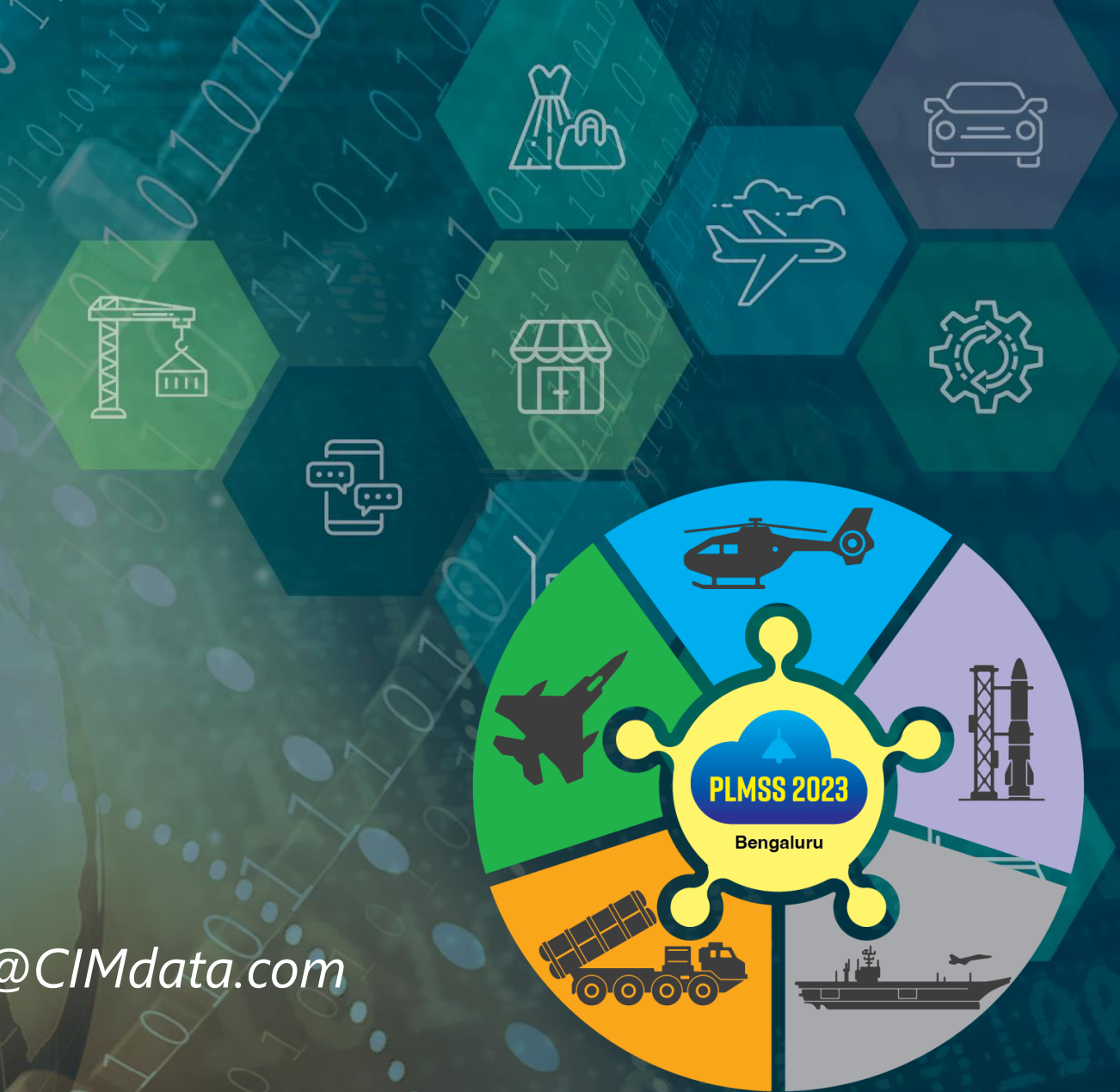# Overview of the Digital Thread in the Aerospace Ecosystem
PLMSS 2023 Workshop

5 December 2023

Peter Bilello, President & CEO, p.bilello@CIMdata.com
+1.734.668.9922

Our Services

CIMdata

Strategic advice & counsel through a comprehensive & integrated set of services

RESEARCH
Foresight

EDUCATION
Leadership

CONSULTING
Success • Invest • Transformation

- Research & analysis
- Technology evaluations
- Market-specific insights
- Industry news & trends

- Industry conferences
- Seminars & webinars
- Certificate programs
- Best practices

- Strategic guidance
- Aligning solutions with needs
- Program management advisement
- Market positioning

Peter A. Bilello, President & CEO

Professional background

- More than 35 years of experience in the development of IT solutions for research, engineering, and manufacturing organizations worldwide

- Led numerous projects in PLM analysis, selection, implementation & management, synchronous and lean manufacturing consulting & software engineering, as well as general data management & governance strategy development and support

- Authored many papers & research reports on PLM and related topics, as well as numerous articles, commentaries, and perspectives that have appeared in publications throughout the NA, EMEA & Asia

- Holds a B.S. in Computer Science (minor in Physics) & M.S.E. in Manufacturing Systems Engineering

Key Takeaways

- The digital thread is one of CIMdata's Critical Dozen Digital Transformation trends & enablers

- Digital threads sew together disciplines, as well as the end-to-end product lifecycle—its processes, technologies & organizations

- The digital thread is best represented as a network of decisions & data nodes—these threads define a digital web/network

- An organization's Digital Network must have a purpose—it is not linear

- Understanding the human factor in digital network enablement is critical, along with data governance
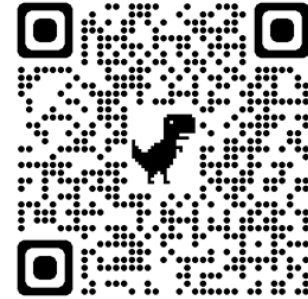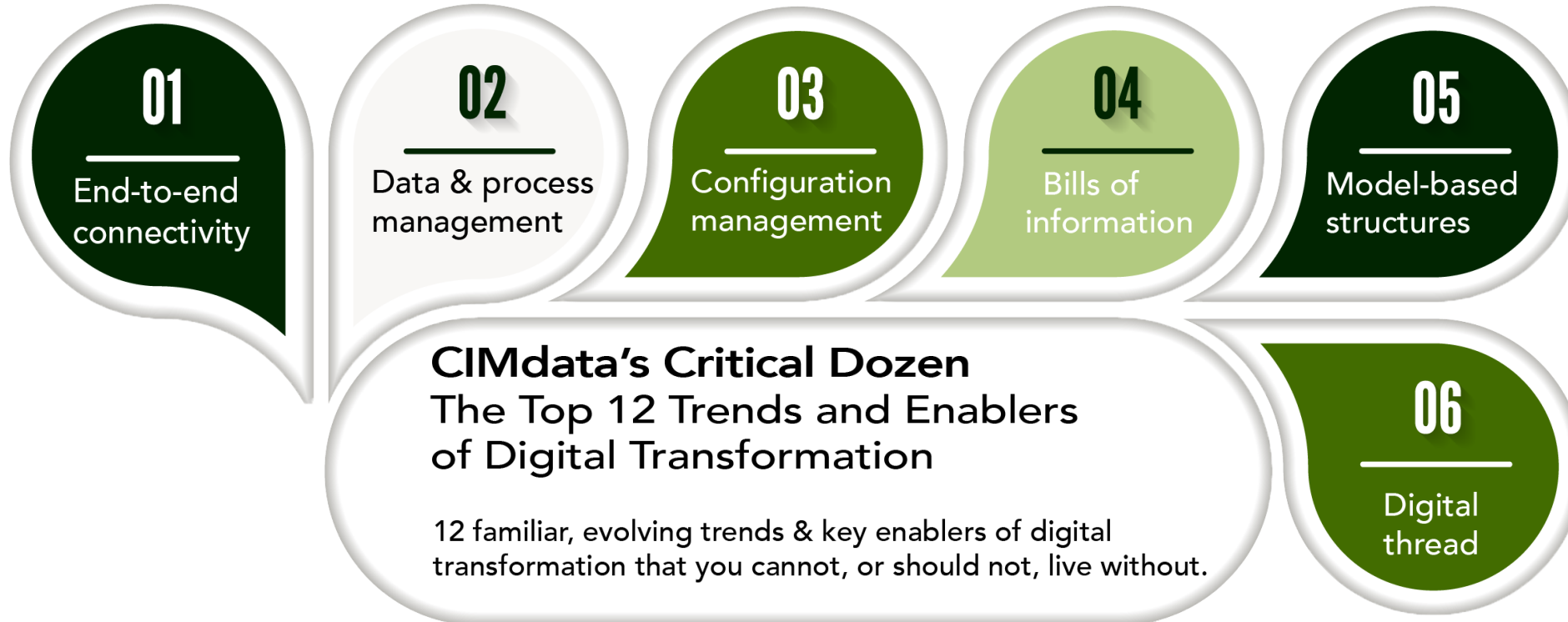
Key Takeaways

- Digital network implementations are never straightforward

- A sound plan to maintain & enhance the organization's digital network throughout its useful life must be defined & maintained

- The value of the digital thread lies in the myriad of links to data that feed & validate decision-making from concept through life

- A digital network is required to support an organization's digital twins—their creation & end-to-end management

- A digital network and it potentially countless digital threads helps us see into every product- or service-related decision

Agenda

- The What & Why of the Digital Thread
- Where are We: An Aerospace Industry Perspective
- The Known & Anticipated Impediments/Obstacles
- The Digital Thread Journey: Where to Start
- The Future of Digital Thread
- How Does One Get Involved
- Concluding Remarks

CIMdata's Critical Dozen: Context

01 — End-to-end connectivity

02 — Data & process management

03 — Configuration management

04 — Bills of information

05 — Model-based structures

06 — Digital thread

CIMdata's Critical Dozen
The Top 12 Trends and Enablers of Digital Transformation

12 familiar, evolving trends & key enablers of digital transformation that you cannot, or should not, live without.

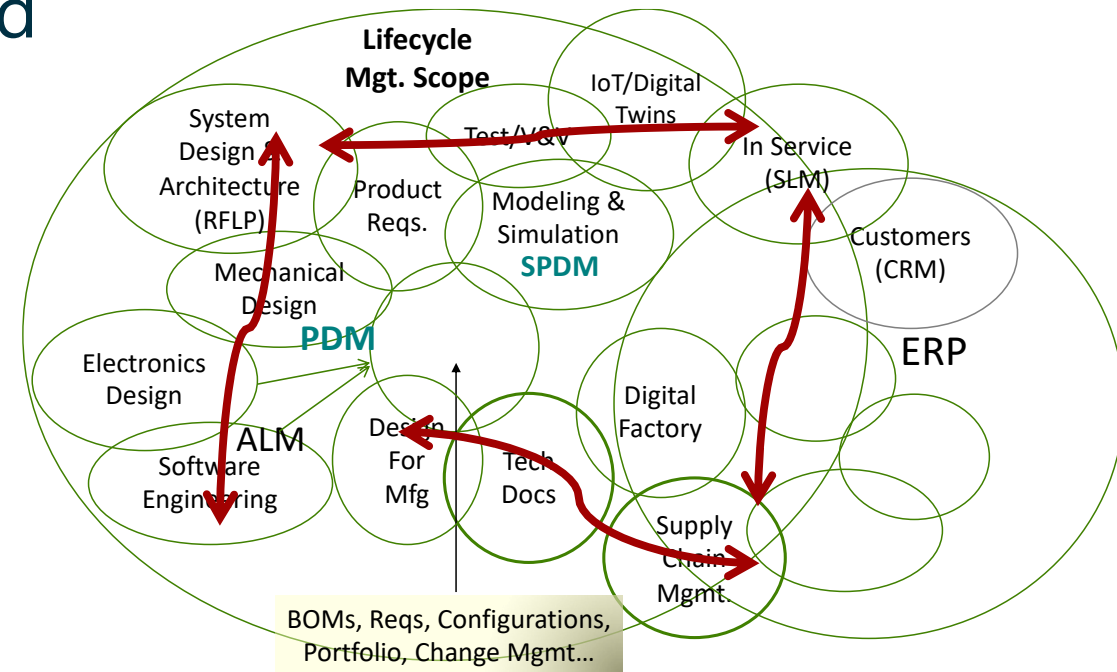# Digital Thread I

- The ***digital thread*** is a communication framework that enables connected data flows for the integrated view of lifecycle artifacts and their resulting asset's data (i.e., digital twin) across traditionally siloed functional product lifecycle domains

Digital thread is enabled and supported by a robust end-to-end and connected systems model and MBSE processes

Digital Thread II

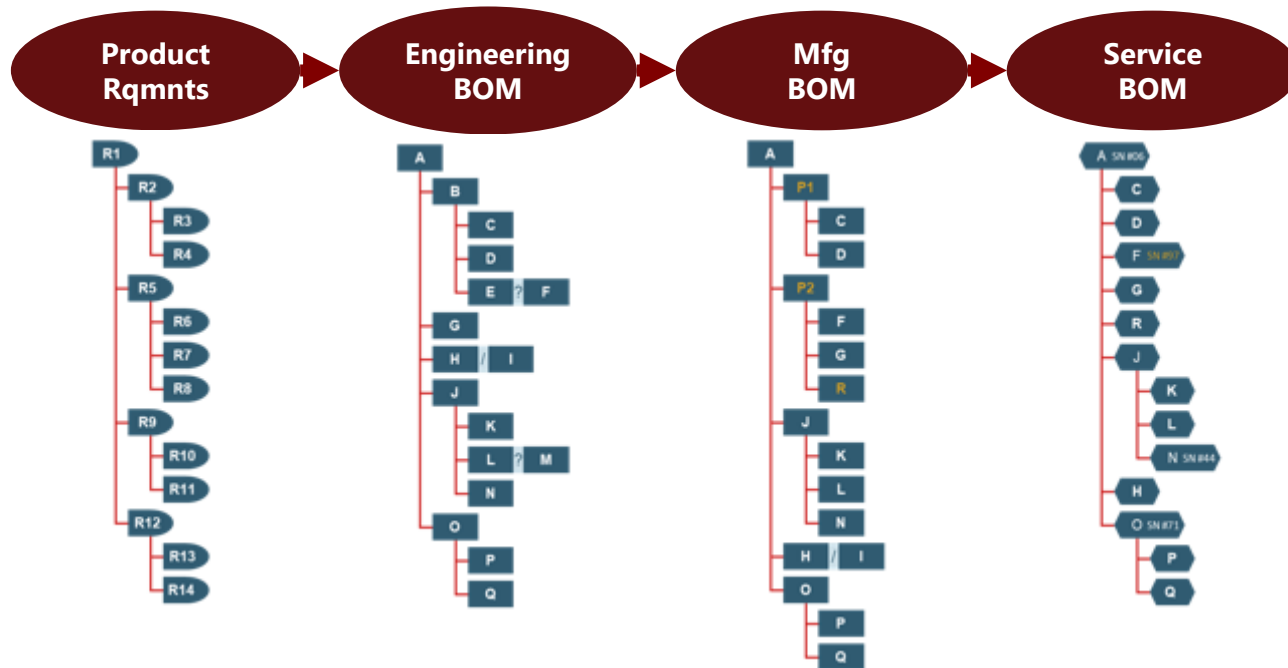*Managing the product lifecycle demands end-to-end connectivity*

Portfolio Management

Planning

Conceptual Design

Product Engineering

Manufacturing Engineering

Simulation & Validation

Requirements

Info

Re-use
Re-purpose
Re-mfg.
Re-cover
Re-cycle
Re-tire

Disposal & Recycling

Maintenance & Repair

In-service Operation

Sales & Distribution

Test & Quality

Build & Produce

E2E: Lifecycle Product Structures

Connections between the four principal structure configurations – Thread vs. Web

Derivative Dependencies (Web)

Product Lifecycle Timeline Sequence (Thread)
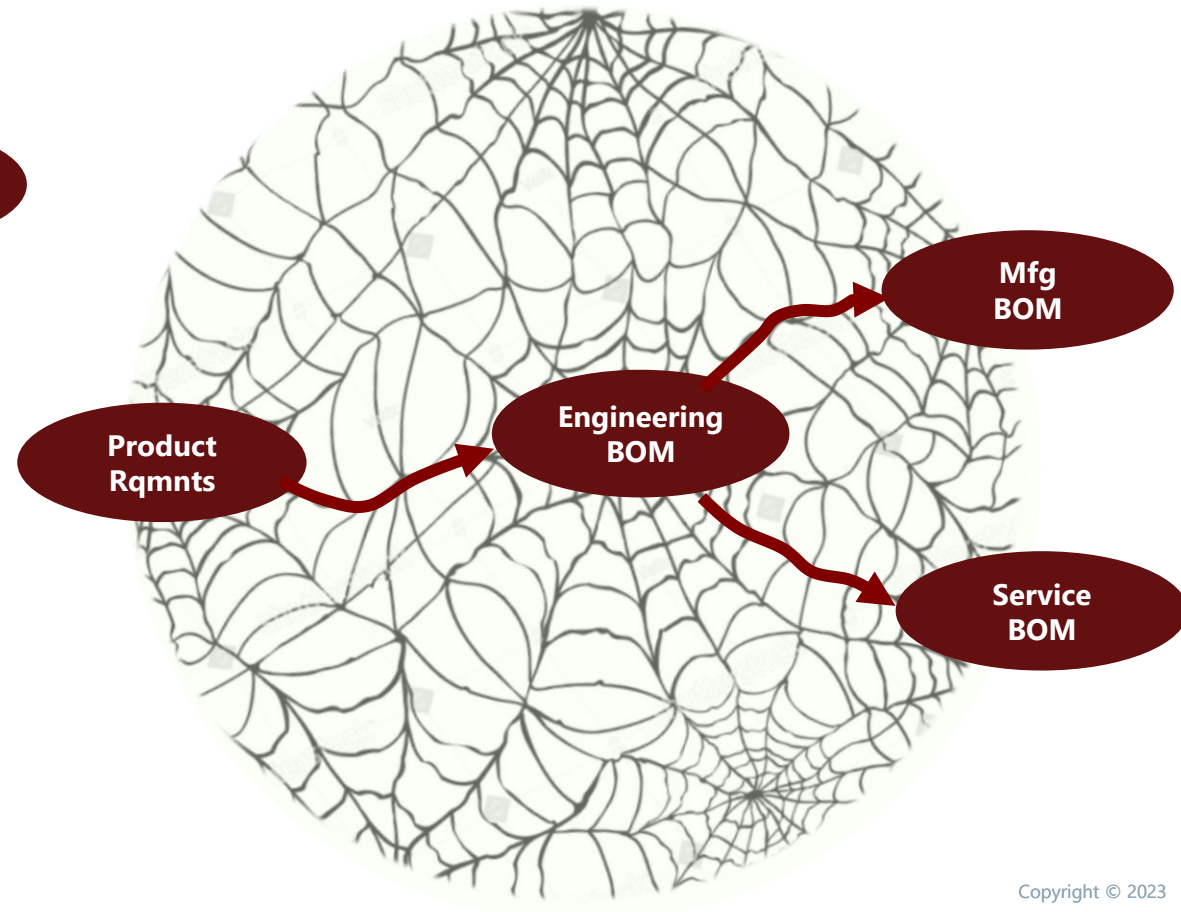
Digital Thread is a Web of Connections
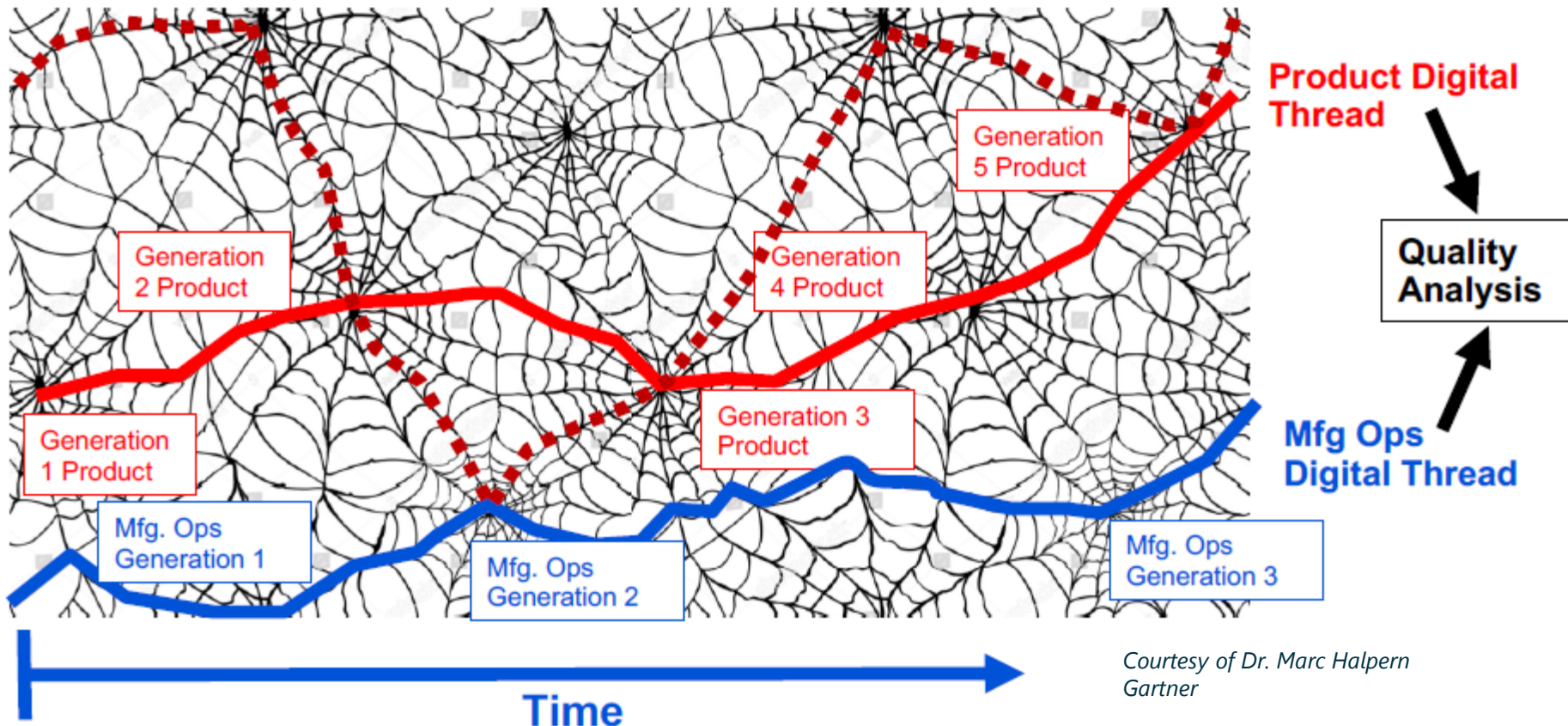
Courtesy of Dr. Marc Halpern
Gartner

Digital Thread: In Summary

CIMdata

In essence, what is a digital thread

- A digital thread/web is a chart, or network, of decisions

- A digital thread must effectively connect data and processes so that digital twins can be created, maintained, and leveraged

- A network is a more realistic representation of how data and processes are interconnected in enterprises

- Each of these networks connects hundreds of informational nodes and data repositories
  - These range from simple flat files to model-based structures, each packed with info critical for making sound process decisions

The Digital Network

A true full E2E lifecycle digital construct
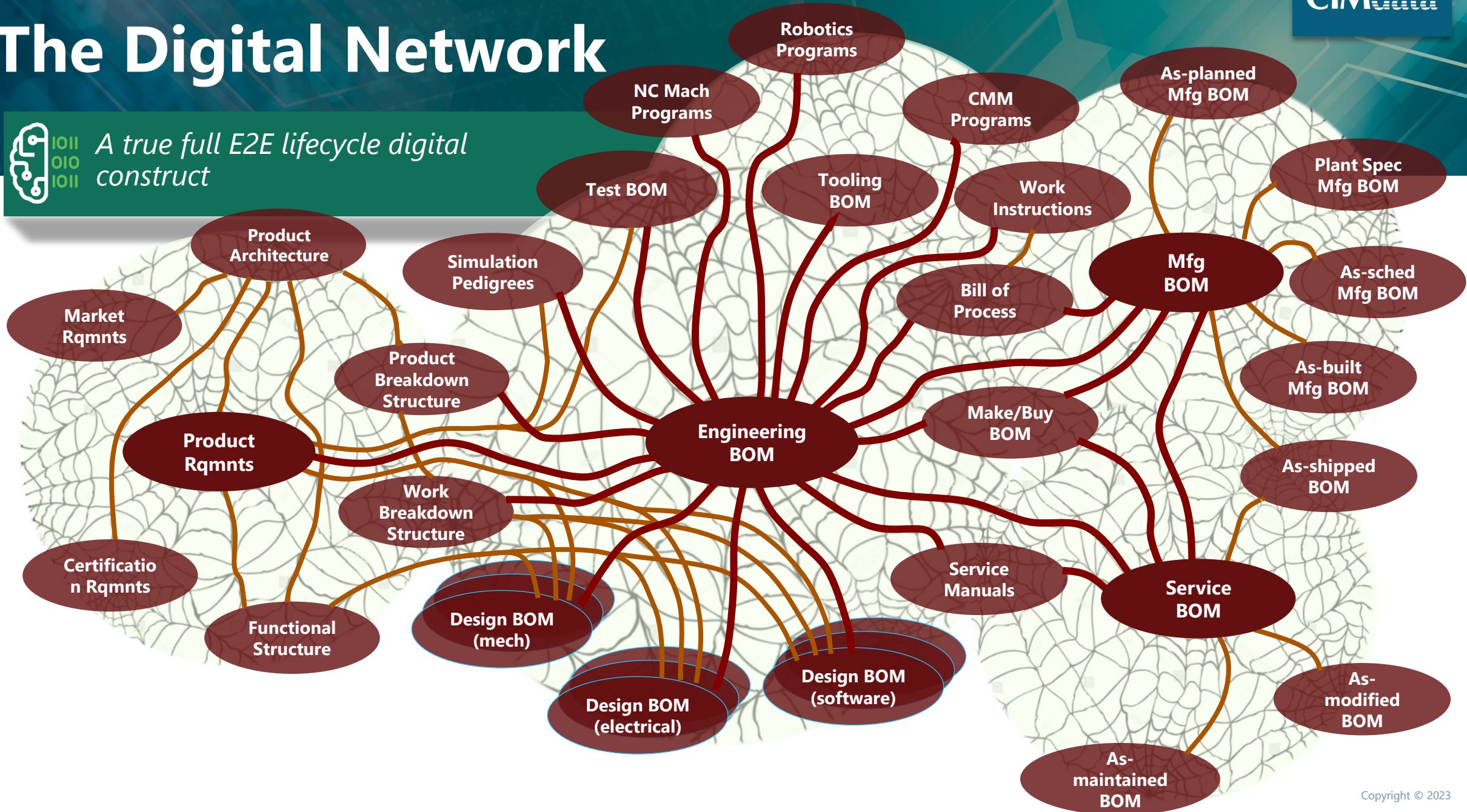
Finding the Digital Network's Value

> *The value of an organization's digital network lies in what it is designed to represent (1 of 2)*

- The value lies in the myriad of links to data & information that feed & validate decision-making from concept through life

- It must enable digital twins of its associated physical assets—an exact, up-to-date digital representation of the enterprise's physical products or services, or even its manufacturing system

- It must capture & represent all the decisions made throughout the lifecycle of a product or service, and the impacts of those decisions

- Building the digital network is about choosing which data nodes & repositories to link in any given process & how to best digitalize

Finding the Digital Network's Value

> *The value of an organization's digital network lies in what it is designed to represent (2 of 2)*

- Once the effort needed to build a digital network is understood, it is more than reasonable to ask, "Why go to all this trouble?"

- Fundamentally, a digital network, and it potentially countless digital threads, helps us see into every product- or service-related decision, and better understand how & why each decision was made
  - If we fail to remember why a decision was made and what we considered in reaching it, we will fail to learn from our past mistakes and risk repeating them
  - Worse, we will be unable to build on our prior successes

- Remember: a digital thread is required to support a digital twin's creation & management
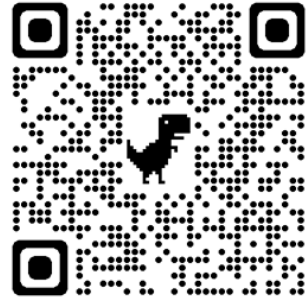
CIMdata's Critical Dozen: What's Next

01 End-to-end connectivity

02 Data & process management

03 Configuration management

04 Bills of information

05 Model-based structures

CIMdata's Critical Dozen
The Top 12 Trends and Enablers of Digital Transformation

12 familiar, evolving trends & key enablers of digital transformation that you cannot, or should not, live without.

06 Digital thread

07 Digital twin

The more comprehensive & effective the digital network, the greater the value of its digital twin to its users

Digital Twin

A&D PLM Action Group Definition

- A **digital twin** is a virtual representation of a physical entity, its behaviors, and the associated processes used to create it
  - An integration of data from various sources (i.e., digital thread) that define a future, existing, or historic item, system, process, or service & operational environments

Digital Twin of the Product

Digital Twin of Production

Digital Twin of Service

Digital twin is enabled & supported by a robust end-to-end & connected systems model & MBSE processes
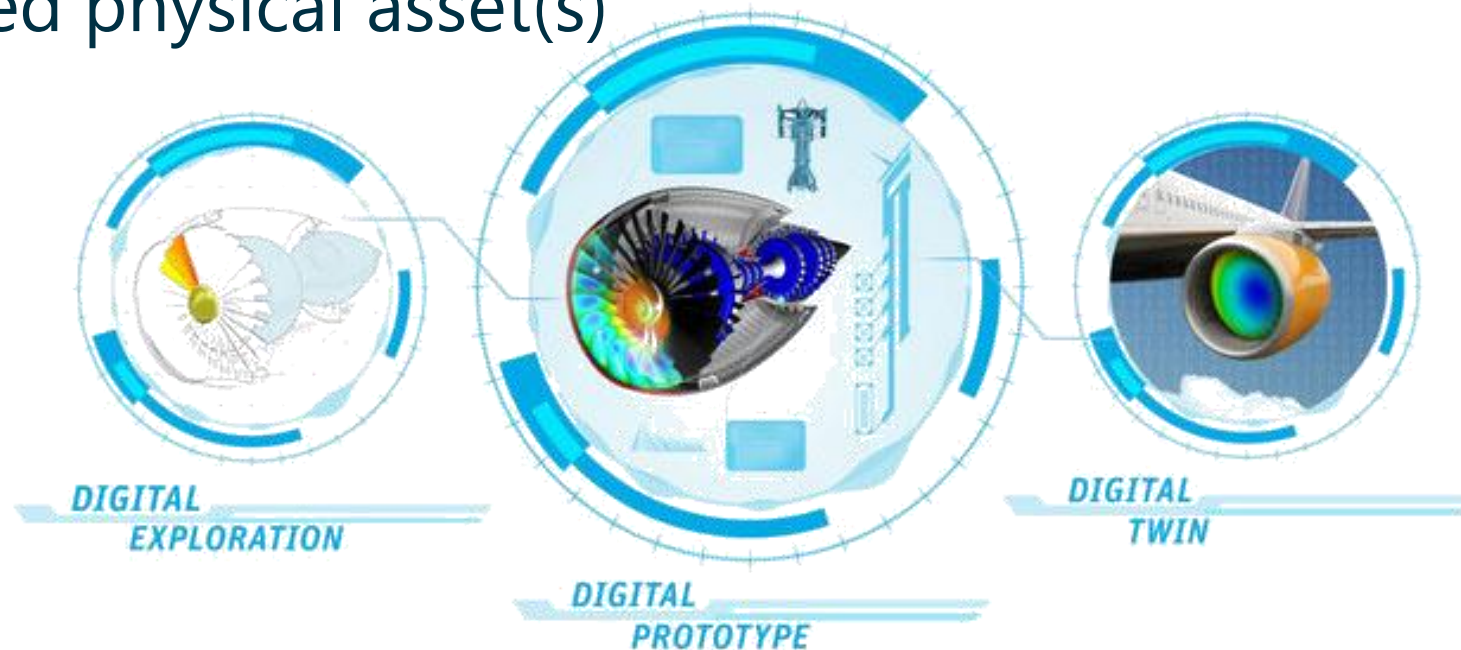
Digital Twins

Key characteristics

- There are multiple Digital Twins for different purposes, each has specific characteristics
  - For example, Data Analytics Digital Twins, MRO Digital Twins, Financial Digital Twins, Engineering Digital Twins, and Engineering Simulation Digital Twins
- Each Digital Twin must have a physical twin (i.e., a physical asset)
  - A virtual representation can and should exist prior to its physical twin
  - The physical asset can be a plant, a ship, infrastructure, a car, etc.
- Each Digital Twin must communication with its Physical Twin
  - It does not have to be real time or electronic

Adapted from input from ASSESS (see www.assessinitiative.com)

Engineering Simulation Digital Twin

CIMdata's preferred definition

- A ***physics-based virtual representation*** of a physical asset or collection of physical assets (physical twin) that allows simulations of the associated physical asset(s)

DIGITAL EXPLORATION

DIGITAL PROTOTYPE

DIGITAL TWIN

(Courtesy of Ansys)

Creating & Maintaining the Digital Twins

Digital Twin vision cannot be achieved without a full product/process model

Digital Twin -- From Design to Operation

Physical Asset

Virtual Prototype

Physics-based analytics

CAD Courtesy of Volvo Cars

http://www.ansys-blog.com/digital-twin-pump/

http://blogs.dnvgl.com/software/2016/04/digital-twins-structural-engineering/
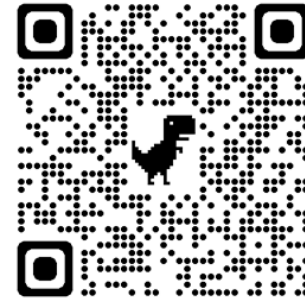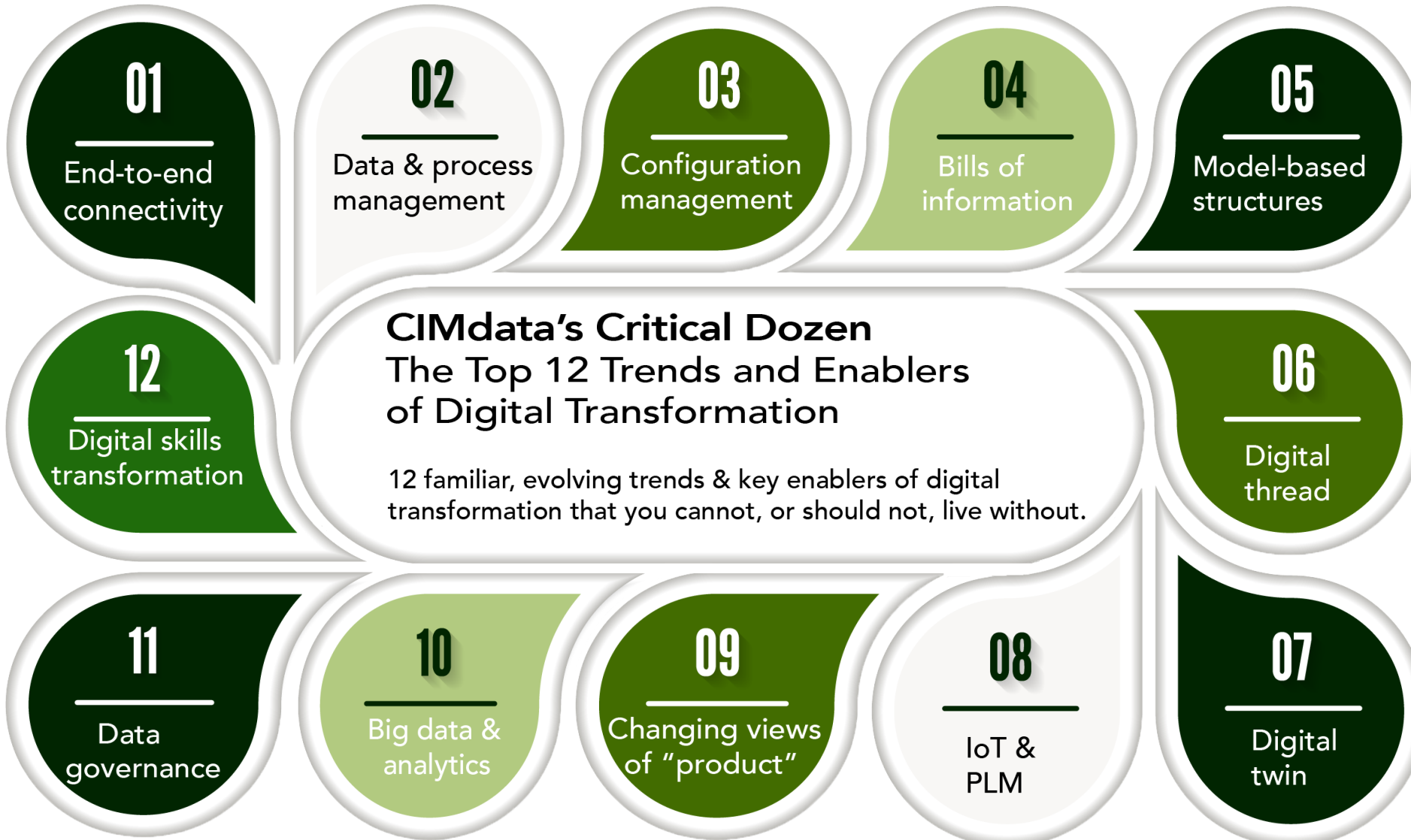
https://community.plm.automation.siemens.com/t5/Tecnomatix-News/Digital-Twin-Blurring-the-lines-between-reality-and-simulation/ba-p/333483

CIMdata's Critical Dozen: What's Beyond

01 End-to-end connectivity

02 Data & process management

03 Configuration management

04 Bills of information

05 Model-based structures

12 Digital skills transformation

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06 Digital thread

11 Data governance

10 Big data & analytics

09 Changing views of "product"

08 IoT & PLM

07 Digital twin

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Collaborative Research Program

Study Digital Thread current state and future trends

Sponsors

AEROSPACE & DEFENSE PLM ACTION GROUP

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Objective

The A&D PLM Action Group members and the PLM solution provider sponsors share a common objective for this research –
To gain understanding of needs and opportunities within industry that will inform Digital Thread solution strategy and roadmap

Information Gathering

Subject matter (domain) expert interviews & an online survey of committed professionals

Interviews

- Interviews were conducted by CIMdata with three communities:
    - 5 participating PLM solution providers,
    - 5 key A&D customers nominated by the participating solution providers, and
    - 5 AD PAG member companies
- The 10 A&D companies interviewed included
    - 9 of the Top 40 (23%),
    - 7 of the Top 20 (35%), and
    - 5 of the Top 10 (50%)
- The learnings from the interviews were applied to develop the line of inquiry in the web-based survey

Survey

- A total of 90 complete and validated online survey responses were received and analyzed
- The survey was intentionally designed to be a challenge for the respondent
    - Answering the questions required a deep understanding of the current status and future plans for digital thread realization within the respondent's company
    - The average time to complete the survey was approximately 30 minutes
- Achieved desired effect
    - Only domain experts on the topic of digital thread invested the time and effort needed to complete the survey

Survey Respondent Demographics

Heavily aerospace & defense with a broad representation across the supply chain

Distribution by Industry

- Other 17%
- Utilities 4%
- Industrial Equipment 9%
- Auto & Other Transportation 13%
- Aerospace and Defense 57%
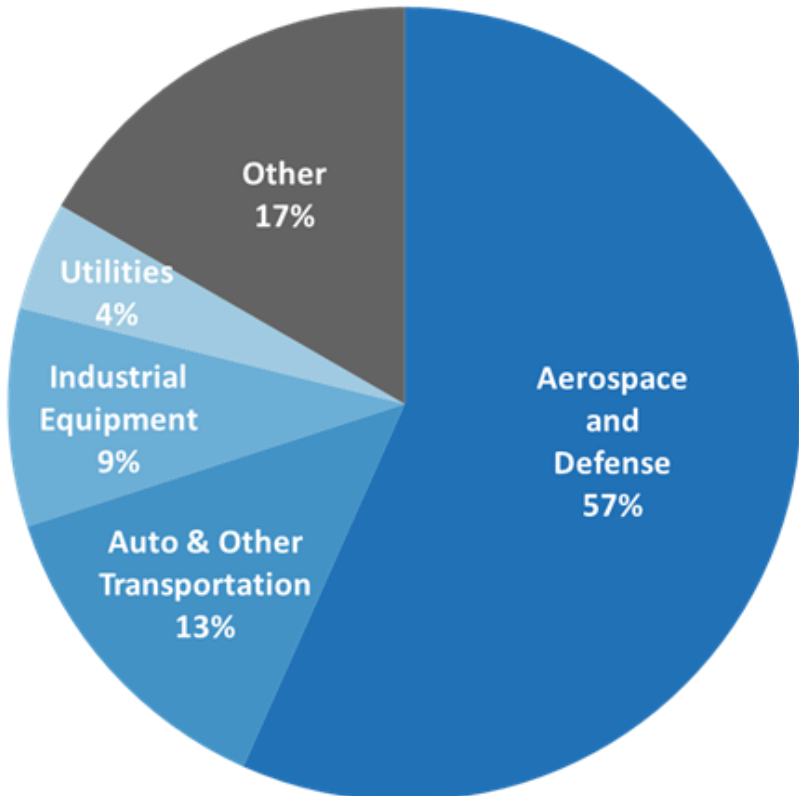
Distribution by Company Revenue

- > $50 billion 26%
- < $500 million 27%
- $10 billion to $50 billion 21%
- $1 billion to 10 billion 24%
- $500 million to $1 billion 2%
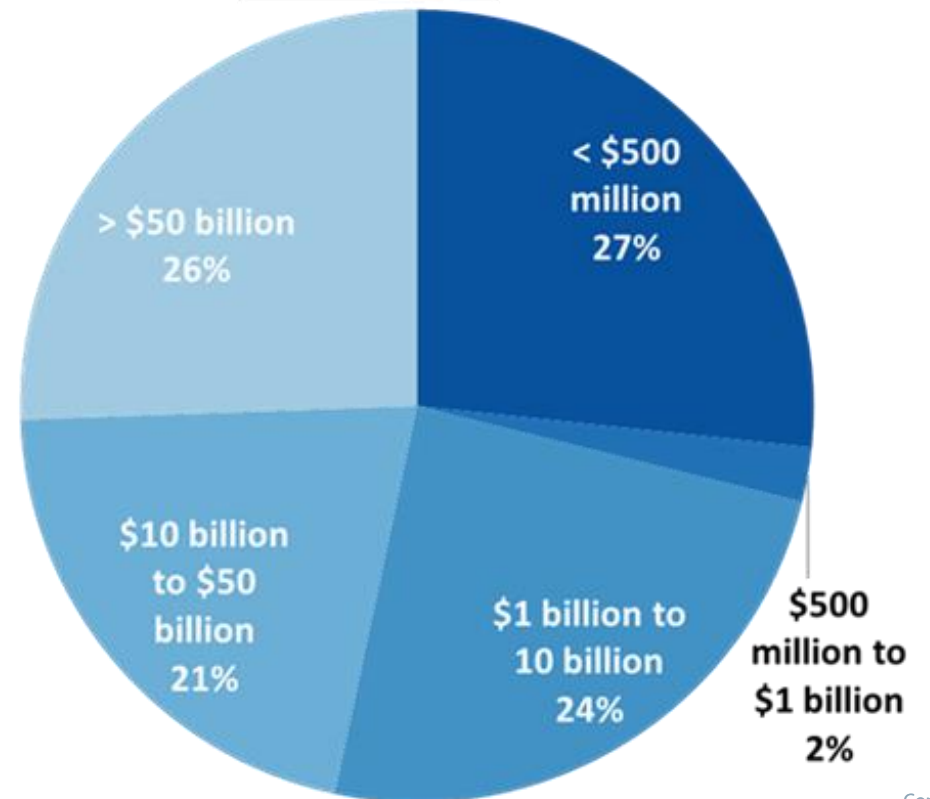
The What & Why of Digital Thread

Conceptual understanding of digital thread within industrial companies is very immature

No Common Definition

- Interviews began with the question "What is your definition of the digital thread?" which yielded 15 different definitions

- Nearly half of survey respondents do not have an agreed to definition within their company; less than a quarter reference a published definition
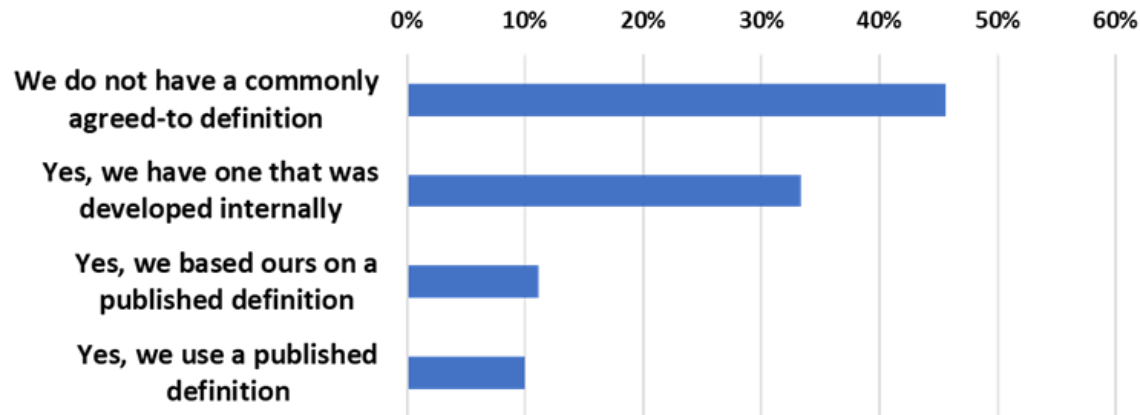
Reasons for Rise to Prominence
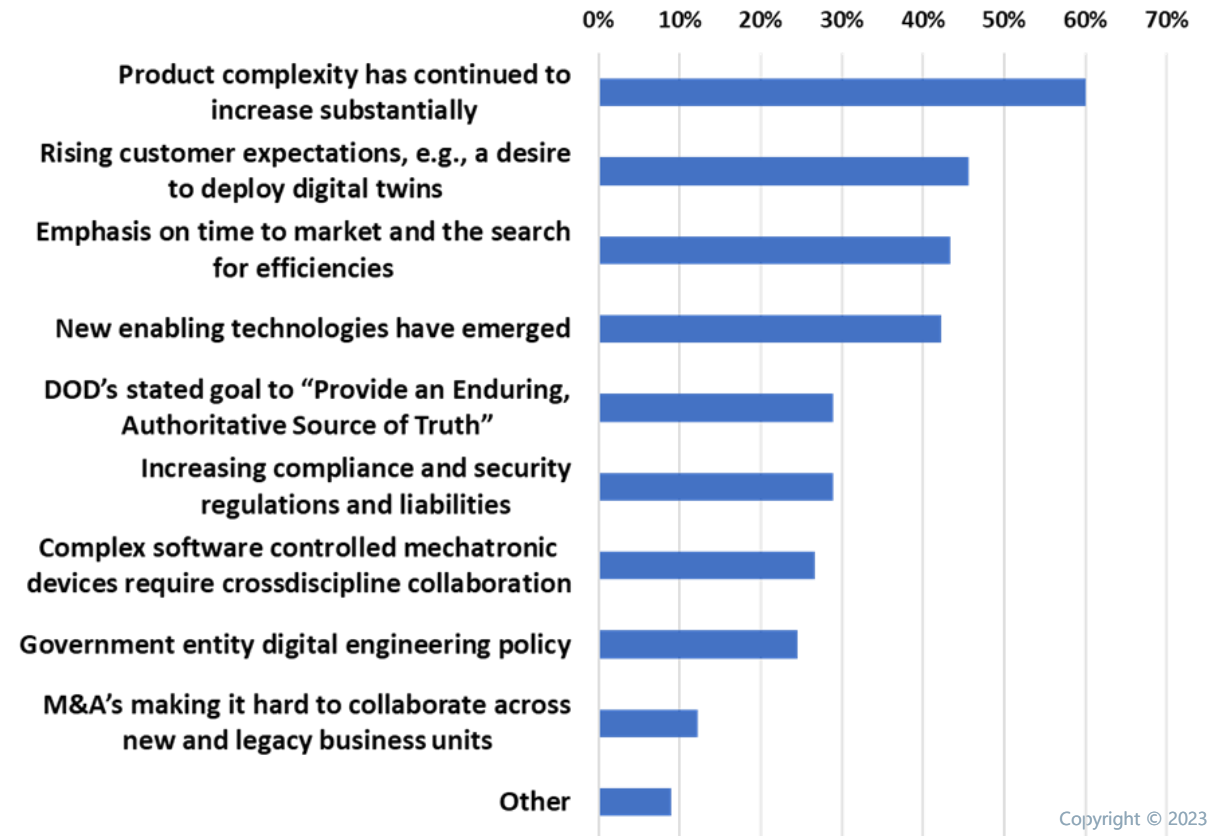
The What & Why of Digital Thread

Among specialists there is a shared perception of what a digital thread does & is

The Digital Thread Does

	0%	10%	20%	30%	40%	50%	60%	70%	80%

Establishes traceability of product information

Across the multiple domains in the lifecycle (mechanical, E/E, software, and firmware)

Meaningful relationship connections between a product's digital assets

Facilitates the handoff of data from stakeholder to stakeholder downstream

Follows the product through all its incarnations, including its physical form

Facilitates flow back upstream to inform change management

Throughout the extended customers and the

Is a prerequisite for a Digital Twin

Other

The Digital Thread Is

	0%	10%	20%	30%	40%	50%	60%	70%	80%

Linkage and traceability between data elements at the meta data level

Interoperability between data elements for interpretation of one by the other

Combination of data model and technologies that facilitate the data model

Being able to measure and monitor traceability

Exists between data elements in tools from a wide range of software providers

Not a software system that is purchased

Virtual data layer that sits on top and

lifecycle implementation

Other

*The most prominent characteristics of what a digital thread **is** and what it **does** relate to "establishing traceability of product information"*

Digital Thread Value Footprint

Use cases – Prevalence of implementations is low; assigned importance is broad & high
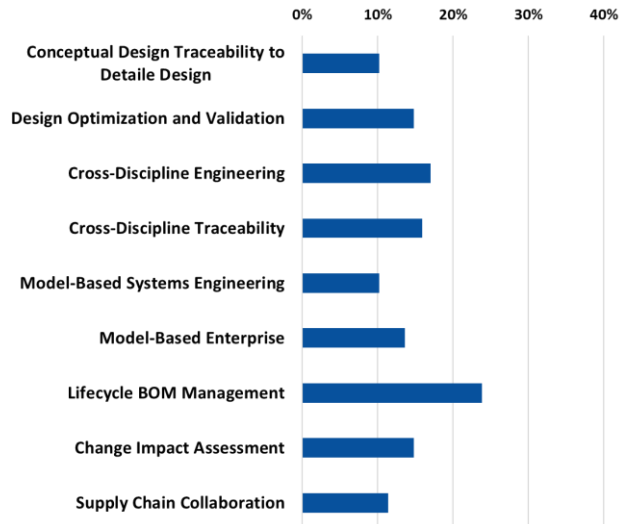
Assigned Importance
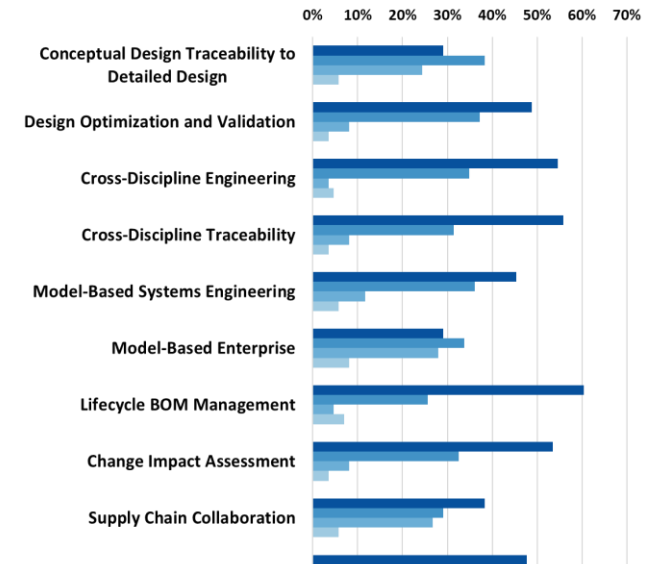
The contrast between the high importance assigned to digital thread use cases and the low prevalence of current implementations is a striking indicator that digital thread investment is in very early days

Self-Assessment

Maturity of digital thread strategy realization
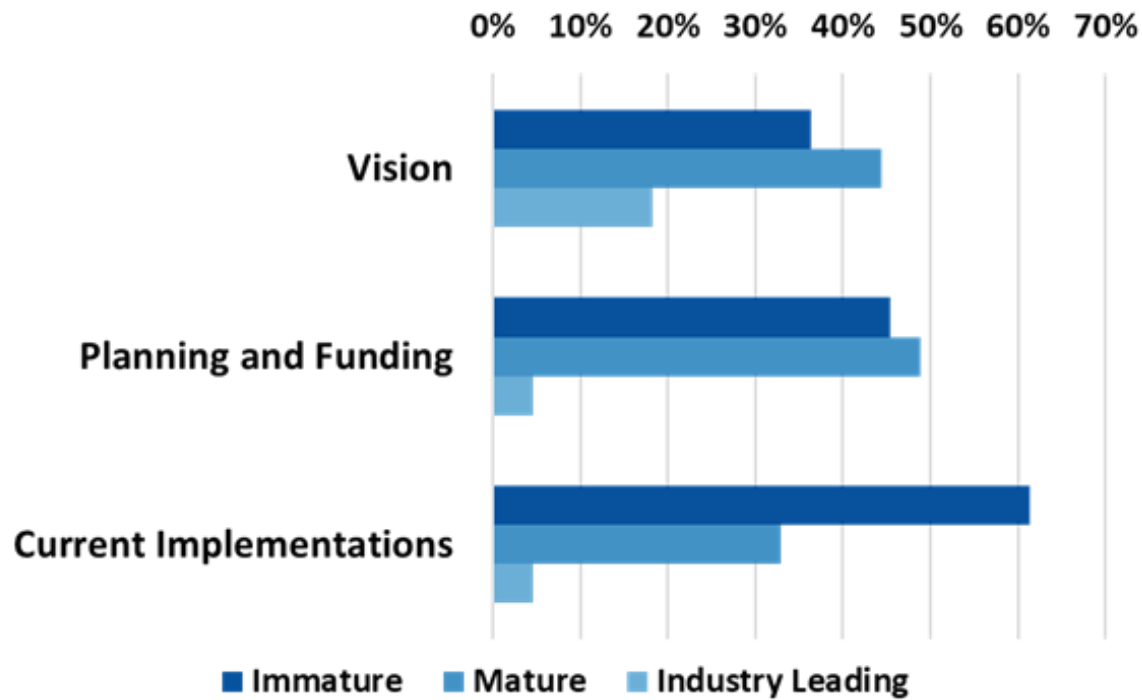
- Most respondents assigned a rating of "mature" or "industry-leading" to their company's vision and level of planning and funding

- This suggests that they are ready to invest in implementations which the majority rate as "immature"

- This gap indicates a major business opportunity for solution providers

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Considering the Human Factor

Understanding the human factor in digital network enablement is critical

- In the development, production, and service of any product, there is a very human tendency to underestimate the range of factors impacting each decision

- Also commonly underestimated is:
  - The vast amount of information available
  - The variety of repositories & other sources
  - The likelihood of unexpected change
  - The complexity of other parts of any process when compared to one's own role

- These result in short-sightedness, and all can be averted or overcome with the appropriate digital network

A Few Additional Considerations

Some of the common challenges

- Digital network implementations are never straightforward, and changes to connections to any one repository may affect feedback loops and links to other data stores

- Not all the repositories are to be found in your business unit or even in your enterprise
  - Almost every organization is part of another organization's digital network

- A significant amount of coding & testing is inevitable

A Few Final Points

Some practical advice (1 of 2)

- Any process can be enabled with a digital network in different ways for different purposes—thereby defining different digital constructs
  - An organization needs to reach agreements with all users on what its digital threads should achieve—their purpose & expected value, why they are needed and by whom—what its digital network must support

- To assure access to the internal technical expertise & outside resources
  - Actively promote the benefits of the digital network & its multiple threads

- Data Governance must be implemented to ensure that all extended enterprise participants have access to clear, concise & valid data
  - i.e., ensure that all information assets are trustworthy

A Few Final Points

Some practical advice (2 of 2)

- Delve deeply into the tools available in your PLM-enabling solution(s), as well as the supported & necessary data standards
  - They are numerous and powerful, but many require significant experience to use effectively
- Enlist help with technical issues, especially connectivity to the variety of repositories and data formats (old & new) that will be encountered
- Develop a sound plan to maintain and enhance the organization's digital network throughout its useful life, just as the underlying processes & threads must be maintained

Standards: A Major Disconnect

ISO
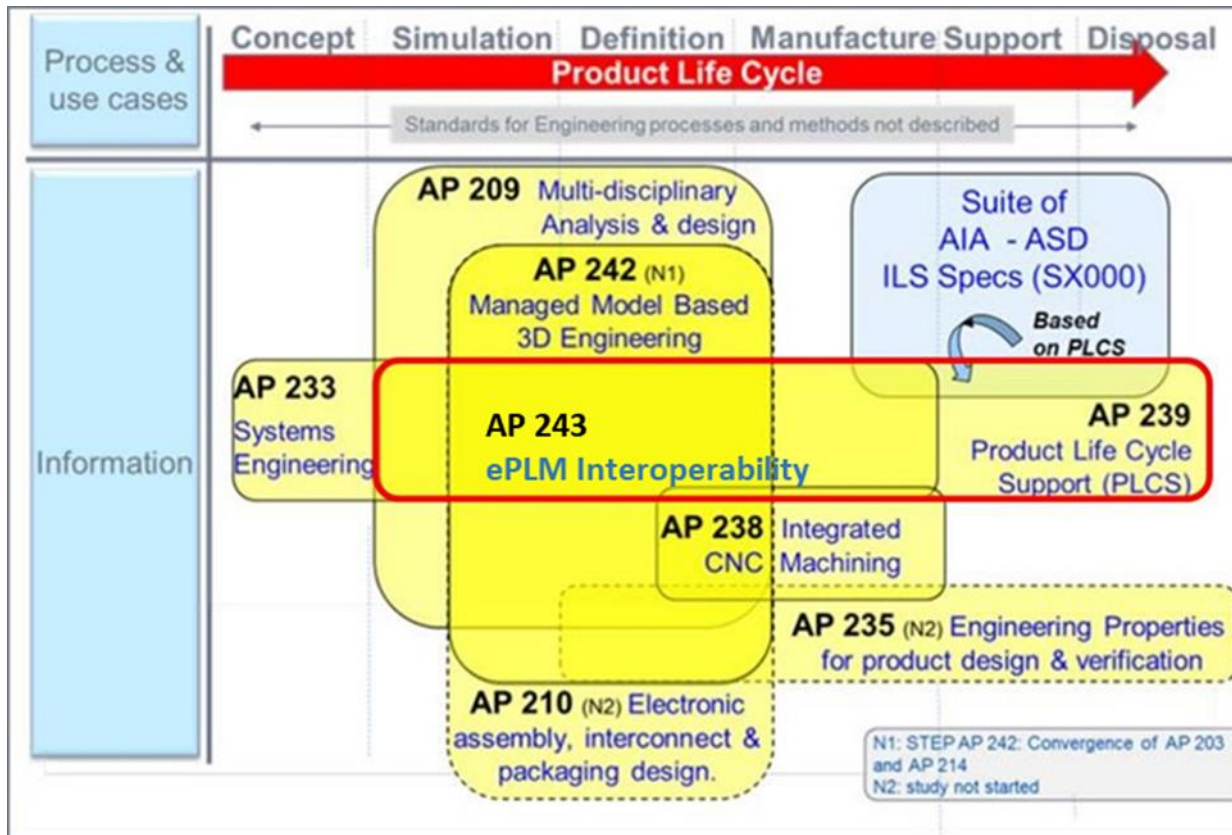
When considering ISO standards mapped against the development process overlapping standards are found. This adds to the confusion.

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Creating a Digital Network: A Starting Point

This means choosing and connecting to the many data repositories relevant for any given process

- Unfortunately, no two business units or departments organize their information in the same way, so establishing these connections can be tedious—but they are crucial

- One should start at the beginning of product conceptualization:
  - Marketplace information on what sells and what does not
  - Add to this any related competitive analyses that try to predict which product features and capabilities will be snapped up and which may be ignored

- With marketplace requirements clearly understood, the organization can more on to building out its digital network

Creating a Digital Network: What's Next

A digital network can & should be systematically defined to maximize benefits (1 of 3)

- Examine regulatory requirements databases—these hold countless must-have requirements

- Examine industry standards, every industrial market has "do" & "don't" data that must not be overlooked

- Find repositories that aggregate customer wants & needs

- Connect with systems & tools used by developers & design engineers to do the primary geometric configurations of new products
  - CAD/CAE, EDA/MDA, PDM/PLM, and simulation & analysis

Creating a Digital Network: What's Next

A digital network can & should be systematically defined to maximize benefits (2 of 3)

- Identify additional configuration refinements for which developers and designers use, e.g., CAM, MES/MOM, M&S, and MRP/ERP

- Build connections to the engineering bill of materials (eBOM) and other BOMs in production, and to the systems that generate BOMs for downstream & upstream use, such as sales, marketing & service

- Identify key repositories in the MBSE domain that the business unit or enterprise implemented in its move away from paper & 2D drawings

- Reach deeper into downstream data repositories where modifications are generated in every new product's later development stages

Creating a Digital Network: What's Next

A digital network can & should be systematically defined to maximize benefits (3 of 3)

- Don't forget a vital connection—engineering change process, a consistent approach to managing & tracking network changes

- Developers & maintainers of digital networks should always be on the lookout for feedback loops

  - Even simple processes may have dozens of loops feeding changes and decisions back "upstream" to the beginnings of processes
  - These loops keep processes up-to-date, playing a major role in the organization's drive for continuous improvement

Creating a Digital Network: Closing the Loop

The final two connections that must be considered for the digital network enablement

- The databases in design engineering that track fast-moving developments in mCAD, CAE, EDA, CAM, MES/MOM, and of course PDM/PLM
    - Monitoring these developments helps digital network users keep up with developers' and designers' new techniques
- The databases that monitor the impacts of technology & economics on customer expectations
    - Tracking these impacts can help users of digital networks anticipate decisions that developers and designers are likely to face near-term
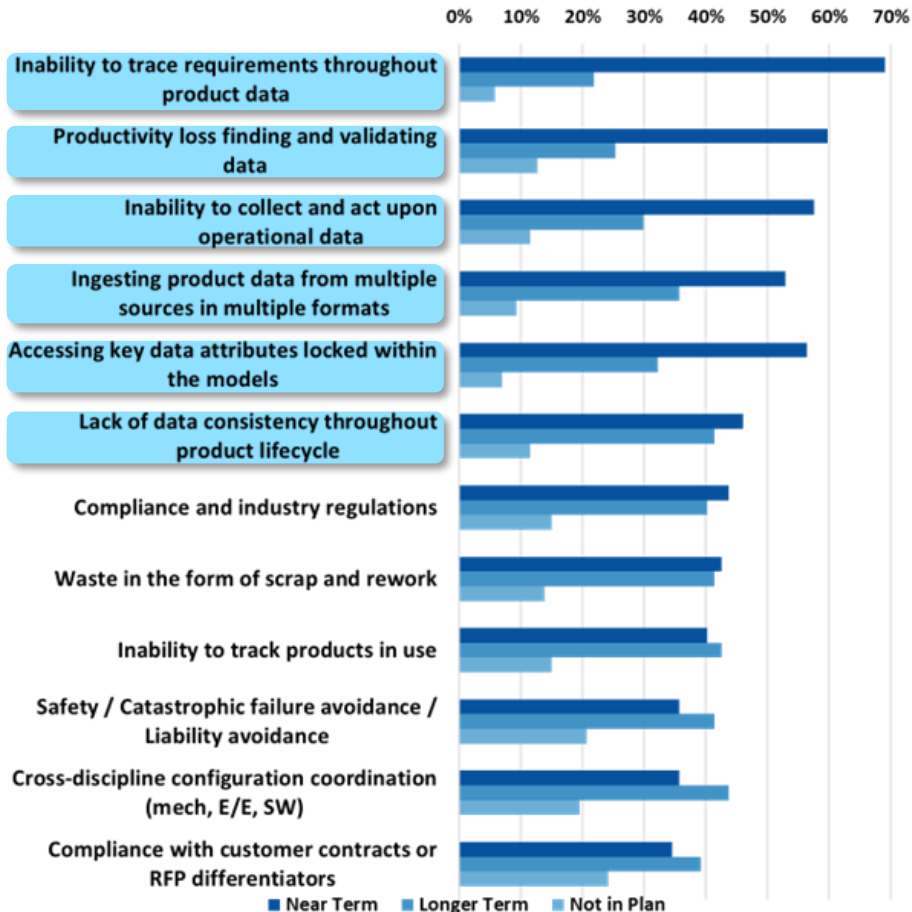- Both can help keep complexity from being overwhelming

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Future Investment Priorities

Top pain points relate to accessibility and traceability; top opportunities relate to SE

Pain Points

- Inability to trace requirements throughout product data
- Productivity loss finding and validating data
- Inability to collect and act upon operational data
- Ingesting product data from multiple sources in multiple formats
- Accessing key data attributes locked within the models
- Lack of data consistency throughout product lifecycle
- Compliance and industry regulations
- Waste in the form of scrap and rework
- Inability to track products in use
- Safety / Catastrophic failure avoidance / Liability avoidance
- Cross-discipline configuration coordination (mech, E/E, SW)
- Compliance with customer contracts or RFP differentiators

Legend: Near Term, Longer Term, Not in Plan

Opportunities

- Systems engineering/MBD/MBE/MBSE
- Quality compliance
- Readiness analysis by integrating PLM, ERP and logistics data
- Closed-loop verification & validation to requirements
- Simulation to design revision traceability
- Full Digital Thread search
- Closed-loop quality
- Digital Twin configuration traceability
- Model-based service
- Measurement of digital thread coverage
- Seamless integration of sub-system suppliers with system OEM
- Enablement of artificial intelligence and machine learning (AI/ML)
- Process enablement with behaviors, events, and semantics

Legend: Near Term, Longer Term, Not in Plan

Digital Thread Value Footprint

Program Stage – Plans to expand current implementations within & across lifecycle

Concept Stage → Development Stage → Production Stage → Utilization Stage / Support Stage → Retirement Stage
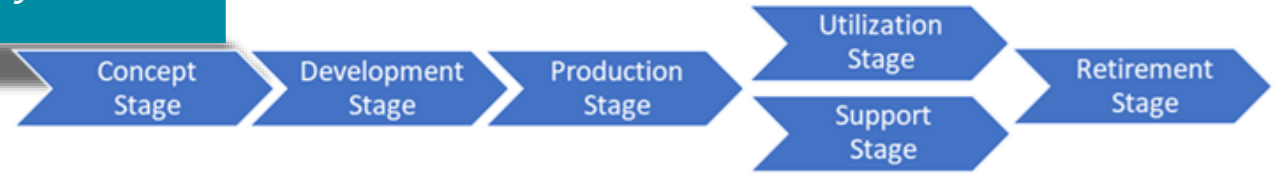
ISO 15288 System Lifecycle

Currently Implemented | **Near Term (<3 years)** | **Longer Term (>3 years)**
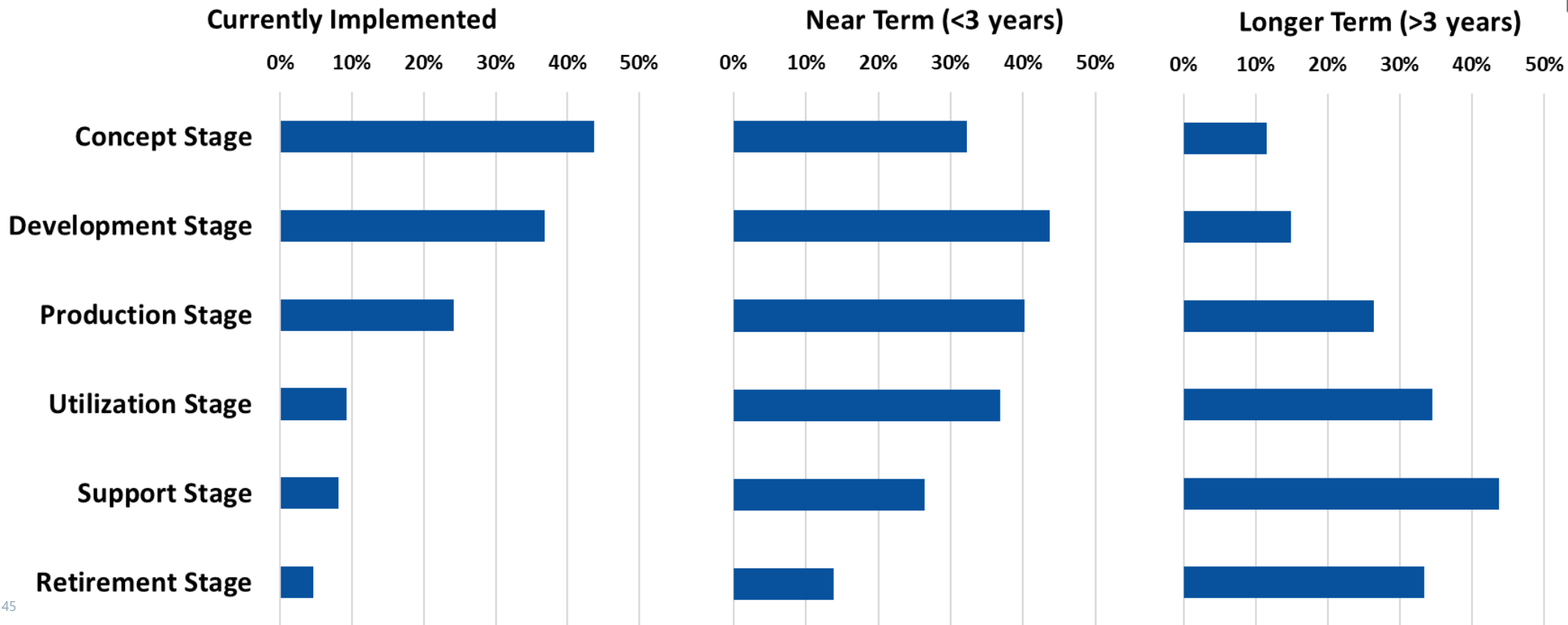
Digital Thread Value Footprint

Data – Plans to enable traceability & SE and then expand across the product lifecycle

Looking to the Future

CIMdata

Industry leaders are taking a broader view as they enter a more complex phase

- There will be more investment in production and service

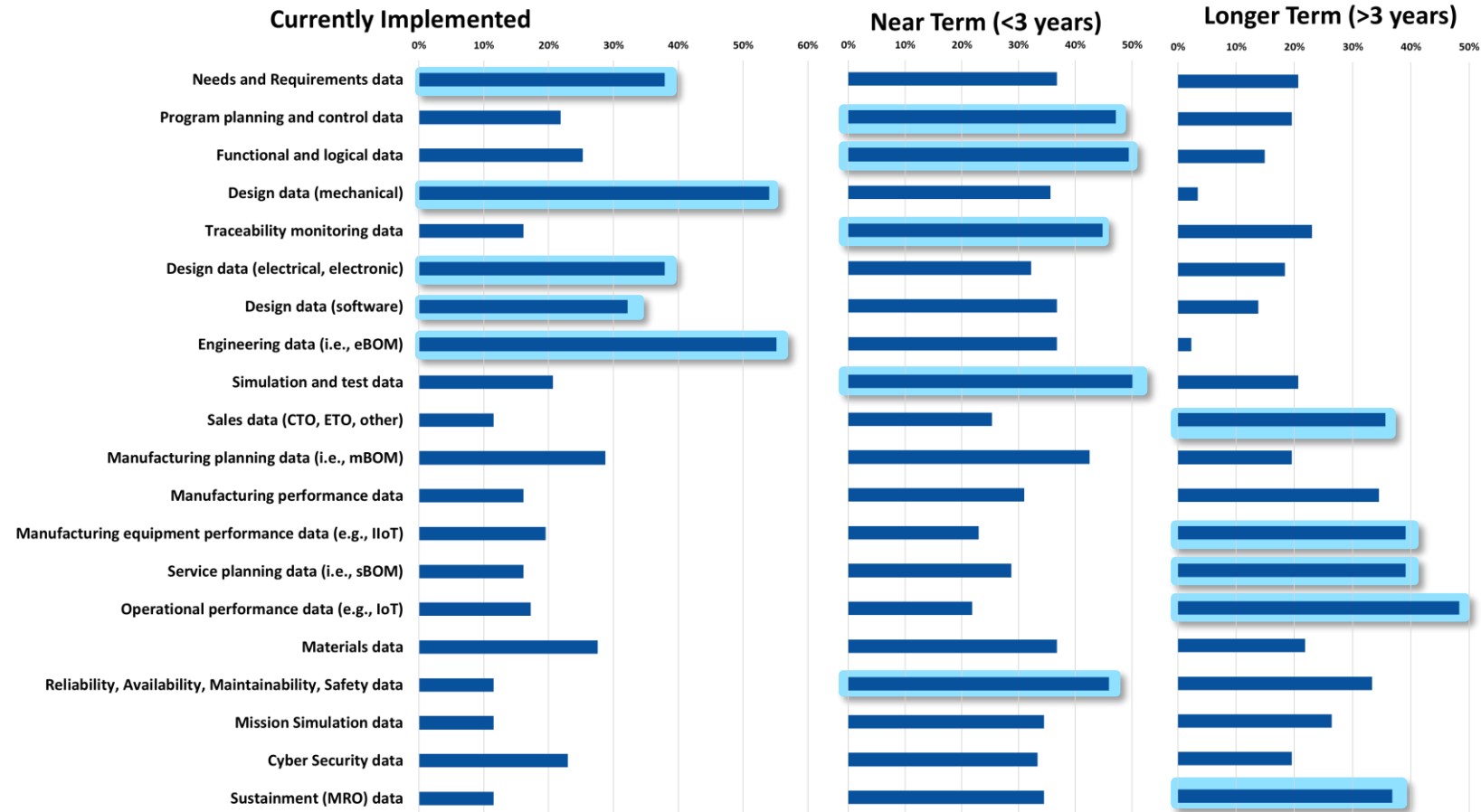- There will be increased emphasis on extending the digital thread community to include customers, partners, and suppliers more fully

- MBSE will be a fundamental driver of future investment

- The next stage will be more complex and transformative

  - There are examples of established programs that enjoy strong support from a well-informed and motivated senior management

  - But many are struggling to build awareness within their leadership and achieve early successes as proof points to motivate executive engagement and funding for execution

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Aerospace & Defense PLM Action Group

Group Overview

Jim Roche
A&D Practice Director

AEROSPACE & DEFENSE PLM ACTION GROUP

AIRBUS

BOEING

GE Aviation

Gulfstream
A GENERAL DYNAMICS COMPANY

PRATT & WHITNEY
DEPENDABLE ENGINES

Rolls-Royce

SAFRAN

Aerospace & Defense PLM Action Group

Facilitating cooperation within the aerospace & defense industry

- Aerospace OEMs and aircraft engine providers within CIMdata's globally recognized community who work as a PLM advocacy group
  - Setting the direction for the aerospace and defense industry on PLM-related topics that matter to members (including promoting, not duplicating, the work of standards bodies)
  - Promoting common industry PLM processes and practices
  - Defining requirements for PLM-related capabilities of common interest
  - Communicating with a unified voice to PLM solution providers
  - Sponsoring collaborative PLM research on prioritized industry and technology topics
- CIMdata administers group operations, coordinates research, and manages the progression of policy formulation

To Learn More...

- Access A&D PLM Action Group resources at www.ad-pag.com
  - Digital Twin/Digital Thread Solution Definition for Aerospace and Defense: Phase 3, position paper, Feb 2023
  - Digital Twin/Digital Thread Solution Definition for Aerospace and Defense: Phase 2, position paper, Jul 2022
  - Multiple View Bill of Materials (BOM) Solution Evaluation Benchmarks, report, Jul 2020
  - Multiple View Bill of Materials, position paper, Feb 2019

- Access CIMdata resources at www.CIMdata.com
  - Multi-view BOM Value Potential, webinar, Apr 2022
  - The Digital Thread is Really a Web, with the Engineering Bill of Materials at Its Center, webinar, Sep 2021
  - Making Multi-view BOM a Reality, webinar, Mar 2020

- Contact for further discussion
  James Roche, Aerospace & Defense Practice Director
  Email: j.roche@CIMdata.com
  Tel: +1.734.668.9922

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- The Known & Anticipated Impediments/Obstacles
- The Digital Thread Journey: Where to Start
- The Future of Digital Thread
- How Does One Get Involved
- Concluding Remarks

Concluding Remarks

Overview of the Digital Thread in the Aerospace Ecosystem (1 of 3)

- Every digital process is precious to its users & vulnerable to a host of detrimental changes

- Incorporating processes into a digital network maximizes the value of its information to its users

- It must have a purpose—it is not linear, it can have countless threads

- A digital network's potential countless digital threads helps us see into every product- or service-related decision

- Its value lies in its myriad of links to data and information that feed & validate decision-making

Concluding Remarks

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Overview of the Digital Thread in the Aerospace Ecosystem (2 of 3)

- The digital thread is one of CIMdata's Critical Dozen Digital Transformation trends & enablers—it sews together disciplines & the end-to-end product lifecycle

- Remember: a digital network is required to support a digital twin's creation & management

- Digital network implementations are never straightforward

- Develop a sound plan to maintain and enhance the organization's digital network throughout its useful life

Concluding Remarks

Overview of the Digital Thread in the Aerospace Ecosystem (3 of 3)

- Industry investment planning is widely based on use cases and the associated ROI

- Digital thread investment within the ecosystem of industrial users, their customers, suppliers, and solution providers is poised for rapid growth

- New realities, such as rising customer expectations (e.g., DoD's authoritative source of truth) and new enabling technologies, are major drivers of the digital thread's rise to prominence

- Current digital thread implementations are relatively modest in comparison to industrial companies' visions and plans

Questions & Answers

Any questions?

CIMdata Defining What Comes Next in Digital Transformation

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