Assessing Model Based Exchange Capabilities

Understanding Digital Collaboration Tools & Supplier MBE Capabilities to Unlock Value

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GLOBAL PRODUCT DATA
INTEROPERABILITY
SUMMIT 2022

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Agenda

1. **Problem/Overview**

2. **Model Based Exchange Tool Capability Assessment**

   - **Assessment Overview**

   - **Requirements Development for Assessment Tool**

   - **Tool Implementation**

   - **Results and Data Driven Feedback**

3. **Supplier MBE Capability Assessment**

   - **Assessment Overview/Value**

   - **Assessment Flow**

   - **SCA Questionnaire (Supplier Self Assessment)**

   - **SCA Combability Test (Data Integrity)**

Vision
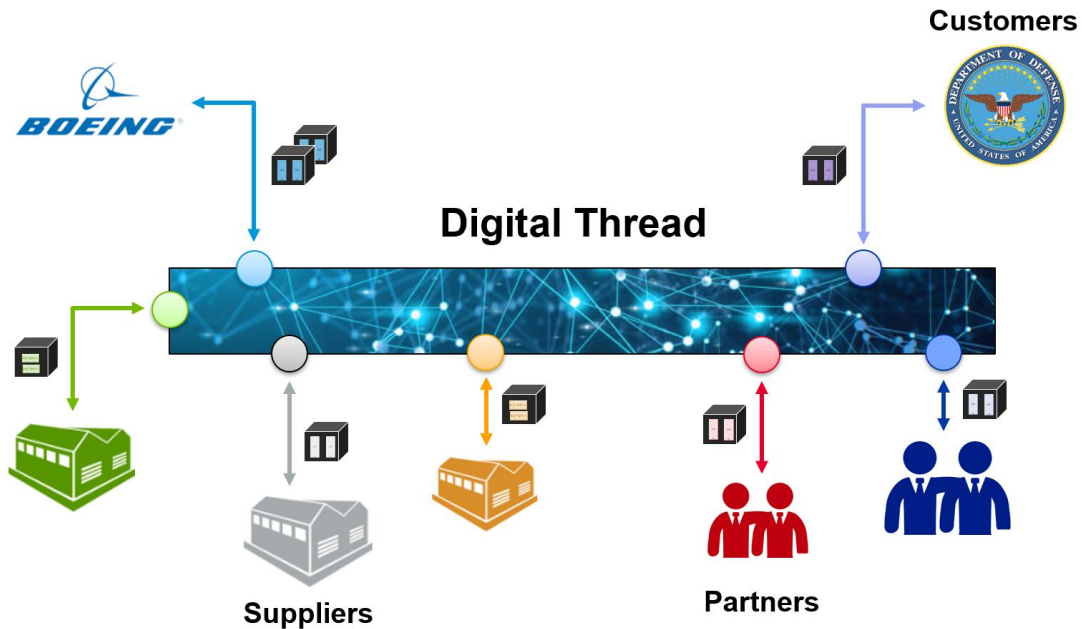
- ✓ driving quality across value stream
- ✓ improving engineering integration and efficiency
- ✓ ensuring data & architecture interoperability

What's the problem?

- *MBE Collaboration* with *Suppliers & Partners* has been underserved in industry Digital Transformations.
- Exchange of Technical Data is mostly *document-*based and/or model *"throw over the wall"*, leading to rework and cost assertions.
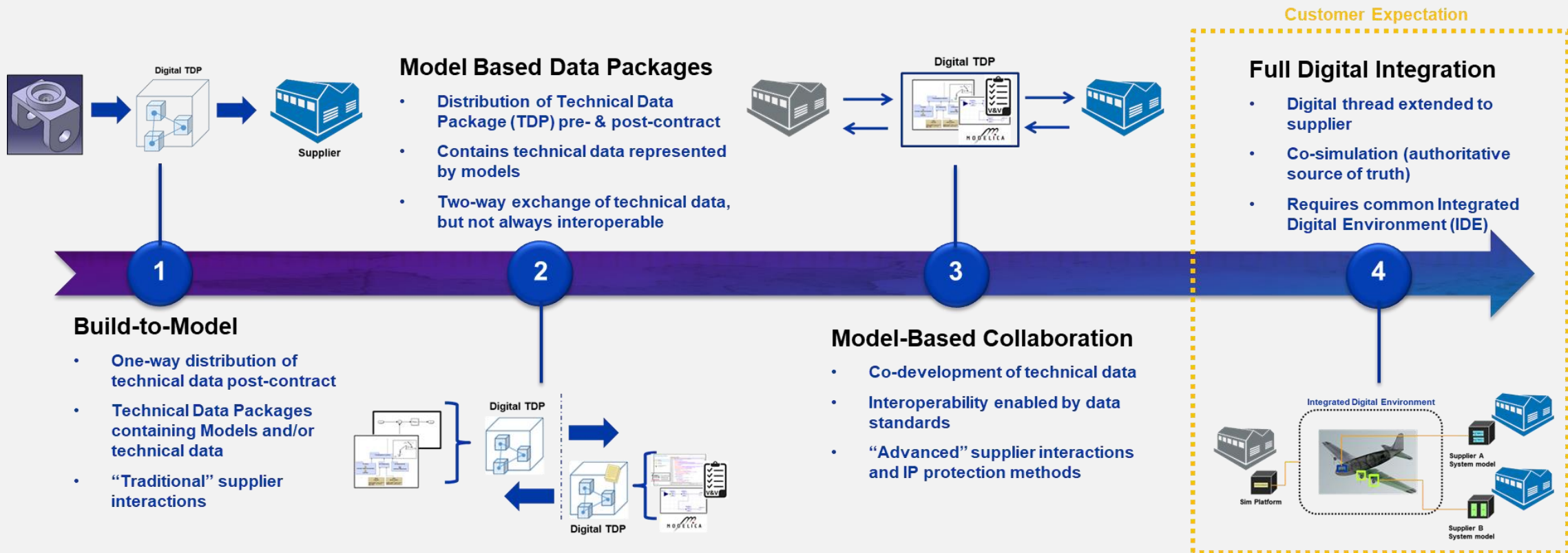
How do we solve it?

- Establish and mature Supplier MBE processes, data and tools – leveraging **data interoperability standards**.
- Guide Suppliers and set clear expectations for collaboration that aligns with Customer needs
- Validate processes, data, and tools through MBE Pathfinders with Suppliers

Extending the Digital Thread to Primary Stakeholders

OEMs and Suppliers must use Digital Engineering (DE) tools and processes to design, develop, test, verify, validate, and certify systems

Customer Expectation

Model Based Data Packages

- Distribution of Technical Data Package (TDP) pre- & post-contract
- Contains technical data represented by models
- Two-way exchange of technical data, but not always interoperable

Full Digital Integration

- Digital thread extended to supplier
- Co-simulation (authoritative source of truth)
- Requires common Integrated Digital Environment (IDE)

Build-to-Model

- One-way distribution of technical data post-contract
- Technical Data Packages containing Models and/or technical data
- "Traditional" supplier interactions

Model-Based Collaboration

- Co-development of technical data
- Interoperability enabled by data standards
- "Advanced" supplier interactions and IP protection methods

New Model Based Exchange (MBX) tools are required to enable digital exchange and collaboration

# Assessing New Tools for Digital Exchange & Collaboration

Emerging technology, tools, and user stories require formal assessment and evaluation
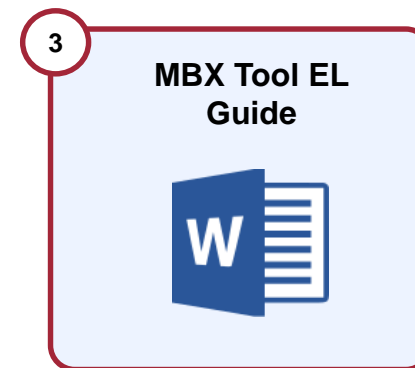
Our approach to fill this knowledge gap is to:

Develop a consistent, unbiased, approach to evaluating MBX tool capabilities

1   MBX Capabilities Evaluation Tool
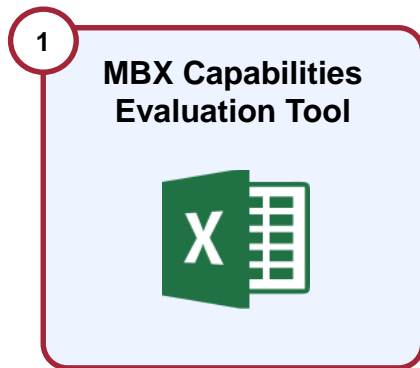
Utilize evaluation results to drive necessary tool enhancements

2   Evaluation Summary Report
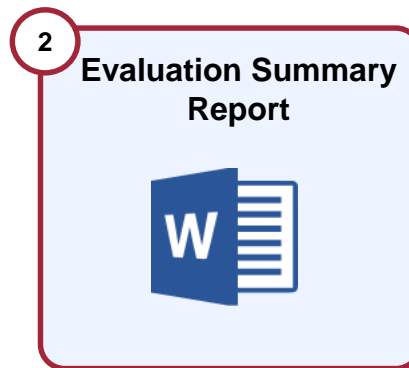
Create better awareness of tool capabilities and deliver the "how to" to programs

3   MBX Tool EL Guide

Assumptions:

- MBX tools would be evaluated separate from any supporting architecture

- Evaluations would be performed by, or with assistance from, users with extensive tool knowledge

- Prior knowledge of or experience with MBE processes would not be necessary to use the Evaluation Tool

Developing a Requirements Driven MBX Capability Evaluation Tool

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Requirements were derived from 75+ user stories, defining interactions enabling the Supplier Engagement Framework

1

MBX Capabilities Evaluation Tool

➢ **Evaluates 150+ Requirements**

➢ **Includes 23 Standards**
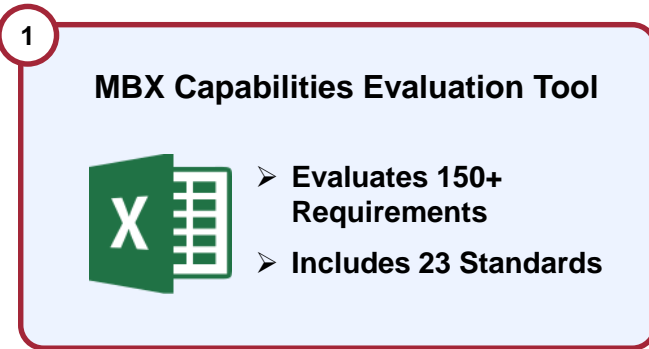
Example Requirements →

Requirements were divided in four categories:

1. **Functional** – How efficient/well designed is the tool?

2. **Repository** – Does the tool have an adequate repository for data management?

3. **Exchange Capability** – How well does the tool facilitate digital exchange and collaboration?

4. **Interoperability** – How well does the tool support brokering and translating capabilities?

Data scalability	10107	Can the tool be scaled for data?
Users scalability	10108	Can the tool be scaled for users (e.g. grant access to external users/stakeholders)?
OS Compatibility	10127	Is the tool OS-agnostic?
Backwards Compatibility	10210	Is the tool compatible with previous versions of the same tool?
Training availability	10105	Is there adequate training available for the tool?
Tool learning	10111	Does the tool require an extensive (or expensive) training in order to be used effectively?
License fee - Supplier	10112	Is the tool affordable for the supplier?

Package Editor	10322	Does the tool allow for the user to open and edit data within a package?
Package Hierarchy/Structure	10310	Does the tool support hierarchical & structured packages?
Limited Distribution	10302	Does the tool control access to packages based on user role?
Access Restriction	10303	Does the tool control access to packages based on data sensitivity?
Access restriction management	10319	Does the tool allow to modify access privileges to a (set of) user(s) based on their role?
Temporary access restriction	10320	Does the tool allow exceptional access restrictions to a (set of) user(s) based on their role?
Reader/Editor Restrictions	10304	Does the tool enforce reader/editor restricted roles?

Ability to Accept/Reject Change	10409	Does the tool allow to comment on supplier modifications to data within the tool?
Comments on Packages	10414	Does the tool allow the creation of comments linked to packages for general purposes?
Configuration Control	10412	Are data within the tool configuration controlled?
Authoritative Data	10413	Does the tool track who authored data within the tool?
Package Manifest	10201	Are models within a package documented, in a manifest, with a stated purpose?
Meta-model	10202	Are model relationships described within the manifest?
Synchronization	10203	Is there evidence that the models within a package are synchronized?

ISO 10303-243 - MoSSEC	EL3A & 3B	20100	Industrial automation systems and integration — Part 243 (MoSSEC)
DDP	EL3A & 3B	20200	Digital Data Package - ProSTEP IVIP
ISO 14721 - OAIS	EL3A & 3B	20300	Space data and information transfer systems — (OAIS)
LOTAR	EL3A & 3B	21800	LOng Term Archiving and Retrieval NAS9300-P500, P520
TDP Message Std.	EL3A & 3B	20400	Technical Data Package Message Standard
OSLC	EL4	20500	Open Services for Lifecycle Collaboration
DCP	EL4	20600	Distributed Co-Simulation Protocol

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Tool Features that Drive Consistency

A standardized evaluation approach was implemented to reduce subjectivity and ambiguity

Each requirement row contains features to assist the evaluator:

EL = Engagement Level (0-4)

Category	Tool feature	ID No.	Capability	Applica-bility	EL0	EL1	EL2	EL3A	EL3B	EL4
Data exchange	Supplier Package Reception	10401	Can the supplier use the tool to receive a package ?	☑	✔	✔	✔	✔	✖	✖
	Supplier Package Delivery	10404	Can the supplier use the tool to send a package?	☑	✖	✖	✔	✔	✖	✖

Each requirement has a unique ID No. for analysis.

Each exchange requirement is mapped to an EL capability.

Applicability can be de-selected, tailoring the evaluation for special circumstances.

3	0 stars - Package reception not supported. ▾
3	0 stars - Package reception not supported.
3	1 stars - Package reception supported but tool not conceived for this purpose.
3	2 stars - Exchange limited (e.g. size, number of packages).
2	3 stars - Excellent exchange capabilities.
2	

A weighted value that indicates the level of importance for that capability.

Scoring between 0 and 3 indicating how well a tool incorporates the capability. Each requirement has unique score descriptions to reduce subjectivity.

Detailed testing performed to deliver an unbiased assessment

Evaluation Results Provide Awareness for Tool Capabilities

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A Results Summary table provides capabilities scores in an easy to understand, practical format

	Category	(A) Evaluation results	(B) Average Score			(C) Warning panel
R E S U L T S	FUNCTIONAL	*The tool can be implemented in the company with certain limitations*	2.1	⭐ ⭐ ☆		3 capabilities of interest still to be assessed. In total, 3 not assessed.
	REPOSITORY	*This tool has good capabilities for data management*	1.8	⭐ ⭐ ☆		
	EXCHANGE	*This tool could be used concurrently by different users and exchange data with certain limitations*	1.6	⭐ ⯪ ☆		
	INTEROPERABILITY	*The current category awaits to be evaluated above.*	TBD	☆ ☆ ☆		27 capabilities of interest still to be assessed. In total, 27 not assessed
	ENGAGEMENT LEVEL 0	*The capabilities of this tool will allow a strong EL0 collaboration*	2.7	⭐ ⭐ ⭐		
	ENGAGEMENT LEVEL 1	*The capabilities of this tool will allow good EL1 collaboration*	2.3	⭐ ⭐ ⭐		
	ENGAGEMENT LEVEL 2	*The capabilities of this tool will allow some degree of EL2 collaboration*	1.9	⭐ ⭐ ☆		
	ENGAGEMENT LEVEL 3A	*The capabilities of this tool will allow some degree of EL3A collaboration*	1.2	⭐ ☆ ☆		
	ENGAGEMENT LEVEL 3B	*The capabilities of this tool will allow some degree of EL3B collaboration*	1.3	⭐ ⯪ ☆		
	ENGAGEMENT LEVEL 4	*The capabilities of this tool will for a very poor or no EL4 collaboration*	1.1	⭐ ☆ ☆		EL4 is lacking 2 out of its 2 key capabilities: ID 10418 ; ID 10434

(A) Evaluation Results
Provides a recommendation for usage of the tool based on the numerical score for a given section.

(B) Average Score
Provides the numerical score for the results for a given section. The score is calculated using a calibrated formula.

(C) Warning Panel
Notifies the user if any capabilities were not assessed, or if the tool lacks a **key capability**.

➢ Key capabilities include requirements that are needed for a tool to accomplish a specific EL

➢ Results are put into the context of the Supplier Engagement Framework, to make them easily understandable

➢ Programs can use these results to determine which MBX tool(s) may be needed to facilitate supplier collaboration

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Results from a 2021 evaluation of 10 MBX Tools indicates gaps in key areas

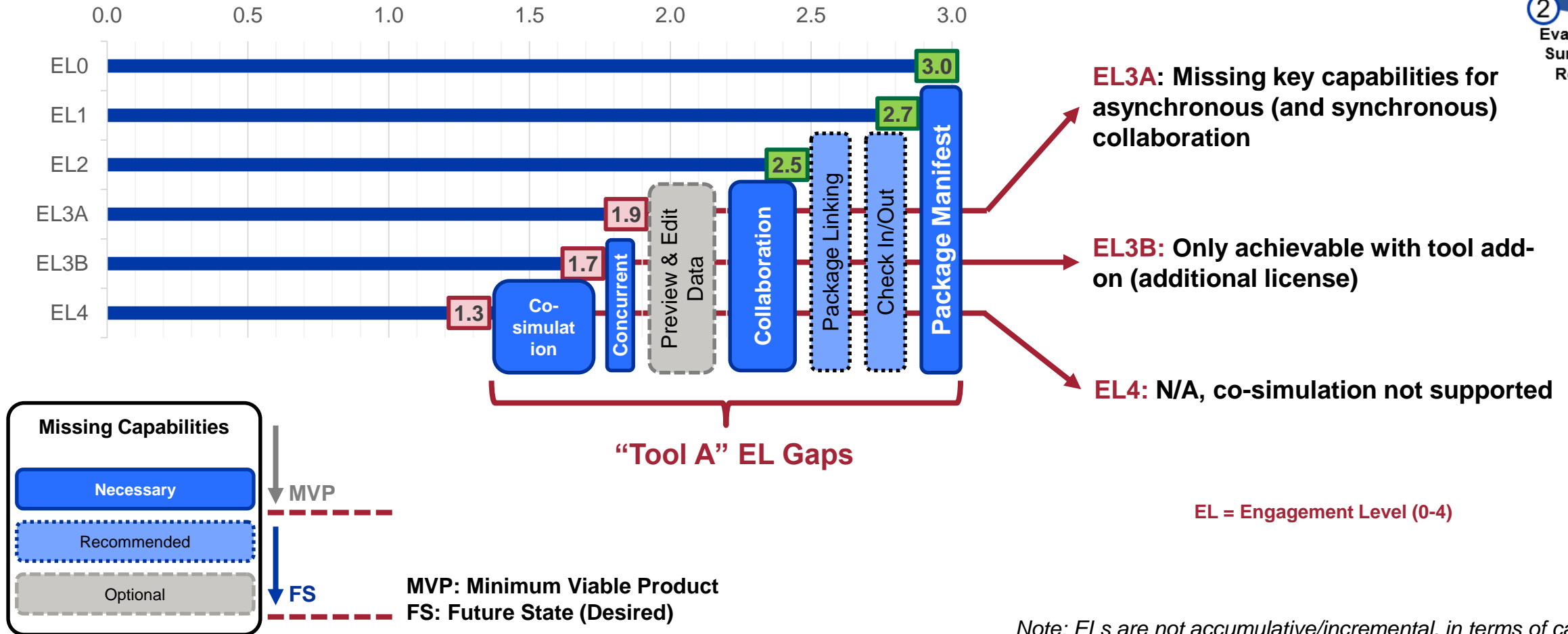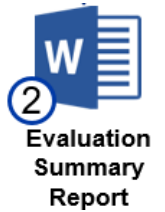Trends from 2021 MBX Tool Capabilities Evaluations
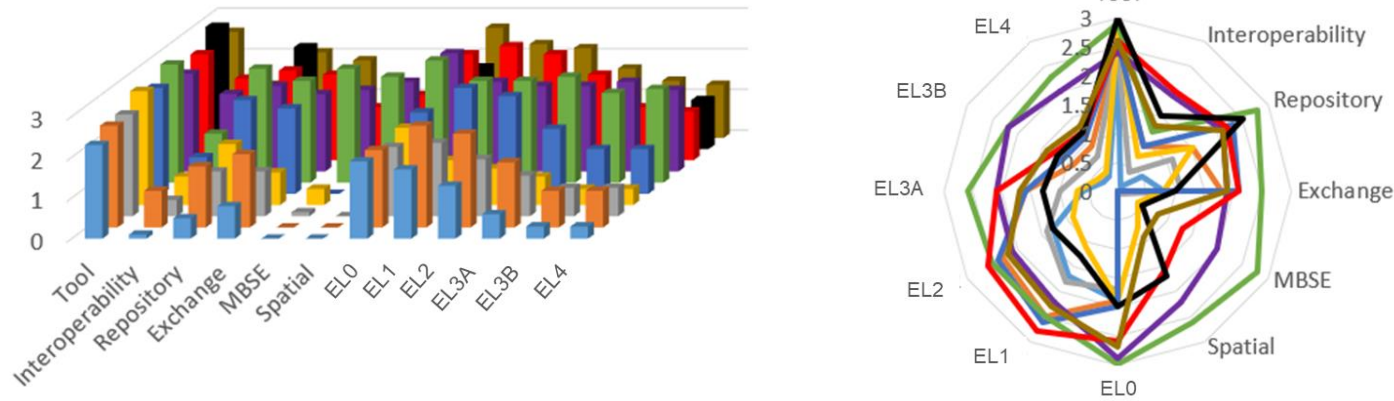
Key Observations:

- ➢ **Lack of robust Engagement Level 3 & 4 Capabilities**
- ➢ **Lack of data standard implementation in available toolsets (industry)**
- ➢ **Domain specific gaps: MBSE (and Spatial) capabilities in current tools**

Results used for gap summary and feedback for vendors

Data Driven Feedback – Example Gap Summary

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Gap summaries provide data to drive tool enhancements (feedback to vendor)


EL3A: Missing key capabilities for asynchronous (and synchronous) collaboration

EL3B: Only achievable with tool add-on (additional license)

EL4: N/A, co-simulation not supported

"Tool A" EL Gaps

Missing Capabilities

- Necessary
- Recommended
- Optional

MVP

FS

MVP: Minimum Viable Product
FS: Future State (Desired)

EL = Engagement Level (0-4)

Note: ELs are not accumulative/incremental, in terms of capabilities

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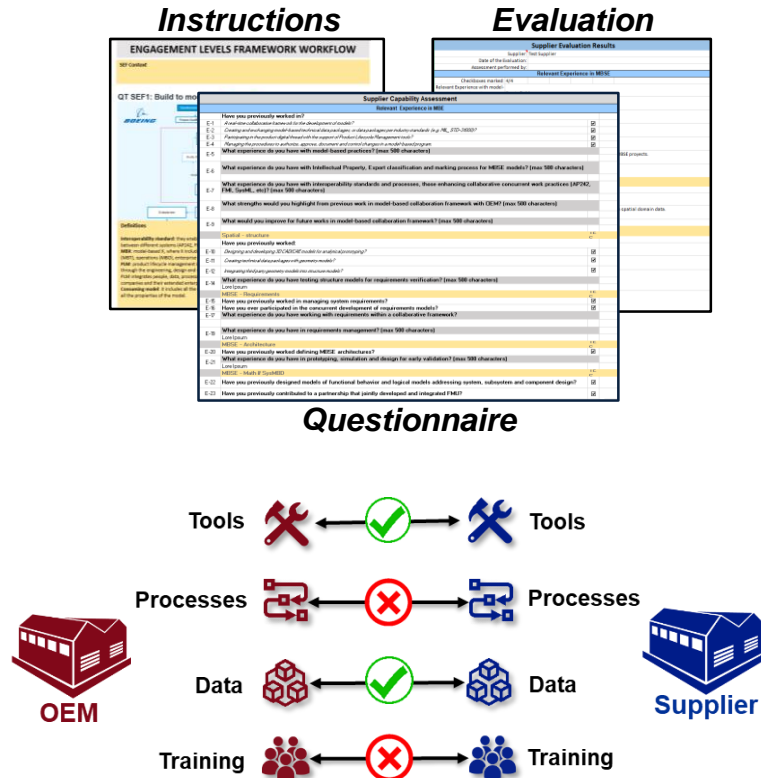## Working with vendors to implement feedback (example)

Priority

- **Package manifest**
  - Align with definition for package manifest (based on TDP Message Header)
  - Export to an .xml file compatible and inclusion into the DDE

- **Other domains, spatial domain oriented**
  - Improve exchange capabilities for non-CAD file formats (e.g., text or models shared as DDE Items and not as Event attachments, which doesn't enable pre-visualization, modification nor revision capabilities, etc.)

- **Configuration management**
  - Enable version control for each data item with restore and compare (e.g., delta) capabilities
  - Access log to shared data (only last access/download is recorded)

- **Collaboration capabilities**
  - Allow further iterations between OEM and vendor(s) in data exchange as DDE
  - Improve revisions capabilities and partial signoff decisions

- **Project tracking**
  - Integrate PM practices (e.g., deadlines, basic KPIs to track progress, etc.)
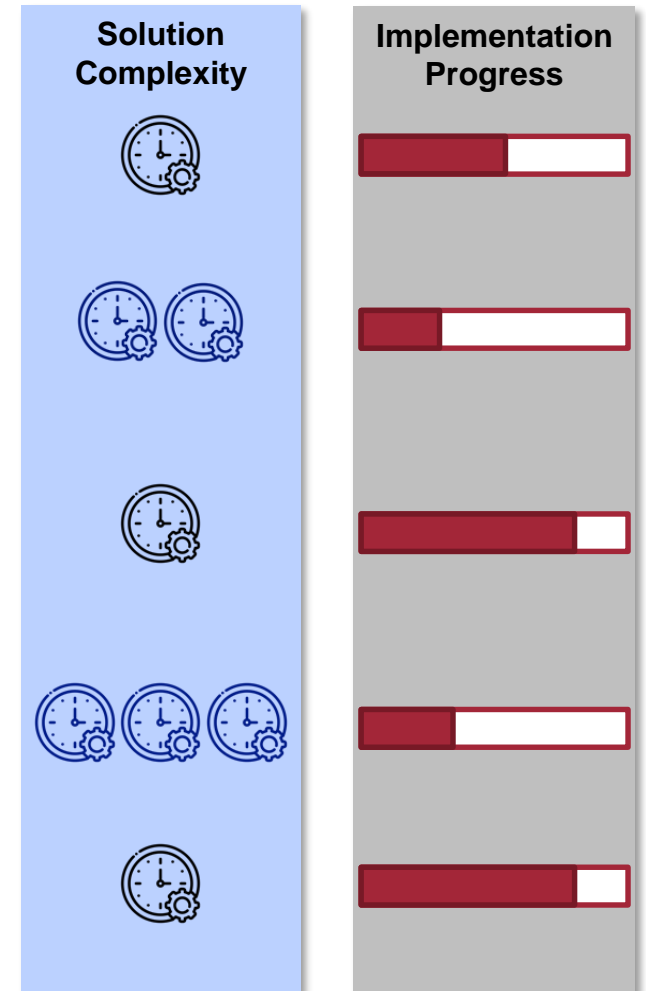
Solution Complexity

Implementation Progress

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How do we determine a supplier's ability to perform to a contract with digital collaboration requirements?

Instructions   *Evaluation*

Questionnaire

Tools ↔ ✔ ↔ Tools

Processes ↔ ✖ ↔ Processes

Data ↔ ✔ ↔ Data

OEM   **Supplier**

Training ↔ ✖ ↔ Training

(A) Supplier MBE Questionnaire (Self Assessment)

- Questions to access suppliers' experience, readiness, and willingness to invest in areas such as:
  - MBSE & product design
  - MBE design & collaboration tools
  - Adaptation of data interoperability standards
- Highlights capabilities in domains of interest, including:
  - Spatial – structures & composites models
  - MBSE – architecture, requirements, & math models
- Includes simple version (for build-to-model suppliers) and full version for suppliers with design authority

(B) MBE Compatibility Tests (Data Integrity)

- Validates suppliers' answers and data quality through practical scenarios using digital models to test:
  - Technical capability in several domains
  - MBX tool usability
  - Standards adoption
  - Model-based related procedures
  - Readiness level to perform collaboration

OEM – Supplier Compatibility is Key for a Successful Collaboration

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MBE Supplier Capability Assessments Create Value
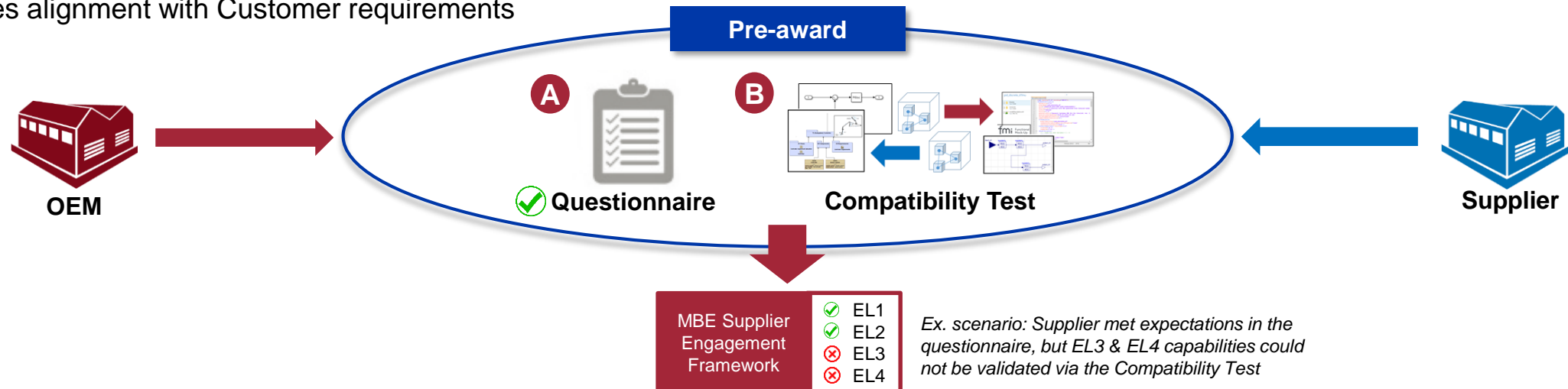
OEM (Developer) Value – Risk Mitigation

Responsible to customer for integrated end item

- Assesses supplier readiness to collaborate in the MBE Supplier Engagement Framework (SEF)
- Provides feedback for selection of the most compatible Suppliers
- Identify Supplier limitations to better adapt the collaboration contract in early phases
- Drive data interoperability into project plans and contracts
- Provides alignment with Customer requirements

Supplier Value – Market Competition

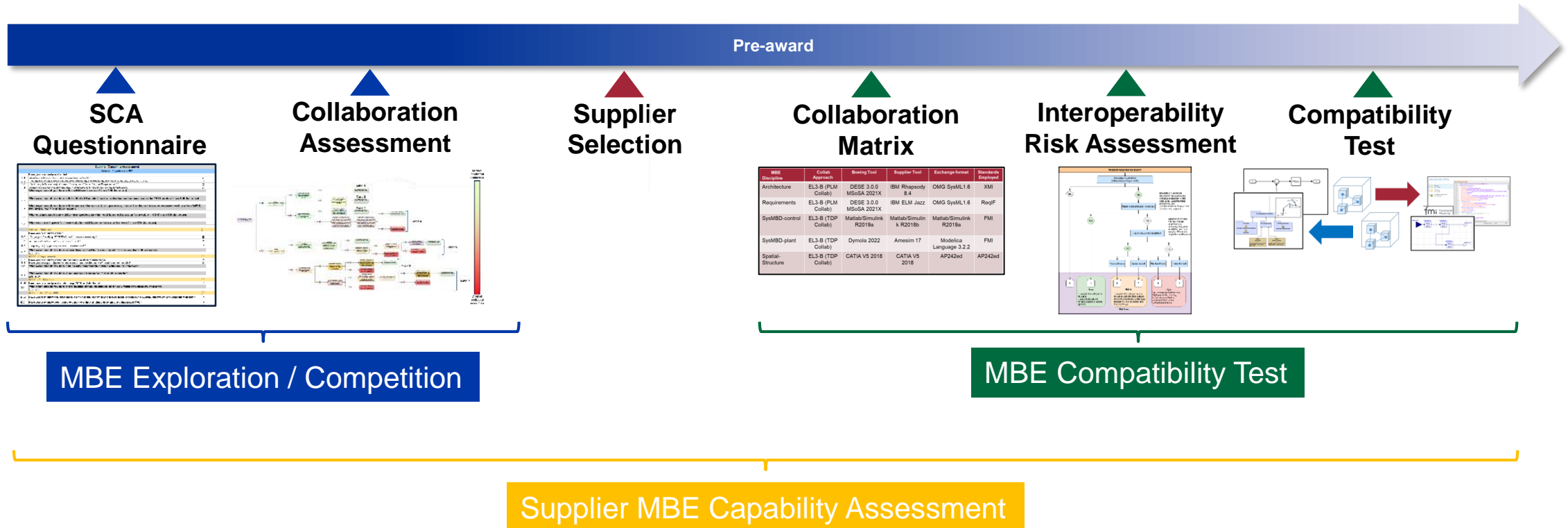**Responsible to developer for allocated portion of the end item**

- Access to a contract with digital engineering/collaboration requirements
- Gain understanding on how to collaborate in the MBE SEF
- Test maturation level in MBSE practices, tools, and procedures
- Identify gaps to collaborate with Developers

Pre-award

A Questionnaire

B Compatibility Test

OEM

Supplier

MBE Supplier Engagement Framework

- ✅ EL1
- ✅ EL2
- ❌ EL3
- ❌ EL4

Ex. scenario: Supplier met expectations in the questionnaire, but EL3 & EL4 capabilities could not be validated via the Compatibility Test

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For Suppliers (or Partners) with responsibility for digital model development (EL2 – EL4)

Pre-award

SCA Questionnaire | Collaboration Assessment | Supplier Selection | Collaboration Matrix | Interoperability Risk Assessment | Compatibility Test

MBE Exploration / Competition

MBE Compatibility Test

Supplier MBE Capability Assessment

Suppliers will need to meet expectations for digital tools, processes, and exchange

Exploring Suppliers' MBE capabilities and their applicability for collaboration in multiple frameworks

AD PLM AG   **Applicable ELs**

Questionnaire sections include:

1. Relevant Experience with MBE
2. Product Engineering & Analysis
3. Tools Implementation
4. Standards Adaption
5. General Modeling Practices

Standard	Interoperability	Domain	AD PLM AG	SCA Ques	SCA CT EL
ISO 44000-44002	business	NA	recommended	yes	none
AADL	data format	architecture	in evaluation	yes	2,3a,3b,4-tbd
AP243 -MoSSEC	processes	model&simulation	recommended	yes	none
FMI	data format	functional	in evaluation	yes	3a, 2
FMU	data format	functional	in evaluation	yes	3a, 3b
IGES	data format	structural		yes	tbd
P510	data format	requirements		yes	2,3a,3b,4
ReqIF	data format	requirements	recommended	yes	2,3a,3b,4
SSP	data format	functional		yes	3a, 2-tbd
STEP (AP242)	data format	structural	recommended	yes	1,2
SysML	data format	architecture	recommended	yes	2
ASME Y14.47	metadata	structural		yes	2to4
BOE-MIC	metadata	structural		yes	2,3a,3b,4
MIL_STD-31000	metadata	structural	in evaluation	yes	2,3a,3b,4
MTDP USAD	metadata	transversal		yes	2,3a,3b,4
XMI	metadata	architecture		yes	2,3a,3b,4-tbd
AP239 ed3 PLCS	processes	transversal	recommended	yes	none
ARP4754	processes	transversal	in evaluation	yes	none
DCP	processes	transversal		yes	4
DO-178	processes	software		yes	tbd
DO-331	processes	software		yes	tbd
NASA-STD-7009	processes	model&simulation		yes	none
OSLC	processes	transversal		yes	none
BOE-SMIC	data format	architecture		no	2,3a,3b,4-tbd
ISO 14306	data format	structural - mbd	recommended	no	
ISO 14739	data format	structural - mbd	recommended	no	
ISO 32000 (3DPDF)	data format	structural - mbd	recommended	yes	1,2,3a
ISO /IEC 15288	processes	software	recommended	no	

Alignment with AD PLM AG – Interoperability Standards for Aerospace & Defense Ed 1.0 recommended standards

Each section address activities in certain domains of interest:

Domain	Description
Composites	Activities related to physical models describing the geometry, inertial properties, material and associated characteristics. Includes structural and composites models.
Requirements	Requirement management related activities (design, validation, verification, traceability) to define the intended product performance and design contains with allocations to design.
Architecture	Activities related to logical models, providing an schematic definition of the product, identifying product elements, connectivity, logical flows and logistical performance characteristics.
Math/sysMBD	Activities related to functional models, which describes the decomposition of product functionalities with performance characteristics and interfaces.
Multi-Physical	Activities related to model files involving different physical domains such as electrical, thermal, or aerodynamics.

Assessment of Standards
- Data formats (STEP, ReqIF, …) – easy to assess
- Metadata (MIL-STD-31000B, ASME, P510) – can be assessed by checklists
- Processes (MoSSEC, AP239) – difficult to assess

✓ Interoperability
✓ Data integrity/loss
✓ Conf. Management

Questionnaire results provide valuable data for programs and determines path forward for SCA

Data from the self assessment informs two subsequent activities:

1 **Evaluator Guide**

- Assists the Evaluator with interpreting Supplier responses
- Facilitates the transfer of data to a Supplier MBE Capabilities database (internal only)
  - Database will be used by programs to understand supplier landscape
  - Can also be used to track industry Digital Transformation progress

2 **Collaboration Assessment**

- Used to determine if it is worth proceeding with the Combability Test
- Outcomes of the compatibly test are predicted and summarized in 7 cases
  - Outcomes based on Supplier Responses
  - Cases correspond to the amount of resources needed to proceed

Proceeding with the SCA requires resources which a program may not be willing to commit

Collaboration assessment informs the compatibility test to determine how OEMS & Suppliers exchange data

MBE Discipline	Collab Approach	Boeing Tool	Supplier Tool	Exchange format	Standards Employed
Architecture	EL3-B (PLM Collab)	DESE 3.0.0 MSoSA 2021X	IBM Rhapsody 8.4	OMG SysML1.6	XMI
Requirements	EL3-B (PLM Collab)	DESE 3.0.0 MSoSA 2021X	IBM ELM Jazz	OMG SysML1.6	ReqIF
SysMBD-control	EL3-B (TDP Collab)	Matlab/Simulink R2019a	Matlab/Simulink R2018b	Matlab/Simulink R2019a	FMI
SysMBD-plant	EL3-B (TDP Collab)	Dymola 2022	Amesim 17	Modelica Language 3.2.2	FMI
Spatial-Structure	EL3-B (TDP Collab)	CATIA V5 2018	CATIA V5 2018	AP242ed	AP242ed

Collaboration Matrix:

- Identifies which tools OEMs & Suppliers will use for design activities and MBX as part of the Project MBE Plan
- Tools would be based on project objectives and results form the SCA Questionnaire

Activities can be iterated until an acceptable risk level is achieved
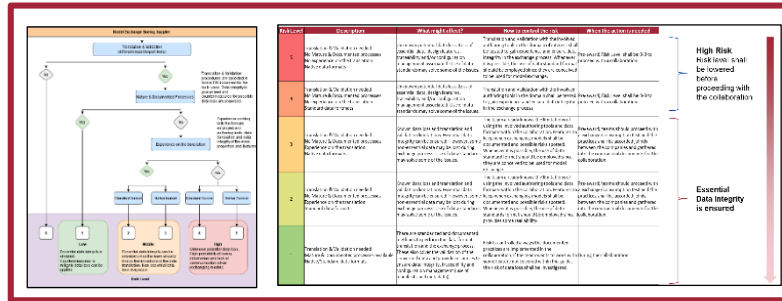
Interoperability Risk Assessment:

From the Collaboration Matrix, risk is anticipated based on:

- Data formats used (native vs. neutral/standard)
- Availability of mature (and documented) processes
- Experience with translation and validation translation

The Risk Assessment Matrix determines if the Compatibility Test can be successfully executed

- If too many resources are needed, the program can choose to abort the SCA
- If risk is deemed totally unacceptable (and cannot be mitigated), the program may want to consider alternative suppliers at this point

Proving Compatibility

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SCA Questionnaire · Collaboration Assessment · Supplier Selection · Collaboration Matrix · Interoperability Risk Assessment · Compatibility Test

Simulating a "real-world" collaboration to uncover issues prior to contract negotiation

Evaluator guide

- Decision process (distribution tool, data format)
- Steps to perform the test
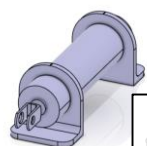- Data to send to supplier
- Questions for the supplier to evaluate

Supplier guide

- EL context
- Steps to perform the test
- Customer expectations
- Tool environment (guide)

Evaluation sheet

- Questions to evaluate capabilities
- To be filled and returned back to evaluator

Developer

Documents package

Separate documents and files for:
- CAD files (STEP format)
- Requirements (doc format)
- Drawings (pdf format)
- Model manifest (txt format)
- Package manifest (txt format)

TDP (2 OPTIONS)

Supplier

Model package

The package includes a package manifest (txt format) and a CAD model (STEP format) with the following information:
- Requirements
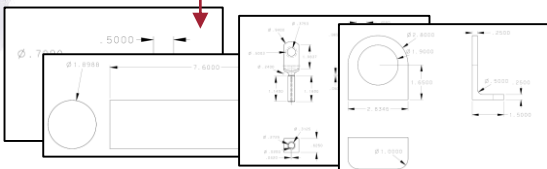- Model dimensions and annotations
- Model metadata

Actuator CAD.stp

Act_65B41247_noreq
Act_Base_noreq
Act_Bracket_noreq
Act_Rod_noreq-.1

Act_65B41247_Requirements
Act_Base_Requirements
Act_Bracket_Requirements
Act_Rod_Requirements

Requirements
- Manufacturing001=The piece shall be manufactured by casting.
- Manufacturing002=The piece shall be heat treated after manufacturin

Materials
- Material=AL-7068

Dataset Markings
- `Proprietary Note`=This document contains information...
- `Boeing Copyright`=

Inertial Properties
- MeasureInertia.1
- Area=5.567in2
- Volume=0.265in3

Work in Progress Compatibility Test for EL2-4

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Applying Results from the SCA

Supplier Capability Assessment

Pre-award

A Questionnaire **B** Compatibility Test
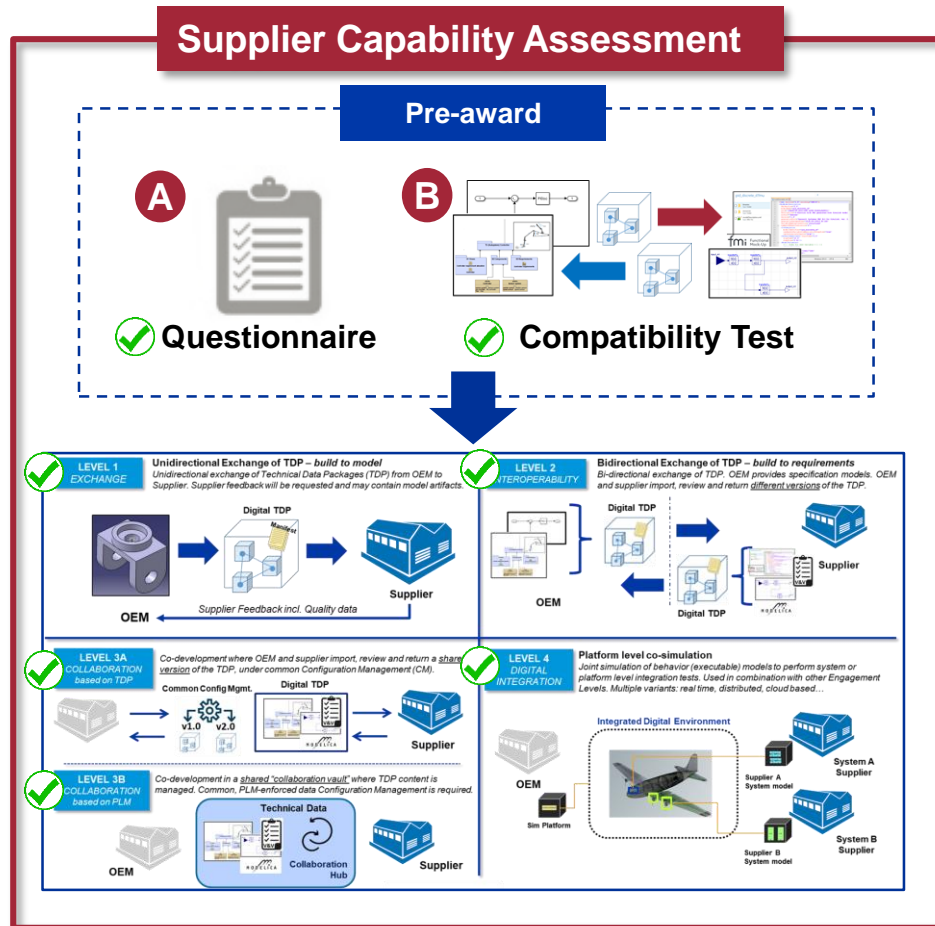
1. Establishes Expectations for the Project Plan

➢ What supplier would be most compatible based on program requirements?

➢ Is the supplier able to collaborate effectively in the desired Engagement Level?

2. Informs Technical Requirements

➢ What boundaries need to be established to avoid data integrity issues?

➢ What is the preferred data format for collaboration?

3. Promotes Smart Contracting Approaches

➢ Do the risks necessitate advanced contracting methods?

➢ Should the risks be used to assist with negotiations?

Creating a Data Driven Approach to Supplier Management

- Customer expectations for digital collaboration are driving the MBE transformation for Supply Chain

- Robust Model Based Exchange (MBX) tools are required to enable digital exchange and collaboration

- Emerging technology, tools, and user stories require formal assessment and evaluation

- Data from assessments should provide guidance for future capabilities development

- Current tools lack capabilities for concurrent collaboration (OEMs must be prescriptive to tool vendors)

- OEM – Supplier Compatibility is key for a successful collaboration (OEMs must also be prescriptive when working with Suppliers)

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Pieter van Gils	**MBE Product Owner, Boeing**
Alvaro Cano Torres	**Systems Engineer, Boeing Contract**
Antonio Garcia Salcedo	**Systems Engineer, Boeing Contract**
Daniel Sanchez-Biezma Zarco	**Systems Engineer, Boeing Contract**
Diego Valera	**Systems Engineer, Boeing Contract**
Victor Garcia Bennett	**Systems Engineer, Boeing Contract**

Q&A placeholder

MBE Supplier Engagement Framework

LEVEL 1
*EXCHANGE*

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.

Digital TDP
Manifest

Supplier

OEM

*Supplier Feedback incl. Quality data*
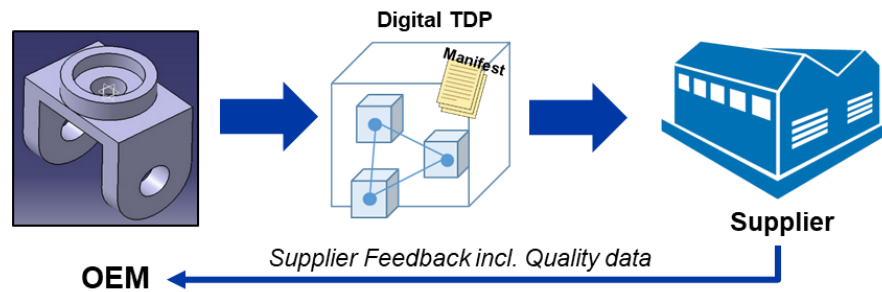
LEVEL 2
INTEROPERABILITY

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

Digital TDP

Supplier

OEM

V&V

MODELICA

Digital TDP
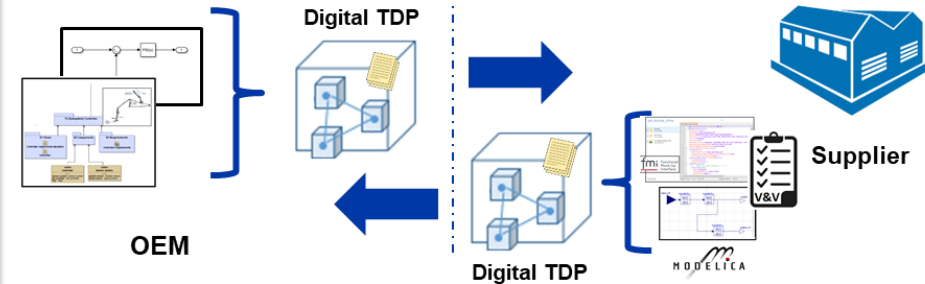
LEVEL 3A
COLLABORATION based on TDP

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

Common Config Mgmt.

Digital TDP

v1.0   v2.0

V&V

MODELICA

Supplier
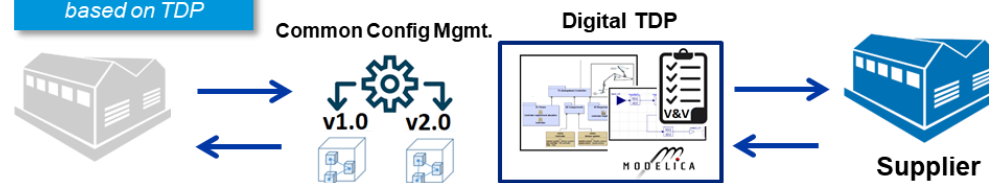
LEVEL 3B
COLLABORATION based on PLM

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

Technical Data

V&V

MODELICA

Collaboration Hub

OEM

Supplier
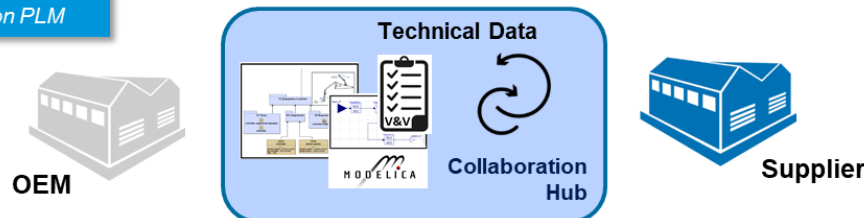
LEVEL 4
DIGITAL INTEGRATION

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…

Integrated Digital Environment

OEM

Sim Platform

Supplier A System model

Supplier B System model

System A Supplier

System B Supplier

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