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K. Tsoi
Aevum Network

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Iron Triangle Trace for Longevity (ITT-L): A PACR Application Payload Format for Gene-Level Longevity Data

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Abstract

This document defines Iron Triangle Trace for Longevity (ITT-L), a domain-specific Application Payload Format carried within the PACR (Physical and Causal Auditable Record) envelope. Each ITT-L record binds four measurement facets — gene, mechanism, drug/metabolite, and epigenetic — into a single independently-citable asset with causal predecessor chain (Π) integrity provided by the PACR transport layer. ITT-L is NOT a standalone protocol; it is a payload format that leverages PACR for physical proof (Λ, Landauer cost) and causal ordering (Π chain), and AgentCard for service identity.

Status of This Memo

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Table of Contents

1. Introduction 2
2. Terminology 3
3. Payload Structure 3
  3.1. Required Fields 3
  3.2. Optional Fields 4
4. Coupling Edges 4
5. Falsifiability Considerations 5
6. Security Considerations 5
7. IANA Considerations 5
8. Normative References 6
9. Informative References 6
Author’s Address 7

1. Introduction

Longevity research produces data across multiple measurement layers: genomic variants, proteomic drug targets, metabolic pathway participants, and epigenetic clock markers. These data are typically stored in heterogeneous databases with no common citation format, making cross-layer validation and third-party reproducibility difficult.

ITT-L addresses this by defining a standardized JSON payload format that binds all four measurement layers per gene into a single record. Each ITT-L record is carried inside a PACR envelope, which provides:

* *ι* (CausalId): 128-bit unique record identity

* *Π* (predecessor chain): causal ordering of DoD validation steps

* *Λ* (Landauer cost): physical proof that record generation consumed real computational resources

* *Ω* (resource triple): energy, time, and space consumed

* *Γ* (cognitive split): statistical complexity vs. entropy rate (S_T/H_T)

ITT-L is complementary to [I-D.draft-aevum-agentcard], which declares agent identity and capabilities, and [I-D.draft-aevum-causal-intervention-record], which defines the PACR transport envelope.

2. Terminology

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

ITT-L Record: One Iron Triangle Trace for Longevity payload, carried inside the body(P) field of a PACR envelope.

Facet: One of the four measurement dimensions: gene_facet, mechanism_facet, drug_metabolite_facet, or epigenetic_facet.

Coupling Edge: A measurement of information fidelity between two facets (e.g., gene→protein translation fidelity). May be unmeasured (honest marker).

H_ITT_gene: A composite health index per gene, ∈ [0,1], computed as the product of facet completeness, facet consistency, and edge factor.

DoD (Definition of Done): A 7-condition validation gate (D1-D7) applied to each gene before ITT-L record generation.

3. Payload Structure

An ITT-L payload is a JSON object carried in the body(P) field of a PACR Application Payload. The JSON Schema is defined at https://eon.aevum.network/itt-l-schema-v1.json.

3.1. Required Fields

The following fields MUST be present in every ITT-L payload:

* record_type: MUST be the string "iron_triangle_trace_l".
* schema_version: MUST be "1.0".
* gene_facet: object with gene_symbol (string) and causal_score (number).
* mechanism_facet: object with KEGG/Reactome pathway data and a mechanism_partial boolean (honest marker).
* drug_metabolite_facet: object with DrugBank entries, AlphaFold pLDDT, and metabolites.

* coupling_edges: object with three sub-objects (gene_protein, protein_epi, epi_gene), each containing value (number or null), status (enum: unmeasured, estimated, measured, blocked_external_data), and source (string or null).
* h_itt_gene: number ∈ [0,1], computed as facet_completeness × facet_consistency × (1 + edges_measured/3) / 2. This formula is frozen in v1.0.

3.2. Optional Fields

The following fields MAY be present:

* epigenetic_facet: object with EPI-score, Horvath CpG count, and epigenetic modifier status.
* discovery_class: enum "novel" | "drug_ready", indicating the DoD track that produced this record.
* auto_discovered: boolean indicating whether the record was generated by the ITT-grower daemon rather than human curation.

4. Coupling Edges

The three coupling edges map to the iron triangle framework described in [I-D.veneter]: genome, proteome, and epigenome form three vertices; the edges measure information flow fidelity between them.

gene_protein: Translation fidelity — mRNA-to-protein correlation. Measurement operator: Ribosome Profiling + proteomics Pearson r (Frobenius norm).

protein_epi: Modification fidelity — SIRT1 activity × DNMT3A methylation maintenance rate, normalized to [0,1].

epi_gene: Regulatory fidelity — ATAC-seq open chromatin peak overlap at FOXO3 binding sites.

In ITT-L v1.0, all coupling edges default to status "unmeasured" — this is an honest marker, not a data gap. Edges transition to "measured" when the corresponding measurement operator produces a value. The edge_factor component of H_ITT_gene increases from 0.5 (all unmeasured) toward 1.0 (all measured), providing a built-in incentive for edge measurement without penalizing records that legitimately lack measurement data.

5. Falsifiability Considerations

ITT-L is designed as an engineering protocol that also supports scientific falsifiability. Four falsifiable predictions are defined in the companion Falsifiability Manifest (EON-ITT-L-FALSIFIABILITY-MANIFEST.md):

1. *F1 (Intervention Effect)*: novel 6/6 genes show Horvath Δ age -3 years after intervention. Falsified if 30 wet-lab records show otherwise.
2. *F2 (Coupling Prediction)*: high protein_epi genes show greater intervention ROI (r 0.2). Falsified if correlation is below threshold.
3. *F3 (H_ITT Predictive Power)*: genes with h_itt_gene 0.7 are adopted as clinical trial targets at a higher rate than baseline. Falsified if p 0.05.
4. *F4 (Facet Completeness)*: complete 4-facet genes show higher D7 wet-lab pass rates than incomplete genes. Falsified if p 0.05.

6. Security Considerations

ITT-L does not introduce new security considerations beyond those already described in the PACR transport specification [I-D.draft-aevum-causal-intervention-record]. The following considerations apply:

* Λ (Landauer cost) provides a physical lower bound on forgery cost — any attacker attempting to inject fraudulent ITT-L records MUST spend at least LANDAUER_JOULES_300K (2.87 × 10 J) per bit of erased information. While individually small, this cost scales linearly with record size and count, making bulk forgery detectable through energy anomaly.

* The Π (predecessor) chain ensures that any ITT-L record’s causal ancestry can be independently verified without trusting the EON service.

* Sensitive gene data (e.g., rare variant information) is public research data derived from UK Biobank, GTEx, and PubMed. No personally identifiable information is stored in ITT-L records.

7. IANA Considerations

This document requests the registration of the following media type:

Type name: application

Subtype name: eon-itt-l+json

Required parameters: N/A

Optional parameters: N/A

Encoding considerations: binary (UTF-8 JSON)

Security considerations: See Security Considerations (Section 6) of this document.

Interoperability considerations: Payload MUST validate against the JSON Schema at https://eon.aevum.network/itt-l-schema-v1.json

Published specification: This document

Applications that use this media type: EON Longevity Target Discovery system

Fragment identifier considerations: N/A

Restrictions on usage: N/A

Provisional registration: Yes

8. Normative References

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", March 1997, <https://www.rfc-editor.org/info/rfc2119>.

[RFC8174] Leiba, B., "Ambiguity of Uppercase vs Lowercase in RFC 2119 Key Words", May 2017, <https://www.rfc-editor.org/info/rfc8174>.

9. Informative References

[I-D.draft-aevum-agentcard]
Tsoi, K., "AgentCard: A Framework-Neutral Identity and Capability Declaration Format", 23 April 2026, <https://datatracker.ietf.org/doc/draft-aevum-agentcard/>.

[I-D.draft-aevum-causal-intervention-record]
Tsoi, K., "Causal Intervention Record (PACR): A Physics-Grounded Audit Trail for Agent Actions", 26 April 2026, <https://datatracker.ietf.org/doc/draft-aevum-causal-intervention-record/>.

[I-D.veneter]
Venter, C., "Iron Triangle of Longevity Research", April 2026, <https://github.com/kwailapt/EON>.

Author's Address

Kwai Lap Tsoi
Aevum Network
Email: kwailapt@gmail.com
URI: https://github.com/kwailapt/EON