Activating the Digital Thread: AI-Driven Automation of the Bill of Process

GLOBAL PRODUCT DATA

INTEROPERABILITY

SUMMIT 2025

BOEING ELYSIUM LOCKHEED MARTIN NORTHROP GRUMMAN Parker PDES, Inc.® Connecting the Digital Enterprise

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Chief Information and Digital Office
Northrop Grumman

Presenters Bio

Sr. Principal Software Developer Analyst
Northrop Grumman

Diverse Engineering Roles

Held positions as Manufacturing and Process Engineer, Digital Manufacturing and Product Owner, providing a broad technical and process background over 15 years.

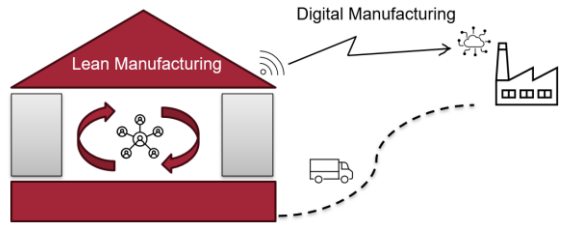
Driving Continuous Improvement

Visualizing process flows, identifying inefficiencies and optimizing processes to uncover the hidden factory.

Education:

B.S. Mechanical Engineering, University of California, Riverside

M.S. Systems Engineering, University of Connecticut



What is the Bill of Process (BOP)?

A Bill of Process (BOP) in manufacturing planning is a detailed document that outlines the specific steps, procedures, and operations required to manufacture a product.

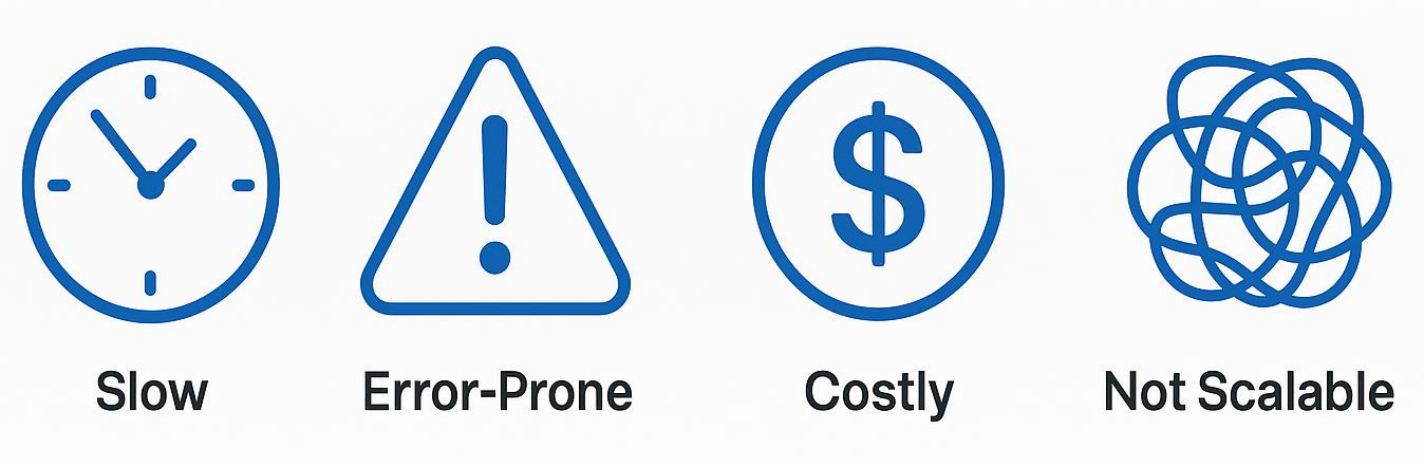
It provides a comprehensive roadmap of the entire production process, ensuring consistency, efficiency, and quality control.

Other terms for BOP:

- Manufacturing Planning
- Routing Sheet
- Work Instructions

The Recipe for Building Products

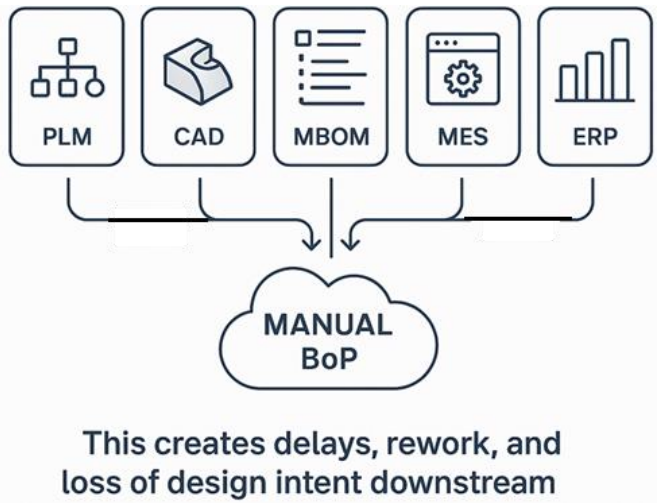
Why Manual Planning Hurts



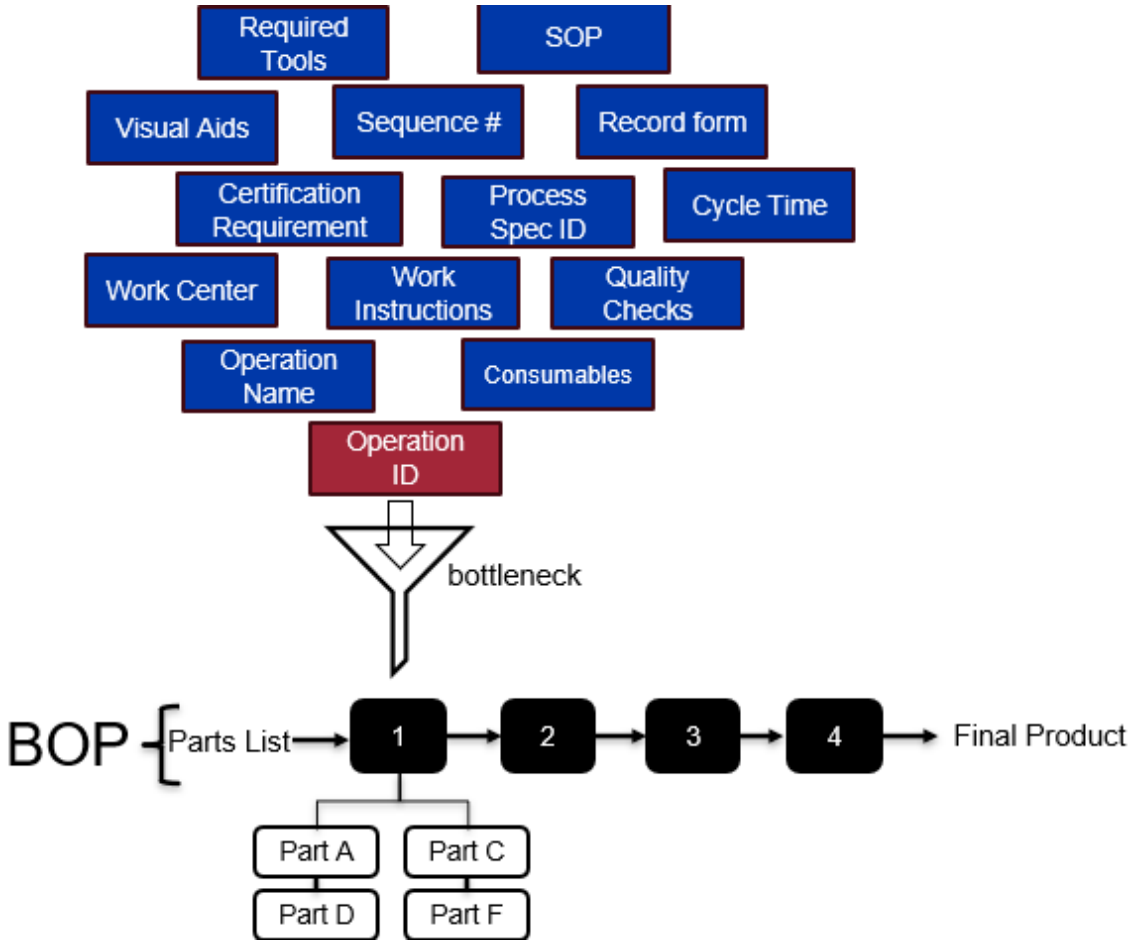
- **Slow** → Days to weeks
- **Error-Prone** → Human mistakes
- **Costly** → Rework & downtime
- **Not Scalable** → Thousands of parts overwhelm

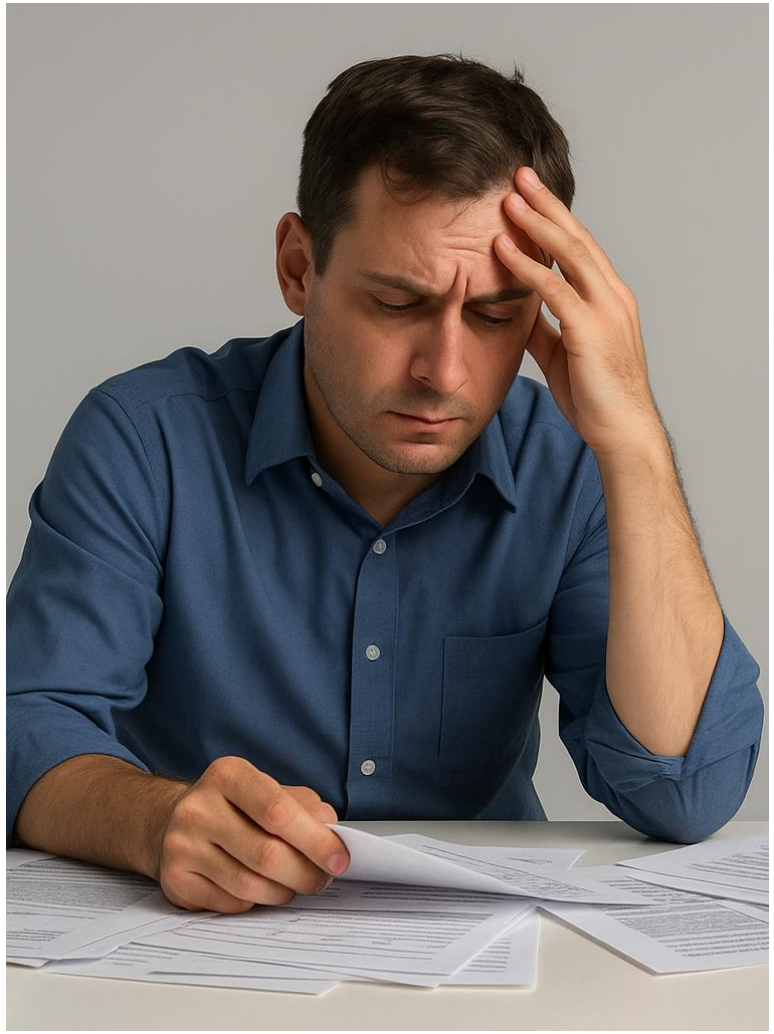
How Factories Plan Today

1. Check parts list
2. Study design drawings
3. Check factory resources
4. Write steps manually
5. Double-check for compliance
6. Enter into systems



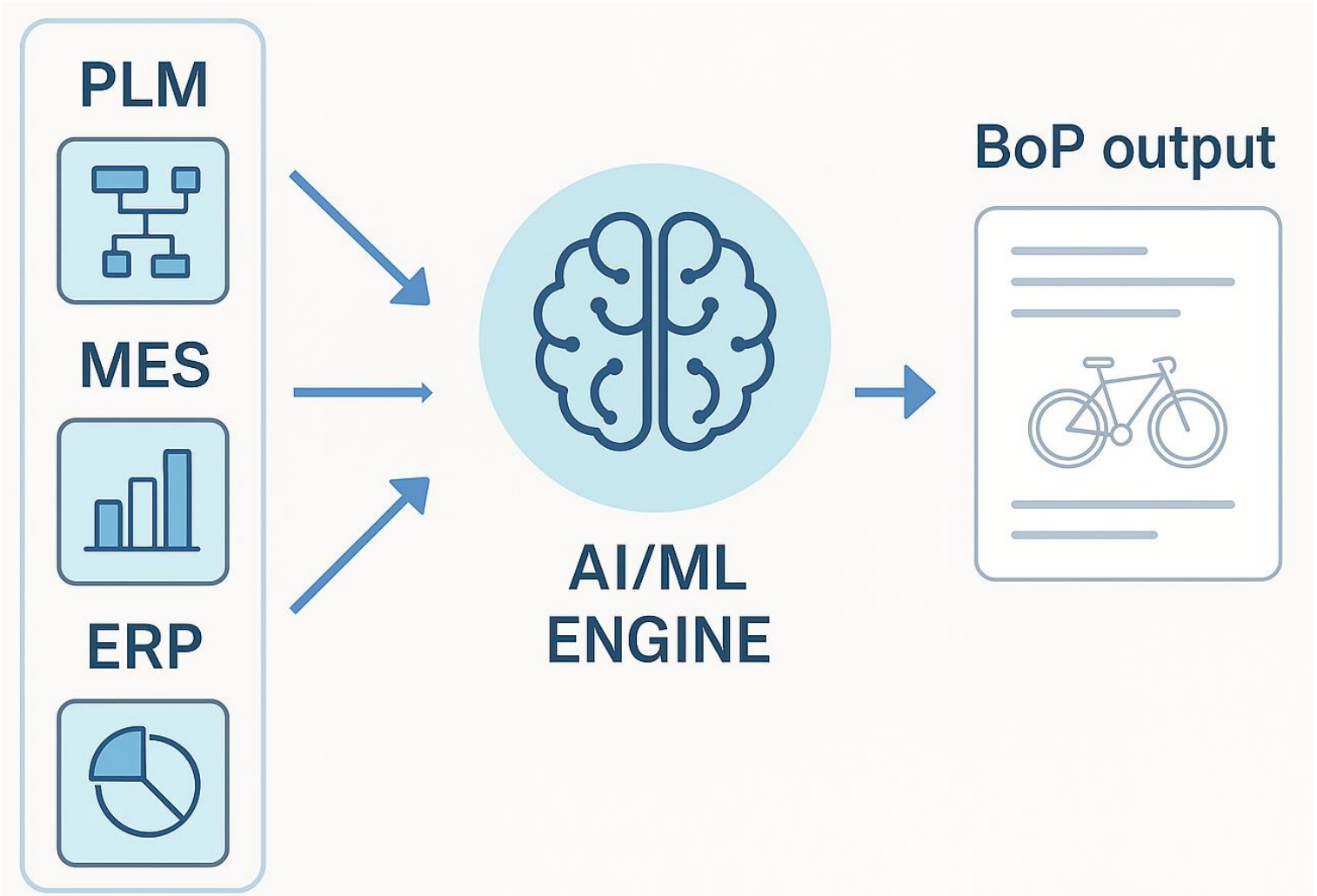
The Bottleneck in Manufacturing: “Enter into systems”



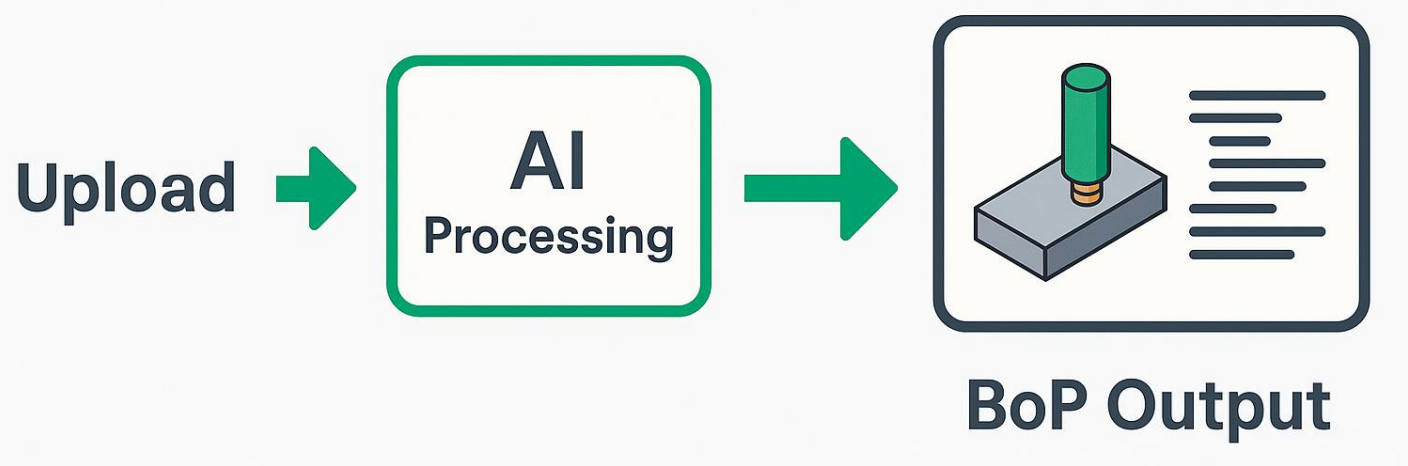


A Smarter Way to Plan

- Connects data (parts, 3D, factory)
- Interprets meaning (semantic AI)
- Generates steps automatically
- Presents plans visually for review



From Upload to Automated BoP



1. Upload parts list
2. Auto-collect design & factory data
3. AI generates steps (e.g., drill, fasten)
4. Verify with 3D visualization
5. Review & save

Manual vs. AI-Driven BOP Creation

Aspect	Manual	AI-Driven
Time	Days to weeks	Minutes to hours
Errors	Medium-High (based on experience)	Low (AI checks)
Cost	High (reworks delays)	Low (faster, fewer mistakes)
Ease of Use	Tedious typing, file juggling	Simple upload & visual review
Scalability	Struggles with complex products, limited	Handles thousands of parts

Connected Data Makes It Work

Dynamic Digital Thread

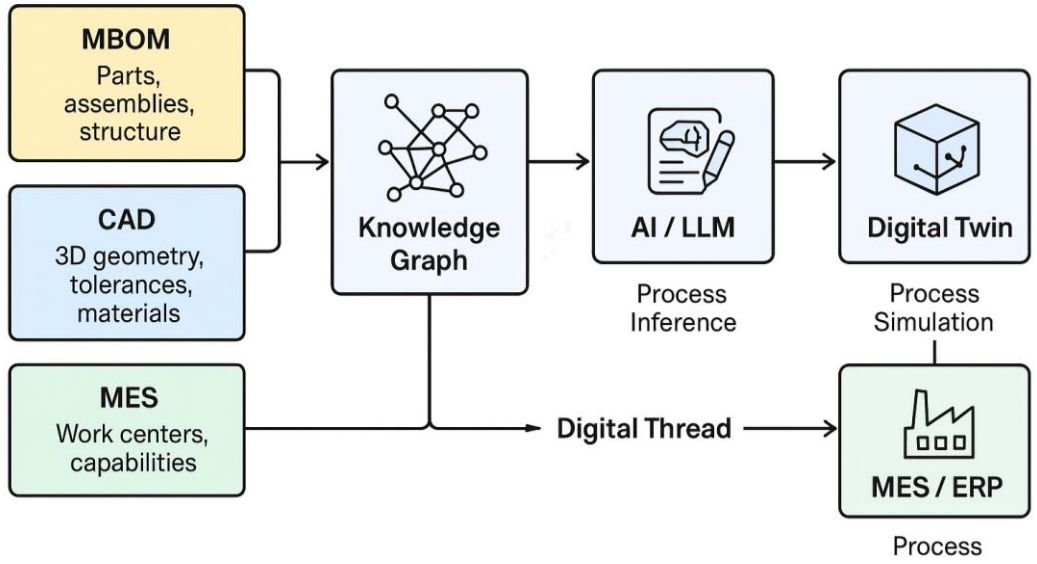
Embedding AI in the Bill of Process transforms static documents into dynamic, intelligent data elements connecting the entire manufacturing workflow.

Intelligent Automation

AI-powered automation analyzes patterns and interprets engineering data, allowing for smarter, adaptive decision-making in manufacturing operations.

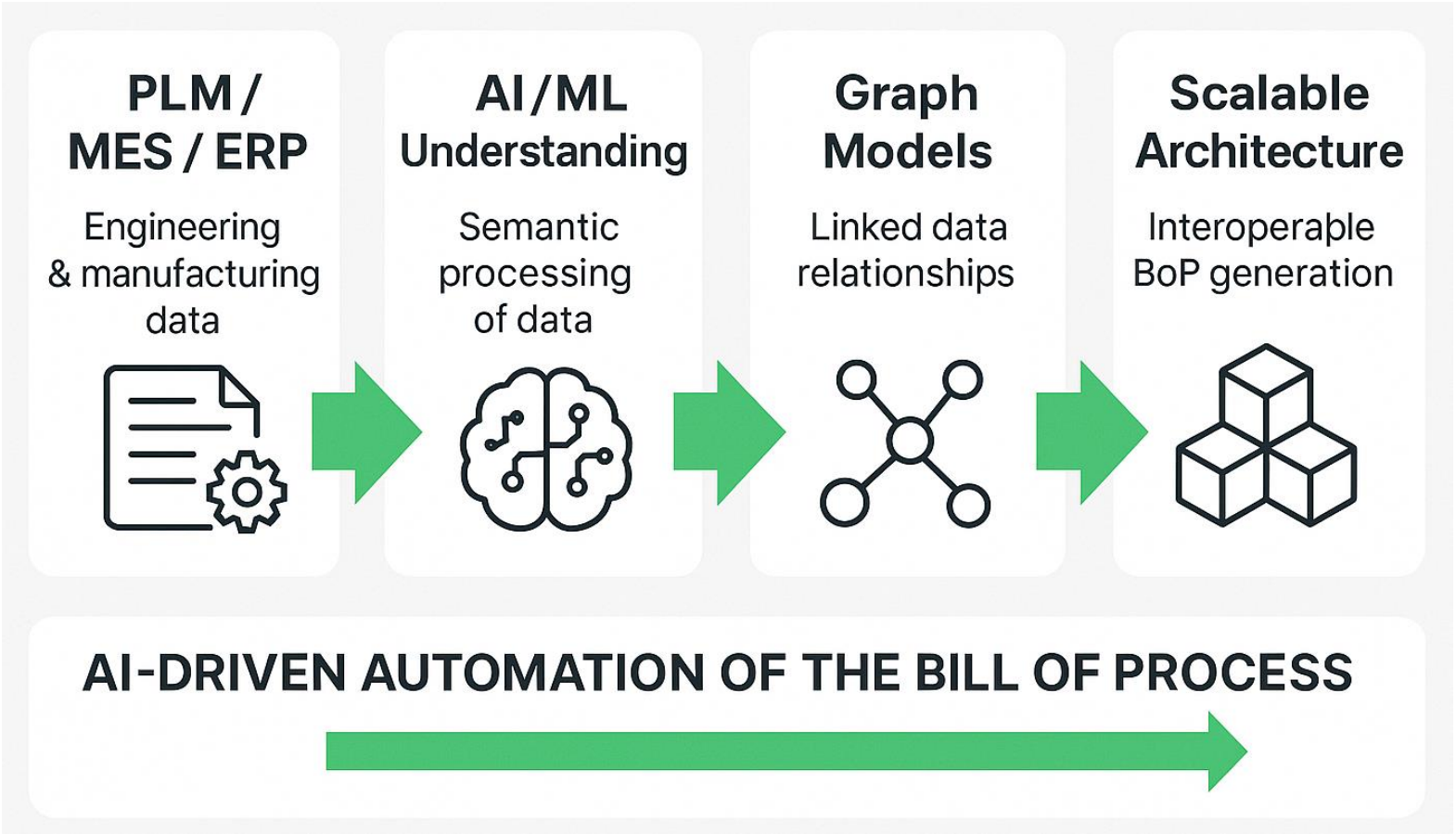
Autonomous Plan Generation

AI can autonomously generate and update manufacturing plans, adapting to complexity beyond the limits of traditional methods.

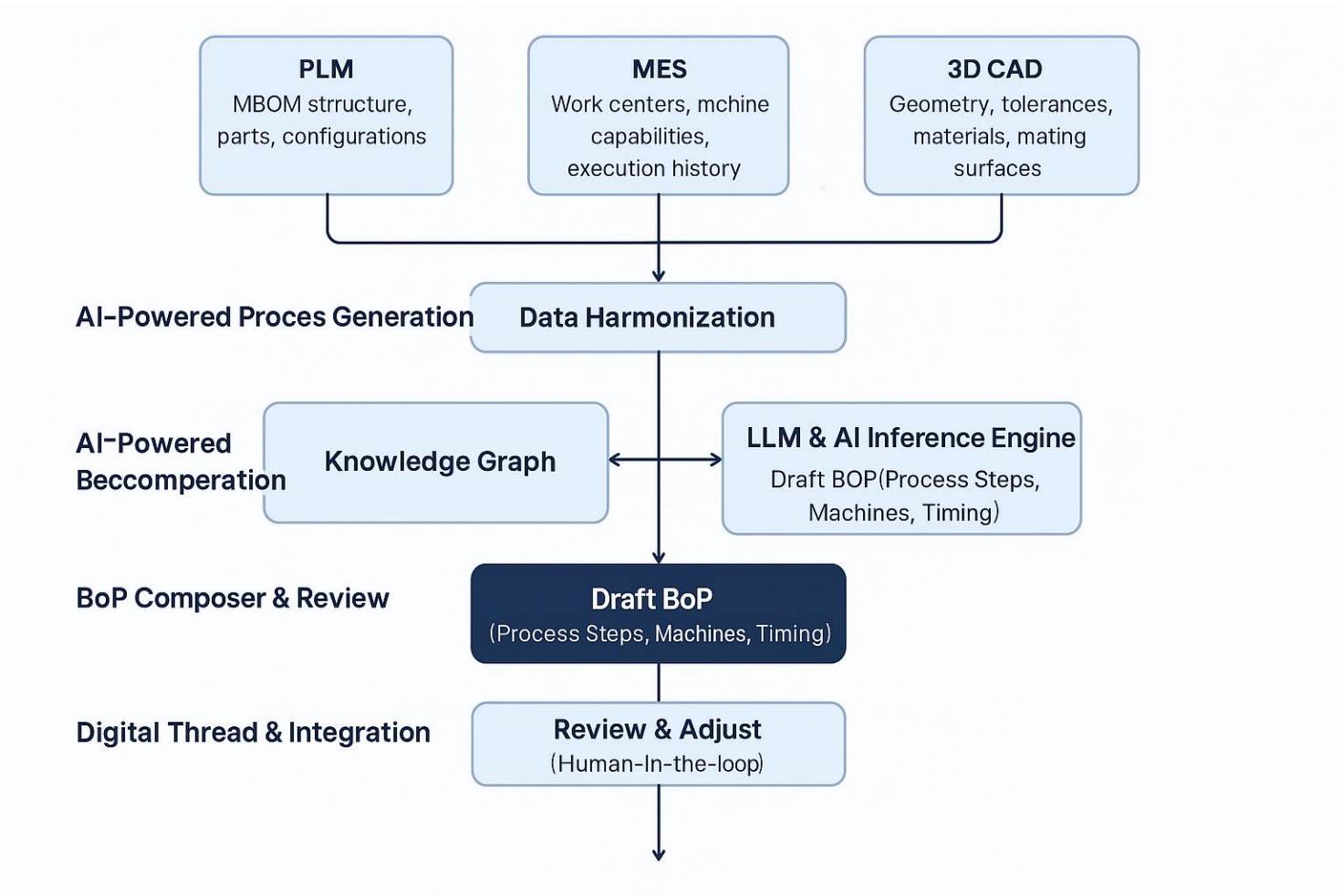


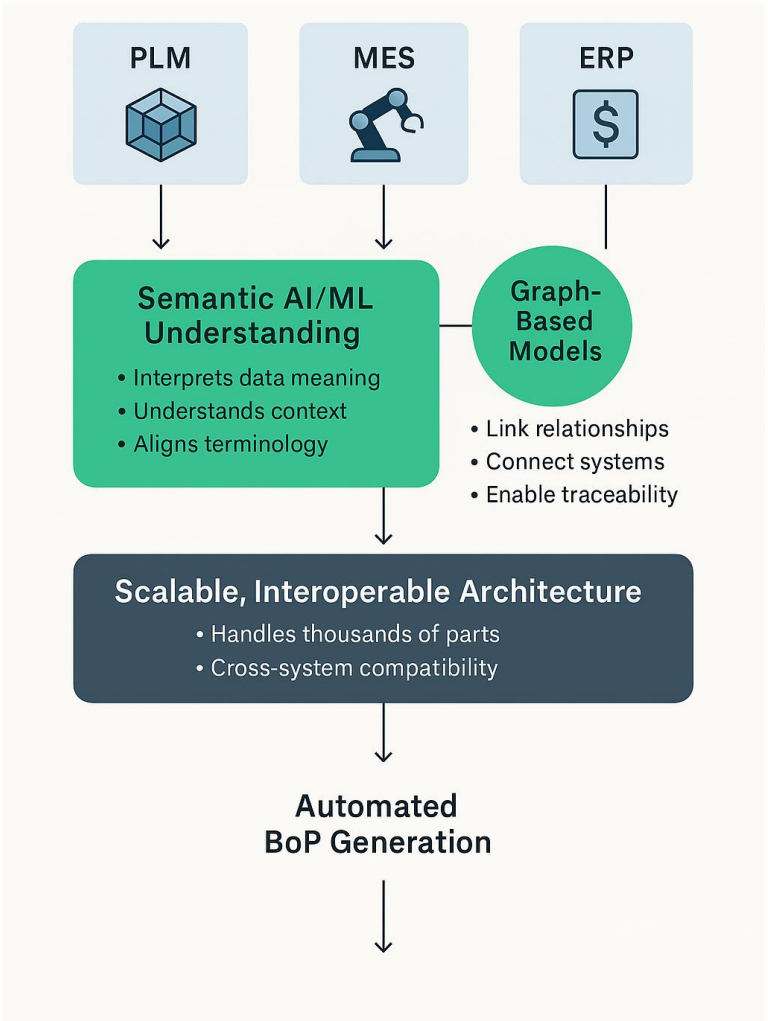
The Technical Foundation

- **Semantic AI/ML**
  - Interprets data meaning
  - Understands context
  - Aligns terminology
- **Graph-Based Models**
  - Link relationships
  - Connect systems
  - Enable traceability
- **Scalable Architecture**
  - Handles thousands of parts
  - Ensures interoperability

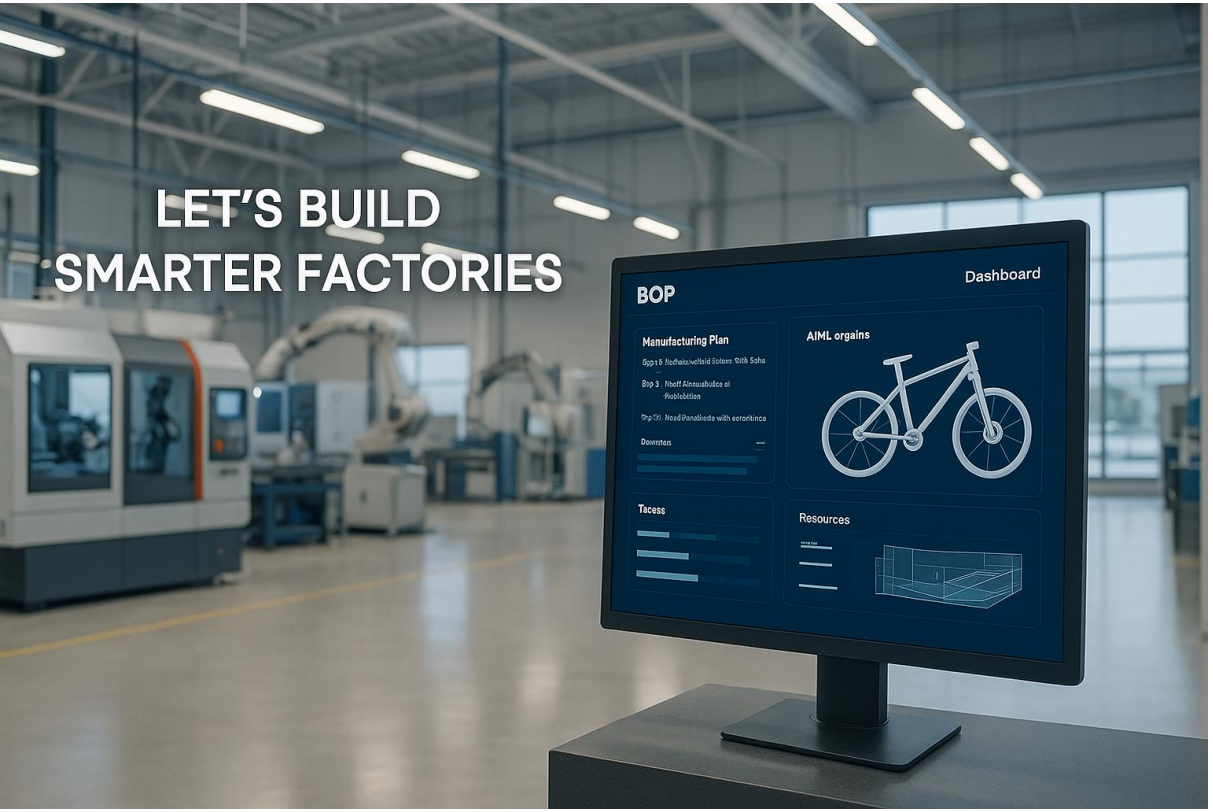


How it Works: High-Level View





A Game-Changer for Manufacturing



Faster Product Launches

- Automation in the BOP enables organizations to introduce new products quickly, significantly reducing time-to-market

Improved Quality and Efficiency

- Automation reduces human errors and minimizes rework, resulting in enhanced product quality and increased operational efficiency.

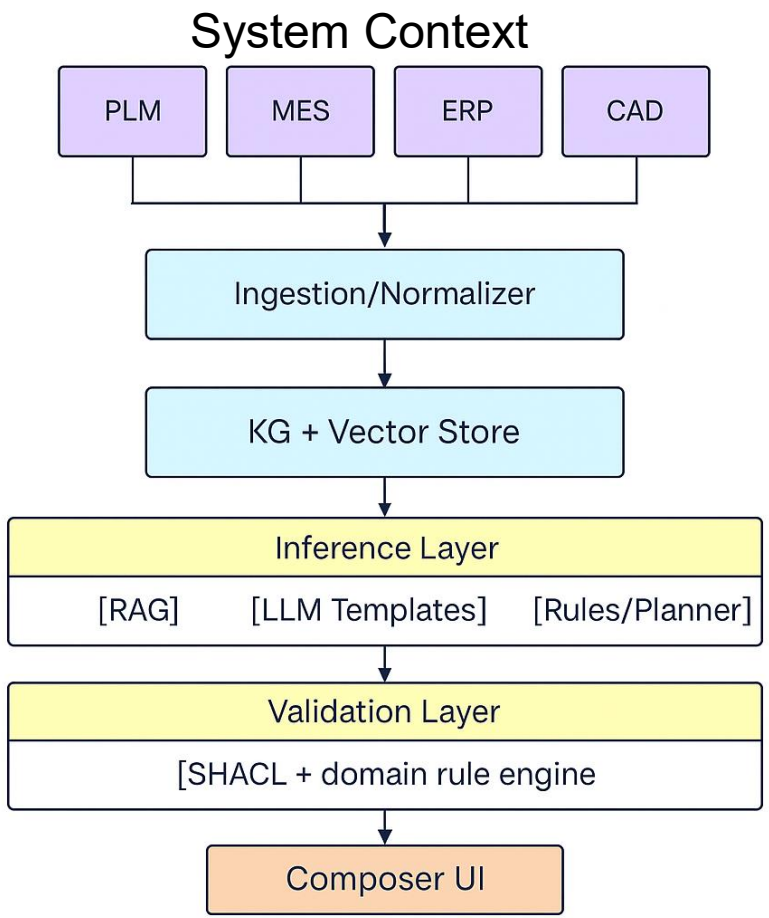
Enhanced Productivity and Cost Savings

- Automation brings better change management, standardized processes, and higher productivity, leading to lower operational costs.

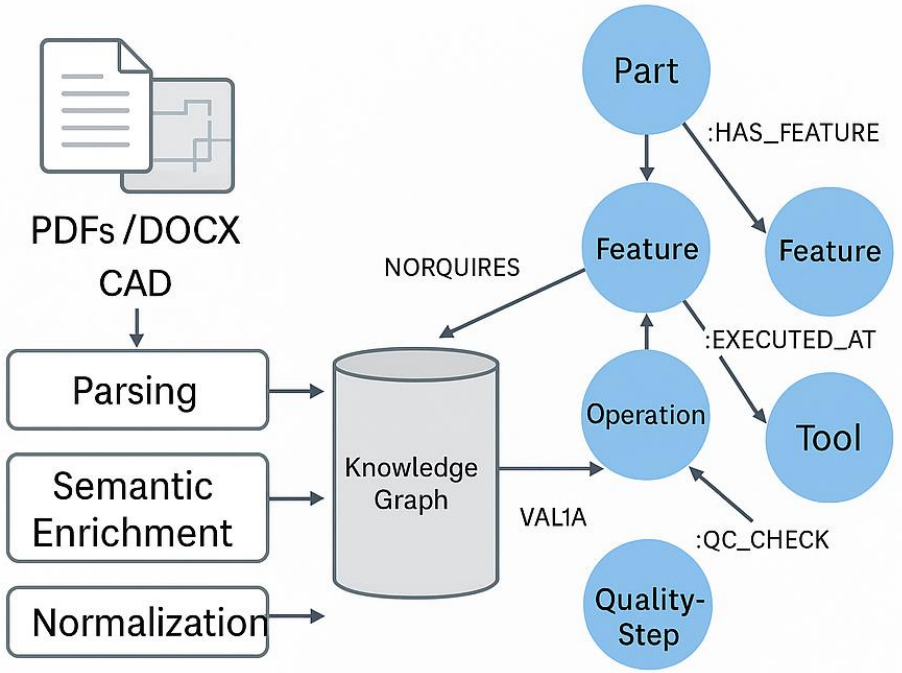
Questions?

Thank you for attending the presentation!

System Architecture for BoP Generation



From Documents & CAD to a Constrained Knowledge Graph



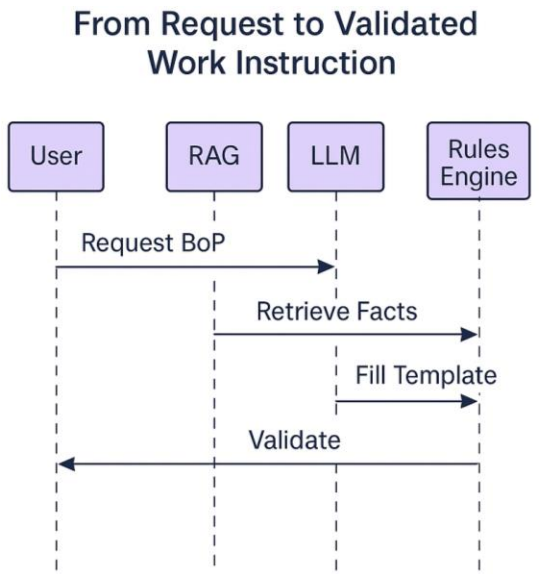
Ontology Rules

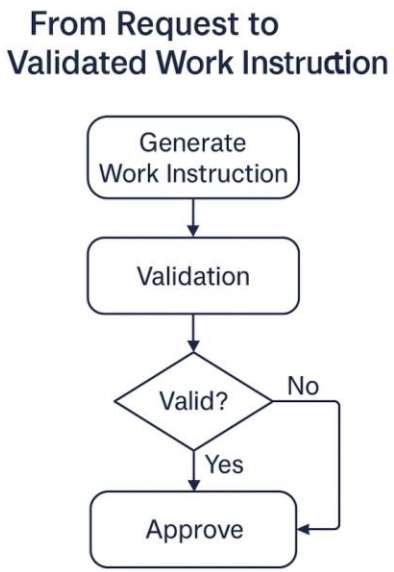
- Every operation must
- Reference a work center
- And a quality step

Unstructured inputs are parsed, semantically enriched, normalized, and validated before being stored in a structured Knowledge Graph. Ontology rules ensure every entity is consistent and complete.

"Enterprise systems feed into the ingestion pipeline and Knowledge Graph. Retrieval, LLM templates, and rules generate BoPs, validated against domain rules, then exported back into PLM/MES."

From Request to Validated Work Instruction





Guardrail Templates

Use deterministic templates the LLM completes only with retrieved facts

Operation: {op_no} {verb} {part/feature}

Tools/Fixtures: {tools} Torque: {value}{unit) (Spec: {spec_id}/clause)

Materials/Consumables: {material_id} Qty: {qty}/uom} Lot: {trace_req}

Method: (method steps referencing spec clause IDs)

Quality Check: {gauge/method} Acceptance: (tolerance) Sample size: (AQL)

Safety/ESD: (requirements

Validate against spec and system checks

Structured Templates Ensure Compliance

"LLMs can only populate predefined fields — such as tools, torque, and QC steps — each backed by citations to source specs. This guarantees compliance and auditability."