STELLA NOVA RESEARCH CENTER

Methodological Note: Material Memory, Technological Latency, and Archaeological Visibility

Version 1.1.0

This tool is a heuristic modeler. It does not determine that contact, migration, diffusion, independent invention, or technological borrowing occurred. It helps users make assumptions explicit, compare those assumptions against curated anchor cases, and describe where delayed archaeological visibility may arise from population scale, material access, technical continuity, and institutional demand.

Interpretive Commitments

The model separates five signals that are often collapsed in speculative or diffusionary arguments: biological signal retention, cultural-form retention, technical-process retention, resource reacquisition, and archaeological visibility. A biological signal can be muted while cultural forms persist; a symbolic form can survive while operational technique is lost; a local technology can be practiced at a scale too small to leave durable evidence; and an imported object can precede local production by generations or centuries.

For that reason, outputs are displayed as latency ranges and bottleneck rankings, not proof statements. Longer latency gaps increase the need to consider independent convergence, later reactivation, unsampled intermediate evidence, and imported-object pathways as competing explanations.

Core Workflow

The user begins by entering a research question. Preset models then populate a complete scenario that can be modified. The scenario includes population estimates, contact or transfer date, visible emergence date, target technological expression, resource distance, and advanced vectors for material visibility, pyrotechnology, mineral-working tradition, specialist survival, craft continuity, elite demand, exchange strength, generation length, assimilation, intermarriage, and knowledge loss.

The MapLibre interface allows the user to place a contact zone, incoming origin, and resource zone. The contact-resource distance updates the resource distance field. The origin-contact distance is retained as a functional context metric and appears in outputs and reports, but it is not treated as proof of a route.

Model Specification

The equations below mirror the implementation in handleRun() and the shared model_config.json file. Slider values on 1-5 scales are normalized internally by dividing by 5. Knowledge-loss, assimilation, and intermarriage values are already 0-1 proportions.

Component	Equation	Plain-language role
Observed latency	`L_obs = abs(visible_emergence_year - contact_year)`	The user-entered gap between the scenario event and first visible archaeological expression.
Resource readiness	`R = 0.55*ore_visibility + 0.25*(1 - distance_penalty) + 0.20*exchange_strength`	Materials are easier to reacquire when ores or raw materials are visible, nearby, and connected by exchange routes.

Thermal readiness	`T = 0.65*pyrotechnology + 0.15*mineral_working + 0.20*craft_continuity`	High-temperature capacity is modeled as a separate bottleneck from knowing that a material exists.
Continuity	`C = 0.34*specialist_survival + 0.28*craft_continuity + 0.13*exchange + 0.10*elite_demand + 0.15*(1 - knowledge_loss)`	Technologies survive when people, apprenticeship, demand, and repeated practice remain stable enough.
Visibility	`V = 0.32*elite_demand + 0.22*exchange + 0.22*craft_continuity + 0.12*mineral_working + 0.12*(1 - assimilation_modifier)`	Archaeological visibility increases when objects are repeatedly produced, exchanged, displayed, discarded, or deposited.
Modeled latency band	`L_band = stage_base_latency * (0.70 + 0.50*difficulty + 0.78*friction + population_adjustment)`	Each technology stage has a base range; bottlenecks lengthen or shorten that range.

Technology Stages

Stage definitions and base latencies live in assets/data/model_config.json. In v1.1 these stages include mineral use, native metal working, copper smelting, arsenical copper, tin-bronze alloying, iron smelting, local casting tradition, and a custom stage. This design keeps the interface controlled while making future extension possible without rewriting the application logic.

The metallurgy sequence distinguishes mineral use from metal production. Iron-ore mirrors, pigments, hematite, magnetite, ilmenite, pyrite, and other worked minerals may be culturally or technically important without implying iron smelting. Similarly, native copper working is not the same process as reducing copper ore into metal.

Sensitivity Analysis

The v1.1 sensitivity mode varies three fixed parameters: knowledge-loss rate, ore/material visibility, and specialist survival. The output is a tornado-style impact view showing how much the modeled midpoint moves when each parameter is varied within a bounded interval. This is intended to show which assumptions drive the result most strongly, not to validate the scenario.

Comparative Anchors

Sample anchors are curated examples used for teaching and comparative reasoning. They include early copper-smelting evidence from the Balkans, native copper working in the Great Lakes, West Mexican metallurgy, central Andean copper-smelting proxies, Formative Mesoamerican mineral exchange, Cascajal Block writing claims, Austronesian/Lapita navigation comparisons, and European Neolithic agricultural spread models. Anchors are not assertions that one case caused another. They are structured comparison points.

Export, Import, and Reproducibility

Exported JSON bundles include the research question, model version, scenario payload, advanced vectors, map markers, model run, sensitivity output when present, comparison output when present, and notes. Imported JSON opens in a preview modal before overwriting the current fields. Reports cite the model version so classroom and research outputs can be reproduced or re-run after the model changes.

Limitations

The model is deliberately coarse. It cannot replace excavation, sourcing, radiocarbon analysis, archaeometallurgical study, residue analysis, linguistic comparison, or genetic evidence. It is best used to identify assumptions, generate evidence predictions, compare alternative pathways, and clarify what kind of data would strengthen or weaken a research question.

Selected References

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