THE MBSE DIGITAL THREAD FOR SYSTEMS FAILURE PREDICTION

22nd Annual Systems and Mission Engineering Conference - October 2019
$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

PHYSICAL WORLD

Innovation Platform

IoT & Analytics | thingworx®
AR/VR | vuforia®
Industrial Connectivity | kepware®

$1B technology investment connects to the PHYSICAL world

“PLM”

30 year heritage in the DIGITAL definition, software, and lifecycle management of things

PLM Solutions

CAD | creo®
PLM | windchill®
ALM | integrity®
SLM | servigistics®
PTC PRODUCTS ARE WIDELY USED ACROSS FA&D

ARMY

NAVY

NASA

US DoE

A&D

FED

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

Product

Smart Product

Smart, Connected Product

Product Systems

System of Systems

Joint Command

Digital Engineering

Digital Twin & Digital Thread

Digital Twin for MBSE/MBPS...

Mission Engineering
OBJECTIVE: MANAGE SUSTAINED SYSTEMS PERFORMANCE TO PREDICT MISSIONS FAILURE

PRODUCT

SMART PRODUCT

SMART, CONNECTED PRODUCT

PRODUCT SYSTEMS

SYSTEM OF SYSTEMS

JOINT COMMAND

Component/Device Failure

Sub-System Failure

System Failure

Ground Radar Systems

Targeting System

Aircraft

Radar System

Detection System

Fleet Management System Platform

Fleet

Smart Depots

Predictive Maintenance Operations

C3 - Command, Control, Communications

Mission Failed

Game Over
DIGITAL TREAD FOR SUSTAINED SYSTEMS PERFORMANCE

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)

System Model

Model-based Condition Assessment

Failure Mode analysis based on condition assessment

Failure Condition Model

Systems Performance analysis:
- Asset functionality
- Level of service
- Availability
- Maintainability / sustainability
- Reliability

Digital threads for systems development and systems failure prediction.
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...

Integrity lifecycle manager

Requirements

Functions

Logical Structure

Product Structure

Software Structure

SCM

Validation

Typical Engineering Lifecycle
2. DIGITAL THREAD
3. DATA MODELS – CONTEXT/ ASSOCIATIVITY
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)
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

- **Changes in Mission Requirements**
  - Windchill® RV&S (Requirements Validation & Source)
  - New Requirements created with the Mission change
  - Input & Output parameters
  - RV&S Manager

- **Windchill® Modeler**
  - Integrity™ modeler
  - Systems Architecture review for affected Systems per the new Requirement

- **Windchill® creo®**
  - ANSYS Twin Builder Workbench
  - ECR-driven new Mission Requirements Simulation Analysis on the current systems and assembly

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**Mission Ready**

- Update for the Systems Architecture and Systems Models with the new Mission Requirements

- Windchill® creo®
  - ANSYS Twin Builder Workbench
  - VVT - Verification, Validation and Testing

- Windchill® creo®
  - Redesign & Validate: ECN-driven Design and Engineering change: traceable Requirements validation
## DIGITAL TWIN FOR MBSE – LANDING GEAR DEMO

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

David Segal - PTC
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Thank You!

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