PORTFOLIO CASE STUDY

SUBOFF submarine hydrodynamics

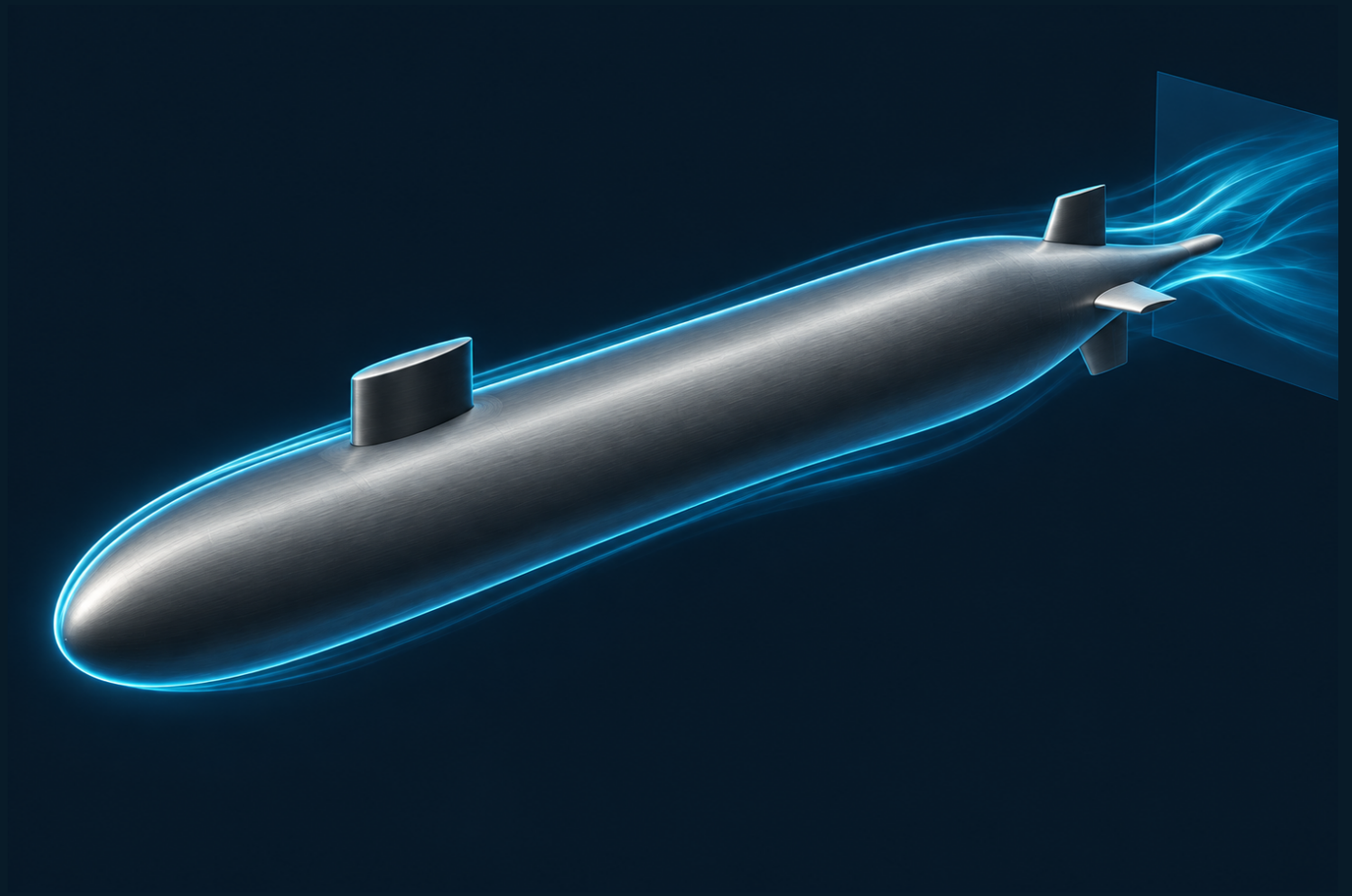
Mesh, flow and wake assessment

How well does a reconstructed appended hull predict the near-stern wake?

A traceable CFD workflow from structured mesh to saved-field inspection and experimental ring-mean comparison.

CURRENT STATUS

Stopped preliminary run. Inner wake disagreement remains; residual and mesh-independence checks are incomplete.



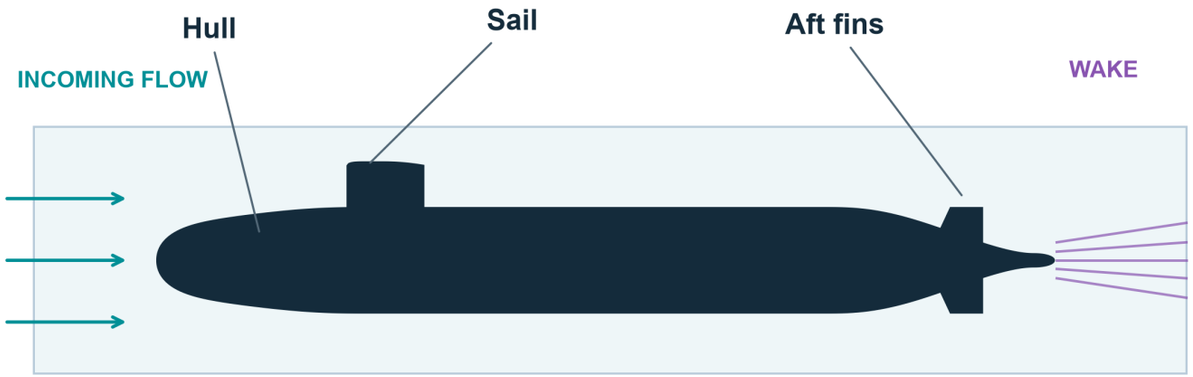
Original conceptual artwork; ribbons are illustrative.

Ramin Mashayekhi / Revision 01

01 / MODEL AND CONDITIONS

A fully appended reference shape

Independent geometry reconstruction: hull, sail and four aft fins. The model has no rotating propeller.



Concept schematic: flow direction and main geometric features.

CONCEPT SCHEMATIC

Feature labels and flow direction are illustrative. Original artwork is preserved; numerical geometry and results are separate evidence.

PHYSICAL DOMAIN

X: -13.0683 to 30.4927 m (-3L to 7L). Cylinder radius: 13.0683 m (3L). Coordinates are metres; no millimetre conversion is applied.

SAVED M3 SETUP

Hull length / max radius
4.3561 m / 0.254 m

Inlet speed / Reynolds number
2.459 m/s / 12,000,803

Water properties
997 kg/m^3; 0.0008899 Pa·s

Solver / closure
CFX 2022 R2; steady SST

Numerics / physical timescale
High Resolution; 0.05 s

Wall treatment
Automatic; no-slip body walls

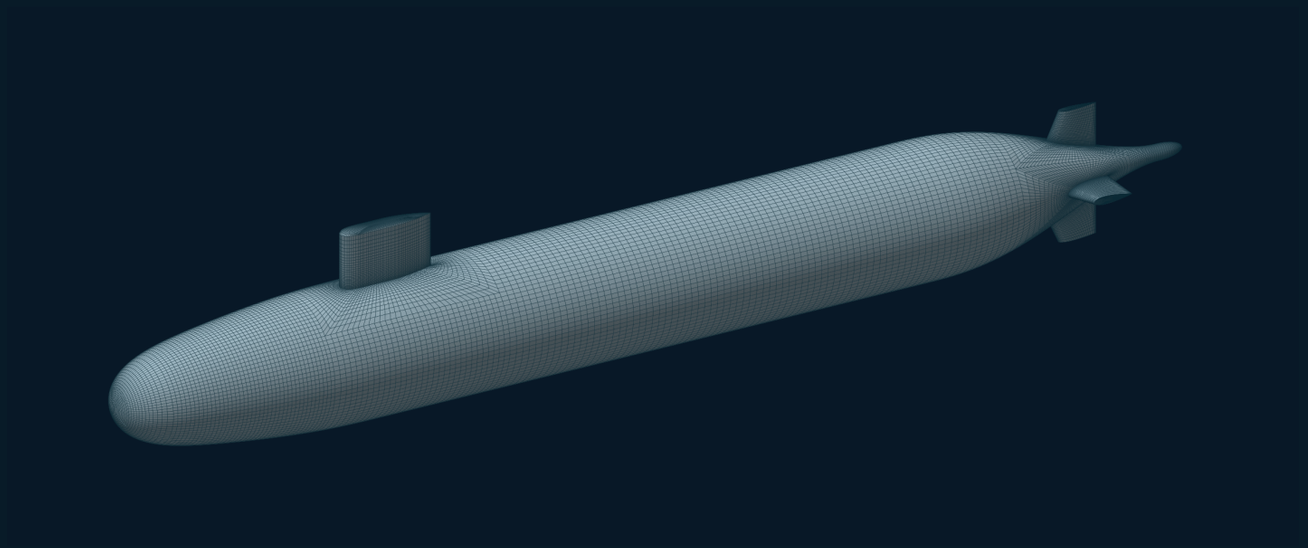
Outer boundary
Cylindrical free-slip wall

The imported Fluent mesh boundary labels and the solved CFX boundary conditions are recorded separately.

02 / GEOMETRY AND MESH

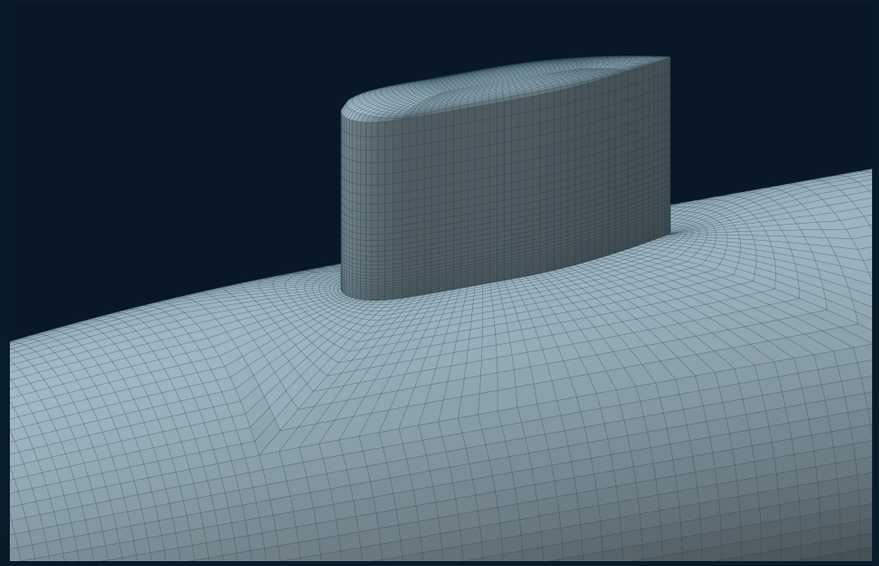
Surface connectivity follows the appendages

Native surface coordinates and connectivity are shown at different magnifications.



HULL AND APPENDAGES

The aft taper, sail junction and fin roots create distinct local mesh requirements.



SAIL ROOT

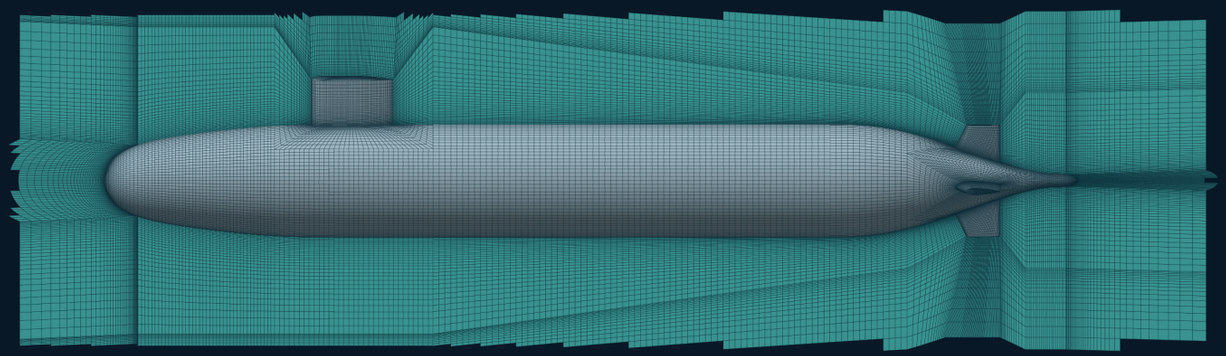
A concentrated surface grid follows the hull-sail intersection. Density alone does not establish solution accuracy.

Geometry caveat: this is an independent reconstruction. Matching the overall SUBOFF form and nominal scale does not establish exact equivalence to the experimental geometry.

03 / VOLUME MESH AND NEAR-WALL RESOLUTION

Cell count is only one part of resolution

M3 contains 3,945,472 HEX8 cells and 4,009,970 nodes. Mesh quality and solved wall distance answer different questions.



AREA-AVERAGE y+

Solved wall	Mean y+
Hull	251.3
Sail	318.0
Top fin	278.7
Bottom fin	271.1
Left / right fins	271.5 / 270.8

These values indicate wall-function use, with no resolved viscous sublayer claim. Maximum body-wall y+ reaches about 492.

FLUID SECTION

The cut exposes cells around the body and stern, alongside the original surface mesh.

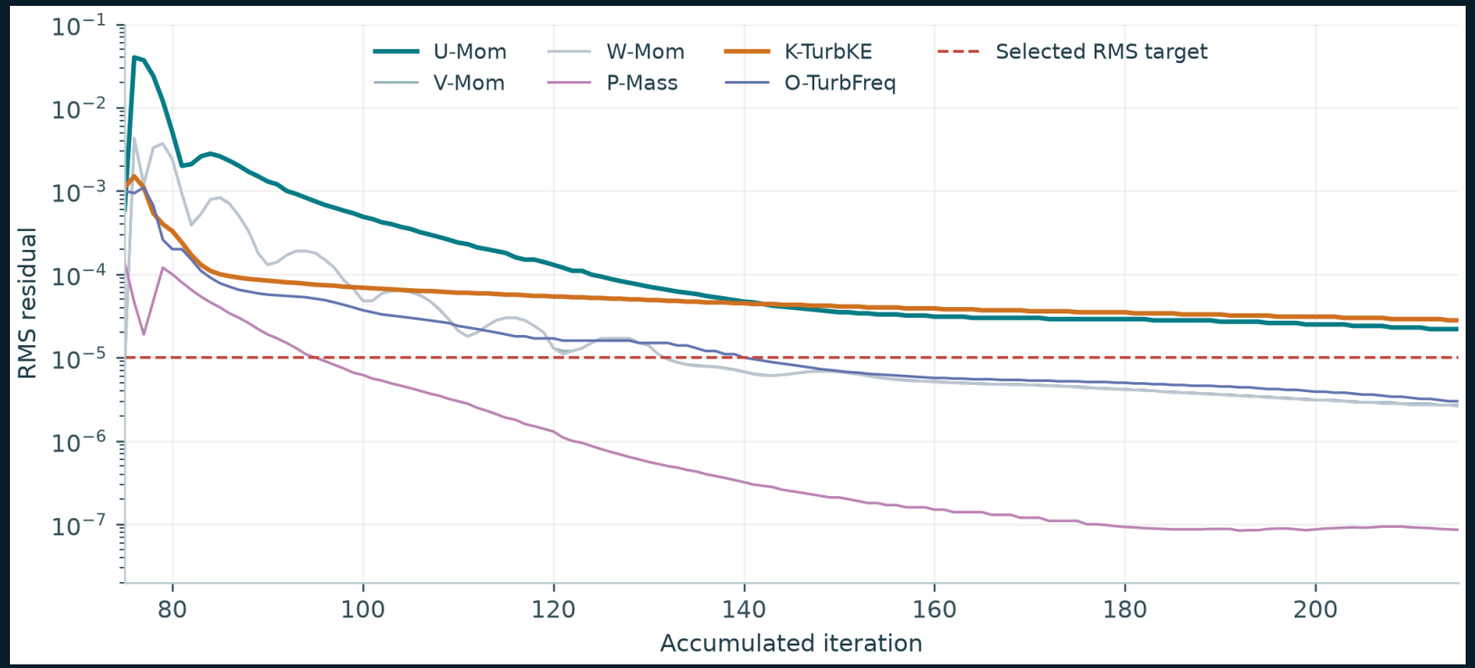
NATIVE FLUENT MESH CHECK

Minimum orthogonal quality: 0.0655
Maximum aspect ratio: 1472
Positive volumes; quality checks do not prove accuracy.

04 / CONVERGENCE EVIDENCE

A stable monitor is not a converged solution

Saved result: CFX_002.res, 10 September 2026. Accumulated iteration 215; 141 iterations after the setup changes.



RMS RESIDUALS, ITERATIONS 75-215

Replotted from the copied solver history. The dashed line marks the selected 1e-5 target.

2.17e-5

Final U-momentum RMS; 2.17 times target

2.82e-5

Final turbulence-k RMS; 2.82 times target

STOP CONDITION

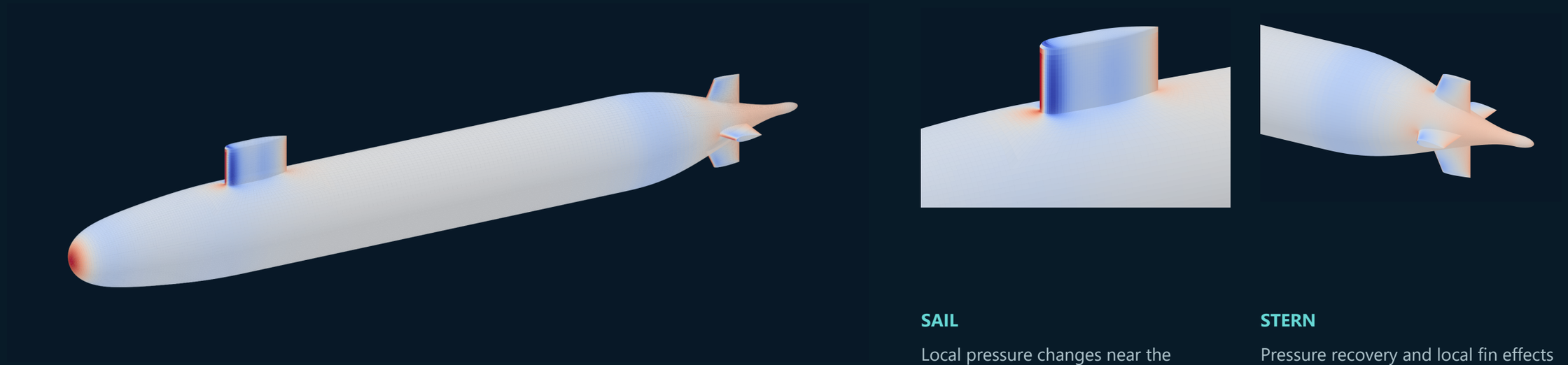
The solver received a stop instruction. Four of the six RMS residuals meet the target; U-momentum and k do not.

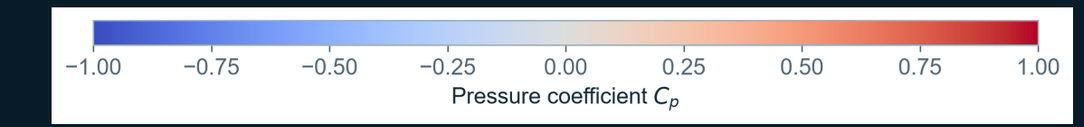
Both unresolved residuals trend downward near the end. Continued iteration and sustained output stability are needed before this result becomes a final mesh-study baseline.

05 / PRESSURE FIELD

Pressure varies across the hull and appendages

Cp = (p - pout) / (0.5 rho $Uinf^2$). All three native surface views use the same pressure-coefficient scale.





SAIL

Local pressure changes near the leading edge and hull junction.

STERN

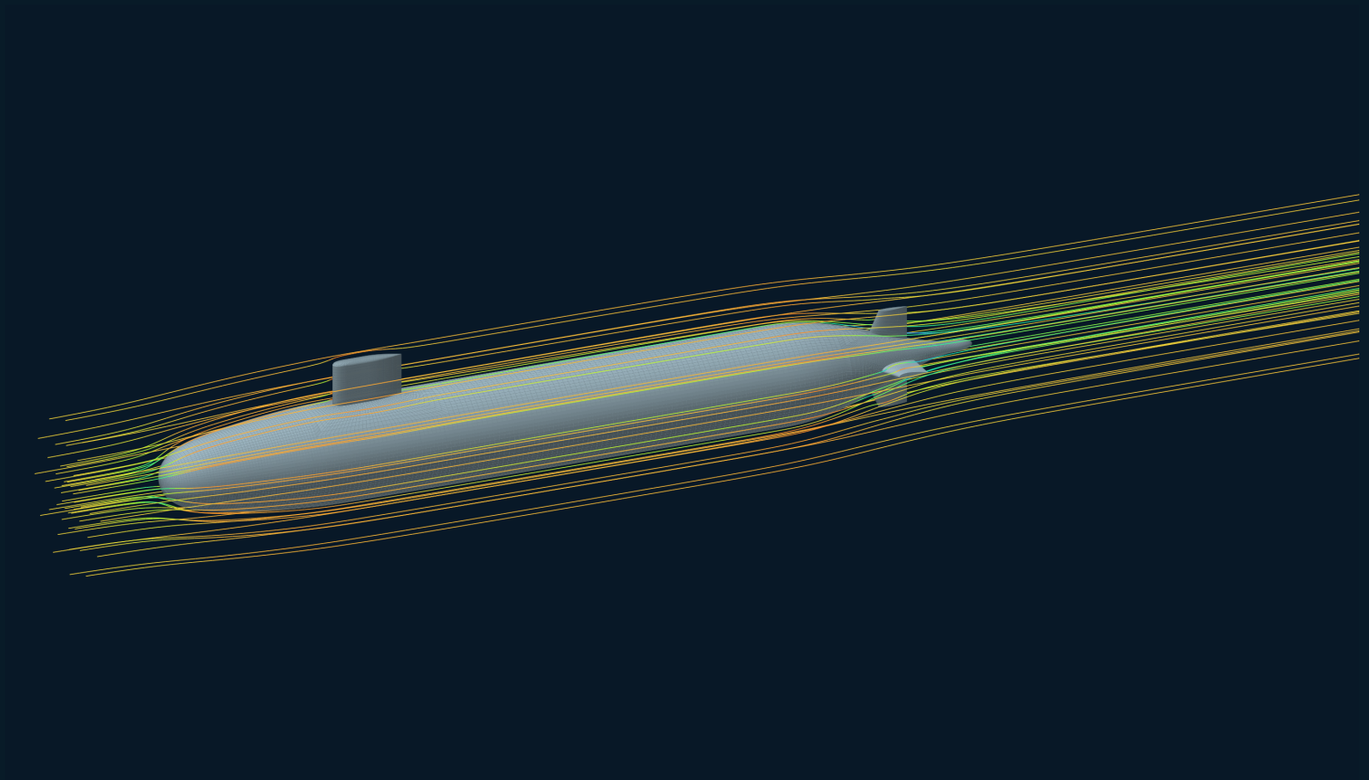
Pressure recovery and local fin effects in the saved field.

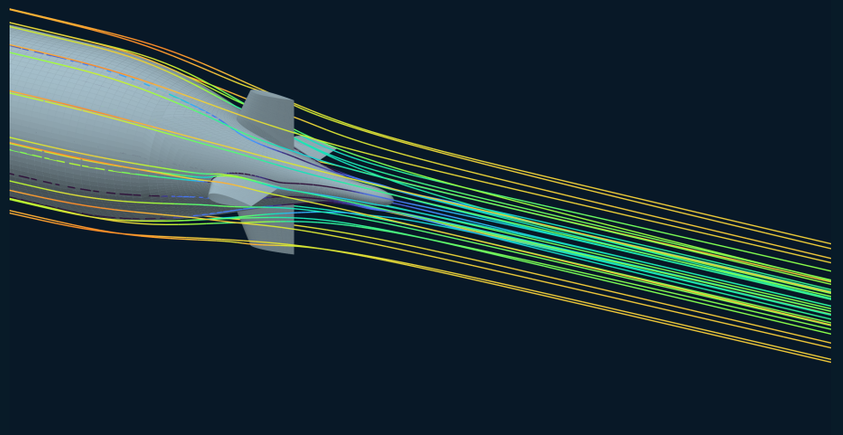
Surface patterns are descriptive CFD evidence. This report does not claim experimental pressure validation or infer force error from the colour map.

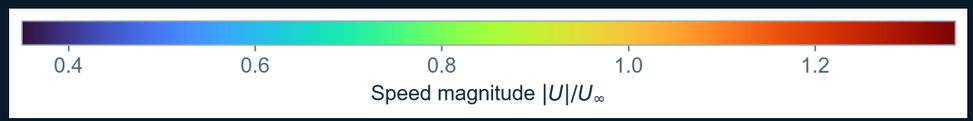
06 / STREAMLINE INSPECTION

Three-dimensional paths through a steady field

Colours show speed magnitude |U|/Uinf. Streamlines were integrated through the saved steady velocity field.







NEAR-STERN SEEDING

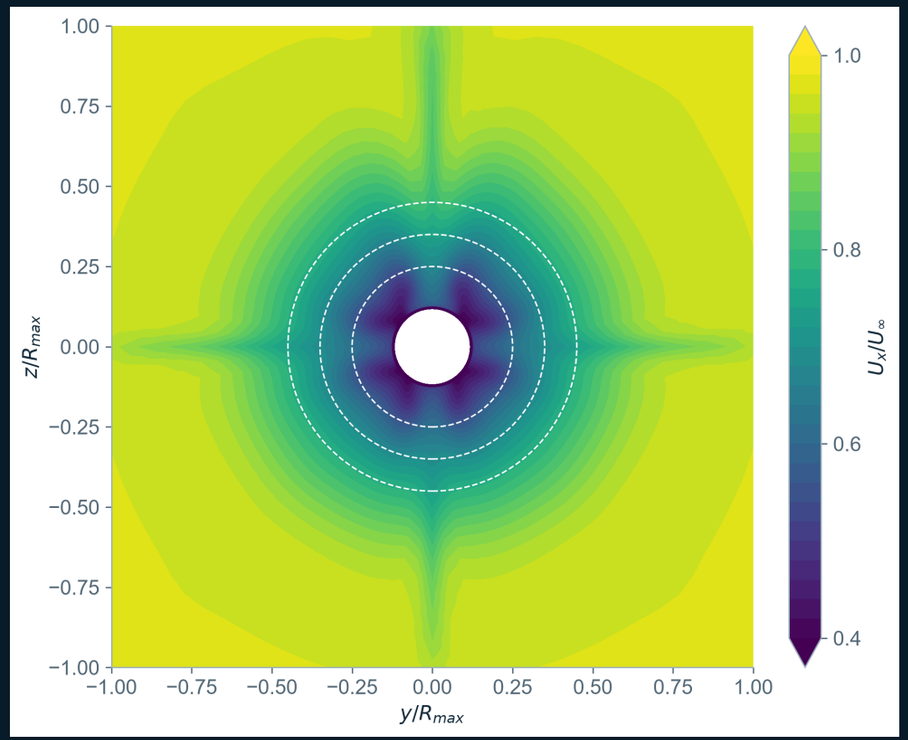
The close view follows paths seeded around the wake and appendages.

These are steady-field paths, not tracked particles from a transient simulation.

07 / AXIAL VELOCITY AND WAKE

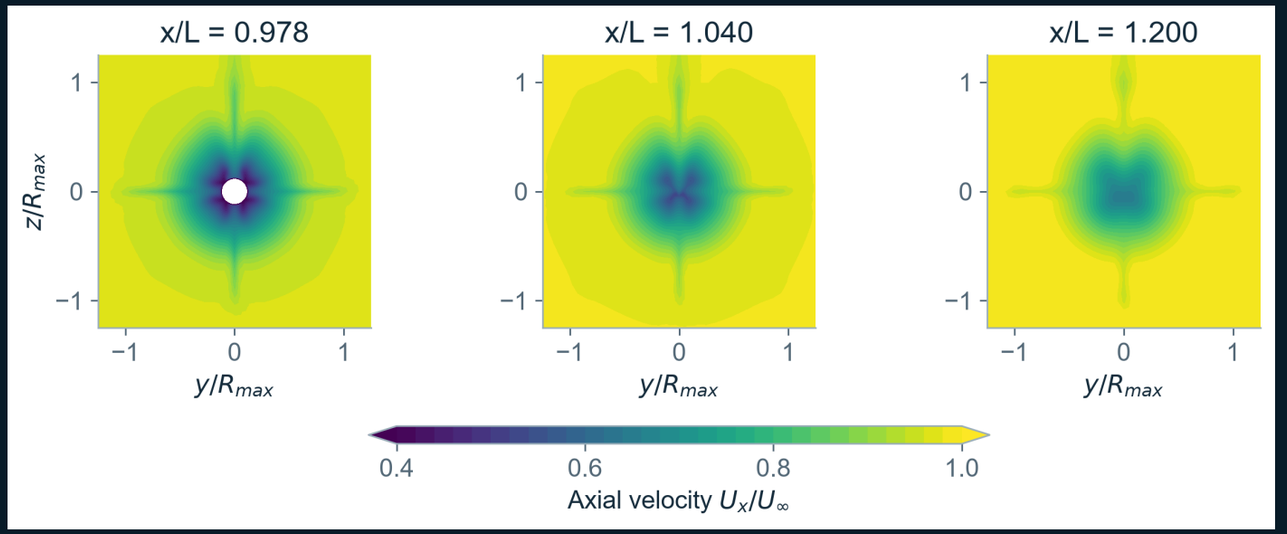
The appendage signature persists downstream

Ux/Uinf is the hull-axis velocity divided by inlet speed. Section coordinates use L = 4.3561 m and Rmax = 0.254 m.



NEAR-STERN PLANE: x/L = 0.978

White central area is solid geometry. Dashed circles mark the three sampling radii.



WAKE DEVELOPMENT

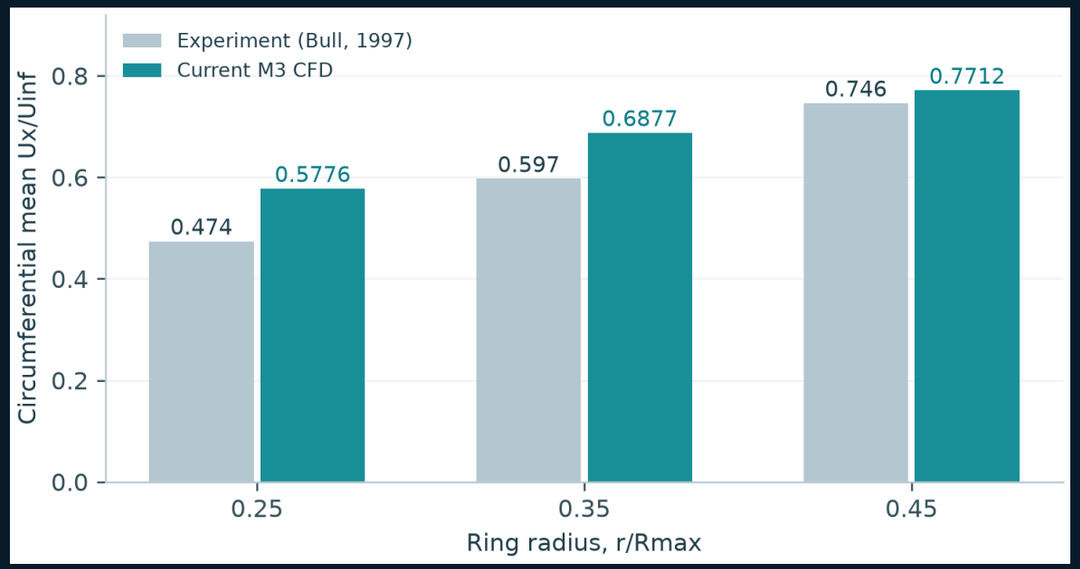
Original contours at x/L = 0.978, 1.040 and 1.200 share a colour scale. The low-speed pattern spreads and becomes smoother downstream.

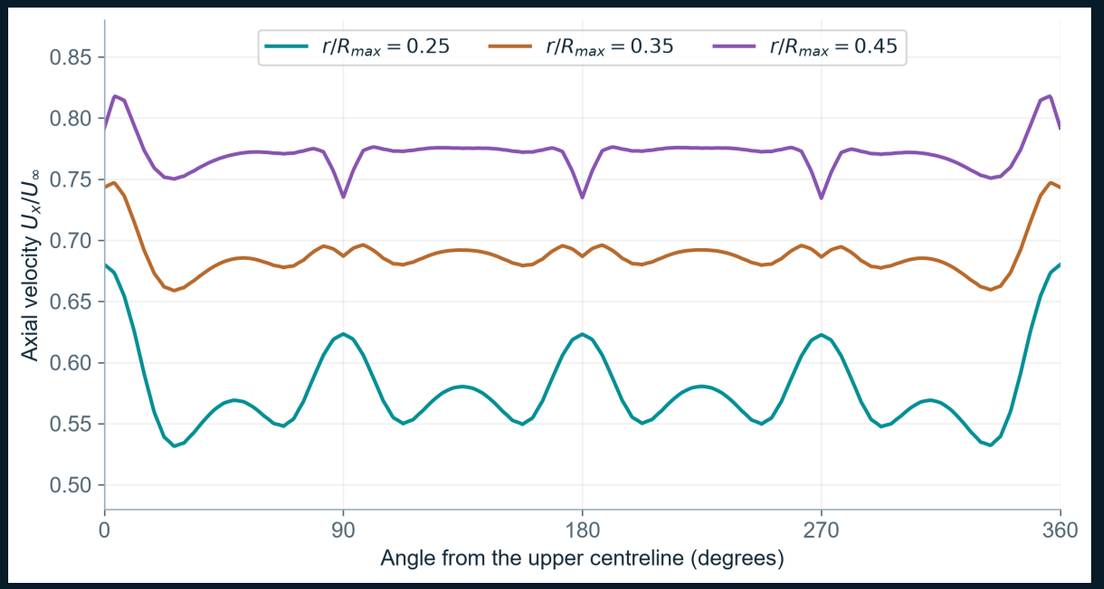
The large panel and the small-panel sequence have separate displayed legends. Read each colour map against its own range.

08 / EXPERIMENTAL COMPARISON

The inner wake is too fast

At x/L = 0.978, all three CFD circumferential means exceed the published experimental means.





EXPERIMENTAL MEANS VS M3

r/Rmax	Experiment	CFD	Relative difference
0.25	0.474	0.5776	+21.8%
0.35	0.597	0.6877	+15.2%
0.45	0.746	0.7712	+3.4%

ORIGINAL CFD ANGULAR PROFILES

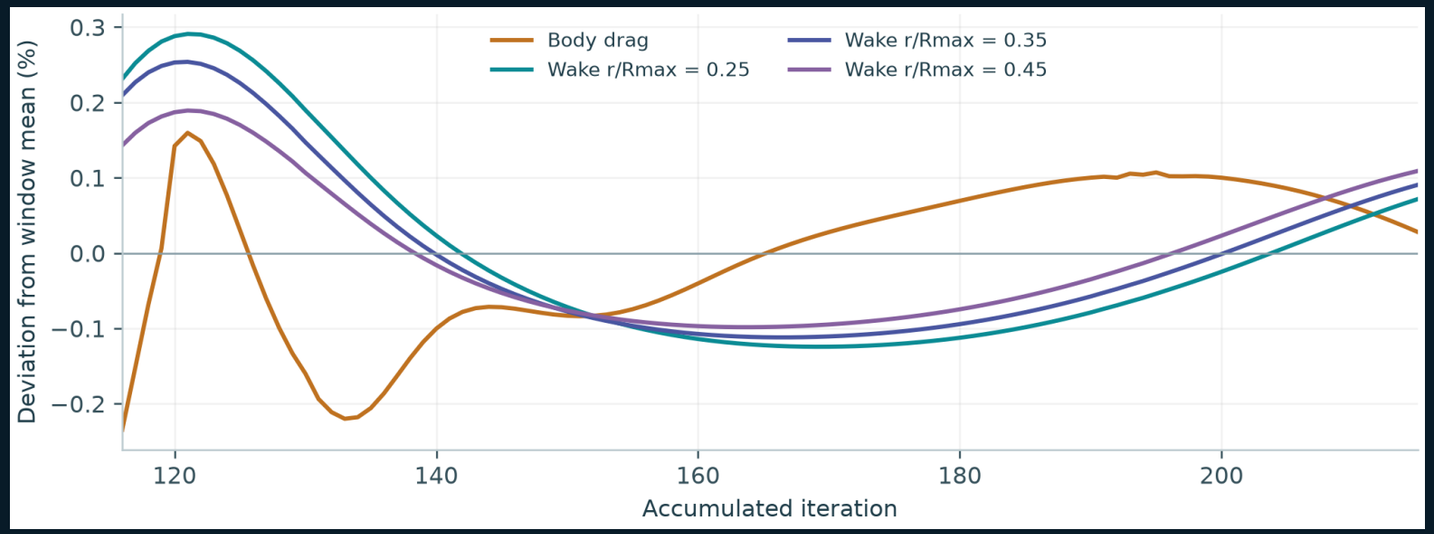
Profiles are CFD only. No experimental angular curves were reconstructed or overlaid. Similarity in a ring mean does not establish agreement in angular variation.

Relative difference = 100 (CFD / experiment - 1). Positive differences mean too little wake deficit. Ring sampling is 0.5°; independent integration agrees with native averages within 1e-5.

09 / FORCE BOOKKEEPING AND MONITOR STABILITY

Drag is a monitored output

The 62.9242 N body drag sums hull, sail and four fins. The outer cylindrical boundary is excluded.



Surface	Axial force (N)
Hull	60.2042
Sail	1.1737
Four fins combined	1.5464
Total body	62.9242

There is no matched experimental drag datum in this comparison, so no experimental drag-error percentage is claimed.

LAST 100 ITERATIONS: 116-215

Each curve is normalized by its own window mean. These are descriptive stability measures, not formal uncertainty estimates.

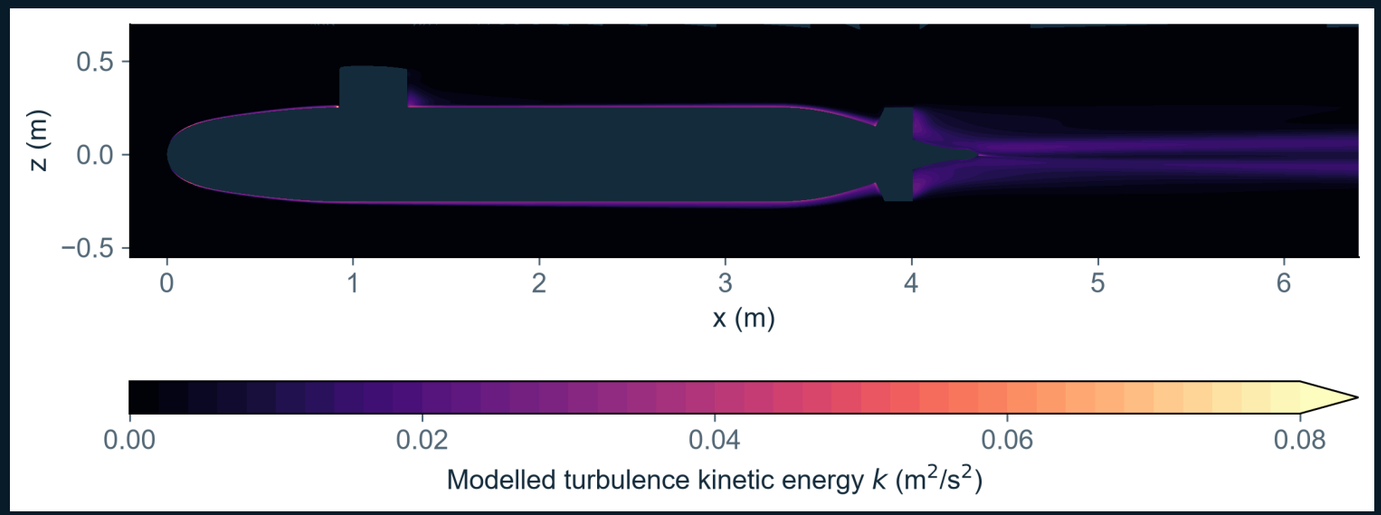
Global mass imbalance is 0.00928 kg/s. The large-domain momentum imbalance percentage is not an uncertainty estimate for the 63 N body drag.

Peak-to-peak changes over the last 100 iterations are below 0.42% for all four monitors. The wake curves still rise near the end; stability alone does not close the residual check.

10 / MODELLED TURBULENCE FIELD

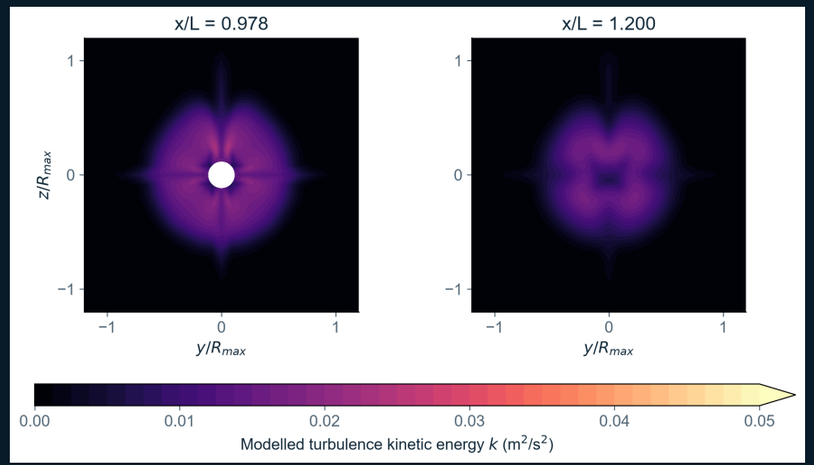
Turbulence energy concentrates near the wake

Native SST turbulence kinetic energy, k, is shown in m^2/s^2. It is a modelled statistical field.



SAIL PLANE

The contour follows the near-body region and the downstream wake. The side view uses a 0 to 0.08 m^2/s^2 displayed scale.



WAKE SECTIONS

Sections at x/L = 0.978 and 1.200 use a 0 to 0.05 m^2/s^2 displayed scale.

The figure does not show individually resolved turbulent eddies. The two figure groups use different colour ranges; their legends are retained.

11 / ASSESSMENT AND EVIDENCE REGISTER

A useful preliminary baseline, with clear next steps

The present result documents the workflow and a persistent inner-wake discrepancy. It does not establish mesh independence or completed validation.

01 **Complete the convergence baseline**

Continue the current physical and numerical setup until residuals and sustained monitor windows support a final baseline.

02 **Compare meshes at matched settings**

Use the same body-force sum, wake circles, fluid properties and numerical choices. M3 alone cannot establish mesh independence.

03 **Isolate remaining modelling differences**

Check reconstructed geometry, inlet turbulence, near-wall spacing and wake resolution. Change one modelling choice at a time.

Editable source, original input assets, chart generator and rendered QA are retained alongside this report. This revision used existing data only; no new flow calculation was run.

SOURCES AND REPRODUCIBILITY

S1 / Original field and mesh visuals

LinkedIn_SUBOFF_v3: figures, concept_art, data and README. Original figures are reused individually; no earlier PDF pages are copied.

S2 / Saved-result evidence

M3_Monitoring/Validation_Run002: solver log, metrics.tsv, residual and monitor histories, wake exports and validation_results.json.

S3 / M3 mesh checks

SUBOFF_M3_Mesh/M3: README, validation.json, Fluent_mesh_check.log and fluent_validation.json. Mesh check: Fluent 2025 R2.

S4 / Experimental reference

P. Bull (1997), The Validation of CFD Predictions of Nominal Wake for the SUBOFF Fully Appended Geometry. In Twenty-First Symposium on Naval Hydrodynamics. Definition: p. 1065; experimental means: p. 1071.

Read reference / National Academies Press / DOI: 10.17226/5870