Raytheon

Customer Success Is Our Mission

Modeling Practices at Raytheon

2013 INCOSE MBSE Workshop, Jacksonville FL

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Agenda

- Who is Raytheon?
- What does Raytheon think of MBSE?
- What has Raytheon done related to MBE/MBSE?
  - Excerpts from presentations made in public workshops/conferences
- Conclusions

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What We Make

Core Market: Sensing

Technologies that acquire data and create accurate, reliable information for effective battlespace decisions.

Core Market: C3I *(Command, Control, Communications and Intelligence)*

Integrated real-time systems that optimize operational planning and execution.

Core Market: Effects

Technologies that achieve specific military actions or outcomes — from striking targets to disabling hostile information systems.

Core Market: Mission Support

Total life-cycle solutions that ensure performance, no matter the mission, no matter the platform.

Systems and solutions to ensure flawless performance.

Slide taken from “Industry and ManTech Interaction Success”, David Baum, NIST TDP Summit 2011

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Common Design Controls and Practices

- Common Product Data Management (PDM) Workflows
- Engineering Documentation Standards (EDS)
- IPDS Best Practices for MBE in Process Asset Library (PAL)

71,000 employees; 2011 net sales: $25 billion*

Slide taken from “Industry and ManTech Interaction Success”, David Baum, NIST TDP Summit 2011, updated as noted

* http://www.raytheon.com/ourcompany

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Raytheon Management Opinion of MBE/MBSE

- Brian Wells Video @ IBM Innovate 2012
  - Vision for MBSE @ Raytheon
- Ongoing corporate investment in various disciplines supports and compliments model based approaches:
  - PDM/Model Based Enterprise (Mechanical CAD, interface to Mfg)
  - Process Re-Invention and Systems for Manufacturing/PRISM (Manufacturing & Procurement)
  - Lean Product Realization (Electrical Design/Manufacturing)
  - Software Innovation for Tomorrow/SWIFT (Software productivity)
- Business Units investing in related technology
  - Virtual Solution Development (Raytheon Missile Systems)
  - Advanced Software Productivity Environments (ASPEN) (Integrated Defense Systems)

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The Model is the [System] Design

- Capture the information once
- Models are the design, there is no other documentation
  - Replace the documents and drawings with a model based description of all aspects of the design
- All aspects of the design are captured and integrated
- Models are automatically cross connected and compatible
- Design changes and updates are applied only to the models
- The Design is maintained by maintaining the models

Revolutionize the methods for defining designs

Slide taken from “The Challenges of MBE and MBSE”, Brian Wells, INCOSE New England MBSE Workshop 2011

Raytheon Publically Discussed Techniques and Methods

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- Software Innovation for Tomorrow (SWIFT)/Advanced Software Productivity Environments (ASPEN)
  - Appropriate application of Agile techniques, Domain Specific Languages and MDSD/MDA for Software Development
- Virtual Solution Development (VSD™)
  - Rapid cross-domain collaboration toward a Point of Departure Design
- Model Based Distributed Integration and Test
- Concept Engineering/Mission Profiling
- SE/SW Interface for Algorithm Development
- Mechanical CAD Model Based Enterprise
- Multi-Disciplinary Design Optimization
- Physics Based Modeling for Embedded Systems
- Lessons from MBSE on AWD

Differences Between DSLs and MDA

- MDA uses UML as the modeling language.
  - General purpose modeling language, not tied to any specific problem domain
  - May not solve every problem (e.g. UML doesn't suit algorithmic design/implementation)
- DSLs use the terminology of the specific problem domain (being able to "speak the lingo"), as opposed to using a generic description. It may be graphical, or textual
  - A component (e.g.message handler) may need many DSLs
    - Field mapping
    - Message mapping
    - Message set importing, viewing, organizing
    - Transport configuration
    - etc

DSLs are specific and MDA is generic

Slide taken from "DSL & MDA: Allies or Enemies", Terri Potts et. al, SSTC2010 (IDS-2056)

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ASPEN

Differences Between DSLs and MDA (Continued)

- MDA requires no up-front investment
  - Expect 1.5 to 3 times your standard productivity for product development
- DSLs have higher initial cost, but over time, cost decreases
  - Once DSL has been created, expect 5-10 times your standard productivity for product development
  - Most of the cost is to develop the DSL; once that is done, using the DSL makes modeling the domain more intuitive and streamlined
  - For one-off systems, difficult to justify the cost of developing a DSL
  - DSLs can require organizational commitment
  - Must anticipate multiple uses of the DSL to get the payback from the DSL development investment
- Language maintenance
  - COTS tool developers maintain MDA modeling language and generators
  - Using organizations maintain DSL modeling language and generators

Slide taken from “DSL & MDA: Allies or Enemies”, Terri Potts et. al, SSTC2010 (IDS-2056)

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Shortcomings of MDSD Program Use

- Tool:
  - Debugging during integration is more complex
  - Need fairly extensive experience with the toolset to make it work properly
  - Training and mentoring was required for success when developers preferred to write code
  - Very simple changes may require knowledge of multiple tools rather than just a programming language and compiler
  - VxWorks integration was immature
- People:
  - Not all engineers adapt well to new methods and levels of abstraction
  - Hands-on training is best for comfort with new tools
  - Mentors must be available
  - MDSD is built on OO. Therefore, a solid OO foundation is beneficial
  - Lots of communication is required

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Advantages of MDSD Program Use

- Trivial task to make some global changes
  - Changed 72-word message format to an 80-word message format for hundreds of messages in **1.5 weeks**
- Application code generated by MDSD resulted in lower defect density
- Design and code are always in sync
- Method enforced common vocabulary and design guidelines
- Collaborative approach to architecture and design

Program Office Quote "The customer was so impressed that for a year the MDSD success was mentioned in their viewgraphs"

Slide taken from "Model Driven Software Development, a Case Study", Gari Palmer, SSTC2011 (IDS-2459)

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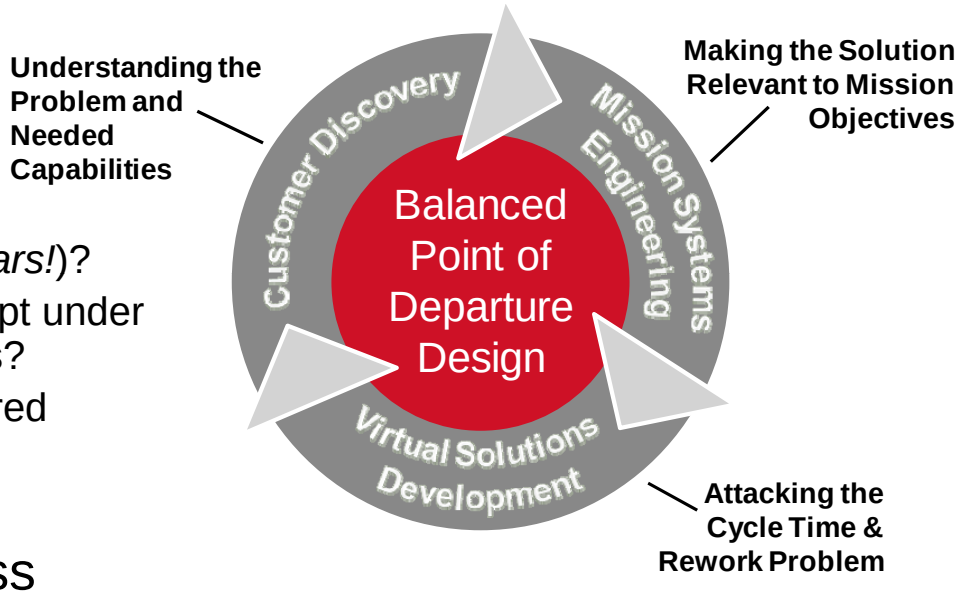
The Virtual Solutions Development… a Journey

- We long ago became VERY computer-model and analysis oriented
  - But not inter-discipline connected
  - Nor levels of maturity connected
- What would it be like if …
  - we migrated data across disciplines?
  - had ready access to our rich history (*60 years!*)?
  - instant awareness of the state of our concept under development and our development process?
  - provided more deeply and broadly considered proposals?
- The challenge: Our infrastructure, expectations and even our business culture make collaboration and information exchange a challenge



Recognizing the need for change we funded an internal project in 2008 called Virtual Solutions Development or VSD™

Slide taken from "Virtual Product Development for Complex Systems", Ron Valles et. al, IBM INNOVATE 2012 (RMS-1958, 1959)

Rapid Cross-Domain Collaboration
The Journey…

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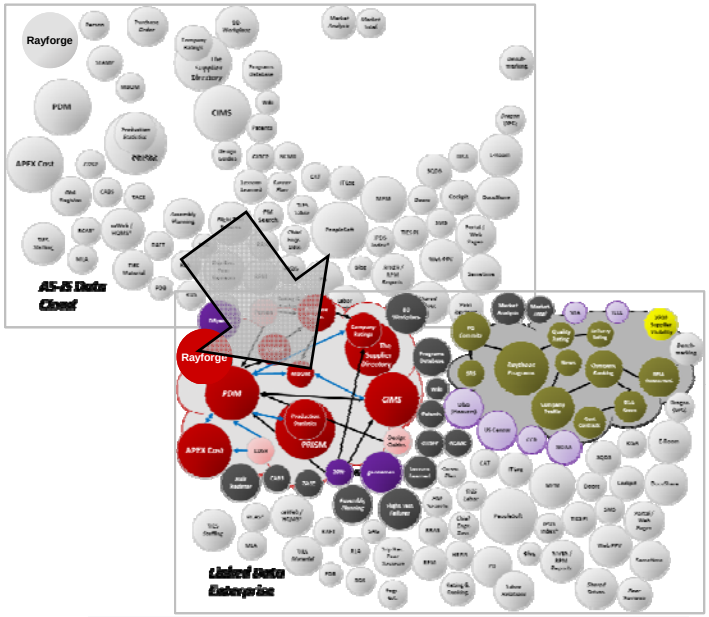
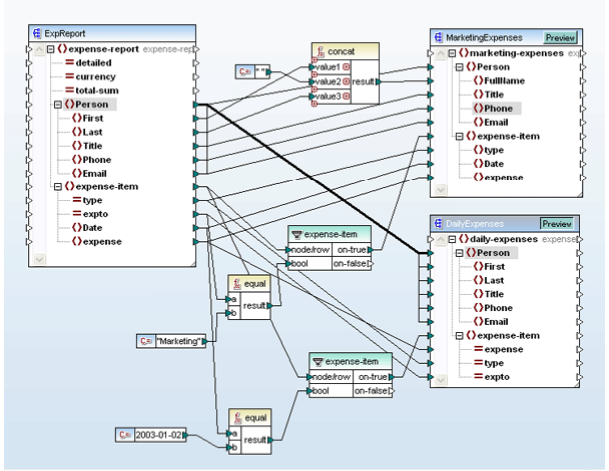
- Purpose: Increase thoroughness and coherence of product development analytics throughout the life cycle
- Improve quality, reduce cycle time and eliminate rework by…
  - being digitally prepared and prototyped
  - being predictive and physics based
  - reducing manual transactions between disciplines & phases
  - managing data transformations between disciplines
  - eliminating non–cognitive work! (e.g. “The Data Hunt” and “Making Charts”)
  - provide analysis of alternatives with cost, performance, and assembly process modeling
- The Information Technology aspect of VSD™ is… HUGE!
- Ample improvement opportunities exist without moving the Information Technology “mountain”
- Support collaboration in a Rapid Concept Development Environment





Slide taken from “Virtual Product Development for Complex Systems”, Ron Valles et. al, IBM INNOVATE 2012 (RMS-1958, 1959)

Rapid Cross-Domain Collaboration
This requires…

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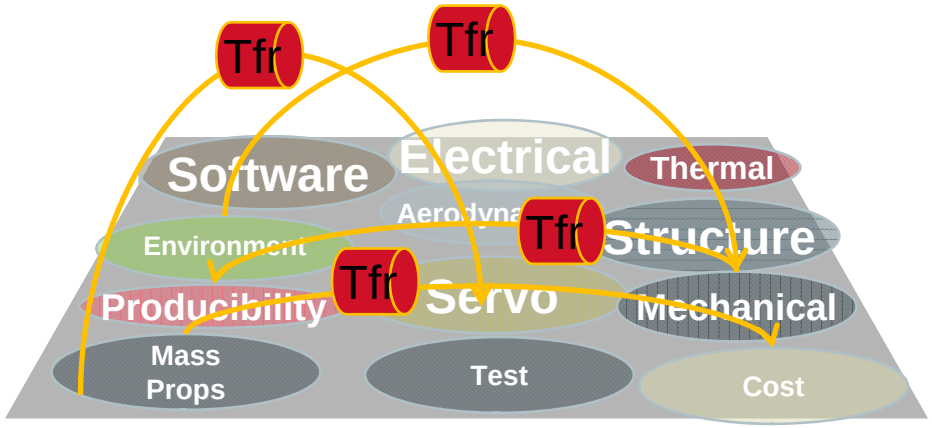
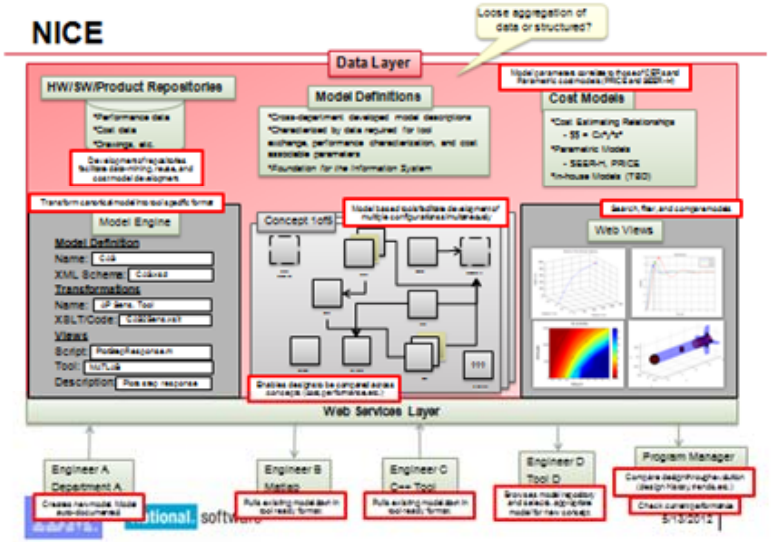
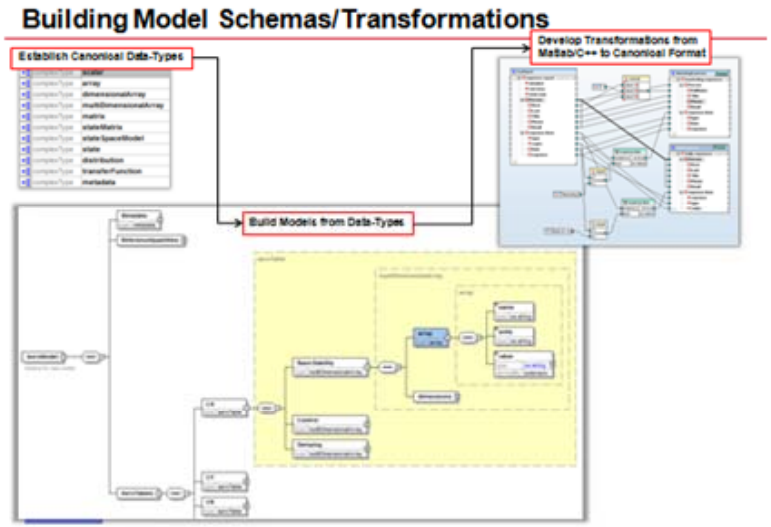
- Piping and transforming our data…the data moves
- We are bringing all of the capabilities of CLM to bear on this problem
- Additionally we are developing a NICE way of connecting our tools
  - Nexus Interchange Collaborative Environment (NICE)
- Opportunity: Aligning VPM with BOM, WBS, PBS, HUM, etc… very powerful!







Slide taken from "Virtual Product Development for Complex Systems", Ron Valles et. al, IBM INNOVATE 2012 (RMS-1958, 1959)

Rapid Cross-Domain Collaboration

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The Virtual Product Model of Tomorrow

- System data doesn't need to "move"
- Tools act directly on system model data
- System model represented in a system modeling language like SysML, Modelica, or (SysML4Modelica)
  - Bond graphs correctly representing power flow in system
  - We don't know the modeling language to do this yet, but SysML is a start!
- A complete, coherent system model a complete virtual version of actual system
  - Achieve the "right" Virtualization Index levels (to be explained)
  - Modeling the "*seams*" of the system
  - "Throttleable" model fidelity driven by system sensitivities, and supporting a managed model lifecycle
- Raises level of abstraction in design of complex systems*
- Enables correct-by-construction designs through model-based verification*
- Synthesizes designs from component model libraries*
- Supports rapid requirements trade-offs*
- Enable optimization for complexity & adaptability, not merely Size Weight and Power (SWaP)*

*Adapted from DARPA's Air Vehicle Make vision

Slide taken from "Virtual Product Development for Complex Systems", Ron Valles et. al, IBM INNOVATE 2012 (RMS-1958, 1959)

Rapid Cross-Domain Collaboration
VSD™ Information System with CLM

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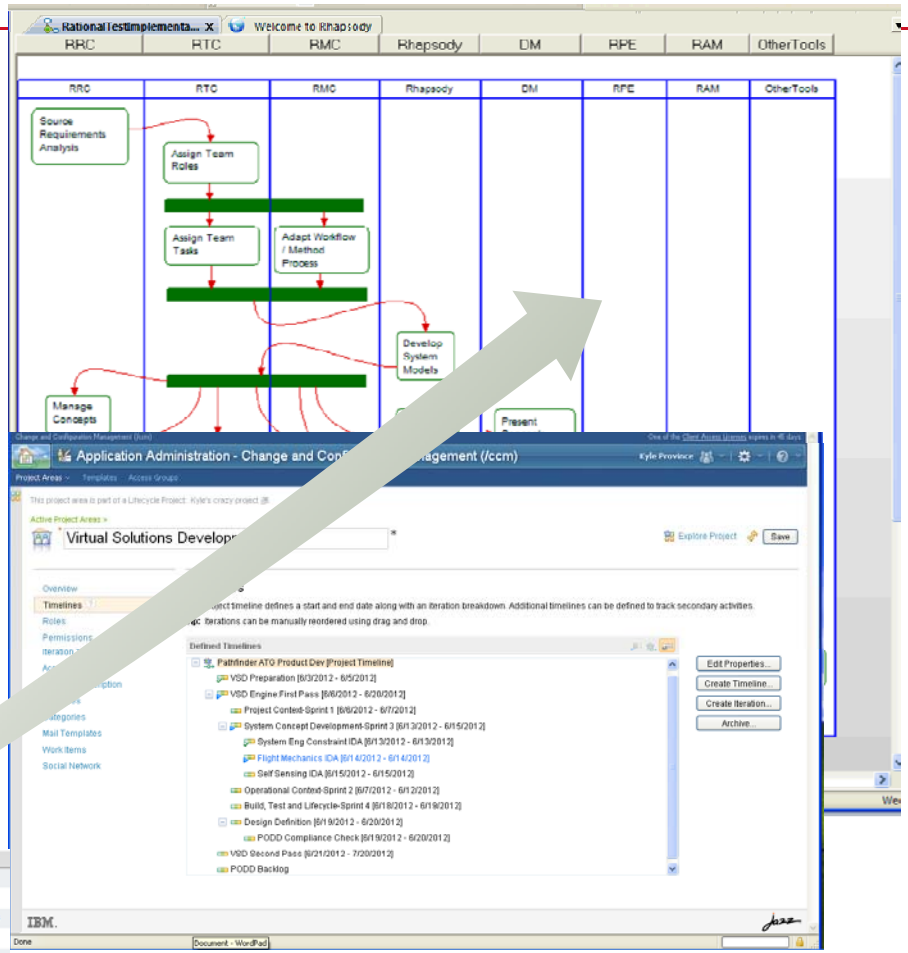
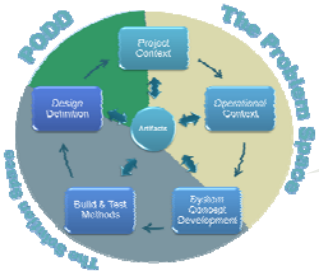
- We thought we'd have to build the VSD™ information system ourselves…
  - While we do need to develop a key subsystem of our information system (NICE),
  - CLM tools provide us *immediate* benefit with growth capabilities that
  - Do not require development or massive sustainment/governance effort





Tracker Type	Tracker Name	Description
Tasks	1-VSD Prep	VSD Prep Actions
Tasks	2- Define ...ext	Define Project Context Actions
Tasks	3-...ational Context	Define Operational Context Actions
Tasks	...elop System Concepts	Develop System Concepts Actions
Tasks	5-Apply Build Test Methods	Apply Build Test Methods Actions
Tasks	6- Develop Design Description	Develop Design Description Actions
	7-Produce PoDD	Produce PoDD Actions

CLM tools enable rapid development of complex systems

Slide taken from "Virtual Product Development for Complex Systems", Ron Valles et. al, IBM INNOVATE 2012 (RMS-1958, 1959)

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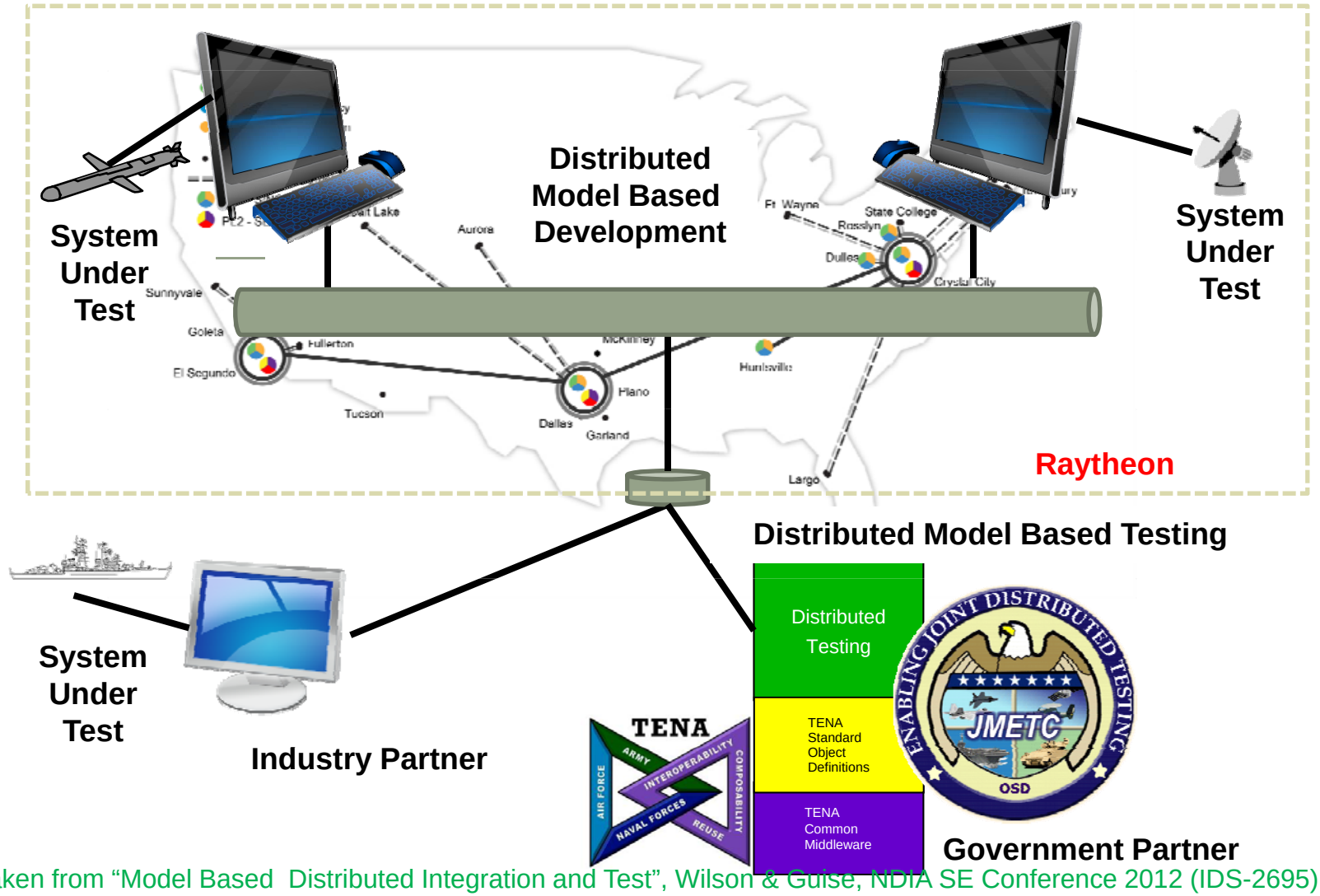
MBDIT Reference Architecture OV-1: Operational Concept

Model Based Distributed Integration and Test (MBDIT)



Slide taken from "Model Based Distributed Integration and Test", Wilson & Guise, NDIA SE Conference 2012 (IDS-2695)

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MBDIT Reference Architecture Use Cases

Use Case	Description	Benefits
Concept Demo/Trade	Access models in distributed nodes to assess or demonstrate performance in different configurations.	Collaborative trade studies using models from different businesses, demonstrate capability of a candidate configuration
Collaborative Development	Geographically dispersed developers collaborate on the same program with access to models in a working and persistent environment.	Collaborative development without travel, incrementally add new capability to an existing configuration to evaluate results.
Distributed Testing	Configure a test environment with synthetic and actual system components to verify system requirements.	Perform distributed testing to access Hardware in the Loop (HWIL) assets in different locations, implement integrated testing so that data collected during DT&E can be made available for independent evaluation by OT&E.

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(MBDIT) Summary

- **Definition:** Model Based Distributed Integration and Test is the ability to perform geographically distributed system integration and test using modeling and simulation as an enabler.
- **Benefits**: Affordability through early information discovery and incremental verification among distributed partners
- **Barriers**: Security, Perceived value for investment, Disconnect between communities
- **Lessons Learned**: Early and continuous collaboration using common definitions
- **Recommendations**:
  - Harmonize standards
  - Create framework for reuse and statistical test design
  - Promote use of M&S for I&T

Slide taken from "Model Based Distributed Integration and Test", Wilson & Guise, NDIA SE Conference 2012 (IDS-2695)

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Mission Profiling

- An iterative Raytheon process for mission analysis with dynamic architecture assessment as a core component
  - Characterize and model the mission
  - Consistent means to capture mission architectural information
  - Plan and conduct assessments through desktop analysis and experimentation
- Adheres to the processes and frameworks for architecture development
  - Raytheon Enterprise Architecture Process, ATAM, etc.
  - Zachman, DoDAF, etc.

Slide taken from “Mission Profiling”, David Proctor, INCOSE New England MBSE Workshop 2011 (IDS-2701)

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Application of Mission Profiling

- Several instances of Mission Profiling application
  - Evaluate Marine Close Air Support mission
  - Evaluate Navy Riverine mission
  - Evaluate Coast Guard Locate Vessel of Interest mission
  - Evaluate architecture alternatives for multi-mission use of sensors
- Address customer-identified mission gap scenarios
- Experiments conducted using all digital simulation environment
- Relevant mission domain elements captured in model form
  - Some using existing customer-supplied UML models

Slide taken from “Mission Profiling”, David Proctor, INCOSE New England MBSE Workshop 2011 (IDS-2701)

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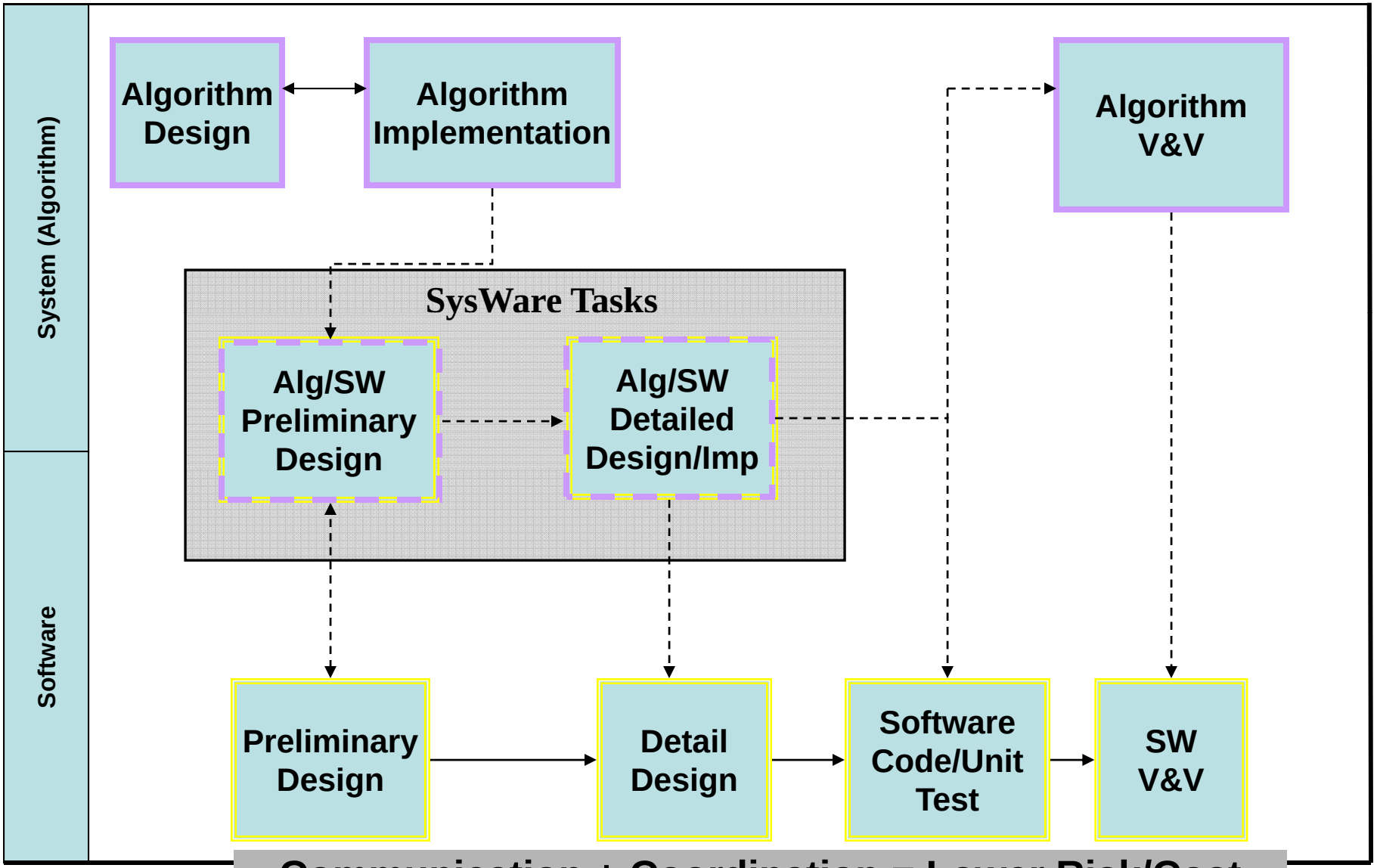
SysWare MDD SE/SW Workflow - Algorithms



Slide taken from "SysWare Engineering for Model Driven Development", J. Herbeck et al, Mathworks Aerospace 2011 (NCS-686)

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Some Lessons Learned

- Use a single Simulink model, that is shared between SE and SW and put it under configuration control early in the development cycle
- Ensure algorithm peer reviews (design and validation/verification) are held for each algorithm in the model and scheduled early enough to support SW design schedule
- Training courses need to be focused on Simulink model development with code generation in mind
- Take advantage of the Simulink Model Advisor early in the model development process
- Run SW static analysis tools on the auto-generated code early in development cycle
- Determine timing budget for each algorithm and monitor during development
- Develop a target platform test framework to facilitate early testing of Simulink auto-code for benchmark purposes
- Testing should be performed in chunks (i.e. don't wait for the model to be completed)

Slide taken from "SysWare Engineering for Model Driven Development", J. Herbeck et al, Mathworks Aerospace 2011 (NCS-686)

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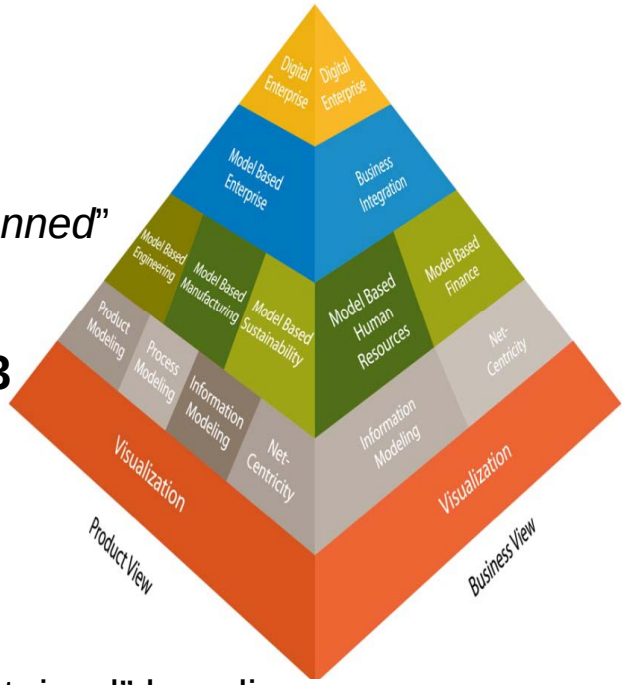
Model Based Enterprise Capability Development

- **Complexity & Functions requires System Decomposition**
  - **Model Based Definition (MBD) – 2011**
    - Enterprise MBD Specification completed in 2010
    - MCAD Models that are Qualified for defined Life Cycle Use Cases (Standards)
    - New visualization tools (ProductView)
  - **Model Based Manufacturing (MBM) – 2012**
    - Global supplier communication and support of product IP
    - MCAD Models transitioned from "*As Designed*" to "*As Planned*"
    - Derivatives from MCAD models used for process plans.
  - **Model Based Systems Engineering (MBSE) – 2013**
    - Virtual verifications at the core of these capabilities
    - Requirement allocations & derivations
    - "As Verified" status linked to PDM
  - **Model Based Life Cycle Support (MBLCS) – 2014**
    - Reuse of MBD for technical manuals, RAM, and "As Maintained" baseline



Model Based Enterprise Framework is Common PDM

Slide taken from "Industry and ManTech Interaction Success", David Baum, NIST TDP Summit 2011

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Common PDM MBD Capability Use Case Requirements

- **Authoring** – defining all the features, annotations, and attributes required of a model for its defined use cases.
- **Checking** – verifying that all Hardware Development Plan (HDP) specified “use cases”, and modeling standards are met for model integrity before formal release to PDM.
- **Design Review** – verifying that the model is complete for form, fit, and function.
- **Concurrent Engineering** – inputs (analysis, annotation, feature changes, etc.) to the design model from functional SME’s determined to be critical to the part/assembly..
- **Configuration Management** – identification of all correct attribute data for formal control.
- **Manufacturing Process Flow**
  - First Article Inspection – Identification of critical features/dimensions in model
  - Assembly Aids – extraction of parts list; geometry for assembly aids/work instructions
  - CNC Programming – geometry and tolerances needed to drive CNC programming
- **Supplier Review** – distribution of a formally controlled model with all information needed for review of HDP planned “use cases”.
- **Technical Manuals** – similar to Assembly Aids with identification of replaceable assemblies.

Use Cases Keep Model Development in Scope

Slide taken from “Industry and ManTech Interaction Success”, David Baum, NIST TDP Summit 2011

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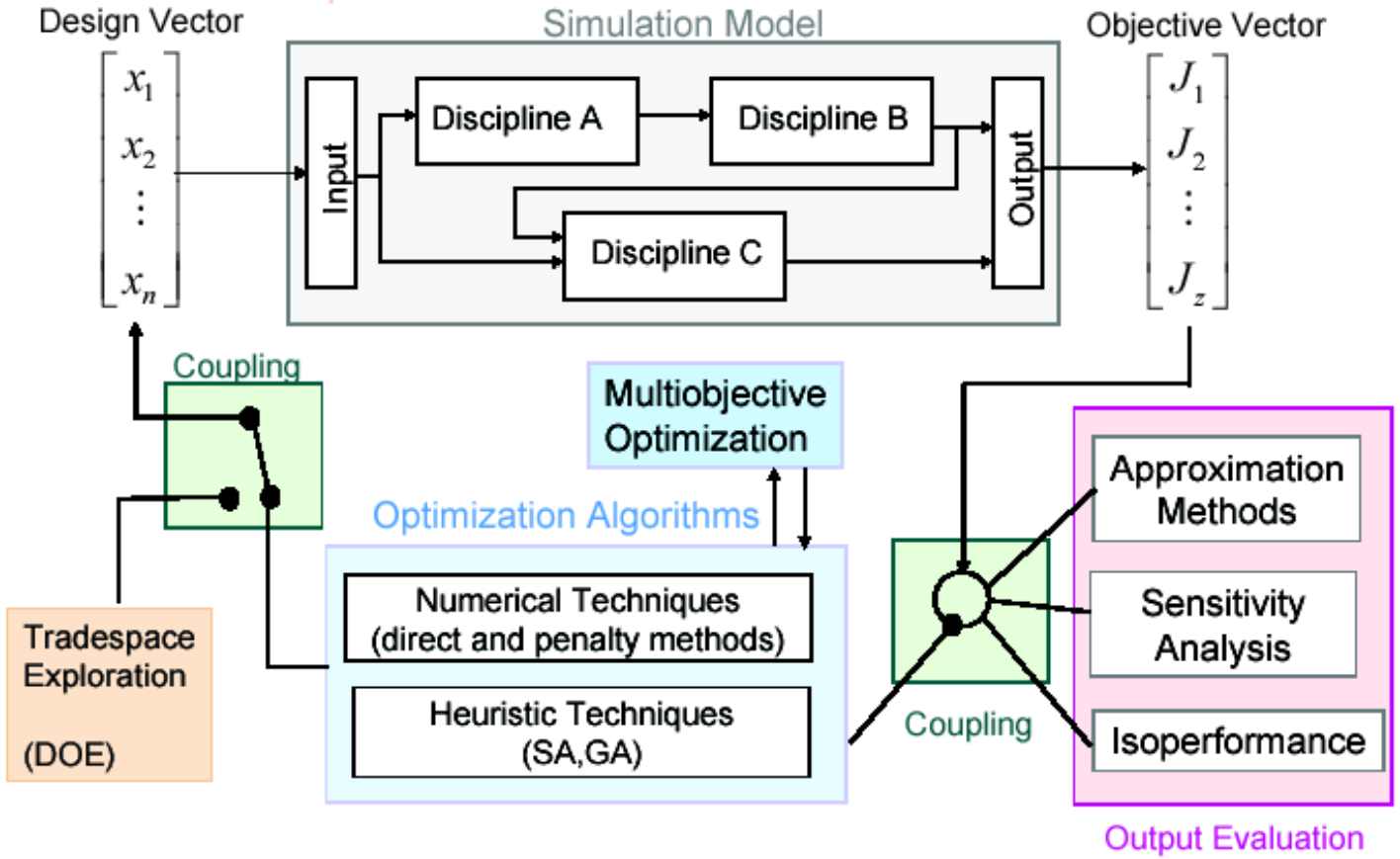
Engineer's Point of View

MIT esd

MSDO Framework

16.888 ESD.77



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Application:

- Everyone's aligned

or

- Alignment is complex

Slide taken from "Deploying MDO", Mike Nolan, Consortium for Multidisciplinary System Design Workshop 2011 (IDS-2581)

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Summary / Discussion

- Application of MDO to new areas meets with varying levels of acceptance
- Individual practitioners are motivated by a range of factors
- Commercial providers, internal providers, academics, open source providers have different needs and come from different angles
- A number of trends are impacting MDO usage

Slide taken from “Deploying MDO”, Mike Nolan, Consortium for Multidisciplinary System Design Workshop 2011 (IDS-2581)

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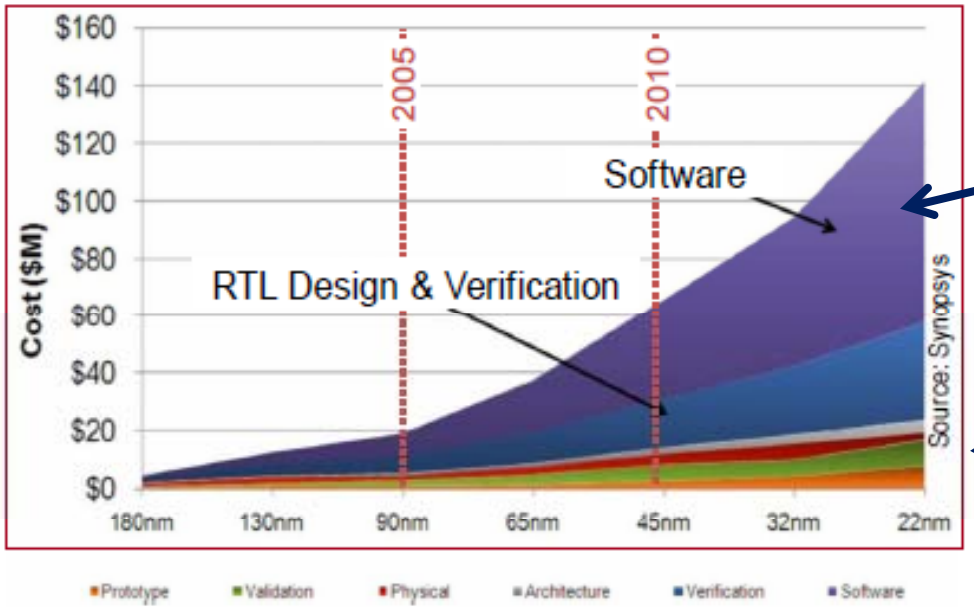
Embedded System Models – Raise Level of Abstraction

- Motivation – focus on right thing
  - Biggest issue is not the scale of SoC, or hardware, but how system works (FCRP paper)
  - Need to re-direct focus from sub-systems to system level



Focus here for biggest impact on system design and performance

Current focus

DARPA FCRP/C2S2 Consortium

Engineering needs expand focus beyond components

Slide taken from "Physical Attributes in Model Based Engineering", R Chandra, unpublished work intended for NDIA Conference on Physics-Based Modeling for U.S. Defense 2012 (RMS-5013)

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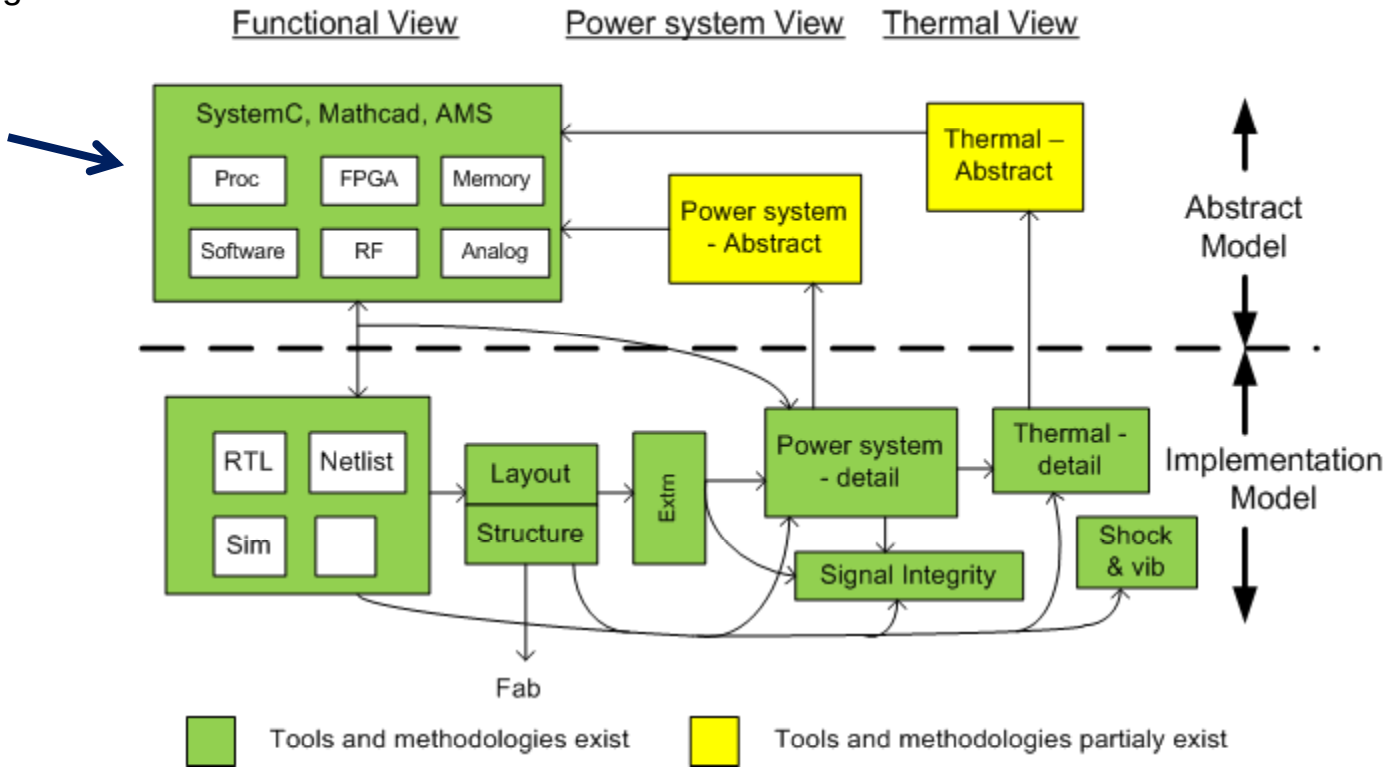
Embedded System Models – Raise Level of Abstraction

- Element of tools and methodologies exist in EDA industry for modeling at higher level abstraction
  - Injection of physical attributes in functional models – i.e., power aware simulation model
  - Equivalency of abstraction and implementation models – use industry methodology
  - Need to investigate missing pieces and tool integration

Behavioral model 'informed' with physical attributes



Fundamentals exist in industry for modeling at higher abstraction level

Slide taken from "Physical Attributes in Model Based Engineering", R Chandra, unpublished work intended for NDIA Conference on Physics-Based Modeling for U.S. Defense 2012 (RMS-5013)

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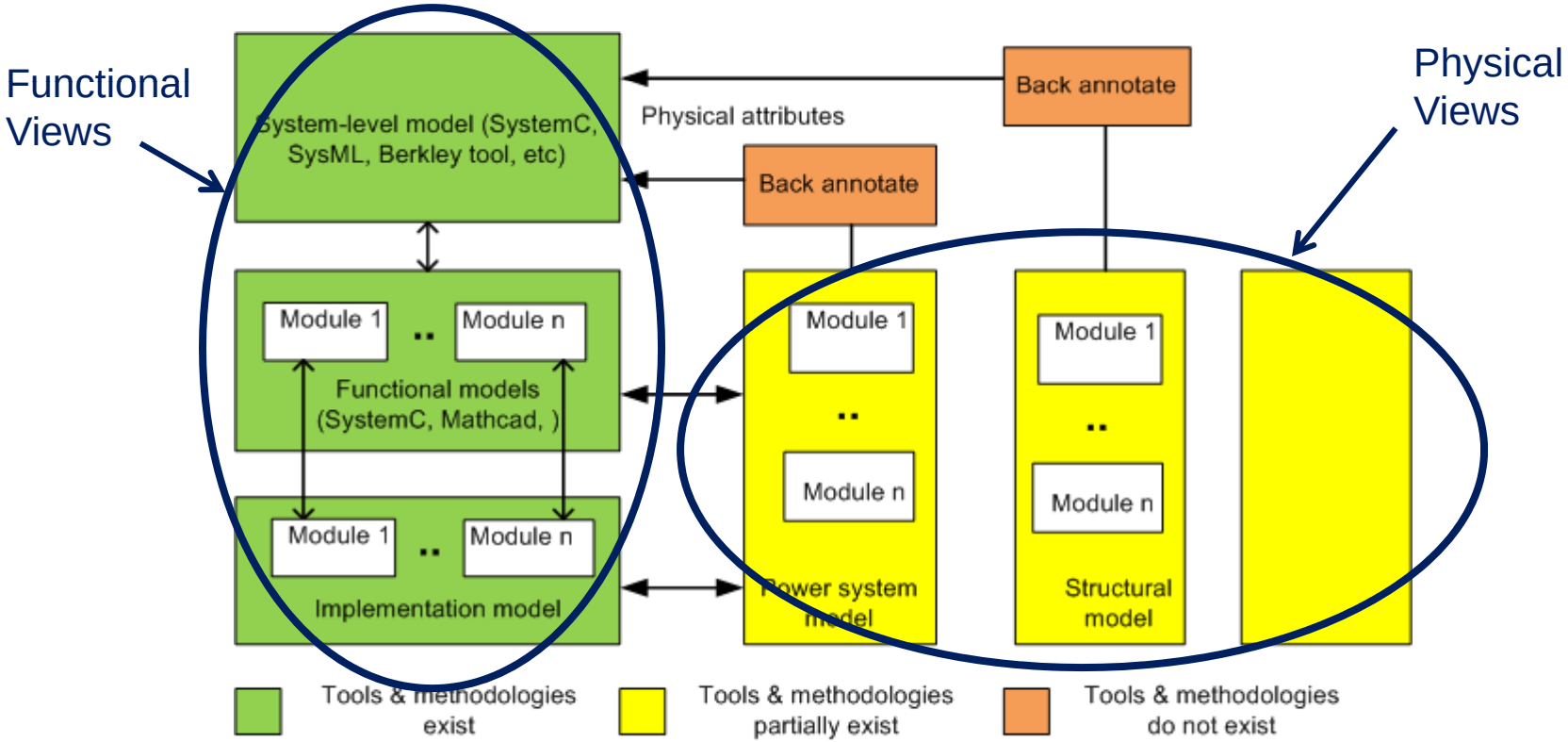
System Level Model – Integration with Embedded System Models

- Depending on system, there may be one or more layers between implementation and system levels
- Need capability to back annotate physical attributes to system level models
  - May require new semantic in system level tools (Sys^{ML}, SystemC, Berkley tool, etc)
  - Different modeling tools may require different hooks to input physical attributes



Slide taken from "Physical Attributes in Model Based Engineering", R Chandra, unpublished work intended for NDIA Conference on Physics-Based Modeling for U.S. Defense 2012 (RMS-5013)

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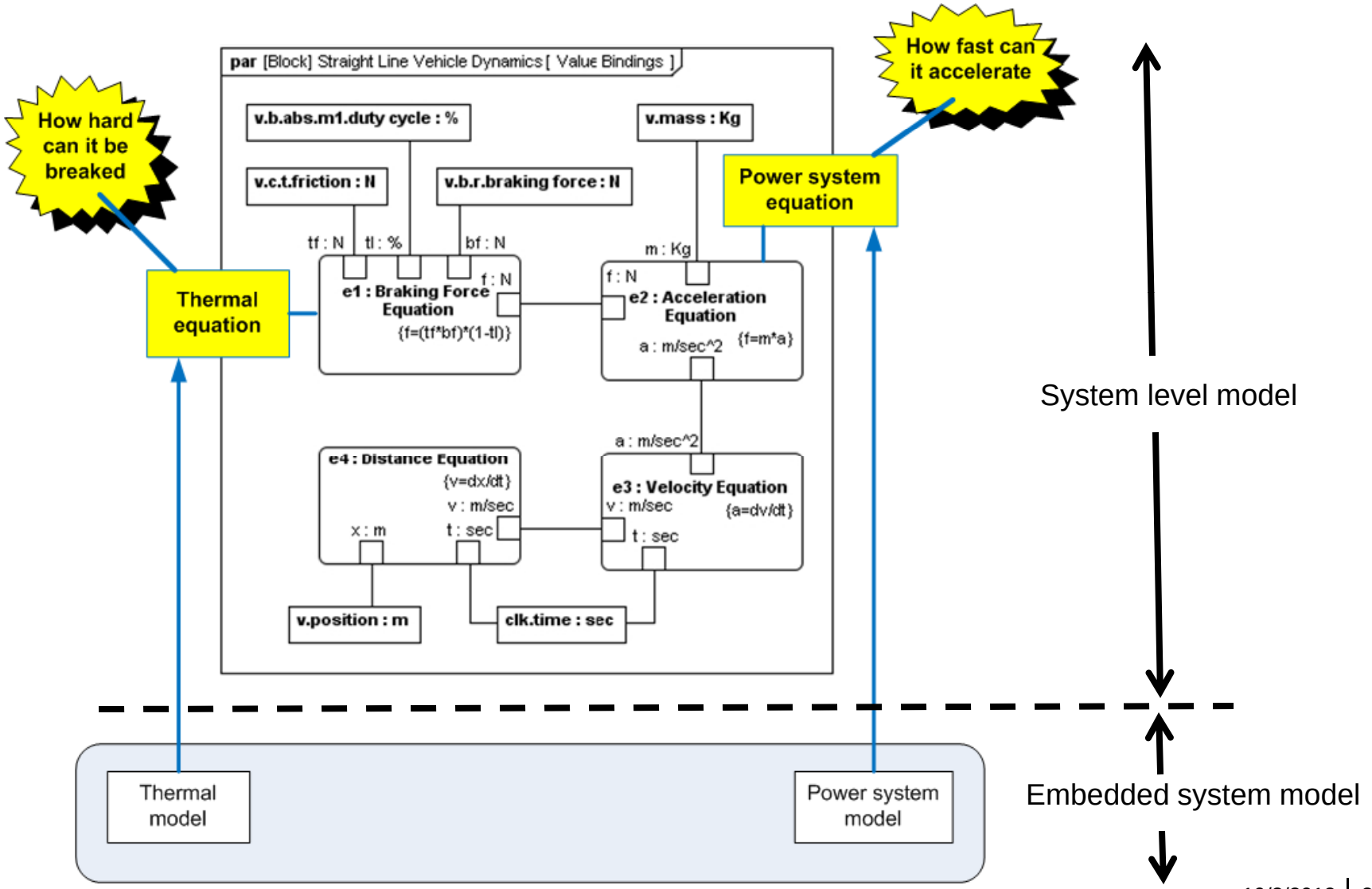
System Level Model – Integration with Embedded System Models Example



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Connecting Concept with Design Through Models

How is Concept Engineering used on AWD – Apply MBSE Where Appropriate

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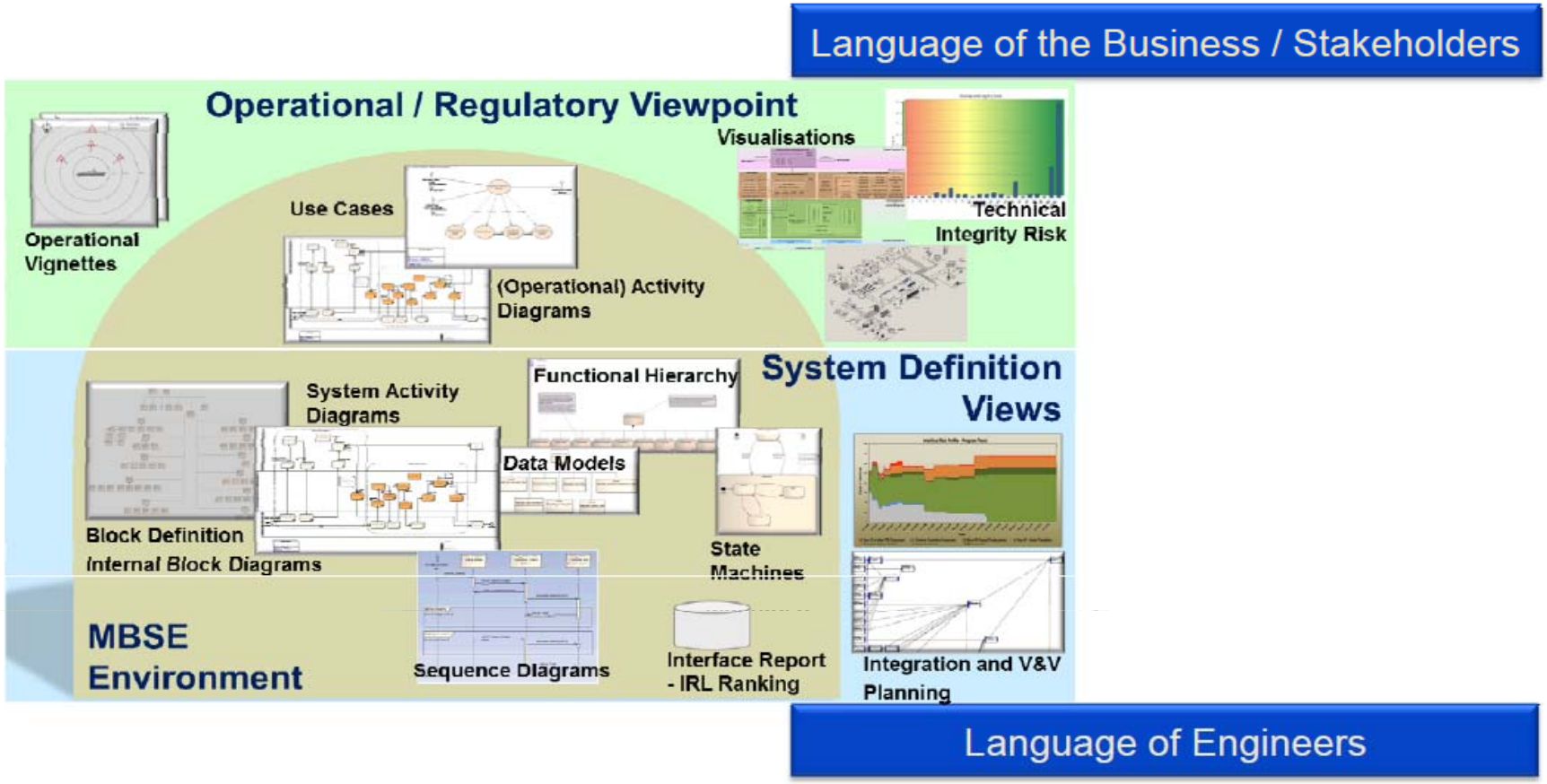

Slide taken from "Employing Concept Definition Techniques to Deliver Value on the RAN Air Warfare Destroyer Program", S. Saunders, DSTO MBSE Symposium 2012 (TBS)

Connecting Concept with Design Through Models

How is Concept Engineering used on AWD –
By-Product: Minimise Integration Risk

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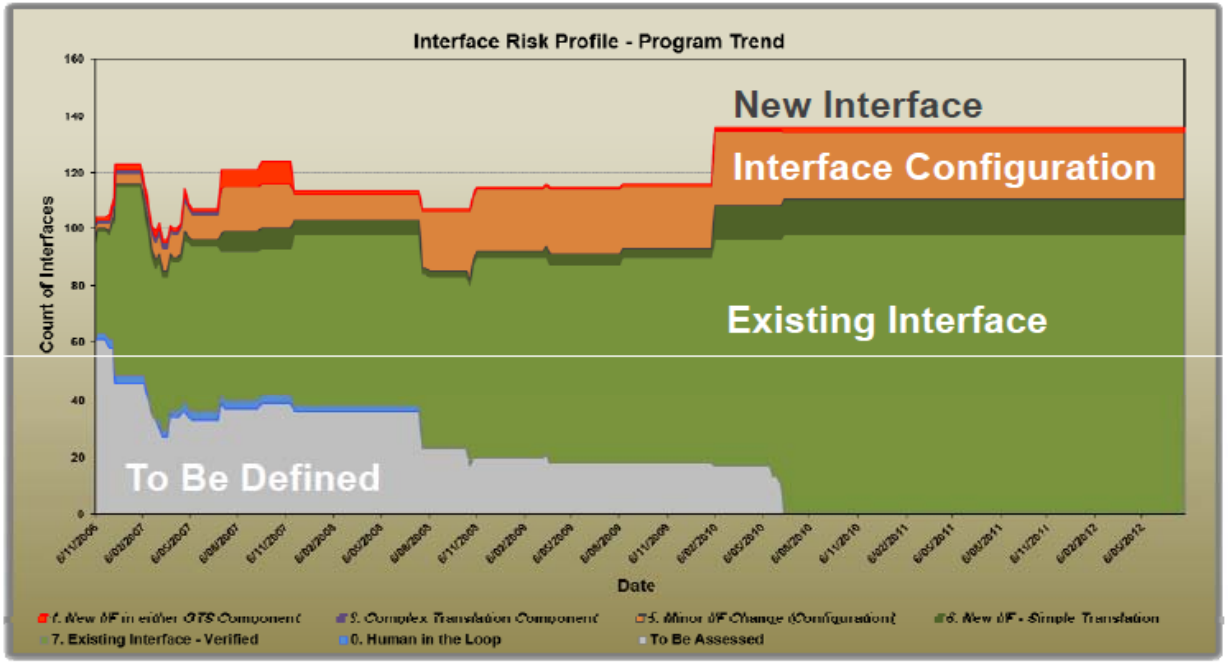
- Model contains all interfaces
  - Assign Interface risks (Interface Technology Level & Complexity)
  - Assess Risk Profile
  - Tune the Architecture
  - Minimise Integration Risk



Slide taken from "Employing Concept Definition Techniques to Deliver Value on the RAN Air Warfare Destroyer Program", S. Saunders, DSTO MBSE Symposium 2012 (TBS)

Connecting Concept with Design Through Models

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Lessons From the AWD Program

- Employ System Architecting early
- Able to model capability using SYSML → Effective CDG Interactions
- Simplified complexity enables effective decision process
  - Employment of CAIV
  - Considerations for System Evolution
  - Considerations of Technology Evolution
  - Integration of Integration Strategies
- Full Employment of all SYSML elements not required (or desired)
- IP / ITAR Restrictions Constrains Completeness of a single model
- Supports Integration Risk Assessment
- MBSE helps highlight compatibility & terminology issues

Up-Front Effort in Concept Engineered increases confidence the capability can be developed and delivered

Slide taken from "Employing Concept Definition Techniques to Deliver Value on the RAN Air Warfare Destroyer Program", S. Saunders, DSTO MBSE Symposium 2012 (TBS)

Connecting Concept with Design Through Models

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Key Take Aways

- Do not start with Requirements!! Define the Problem
- Undertake Concept Definition in the Customer/User Language
- Hide Complexity → Complexity is an enemy
- Iterate the reference architecture / consider broad business considerations
- Balance near term (Delivery) as well as Sustainment needs
- Apply MBSE concepts in a targeted manner rather than theoretical
  - OV-5b (Activity Model) most beneficial in concept definition phase

Do not skip Concept Engineering Activities!

Slide taken from "Employing Concept Definition Techniques to Deliver Value on the RAN Air Warfare Destroyer Program", S. Saunders, DSTO MBSE Symposium 2012 (TBS)

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Summary Points

- Raytheon continues to be largely a technology-driven company
  - High-tech sensors and effectors comprise ***most*** of our business
  - Still have opportunities to leverage MBSE for large scale system integration of sensors and effectors.
- Top Management sees value in Model Based approaches
  - "The model is the design"
  - "Design anywhere, build anywhere, support anywhere"
- Ongoing corporate investment in various disciplines supports and compliments model based approaches
- Product Lines are becoming more important
  - Starting to understand development and governance issues
  - Starting to recognize MBE as an enabler for product line architectures
- "Model Based" needs an incremental deployment strategy

Raytheon is on the threshold of major MBE/MBSE deployment, and is still defining the desired impact on or our business & our people.

BACKUP

Strengths

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MDA	DSL
Based on UML, the same modeling language can be used for many applications, or most of a single app. Anyone can learn it	Modeling language is specific to application domain, maximizing application development productivity
Uses models to design system	Uses models to design system
Improves software development productivity 1.5 – 3 times the standard development rate	Improves software development productivity 3+ times the standard development rate
Increases software quality (decreases defect density 2-10x)	Increases software quality (decreases defect density 10x +)
Small investment in commercial tools means savings begin in first few months of development	Lends itself to product line software development

Each has its own strengths

Slide taken from “DSL & MDA: Allies or Enemies”, Terri Potts et. al, SSTC2010 (IDS-2056)

Weaknesses

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MDA	DSL
Generic UML language doesn't lend itself to all domains (e.g. signal processing, algorithm processing, etc)	Must invest time and $ in DSL development before application development can begin
Some training needed to create most effective models	DSL development is a significant investment
Models often follow a modeling standard needed for the code generator, which may be unique for each tool	To create useful DSLs, need domain subject matter experts dedicated to designing DSL (these experts are often difficult to break free from jobs)
Models may be less concise than DSL models and subject to ambiguity	Need software developers that are experts in DSL development
	Coordination of changes to DSL across multiple programs can be a challenge

Each has its own weaknesses

Slide taken from "DSL & MDA: Allies or Enemies", Terri Potts et. al, SSTC2010 (IDS-2056)

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The Physical Layout

- **We needed**
  - Wall space for “PnP” Technology
    - Large video displays above
  - Place to break into teams ~9
  - Place for engineers to go “head down” and work but be close.
  - A place to have a larger team meet
    - Rapid multi-displays
  - Needed to secure room
  - Looking for a “Nickel” Solution
- **We considered**
  - JPL TeamX
  - Whitehouse Situation Room
  - Bridge of the Starship Enterprise
  - WWII Command Rooms

• Small multi-disciplinary work groups collaborate and perform interdisciplinary design activities (IDAs) focused on specific design solutions
• Groups are created and dissolved as needed. Participants move between groups and IDAs based on workflow

The VSD™ Rapid Concept Development Environment

Human factors necessitate a physical layout for the foreseeable future

Slide taken from “Virtual Product Development for Complex Systems”, Ron Valles et. al, IBM INNOVATE 2012 (RMS-1958, 1959)

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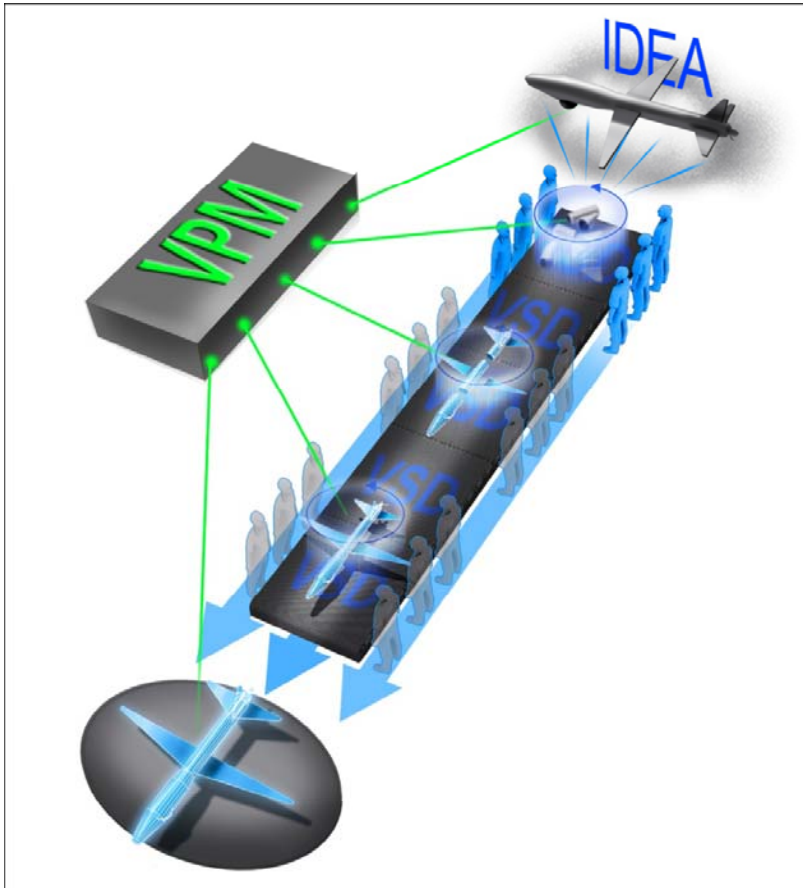
Moving toward a future state where we…



- Collaborate to solve engineering problems using:
  - Right-fidelity models
  - Appropriate levels of detail for the program phase
  - Engineers communicating with each other using their models to jointly build the same VPM
- Constantly assessing fit, balance and requirements
- Developing robust subsystem requirements
- Eliminating *non-cognitive* activities which slow our product development and stifle innovation

Enable Development Teams to better

Understand, Collaborate, Innovate, Synthesize and Optimize

Slide taken from "Virtual Product Development for Complex Systems", Ron Valles et. al, IBM INNOVATE 2012 (RMS-1958, 1959)

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Virtual Solutions Development™

Virtual Product Model (VPM):
- The set of all models and their development histories and contains all concepts
- The heart of Model Based Design and primary way the product development team is integrated at a data and model level
- A "snapshot" of the "finished" VPM is the PODD

Information System:
- Information system stores and maintains model sets and searchable development histories for each concept
- COTS, legacy and internal tools are connected to information system
- Information system provides customizable situational awareness of current state of concepts and development process status.

Workflow:
- Workflow provides a clear way through the woods
- Easily adaptable to suit capture needs
- Quick design loops rapidly identify key design drivers
- Comprehensive design protocols assess risk, schedules, and costs

Tools:
- Tools act on models which are kept "in the cloud"
- SME's tools are used to develop models
- Tools are connected through the information system to models and other tools

Slide taken from "Virtual Product Development for Complex Systems", Ron Valles et. al, IBM INNOVATE 2012 (RMS-1958, 1959)

VSD™ Engine: Generating Product Solutions

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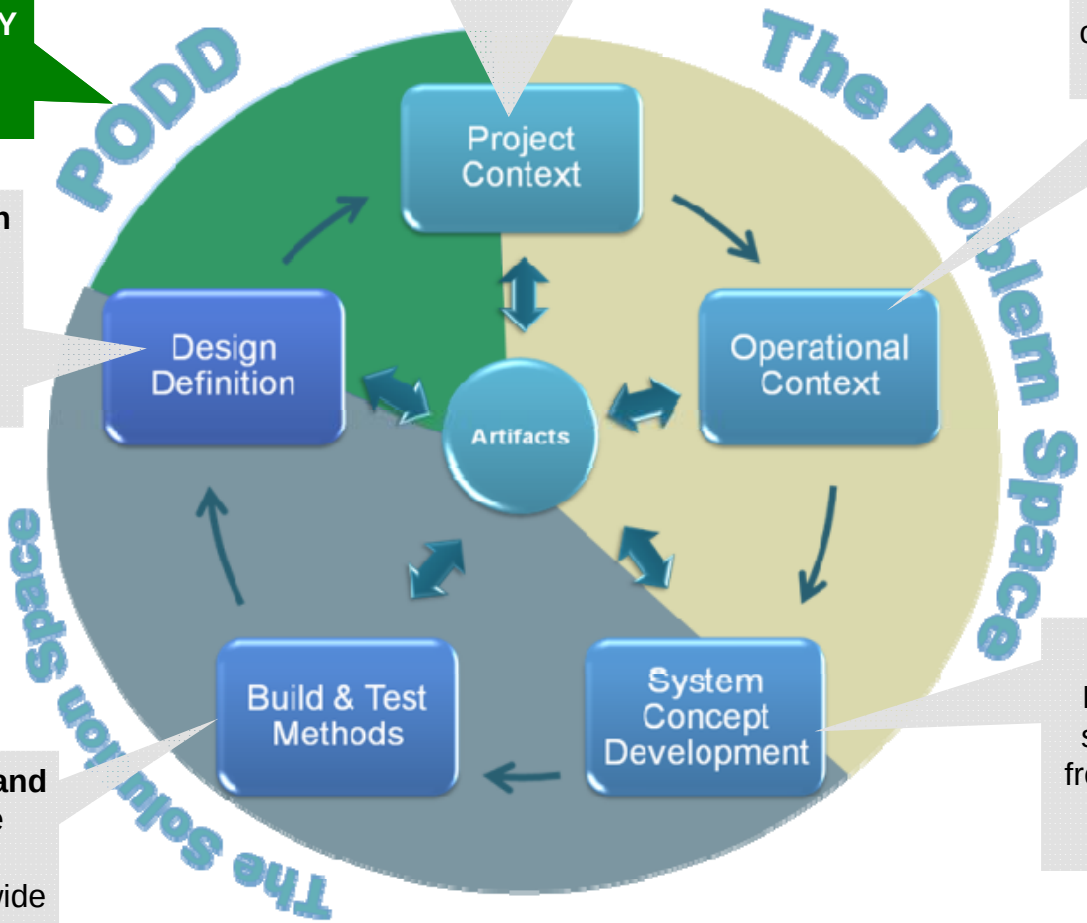
Workflow

Project Context Definition combines business plan and technical objectives to shape the team direction

Exit Criteria
- **PODD compliance assessed CONTINUALLY**
- **PODD sufficient fidelity for preliminary design**

Operational Context Definition develops the operational structure and allocations

Systems Design definition
- Seamless iterative design
- Cost and risk evaluation
- Virtual Product Model defines PODD



System Context Definition defines the system solution model from physical and logical perspectives

Design/Build Methods and Constraints detail the project development environment enterprise wide

Virtual Solutions Development™

Slide taken from "Virtual Product Development for Complex Systems", Ron Valles et. al, IBM INNOVATE 2012 (RMS-1958, 1959)

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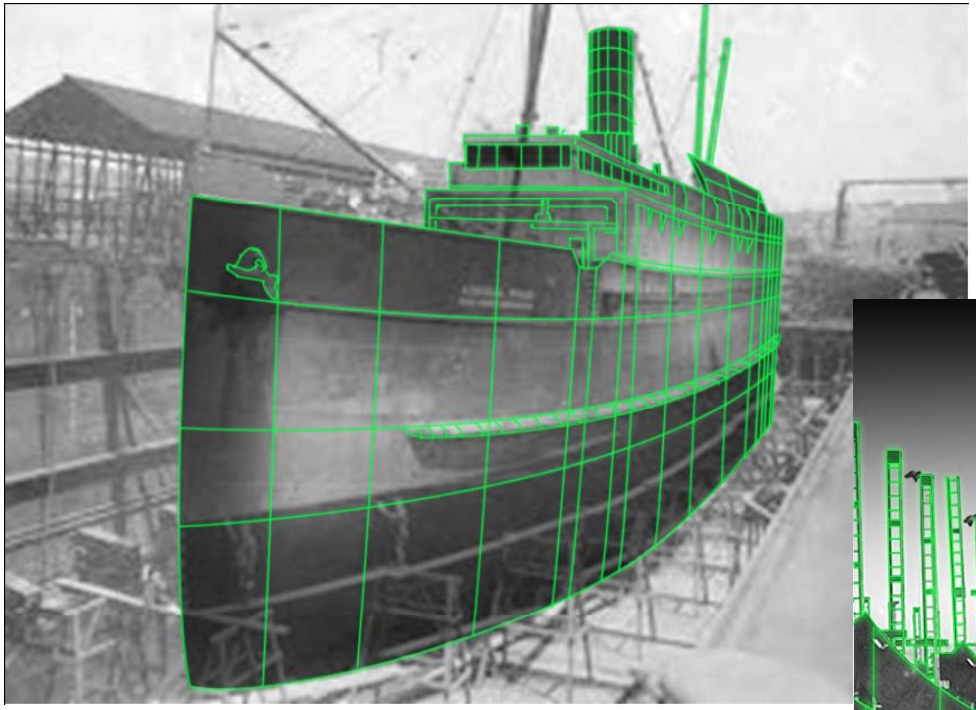
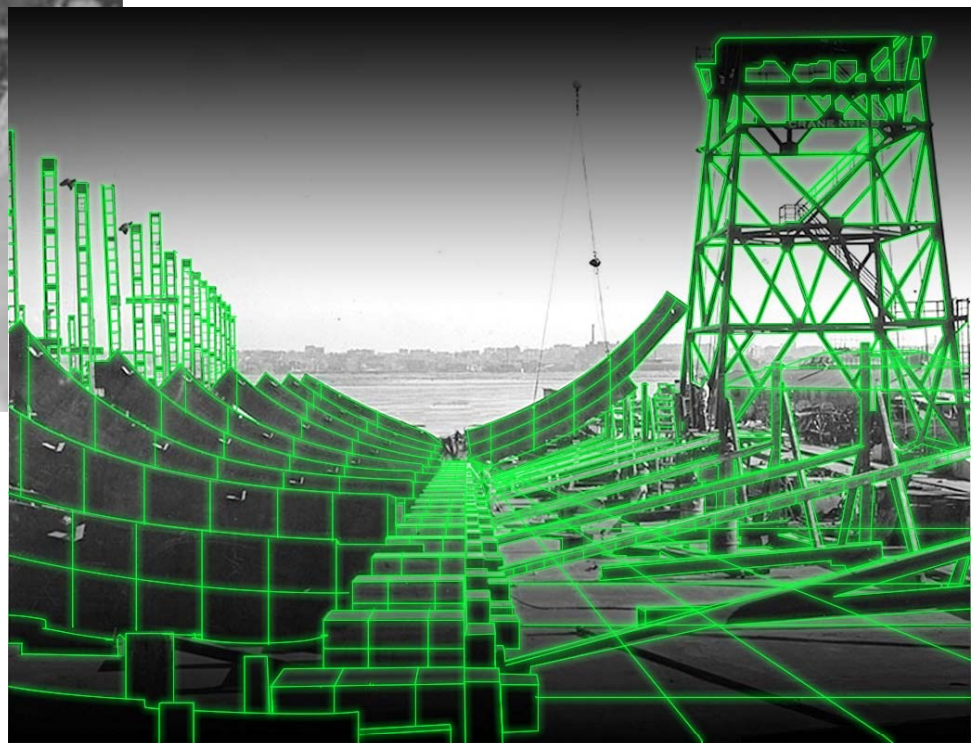
The Virtual Dry Dock and The Virtual Ship



Before we “bend and cut metal,” we want to build a virtual ship!

The virtual ship is our VPM!



To build a virtual ship we need a virtual “Dry Dock”

The virtual dry dock is VSD™!

We’re building a “better” (virtual) dry dock so we can build better “ships”

Slide taken from “Virtual Product Development for Complex Systems”, Ron Valles et. al, IBM INNOVATE 2012 (RMS-1958, 1959)

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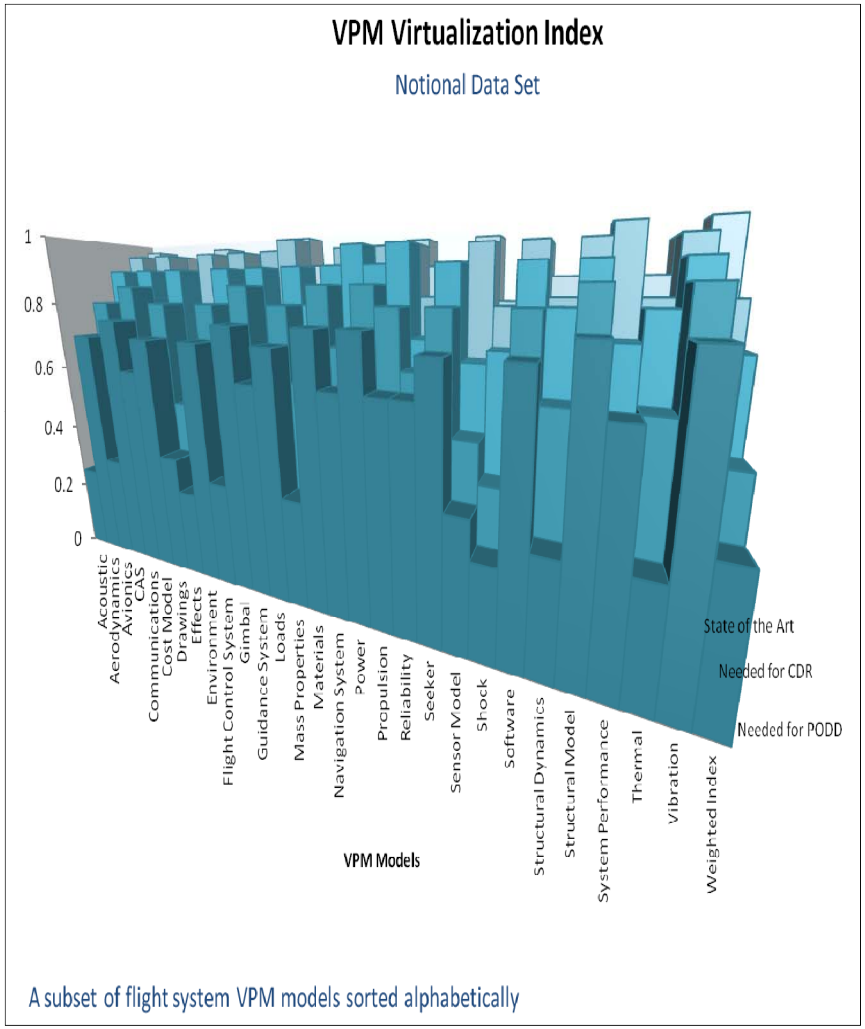
Interdisciplinary Design Activity (IDA) Description

- **The IDA is an innovative, affordability-aware approach to the objective and interdisciplinary pieces of systems engineering**
- **In brief IDAs are RIGHT, RAPID, and IN-BOUNDS.**
  - **RIGHT**
    - Include all disciplines necessary for the system-level questions
    - SME engagement in model use
    - Iterate to converge and to understand surrounding cliffs or pitfalls
    - Concentrate on the “seams” (i.e. interfaces)
  - **RAPID**
    - Include only disciplines necessary for the system-level questions
    - Use the lowest fidelity models sufficient for the system-level questions (Virtualization Index)
    - Provide streamlined connections of these models
  - **IN-BOUNDS**
    - Cost constraints used as boundaries for iteration
    - Other constraints from Project Context and Operational Context included to fullest extent possible
- **IDA classes: Physics Based, Functional Architecting, Quality Attribute Discovery**

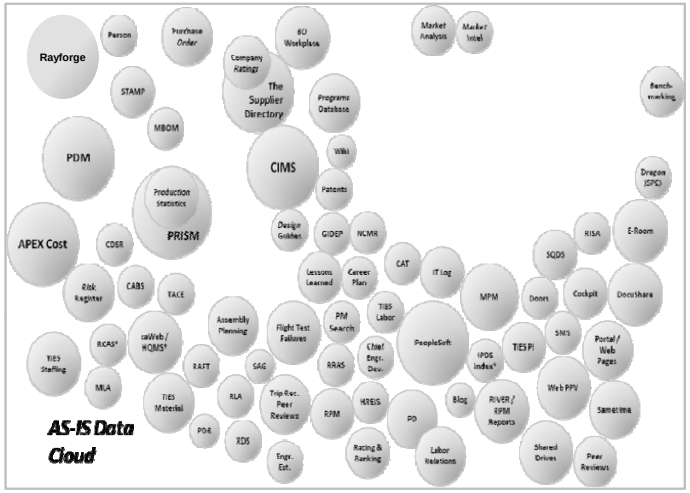


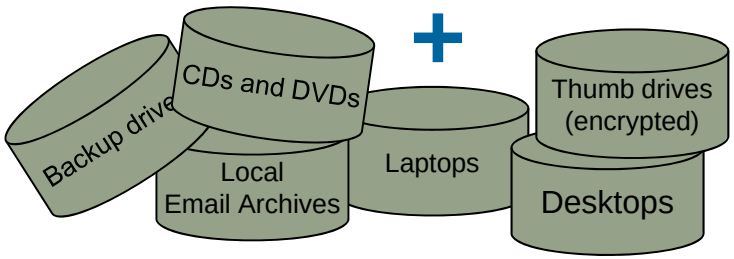
Slide taken from “Virtual Product Development for Complex Systems”, Ron Valles et. al, IBM INNOVATE 2012 (RMS-1958, 1959)

Need for Information System

- Associated models and data were located in multiple locations which in many cases had little to no configuration control or backup/disaster recovery methodologies. Thus, the potential for data acquisition in support of information reuse was low while the likelihood for loss of key information was high
- Key care-abouts:
  - Availability & reliability
  - Compliant with business IT requirements
  - ITAR compliant
  - Security compliant
  - Access rights control
  - Protection against data loss [Goal - 24 hours to 1 hour at peak]
  - External User Capability
  - VPN Compatibility
  - Configuration management
  - Compatible across range of engineering file types, tools, databases
  - Provide situational awareness!

"AS-IS" Data Model





= Data Sprawl!

Email used as a primary way to transfer information – Yikes!

Slide taken from "Virtual Product Development for Complex Systems", Ron Valles et. al, IBM INNOVATE 2012 (RMS-1958, 1959)

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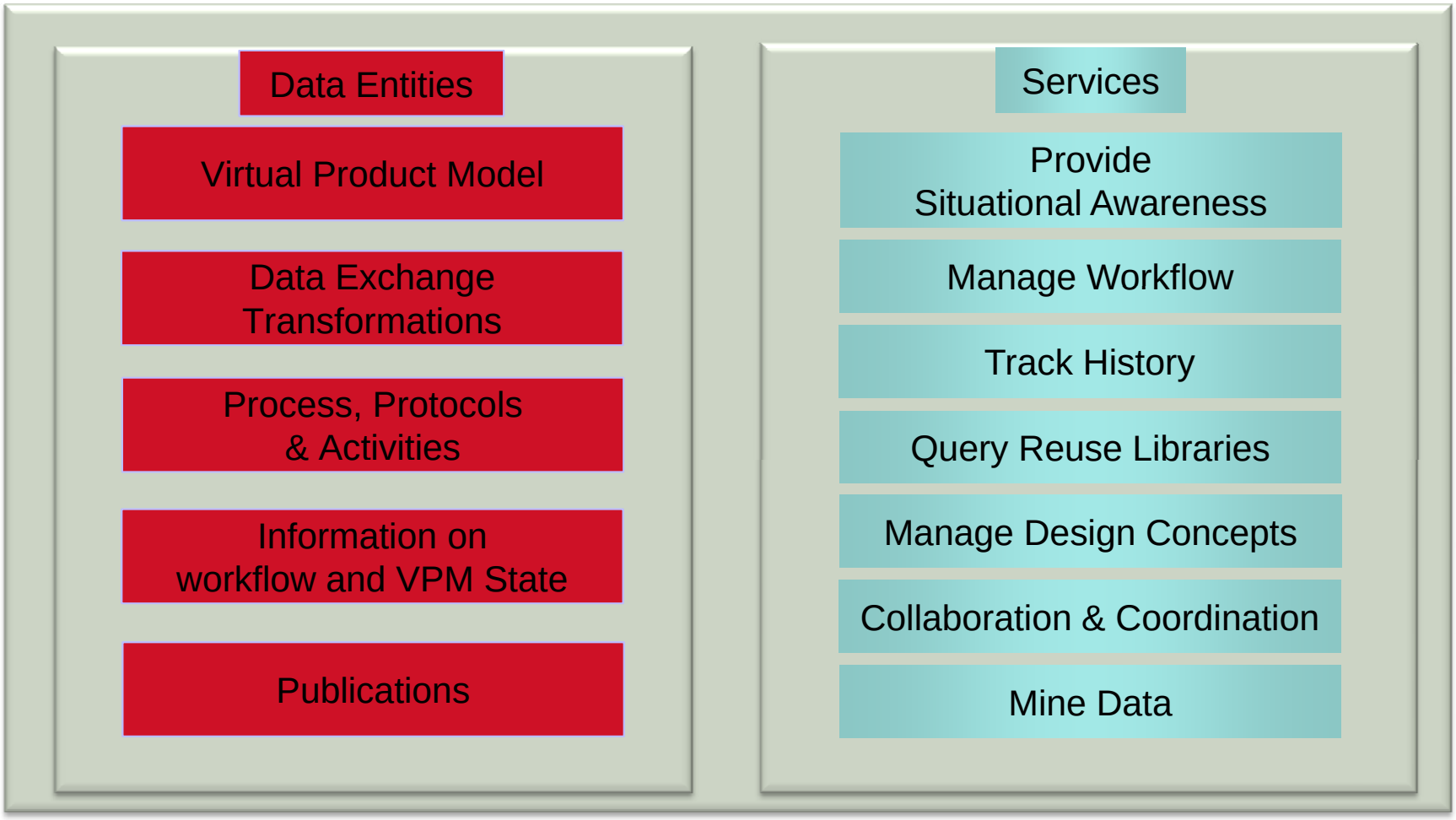
Key Information System Elements



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