David Segal
Sr. Director,
FA&D Industry

THE MBSE DIGITAL THREAD FOR SYSTEMS FAILURE PREDICTION

22nd Annual Systems and Mission Engineering Conference – October 2019

ptc

- $1.25B global software company, headquartered in Boston, MA
  - Innovation Platform: IOT & AR/VR
  - Digital Twin Solutions: CAD & PLM
- 28,000 active customers
- 6,000 employees
- Strategic technology partner to world-leading manufacturing companies
- NASDAQ:PTC - market cap ~$10B

CONVERGENCE HAS SHAPED OUR **IDENTITY**

ptc

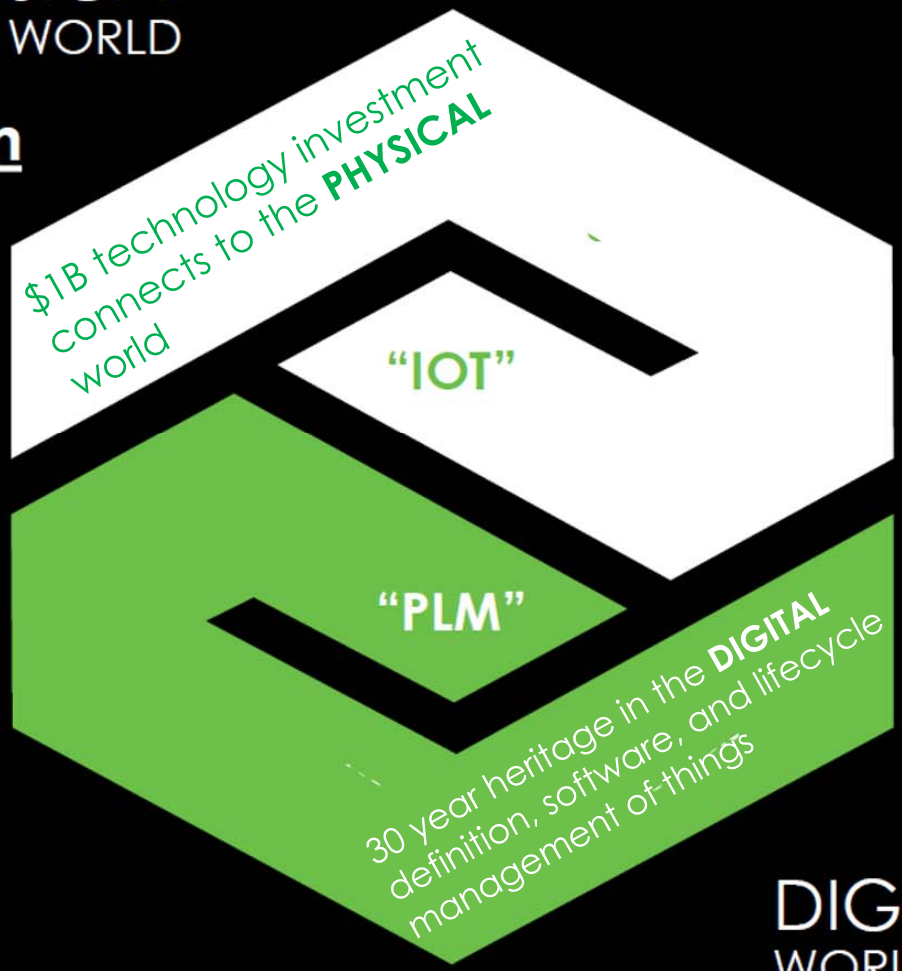
PHYSICAL
WORLD

Innovation Platform

IoT & Analytics | thingworx

AR/VR | vuforia

Industrial Connectivity | kepware



PLM Solutions

CAD | creo

PLM | windchill

ALM | integrity

SLM | servigistics

DIGITAL
WORLD

PTC PRODUCTS ARE WIDELY USED ACROSS FA&D

ptc

ARMY

NAVY

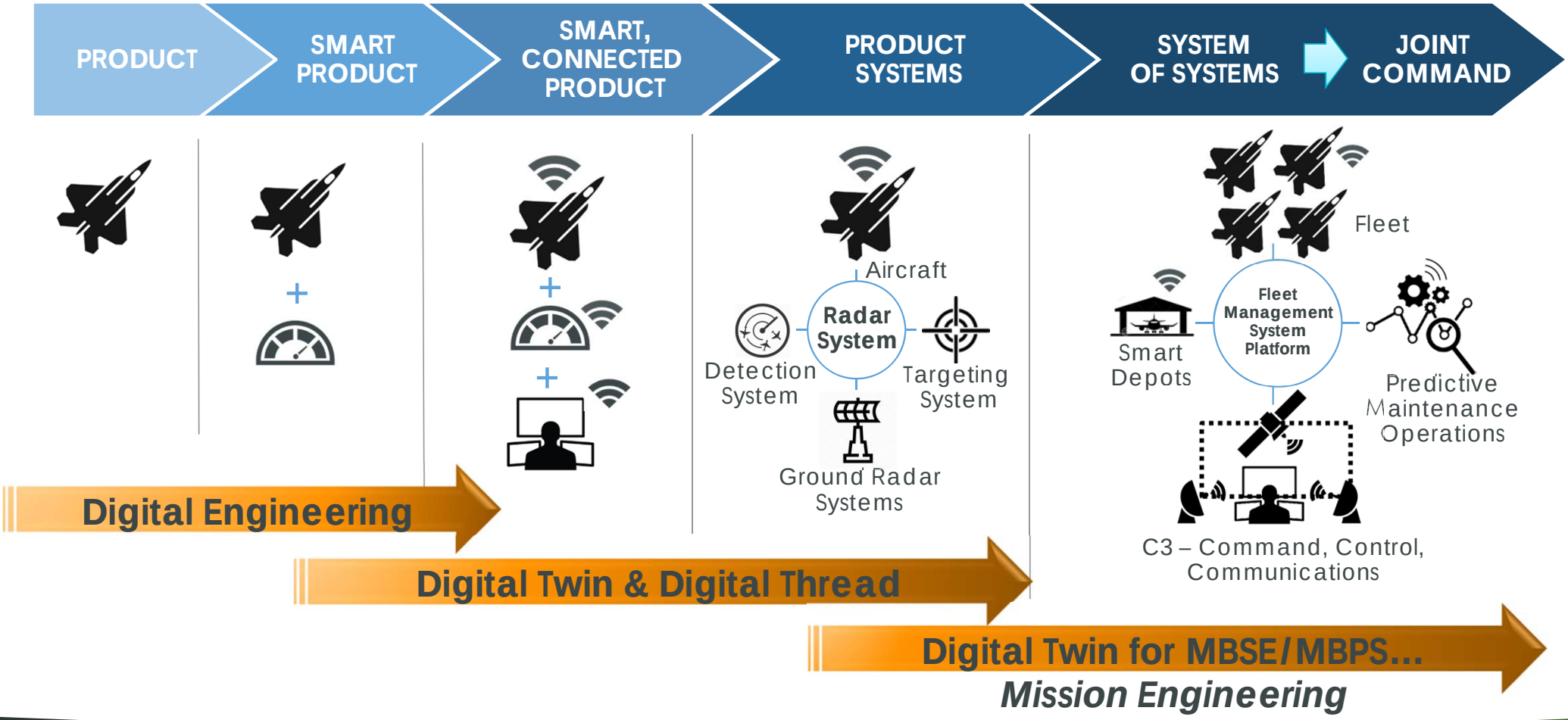
NASA

US DoE

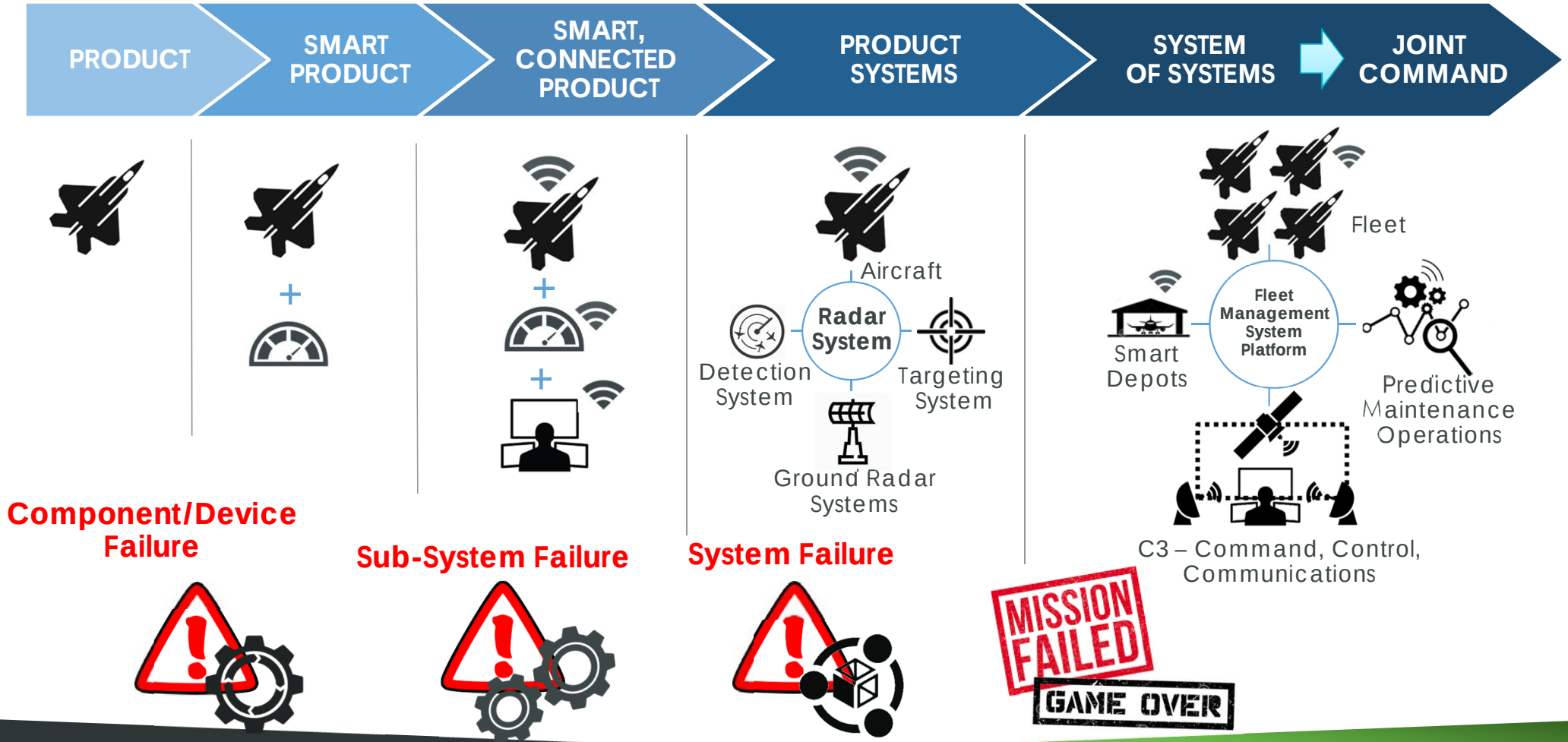
A&D

FED

DIGITAL TWIN FOR MODEL-BASED…'X'= SE/PS/DE…



OBJECTIVE: MANAGE **SUSTAINED SYSTEMS PERFORMANCE** TO PREDICT MISSIONS FAILURE



DIGITAL TREAD FOR SUSTAINED SYSTEMS PERFORMANCE

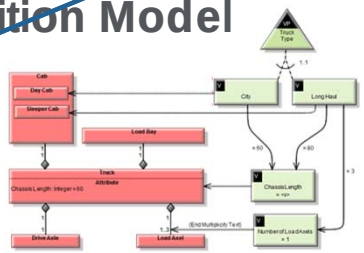
ptc

Combining the digital threads for systems development and systems failure prediction

MBSE Digital Tread for Digital Engineering:

- Systems of Record (SoR)
- Systems of Engagement (SoE)
- System of Intelligence (SoI)

Failure Condition Model



System Model

Model-based Condition Assessment

Systems Performance analysis:

- Asset functionality
- Level of service
- Availability
- Maintainability / sustainability
- Reliability

Failure Modes analysis based on condition assessment

PREDICTIVE FUNCTIONAL BEHAVIOR SIMULATION

MBSE Digital Thread enables early validation of complex behaviors

- **Driven by** *(dynamic…)***:**
  - Mission and System requirements
  - Logical and functional System models (Systems architecture)
  - IOT data in-the-loop - Closed-loop system level IoT modeling
- **Based on** *(static…)***:**
  - Connected Digital Twin data (CAD/PLM/EAM/In-Service/Software)
  - Hardware-in-the-loop - IOT-connected devices

Dynamic Systems Behavior Modeling & Simulation

THE MBSE DIGITAL THREAD FOR SYSTEMS FAILURE PREDICTION

HOW DO WE BUILD IT?

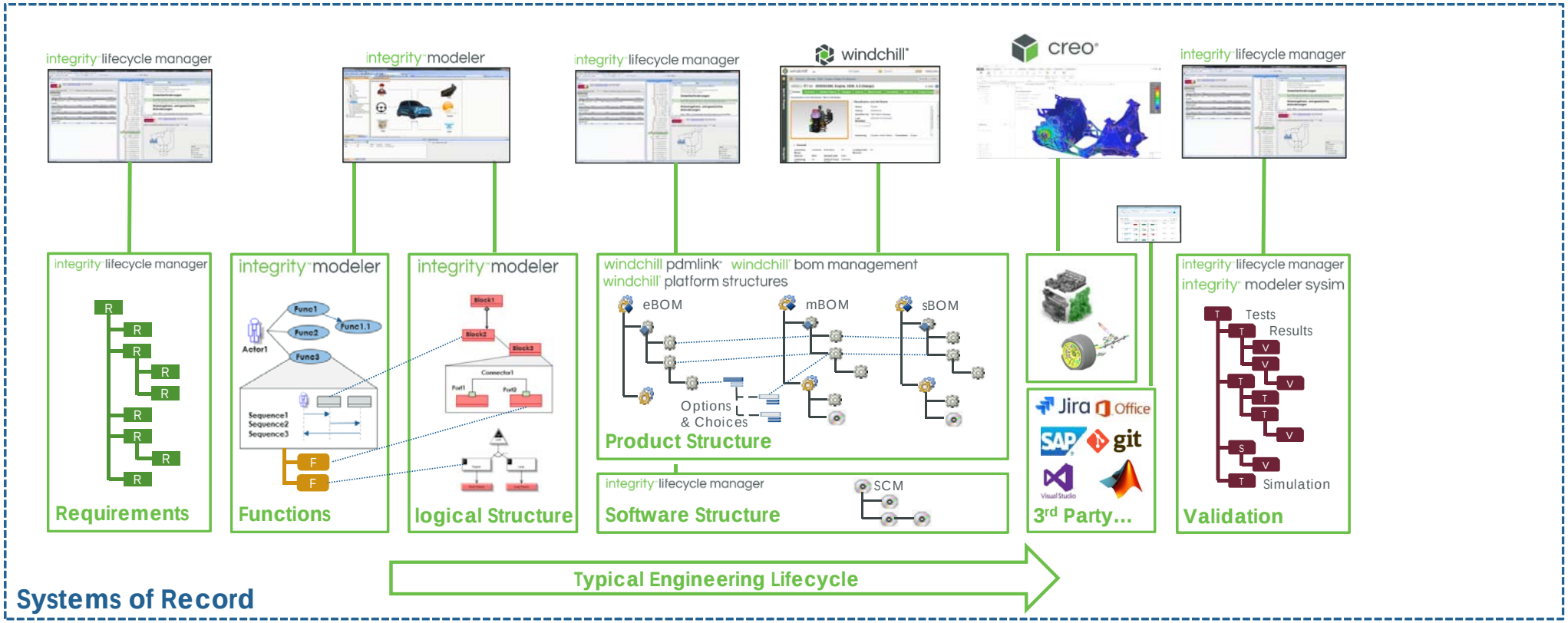
INFRASTRUCTURE, CONNECTIVITY, PROCESS, ADAPTABILITY

1. SYSTEMS OF RECORD

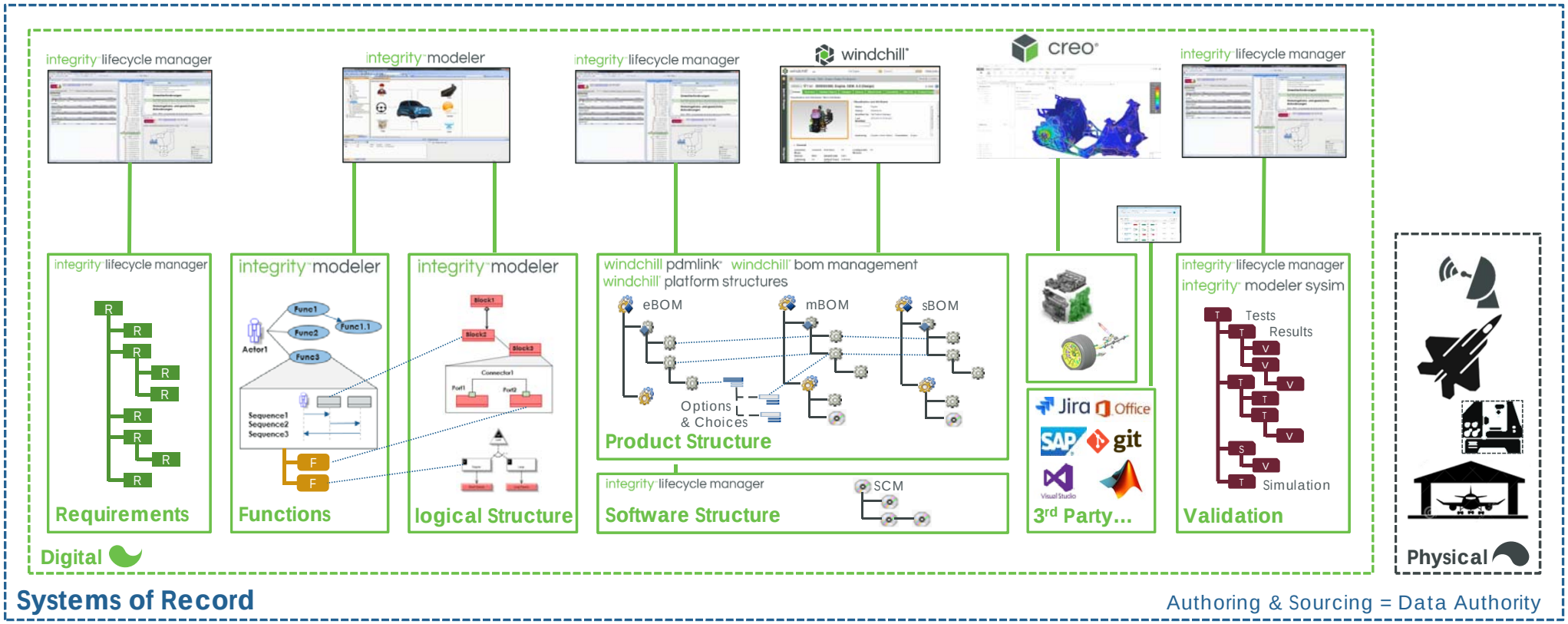
windchill pdmlink
windchill bom management
windchill platform structures

integrity lifecycle manager
integrity modeler

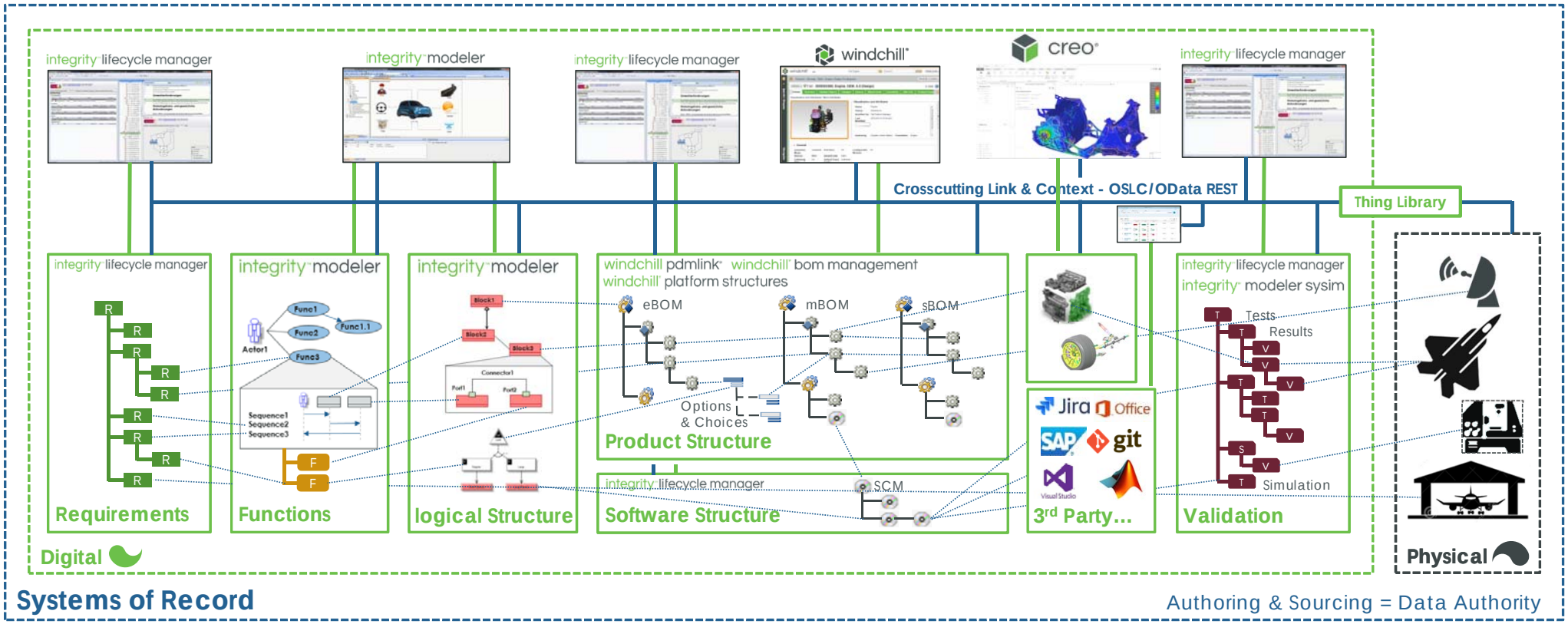
others...

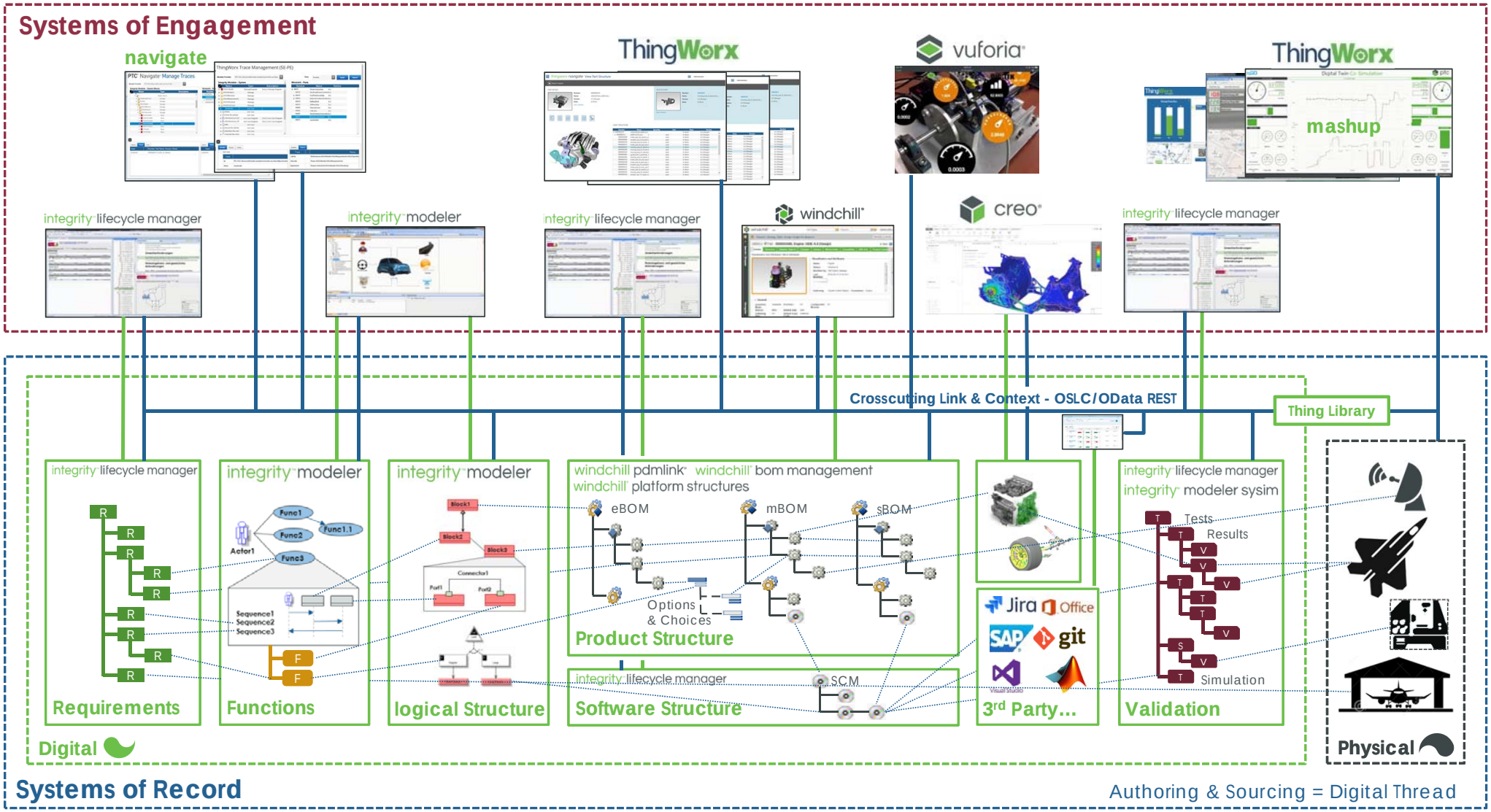


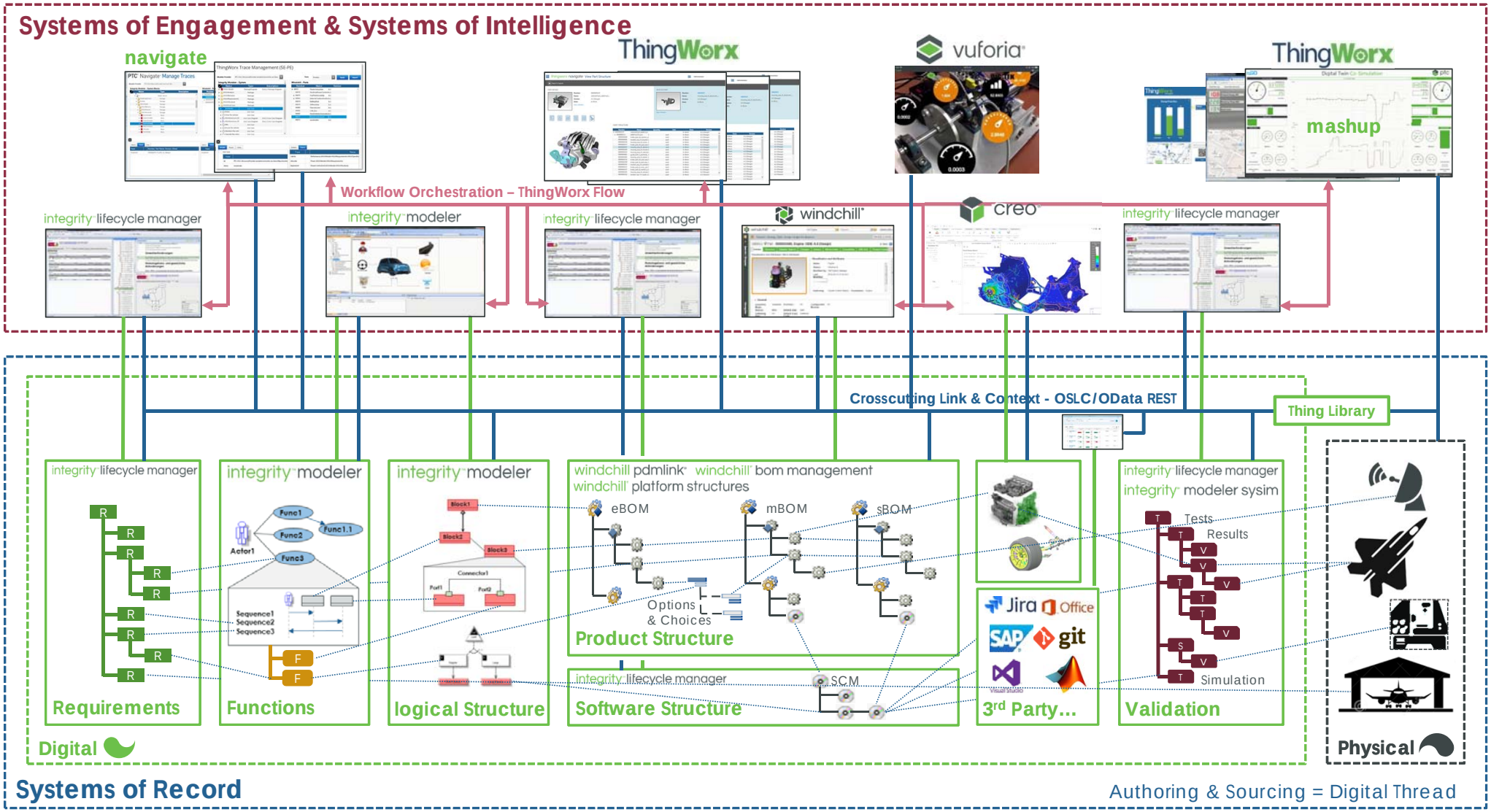
2. DIGITAL THREAD



3. DATA MODELS – CONTEXT / ASSOCIATIVITY




Systems of Engagement
navigate
ThingWorx
vuforia
ThingWorx
mashup
integrity lifecycle manager
integrity modeler
integrity lifecycle manager
windchill
creo
integrity lifecycle manager
Crosscutting Link & Context - OSLC/OData REST
Thing Library
integrity lifecycle manager
Requirements
integrity modeler
Functions
integrity modeler
logical Structure
windchill pdmlink windchill bom management
windchill platform structures
eBOM
mBOM
sBOM
Options & Choices
Product Structure
integrity lifecycle manager
SCM
Software Structure
Jira
Office
SAP
git
3rd Party...
integrity lifecycle manager
integrity modeler sysim
Tests
Results
Simulation
Validation
Digital
Physical
Systems of Record
Authoring & Sourcing = Digital Thread


Systems of Engagement & Systems of Intelligence
navigate
ThingWorx
vuforia
ThingWorx
mashup
Workflow Orchestration – ThingWorx Flow
integrity lifecycle manager
integrity modeler
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SCM
Software Structure
Jira
Office
SAP
git
3rd Party...
integrity lifecycle manager
integrity modeler sysim
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Systems of Record
Authoring & Sourcing = Digital Thread

MBSE DIGITAL THREAD FOR SYSTEMS FAILURE PREDICTION

Dynamic Systems Behavior Modeling & Simulation

- Systems reliability improvement and failure prediction
- Simulate behaviors of systems components and overall product functional behavior
- Predict, Plan and design systems changes based on real-life IoT operational data
- Systems comparability problem solving
- Plan systems functional behavior with system and software parameters
- Predict impact of environment/mission changes to systems behavior
- Prevent future system failures by eliminating them in the design phase
- Integration of Augmented Reality (AR) to visualize the physical impact of changes

DEMO

DIGITAL TWIN FOR SIMULATION IN MBSE

DIGITAL TWIN FOR MBSE

- Digital Twin in the Model-based Systems Engineering process with high-fidelity simulations, enables efficient mission operations changes for 'assets in mission', in the A&D industry

- PTC Model-based Systems, Requirements and Software Engineering solution provides the platform to manage complexity in systems specification, models architecture and requirements traceability

- PTC Digital Twin 3D CAD Design and Engineering Change Management capabilities enable seamless Model-based Systems Engineering process across multiple engineering functions, data exchange, integration and interoperability (*including OSLC – based data exchange*)

- ANSYS Simulation capabilities, integrated into Digital Twin process, enable structural, functional and behavior product simulation, based on systems models

DIGITAL TWIN FOR MBSE – LANDING GEAR DEMO

Connecting Mission Operations to Design Team through Traceable Change Management Process

Demo Objective: Efficiently explore mission changes impact to Aircraft systems; trace and implement new mission requirements in engineering design with systems functional behavior simulation

Mission changes that affecting landing gear downforce, braking force and distance at takeoff and landing:

1. **Change in runway length**

2. **Change in Payload weapon**

3. **New Requirements created for the Mission Changes:**
   - **Input Parameters:** Payload mass, Landing and Braking deceleration
   - **Output Parameters:** Stress and Safety Factor and Fatigue (# of cycles-to-failure)

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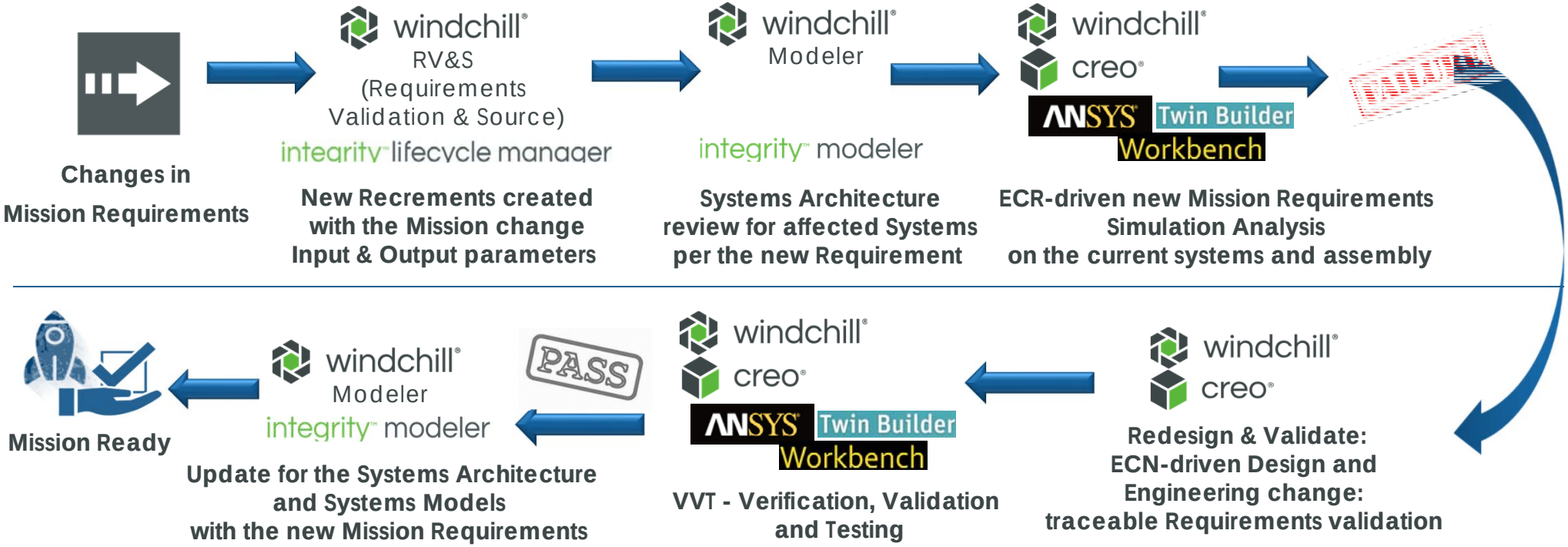

DIGITAL TWIN FOR MBSE – LANDING GEAR DEMO

Role	Software Tool	Function	Input/Output
Lead Mission Engineer	Windchill RV&S (Requirements Validation & Source) Former Integrity Lifecycle Manager	Mission Change recorded as a Requirement in the Integrity Lifecycle Manager New Requirement created with mission change input and output parameters	
Systems Architect / Systems Engineer	Windchill Modeler, Windchill Former Integrity Modeler	Analyze Systems Architecture and Identify Systems affected by the new Requirement Create ECR with affected Systems Assembly for Simulation Analysis/Test and link new Requirement to the Assembly for traceability	CSV file with requirement parameters OSLC data input
Simulation Analyst	Windchill, CREO, ANSYS Twin Builder, ANSYS Workbench/Mechanical	Load affected Sub-assembly and the test Requirements into simulation environment and perform simulation analysis Simulation Test **FAILS**, based on the new Requirement parameters Link simulation report to the ECR for Decision Review	Input: CSV file Output: Simulation report as document
Lead Engineer	Windchill	Create ECN for Design Change in affected Sub-Assembly Create new Revisions for affected Parts and Assemblies	Input: Simulation Test report, New Requirement
Designer	Windchill, CREO	Redesign & Validate: Update new revision of the affected sub-assembly per the new Requirement	
Simulation Analyst	Windchill, CREO, ANSYS Twin Builder, ANSYS Workbench/Mechanical	VVT - Verification, Validation and Testing: Load re-designed Sub-assembly and the test Requirements into simulation environment and perform simulation analysis Simulation Test **PASSES,** based on the new Requirement parameters Link simulation report to the ECN for Decision Review	Input: CSV file Output: Simulation report as document
Lead Engineer	Windchill	Release of ECN and the new revision for the affected Assembly, Requirements and the Systems Architecture	
Systems Architect / Systems Engineer	Windchill, Integrity Modeler	Update Systems Logical and Functional Architecture diagram with the new Mission Parameters	CSV file OSLC data input

Digital Twin for MBSE:
Connecting Mission Operations to Design Team through Traceable Change Management Process

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Craig Miller - ANSYS
Bill Pollock - PTC
Lance Lambert - PTC

Thank You!

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