THE DIGITAL TWIN THROUGHOUT THE SYSTEM LIFECYCLE

Matthew Hause
Engineering Fellow, MBSE Specialist

October, 2018
• Introduction
• The Digital Twin
• MBSE and the Digital Twin
• The System Lifecycle
• Conclusions
• Questions and Answers?
WHAT IS THE DIGITAL TWIN?

• A TRUE Digital Twin needs two components:
  - The digital definition. (Universal Access)
  - The physical experience. Without the specific physical experience such as environmental data from an operating asset, all you have is a digital sibling but no twin

• The ‘Digital Twin’ requires a complete digital understanding of the product – the development, history, service records, as-maintained BOM, configurations, CAD analysis, IoT readings, software versions, options and variants, etc.

• With Augmented Reality (AR) ‘Digital Twins’ you can see a “twin” of your product, factory or office without needing the physical product or to be there in real time
A holistic, multi-disciplinary and collaborative approach to designing and maintaining complex systems throughout the systems lifecycle.
Nearly every stakeholder can benefit from the wealth of information generated:

- Engineering can make better decisions to improve the product
- Legal and quality assurance can gain complete traceability to ensure security and legal requirements
- Service technicians can better maintain and repair the product
- Marketing can determine better ways to position the product in the market
- Sales can identify future sales and upgrade opportunities
- Customers can visualize the product in its deployed environment
- System operators can more closely visualize the system in operational mode
- Predictive analysis can be performed on the system more effectively
- Etc.
The digital twin does not spring into life fully formed straight from the CAD model. It requires an informed systems engineering approach to ensure that the integration between physical and digital is fit for purpose.

- The form and function of the digital and physical form a synergy
- The right measurements are captured and made available
- The right amount of data is captured
- The communications infrastructure is sufficient to support this data
- Security controls are in place to deter unwanted capture of data or worse control of the physical asset
- The operational and maintenance data of the asset support the operational and maintenance needs of the system of systems
- Sufficient computing power is made available for predictive analysis
- The digital and physical assets can evolve to meet the changing needs of the system of systems.
- Etc.
MBSE AND THE DIGITAL TWIN

• The NDIA defines Model-Based Systems Engineering (MBSE) as “an approach to engineering that uses models as an integral part of the technical baseline that includes the requirements, analysis, design, implementation, and verification of a capability, system, and/or product throughout the acquisition life cycle.”

• With the addition of simulation, the Internet of Things (IoT) and connected models, MBSE also provides value in the operations and maintenance phases.

• The digital twin is an enabling technology that used in conjunction with MBSE will help achieve the goals of these initiatives.
PAVING THE WAY – JOURNEYS OF TRANSFORMATION

Digital Engineering

Manufacturing

Service
A fully digital representation of the product is developed for connectivity and is used across all functions, enabling connected manufacturing and service, product performance feedback and traceability, automation simulation, artifact creation, and collaboration.
SYSTEMS ENGINEERING AT THE CORE OF DIGITAL ENGINEERING

- Digital Product Traceability
- Universal Data Access
- Design for Connectivity
- Performance Based Analysis & Data Driven Design

Digital Product Definition
- SE System of Record
- Requirements
- System Functions
- System Structures
- Engineering Processes

Democratization
- Navigate™
- Web UIs
- Role Based UIs
- Visual Modeling

Link & Trace
- R-F-L-P
- Design Flow
- Impact Analysis
- Certification

Systems of Systems
- Modular Design
- Component Reuse
- IoT Design
- Flow to Software

Simulation - V&V
- Co-simulation
- x-in-the-loop
- Trade Studies
- Test Management

Part of Twin
System PLE
Requirements…..‘satisfied by’ System Functions…..’allocated to’ Logical Parts…
…’implemented by’ Physical Parts…..’sending & receiving’ real world data
FROM REQUIREMENTS TO PROTOTYPE-IN-THE-LOOP VALIDATION

MODEL-IN-THE-LOOP
- Requirements & Acceptance Criteria
- System Model Structure & Behaviour
- Behaviour Simulation

SOFTWARE-IN-THE-LOOP
- Integration and Validation (Test)
- (Embedded) Software Code

PROTOTYPE-IN-THE-LOOP
- Real-time Validation in operational use
- IoT-Dashboard & Edge-Device Connectivity

Development Progress
HIGH-LEVEL SYSTEM DESIGN

- Objective(s): Design the high level concepts (& context) of the whole product
- Scenario: Model the high-level GO car concepts
- Role(s): Whole Systems Engineer
- Product(s): Integrity Modeler (refining Integrity Lifecycle Manager requirements)
- Open Standards: SysML & OSLC
- Benefits: Visual design for stakeholder agreement & feature allocation
THE SYSTEM UNDER DEVELOPMENT

e.GO Life  An Electric Vehicle Under Development
THE ELECTRIC CAR CONTEXT DIAGRAM
**SYSTEM REQUIREMENTS**

**Driver Requirements**
- The Driver shall be able to operate the eGO

**PowerTrain Requirements**
- The system shall balance power according to the Gas Pedal set point
- The system shall maximise Battery life

**System Requirements**
- The驱动 shall be able to achieve 0 to 100 km/h in less than 18 s
- The eGO shall be compliant with regulation regarding braking distance
The system shall balance power according to the Gas Pedal set point

The driver shall be able to achieve 0 to 100 km/h in less that 18 s

The eGO shall be compliant with regulation regarding braking distance

The driver shall be able to operate the eGO

The system shall maximise Battery life

Drive the Vehicle

Accelerate

Brake

Balance Power

Limit Skid

Load Driver Profile

Driver Requirements

PowerTrain Requirements
SYSTEM USE CASES

Driver

- Drive the Vehicle
  - Accelerate
  - Steer
  - Brake

- Functional Requirement:
  Traction control shall avoid skidding at maximum acceleration to max ucd
MAIN VEHICLE SUBSYSTEMS
POWER TRAIN SUBSYSTEM STRUCTURE

- PowerTrain CU
- Motor
- Drive Shaft
- Differential cast
Accelerate
Description

Gas Pedal

par

Get Gas Pedal position
Balance Power
Set Motor load

also par

If traction loss
Limit Skid
End If

end par

Get Pedal Position
Balance Power
Set Load

If traction loss
Limit Skid

End If

deployment
deployment

ACCELERATE USE CASE SEQUENCE
Digital Twin: A digital representation of a unique occurrence of a physical product, used to gain greater insight into that product’s state, performance and behavior.
REAL-WORLD DATA DRIVEN DESIGNS
DESIGN MODEL OPTIMIZATION

Digital Prototype

Product Population

ASSUMPTION

REALITY
DESIGN MODEL OPTIMIZATION BY FEEDING BACK FIELDDED SENSOR DATA INTO DESIGN MODEL
SYSTEM MODEL OPTIMIZATION BY FEEDING BACK FIELDDED SENSOR DATA INTO INTEGRITY MODELER SYSIM
EGO LIFE USE CASE
Digital Twin Co-Simulation

Physical

Digital
COLLABORATIVE AR/VR DESIGN

More frequent and immersive design reviews throughout the product development process

- Increase participation of stakeholders from disparate locations
- Make better decisions by capturing voice, drawn, and text input directly into the design history of the product
- Reduce costs associated with sophisticated design reviews by identifying potential issues early in the process

Collaborative AR/VR Design

PTC Solutions:

- creo®
- Windchill®
- thingworx®
EASY ACCESS TO THE DIGITAL PRODUCT DEFINITION FOR THE ENTIRE ENTERPRISE WITH CONNECTED DIGITAL ENGINEERING
AGILE, PROTOTYPE-DRIVEN DEVELOPMENT THROUGH AUGMENTED REALITY
AGILE, PROTOTYPE-DRIVEN DEVELOPMENT THROUGH AUGMENTED REALITY
PROTOTYPE-DRIVEN DEVELOPMENT THROUGH AR - VIDEO
Nespresso Hor

Brew "My Cup"
Brew Espresso
Brew MAX

Point camera at ThingMark
AUGMENTED REALITY WILL DRAMATICALLY INCREASE VALUE CREATION

Why Every Organization Needs an Augmented Reality Strategy

BY MICHAEL E. PORTER AND JAMES E. HEPPELMANN

There is a fundamental disconnect between the wealth of digital data available to us and the physical world in which we apply it. While reality is three-dimensional, the rich data we now have to inform our decisions and actions remains trapped on two-dimensional pages and screens. This gulf between the real and digital worlds limits our ability to take advantage of the torrent of information and insights produced by billions of smart, connected products (SCPs) worldwide.
CONCLUSIONS

• The Digital Twin provides a means of visualizing a system at all phases of development
  – Concept
  – Design
  – Operations
  – Maintenance
  – Etc.

• A Digital Twin requires both the physical system and the digital representation

• Digital Twins can be combined with simulation, MBSE models, AI analytics, etc.
THE ANALOG TWIN
Thank You!