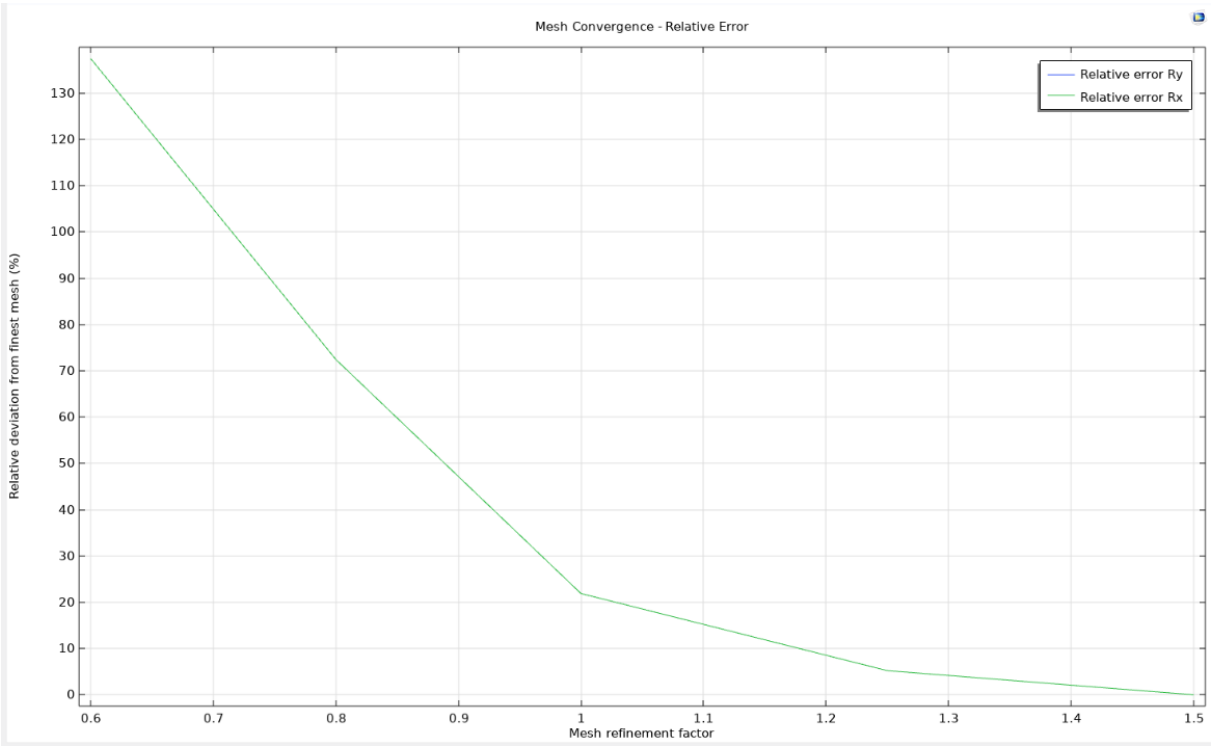
V1.0A ENGINEERING BUILD FOR COMSOL MULTIPHYSICS 6.4

PHYSICAL LAB Simulation Verification Auditor

Turn mesh refinement into a repeatable, quantity-based engineering decision

A numerical solver reaching a solution does not prove that the answer is independent of the chosen mesh. Different engineering outputs can stabilize at different rates. The Auditor evaluates selected quantities of interest across a controlled refinement sequence and reports the numerical evidence behind a recommendation.



Authentic COMSOL convergence plot with complete axes: relative deviation from the finest sampled mesh [%] versus mesh refinement factor. Ry and Rx are diagnostic series from the source study.

- Verify the outputs that drive the decision, not mesh density in isolation.
- Apply a relative or unit-safe absolute tolerance individually to each selected QoI.
- Require two consecutive accepted transitions before recommending a mesh level.

SCIENTIFIC SCOPE	Mesh convergence tests numerical consistency for the chosen QoIs. It does not prove that the physics, boundary conditions, materials or real-world prediction are correct.

How the Auditor works

The current build works around explicit COMSOL targets and Derived Values. The model remains the source of truth; the Auditor structures the repeated runs and the numerical decision.

Step	Action	Evidence produced
1	Select component, mesh and study	Unambiguous model targets
2	Discover and select QoIs	Dataset, unit and expression context
3	Configure at least three mesh levels	Ordered refinement sequence
4	Assign relative or unit-safe absolute tolerances	Per-QoI acceptance rules
5	Run preflight and audit	Rejected invalid targets or traceable results
6	Compare successive levels	Relative/absolute changes for each QoI
7	Evaluate two consecutive transitions	QoI and overall PASS/FAIL
8	Review numerical effort	DOF, mesh time and solve time
9	Issue recommendation	Coarsest level satisfying the configured rule

Current V1.0a capability

Implemented	What it means
Dynamic levels	A minimum of three refinement levels; sequence length is configured for the audit
Per-QoI rules	User-selected QoIs with individual relative or unit-safe absolute tolerances
Decision logic	Two consecutive accepted transitions, QoI and overall PASS/FAIL, and a mesh recommendation
Diagnostics	Convergence classification plus DOF, mesh-time and solve-time reporting
Preflight	Invalid component, mesh, study or dataset combinations stop before a numerical conclusion

The current software reports convergence and numerical effort; mesh-quality visualization is outside the implemented V1.0a scope.

Convergence evidence from the source study

The table replaces the former single displacement image. It transcribes two real QoIs from the original COMSOL mesh-study table and calculates the adjacent-level relative change using the current documented project convention.

$\varepsilon_i = 100 \times \lvert Q_i - Q_{i-1} \rvert / \lvert Q_i \rvert$	Current documented adjacent-level relative-change convention used for the values below. Relative and unit-safe absolute acceptance modes are configured per QoI in the Auditor.

Level	Refinement factor	Warpage [µm]	Δ [%]	Max Si disp. [µm]	Δ [%]
L1	0.60	3.4543	-	26.809	-
L2	0.80	3.4551	0.023	26.811	0.007
L3	1.00	3.4641	0.260	26.812	0.004
L4	1.25	3.4541	0.290	26.813	0.004
L5	1.50	3.4705	0.473	26.813	0.000

Source: PHYSICAL LAB COMSOL source study, ‘Study 3 Mesh Convergence’, 9 August 2026. Values are transcribed; Δ values are recomputed from those values. No PASS/FAIL is assigned here because the source capture does not record a configured tolerance.

What the table shows

- The maximum silicon displacement stabilizes quickly, while the warpage QoI remains non-monotonic evidence that different outputs can converge differently.
- A configured tolerance must be satisfied for two successive transitions before the Auditor recommends the coarsest accepted level.
- DOF measures problem size and helps expose the cost of refinement; mesh and solve times show where extra numerical effort is being spent.

RECORDED EFFORT	Visible source-run log entries span 254,385 to 1,542,735 solved DOF (plus one internal DOF). They are not mapped into the table because the screenshot does not preserve an unambiguous row-to-level association.

Why numerical verification matters

Engineering risk	How the audit helps
False confidence	Separates solver completion from evidence that selected outputs are mesh-stable
Excessive refinement	Supports selection of the coarsest level that satisfies the configured consecutive-transition rule
Hidden QoI conflict	Shows when one output stabilizes while another remains sensitive or non-monotonic
Unrepeatable review	Preserves target, level, tolerance, PASS/FAIL, recommendation and numerical-effort context
Wasted solver time	Pairs convergence evidence with DOF, mesh time and solve time for a cost-aware decision

What the outputs mean

Output	Interpretation
QoI PASS/FAIL	Whether the configured rule is satisfied for that quantity
Overall PASS/FAIL	Combined decision across selected QoIs and the consecutive-transition rule
Mesh recommendation	Coarsest accepted level supported by the configured evidence
Classification	Diagnostic description of the convergence pattern; not an independent pass criterion

Scientific boundary

Mesh convergence establishes numerical consistency under refinement. It does not prove that the physics formulation, boundary conditions, material properties or experimental correlation are correct. Those questions require model validation and engineering review.

Status	Scope
CURRENT	V1.0a engineering build for COMSOL Multiphysics 6.4 with the workflow and outputs described in this brochure
NOT CURRENT	Mesh-quality visualization or automatic physical-model validation
DEVELOPMENT POSITION	Active engineering build and early-access candidate; broader solver/model coverage is not claimed

NEXT STEP

Request Early Access

Discuss a model-specific verification pilot | physical-lab.com/contact