# Digital Thread Standards, Frameworks, Tools & Technologies

*Workshop*

December 2023



Boeing | RROI # 23-179797-ETT

# Speaker Profile

Dr. Robert Rencher
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As a Sr. System Engineer, Robert provides leadership in facilitating a common understanding, strategic roadmap, and functional utilization of Digital Twins and Digital Threads standards across Boeing and the aerospace industry. Robert represents Boeing in the aerospace and defense industry standards bodies (AIA, ISO, SAE International, OMG Digital Twin Consortium, and the A&D PLM Action Group) to establish standards for the design and operational deployment of digital twin and digital thread. In prior assignments, Robert's design and technical expertise has been applied in the identification, validation, and integration of strategic Information Technology solutions for Boeing and the aerospace industry.

## COMMERCIAL AIRPLANES

A complete family of the world's most versatile commercial airplanes

## DEFENSE, SPACE & SECURITY

The world's leader in delivering decisive mission advantage to its global customers through cutting-edge capabilities

## GLOBAL SERVICES

A dedicated services business focused on keeping the world's fleet flying safely, sustainably and efficiently




**Protect, connect and explore our world and beyond**

Boeing | RROI # 23-179797-ETT

# OUR VALUES

## HOW WE OPERATE:

**Start with engineering excellence**

**Be accountable — from beginning to end**

**Apply Lean principles — eliminate traveled work**

**Crush bureaucracy**

**Reward predictability and stability — everywhere in our business**

## HOW WE ACT:

**Lead on safety, quality, integrity and sustainability**

**Foster a Just Culture grounded in humility, inclusion and transparency**

**Import best leadership practices**

**Earn stakeholder trust and preference**

**Respect one another and advance a global, diverse team**

**Innovate and operate to make the world better**

# OUR PRIORITIES

**Live our values**

**Rebuild trust**

**Inculcate Safety and Quality Management Systems and Lean**

**Restore operational stability and business health**

**Invest in capabilities for Boeing's future**

**Attract, retain and develop the best global, diverse talent, intent on building careers in aerospace**

**We'll achieve our priorities by empowering our people**

# WHERE WE ARE

## Global Boeing

**$66.6 BILLION**

in 2022 revenues

Products and services support to customers in more than **150 COUNTRIES**

Manufacturing, service and technology partnerships with companies around the world

Contracts with more than **12,000** suppliers globally

More than **158,000 BOEING EMPLOYEES**

across the United States and in more than **70 COUNTRIES**

Research, design and technology development centers and programs in multiple countries


of commercial airplane revenue historically from customers outside the United States


**Partnering worldwide for mutual growth and prosperity**

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# Abstract – Digital Thread Standards

This workshop presentation introduces and discusses opportunities with establishing Digital Thread standards. During the workshop discussion, questions for digital thread standards will be asked of participants:

- Is there a need for Digital Thread Standards?
- How should Digital Thread Standards be Organized?
- When should Digital Thread Standards be utilized?

An Approach to Organizing and Evaluating Digital Thread Standards will be proposed and discussed. Lastly, we will capture questions you may have, provide answers and how to follow-up through participation with the SAE international G-31 Digital Communications committee.

# Introduction

- The Digital Thread: Opportunity/Problem/Challenge
- First Question – Is there a need for Digital Thread Standards?
- PLM Standards – Digital Thread
- Second Question – Organizing Digital Thread Standards?
- Standards Frameworks
- Third Question – Utilization of Digital Thread Standards?
- An Approach to Organizing and Evaluating Digital Thread Standards
- Many Questions – Few Answers

# The Digital Thread: Opportunity/Problem/Challenge

- The Digital Thread – catalyst of interest
- Resulting in a resurgent interest in data and information
- Who is responsible for managing data and information
  - Information Technology – System Engineering?
- How do we share information between organizations – between companies
- Are there standards that we can use to share/exchange data and information?

# First Question – Digital Thread Standards

- Where do we find Digital Thread standards?
- Are you aware of any Digital Thread standards?

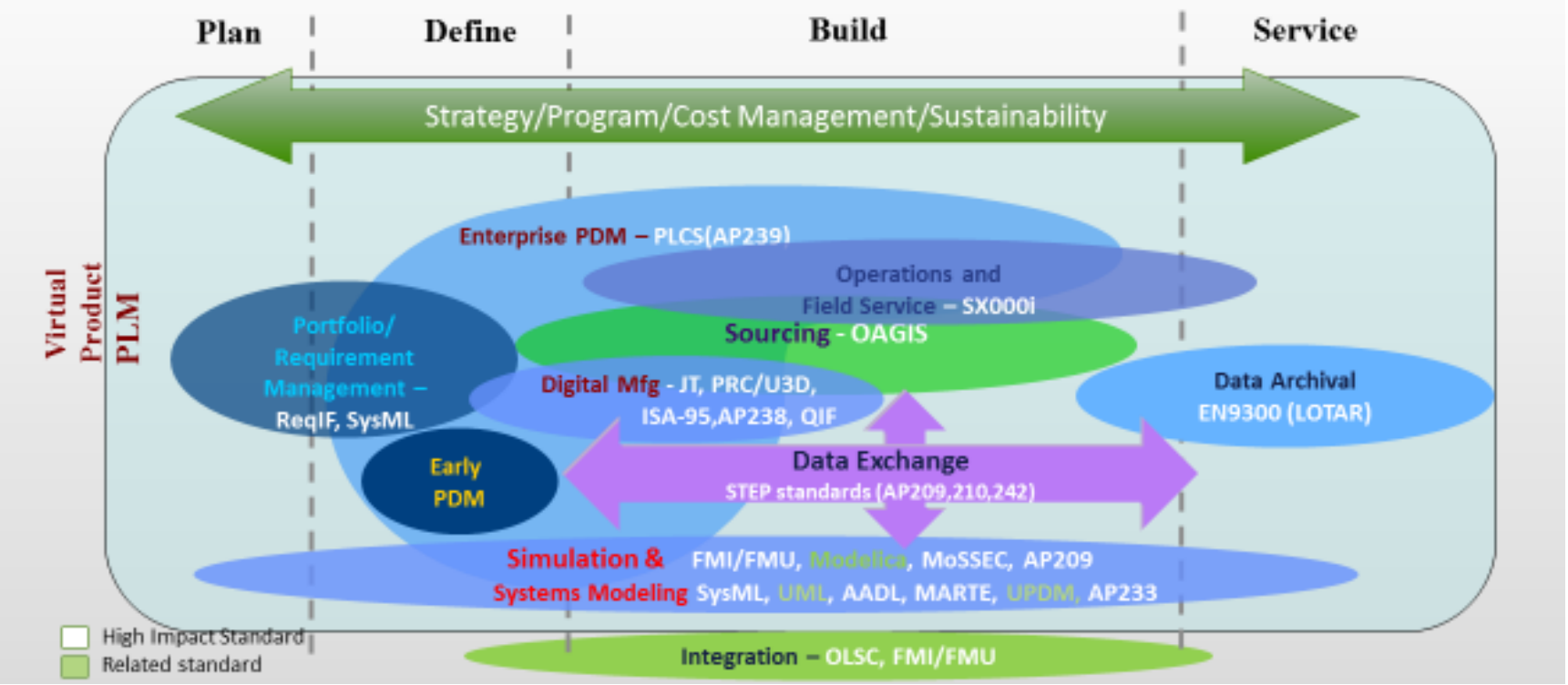
# PLM Standards – Digital Thread

- Over 25 standards organizations are defining digital thread standards.

| Standards Body Acronym | Organization Title | Standards Type [Artifacts, Models/Data, Tools/Methods] | Organization URL |
|---|---|---|---|
| AIAA | American Institute of Aeronautics and Astronautics | Artifacts | https://www.aiaa.org/ |
| AIA | Aerospace Industries Association | Artifacts | https://www.aia-aerospace.org/about/ |
| AFNeT | Association of Internet users and networked Society | Models/Data, Tools/Methods | https://www.afnet.fr/en/ |
| AFNOR | Association Française de Normalisation | Artifacts, Tools/Methods | https://www.afnor.org/en/ |
| ANSI | American National Standards Institute | Models/Data | https://www.ansi.org/ |
| ASD-STAN | AeroSpace and Defence Industries Association – Standards | Artifacts, Models/Data | https://asd-stan.org/ |
| ASME | American Association of Mechanical Engineers | Tools/Methods | https://www.asme.org |
| ATA | ATA e-Business Program | Models/Data | https://ataebiz.org/ |
| INCOSE | International Council on Systems Engineering | Tools/Methods | https://www.incose.org/ |
| ISO | International Organization for Standardization | Models/Data | https://www.iso.org/home.html |
| LOTAR | Long Term Archiving and Retrieval | Models/Data | https://lotar-international.org |
| Modelica | The Modelica Association | Models/Data, Tools/Methods | https://modelica.org/ |
| NAFEMS | National Agency for Finite Element Methods and Standards | Models/Data, Tools/Methods | https://www.nafems.org/ |
| NIST | National Institute of Standards and Technology | Artifacts, Models/Data | https://www.nist.gov/ |
| NQA-1 | Nuclear Quality Assurance Certification Program | | https://www.nqa.com/en-us |
| OAGi | Open Applications Group Integration | Artifacts | https://www.oagi.org |

Source: CIMdata A&D PLM AG Digital Twin/Thread Project [https://www.cimdata.com/en/memberships/aerospace-defense-plm-action-group]

# High Level View of Digital Thread Standards

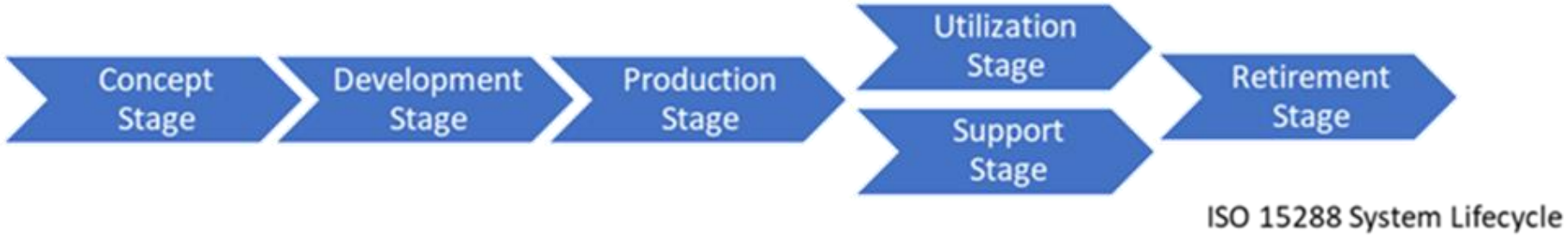



- There is overlap between the data thread standards across various product lifecycle stages
- Potential opportunities to consolidate and streamline the data thread standards
- Increased need to monitor the level of digital thread standards being implemented across industries
- “Digital Thread Index” could be an effective way to measure the efficacy of Digital thread data standards

Source: SAE International G31 Digital Communications Committee

# Second Question – Organizing Digital Thread Standards

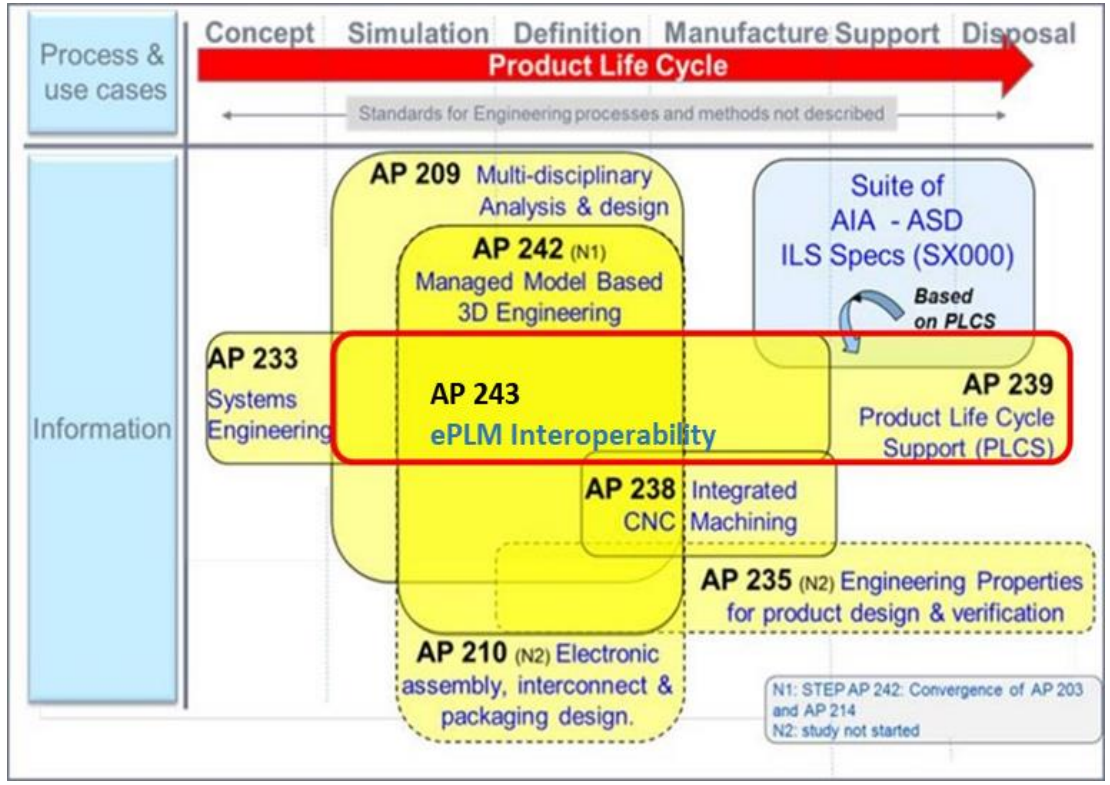
- How should Digital Thread Standards be organized?



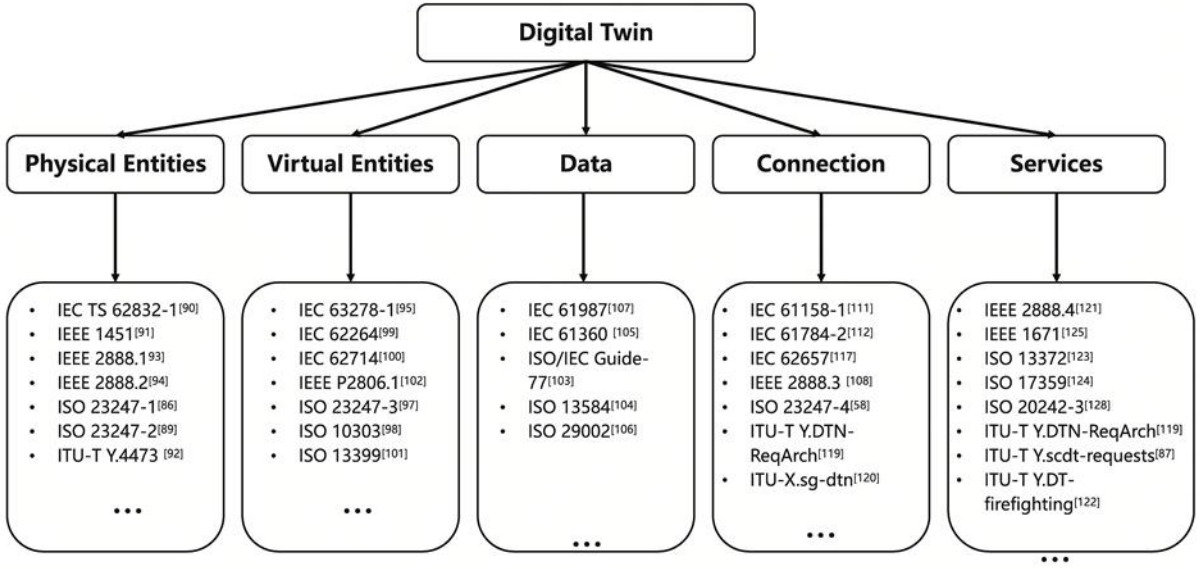

ISO 15288 System Lifecycle

# Standards Frameworks

*Reference frameworks from industry*




STEP Application Protocol (AP) Standards

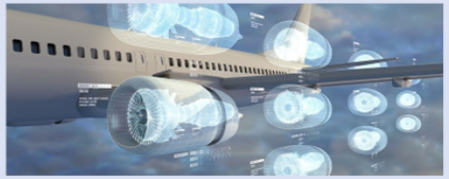



Digital Twin Standards by Type (Wang et al. (2022)

Source: CIMdata A&D PLM AG Digital Twin/Thread Project
[https://www.cimdata.com/en/memberships/aerospace-defense-plm-action-group]

# Organizing Digital Thread Standards

**Digital Twin/Thread Definition Framework**



| | | Supplier | OEM | | | | Customer/User/Owner/Operator | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Part/ Component/ Material | Requirements | Design | Engineer | Manufacture | Operation | Maintenance | Disposition |
| **Business** | Artifacts | | | | | | | | |
| **System** | Models and Data | | | | | | | | |
| **Technical** | Tools and Methods | | | | | | | | |

- An organizing framework – Product Lifecycle
- Align Standards to the product lifecycle

Source: CIMdata A&D PLM AG Digital Twin/Thread Project [https://www.cimdata.com/en/memberships/aerospace-defense-plm-action-group]

# Third Question – Utilization Digital Thread Standards

- How do we integrate digital thread standards?

# Aerospace OEMs Standards Utilization

| Domain | High Impact Standard | Leading Organizations: Solution Providers | Leading Organizations: Industrial Firms |
|---|---|---|---|
| MBSE | | | |
| | FMI/FMU | Numerous M&S software providers | Widespread automotive use |
| | SysML | Siemens PLM (LMS), NoMagic, PTC (ATEGO) | Large A&D firms (Boeing, Airbus etc.), NASA/JPL |
| | MARTE | ignore | ignore |
| | AADL | CMU/SEI | Boeing |
| | MoSSEC | Dassault, Siemens PLM, MSC, Eurostep | Airbus |
| | ISO 10303 Part 209 | Jotne | LM Aerospace |
| | ISO 10303 Part 233 | Siemens PLM, IBM Rational | Large A&D firms (Boeing, Airbus etc.) |
| MBD | | | |
| | ISO 10303 Part 210 | No COTS implementation | None |
| | ISO 10303 Part 238 | No COTS implementation | GM, Boeing, Siemens |
| | ISO 10303 Part 242 ed1 & ed2 | PLM providers are working on ed2 implem | Large A&D firms (Boeing, Airbus etc.) |
| Advanced Mfg & Robotics | | | |
| | QIF | Siemens PLM | LM, Honeywell |
| PLM Data | | | |
| | ReqIF | Siemens PLM, PTC, IBM Rational | German Automotive firms |
| | VDA 4968 VEC KBL | ignore | ignore |
| | OSLC | IBM, Siemens PLM, PTC, Aras | Numerous |
| | PRC/U3D | Siemens PLM | Numerous |
| | ISO 140306 JT V1&V2 | Siemens PLM | Numerous |
| | ISO 10303 Part 239 (PLCS) | Eurostep, PDES Inc. | Large A&D firms (Boeing, Airbus etc.) |
| PLM Process Domain | | | |
| | EN9300-120 ed1 (LOTAR) | No COTS implementation | Large A&D firms (Boeing, Airbus etc.) |

*There are many data standards available in each product life cycle domain and many of them are being used by major OEMs and there is an opportunity to consolidate with an efficient and effective data standards*

Source: SAE International G31 Digital Communications

# SAE International G31 Digital Communications

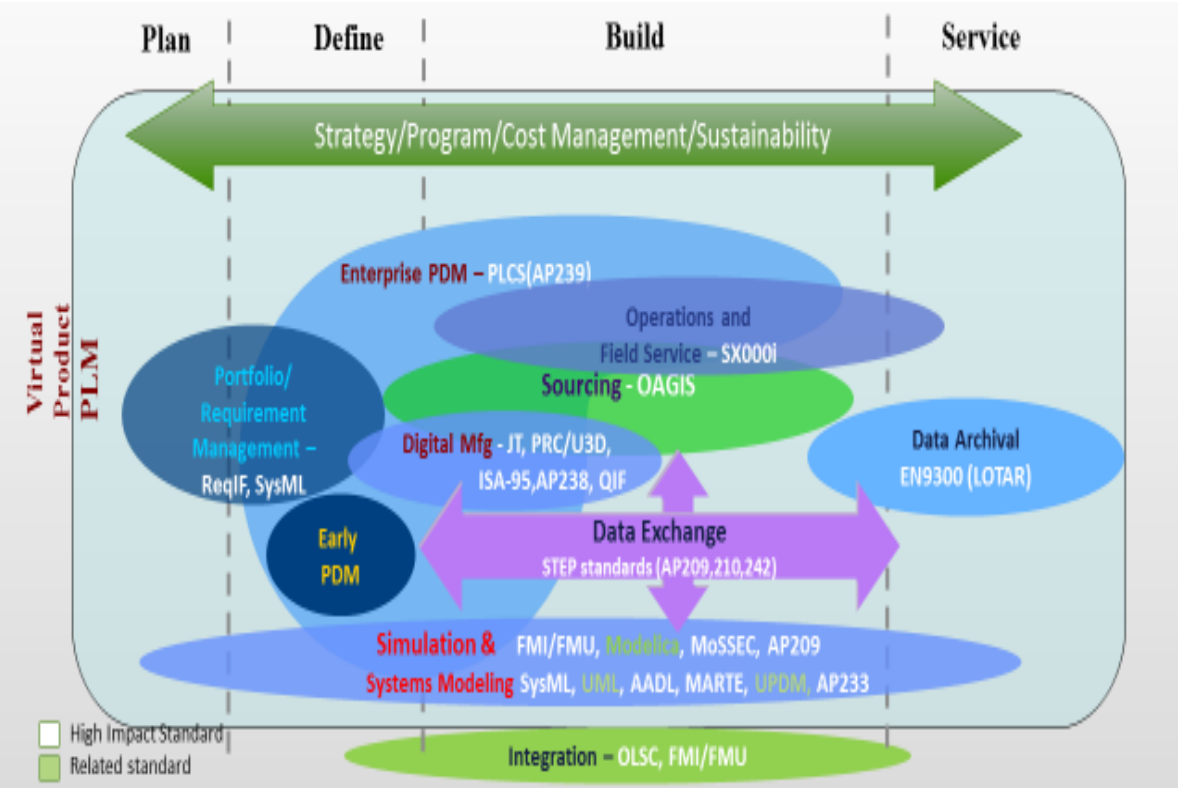
A Proposed Approach to Organizing Digital Thread Standards

Ravi Udali – Infosys

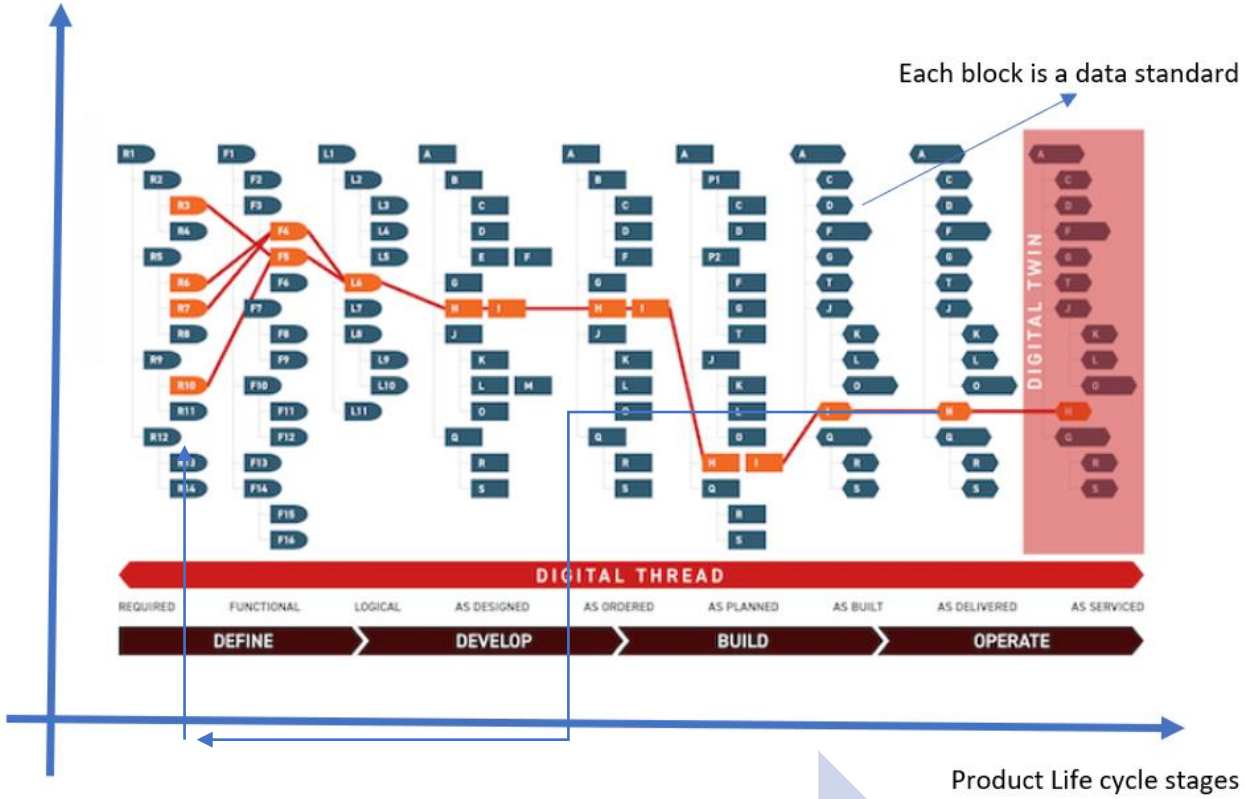
Robert Rencher - Boeing

# Digital Thread Standards - Monitoring

Current state of Digital thread data standards




Future state of Digital thread data standards




Identify high usage data standards

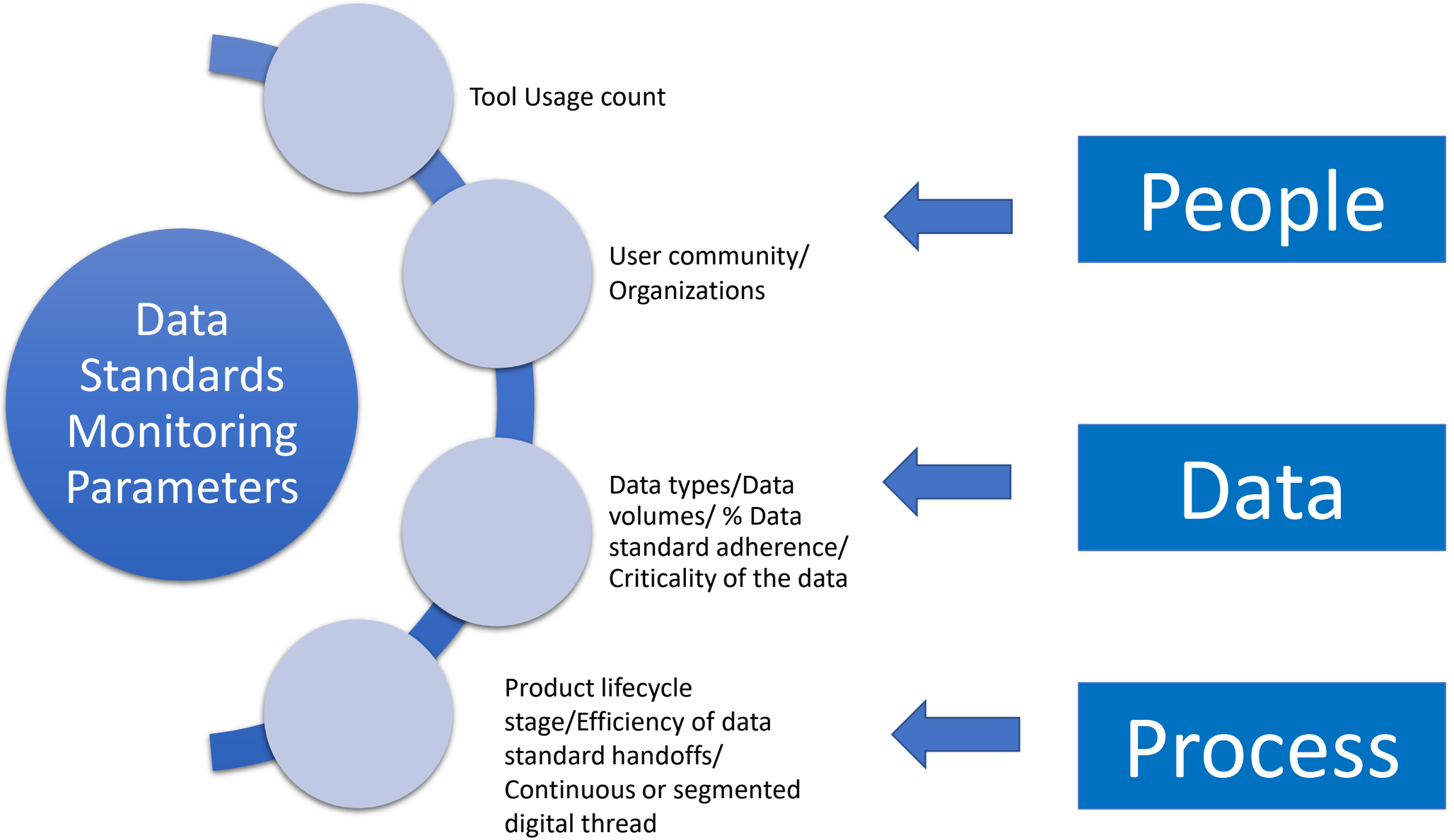
Calculate % adherence of data standards

Rank the applicable data standards based on volume of data blocks

Monitor and improve the standards applicability

Source: SAE International G31 Digital Communications

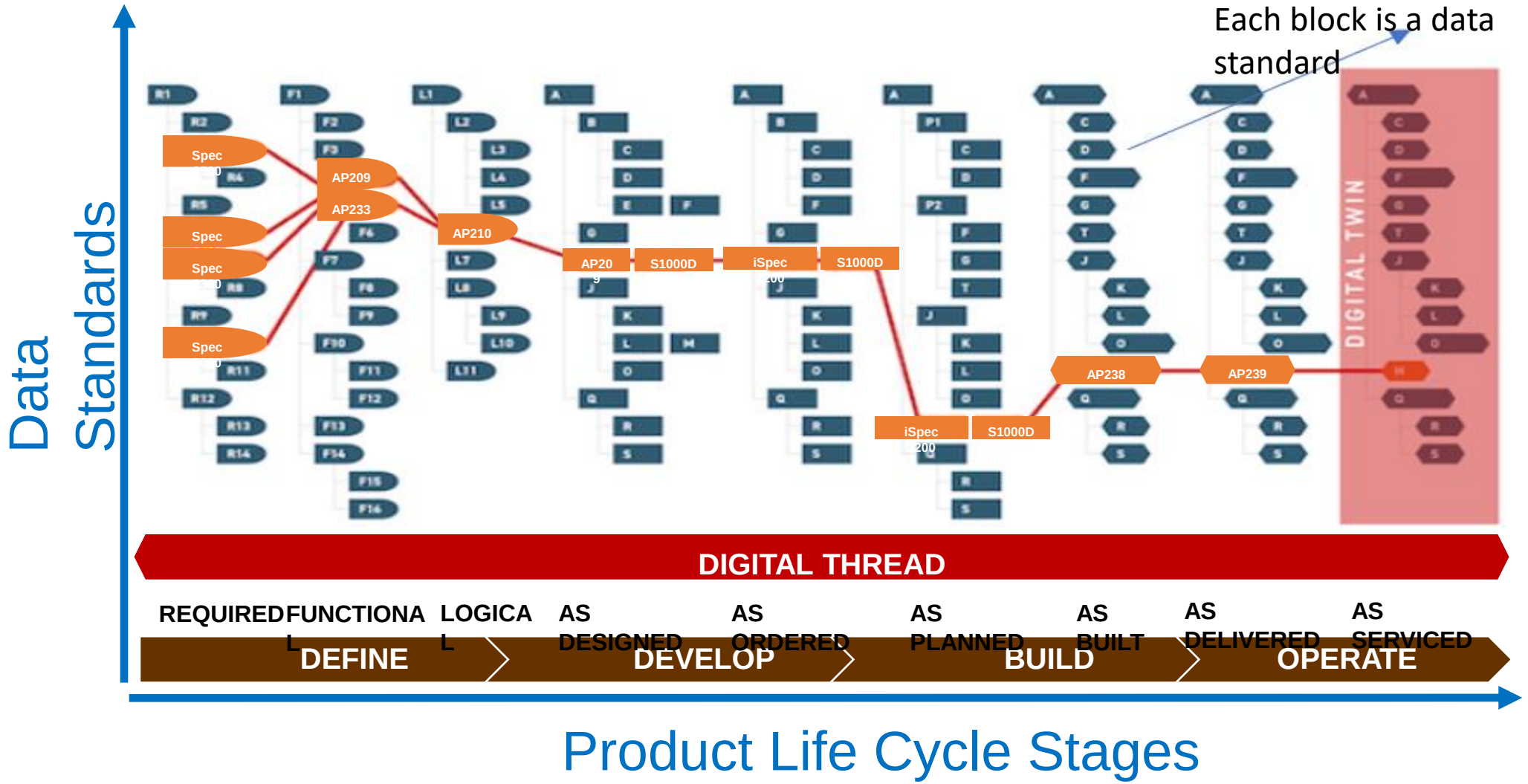
# Proposed Digital Thread Data Standards Monitoring parameters





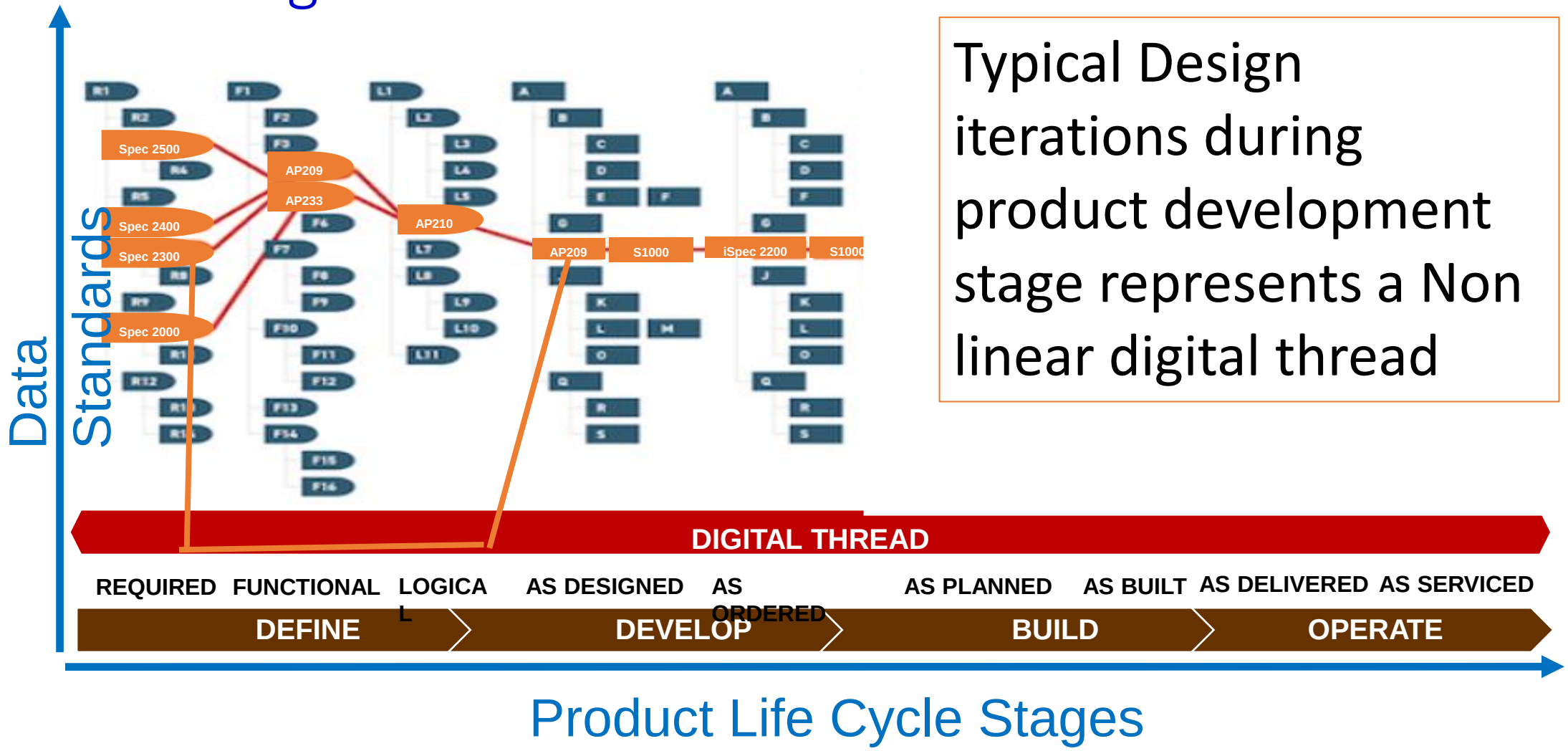

Source: SAE International G31 Digital Communications Committee

# Digital Thread Representation for PLM – Example of Linear sequential threading




Source: SAE International G31 Digital Communications Committee

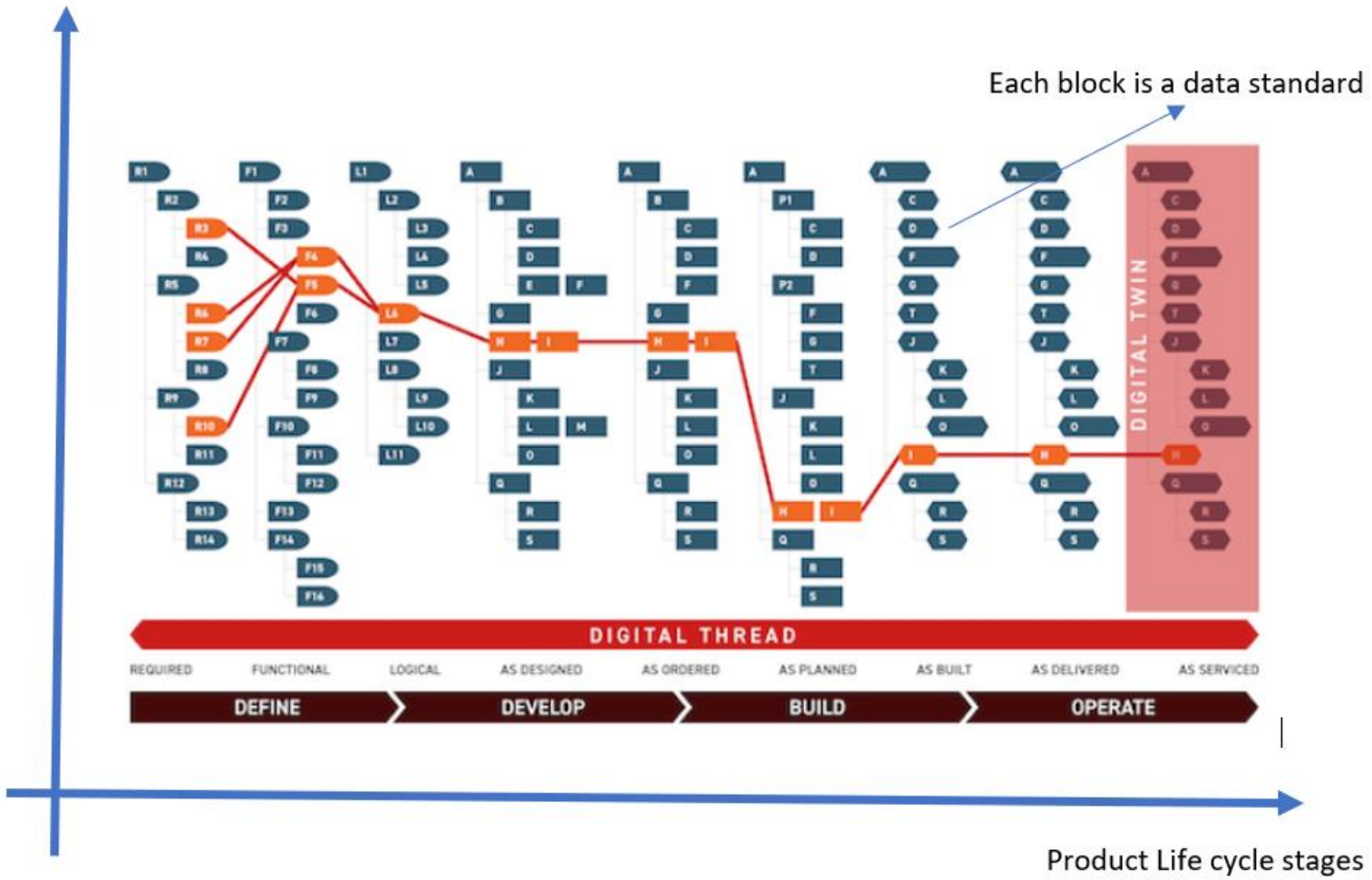
# Digital Thread Representation for Engineering – Example of Non Linear threading




Typical Design iterations during product development stage represents a Non linear digital thread

Source: SAE International G31 Digital Communications Committee

# Proposed Digital Thread Index Definition – Quantification of Effectiveness of Digital Thread



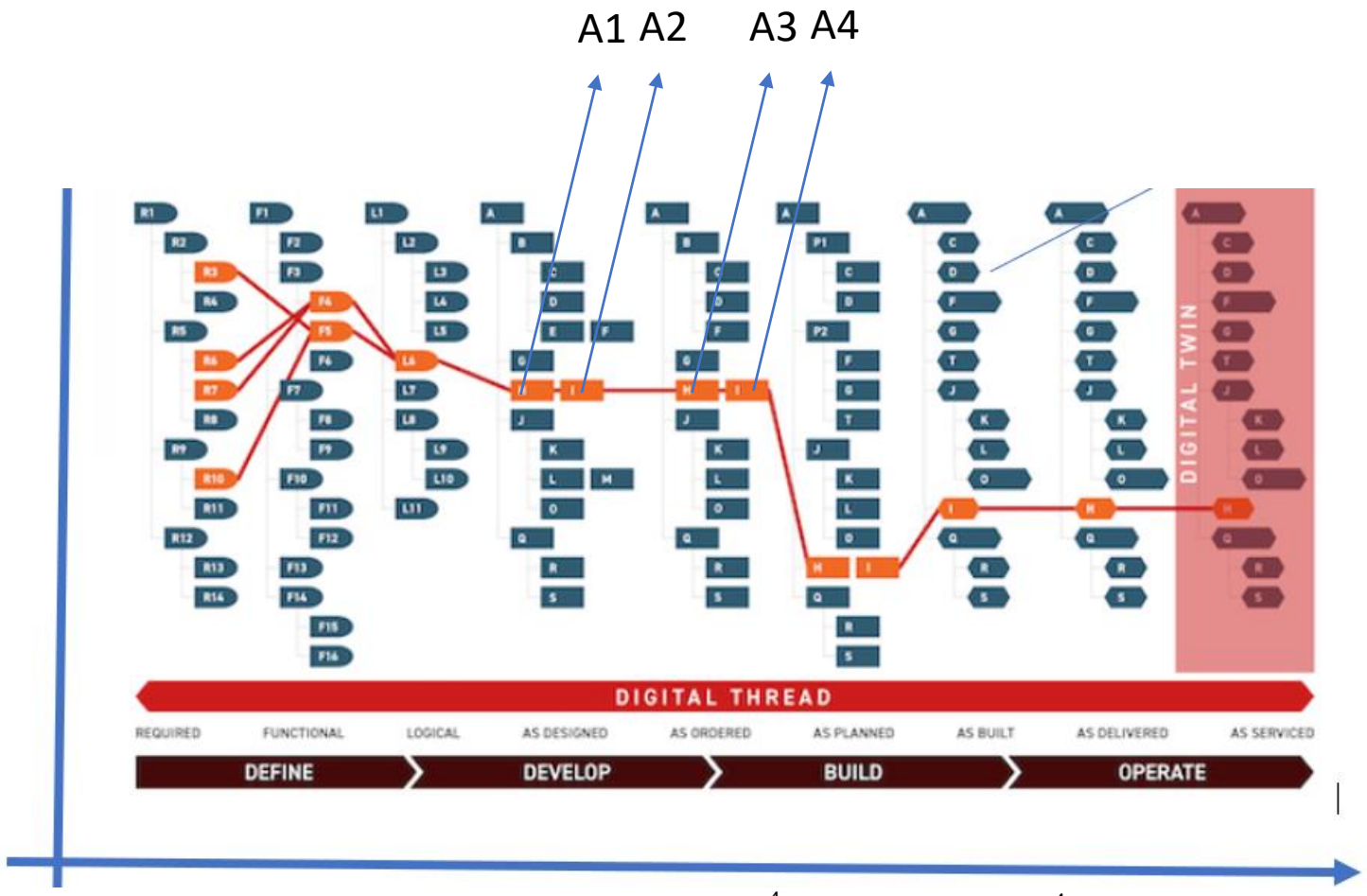

Source: SAE International G31 Digital Communications Committee

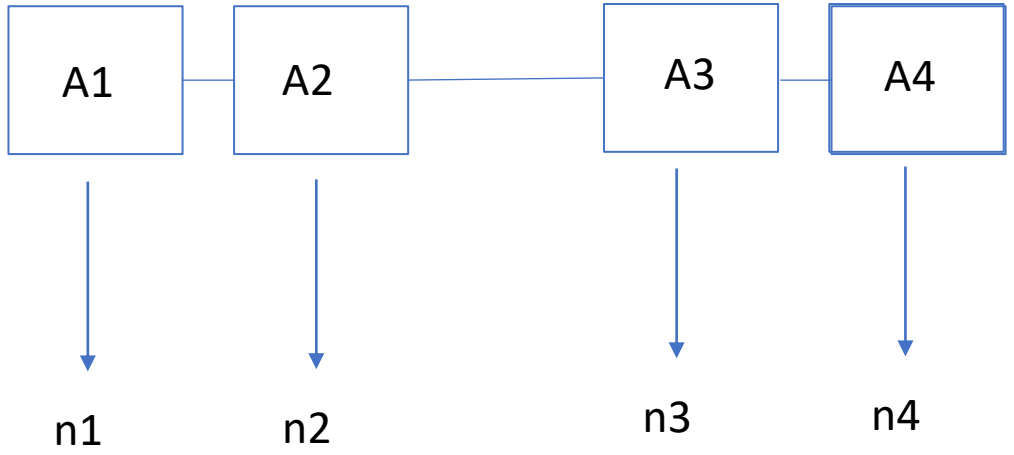
## Digital Thread Index

| | | |
|---|---|---|
| % adherence of data standard for each block | = | A |
| | * | |
| Efficiency of data transfer from one lifecycle stage to other | = | B |
| | * | |
| Extent of coverage across entire product lifecycle | = | C |
| | * | |
| Number of vertical data standards blocks | = | D |

# Digital Thread Index Definition – Factor A

**% adherence of data standard for each block** = **A**



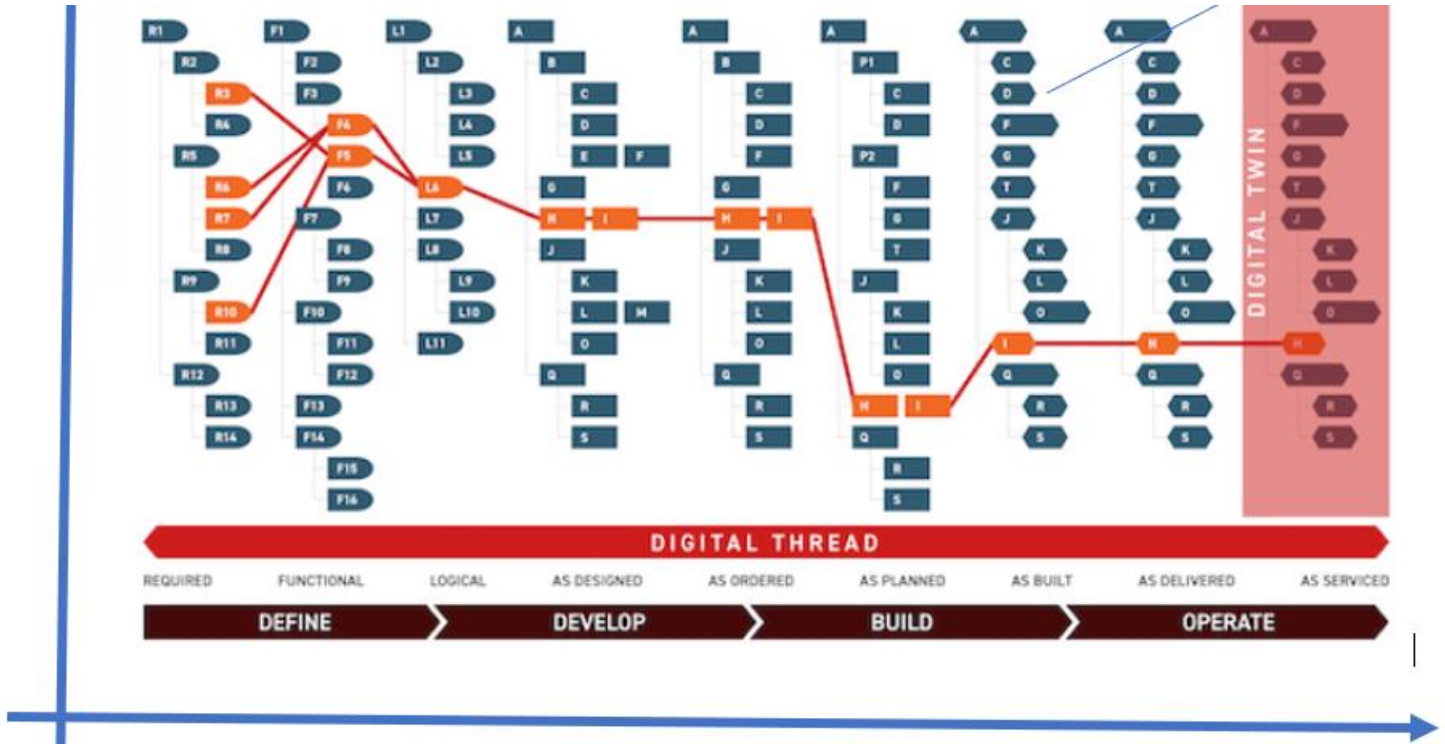

$$A_{Cumulative} = \sum_{i=1}^{4} Ai * ni \; / \; \sum_{i=1}^{4} Ai$$

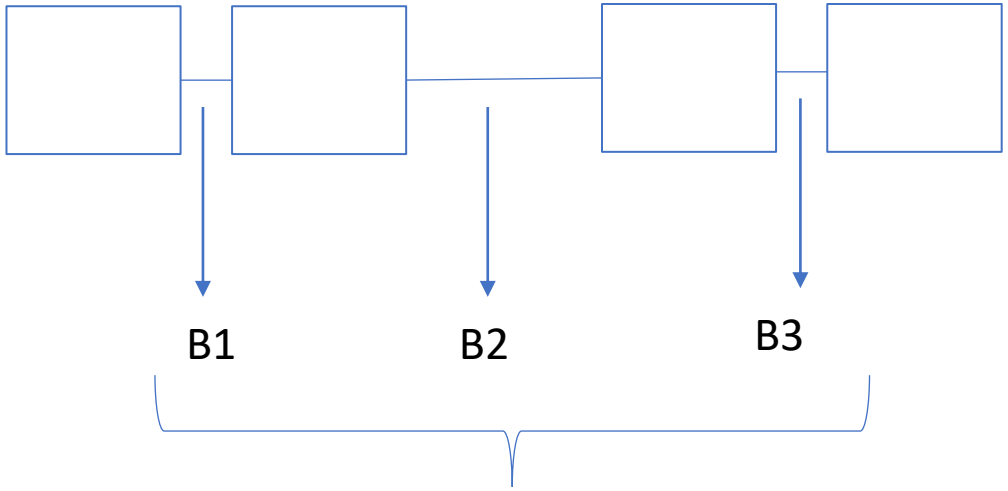
**n represents the criticality of the data (qualitative) , for example certification data, weight/cost data, performance/design data etc..**

Source: SAE International G31 Digital Communications Committee

# Digital Thread Index Definition – Factor B

**Efficiency of data transfer from one lifecycle stage to other** = **B**




Efficiency of data transfer (or) measure of extent of Digital thread breakage.. Primarily represents combination of speed and accuracy of data transfer

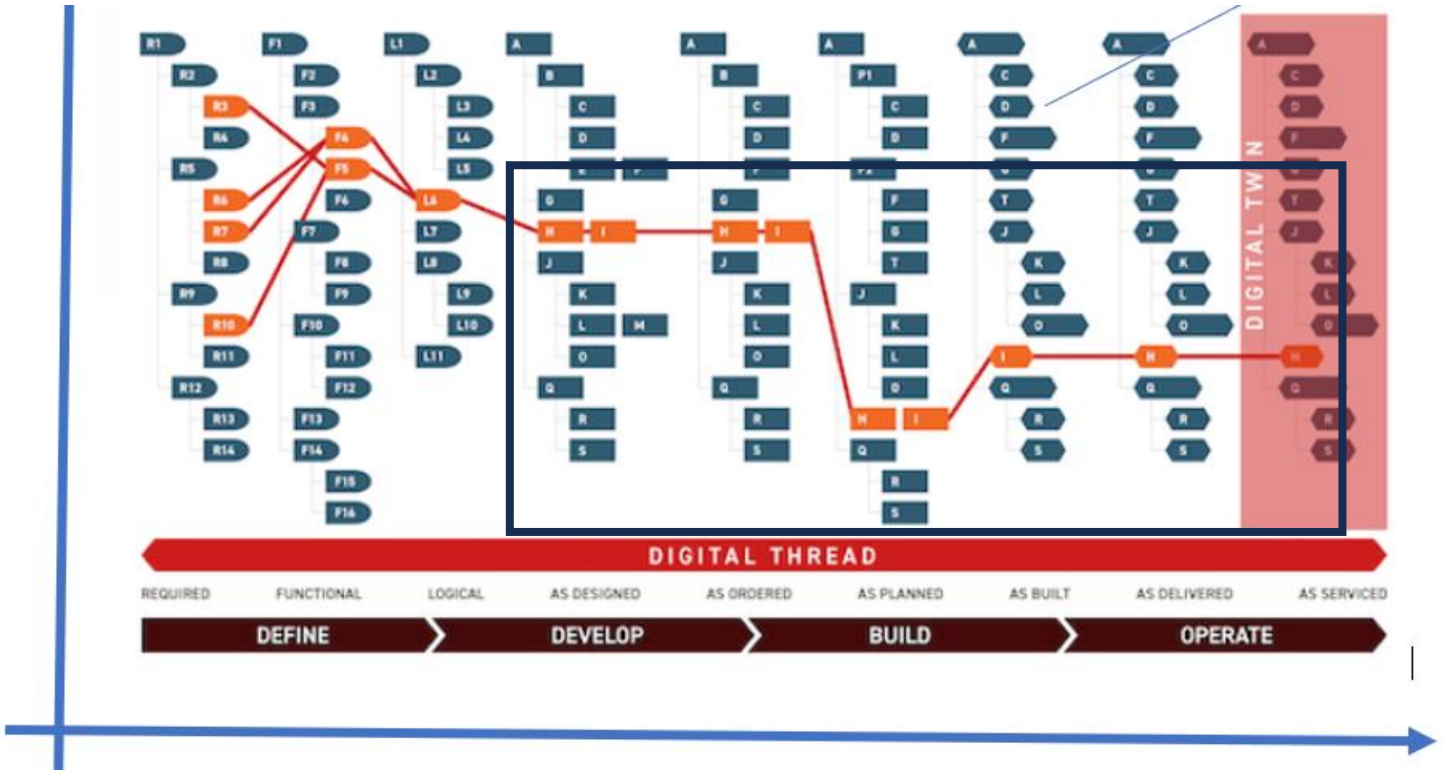
$B_{Cumulative}$ = Function of (B1, B2, B3)



Source: SAE International G31 Digital Communications Committee

# Digital Thread Index Definition – Factor C

**Extent of coverage across entire product lifecycle** = **C**




C1 – Continuous Digital thread

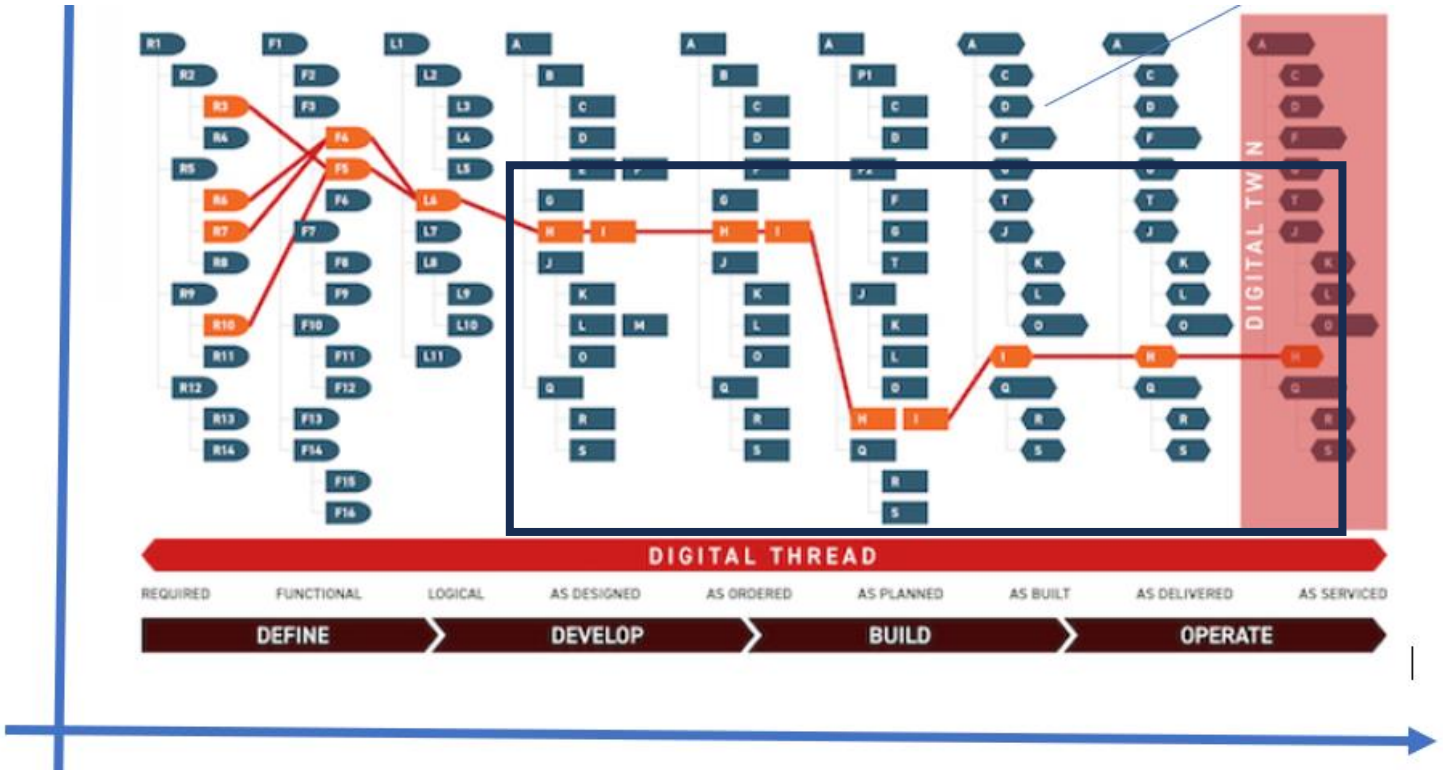
C2 – Segmented Digital thread

C3 – Hybrid Digital thread

$C_{Cumulative}$ = Function of (C1, C2, C3)

Source: SAE International G31 Digital Communications Committee

# Digital Thread Index Definition - Composite factor




Digital thread index is

A Cumulative * B Cumulative *
C Cumulative * D Cumulative

Source: SAE International G31 Digital Communications Committee

# Wrap up

- The Digital Thread: Opportunity/Problem/Challenge
- First Question – Digital Thread Standards?
- PLM Standards – Digital Thread
- Second Question – Organizing Digital Thread Standards?
- Standards Frameworks
- Third Question – Utilization Digital Thread Standards?
- An Approach to Organizing Digital Thread Standards

# Feedback and Questions?