Multiple View Bill of Materials (BOM) Solution Evaluation Benchmarks

Report of Findings and Conclusions

General Availability Edition

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AEROSPACE & DEFENSE PLM ACTION GROUP

Abstract

An Aerospace & Defense PLM Action Group (AD PAG) sponsored project team proposed validating their recently defined Multiple-view Bill of Materials (Multi-view BOM) requirements by benchmarking use cases using commercially available PLM software. Domain experts from eight AD PAG member companies and one Tier 1 supplier engaged with four leading software providers to execute the benchmarks. Results were consolidated, analyzed, and configured to enable each of the participating software providers to have visibility to the benchmark scores for their solution, while publicly reported results were generalized to mask specific solution performance.

This report documents the definition of use cases that encapsulate requirements for Multi-view BOM management within an aerospace OEM, and the findings and conclusions from evaluating the capability of commercially available PLM software to fulfill those requirements. The report concludes that the use cases are valid, and that commercial technology has matured to a level where implementation of Multi-view BOM management within an aerospace OEM is a practical possibility, albeit with caveats.

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Revision Record

Release	Date	Description
1.0	July 2020	Initial release of general availability version

Multiple View Bill of Materials (BOM) Solution Evaluation Benchmarks

Executive Summary

After three years of effort, and publication of a comprehensive position paper, an Aerospace & Defense PLM Action Group (AD PAG) project workstream matured to a new stage. In April 2019, the Multiple-view Bill of Materials (Multi-view BOM) project team proposed engagement with PLM solution providers to validate their recently defined Multi-view BOM requirements by benchmarking use cases using commercially available software. The AD PAG leadership agreed that this next stage was consistent with the Group's mission and was willing to make the necessary investment. They invited four leading PLM software providers to collaborate with the project team to demonstrate Multi-view BOM use cases on their software. Over the following three months, the Multi-view BOM project team drafted a set of use cases and CIMdata developed a plan for conducting the solution evaluation benchmarks in compliance with the following guidance:

- Maximize efficiency and minimize cost to the participating solution providers and to the AD PAG members
- Provide benefit to both the AD PAG participants and the participating solution providers
- Extract and report objective, fact-based information and insights from the benchmark that provide a generalized assessment of the state of the industry and not a competitive comparison between the benchmarked solutions

Objectives

Objectives for the solution evaluation benchmarks were as follows:

Primary

1. Define an initial set of Multi-view BOM use cases that are complex enough to provide a realistic test that is representative of AD PAG members' business
2. Determine the degree to which the participating PLM providers' technologies fulfill Multi-view BOM requirements by performing benchmark demonstrations using the providers' current and under development solutions
3. Manage communication of benchmark evaluation results to promote the advancement of multi-BOM technologies and industry best practices within the PLM ecosystem[1]

Secondary

4. Gain process experience that would be useful for future planning of engagement with an Interoperability Forum (IF) type organization for ongoing evaluation of PLM software compliance with Multi-view BOM requirements

[1] This should provide useful guidance to the participating PLM software solution providers as they plan future development of their offerings to address Multi-view BOM requirements.

Evaluation Participants

The following software providers were invited to participate in benchmark evaluation of their solutions:

- Aras
- Dassault Systèmes
- PTC
- Siemens Digital Industries Software (Siemens DIS)

The following AD PAG member companies and invited Tier 1 supplier provided domain experts to participate as benchmark demonstration evaluators. Those who were assigned had decades of aerospace PLM and configuration management experience.

- Airbus
- Boeing
- Embraer
- GE Aviation
- Gulfstream
- Mitsubishi
- Pratt & Whitney
- Rolls-Royce
- SAAB

CIMdata was engaged to facilitate the planning and to manage the execution of the solution evaluation benchmarks process.

Benchmark Use Cases and Data Set

The benchmark use cases were defined within the context of the AD PAG member companies' current and future work processes. Twelve use cases were defined in the following four focus areas.

- Engineering release
- Supplier collaboration
- Bolted join
- Engineering to manufacturing

The use cases required traceability of requirements from one structure to a second structure. Many of the use cases required identification of specific usages of a part or requirement, not changes to all usages of the item.

Boeing contributed the *Model-Based Engineering Demonstrator Reference Model*, an aircraft data set consisting of 900+ parts in hierarchical view, in CATIA v5 and AP242 formats. The model is available as open source.

Process and Schedule

The Multi-view BOM Solution Evaluation Benchmark process was adapted from CIMdata's best practice *Solution Evaluation and Selection* methodology. The process proceeded according to the following five steps:

- Engagement and plan finalization
- Benchmark preparation
- Benchmark execution
- Analysis
- Report out

Project activity began with AD PAG leadership approval in mid-July 2019. The flow of project activities spanned the period from July 2019 through May 2020.

The AD PAG domain experts who drafted the use cases and participated in the benchmark requirements review served as demonstration evaluators. Some were present onsite to observe and evaluate; others participated remotely via Web conferencing.

Results consolidation, analysis and reporting were managed by CIMdata so that each participating software provider was given visibility to results for their solution, while reported results, whether for AD PAG members or for public release, were generalized to avoid disclosure of specific solution results.

Results

Deliverables were defined and results were achieved in four main categories:

- PLM software provider engagement
- Multi-view BOM use case validation
- PLM software capabilities evaluation
- Interoperability forum engagement

PLM Software Provider Engagement

All four PLM software providers did engage, though at varying levels. Three willingly engaged and invested substantial effort of high value domain experts in a collaborative effort at the request of AD PAG leadership. Their performance was professional, cooperative and of high value, demonstrating a sincere leadership commitment to partnership and the successful attainment of AD PAG objectives.

Multi-View BOM Use Case Validation

After multiple rounds of online interactive reviews and subsequent revisions, the 12 Multi-view BOM use cases were accepted as complete, understandable, and valid by three leading PLM software providers.

PLM Software Capabilities Evaluation

Assessments of the Multi-view BOM management capabilities of the evaluated software solutions are reported on three levels:

- General Evaluation
- Capability Gaps
- Ease of Use

General Evaluation

To develop a general assessment of the capability available from the software solutions, evaluators were instructed to assess performance of the benchmark demonstrations and assign ratings from 0 to 5 for each of several evaluation criteria on individual use case grading sheets. The system of ratings and the assessment at each level are as follows:

5 – Far exceeds requirement

4 – Exceeds requirement

3 – Meets requirement

2 – Mostly meets requirement

1 – Minimally meets requirement

0 – Not shown

As an illustration of the results reporting format, the evaluation summary for use case *SC-01: 150% BOM export/import* is shown in Table 1.

Table 1 – Excerpt from Multiple View Bill of Materials (BOM) Management Capabilities Evaluation Summary (The complete results can be seen in Table 4)

Use Case Evaluation Criteria	Score	Criteria Satisfaction (# of Solutions at Each Level)					
	Average	Not Shown	Minimally Meets	Mostly Meets	Meets	Exceeds	Far Exceeds
2-Supplier Collaboration							
SC-01 ***150% BOM export / import***							
Goal Demonstrate that 150% BOM can be fully consumed into a supplier's PLM system and reconciled.	1.88	1	1		2		
Key Actions							
1 The 150% BOM (containing two unit configurations) is exported out of the OEM's PLM.	2.01		2		2		
2 Exported 150% BOM is imported into a second PLM system representing the supplier's PLM.	1.90	1	1		2		
3 System performs an automatic validation and reports any mismatches or fallout.	1.65	2			2		
Summary Rating							
Actions (calculated weighted average):	1.75	1	1		2		
Ease of Use:	2.20	1		1	2		
Final Grade (assigned by evaluator):	1.98	1	1		2		

Each of the four software solutions was examined to determine the number of evaluation criteria that were satisfied at each Criteria Satisfaction Level (i.e., received a Score of 0 to 5). It was then possible to calculate the percentage of criteria satisfied at each Criteria Satisfaction Levels for the four solutions on average, for the weakest solution, and for the strongest solution.

The summary results of this analysis were as follows:

- The four solutions, on average, **Met 50%** of the evaluation criteria, with results ranging from 33% to 99%
- The four solutions, on average, **Met** or **Mostly Met** 73% of the evaluation criteria, with results ranging from 49% to 100%.
- The four solutions, on average, **Failed to Show** or **Minimally Met 27%** of the evaluation criteria, with results ranging from 0% to 51%.

Capability Gaps

Looking deeper to localize and characterize capability gaps required analysis of the performance scores for each use case. A "Level of Concern" was assigned to each use case that reflects the value of two dimensions

- Completeness of capability, and
- Breadth of availability

Assessing the completeness of capability and breadth of availability across the four software solutions resulted in assigning a Level of Concern for each use case as documented in Table 2.

Table 2 - Level of Concern for Completeness and Breadth of Availability of Multiple View Bill of Materials (BOM) Management Capabilities in Commercial PLM Software Solutions for Each Use Case

Use Case	Level of Concern
Focus Area 1 – Engineering Release	
ER-01: Adapting and consuming tolerances after restructuring	High
ER-02: Consume documents linked to specific EBOM items after restructuring	Low-Mod
ER-03: Consume documents linked to specific EBOM items with effectivity revision after restructuring	Moderate
ER-04: Consume annotations after restructuring	Low-Mod
Focus Area 2 – Supplier Collaboration	
SC-01: 150% BOM export/import	Moderate
SC-02: Articulating changes within 150% BOM	Moderate
Focus Area 3—Bolted Join	
BJ-01: Bolted join	Low-Mod
Focus Area 4—Engineering to Manufacturing	
EM-01: Condition of supply	Low
EM-02: Manufacturing assembly	Low-Mod
EM-03: Engineering only change	Low-Mod
EM-04: Manufacturing only change	Low-Mod
EM-05: Engineering change	Moderate

The level of concern was low (i.e., the full capability is broadly available) for only one use case. The level of concern was high (i.e., the full capability is not available) for one use case. Capabilities required for all the other use cases are available but not broadly. These results should provide useful guidance to the participating PLM software solution providers as they plan future development of their offerings to address Multi-view BOM requirements.

Ease of Use

In general, Ease of Use ratings track to and are slightly higher than capability (i.e., Action) ratings. The average delta is +0.15, and the maximum delta is +0.67.

Interoperability Forum Engagement

Over the period from September through November 2019, a series of conversations occurred between CIMdata and PDES, Inc., an organization responsible for management of key Interoperability Forums. The result was agreement that there are common interests and synergies worthy of further exploration. Unfortunately, calendars could not be aligned successfully for a December meeting and scheduling has not been aggressively pursued in the new year.

Conclusions

Overall, the project was successful. Each of the three primary objectives was achieved and the single secondary objective was partially achieved.

The results of this project support the following conclusions:

1. A&D Original Equipment Manufacturer (OEM) Multi-view BOM management use cases have been validated.
2. A&D OEM Multi-view BOM management requirements are met or mostly met by multiple commercially available PLM software solutions.
3. It was possible to characterize gaps in capability and localize gaps to specific Multi-view BOM use cases as guidance to the PLM software solution providers.
4. Usability of commercially available PLM software solutions' Multi-view BOM management capabilities will not inhibit adoption or efficiency.
5. Initial outreach to the Interoperability Forum community was promising but inconclusive.
6. The leading PLM software solution providers regard the A&D PLM Action Group as an organization of importance and one worthy of their attention and support.

Introduction

Beginning in 2016, the A&D PLM Action Group (AD PAG) has sponsored and staffed a project team of domain experts from member companies to define objectives, requirements, and roadmaps for reducing cost and complexity of PLM solutions for creating and managing multiple views of product structure through the product lifecycle.

During their first workshop in March 2017, the Multiple View Bill of Materials (Multi-BOM) project team defined a set of 6 sub-projects to be executed over a period of two years:

- Data dictionary
- Part level eBOM/mBOM accountability
- Engineering process requirements
- Assembly requirements
- Change/action propagation
- Downstream BOM restructuring, with substitutes

In 2018, the project team added two more sub-project topics and extended the project timeline to three years:

- Effectivity
- Supplier and partner collaboration

The project team's work has been documented in a series of position papers, which have been published and are available at www.ad-pag.com.

Multi-View BOM Solution Evaluation Benchmarks

During their most recent workshop in March 2019, the AD PAG Multi-view BOM project team determined that their work was sufficiently mature to warrant engagement in benchmark evaluation of commercial technology capabilities for an initial set of use cases. In their workshop report out at the AD PAG leadership annual meeting in April, the team proposed engaging with four leading PLM software providers to demonstrate the team's initial set of defined use cases. The AD PAG leadership agreed to support the proposed engagement and asked each of those PLM software providers to collaborate with the AD PAG Multi-view BOM project team to demonstrate Multi-view BOM use cases on their software.

Over the following three months, the Multi-view BOM project team drafted a set of use cases for conducting solution evaluation benchmarks.

Concurrently, CIMdata was asked to develop a plan with the following considerations in mind:

- Maximize efficiency and minimize cost to the participating solution providers and to the AD PAG members
- Provide benefit to both the AD PAG participants and the participating solution providers
- Extract and report objective, fact-based information and insights from the benchmark that provide a generalized assessment of the state of the industry and ***not*** a competitive comparison between the benchmarked solutions

Purpose of this Document

The intent of this document is to convey to the ecosystem of industrial PLM users, standards organizations and PLM software and service providers -

- the definition of a set of use cases that encapsulate requirements for multiple-view bill of materials (BOM) management within an A&D OEM, and
- the findings and conclusions from evaluation of the capability of commercially available PLM software to fulfill those requirements.

Objectives and Constraints

The Multi-view BOM solution evaluation benchmarks were planned to achieve the following objectives. In addition, the plan was guided by the following success criteria and constraints.

Objectives

Objectives for the Multi-view BOM solution evaluation benchmarks were as follows:

Primary

1. Define an initial set of Multi-view BOM use cases that are complex enough to provide a realistic test that is representative of AD PAG members' business
2. Determine the degree to which the participating PLM providers' technologies fulfill Multi-view BOM requirements by performing benchmark demonstrations using the providers' current and under development solutions
3. Manage communication of benchmark evaluation results to promote advancement of Multi-view BOM technologies and industry best practices within the PLM ecosystem[2]

Secondary

4. Gain process experience that would be useful for future planning of engagement with an Interoperability Forum (IF) type organization for evaluation of PLM software compliance with Multi-view BOM requirements

Success Criteria and Constraints

Success criteria and constraints for the Multi-view BOM solution evaluation benchmarks follow.

Success Criteria

Success criteria for the Multi-view BOM solution evaluation benchmarks were as follows:

- Agreement is reached with the selected PLM software providers to participate in the evaluation activity as planned
- The results of the evaluation provide a useful indication of the level of capability of each evaluated product to satisfy the defined Multi-view BOM use cases and requirements
- All participants in the evaluation benchmarks, including AD PAG members and PLM software providers, judge the execution to be thorough and balanced and the results to be fair and meaningful
- Planning and execution of the evaluation benchmarks provide useful experience for empowering an Interoperability Forum type organization for future Multi-view BOM software compliance evaluation

Constraints

Constraints for the Multi-view BOM solution evaluation benchmarks were as follows:

- Planning, execution and reporting of results from this Multi-view BOM solution evaluation are conducted in strict conformance with AD PAG anti-trust guidelines

[2] This should provide useful guidance to the participating PLM software solution providers as they plan future development of their offerings to address Multi-view BOM requirements.

- Participating PLM software providers bear their own cost for participation
- Participating PLM software providers' costs are minimized by staging and executing the benchmark demonstrations at each provider's location
- AD PAG members' costs are minimized by providing the capability for member domain experts to observe the benchmark demonstrations remotely via web access from their home location

Scope

The scope of the Multi-view BOM solution benchmarks was defined in several dimensions below.

Evaluation Participants

Candidate Software Providers

The following software providers were selected by the AD PAG Multi-BOM project domain experts for invitation to participate in benchmark evaluations of their solutions:

- Aras
- Dassault Systèmes
- PTC
- Siemens Digital Industries Software (Siemens DIS)

AD PAG Multi-View BOM Project Domain Expert Evaluators

The following AD PAG member companies and Tier 1 supplier partner contributed domain experts for participation in this activity as use case authors and benchmark demonstration evaluators. The individuals who were assigned had decades of aerospace PLM and configuration management experience.

- Airbus
- Boeing
- Embraer
- GE Aviation
- Gulfstream
- Mitsubishi
- Pratt & Whitney
- Rolls-Royce
- Saab

Benchmark Administrator

CIMdata was engaged to facilitate the planning and to manage the execution of the solution evaluation benchmarks process.

Evaluation Inputs

Primary inputs were use cases and data sets necessary to exercise and evaluate the PLM software provider solutions.

Use Cases

The benchmark use cases were defined within the context of the AD PAG member companies' current and future work processes. A total of twelve use cases were provided by Multi-view BOM project domain experts in four focus areas. The use cases, each with a brief description, are listed below. Please refer to the *Appendix: Multi-View BOM Use Cases* for complete documentation.

Focus Area 1 – Engineering Release

ER-01: Adapting and consuming tolerances after restructuring – Demonstrate that tolerances linked to EBOM items can be adapted and consumed in the proper MBOM in any restructuring use case.

ER-02: Consume documents linked to specific EBOM items after restructuring – Demonstrate that documents linked to EBOM items (such as test requirements) can keep the link to the appropriate items and then consumed in the proper MBOM in any restructuring use case.

ER-03: Consume documents linked to specific EBOM items with effectivity revision after restructuring – Demonstrate that documents linked to EBOM items with effectivity revision (such as manufacturing processes linked to the EBOM) can keep the link to the appropriate items and then be consumed in the proper MBOM in any restructuring use case.

ER-04: Consume annotations after restructuring – Demonstrate that annotations (item specific and assembly specific) linked to EBOM items can keep the link to the appropriate items and then be consumed in the proper MBOM in any restructuring use case.

Focus Area 2 – Supplier Collaboration

SC-01: 150% BOM export/import – Demonstrate that 150% BOM can be fully consumed into a supplier's PLM system and reconciled.

SC-02: Articulating changes within 150% BOM – Demonstrate that changes to a 150% BOM can be fully consumed into a supplier's PLM system and reconciled.

Focus Area 3 – Bolted Join

BJ-01: Bolted Join – Ensure full consumption of bolts and associated torque values. Allocate bolts from EBOM to MBOM.

Focus Area 4 – Engineering to Manufacturing

EM-01: Engineering to manufacturing equivalence – Allow different structure between BOM views while maintaining equivalence. Engineering may specify a unique assembly.

EM-02: Manufacturing assembly – Allow different part hierarchies between different BOM views. Allocation from EBOM to MBOM.

EM-03: Engineering only change – Enable automatic reapplication of manufacturing consumption. Allocation from EBOM to MBOM.

EM-04: Manufacturing only change – Enable automatic reapplication of manufacturing consumption. Allocation from EBOM to MBOM.

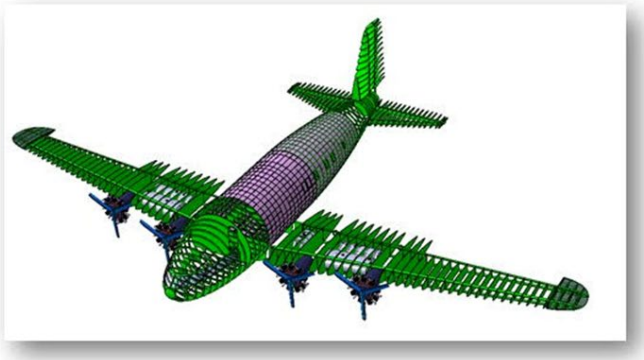
EM-05: Engineering change – Enable automatic reapplication of manufacturing consumption. Allocation from EBOM to MBOM.

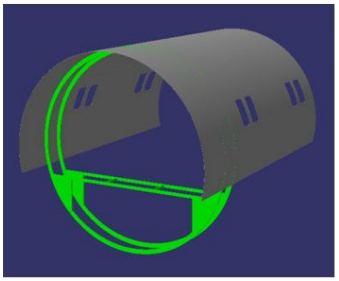
Data Set

The Multi-view BOM project team was responsible for providing data sets of appropriate size and complexity to adequately test use case performance. Boeing contributed the *Model-Based Engineering Demonstrator Reference Model*, an aircraft data set consisting of 900+ parts in hierarchical view, in CATIA v5 and AP242 formats.

The model is available as open source at this Link.

Two views of the model are shown in Figure 1.





Reference Model Section identified for ER, EM Use Cases

Figure 1 – Model-Based Engineering Demonstrator Reference Model, which is Available as Open Source

Attributes were added to the model to support the Engineering Release (ER) and Engineering to Manufacturing (EM) use cases.

Methodology

The Multi-view BOM Solution Evaluation Benchmark process was adapted from CIMdata's best practice *Solution Evaluation and Selection* methodology. The process proceeded according to the following five steps:

- Engagement and plan finalization
- Benchmark preparation
- Benchmark execution
- Analysis
- Report out

Unless otherwise stated, each enumerated task was performed by CIMdata. For simplicity, the five steps are described in past tense, but the individual steps are presented as declarative statements.

Engagement and Plan Finalization

Engagement with the candidate PLM software providers and then balancing the objectives and interests of all participants to reach a best match final evaluation plan was the least precise step in the overall activity. A set of necessary tasks, listed below, had to be accomplished, but the details and timing of back and forth negotiation and accommodation could not be defined with precision.

1. Draft Multi-view BOM Solution Evaluation – Benchmark Guidelines document

   Note: Submitted for review by AD PAG domain experts and AD PAG leadership; revised in response to comments received
2. Draft Multi-view BOM Solution Evaluation – Scoring and Reporting document

   Note: Scoring dimensions and weights, and designation of reporting audiences and content determined by AD PAG domain experts in a CIMdata facilitated session
3. Prepare an Accountability Mapping Software Evaluation briefing package for engaging candidate PLM software providers, including *Multi-view BOM Solution Evaluation – Benchmark Guidelines* and *Multi-view BOM Solution Evaluation – Scoring and Reporting* documents
4. Invite candidate PLM software providers to participate in the evaluation benchmark and request feedback on *Multi-view BOM Solution Evaluation – Benchmark Guidelines* and *Multi-view BOM Solution Evaluation – Scoring and Reporting* documents
5. Reach out to Interoperability Forum organization and request feedback on *Multi-view BOM Solution Evaluation – Benchmark Guidelines* document
6. Finalize *Multi-view BOM Solution Evaluation – Benchmark Guidelines* and *Multi-view BOM Solution Evaluation – Scoring and Reporting* documents and plan
7. Confirm final list of participating PLM software providers

Benchmark Preparation

Three weeks before the Multi-view BOM solution evaluation benchmark start date, CIMdata issued invitations to those PLM software providers selected to participate.

8. Issue formal invitation to participate in the Multi-view BOM solution evaluation benchmark

Note: Use cases, requirements and data sets will be delivered along with the invitation to each participate

9. Each participating PLM software provider identifies and assigns their team of technical software demonstration experts and prepares their internal workspace
10. Each participating AD PAG member company identifies and assigns their AD PAG domain experts

Benchmark Execution

After the three-week preparation period the Multi-view BOM solution evaluation benchmark activity was to begin. Over a six-week period, activities were to progress through three stages: requirements review, solution definition and software configuration, and software configuration and review. These stages were not to be managed with "hard stops," but rather with a gradual transition in the type of activities over time. The working relationship throughout the evaluation benchmark execution was intended to be highly collaborative between AD PAG domain experts and the software providers. It was expected that there would be give and take, and flexibility in the definition of work products generated during benchmark execution. That said, much was to be done, so schedules were to be published and managed to keep the overall flow of work on track.

Requirements Review

During the first stage of benchmark execution activity, the emphasis was to be on review and refinement of the use cases drafted by AD PAG domain experts. The desired outcome was for the software provider to understand each focus area and the defined use cases – why they are important and what the essential elements are that need to be demonstrated to achieve the project objectives.

11. AD PAG domain experts conference with each software provider team to review and discuss all of the use cases and requirements, answer questions and respond to suggestions
12. AD PAG domain experts conference with each software provider team to review revised use cases and requirements and any follow up suggestions

Solution Definition and Configuration

During the second stage of benchmark execution activity, the emphasis was to be on solution definition and software configuration by the software providers' technical demonstration experts.

13. AD PAG domain experts are available on certain days for interactions with each software provider's technical demonstration experts

    Note: In general, the interactions are expected to be ad-hoc and informal. However, a sign-up sheet will be available for scheduling meeting times as an option.

Software Configuration and Review

During the final stage of benchmark evaluation activity, the emphasis was on solution demonstration by the software provider's technical demonstration experts and evaluation by AD PAG domain experts. Some AD PAG domain experts were present onsite to observe and evaluate, while others were participating remotely via webcast. To assure an adequate rate of progress, demonstration sessions were to be scheduled on a daily basis with fixed times and agendas.

14. CIMdata publishes a complete schedule of use case demonstrations to be held during this period to each software provider five (5) business days in advance

15. Software providers' technical experts perform demonstrations of use cases and AD PAG domain experts evaluate and grade these demonstrations

Analysis

Following completion of the Multi-view BOM solution evaluation benchmark demonstrations, scores from individual AD PAG domain expert evaluators were consolidated and analyzed. Group discussions were conducted to reconcile outliers and develop consensus on final scores for evaluation dimensions of each use case and requirement. A set of summary ratings were then calculated for each use case and for sets of use cases that constitute a predefined class of software capability.

16. CIMdata consolidates Multi-view BOM solution evaluation benchmark demonstrations scores and performs preliminary analysis
17. CIMdata facilitates AD PAG domain expert discussions to reach consensus scores
18. CIMdata applies weighting factors and calculates ratings for use cases and requirements and the resultant ratings of software capabilities

Report Out

Multiple reports were generated in accordance with the scheme decided prior to Benchmark Execution. This set of reports was subjected to review and revision prior to release and distribution to the targeted communities.

19. CIMdata develops a set of draft reports on the Multi-view BOM solution evaluation benchmark results
20. CIMdata delivers the draft reports to AD PAG domain experts and then to AD PAG leadership for their review and comment
21. CIMdata incorporates revisions in response to comments received and publishes the final reports

Schedule

Project activity began with AD PAG leadership approval in mid-July 2019. The flow of project activities and the original and actual project timelines are shown in Figure 2.

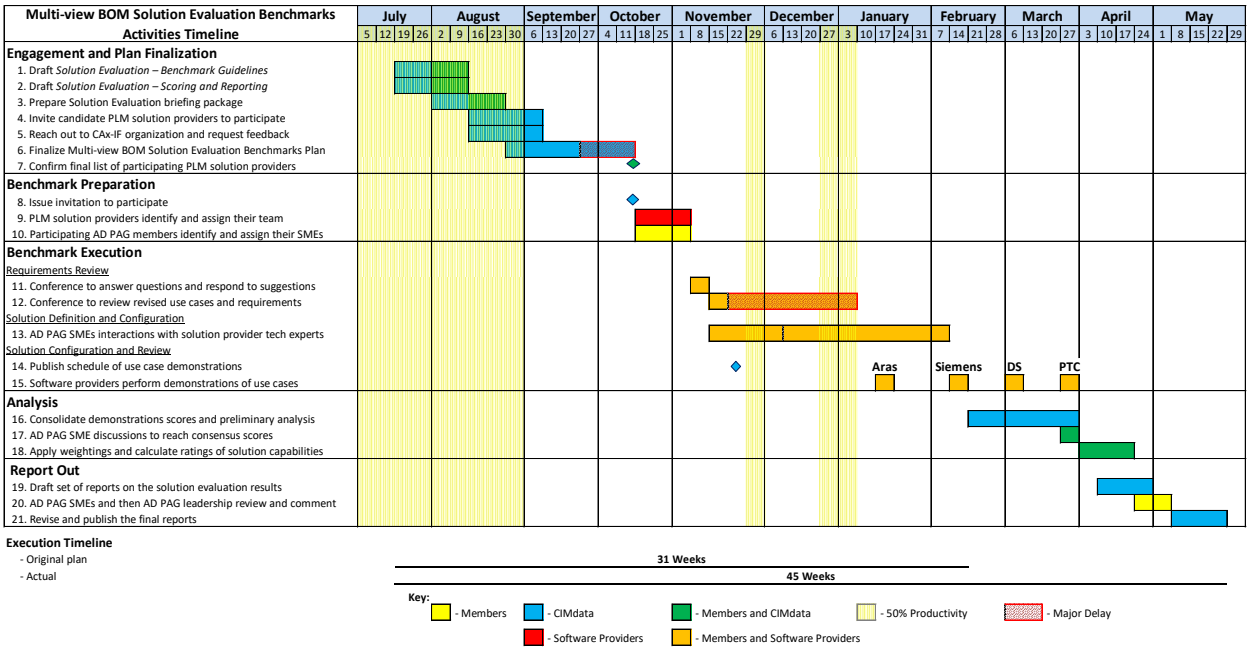


Figure 2 – Multi-view BOM Solution Evaluation Benchmarks Activities Timeline

Results

Deliverables were defined and results expected at each step in the project plan. These results fall into four main categories:

- PLM software provider engagement
- Multi-view BOM use case validation
- PLM software capabilities evaluation
- Interoperability Forum engagement

Results are presented below in each of these categories, along with discussion and observations.

PLM Software Provider Engagement

In April 2019, all four PLM software providers of interest expressed willingness to engage in planning discussions. In August, a formal invitation was issued to each of the four. Participation was requested in project activities for completion of three major deliverables:

- Finalization of the Multi-view BOM Solution Evaluation Benchmarks Plan
- Validation of the Multi-view BOM use cases
- Demonstration of the Multi-view BOM use cases on their software

Assessment

All four PLM software providers did engage, though at varying levels as noted in Table 3.

Table 3 - Level of Collaborative Engagement of the Four PLM Software Providers in Completion of Multi-View BOM Solution Evaluation Benchmarks Deliverables

Deliverable	Aras	Dassault Systèmes	PTC	Siemens DIS
Finalize Multi-view BOM Benchmarks Plan	Yes	Yes	Yes	Yes
Validate Multi-view BOM Use Cases	Yes	No	Partial	Yes
Demonstrate Multi-view BOM Use Cases	Yes	No	Yes	Yes

Three of four software providers willingly engaged and invested substantial effort of high value domain experts in a collaborative effort at the request of AD PAG leadership.

Their performance was professional, cooperative and of high value, demonstrating a sincere leadership commitment to partnership and the successful attainment of AD PAG objectives.

Comments

Dassault Systèmes initially agreed to fully support the project but later withdrew. Consequently, the benchmark demonstrations on Dassault Systemes' software were performed by domain experts from an AD PAG member company on production software installed at their site.

Unlike the other three solution demonstrations, PTC performed the demonstrations on their software on a cloud instance with all AD PAG domain expert evaluators participating remotely.

Multi-View BOM Use Case Validation

Prior to initiation of this project, the twelve Multi-view BOM use cases had been submitted by the authors for review by their peers within the project team as well as by colleagues within the AD PAG member companies.

As the first step of benchmark execution, the AD PAG use case authors conducted online interactive reviews with domain experts from the participating PLM software providers. Subsequent to these reviews, the authors revised the use cases in response to comments received. Revisions included clarification of wording, expansion of detail and inclusion of figures within the use case writeup, and in a few cases, modification of the supporting data set.

Assessment

After multiple rounds of online interactive reviews and subsequent revisions, the twelve Multi-view BOM use cases were accepted as complete, understandable, and valid by three leading PLM software providers.

PLM Software Capabilities Evaluation

Assessments of the Multi-view BOM management capabilities of the evaluated software solutions are reported on three levels:

- General evaluation
- Capability gaps
- Ease of use

Introduction

The software solution capabilities assessments are better understood with knowledge of how the evaluation data was generated, collected, consolidated, and analyzed. It is also important to appreciate certain limitations on how the results should be interpreted.

Process

The AD PAG domain experts who drafted the use cases and participated in the benchmark requirements review served as demonstration evaluators. An individual grading sheet was drafted for each of the twelve use cases with space to grade and comment on each use case action, plus space to grade how well the use case goal was achieved and to grade ease of use. The evaluators went through a training class in advance of the benchmark demonstrations. Training addressed topics including benchmark objectives and constraints, confidentiality, antitrust compliance, and demonstration scoring and reporting protocol.

The grading sheets for each use case were distributed to each of the evaluators prior to the demonstration session with each of the participating solution providers. Completed grading sheets were returned to and remained under the control of the Benchmark Administrator.

Individual scores were extracted from the grading sheets and recorded in a master grading MS Excel workbook. An importance weighting factor was agreed upon and assigned to each use case action by the domain expert evaluators prior to the start of benchmark demonstrations. Transfer of

individual grades to summary sheets, application of weights and calculation of summary grades was entirely automated within the workbook.

Scores consolidation, analysis and reporting were managed by CIMdata so that reported results, whether for AD PAG members or for public release, would be generalized to avoid disclosure of specific solution results.

Rating System

Evaluators were instructed to assess performance of the benchmark demonstrations and assign ratings from 0 to 5 on the grading sheet. The system of ratings and the assessment at each level are as follows:

5 – Far exceeds requirement

4 – Exceeds requirement

3 – Meets requirement

2 – Mostly meets requirement

1 – Minimally meets requirement

0 – Not shown

Data Reduction Detail

Each PLM solution demonstration was observed by six to ten AD PAG evaluators. According to plan, the evaluator scoring sheets were returned to the Benchmark Administrator, and the individual benchmark scoring detail was transcribed to a master grading MS Excel workbook.

During the score consolidation process, evaluators and evaluated PLM solutions were assigned random identifiers. For each PLM solution, the evaluators' scores were tabulated in columns. For each evaluation criterion, the minimum, average, maximum, and the spread between minimum and maximum evaluator scores were calculated and examined to check for data entry errors and outlier evaluator patterns.

Prior to consolidation of the four sets of PLM solution scores onto a single summary worksheet, the number of evaluation criteria was reduced by dropping all use case actions with an assigned weight of less than 20%. The resulting reduced set of evaluation criteria for each of the twelve use cases is as follows:

- Use Case Goal
- Key Use Case Actions – For each use case, this reduced set ranges from 2 to 4 actions out of an original count of 4 to 10 actions.
- Summary Ratings
    - Actions (calculated weighted average of action scores)
    - Ease of Use
    - Final Grade

For each of the four PLM solutions, the average score for each criterion in the reduced set was then copied to the summary worksheet. On the summary worksheet, the average was calculated

and recorded for each evaluation criterion. The distribution of the four PLM solutions' scores was also tabulated for each evaluation criterion. This evaluation summary is presented in Table 4.

Table 4 –Multiple View Bill of Materials (BOM) Management Capabilities of Commercial PLM Software Solutions Evaluation Summary (page 1 of 4)

Use Case Evaluation Criteria	Score	Criteria Satisfaction (# of Solutions at Each Level)					
	Average	Not Shown	Minimally Meets	Mostly Meets	Meets	Exceeds	Far Exceeds
1-Engineering Release							
ER-01 ***Adapting and consuming tolerances after restructuring***							
Goal Demonstrate that tolerances linked to EBOM items can be adapted and consumed in the proper MBOM in any restructuring use case.	2.22		1	2	1		
Key Actions							
7 System checks coherency between tolerances in the EBOM and the tolerances in MBOM.	1.69		2	2			
10 System checks coherency between tolerances in the EBOM and the tolerances in MBOM.	1.98		2	1	1		
Summary Rating							
Actions (calculated weighted average):	2.06		1	2	1		
Ease of Use:	2.78			1	3		
Final Grade (assigned by evaluator):	2.19			3	1		
ER-02 ***Consume documents linked to specific EBOM items after restructuring***							
Goal Demonstrate that documents linked to EBOM items (such as tests requirements) can keep the link to the appropriate items and then consumed in the proper MBOM in any restructuring use case.	2.27		1	1	2		
Key Actions							
7 System checks coherency between original "document to EBOM items" links and the resulting "document to MBOM items" links.	1.89		2	1	1		
10 System checks coherency between the original "document to EBOM items" links and the resulting "document to MBOM items" links.	1.79		2	1	1		
Summary Rating							
Actions (calculated weighted average):	2.04		2	1	1		
Ease of Use:	2.65		1		2	1	
Final Grade (assigned by evaluator):	2.36		1	1	2		
ER-03 ***Consume documents linked to specific EBOM items with effectivity revision after restructuring***							
Goal Demonstrate that documents linked to EBOM items with effectivity revision (such as manufacturing processes linked to the EBOM) can keep the link to the appropriate items and then be consumed in the proper MBOM in any restructuring use case.	2.12		2	1	1		
Key Actions							
7 System checks coherency between the original "document to EBOM items links and effectivity" and the resulting "document to MBOM items links and effectivity".	1.46	2		1	1		
10 System checks coherency between original "document to EBOM items links and effectivity" and the resulting "document to MBOM items links and effectivity".	1.46	2		1	1		
Summary Ratings							
Actions (calculated weighted average):	1.84		2	1	1		
Ease of Use:	2.27	1		2		1	
Final Grade (assigned by evaluator):	2.02		2		2		

Table 4 – Multiple View Bill of Materials (BOM) Management Capabilities of Commercial PLM Software Solutions Evaluation Summary (page 2 of 4)

Use Case Evaluation Criteria	Score	Criteria Satisfaction (# of Solutions at Each Level)					
	Average	Not Shown	Minimally Meets	Mostly Meets	Meets	Exceeds	Far Exceeds
1-Engineering Release							
ER-04 ***Consume annotations after restructuring***							
Goal Demonstrate that annotations (item specific and assembly specific) linked to EBOM items can keep the link to the appropriate items and then be consumed in the proper MBOM in any restructuring use case.	2.07		2	1	1		
Key Actions							
7 System checks coherency between the original "annotations linked to EBOM(s) and EBOM items" and the resulting "annotations linked to MBOM(s) and MBOM items".	1.87		2	1	1		
10 System checks coherency between the original "annotations linked to EBOM(s) and EBOM items" and the resulting "annotations linked to MBOM(s) and MBOM items".	1.73	1	1	1	1		
Summary Rating							
Actions (calculated weighted average):	1.96		2	1	1		
Ease of Use:	2.35		1	1	1	1	
Final Grade (assigned by evaluator):	2.18		2		2		
2-Supplier Collaboration							
SC-01 ***150% BOM export / import***							
Goal Demonstrate that 150% BOM can be fully consumed into a supplier's PLM system and reconciled.	1.88	1	1		2		
Key Actions							
1 The 150% BOM (containing two unit configurations) is exported out of the OEM's PLM.	2.01		2		2		
2 Exported 150% BOM is imported into a second PLM system representing the supplier's PLM.	1.90	1	1		2		
3 System performs an automatic validation and reports any mismatches or fallout.	1.65	2			2		
Summary Rating							
Actions (calculated weighted average):	1.75	1	1		2		
Ease of Use:	2.20	1		1	2		
Final Grade (assigned by evaluator):	1.98	1	1		2		
SC-02 ***Articulating changes within 150% BOM***							
Goal Demonstrate that changes to a 150% BOM can be fully consumed into a supplier's PLM system and reconciled.	1.59	1	1	1	1		
Key Actions							
2 Only the changes (net change) are exported out of the OEM's PLM and sent to the supplier.	1.33	1	2		1		
3 Changes are imported into a second PLM system, representing the supplier's PLM.	1.74	1	1		2		
Summary Rating							
Actions (calculated weighted average):	1.49	1	1	1	1		
Ease of Use:	1.96	1	1		2		
Final Grade (assigned by evaluator):	1.48	1	2		1		

Table 4 – Multiple View Bill of Materials (BOM) Management Capabilities of Commercial PLM Software Solutions Evaluation Summary (page 3 of 4)

Use Case Evaluation Criteria	Score	Criteria Satisfaction (# of Solutions at Each Level)					
	Average	Not Shown	Minimally Meets	Mostly Meets	Meets	Exceeds	Far Exceeds
3-Bolted Join							
BJ-01 ***Bolted join***							
Goal Ensure full consumption of bolts and associated torque values. Allocate bolts from EBOM to MBOM.	2.55			2	2		
Key Actions							
8 Allocates all the bolt torques set by design against the EBOM to later operation in assembly process plan 2.	2.64		1		3		
9 Runs a check to show the state of part consumption.	2.33		1	2	1		
Summary Rating							
Actions (calculated weighted average):	2.55			2	2		
Ease of Use:	3.00			1	2	1	
Final Grade (assigned by evaluator):	2.70			1	3		
4-Engineering to Manufacturing							
EM-01 ***Engineering to manufacturing equivalence***							
Goal Allow different structure between BOM views while maintaining equivalence. Engineering may specify a unique assembly.	2.97				4		
Key Actions							
2 Manufacturing engineer reviews the installation or assembly EBOM and decides to manufacture the installation in a different order.	3.03				4		
3 Manufacturing engineer modifies the geometry of the manufacturing-only part by adding Full Size Determinate Assembly Holes (FSDA), removing holes, and modifying some holes into pilots.	2.90			1	3		
Summary Rating							
Actions (calculated weighted average):	2.83				4		
Ease of Use:	3.08				4		
Final Grade (assigned by evaluator):	3.19				4		
EM-02 ***Manufacturing assembly***							
Goal Allow different part hierarchies between different BOM views. Allocation from EBOM to MBOM.	2.84			2	2		
Key Actions							
2 Manufacturing engineer propagates the manufacturing-only assembly to all other instances of the original EBOM defined assembly within a specified level of the EBOM product structure.	2.79			2	2		
3 Manufacturing engineer allocates the manufacturing assemblies to a fabrication/installation plan.	3.19				3		
6 Manufacturing engineer creates an operation within the plan to drill the omitted holes within the manufacturing-only bracket assemblies. Defined the MOA EBOM Components	2.59			1	3		
Summary Rating							
Actions (calculated weighted average):	2.50			2	2		
Ease of Use:	2.86			1	3		
Final Grade (assigned by evaluator):	2.90			1	3		

Table 4 – Multiple View Bill of Materials (BOM) Management Capabilities of Commercial PLM Software Solutions Evaluation Summary (page 4 of 4)

Use Case Evaluation Criteria	Score	Criteria Satisfaction (# of Solutions at Each Level)					
	Average	Not Shown	Minimally Meets	Mostly Meets	Meets	Exceeds	Far Exceeds
4-Engineering to Manufacturing							
EM-03 ***Engineering only change***							
Goal Enable automatic reapplication of manufacturing consumption. Allocation from EBOM to MBOM.	2.83			1	3		
Key Actions							
1 Design engineer makes a change to a component of the assembly that is not part of the manufacturing assembly effective at unit X.	2.86				4		
3 Manufacturing engineer confirms that the engineering change has no impact on manufacturing.	2.90				4		
4 Manufacturing engineer runs an accountability check on the engineering assembly at unit X-1.	2.48			2	2		
5 Manufacturing engineer runs an accountability check on the engineering assembly at unit X.	2.48			2	2		
Summary Rating							
Actions (calculated weighted average):	2.62			1	3		
Ease of Use:	2.90			1	3		
Final Grade (assigned by evaluator):	2.88			1	3		
EM-04 ***Manufacturing only change***							
Goal Enable automatic reapplication of manufacturing consumption. Allocation from EBOM to MBOM.	2.33		1	1	2		
Key Actions							
1 Manufacturing engineer makes a change to the part affected by the condition of supply (i.e., defines new condition of supply) effective at unit Z (Z > X).	2.60			1	3		
2 Manufacturing engineer runs an accountability check on the engineering assembly at unit Z-1.	2.21		1	1	2		
Summary Rating							
Actions (calculated weighted average):	2.30		1	1	2		
Ease of Use:	2.50			2	2		
Final Grade (assigned by evaluator):	2.42			2	2		
EM-05 ***Engineering change***							
Goal Enable automatic reapplication of manufacturing consumption. Allocation from EBOM to MBOM.	1.27		3		1		
Key Actions							
1 Design engineer applies change to the part affected by the condition of supply at unit Y (X < Y < Z).	1.63	1	1	1	1		
2 Manufacturing engineer runs an accountability check on the engineering assembly effective from Y – inf.	1.43	1	2		1		
Summary Rating							
Actions (calculated weighted average):	1.53	1	2		1		
Ease of Use:	1.30	2		1	1		
Final Grade (assigned by evaluator):	1.75	1		2	1		

Interpretation of the Results

With very few exceptions, demonstrations were performed on out of the box implementations of released software versions. This was the case even though the solution providers were offered the option of demonstrating on prerelease or development versions. The impact is that the evaluation results do not require adjustment or speculation as to when in the future the observed capabilities would be generally available.

As noted earlier in this report, the intent of conducting benchmarks was to evaluate the general availability of capabilities within commercial PLM software solutions to meet the requirements of A&D OEMs and their tier 1 suppliers for Multi-view BOM management. The intent was not to conduct a comparative evaluation of the solutions. Consistent with that intent, the scores for each of the solutions have been neutralized and generalized, and results are reported as statistical abstractions, i.e., averages and distributions.

Since the scoring was to be analyzed and interpreted more generally than would be the case in a competitive evaluation, a level of variability in execution was judged to be acceptable. Points of variability in execution that likely impacted the resultant ratings for individual software solutions include the following:

- One provider's ratings may have been lowered due to their declining to participate, thereby necessitating execution of the demonstrations by member domain experts on versions of software that were not the latest releases
- One provider's ratings may have been lowered due to their inconsistent commitment to participation, thereby truncating the preparation prior to execution of the demonstrations
- A software provider's position in the demonstration sequence may have affected their score due to refinement of the AD PAG evaluators' approach to scoring as they gained experience

In view of the above considerations, the reported results should be interpreted as **indicative rather than absolute**. Assessments and conclusions can be drawn with confidence from clear and substantial trends in the results, but not from specific data points.

General Evaluation

To develop a general assessment of the capability available from the evaluated software solutions, each of the four was examined to determine the percentage of evaluation criteria that were satisfied at each Criteria Satisfaction Level (i.e., received a Score of 0 to 5). It was then possible to calculate percentage satisfaction at each Criteria Satisfaction Levels for the four solutions on average, for the weakest solution, and for the strongest solution.

Assessment

Analysis of the scores of each of the four evaluated PLM software solutions revealed the following:

1. The four solutions, on average, **Met 50%** of the evaluation criteria, with results ranging from 33% to 99%
2. The four solutions, on average, **Met** or **Mostly Met 73%** of the evaluation criteria, with results ranging from 49% to 100%
3. The four solutions, on average, **Failed to Show** or **Minimally Met 27%** of the evaluation criteria, with results ranging from 0% to 51%

Comment

By referencing findings 2 and 4 it can be inferred that one or more leading commercially available PLM software solutions Met or Mostly Met nearly all of the evaluation criteria. This finding sheds light on one of the fundamental questions motivating this project, i.e., has commercial technology matured to a level where implementation of Multi-view BOM within an aerospace OEM is a practical possibility? The answer appears to be "Yes," albeit with certain caveats.

Capability Gaps

Looking deeper to localize and characterize gaps in capability required analysis of the performance scores for each use case. The goal of this characterization was to assign a "Level of Concern" to each use case that would reflect the value of the following two dimensions

- Completeness of capability
- Breadth of availability

A hierarchical characterization representing the paired values of these dimensions for key actions of a use case is shown in Table 5. The Level of Concern is inversely related to completeness and availability of required capabilities.

Table 5 – Characterization of Multiple View Bill of Materials (BOM) Management Capabilities Completeness and Breadth of Availability in Commercial PLM Software Solutions, with Associated Level of Concern

Completeness and Breadth of Availability in Commercial PLM Software Solutions of Capability Required to Perform Use Case Key Actions	Level of Concern
Key Action requirements **Met** by **all** PLM software solutions	None
Key Action requirements **Met** by **most** PLM software solutions (i.e., 3 out of 4)	Low
Key Action requirements **Met** by **one or two** PLM software solution(s) and **Mostly Met** by **other** PLM software solution(s)	Low-Moderate
Key Action requirements **Met** by **one or two** PLM software solution(s)	Moderate
Key Action requirements **Mostly Met** by **multiple** PLM software solutions	High
Key Action requirements **Mostly Met** by **only a single** PLM software solution	Extremely High

Assessment

The distribution of Criteria Satisfaction ratings of the four software solutions shown in Table 4 for the key actions of each use case provides the information needed for this assessment. The assessed Level of Concern regarding capability gaps for each use case is presented in Table 6.

Table 6 - Level of Concern for Completeness and Breadth of Availability of Multiple View Bill of Materials (BOM) Management Capabilities in Commercial PLM Software Solutions for Each Use Case

Use Case	Level of Concern
Focus Area 1 – Engineering Release	
ER-01: Adapting and consuming tolerances after restructuring	High
ER-02: Consume documents linked to specific EBOM items after restructuring	Low-Mod
ER-03: Consume documents linked to specific EBOM items with effectivity revision after restructuring	Moderate
ER-04: Consume annotations after restructuring	Low-Mod
Focus Area 2 – Supplier Collaboration	
SC-01: 150% BOM export/import	Moderate
SC-02: Articulating changes within 150% BOM	Moderate
Focus Area 3—Bolted Join	
BJ-01: Bolted join	Low-Mod
Focus Area 4—Engineering to Manufacturing	
EM-01: Condition of supply	Low
EM-02: Manufacturing assembly	Low-Mod
EM-03: Engineering only change	Low-Mod
EM-04: Manufacturing only change	Low-Mod
EM-05: Engineering change	Moderate

The Level of Concern was low (i.e., full capability broadly available) for only one use case. The level of concern was high (i.e., full capability not available) for one use case. For all of the other use cases, required capabilities are available but not broadly available from commercial software solutions. These results should provide useful guidance to the participating PLM software solution providers as they plan future development of their offerings to address Multi-view BOM requirements.

Ease of Use

It can be argued that the ease with which a use case can be executed is not as important as whether the capability exists in the software to execute the use case, but ease of use is critical to solution adoption and efficiency of execution. In recognition of this reality, each AD PAG domain expert evaluator rated the ease of use for each use case. The same grading system was used, where a score of 3 was assigned if the software solution met the qualitative expectations of the evaluator.

Assessment

To assess Ease of Use, the rating for this criterion was compared to the capabilities rating (i.e., Actions Summary Rating) for each use case. In general, Ease of Use ratings track to and are slightly higher than the corresponding capabilities ratings. The average delta is +0.15, and the maximum delta is +0.67. In no case, does the Ease of Use rating fall significantly below the capabilities rating. For two use cases, the Ease of Use rating was significantly higher than the capabilities rating.

Interoperability Forum Engagement

Over the period from September through November 2019, a series of conversations occurred between CIMdata and PDES, Inc.'s management regarding this evaluation. The result was agreement that there is common interest and synergies worthy of further exploration.

The agreed next step was to hold an online meeting between the Interoperability Forum stakeholders and CIMdata in early December. The purpose of this two-hour meeting was to have a discussion between PDES, Inc. and CIMdata / AD PAG to explore the possibility of collaboration between the Interoperability Forum and the AD PAG Multi-view BOM Benchmark project. Details for the meeting were as follows:

Attendees

- CAx IF Facilitators
- Implementor Forum framework team representatives
- PDES, Inc. Management
- CIMdata
- LOTAR

Agenda

- Objective: Collaborate with the CIMdata Community
- Benchmarking
- CAx IF Test Rounds
- A&D Action Group Approach (based on the shared AD PAG Multi-view BOM – Solution Evaluation Benchmark
- Process Management Plan
- Scoring and Reporting
- Guidelines
- Benefits of Collaboration
- Type of Collaboration
- Methodology
- Test Data
- Differences to be Overcome

Unfortunately, calendars could not be aligned successfully for a December meeting and scheduling has not been pursued aggressively in the new year.

Conclusions

Overall, the project was successful, with each of the three primary objectives being achieved and the single secondary objective being partially achieved.

The results of this project support the following conclusions.

1. **A&D OEM Multi-view BOM management use cases have been validated.**

   Before starting this project, the twelve Multi-view BOM use cases were submitted by the authors to review by their peers within the project team and colleagues within the AD PAG member companies. After multiple rounds of online interactive reviews with three leading PLM software providers and subsequent revisions, the 12 Multi-view BOM use cases were accepted as complete, understandable, and valid by those providers.

2. **A&D OEM Multi-view BOM management requirements are met or mostly met by multiple commercially available PLM software solutions.**

   By referencing the analysis of the benchmark demonstration evaluation scores, it can be inferred that one or more than one of the leading commercially available PLM software solutions Meet or Mostly Meet nearly all of the evaluation criteria.

3. **It was possible to characterize gaps in capability and localize gaps to specific Multi-view BOM use cases as guidance to the PLM software solution providers.**

   A "Level of Concern" was assigned to each use case that reflects the completeness of capability, and breadth of availability. The assessed Level of Concern regarding capability gaps for each use case can provide useful insight to guide future development investment of the PLM software providers.

4. **Usability of commercially available PLM software solutions' Multi-view BOM management capabilities will not inhibit adoption or efficiency.**

   AD PAG benchmark evaluators' usability expectations were mostly met by multiple commercially available PLM software solutions. In no case, does the Ease of Use rating fall significantly below the capabilities rating. For two use cases, the Ease of Use rating was significantly higher than the capabilities rating.

5. **Initial outreach to the Interoperability Forum community was promising but inconclusive.**

   A series of conversations occurred between CIMdata and PDES, Inc. management, and it was agreed to hold an online meeting between the Interoperability Forum stakeholders and CIMdata. Unfortunately, that meeting has not been held as of the date of this release.

6. **Leading PLM software solution providers regard the A&D PLM Action Group as an organization of importance and one worthy of their attention and support.**

   All invited software solution providers agreed to support the Multi-view BOM Solution Evaluation Benchmarks. Three made significant investments of effort from high value domain experts and worked cooperatively and with a high degree of professionalism throughout the extended project timeline.

About A&D PLM Action Group

The Aerospace & Defense PLM Action Group (www.ad-pag.com) is an association of aerospace and defense companies within CIMdata's globally recognized PLM Community Program, which functions as a ***PLM advocacy group*** to:

- Set the direction for the aerospace & defense industry on PLM-related topics that matter to members (*including promoting, not duplicating, the work of standards bodies*)
- Promote common industry PLM processes and practices
- Define requirements for common interest PLM-related capabilities
- Communicate with a unified voice to PLM solution providers
- Sponsor collaborative PLM research on prioritized industry and technology topics

CIMdata administers Group operations, coordinates research, and manages the progression of policy formulation.

About CIMdata

CIMdata, a leading independent worldwide firm, provides strategic management consulting to maximize an enterprise's ability to design and deliver innovative products and services through the application of Product Lifecycle Management (PLM) solutions. Since its founding over thirty years ago, CIMdata has delivered world-class knowledge, expertise, and best-practice methods on PLM solutions. These solutions incorporate both business processes and a wide-ranging set of PLM-enabling technologies.

CIMdata works with both industrial organizations and providers of technologies and services seeking competitive advantage in the global economy. CIMdata helps industrial organizations establish effective PLM strategies, assists in the identification of requirements and selection of PLM technologies, helps organizations optimize their operational structure and processes to implement solutions, and assists in the deployment of these solutions. For PLM solution providers, CIMdata helps define business and market strategies, delivers worldwide market information and analyses, provides education and support for internal sales and marketing teams, as well as overall support at all stages of business and product programs to make them optimally effective in their markets.

In addition to consulting, CIMdata conducts research, provides PLM-focused subscription services, and produces several commercial publications. The company also provides industry education through PLM certification programs, seminars, and conferences worldwide. CIMdata serves clients around the world from offices in North America, Europe, and Asia-Pacific.

To learn more about CIMdata's services, visit our website at www.CIMdata.com or contact CIMdata at: 3909 Research Park Drive, Ann Arbor, MI 48108, USA. Tel: +1 734.668.9922. Fax: +1 734.668.1957; or at Oogststraat 20, 6004 CV Weert, The Netherlands. Tel: +31 (0) 495.533.666.

Appendix: Multi-View BOM Use Cases

ER-01

USE CASE NUMBER: ER-01	**Focus Area:** 1 – Engineering Release
Use Case Owner:	

USE CASE TITLE: Adapting and consuming **tolerances** after restructuring

Goal & Overview: (Functionality)	Demonstrate that tolerances linked to EBOM items can be adapted and consumed in the proper MBOM in any restructuring use case.
Use Case Product Scope:	☒ Airframe ☐ Systems ☐ Equipment ☒ Engine
Use Case Frequency:	☒ Daily ☐ Weekly ☐ Monthly ☐ Yearly
Impacted Companies:	☒ Airframer ☒ Engine Manufacturer ☒ Design & Build Supplier ☐ Built to Print Supplier ☐ Design Only Supplier
Impacted Population Per Event:	☐ Less than 10 ☐ Between 10 and 100 ☒ Between 100 and 1000 ☐ More than 1000
Impacted Organizations:	☒ Airframer ☒ Engine Manufacturer ☒ Design & Build Supplier ☐ Built to Print Supplier ☐ Design Only Supplier
Preconditions:	Tolerances information available in the data set.

Normal Course of Events:		**Action:**	**Result:**
	1.	Manufacturing engineer identifies and selects relative tolerances existing between two EBOM items that need restructuring.	Tolerances existing between two EBOM items are selected.
	2.	Manufacturing engineer can assign specific tolerances to the target MBOM(s).	Tolerances are assigned to the appropriate MBOM/items.

	3.	System checks coherency* between tolerances in the EBOM and tolerances in the MBOM. * Tolerances are the same after restructuring.	System identifies if the result is OK/KO.
	4.	There is an EBOM change due to a tolerance change after the previous steps are completed.	System alerts that there is a change in the EBOM. System is able to identify the specific MBOM(s) affected by the tolerance change in the EBOM.
	5.	Manufacturing engineer identifies and selects relative tolerances existing between two EBOM items that need restructuring.	Tolerances existing between two EBOM items are selected.
	6.	Manufacturing engineer assigns specific tolerances to the **wrong** item in the target MBOM(s).	Tolerances are assigned to the MBOM/item.
	7.	System checks coherency between tolerances in the EBOM and the tolerances in MBOM.	System identifies the result as KO: tolerance assigned to the wrong item.
	8.	Manufacturing engineer identifies and selects relative tolerances existing between two EBOM items that need restructuring.	Tolerances existing between two EBOM items are selected.
	9.	Manufacturing engineer does not complete the assignment of all the concerned tolerances in the target MBOM(s).	Some of the tolerances are not assigned to the MBOM/item.
	10.	System checks coherency between tolerances in the EBOM and the tolerances in MBOM.	System identifies the result as KO: data not fully accounted for in the downstream MBOM.
Alternate Course(s) of Events:	None.		
Data & Attributes & Validations:	None.		
Use Case Data Set:	Model-Based Engineering Demonstrator Reference Model CAD assembly is used to create EBOM in the PLM system.		

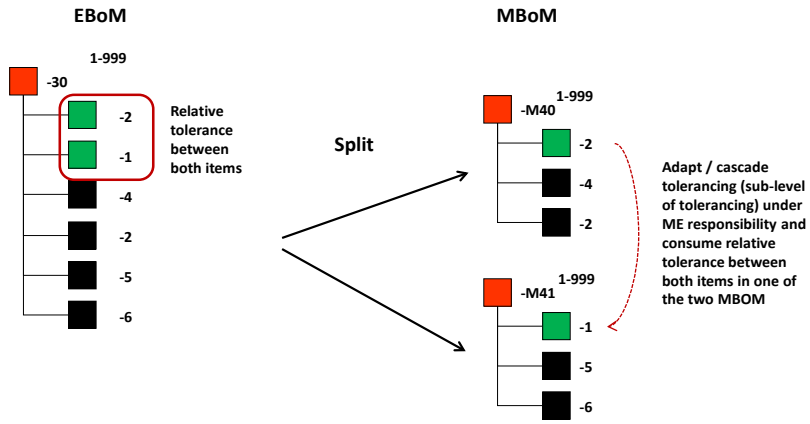
Other Special Requirements:	This use case shall be repeated for any restructuring scenario described in the Multiple View Bill of Materials (BOM) Appendix B: Concept Definition and Use Cases position paper. • Static View – No Effectivity Applied 1. EBOM and MBOM > 1 to N Restructuring 2. EBOM and MBOM > N to M Restructuring • Dynamic View – Effectivity Applied 1. EBOM Effectivity Change **2.** MBOM Effectivity Change, EBOM and MBOM > 1 to N Restructuring

Notes:

Generic Case Overview

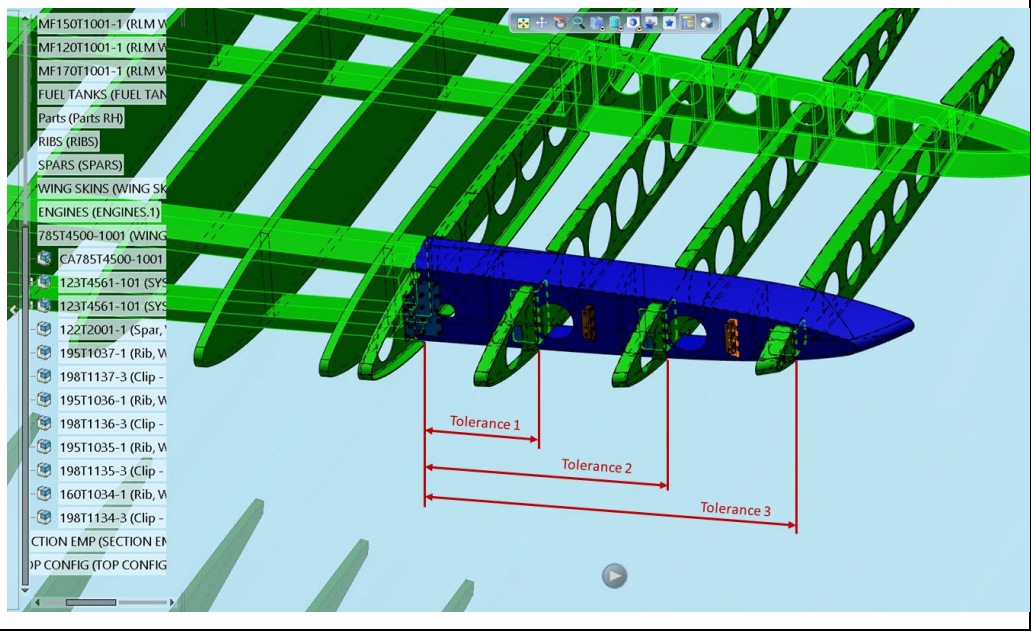
Engineering Requirements use cases

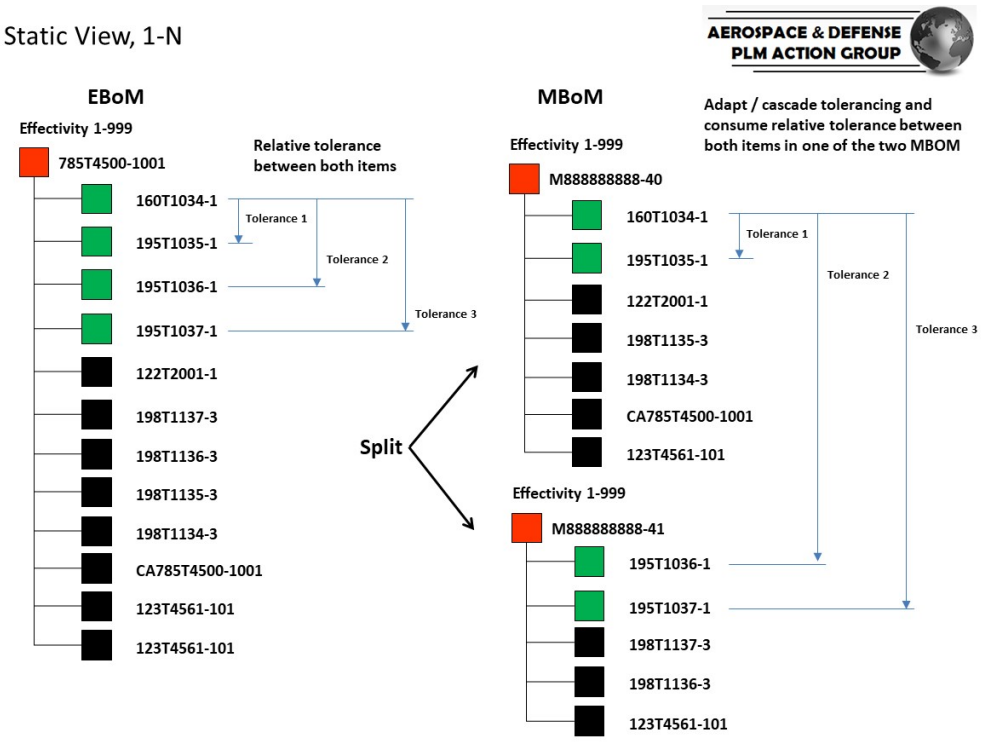
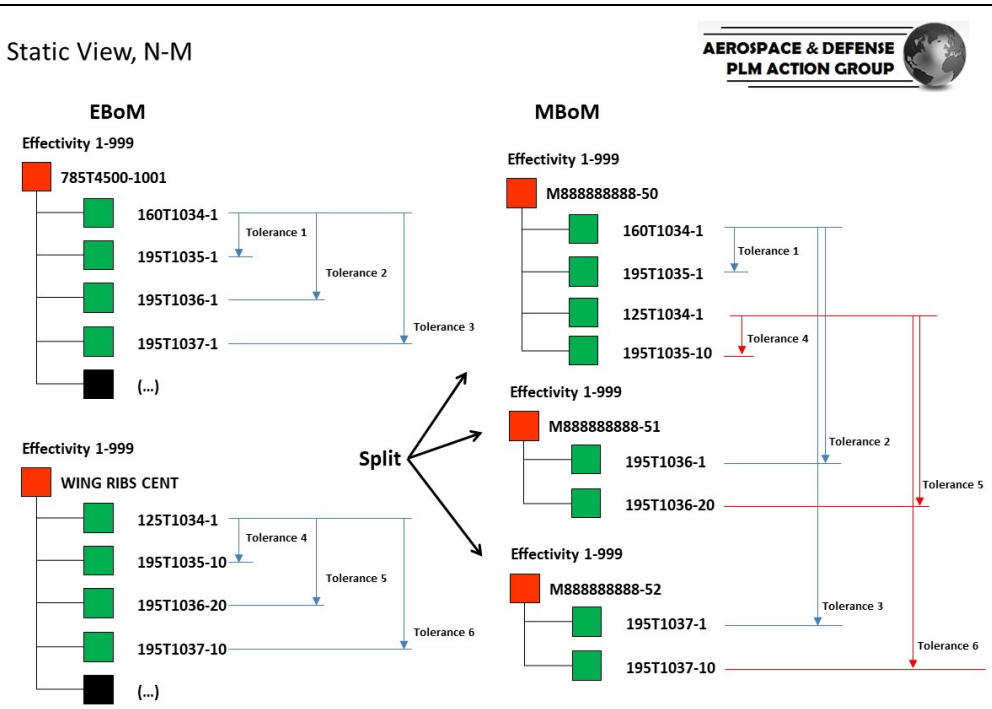
Adapting and consuming **tolerances** after restructuring



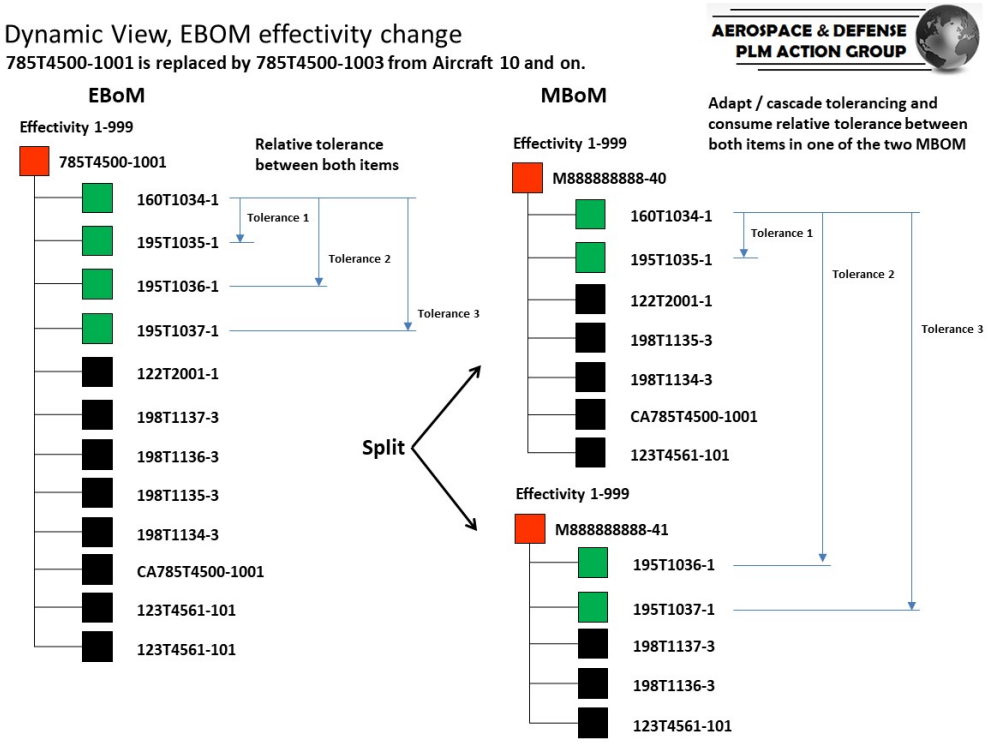
This use case shall be demonstrated for all types of restructuring scenario according to Position Paper use cases X, Y, Z…

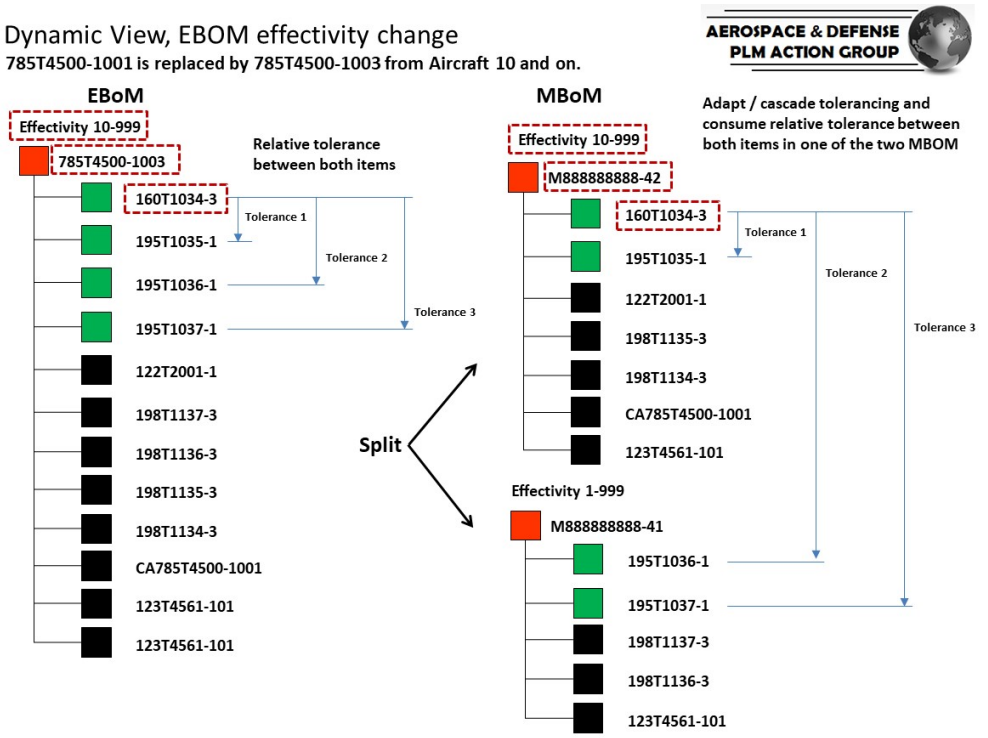
Illustrative tolerances. Tolerances information shall be created and linked to EBOM in the data set by the PLM provider prior to the test following the use cases description.

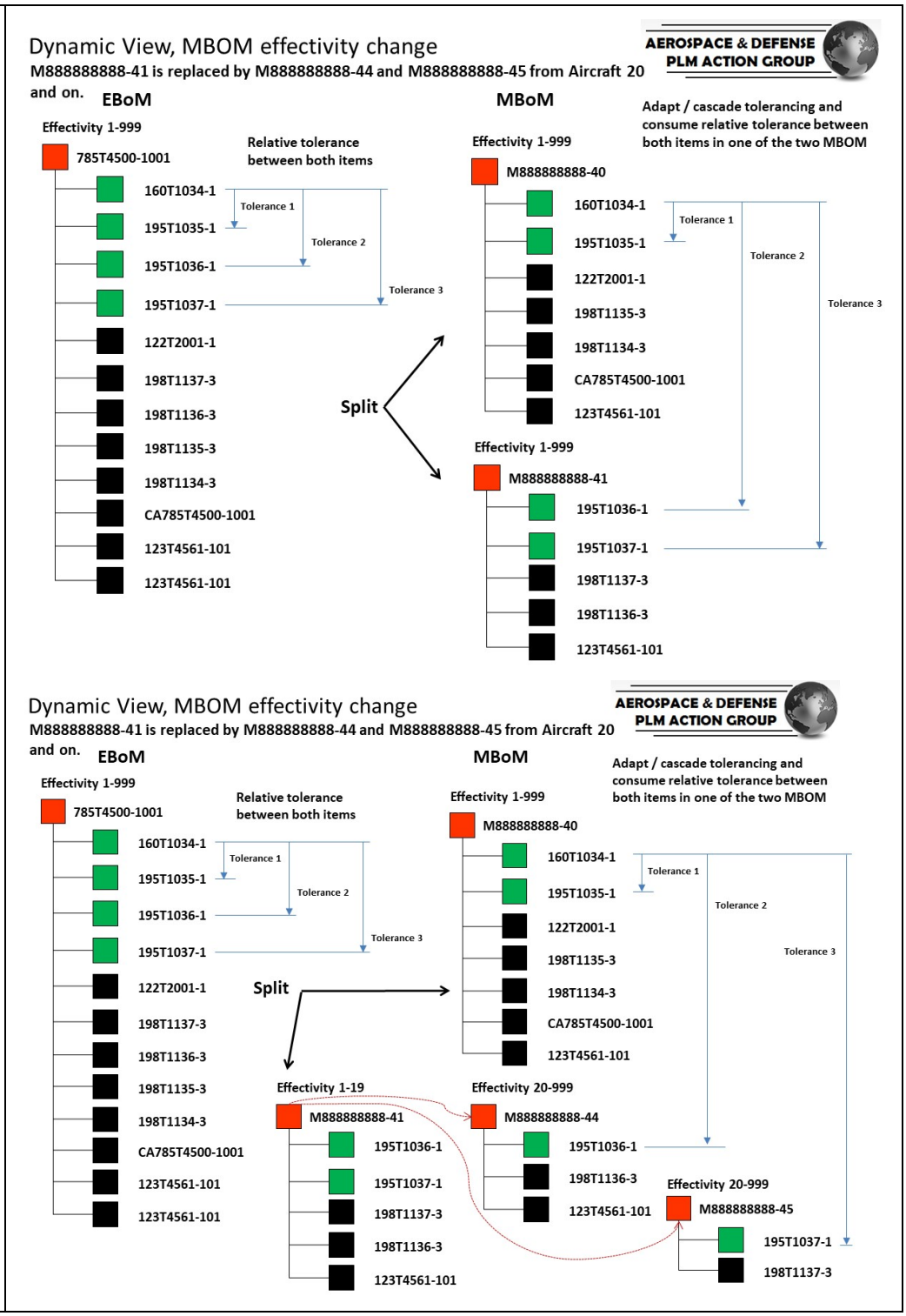


Static View, Case 1	
Static View, Case 2	

Dynamic View, Case 1





Dynamic View, Case 2	

Revision:	Description:	Revision Date:	Revised By:
Release 1.0	Pre-release to PLM SW Providers	7 Oct 2019	
2	Updated based on feedback from PLM Providers	30 Dec 2019	
Release 1.2	Release to PLM SW Providers	3 Jan 2020	
Release 1.3	Final release	26 Jan 2020	

ER-02

USE CASE NUMBER: ER-02	**Focus Area:** 1 – Engineering Release
Use Case Owner:	

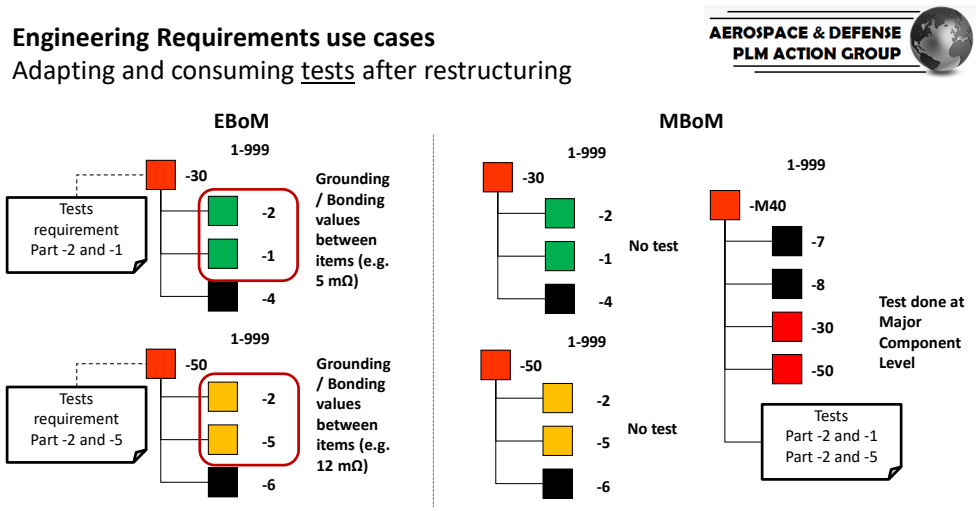
USE CASE TITLE: Consume documents linked to specific EBOM items after restructuring

Goal & Overview: (Functionality)	Demonstrate that documents linked to EBOM items (such as tests requirements) can keep the link to the appropriate items and then be consumed in the proper MBOM in any restructuring use case.
Use Case Product Scope:	☒ Airframe ☒ Systems ☒ Equipment ☒ Engine
Use Case Frequency:	☒ Daily ☐ Weekly ☐ Monthly ☐ Yearly
Impacted Companies:	☒ Airframer ☒ Engine Manufacturer ☒ Design & Build Supplier ☐ Built to Print Supplier ☐ Design Only Supplier
Impacted Population Per Event:	☐ Less than 10 ☐ Between 10 and 100 ☒ Between 100 and 1000 ☐ More than 1000
Impacted Organizations:	☐ Design Engineering ☒ Manufacturing Engineering ☐ Production ☐ Services
Preconditions:	Documents are linked to EBOM items that are available and are linked to the EBOM in the data set.

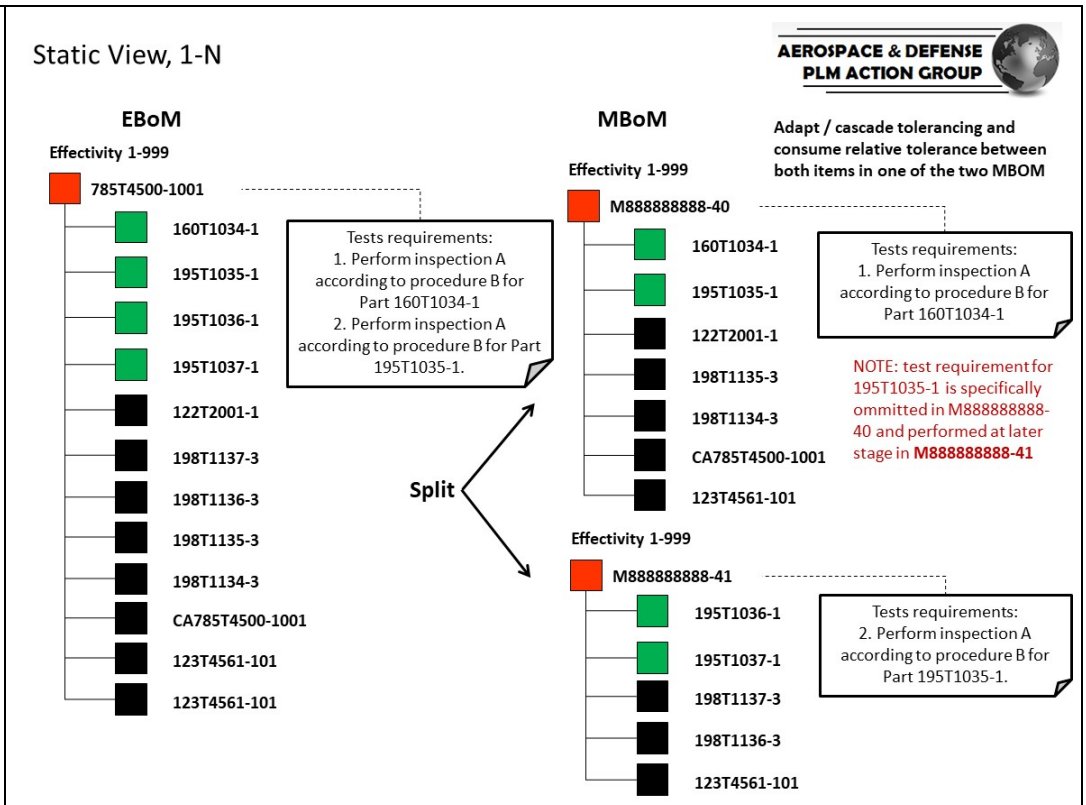
Normal Course of Events:

	Action:	**Result:**
1.	Manufacturing engineer identifies and selects a document linked to specific EBOM items that need restructuring.	Document linked to EBOM items is selected.
2.	Manufacturing engineer can assign the specific document to the targeted MBOM(s).	Document originally linked to the EBOM is assigned to the appropriate targeted MBOM.
3.	System checks coherency between the original “document to EBOM items” links and the resulting “document to MBOM items” links.	System identifies if the result is OK/KO.

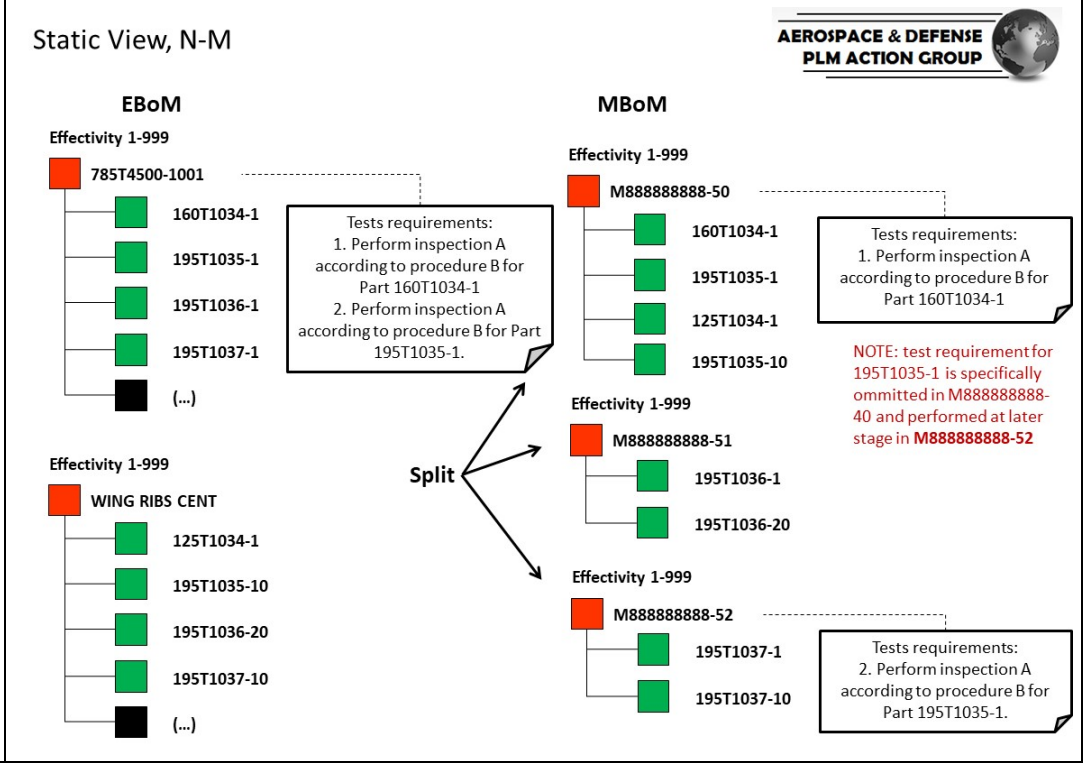
	4.	There is an EBOM change affecting linked documents after previous steps are completed.	System alerts that there is a change in the EBOM. System is able to identify the specific MBOM(s) affected by the linked documents changed in the EBOM.
	5.	Manufacturing engineer identifies and selects a document linked to specific EBOM items that need restructuring.	Document linked to EBOM items is selected.
	6.	Manufacturing engineer assigns a specific document to the item in the targeted MBOM(s).	Documents are assigned to the items in the targeted MBOM.
	7.	System checks coherency between the original “document to EBOM items” links and the resulting “document to MBOM items” links.	System identifies that the result is KO: document assigned to the wrong item.
	8.	Manufacturing engineer identifies and selects a document linked to specific EBOM items that need restructuring.	Document linked to EBOM items is selected.
	9.	Manufacturing engineer does not complete the assignment of all specific documents in the targeted MBOM(s).	Some of the documents are not assigned to the MBOM/item.
	10.	System checks coherency between the original “document to EBOM items” links and the resulting “document to MBOM items” links.	System identifies that the result is KO: data not fully accounted for in the downstream MBOM.
Alternate Course(s) of Events:	None.		
Data & Attributes & Validations:	None.		
Use Case Data Set:	Model-Based Engineering Demonstrator Reference Model CAD assembly is used to create EBOM in the PLM system.		

Other Special Requirements:	This use case shall be repeated for any restructuring scenario described in the Multiple View Bill of Materials (BOM) Appendix B: Concept Definition and Use Case position paper. • Static View – No Effectivity Applied 1. EBOM and MBOM > 1 to N Restructuring 2. EBOM and MBOM > N to M Restructuring • Dynamic View – Effectivity Applied 1. EBOM Effectivity Change **2.** MBOM Effectivity Change, EBOM and MBOM > 1 to N Restructuring
Notes: Generic Case Overview	

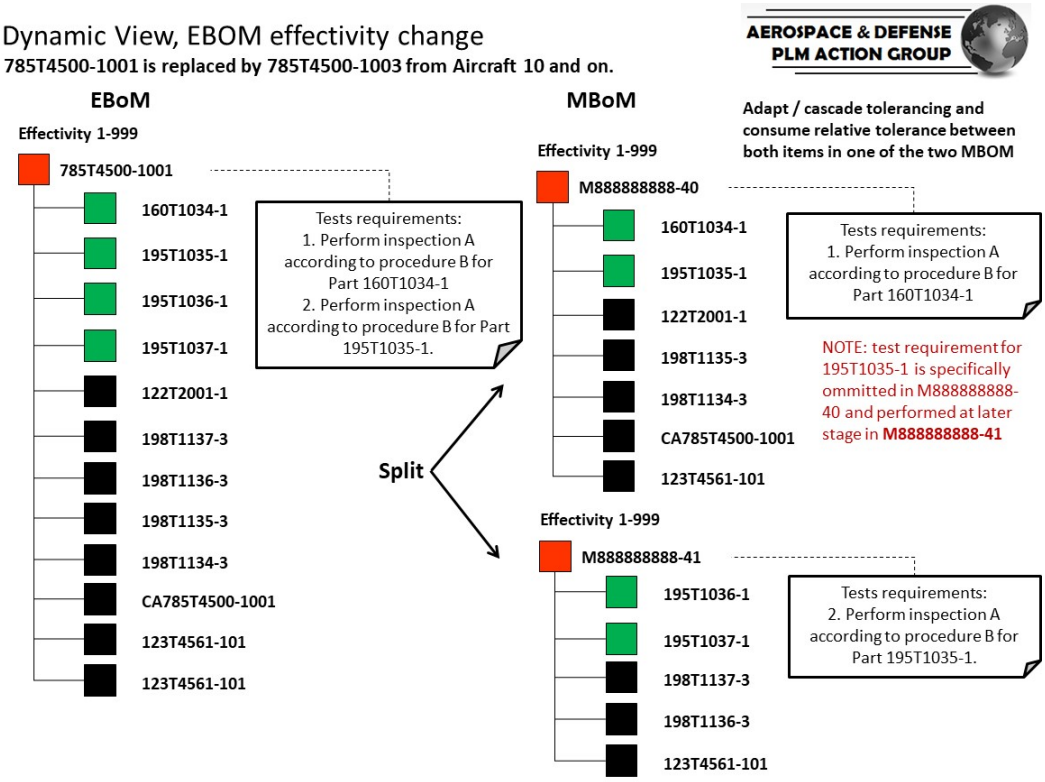
Static View, Case 1

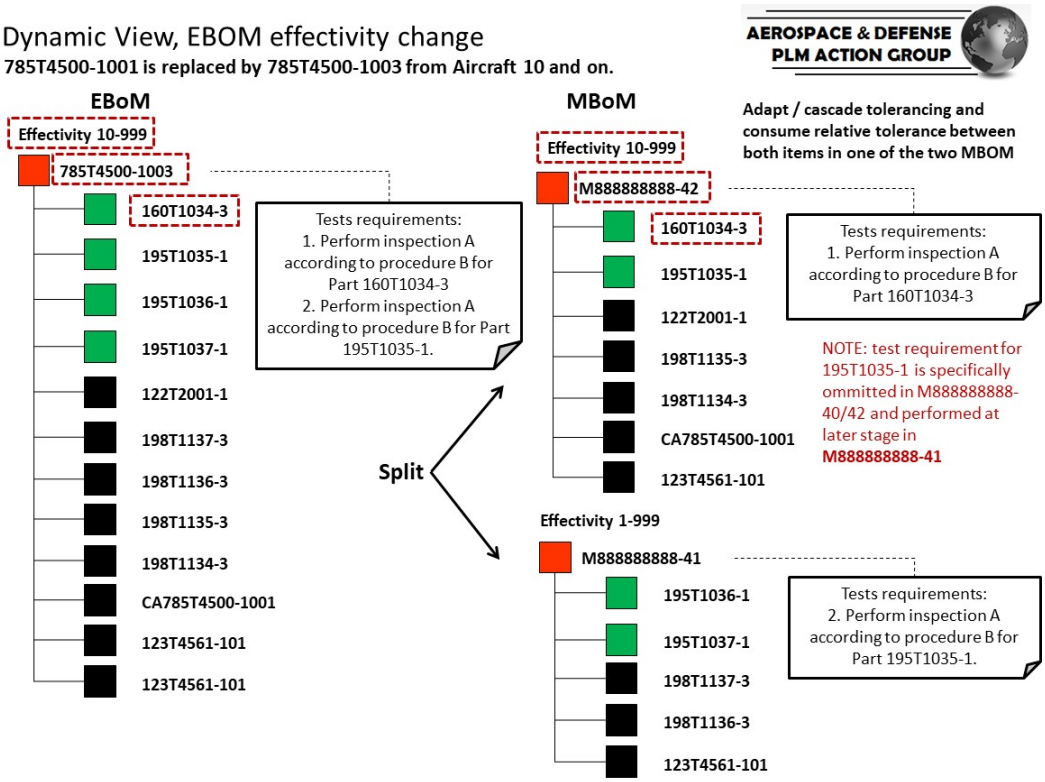


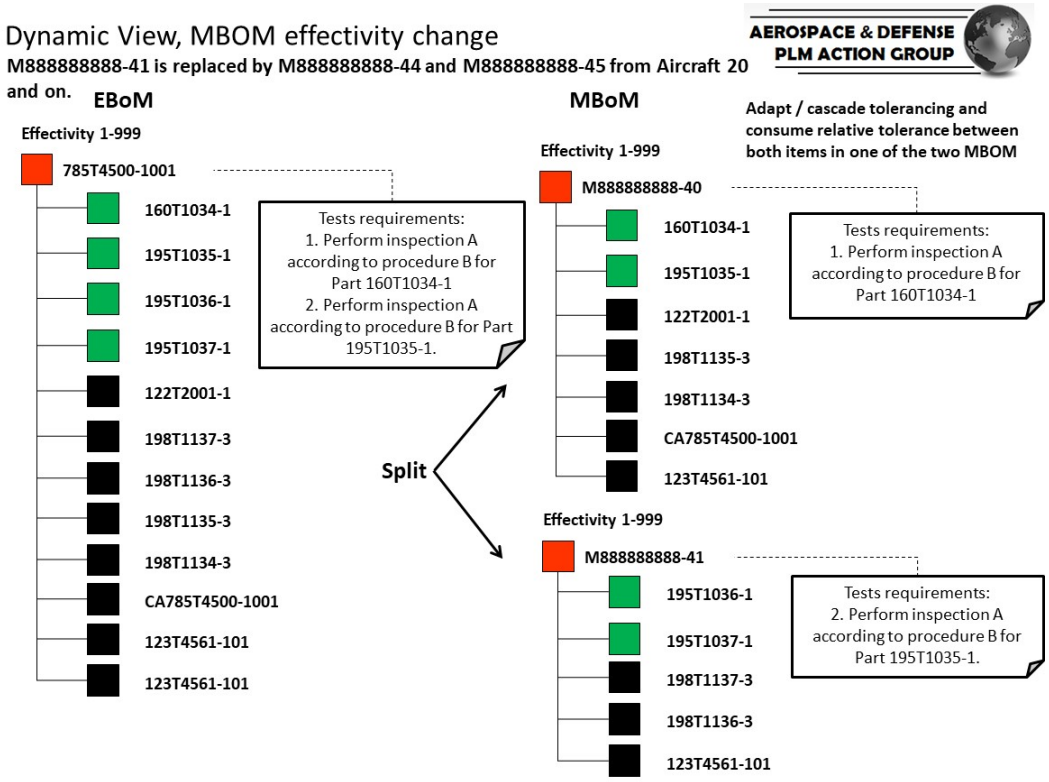
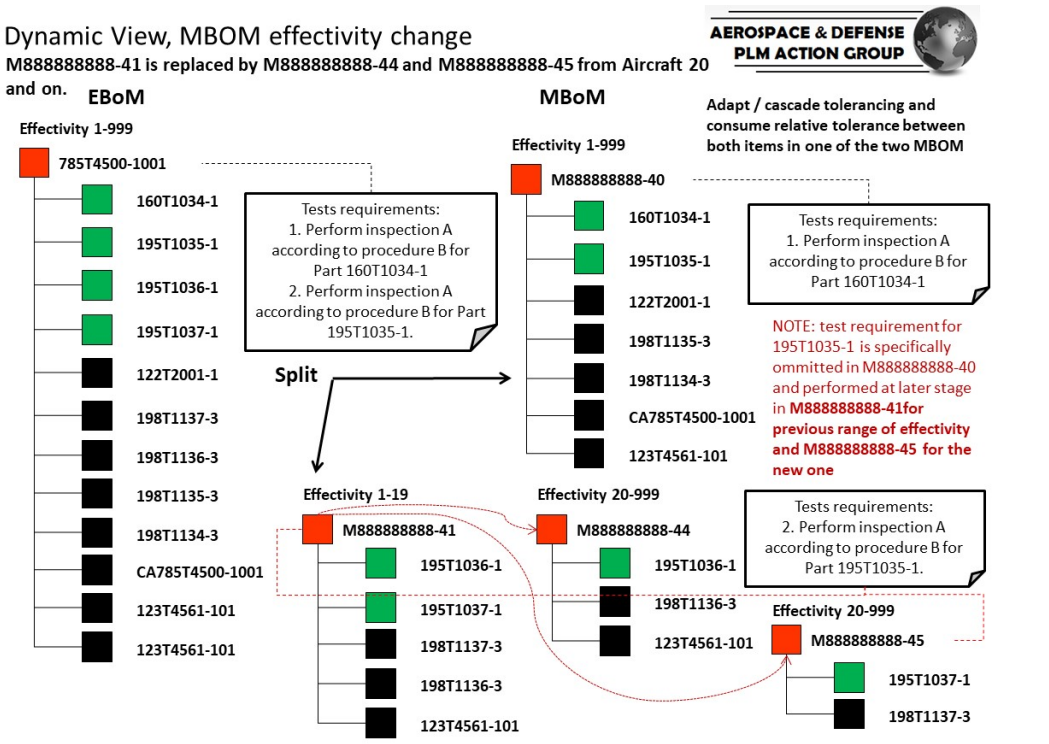
Static View, Case 2



Dynamic View, Case 1





Dynamic View, Case 2	 

Revision:	Description:	Revision Date:	Revised By:
Release 1.0	Pre-release to PLM SW Providers	7 Oct 2019	
Release 1.1	Punctuation changes	9 Oct 2019	
2	Updated based on feedback from PLM Providers	30 Dec 2019	
Release 1.2	Release to PLM SW Providers	6 Jan 2020	

ER-03

USE CASE NUMBER: ER-03	**Focus Area:** 1 – Engineering Release
Use Case Owner:	

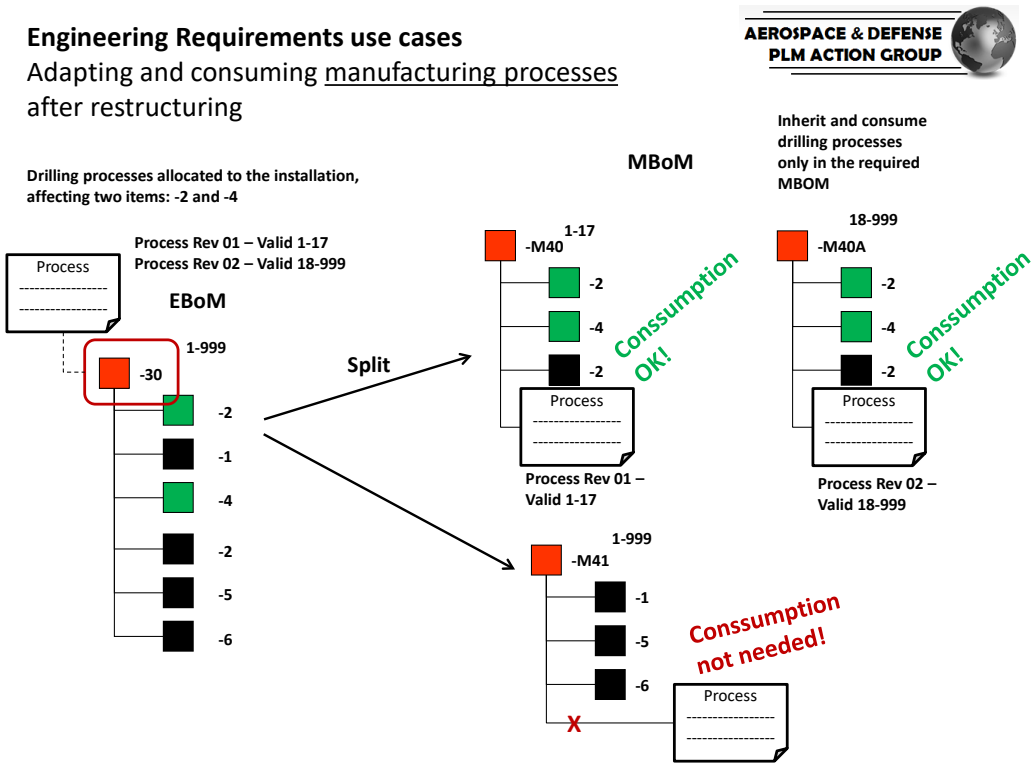
USE CASE TITLE: Consume documents linked to specific EBOM items with effectivity revision after restructuring

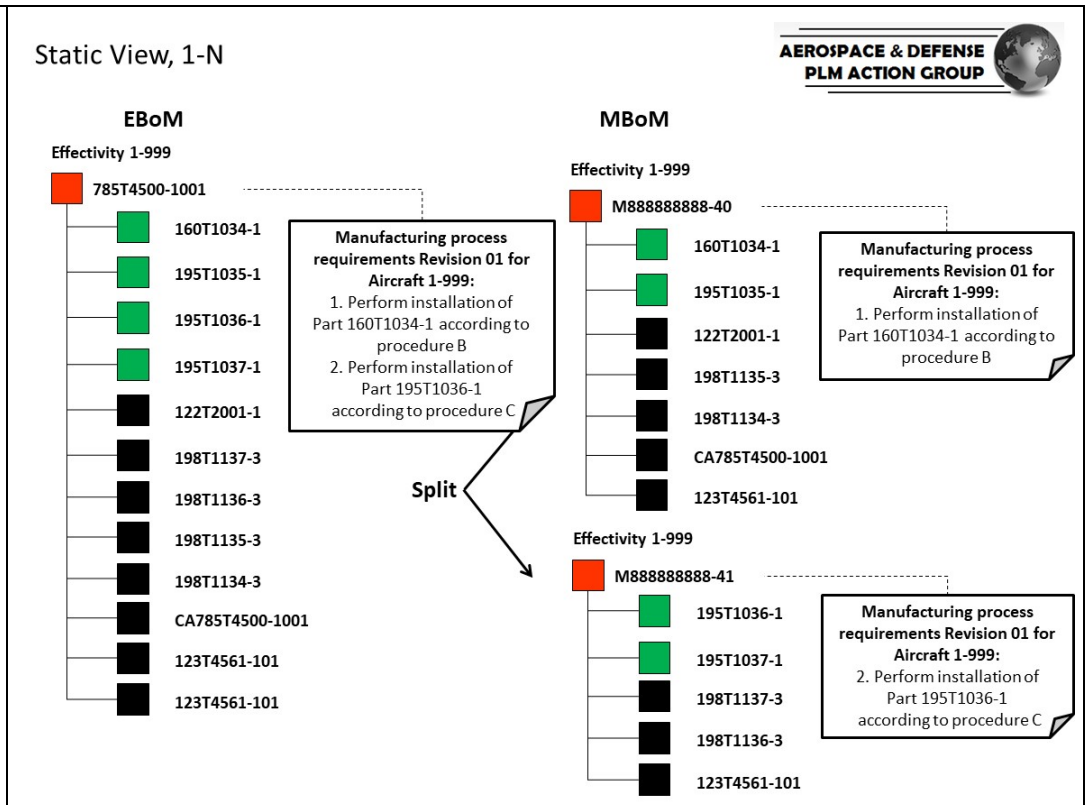
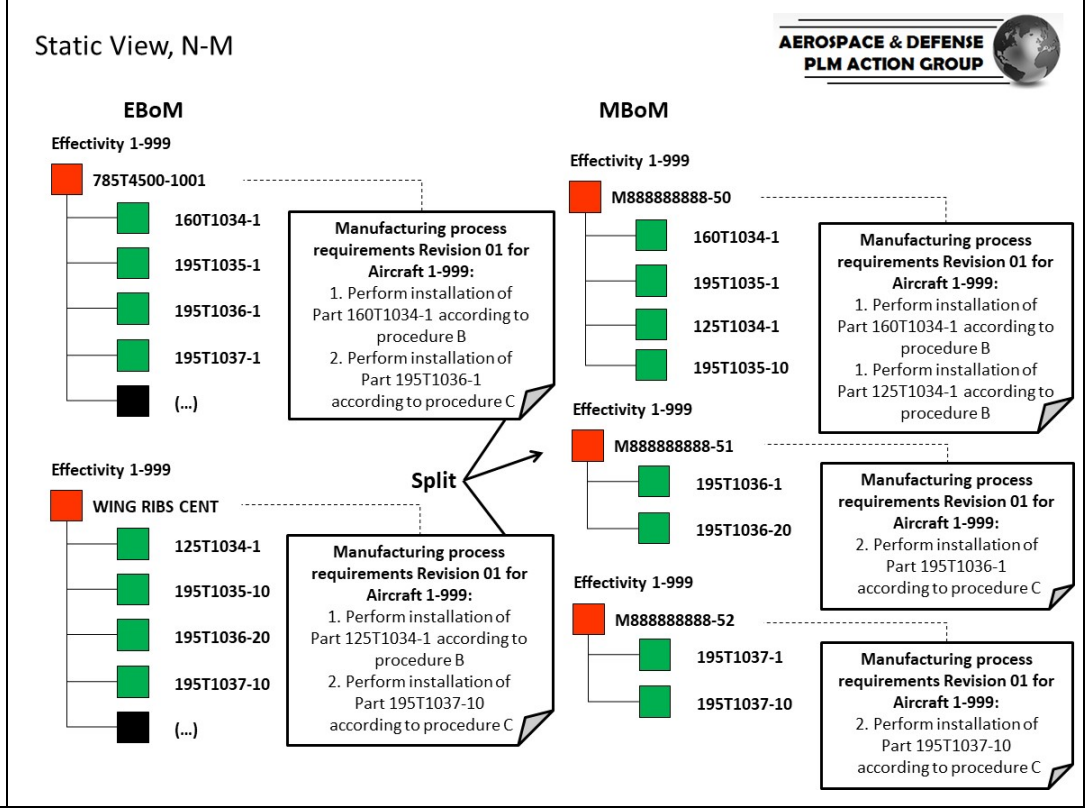
Goal & Overview: (Functionality)	Demonstrate that documents linked to EBOM items with effectivity revision (such as manufacturing processes linked to the EBOM) can keep the link to the appropriate items and then be consumed in the proper MBOM in any restructuring use case.
Use Case Product Scope:	☒ Airframe ☒ Systems ☒ Equipment ☒ Engine
Use Case Frequency:	☐ Daily ☒ Weekly ☐ Monthly ☐ Yearly
Impacted Companies:	☒ Airframer ☒ Engine Manufacturer ☒ Design & Build Supplier ☒ Built to Print Supplier ☐ Design Only Supplier
Impacted Population Per Event:	☐ Less than 10 ☐ Between 10 and 100 ☒ Between 100 and 1000 ☐ More than 1000
Impacted Organizations:	☐ Design Engineering ☒ Manufacturing Engineering ☐ Production ☐ Services
Preconditions:	Documents linked to EBOM items are available and linked to the EBOM in the data set.

Normal Course of Events:

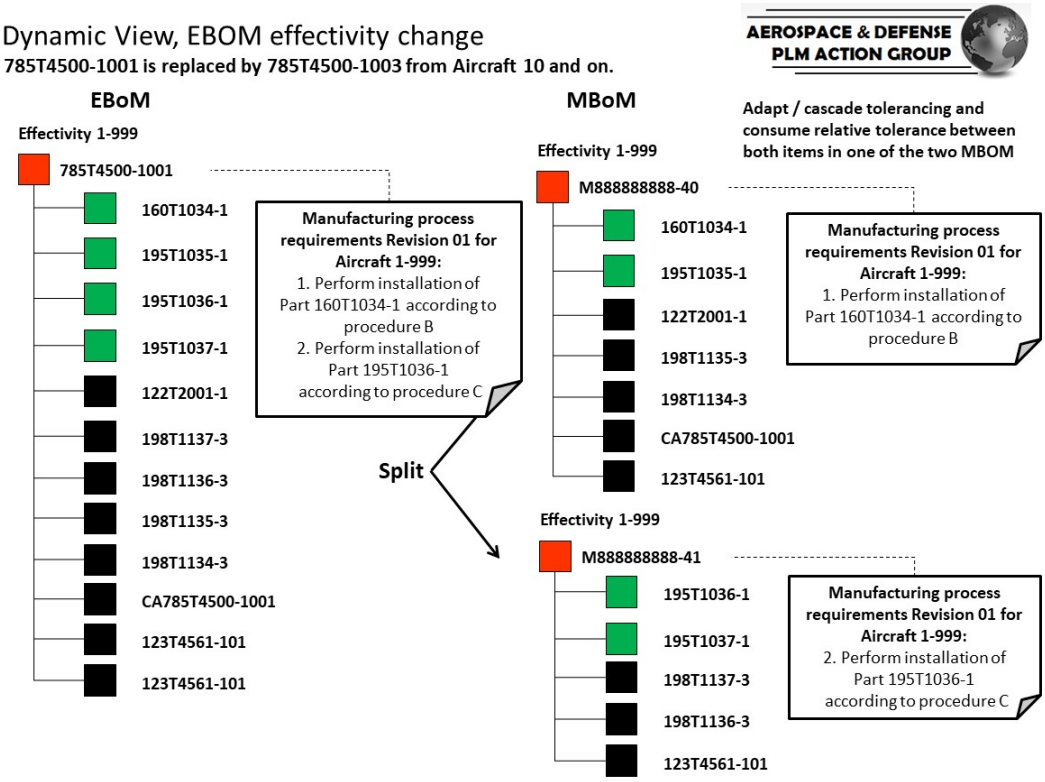
	Action:	Result:
1.	Manufacturing engineer identifies and selects a document linked to specific EBOM items that need restructuring.	Document linked to EBOM items is selected
2.	Manufacturing engineer can assign the specific documents to the targeted MBOM(s).	Documents are assigned to the appropriate EBOM items in the targeted MBOM.
3.	System checks coherency between the original “document to EBOM items links and effectivity” and the resulting “document to MBOM items links and effectivity”.	System identifies if the result is OK/KO.

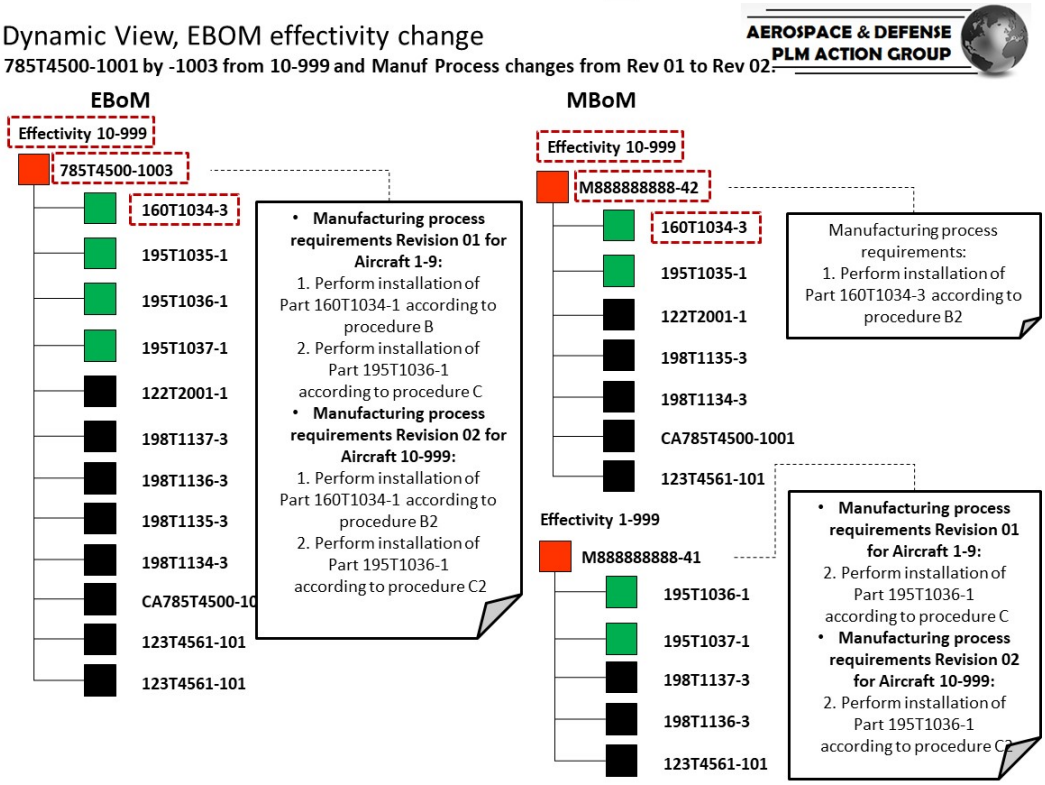
	4.	There is an EBOM change affecting linked documents after the previous steps are completed.	System alerts that there is a change in the EBOM. System is able to identify the specific MBOM(s) affected by the linked documents changed in the EBOM.
	5.	Manufacturing engineer identifies and selects a document linked to specific EBOM items that need restructuring.	Document linked to EBOM items is selected.
	6.	Manufacturing engineer assigns the specific document to a targeted MBOM(s) whose effectivity is not compatible with the original EBOM(s).	Documents are assigned to the MBOM(s).
	7.	System checks coherency between the original “document to EBOM items links and effectivity” and the resulting “document to MBOM items links and effectivity”.	System identifies that the result is KO: MBOM(s) effectivity is not compatible with the original EBOM(s).
	8.	Manufacturing engineer identifies and selects a document linked specifically to EBOM items that need restructuring.	Document linked to EBOM items is selected.
	9.	Manufacturing engineer does not complete the assignment of all specific documents in the targeted MBOM(s).	Some of the documents are not assigned to the MBOM/item.
	10.	System checks coherency between original “document to EBOM items links and effectivity” and the resulting “document to MBOM items links and effectivity”.	System identifies the result as KO: data not fully accounted for in the downstream MBOM.
Alternate Course(s) of Events:	None.		
Data & Attributes & Validations:	None.		
Use Case Data Set:	Model-Based Engineering Demonstrator Reference Model CAD assembly is used to create EBOM in the PLM system.		

Other Special Requirements:	This use case shall be repeated for any restructuring scenario described in the Multiple View Bill of Materials (BOM) Appendix B: Concept Definition and Use Cases position paper. • Static View – No Effectivity Applied 1. EBOM and MBOM > 1 to N Restructuring 2. EBOM and MBOM > N to M Restructuring • Dynamic View – Effectivity Applied 1. EBOM Effectivity Change
Notes: Generic Case Overview	

Static View, Case 1	
Static View, Case 2	

Dynamic View, Case 1





Revision:	Description:	Revision Date:	Revised By:
Release 1.0	Pre-release to PLM SW Providers	7 Oct 2019	
Release 1.1	Punctuation changes	9 Oct 2019	
2	Updated based on feedback from PLM Providers	30 Dec 2019	
Release 1.2	Release to PLM SW Providers	6 Jan 2020	

ER-04

USE CASE NUMBER: ER-04	**Focus Area:** 1 – Engineering Release
Use Case Owner:	

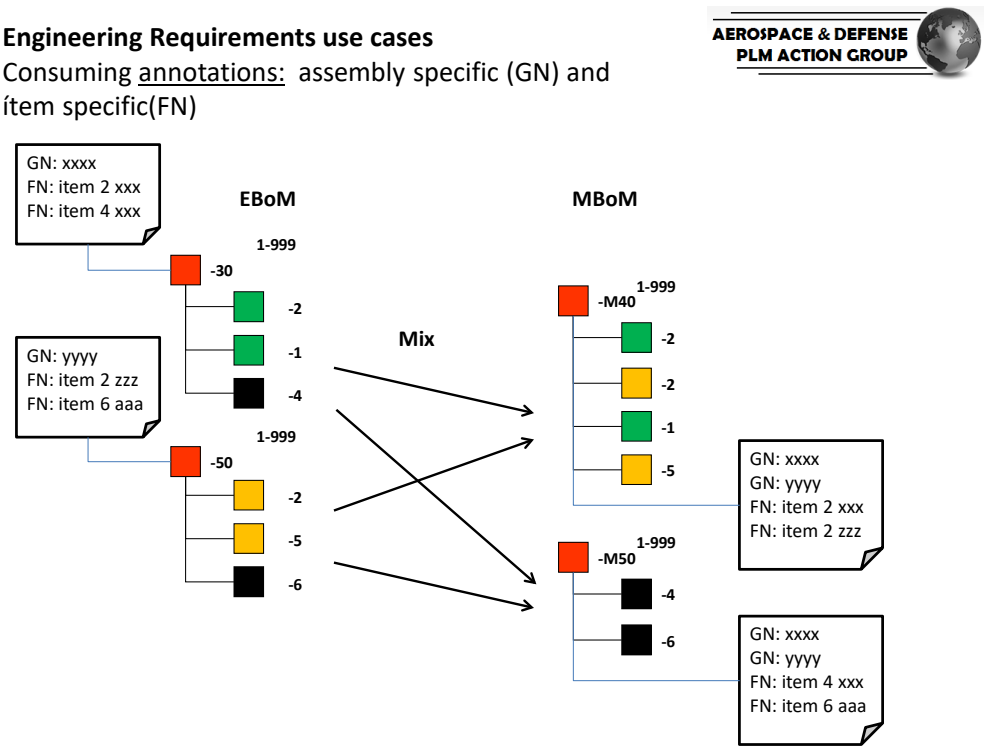
USE CASE TITLE: Consume annotations after restructuring

Goal & Overview: (Functionality)	Demonstrate that annotations (item specific and assembly specific) linked to EBOM items can keep the link to the appropriate items and then be consumed in the proper MBOM in any restructuring use case.
Use Case Product Scope:	☒ Airframe ☒ Systems ☒ Equipment ☒ Engine
Use Case Frequency:	☒ Daily ☐ Weekly ☐ Monthly ☐ Yearly
Impacted Companies:	☒ Airframer ☒ Engine Manufacturer ☒ Design & Build Supplier ☐ Built to Print Supplier ☐ Design Only Supplier
Impacted Population Per Event:	☐ Less than 10 ☐ Between 10 and 100 ☒ Between 100 and 1000 ☐ More than 1000
Impacted Organizations:	☐ Design Engineering ☒ Manufacturing Engineering ☐ Production ☐ Services
Preconditions:	Notes shall be available and linked to the EBOM in the data set. Notes may be managed in the CAD environment or as PDM objects.

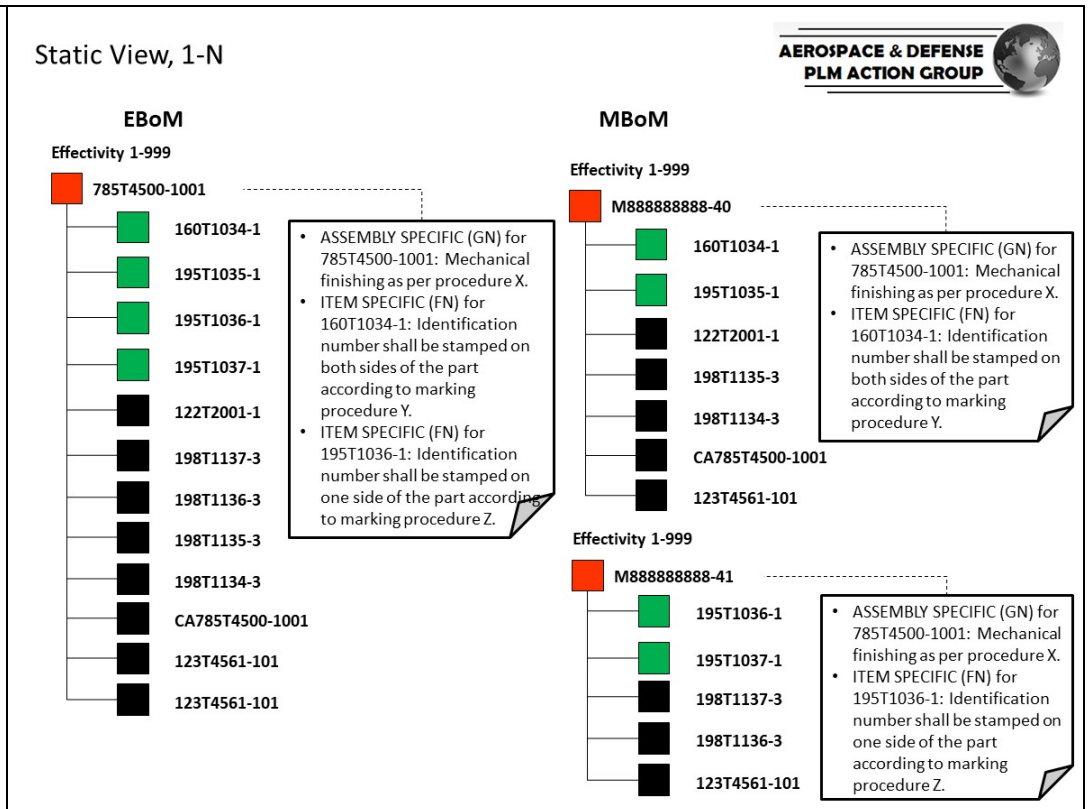
Normal Course of Events:

	Action:	Result:
1.	Manufacturing engineer identifies and selects annotations linked to specific EBOM items that need restructuring.	Annotations linked to EBOM items are selected.
2.	Manufacturing engineer can assign specific annotations to the targeted MBOM(s).	Annotations are assigned to the appropriate EBOM items in the targeted MBOM.
3.	System checks coherency between the original “annotations linked to EBOM(s) and EBOM items” and the resulting “annotations linked to MBOM(s) and MBOM items”.	System identifies if the result is OK/KO.

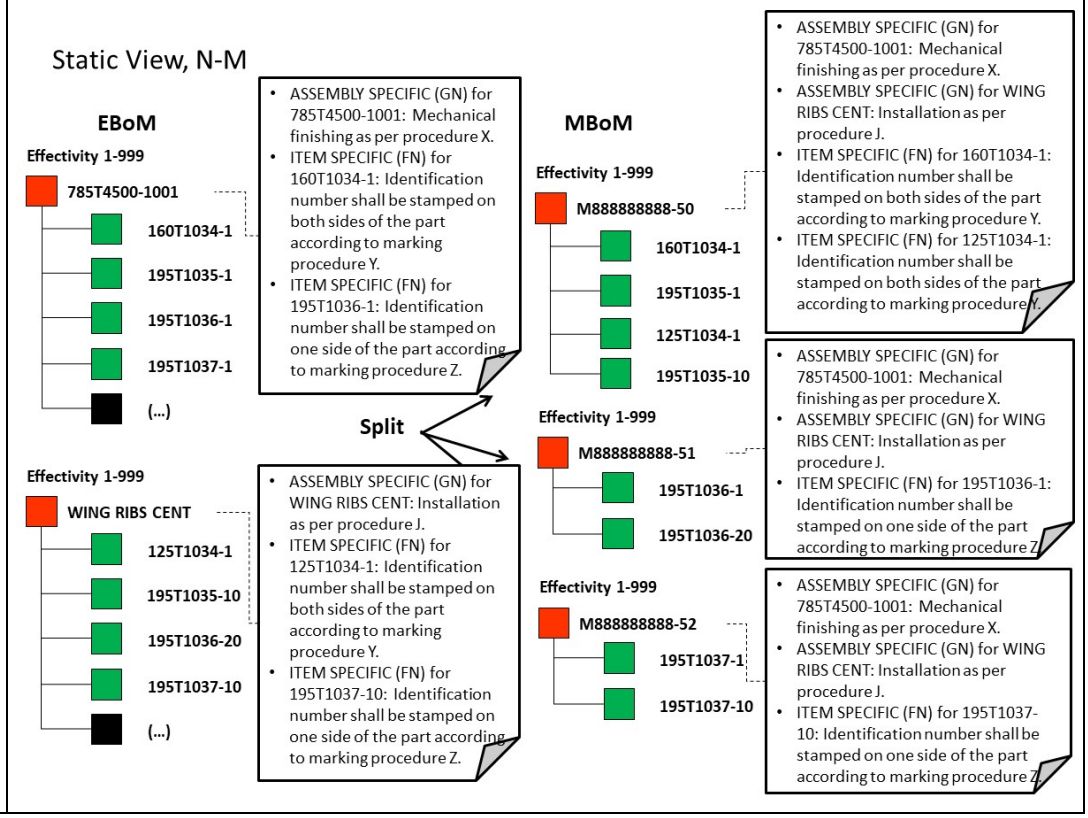
	4.	There is an EBOM change affecting linked annotations after the previous steps are completed.	System alerts that there is a change in the EBOM. System is able to identify the specific MBOM(s) affected by the annotations change in the EBOM.
	5.	Manufacturing engineer identifies and selects annotations linked to specific EBOM items that need restructuring.	Annotations linked to the EBOM items are selected.
	6.	Manufacturing engineer assigns specific annotations to the **wrong** MBOM(s)/MBOM items.	Annotations are assigned to the wrong MBOM(s)/MBOM items.
	7.	System checks coherency between the original “annotations linked to EBOM(s) and EBOM items” and the resulting “annotations linked to MBOM(s) and MBOM items”.	System identifies that the result is KO: “annotations X, Y, Z linked to MBOM(s) and MBOM items” are not compatible with the “annotations linked to EBOM(s) and EBOM items”
	8.	Manufacturing engineer identifies and selects the annotations linked to specific EBOM items that need restructuring.	Annotations linked to EBOM items are selected.
	9.	Manufacturing engineer does not complete the assignment of all specific annotations in the targeted MBOM(s).	Some of the annotations are not assigned to the MBOM/item.
	10.	System checks coherency between the original “annotations linked to EBOM(s) and EBOM items” and the resulting “annotations linked to MBOM(s) and MBOM items”.	System identifies the result as KO: annotations are not fully accounted for in the downstream MBOM.
Alternate Course(s) of Events:	None.		
Data & Attributes & Validations:	None.		
Use Case Data Set:	Model-Based Engineering Demonstrator Reference Model CAD assembly is used to create EBOM in the PLM system.		

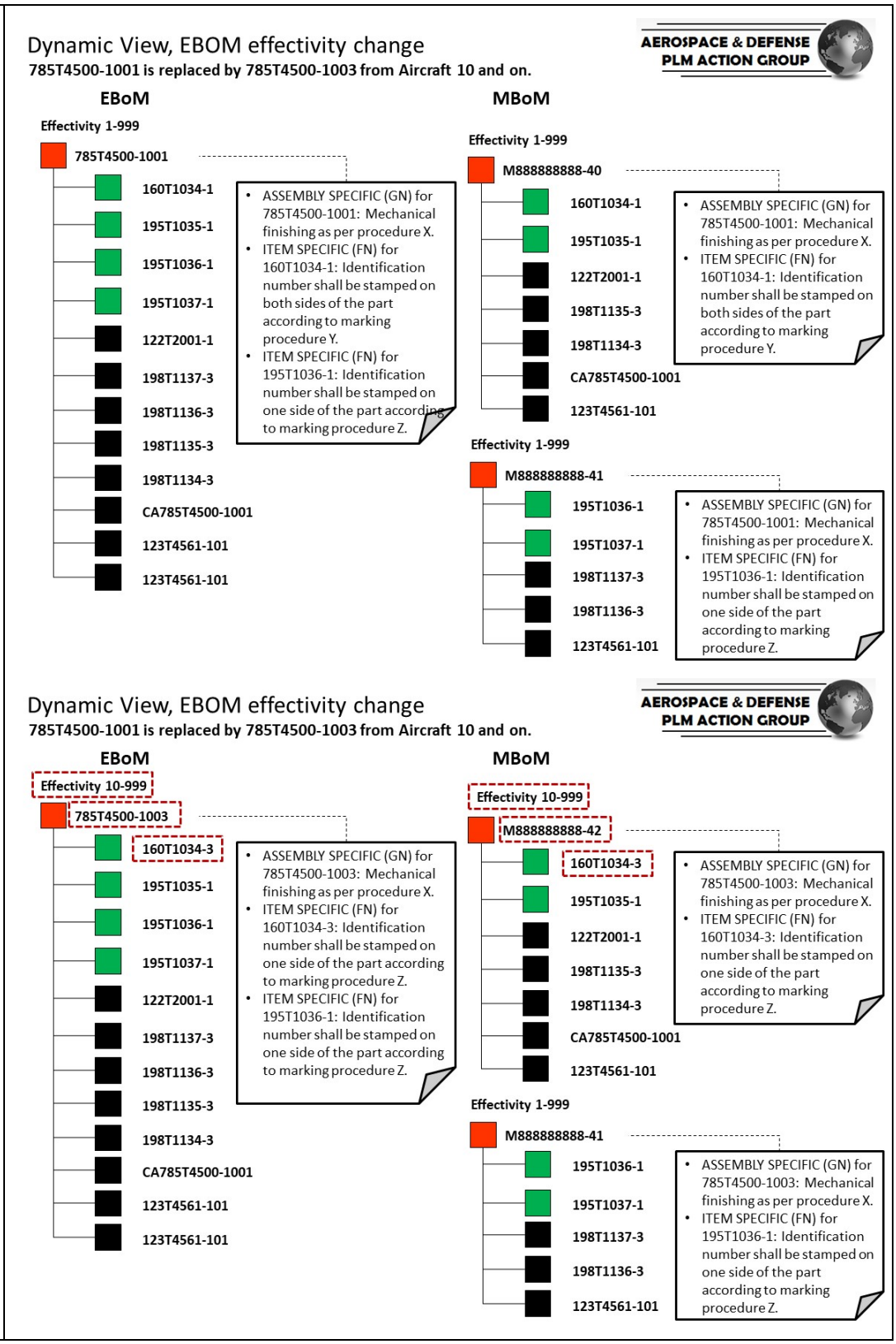
Other Special Requirements:	This use case shall be repeated for any restructuring scenario described in the Multiple View Bill of Materials (BOM) Appendix B: Concept Definition and Use Cases position paper. • Static View – No Effectivity Applied 1. EBOM and MBOM > 1 to N Restructuring 2. EBOM and MBOM > N to M Restructuring • Dynamic View – Effectivity Applied 1. EBOM Effectivity Change 2. MBOM Effectivity Change, EBOM and MBOM > 1 to N Restructuring
Notes: Generic Case Overview	 NOTE: Item-specific annotations are flagged as FN in the illustration. Assembly-specific annotations are flagged as GN. Example of annotations: - Assembly specific (GN) for Installation -30: Mechanical finishing as per procedure xxxxxxxx. - Item specific (FN) for Item 2: Identification number shall be stamped on both sides of the part according to the marking procedure xxxxxxxxxxx.

Static View, Case 1

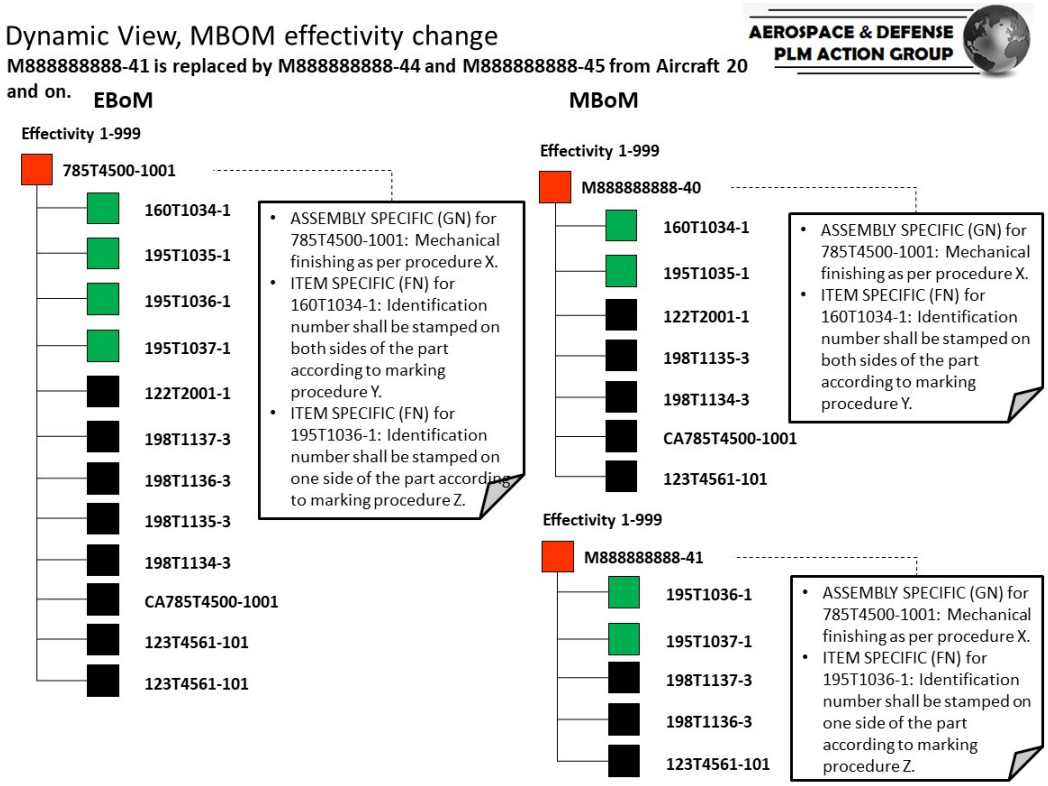


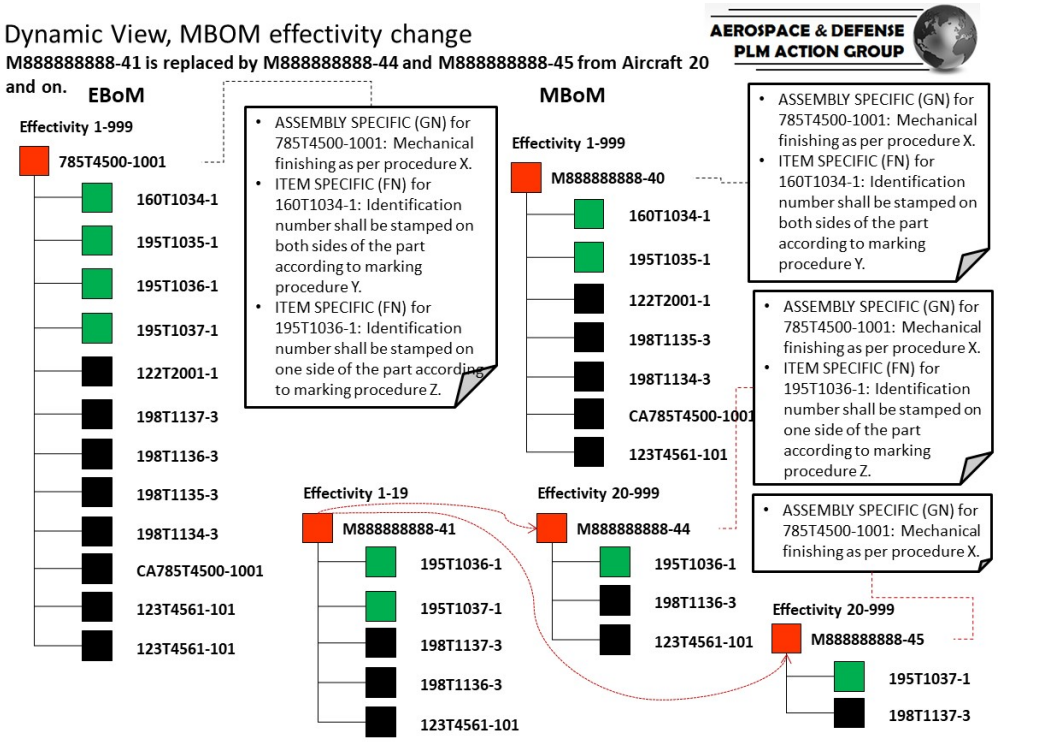
Static View, Case 2



Dynamic View, Case 1	

Dynamic View, Case 2





Revision:	Description:	Revision Date:	Revised By:
Release 1.0	Pre-release to PLM SW Providers	7 Oct 2019	
Release 1.1	Punctuation changes	9 Oct 2019	
2	Updated based on feedback from PLM Providers	30 Dec 2019	
Release 1.2	Release to PLM SW Providers	6 Jan 2020	

SC-01

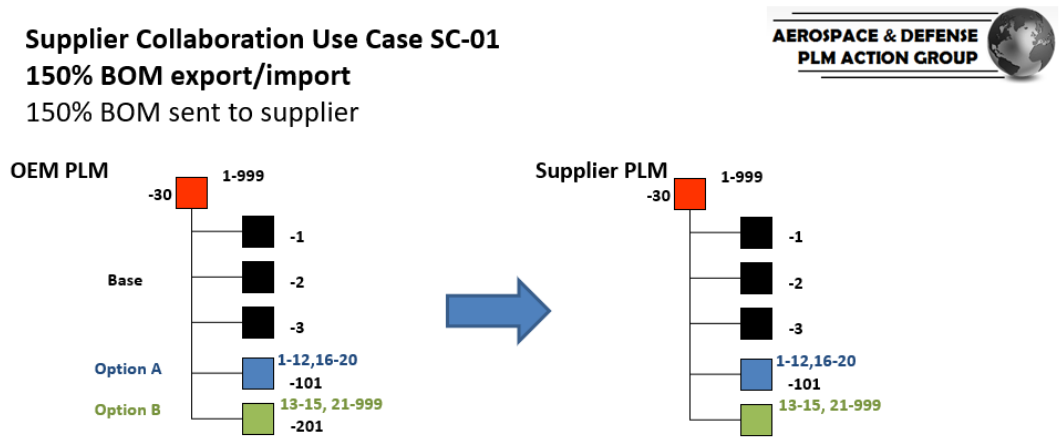
USE CASE NUMBER: SC-01	**Focus Area:** 2 – Supplier Collaboration
Use Case Owner:	

USE CASE TITLE: 150% BOM export / import

Goal & Overview: (Functionality)	Demonstrate that 150% BOM can be fully consumed into a supplier's PLM system and reconciled.
Use Case Product Scope:	☒ Airframe ☒ Systems ☒ Equipment ☒ Engine
Use Case Frequency:	☒ Daily ☐ Weekly ☐ Monthly ☐ Yearly
Impacted Companies:	☐ Airframer ☐ Engine Manufacturer ☐ Design & Build Supplier ☒ Built to Print Supplier ☐ Design Only Supplier
Impacted Population Per Event:	☐ Less than 10 ☒ Between 10 and 100 ☐ Between 100 and 1000 ☐ More than 1000
Impacted Organizations:	☒ Design Engineering ☒ Manufacturing Engineering ☒ Production ☒ Services
Preconditions:	It is common that supplier PLMs are not the same software providers or do not have the same version as the OEM. Exports should be in AP242 ed1 format that is agnostic towards the supplier's PLM system.

Normal Course of Events:

	Action:	Result:
1.	The 150% BOM (containing two unit configurations) is exported out of the OEM's PLM.	The BOM is exported in AP242 ed1 format that can be easily re-ingested into a second PLM system, representing a supplier's PLM.
2.	Exported 150% BOM is imported into a second PLM system representing the supplier's PLM.	The BOM is fully imported into the second PLM system. Unit configuration is maintained.
3.	System performs an automatic validation and reports any mismatches or fallout.	Any mismatches or fallout are systematically reported without manual reconciliation.

Alternate Course(s) of Events:	None.
Data & Attributes & Validations:	BOM.
Use Case Data Set:	Model-Based Engineering Demonstrator Reference Model CAD assembly is used to create EBOM in the PLM system.
Other Special Requirements:	Ideally export out of one PLM software/version and into a completely different PLM software/version, representing the supplier's PLM.
Notes:	

Revision:	Description:	Revision Date:	Revised By:
1	Initial issue	15 May 2019	
2	Inclusion of schematic	22 Aug 2019	
3	Wording clarification and formatting	3 Oct 2019	
4	Added AP242 format	11 Nov 2019	
Release 1.2	Release to PLM SW Providers	6 Jan 2020	

SC-02

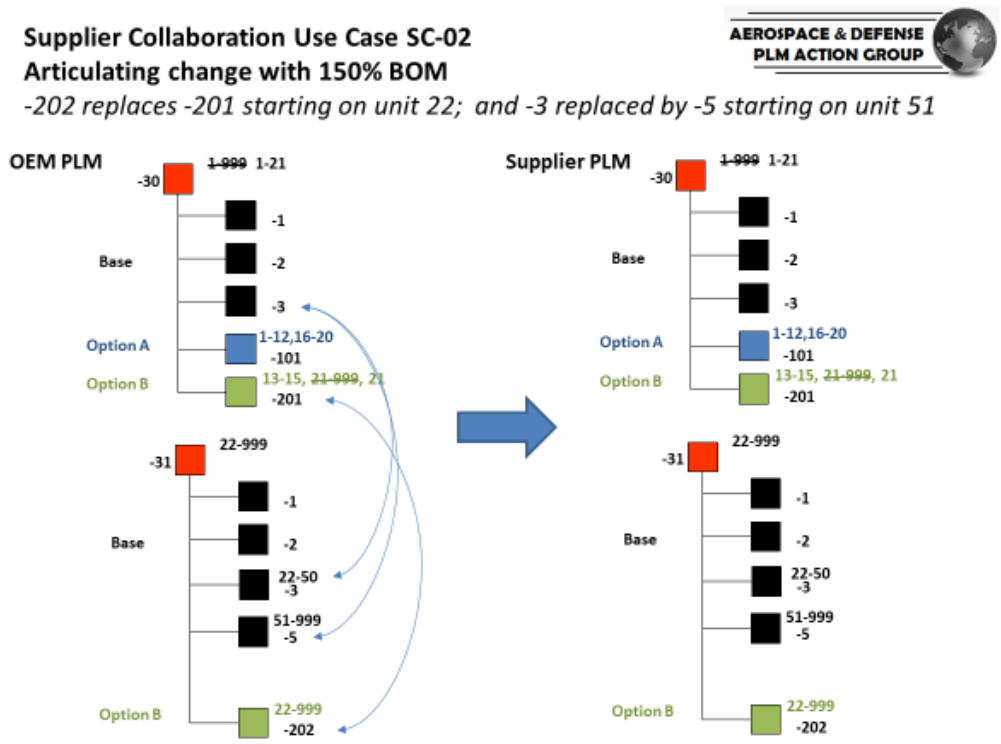
USE CASE NUMBER: SC-02	**Focus Area:** 2 – Supplier Collaboration
Use Case Owner:	

USE CASE TITLE: Articulating changes within 150% BOM

Goal & Overview: (Functionality)	Demonstrate that changes to a 150% BOM can be fully consumed into a supplier's PLM system and reconciled.
Use Case Product Scope:	☒ Airframe ☒ Systems ☒ Equipment ☒ Engine
Use Case Frequency:	☒ Daily ☐ Weekly ☐ Monthly ☐ Yearly
Impacted Companies:	☐ Airframer ☐ Engine Manufacturer ☐ Design & Build Supplier ☒ Built to Print Supplier ☐ Design Only Supplier
Impacted Population Per Event:	☐ Less than 10 ☒ Between 10 and 100 ☐ Between 100 and 1000 ☐ More than 1000
Impacted Organizations:	☒ Design Engineering ☒ Manufacturing Engineering ☒ Production ☒ Services
Preconditions:	150% BOM has already been sent/synced with the supplier.

Normal Course of Events:

	Action:	**Result:**
1.	Two part changes are introduced: one in the Base product and one in an Option B.	The BOM is properly updated in the OEM's PLM.
2.	Only the changes (net change) are exported out of the OEM's PLM and sent to the supplier.	Only what has changed in the BOM structure is exported in a same AP242 ed1 format as in the original export.
3.	Changes are imported into a second PLM system, representing the supplier's PLM.	The BOM changes are fully imported into the second PLM system. Unit configuration is maintained.
4.	System performs a validation and reports any mismatches or fallout.	Mismatches and fallout are systematically reported without manual reconciliation.

Alternate Course(s) of Events:	None.
Data & Attributes & Validations:	BOM.
Use Case Data Set:	Model-Based Engineering Demonstrator Reference Model CAD assembly is used to create EBOM in the PLM system.
Other Special Requirements:	Ideally, export out of one PLM software/version and into a completely different PLM software/version representing the supplier's PLM.
Notes:	

Revision:	Description:	Revision Date:	Revised By:
1	Initial issue	15 May 2019	
2	Inclusion of schematic	22 Aug 2019	
3	Wording clarification and formatting	3 Oct 2019	
4	Added AP242 format, updated diagram to reflect no Option A on -31	11 Nov 2019	
Release 1.2	Release to PLM SW Providers	6 Jan 2020	

BJ-01

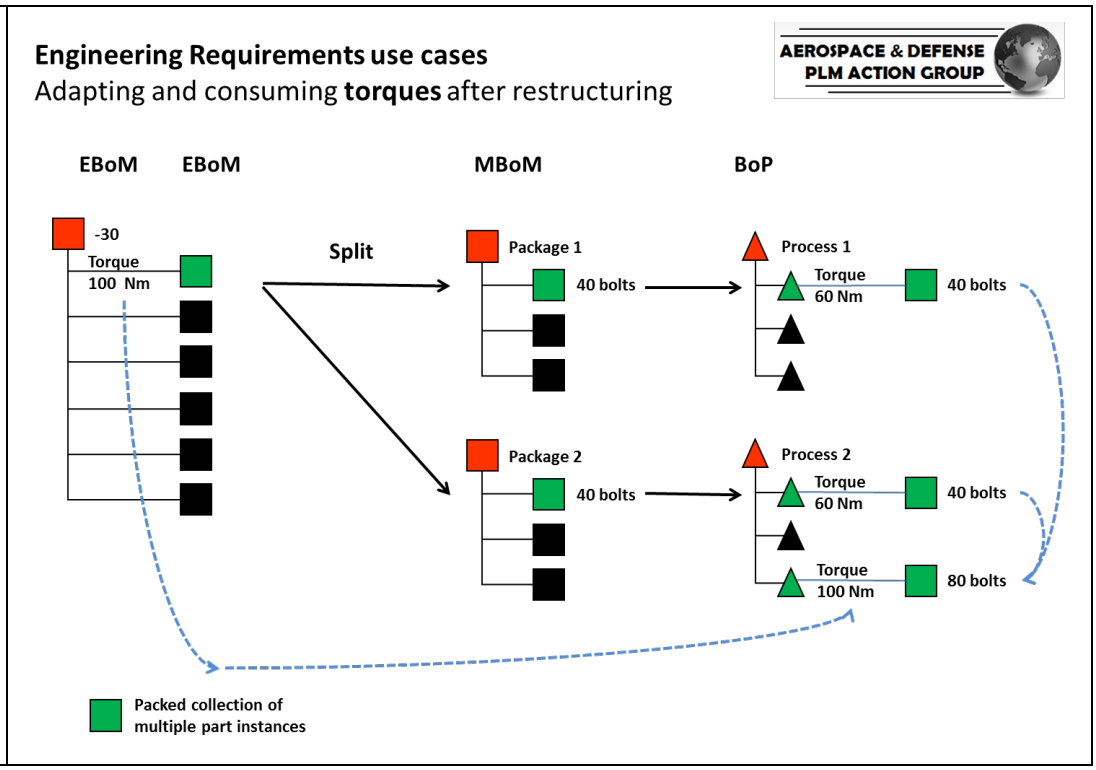
USE CASE NUMBER: BJ-01	**Focus Area:** 3 – Bolted Join
Use Case Owner:	

USE CASE TITLE: Bolted Join

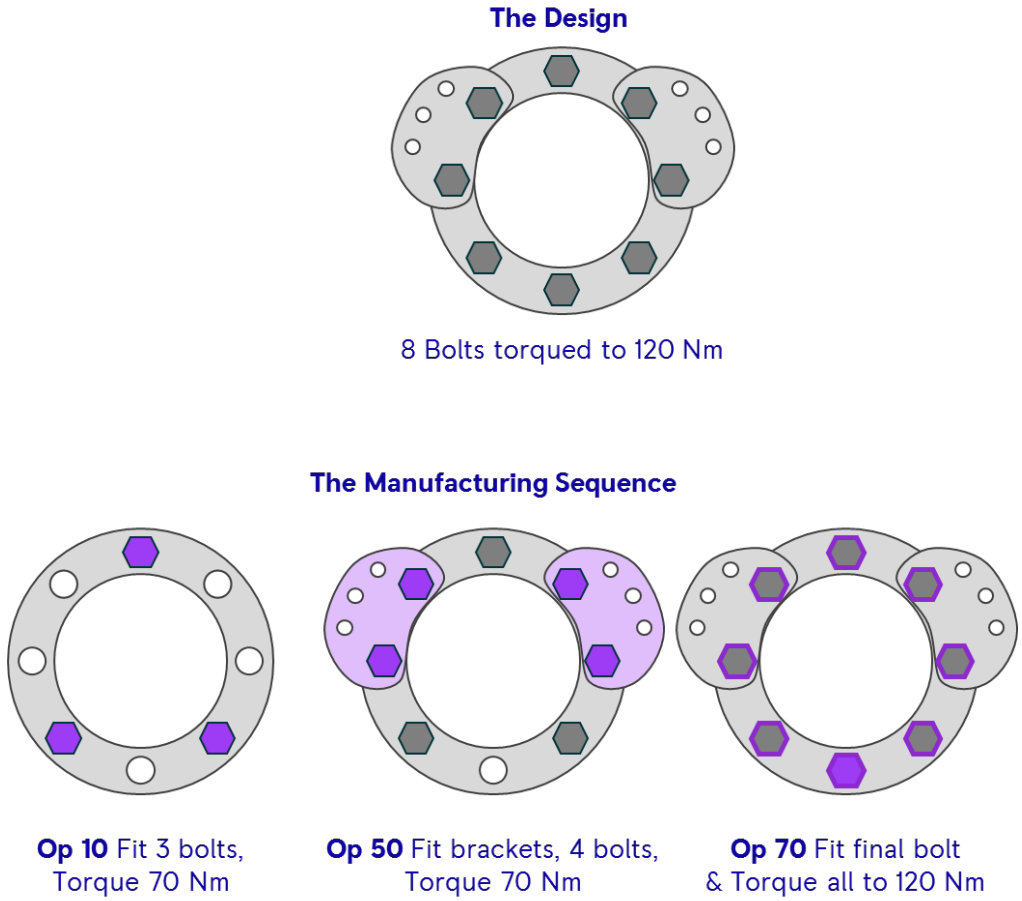
Goal & Overview: (Functionality)	Ensure full consumption of bolts and associated torque values. Allocate bolts from EBOM to MBOM.
Use Case Product Scope:	☒ Airframe ☐ Systems ☐ Equipment ☒ Engine
Use Case Frequency:	☐ Daily ☒ Weekly ☐ Monthly ☐ Yearly
Impacted Companies:	☒ Airframer ☒ Engine Manufacturer ☒ Design & Build Supplier ☐ Built to Print Supplier ☐ Design Only Supplier
Impacted Population Per Event:	☐ Less than 10 ☒ Between 10 and 100 ☐ Between 100 and 1000 ☐ More than 1000
Impacted Organizations:	☐ Design Engineering ☒ Manufacturing Engineering ☐ Production ☐ Services
Preconditions:	Bolts and torques defined in the EBOM.

Normal Course of Events:		**Action:**	**Result:**
	1.	Assembly planner locates the bolts in the EBOM.	
	2.	Manufacturing engineer allocates half of the bolts to the MBOM in package 1 for loose assembly of the casings. These will probably be every other bolt around the join.	The selected bolts appear in MBOM package 1.

	3.	Runs a check to show the state of the part consumption.	System shows half of the bolt instances have not been consumed in the MBOM, and none of the bolt torques have been consumed.
	4.	Allocates the remaining bolts to package 2 for final assembly of the casings.	The selected bolts appear in MBOM package 2.
	5.	Runs a check to show the state of part consumption.	System shows all of the bolt instances have been consumed in the MBOM, and none of the bolt torques have been consumed.
	6.	Allocates the package 1 bolts to an operation in the assembly process plan 1 with a low torque value.	The bolts are consumed in the first operation with a low torque value.
	7.	Allocates the package 2 bolts to an operation in the assembly process plan 2 operation 1 with a low torque value.	The bolts are consumed in the operation with a low torque value.
	8.	Allocates all the bolt torques set by design against the EBOM to later operation in assembly process plan 2.	The operation shows the full torque values against all the bolt instances.
	9.	Runs a check to show the state of part consumption.	System shows all of the bolt instances and all of the bolt torques have been consumed.
Alternate Course(s) of Events:	First set of bolts may be temporarily removed and reinserted before final assembly operations. The splitting of design quantities across multiple production operations can also apply to the joining of assemblies by drilling and riveting. This would not have an equivalent to the final torque setting step.		
Data & Attributes & Validations:	Two casings fastened together with X bolts torqued to Y Nm equally spaced around the casing flanges.		
Use Case Data Set:	Bolted Join Use Case data set.		
Other Special Requirements:	Wherever possible, the user can allocate groups of part instances as a single transaction and not have to assign each instance separately.		
Notes:	1. EBOM to MBM to BOP Flow Example:		


Engineering Requirements use cases
Adapting and consuming torques after restructuring
AEROSPACE & DEFENSE PLM ACTION GROUP
EBoM
EBoM
MBoM
BoP
-30
Torque
100 Nm
Split
Package 1
40 bolts
Process 1
Torque
60 Nm
40 bolts
Package 2
40 bolts
Process 2
Torque
60 Nm
40 bolts
Torque
100 Nm
80 bolts
Packed collection of
multiple part instances

2. Simple Visual Example:



Revision:	Description:	Revision Date:	Revised By:
0	Initial issue – draft 2	10 May 2019	
1	Updated to new template	28 Aug 2019	
2	Added alternative use based on rivets & drilling	17 Sep 2019	
3	Added additional figures as examples	24 Sep 2019	
4	Editorial review	4 Oct 2019	
Release 1.0	Pre-release to PLM SW Providers	7 Oct 2019	
Release 1.1	Added numeric torque values	13 Nov 2019	
Release 1.2	Release to PLM SW Providers	6 Jan 2020	

EM-01

USE CASE NUMBER: EM-01	**Focus Area:** 4 – Engineering to Manufacturing
Use Case Owner:	

USE CASE TITLE: Engineering to manufacturing equivalence

Goal & Overview: (Functionality)	Allow different structure between BOM views while maintaining equivalence. Engineering may specify a unique assembly.
Use Case Product Scope:	☒ Airframe ☐ Systems ☐ Equipment ☐ Engine
Use Case Frequency:	☐ Daily ☒ Weekly ☐ Monthly ☐ Yearly
Impacted Companies:	☒ Airframer ☐ Engine Manufacturer ☐ Design & Build Supplier ☐ Built to Print Supplier ☐ Design Only Supplier
Impacted Population Per Event:	☐ Less than 10 ☐ Between 10 and 100 ☐ Between 100 and 1000 ☒ More than 1000
Impacted Organizations:	☒ Design Engineering ☒ Manufacturing Engineering ☒ Production ☐ Services
Preconditions:	None.

Normal Course of Events:

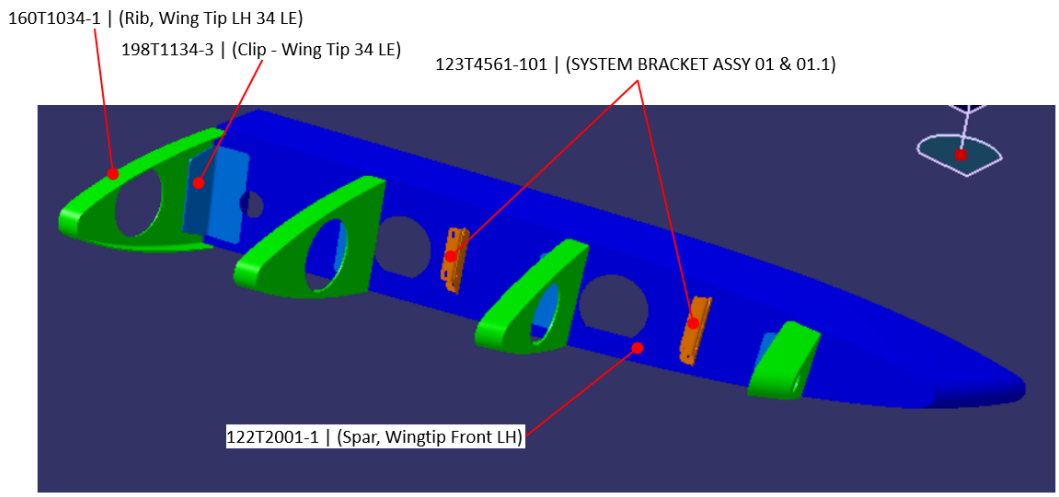
	Action:	**Result:**
1.	Design engineer creates an engineering assembly or installation (EBOM).	EBOM is created consisting of installation/assembly part, details parts, and installation/assembly specifications.
2.	Manufacturing engineer reviews the installation or assembly EBOM and decides to manufacture the installation in a different order.	The manufacturing view shows identical geometry, but parts within the assembly have a manufacturing-only identifier.
3.	Manufacturing engineer modifies the geometry of the manufacturing-only part by adding Full Size Determinate Assembly Holes (FSDA), removing holes, and modifying some holes into pilots.	The manufacturing view shows the same parts but with FSDA and pilot holes and without the removed holes.

	4.	Design engineer accesses the original EBOM assembly.	The geometry shows the original part number and bracket with holes.
Alternate Course(s) of Events:	None.		
Data & Attributes & Validations:	Engineering sees EBOM assembly and part numbers. Manufacturing sees MBOM assembly and part numbers with EBOM consumption/equivalence indicators.		
Use Case Data Set:	Model-Based Engineering Demonstrator Reference Model CAD assembly is used to create EBOM in the PLM system.		
Other Special Requirements:	None.		

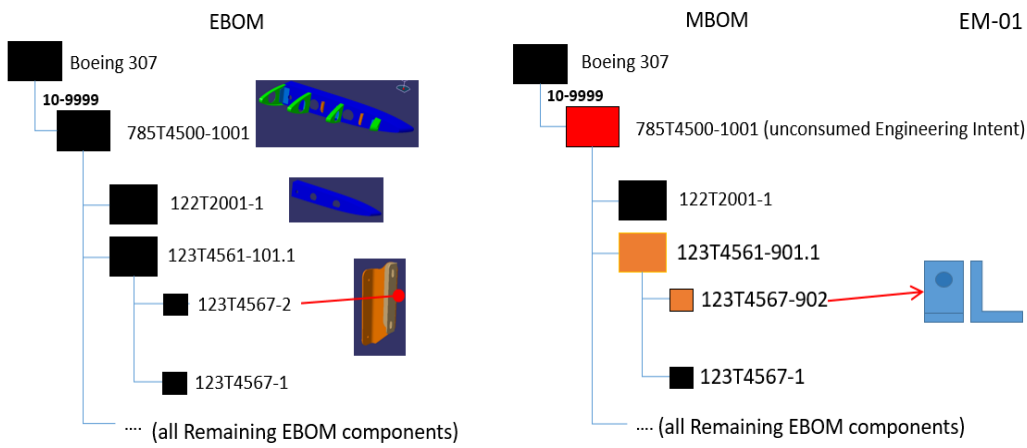
Notes:

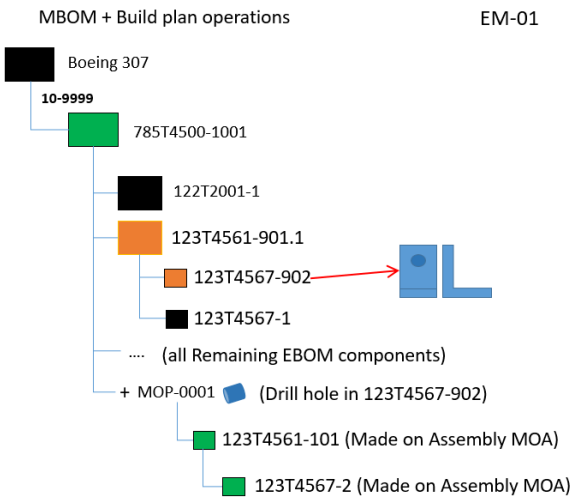
Product Structure:

785T4500-1001 | (WING TIP RIB FWD ~~INSTALL~~ Assy ~~01~~)



Steps 1 & 2



	Reference next stage (Build Plan) – within EM-02 

Revision:	Description:	Revision Date:	Revised By:
Release 1.0	Pre-release to PLM SW providers	7 Oct 2019	
2	Updated to Model-Based Engineering Demonstrator Reference Model release 1.4.1 Physical Product part numbers	12 Dec 2019	
3	Incorporated corrections based on Aras demo feedback	22 Jan 2020	
Release 1.3	Release to PLM SW Providers	26 Jan 2020	

EM-02

USE CASE NUMBER: EM-02	**Focus Area:** 4 – Engineering to Manufacturing
Use Case Owner:	
Goal & Overview: (Functionality)	Allow different part hierarchies between different BOM views. Allocation from EBOM to MBOM.
Use Case Product Scope:	☒ Airframe ☐ Systems ☐ Equipment ☐ Engine
Use Case Frequency:	☐ Daily ☒ Weekly ☐ Monthly ☐ Yearly ☐
Impacted Companies:	☒ Airframer ☐ Engine Manufacturer ☐ Design & Build Supplier ☐ Built to Print Supplier ☐ Design Only Supplier
Impacted Population Per Event:	☐ Less than 10 ☐ Between 10 and 100 ☐ Between 100 and 1000 ☒ More than 1000
Impacted Organizations:	☒ Design Engineering ☒ Manufacturing Engineering ☒ *Production ☐ Services
Preconditions:	EM-01.

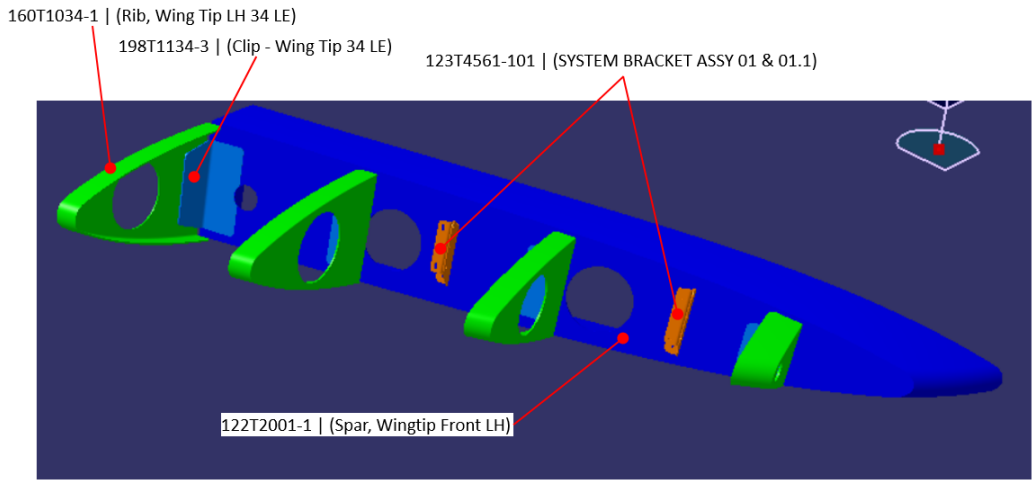
Normal Course of Events:		**Action:**	**Result:**
	1.	Manufacturing engineer chooses the manufacturing-only assembly (bracket assembly with hole omitted).	A manufacturing assembly with a new part number is selected.
	2.	Manufacturing engineer propagates the manufacturing-only assembly to all other instances of the original EBOM defined assembly within a specified level of the EBOM product structure.	All other instances of the engineering assembly are replaced with the appropriate manufacturing-only assembly. System notifies the user if any other instances of the engineering assembly (as well as of their manufacturing consumption) have been released already.
	3.	Manufacturing engineer allocates the manufacturing assemblies to a fabrication/installation plan	The manufacturing assembly components are consumed.

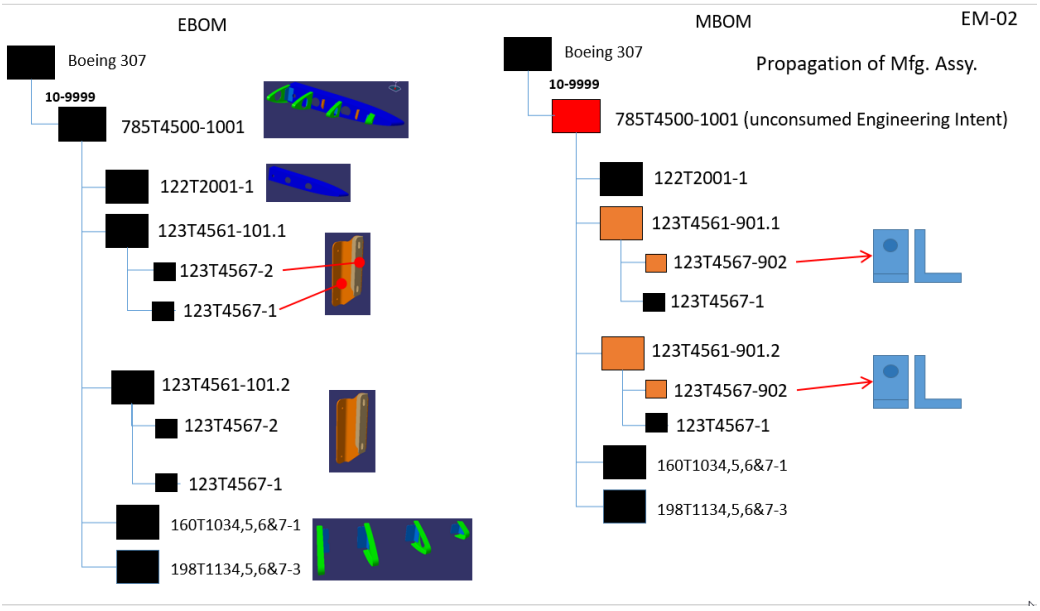
	4.	Manufacturing engineer runs an accountability check on the engineering assembly.	Only the manufacturing assembly components show as consumed for the entire effectivity range.
	5.	Manufacturing engineer allocates the rest of the engineering elements to another factory installation/assembly plan.	The other components are consumed. All COS engineering intent completed for the Made On Assembly (MOA) EBOM defined components.
	6.	Manufacturing engineer creates an operation within the plan to drill the omitted holes within the manufacturing-only bracket assemblies. Defined the MOA EBOM Components.	Manufacturing Build plan operation created. MOA EBOM components defined.
	7.	Manufacturing engineer runs an accountability check on the engineering assembly.	All components show as consumed for the entire effectivity range.
Alternate Course(s) of Events:	2. Manufacturing engineer does not propagate the manufacturing-only assembly to the other instances of the engineering assembly. (This scenario is performed during execution of EM-01.) No other instances of the engineering assembly are restructured. 5. Manufacturing engineer allocates all engineering elements to another factory installation plan. System prevents the user from completing the action because that would cause double consumption of the manufacturing assembly components.		
Data & Attributes & Validations:	Engineering sees all EBOM parts as direct “children” of the original assembly. Manufacturing sees manufacturing assembly containing two parts, including the bracket without the hole. Manufacturing can see the traceability of the manufacturing assembly to the engineering assembly from which it consumed part instances.		
Use Case Data Set:	Model-Based Engineering Demonstrator Reference Model CAD assembly is used to create EBOM in the PLM system.		
Other Special Requirements:	None.		

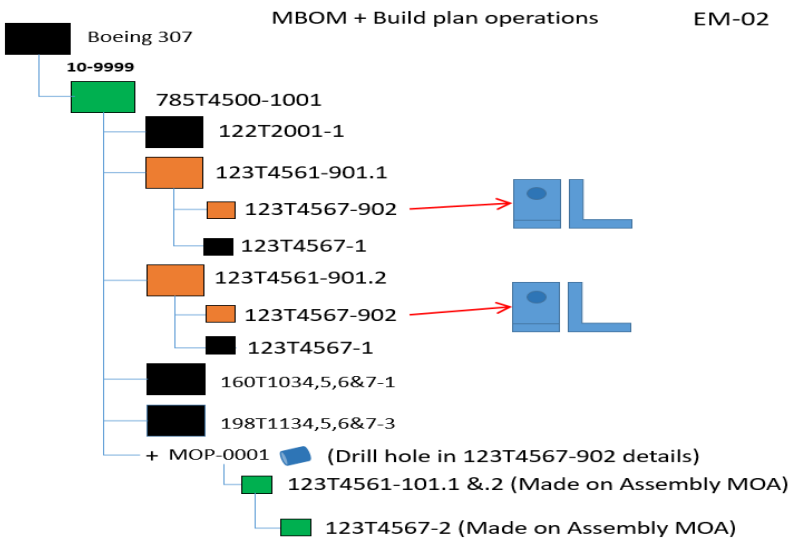
Notes:

Product Structure

785T4500-1001 | (WING TIP RIB FWD ~~INSTALL~~ Assy ~~01~~)







Revision:	Description:	Revision Date:	Revised By:
Release 1.0	Pre-release to PLM SW providers	7 Oct 2019	
2	Updated to Model-Based Engineering Demonstrator Reference Model release 1.4.1 product	12 Dec 2019	
3	Incorporated corrections based on Aras demo feedback.	22 Jan 2020	
Release 1.3	Release to PLM SW Providers	26 Jan 2020	

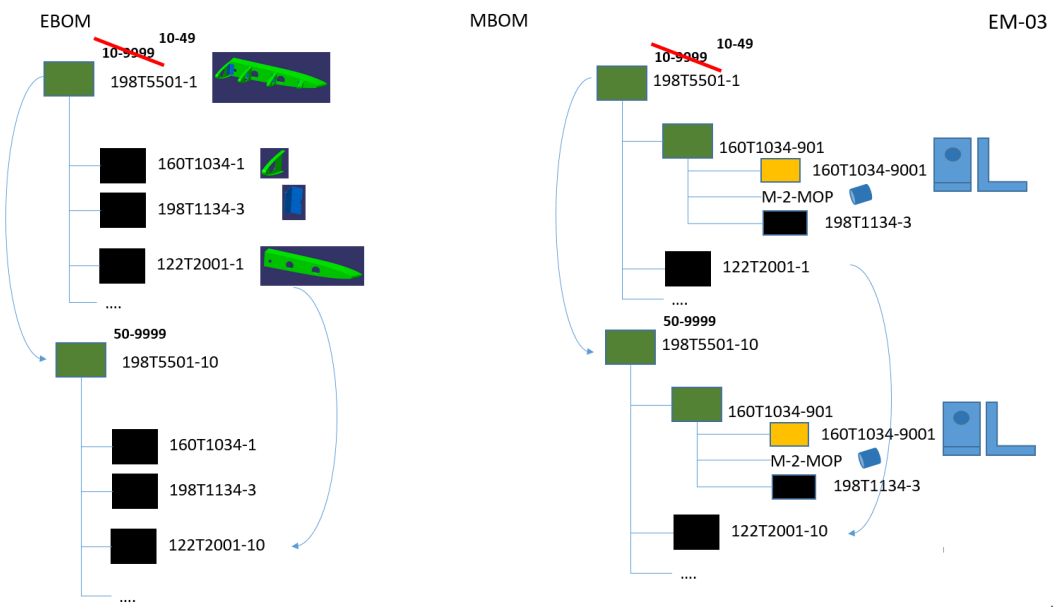
EM-03

USE CASE NUMBER: EM-03	**Focus Area**: 4 – Engineering to Manufacturing
Use Case Owner:	

USE CASE TITLE: Engineering only change

Goal & Overview: (Functionality)	Enable automatic reapplication of manufacturing consumption. Allocation from EBOM to MBOM.
Use Case Product Scope:	☒ Airframe ☐ Systems ☐ Equipment ☐ Engine
Use Case Frequency:	☐ Daily ☒ Weekly ☐ Monthly ☐ Yearly
Impacted Companies:	☒ Airframer ☐ Engine Manufacturer ☐ Design & Build Supplier ☐ Built to Print Supplier ☐ Design Only Supplier
Impacted Population Per Event:	☐ Less than 10 ☐ Between 10 and 100 ☐ Between 100 and 1000 ☒ More than 1000
Impacted Organizations:	☒ Design Engineering ☒ Manufacturing Engineering ☒ Production ☐ Services
Preconditions:	Mfg 160T1034-901 Assembly (EBOM Restructure) & 160T1034-9001 Detail (Condition of Supply)

Normal Course of Events:		**Action:**	**Result:**
	1.	Design engineer makes a change to a component of the assembly that is not part of the manufacturing assembly effective at unit X.	System detects that the engineering change does not impact the manufacturing restructure and reapplies the manufacturing assembly restructure to the new evolution of the engineering assembly.
	2.	—	System notifies the manufacturing engineer responsible for the allocation to the second factory work order of the impacting engineering change.
	3.	Manufacturing engineer confirms that the engineering change has no impact on manufacturing.	System automatically reapplies all manufacturing consumption of all engineering elements for the second factory work order.

	4.	Manufacturing engineer runs an accountability check on the engineering assembly at unit X-1.-	All components show as consumed for the entire effectivity range.
	5.	Manufacturing engineer runs an accountability check on the engineering assembly at unit X.	All components show as consumed for the entire effectivity range.
Alternate Course(s) of Events:	None.		
Data & Attributes & Validations:	All components show as consumed for the entire effectivity range.		
Use Case Data Set:	Model-Based Engineering Demonstrator Reference Model CAD assembly is used to create EBOM in the PLM system.		
Other Special Requirements:	None.		
Notes:	X=50  		

Revision:	Description:	Revision Date:	Revised By:
Release 1.0	Pre-release to PLM SW providers	7 Oct 2019	
2	Updated to Model-Based Engineering Demonstrator Reference Model release 1.4.1 product	12 Dec 2019	

3	Incorporated corrections based on Aras demo feedback.	22 Jan 2020	
Release 1.3	Release to PLM SW Providers	26 Jan 2020	

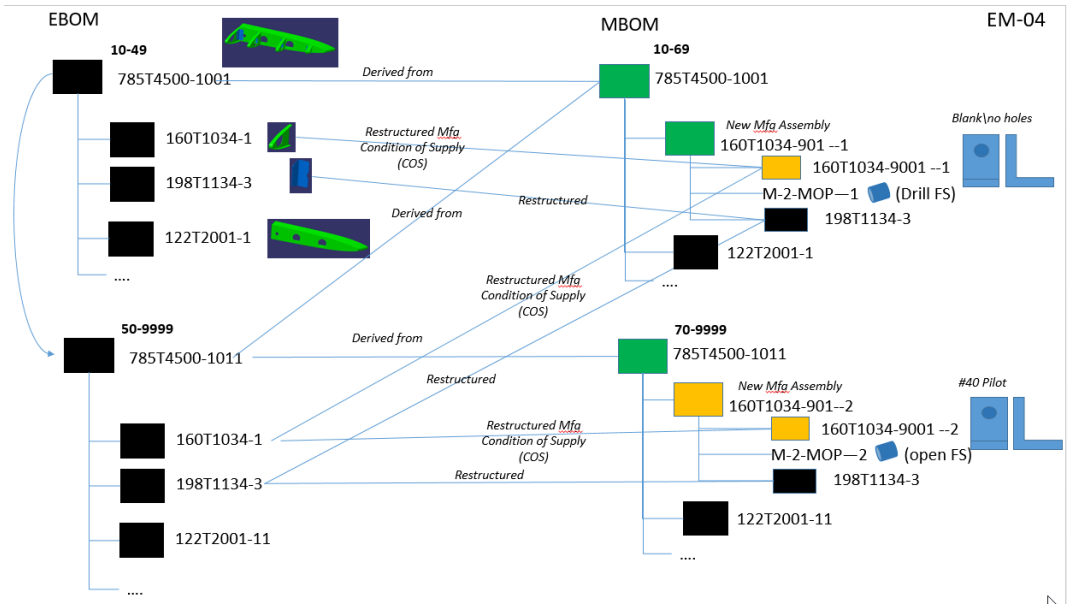
EM-04

USE CASE NUMBER: EM-04	**Focus Area:** 4 – Engineering to Manufacturing
Use Case Owner:	

USE CASE TITLE: Manufacturing only change

Goal & Overview: (Functionality)	Enable automatic reapplication of manufacturing consumption. Allocation from EBOM to MBOM.
Use Case Product Scope:	☒ Airframe ☐ Systems ☐ Equipment ☐ Engine
Use Case Frequency:	☐ Daily ☒ Weekly ☐ Monthly ☐ Yearly
Impacted Companies:	☒ Airframer ☐ Engine Manufacturer ☐ Design & Build Supplier ☐ Built to Print Supplier ☐ Design Only Supplier
Impacted Population Per Event:	☐ Less than 10 ☐ Between 10 and 100 ☐ Between 100 and 1000 ☒ More than 1000
Impacted Organizations:	☒ Design Engineering ☒ Manufacturing Engineering ☒ Production ☐ Services
Preconditions:	EM-03.

Normal Course of Events:		**Action:**	**Result:**
	1.	Manufacturing engineer makes a change to the part affected by the condition of supply (i.e., defines new condition of supply) effective at unit Z (Z > X).	System assists the manufacturing engineer in creating a new version of the parent manufacturing assembly. The new manufacturing components inherit the consumption links to the engineering parts, and the allocations to factory control stations are reapplied. There are no new engineering revisions or changes to engineering effectivity ranges as a result of this change. System does not allow breaks in effectivity ranges on the consumption links.

	2.	Manufacturing engineer runs an accountability check on the engineering assembly at unit Z-1.	All components show as consumed for the entire effectivity range. The engineering element affected by the condition of supply is traced to the previous version of the manufacturing assembly and condition of supply.
	3.	Manufacturing engineer runs an accountability check on the engineering assembly at unit Z.	All components show as consumed for the entire effectivity range. The engineering element affected by the condition of supply is traced to the new version of the manufacturing assembly and condition of supply.
Alternate Course(s) of Events:	None.		
Data & Attributes & Validations:	All components show as consumed for the entire effectivity range.		
Use Case Data Set:	Model-Based Engineering Demonstrator Reference Model CAD assembly is used to create EBOM in the PLM system.		
Other Special Requirements:	None.		
Notes:			

Revision:	Description:	Revision Date:	Revised By:
Release 1.0	Pre-release to PLM SW providers	7 Oct 2019	

2	Updated for Model-Based Engineering Demonstrator Reference Model release 1.4.1 product	12 Dec 2019	
3	Added step Weighting	22 Jan 2020	
Release 1.3	Release to PLM SW Providers	26 Jan 2020	

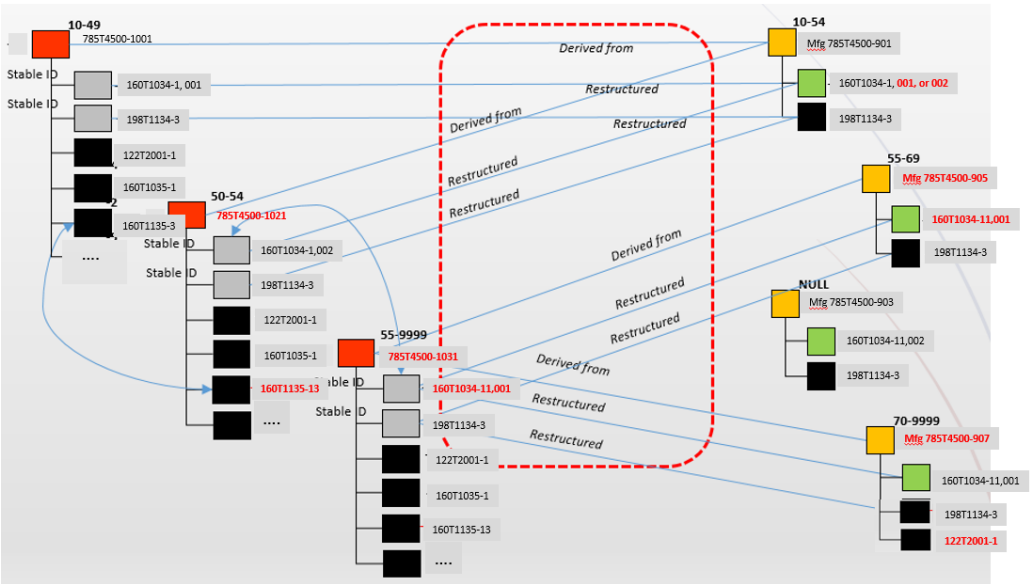
EM-05

USE CASE NUMBER: EM-05	**Focus Area:** 4 – Engineering to Manufacturing
Use Case Owner:	

USE CASE TITLE: Engineering change

Goal & Overview: (Functionality)	Enable automatic reapplication of manufacturing consumption. Allocation from EBOM to MBOM.
Use Case Product Scope:	☒ Airframe ☐ Systems ☐ Equipment ☐ Engine
Use Case Frequency:	☐ Daily ☒ Weekly ☐ Monthly ☐ Yearly
Impacted Companies:	☒ Airframer ☐ Engine Manufacturer ☐ Design & Build Supplier ☐ Built to Print Supplier ☐ Design Only Supplier
Impacted Population Per Event:	☐ Less than 10 ☐ Between 10 and 100 ☐ Between 100 and 1000 ☒ More than 1000
Impacted Organizations:	☒ Design Engineering ☒ Manufacturing Engineering ☒ Production ☐ Services
Preconditions:	EM-04.

Normal Course of Events:		**Action:**	**Result:**
	1.	Design engineer applies change to the part affected by the condition of supply at unit Y (X < Y < Z).	System detects **both** manufacturing assemblies affected by the change and notifies the manufacturing engineer. System assists the manufacturing engineer in applying the engineering changes to the condition of supply. System does not allow breaks in effectivity.
	2.	Manufacturing engineer runs an accountability check on the engineering assembly effective from Y – inf.	All components show as consumed for the entire effectivity range. The system identified two manufacturing assemblies consuming the parts of the engineering assembly: one for Y – (Z-1) and one for Z – inf.

Alternate Course(s) of Events:	None.
Data & Attributes & Validations:	All components show as consumed for the entire effectivity range.
Use Case Data Set:	Model-Based Engineering Demonstrator Reference Model CAD assembly is used to create EBOM in the PLM System.
Other Special Requirements:	None.
Notes:	EM-05 

Revision:	Description:	Revision Date:	Revised By:
Release 1.0	Pre-release to PLM SW Providers	7 Oct 2019	
Release 1.1	Punctuation and Precondition changed from EM-05 to EM-04	10 Oct 2019	
2	Updated to Model-Based Engineering Demonstrator Reference Model part numbers	23 Dec 2019	
Release 1.2	Release to PLM SW Providers	6 Jan 2020	