



Collaboration
Synergies Inc.

Evolving from Manual Data Collection To Digital Thread and AI

A concise, manufacturing-centric historical outline that traces how information systems evolved from basic data capture to today's **Digital Thread and AI paradigms**

The emphasis is *why* each layer emerged, *what information it managed*, and *how it changed manufacturing decision -making*.

1. Pre-Computer & Early Computer Era (1950s–1960s)

Manual Data Gathering & Accounting Systems

Primary focus: Cost control and inventory accounting

- Paper travelers, route cards, time clocks, and manual inspection logs
- Batch reporting; data was historical and lagging
- Early mainframes used for payroll and inventory valuation

Key characteristics

- Information captured *after the fact*
- No operational feedback loop
- Manufacturing knowledge resided in people, not systems

Impact

- Enabled basic financial control
 - Little influence on shop-floor execution or engineering decisions
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2. MRP Era (1970s)

Material Requirements Planning

Primary focus: Planning material availability from demand

- Explosion of Bills of Material (BOMs)
- Time-phased planning (lead times, lot sizes)
- Driven by forecasts and MPS (Master Production Schedule)

Systems

- Standalone MRP systems on mainframes

Limitations

- Assumed infinite capacity
- No real-time feedback from manufacturing
- Engineering changes were slow to propagate

Impact

- First structured linkage between product structure and manufacturing supply

- Data still siloed and plan-centric
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3. MRP II Era (1980s)

Manufacturing Resource Planning

Primary focus: Synchronizing materials, capacity, and cost

- Added capacity planning, shop-floor control, and costing
- Introduced “closed-loop” planning (feedback to plans)

Systems

- MRP II suites integrating planning and execution data

Limitations

- Still batch-oriented
- Weak engineering integration
- Manufacturing data primarily summarized, not contextual

Impact

- Manufacturing recognized as a system, not a department
 - First operational feedback loops
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4. ERP Era (1990s)

Enterprise Resource Planning

Primary focus: Enterprise-wide transaction integration

- Unified finance, HR, procurement, inventory, manufacturing
- Standardized data models and processes

Systems

- SAP, Oracle, Baan, JD Edwards

Limitations

- Manufacturing execution abstracted into transactions
- Poor representation of product intent and process detail
- Engineering and manufacturing largely decoupled

Impact

- Financial and supply-chain visibility improved
- Manufacturing became a transactional node, not a knowledge source

5. PLM & Engineering Data Management (1990s–2000s)

Product Lifecycle Management

Primary focus: Managing product definition and change

- CAD, PDM, configuration management
- Engineering BOM (EBOM) ownership
- Formal change control (ECOs)

Systems

- Dassault ENOVIA, Siemens Teamcenter, PTC Windchill

Limitations

- Weak manufacturing process context
- Limited operational feedback
- Manufacturing BOM (MBOM) often disconnected

Impact

- Digital authority for product definition
- Engineering rigor improved, but downstream visibility limited

6. MES & MOM Era (2000s–2010s)

Manufacturing Execution & Operations Management

Primary focus: Real-time execution and control

- Work instructions, dispatching, quality, genealogy
- Traceability and compliance
- Connection to automation (PLC, SCADA)

Systems

- MES, MOM platforms

Limitations

- Often isolated from PLM and ERP
- Contextual data trapped at plant level

- Limited lifecycle continuity

Impact

- Manufacturing becomes data-rich
 - Shop-floor knowledge digitized but not fully leveraged
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7. IIoT & Analytics Era (2010s)

Connected Assets & Advanced Analytics

Primary focus: Machine-level data and performance insight

- Sensor data, condition monitoring, OEE
- Time-series data at scale
- Cloud platforms emerge

Systems

- IIoT platforms, data lakes

Limitations

- Data volume without product context
- Difficult to relate asset behavior to product design or requirements

Impact

- Shift from descriptive to predictive analytics
 - Highlighted the need for contextual integration
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8. Digital Thread Era (Late 2010s–Present)

End-to-End Product & Manufacturing Continuity

Primary focus: Lifecycle coherence and decision traceability

- Persistent digital linkage from:
 - Requirements → Design → Manufacturing → Operation → Service
- Bi-directional information flow
- Context preserved across domains

Key Concepts

- Authoritative data sources by domain
- Semantic models and digital twins
- Closed-loop learning (design informed by manufacturing and field data)

Systems Involved

- PLM, MES/MOM, ERP, IIoT, analytics platforms
- Integration via APIs, event streams, and data models

Impact

- Manufacturing becomes a knowledge generator
- Decisions are traceable, explainable, and improvable
- Foundation for AI-driven engineering and operations

Summary View (Conceptual Progression)

Era	Primary Question Answered
Manual	“What happened?”
MRP	“What should we buy?”
MRP II	“Can we make it?”
ERP	“What did it cost?”
PLM	“What is the product?”
MES	“How is it being built?”
IIoT	“How is it performing?”
Digital Thread	“Why did this happen—and how do we improve it?”

Key Insight

The **Digital Thread is not a single system**. It is the culmination of decades of incremental information capture, progressively shifting manufacturing from *transactional reporting* to *contextual, lifecycle intelligence over the life of a product*.

Michael McClellan