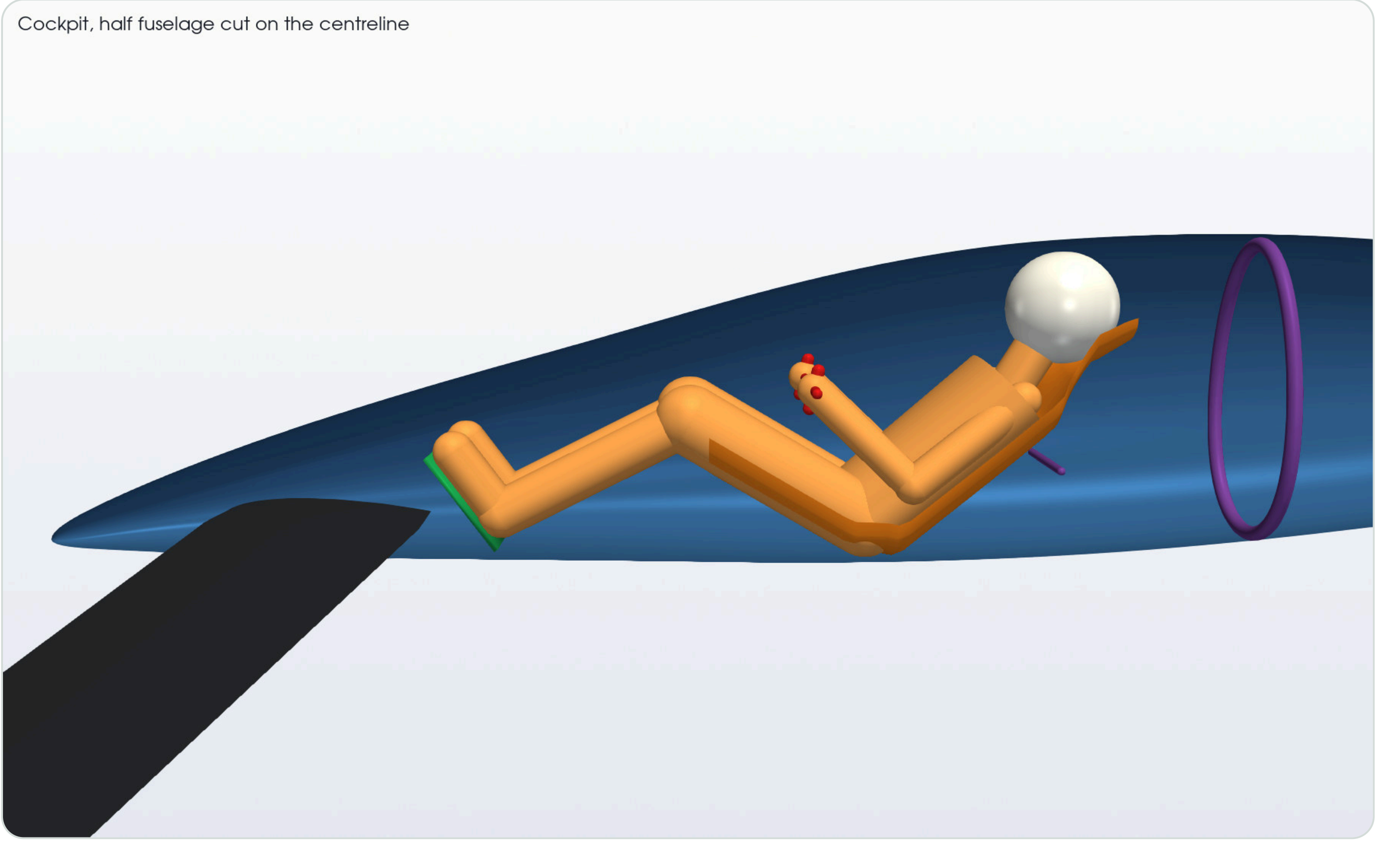
Front — 5.5 m track

Plan

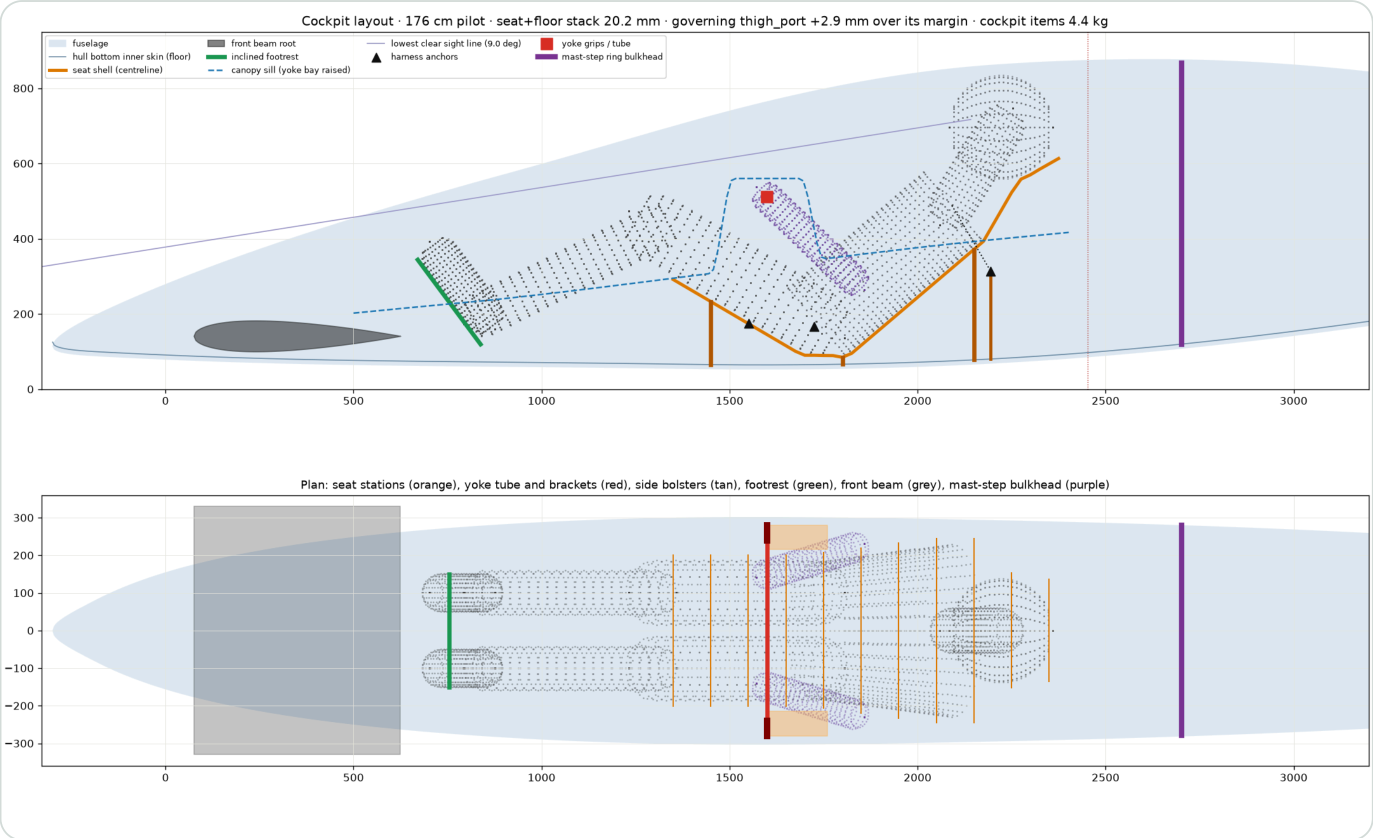
PARAMETER	VALUE	NOTE
Overall length	5.974 m	Dimensioned from the original drawing
Track (runner to runner)	5.50 m	2026 redesign; original was 3.50 m
Hull width / crown height	0.602 m / 0.877 m	Faired single-skin carbon hull
Rigid sail	Wortmann FX 63-137, 4.0 m tall, 4.0 m²	Retained from the original concept
Sail chord (root / tip)	1.380 m / 0.620 m	Aspect ratio 6.2
Crossbeams	Two full-span one-piece CFRP beams	Replaces the original's fixed-incidence inverted wings
Ventral fin	Modified NACA 0010-65, 1.645 m long	2026 addition: rear roll-torque load path
Runners	Four, steel blade on ice	Front pair steers
All-up mass (comparison)	230 kg	145 kg vehicle + 85 kg pilot
Pilot accommodated	176 cm, reclined, 5-point harness	Verified by 3-D fit study

Does a pilot actually fit?

The original design did not resolve pilot accommodation. In a vehicle whose entire performance case rests on a small frontal area, this matters: every millimetre of cabin height is paid for in drag. The 2026 study places a 176 cm pilot inside the hull in three dimensions, with seat, inclined footrest, steering yoke, five-point harness, mast-step bulkhead and a checked forward sight line.



The hull cut on its centreline with the pilot in the driving position — reclined, feet braced on the footrest, hands on the yoke, helmet clear of the crown.

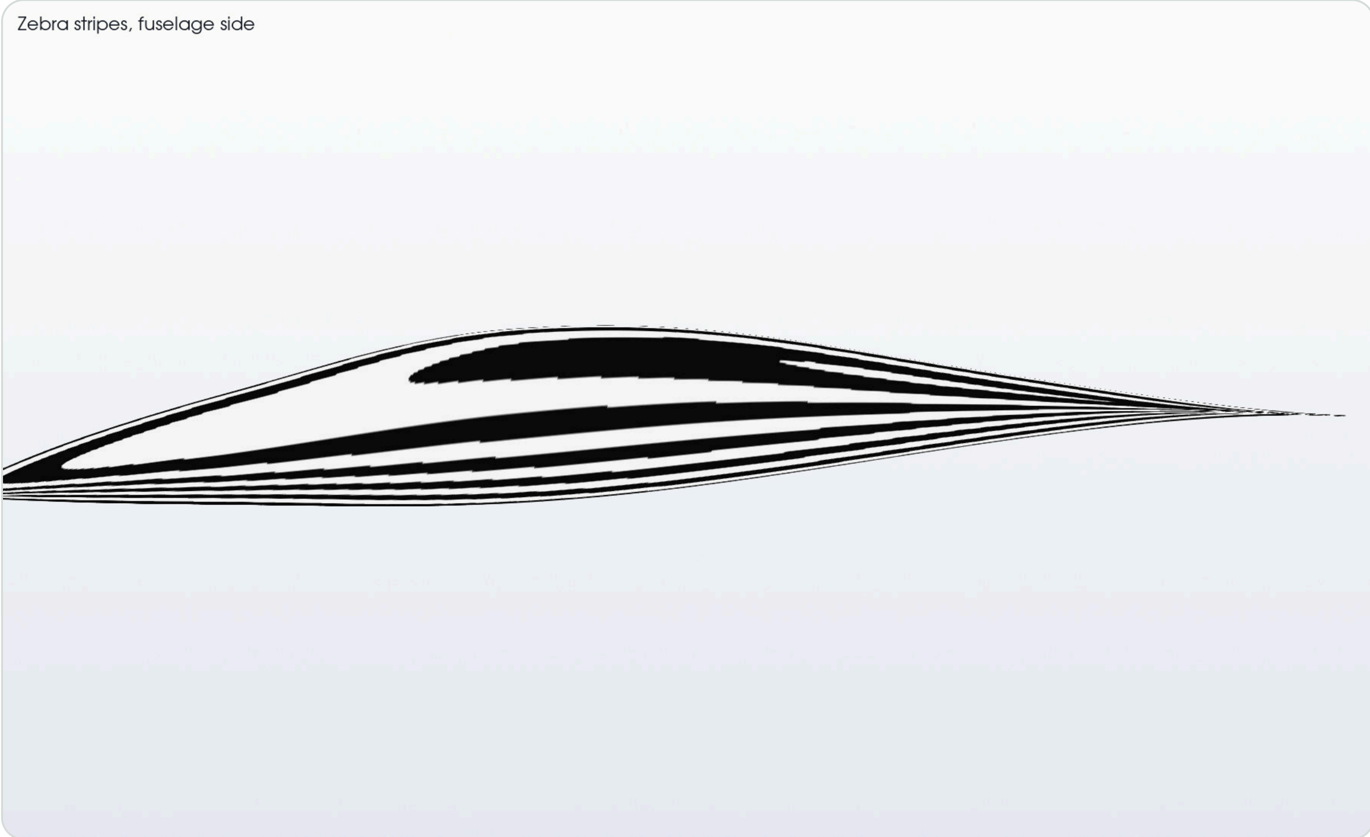


The same layout as an engineering drawing: seat shell, footrest, yoke and brackets, harness anchors, canopy sill, bulkhead, and the lowest clear sight line.

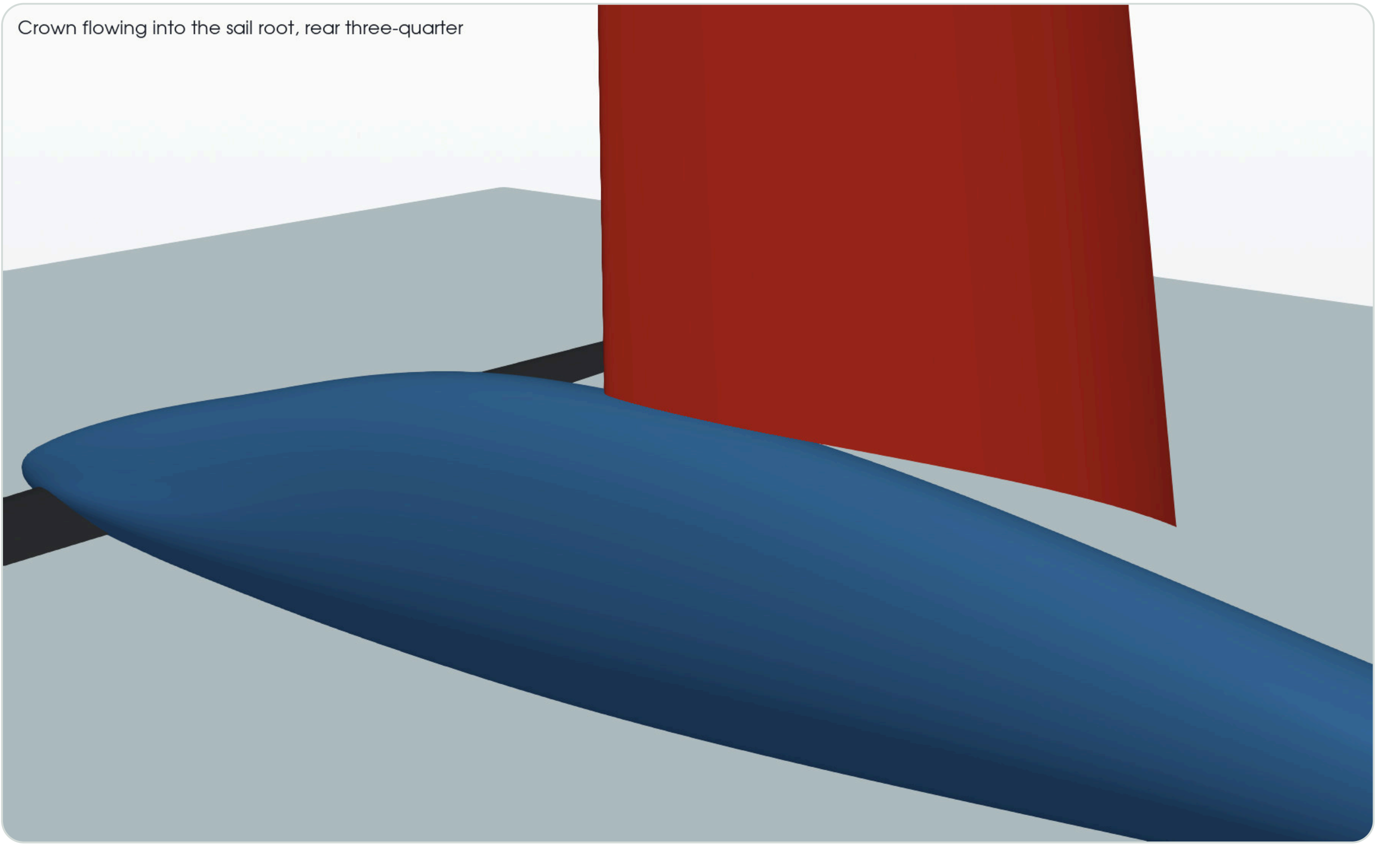
Clearances are tight but positive throughout, the governing point being the pilot's thigh with 2.9 mm to spare. Cockpit structure and fittings total 4.4 kg.

Surface quality

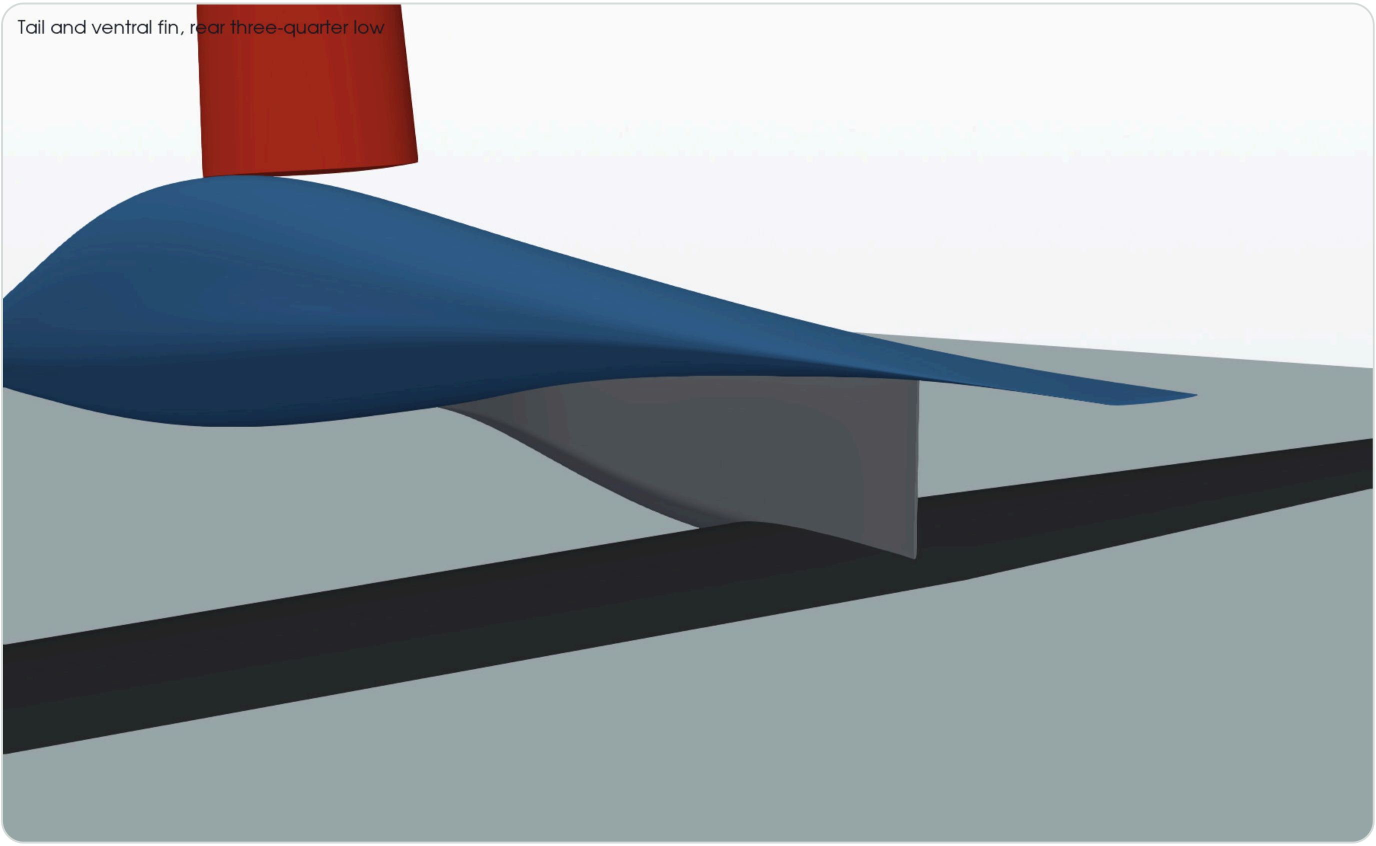
A body shaped for 240 km/h cannot have subtle waviness in its surfaces. The hull is checked with zebra striping — a standard surfacing technique in which reflected stripes reveal curvature discontinuities the eye would otherwise miss. Smooth, evenly-flowing stripes mean a fair surface.



Zebra analysis of the hull flank. The stripes run cleanly from nose to tail without kinking or bunching, confirming the faired single-skin form.



Sail root meeting the hull crown.



Tail and the new ventral fin, which carries rear roll torque into the hull.

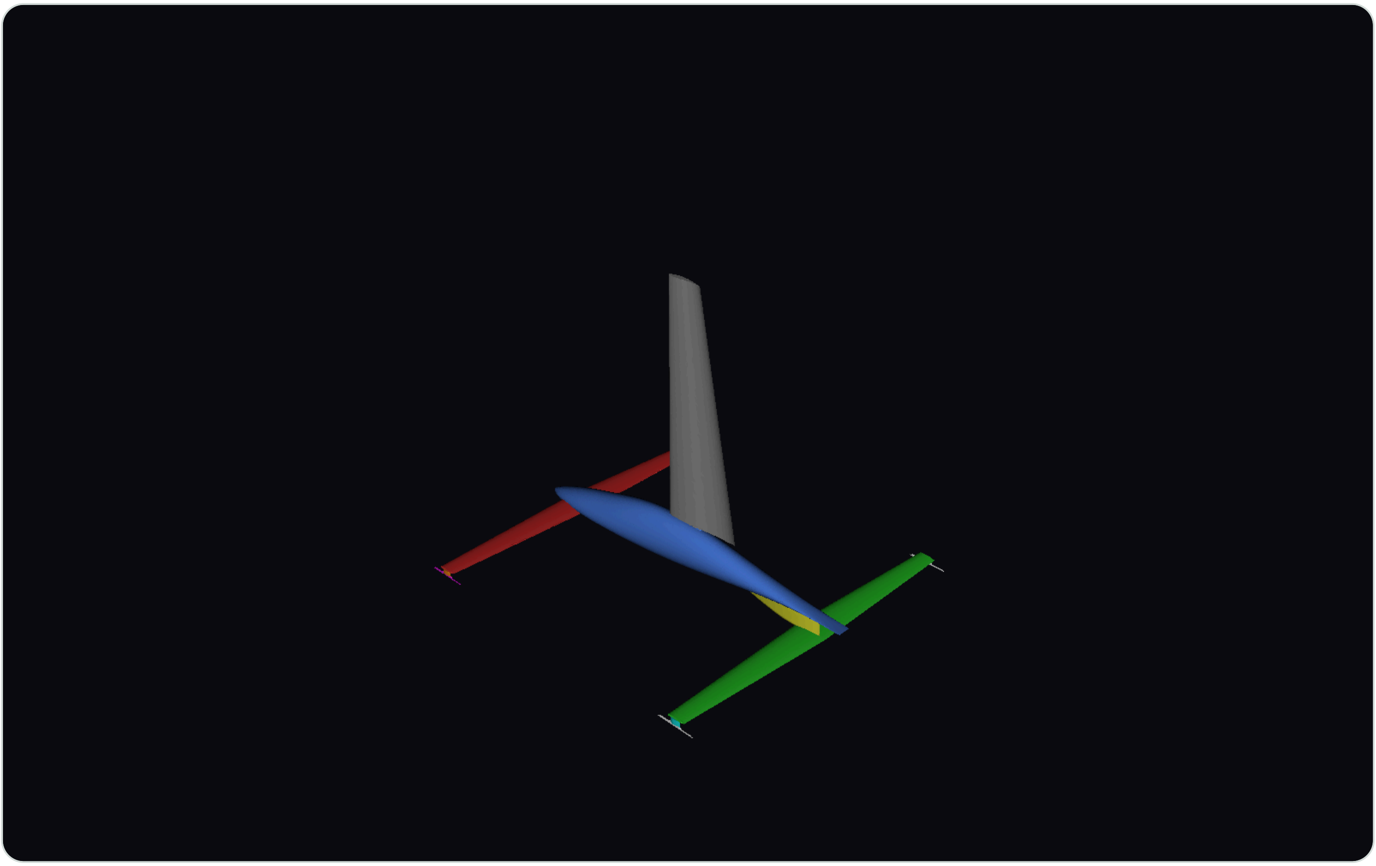
The engineering toolchain

Every result in this study is produced by open, scriptable, reproducible tools — no manual modelling steps and no unrecorded hand calculations.

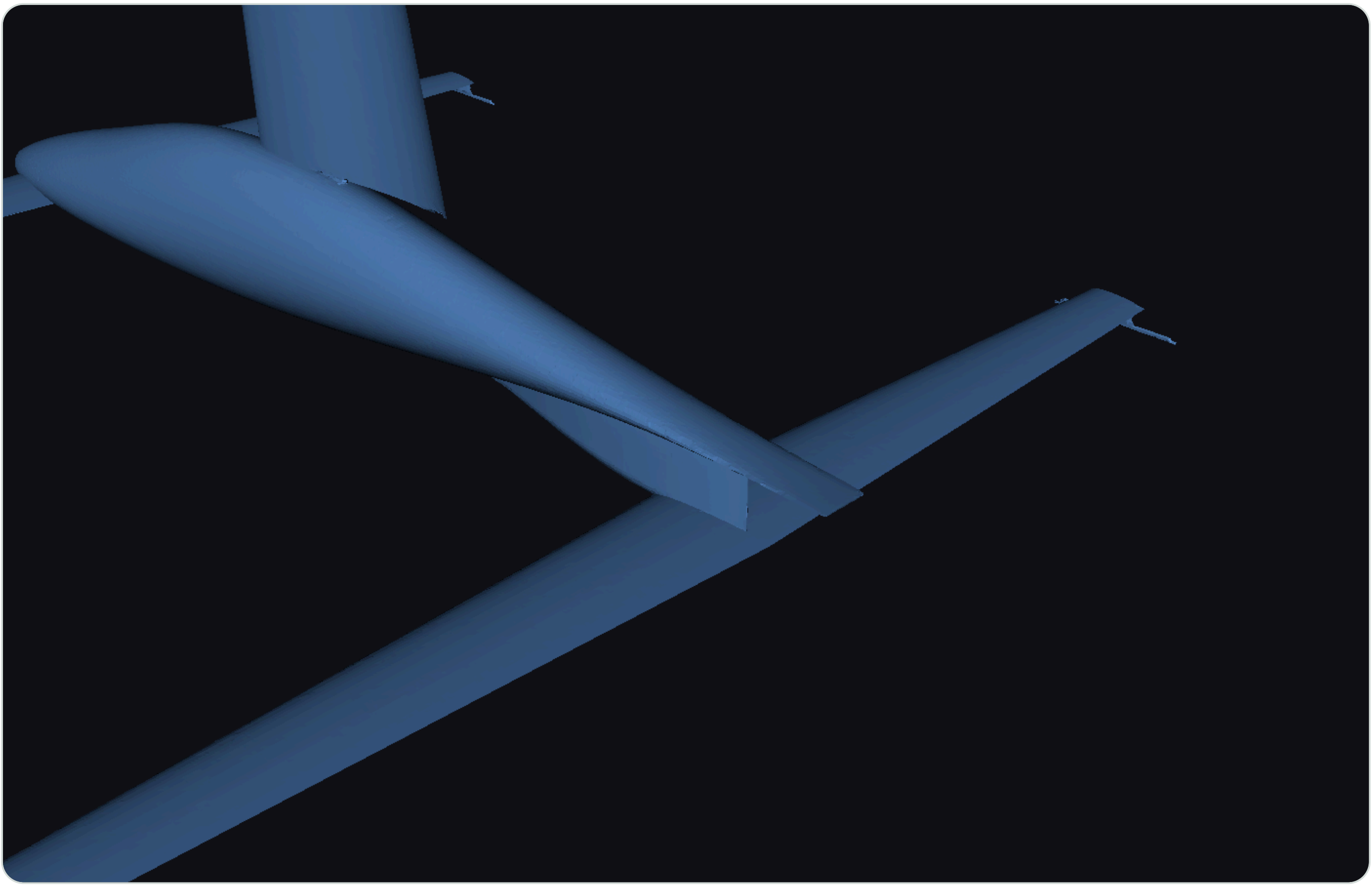
STAGE	TOOL	ROLE
Geometry / CAD	CadQuery 2.8.0 on OpenCASCADE (OCP 7.9.3.1.1)	Parametric 3-D model, scripted and reproducible from source
Geometry verification	OpenCASCADE BRepExtrema, exact point-to-surface distance	Every tessellation checked against the exact CAD, not against another mesh
2-D aerofoil analysis	XFOIL 6.996	Sail and beam section polars across Reynolds number
Surface meshing	Gmsh 4.15.2	Used in earlier meshing routes
Volume meshing	snappyHexMesh (OpenFOAM 14)	Castellated hex-dominant mesh with surface snapping
CFD solver	OpenFOAM 14, steady RANS (SIMPLE), k-ω SST	Full-vehicle 3-D viscous flow, 8-way parallel
CFD solver (alternative)	SU2 8.5.0 “Harrier”	Installed as a cross-check route; not used for this result
Post-processing	VTK 9.6, foamToVTK	Surface fields, force integration, rendering
Compute	Ubuntu 24.04 ARM64 VM, 8 vCPU / 12 GB	Isolated, reproducible solver environment

Simulating the complete vehicle

The vehicle is enclosed in a virtual wind tunnel and the space around it divided into 618,030 cells, finest at the surfaces and in the wake. The solver then computes the steady airflow, pressure and wall friction over the whole machine at racing speed.



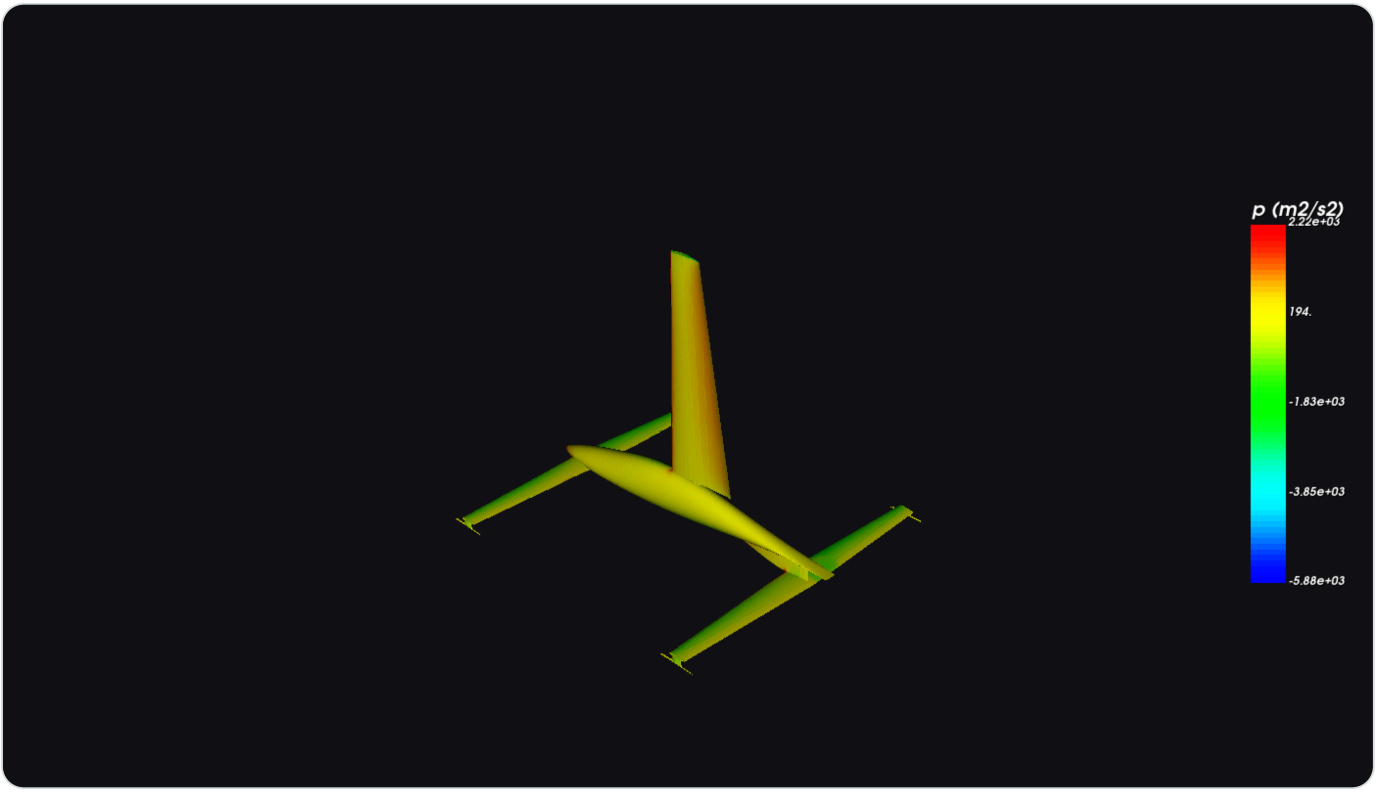
The thirteen components presented to the mesher, each coloured separately: hull, sail, two crossbeams, ventral fin, four pylons and four runners.



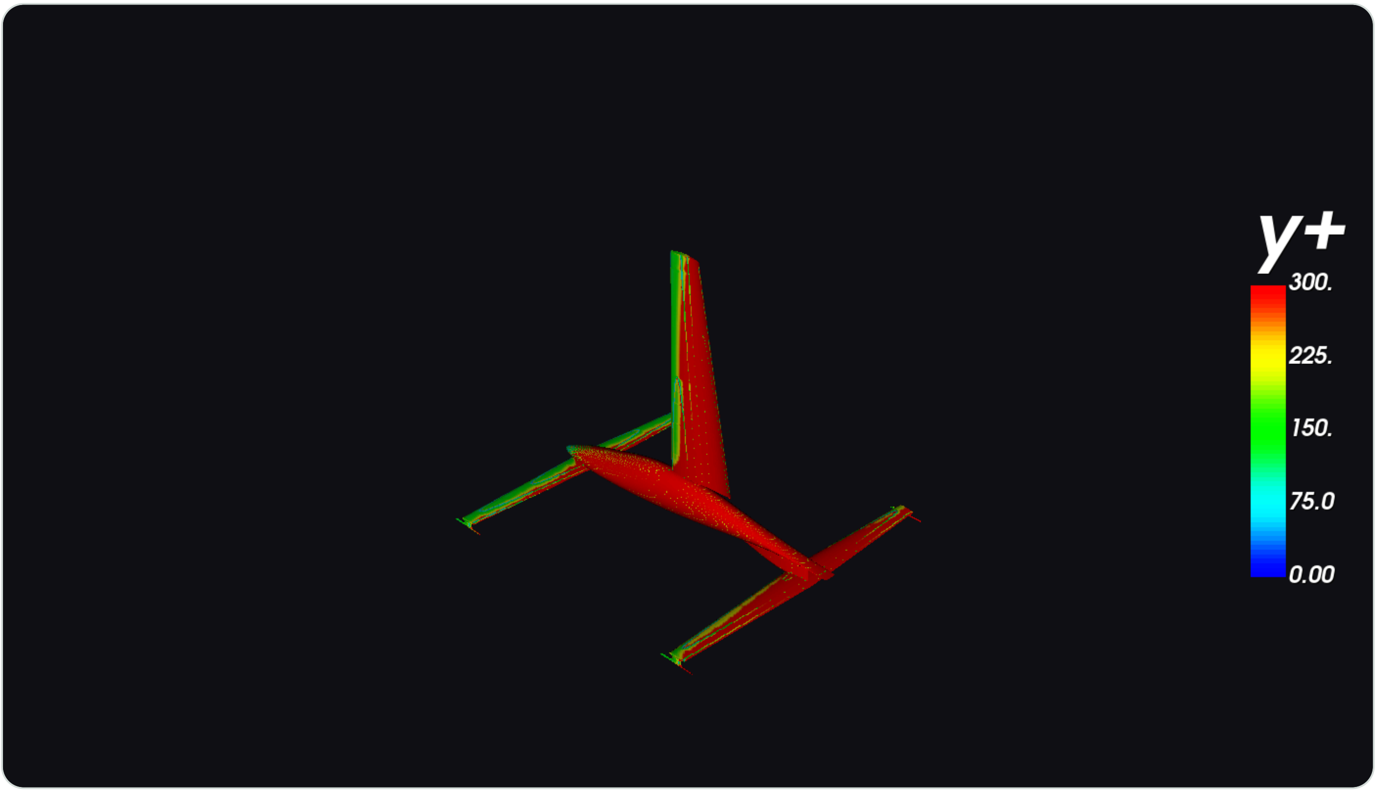
Surface detail where the ventral fin, hull and rear crossbeam meet — the hardest region of the vehicle to mesh.

Operating condition: 239.1 km/h with an 66.9 m/s apparent wind at 7.12° of yaw — a beam reach at racing speed. Steady RANS, k-ω SST turbulence, 4,500 iterations to convergence.

The flow field



Surface pressure. High pressure at the nose and along the sail's leading edge, suction over the sail's leeward face — the sail is doing the work, exactly as intended.



Near-wall resolution (y+). Red indicates regions where the mesh is coarser than the turbulence model would ideally like — the principal known limitation of this first pass.

What the simulation found

FORCE / MOMENT	VALUE	RUN-TO-RUN VARIATION
Fx drag (N)	-356.0	1.56%
Fy side (N)	15,233.8	0.62%
Fz vertical (N)	-2,816.5	0.46%
Mx overturning (Nm)	-35,595.6	0.42%

Averaged over the final 500 of 4,500 solver iterations. Forces act in vehicle axes: x along the hull, y across it, z vertical.

> **The sail dominates, and that result is solid.** The 15,234 N sideways force is more than forty times the net force along the hull, and it is stable to within 0.6% — it survived every check applied to it. The much smaller along-hull force is the difference between two large opposing quantities, which makes it proportionally far more delicate.

Two limitations, measured rather than assumed

Both were found by the review process, and both are quantified rather than merely flagged.

67%
of the surface has near-wall mesh spacing coarser than the turbulence model's ideal range — because this first-pass mesh omits boundary layers

up to 26%
swing in the along-hull force depending on how the sharp, unfilleted component junctions are treated

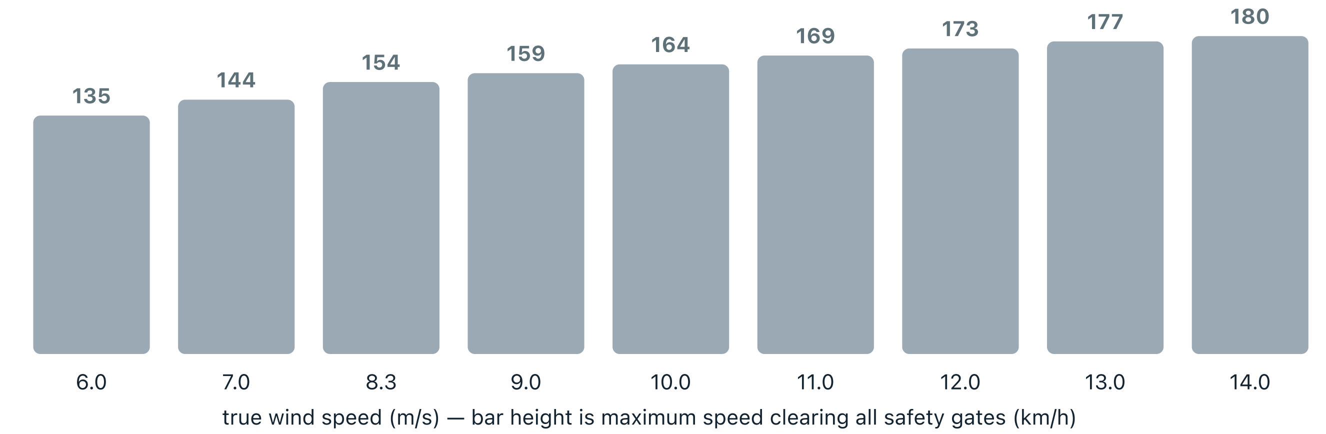
JUNCTION REGION EXCLUDED	SHARE OF SURFACE	CHANGE IN ALONG-HULL FORCE	CHANGE IN SAIL SIDE FORCE
10 mm	0.002%	+0.1%	+0.00%
30 mm	0.032%	+1.8%	-0.02%
100 mm	0.552%	+6.0%	-0.35%
250 mm	3.330%	+25.9%	-3.02%

Progressively excluding the sharp junction corners barely moves the dominant sail force, but moves the small along-hull force substantially — which is why this study reports the sail force with confidence and the drag figure as indicative.

What it means for the vehicle

Feeding the simulated aerodynamic drag into the project’s vehicle model — which also accounts for sail trim, runner friction, weight transfer, roll stability and runner loading — gives the speed the vehicle could actually sustain while remaining safe and controllable.

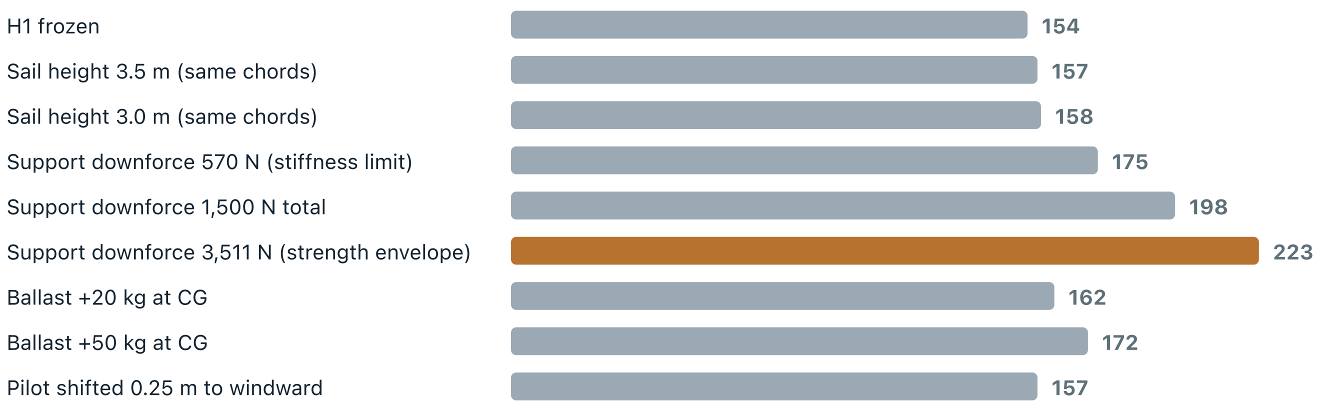
SOURCE OF THE DRAG ESTIMATE	DRAG AREA (M²)	
Design target The drag budget the 2026 project set itself as a goal	0.0540	
Original study's own figure Implied by the 1999/2000 report's force tables	0.0703	
This study's 3-D CFD measurement Hull, beams, fin and runners, excluding the sail	0.1230	this study
Earlier CFD attempt (superseded) Produced on a geometry later found to be flawed	0.1576	



Maximum speed at which the vehicle still clears its roll-stability and runner-load safety limits, as a function of wind strength. More wind means more available thrust — performance is strongly condition-dependent, not a single figure.

A safety finding the original analysis could not have produced. At the original design's target speed, the vehicle does not clear its roll-stability margin or keep adequate load on its windward runners — the leeward side unloads. This is the first time the concept's stability has been checked against its own predicted aerodynamic loads. It is a solvable problem, not a fatal one, and the options below quantify the fix.

What would close the gap



Maximum safe speed for each single design change, evaluated one at a time. Adding aerodynamic downforce through the crossbeams — up to the structure's strength limit — is by a wide margin the strongest lever.

DESIGN CHANGE	ROLL MARGIN	WINDWARD RUNNER LOAD	MAXIMUM SAFE SPEED
H1 frozen	0.40	-1,045 N	154 km/h
Sail height 3.5 m (same chords)	—	—	157 km/h
Sail height 3.0 m (same chords)	—	—	158 km/h
Support downforce 570 N (stiffness limit)	0.49	-854 N	175 km/h
Support downforce 1,500 N total	0.64	-597 N	198 km/h
Support downforce 3,511 N (strength envelope)	0.92	-141 N	223 km/h
Ballast +20 kg at CG	0.43	-976 N	162 km/h
Ballast +50 kg at CG	0.48	-889 N	172 km/h
Pilot shifted 0.25 m to windward	0.41	-1,022 N	157 km/h

Roll margin must reach 1.25 and runner load must stay above 200 N for the vehicle to be considered controllable. No single change reaches the original 239 km/h target; the strongest reaches 223 km/h.

Compared with the original study

	ORIGINAL (1999/2000)	THIS STUDY (2026)
Geometry	2-D dimensioned drawing: three orthographic views	Parametric 3-D solid model, surface-faired and verified to 0.2 mm against the exact CAD
Aerodynamic method	2-D inviscid panel estimates, averaged into a body drag figure; ideal sail efficiency assumed	Full-vehicle 3-D viscous RANS on a 618,030-cell mesh, with wall-modelled turbulence
Ground effect	Acknowledged in the text, then excluded from the calculation	Present in the solved 3-D flow field
Pilot accommodation	Not resolved	3-D fit study: 176 cm pilot, seat, footrest, yoke, harness, sight line, egress
Independent checking	None reported	Two independent reviews of the geometry and flow fields, the second performed blind
Uncertainty	None stated — the project's own audit of the source records "no formal uncertainty or validation plan"	Two sources identified, located and measured, and reported alongside the result
Structural check against its own predicted loads	Not performed. The audit flags roughly 11 kN of predicted downforce — about 5.4× the vehicle's weight — never checked against structure	Performed: roll-margin and runner-load safety gates evaluated against the simulated aerodynamic loads
Top speed claim	231.3 km/h in Appendix I, 234.65 km/h in the main text — the two disagree	154 km/h in the nominal 8.3 m/s wind, rising to 223 km/h with the strongest design change identified

Read honestly: this study predicts a slower vehicle than the original claimed. That is the expected consequence of including what the original left out — viscous drag, three-dimensional flow, ground proximity, runner friction, and the structural consequences of the vehicle's own aerodynamic loads. The original's figure was internally inconsistent between its own appendix and main text, rested on 2-D inviscid estimates, and was never checked against structure. The value of this work is not a bigger number; it is a defensible one, with its uncertainty stated and its failure modes located.

Limitations of this study

- One mesh and one operating condition. Grid-independence has not yet been demonstrated, so these figures cannot close a formal design gate on their own.
- The first-pass mesh omits boundary layers, leaving near-wall resolution coarser than ideal over much of the vehicle.
- Junction fillets present in the approved CAD are absent from this simulation surface, a deliberate simplification that introduces measurable local errors at those corners.
- Steady-state simulation: gusts, manoeuvres, suspension motion and ice-surface roughness are not modelled.
- The vehicle-level speed figures come from a screening model intended for design comparison, not certification.
- This is a research and design study. It is not a construction release, and a vehicle of this type would require independent aerodynamic, structural and safety review before any physical build.

Next steps

- Refine the near-wall mesh specifically to bring surface resolution into the turbulence model’s valid range, which would tighten the drag figure.
- Reinstate fillets at the two junctions shown to matter, rather than across the whole vehicle.
- Evaluate crossbeam downforce as the primary route to closing the stability gap, within the structure’s measured strength envelope.