Framework for Developing Model-Based Buy Packages

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Neil Lichty
*The Boeing Company*

RROI #19-160216-CORP
<table>
<thead>
<tr>
<th>Name</th>
<th>Title</th>
<th>Email</th>
<th>Phone</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCGOWAN, DOUG</td>
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<td>425-876-5056</td>
</tr>
</tbody>
</table>

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 2\textsuperscript{nd} 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

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• 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
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- 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

Initial Model-Based Buy-Package Content

- Program Management / Supplier Contracts
- Customer Specification Requirements
- Behavioral Models
- Architecture Models
- Manufacturing Models
- Mechanical and Electrical Models
- Software Models
- Product Support
- Verification & Validation

Potential Model-Based Data Item Deliverables
Framework
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- Designer
- Author
- Stakeholders
- Eng. Mgrs. / Approvers
- Supply Chain (SC)
- Suppliers
- Establish Model Exchange Practices
- Determine Model-Based Content
- Create Technical Data Package
- Deploy Tools Supporting Collaboration
- Model Collaboration
- Technical Data Package
- Model Collaboration
Framework Overlaid with Typical Buy-Package Process

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- Designer/Author
- Stakeholders
- Eng. Mgrs./Approvers
- Supply Chain (SC)
- Suppliers

Initiate Buy-Package Specification → Determine Model-Based Content → Produce Product and Task Rqmts Artifacts → Create Technical Data Package → Buy Package Stakeholder Review → Approve Buy-Package Content

Deploy Tools Supporting Collaboration → Review/Authorize Buy-Package Distribution → Package Exchange → Model Collaboration

Establish Model Exchange Practices

Supporting Collaboration

Model Collaboration
Establish Model Exchange Practices

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

Tier 0 (Airplane) → Mission Requirements
Tier 1 (Airplane) → Major Section & Propulsion Requirements
Tier 2 (System) → System Requirements and Allocations
Tier 3 (Subsystem) → Subsystem Requirements and Allocations
Tier 4 (Component) → Component Requirements and Allocations

Program Launch

OEM Development Space
OEM: Owner

Collaborative Development Space
OEM: Primary Owner

Supplier Development Space
OEM: Reviewer

System Requirements

Data Item Deliverables

Model-Based Buy Package

Airplane Level Systems Architect
Systems Architect
Hardware & Software Architects
Hardware & Software Designers

Detailed Designs

Detailed Designs

OEM: Owner

OEM: Primary Owner

OEM: Reviewer

OEM: Reviewer

OEM: Reviewer

OEM: Reviewer

OEM: Reviewer

OEM: Reviewer

OEM: Reviewer
### Strive for Increased Interoperability

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

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

<table>
<thead>
<tr>
<th>Exchange Environment</th>
<th>Support for Diverse Software</th>
<th>Single Source of Truth</th>
<th>Configuration Management</th>
<th>Native Query Capability</th>
<th>Review / Commenting</th>
<th>Security</th>
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<tr>
<td>Published Views of Model</td>
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</tbody>
</table>
Link and Integrate Data

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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

Establish Model Exchange Practices

Stakeholders

Eng. Mgrs. / Approvers

Supply Chain (SC)

Suppliers

Determining Model-Based Content

Create Technical Data Package

Deploy Tools Supporting Collaboration

Model Collaboration
• Utilization of electronically readable industry standard formats for consumption
• Selection of models for collaborative development based on business case
Use of Model Identity Cards

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

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Remarks</th>
<th>Type</th>
<th>Example</th>
<th>Main Class</th>
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</thead>
<tbody>
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<td>Generic Name</td>
<td>Physical component group</td>
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<td>Engine</td>
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<tr>
<td>Specific Name</td>
<td>Unique Identifier</td>
<td>String</td>
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<td>Granularity Level</td>
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<td>Developer Name</td>
<td>Smith, John</td>
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<td>Model Ownership</td>
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<td>Creation Date</td>
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<td>Date</td>
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<td>Revision Date</td>
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<td>Model Dimension</td>
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<td>Chosen Method</td>
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<td>String</td>
<td>Finite Difference</td>
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<td>Time Step</td>
<td>List (Second, Minute, Millisecond, Hour, Steady State)</td>
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<td>Second</td>
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<tr>
<td>Time Computation</td>
<td>List (Elapsed Time / Real Time)</td>
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<td>Elapsed Time</td>
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<tr>
<td>Scalability</td>
<td>List (Yes/No)</td>
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<td>Yes</td>
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<td>Tool Name</td>
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<tr>
<td>Tool Version</td>
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<td>Information Classification</td>
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<td>White Box</td>
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</table>

<table>
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<th>Remarks</th>
<th>Type</th>
<th>Example</th>
<th>Main Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Port Name</td>
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<td>String</td>
<td>Compression-input</td>
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<tr>
<td>Nature</td>
<td>Control (I/O), Parameter, Physical</td>
<td>String</td>
<td>Physical</td>
<td></td>
</tr>
<tr>
<td>Direction</td>
<td>Input, Output, Bidirectional</td>
<td>String</td>
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<tr>
<td>Sub-Domain</td>
<td>Fluid Mechanics (Acoustics, External aerodynamics, Reactive/diphasic flow), Thermodynamic, Chemistry…</td>
<td>String</td>
<td>Reactive/ diphasic flow</td>
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<tr>
<td>Variable</td>
<td>Digital (CAN, Ethernet, Optic Fiber), Analogic (Filaire, Radio), Evaluation(Acoustic, Comfort, Vibration Comfort, Thermal Comfort, Performance, Durability, Drivability, Ergonomic, Consumption), Pressure…</td>
<td>String</td>
<td>Pressure</td>
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<td>Unit</td>
<td>List (C, K, kW, W, bar, Pa…)</td>
<td>String</td>
<td>Mpa</td>
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<td>Offset</td>
<td></td>
<td>String</td>
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</tr>
<tr>
<td>Size</td>
<td>List(Scalar, Vector, Matrix)</td>
<td>String</td>
<td>Scalar</td>
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</tr>
<tr>
<td>Min</td>
<td></td>
<td>String</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max</td>
<td></td>
<td>String</td>
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</tr>
</tbody>
</table>

**Example Model Attribute Metadata**

**Example Port Attribute Metadata**

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Model Identity Card adapted from:
Gökknur Sirin, Christiaan J. J. Paredis, Bernard Yannou, Eric Coatanèa, and Eric Landel (2015),
Model Identity Card to Support Simulation Model Development Process in a Collaborative Multidisciplinary Design Environment
Deploy Tools Supporting Collaboration

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

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<table>
<thead>
<tr>
<th>Access Type</th>
<th>Interface Data</th>
<th>Internal Formulations</th>
<th>Parameters</th>
<th>Modification</th>
<th>Review Granularity</th>
<th>Level of Collaboration Supported</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>White Box</strong></td>
<td>Exposed</td>
<td>Exposed</td>
<td>Exposed</td>
<td>Available</td>
<td>High</td>
<td>Integration / Analysis / Co-Development</td>
</tr>
<tr>
<td><strong>Gray Box</strong></td>
<td>Exposed</td>
<td>Partially Exposed</td>
<td>Partially Exposed</td>
<td>Not Available</td>
<td>Medium</td>
<td>Integration / Analysis</td>
</tr>
<tr>
<td><strong>Black Box</strong></td>
<td>Exposed</td>
<td>Obfuscated</td>
<td>Partially Exposed</td>
<td>Not Available</td>
<td>Low</td>
<td>Integration</td>
</tr>
</tbody>
</table>

*Comparison of IP Protection Approaches*
### Deliverables - Data Requirements Determined Early

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

*Example of Supplier Data Requirements List*
Create Technical Data Package

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- 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
Create Technical Data Package
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- 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

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

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

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<table>
<thead>
<tr>
<th>Designer Author</th>
<th>Determine Model-Based Content</th>
<th>Create Technical Data Package</th>
<th>Model Collaboration</th>
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</thead>
<tbody>
<tr>
<td>Stakeholders</td>
<td>Establish Model Exchange Practices</td>
<td>Deploy Tools Supporting Collaboration</td>
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<tr>
<td>Eng. Mgrs. / Approvers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supply Chain (SC)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Suppliers</td>
<td></td>
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</tr>
</tbody>
</table>
Collaborative development is the process of exchanging a single model between parties. Review/commenting/change acceptance process should be established. MBSE tools can improve to provide element-level configuration control.
Boeing pathfinders demonstrate iterative design reviews using MBSE tools

Source: Exchanging Digital Artifacts for the Engineering Life Cycle (Zimmerman)
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