Model Based Systems Engineering, Digital Ecosystems, and the Importance of Interoperability Throughout the Execution Lifecycle

GLOBAL PRODUCT DATA

INTEROPERABILITY

SUMMIT 2025

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

Dr. Trisha Hinners, Northrop Grumman Fellow
Northrop Grumman Corporation

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Dr. Trisha Hinners

Northrop Grumman Fellow – Systems Engineering & Architecture

Formal Education

- Ph.D. Physics (Florida State University)
- B.S. Physics (Southern Illinois University Edwardsville)

Professional Background

- Joined Northrop Grumman in 2008
- Focus areas: Systems Engineering & Architecture, Model-Driven Engineering, Digital Transformation
- Highlighted Roles:
  - MBSE practitioner since 2008
  - Chief Engineer multiple programs
  - Chief Architect multiple programs
  - Currently driving digital ecosystem architectures and adoption

Other things about me…

- Married – my husband and I met in physics grad school, and he also works at Northop Grumman
- Hobbies – Yoga, weight training/fitness, reading, cooking, spending time with friends and our cats

Photos credit :Trisha Hinners

Outline

- Introduction/Motivation for Interoperability
- What is a Digital Ecosystem?
- What is a Digital Thread?
- Importance of Data Governance
- Industry's Internal Investments
- Complexities and Challenges Achieving Interoperability
- Suggested Solutions
- Summary

Introduction/Motivation for Interoperability

The digitization of product development from early conceptual design stage all the way through the entire product lifecycle is a major goal across industry today*

What do we mean by digitization/ digitalization?

- **Digitization**: the conversion of text, pictures, or sound into a digital form that can be processed by a computer.
- **Digitalization**: adaptation of a system, process, etc. to be operated with the use of computers and the internet.

In aerospace/defense we have found we need to do a little digitization to achieve a future where the way we work is digitalized through an end-to-end digital and model-based strategy

What does this move from document-based to model-based achieve?

- Increased profitability and faster time to market
- Greater innovation
- Increased productivity
- Improved product quality
- Reduction in lifecycle costs
- Compliance with industry standards

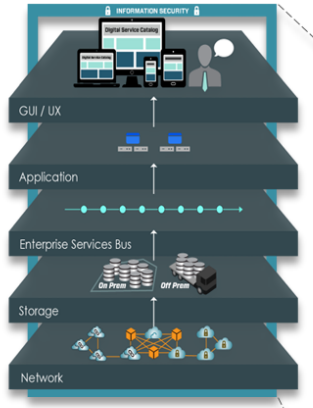
**Model-Based Systems Engineering (MBSE) Data Interoperability, AD PAG Position Paper Release 1.0, 2019*

Integrated Digital Ecosystem Terminology

Integrated Digital Ecosystem – the full overarching view of a full tech stack integrated together across both horizontal functions (e.g., engineering), programmatic functions (e.g., IPTs), supply chain, and mission needs

Integrated Digital Enterprise – Integrates functional and programmatic views containing:

- **Integrated Digital Environment –** The environment a given program chooses to operate within
- **Integrated Development Environment –** The environment where engineers do their integrated work by discipline (SW Dev IDE, MBSE Development, etc..)



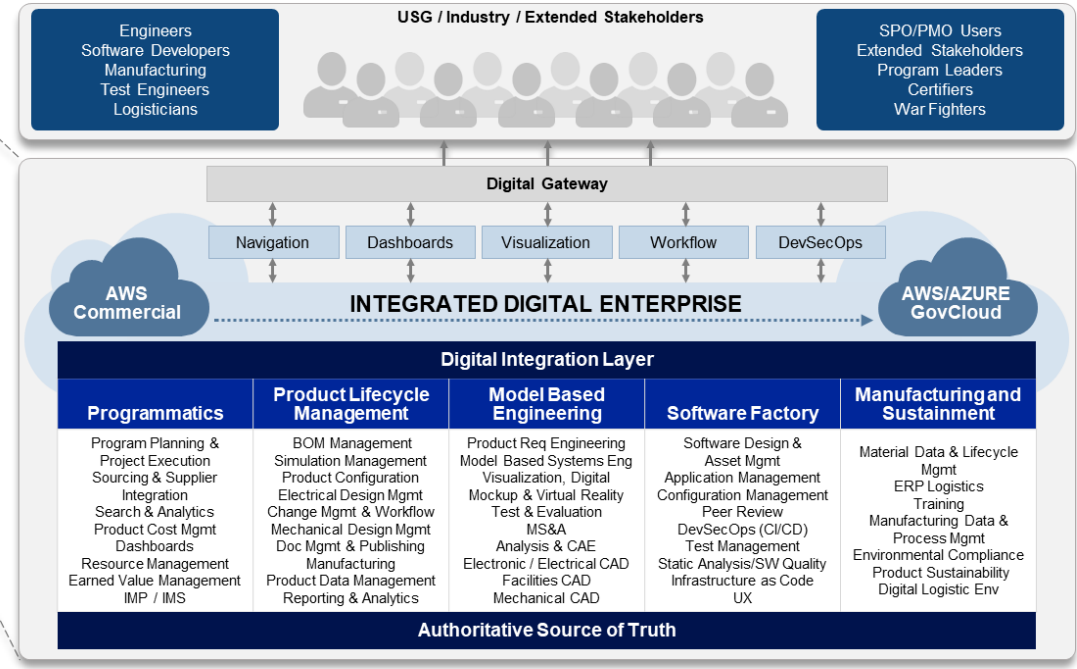


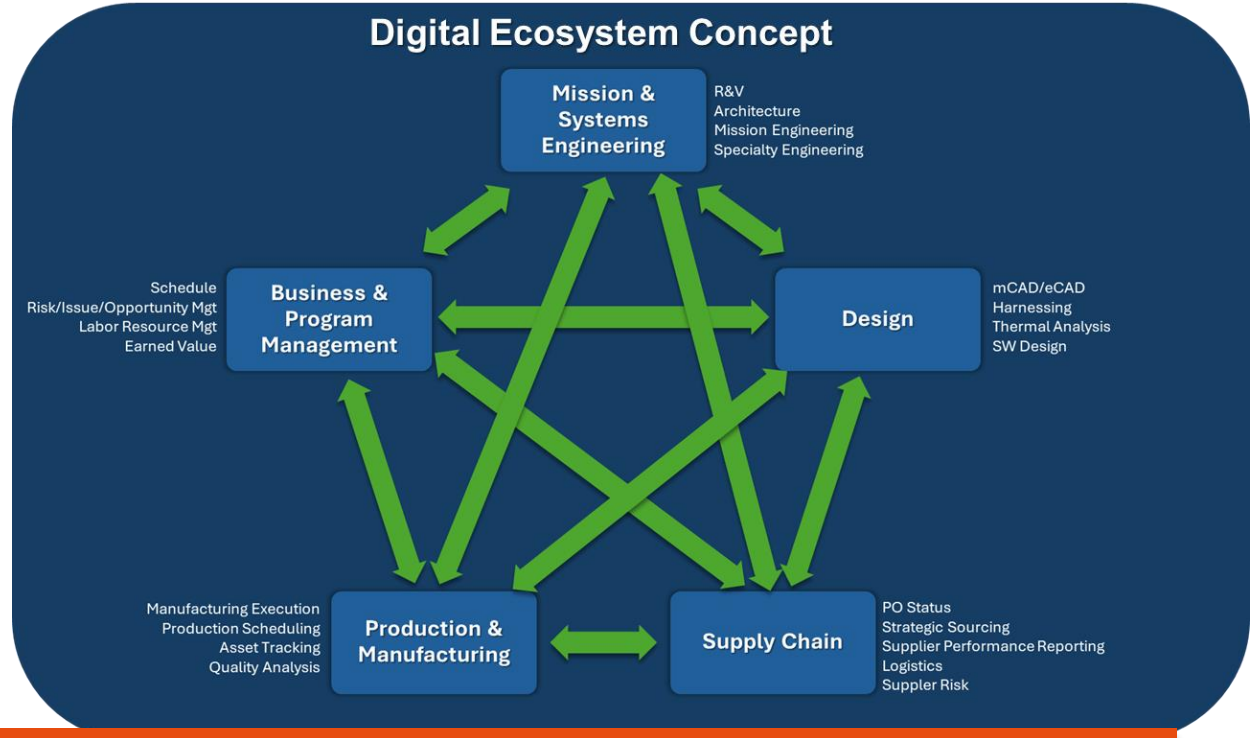
Image Credit: Northrop Grumman, Paul Nelson

What is a Digital Thread?

A Digital Thread is a data-driven, interconnected system of ASOTs that links data gathered/defined throughout the Product Lifecycle from Stakeholder Requirements Definition through Manufacturing and into Sustainment. Is the authoritative data and communication platform to investigate traceability and impacts.

Benefits and Dependencies:

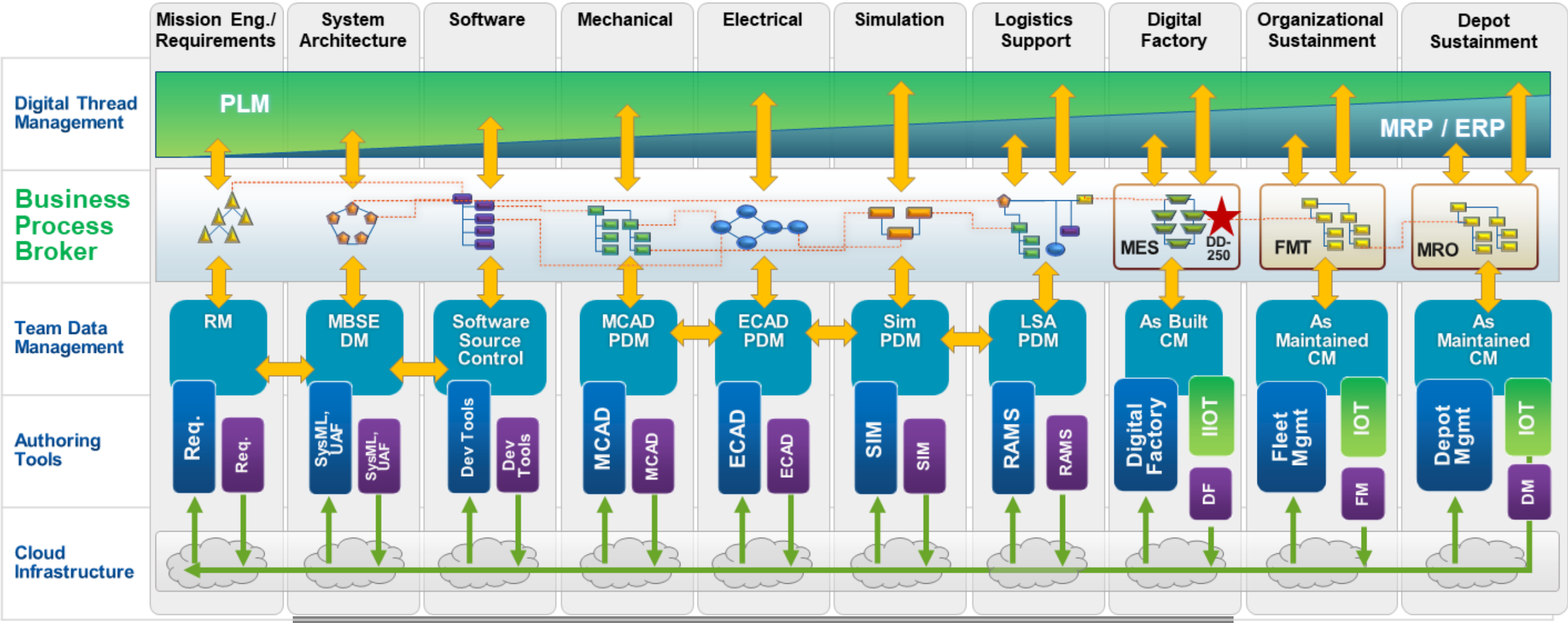
- ➢ Quick assessment that all requirements are satisfied by architecture and design
- ➢ Quick analysis of change impacts across the baseline
- ➢ Enhanced communication both internally and with stakeholders
- ❖ Requires increased engineering and configuration management discipline
- ❖ Potentially limits customization and requires adoption of enterprise standards
- ❖ Can drive common tool suite



The Digital Thread is at the heart of the Digital Ecosystem providing improved insights

Image Credit: Northrop Grumman, Trisha Hinners

Digital Thread – A Complex System of Systems



Shared Ownership of the Digital Thread

Image Credit: Northrop Grumman, Paul Nelson

Program Digital Thread

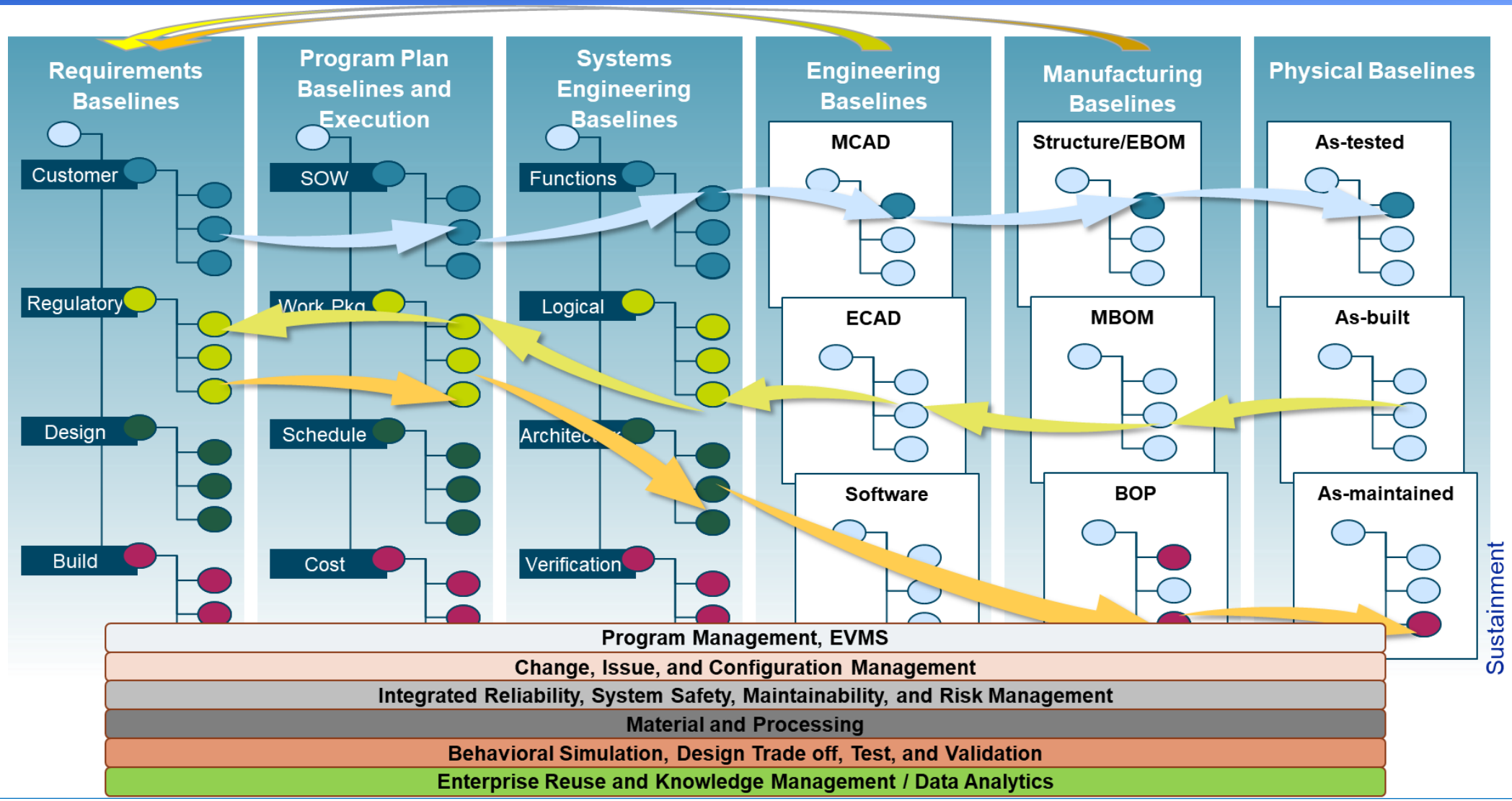


Image Credit: Northrop Grumman, Paul Nelson

Program Digital Thread

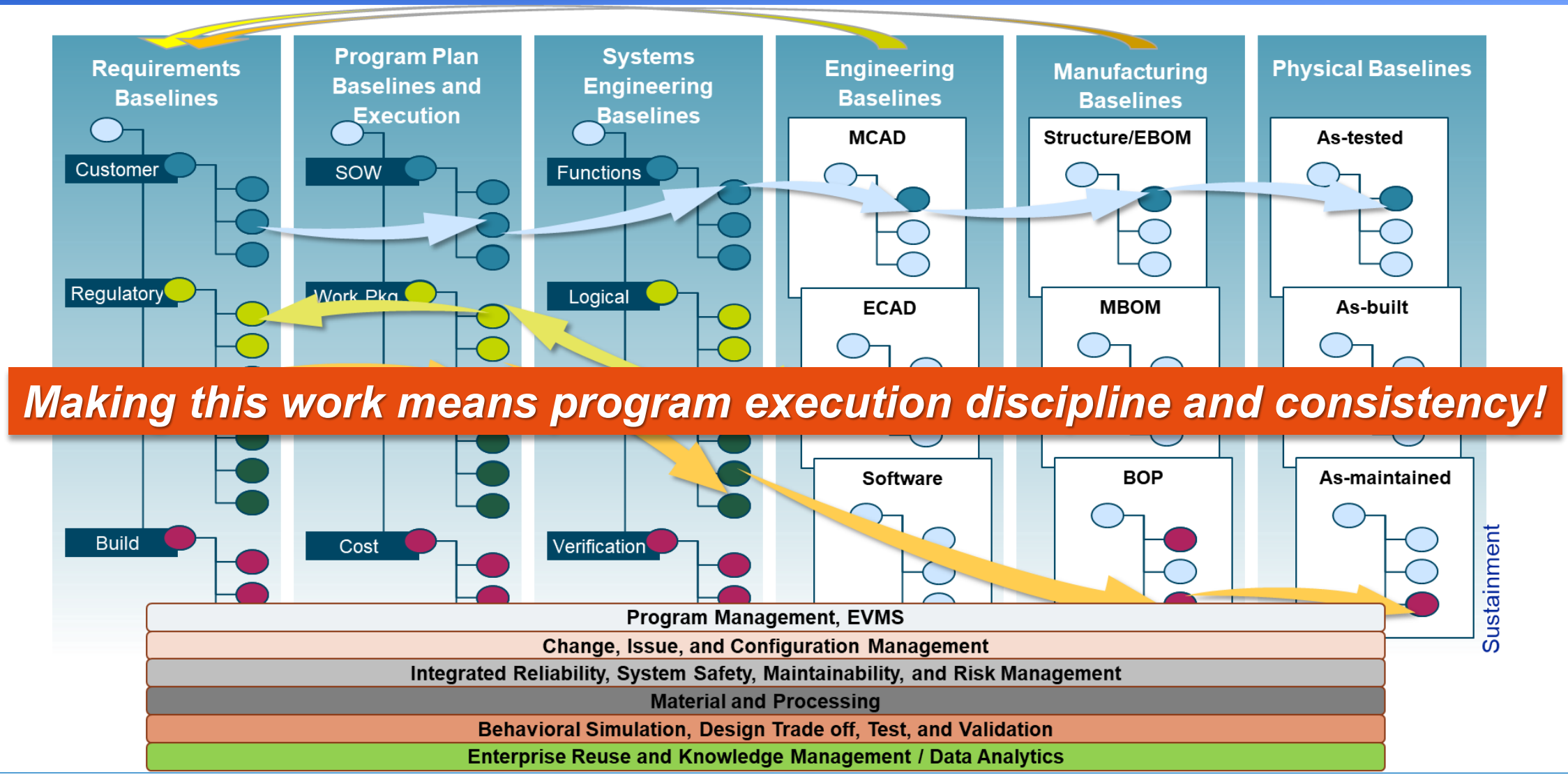


Image Credit: Northrop Grumman, Paul Nelson

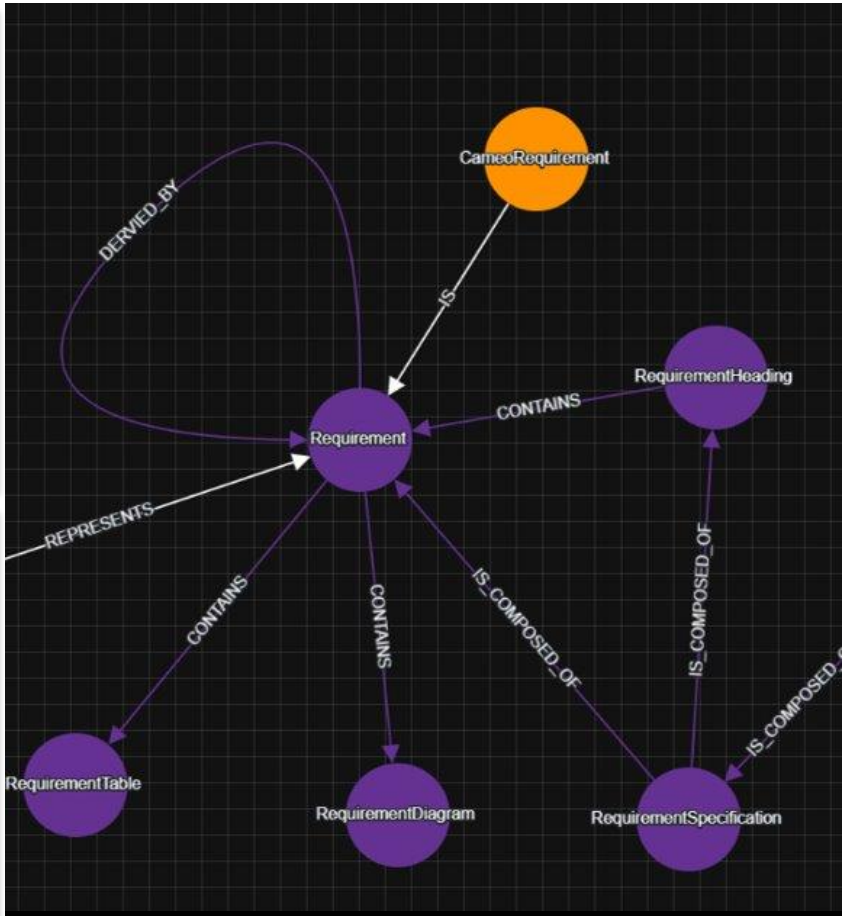
Our Digital Ecosystem Is Only As Good As Our Data…

To have confidence in our data means we need enhanced data governance for every piece of data created throughout program execution through sustainment.

- **Common Data Model** to ensure consistent and accepted data relationships are well defined
- **Data Governance** to ensure that those accepted data relationships are used correctly in their respective ASOTs

Data Governance:

- Develop Common Data Model in alignment with program goals, digital ecosystem, and customer needs
- Deploy data governance with ERBs to ensure adherence
  - Develop checklists/template for these boards to consult
- Each engineer needs to understand the importance of data and data relationships in developing a system that can be maintained for the life of the program



Example Data Ontology

Data Governance takes a central place throughout the Program Lifecycle

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Image Credit: Northrop Grumman, Trisha Hinners

Digital Processes & Education

Digital Process modernization and Digital Education is crucial to ensure that we're developing our data in a way that not only provides efficiency of using ASOTs, but also ensures data consistency and integrity

Developing engineering, programmatic, and manufacturing products needs to be done in a way that uses the streamlined processes enabled by digital transformation while conforming to data standards

Each company has their own in-house developed processes, work instructions, and required training based on the methodologies, tools, and specific domains they may execute within

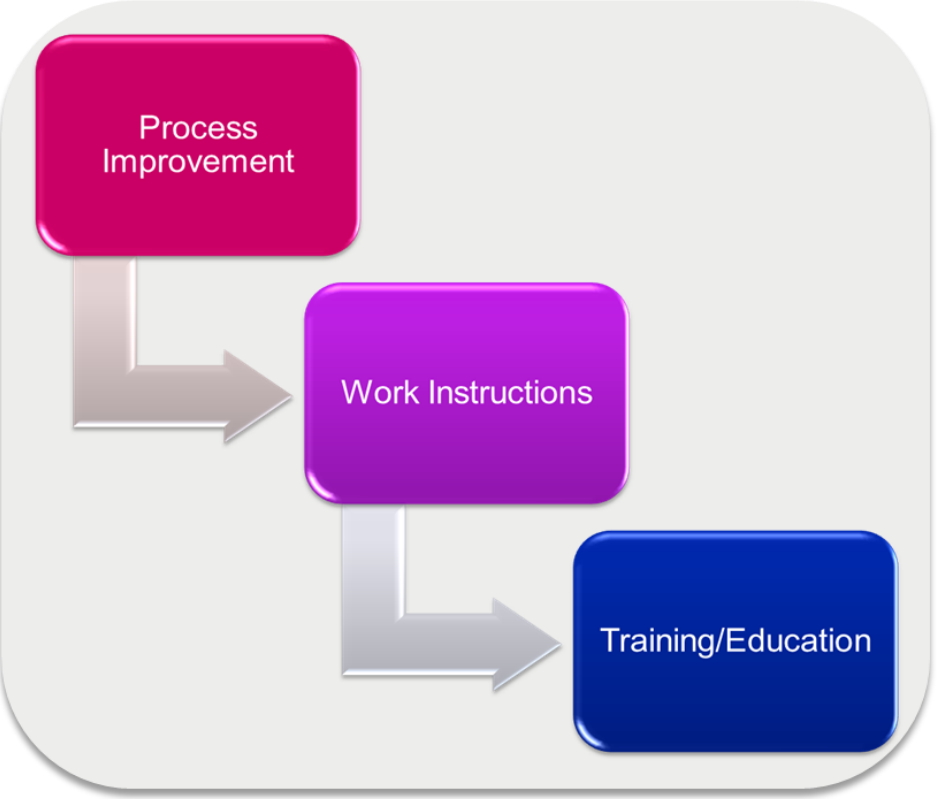
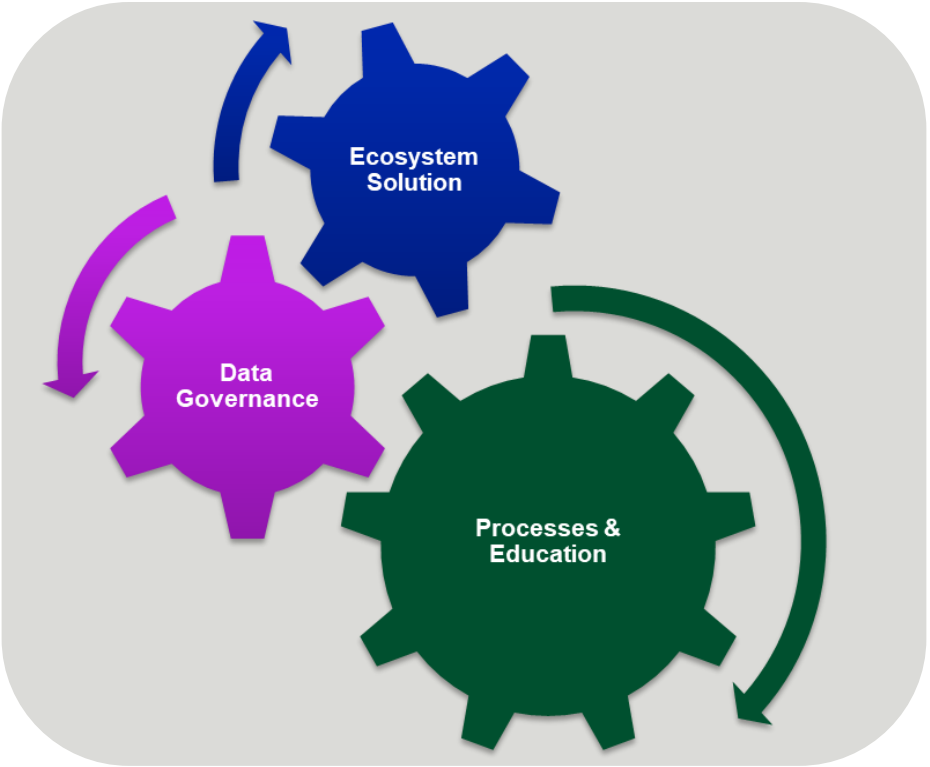


Image Credit: Northrop Grumman, Trisha Hinners

It's Even More Complex…

- **Data Driven Ecosystems are dependent on:**
  - Digital Ecosystem Solutions
  - Data Governance
  - Process Modernization
  - Digital Education and Coaching
- **Each of these requires large technical and cultural change on behalf of the organization**
- **Companies make internal investments on**
  - Methodologies, Common Data Models, Data Governance approaches, processes, and the education resources



What happens if any of these parameters such as the modeling methodology or the common data model change? – suddenly that investment is less useful

Interoperability is crucial for the system to work, but to who's definitions? And how do we overcome decades of internal best practices to fit in a different box? What are the data standards we should adopt?

Image Credit: Northrop Grumman, Trisha Hinners

The Problem and Interoperability

To achieve a digital thread, we need to connect data, information, and insights from various domains across the lifecycle

This has several big challenges:

- Authoritative data is spread across a multitude of tools
- Tools were not designed to talk to each other – especially those from different vendors
- Selecting tools from a single vendor to get out of the box threading results in vendor lock in
- Tool selections can be different from our partners and customers creating issues with interoperability between organizations
- We all do not define our models in the same way – nor should we (we're all solving different problems at different scale)

Department of Defense, "DoD Digital Engineering Strategy," June 2018.
"The appearance of U.S. Department of Defense (DoD) visual information does not imply or constitute DoD endorsement.").

Single ASOT Interoperability - MBSE

- Breaking the problem down into a single ASOT, I'll use Model-Based Systems Engineering as our starting example
  - MBSE performs a very important and integral part of the ecosystem
  - Provides systems engineering ASOT and all the efficiencies associated with being Model-Driven
  - Many things touch requirements/architecture/verification, so it provides the glue for much of the digital thread through engineering
- Requires knowing our profiles, stereotypes, and allowed data relationships before we even create a model for our effort
- Challenging but doable within an organization
- When extended out to partners and customers where we also need connectivity things can start to break down

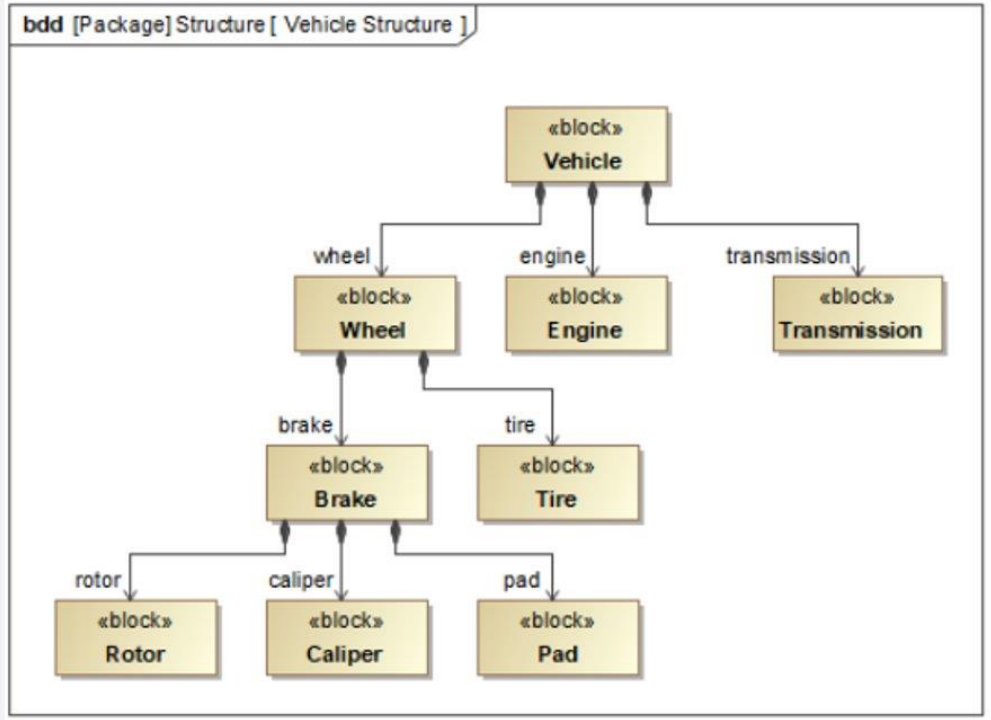


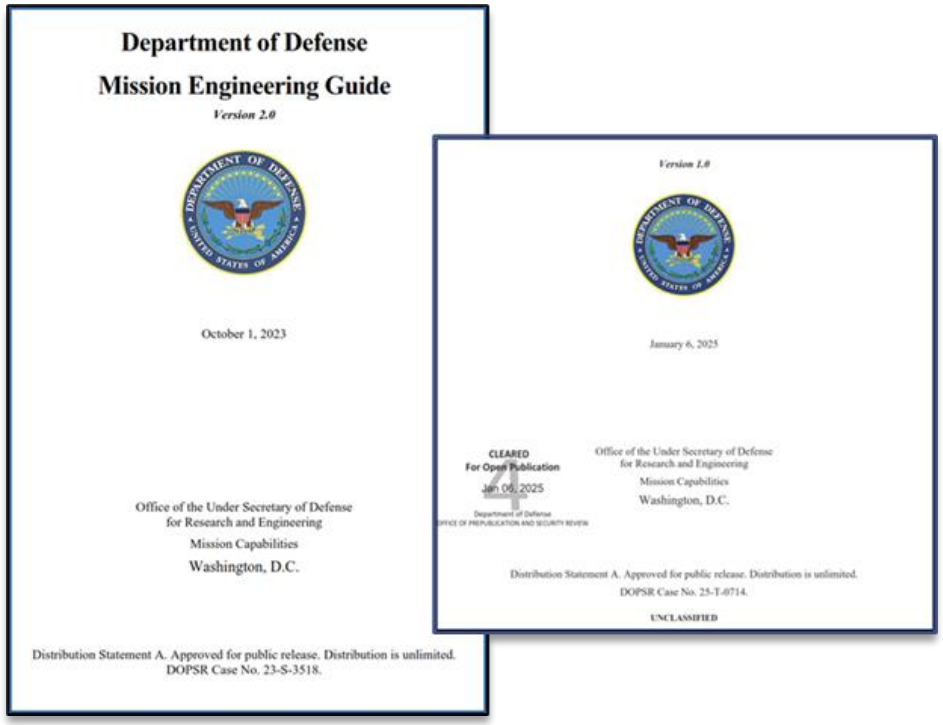
Image Credit: Northrop Grumman, Carreon (23-1991)

How Is This Inter-organizational Interoperability Being Solved Today?

- The current solution we're seeing either from our customers or prime contractors is adherence to a style guide or profile with a set of validation rules
- Examples include:
  - SAIC style guide*, ORCUS** (Johns Hopkins APL), DoD Mission Engineering Guide, MSIW, and many others
  - Some of these are SysML based others are UAF based
- This comes with a set of benefits and drawbacks
  - Benefits
    - Common data definitions, diagram content, and "almost" guaranteed connectivity between models created by different organizations
  - Drawbacks
    - Can be more costly for organizations to develop models
      - Multiple approaches need to be taught
      - Internal digital capabilities and processes may not align to the prescribed style guide
    - Profile of choice (while with the best intentions) may not be adequate to define/describe the architecture or problem

*"Digital Engineering Validation Tool", SAIC, December 2019

**ORCUS (Object Recognition for Compliance, Usability, and Sustainment) Cameo Plugin 2.0, Johns Hopkins, APL



"Mission Engineering Guide," Office of the Deputy Director for Engineering, Office of the Under Secretary of Defense for Research and Engineering, Washington, DC: U.S. Department of Defense (DoD), November 2020 "The appearance of U.S. Department of Defense (DoD) visual information does not imply or constitute DoD endorsement.").

Conflicts Between the Instructions…

DoD Mission Engineering Guide (MEG 2.0)	SAIC Digital Engineering Style Guide & Validation Tool
UAFML Based approach	**SysML Based Approach**
Mission Engineering steps overlayed on UAF Viewpoints	**No counterpart**
Options for SysML after the Mission Engineering phase	**Interpreted to not allow customization to mimic UAF. No planned support for MEG 2.0**
Swimlane preferred approach to Activity diagrams	**Operations based approach to activity diagrams.**

- This is only a short comparison between two style guides where there are many additional style guides, validation suites, and approaches not only for our customers, but internally to each company as well
- To accommodate each approach investments are required in:
  - Training
  - Processes
  - Tool licensing
  - Unique Ecosystem and infrastructure variants

Implementation and sustainment costs skyrocket when accommodating multiple approaches!

What Happens When Multiple ASOTs Are Involved?

- As we start to consider the problem of interoperability a little further it extends beyond a single ASOT and starts to consider how we connect to others ASOTs within the lifecycle
- This is a very complex problem! And organizations have been investing in their own Digital Ecosystems to enable the Digital Thread and facilitate data sharing between ASOTs
- When external validation rules are imposed, we see a similar cost driver emerge again where to accommodate adherence to the style guide requires more and more variants of an ecosystem, processes, training, and governance

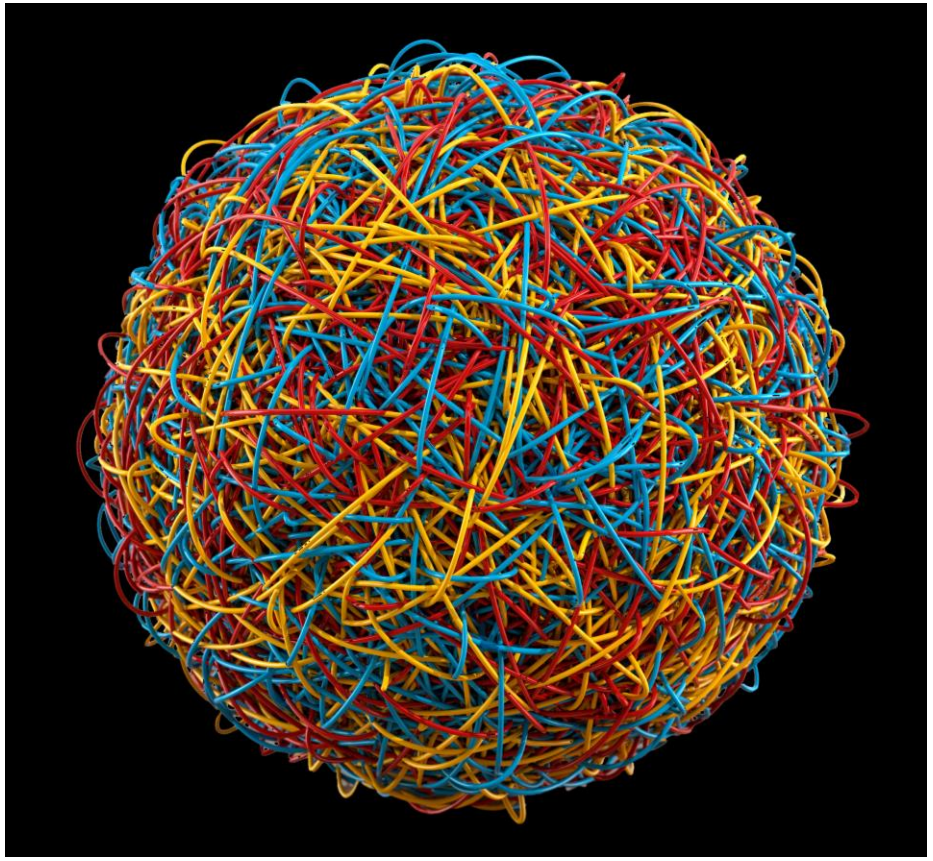


Image Credit: Getty Images

How Do We Solve the Problem Together as a Community?

- Communicate with our customers about our integrated ecosystem solutions and their dependency on our internal methodologies and data definitions which may clash with their prescribed modeling methodology or profiles
  - Clearly communicate the increased cost and schedule to deliver a system when we deviate from our internal processes
- Proposed actions for us going forward:
  - Industry/customer community develop ICDs to ensure our models fit together without dictating modeling methodologies
  - Work closely with vendors like Dassault and Sodius to develop model-translation tools
    - Enables us to model such that we can reuse our data engineering suites while also meeting customer requested formats and being interoperable with each other when partnering

Image Credit: Getty Images

Communication and Collaboration is Key to Enabling our Digital Future

Summary & Conclusions

- Data-Centric Digital Ecosystems have the promise to create efficiencies and cost/schedule savings in program execution while improving first-time quality but is only possible with strong data governance
- Up until recently, Model-Based efforts have had the flexibility and freedom to choose their own methodologies and approaches
- With the need for integrated, consistent data within a Digital Ecosystem, interoperability internally and externally becomes crucial
- Communication and collaboration both with industry partners and our customers will help to address all stakeholder needs, find common solutions, while still maximizing reuse of each of our internal investments

Image Credit: Getty Images