Innovation Insight for the Digital Thread

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Initiatives: Manufacturing Digital Transformation and Innovation

Manufacturers of complex, highly configured products with long service lives such as aircraft and other large machinery must have quick access to critical data for service life cycle support. CIOs must work together with supply chain leaders to implement digital threads for this need.

Overview

Key Findings

- Rising complexity across products and value networks requires improved connectivity and traceability of data to lessen risk and accelerate innovation without compromising product integrity.

- The digital thread links data from various sources across value chains in a manner that improves ability to understand the evolution of products, manufacturing choices and product service choices.

- Although digital threads save time and money and improve business continuity, the investment and effort to maintain and upgrade them will be significant.

- Organizational, data compatibility and data connectivity issues create challenges for manufacturers to create and maintain a digital thread.

Recommendations

CIOs responsible for manufacturing digital transformation and innovation, and seeking to reap the potential of a digital thread, should:

- Focus on building the digital thread as a framework to connect and synchronize product and process data and information across all product life cycle activities by engaging supply chain stakeholders to map data flows.

- Create a data governance strategy for a digital thread across your entire value network by planning for data oversight, data orchestration, data curation and data management.

- Cultivate the long-term viability of digital threads, and limit your dependence on software vendors by defining guidelines for adopting standards for data whenever possible.
Introduction

Growing volumes of structured, unstructured and fragmented data and information from engineering, manufacturing, supply chain, service and aftermarket call for new methods to access and use them to optimize performance. The digital thread offers an organizing framework to help manage the necessary structured and unstructured datasets, and to improve how decisions are made over the life cycle of a product and the lifetime of production and service environments.

Description

A digital thread is a framework that enables the connection, organization and presentation of data for multiple factors influencing a product and/or process, and their evolutions over the life cycle of the products and data.

This linking of data and information by digital threads allows many users to access, integrate, organize, trace and transform product- and manufacturing-related content from multiple operational- and enterprise-level systems.

A digital thread spans design, manufacturing, supply chain, product service and aftermarket by linking the evolution of product requirements from design through production and then delivery and service to ensure that a compliant and quality product is delivered to the customer.

Figure 1 shows digital threads that span all activities that influence products throughout their life cycles.
As Figure 1 shows, digital threads capture the relationships among the data belonging to categories of content such as:

- Product requirements
- Design revisions
- Transformations of designs to manufactured products
- Modifications of products through service life
- Evolution of products to next-generation products
- Sharing design content across different products

The related content can include bills of material (BOMs), requirements, specifications and design content (drawings, documents, computer-aided design [CAD models], simulation models, simulation results, production histories, audits and certifications, and other streams of data in disparate systems and databases). The relationships do not need to include all of this content; they include the content that the business needs through the product life.
For example, digital threads used for maintenance of jet engines on aircraft do not necessarily need to capture content strictly associated with the entertainment systems. Yet, digital threads should be open and extensible so new categories of data can be added as business circumstances change. If there are changes made to products and subsystems, the digital thread should record information such as:

- When changes to products or processes were made
- The reason for the switch
- The nature of the change
- Certification of the change
- The roles and people involved

It is important that these categories (and other information as appropriate) are not just added. They need to be dynamically connected and possibly disconnected from other digital thread content as a use case requires.

Although the concept of a digital thread is more familiar to producers of complex and highly engineered products, it has broader potential across supply chains and value networks in multiple industries. Those could include high-volume manufacturing such as consumer electronics, personal care products and home appliances.

The traceability inherent to digital threads makes compliance more manageable for regulated products produced in high-volume such as food and beverages, pharmaceuticals, cosmetics, consumer electronics and home appliances. For example, visibility to original product specifications and manufacturing operations provides insight into what types of product changes are allowable and how those changes might influence cost, quality and regulatory compliance.

> The digital thread is often confused with a digital twin. Digital twins require digital threads.

**Benefits and Uses**

Digital threads improve the efficiency of decision making, cost, quality, traceability and regulatory compliance. For example, cost and quality are associated with both product design and manufacturing. Therefore, insights to changes in cost and quality metrics can be gleaned by understanding changes to product designs and configurations through digital threads.

In one instance, a producer of heavily engineered- and configured-to-order products reduced the labor hours for its material review board (MRB) by 30% by using the concept of a digital thread. The digital thread improved the integration across various in-house and supplier data sources, and was supported by search to shorten the time to pinpoint specific quality issues and their root causes.
At the content level, product digital threads:

- Provide a richer understanding of how and why product and process content evolves and reaches its current state by connecting data from multiple sources. This could include requirements documents, CAD models, product manufacturing information (PMI), simulation models, recipes and inspection plans, simulation results, lab tests, revision histories (accepted and rejected), work instructions and equipment settings.

- Improve how designers and planners evolve and optimize requirements and solutions by managing the impact of product features, behaviors and functions on product performance, reliability, maintenance and service costs and customer satisfaction.

- Enhance traceability for managing the detailed convergence of multiple processes and workflows. This includes audits and inspections, orders, BOMs, specifications and label changes (including why accepted or rejected), as well as internal and supplier-facing corrective and preventive actions (CAPAs).

- Continually improve how work is executed. Digital threads can keep suppliers engaged with their partners as products and processes are concurrently improved.

- Help organizations decide on priorities when constructing digital twins. For example, using digital thread to understand root causes for quality and performance vulnerabilities as well as patterns in product repairs during service life offers insight into the critical features to include in digital twins to track, which:
  - Enables proactive maintenance and repairs
  - Reduces service life costs
  - Increases customer satisfaction

Digital threads also offer manufacturers and their value network participants longer-term potential to create greater agility spanning different supply chain and business functions, with the following benefits:

- Improving knowledge management and decision support across the life cycle of an individual product or complete family/portfolio. A comprehensive understanding of customers, orders, product versioning and market feedback can identify innovation potential for creating new products and/or enhancing existing ones. This includes potentially transforming business models and customer experiences by adding data and information-based services as part of the offering(s). This is especially important as the proliferation of connected products continues and more organizations explore (exploit) market opportunities (see Providing Amazing Customer Experiences Through Connected Products).
Mitigating regulatory compliance risks. This spans U.S. FDA/ICH requirements for regulatory filing and product registration, labeling and packaging requirements, and chain of custody, as well as their international counterparts. Digital threads also reduce the complexities of managing multiple specifications and suppliers to ease some requirements for International Traffic in Arms Regulations (ITAR) and the Food Safety Modernization Act (FSMA).

Shortening suppliers’ (and external partners’) qualification cycles for new designs, materials and specifications, especially for 3D printing (3DP) — dynamically evolving techniques, technologies and materials.

Providing a complete view of life cycle costs (connecting R&D and engineering costs, production costs, supplier qualifications, cost of procurement, COQ [including COPQ] and cost of service). This disintermediates any inconsistencies and reduces profit loss, material yields (based on scrap and rework levels), and other potential customer-facing risks as products are serviced and discarded at end of life. In turn, this helps to manage mounting portfolio complexity while optimizing cost and service trade-offs.

Improving insights and decision making by empowering the use of advanced analytics, artificial intelligence (AI) across a product’s life cycle. Using search and discovery across engineering data or pattern analysis of (supplier and in-house) production histories to identify hidden variability. Or developing algorithms that can automatically detect causes of problems and provide the necessary context that contributes to advanced problem solving and decision making in order to create the next generation of products.

**Risks**

**Intellectual Property and Cyber Risk**

The data management for a digital thread might require cloud services and setting collaboration rules with suppliers for accessing their data. That could produce three results:

- Some OEMs and brand owners may fear disintermediation from revealing both their process structures and suppliers in their value networks.
- Suppliers, customers and business partners may not want to contribute to the digital thread initiative.
- Customers or suppliers may refuse to share data that is important to the digital thread, or security measures may make it impossible for a supplier, partner or customer to share data.

**Difficulty Achieving Consensus on Architecture, Scope and Implementation**

Many different roles in manufacturing companies and value chains have a stake in digital threads, including product development organizations, manufacturing operations, service teams, procurement, suppliers and customers. Each of these roles has different priorities, different content needs and different ways of interacting with data. Satisfying each role can make the architecture complicated, fragile and expensive. Also, roles with greater political power might influence the digital threads to
service their needs but undermine other roles and other members of the value chain. Open, honest and constructive discussion about priorities and architecture are key but can be challenging to achieve.

**Vendor Lock-In**

Manufacturers that rely on few vendors to deliver large “chunks” of digital threads will likely become increasingly dependent on that vendor, particularly as the content and workflows added to a digital thread increases over time. Select categories of applications that vendors provide play foundational roles to fill out key digital thread workflows and content management, such as:

- Enterprise resource planning (ERP)
- Product life cycle management (PLM)
- Manufacturing execution systems (MES)
- Master data management (MDM)

The huge presence of only a few vendors offering broad business suggests IT homogeneity and business efficiency. However, dependency on few vendors for digital threads can undermine both contract negotiations and competitiveness. When vendors aggressively insist on price increases during contract renewals, they have the advantage of holding large amounts of customer data and workflow in their proprietary formats. Also, when customers ask for enhancements or bug fixes not high on the vendors’ priority lists, it can become increasingly difficult to get timely action.

**Technology Obsolescence**

Technologies and tools have been advancing the market to access, verify, validate and synchronize data. Technology advances over the past 10 years expand the business possibilities of digital threads. Some of these technologies include microservices, Semantic Web, service-oriented architectures, low-coding solutions, the cloud, analytics and artificial intelligence (AI) (see *Successful Manufacturing Digitalization Requires Application Modernization and Integration*).

Also there have been significant advances in several of these individual technologies since their introduction — for example, in Internet of Things (IoT) technology and standards as a digital thread enabler (see *Hype Cycle for IoT Standards and Protocols, 2020*). Industrial Internet of Things (IIoT), included on the Hype Cycle, now offers potential through edge devices and proliferation of sensors that can capture and process data from products and equipment in service. Appropriate combinations of IoT/IIoT with technologies such as application programming interfaces (APIs), low coding, graph databases, microservices and Semantic Web can replace remaining pockets of manual processes that still exist today. Technology providers already claim that Semantic Web has proven abilities to link related data across data silos in ways that would have been impossible 10 years ago. There is also an opportunity to train machine learning technology that can further connect and share relevant categories of data when users query digital threads for information.
The risk of obsolescence derives from committing to digital thread architectures and technologies that become obsolete before the intended life span of the digital thread. This is particularly true when depending on few vendors for large amounts of the digital thread and those vendors fall behind the pace of technology innovation. Also, since digital threads can connect so much data from different sources, there is a risk of incompatibility and interoperability, and issues relating to data conversion, latency and more general technology maturity.

Adoption Rate

Figure 2 summarizes digital thread adoption status or plans as of year-end 2020.

![Figure 2: Adoption of Digital Threads](image-url)

**Adoption Status or Plans for Digital Thread**

- **28%** Implementing
- **32%** In Use
- **10%** Piloting or Testing
- **9%** No Plans
- **21%** Plan to Deploy in the Next 2 Years

**n = 406 supply chain professionals, excluding don’t know**

Q. For each of the following technology areas, please indicate your organization’s adoption status or plans.

Source: 2020 Gartner Smart Manufacturing Strategy and Implementation Trends

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The Gartner Smart Manufacturing Strategy and Implementation Trends Survey reveals that, as of year-end 2020, seven in 10 companies surveyed were in some stage of piloting, implementing or using digital threads. An additional 21% had plans to deploy in the next two years.
Figure 3 displays the adoption status of digital threads by manufacturing industries.

**Adoption Status or Plans for Digital Threads by Manufacturing Industries**

<table>
<thead>
<tr>
<th>Industry</th>
<th>Piloting or Testing</th>
<th>Implementing</th>
<th>In Use</th>
<th>Plan to Deploy in the Next 2 Years</th>
<th>No Plans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Healthcare/Life Sciences (n = 74)</td>
<td>9%</td>
<td>35%</td>
<td>26%</td>
<td>18%</td>
<td>12%</td>
</tr>
<tr>
<td>High Tech (n = 73)</td>
<td>15%</td>
<td>26%</td>
<td>36%</td>
<td>18%</td>
<td>5%</td>
</tr>
<tr>
<td>Industrial - Process (n = 87)</td>
<td>14%</td>
<td>30%</td>
<td>22%</td>
<td>26%</td>
<td>8%</td>
</tr>
<tr>
<td>Industrial - Discrete (n = 88)</td>
<td>6%</td>
<td>26%</td>
<td>39%</td>
<td>20%</td>
<td>9%</td>
</tr>
<tr>
<td>Consumer Products (n = 84)</td>
<td>6%</td>
<td>24%</td>
<td>37%</td>
<td>21%</td>
<td>12%</td>
</tr>
</tbody>
</table>

Base: Excludes Don’t Know/NA

Q. For each of the following technology areas, please indicate your organization’s adoption status or plans.

Source: Gartner’s Smart Manufacturing Strategy & Implementation Trends, 2020

The pace at which the digital thread is adopted is a factor in how manufacturers can use the data to add context to decision making, manage traceability and create knowledge as products and services evolve over varying product life cycles.

Manufacturing industries such as aerospace, automotive and life sciences are strongly motivated, given stringent regulatory requirements regarding potential safety risks to customers. Adoption rates will accelerate as companies connect and extend the value of the digital thread to broader initiatives, such as technology transfer and new product introduction (NPI), complexity reduction and traceability. These initiatives can help to optimize costs and improve customer service.

The challenges and complexities of managing digital threads as described under risks may be inhibitors to adopting digital threads. When evaluating investing in the digital thread, expect improved competitiveness. Cost optimization and time savings come from shortened decision cycles and
improved agility on both global and local bases. Also, don't overlook the benefits of accelerating innovation and bringing new products to market.

Recommendations

- Focus on building the digital thread as a framework to connect and synchronize product and process data and information across engineering, manufacturing and supply chain, and to evolve the model over product and process life cycles.

- Create a data governance strategy for a digital thread with members of your value network for planning data oversight, data orchestration, data curation and data management.

- Cultivate long-term viability of digital threads and limit large-vendor dependency by defining guidelines for using proprietary data formats versus using sufficiently mature standards-based data formats, such as those proposed by ISO.

- Evaluate the impacts and consequences of combining engineering technology (ET), information technology (IT), and operational technology (OT) as part of combining technologies to create digital threads as new categories of data and technologies are introduced (see Innovation Insight for Engineering Technology: Why ET, IT and OT Are More Than the Sum of Their Parts).

- Map value streams diligently, and identify the relationships of different digital assets and data points necessary to gather knowledge across a product and/or process's life cycle, then determine which feedback loops are necessary.

Representative Providers

- Amazon Web Services (AWS)
- Aras
- Contact Software
- Dassault Systèmes
- DataNovation
- EQ-Technologic
- Eurostep
- Microsoft
- Oracle
- ProSTEP
- PTC
Evidence

2020 Gartner Smart Manufacturing Strategy and Implementation Trends Survey. This study was conducted online from 23 October 2020 through 3 December 2020, to help develop and ratify roadmaps, assess organizations’ strategies against a collective market perspective, and ensure that their strategies for recovery and renewal are as future-proof as possible. In total, 439 respondents were interviewed in their native language across North America (36%, n = 160, including the U.S. and Canada), Western Europe (42%, n = 184, including the U.K., France, Germany and Sweden), and APAC (22%, n = 95, including Australia, New Zealand and Singapore).

Qualifying organizations operate in the manufacturing industries and report enterprisewide annual revenue for fiscal year 2019 of at least $500 million (at least $1 billion in the U.S.) USD or equivalent. Companies must have a smart manufacturing strategy or plans to deploy.

Qualified participants have a role tied to a supply chain function and are in director or above roles. All respondents are involved in their company’s decisions regarding manufacturing operations and/or overall manufacturing strategy.

The study was developed collaboratively by Gartner analysts and the Primary Research Team.

Disclaimer: Results of this study do not represent global findings or the market as a whole, but reflect sentiment of the respondents and companies surveyed.

Document Revision History

Innovation Insight for the Digital Thread - 19 December 2018

Recommended by the Authors

Hype Cycle for IoT Standards and Protocols, 2020
Hype Cycle for Manufacturing Operations Strategy, 2020
The Digital Thread Requires Manufacturing Process Management and Model-Based Manufacturing
How to Achieve Better Business Model Strategies With Industry Data Governance
How Innovative TSPs Can Utilize the Product Data Backbone Concept to Succeed in Manufacturing Industries
Innovation Insight for Engineering Technology: Why ET, IT and OT Are More Than the Sum of Their Parts
Providing Amazing Customer Experiences Through Connected Products
Three Steps for Supply Chain Leaders to Create Essential Collaboration With Product Management in the Digital Age

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