Future Directions for MBSE and SysML

For INCOSE North Texas Chapter

October 13, 2020

Chris Schreiber

Systems Engineering Sr. Mgr. – Lockheed Martin Space

About Me . . .

**Senior Manager –
Systems Engineering
Modernization**

Space Systems Company
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Career

Systems and Software Management Consulting

Manufacturing and ERP

Systems and Software Engineering

At Lockheed Martin for 13 years

Focus Areas

Civil Space
Commercial Space
Missile Defense
LM Space and Corporate Engineering & Technology
- **Digital Transformation**
- **SE Modernization**
  - SSC MBSE Implementation
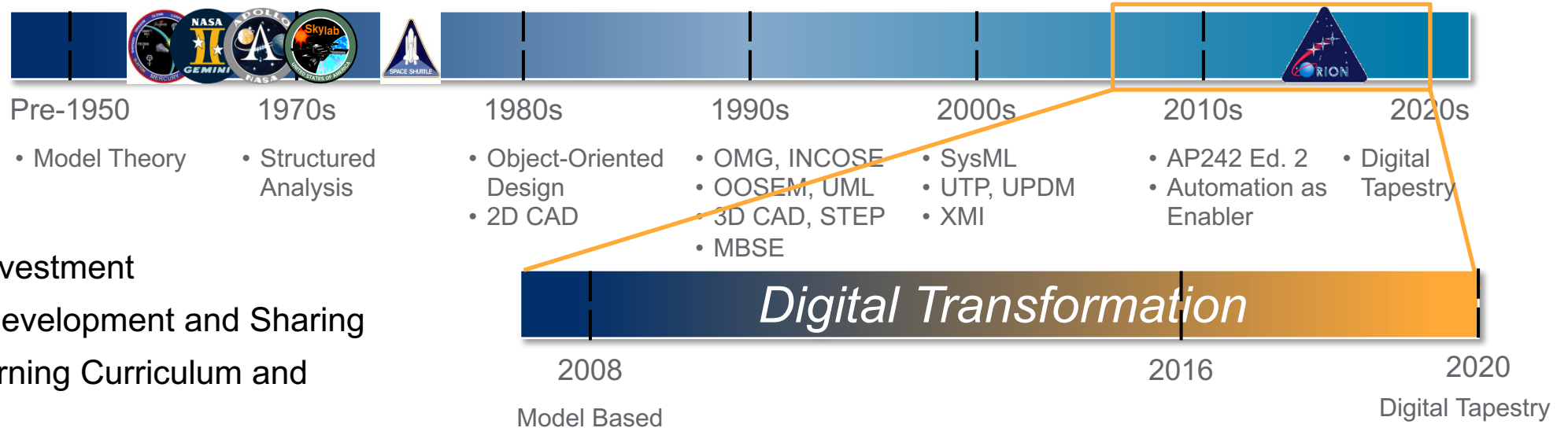 - Advanced SE Practices

Organizations/Affiliations

OMG SE-DSIG, SysML 2.0 Working Group & B.o.D.
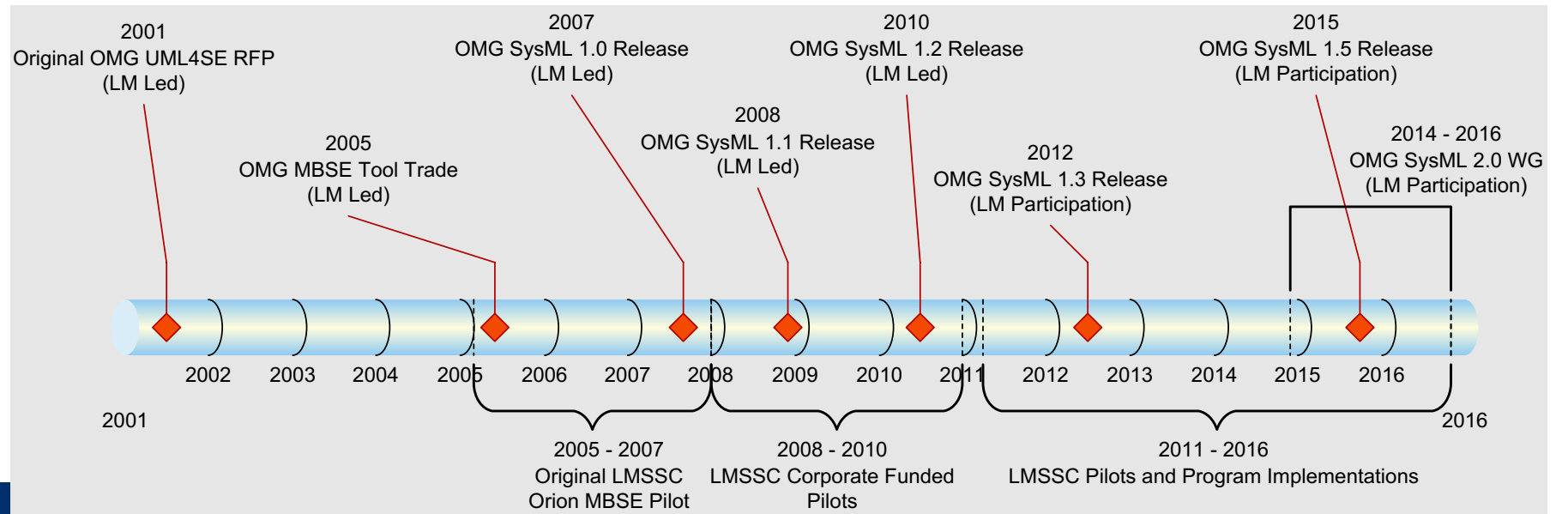
NDIA SE Division M&S CO-Chair

DEIXWG Co-Chair

INCOSE Member - RMFR

History of MBSE @ Lockheed Martin

Pre-1950
- Model Theory

1970s
- Structured Analysis

1980s
- Object-Oriented Design
- 2D CAD

1990s
- OMG, INCOSE
- OOSEM, UML
- 3D CAD, STEP
- MBSE

2000s
- SysML
- UTP, UPDM
- XMI

2010s
- AP242 Ed. 2
- Automation as Enabler

2020s
- Digital Tapestry
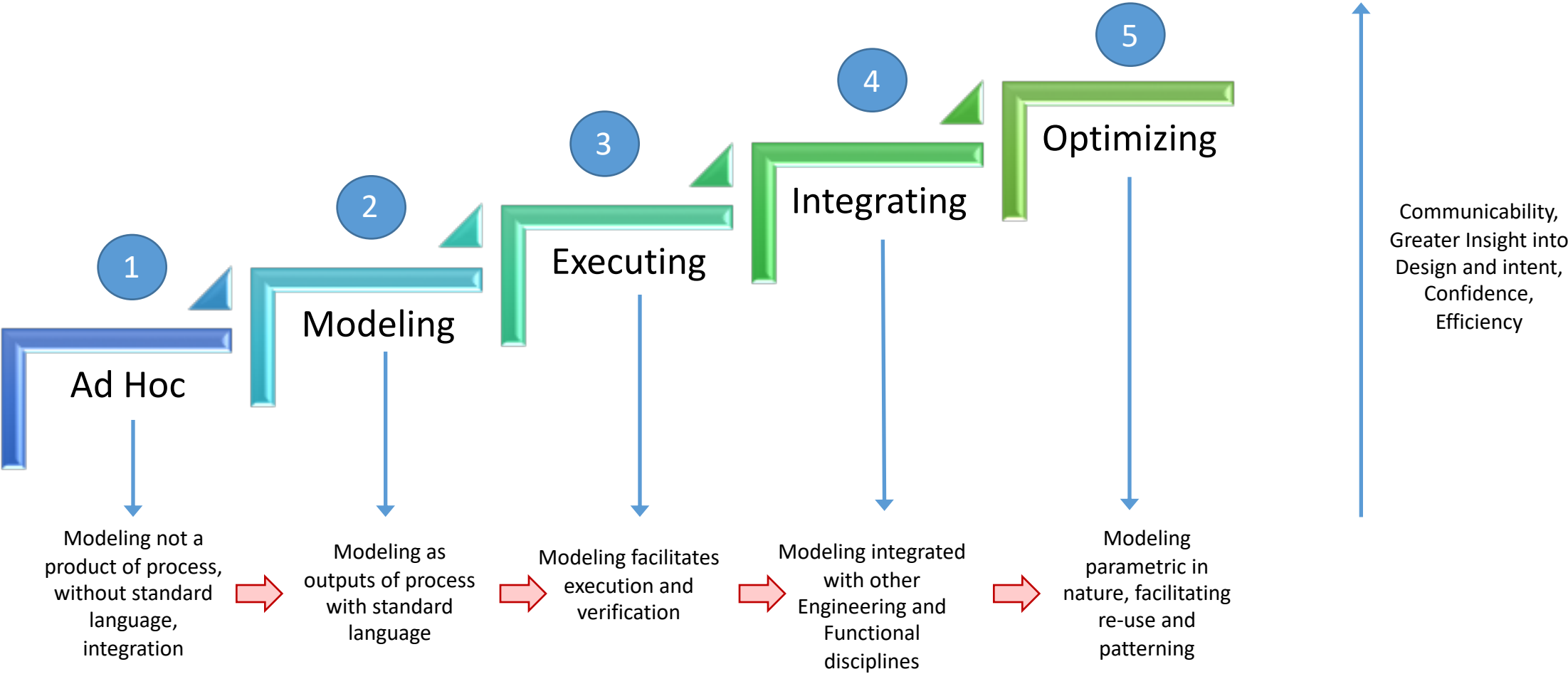
- Focused Company Investment
- Technical Expertise Development and Sharing
- Incorporated into Learning Curriculum and Development Tracks

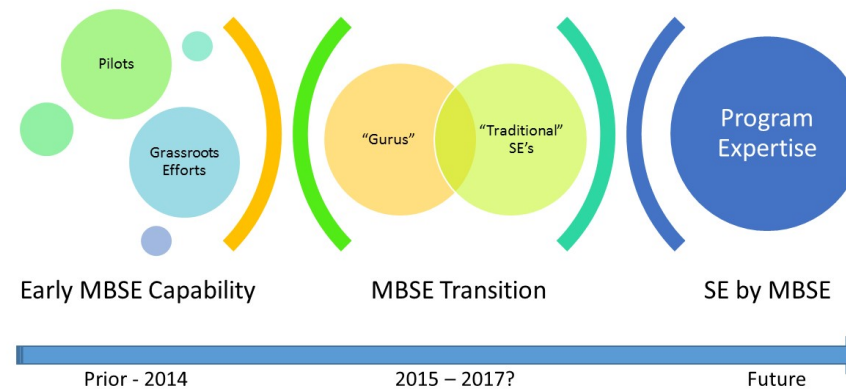*Digital Transformation*

2008
Model Based

2016

2020
Digital Tapestry

2001
Original OMG UML4SE RFP
(LM Led)

2005
OMG MBSE Tool Trade
(LM Led)

2007
OMG SysML 1.0 Release
(LM Led)

2008
OMG SysML 1.1 Release
(LM Led)

2010
OMG SysML 1.2 Release
(LM Led)

2012
OMG SysML 1.3 Release
(LM Participation)

2015
OMG SysML 1.5 Release
(LM Participation)

2014 - 2016
OMG SysML 2.0 WG
(LM Participation)

2001   2002   2003   2004   2005   2006   2007   2008   2009   2010   2011   2012   2013   2014   2015   2016   2016

2005 - 2007
Original LMSSC
Orion MBSE Pilot

2008 - 2010
LMSSC Corporate Funded Pilots

2011 - 2016
LMSSC Pilots and Program Implementations

18 years Experience with SysML Development

An MBSE Maturity Model

1 Ad Hoc

2 Modeling

3 Executing

4 Integrating

5 Optimizing

Communicability, Greater Insight into Design and intent, Confidence, Efficiency

Modeling not a product of process, without standard language, integration

Modeling as outputs of process with standard language

Modeling facilitates execution and verification

Modeling integrated with other Engineering and Functional disciplines

Modeling parametric in nature, facilitating re-use and patterning

Lessons learned from early MBSE maturity

Certification

Web-Based Modules

- People

- Training

- Tools

- Usability

- Data Management

Early MBSE Capability   MBSE Transition   SE by MBSE

Prior - 2014   2015 – 2017?   Future

Drawing Activity Diagrams with SysML

- **Modernize SE Toolset for MBSE and Digital Tapestry**
  — Evaluate current tools baselines and gaps
  — Improve usability of current tools
  — Identify tools that meet the "SE Tool Manifesto"
    - Easy to use
    - Light-weight "viewer"
    - Readily Integratable (APIs)
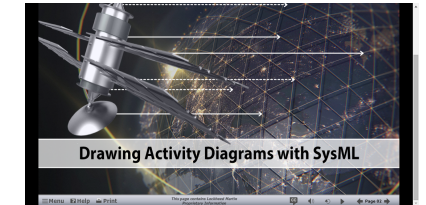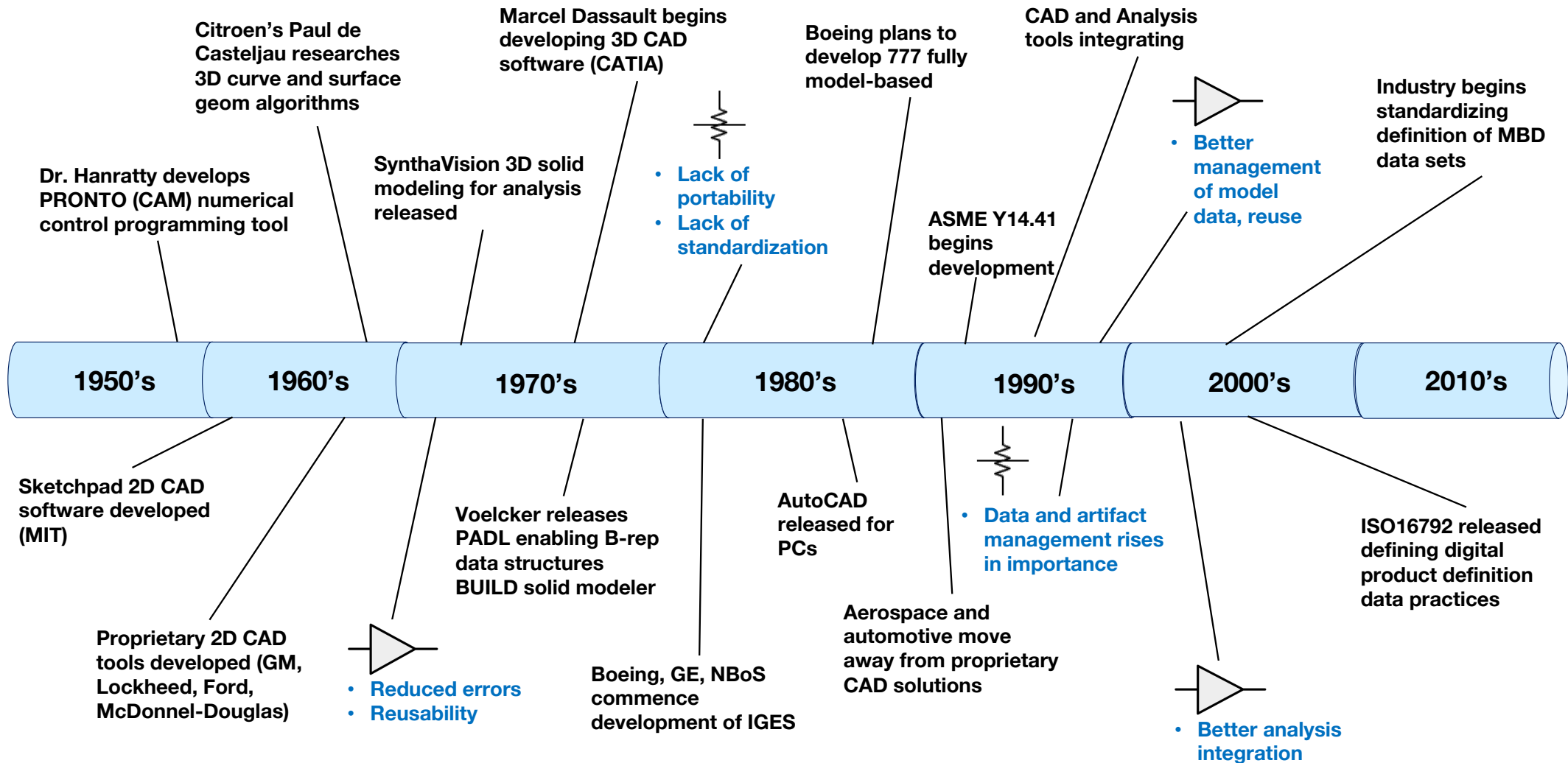   - Adaptable and "Shape-able"
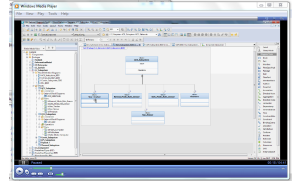
Adapt MBS
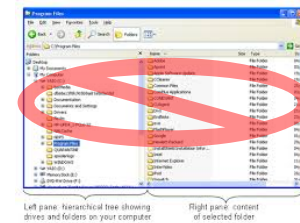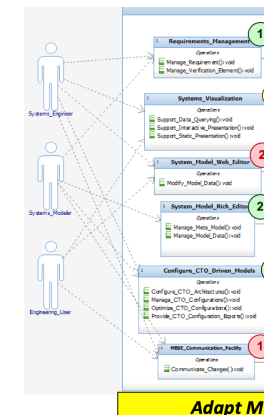
Evolution of a Model-Based Practice

Citroen's Paul de Casteljau researches 3D curve and surface geom algorithms

Marcel Dassault begins developing 3D CAD software (CATIA)

Boeing plans to develop 777 fully model-based

CAD and Analysis tools integrating

Industry begins standardizing definition of MBD data sets

Dr. Hanratty develops PRONTO (CAM) numerical control programming tool

SynthaVision 3D solid modeling for analysis released

- Lack of portability
- Lack of standardization

ASME Y14.41 begins development

- Better management of model data, reuse

1950's · 1960's · 1970's · 1980's · 1990's · 2000's · 2010's

Sketchpad 2D CAD software developed (MIT)

Voelcker releases PADL enabling B-rep data structures BUILD solid modeler

AutoCAD released for PCs

- Data and artifact management rises in importance

ISO16792 released defining digital product definition data practices

Proprietary 2D CAD tools developed (GM, Lockheed, Ford, McDonnel-Douglas)

- Reduced errors
- Reusability

Boeing, GE, NBoS commence development of IGES

Aerospace and automotive move away from proprietary CAD solutions

- Better analysis integration

Automated Design-to-Production

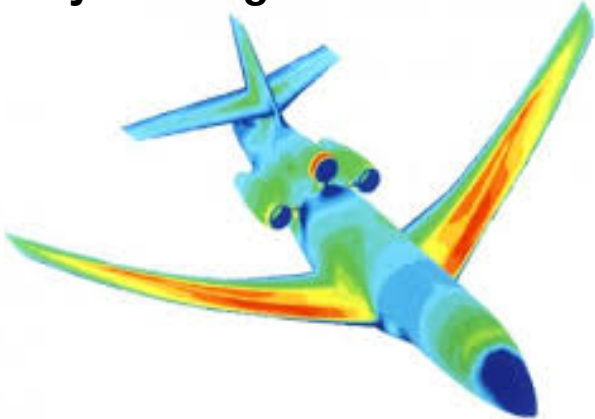* Image credit – directindustry.com

Analysis-Integrated Simulation

* Image credit – inceptra.com

Enhanced Visualization
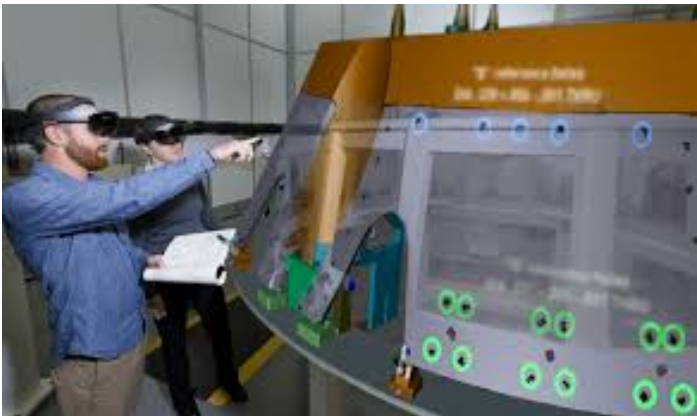
* Image credit –digitaltrends.com

Analysis-Integrated Design

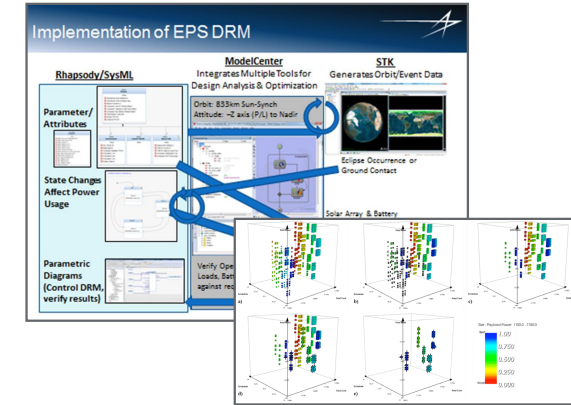* Image credit – engineering.com

Data and Configuration Management

* Image credit – medium.com

Automated Design-to-Production
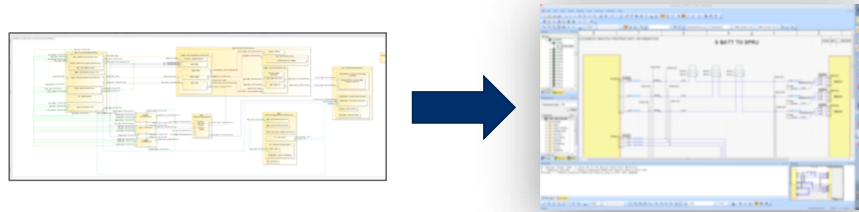
Analysis-Integrated Simulation

Enhanced Visualization

Structured File Extract

SysML Diagrammatic

Tabular Data View

Architecture Geometry

Diagram Differencing

Dynamic Visualization

Semantic Zoom
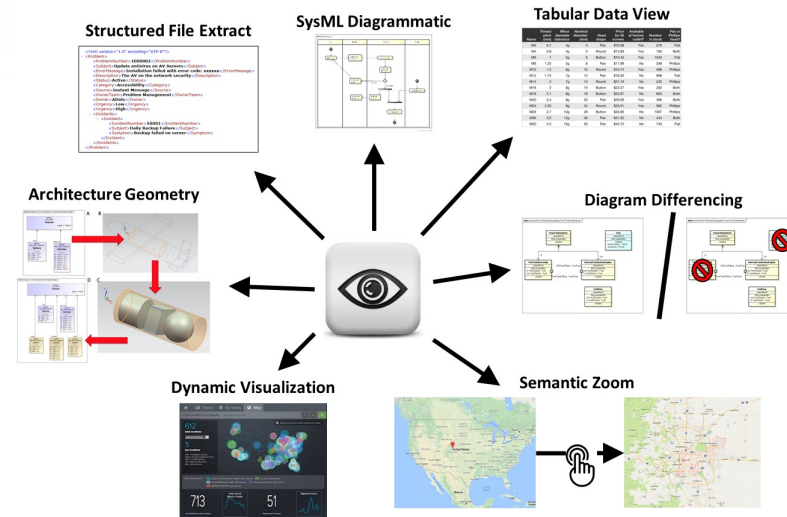
Analysis-Integrated Design

Data and Configuration Management

Qual Data

Test DM

MES

SE-DM

CM of CMs

ALM

PLM

SDM
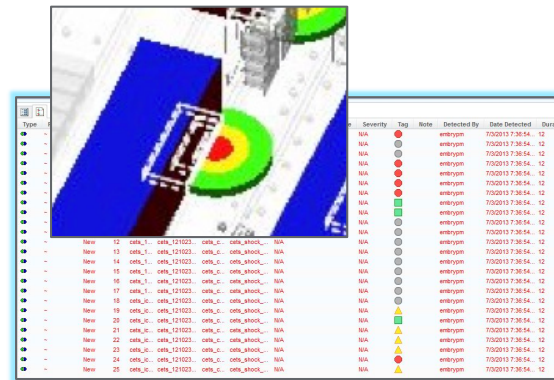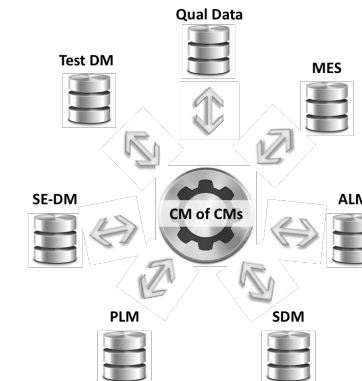
. . . beyond simply capturing Systems Engineering design, to enabling a better way of engineering systems

Emerging Needs for Higher MBSE Maturity

- Improvements to language, expressiveness

- Management of data at a more granular level

- Management of model data relationships

- Integration of model data "Sources of Truth"

- Web, Services, the Cloud

. . . More expressive language, with API and data model that provide more interoperability

SysML v2.0

Integrated Views of a System
SysML v2 Enhancement Areas over SysML v1

Improved integration with Analysis

Geometric View

Trade Studies

System Black Box

Variant Modeling & Design Configurations

Improved integration between Behavior & Structure

Property-based requirements

Source: Architecting Spacecraft with SysML

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10/8/2017

Layered Architecture

Users

External Sources (e.g., Tools, Plugins)

GUI

API

Services (construct, visualize, analyze, manage, ..)

Data (including metadata)

Platform

Standard API enables interoperability and access to modeling services

10/8/2017

https://www.omg.org/news/releases/pr2018/01-24-18.htm

SST Participating Organizations

SST

| Academia/Research End User | Tool Vendors Government Rep | INCOSE rep * |

- Aerospace Corp
- Airbus
- ANSYS medini
- Aras
- Army Aviation & Missile Center
- BAE
- BigLever Software
- Boeing
- CCDC Armaments Center
- CEA
- Contact Software
- Draper Lab
- Elbit Systems of America
- ESTACA
- Ford
- Fraunhofer FOKUS
- General Motors
- George Mason University
- GfSE
- Georgia Tech/GTRI
- IBM
- Idaho National Laboratory

- IncQuery Labs
- Intercax
- Itemis
- Jet Propulsion Lab
- John Deere
- Kenntnis
- LieberLieber
- Lightstreet Consulting
- Lockheed Martin
- LSST
- Maplesoft
- Mgnite Inc
- MITRE
- ModelAlchemy Consulting
- Model Driven Solutions
- Model Foundry
- NIST
- No Magic/Dassault Systemes
- OAR
- Obeo
- OOSE
- Ostfold University College

- Phoenix Integration
- PTC
- Qualtech Systems, Inc (QSI)
- Raytheon
- Rolls Royce
- SAF Consulting *
- SAIC
- Siemens
- Sierra Nevada Corporation
- Simula
- System Strategy *
- Tata Consultancy Services
- Thales
- Thematix
- Tom Sawyer
- UFRPE
- University of Cantabria
- University of Alabama in Huntsville
- University of Detroit Mercy
- University of Kaiserslautern / VPE
- Vitech
- 88solutions

05 November 2019

Key Elements of SysML v2

- New Metamodel that is not constrained by UML
  - ○ Grounded in formal semantics
- Robust visualizations based on flexible view & viewpoint specification and execution
  - ○ Graphical, Tabular, Textual
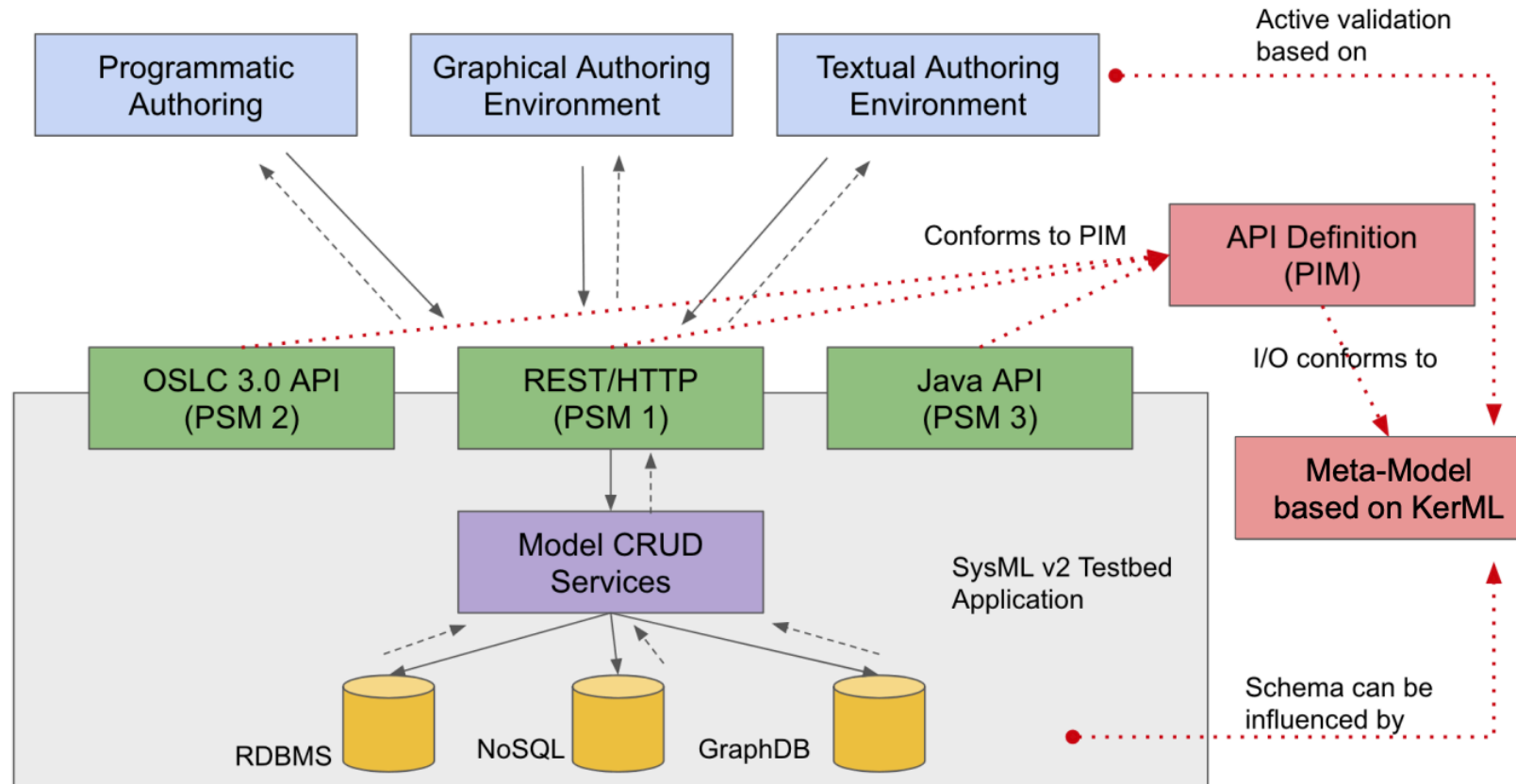 - ○ Document generation
- Standardized API to access the model

26 January 2020

Pilot Implementation Using Standard API

SST

High-Level Architecture of SysML v2 Testbed

26 January 2020

Digital Engineering Information Exchange Working Group

A Standardized way to Offer, Request and Exchange Digital Artifacts

Products

- **DEIXPedia:** Micropedia of digital engineering topics to explain relevant DEIX topics. **STATUS: In place and Maintaining. See link below**

- **Primer:** A narrative that describes the concepts and interrelationships between digital artifacts, enabling systems, and exchange transactions **STATUS: In Process, DRAFT planned for IS2020**

- **Digital Engineering Information Exchange Model (DEIXM):** A prescriptive system model for exchanging digital artifacts in an engineering ecosystem **STATUS: In process, DRAFT planned for IS2020**

- **Digital Viewpoint Models (DVM):** Descriptive information models of digital views that form content for ISO 15288.2 reviews **STATUS: DRAFT DVM developed, working with TIMLM on DEIX challenge to Validate at IS2020**

- **DEIX Standards Framework (DEIX-SF):** A framework for official standards related to MBE Information Exchanges **STATUS: DRAFT DEIX-SF DRAFT developed**

Contributing Team:
- Sean McGervey, JHU/APL, (Chairperson)
- Chris Schreiber, Lockheed Martin (Co-Chair)
- Frank Salvatore, SAIC (Co-Chair)
- Tamara Hambrick, Northrop Grumman (Co-Chair)
- Celia Tseng, Raytheon (Co-Chair)
- Dr. John Coleman, SAIC
- CAPT John McCrea, AFNWC

- Arno Granados, Sandia
- Terri Chan, Boeing
- Ken Zhang, L3 Harris
- Russell Peak, GTRI
- Mark Blackburn, Stevens
- Gan Wang, BAE Systems
- Mike Vinarcik, SAIC
- Mary Tolbert, MITRE

Information Exchange Model for Digital Engineering Ecosystem
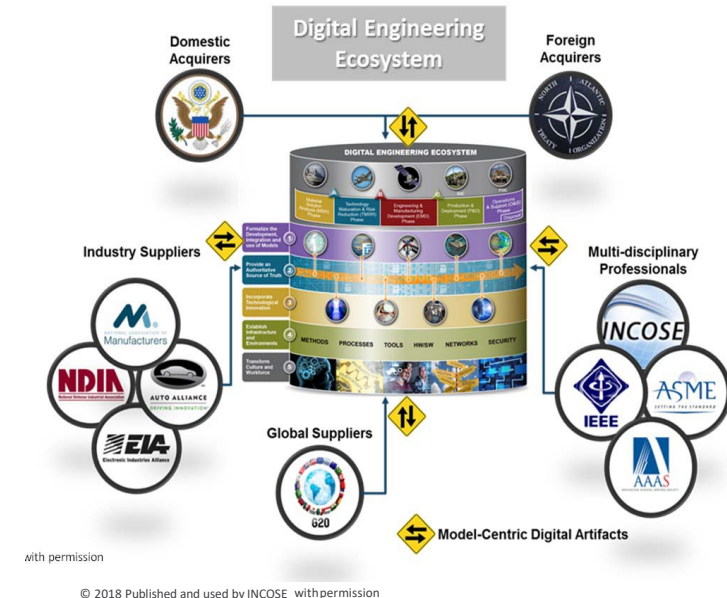
with permission

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For more details see the Digital Engineering Information Exchange Working Group (DEIX WG) WIKI page at: http://www.omgwiki.org/MBSE/doku.php?id=mbse:deix

Thank You!!

Questions?

BACKUP

2020 DEIX Challenge

- The DEIX Challenge is an opportunity for anyone in the Systems Engineering community to produce a set of self-consistent, authoritative Digital Views. Successful DEIX Challenge solutions will involve developing novel ways to synthesize Digital Information from a collection of SysML, Matlab, MCAD, FEA, and other types of Digital Artifacts into a Digital View that addresses a chosen scenario of specific perspectives and needs.

- Outbrief presentation at the 2020 NDIA Systems and Mission Engineering Conference, with a detailed Results Outbrief held virtually afterwards.
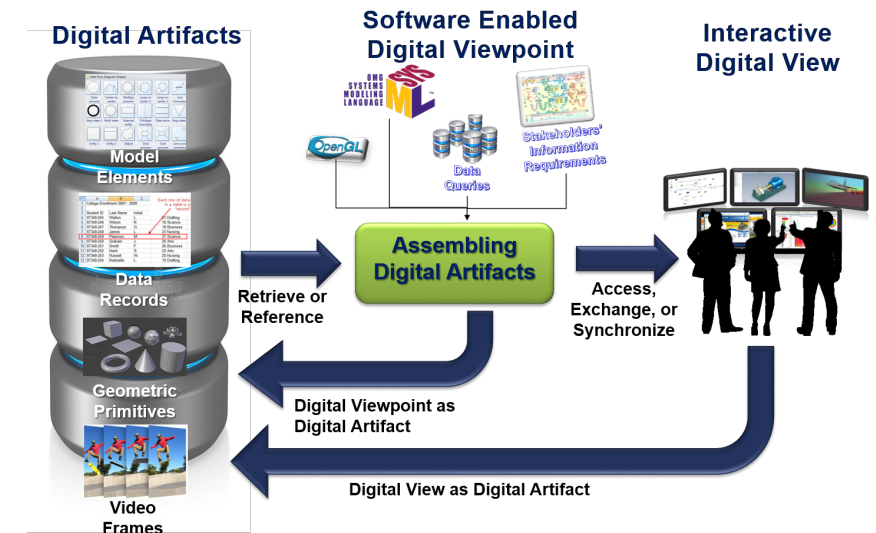
For more information visit challenge website:

http://www.omgwiki.org/MBSE/doku.php?id=mbse:deix:challenge

INCOSE DEIX Challenge 2020

- Challenge Participants will, at a minimum, propose conceptual Digital Views that support the exchange and consumption of Digital Artifacts
- Challenge "RFP" will scope the requested Digital Views to revolve around participant-defined User Stories that describe a typical need for exchange of Digital Artifacts, based on ISO/IEC/IEEE 15288
  - *Acquirer* perspective for *Interface Design Compliance* and *Assurance of Test Readiness*
  - Assume assessment consistent with decision analysis at a typical Critical Design Review (CDR) a level of system maturity
- Challenge "RFP" will provide guidance on "what" the proposed Digital Views should provide, not "how" the Digital Views should be implemented, to provide creative freedom for Challenge Participants

DEIX Challenge Submissions Extend DVM Concept Model

Stakeholder Ontology

Process Ontology

Product Ontology

Will provide guidance on the objectives of Digital Views; Challenge Participants have the freedom to decide what Digital Artifacts and how they relate to one another to feed Digital Views to meet objectives
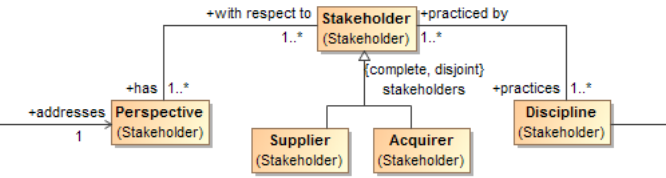
Provides basis for User Stories (along with possible refinement by Challenge Participants) to provide context for the Digital Exchange
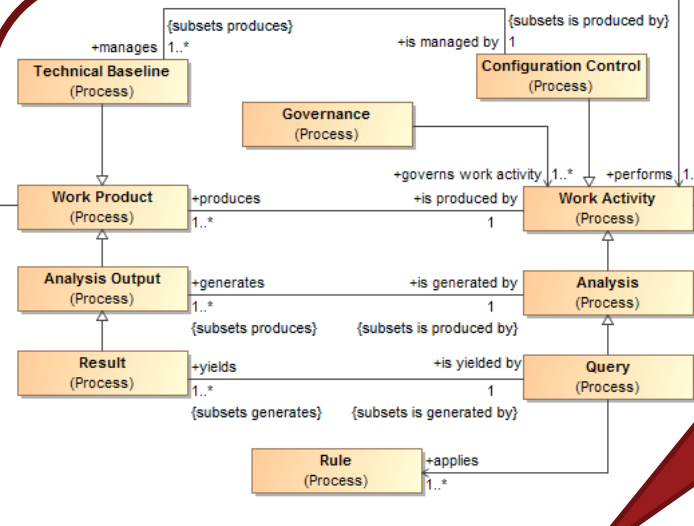
Process to create, curate, and exchange Digital Artifacts as a proposed Digital View will be developed by the Challenge Participants

Example Extension of DVM Concept Model by Participants

bdd [Package] CDR Vendor Challenge Views [bdd.02a.CDR Vendor Challenge Product Ontology - Interface Design]

«perspective»
Interface Design Compliance

addresses

«digital viewpoint»
Interface Design

«refine»

«user story»
Assess and validate traceability of design to interface requirements

«user story»
Evaluate detailed interface design against required performance and capability

«refine»

«user story»
Evaluate interface design against for required regulatory compliance

«refine»

«user story»
Evaluate interface design for cybersecurity and resiliency

«refine»

«digital view»
RTVM

«digital view»
Logical Design Descriptions

«digital view»
Software Design Descriptions

«digital view»
Hardware Design Descriptions

«digital view»
Test Configuration and Procedures

Given a Perspective and associated User Stories, Challenge Participants will propose Digital Views that meet the needs of the Digital Engineering Information Exchange

Example Extension of DVM Concept Model by Participants

bdd [Package] CDR Vendor Challenge Views [bdd.02b.CDR Vendor Challenge Product Ontology - Interface Design]

«perspective»
Interface Design Compliance

addresses

«digital viewpoint»
Interface Design

«technical review»
CDR

«refine»

«user story»
Assess and validate traceability of design to interface requirements

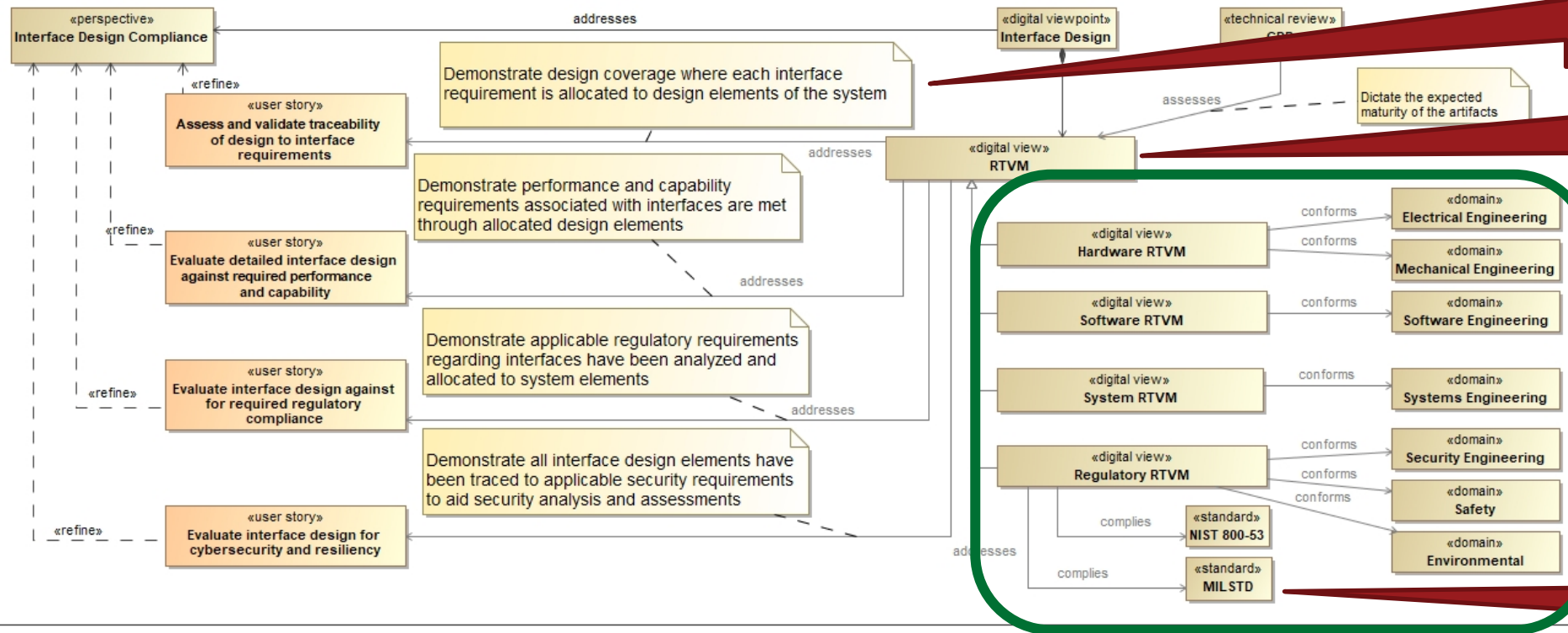Demonstrate design coverage where each interface requirement is allocated to design elements of the system

assesses

Dictate the expected maturity of the artifacts

Describe how the proposed Digital View can meet the need of a given User Story

addresses

«digital view»
RTVM

Further define different instantiations of digital view per domain

«refine»

«user story»
Evaluate detailed interface design against required performance and capability

Demonstrate performance and capability requirements associated with interfaces are met through allocated design elements

addresses

«digital view»
Hardware RTVM

conforms — **«domain»** Electrical Engineering
conforms — **«domain»** Mechanical Engineering

«digital view»
Software RTVM

conforms — **«domain»** Software Engineering

«refine»

«user story»
Evaluate interface design against for required regulatory compliance

Demonstrate applicable regulatory requirements regarding interfaces have been analyzed and allocated to system elements

addresses

«digital view»
System RTVM

conforms — **«domain»** Systems Engineering

Conceptualizing Digital Views; Participant has the freedom to develop concept to best meet the needs of the user stories with Digital Views

Demonstrate all interface design elements have been traced to applicable security requirements to aid security analysis and assessments

«digital view»
Regulatory RTVM

conforms — **«domain»** Security Engineering
conforms — **«domain»** Safety
conforms — **«domain»** Environmental

«refine»

«user story»
Evaluate interface design for cybersecurity and resiliency

addresses

complies — **«standard»** NIST 800-53

complies — **«standard»** MILSTD

Identify relationships to applicable standards

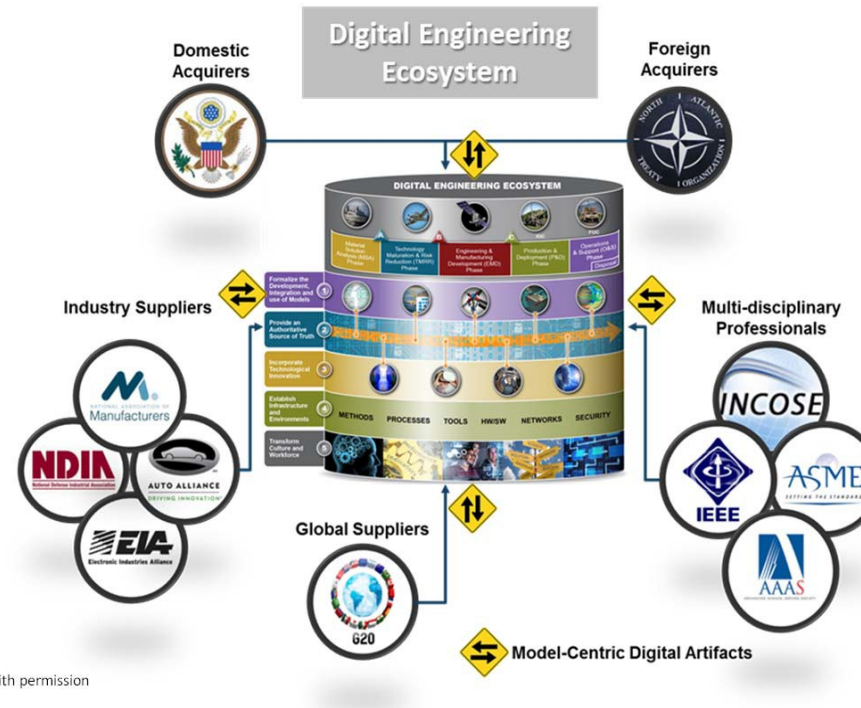# Example Extension of DVM Concept Model by Participants
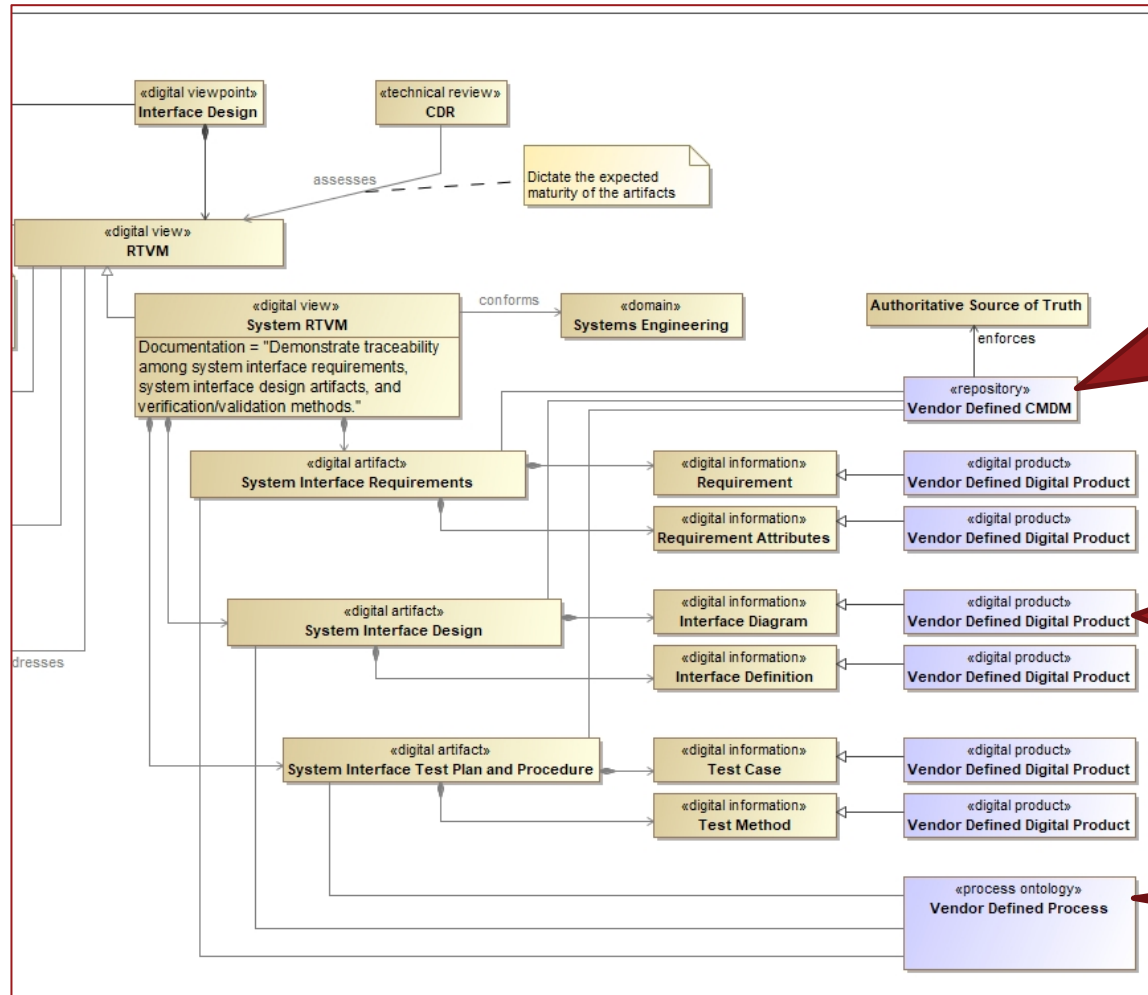
CM/DM process to be identified by Participant to demonstrate the presented material is the authoritative source of truth. Participant can also reference applicable standards instead of specifying particular tool or procedures.

Participant to define the format and presentation of Digital Information to compile as part of the identified Digital Views

Participant to define work product development process

Question?

For more details see the Digital Engineering Information Exchange Working Group (DEIX WG) WIKI page at:
http://www.omgwiki.org/MBSE/doku.php?id=mbse:deix