Title: Executable Architectures: Integrating Ontology, SysML v2, DEVS, and Agentic AI to Realize the Digital Thread

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Abstract:

The Department of Defense has embraced digital engineering as a foundational discipline, yet the long-promised "digital thread" remains fragmented and largely aspirational. Requirements, architectures, models, and verification artifacts are still exchanged through documents, spreadsheets, and manual reconciliation rather than through formal semantics and machine-verifiable relationships. As a result, Modeling & Simulation (M&S) continues to function primarily as a downstream analysis activity instead of the authoritative, executable representation of the architecture itself. This paper presents an end-to-end methodology that elevates M&S into the execution engine of the digital thread by unifying formal ontology, SysML v2 architecture, mathematically closed DEVS simulation, and agentic AI acceleration within a single traceable engineering pipeline.

The methodology begins with an operational ontology that establishes authoritative mission semantics through formally defined classes such as Mission, Capability, Resource, Function, Behavior, Requirement, and Verification, along with the relationships governing their transformation. This ontology becomes the semantic anchor for a SysML v2 model of record, leveraging SysML v2's textual syntax, KerML foundation, and improved semantic consistency to preserve traceability and analytical integrity beyond what traditional SysML v1 workflows have historically achieved.

The SysML v2 architecture is then transformed directly into a coupled Discrete Event System Specification (DEVS) simulation environment. Each subsystem becomes an atomic model with formally defined input/output sets, transition functions, output functions, and time-advance behaviors. Because DEVS is mathematically closed under coupling, federated execution remains within a single formalism, avoiding brittle integrations across heterogeneous tools. A federation data spine continuously returns execution evidence, performance metrics, and verification artifacts back into the architecture layer, creating a

closed-loop verification and validation process with bidirectional traceability from mission need to executable evidence.

Agentic AI is integrated throughout the workflow as an accelerator, not a replacement, for engineering rigor. AI agents assist in decomposing operational problems, proposing ontology structures, identifying cross-domain dependencies, surfacing integration risks, and orchestrating transformations between ontology, architecture, and simulation layers. All AI-generated artifacts remain source traceable and subject to human review, ensuring credentialed engineers retain authority over validated mission truth.

The methodology is demonstrated through a notional collective defense scenario spanning cyber, space, air, maritime, and land domains across the phases of plan, prepare, execute, and analyze. Threat behaviors are modeled using Markov processes; cyber and electronic warfare effects dynamically degrade data-link performance; and PNT resilience is assessed across correlated space and terrestrial assets. The complete pipeline, from plain-language doctrine through ontology generation, SysML v2 architecture, executable DEVS federation, and verification artifact creation, was executed within a single working day, producing hundreds of traceable verification artifacts across the operational and engineering stack.

The presentation details the ontology schema, SysML v2-to-DEVS transformation methodology, federation data spine architecture, and human-in-the-loop governance model for agentic AI, while addressing scalability, mission engineering alignment, and integration with existing LVC and HLA ecosystems.