From Typed CAD Operations to Checked Exact Geometry

LYON INDUSTRIES

A local mechanical-engineering working-paper checkpoint

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Cover: J58 turbojet in a ground test, NASA AFRC, 4 April 1997. NASA image used with attribution under the agency's media-usage guidance.

Abstract

This programme asks whether language-model agents can support mechanical design from requirements to manufactured and inspected parts without displacing the CAD model, validation rules, or human release decision. This working-paper checkpoint examines a narrower question: what transaction and artifact evidence did a frozen local service preserve during one incompletely archived post-freeze fixture case? Before the case, two neutral preparation runs produced identical state and model digests from an empty scene. The fixture run reached version 17 through 12 accepted versions and preserved seven rejected calls after the empty freeze. The accepted model contains one valid solid with 140 by 90 by 25 mm bounds and an OCCT B-rep-computed volume of 138,936.968 mm^3. STEP reimport matched the recorded solid count and volume within floating-point output; the maximum world-bound delta was 0.001943 mm. The GLB geometry nodes formed one watertight connected mesh component and remained within the declared tessellation tolerances. These are local pre-manufacturing software results. The run did not test drawings, tolerances, fits, interference, structural behaviour, machining, inspection, safety, repeatability across tasks, or commercial value. It also lacks a durable copy of the initiating natural-language prompt and exact model identifier. The result supports continued method research and a manufactured-part experiment; it does not support a general CAD or mechanical-engineering capability claim.

Scope of claims. A frozen local transaction service accepted typed generic CAD operations, preserved rejected calls, rebuilt one exact OCCT solid, and produced checked STEP and GLB artifacts for the recorded fixture case. No physical part, manufacturing release, material verification, structural result, safety result, customer outcome, or general-purpose CAD capability is claimed.

1 Decision and research question

The expensive decision is whether this method merits the next experiment: a reviewed drawing and manufacturing package followed by production and dimensional inspection of a low-risk part. The full research goal is a traceable mechanical-engineering workflow in which requirements, exact geometry, release files, manufactured units, inspection results, and failures remain linked. This revision tests only the transaction from typed agent calls to exact geometry and checked exchange files.

The design choice under test is deliberately narrow. A language-model agent selects and orders operations. A schema rejects malformed calls. An OCCT-based service constructs and validates the B-rep, records accepted and rejected events, and exports STEP and GLB. The browser displays GLB but does not own or edit geometry. This division follows the capabilities of OCCT as an exact modelling and exchange library [6, 7]. CadQuery provides the Python modelling interface and documented STEP output path [2]. MCP provides discoverable tools with JSON Schema input and optional structured output schemas [4].

2 Related work and contribution

Versioned exact geometry, CAD modification history, and exchange validation are established capabilities. OCCT's application framework records attributes, parametric dependencies, persistence, and modification history [6]. STEP AP242 covers managed model-based three-dimensional engineering, and NIST has published downstream validation work joining STEP models to manufacturing and coordinate metrology [3, 1]. Scripted parametric CAD is also an established use of CadQuery [2].

The contribution tested here is not versioned CAD or STEP validation individually. It is one local transaction record that binds typed agent calls and rejected mutations to canonical exact state and checked STEP and GLB artifacts. This checkpoint tests whether that joined record is inspectable in one case. It does not claim a new product-data standard, feature-history model, or exchange-validation method.

3 Method

3.1 Frozen instrument preparation

The preparation started from an empty schema-version-2 scene. The frozen tool set exposed boxes, cylinders, regular prisms, copy, transform, removal, properties, Boolean operations, holes, slots, fillets, chamfers, measurement, validation, state inspection, and recent events. World coordinates were limited to -10,000 through +10,000 mm. The evidence protocol set maximum differences of 0.005 mm for STEP world bounds, 0.001 mm^3 for STEP total volume, 0.25 mm for GLB world bounds, and the greater of 0.1 mm^3 or 0.01 percent of exact body volume for each GLB body.

Two neutral coupon runs began empty and exercised all frozen operation classes. Both ended with six solids, 52,498.106 mm^3 OCCT B-rep-computed volume, model digest `22f06f289c6aca71aa4e0da62585955d0aaa0cd9c9f52`

adef8be485e219a055b, and state digest 179f15ea6a66cf79e44325eb25b94a9d8a7735e319da7c94343c132e99d50c4b. Canonical replay, STEP reimport, GLB parsing, measurements, and regenerated artifact digests passed in both runs. The first and reproduced run files are different because they contain timestamps and temporary paths; the geometry and canonical state identifiers agree.

3.2 Post-freeze fixture case

The fixture case ran in a fresh agent process after the operation set and empty scene were frozen. The repository does not contain the exact initiating natural-language prompt or the exact model identifier. The event log does contain every accepted operation, each rejected request or schema failure, and the immutable version bundles used in this analysis. This makes the work an engineering transaction case rather than a reproducible model evaluation.

After the initial review, the 12 accepted operation batches were extracted in order and replayed through the frozen STDIO MCP from a clean schema-version-2 empty workspace. The replay input SHA-256 was f0a9fe577d880ab50c5d49ee4b44938f85eec5657fedde0559043047f04859a0. The replay used new version numbers and idempotency keys, so its state digest differed. It reproduced the original model digest, measurements, and byte-identical STEP and GLB artifacts. Rejected calls were not replayed; their original error events remain in the recorded timeline.

The accepted sequence created a 140 by 90 by 10 mm base; created and united a 50 mm diameter boss; rebuilt the part to apply a 2 mm top-edge chamfer before 5 mm corner fillets; added a 20 mm through-hole and two 40 by 10 mm through slots; and attached Aluminium 6061 density metadata and a viewport colour. The material field is metadata. No sample was inspected to establish alloy or density.

Table 1: Evidence classes and observed counts for the local case.

Record	Observed value	Meaning
Frozen preparation	2 passing runs	Same canonical model and state digests.
Post-freeze versions	12 accepted	Versions 6 through 17 became immutable bundles.
Post-freeze rejections	7	Schema, selector, geometry, or export checks blocked the call.
Final topology	1 valid solid	OCCT topology check and STEP reimport agreed.
Final bounds	140 by 90 by 25 mm	Exact CAD-world minimum and maximum coordinates.
Final volume	138,936.968 mm^3	OCCT B-rep-computed volume recorded by version 17.

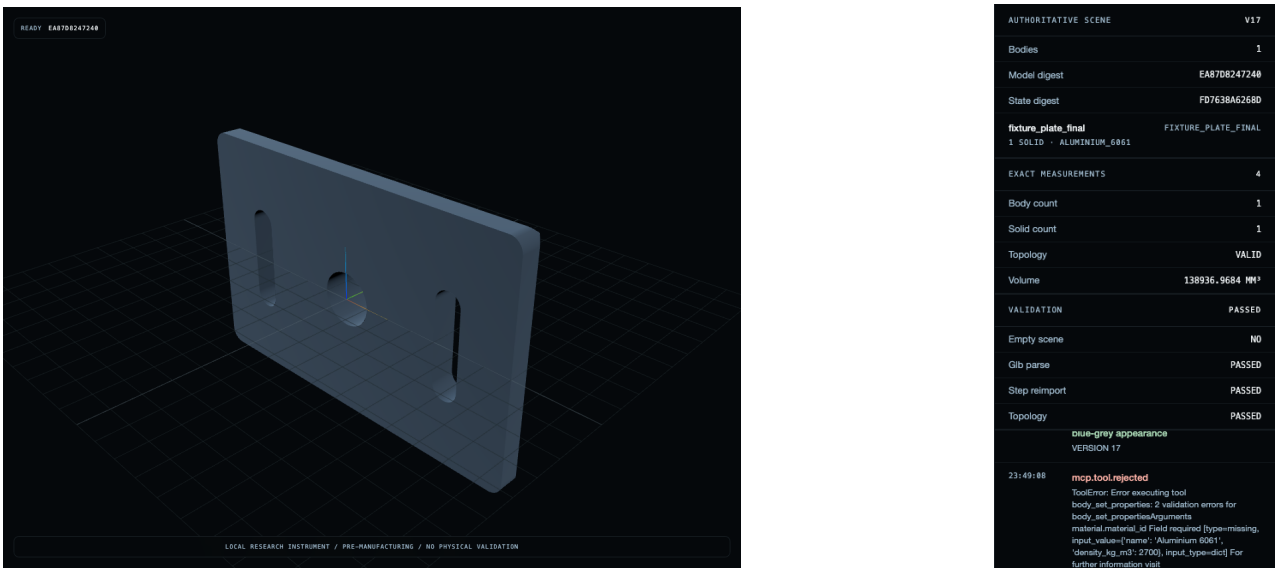

Figure 1: Local HMI capture of version 17, split into the pre-manufacturing GLB render and an enlarged evidence rail. The rail shows the one-solid state, truncated model and state digests, OCCT volume, STEP and GLB pass states, and the most recent rejected call. This is not a photograph or a physical test.

4 Observed result

Version 17 records model digest `ea87d82472402e39b2d48269cb874504a1768c297ad98ff34b5b247319da118d` and state digest `fd7638a6268d873c25933faf217a5d23a4ca7d9b2b11ce8ed3e6854125a95ab3`. The STEP file is 96,806 bytes with SHA-256 `f8d49a7d55d30e5dc78645020b899c61587a086756ad37d57cbb785f0617e19d`. The GLB is 170,504 bytes with SHA-256 `ddc24b5516a6c419e019551f93624500151e2a79624602645b70c670d74b1a24`.

STEP reimport returned one solid, a floating-point volume difference below 0.000001 mm^3, and a maximum world-bound difference of 0.001943 mm. GLB parsing returned 25 named geometry nodes that combined into one watertight connected mesh component associated with the recorded body, a 2.117939 mm^3 tessellated-volume difference, and a maximum CAD-world bound difference of 0.001943 mm. Each value remained inside the frozen limit. Agreement is evidence that the accepted exact state and its two exchange representations describe the same bounded result under the stated checks. It is not evidence that another CAD system will preserve every design intent, tolerance, name, or material field.

5 What the rejected calls changed

The rejected calls are part of the result. The first box request used arrays and an incorrect pose field, so schema validation rejected it before geometry. Two standalone boss attempts failed because the GLB body's tessellated volume did not satisfy the per-body check. Creating and uniting the boss in one transaction passed. Two fillet requests used an unsupported selector tag or omitted the maximum selection distance. A chamfer after filleting exceeded the STEP bound tolerance by 0.012345 mm. The agent removed the intermediate body and rebuilt it with chamfer before fillets. The first material request used a name field where the schema required a stable material identifier.

These failures show that strict schemas and artifact checks can stop several classes of malformed or inconsistent change. They do not show that the system can identify a wrong requirement, an unsafe shape, a poor tolerance, an unmachinable feature, or a bad engineering decision. The rebuild also depended on the agent interpreting error messages. No controlled comparison tested whether this method reduces time or defects.

6 Interpretation and alternative explanations

The strongest defensible contribution is the transaction record: one version joins ordered typed operations, exact state, rejected calls, model and state digests, STEP and GLB bytes, and reimport checks. This is useful because an agent's success message or a visually plausible mesh cannot establish that a durable exact model exists.

Several alternative explanations remain credible. The fixture is simple enough that a conventional CAD user or a short script could produce it faster. The frozen operations may fit this case unusually well. The procedural prompt separation was not enforced by an independent evaluator, and the initiating prompt was not archived. The agent could have benefited from context outside the private evidence package. Passing STEP and GLB checks may reflect one OCCT version and one model family rather than portable exchange quality. Finally, the validation rules check representation consistency, not mechanical fitness.

7 Application and cost

The plausible application is not a replacement for mechanical CAD. It is a reviewable change path for bounded parts where repeated geometry edits, release files, and evidence must remain connected. An AEE mechanical study could use the method to join component envelopes, mounting requirements, connector access, cable clearances, drawings, releases, and inspection records. That application remains a hypothesis until a manufactured electrical-mechanical assembly catches deliberate cross-domain faults.

The local experiment used existing hardware, open-source software, and no paid service. The approved exception capped direct spend at NOK 0 and focused effort at 12 hours. Actual elapsed and labour time were not recorded. A real programme must count engineering review, CAD-kernel and dependency maintenance, source and artifact storage, drawing and tolerance work, machining, inspection, rework, release liability, support, and long-term migration. No cost saving is claimed.

8 Limitations, invalidators, and next experiment

This checkpoint has not tested sketches or constraints, assemblies or mates, drawings, geometric tolerances, interference, clearance, wall thickness, fasteners, supplier models, machining rules, structural or thermal anal-

ysis, physical material, dimensional inspection, repeatability across tasks, security, or customer demand. The author conducted the implementation and review. No independent technical reviewer signed the result. The PDF is not peer reviewed.

The method should be rejected or narrowed if a clean reproduction changes the canonical digests; if a future task requires target-specific code after the prompt; if a second CAD implementation cannot read the STEP result inside a declared tolerance; if drawings or inspection cannot trace dimensions to the accepted model; if physical measurements exceed the stated tolerances; or if review and maintenance cost exceeds the value of the audit trail.

The next experiment is one low-risk machined or printed part. Freeze the requirements, drawing, datums, tolerances, material, process, inspection plan, cost limit, and acceptance rule before modelling. Have a mechanical engineer review the native result and exchange file. Manufacture the part under owner approval, measure the named dimensions, record nonconformance and rework, and feed every failure back into a requirement or validation rule. Repeat on a materially different part before making a wider capability claim.

9 Conclusion

The local method moved beyond a rendered demo. A frozen typed operation set produced reproducible neutral fixtures, preserved rejected calls, and created one checked exact fixture model with versioned STEP and GLB artifacts. The accepted evidence is still pre-manufacturing software evidence. It supports a physical falsification experiment, not a general mechanical-engineering claim. The programme advances only when the exact model survives drawing review, manufacture, inspection, and a second distinct case.

A Local artifact-integrity record

Table 2: Selected immutable identifiers.

Item	SHA-256
Frozen source digest	`55bd5e45113277e0a28b43d799a77a48dfb0e7e2e8abc47336f939c69ac49747`
Generic preparation record	`c6ded505b28b88438ca14fc1d8e937bc983f40b76ae5be19789c165a351d9a2c`
Generic reproduction record	`a441beebe03ea9b14bfa637cf08db73b24a512a95190410c84ff74c6bb27becf`
Version 17 STEP	`f8d49a7d55d30e5dc78645020b899c61587a086756ad37d57cbb785f0617e19d`
Version 17 GLB	`ddc24b5516a6c419e019551f93624500151e2a79624602645b70c670d74b1a24`
Version 17 canonical JSON	`68fbcfe158f958ef6c9e59ccda4d349a11391fcf6708798f738bdf4eeafab92d`

Data availability. The source, schemas, tests, event log, JSON run records, version manifests, and versioned CAD artifacts are tracked in a private Lyon Industries repository at this checkpoint. The PDF and HTML companion are public; the raw CAD evidence package is not publicly inspectable. The initiating natural-language prompt, exact model identifier, and complete child-process transcript were not preserved.

References

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[4] Model Context Protocol contributors. Model context protocol specification 2025-11-25: Tools. `https://modelcontextprotocol.io/specification/2025-11-25/server/tools`, 2025. Accessed 15 July 2026.

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