Framework for Developing Model-Based Buy Packages

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Doug is a Systems Engineer at Boeing that is supporting Model-Based Systems Engineering and systems architecture initiatives for the company's Digital Engineering transformation. While working as a Systems Engineer, he has supported the 2nd Century Enterprise Systems organization and the Presidential Aircraft Recapitalization program.

Doug also has experience as a Qualifications Engineer working to improve Quality and Manufacturability of supplied Composite parts. He has supported internal efforts to implement manufacturing inspection and verification methods on the 777X Composite Wing and other commercial programs.

Framework for Developing Model-Based Buy Packages

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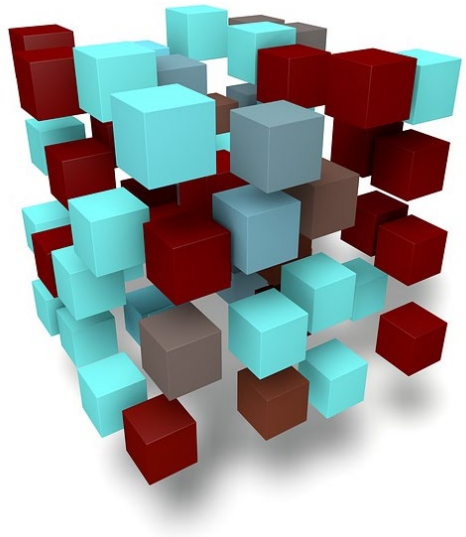
Neil is a Subject Matter Expert at Boeing in Business Capabilities development and a specialist in the Supplied Parts business lifecycle. He is responsible for long term Boeing Business Process & Tool Strategies in these areas, where he influences new and emerging Boeing technologies evolving Supplied Parts Business lifecycle.

Neil represents Boeing at Industry forums to configure Standards, drive strategies and support Boeing initiatives to evolve the engineering products and the digital thread enabling the interoperability across company organizations.

Developing Model-Based Buy Packages

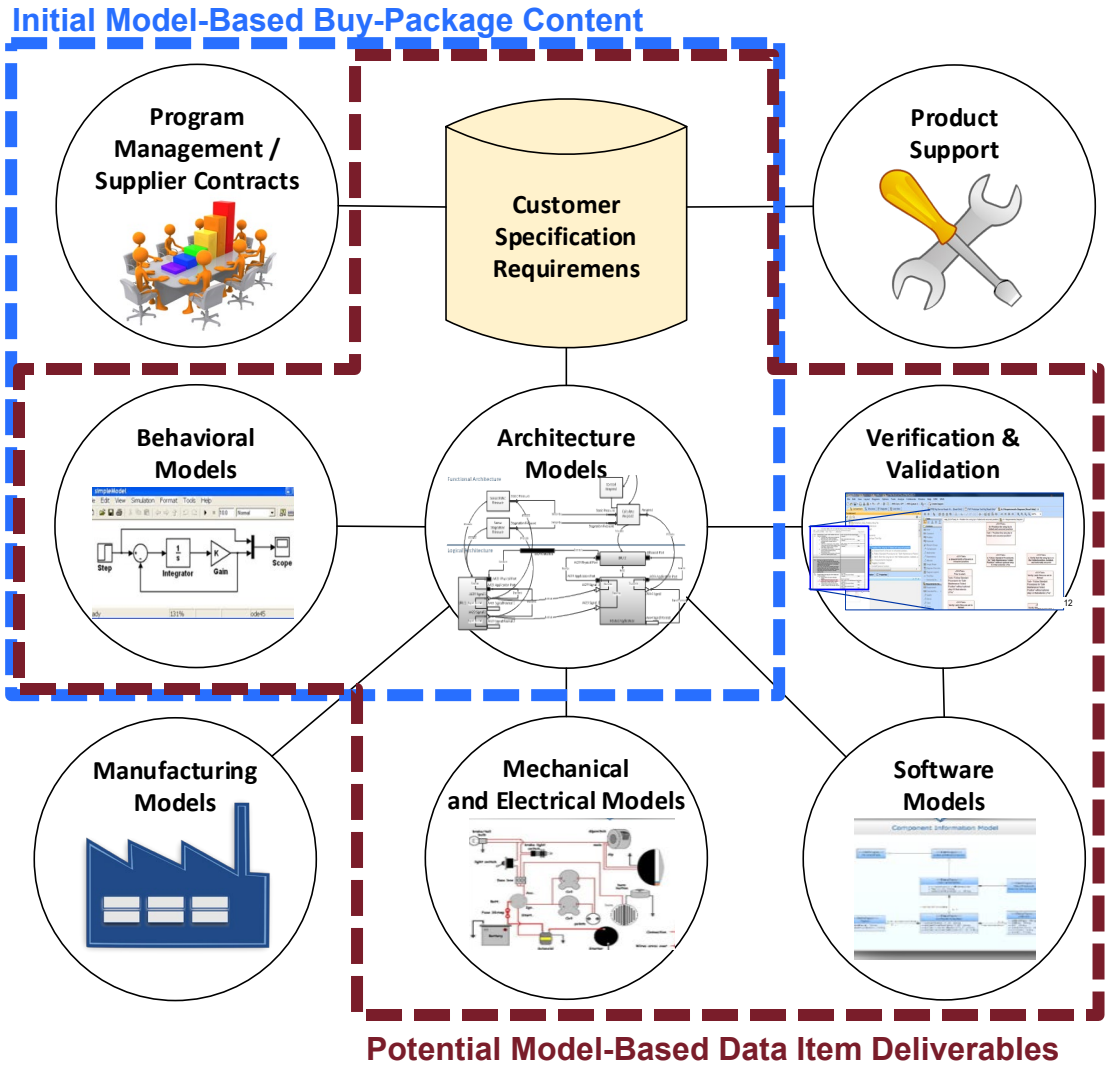
- **Opportunity**
- **Process Overview**
- **Framework:**
  - **Establish Model Exchange Practices**
  - **Determine Model-Based Content**
  - **Deploy Tools Supporting Collaboration**
  - **Create Technical Data Package**
  - **Model Co-Development/Collaboration**
- **Conclusion**

Opportunity

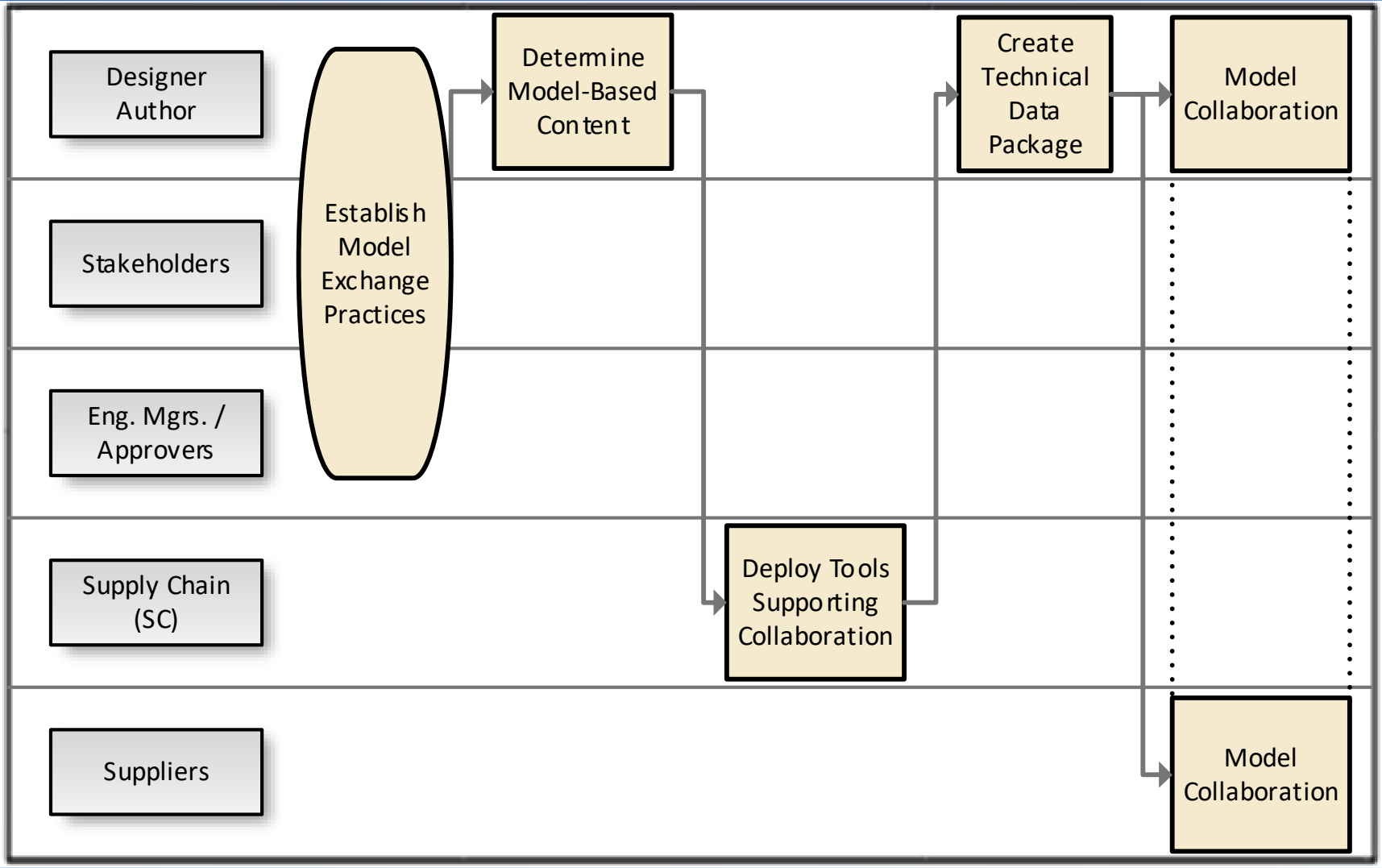


- **Improve collaboration and integration**
- **Consistent and repeatable framework**
- **Model-based Buy Packages *Not Documents*:**
  - **Improve understanding of intent and clarify requirements**
  - **Improve design outcomes**
  - **Reduce document dependencies**
  - **Interconnectivity/traceability between elements enabling the digital thread**
  - **More iterative development and review process**

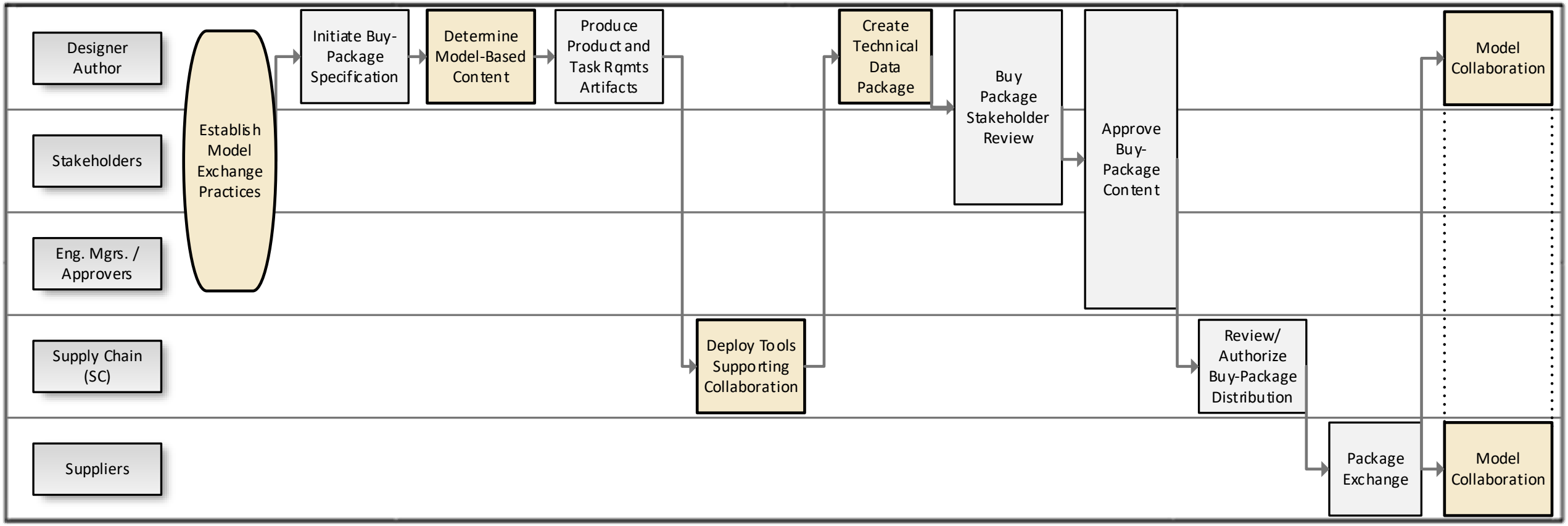
Model-Based Specifications Foster Collaboration



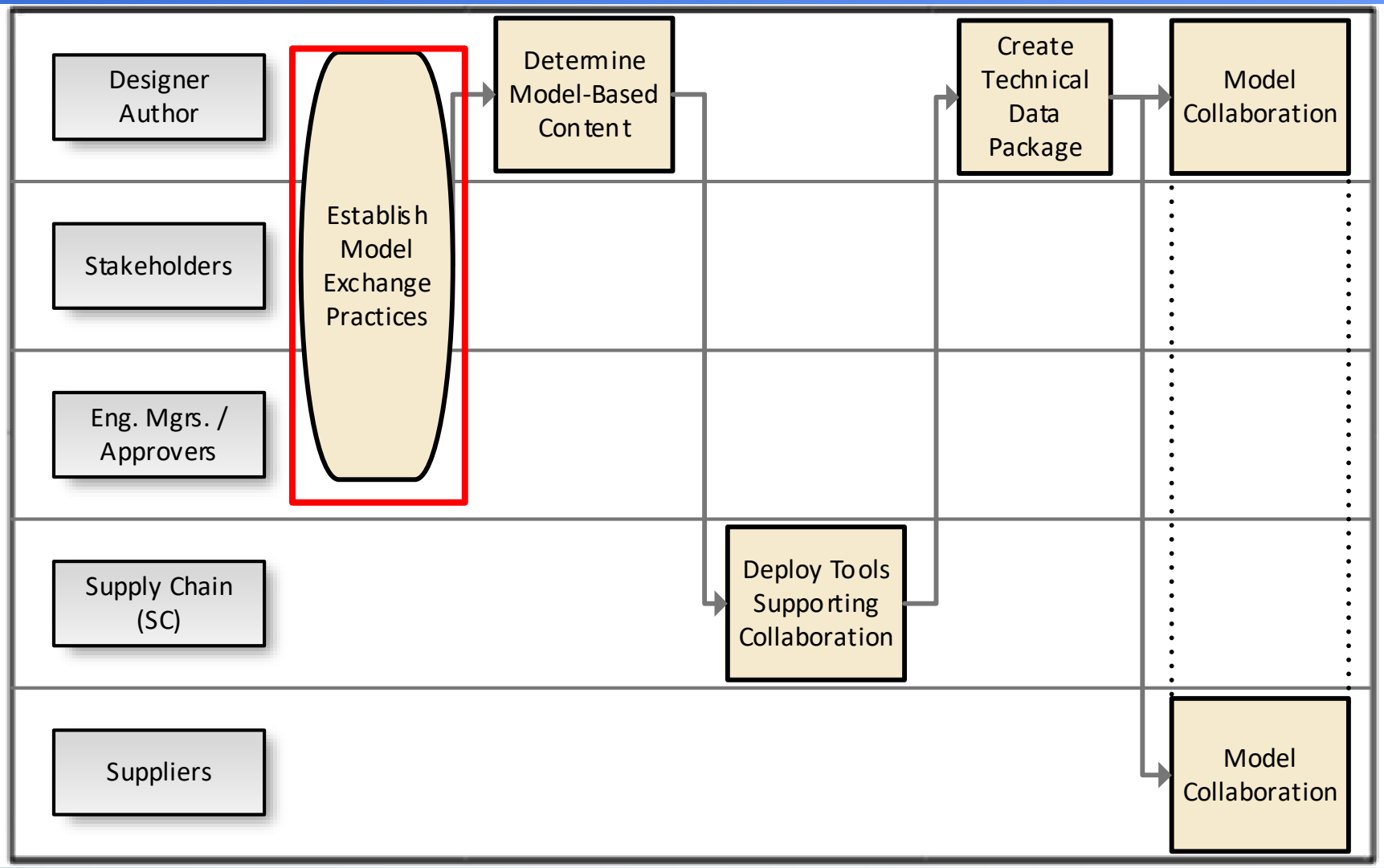
Framework


Designer Author
Stakeholders
Eng. Mgrs. / Approvers
Supply Chain (SC)
Suppliers
Establish Model Exchange Practices
Determine Model-Based Content
Deploy Tools Supporting Collaboration
Create Technical Data Package
Model Collaboration
Model Collaboration

Framework Overlaid with Typical Buy-Package Process



Establish Model Exchange Practices

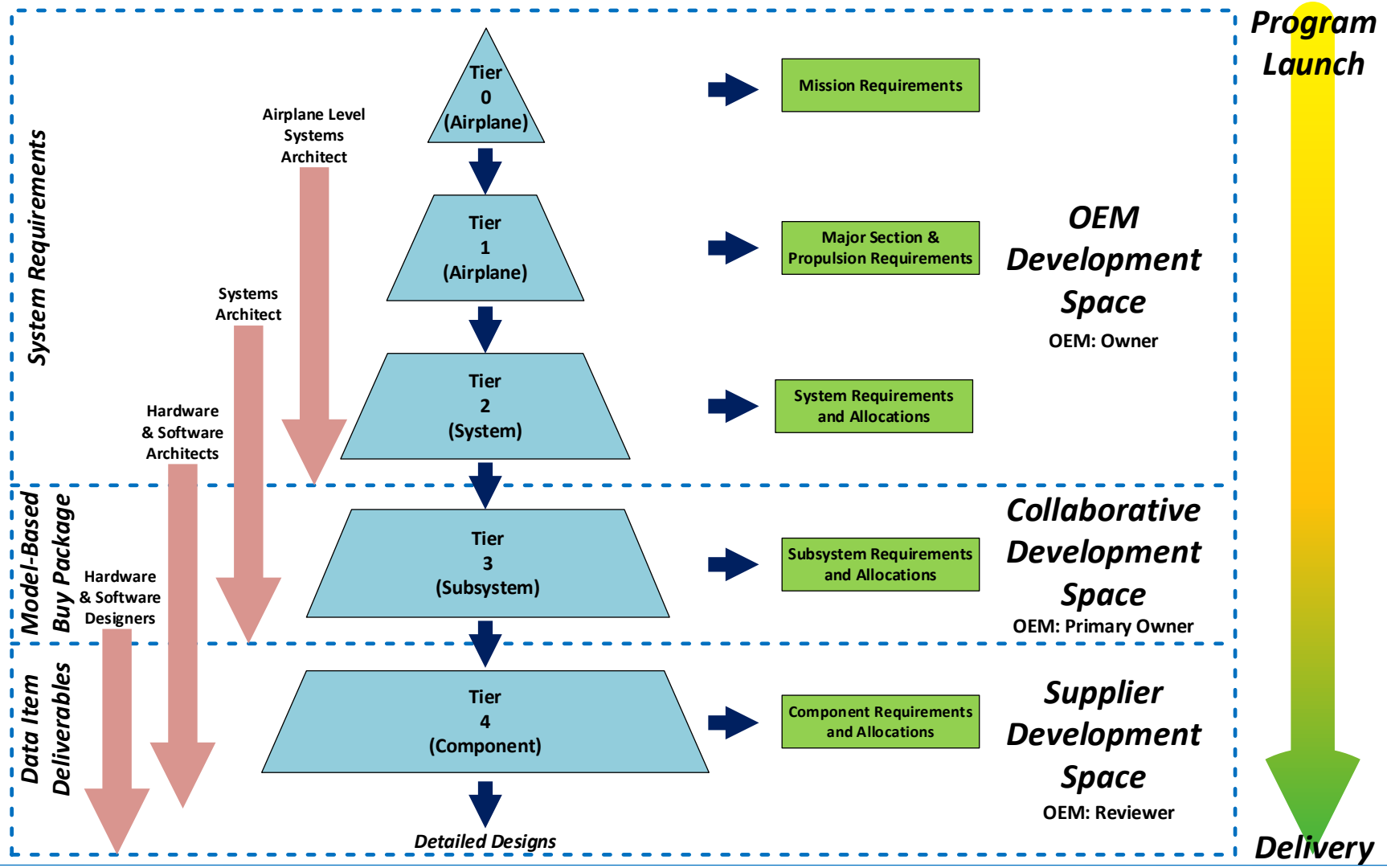


Review/Establish Program Model Management Plan

- **The Program's model management plan governs how the models will be curated within the digital ecosystem**
- **Typically addresses:**
  - **Initial verification and validation of the models**
  - **Governing the inputs to the models**
  - **Model types and relationships between the models**
  - **Model end of life and renewal planning / re-use**
  - **Defining the model owner(s)**
  - **Model configuration management**
  - **Model exchange and re-integration processes**
  - **Process for model changes over the lifecycle**
  - **Communicating model results**
  - **Intellectual Property Controls**

Key Factors to Support Effective Model Exchange and Review

Define the Model Owners and Collaboration Space



Example of a Collaboration Concept

Strive for Increased Interoperability

Increased Collaboration

Type of Exchange	Description	Examples
Full Collaboration	Multiple parties use a common configuration management system	Access to single hosted corporate network Cloud environment
Model Interoperability	Multiple parties augment the same digital model	Supplier/Buyer software synchronization Data Standards
Digital Data Exchange	Using data translation tools for consumption	**Supplier Requirements Exchange (SRX) System** Cameo Inter-op
Data Hand-Off	Standard practice for documents	Email

Improved Digital Thread

Selection of Exchange Environment

- **Exchange process could vary by model type (SysML, FMI, 3D MBD, etc)**

Exchange Environment	Support for Diverse Software	Single Source of Truth	Configuration Management	Native Query Capability	Review / Commenting	Security
Cloud Development	✓	✓	✓	✓	✓	?
Access to Corporate Network	X	✓	✓	✓	✓	?
Interoperable Model Exchange	✓	X	✓ (package mgmt)	X	✓	?
Translated Model Exchange	✓	X	✓ (package mgmt)	X	✓ (if supported)	?
Published Views of Model	X	X	X	X	✓	?

Notional

Link and Integrate Data

Internal to the models

- **Unique identification numbers**
- **Traceability between models, requirements**
- **Traceability between parent-child objects**
- **Links + IDs will automate the creation of indices**

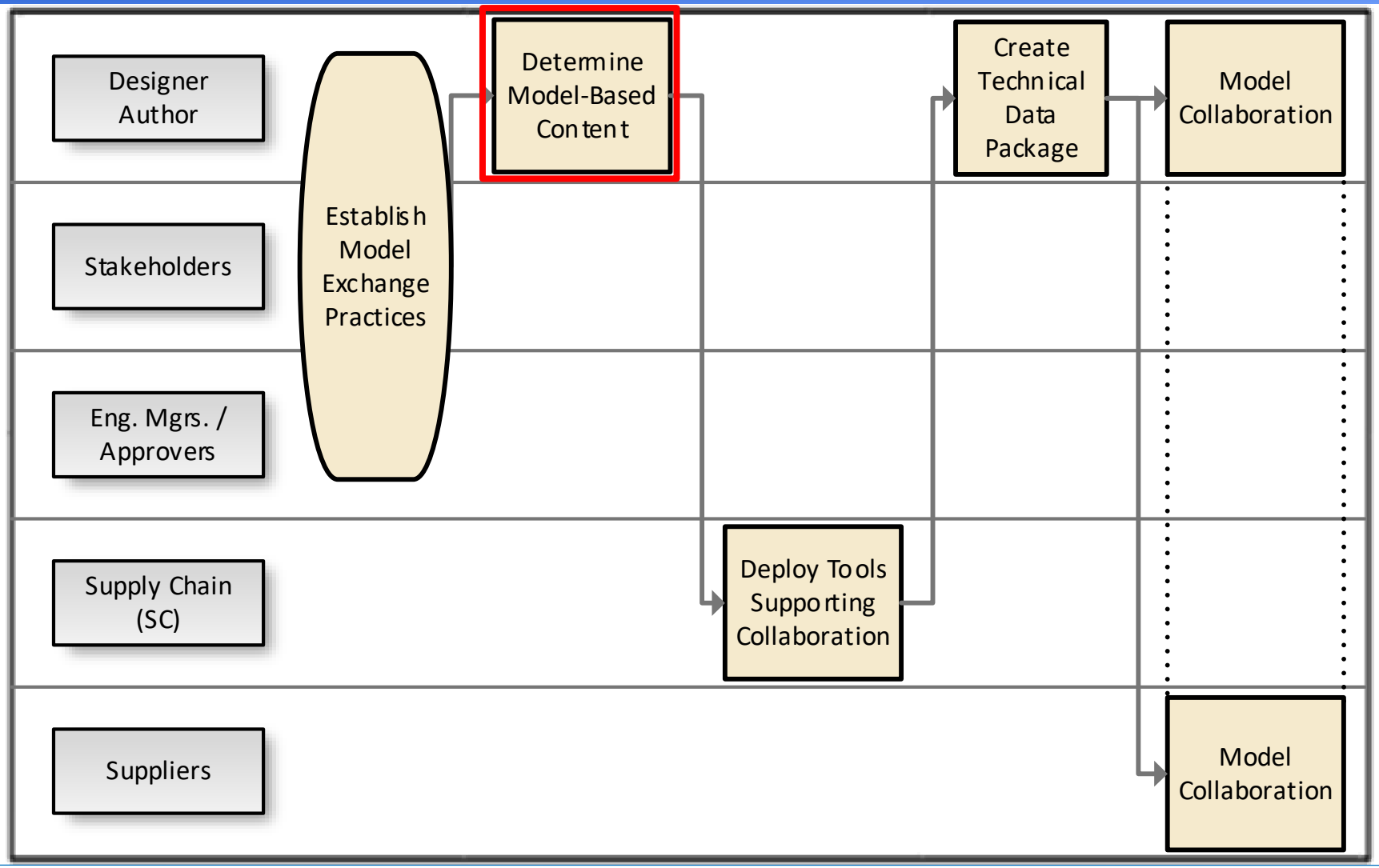
Between Models and Other Data

- **Build point2point OSLC Links**
- **Exchange RDF (OWL) representations**
- **Link to another model thus may be assigned a property linking it to its next higher level or next lower level component**

Across Databases

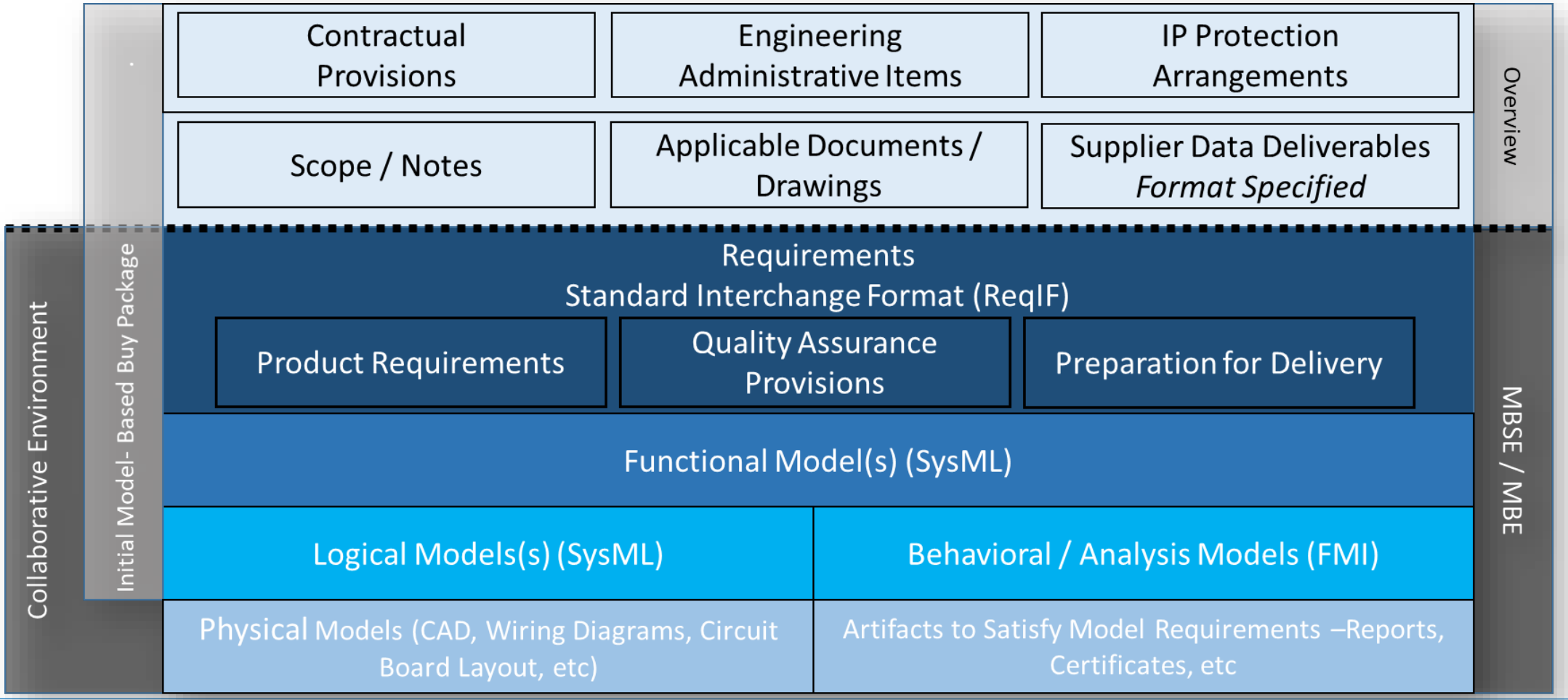
- **Thus, models hosted on a model management service (with queriable database) may be queried to reconstruct full traceability from requirement to behavioral or physical components**

Determine Model-Based Content



Typical Model-Based Buy Package Content

- **Utilization of electronically readable industry standard formats for consumption**
- **Selection of models for collaborative development based on business case**



Use of Model Identity Cards

- **Provides valuable metadata for use by model developers and consumers. May automate model integration.**

Attributes	Remarks	Type	Example	Main Class
Generic Name	Physical component group	String	Engine	Object Description
Specific Name	Unique Identifier	String	Compressor 7V16	
Granularity Level	List(System/Sub-system/component)	String	Sub-system	
Developer Name		String	Smith, John	
Model Ownership	Company	String	XYZ, Inc.	
Creation Date		Date	1/4/2019	
Revision Date		Date	8/14/2019	
Model Dimension	List(0D-3D, mix)	String	1D	Method
Chosen Method	List(Finite Volumes, Finite Elements, Finite Difference, OD…)	String	Finite Difference	
Physical Equations	List(Chemistry, Dynamic behavior of materials, Maxwell, Navier-Stokes, Strength of materials, Electric, Signal, Runge Kutta)	String	Navier-Stokes	
Time Step	List (Second, Minute, Millisecond, Hour, Steady State)	String	Second	
Time Computation	List (Elapsed Time / Real Time)	String	Elapsed Time	Usage
Scalability	List (Yes/No)	String	Yes	
Tool Name	List (Amesim, Matlab Simulink, GT-Power, Modelica…)	String	Matlab Simulink	
Tool Version	x.x format	String	7.3	
Information Classification	List (Proprietary, Sensitive, Secret, Top Secret)	String	Proprietary	
Export Control Code Number		String	9E991	
Collaboration Approach	List (White, Gray, Black)	String	White Box	

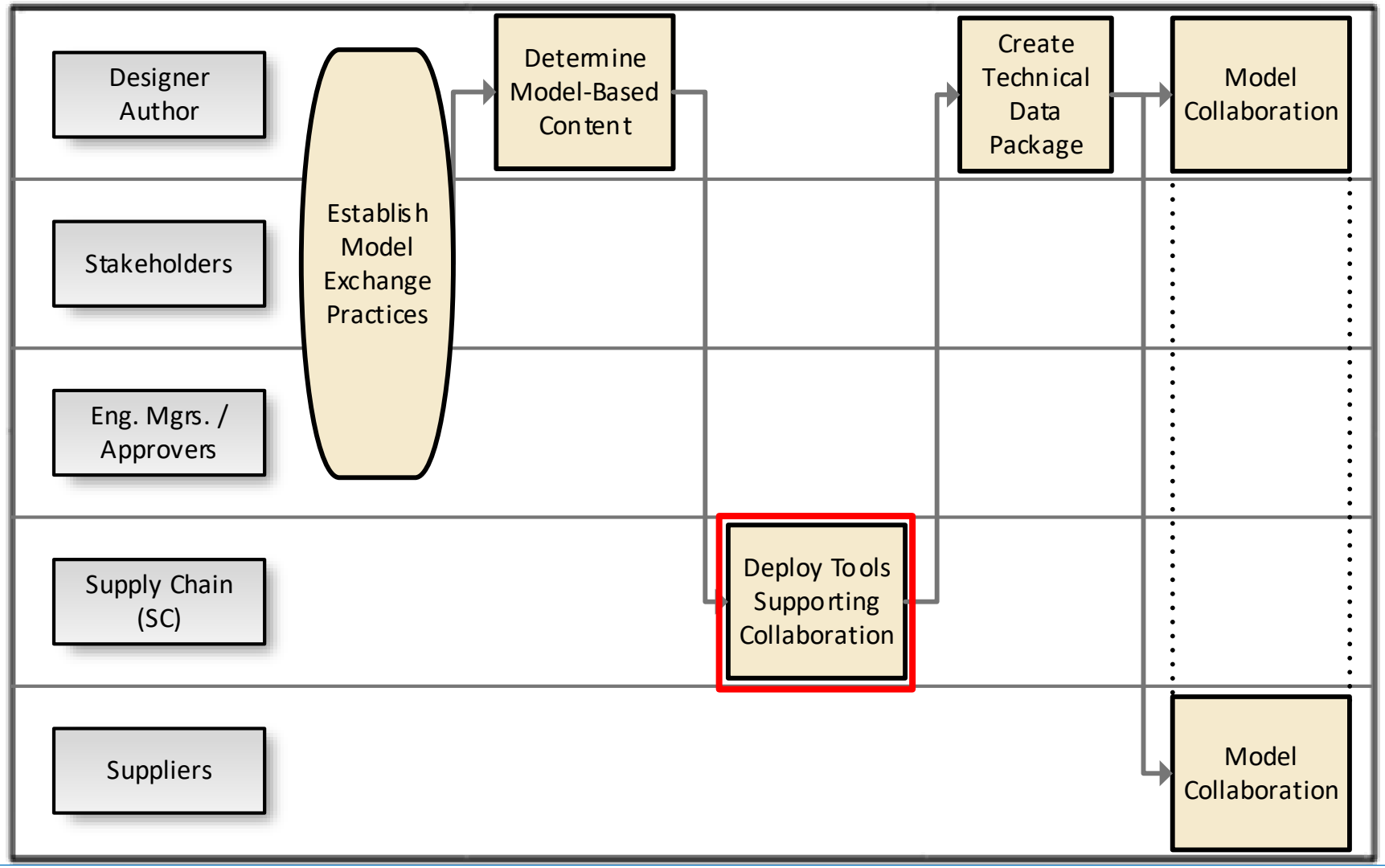
Example Model Attribute Metadata

Attributes	Remarks	Type	Example	Main Class
Port Name		String	Compression-input	Interface
Nature	Control (I/O), Parameter, Physical	String	Physical	
Domain	Solid Mechanics, Fluid Mechanics, Thermodynamics, Chemistry, Electromagnetism, Optics, Geometry, Biophysics, Signal, Human, Monitor, Geometry, Durability, Solid Mechanics…	String	Fluid Mechanics	
Direction	Input, Output, Bidirectional			
Sub-Domain	Fluid Mechanics (Acoustics, External aerodynamics, Reactive/diphasic flow), Thermodynamic, Chemistry…	String	Reactive/ diphasic flow	
Variable	Digital (CAN, Ethernet, Optic Fiber), Analogic (Filaire, Radio), Evaluation(Acoustic, Comfort, Vibration Comfort, Thermal Comfort, Performance, Durability, Drivability, Ergonomic, Consumption), Pressure….	String	Pressure	
Unit	List (C, K, kW, W, bar, Pa…)	String	Mpa	
Offset		String		
Size	List(Scalar, Vector, Matrix)	String	Scalar	
Min		String		
Max		String		

Example Port Attribute Metadata

Model Identity Card adapted from:
Göknur Sirin, Christiaan J. J. Paredis, Bernard Yannou, Eric Coatanéa, and Eric Landel (2015),
Model Identity Card to Support Simulation Model Development Process in a Collaborative Multidisciplinary Design Environment

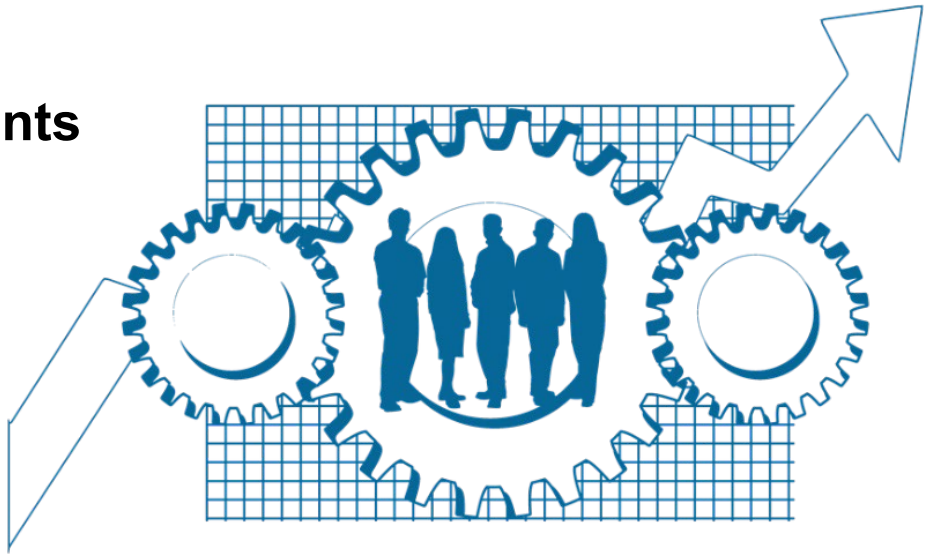
Deploy Tools Supporting Collaboration



How Do We Encourage and Promote Collaboration?

- **How can we encourage digital engagement and collaboration?**
  - **Mutual goals**
  - **Healthy communication**
  - **Robust intellectual property controls**
  - **Joint maximization of benefit**
  - **Working in good faith**

- **What are the outcomes?**
  - **Working together to develop and validate requirements**
  - **Real-time visibility of requirements and architecture**
  - **Leads to First-Time Quality**



Summary of Intellectual Property Protection Approaches

Access Type	Interface Data	Internal Formulations	Parameters	Modification	Review Granularity	Level of Collaboration Supported
White Box	Exposed	Exposed	Exposed	Available	High	Integration / Analysis / Co-Development
Gray Box	Exposed	Partially Exposed	Partially Exposed	Not Available	Medium	Integration / Analysis
Black Box	Exposed	Obfuscated	Partially Exposed	Not Available	Low	Integration

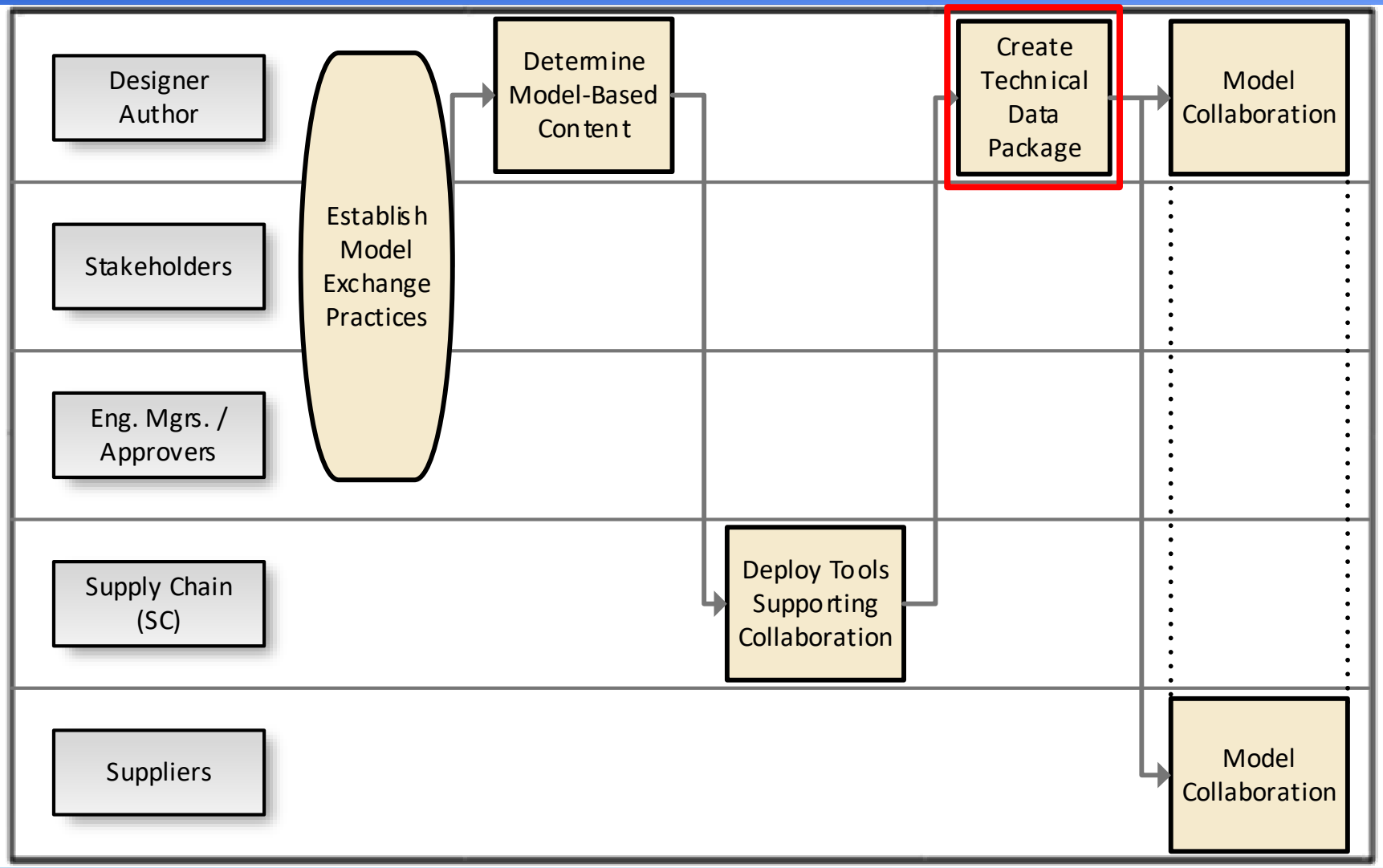
Comparison of IP Protection Approaches

Deliverables - Data Requirements Determined Early

Data Item	Data Item Description	Data Standard	Filetype	IP Approach
DOORS Requirements Module	Subsystem Requirements	ReqIF	.xmi	White Box
Block Diagram (Functional and Interface)	Subsystem Architecture Model (Functional and Logical Decomposition)	SysML	.xmi	White Box
Interface Control Document	Subsystem Interface Requirements	-	.xmi	White Box
System Drawing	Subsystem Level 1 Component Schematic	SysML	.xmi	White Box
Performance Analysis	Subsystem Behavioral Model	Functional Mockup Interface Standard (FMI)	.fmu	Black Box

Example of Supplier Data Requirements List

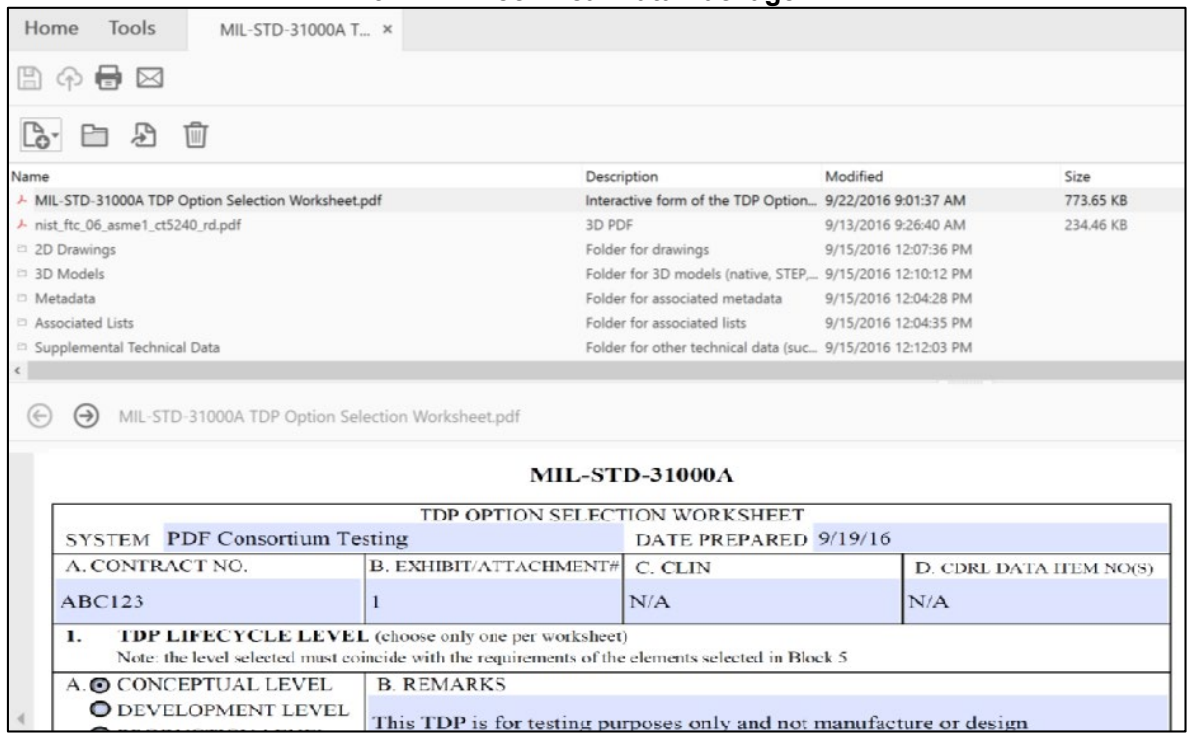
Create Technical Data Package



Create Technical Data Package

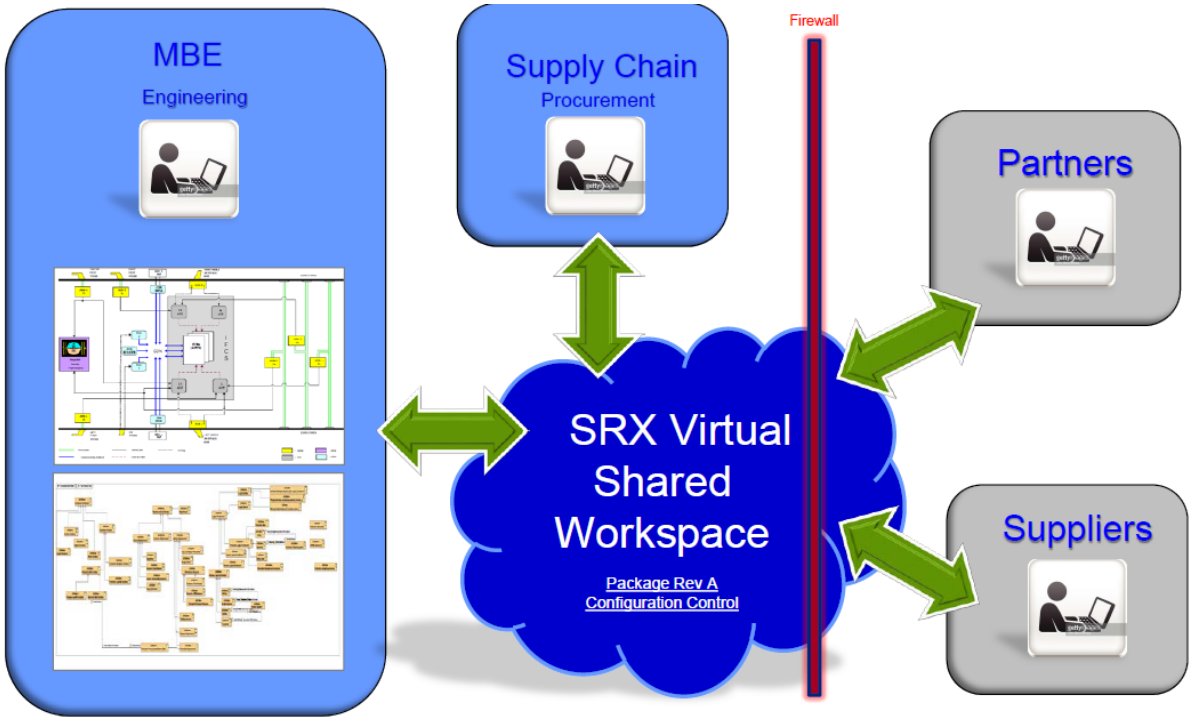
- **Packages should be sent using dedicated packaging tools:**
  - **Manage model relationships**
  - **Manifest management**
  - **Configuration control**
- **Current state of the art requires hand-off and model consumption/re-integration**

3D PDF Technical Data Package

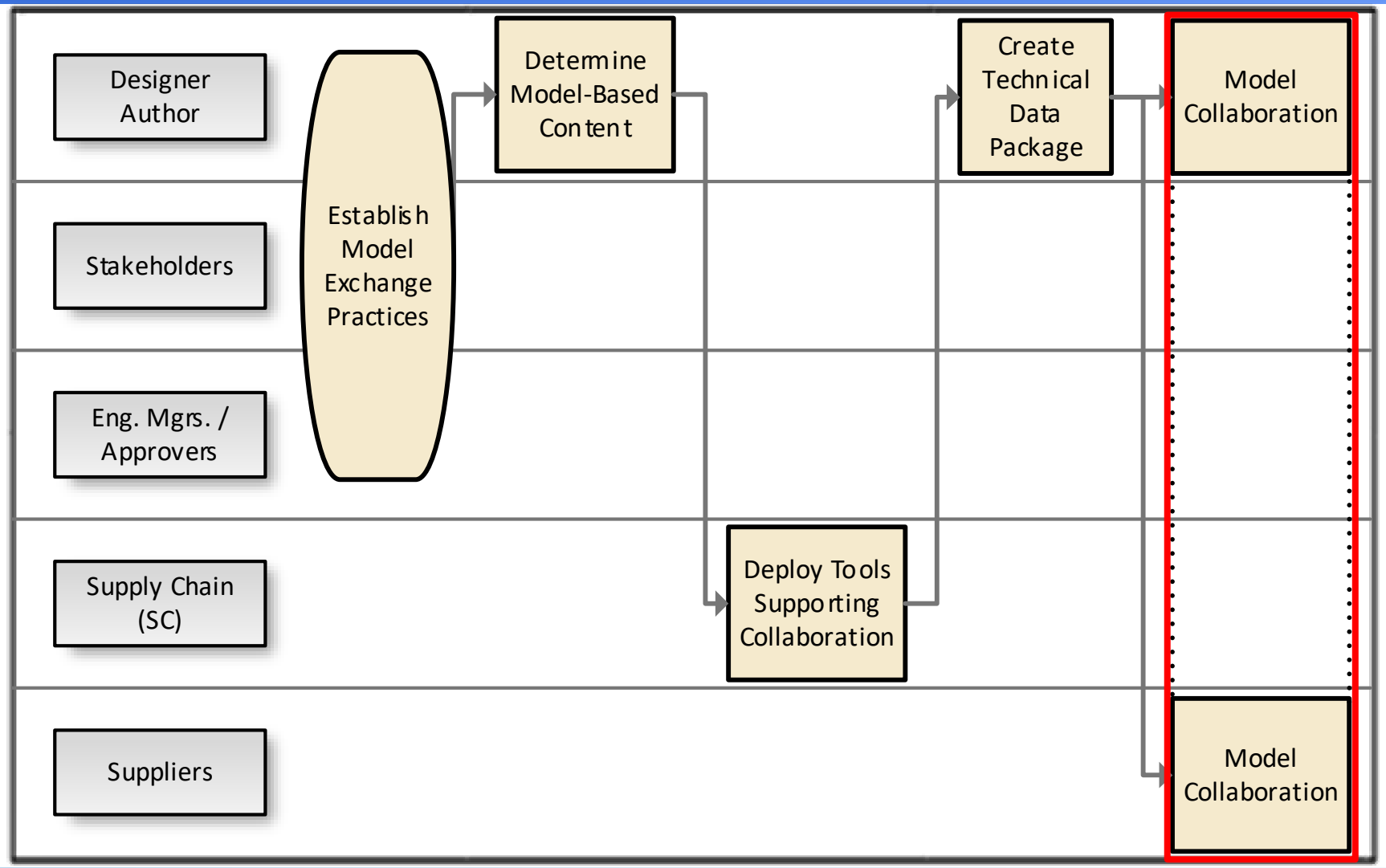


Source: 3D PDF Consortium (http://3dpdfconsortium.org/presentations/)

Web Based Collaboration Service / Boeing Supplier Requirements Exchange (SRX)

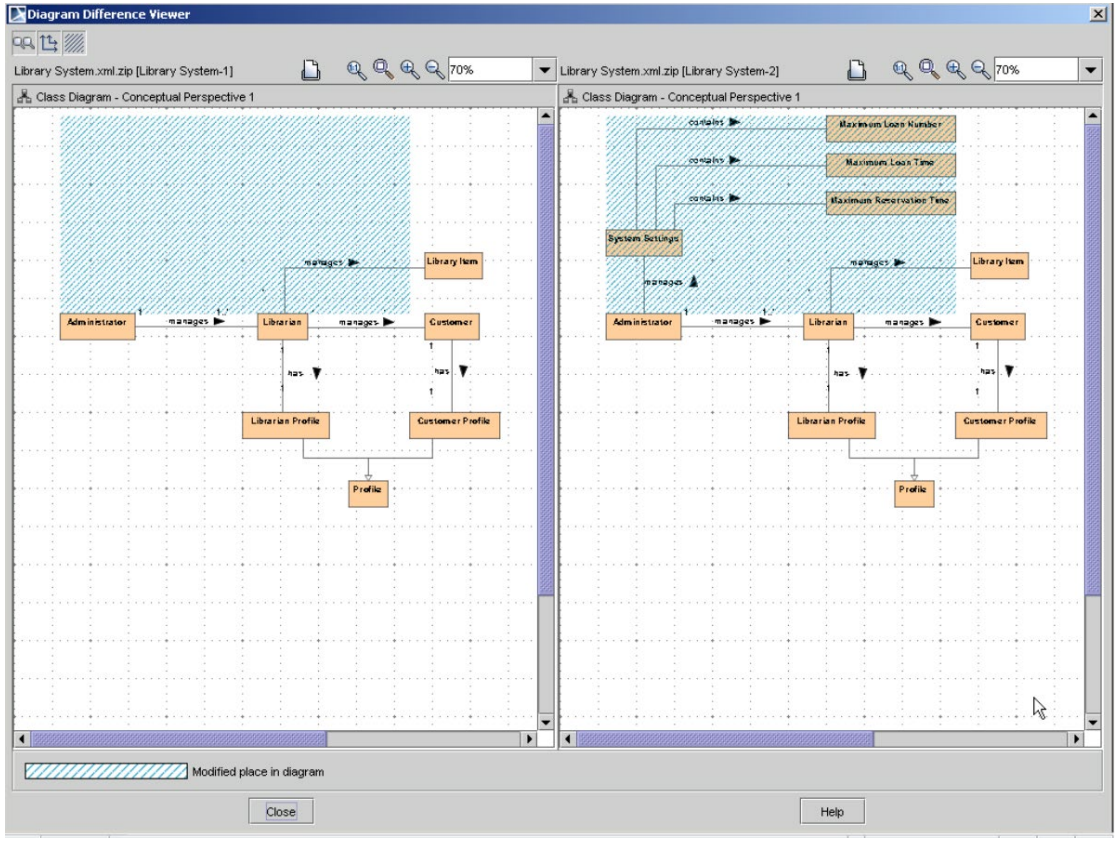


Model Collaboration



Model Reviews

- **Collaborative development is the process of exchanging a single model between parties**
- **Review/commenting/change acceptance process should be established**

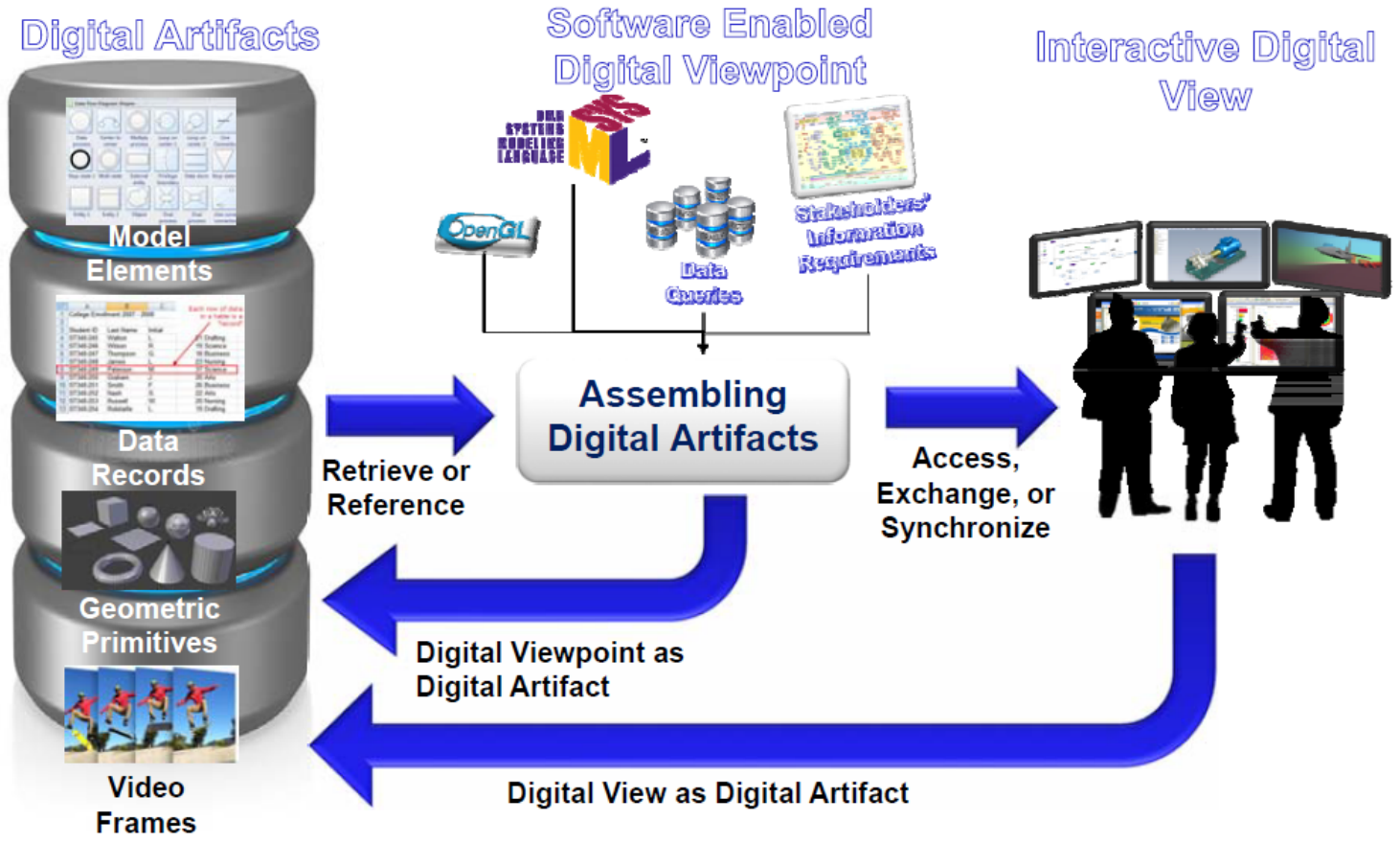


Example of a Model Comparison Tool
Source: https://www.nomagic.com/support/demos

- **MBSE tools can improve to provide element-level configuration control**

Design Reviews

- **Boeing pathfinders demonstrate iterative design reviews using MBSE tools**



Concept of Operations for Interactive Iterative Reviews
Source: Exchanging Digital Artifacts for the Engineering Life Cycle (Zimmerman)
(https://www.acq.osd.mil/se/briefs/2018_21337_Zimm_Artifact.pdf)

Summary

- **MBE and MBSE have potential to streamline collaborative design processes**
  - **Shared real-time visibility of requirements and architecture facilitates First-Time Quality**
  - **Improves system functional and logical decomposition**
  - **Allows Engineers to focus on value-added work**

- **Model-Based Buy Packages can**
  - **Enable a single source of truth for the digital system model**
  - **Provide traceability and relationships between requirements and model elements**
  - **Facilitate interoperability and data exchange**

- **Following a framework will improve outcomes**
  - **Supports decisions on infrastructure and development environments**
  - **Provides baseline for further improvement as technology advances**
  - **Mutual understanding of collaboration practices**
  - **System and industry-wide Benefits**