



DIGITAL MODEL
Product Data
+
DIGITAL THREAD
Traceability
+
DIGITAL THREAD
Configuration
=



Reflecting on 40 Years of PDM/PLM: Are We Where We Wanted to Be

PLM Road Map™ & PDT North America 2025

PLM's Integral Role in Digital Transformation From Strategy to Execution

*Elevating PLM to an Enterprise Business Solution,
the PLM Professional's Road Map to Success*

CIMdata

May 7 & 8

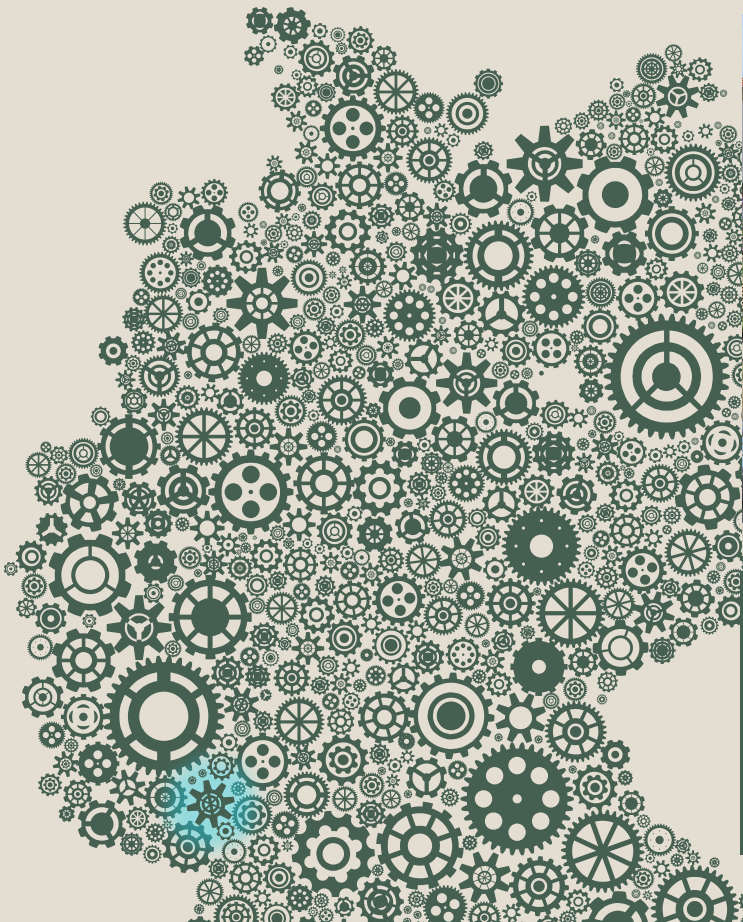
europstep

Prof. Dr.-Ing. Martin Eigner
EIGNER ENGINEERING CONSULT
Baden-Baden





Professor Dr.-Ing. Martin Eigner



2009 Awarded with **UNICUM Germany's Professor of the Year 2009**

2014 „Lehre Plus“ award of the University of Kaiserslautern for „Industry 4.0“, Information Technology and Crowd Engineering

- 1968 – 1971 **Toolmaker**
- 1971 – 1976 **University of Karlsruhe (TH)**
Studies in Mechanical Engineering and Economy
- 1977 – 1980 **University of Karlsruhe (TH)**
PhD Institute of Computer Applications in Design
- 1980 – 1985 **Robert Bosch GmbH**
Head of Department Technical IT and Organization, Electronic Predevelopment
- 1985 – 2003 **Eigner & Partner GmbH, AG, Inc.**
Solution Provider for PLM Solutions
Until 2001 chief executive office
Until 2003: chairman of the board / CTO
- since 2003 **EIGNER Engineering Consult (CEO)**
Consulting Company for Engineering Processes (PLM, CM, ERN/ECM, MBSE, BOM, MPP, ERP-Interface)
- since 2004 **University of Kaiserslautern**
until 10/17 **Institute of Virtual Product Engineering (VPE)**

- since 1992 **University of Karlsruhe (TH)** Guest Professor
- since 1999 **TU Sofia, Bulgaria** Visiting professor
- since 2017 **EGE-University, Izmir** Guest Professor
- Since 2014 Honored Member of the ProSTEP Association
- Since 2020 Beirat der Zeitschrift Zwf



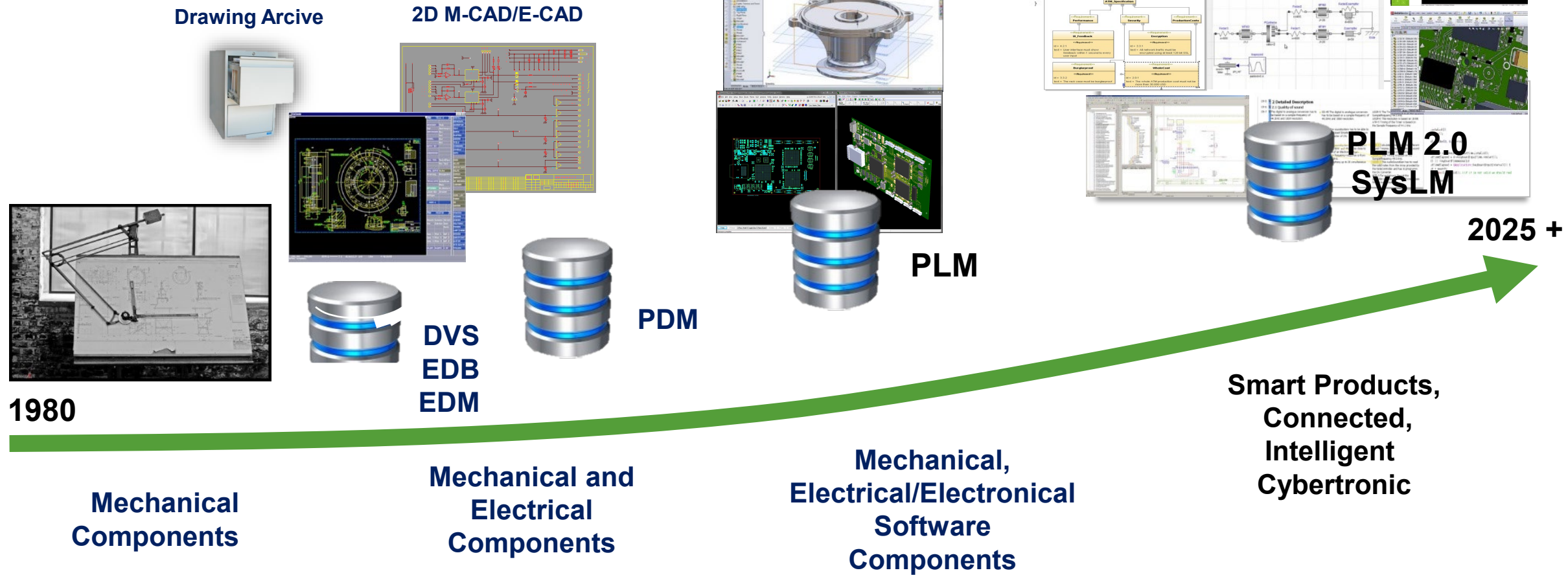
The History of PDM/PLM – An Overview



40 Years: DVS -> PDM -> PLM -> ?

Interdisciplinary, Model Based

Mechanic-focused, Document-centric



40 Years Mobilphone Technologie



Motorola Dynatac
1983



Motorola 3200
GSM 1992



Sharp J-SH04
2000



Apple Iphone
2007



Apple Iphone 16
mit Ultra Watch
2024



DVS
EDB
EDM



PDM



PLM



PLM 2.0
SysLM

1980

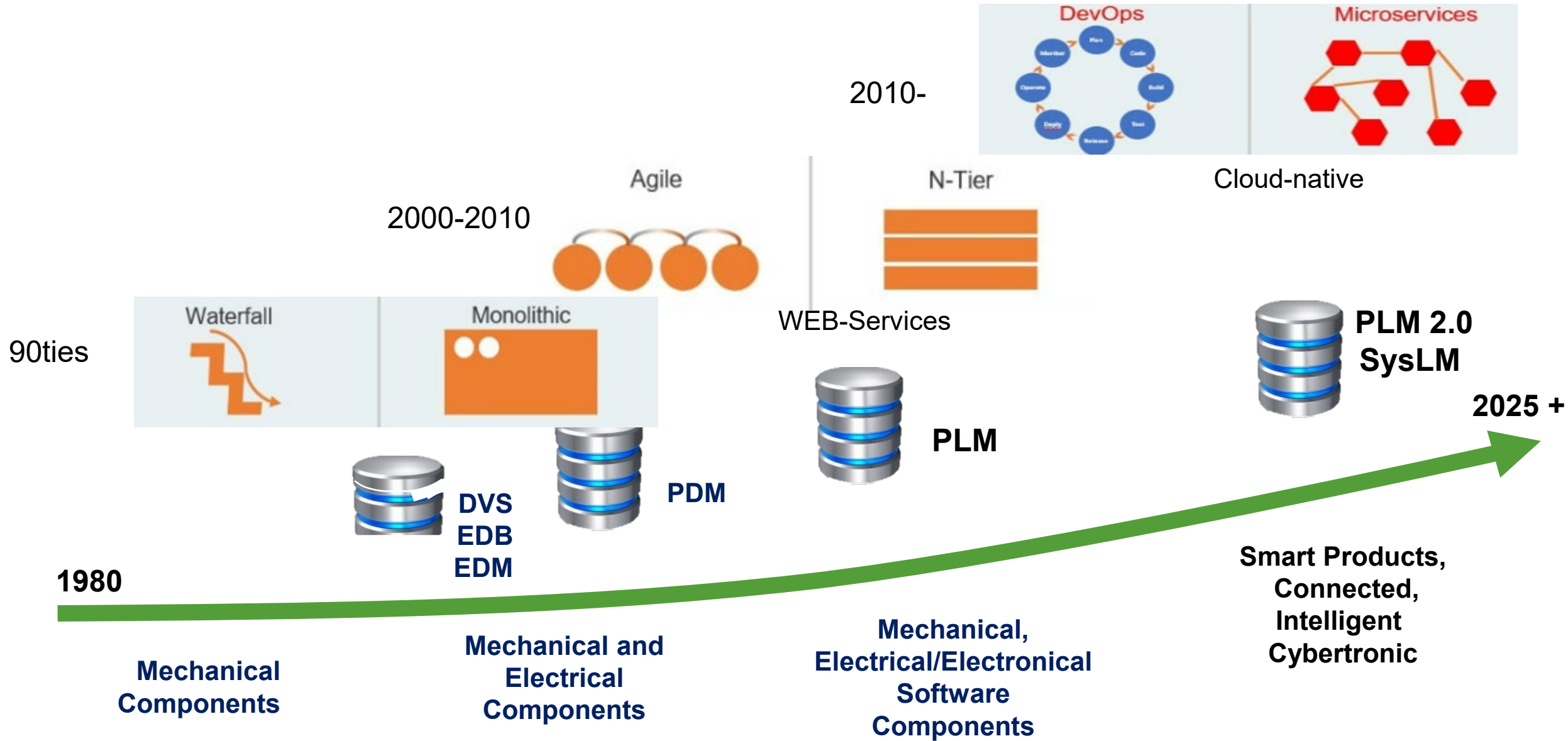
Mechanical
Components

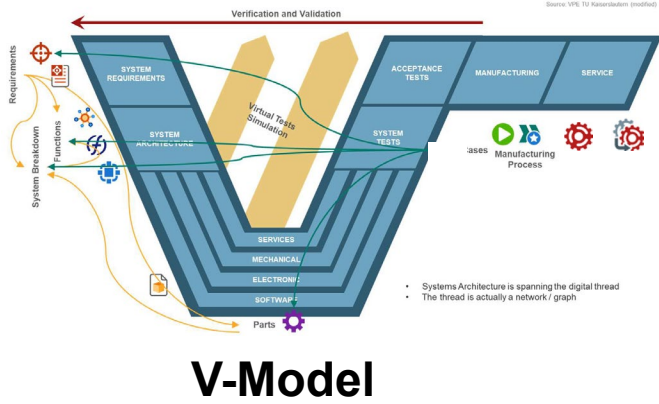
Mechanical and
Electrical
Components

Mechanical,
Electrical/Electronic
Software
Components

Smart Products,
Connected,
Intelligent
Cybertronic

2025 +





V-Model



MBSE

Lifecycle Assessment

Agile Development

WEB-Services

The Omniverse

Artificial Intelligence

Digital Thread and Twin

IoT/IoS

Lean Management



**DVS
EDB
EDM**

CORBA

World Wide WEB



PDM



PLM



**PLM 2.0
SysLM**

2025 +

1980

**Mechanical
Components**

**Mechanical and
Electrical
Components**

**Mechanical,
Electrical/Electronic
Software
Components**

**Smart Products,
Connected,
Intelligent
Cybertronic**



- **The most important objects in PDM Systems are:**

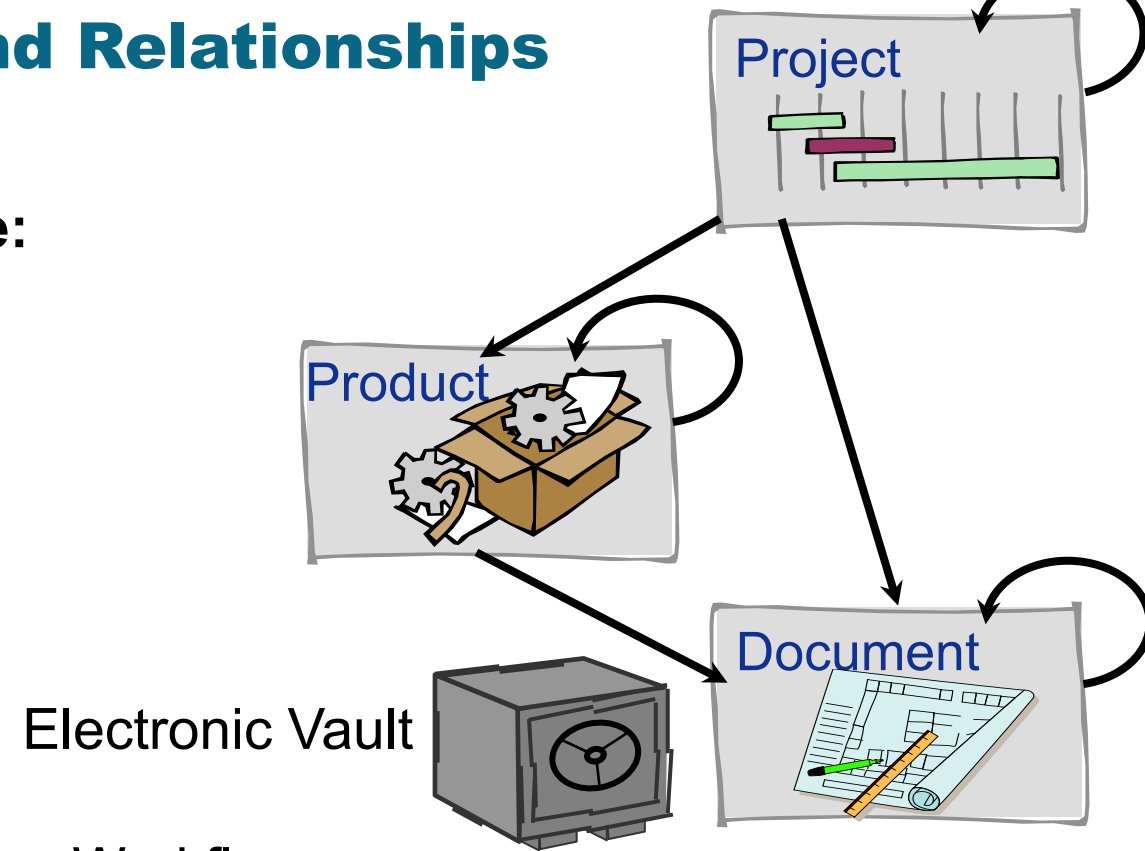
- Articles (parts, components, products)
- Different product structures (e.g. as designed / as planned, as build BOM)
- Paper or computer-generated documents, with or without security-relevant file management
- Document Structures
- (Projects)

- **Various relationships are defined between the objects:**

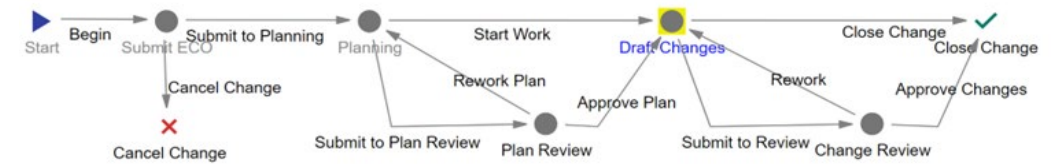
- Project - Article
- Articles - Articles
- Article - Document
- Document – Document
- Document - File...

- **Other objects are available:**

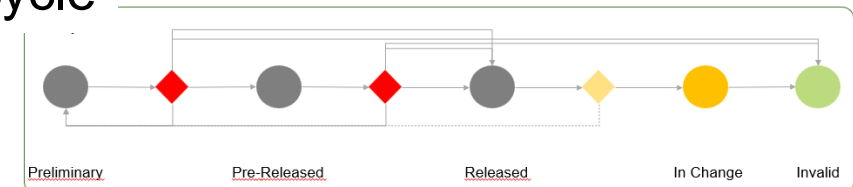
- Workflows for simple ECR/ECM
- Lifecycle
- Variants
- customer-specific objects on request.



Workflow



Lifecycle



Axalant UI (EIGNER Inc. 1998)

The First WEB-UI developed together with CERN (CH)

CADIM/EDB WWW-Interface

Projekte Artikel Dokumente Workflow MyCADIM

Artikel - Formular Einfügen Suchen XML-Export

Artikel Nr. lego-8215
Artikel Name Gyrocopter
Material PP - Polypropylen
Preis 19,80 - DM
Gewicht 71 - g
Status 230 - Freigegeben

Stückliste	Verwendung	Dokumente	Projekte	SML	Historie
12	0	4	1	0	3

Bild	PNr.	Artikel Nr.	Ver.	Rev.	Name	Menge	Einheit	FK	Gültig ab	Gültig bis	Akt.
	1	lego-8215-233	0	0	Kabine Rahmen Baugruppe	2.00	Stk	230	12.11.1998 21:25:24	01.01.3000 00:00:00	y
	2	lego-8215-002	0	0	Gyrocopter Getriebe Baugruppe	1.00	Stk	230	12.11.1998 21:25:24	01.01.3000 00:00:00	y
	3	lego-8215-001	0	0	Gyrocopter Chassis Baugruppe	1.00	Stk	230	12.11.1998 21:25:24	01.01.3000 00:00:00	y
	4	lego-8215-111	0	0	Gyrocopter Hinterradaufhängung Baugruppe	1.00	Stk	230	12.11.1998 21:25:24	01.01.3000 00:00:00	y

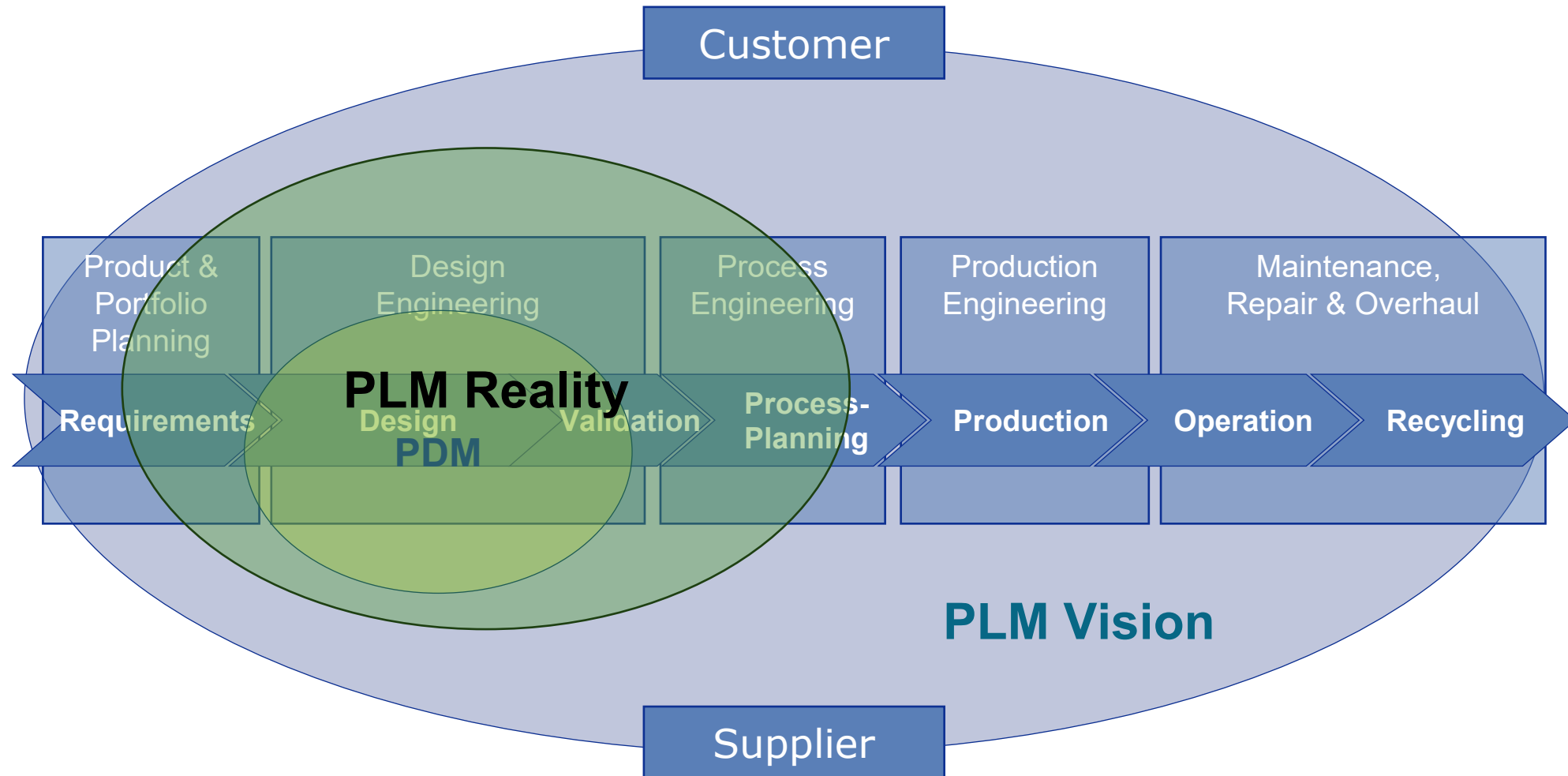
Lokales Intranet

Product Lifecycle Management (PLM) is the company-wide concept for information management of product and process-related data along the Product Lifecycle. It incorporates requirements, concept, design, planning, manufacturing, operation and recycling and is required for the holistic management of all data, documents, resources, and processes throughout the entire product lifecycle (→ **Single Source of Truth SSoT**). All people who must solve certain tasks together independently of their location and organizational association work together.

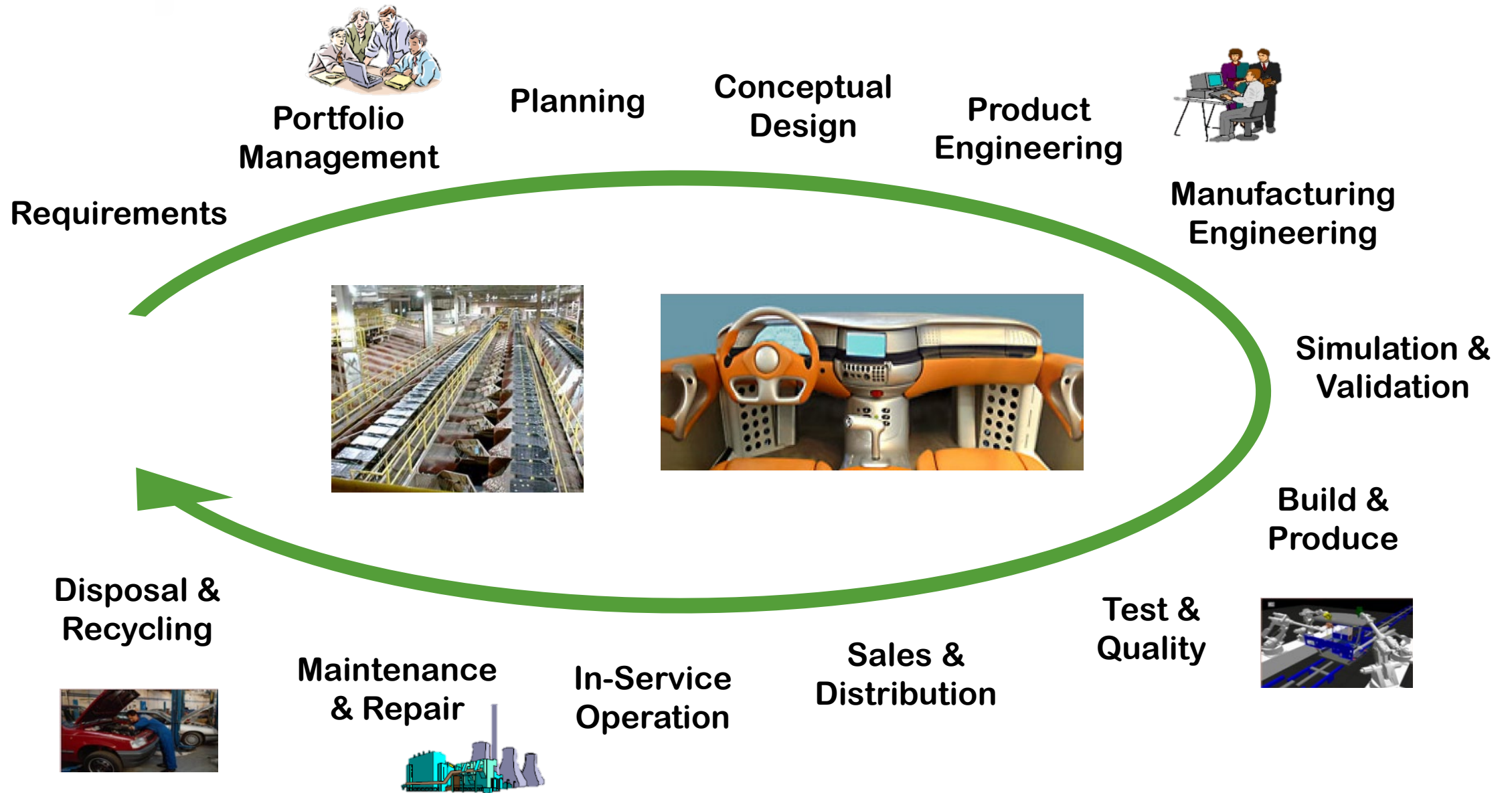
→ **Engineering Collaboration**



Product Lifecycle Management (PLM) vs. Product Data Management (PDM)



PLM Vision CIMdata ~2001?





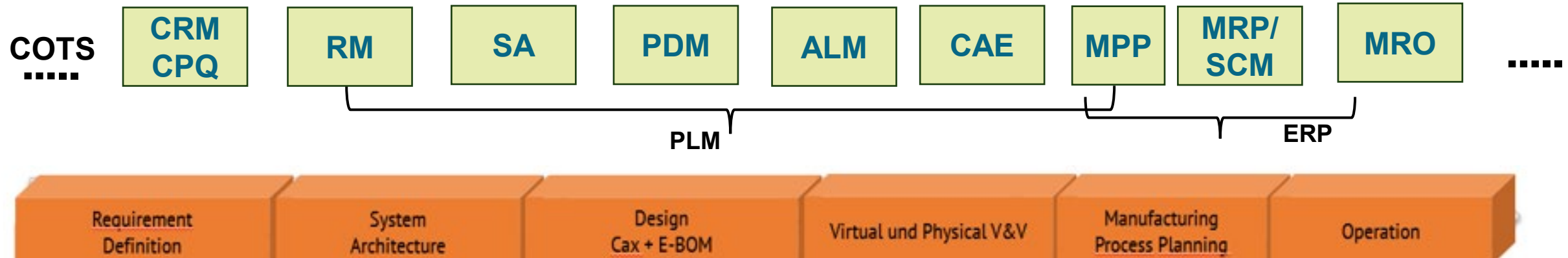
While the PLM vision was still being discussed, PDM vendors were hijacking the term PLM and using it for their PDM solutions. The same companies and the same systems mutated from PDM to PLM virtually overnight. Over time, the capabilities were expanded. However, they were still far from covering the entire product lifecycle and often the in PLM integrated functionality was lower as special solutions (RM, ALM, QMS, MPP, ...)

The Current Landscape: Fragmentation and Many Legacy Systems Mostly Based on Old SW Technology



No cross-system processes:

- Release and Change Management (ECR(ECM))
- Configuration management (CM)
- Quality Management (QMS)



Product Lifecycle

CRM = Customer Relations Mgmt. RM = Requirement Management SA = System Architecture PDM = Product Data Mgmt.

ALM = Application Lifecycle Mgmt. CAE = Computer Aided Engineering CPQ = Configure, Price, Quote

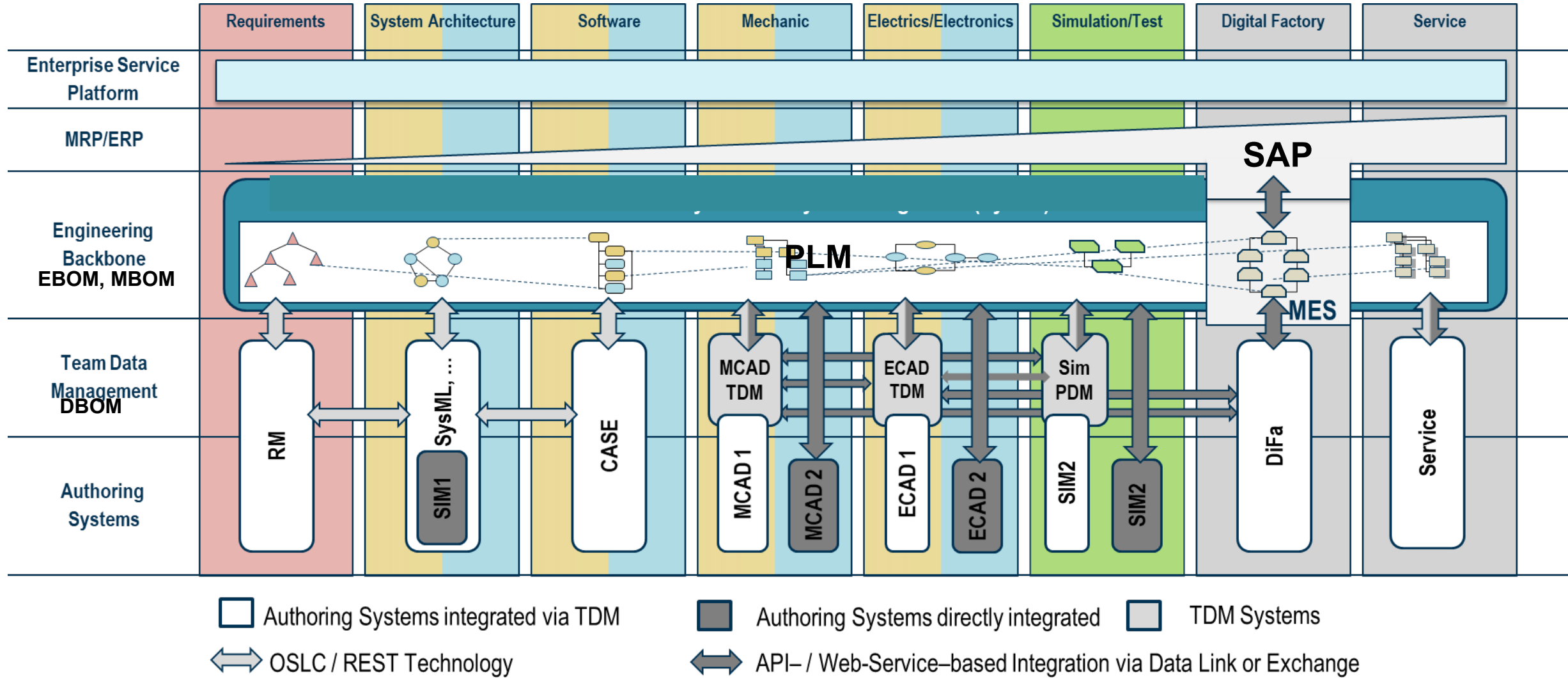
MPP = Manufacturing Process Planning MRP = Material Resource Planning

SCM = Supply Chain Mgmt. MRO = Maintenance, Repair and Overhaul

COTS = Commercial off the Shelf (The traditional Legacy Systems along the Product Lifecycle)

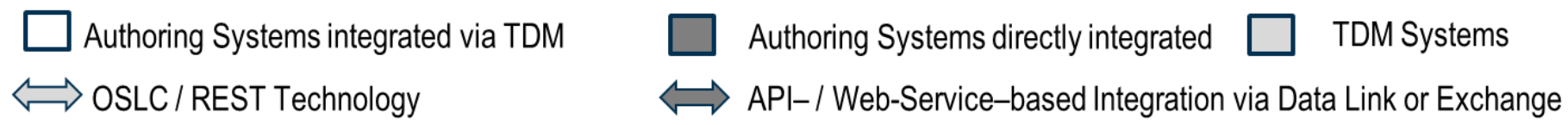
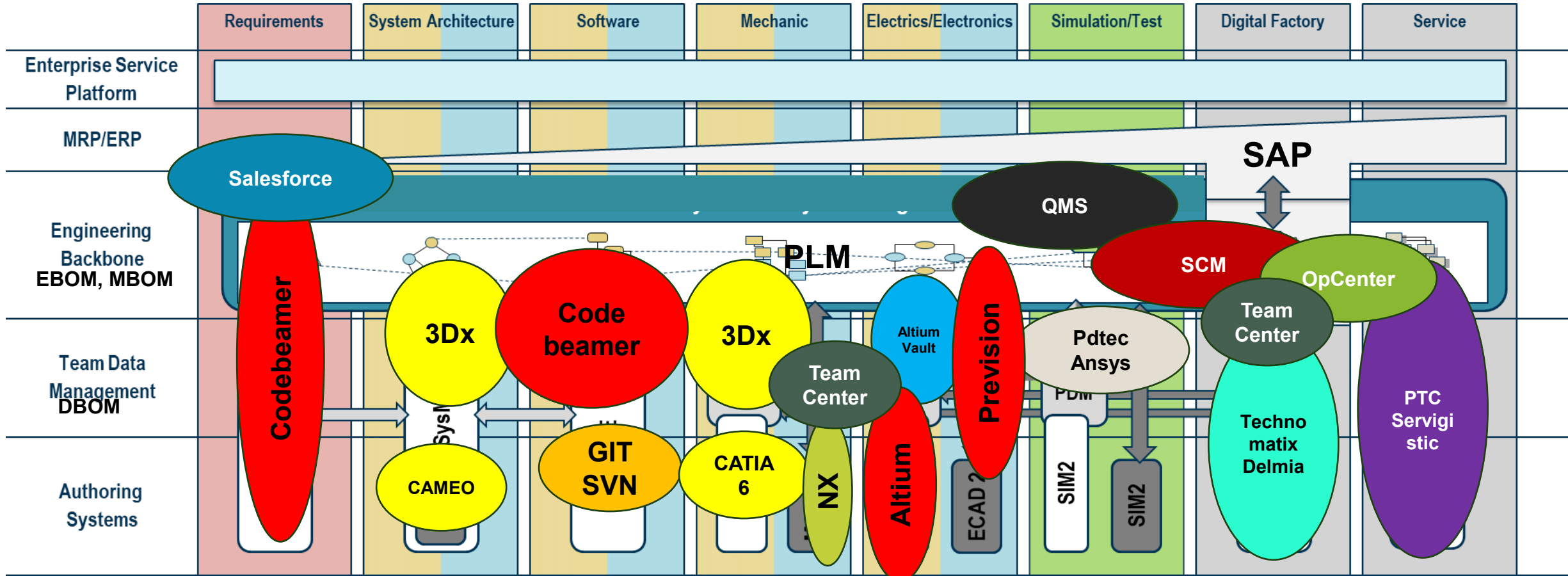
IT Architecture based on VDA 4-Level Concept

The Reality!

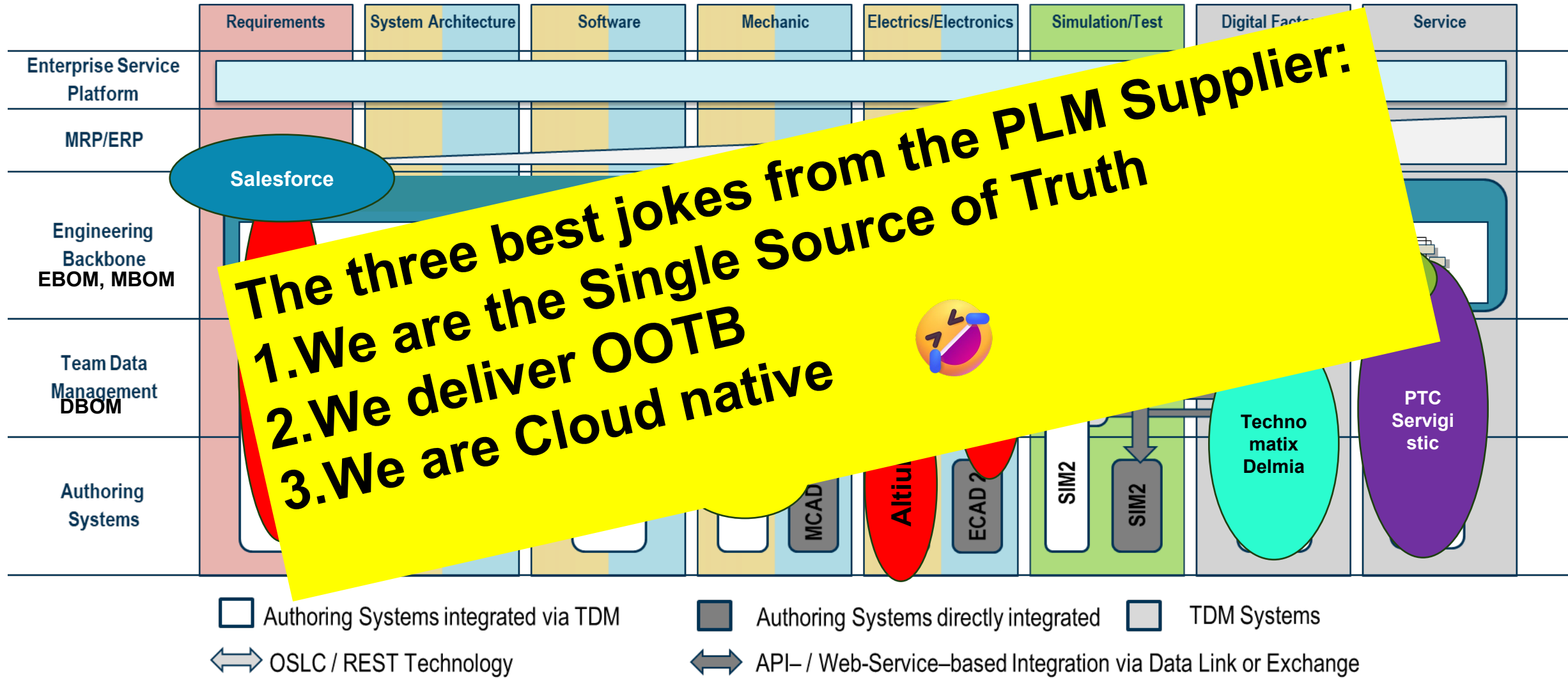


IT Architecture based on VDA 4-Level Concept

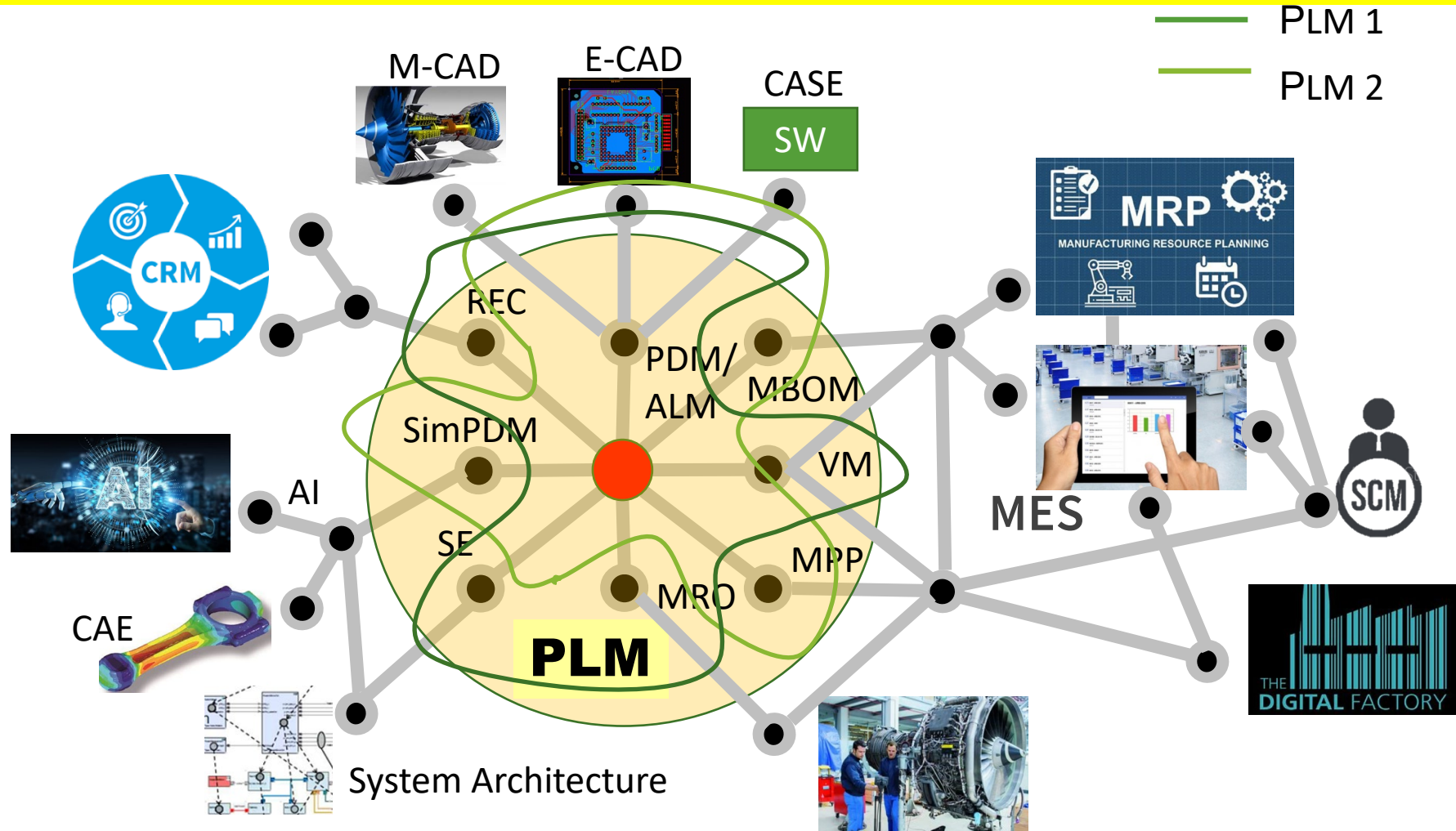
The Reality!












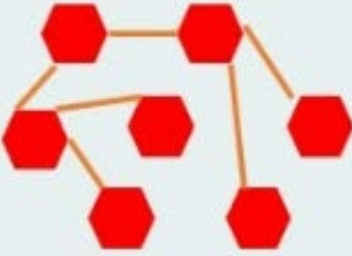
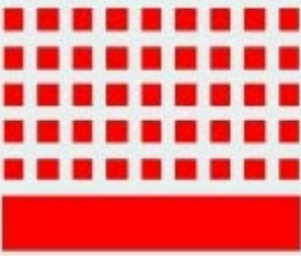

IT Architecture based on VDA 4-Level Concept The Reality!

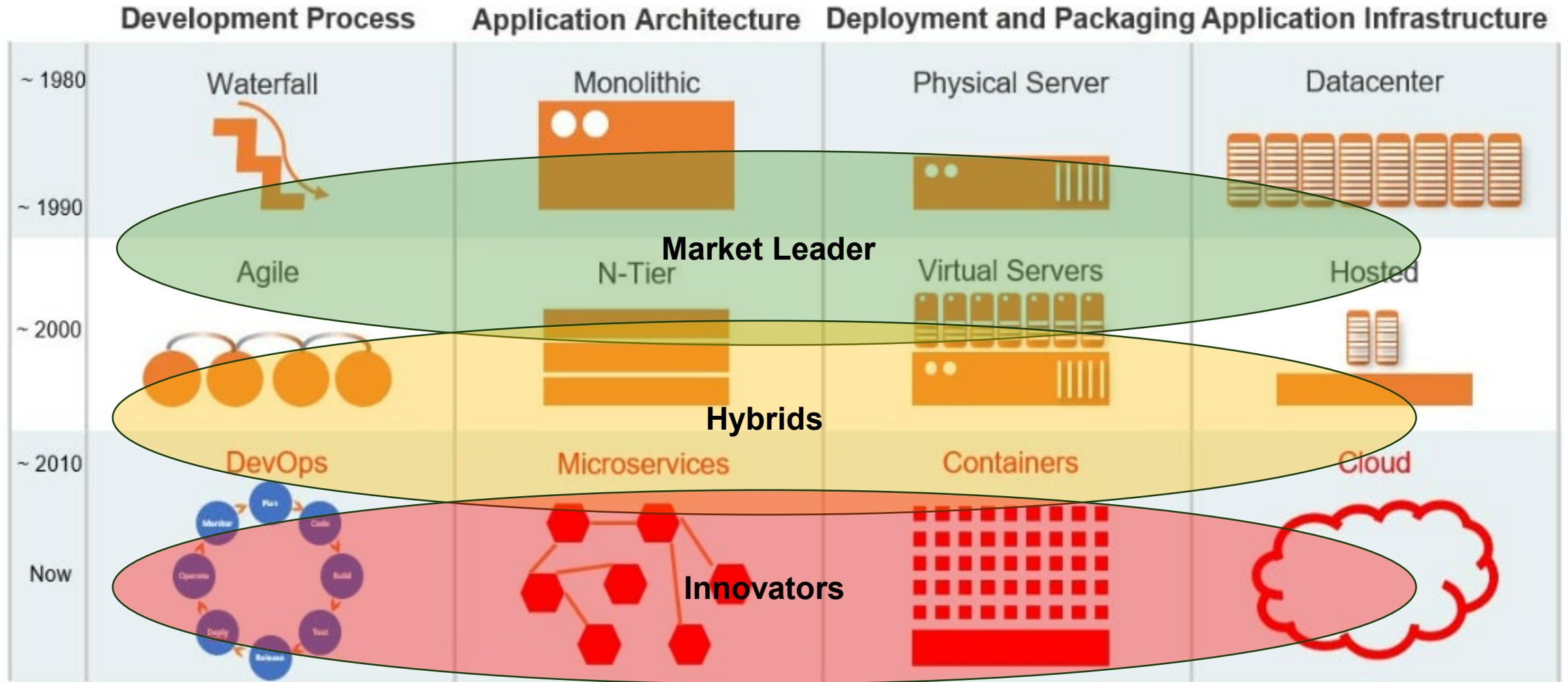


Specialized stand-alone solutions often offer better functionality than solutions integrated into PLM (e.g., requirements, QMS, assembly planning, etc.).



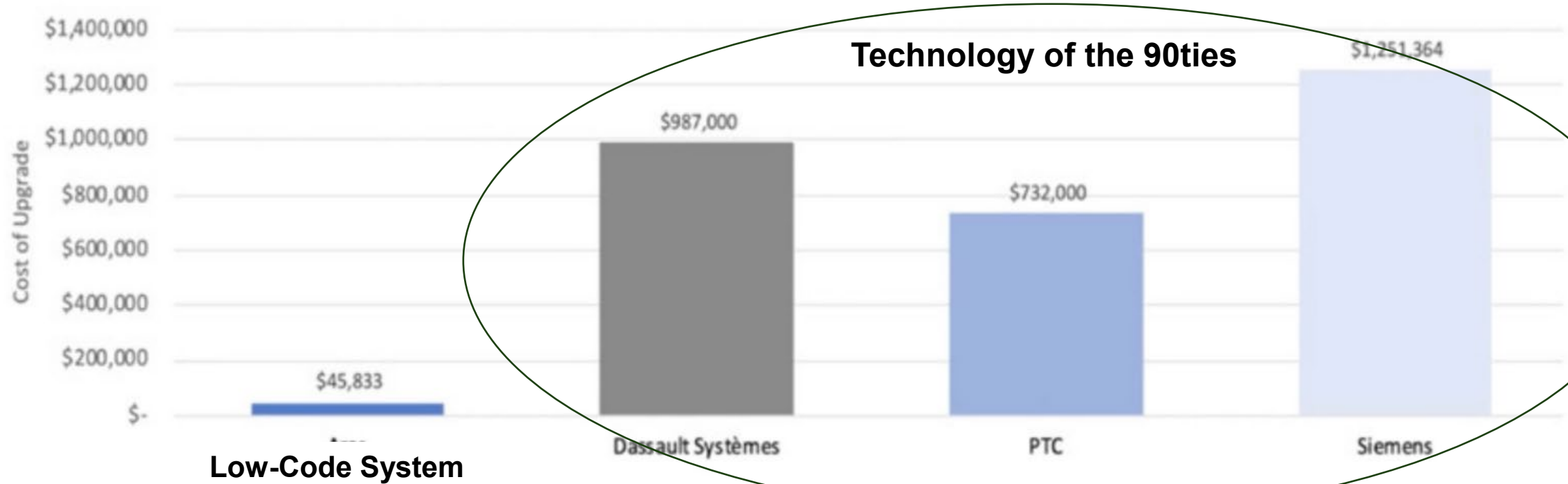
- REC:** Requirements, Function
- MPP:** Manufacturing Process Planning
- MES:** Man. Execution System
- VM:** Variant Management
- SE:** Systems Engineering
- ALM:** Application Lifecycle Mgmt.

	Development Process	Application Architecture	Deployment and Packaging	Application Infrastructure
~ 1980	<p>Waterfall</p> 	<p>Monolithic</p> 	<p>Physical Server</p> 	<p>Datacenter</p> 
~ 1990				
~ 2000	<p>Agile</p> 	<p>N-Tier</p> 	<p>Virtual Servers</p> 	<p>Hosted</p> 
~ 2010	<p>DevOps</p> 	<p>Microservices</p> 	<p>Containers</p> 	<p>Cloud</p> 
Now				



Average Cost of the Last PLM Upgrade

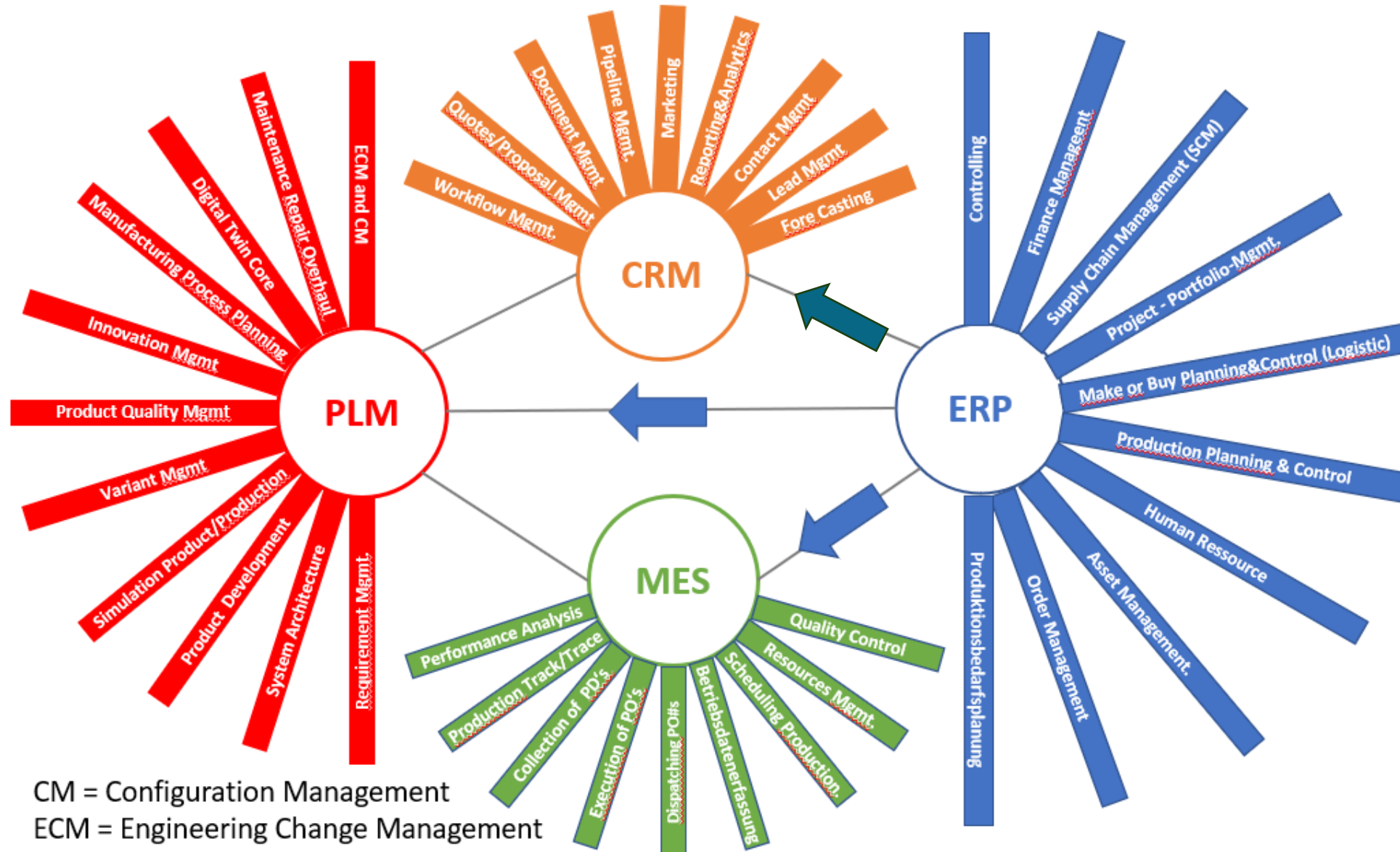
The higher the cost, the longer the ROI



n=68

* The analysis was completed using data populated by those who completed this portion of the survey on the cost of their latest upgrade.

Trend 1: Enrichment of PLM



CM = Configuration Management
ECM = Engineering Change Management

Trend 2: Do we Need PLM-Systems



Source: Prof. Dr.-Ing. Jörg Fischer

How Can We Get Closer to our PLM Vision From the 90s?

- **Mindshift in integrated and interdisciplinary Thinking**
- **Change and Acceptance Management**
- **New Methodologies (Methods, Processes and Tools)**
- **New Software Technology**
- **Digital Thread and Digital Twin**
- **Artificial Narrow Intelligence**
- **PLM and AI are Part of Digital Transformation**

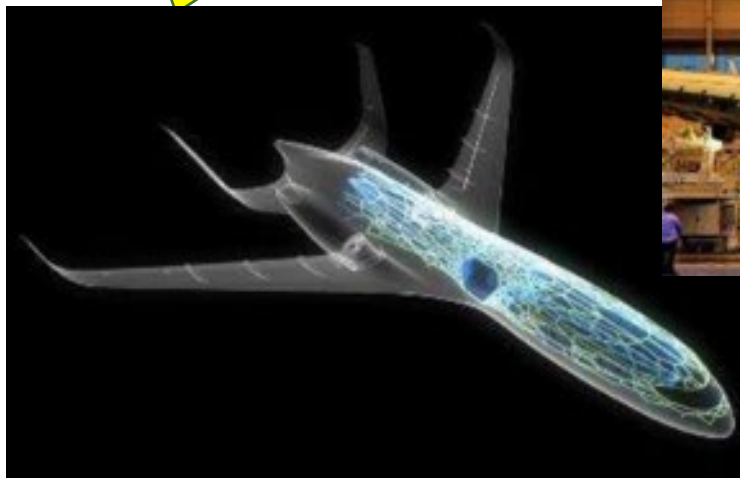


Solve The Chief Engineer's Dilemma!

Traceability, Interdisciplinarity, Complexity, Sustainability, Compliance

If I must make a change, how do I know what we're changing? My system definition and my requirements are in fragmented and isolated IT solution, f.e. my software is in ALM and my Hardware in PLM and SAP!!!

How can I develop Service Oriented BMs?



as designed



as built



as maintained

NECESSITY FOR CONTROLLED CHANGE

What's the Carbon Footprint of my product?

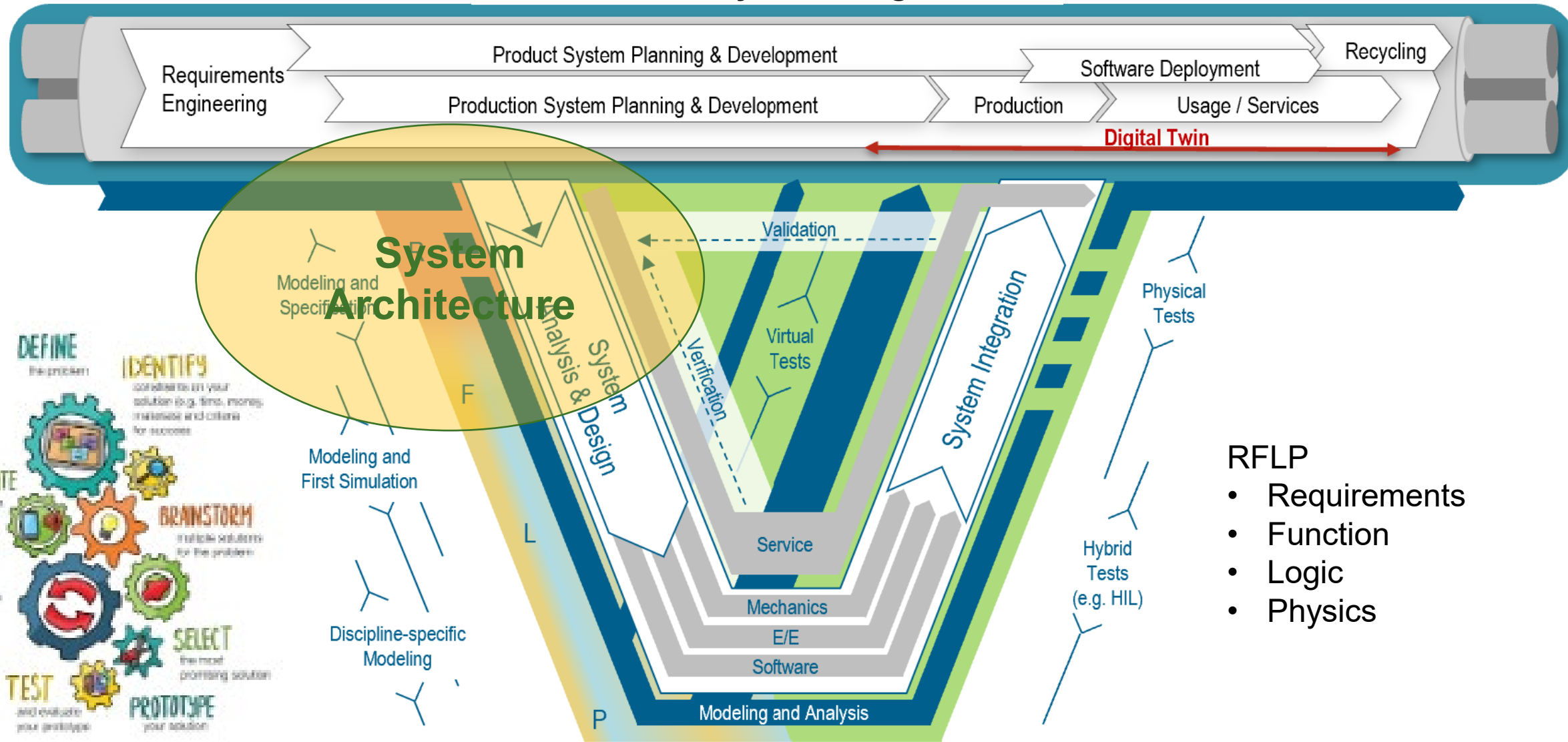
How can I trace back a failure?

Are we able to fulfill the compliance rules

How am I supposed to Do impact analysis?

Base of an Interdisciplinary Engineering Process: Extended V-Model System Thinking and MBSE

Product Lifecycle Management



SW Technology and Architecture

- WEB-Services + Containering
- Microservices Architecture
- Connected and Federated
↳ no Monolithically IT-Structure
- Multi-Tenant Databases
- Polyglot Persistence
- SaaS Cloud Services
- Data Linkage based on REST/RDF
- Code for Openness
- Interactive Repository
- Easy to Configure* / Customize**
- Easy to Upgrade
- Flexible and Scalable

* = interactive ** = via APIs



OpenBOM: Architecture & Technology
Oleg Shilovitsky, www.openbom.com

Digital Thread

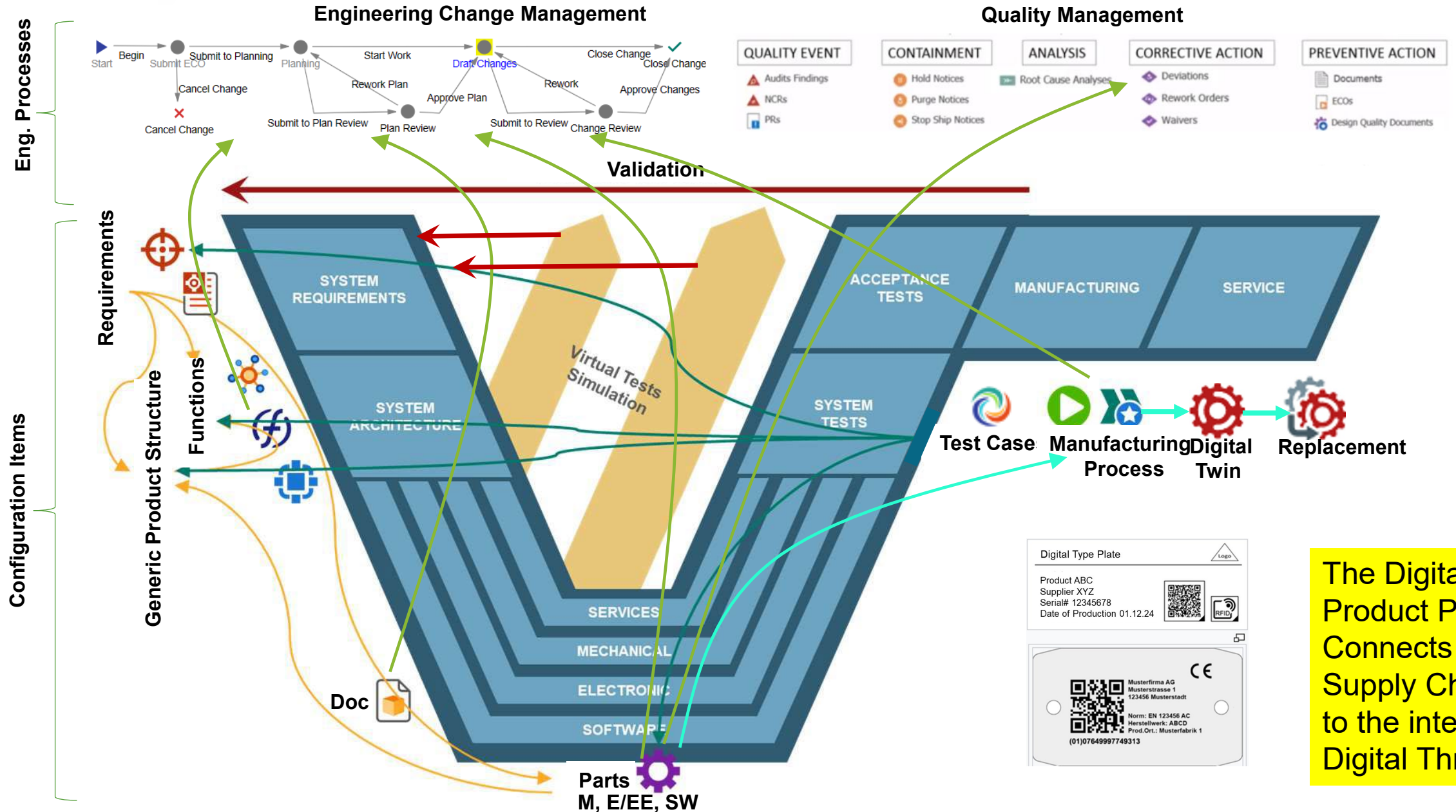


The Extended Digital Thread



- **All possible Configuration Items* (CIs) and other items along the PLC within the digital model as well as the synchronization with the instantiated digital twin with one another.**
- **All relevant Engineering Processes CIs are involved (ECR, ECM, CM, QMS,...)**
- **Analyzing and evaluating the networking of all CIs across all PLC phases, for example, when a part is damaged, which simulations were carried out, which requirements persisted, and how the part is produced.**
- **Change and configuration management across different legacy systems. Changes can be traced. To ensure this, it is necessary that every type of evolution of the Digital Model, Digital Thread and Digital Twin is revisioned.**

* Configuration Items are technical elements along the product lifecycle which are revised according to operational agreement potential in changes and thus are subject to configuration management. The elements really affected by a change are referred to as an affected or impacted item (ISO 10007)



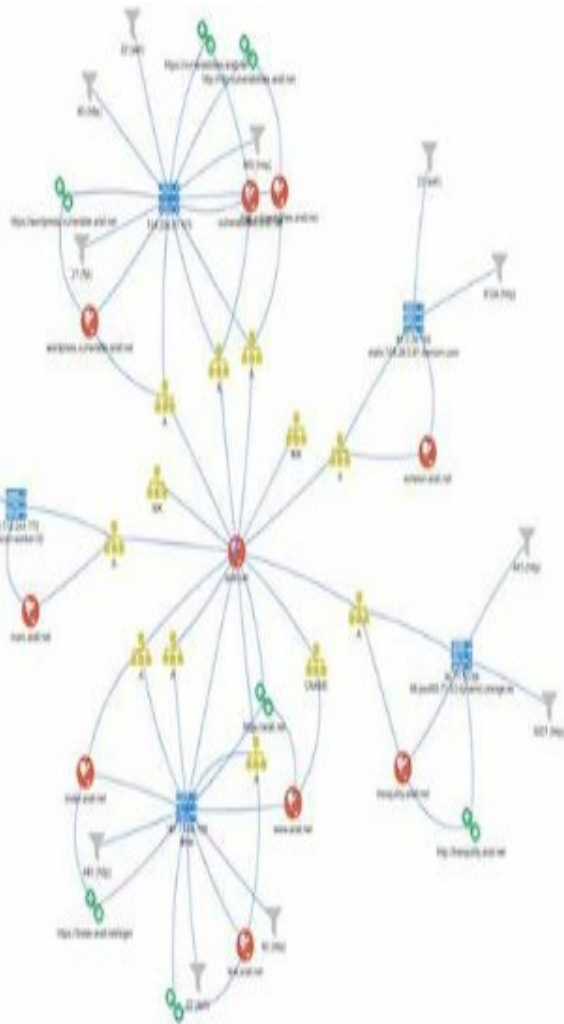
The Digital Product Pass Connects the Supply Chain to the internal Digital Thread

A knowledge graph is a data structure that represents knowledge in a machine-readable format. It connects data points and relationships, enabling a more comprehensive view of information. Knowledge graphs play a crucial role in enhancing **traceability by providing a unified framework for storing and accessing data across legacy systems**. They facilitate the exploration of relationships between various entities, improving decision-making and data discovery.

Source: Oleg Shilovitsky, MyAgilePLM, Jan 8 th, 2024

The Product Knowledge Graph (PLG) is building and collecting both product and process knowledge together and the PLG is becoming a foundation of product AI LLM (large language model).

Source: Martijn Dullaart, ASMLShaping the future of CM | Book: The Essential Guide to Part Reidentification: Unleash the Power of Interchangeability & Traceability, Nov. 2023



Graph databases store data as nodes and edges, offering flexible schemas and maintaining consistent performance, even with large datasets. This makes them ideal for applications like social networks and knowledge graphs.



Superior Technology: Relationships are stored directly with nodes, eliminating the need for joins, resulting in superior performance.

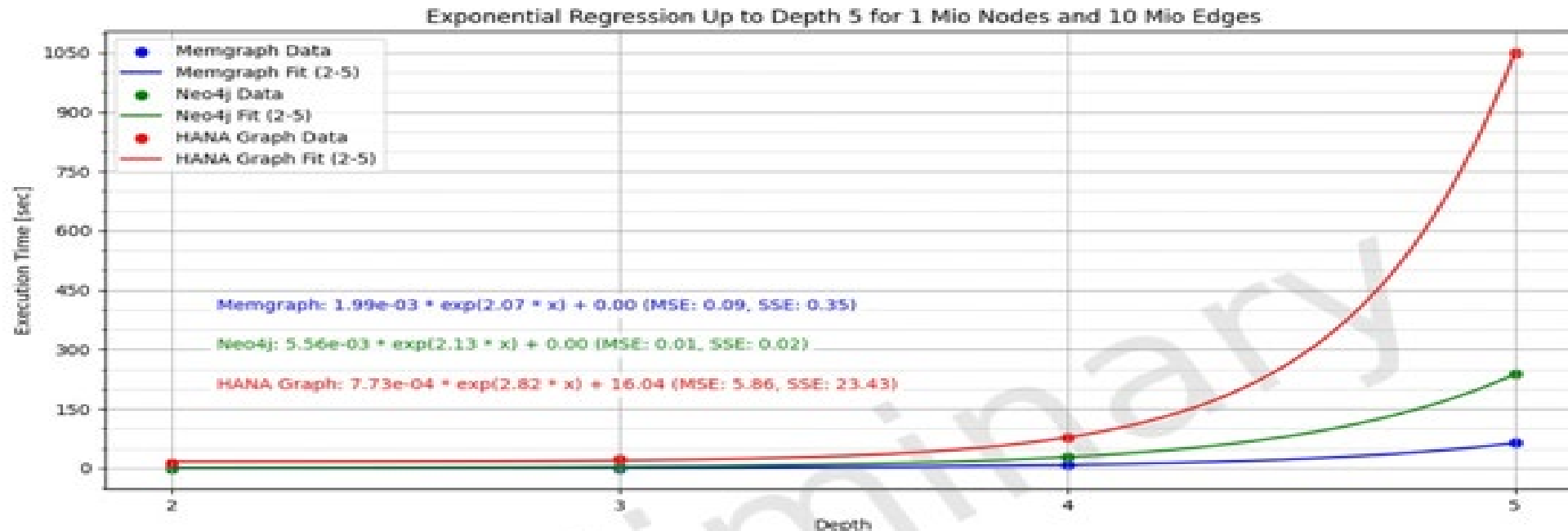


Fast Querying: Constraint-based filtering is efficient due to the use of labels and properties.



Easy Customization: Flexible schema allows for simple configuration and customization, significantly reducing implementation costs.

The key advantage of native graph databases with Labeled Property Graphs: Relations can have attributes.

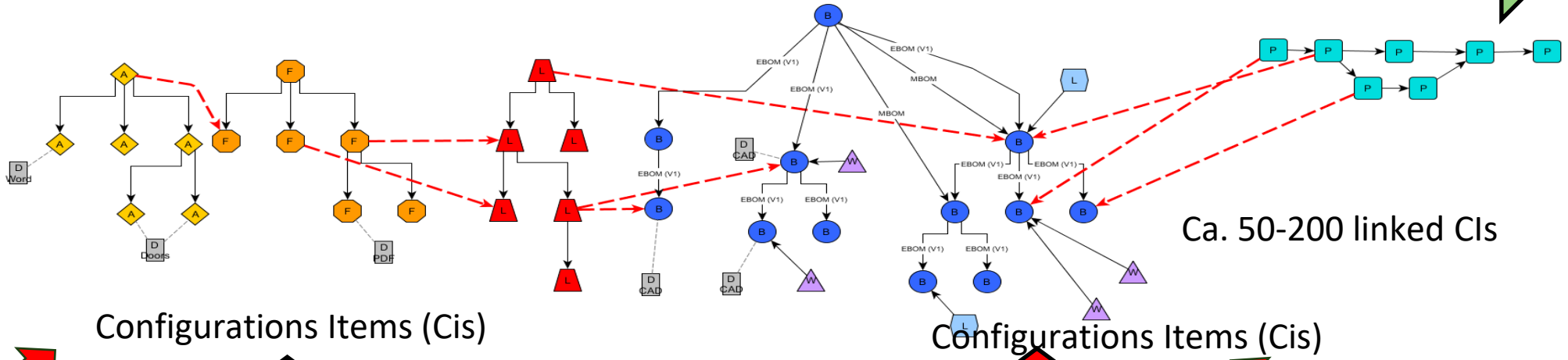


Digital Thread as Knowledge Graph of Connected Cis (SAP R&D Project)

Engineering Processes: ECR, ECM, Traceability, QMS, Digital Twin Core

SW-Technologie

- Low Code
- Interactive Repository
- Graph. DB
- Microservices
- Data Linkage RDF/REST
- Easy to configure
- Open



Configurations Items (Cis)

Configurations Items (Cis)

CRM

CPQ

ALM

SAP EPD/PLM
oder
allg. PLM
System

Master Data
E-BOM
Documents
M-BOM
BOP/MPP

PLMSI

SAP S/4HANA

SAP

MES/MOM

SCM

Digitale
Fabrik

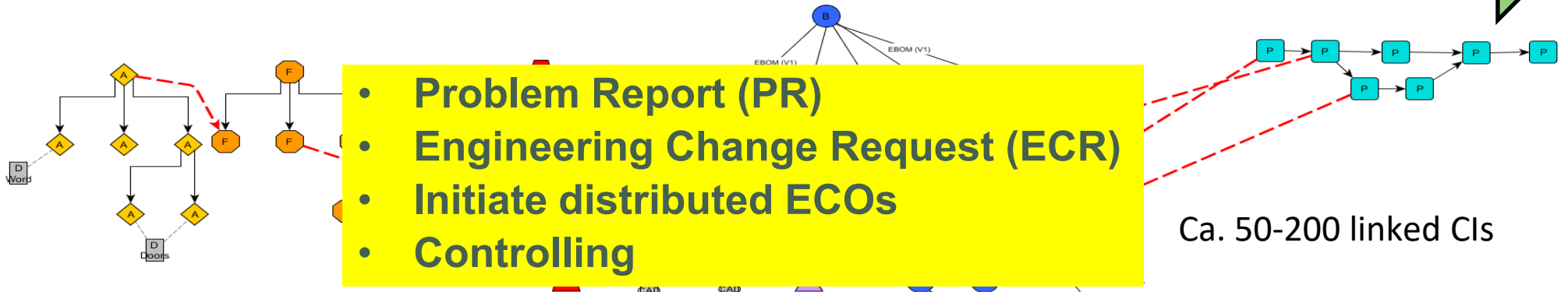
Prio 1 (ca 70-80% der Cis)

Digital Thread as Knowledge Graph of Connected Cis (SAP R&D Project)

Engineering Processes: ECR, ECM, Traceability, QMS, Digital Twin Core

SW-Technologie

- Low Code
- Interactive Repository
- Graph. DB
- Microservices
- Data Linkage RDF/REST
- Easy to configure
- Open



- **Problem Report (PR)**
- **Engineering Change Request (ECR)**
- **Initiate distributed ECOs**
- **Controlling**

Ca. 50-200 linked Cis

Configurations Items (Cis)

Configurations Items (Cis)

CRM

CPQ

ALM

**SAP EPD/PLM
oder
allg. PLM
System**

Master Data
E-BOM
Documents
M-BOM
BOP/MPP

PLMSI

SAP S/4HANA
SAP

MES/MOM

SCM

Digitale Fabrik

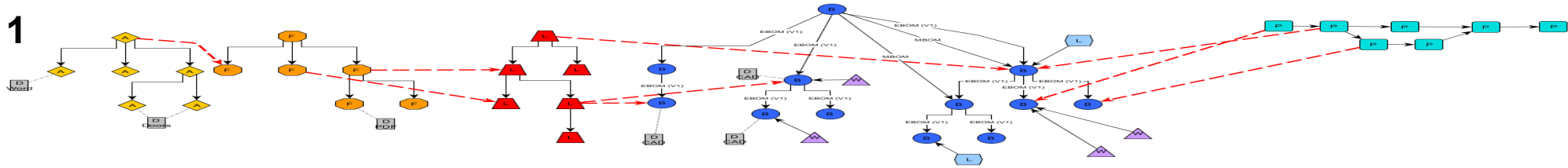
Prio 1 (ca 70-80% der Cis)

1. Digital Thread can be implemented **On-Premise (DT)** or as **Digital Thread as a Service (DTaaS)**.
2. DT/DTaaS can be operated as a **passive, non-persistent warehouse**, e.g. to create an information base for AI analysis or simply a snapshot for decision making.
3. This alternative is an **actively controlled design of DT/DTaaS**. This enables processes that provide bi-directional control between the connected legacy systems and the knowledge graph, e.g. active ECM, CM and QMS.
4. DT/DTaaS could be a **Stand-Alone solution** or realized in one of the **Legacy Systems**, f.e. PLM or ERP.



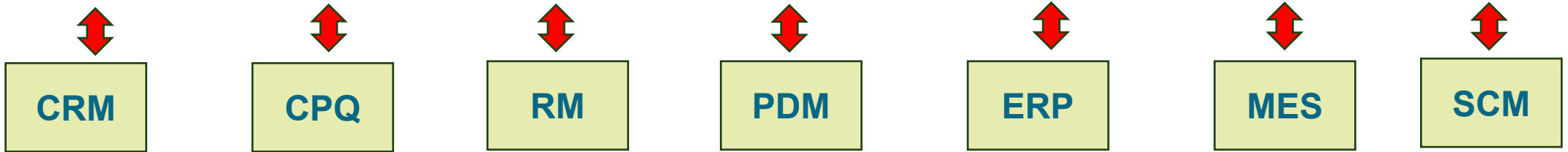
Two possible Solution for a DT/DTaaS Implementation

Solution 1

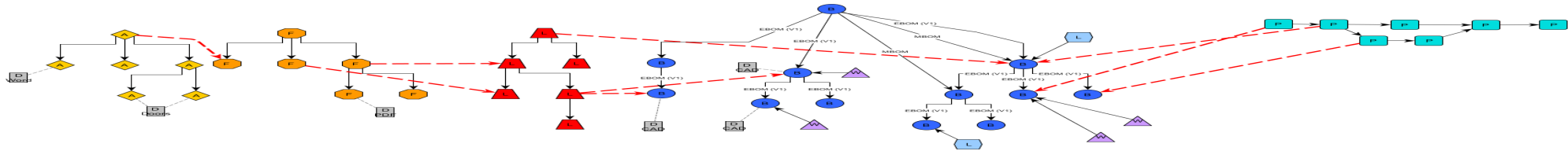


Level of DTaaS with minimal redundancy and linked data (PLM vision)

COTS Level



Solution 2



Level of DTaaS with minimal redundancy and linked data (PLM vision)

COTS Level



Welcome to Your Digital Thread Graph Platform

Choose an option below to get started



Home



No-Code Schema
Modeling Engine



No-Code Graph
Explorer



No-Code Graph
Builder



Database
Management

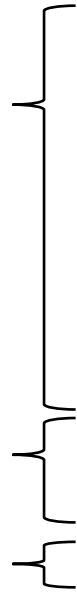
Filter for:


- object type (label)
- relation type (label)
- object properties
- Relation properties

The filters have an OR relationship for generating views.

Any number of filters can be created.

Realignment of the graph





Right mouse button: Display the details of an object

Double click: Display the neighboring objects

Right-click to display relations and object details

Node Filter

Node Label: All

Edge Filter

Relationship Type: All

Node Property Filter

Property: All

Value: Enter property value

Edge Property Filter

Property: All

Value: Enter property value

Add Filter

Filter Type: Node Label

Add Filter

Center Graph

Details

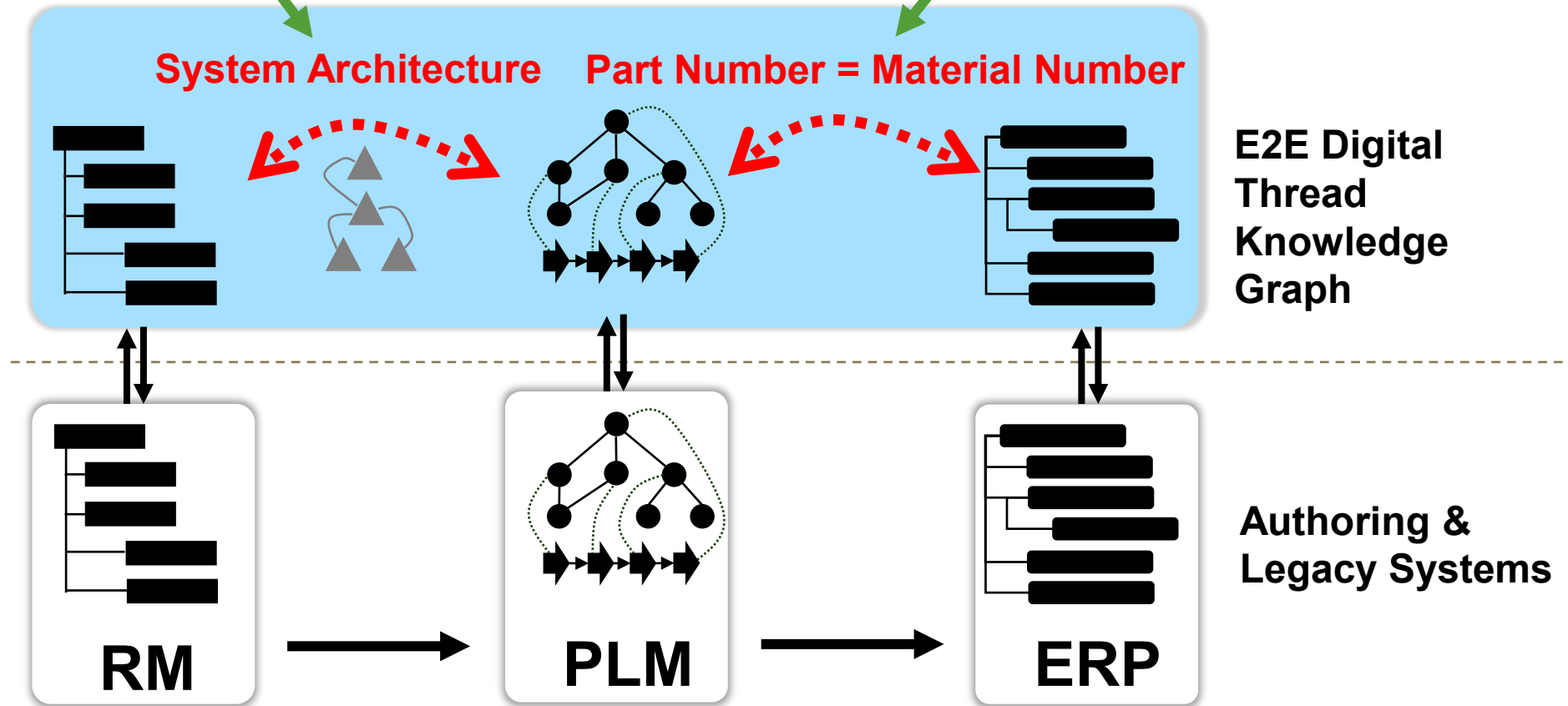
UUID	bded5160-63b3-4c17-9ab0-d5bd07c5b39f
Label	FUNCTION
name	Power Generation
valid_from	20230101
valid_until	99990101
version	1

How are sub-structures from legacy systems connected at the Digital Thread level?

Legacy systems stay isolated without logical links.

Without system architecture, requirements remain disconnected.

Consistent IDs create the logical backbone between PLM and SAP.

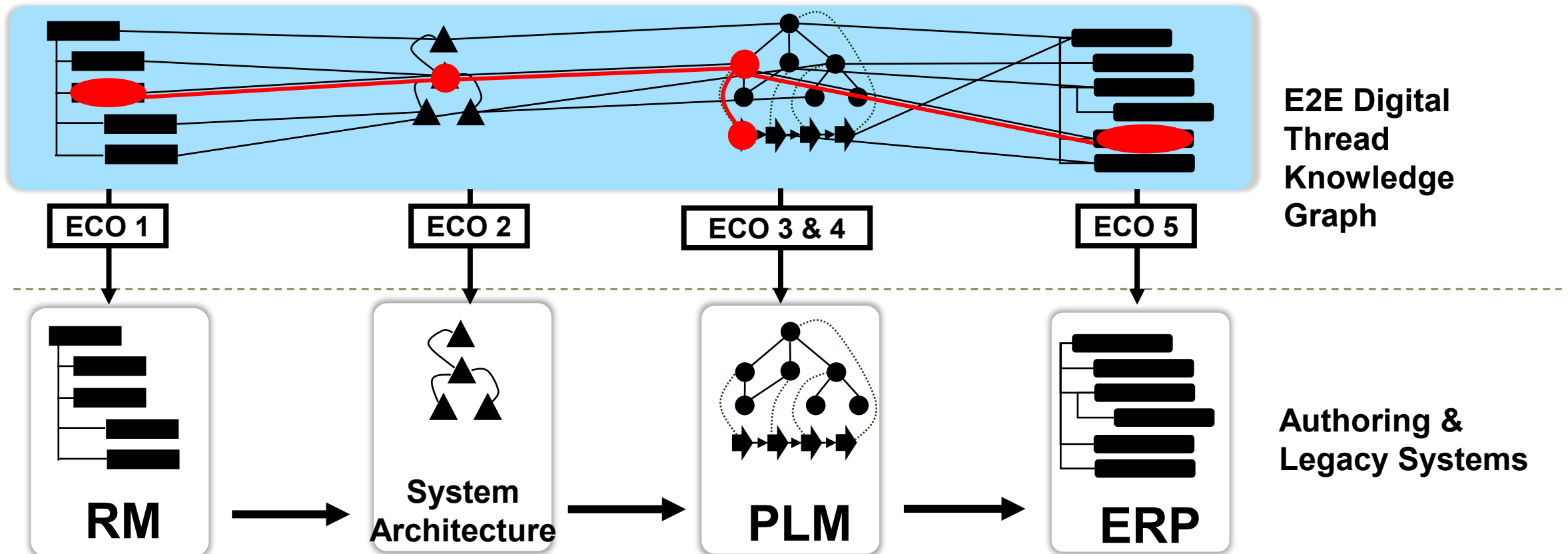


Active Interface-Based Distribution and Synchronization of ECOs to Legacy Systems

After identifying the affected items, ECOs must be sent to the legacy systems.

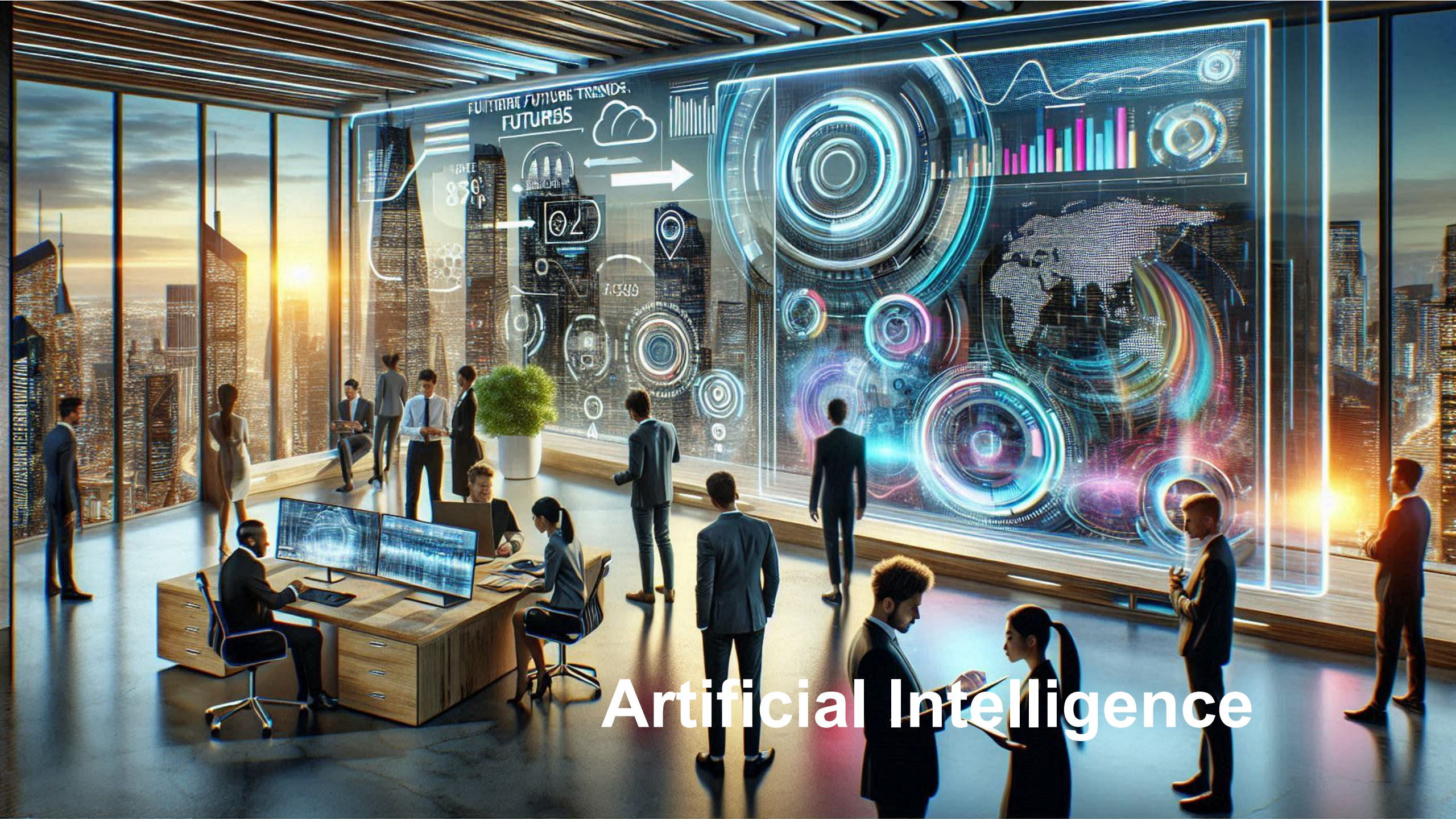
Two questions:

- How are ECOs executed at the legacy level?
- How is implementation status reported back?



Who is Working on This Topic?

- Microsoft / NVIDIA
- Amazon
- SAP
- SPREAD.AI
- Elevating Patterns (EP)
- eQube
- SnapLogic
- ConWeaver

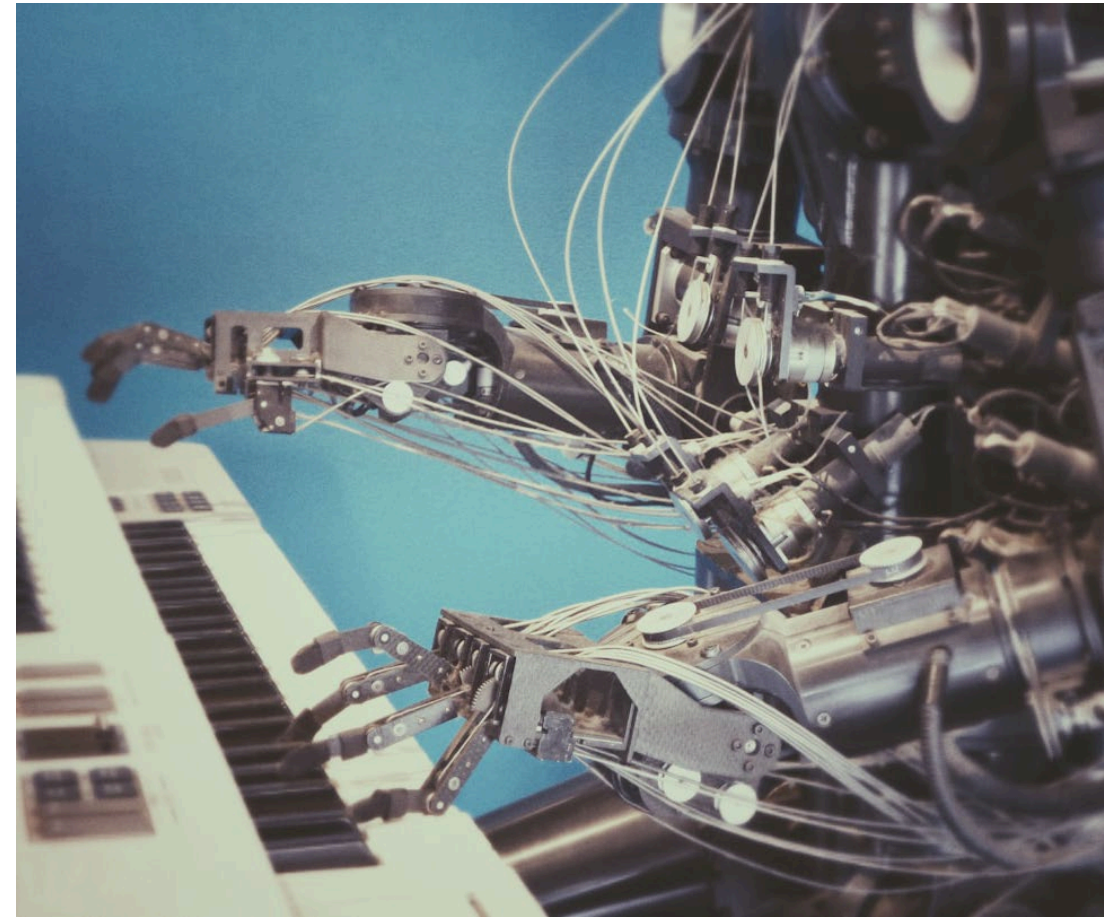


Artificial Intelligence

"Artificial intelligence describes the ability of machines to perform tasks autonomously based on algorithms and to react adaptively to unknown situations. Their behavior is thus similar to that of humans: They not only perform repetitive tasks, but also learn from success and failure and adapt their behavior accordingly."

We define four Levels:

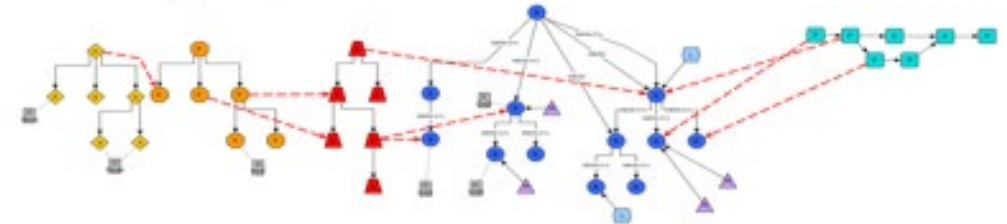
- **Human Intelligence**
- **Artificial Narrow Intelligence (ANI)**
- **Artificial General Intelligence (AGI)**
- **Artificial Super Intelligence (ASI)**



- Projection of light edges onto free-form surfaces (a). Interactive displacement creates the surface changes desired by the design (EC Fiores project, RPE, RPTU).
- Derive a digital thread across multiple legacy systems to identify affected elements in the event of a change (b).
- Generation of printable volumes from specified parameters (nTop) (c)
- Routing of double layer boards (d),



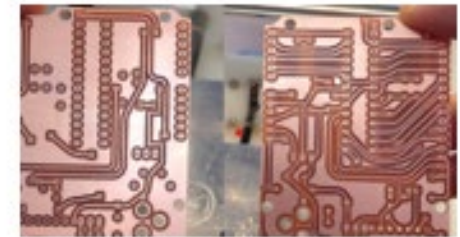
a) Projekt Fiores, VPE, RPTU



b) PhD Nico Kasper, VPE, RPTU



c)  nTop



d)  JAMINDO PCBA
JIADUN GAOSHI

Level 2 (ANI) „Generate Code to transfer a BOM from OnShape to OpenBOM“ with ChatGPT

```
import requests
# Onshape API credentials
onshape_api_key = 'YOUR_ONSHAPE_API_KEY'
onshape_access_key = 'YOUR_ONSHAPE_ACCESS_KEY'
# OpenBOM API credentials
openbom_api_key = 'YOUR_OPENBOM_API_KEY'
openbom_access_key = 'YOUR_OPENBOM_ACCESS_KEY'
# Onshape document details
document_id = 'YOUR_DOCUMENT_ID'
workspace_id = 'YOUR_WORKSPACE_ID'
element_id = 'YOUR_ELEMENT_ID'
# Get BOM from Onshape
onshape_url = f'https://cad.onshape.com/api/assemblies/d/
{document_id}/w/{workspace_id}/e/{element_id}/bom'headers =
{'Accept': 'application/json', 'Authorization': f'Bearer {onshape_api_key}'}
response = requests.get(onshape_url, headers=headers)
bom_data = response.json()
# Load BOM to OpenBOM
openbom_url = 'https://api.openbom.com/v1/bom'headers =
{'Content-Type': 'application/json', 'Authorization': f'Bearer {openbom_api_key}'}
response = requests.post(openbom_url, headers=headers, json=bom_data)
if response.status_code == 200: print('BOM successfully loaded to OpenBOM')
else: print('Failed to load BOM to OpenBOM')
```

Level 2 (ANI) „Generate Code to transfer a BOM from OnShape to OpenBOM“ with ChatGPT

```
import requests
# Onshape API credentials
onshape_api_key = 'YOUR_ONSHAPE_API_KEY'
onshape_access_key = 'YOUR_ONSHAPE_ACCESS_KEY'
# OpenBOM API credentials
openbom_api_key = 'YOUR_OPENBOM_API_KEY'
openbom_access_key = 'YOUR_OPENBOM_ACCESS_KEY'
# Onshape document details
document_id = 'YOUR_DOCUMENT_ID'
workspace_id = 'YOUR_WORKSPACE_ID'
element_id = 'YOUR_ELEMENT_ID'
# Get BOM from Onshape
onshape_url = f'https://api.onshape.com/api/v2/document/{document_id}/workspace/{workspace_id}/element/{element_id}/bom'
headers = {
    'Access-Token': f'Bearer {onshape_api_key}'
}
response = requests.get(onshape_url, headers=headers)
bom_data = response.json()
# Transfer BOM to OpenBOM
openbom_url = 'https://api.openbom.com/v1/bom'
headers = {
    'Content-Type': 'application/json', 'Authorization': f'Bearer {openbom_api_key}'
}
response = requests.post(openbom_url, headers=headers, json=bom_data)
if response.status_code == 200: print('BOM successfully loaded to OpenBOM')
else: print('Failed to load BOM to OpenBOM')
```

Do we need programmed interfaces between different Legacy Systems or can we use AI Agents

Level 2: UI Copilot on Top of PLM and ERP

Open Debugger

Welcome to EDB.AI Copilot

Your AI-powered copilot for EDB queries.



Here are some questions you can ask

List me the Items which are not dangerous goods

List me the Items with Status Released

List me the Items where the dangerous status is unknown

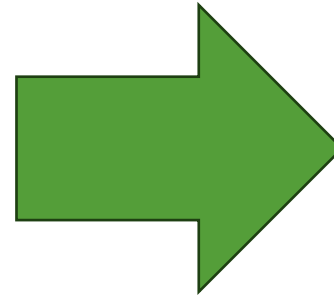
List me the Items which are not dangerous goods

Which Manufactures are located in Hamburg?

Ask me a question about your data that I can turn into SQL.

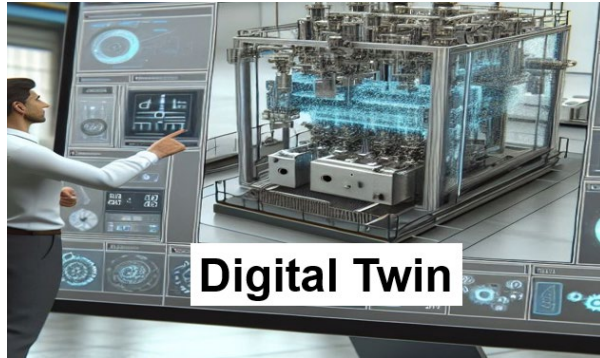
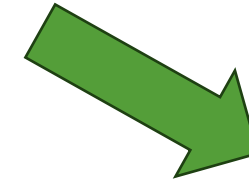
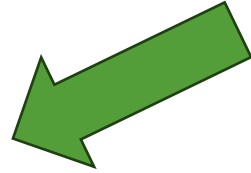


My Dream: AI-Agent for Intelligent Engineering Change Management

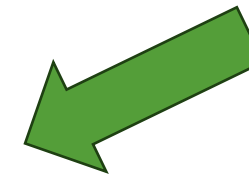
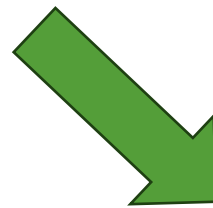
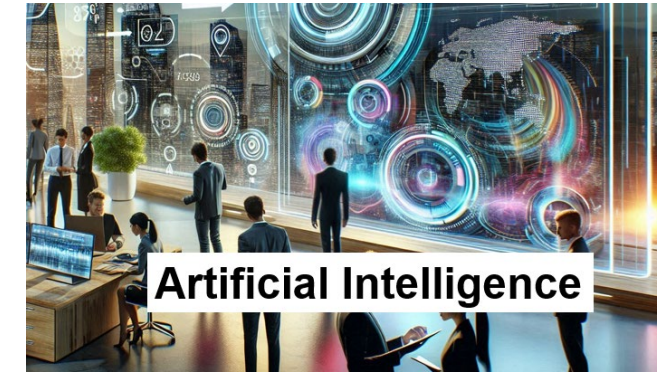


Source: Oleg Shilovitsky

Yes, We Can Realize Our PLM Vision



NVIDIA and Microsoft to Bring the Industrial Metaverse and AI to Hundreds of Millions of Enterprise Users via Azure Cloud





The overarching Digital Thread on Premise or as a Service (DTaaS) with Knowledge Graphs connected with the Digital Twin and AI (GenAI) and optionally creating an Omniverse will significantly boost business opportunities and ROI. Enhanced data connectivity and traceability will improve decision making and support AI application development. This digital transformation will revolutionize product development, optimize processes, reduce costs, and positioning companies at the forefront of their industries..... **And we are coming back to our original PLM vision the nearest “Single Source of Truth”!**

DIGITAL MODEL

Product Data

+

DIGITAL PROCESS

ECM and CM

+

DIGITAL TWIN

Configuration

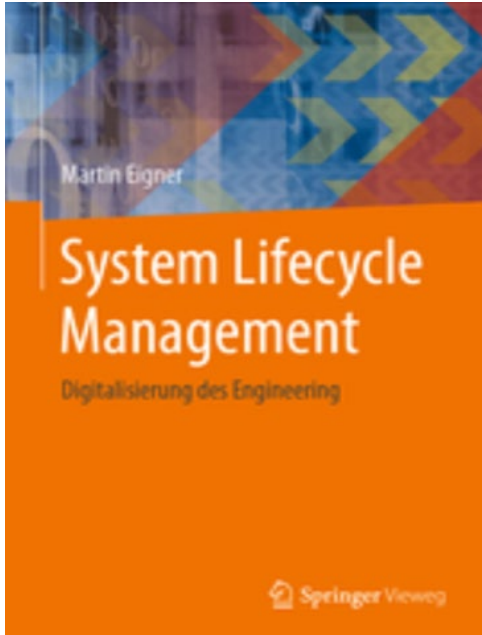
+

DIGITAL THREAD

Traceability

=

Context



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PLM Road Map™ & PDT North America 2025

PLM's Integral Role in Digital Transformation From Strategy to Execution

Elevating PLM to an Enterprise Business Solution,

the PLM Professional's Road Map to Success

May 7 & 8

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