Gan Wang, Ph.D.

BAE SYSTEMS

Implementing a Model-Based, Digital Engineering Enterprise for a Defense Systems Integrator – an Ongoing Journey

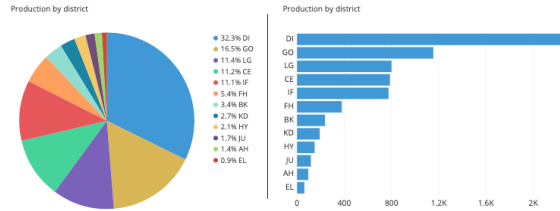# Outline

- Business context

- Practical challenges

- Implementation & deployment experience
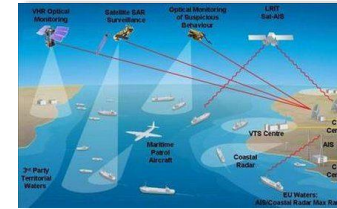
- Benefits observed

- A few lessons learned

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What Does "MBSE" Mean to You?
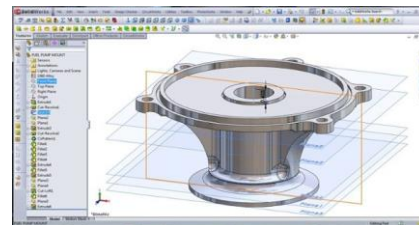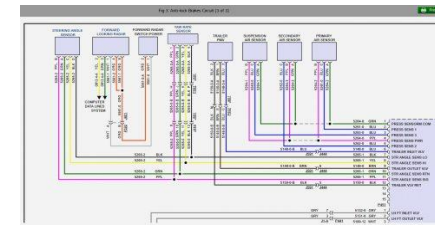

Spreadsheet Model

"Digital Twins"

"OV-1"

Visio Diagrams
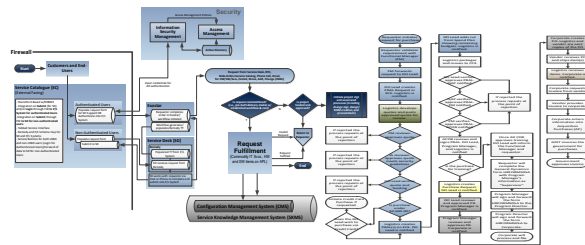

High-end Computers

CAD Models

Wiring Diagrams

"Model-Based Systems Engineering" is…

- **INCOSE**: *"the formalized application of modeling to support system requirements, design, analysis, verification and validation activities beginning in the conceptual design phase and continuing throughout development and later life cycle phases."*

- **SysML.org**: *"a Systems Engineering process paradigm that emphasizes the application of rigorous architecture modeling principles and best practices to Systems Engineering activities throughout the System Development Life Cycle (SDLC).*

# BAE Systems: Digital Engineering (DE) Enterprise Vision
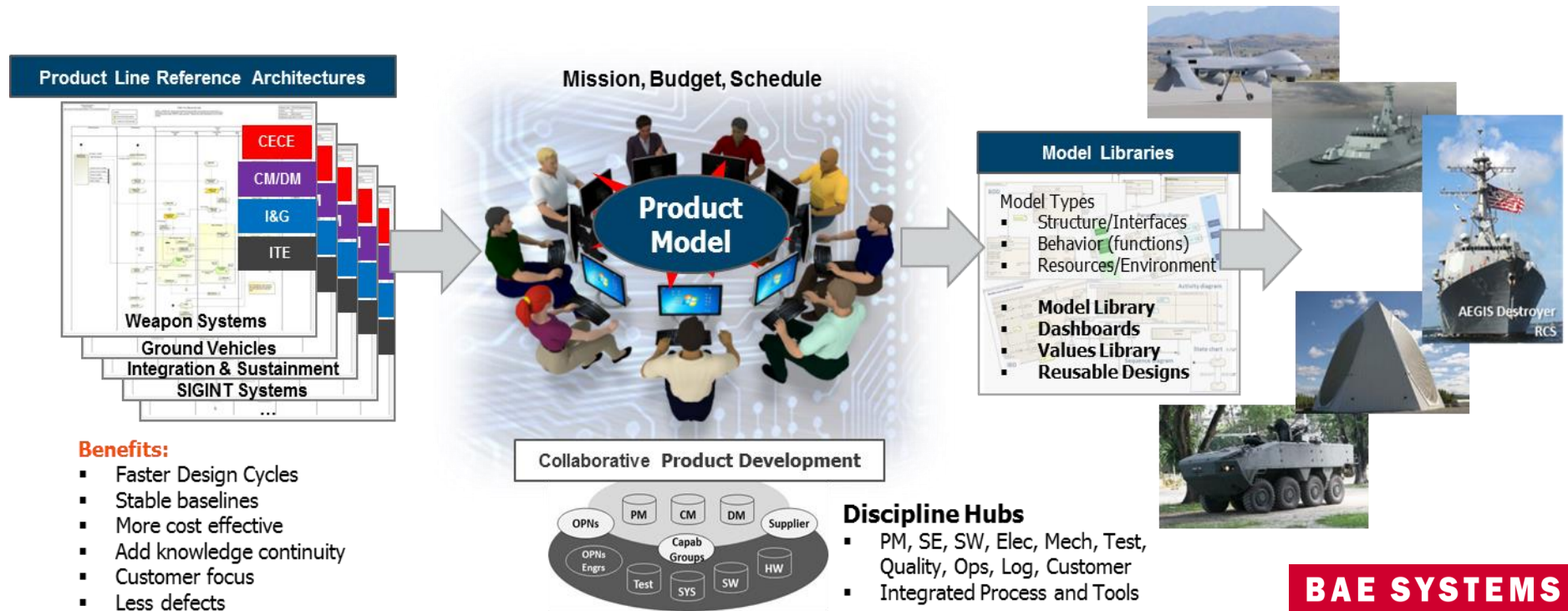
@ Corporate Systems Engineering Working Group (SEWG)

"Connecting Desktop to the Factory Floor and to Force Readiness"

Business Drivers: Heard from Customers and Industry…

- Digital Engineering Strategy (DoD):
  - Use of models
  - Enduring Authoritative Source of Truth
  - Technological innovation
  - Infrastructure and environments
  - Culture and workforce

- "Going Digital:" Better Engineered Systems
  - Bringing the right side of the System V to the left
  - Clearer requirements, earlier V&V, reduced defects
  - Systematic reuse

- Collapsing Cycle Time
  - Increased speed of capabilities… in a Model Based Digital Environment
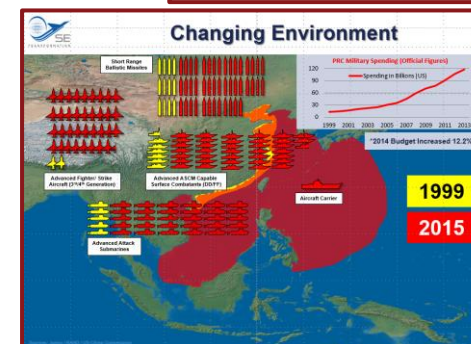 - "Sense of Urgency:" to accelerate agile delivery
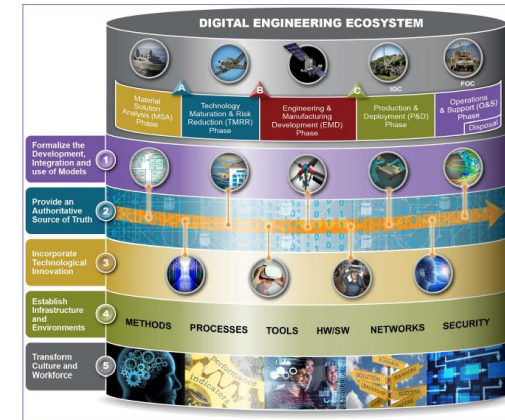
(Source: OUSD)

(Source: NAVAIR SET)

(Source: NAVAIR SET)

Practical Challenges in Adopting MBSE/MBE

Organizational dichotomy...

Experienced Workforce:

- Franchise programs
- Mission understanding
- System / product knowledge
- Customer intimacy

MBSE Challenges:

- Legacy SE skills and processes
- Lack of practical knowledge in MBSE
- Culture… adverse to change
  - *"This has always been how we do things"*
  - *"We have deadlines to make"*
  - *"Your tool doesn't work!"*
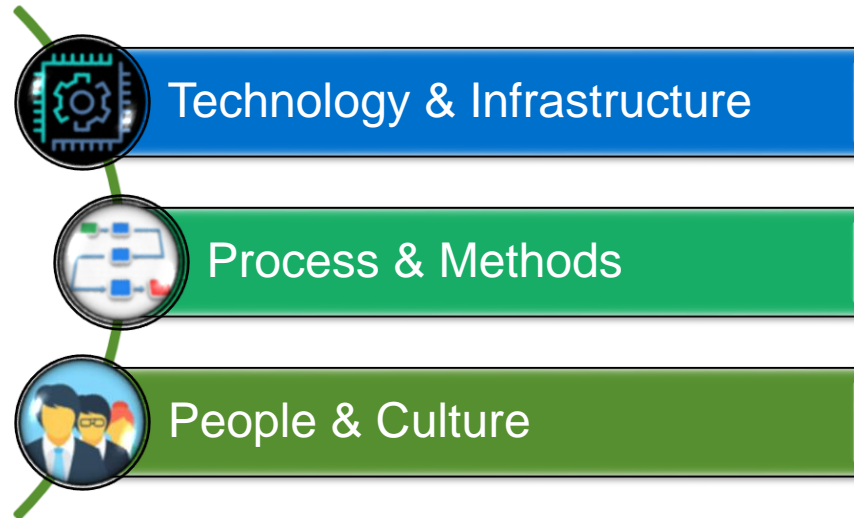
"MBSE… what does it do for you?…"

Multi-year, Multipronged Investment Strategy

STRATEGIC
Investments

Built on an Architectural Vision

- Technology & Infrastructure
- Process & Methods
- People & Culture

ADAMS™ Reference Architecture: Implementing an MBSE/MBE Environment Across the Complete System Lifecycle

- **Digital backbone** for integrated business process
  - Federated tool suite
  - Interconnected data & model traceability
  - Paperless, multi-function Collaboration
- **Digital thread** as a value stream
  - "Owning the technical baseline" and change management
  - "Authoritative source of truth"
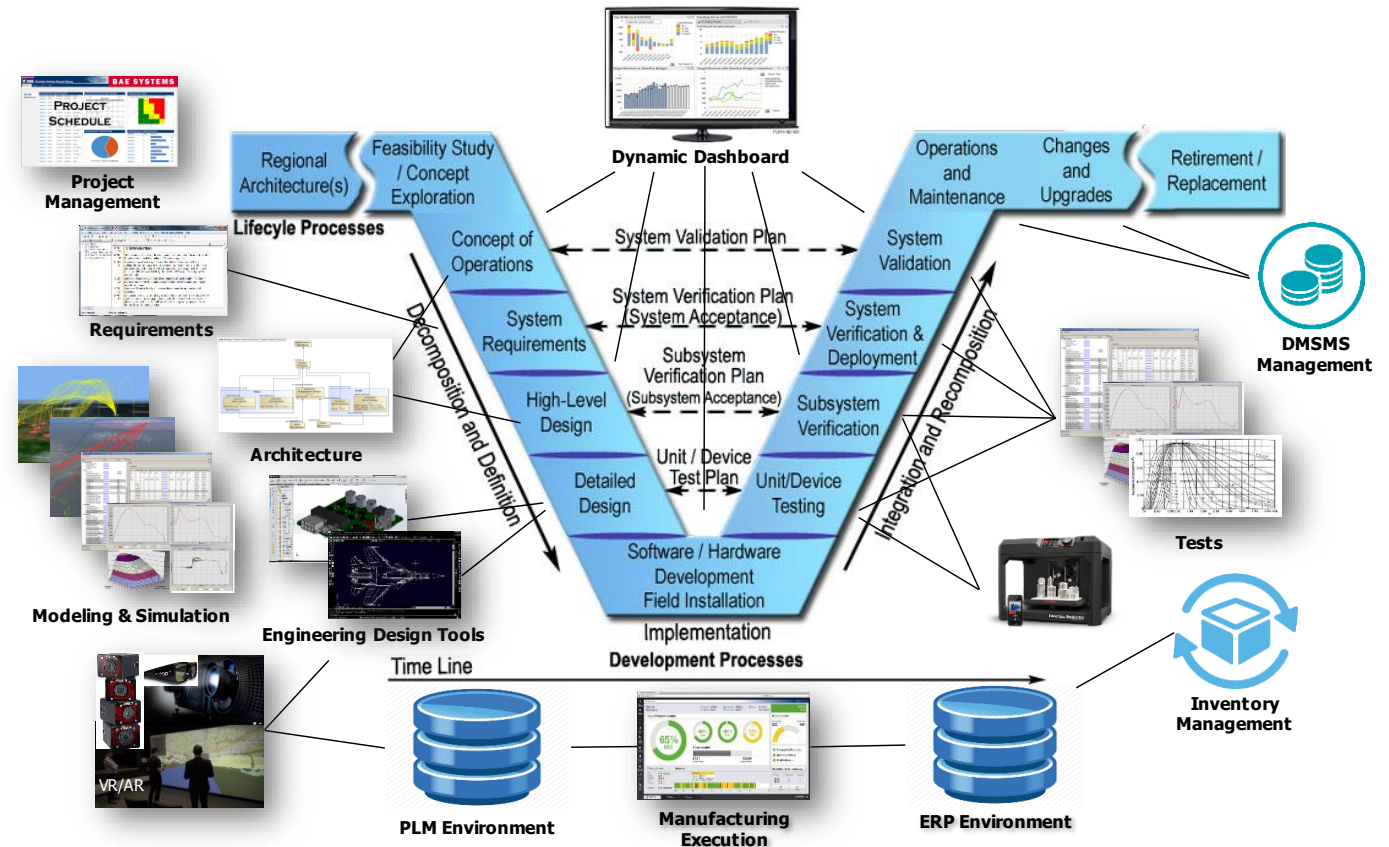
**Concept ◊ Design ◊ Build ◊ Integration ◊ V&V ◊ Sustainment**

Technology & Infrastructure: Integrated Data Environment (IDE) Implementation

- Collaborative modeling environment
  - Multi-site, collaborative teams
  - Project-based (vice location-based) & create/modify access from any site
- Services hosted in corporate cloud / datacenter
  - Servers & databases
  - Central admin/support and license management
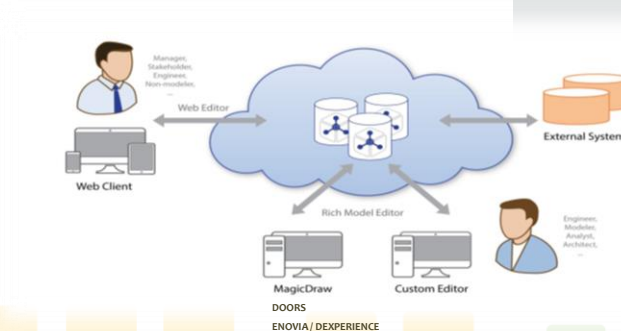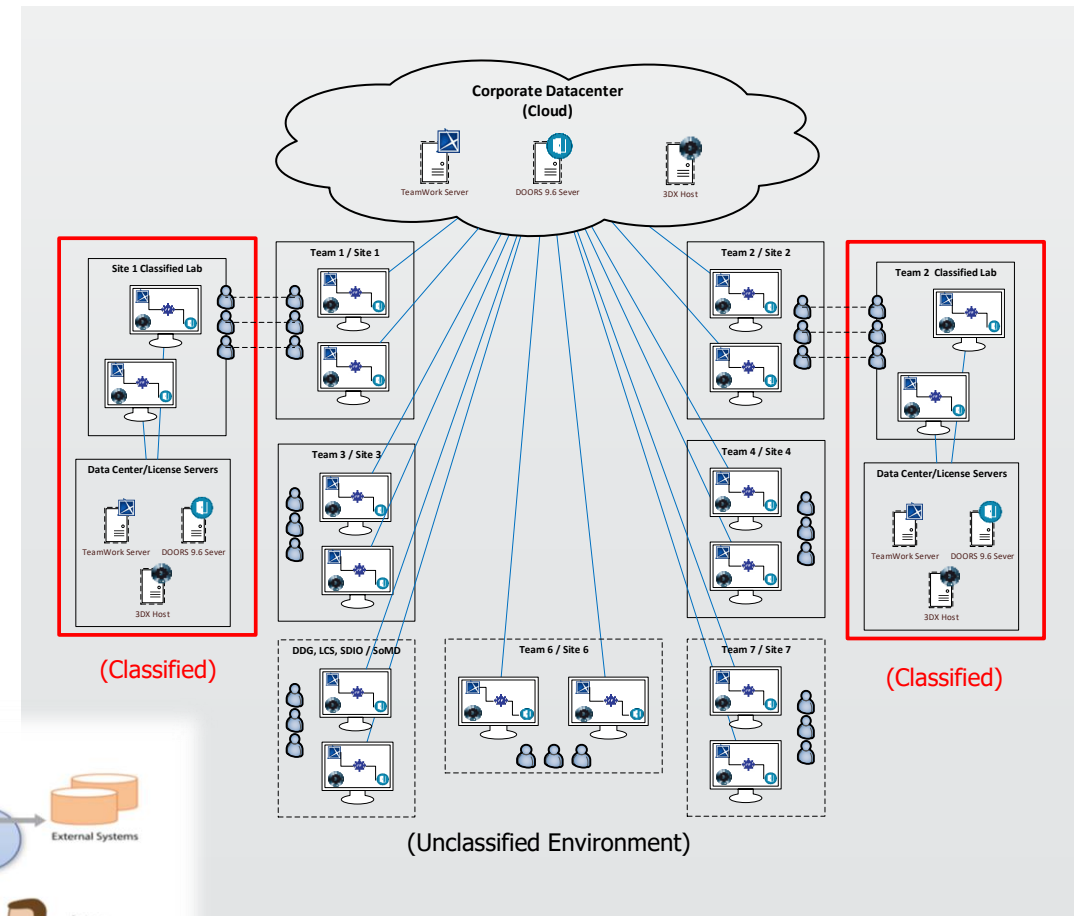
# Technology & Infrastructure: Integrated PLM-ERP Implementation

- **ENOVIA** Implementation:
  - Product/object-oriented, configuration-controlled design lifecycle process
  - Parts, eBOM, drawings, test plans, documents, and other engineering artifacts
  - Design reuse, change impact analysis, trade studies, collaborations

- Integrated **CAD-PLM**:
  - Single, unified user environment
  - Solidworks, CATIA, AutoCAD, Inventor
  - Native parametric modeling, sub-assembly level, configuration-controlled design collaborations

- Integrated **PLM-ERP**:
  - ENOVIA-CostPoint data connector
  - Automated, controlled release of eBOM to mBOM
  - Integrated CR/CO/CA–PR/PO workflows

# Integrated Business Process: Cross-Functional Process Embedded in Environment

- Integrated, consistent business process / workflows

  - PLM: CR/CO/CA, engineering design, component engineering

  - ERP: PR/PO, material planning, logistics

  - Automated, controlled release of eBOM to mBOM

  - CCB, design/peer reviews, Release Approval

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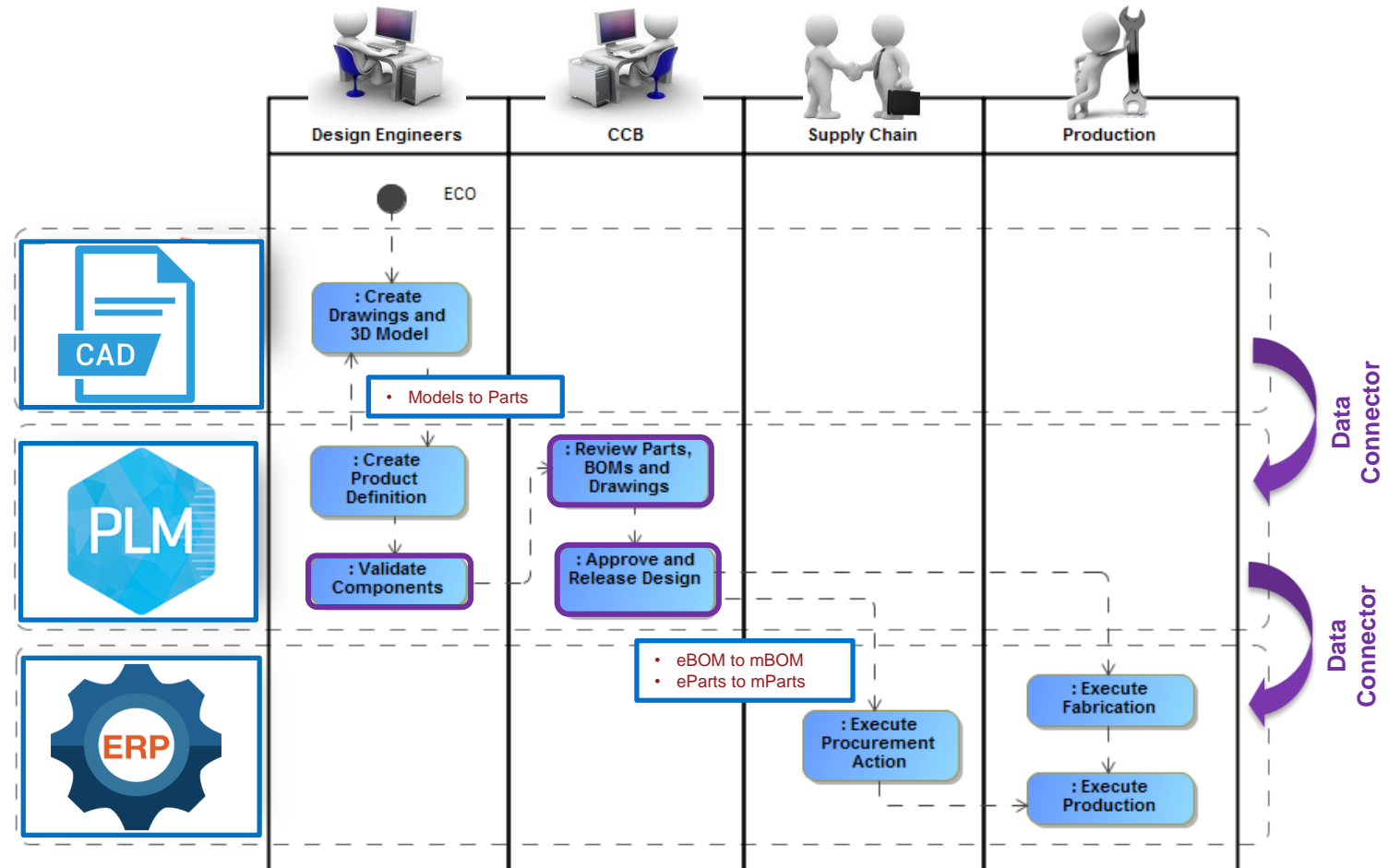
Methodology: Developing Methods through Pilot Use Cases
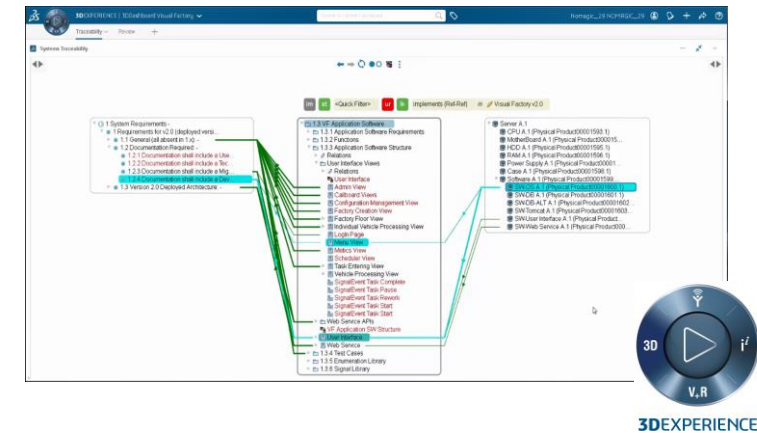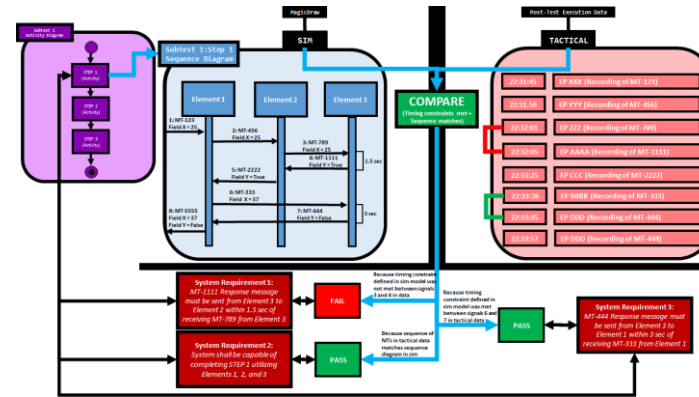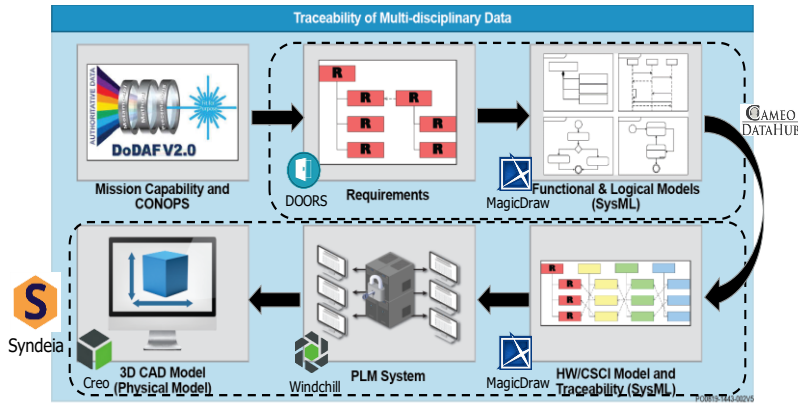
Integrated System/SoS Architecture:

- Cross-domain digital thread
- Reqt → Functional → Logical (HWCI) → Physical (eBOM) → 3D Models
- Requirement verification, architecture design trades

Model-based System Test & Evaluation (ST&E) strategy:

- Two-stage, model-based requirement IV&V approach
- Early verification through model execution & integration of late-cycle system test events
- System functional testing automation
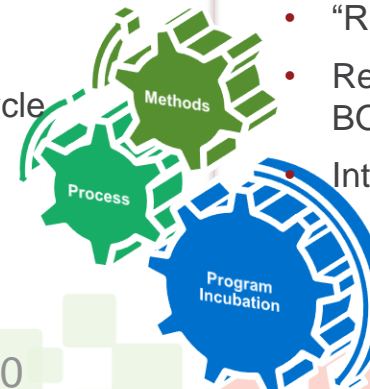
Model-Based Engineering (MBE) with 3DExperience Platform:

- Integrated MBE environment
- "RFLP" Traceability
- Requirement → Logical & Functional → BOM/Parts/Multi-CAD
- Integrated Project Management

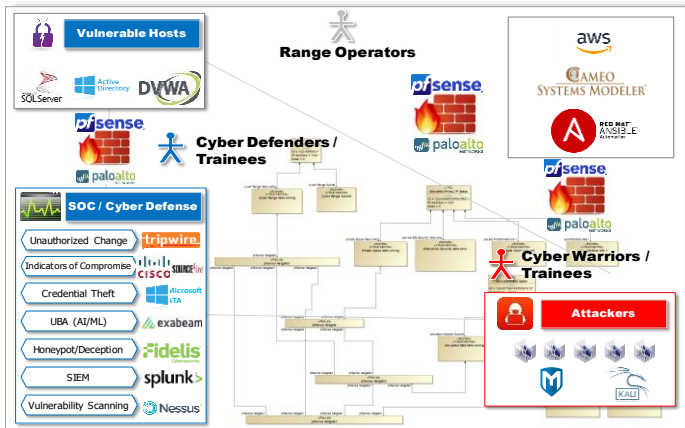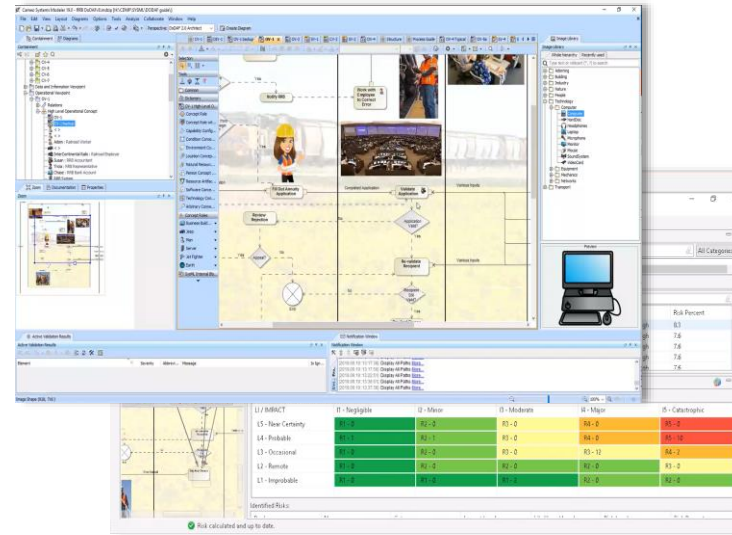# **Methodology:** Developing Methods through Pilot Use Cases (cont.)

Model-based Cyber Range Operations:

- Virtual cyber range in Cloud
- Model-based range architecture
- Training, exercises, system testing
- Range build-up, tear-down, and verification directly from system models

Model-based Cyber Risk Assessment:

- Architecture-driven cybersecurity threat & system vulnerability assessment
- DoDAF/UAF and SysML models
- RMF automation, mitigation actions, report generation, POA&M
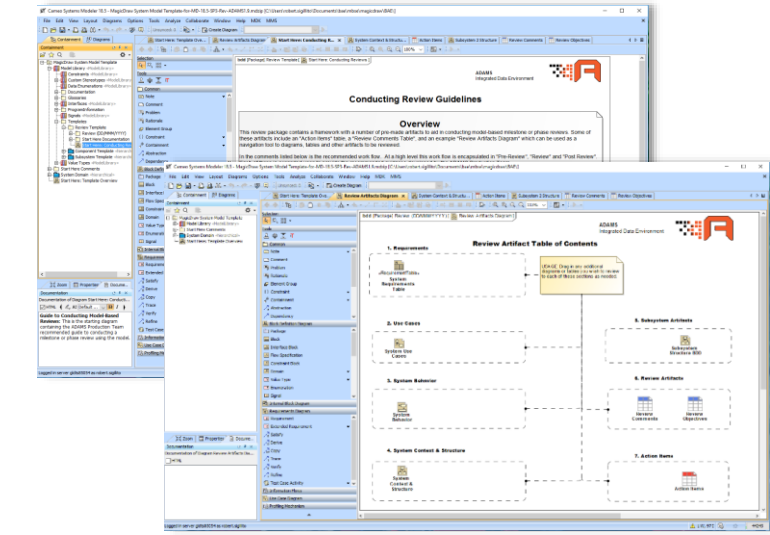
Model-based Design Reviews & Standard IDE Template:

- Standard project templates with instructions
- "Drag & drop" review baseline views
- Comments and model redlining
- Corporate LCM process

People: MBSE Catalyst Program

Architecture

Test & Evaluation

Learn Skills...

Develop Pilots...

Show Demos

Design

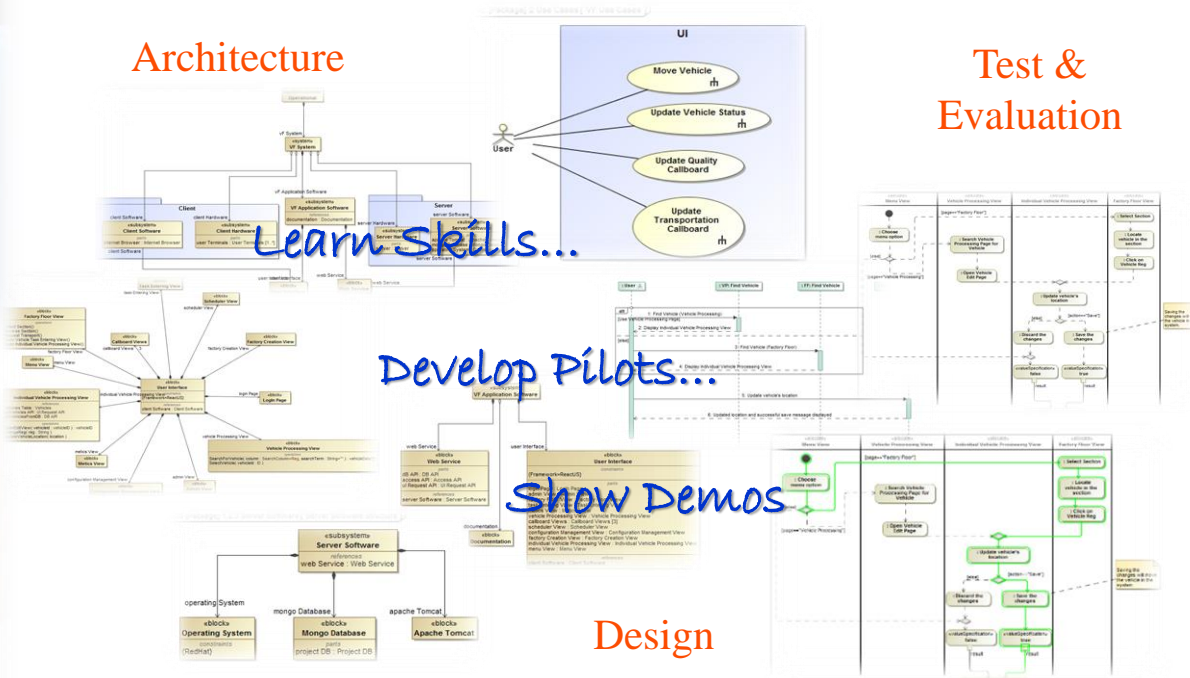**Structured Training Program ~ Selective Engineering "HiPots"**

People: MBSE Catalyst Program Curriculum

Candidate Selection

Deploy & Expand

Stage 1: Self-Learning & Prep

- I&SU MBSE Pathway
  - Level 1: Engineer Track
  - Level 2: Modeler Track
- Pilot project planning

Stage 2: Classroom Training & Labs

- System Modeling & Design
  - Language: SysML
  - Tools: MagicDraw, PLM
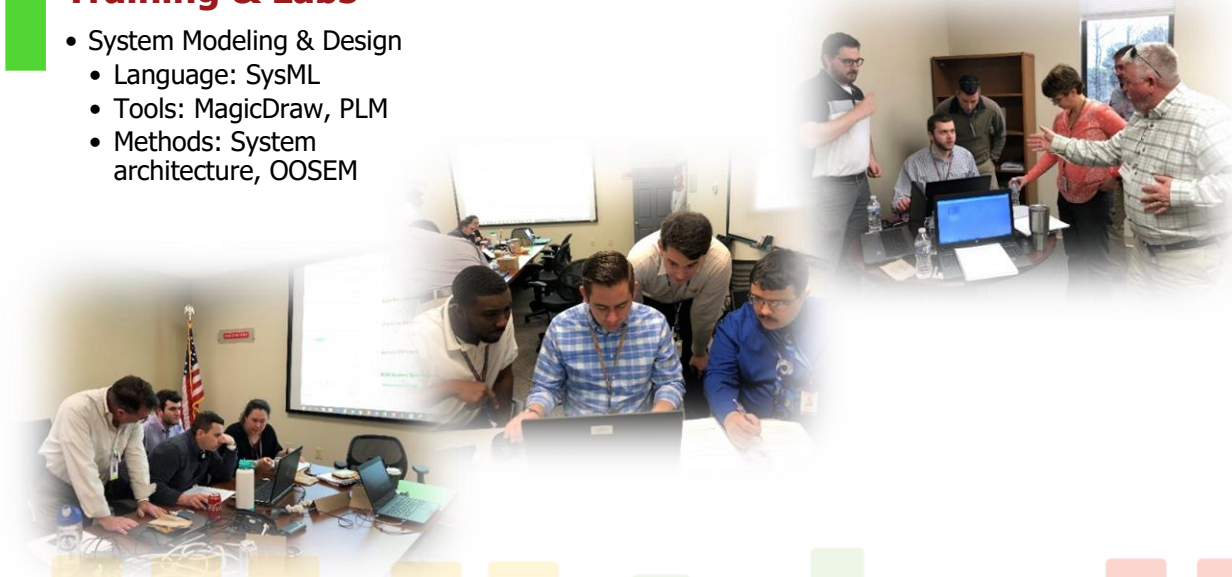 - Methods: System architecture, OOSEM

Stage 3: Projects

- Pilot projects
  - Customer-facing pilot use cases
  - Deliverables: demos

Stage 4: Demos

- Internal & external stakeholder (customer) demos
- Technical feedback & recommendations

People & Culture: Implementation and Deployment

- Leadership Workshops: Senior Managers
  - "MBSE 101" training
  - Challenges & opportunities
  - Implementation roadmaps & tech info sessions

- Training & Certification: SMEs
  - Training pathways
  - Certification incentives
  - Tools: train-the-trainers
  - First-line support

- Communities of Practice: Practitioners
  - Coordinate, collaborate, interchange and sharing
  - Best practice stories, demos
  - Internal & external speakers
  - Training and modeling assets
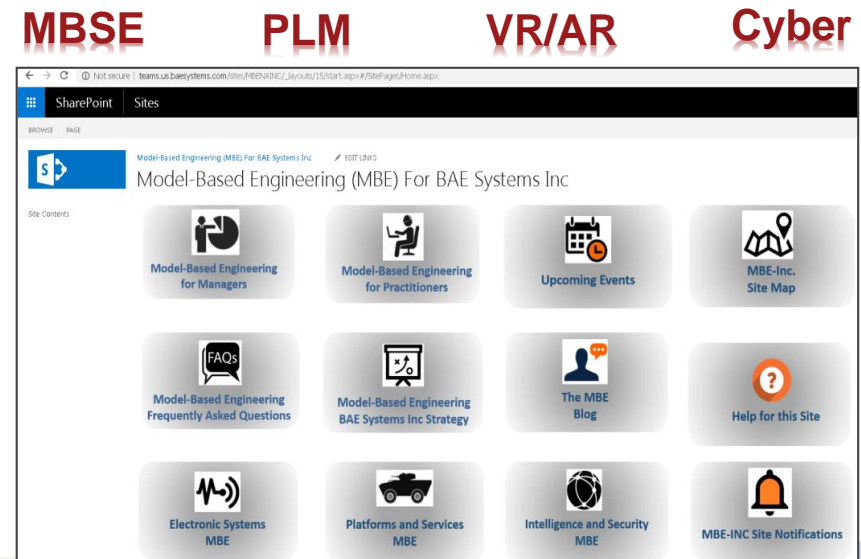
Key Benefits: Digital Transformation to Empower Our Teams Better Supporting Customer Missions
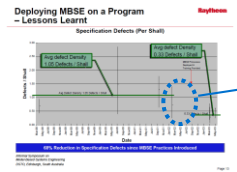
Cost Reduction / Take-out

- *Architecture trades enabling system understanding much earlier in life cycle*
- *Reduced defect rates & cost of poor quality avoidance*

Specification Defects Reduced 68%

- *Reduction of transactional costs*
- *Lean engineering, productivity & effectiveness*

Cycle Time Reduction

- *Rapid engineering change responses*
- *Systematic design reuse*
- *Early architecture decisions*
- *Fleet Readiness (dependable, state-of-the-art, "Up" systems)*

External/customer collaborations
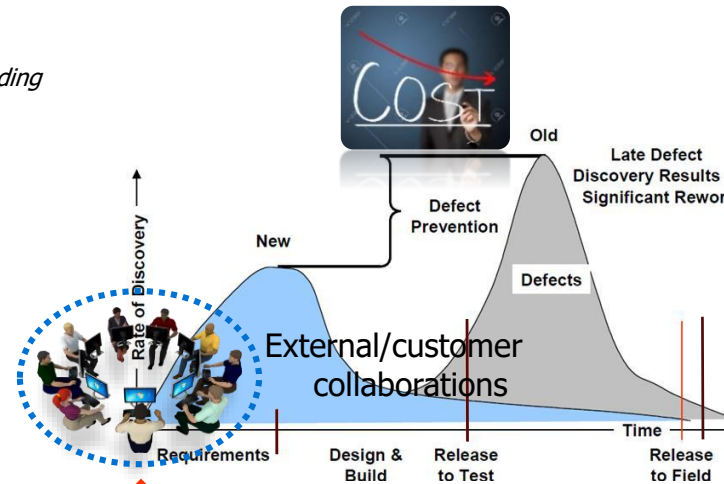
MBE: *Left-Shifting Engineering*
- Earlier Design Decision Reduces Lifecycle Costs
- Earlier Defect Detection & Reduced Rework

Improved Capabilities to Customers

- *Robust Technical Baseline and change management*
- *Agile, rapid engineering change responses*
- *Early architecture decisions, reduced risks, and collapsed cycle time*
- *Deeper insights and improved acquisition decisions*

Knowledge Transfer

- *Expedited knowledge transfer enabled by systematic knowledge management*
- *From "grey beard" to codification of corporate knowledge*
- *Institutionalization of IP, trade secret & product know-how*
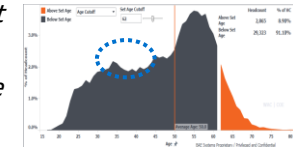
Empowered Teams

- *Engineering workforce empowered by advanced engineering tools*
- *Changed work style from transactional to transformational*
- *Inspired Millennial generation by state-of-the-art technology and capabilities*

Inspired Work – Performance Excellence – Enabled Customer Missions

A Few **Lessons** from Early Experience…

- An overarching architectural vision is important
  - Communications of vision and roadmap
  - Prioritization of development, guideline for investment

- People is key… the right people
  - Requires believers / leaders / champions at all levels

- Management buy-in is critical…
  - But they are hard to convince: ROI?

- Culture… is the hardest problem to tackle
  - No "silver bullets"

- Be resilient… stick with the vision, work your way through problems and reinvent on the way
  - Incremental implementation: crawl-walk-run
  - Small pilots lead to small successes

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It's an Ongoing Journey…

- Digital Engineering transformation is an enterprise-level, multipronged endeavor
    - Technology and infrastructure
    - Processes & methods
    - People & culture

- The journey continues…

Believe in it!

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Thank You