

Digital Thread for Photopolymer Manufacturing: Requirements, Geometry, Material, Process, Inspection and Release

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Abstract

Digital Thread for Photopolymer Manufacturing is evaluated as the bounded decision of whether the released part can be traced through one controlled chain from requirement and geometry to material lot, process history, inspection evidence and disposition. The controlled state comprises requirement baseline, design revision, build file, machine configuration, material lot, process recipe, post-processing, inspection result, deviations and release authority. For ER-291, the three cited sources are used only for the evidence roles stated below and only within their demonstrated scope. ER-291 defines measurements, transfer logic, failure modes and release gates specific to this subject; no universal process window, product recipe or compliance conclusion is inferred.

Keywords: digital thread; requirements; geometry; material; process; inspection; release; configuration management

1. Significance, scope and ownership

ER-291 owns whether the released part can be traced through one controlled chain from requirement and geometry to material lot, process history, inspection evidence and disposition. The review is organised around the decision-specific evidence chain and leaves neighbouring ownership intact.

1.1. Corpus boundary

The digital thread is the continuity mechanism across records; it is not a substitute for the specialised controls carried by neighbouring reviews. ER-292 retains requirement-to-evidence traceability, ER-293 requalification after change, and ER-298 data integrity. ER-291 owns the linkage among requirement, geometry, material, process, inspection and release states.

2. Subject-specific state model and causal chain

For ER-291, causal interpretation begins by freezing requirement baseline, design revision, build file, machine configuration, material lot, process recipe, post-processing, inspection result, deviations and release authority. The thread fails when one state transition loses identity or provenance, even if every individual database remains internally complete.

3. Direct evidence and point-of-use source map

ISO/IEC/IEEE 15288:2023 provides a systems life-cycle process framework, ISO 10007:2017 provides configuration-management guidance, and ISO/ASTM 52920:2023 defines AM production-site qualification principles. ER-291 connects those architectures to the photopolymer manufacturing record without making the thread a software product. Reference [1] is used for system life-cycle process architecture. Reference [2] is used for configuration-management guidance. In ER-291, reference [3] supplies the industrial additive-manufacturing qualification context used at this point.

4. Measurement architecture

The measurement architecture for ER-291 is built around persistent identifiers, controlled revision relationships, immutable or auditable event records, material/build linkage, inspection linkage, deviation lineage and release-status consistency. Identifiers and timestamps are insufficient unless the chain also preserves version, configuration and evidence linkage across geometry, material, process, inspection and release.

5. Qualification and transfer

Digital-thread transfer is a configuration-management problem: a new tool, file format or system interface is accepted only after proving that identity, version and evidence links survive the hand-off without ambiguity.

6. Failure modes and interpretation traps

The central interpretation trap in ER-291 is that files exist but cannot be causally linked; a revised CAD is paired with an old build or inspection record; release status changes without traceable authority. A digital thread fails if any required hand-off loses identity, version or evidence linkage; completeness in another segment does not compensate for that break.

7. Non-compensatory release gates

Gate	Minimum evidence	Blocking failure
Requirement identity	Controlled requirement set with IDs	Unversioned prose requirement
Geometry	CAD/build-file revision linked	Released geometry ambiguous
Material	Supplier/lot/storage state linked	Material family only
Process	Machine/recipe/post-process history retained	Nominal printer settings
Inspection	Result tied to method/equipment/version	Orphan test result
Release	Disposition authority and accepted evidence recorded	File publication inferred as release
Change lineage	Supersession/impact links maintained	Silent overwrite
Provenance	Identifiers/checksums or equivalent lineage	Chain cannot be reconstructed

8. Minimum verification experiment

Select one released part and reconstruct its lineage from requirement to final disposition using only controlled records. Then introduce a simulated design, material or process change and verify that every affected downstream object is identified, superseded or requalified rather than silently reused.

9. Knowledge boundary

Digital-thread standards define architecture, not the exact data model required by every photopolymer factory. Interoperability across slicers, printers, inspection systems and repositories remains implementation-specific.

10. Conclusions

ER-291 defines a digital thread as preserved identity and provenance across requirement, geometry, material, process, inspection and release, not merely as coexistence of digital files.

References

1. International Organization for Standardization, International Electrotechnical Commission, Institute of Electrical and Electronics Engineers. ISO/IEC/IEEE 15288:2023 Systems and software engineering — System life cycle processes. 2023.
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3. International Organization for Standardization and ASTM International. ISO/ASTM 52920:2023 Additive manufacturing — Qualification principles — Requirements for industrial additive manufacturing processes and production sites. 2023.

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