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Model-Based Systems Analysis and Engineering: Comprehensive/Narrow Model Sharing and Collaboration Approaches

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August 2025

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Abstract

Model sharing approaches have been developed by Boeing and its partners to address an industry wide need of methods and standards in the collaboration and exchange of models for various domains and use cases. Comprehensive and Narrow Sharing are current and new approaches to address NASA's for Model-Based Systems Analysis & Engineering (MBSA&E). The framework for Comprehensive and Narrow sharing has been built upon the Supplier Engagement Framework which has been undergoing proof of concept at Boeing through close collaboration with industry partners such as Collins. Comprehensive and Narrow Sharing also leverages Boeing internal best practices and external industry standards and methods for protection of Intellectual Property, model markings, configuration management and model identity meta data to aid in the formation of Technical Data Packages. The chosen approach whether Comprehensive or Narrow is unique to each use case and partners needs to allow for substantial data protection or data obfuscation. The developed workflows allow for OEM and supplier exchange and collaboration to accelerate the development and collaboration of systems.

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Nomenclature

EL	Engagement Level
FMI	Functional Mock-up Interface
FMU	Functional Mock-up Unit
IP	Intellectual Property
MBD	Model-Based Definition
MBSE	Model-Based Systems Engineering
MBSA&E	Model-Based Systems Analysis & Engineering
MBX	Model-Based Exchange
MIC	Model Identity Card
MoSSEC	Modeling and Simulation information in a collaborative Systems Engineering Context
OEM	Original Equipment Manufacturer
SEF	Supplier Engagement Framework
SoI	System of Interest
SRX	Supplier Requirements eXchange
SW	Software
SMIC	SysML Model Identity Card
sysMBD	System Model-Based Definition
TDP	Technical Data Package

Introduction

The transition from documentation artifacts and 2D drawings as the mechanism for exchange of information in the development of engineering complex systems to that of digital engineering or engineering models has posed various challenges. Boeing and its partners have been engaged in addressing and discovering the challenges through various use cases involving Original Equipment Manufacturer (OEM) its contractors, partners and suppliers. As such advancements have been made in the aerospace industry to solve such challenges. Boeing's efforts have adapted and developed standards and methods for collaboration and exchange of digital information in the model form. The discovered challenges include Intellectual Property protection and Data marking, Engagement frameworks, tool and language interoperability and compatibility, and configuration control. The challenges have required the adoption of standards and methods which will be used to provide NASA with solutions for Comprehensive Model Sharing and Collaboration as well as Narrow Model Sharing and Collaboration. The solutions bring an opportunity to drive first pass quality and accelerate the conceptual design lifecycle as well as push industry improvements forward as well as the integration between MBSE and MDAO. This paper will provide the collaborative effort that was executed for this project between Boeing, Collins and NASA which culminated in the development of a detailed workflow which included demonstrations for each type of exchange approach. It is important to note many of the building blocks for the approaches Narrow and Comprehensive are derived and implemented from shared concepts.

Approach

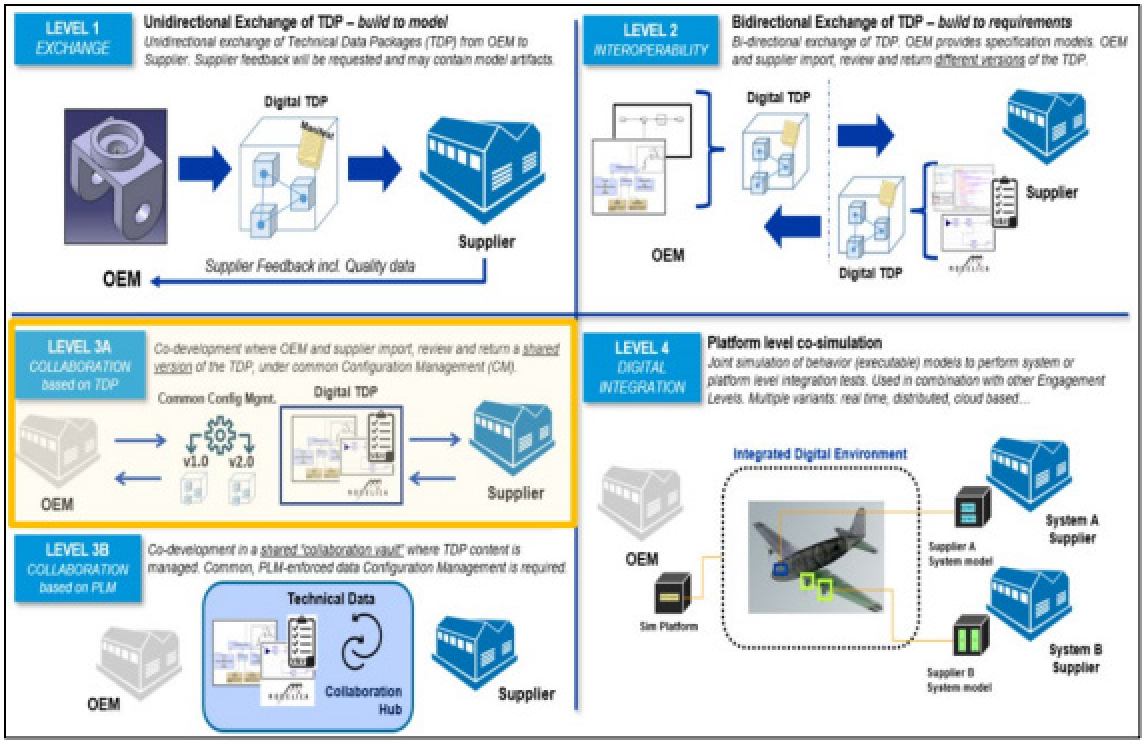
The initial starting point for the approaches implemented in this contract came from existing proof of concepts and pathfinders which have been ongoing for several years between Boeing and some of its Suppliers. Collins was chosen to assist in this project as it has been collaborating with Boeing Product Development teams, Boeing Research and Technology teams and many others to advance MBE Supplier Sharing and Collaboration. Recent POC's and pathfinders have allowed Boeing and suppliers to understand and identify the tools and processes, legal aspects that should be addressed in the development and exchange of models for advancing the digital engineering domains, from conceptual design to as built. The following framework was used as the basis for the statement of work on this project. Boeing focused on Engagement Framework Level 3A which enables the unidirectional exchange of the Technical Data Package.

Utilization of Suppler Engagement Framework

The Boeing Model Based Engineering Supplier Engagement Framework (SEF) is the framework used to define the level of collaboration between Boeing and Collins for this project. It outlines the distribution of data, the data exchange, expected interoperability. The SEF has defined four distinct engagement levels which allow for a variety of scenarios with which may be appropriate for some exchanges and allows for the maturity of Model Based Engineering in the future. The level of engagement 3A was selected for this project reflected the level of confidence Boeing has from prior proof of concept work with Collins and other industry partners and was also deemed appropriate to satisfy the projects goals and objectives.

Engagement Level 3A

The EL 3A provisions for the co-development and the use of the Technical Data Package. It provisions for the co-development of a (sub-) system where an OEM and supplier will utilize a central data repository. In the case of this project Boeing was in the role of the OEM and Collins in the role of supplier. EL 3A allows for additional parties to also engage in the collaboration/co-development within the same project space. For the purposes of this project NASA was given access to the central data repository in this case the Boeing's SRX.



Unidirectional Exchange of TDP – *build to model*
Unidirectional exchange of Technical Data Packages (TDP) from OEM to Supplier. Supplier feedback will be requested and may contain model artifacts.

Bidirectional Exchange of TDP – *build to requirements*
Bi-directional exchange of TDP. OEM provides specification models. OEM and supplier import, review and return different versions of the TDP.

Co-development where OEM and supplier import, review and return a shared version of the TDP, under common Configuration Management (CM).

Co-development in a shared "collaboration vault" where TDP content is managed. Common, PLM-enforced data Configuration Management is required.

Platform level co-simulation
Joint simulation of behavior (executable) models to perform system or platform level integration tests. Used in combination with other Engagement Levels. Multiple variants: real time, distributed, cloud based...

Boeing's MBE Supplier Engagement Framework – SEF Level 3A (Pathfinder).

Figure 1 Boeing MBE Supplier Engagement Framework

Solution Architecture

A significant amount of time was spent level setting the teams around the Solution Architecture in order to assure the unfolding solutions would meet NASA’s needs and vision. This architecture is showcased in Figure 2. The model exchange portion, at the bottom of the graphic, demonstrates how it is utilized to transfer models between two organizations in order to then use those models in the larger Model-Based Systems Analysis & Engineering (MBSA&E) model workflow.

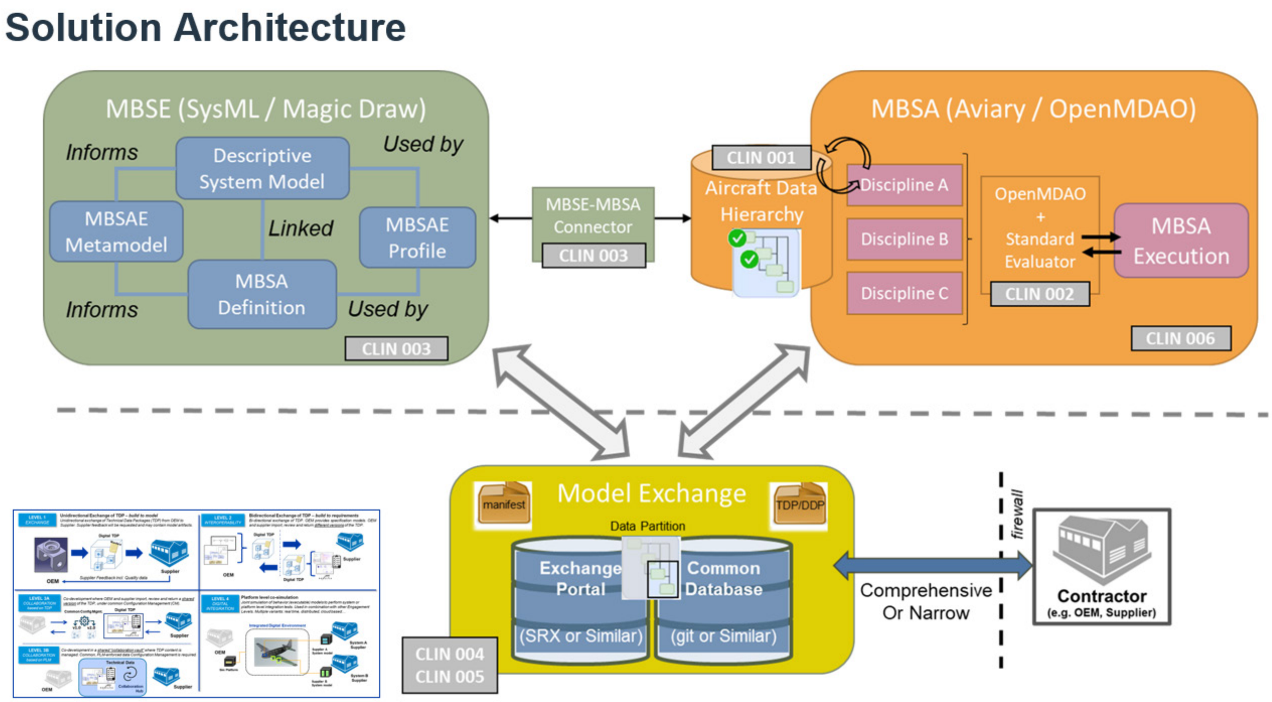
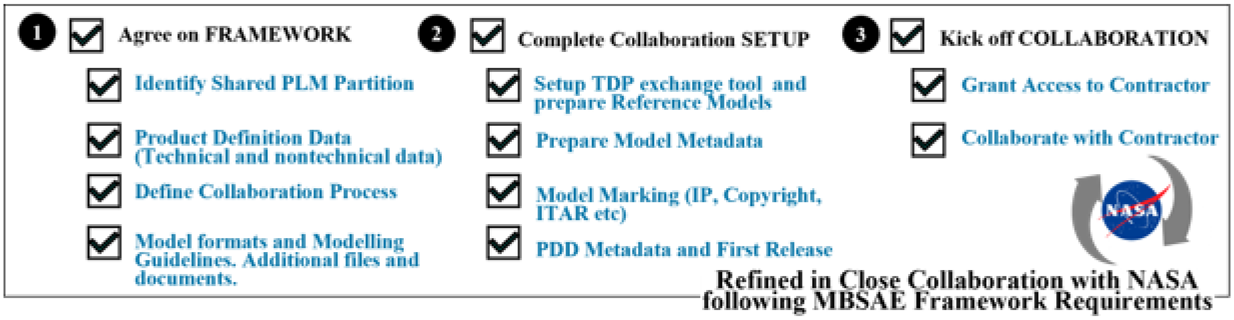


Figure 2 Solution Architecture

Development of Tool Agnostic Workflow

The starting point for tool agnostic workflows began with a high-level checklist of activities.



❶ ☑ Agree on FRAMEWORK
- ☑ Identify Shared PLM Partition
- ☑ Product Definition Data (Technical and nontechnical data)
- ☑ Define Collaboration Process
- ☑ Model formats and Modelling Guidelines. Additional files and documents.

❷ ☑ Complete Collaboration SETUP
- ☑ Setup TDP exchange tool and prepare Reference Models
- ☑ Prepare Model Metadata
- ☑ Model Marking (IP, Copyright, ITAR etc)
- ☑ PDD Metadata and First Release

❸ ☑ Kick off COLLABORATION
- ☑ Grant Access to Contractor
- ☑ Collaborate with Contractor

Refined in Close Collaboration with NASA following MBSAE Framework Requirements

Figure 3 Initial Workflow Checklist

The workflow matured because of an existing understanding of how to engage and the steps required to address the specific needs of all parties involved in this case the use case between Boeing and Collins to evolve the solution show in the solution architecture the specific solution of MBSA&E. The workflows are intended to be tool agnostic which require some understanding of how tools and process must align to execute the workflow. More details will be shared further into the report regarding tool agnostic requirements. The uniqueness between Comprehensive and Narrow workflows are intended to provision for a variety of situations or circumstances where the protection of intellectual property is of high interest. Within private industry it is well understood that intellectual property is of increasing consideration when co-development or collaboration is underway. Hence it will be discussed further in detail when methods of protection are considered. For the purposes of workflow, the distinction should be known as Comprehensive Model sharing and collaboration is for cases where model information and data being shared can be completely transparent to all or some of the parties. Narrow Model sharing and collaboration will be defined as the approach that is taken when some or all parties intend or have a need to protect more of the model and data that is necessary for the conceptual design intended.

Boeing Collins ECS Use Case

For the purposes of time and efficiency Boeing, Collins and NASA agreed upon a use case which involved the Environmental Control System – which is a system well known to Boeing and Collins. Utilizing this existing opportunity gave the team confidence in moving quickly past the engineering design specific details and to focus on the processes in development for first phase of the Collaboration.

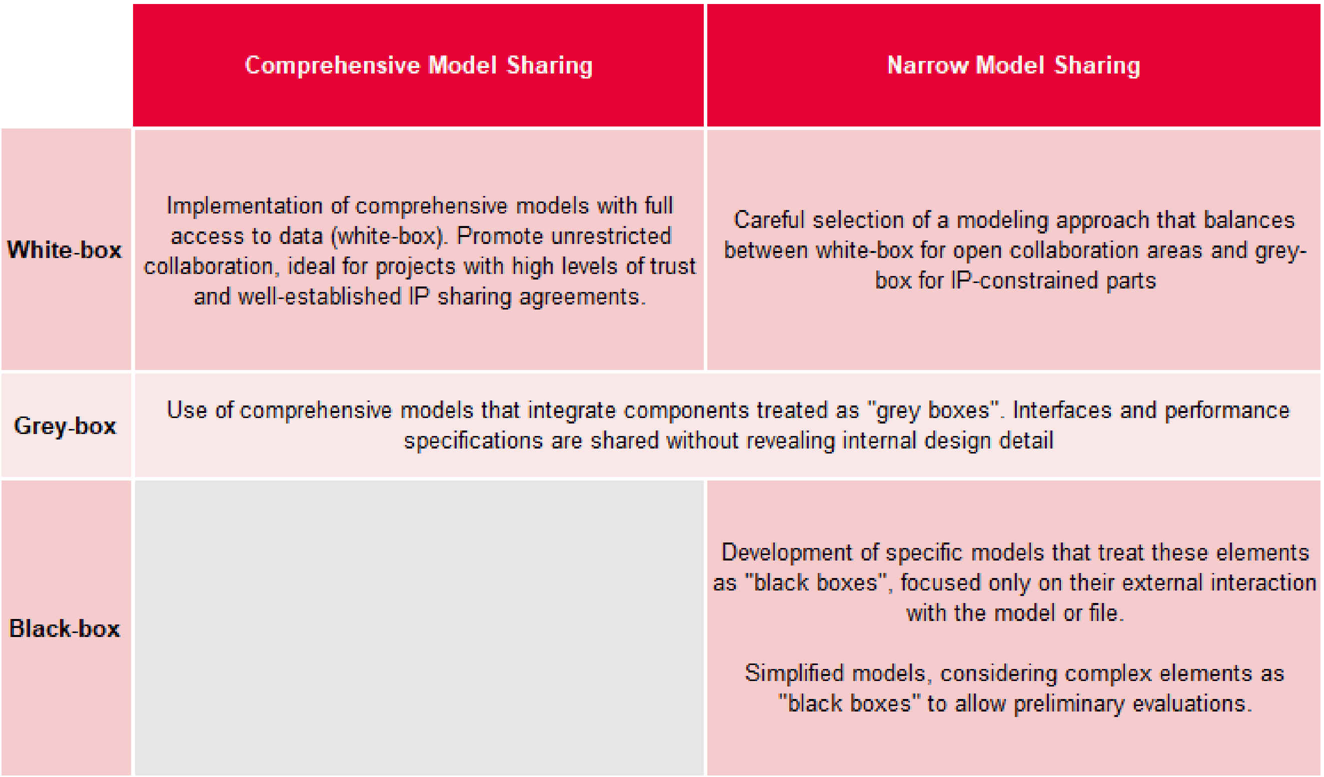
Working with Supplier (Collins) Use Case Environmental Control System (ECS) Functional Mockup Unit (FMU) analysis domain: obfuscation for Intellectual Property Protection

Model Boundary Definition

During the initial collaboration kick off the model boundary definitions should be agreed upon to understand how the model or models will be developed and by whom. An understanding of white, grey and black box definitions for the model content should be had by all parties. In the case of the ECS collaboration and model exchange the teams agreed upon the models Collins would deliver to Boeing. A unique set of models was delivered for MBSE Architecture domain and for System Model-Based Definition (sysMBD) Behavioral domain.

White, Grey and Black Box Concepts

The project use case required the introduction of concepts to facilitate the boundaries of the co-development between Boeing and Collins and to introduce the NASA MBSA&E team to the concepts. Each sharing and collaboration approach uses white-box and grey-box but Narrow being the most sensitive to Intellectual Property provision for black-box sharing and is considered the greatest level of protection of models being exchanged.



	Comprehensive Model Sharing	Narrow Model Sharing
White-box	Implementation of comprehensive models with full access to data (white-box). Promote unrestricted collaboration, ideal for projects with high levels of trust and well-established IP sharing agreements.	Careful selection of a modeling approach that balances between white-box for open collaboration areas and grey-box for IP-constrained parts
Grey-box	Use of comprehensive models that integrate components treated as "grey boxes". Interfaces and performance specifications are shared without revealing internal design detail	
Black-box		Development of specific models that treat these elements as "black boxes", focused only on their external interaction with the model or file. Simplified models, considering complex elements as "black boxes" to allow preliminary evaluations.

Figure 4 White box, Grey-box and Black box Definitions for Comprehensive and Narrow Model Sharing

IP Protection and Obfuscation Methods

Investigations into tools for the purposes of IP protection also referred to as obfuscation were conducted. Four specific tools were reviewed and assessed for pro's and con's and ability to protect at the level deemed applicable for the use case.

Obfuscation Methods

Obfuscator Plugin within the Cameo tool, this method provided a high-level degree of obfuscation for whole projects providing strong information protection and security. The downside there was no ability to perform partial obfuscation within the project or to unencrypt the information once encrypted.

PLE Plugin a plug in for Cameo, this method provided a high level of flexibility, and ability to control at the element-level as well as controlled. The PLE method did not provide an encrypting capability there it is deemed weak for information protection and security.

MBSE Reference Model

An example Reference Model template was provided to NASA as part of this project. The template can be used to build architecture models that comply to the agreed upon Framework to include methodology, modeling guidelines, standards, tools and modeling language. It allows for alignment between the OEM and the Suppliers or partners.

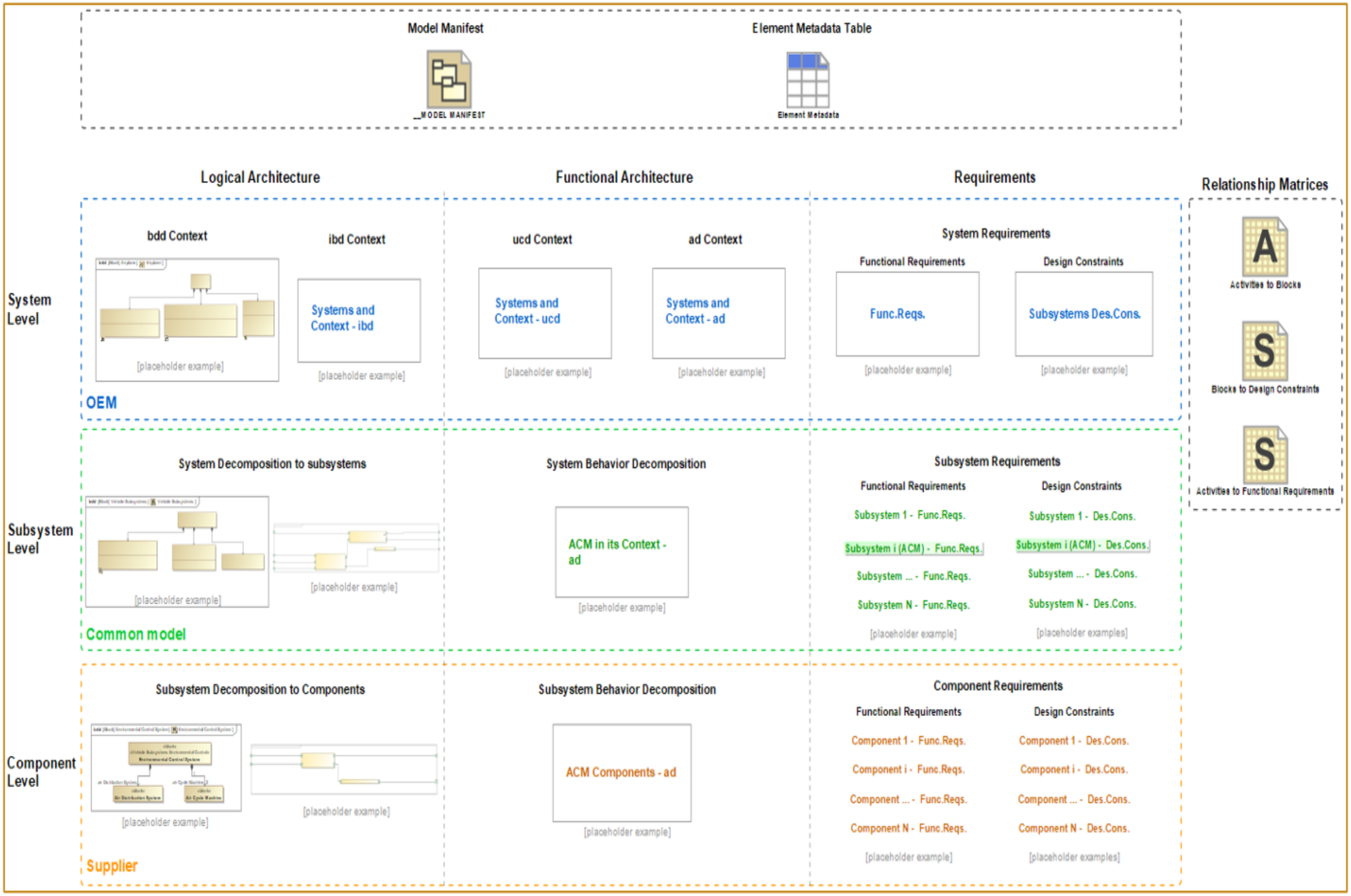


Figure 5 Reference Model Template showing Tier Decomposition of System of Interest

Technical Data Package

The Technical Data Package (TDP) is a standard package defined as part of the SEF used by Boeing and Collins for this project to meet the objectives for sharing standard neutral formats from MBSE models containing requirements, architecture, behavioral or analysis data. It also allowed the sharing of model entity metadata contained in neutral formats also known as Model Identity Cards (MIC) editable with Boeing developed model identity card editors. The TDP may contain any number of artifacts whether files, models and model manifests. The TDP manifest describes the contents of data within the TDP. A TDP manifest was created as part of the workflow process demonstration.

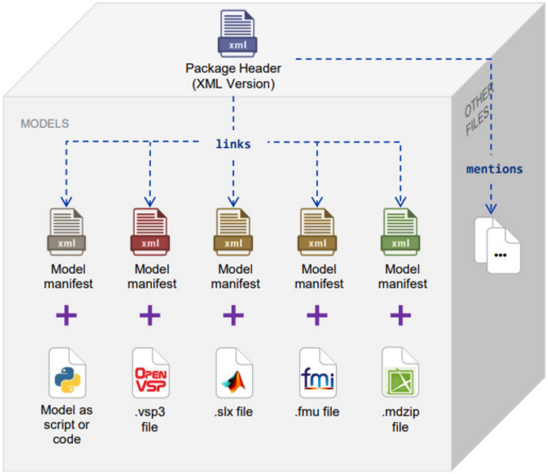
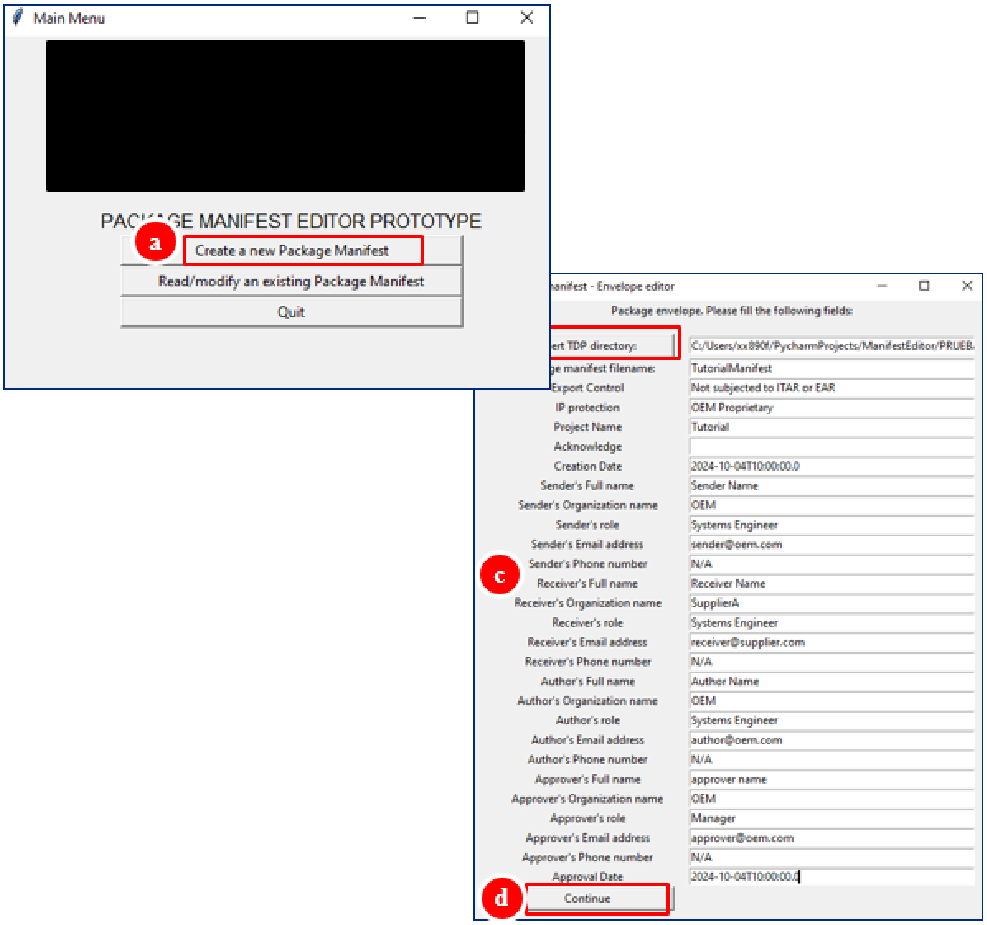


Figure 6 Package Manifest Example Structure



Package envelope. Please fill the following fields:

ert TDP directory:	C:/Users/xx890f/PycharmProjects/ManifestEditor/PRUEB
ge manifest filename:	TutorialManifest
Export Control	Not subjected to ITAR or EAR
IP protection	OEM Proprietary
Project Name	Tutorial
Acknowledge	
Creation Date	2024-10-04T10:00:00.0
Sender's Full name	Sender Name
Sender's Organization name	OEM
Sender's role	Systems Engineer
Sender's Email address	sender@oem.com
Sender's Phone number	N/A
Receiver's Full name	Receiver Name
Receiver's Organization name	SupplierA
Receiver's role	Systems Engineer
Receiver's Email address	receiver@supplier.com
Receiver's Phone number	N/A
Author's Full name	Author Name
Author's Organization name	OEM
Author's role	Systems Engineer
Author's Email address	author@oem.com
Author's Phone number	N/A
Approver's Full name	approver name
Approver's Organization name	OEM
Approver's role	Manager
Approver's Email address	approver@oem.com
Approver's Phone number	N/A
Approval Date	2024-10-04T10:00:00.0

Figure 7 Example Technical Data Package Manifest Editor

Model Manifests and Metadata

Boeing made use of the “model metadata” as part of the project. The model metadata is an important concept in the overall exchange and collaboration of models whether using the Comprehensive or Narrow approach. Model metadata is the collection of data pertinent to a model in any domain. It may be embedded as in the case of the MBSE model for this project or accompany the model and described in the model manifest a concept also introduced and used throughout the demonstrations during this project. The metadata is used to inform information about the model such as exchange context, ID, authoring, marking and other appropriate information for the specific domain. Boeing and Collins leverage metadata standards such as AP243 and MoSSEC.

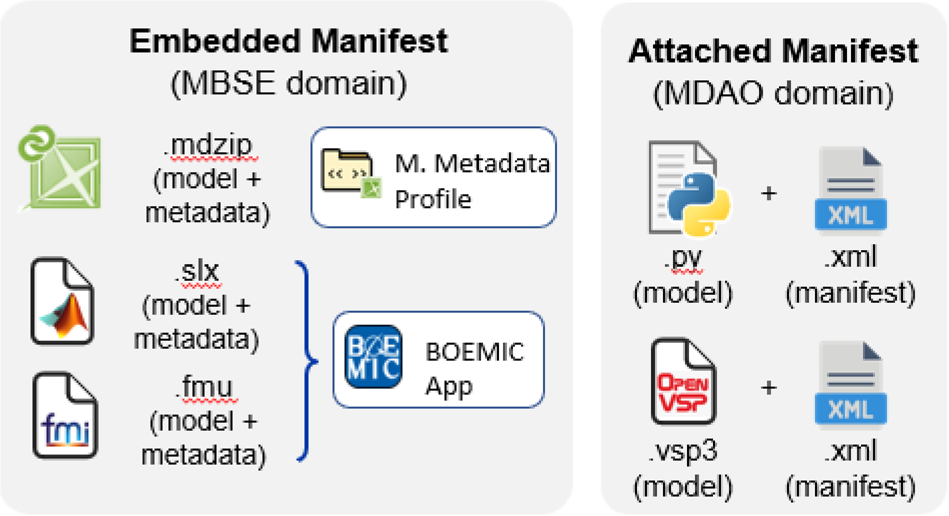


Figure 8 Model Manifests MBSE Domain (Embedded) while MDAO Domain (Attached)

Model Identity Cards and Editors

Model identity cards (MIC) play an important role in the exchange of "model metadata" providing the users and collaborators of the models and the metadata to be accessed via the editor and editing capability that imports an .xml neutral format which would be more cumbersome to edit in the neutral format. Each model type had an editor which was part of the demonstrations throughout the project and a final demonstration for each sharing type Narrow and Comprehensive. It is the responsibility of the model creator to populate the meta data as well as assure the appropriate contents are captured.

Tools Utilized

Tool	Domain	Output Format
PACKAGE MANIFEST EDITOR	TDP Package	.xml
BOE-SMIC PROFILE	MBSE/Architecture	.mdzip
BOE-MIC EDITOR	sysMBD/Behavioral	.xml
3D-MIC EDITOR	3D-MBD/Spatial	.xml
C-MIC EDITOR	Code/Script	.xml
SRX	Exchange	N/A
BOEING ENCRYPTION PLUGIN	MBSE/Architecture	N/A

Utilization/Implementation of Standards in the Workflow

Standards and Application Protocols

Boeing and Collins used applicable standards and protocols in the model identity cards and package manifests. Implementation of standards is important to the industry as MBE continues to mature which is a large focus of the pathfinding and proof of concept work. Boeing continues to collaborate across the industry to drive the best standards into the workflows internal to Boeing and with its suppliers and partners. To maintain alignment these standards were brought into the NASA project.

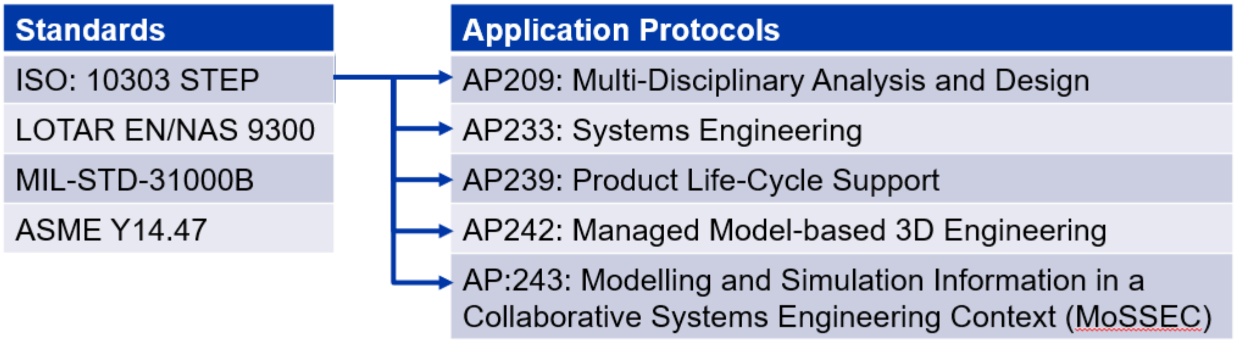


Figure 9 Standards and Application Protocols Aligned to Model Preparation

Tool Agnostic Requirements

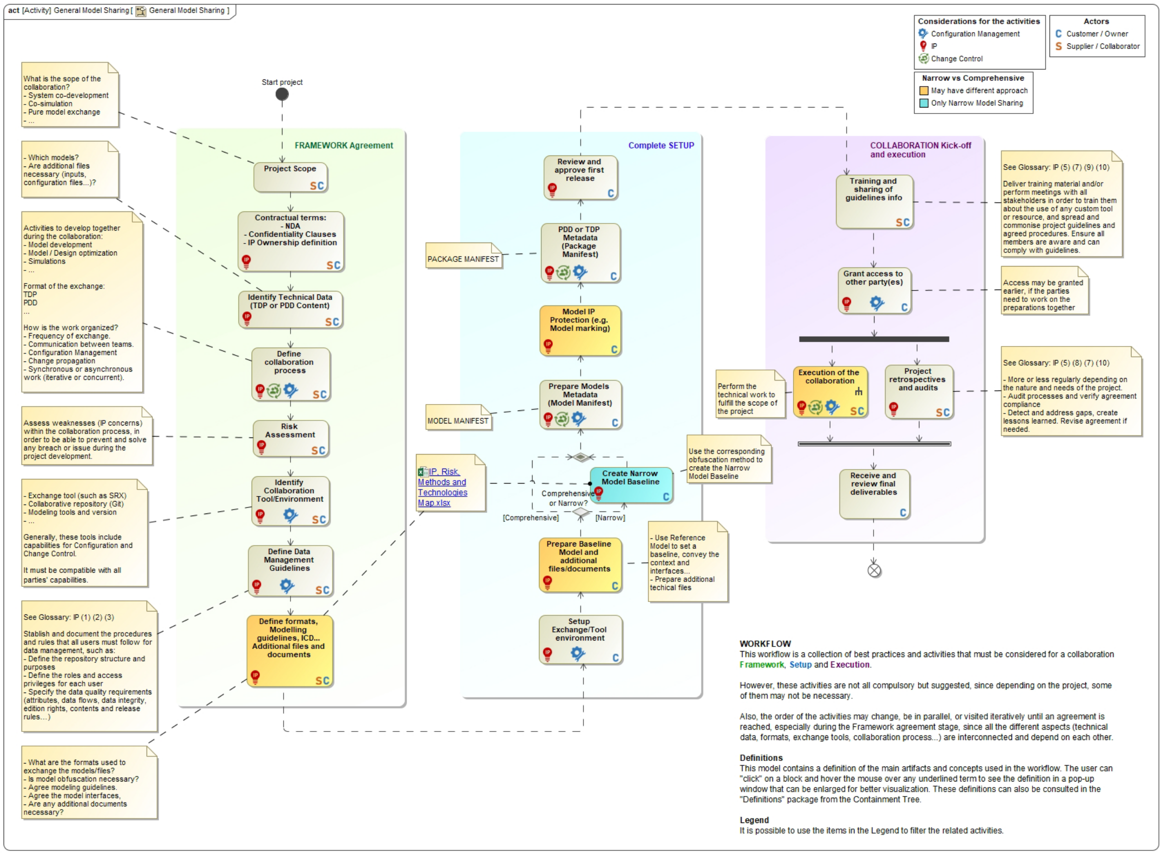
The matured general workflow was demonstrated utilizing internal Boeing tools which not readily available to NASA's MBSA&E which led the Boeing team to deliver a set of example tool agnostic requirements that convey the approach Boeing would take to select a tool that would satisfy the need to implement the developed and delivered workflow.

Results

The results of this project were developed in collaboration between Boeing as OEM and Collins as Supplier with input from the MBSA&E NASA team.

Matured General Workflow

The following General Workflow was matured during this MBSA&E contract using previous work developed between Boeing and industry partners and with the objectives outlined between the Boeing, Collins and NASA teams. The three main areas of the workflow are Framework Agreement, Complete SETUP and Collaboration Kick-off and execution. The workflow is a guideline of suggested activities which may be applicable depending on the scope of the project. The Framework Agreement suggests questions to consider during the start of the for example the scope of the collaboration and what kind of development agreement will be necessary, also consider the types of model and files to be shared and exchanged, what IP concerns should be discussed as assess risks, of course other questions may be added as the understanding of the project evolves. During the Framework Agreement it is important to consider and agree upon the tools and environment to be used. Modeling tools and version should be considered in advance of commencing work, potential tool compatibility issues should be identified in advance of collaboration and execution. Access to shared repositories and data protection should be well thought out when collaborating with multiple stakeholders. In the Complete Setup the tools and environment are setup model domains will drive the model preparations for the exchanges in this project as mentioned the Technical Data Package was utilized. In the Collaboration Kick-off and execution, the stakeholders are now ready to perform detailed technical work.



What is the sope of the collaboration?
- System co-development
- Co-simulation
- Pure model exchange
- ...

- Which models?
- Are additional files necessary (inputs, configuration files...)?

Activities to develop together during the collaboration:
- Model development
- Model / Design optimization
- Simulations
- ...

Format of the exchange:
TDP
PDD
...

How is the work organized?
- Frequency of exchange.
- Communication between teams.
- Configuration Management
- Change propagation
- Synchronous or asynchronous work (iterative or concurrent).

Assess weaknesses (IP concerns) within the collaboration process, in order to be able to prevent and solve any breach or issue during the project development.

- Exchange tool (such as SRX)
- Collaborative repository (Git)
- Modeling tools and version
- ...

Generally, these tools include capabilities for Configuration and Change Control.

It must be compatible with all parties' capabilities.

See Glossary: IP (1) (2) (3)

Stablish and document the procedures and rules that all users must follow for data management, such as:
- Define the repository structure and purposes
- Define the roles and access privileges for each user
- Specify the data quality requirements (attributes, data flows, data integrity, edition rights, contents and release rules...)

- What are the formats used to exchange the models/files?
- Is model obfuscation necessary?
- Agree modeling guidelines.
- Agree the model interfaces,
- Are any additional documents necessary?

- Use Reference Model to set a baseline, convey the context and interfaces...
- Prepare additional techical files

Use the corresponding obfuscation method to create the Narrow Model Baseline

Perform the technical work to fulfill the scope of the project

See Glossary: IP (5) (7) (9) (10)

Deliver training material and/or perform meetings with all stakeholders in order to train them about the use of any custom tool or resource, and spread and commonise project guidelines and agreed procedures. Ensure all members are aware and can comply with guidelines.

Access may be granted earlier, if the parties need to work on the preparations together

See Glossary: IP (5) (8) (7) (10)

- More or less regularly depending on the nature and needs of the project.
- Audit processes and verify agreement compliance
- Detect and address gaps, create lessons learned. Revise agreement if needed.

WORKFLOW
This workflow is a collection of best practices and activities that must be considered for a collaboration **Framework**, **Setup** and **Execution**.

However, these activities are not all compulsory but suggested, since depending on the project, some of them may not be necessary.

Also, the order of the activities may change, be in parallel, or visited iteratively until an agreement is reached, especially during the Framework agreement stage, since all the different aspects (technical data, formats, exchange tools, collaboration process...) are interconnected and depend on each other.

Definitions
This model contains a definition of the main artifacts and concepts used in the workflow. The user can "click" on a block and hover the mouse over any underlined term to see the definition in a pop-up window that can be enlarged for better visualization. These definitions can also be consulted in the "Definitions" package from the Containment Tree.

Legend
It is possible to use the items in the Legend to filter the related activities.

Figure 10 General Workflow

Configuring a Shared Repository

The use of Boeing's internal tool SRX was used and configured to allow for collaboration by Collins and NASA. A critical step requires a folder structure be created for the Technical Data Package. The creation of the folder structure should consider the model domains that will be exchanged. In the following example a folder structure (Figure 11) was created for CLIN4 technical data package for exchange of models in the domains MBSE and MBSA.

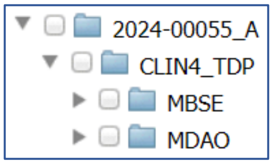


Figure 11 TDP Model Folder Structure

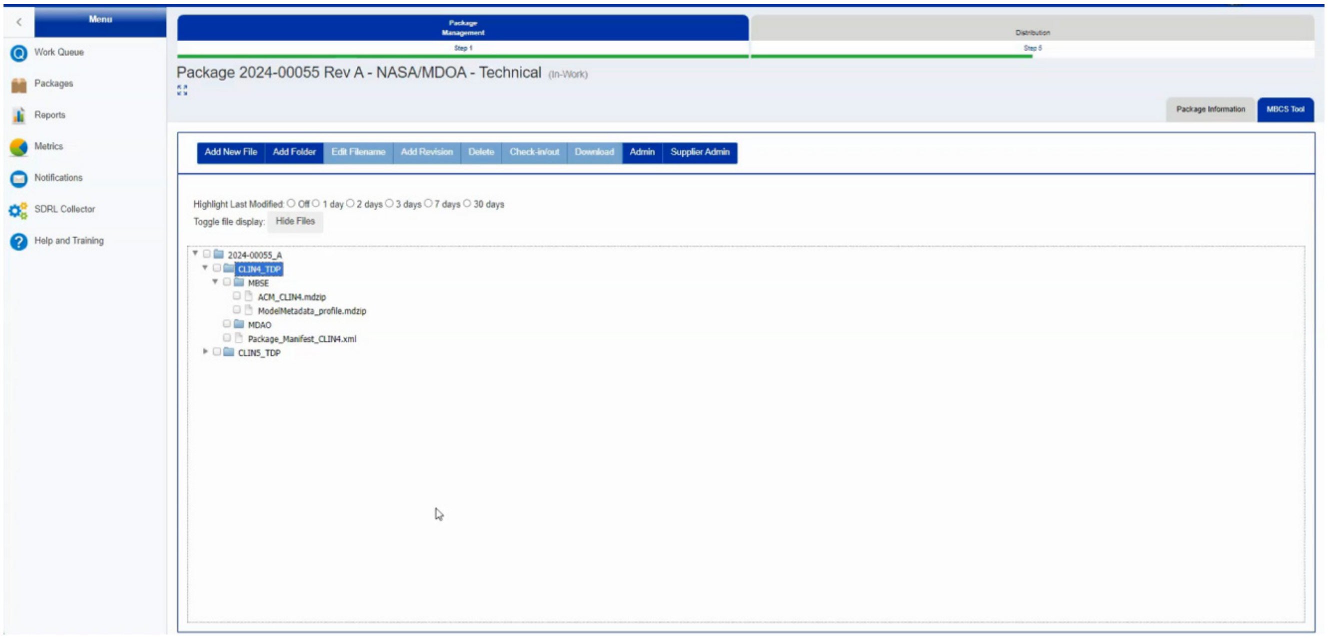


Figure 12 SRX Tool - Shared Repository

Model Preparation

Attached Manifest

Model Preparation is another step in the general workflow and was demonstrated as part of the project milestones. Below is the 3D MBD Model Preparation used for this demonstration. The 3D MBD Model required an attached model manifest. The model manifest would be included in the Technical Data Package. The files for the 3D MBD domain are 3D MBD .vsp3 and the Model Manifest .xml make up the Model Manifest (Figure 13). In this case the manifest is attached and not embedded.

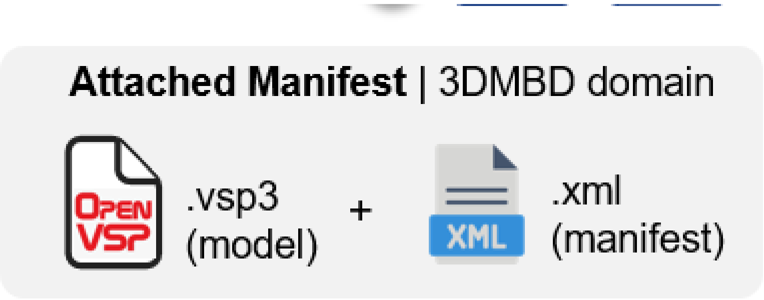


Figure 13 Attached Manifest for 3DMBD domain

A 3D Model Manifest Editor was utilized to prepare the manifest and exported to a .xml file. Using the 3D Model Manifest Editor (Figure 14) the user is able to access the data from the .xml file to view and edit the information as necessary.

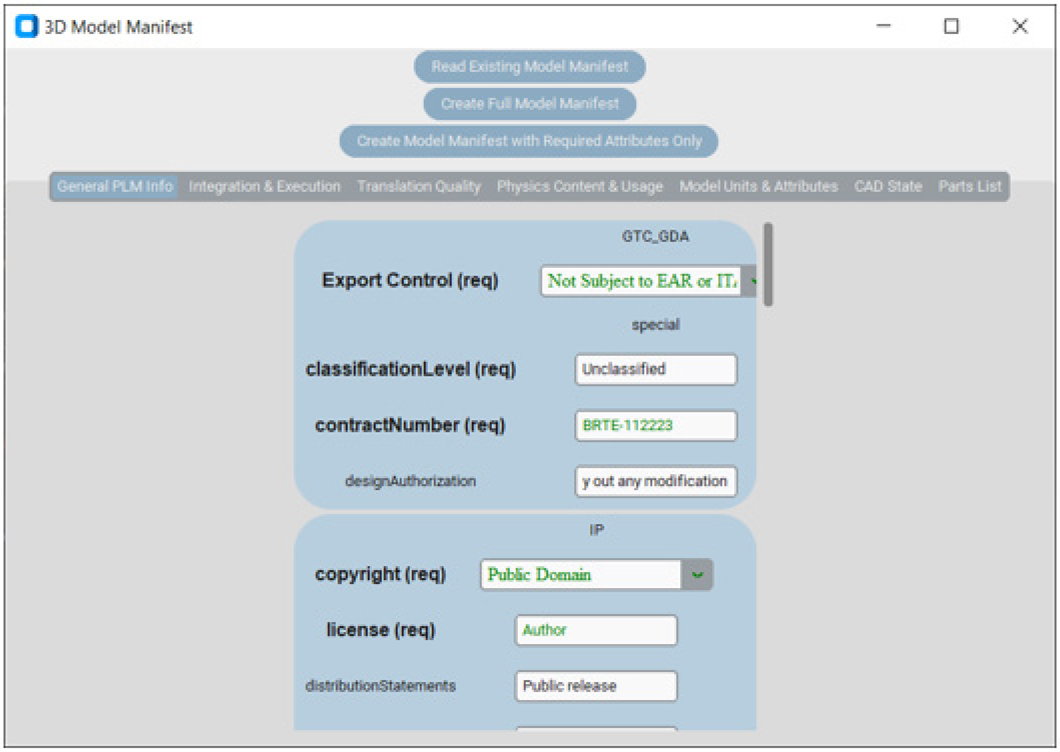


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Figure 14 3D Model Manifest Editor

Embedded Manifest

As mentioned, there are two approaches to creation of a model manifest if available in the tool an embedded manifest may be used. To prepare the MBSE Model for exchange through the Technical Data Package, a Metadata profile was used to create the Model Manifest embedded in o the same model. This was accomplished within the Cameo tool. In the Cameo tool the metadata profile was applied to the model and a .mdzip was created (Figure 15) to exchange the MBSE model and embedded manifest.

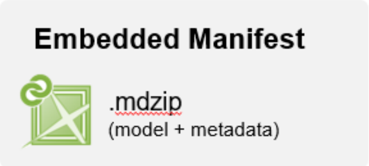


Figure 15 Embedded Manifest MBSE Domain

MBSE Reference Model

The following reference model template was created for the MBSA&E project. The OEM Reference Model should be used in the development of Architecture Models using Cameo and sysML. The containment Tree of the Reference model follows a hierarchy based on system of interest or component tiers. The root of the containment tree are folders containing information about the top tier product/system/component. For each level of decomposition there is a folder for each behavior, components, requirements of the product, system or com ponent and a block that represents it. The pattern of hierarchy will follow until the lowest tier of model architecture is decomposed. The dashboard is the diagram showing the overview of the model and links to the main model elements and diagrams. It can be seen in the containment tree as "_Views" folder (Figure 16). The dashboard (Figure 17) is divided into sections: the top are links to the model manifest and the Element Metadata table, the right are resources like allocation matrices, the center or main section is the model architecture area. The model architecture is horizontally divided by Logical Architecture (Block Definition Diagrams and Internal Block Diagrams), Functional Architecture (Use Case Diagrams and Activity Diagrams) and Requirements. Vertically the model is divided by system tiers, and is classified as OEM, Common Model and Supplier areas. The information in the tiers depicts the working domain of each party involved and may require obfuscation to protect intellectual property. The intent of the Reference Model template is to allow modelers a starting point with which to replace real architecture in the blocks and diagrams, while keeping the folder structure and dashboard intact. Once the Reference Model has been populated with System of Interest content development may commence. At the point where the Reference Model contains the necessary information for development it is then transitioned to a Skeleton Model.

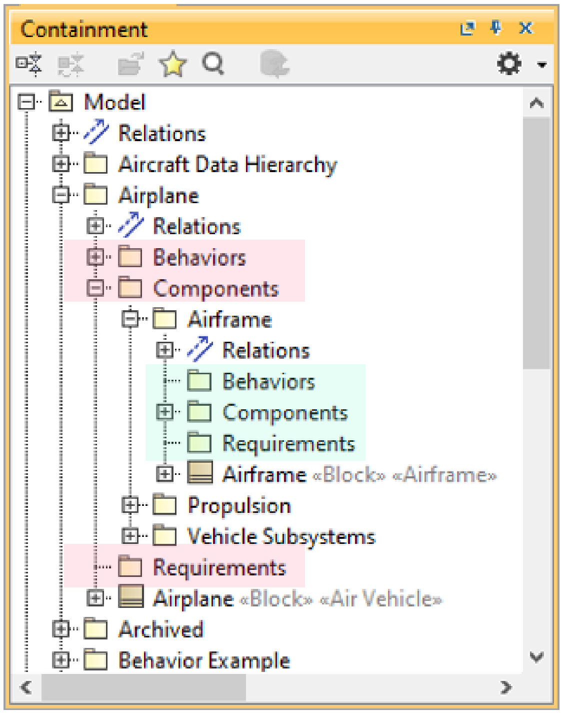


Figure 16 Containment Tree for Reference Model Template

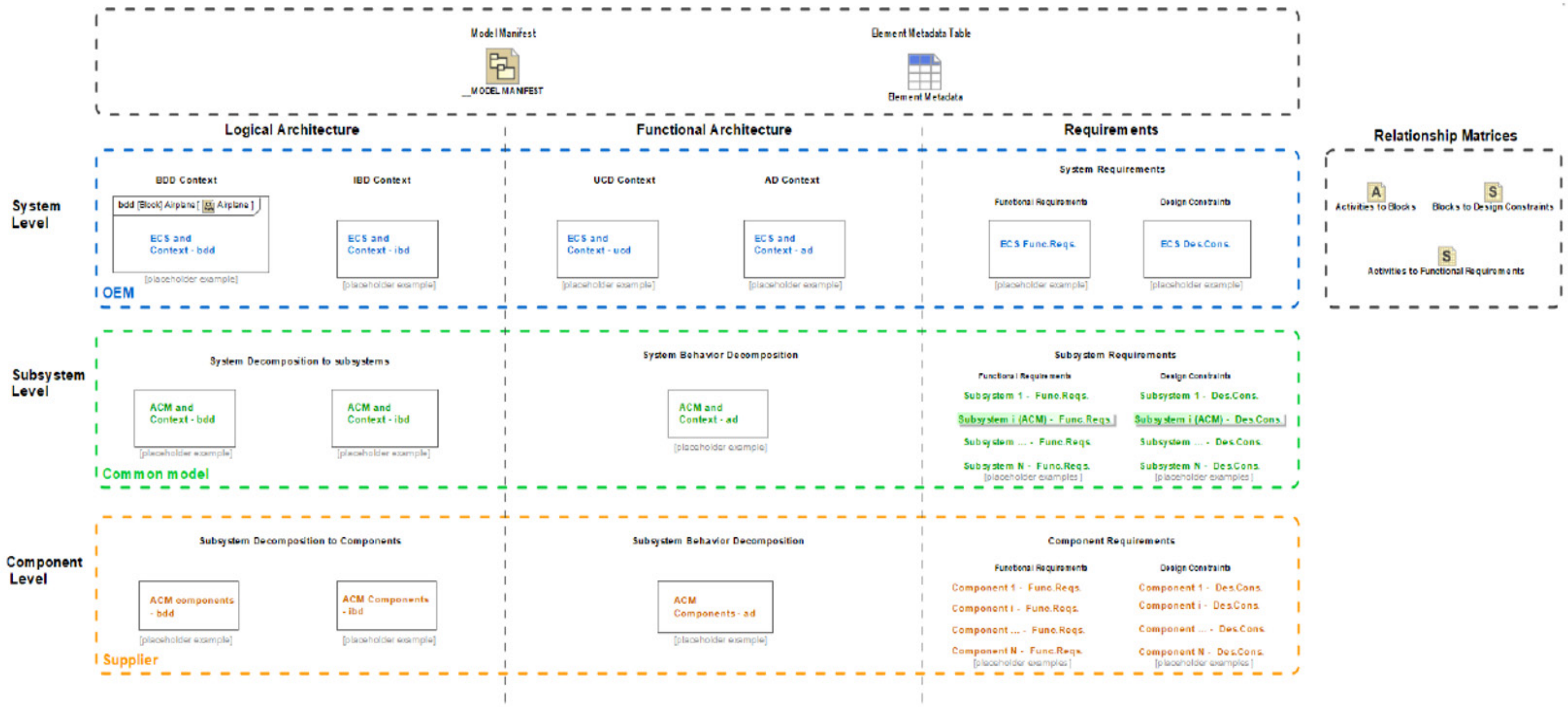
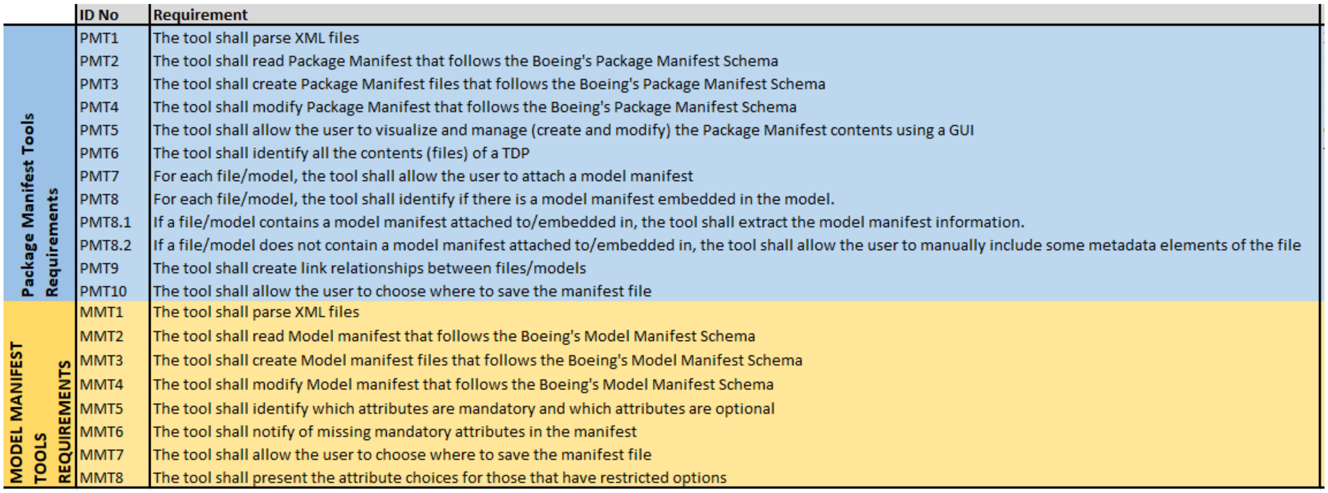


Figure 17 Dashboard for the Reference Model Template

Tool Agnostic Requirements

The following requirements were developed as examples to assist in future tool acquisition by the NASA MBSA&E when implementing the general workflow. Because it is each project and stakeholders may have unique needs regarding tools, the Boeing team has experience developing tool agnostic processes which would drive the tool agnostic requirements. The Boeing team considered the NASA team may not have the same experience in the developing such requirements and have provided NASA with the example specific to Package Manifest Tools and Model Manifest Tools (Figure 18).



	ID No	Requirement
Package Manifest Tools Requirements	PMT1	The tool shall parse XML files
	PMT2	The tool shall read Package Manifest that follows the Boeing's Package Manifest Schema
	PMT3	The tool shall create Package Manifest files that follows the Boeing's Package Manifest Schema
	PMT4	The tool shall modify Package Manifest that follows the Boeing's Package Manifest Schema
	PMT5	The tool shall allow the user to visualize and manage (create and modify) the Package Manifest contents using a GUI
	PMT6	The tool shall identify all the contents (files) of a TDP
	PMT7	For each file/model, the tool shall allow the user to attach a model manifest
	PMT8	For each file/model, the tool shall identify if there is a model manifest embedded in the model.
	PMT8.1	If a file/model contains a model manifest attached to/embedded in, the tool shall extract the model manifest information.
	PMT8.2	If a file/model does not contain a model manifest attached to/embedded in, the tool shall allow the user to manually include some metadata elements of the file
	PMT9	The tool shall create link relationships between files/models
	PMT10	The tool shall allow the user to choose where to save the manifest file
MODEL MANIFEST TOOLS REQUIREMENTS	MMT1	The tool shall parse XML files
	MMT2	The tool shall read Model manifest that follows the Boeing's Model Manifest Schema
	MMT3	The tool shall create Model manifest files that follows the Boeing's Model Manifest Schema
	MMT4	The tool shall modify Model manifest that follows the Boeing's Model Manifest Schema
	MMT5	The tool shall identify which attributes are mandatory and which attributes are optional
	MMT6	The tool shall notify of missing mandatory attributes in the manifest
	MMT7	The tool shall allow the user to choose where to save the manifest file
	MMT8	The tool shall present the attribute choices for those that have restricted options

Figure 18 Sample Tool Agnostic Requirements

MBSE Architecture Model

The following Architecture Model was exchanged to demonstrate part of the Narrow Sharing and Collaboration portion of this project. Collins provided the Air Cycle Machine architecture model to demonstrate white box, grey box and black box concepts. For narrow sharing the Air Cycle Model provided was configured in black box to protect intellectual property of the Air Cycle Machine components.

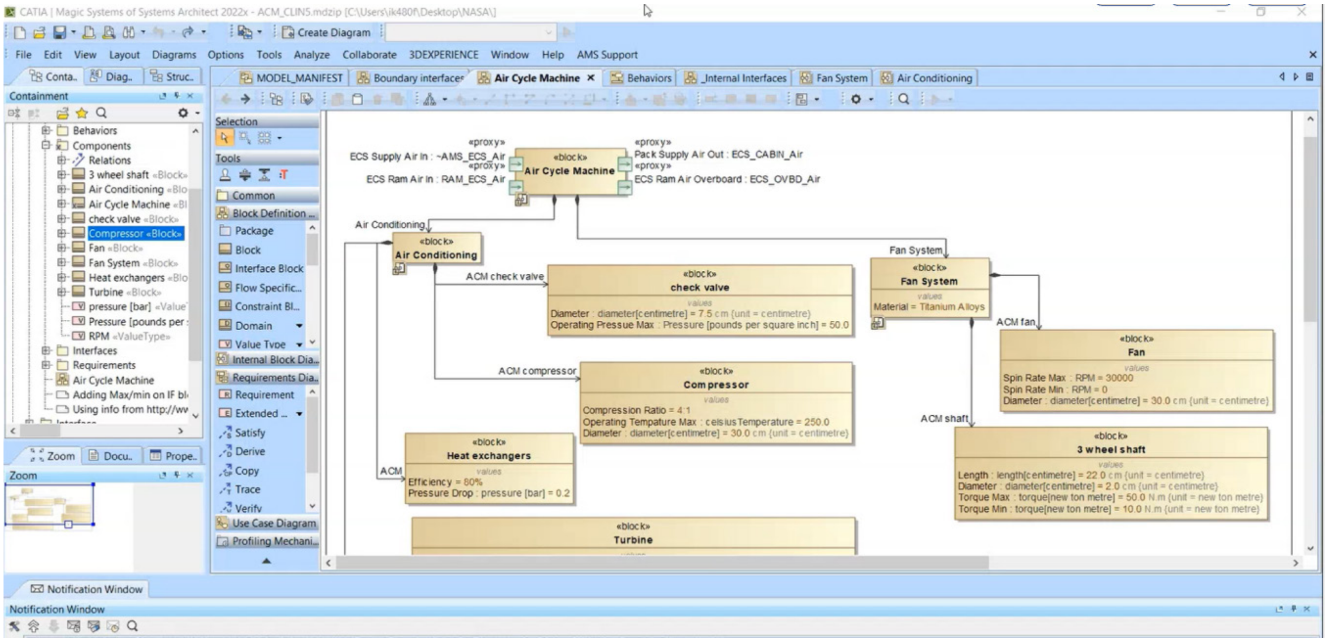
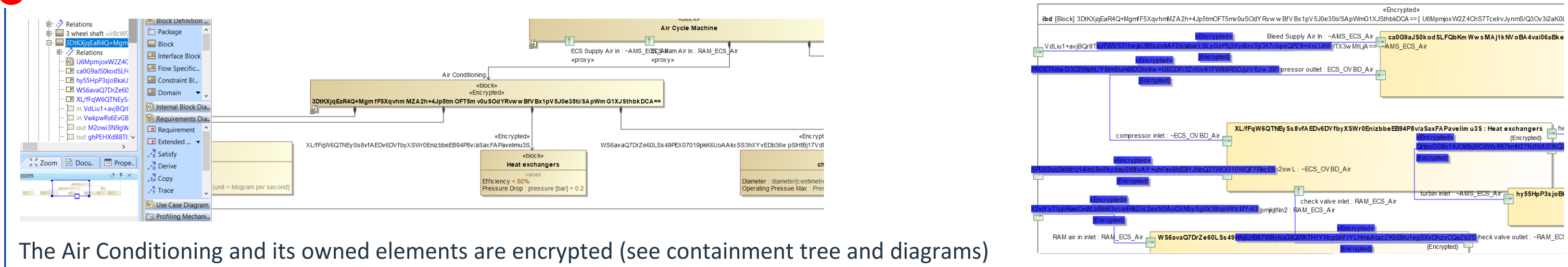


Figure 19 Architecture Model of Air Cycle Machine

MBSE Obfuscation

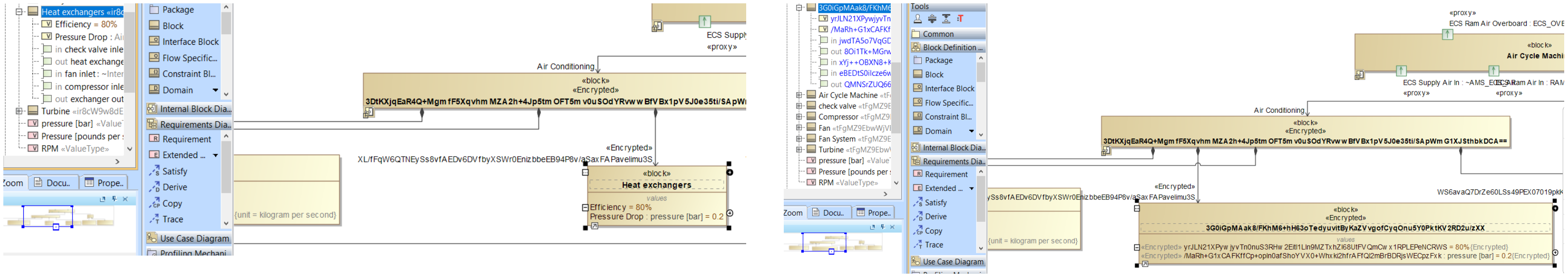
The following figures are results of encryption and de-encryption of the element “Heat Exchange” within the MBSE Air Conditioning Model. The Collins Architecture Model was also used to demonstrate the encryption (Figure 20) and decryption (Figure 21) capabilities being investigated during the project.

c



The Air Conditioning and its owned elements are encrypted (see containment tree and diagrams)

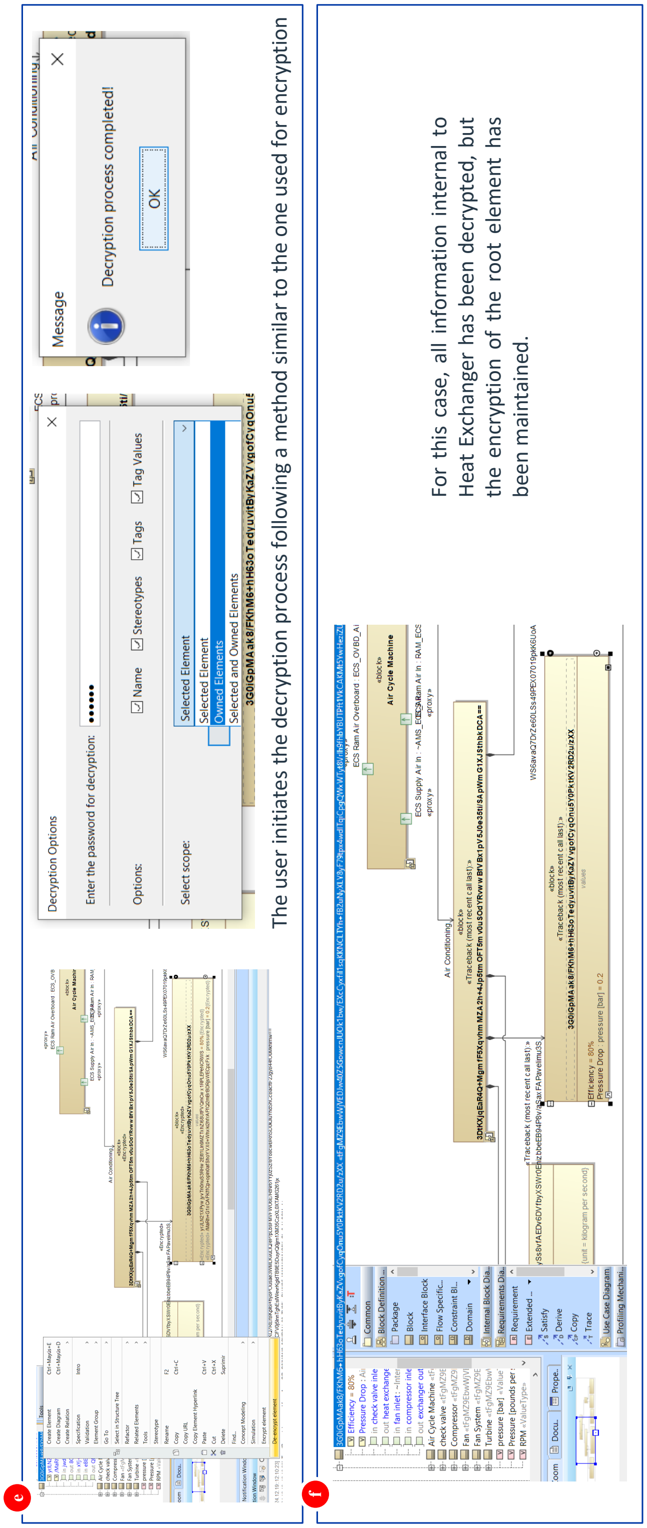
d



The user iterates to encrypt the element “Heat exchangers”, one level below the Air Conditioning, and its owned elements

Figure 20 Encryption of Air Conditioning Architecture Model

Decryption demonstration using the internally developed Boeing Encryption capability. The technology is still being refined and is not yet being made available to external parties, the intent is to be able to bring this to industry.



Decryption Options

Enter the password for decryption: ••••••

Options: ☑ Name ☑ Stereotypes ☑ Tags ☑ Tag Values

Select scope: Selected Element
Selected Element
Owned Elements
Selected and Owned Elements

Message

Decryption process completed!

OK

The user initiates the decryption process following a method similar to the one used for encryption

For this case, all information internal to Heat Exchanger has been decrypted, but the encryption of the root element has been maintained.

Efficiency = 80%
Pressure Drop : pressure [bar] = 0.2

Figure 21 Decryption using Boeing Internal Tool

Behavioral Domain Obfuscation

The following is the resultant sysMBD Simulink FMU ECS Model provided by Collins for use in the exchange for the Narrow Sharing approach portion of the ECS. The obfuscation method is an Functional Mockup Interface (FMI) standard, an industry standard that is used to deliver a black box model or FMU, where only interfaces to the model are made available to the OEM in this case Boeing.

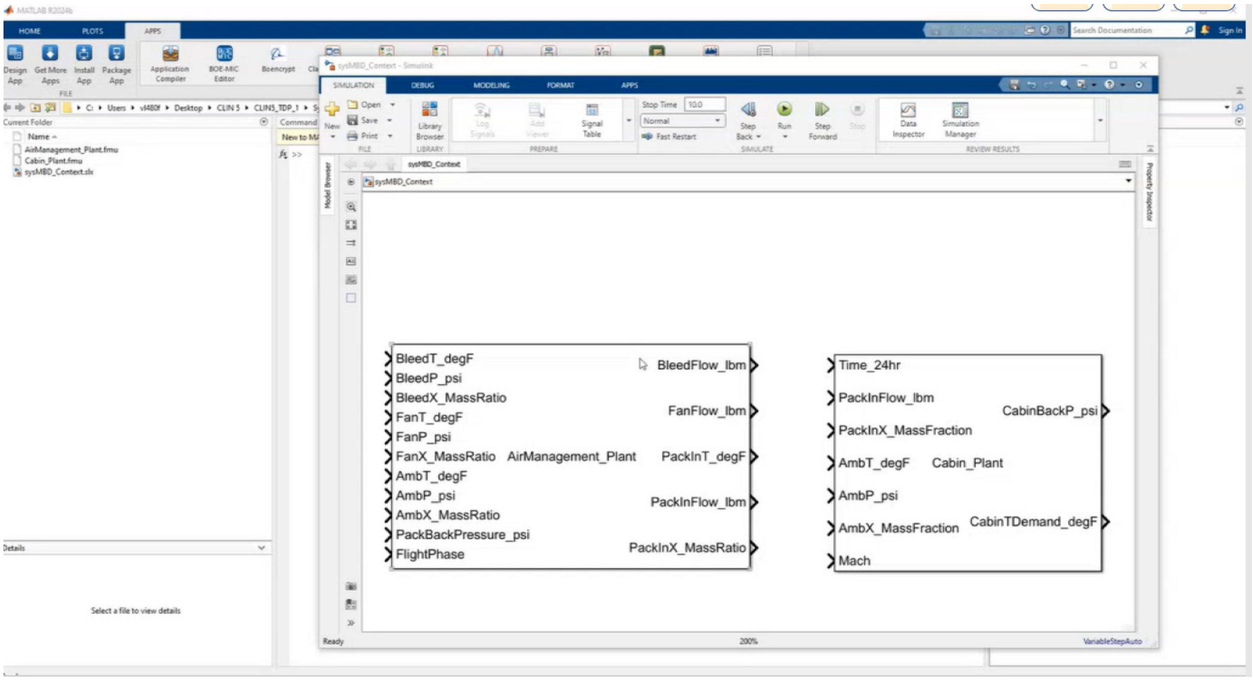


Figure 22 Simulink FMU Model

Conclusion

In conclusion this project brought forth an opportunity to bring together in a more cohesive manner many of concepts and best practices that had been implemented between Boeing and its supplier partners. The goals and objectives met by this project shed light on gaps in the concepts and practices to advance industry. The area of Intellectual Property is of high concern when collaborating and tools have been found to lack the capabilities at this time, however Boeing is working to remedy this with internal development. Providing the necessary tools and processes to mature the product lifecycle from conceptual design to in service is no small feat. Bringing the tool agnostic workflow with the underlying engagement framework to the conceptual design phase of MBSE to MBSA has been a unique opportunity. Additional proof of concepts using the general workflow are suggested with multiple parties and tools that NASA will acquire.