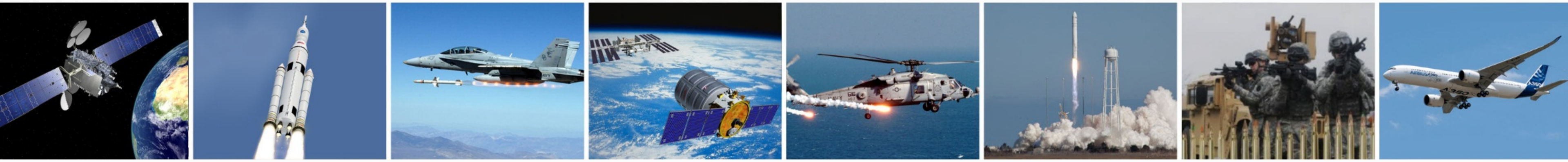
The emerging relationship between PLM and Systems Engineering

Paul Nelson
PLM Systems Engineer

15 October 2015
Purdue University PLM COE Fall Meeting



Outline

- Personal Introduction
- Company Overview
- Taxonomy Level Set (syseng, model based, PLM, etc.)
- Systems Engineering Trends
- PLM Trends
- Systems Engineering and PLM are converging
- Conclusions and Recommended Actions

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Personal Introduction – Paul Nelson

- Two years in central Siberia
- B.S. and M.S. in MeEn at BYU (Internships at GM and Pratt & Whitney)
  - Thesis in Multi-physics simulations and visualizations and Global Product Development Course
- Boeing / Siemens PLM – ~5 years
  - St. Louis – F16/18/etc., Houston – Space Station, many other customers
- Orbital ATK – ~7 years - Promontory, Utah
  - Engineering Technology and Systems – Propulsion Systems
  - Corporate PLM Center of Excellence
- Began my career MCAD Management focused
- Quickly matured into core PDM / EBOM / Change / Document Management (CMIIP certification)
- More recently matured into Systems Engineering focus towards requirements engineering and MBSE (University of Utah graduate certificate in systems engineering and INCOSE CSEP certification)
- Now focused as a "**PLM Systems Engineer**" on orchestrating holistic PLM by working the above plus:
  - Manufacturing Engineering / ERP / MES tie ins
  - Simulation Process and Data Management
  - Materials and Mass Properties Management
  - ECAD and Software integrations
  - Foundational elements such as security, UI, Etc.
- Grateful for a career path that has allowed me to work big picture product development/delivery issues
- Enjoy my 5 kids, sweet wife, playing with LEGO robotics and exploring mountains

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Orbital ATK Overview

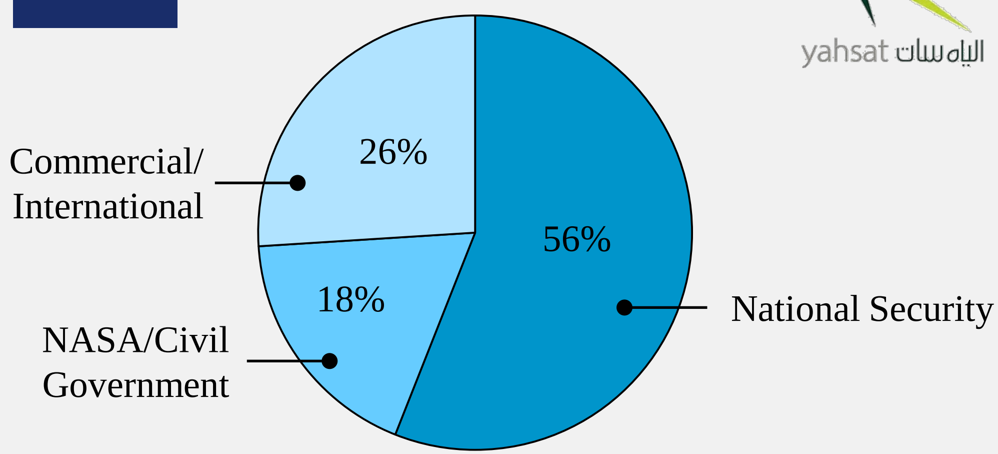
Innovation You Can Count On®

Aerospace Systems
Defense Systems

Innovation… Delivered

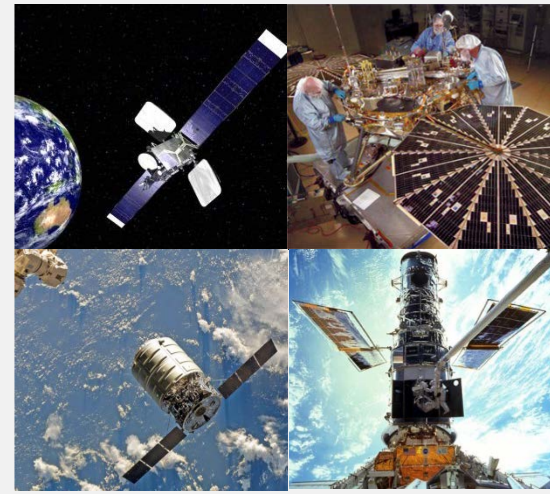
- New Global Aerospace and Defense Systems Company Established by Merger of Orbital and Alliant Techsystems in February 2015
- Leading Developer and Manufacturer of Reliable, Innovative and Affordable Products for Government and Commercial Customers
  - Launch Vehicles, Propulsion Systems and Aerospace Structures
  - Tactical Missile Products, Defense Electronics, Armament Systems and Ammunition
  - Satellites, Advanced Systems, Space Components and Technical Services
- About $4.4 Billion in Pro Forma Revenue Targeted for Calendar Year 2015
- More Than 12,000 Employees, Including 4,300 Engineers and Scientists
- Over $12 Billion in Contract Backlog With Strong Near-Term Growth Prospects
- Strong Revenue Growth, Earnings Accretion and Cash Flow Outlook

Top Customers and Revenue Composition



Approximate CY 2015 Pro Forma Revenue Distribution

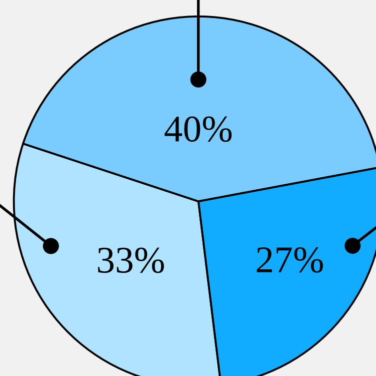
Three Operating Groups and 12 Product Lines



Flight Systems Group
- Space Launch Vehicles
- Rocket Propulsion Systems
- Missile Defense Systems
- Aerospace Structures

Defense Systems Group
- Tactical Missile Products
- Defense Electronic Systems
- Armament Systems
- Ammunition and Energetics

Space Systems Group
- Commercial Satellites
- Government Satellites
- Spacecraft Components
- Space Technical Services



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Systems Engineering Definition

- Orbital ATK defines Systems Engineering as the interdisciplinary incorporation of the following integrated elements:
  - Requirements – definition, allocation, flow down, traceability
  - Qualification / Verification / Validation
  - System Design / System Integration
  - Configuration Management
  - Risk Management
  - Technical Planning and Scheduling
  - Technical Reviews
  - Process Definition

CM and PLM Definitions

- CM ≡ traditional Configuration Management – serves to plan how identification, change control, status accounting, and audits will be performed on each product. Scoped to Engineering.
- CMII ≡ CM version 2 – Configuration Management scoped to include all information that could impact safety, security, quality, schedule, cost, profit, or the environment. Scoped to the Enterprise, not just Engineering. The goal is to keep requirements clear, concise, and valid and to accommodate change. Ultimate goal to achieve IPE and drive intervention resources to zero.
- IPE ≡ Integrated Process Excellence – CMII best practice processes for generic product development integrated and automated within a world class PLM framework. Resources spent on corrective action are in a state of decline and real improvements are occurring.
- PLM ≡ Product Lifecycle Management – Orbital ATK's definition:
  - The application of a *consistent* set of processes and technology in support of the *collaborative* creation, *management*, dissemination, and use of product information across the extended enterprise from concept to end of life.
  - Consistent processes and tools allowing programs to share product information, leverage knowledge and to provide the right information at the right time to make the right decision.
  - PLM is more than a software tool; it is a business strategy.

Documented Requirements

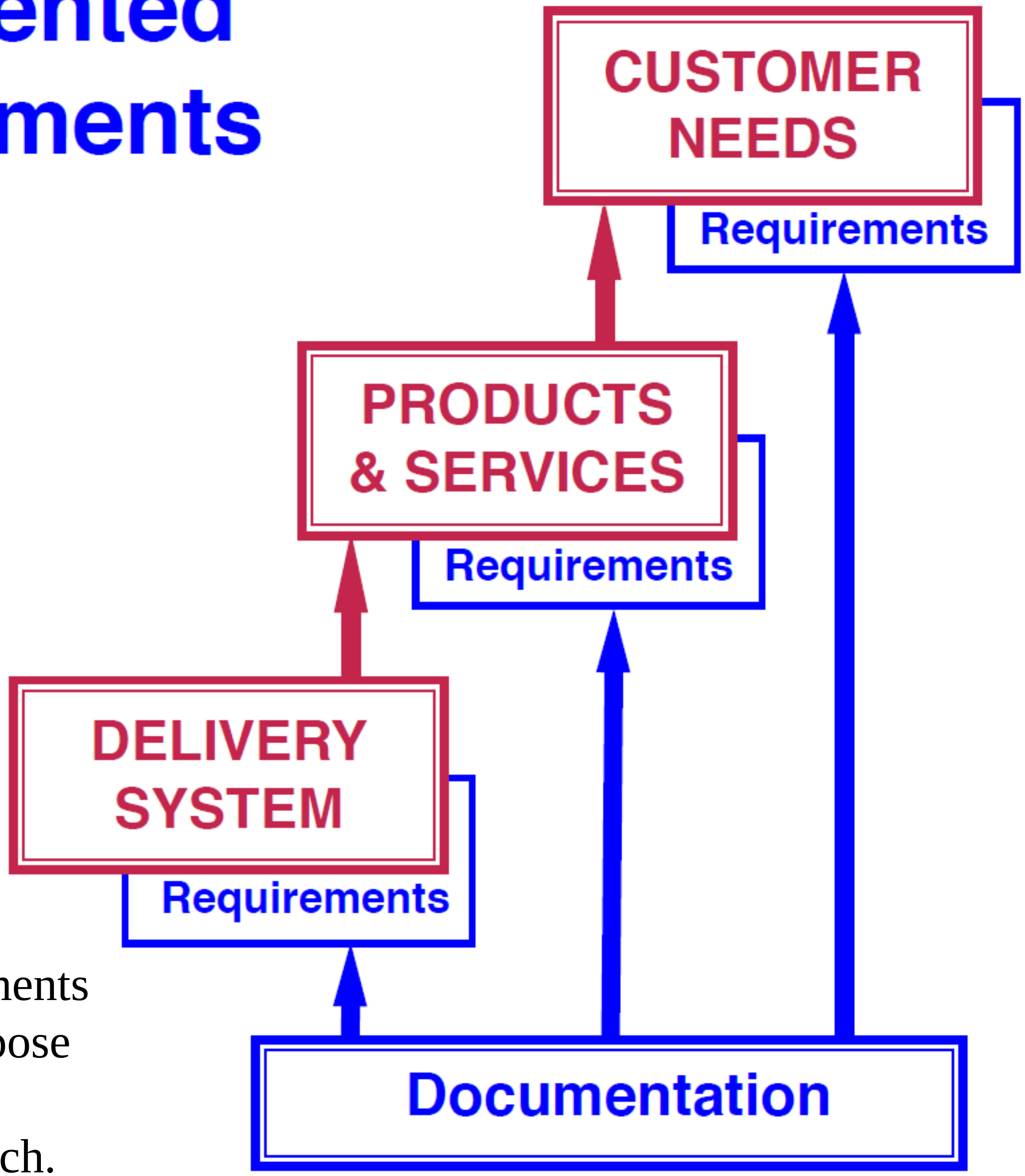
ISO 9000:

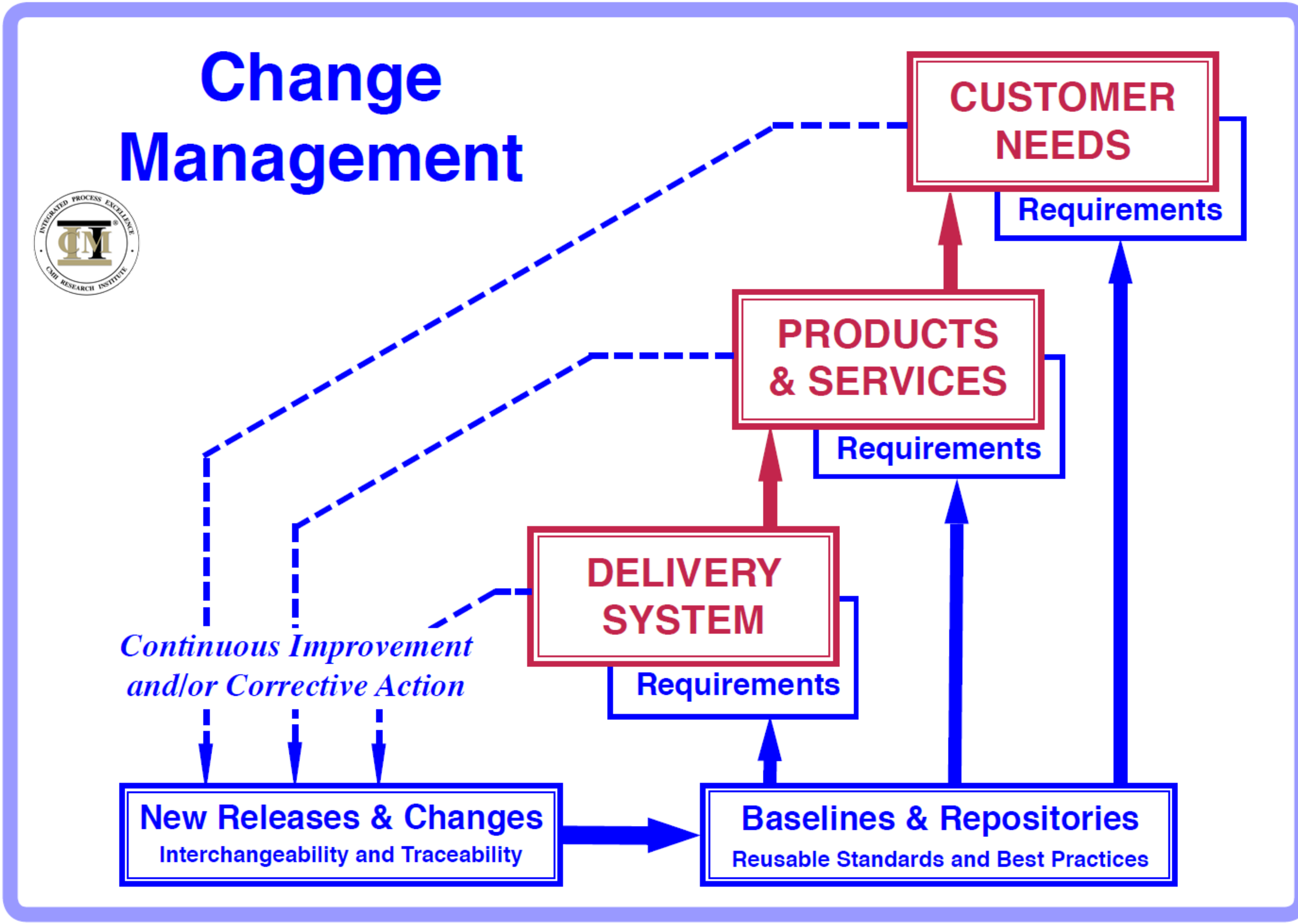
"Document what you do; do what you document."

CMII Rule:

"A requirement is not a requirement until it is documented, validated and released."

No longer have to batch requirements into documents, but can decompose and handle requirement by requirement in a MBSE approach.




Change Management
CUSTOMER NEEDS
Requirements
PRODUCTS & SERVICES
Requirements
DELIVERY SYSTEM
Requirements
Continuous Improvement and/or Corrective Action
New Releases & Changes
Interchangeability and Traceability
Baselines & Repositories
Reusable Standards and Best Practices

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System Engineering Trends[1]

- Application of systems engineering
  - Applying systems engineering across industry domains
  - Applying systems engineering to policy
- Transforming systems engineering (see next chart for details)
- Maturing systems engineering foundations
  - Shoring up the theoretical foundation
  - Systems engineering body of knowledge
  - Systems theories across disciplines
- Commonly defined roles and competencies
  - The broadening role of the systems engineer
  - Consistency in essential systems engineering competencies
- Education and training
  - Building the future systems engineering workforce
  - The systems engineering curriculum
  - Lifelong learning

1 INCOSE Systems Engineering Vision 2025 – see copyright on chart #39

Transforming Systems Engineering[1]

Five key systems engineering challenges:

1. Mission complexity is growing faster than our ability to manage it
2. System design emerges from pieces, rather than from architecture
3. Knowledge and investment are lost at project life cycle phase boundaries
4. Knowledge and investment are lost between projects
5. Technical and programmatic sides of projects are poorly coupled

- Most major system failures have resulted from failure to recognize and deal with risks

Systems Engineering Trending Improvements:

- Value Driven Practices
- Complex System Understanding
- Leveraging Technology for Systems Engineering Tools (e.g. MBSE)
- Collaborative Engineering: Integrating Teams and Organizations Across All Boundaries
- System Design In a System of Systems Context
- Architecting Systems to Address Multiple Stakeholder Viewpoints
- Architecting and Design of Resilient Systems
- Cyber Security – Securing the System
- Decision Support: Leveraging Information and Analysis for Effective Decision Making
- Virtual Engineering: Part of The Digital Revolution
  - Simulation and Visualization
  - Integrated Model-based Approaches
  - Transforming Virtual Model to Reality

1 INCOSE Systems Engineering Vision 2025 – see copyright on chart #39

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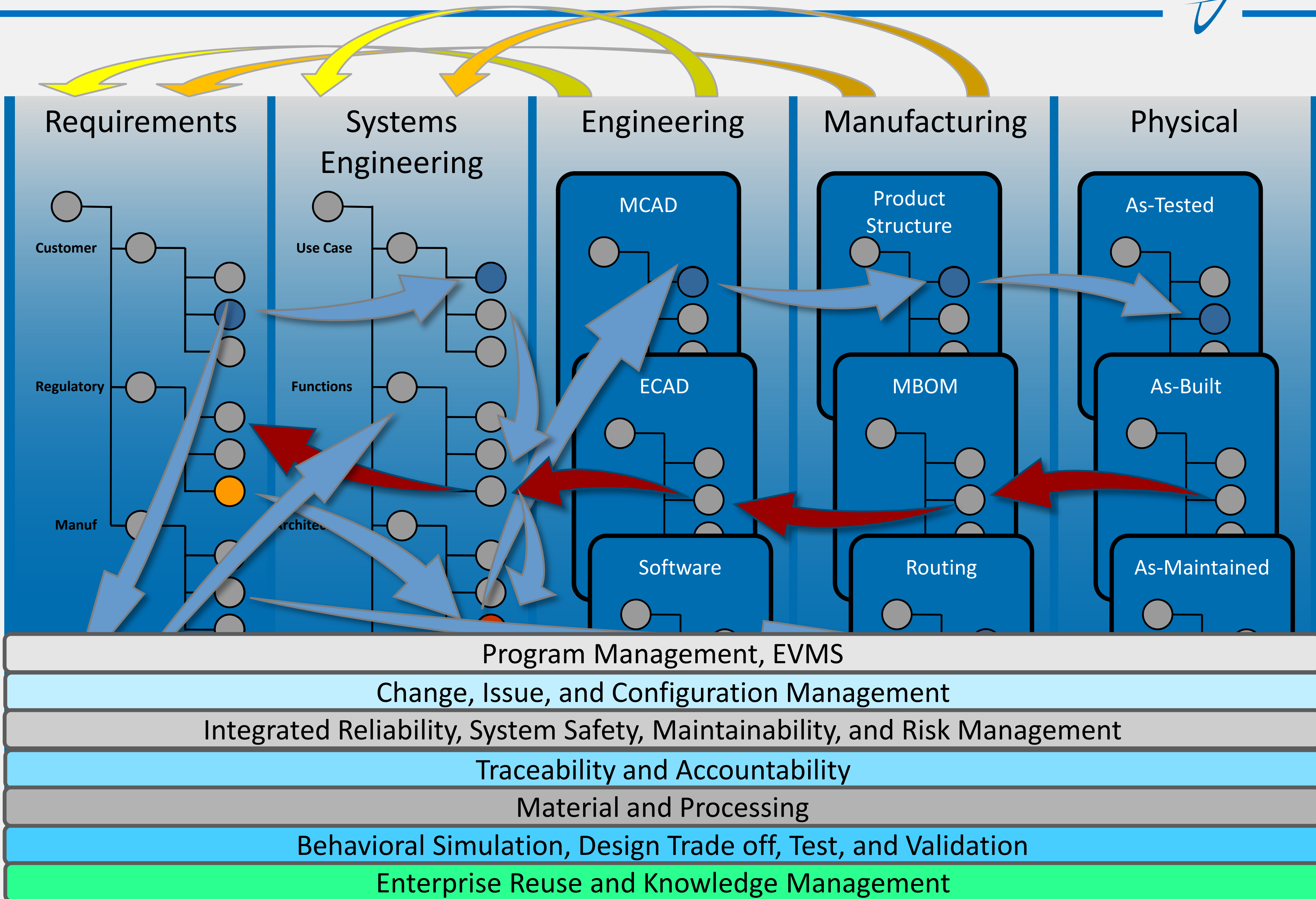
PLM Trends

- PLM is a System of Systems (SoS) problem (or Fractal Zoom) with recurring principles/patterns
- Trends in PLM:
  - Integrate – Deeper integrations for CAx and PLM modules)
  - Simplify – UIs and implementation approaches
  - Scale – 100ks to 1-10Ms
  - Broaden scope – more modules such as cost, testing, etc.
  - Closed loop product development – Architecture tied to mechanical, electrical, software design/analysis with testing in the loop
  - Specialize by industry – e.g. Aerospace and Defense template
  - Connecting Product and Production
  - Internet of things (or industry 4.0)
  - Move to Cloud
  - Big Data Analytics
  - Faster, better, cheaper

Closed Loop PLM



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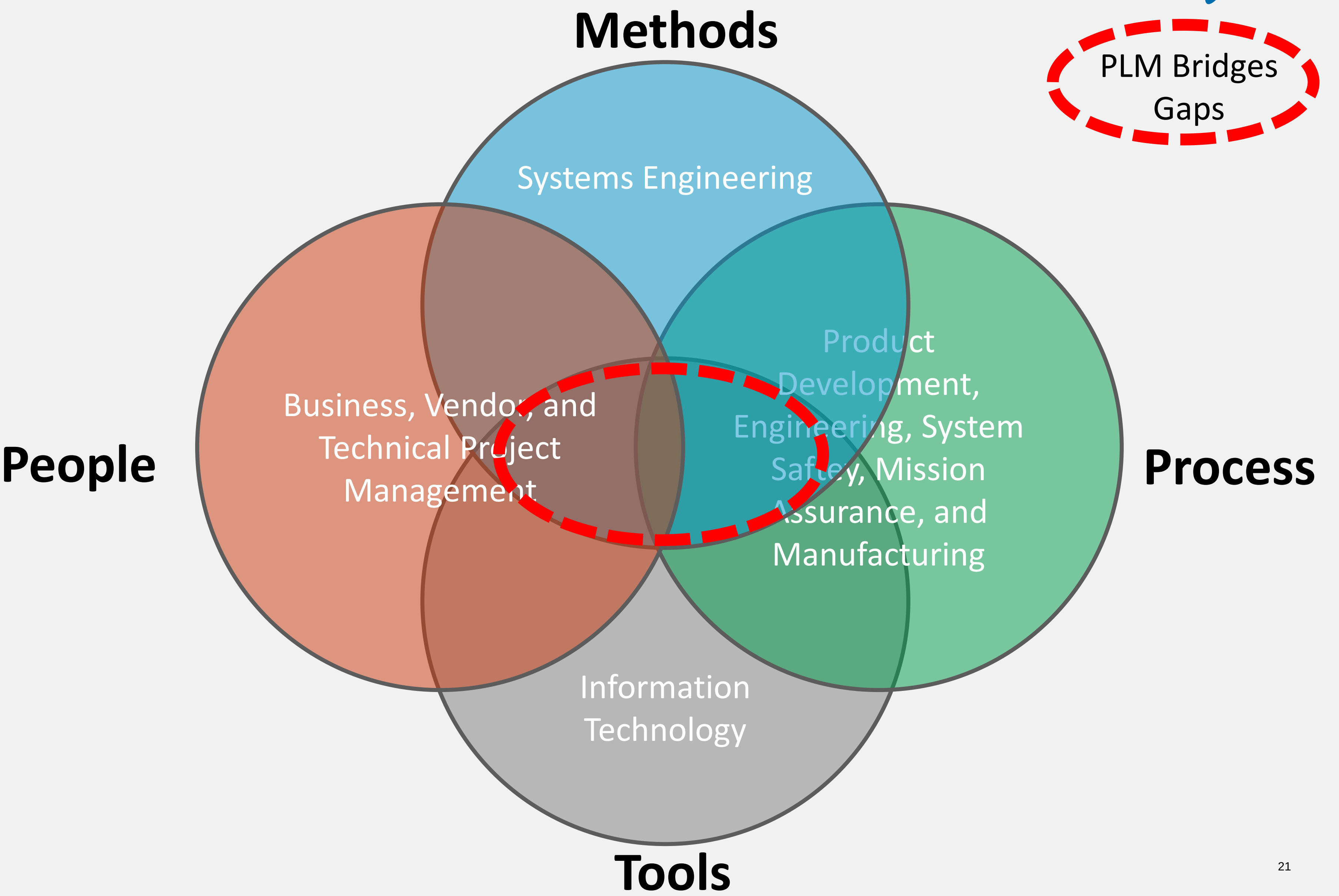
Address the System Challenges



PS PLM IPT (Integrated Product Team)

Orbital ATK

KEY:
Function
IPT SME
Management Sponser

EBOM
Mary Lavery
Angie Harbert

MBOM
Steven Busby
Richard Hawkes

Analysis
Brett Verhoef
Vicki Call

Mfg Planning
Chuck Goodin
Kathy Philpot

Design Engineering
Nathan Holyoak
Fred Perkins

Quality Control
Kaylene Sullivan
Sarah Hiza

Project Engineering
Scott Eaker
Luke Whipple
Tony Kelley / Dave Starrett

Safety & Mission Assurance
Peter Reed
Dan Pulleyn / Janica Cheney

ERP System Owner – Steven Busby / Jim Beck
PLM System Owner – Paul Nelson / Jon Jarrett / Kent Liechty
MES System Owner – Chuck Goodin / Kathy Philpot
Quality System Owner – Kaylene Sullivan / Sarah Hiza

Configuration Management – Angie Harbert / Jon Jarrett
Material and Processing – Larry Robison / Michael Killpack*
Information Technology – Matt McNeal / Taryn Salmon

Test
Ben Bodrero
?

Master Schedule
Matt Jeppsen
Richard Hawkes

Future Functions to Add:
Test, Facilities, Maintenance, Disposal, Environmental Services, EICO/Security, ATK University, PES, Research and Development Labs, As Built, As Maintained, etc.

As Built
Tommy Stokes or replacement?

Systems Engineering
Michael Lamoreaux
Ben Goldberg*

Program Management
Invite to Jeff Vosburgh
Charlie Precourt

As Maintained
?
?

Business Development
Brian Allen*
Erik Gross

* Technical Fellow

Cross Reference Functional Interactions

- PS PLM IPT is working to identify major interaction points / major handoffs
- Help ensure process improvement investments address largest disconnects

	Sched	$$	Scope	CAE	Req	Verif	Comply	EBOM	CAD	MBOM	Proc	QC	S&MA	MDS	CM
Sched		1													
$$	2		15												
Scope	3	16				17									
CAE	4		18		20 (2, 15)		21 (2, 15)							60 (1, 2, 15)	67 (2, 15)
Req	5			22 (2, 15)	25 (8, 11)	26 (8, 11), 27 (8, 11)		28 (9)	29 (9)	30 (11)	31				68
Verif	6, 7		19	23 (2, 15)	32 (8, 11)	35 (8, 11), 36 (8, 11)	37 (8, 11)								69
Comply	8					38 (8, 11)							41		70
EBOM	9				33 (9)	39 (9)		43, 44	45	46	47			61 (1)	71
CAD	10			24 (2, 15)					48	49		50 (3)			72
MBOM	11									51	52	53 (3)		63 (1)	73
Proc	12									54	55, 77 (6)	56 (3)			74
QC	13						42 (11)							65	75
S&MA	14				34	40					57				76
MDS	58 (1)			59 (1, 2, 15)					62 (1)	64 (1)					
CM	66														

Only add/modify data in the colored fields in the matrix, the interaction description list, and the list of discussion items.

Initiatives	From	To	ID	Interaction Desc
	Sched	$$	1	Schedule affects budget - activities being drawn out longer can result in additional costs
	$$CAEMDS	SchedCAEM	2	Funding profile should be an input into the schedule. May need to move high value activities fwd/back depending on funding
	Scope	Sched	3	Activities in scope should be inputs into the schedule
	CAE	Sched	4	Analysis activities need to be scheduled
	Req	Sched	5	Generation of specifications needs to be scheduled
	Verif	Sched	6	Generation of verification plans needs to be scheduled
	Verif	Sched	7	Verification activities need to be scheduled
	Comply	Sched	8	Generation of compliance reports needs to be scheduled
	EBOM	Sched	9	Generation of EBOM needs to be scheduled
	CAD	Sched	10	Generation of CAD objects needs to be scheduled
	MBOM	Sched	11	Generation of MBOM objects needs to be scheduled, needs to be done in time to accommodate the fabrication process/schedule
	Proc	Sched	12	Generation of procedures needs to be scheduled
	QC	Sched	13	QC inspections need to be scheduled
	S&MA	Sched	14	S&MA activities need to be scheduled
	$$	Scope	15	Available budget can affect the work scope and indirectly what activities are used for verification

Key:	
Sched	Schedule data
$$	Budget data
Scope	Work scope data, SOW
CAE	Computer aided engineering (analysis)
Req	Requirements
Verif	Verification planning
Comply	Compliance data
EBOM	Eng BOM (Parts)
CAD	Computer aided drafting
MBOM	Manufacturing BOM
Proc	Process BOM (manufacturing)
QC	Quality control
S&MA	Savety and Mission Assurance
MDS	Material data system
CM	Configuration Management

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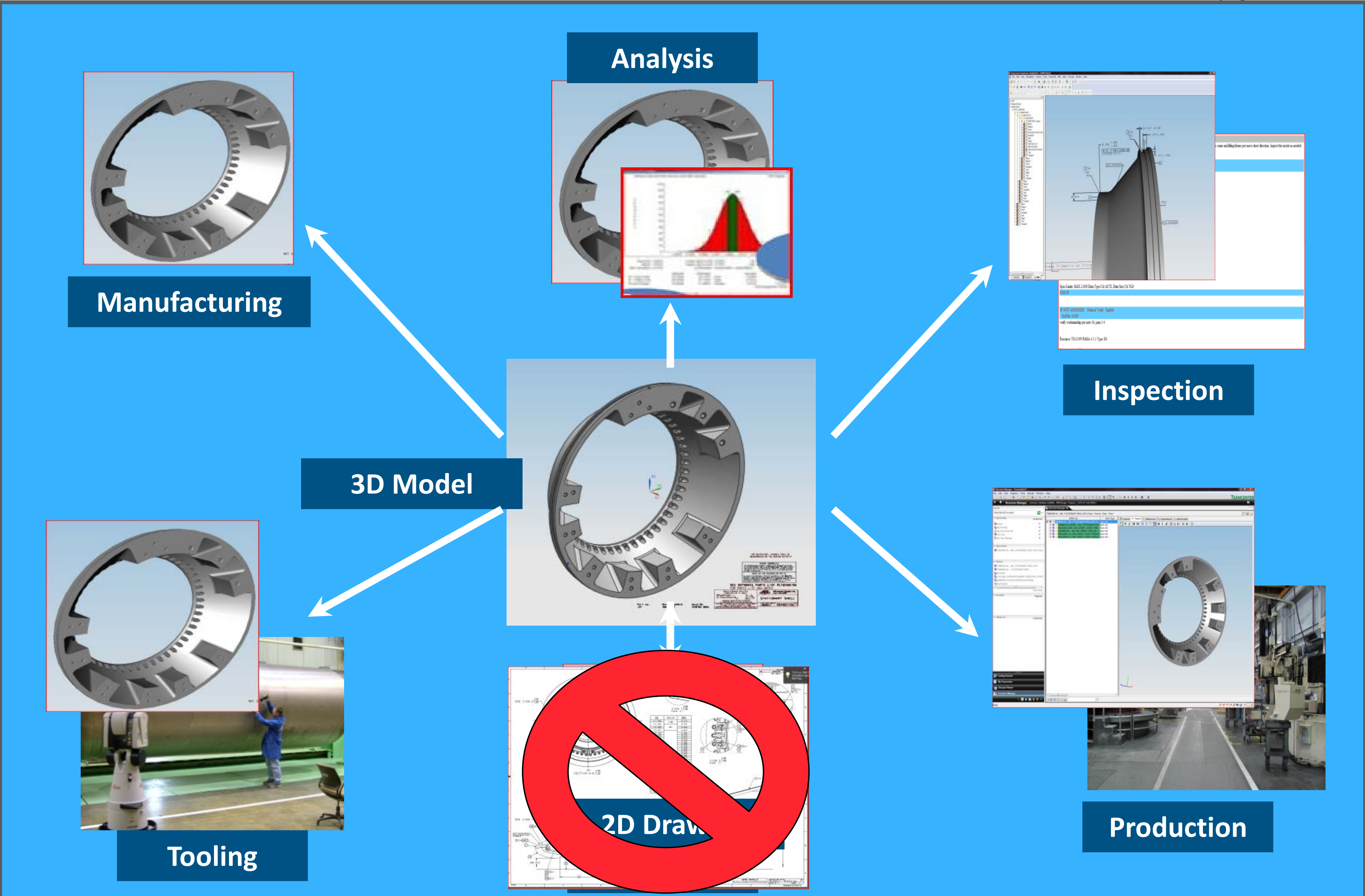
Model Based Plan



3D Modeling Return On Investment

The 100% is a benchmark line to measure from

Controlled 2D

2D Drawing Only	Aux	2D	3D
Drafting		100%	100%
Integration • Vehicle Profile Drawing • Layout Drawing • Harness Layout Drawing • IICD's	 10% 100% 300% 20%		
Manufacturing • CNC • Mfg. Instructions		0%	80%
Quality/Inspection • CMM • Inspection Plan		0%	80%
Total 790%	430%	100%	260%

Controlled 2D and 3D

2D with associated 3D	2D	3D
Drafting	100%	100%
Integration		0%
Manufacturing • CNC • Mfg. Instructions	0%	0%
Quality/Inspection • CMM • Inspection Plan	0%	0%
Total 200%	100%	100%

Controlled 3D

3D Annotated Model	2D	3D
Drafting		150%
Integration		0%
Manufacturing • CNC • Mfg. Instructions	20%	0%
Quality/Inspection • CMM • Inspection Plan	20%	0%
Total 190%	40%	150%

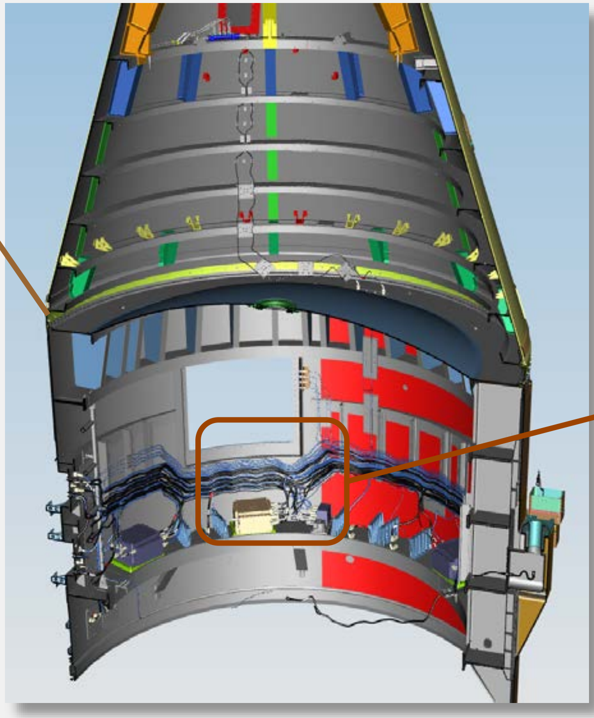
ROI Summary

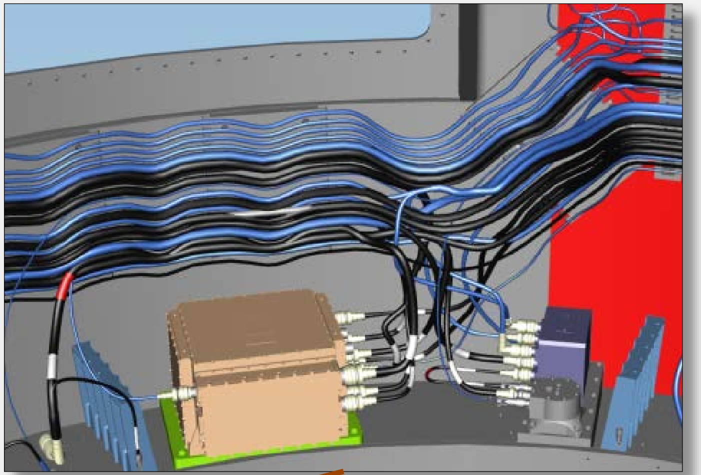
- The biggest productivity gains come with 3D models (even with 2D drawings)
- Companies have been slower to adopt 3D annotation (PMI) because it offers modest gains over associated drawings. It is however an area where gains can be realized.

3D models can yield a 600% cost savings over 2D drawings

Example: Benefits on the Ares – SLS Avionics

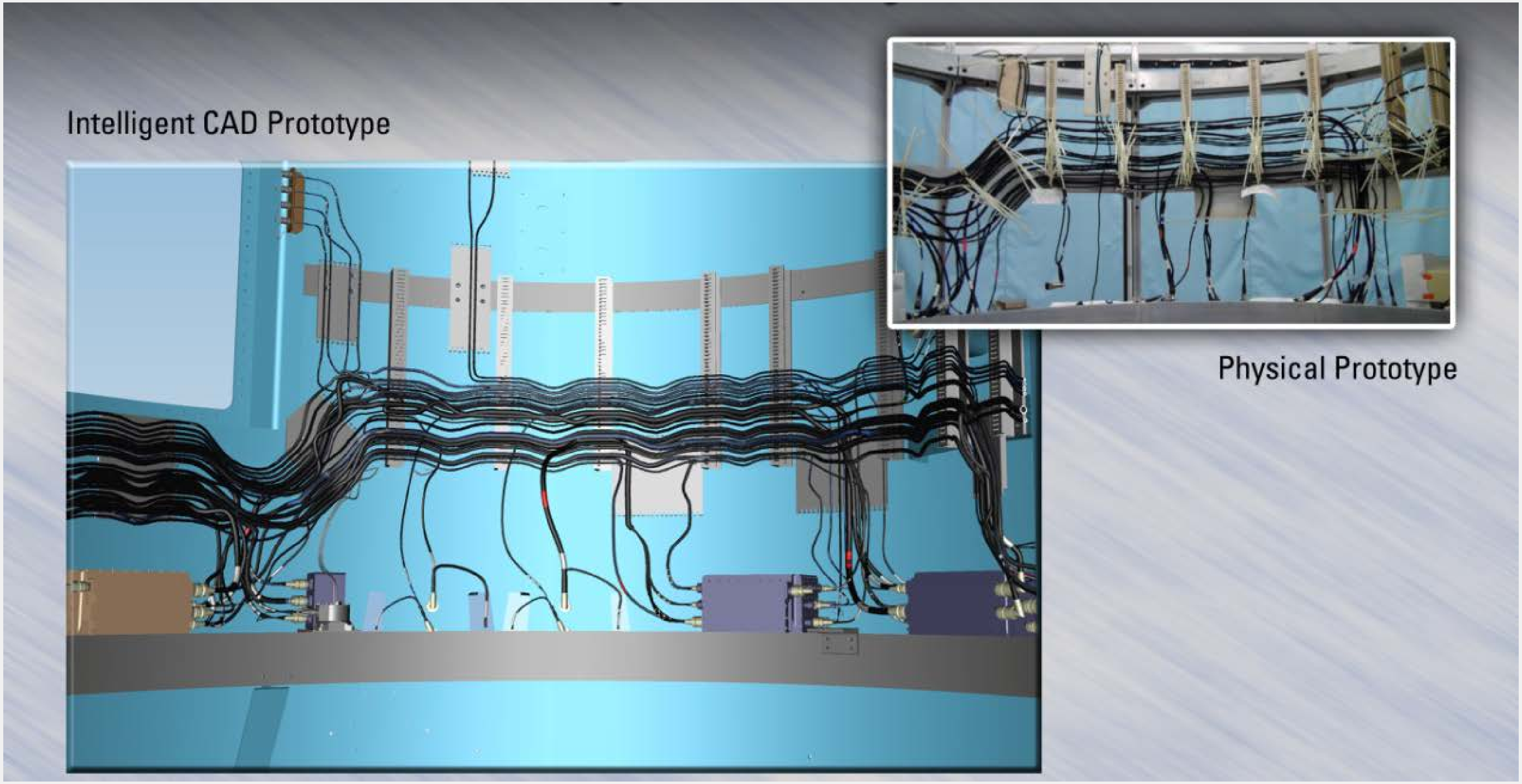
Making it work and work well with models





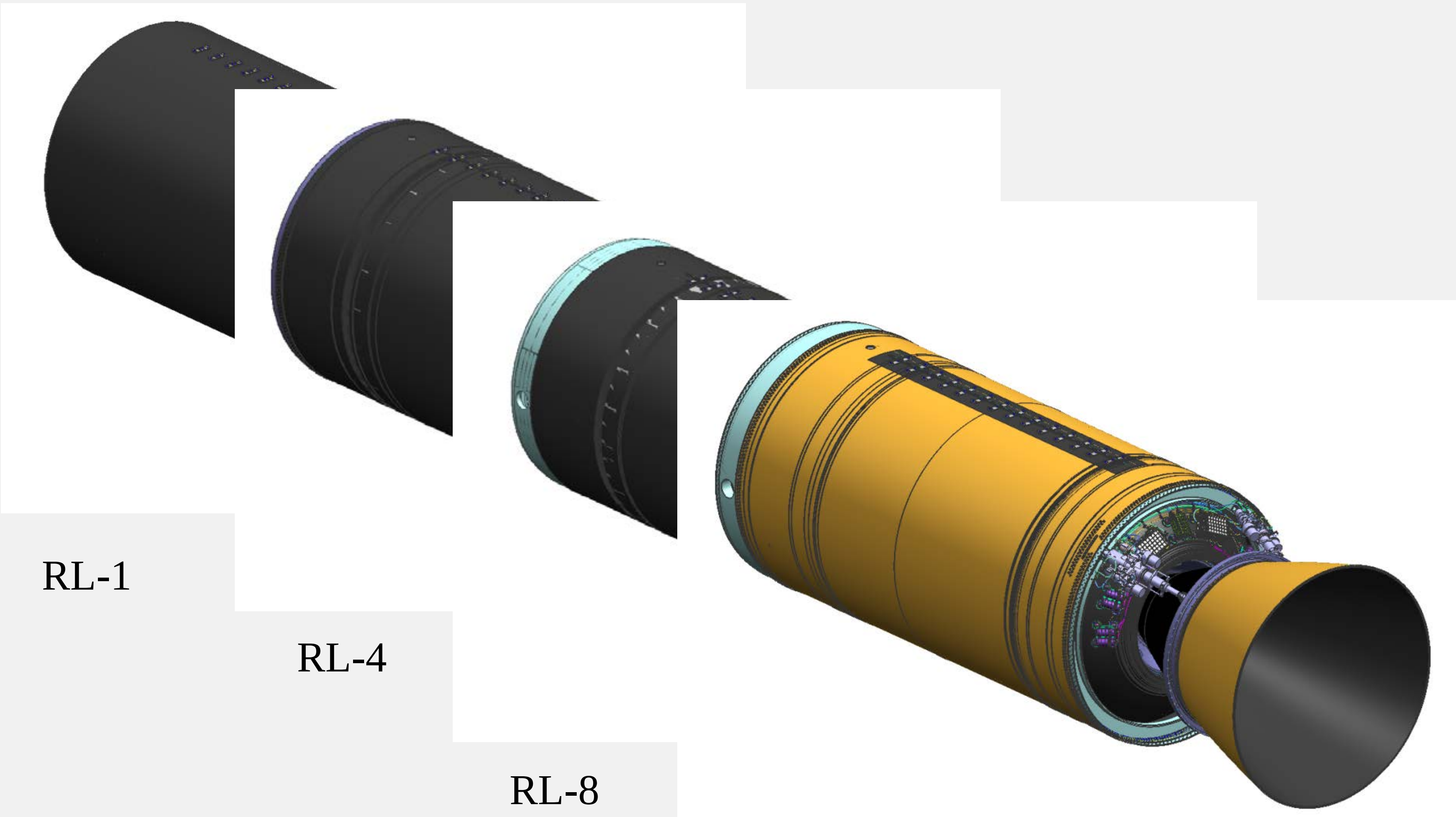
- Virtual prototype
- Electronic CAD and mechanical CAD
- All the information was stored on each model

Example: Benefits on the Ares – SLS Avionics



The prototype used to verify the routing was significantly less expensive

Rapid Learning Cycles –
Agile Scrum/Sprints for Engineering



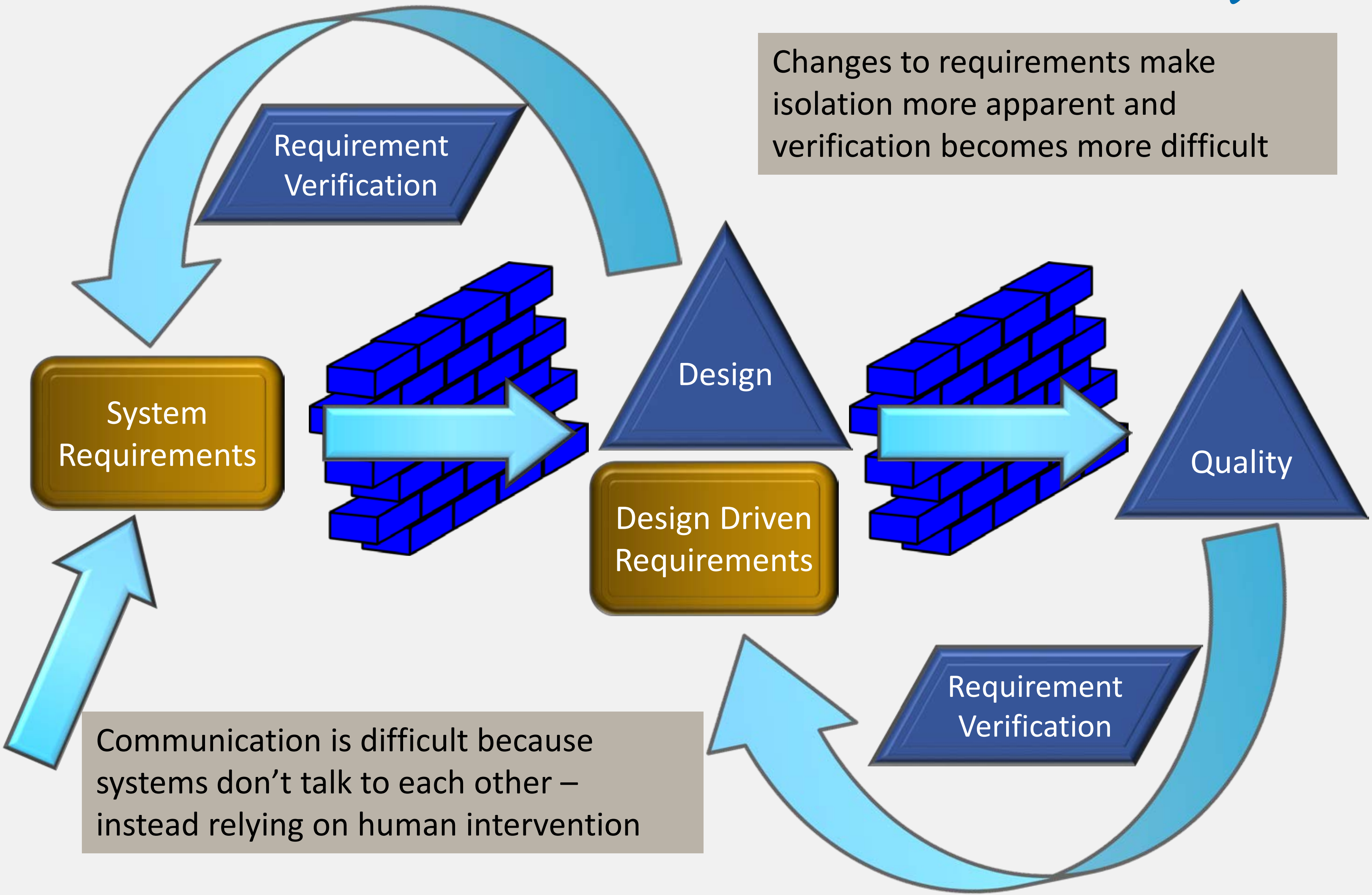
RL-1

RL-4

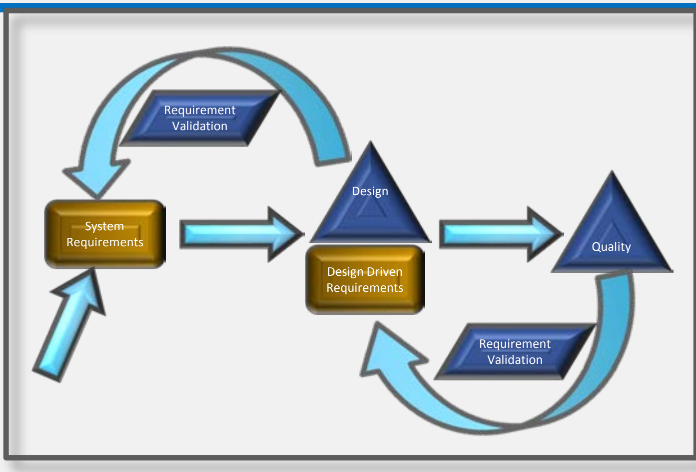
RL-8

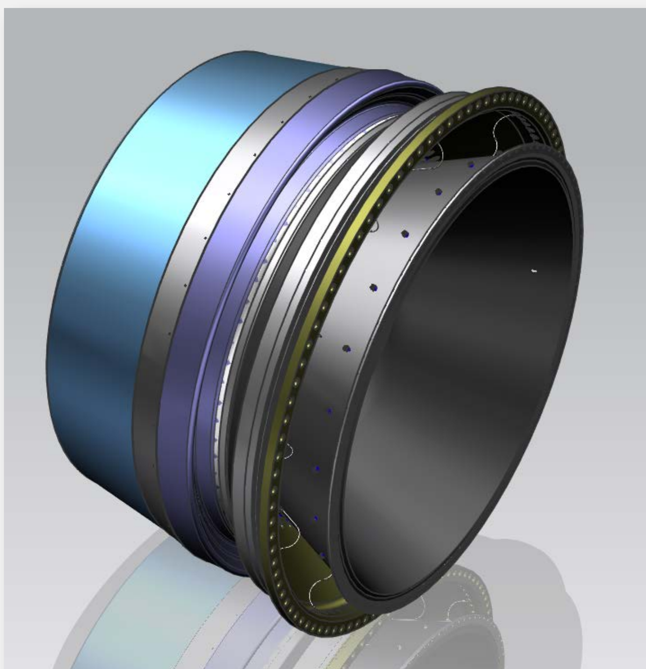
RL-17

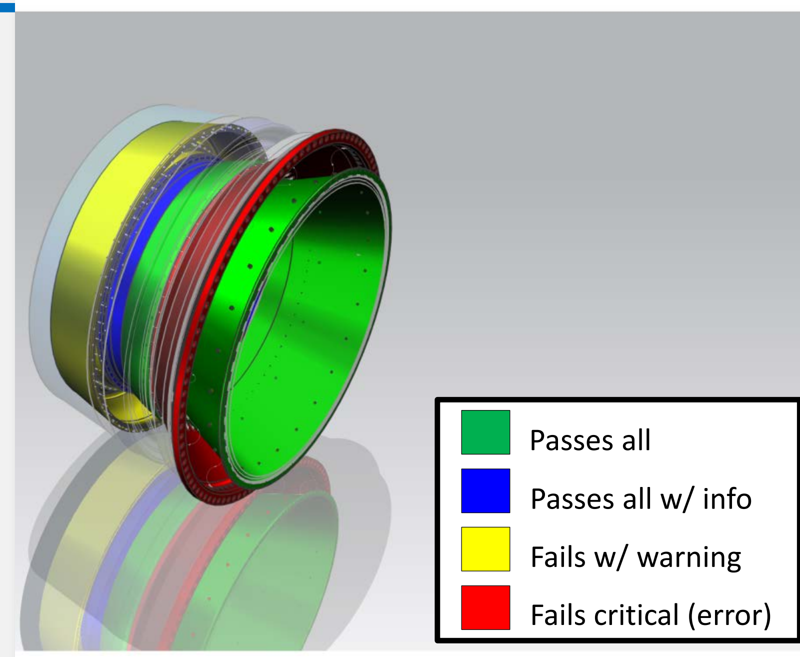
Requirement Flow Through Design and Verification

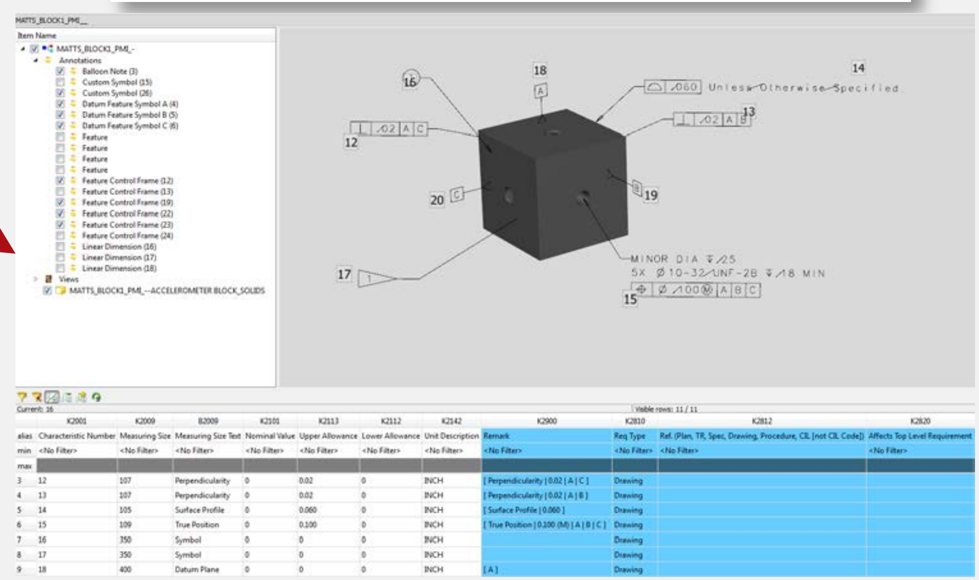


Requirement Flow Through Design









Systems Engineering and PLM are Converging

- PLM and systems engineering are the same problem from different vantage points
- PLM = tools and business strategy vantage point
- Systems engineering = process and methodology vantage point
- Marry people, process, tools, and methods and it is powerful
  - e.g. Rubik's cube/LEGO Robot
- Key Systems Engineering method is an NxN coupling matrix
  - Let's look at the interactions between systems engineering and PLM

Only most urgent interactions identified

- Vendor Capability, but not core PLM
- Production PLM Capability
- No Fill = Little to no core PLM Capability
- INCOSE Certificaiton Emphasis
- x = interaction that requires attention
- c = non-integrated capability
- i = integrated interaction

			General PLM Solution Categories: Portfolio Management	Program / Project Management	Systems Engineering	Requirements Management	Schedule Management	Product Cost	Styling / Marketing	Computer Aided Design (Multi-CAD)	Design Mangement	Materials / Mass Property Management	Packaging	Visualization	Computer Aided Engineering (CAE or S	Simulation Management	Software / Application Management	Configuration Backbone / BOM	Change Management	Process Execution (Workflows / Lifecycle	Document / Content Management	Manufacturing BOM	Computer Aided Manufacturing (CAM)	Manufacturing Simulations	BOP / Work Instructions	As Built	Service Management	Internet of Things	Supplier Integration	Quality Management	Environmental Compliance / Sustainabil	Test Management	Business Intelligence / Reporting / Metrics	ERP Integration	MES Integration
Technical Processes		Business or Mission Analysis Process	c	x	c	x		x						c	x			x			x			x		x	x		x						
	Requirements Engineering	Stakeholder Needs & Requirements Definition Process	x	x	c	i		x	x		c			i	x			c	c	x	c			x	x	x	x		x				x		
		System Requirements Definition Process		x	c	i		x	x	i	i	i	x	i			x	i	i	x	i			c	c	c	c						x		
	Architecture / Design Development	Architecture Definition Process		x	c	c		x			x	x		x	x		x	c	x		c	x		c				x			x				
		Design Definition Process		x	x	i		x		i	i	i	c	i			x	c	i	i		x	c					x	c				x		
		System Analysis Process		x	x	c					c	c		c	c	i		x	i	i								x					x		
		Implementation Process		x	x	c	x			i	i	i		i			x	i	i	i	i	x	c					x	x				x		
	System Integration	Integration Process		x	x	x				i	i			i		i	x	i	i	i									x				x		
	Qualification, Verification, and Validation	Verification Process		x	x	c					i			i	c	c	x	c	i	x												x	x		x
		Transition Process		x	x	x					i			i				c	c	x												x	x		
	Qualification, Verification, and Validation	Validation Process		x	x	c			x		c			c	c	c		c	c	x		x	c					x	x	x		x	x		x
		Operation Process		x							c	x		c			x	x	x	x		c	c		i	i	i	x		x			x	x	x
		Maintenance Process		x							c			x				x	x	x						i	i	x		x			x		
		Disposal Process		x							c	x	x	x				x	x	x							x		x				x		
Technical Management Processes	Technical Planning	Project Planning Process	x	x	x	x	i	c	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Technical Effort Assessment	Project Assessment and Control Process	x	x	x	x	c	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
		Decision Management Process		x	x	x	x	x		x	x	x	x	c	c	c	x	c	c	i	x			x				x	x	x		x	x	x	
	Risk and Opportunity Management	Risk Management Process		x	x	x	x	x	x	x	x	x	x	x	c	c	x	c	c	x	x			x				x	x	x		x	x		
	Baseline Control / Configuration Management	Configuration Management Process	x	x	x	i	i	x	x		i	i	i	i		i	x	i	i	i	i	i	c	c	i	i	i	x	x	x	x	x	c	c	x
	Tool Support	Information Management Process		x	c	i	i	x			i	i	c	i		i	x	i	i	i	i	i	c	c	i	i	i	x	x	x	x	x	c	c	x
		Measurement Process		x	x	c	x	x		i	i	x		i		x		x	x	x	x				x	x	x	x				x	i		
	Quality Assurance	Quality Assurance Process		x				x		i	i			c				x												x		x	x		x
Agreement Processes		Acquisition Process		x				x		c	c	x		c				x	x	x	x		x			x	x		c	x		x	x		
		Supply Process		x				x		c	c	x		c				x	x	x	x		x			x	x		c	x		x	x		
Organizational Project-Enabling Processes	Process Definition	Life Cycle Model Management Process	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
		Infrastructure Management Process																																	
	Risk and Opportunity Management	Portfolio Management Process	c					x																											
	Training	Human Resource Management Process			x															x															
		Quality Management Process	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
		Knowledge Management Process	x	x	x	c	x	x	x	c	c	c	x	c	c	c	x	c	c	c	x	x	x	c	x	c	c	x	x	x	x	c	c	x	x
Specialty Engineering		Affordability / Cost-Effectiveness / Lifecycle Cost Analysis	x	x	x		x	x		x	x	x		x	c	c		x				x	x												
		Electromagnetic Compatibility								c	c			x	c	c																x			
		Environmental Engineering / Impact Analysis									x	x										x									c				
		Interoperability Analysis								i	i	x			c	c		i																	
		Logistics Engineering								c	c		x																					x	
		Manufacturing and Producibility Analysis			x					c	c	x	x	c								x	x	x	x	x	x							x	x
		Mass Properties Engineering								i	i	i		i																					
		Reliability, Availability, and Maintainability		x	x						x	x										x				x	x			x					
		Resilience Engineering			x						x	x			c	c											x			x		x			
		System Safety Engineering		x	x	x					x	x			c	c									x					x		x			x
		System Security Engineering		x	x	x					x						x															x			
		Training Needs Analysis		x							x			x																x					
		Usability Analysis / Human Systems Integration		x	x				x	i	i			c															x						
		Value Engineering		x				x		c	c	x	x				x																		
Other Cross Cutting Systems Engineering Methods		Modeling and Simulation		x	c	c				i	i	c		i	i	i		c	c	c			i	c	c							x	x		
		Model-Based Systems Engineering		x	c	x				x	x						x			x												x	x		
		Functions-Based Systems Engineering Method		x	c	x				x	x																						x		
		Object-Oriented Systems Engineering Method		x	c	x				x	x																						x		
		Prototyping						x		c	c	x			c	c						x	c									x		x	x
		Interface Management			x	x				i	i						x		c	x	x			c	x							x	x	x	x
		Integrated Product and Process Development		x	x	x					i							x	c		x												x		
		Lean Systems Engineering		x	x		x	x			x								x														x		
		Agile Systems Engineering		x	x		x	x			x								x														x		

General PLM Solution Categories

Only most urgent interactions identified

- Vendor Capability, but not core PLM
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- x = interaction that requires attention
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Process Group	INCOSE Certificaiton Emphasis	Process	Portfolio Management	Program / Project Management	Systems Engineering	Requirements Management	Schedule Management	Product Cost	Styling / Marketing	Computer Aided Design (Multi-CAD)	Design Mangement	Materials / Mass Property Management	Packaging	Visualization	Computer Aided Engineering (CAE or S	Simulation Management	Software / Application Management	Configuration Backbone / BOM	Change Management	Process Execution (Workflows / Lifecycle	Document / Content Management	Manufacturing BOM	Computer Aided Manufacturing (CAM)	Manufacturing Simulations	BOP / Work Instructions	As Built	Service Management	Internet of Things	Supplier Integration	Quality Management	Environmental Compliance / Sustainabil	Test Management	Business Intelligece / Reporting / Metrics	ERP Integration	MES Integration
Technical Processes		Business or Mission Analysis Process	c	x	c	x		x						c	x			x			x			x		x	x		x						
	Requirements Engineering	Stakeholder Needs & Requirements Definition Process	x	x	c	i		x	x		c			i	x			c	c	x	c			x	x	x	x		x				x		
		System Requirements Definition Process		x	c	i		x	x	i	i	i	x	i			x	i	i	x	i			c	c	c	c						x		
	Architecture / Design Development	Architecture Definition Process		x	c	c		x			x	x		x	x		x	c	x		c	x		c				x			x				
		Design Definition Process		x	x	i		x		i	i	i	c	i			x	c	i	i		x	c					x	c				x		
		System Analysis Process		x	x	c					c	c		c	c	i		x	i	i								x					x		
		Implementation Process		x	x	c	x			i	i	i		i			x	i	i	i	i	x	c					x	x				x		
	System Integration	Integration Process		x	x	x				i	i			i		i	x	i	i	i									x				x		
	Qualification, Verification, and Validation	Verification Process		x	x	c					i			i	c	c	x	c	i	x												x	x		x
		Transition Process		x	x	x					i			i				c	c	x												x	x		
	Qualification, Verification, and Validation	Validation Process		x	x	c			x		c			c	c	c		c	c	x		x	c					x	x	x		x	x		x
		Operation Process		x							c	x		c			x	x	x	x		c	c		i	i	i	x		x			x	x	x
		Maintenance Process		x							c			x				x	x	x						i	i	x		x			x		
		Disposal Process		x							c	x	x	x				x	x	x							x		x				x		
Technical Management Processes	Technical Planning	Project Planning Process	x	x	x	x	i	c	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Technical Effort Assessment	Project Assessment and Control Process	x	x	x	x	c	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
		Decision Management Process		x	x	x	x	x		x	x	x	x	c	c	c	x	c	c	i	x			x				x	x	x		x	x	x	
	Risk and Opportunity Management	Risk Management Process		x	x	x	x	x	x	x	x	x	x	x	c	c	x	c	c	x	x			x				x	x	x		x	x		
	Baseline Control / Configuration Management	Configuration Management Process	x	x	x	i	i	x	x		i	i	i	i		i	x	i	i	i	i	i	c	c	i	i	i	x	x	x	x	x	c	c	x
	Tool Support	Information Management Process		x	c	i	i	x			i	i	c	i		i	x	i	i	i	i	i	c	c	i	i	i	x	x	x	x	x	c	c	x
		Measurement Process		x	x	c	x	x		i	i	x		i		x		x	x	x	x				x	x	x	x				x	i		
	Quality Assurance	Quality Assurance Process		x				x		i	i			c				x												x		x	x		x
Agreement Processes		Acquisition Process		x				x		c	c	x		c				x	x	x	x		x			x	x		c	x		x	x		
		Supply Process		x				x		c	c	x		c				x	x	x	x		x			x	x		c	x		x	x		
Organizational Project-Enabling Processes	Process Definition	Life Cycle Model Management Process	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
		Infrastructure Management Process																																	
	Risk and Opportunity Management	Portfolio Management Process	c					x																											
	Training	Human Resource Management Process			x															x															
		Quality Management Process	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
		Knowledge Management Process	x	x	x	c	x	x	x	c	c	c	x	c	c	c	x	c	c	c	x	x	x	c	x	c	c	x	x	x	x	c	c	x	x
Specialty Engineering		Affordability / Cost-Effectiveness / Lifecycle Cost Analysis	x	x	x		x	x		x	x	x		x	c	c		x				x	x												
		Electromagnetic Compatibility								c	c			x	c	c																x			
		Environmental Engineering / Impact Analysis									x	x										x									c				
		Interoperability Analysis								i	i	x			c	c		i																	
		Logistics Engineering								c	c		x																					x	
		Manufacturing and Producibility Analysis			x					c	c	x	x	c								x	x	x	x	x	x							x	x
		Mass Properties Engineering								i	i	i		i																					
		Reliability, Availability, and Maintainability		x	x						x	x										x				x	x			x					
		Resilience Engineering			x						x	x			c	c											x			x		x			
		System Safety Engineering		x	x	x					x	x			c	c								x						x		x			x
		System Security Engineering		x	x	x					x						x															x			
		Training Needs Analysis		x							x			x																x					
		Usability Analysis / Human Systems Integration		x	x				x	i	i			c															x						
		Value Engineering		x				x		c	c	x	x				x																		
Other Cross Cutting Systems Engineering Methods		Modeling and Simulation		x	c	c				i	i	c		i	i	i		c	c	c			i	c	c							x	x		
		Model-Based Systems Engineering		x	c	x				x	x						x			x												x	x		
		Functions-Based Systems Engineering Method		x	c	x				x	x																						x		
		Object-Oriented Systems Engineering Method		x	c	x				x	x																						x		
		Prototyping						x		c	c	x			c	c						x	c									x		x	x
		Interface Management			x	x				i	i						x		c	x	x			c	x							x	x	x	x
		Integrated Product and Process Development		x	x	x					i							x	c		x												x		
		Lean Systems Engineering		x	x		x	x			x								x														x		
		Agile Systems Engineering		x	x		x	x			x								x														x		

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Technical Processes		Business or Mission Analysis Process	c	x	c	x		x						c	x			x			x			x		x	x		x						
	Requirements Engineering	Stakeholder Needs & Requirements Definition Process	x	x	c	i		x	x		c			i	x			c	c	x	c			x	x	x	x		x				x		
		System Requirements Definition Process		x	c	i		x	x	i	i	i	x	i			x	i	i	x	i			c	c	c	c						x		
	Architecture / Design Development	Architecture Definition Process		x	c	c		x			x	x		x	x		x	c	x		c	x		c				x			x				
		Design Definition Process		x	x	i		x		i	i	i	c	i			x	c	i	i		x	c					x	c				x		
		System Analysis Process		x	x	c					c	c		c	c	i		x	i	i								x					x		
		Implementation Process		x	x	c	x			i	i	i		i			x	i	i	i	i	x	c					x	x				x		
	System Integration	Integration Process		x	x	x				i	i			i		i	x	i	i	i									x				x		
	Qualification, Verification, and Validation	Verification Process		x	x	c					i			i	c	c	x	c	i	x												x	x		x
		Transition Process		x	x	x					i			i				c	c	x												x	x		
	Qualification, Verification, and Validation	Validation Process		x	x	c			x		c			c	c	c		c	c	x		x	c					x	x	x		x	x		x
		Operation Process		x							c	x		c			x	x	x	x		c	c		i	i	i	x		x			x	x	x
		Maintenance Process		x							c			x				x	x	x						i	i	x		x			x		
		Disposal Process		x							c	x	x	x				x	x	x							x		x				x		
Technical Management Processes	Technical Planning	Project Planning Process	x	x	x	x	i	c	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Technical Effort Assessment	Project Assessment and Control Process	x	x	x	x	c	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
		…ent Process		x	x	x	x	x		x	x	x	x	c	c	c	x	c	c	i	x			x				x	x	x		x	x	x	
		…rocess		x	x	x	x	x	x	x	x	x	x	x	c	c	x	c	c	x	x			x				x	x	x		x	x		
	Ba…	…agement Process	x	x	x	i	i	x	x		i	i	i	i		i	x	i	i	i	i	i	c	c	i	i	i	x	x	x	x	x	c	c	x
		…ent Process		x	c	i	i	x			i	i	c	i		i	x	i	i	i	i	i	c	c	i	i	i	x	x	x	x	x	c	c	x
		…ess		x	x	c	x	x		i	i	x		i		x		x	x	x	x			x	x	x	x					x	i		
	Quality Assurance	Quality Assurance Process		x				x		i	i			c				x												x		x	x		x
Agreement Processes		Acquisition Process		x				x		c	c	x		c				x	x	x	x		x			x	x		c	x		x	x		
		Supply Process		x				x		c	c	x		c				x	x	x	x		x			x	x		c	x		x	x		
Organizational Project-	Process Definition	Life Cycle Model Management Process	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
		Infrastructure Management Process																																	
	Risk and Opportunity Management	Portfolio Management Process	c					x																											
		…anagement Process			x															x															
		…nt Process	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
		…ement Process	x	x	x	c	x	x	x	c	c	c	x	c	c	c	x	c	c	c	x	x	x	c	x	c	c	x	x	x	x	c	c	x	x
		…Effectiveness / Lifecycle Cost Analysis	x	x	x		x	x		x	x	x		x	c	c		x				x	x												
		…mpatibility								c	c			x	c	c																x			
		…neering / Impact Analysis									x	x										x									c				
		…lysis								i	i	x			c	c		i																	
		Logistics Engineering								c	c		x																					x	
	Specialty…	Manufacturing and Producibility Analysis			x					c	c	x	x	c								x	x	x	x	x	x							x	x
		Mass Properties Engineering								i	i	i		i																					
		…ty, and Maintainability		x	x						x	x										x				x	x			x					
		…ri…			x						x	x			c	c											x			x		x			
		…neering		x	x	x					x	x			c	c								x						x		x			x
		System Security Engineering		x	x	x					x						x															x			
		Training Needs Analysis		x							x			x																x					
		Usability Analysis / Human Systems Integration		x	x				x	i	i			c															x						
		Value Engineering		x				x		c	c	x	x				x																		
		Modeling and Simulation		x	c	c				i	i	c		i	i	i		c	c	c			i	c	c							x	x		
		Model-Based Systems Engineering		x	c	x				x	x						x			x												x	x		
		…ems Engineering Method		x	c	x				x	x																						x		
		…ms Engineering Method		x	c	x				x	x																						x		
								x		c	c	x			c	c						x	c									x		x	x
		Interface Management			x	x				i	i						x		c	x	x			c	x							x	x	x	x
	Methods	Integrated Product and Process Development		x	x	x					i							x	c		x												x		
		Lean Systems Engineering		x	x		x	x			x								x														x		
		Agile Systems Engineering		x	x		x	x			x								x														x		

Nate Hartman (computer graphics) – MBD and minimum information model

Tom Brush (Business) – supply chain and PLM integration

Michael Witt (Library Science) – LOTAR
Mihaela Vorvoreanu (computer graphics) – UI/UX and PLM Implementation

Elisa Bertino (CS) – Cyber Security and PLM

Dan Delaurentis (Aero Eng.) – MBSE and PLM

Outline

- Personal Introduction
- Company Overview
- Taxonomy Level Set (syseng, model based, PLM, etc.)
- Systems Engineering Trends
- PLM Trends
- Systems Engineering and PLM are converging
- **Conclusions and Recommended Actions**

Conclusions

- Q: Is there an emerging relationship between PLM and Systems Engineering?
- A: Yes, my company role as a PLM Systems Engineer is proof of that; the NxN matrix just reviewed also articulates this relationship
- However, we have only just started to scratch the surface and there is a great deal of work ahead; we need to get all interactions green
- Orbital ATK defines Systems Engineering as the interdisciplinary incorporation of the following integrated elements:
  - Requirements – definition, allocation, flow down, traceability
  - Qualification / Verification / Validation
  - System Design / System Integration
  - Configuration Management
  - Risk Management
  - Technical Planning and Scheduling
  - Technical Reviews
  - Process Definition

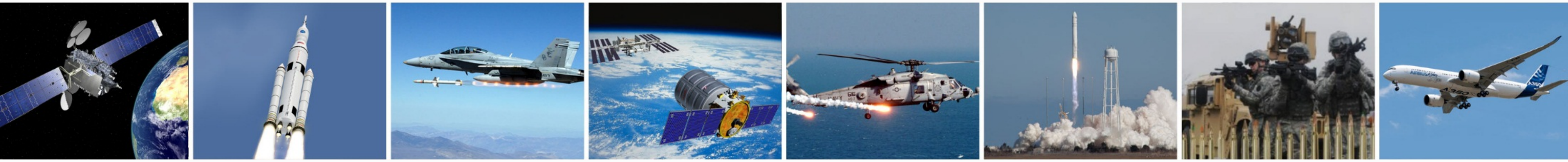
Recommendations for Research

- Don't loose focus on delivering the holistic system
  - ➢ While taking on new scope and tackling systems engineering and PLM interactions it is important to not degrade in areas that are strong today
  - ➢ Continue to optimize subsystems, but spend more time on how they impact the whole
  - ➢ Don't just think technical, but cost and schedule too
  - ➢ Focus on interactions – herein lies the major risk and payback opportunity
  - ➢ It is time to take the system level problem out of the "too hard pile"
- Provide students challenging projects and research that address system needs
- Research and methods to help mitigate key Systems of Systems (SoS) risks for PLM/Systems Engineering:
  - ➢ System elements operate independently
  - ➢ System elements have different life cycles
  - ➢ The initial requirements are likely to be ambiguous
  - ➢ Complexity is a major issue
  - ➢ Management can overshadow engineering
  - ➢ Fuzzy boundaries cause confusion
  - ➢ SoS engineering is never finished

Questions and Discussion

Paul Nelson
PLM Systems Engineer

15 October 2015
Purdue University PLM COE Fall Meeting



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