Multiple View Bill of Materials (BOM)

Appendix B: Concept Definition and Use Cases

Release 1.0

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AEROSPACE & DEFENSE PLM ACTION GROUP

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Revision Record

Release	Date	Description
1.0	January 2019	Initial release

Multiple View Bill of Materials (BOM)

Appendix B: Concept Definition and Use Cases

Introduction

This technical Appendix, which is most appropriate for Subject Matter Experts (SMEs), provides a walkthrough example and a list of use cases to illustrate BOM Restructuring and Accountability requirements.

Example Scenarios

This Appendix explains best practices used with multi-view BOM: EBOM, MBOM. It addresses the capability of managing instance and assembly information between EBOM and MBOM after split. Walkthrough change examples of multi-view BOM management include:

1. Establishing an engineering baseline
2. Applying an engineering change to the baseline
3. Introducing a manufacturing change post engineering change

This document provides use case examples for each of the above.

EBOM Assumptions and Rules for Scenarios

The figures below show how to understand the use case scenarios that follow.

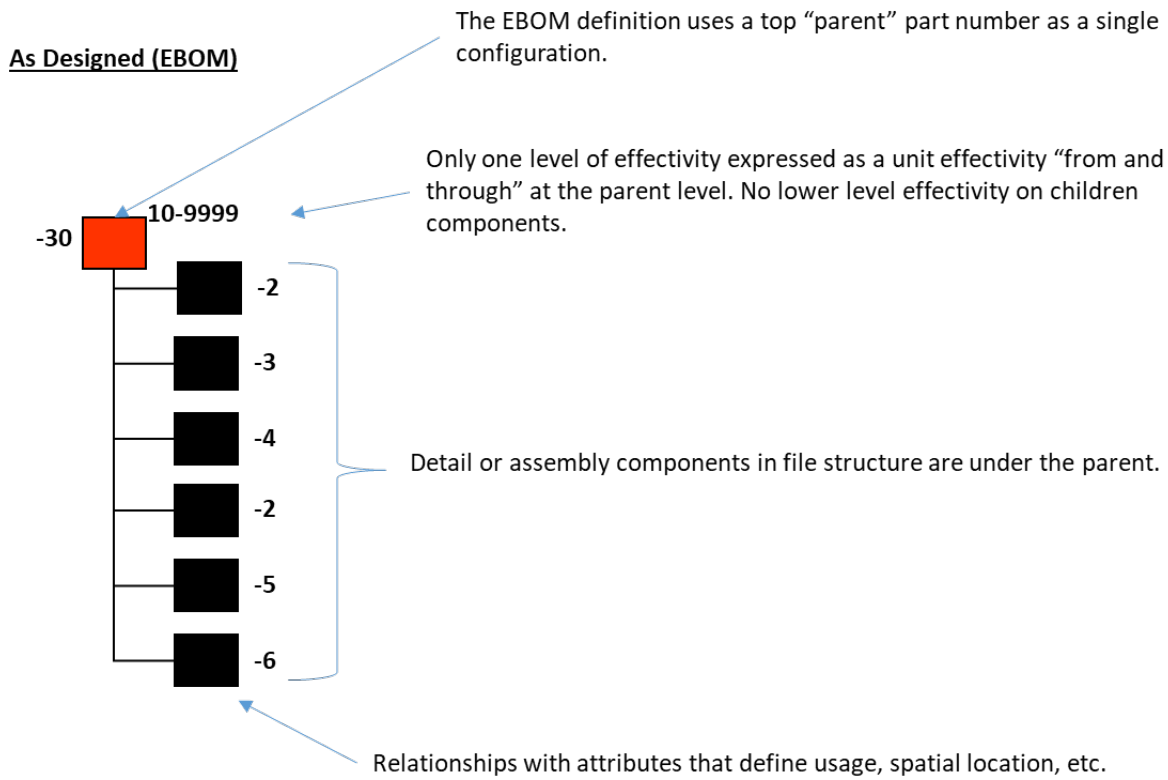


Figure 1 – As-Designed EBOM Structure

The MBOM has two key areas that must be understood for BOM structure and accountability:

1. Creating and managing the BOM that must be ordered from suppliers and internal fabrication sites.
2. Consuming parts into an airplane level process structure that accounts for the completeness and accountability of each airplane.

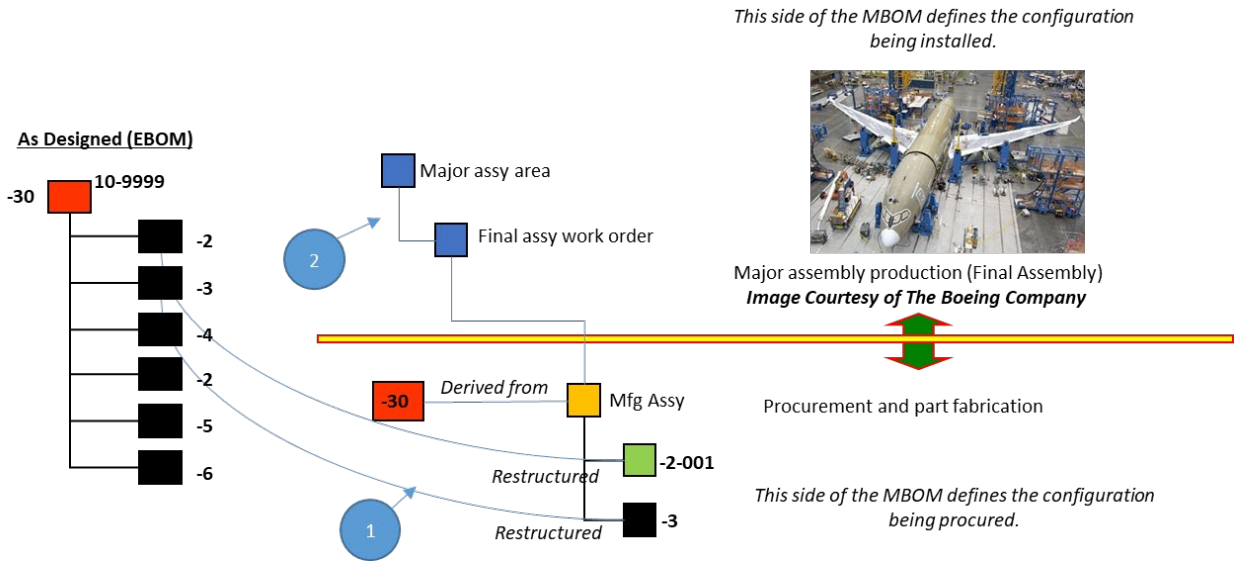


Figure 2 – MBOM Structure and Accountability areas

Multi-View BOM Accountability Change Scenarios

This section illustrates change scenarios of multi-view BOM accountability.

Multi-View BOM Accountability

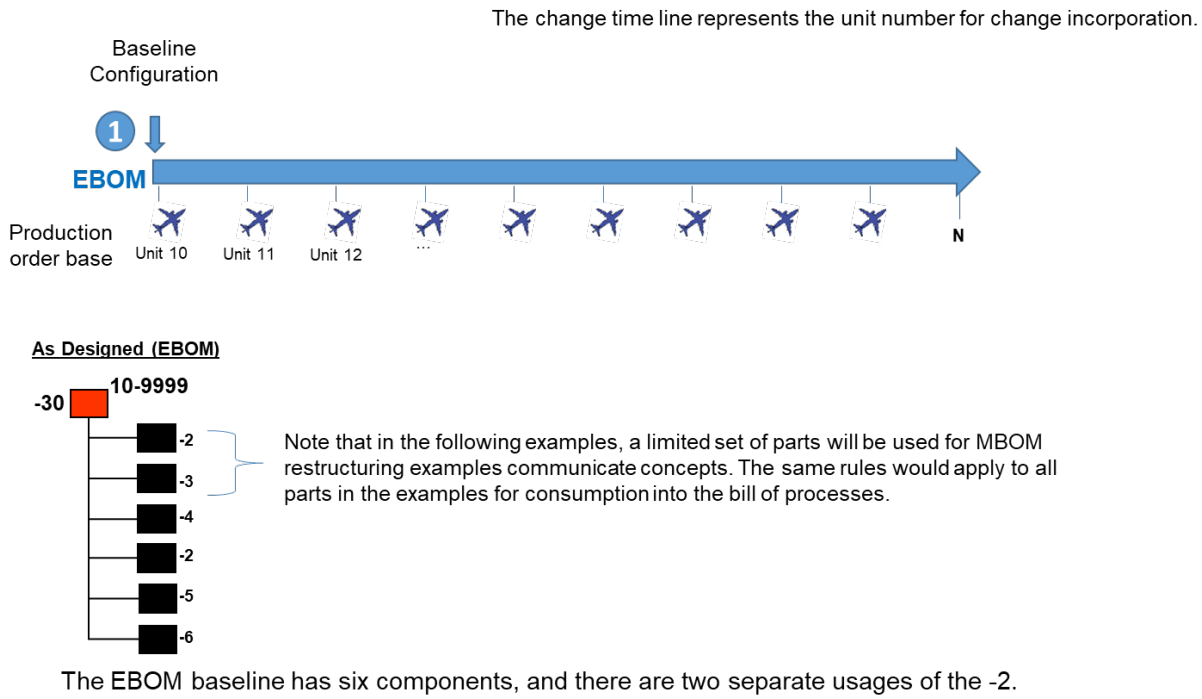


Figure 3 – Multi-View BOM Accountability: Engineering Baseline Configuration

Configuration Control Zone (CCZ)

The CCZ concept is intended to facilitate the understanding of business rules embedded within the computing technology to manage configured items. This section provides examples of CCZ.

Configuration Control Zone Examples

These examples demonstrate how the EBOM is restructured into an MBOM with configuration control zones (CCZ). The accountability map concept in these examples uses a separate CCZ from the engineering definition and the manufacturing plan revision. It is fundamental to understand that these examples use three separate CCZs.

1. EBOM CCZ is the typical engineering assembly CCZ where the parent part number owns the usages of the children. This defines the standard PLM functionality and configuration management practices used today.
2. Accountability Map CCZ owns the relationships and attributes that map between the EBOM and the MBOM. This CCZ provides computer-sensible enforcement of the data and relationships between BOM structures and demonstrates how to enable persistent BOM accountability.
3. Manufacturing (Mfg) plan CCZ defines the plan-to-operation instruction relationships that are needed for production work orders. In these examples, the plan CCZ does not own the parts consumption. Part assignment-to-plan is performed in the Accountability Map CCZ. Note: Each Installation (Instl) plan has its own CCZ. In the example, two CCZs are shown because two plans are used.

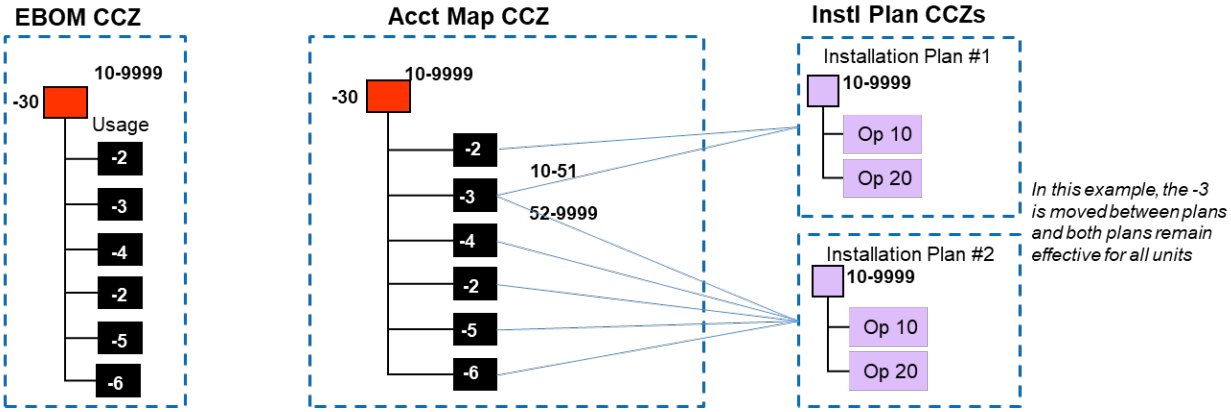


Figure 4 – EBOM, Accountability Map, and Installation Plan CCZs

Configuration Control Zone Assumptions

The following figure illustrates and describes the CCZ assumptions for multi-view BOM accountability.

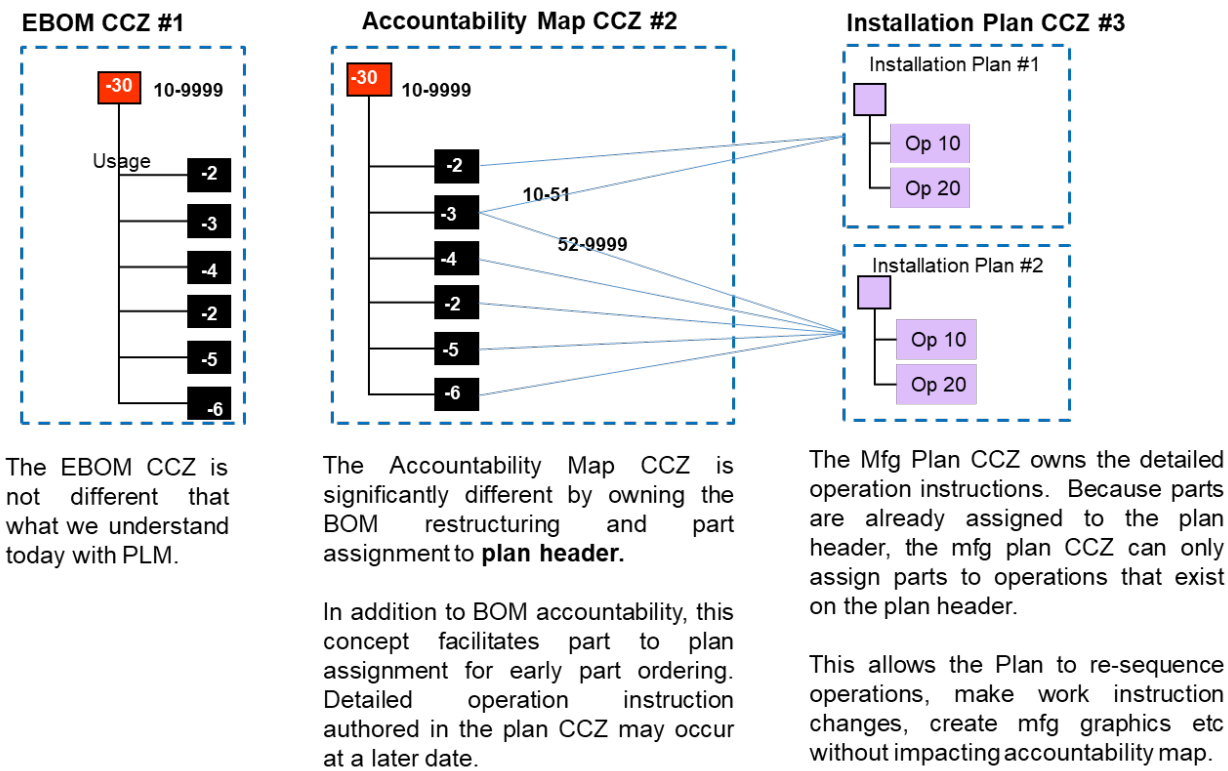


Figure 5 – CCZ Assumptions for EBOM, Accountability Map, and Installation Plan

ERP View of PLM Data

The following figure illustrates the typical Enterprise Resource Planning (ERP) view of the bill of process and the bill of materials (BOM).

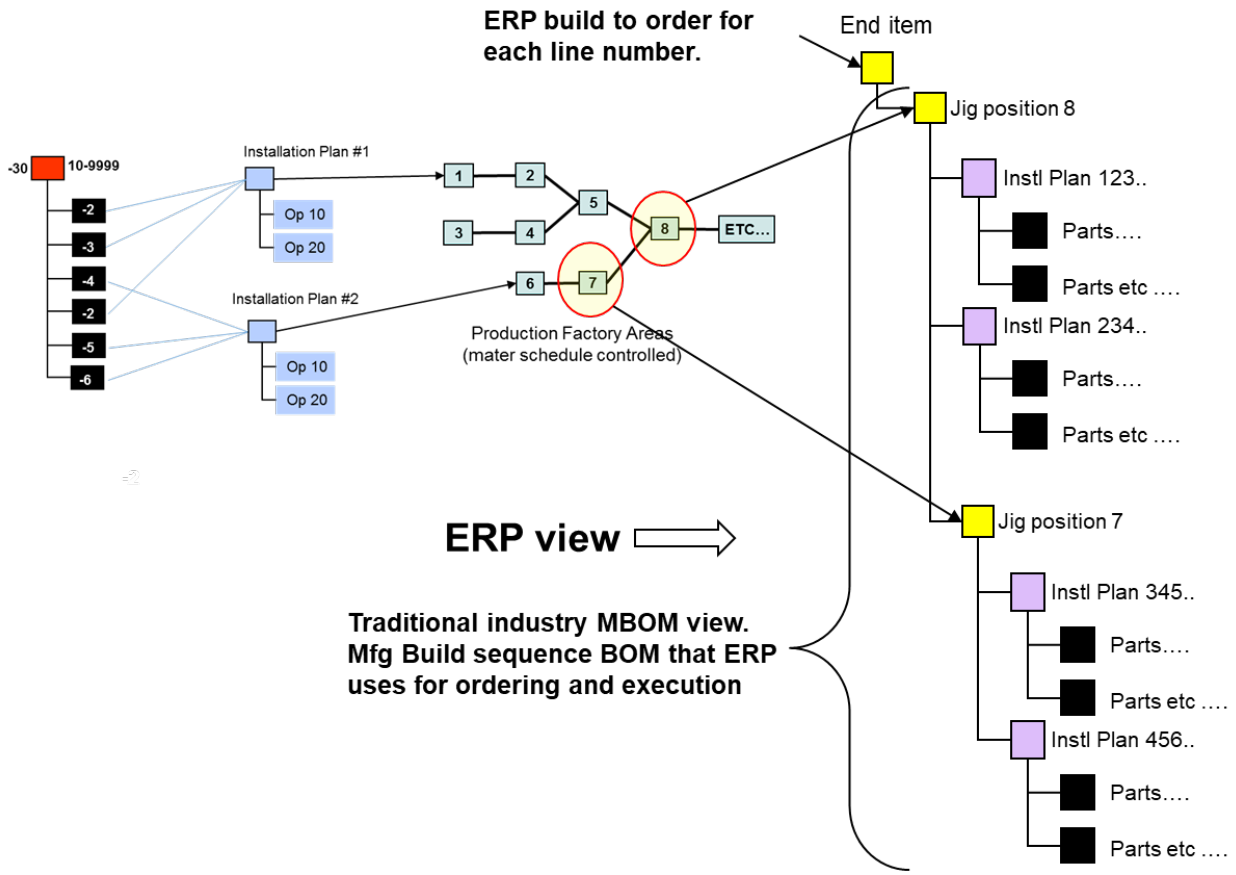


Figure 6 – ERP View

Multi-View BOM Integration Between PLM and ERP

This section covers multi-view BOM integration between PLM and ERP through figures that include descriptions.

PLM Used for EBOM-Only Example

The following figure illustrates PLM for EBOM only.

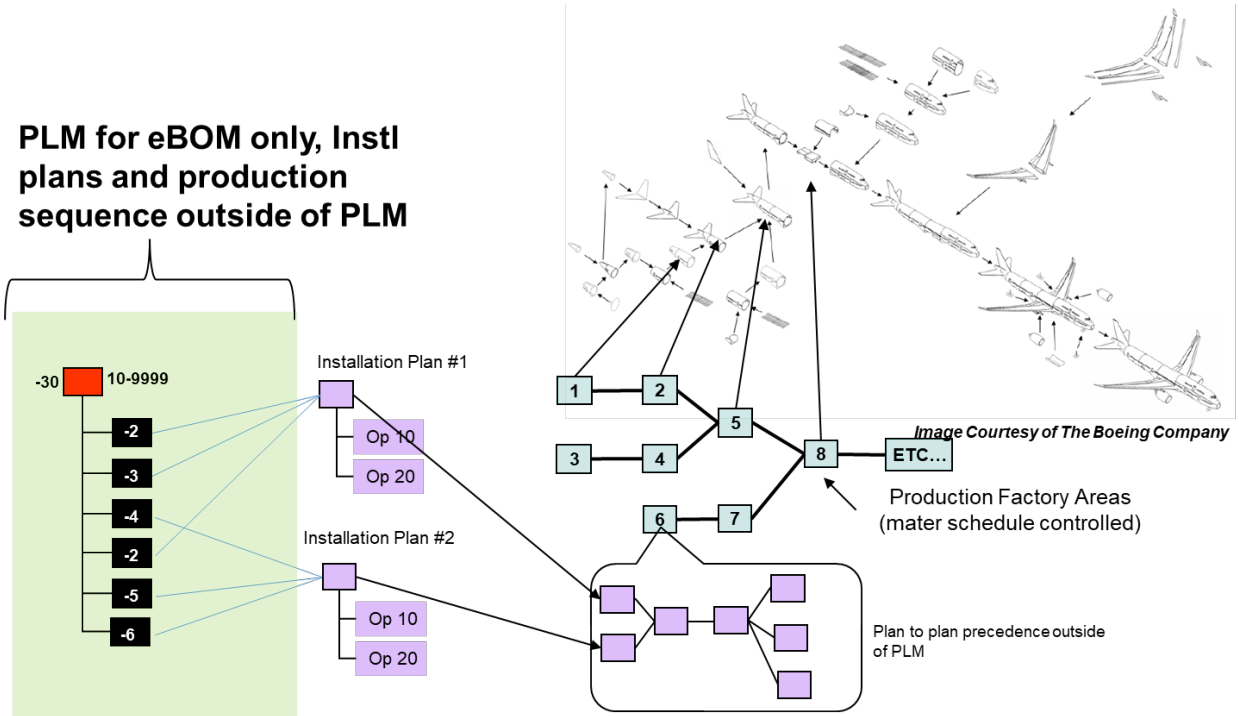


Figure 7 – PLM for EBOM Only

PLM Used for Both EBOM and MBOM Example

An example of PLM used for both EBOM and MBOM follows.

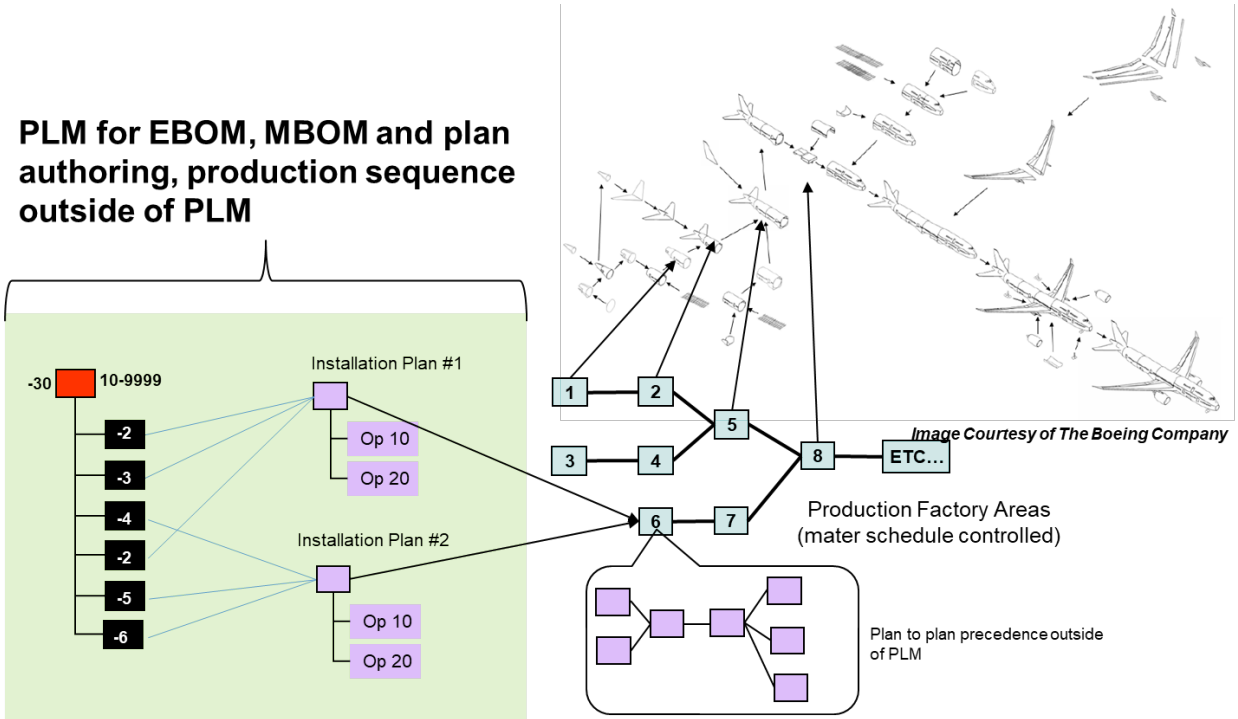


Figure 8 – PLM used for EBOM and MBOM

PLM Used for EBOM, MBOM, and Production Sequence Example

The following figure shows PLM for EBOM, MBOM, and production sequence.

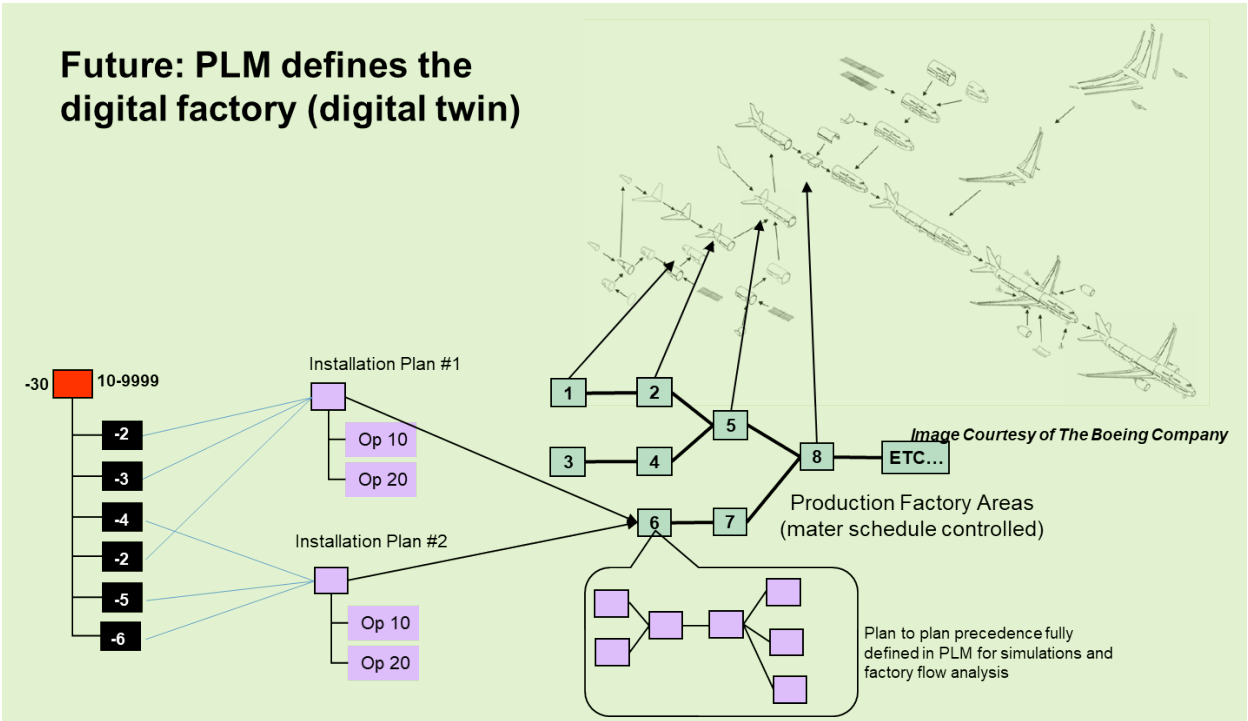


Figure 9 – PLM Used for EBOM, MBOM, and Production Sequence

Accountability Change Scenarios

Multi-view BOM accountability becomes more complex as change is introduced. The following scenarios demonstrate the complexity using a change timeline against the BOM structures.

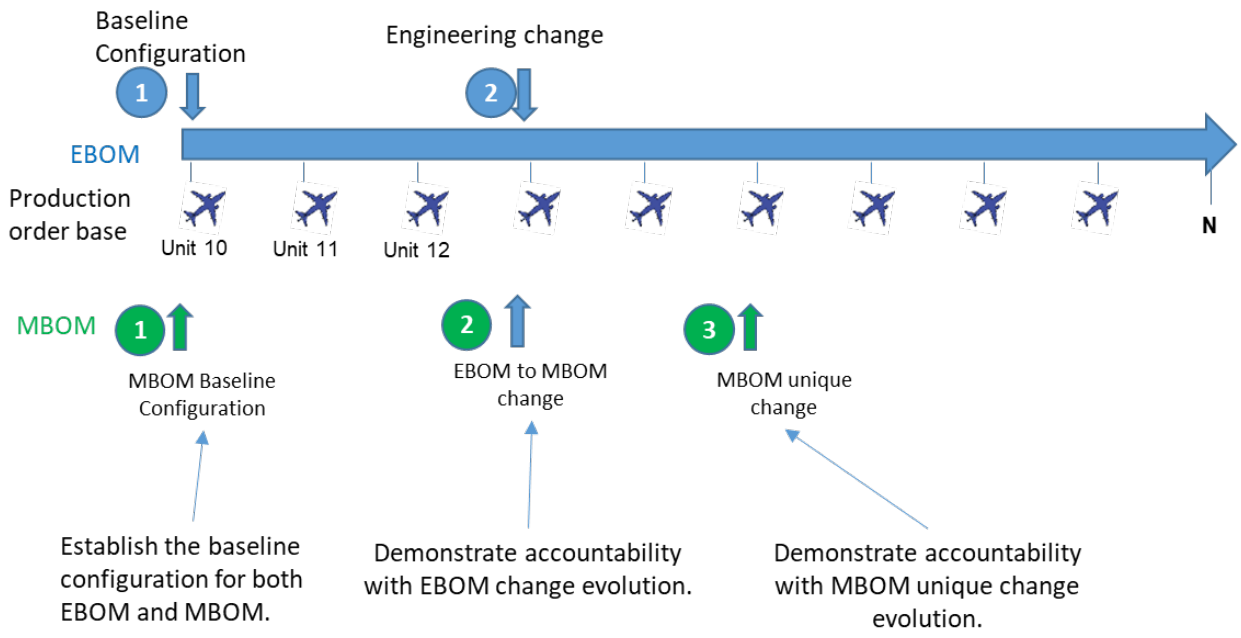


Figure 10 – Accountability Change Scenarios

Scenario 1

Scenario 1 defines the MBOM baseline with two manufacturing deviations to the EBOM for the parts that need to be procured and the consumption of the manufactured parts into the final assembly process structure.

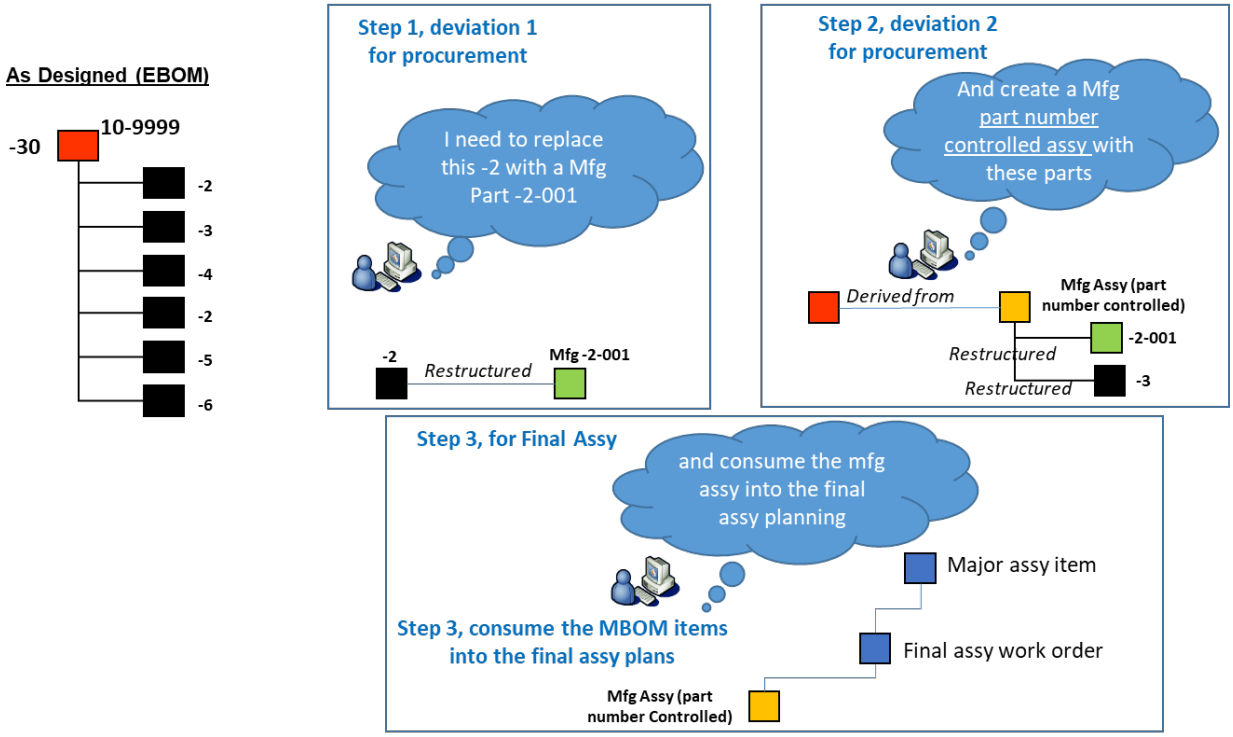
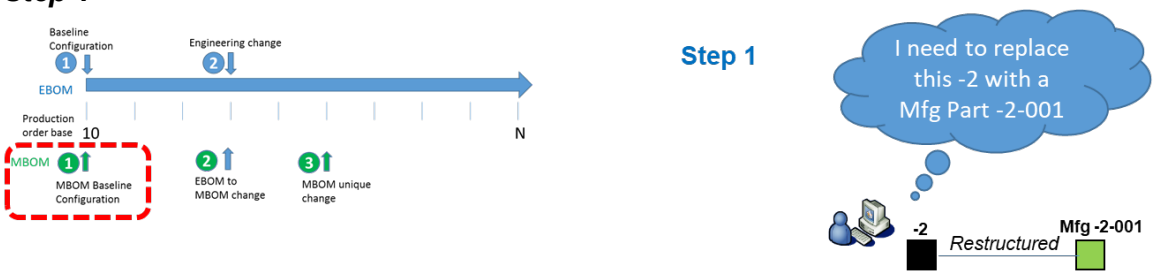


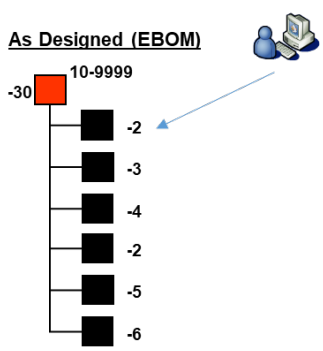
Figure 11 –Scenario 1 with Two Manufacturing Deviations to the EBOM

Accountability Scenario

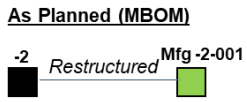
This section of figures illustrates the three-step accountability process.

Step 1





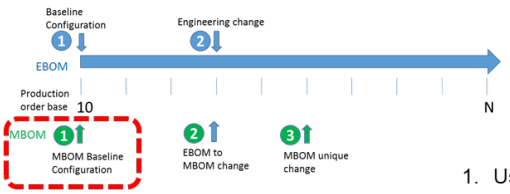
1. User selects the -2 and selects "create manufacturing part replacement".
2. The PLM system creates a dialog for the user to define the new manufacturing part number along with the required information to define the manufacturing part with allowed deviations.
   - e.g. "New -2-001 same as -2 except all pilot holes omitted for use at location XYZ. Reference Mfg change request."
3. PLM system creates the -2-001 and also creates a "restructured" relationship between the -2 and new -2-001.



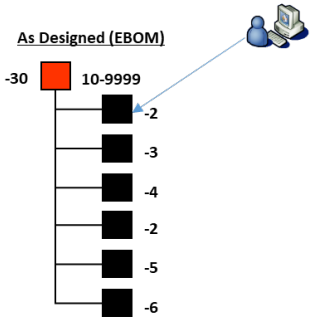
Baseline Scenario: Create the MBOM for procured parts.

Figure 12 – Accountability Scenario – Step 1

Step 2



Baseline Scenario: Create the MBOM for procured parts.



Step 2

1. User selects -2-001 and the -3 and selects "create new manufacturing assembly".
2. The PLM system creates a dialog for the user to define the new manufacturing assembly.
   - e.g. "New mfg assy -901 same creates a sub assembly with -2-001 and -3 using installation requirements from -30. Reference Mfg change request…."
3. PLM system creates the -901 and also creates a "restructured" relationship between the -901,-2-001 and -3.
4. Note that the -901 also requires data from the -30 for the geometry and engineering requirements necessary to assemble the -2 and -3 together. The "derived from relationship" allows manufacturing assembly -901 to be linked to -30 for this reason. This relationship may also be used to keep effectivity synchronized between -30 and -901.

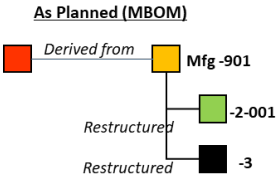
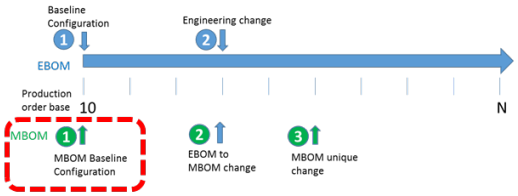


Figure 13 – Accountability Process – Step 2

Step 3



Step 3

1. In order to complete the MBOM accountability, Mfg Assy -901 must be consumed into a work order to install the assy on the Airplane.
2. If the user manually runs an accountability check prior to approval the system will ensure mfg -901 is consumed for the same effectivity ranges as engineering.
3. As part of the release process, the accountability map is used to validate system enforced accountability processes and all consumption is complete

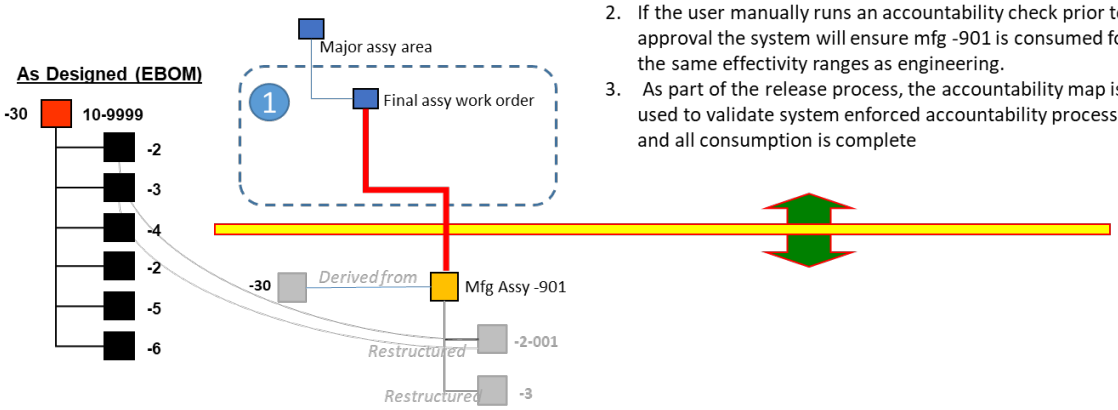
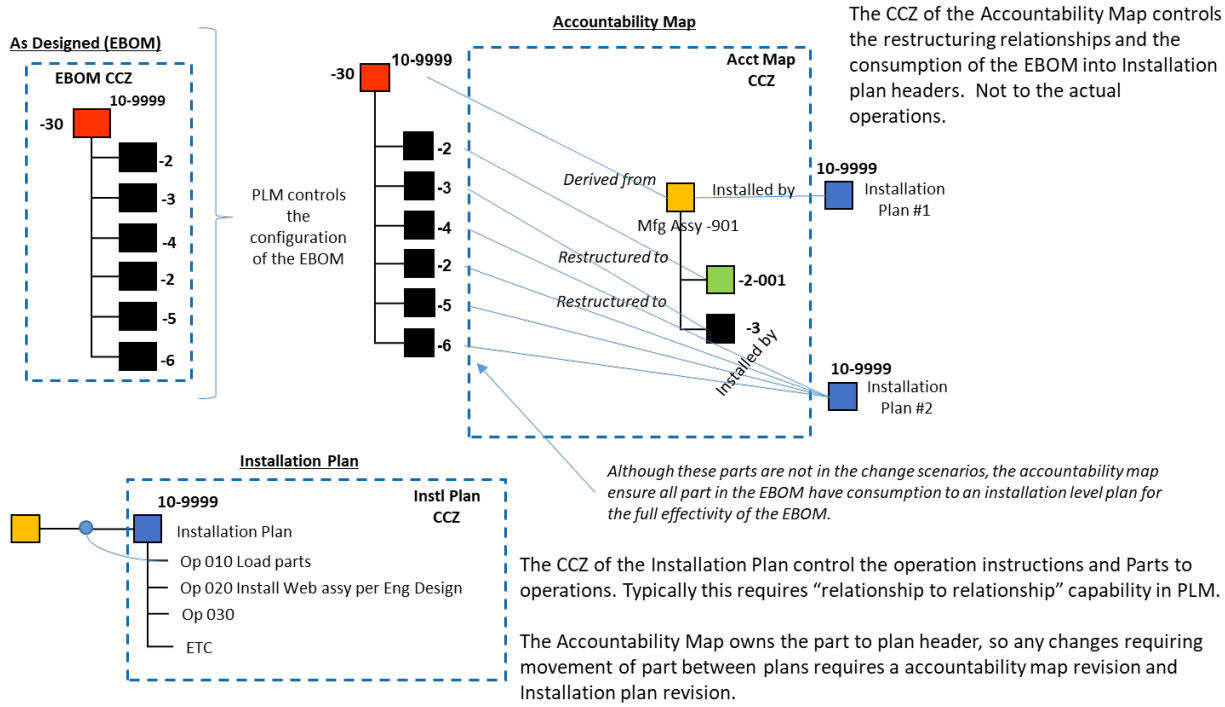


Figure 14 – Accountability Process – Step 3

Accountability Map View of Scenario

The following image is an accountability map of scenario 1.



The CCZ of the Installation Plan control the operation instructions and Parts to operations. Typically this requires "relationship to relationship" capability in PLM.

The Accountability Map owns the part to plan header, so any changes requiring movement of part between plans requires a accountability map revision and Installation plan revision.

Figure 15 – Accountability Map view

Engineering Change Scenario

This section illustrates an engineering change and its influence on EBOM, MBOM, and manufacturing.

Initial Conditions

The following figure illustrates an initial engineering change.

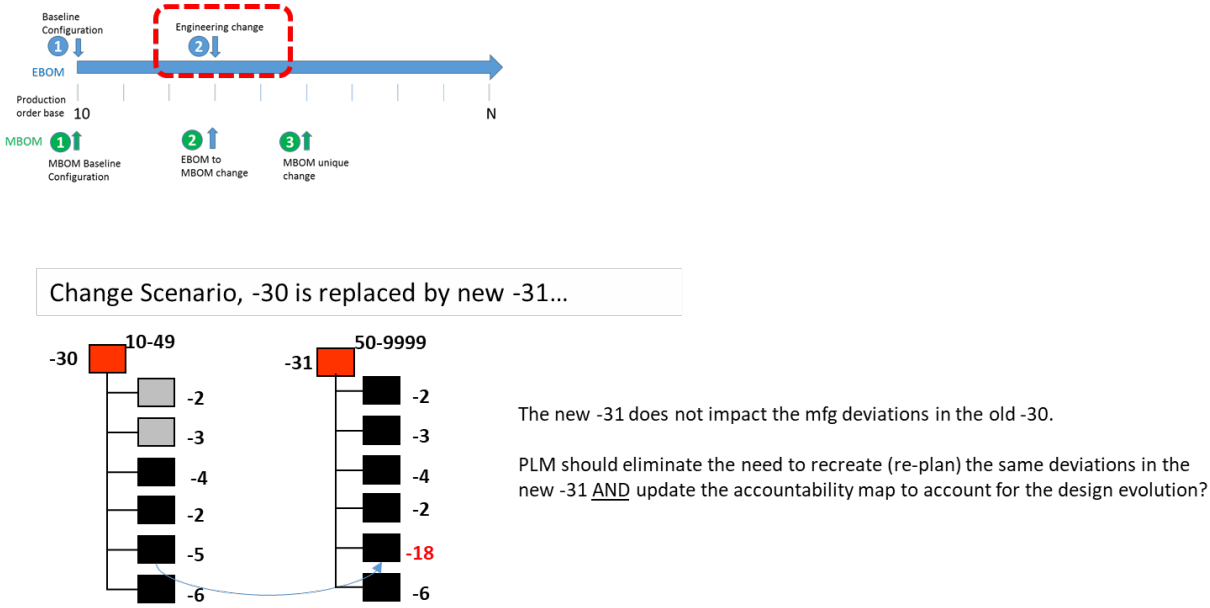
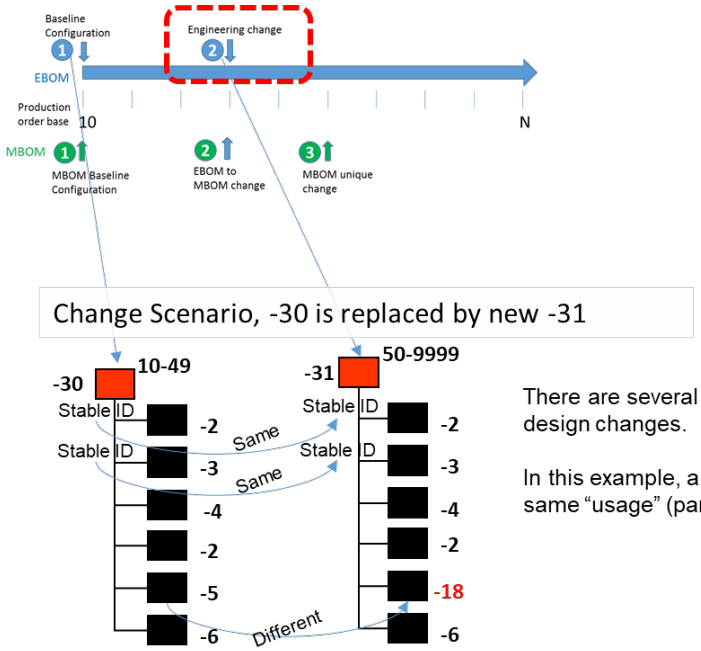


Figure 16 – Initial Condition of an Engineering Change

EBOM Impacts

This figure shows the change's impact on EBOM.



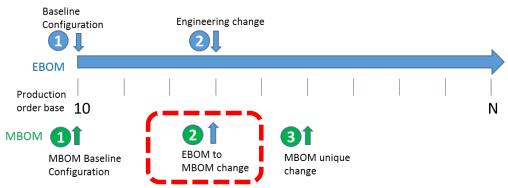
There are several ways PLM could carry forward relationships for design changes.

In this example, a Stable ID is used to identify the -2 and -3 as the same "usage" (part at location, etc.) in both the -30 and -31.

Figure 17 – EBOM Impact

MBOM Impacts

The change affects MBOM as well, as shown in the following figure.



The MBOM restructuring configuration between -30 and -31 is common. PLM shall notify and allow the user to automatically re-apply the original restructures in the -30 to the new -31.

In this example, new relationships must be created by PLM to update the accountability map to validate the configuration and effectivity of the MBOM related to both the -30 and -31.

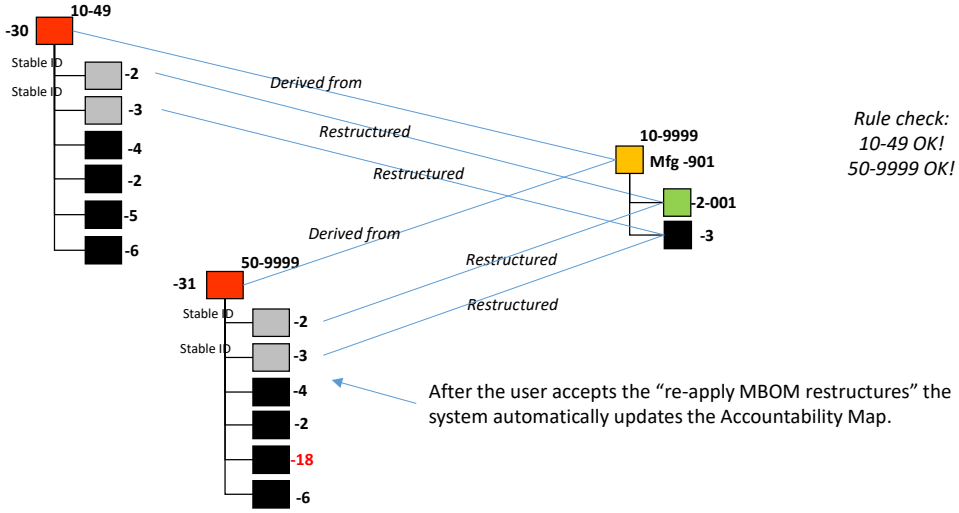


Figure 18 – MBOM Impact

Manufacturing Change Impacts

The engineering change also impacts manufacturing. The following figure presents the multiple manufacturing changes required.

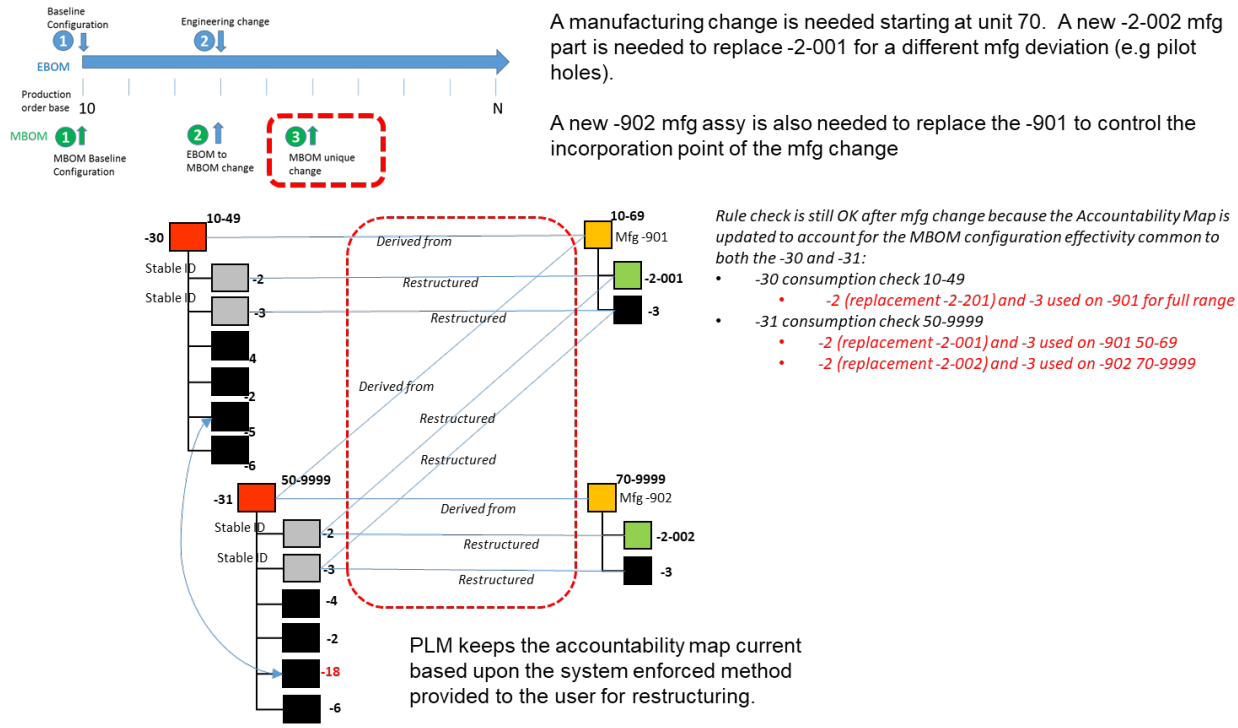


Figure 19 – Manufacturing MBOM Unique Change Impacts

Additional Restructuring Types

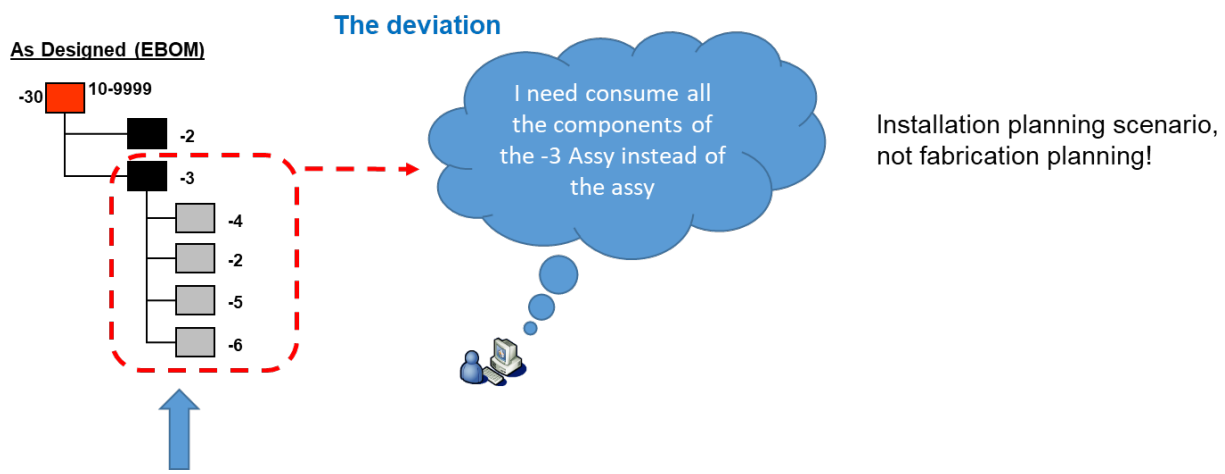
Additional restructuring types are as follows.

1. Previous figures
    a. Replacement restructure (-2 replaced by -2-001)
    b. Manufacturing assembly -901 (Airbus -3001)
2. Phantom Assembly (Or Make On Assembly)
3. Alternate part
4. Subset manufacturing assembly (single EBOM to one manufacturing assembly)
5. Super Set Assembly (many EBOMs to one manufacturing assembly)
    a. Easy example
    b. Hard example
6. Unitized Manufacturing Assembly (many EBOMs to one manufacturing assembly that is NOT part number controlled)

The key point is about the rules enforcement of the business logic to support effectivity in the restructure.

Phantom Assembly

The following figure presents the phantom assembly, which needs to consume all components of the assembly, not just one.



Note: The Accountability Map would not need to account for components of the -3 assy in the normal condition where the -3 assy is actually issued to manufacturing as an assy. The Phantom condition creates new rules for the Accountability Map because the lower level components of the -3 need the same level of reconciliation as the -3

Figure 20 – Phantom Assembly

Step 1: Restructure Needs Identified

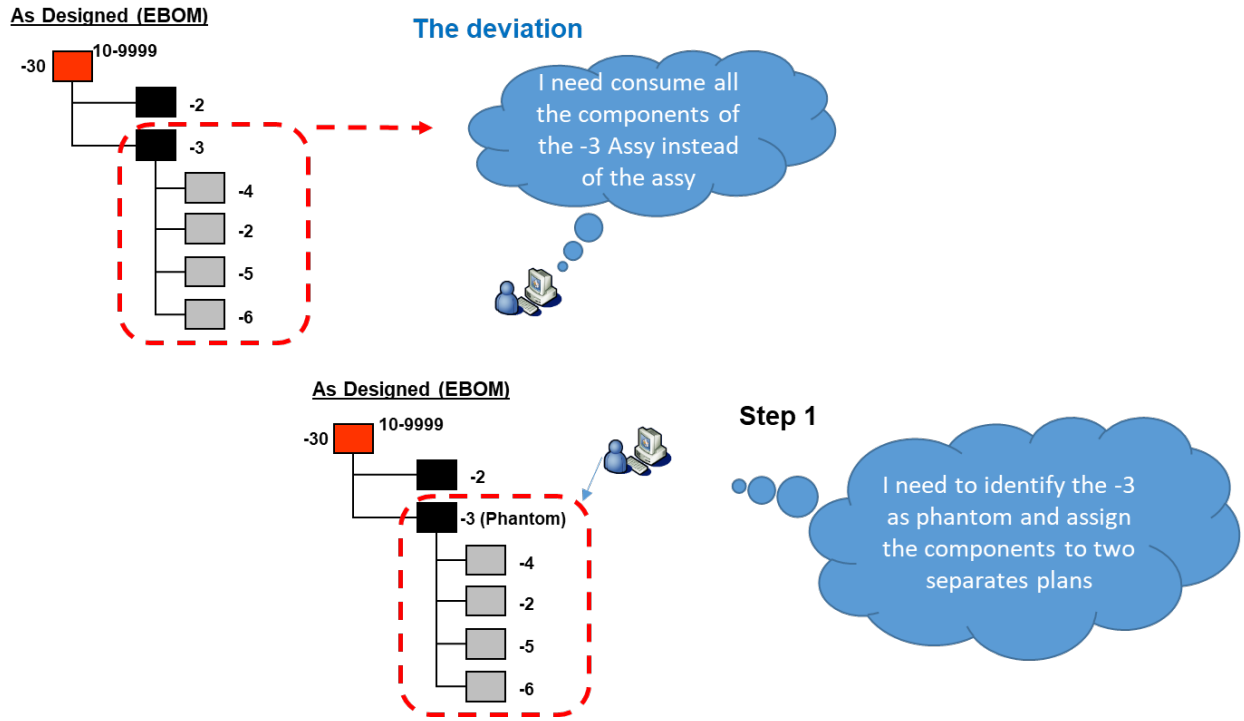
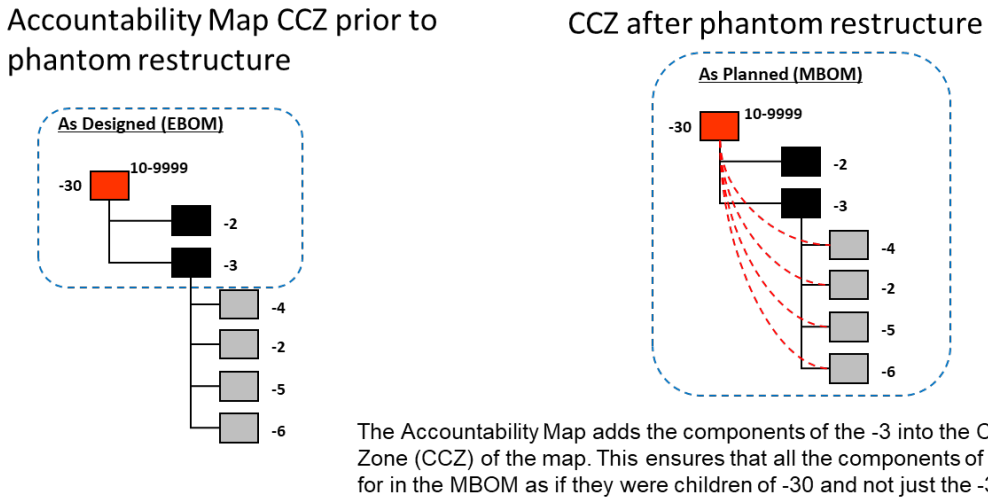


Figure 21 – Phantom Assembly – Step 1

Step 2: PLM Accountability Map Update Triggered by Restructure



The Accountability Map adds the components of the -3 into the Configuration Control Zone (CCZ) of the map. This ensures that all the components of the -3 are accounted for in the MBOM as if they were children of -30 and not just the -3.

Figure 22 – Phantom Assembly – Step 2

Step 3: User Consumes Components of -3 into Installation Level (Final Assy) Plans

Step 3 ensures that all components are consumed.

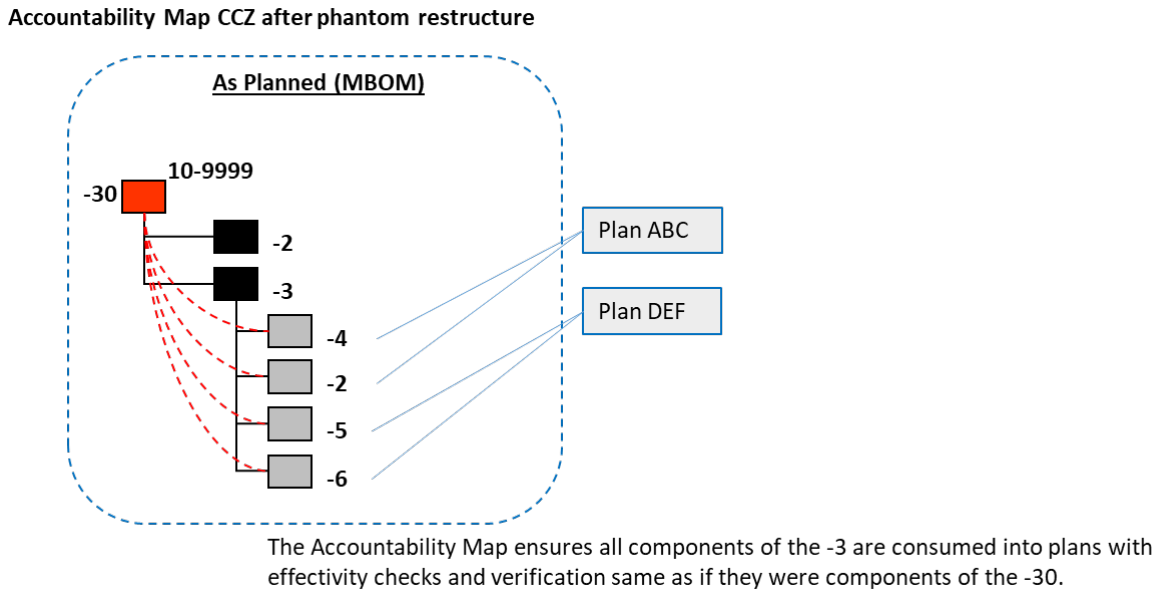
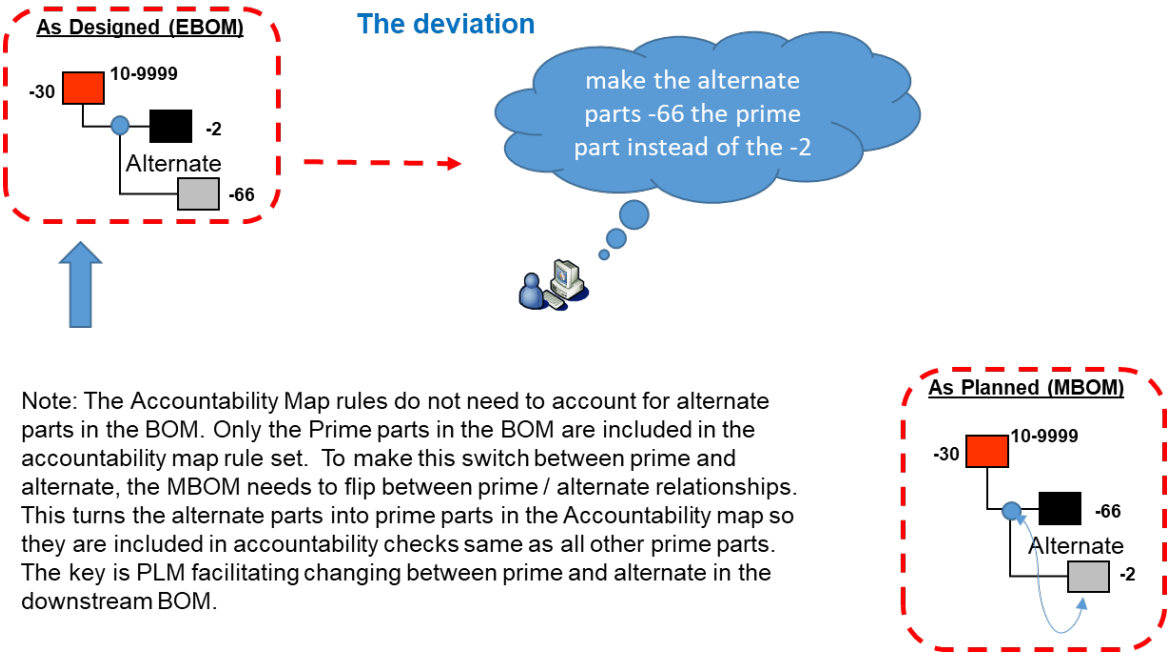


Figure 23 – Phantom Assembly – Step 3

Alternate Parts

This section provides examples of prime and alternate parts use, ranging from a simple version to complex and in between.

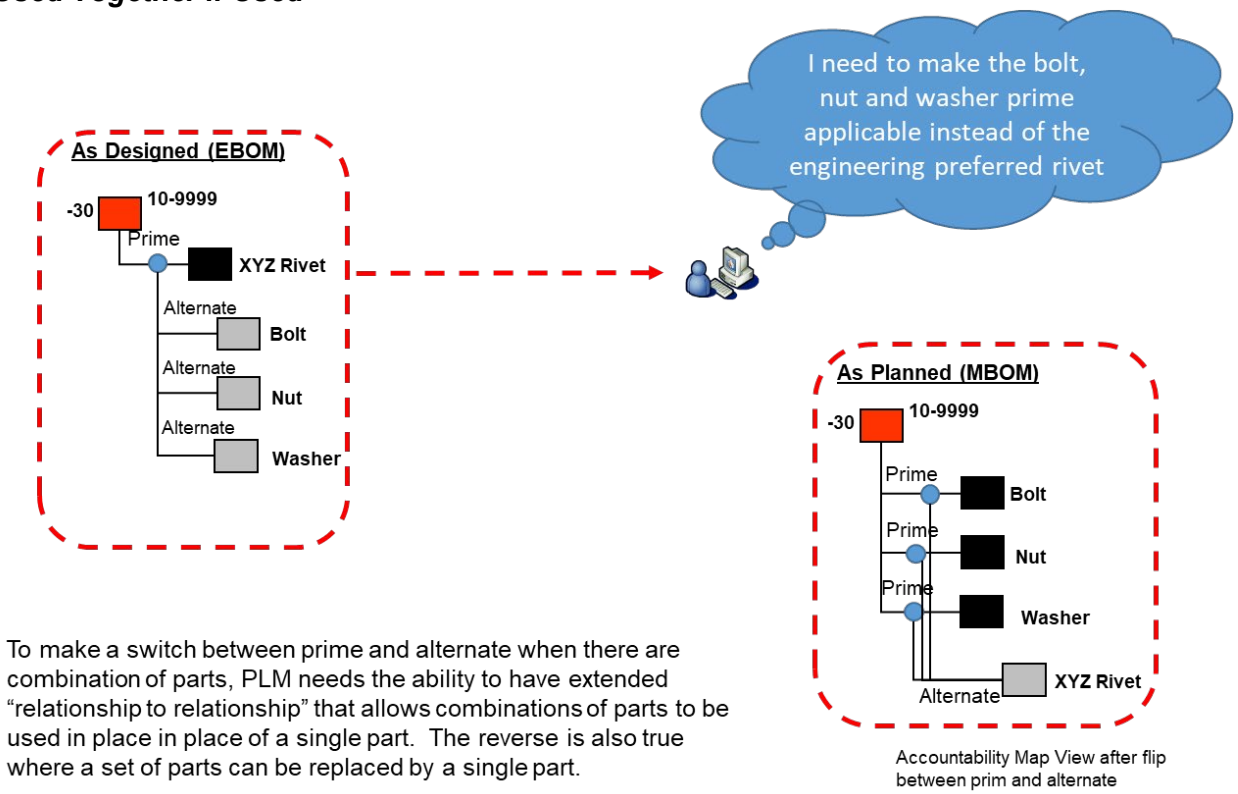
Example 1: Simple Version



Note: The Accountability Map rules do not need to account for alternate parts in the BOM. Only the Prime parts in the BOM are included in the accountability map rule set. To make this switch between prime and alternate, the MBOM needs to flip between prime / alternate relationships. This turns the alternate parts into prime parts in the Accountability map so they are included in accountability checks same as all other prime parts. The key is PLM facilitating changing between prime and alternate in the downstream BOM.

Figure 24 – Simple Version of Alternate Parts Use

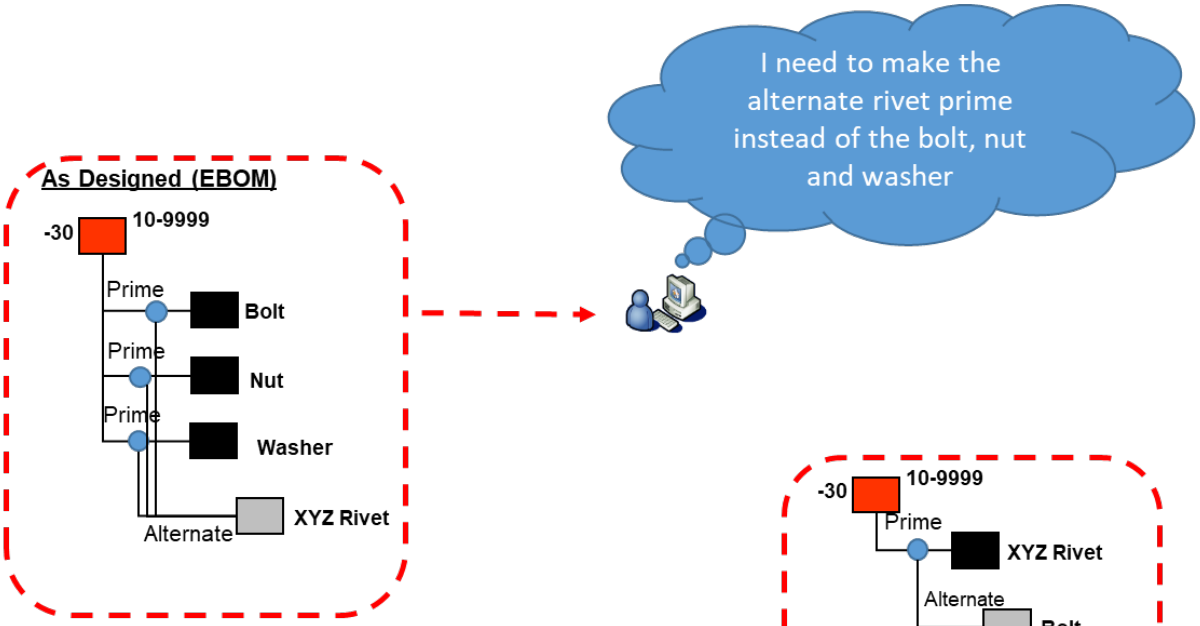
Example 2: Complex Version – One Prime Part with a Set of Alternate Parts that Must Be Used Together if Used



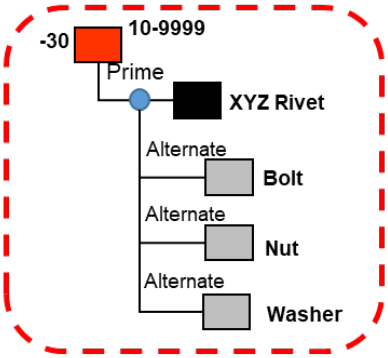
To make a switch between prime and alternate when there are combination of parts, PLM needs the ability to have extended "relationship to relationship" that allows combinations of parts to be used in place in place of a single part. The reverse is also true where a set of parts can be replaced by a single part.

Figure 25 – Complex Version of Phantom Assembly

Example 3: Set of Prime Parts that can be Replaced by a Single Alternate Part if Used



This example is the reverse of the previous example for the starting point establishing what is prime in the EBOM. The key to this example is ensuring the restructure does not result in the rivet increasing in quantity as one rivet replaces all three alternate parts. This creates a more complicated rules set for in the accountability map for "many to one" alternate part relationships



Accountability Map View after flip between prim and alternate

Figure 26 – Set of Prime Parts Replaced by a Single Alternate Part

Manufacturing Subset Assemblies

The following figure illustrates and explains the use of manufacturing subset assemblies.

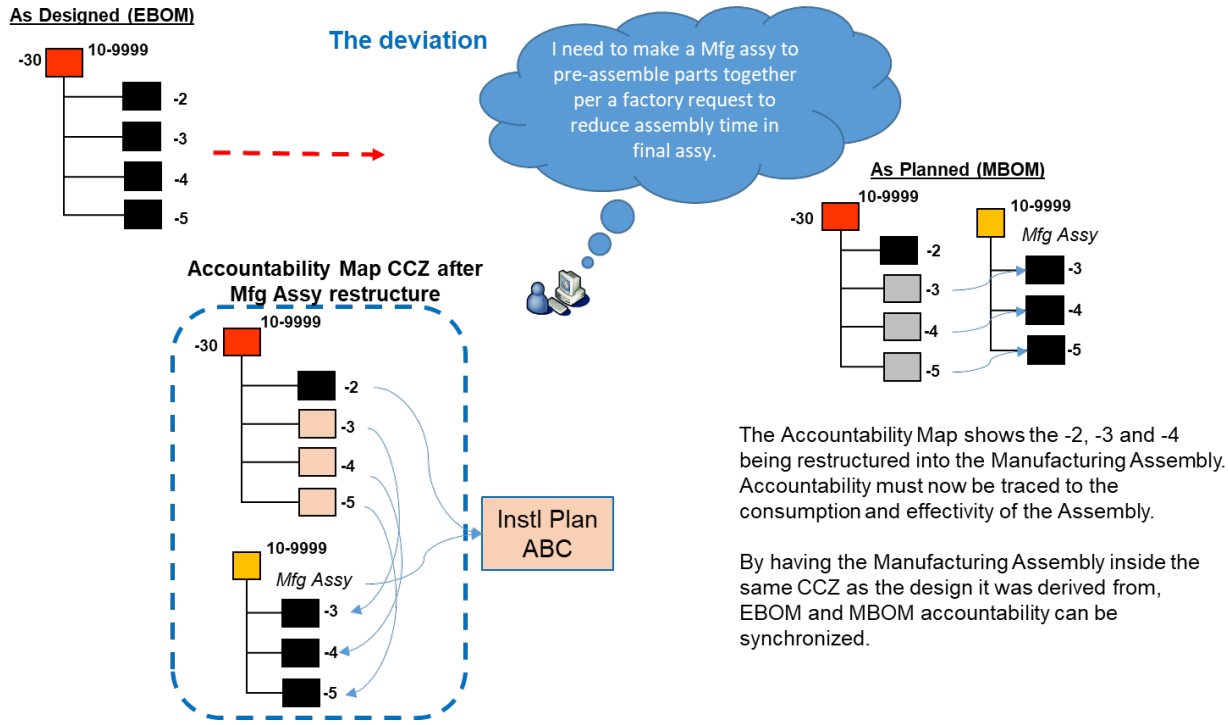


Figure 27 – Manufacturing Subset Assemblies

Manufacturing Unique Changes to a Subset

This section's figure illustrates the concept of manufacturing unique changes to the subset.

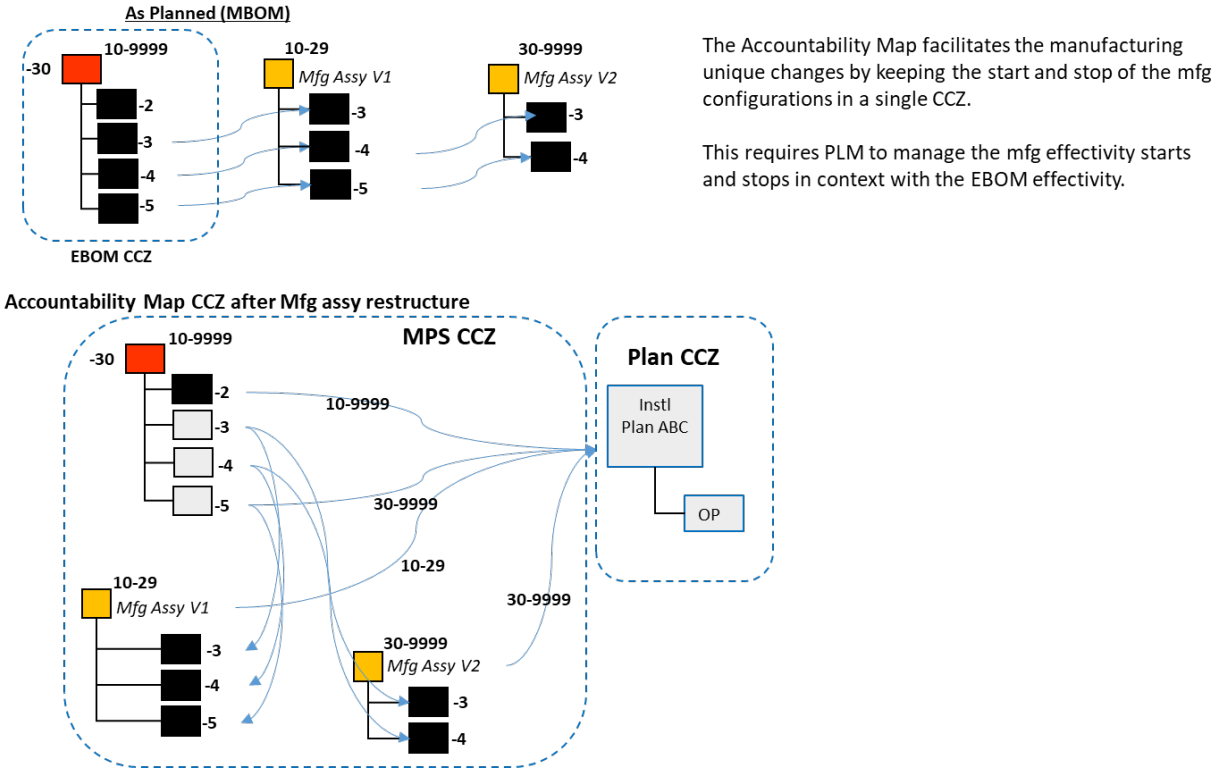


Figure 28 – Manufacturing Unique Changes to a Sunset

Manufacturing Subset Assemblies with an Engineering Change

This section addresses aspects of manufacturing subset assemblies with an engineering change.

Design Evolution can Reuse Existing Manufacturing Assembly

By having an Accountability Map that expands as designs evolve, Mfg Subset Assys that are not impacted when design changes are made can be reused without rolling their part number.

The Accountability Map must still re-map the usage of parts shared between design to the mfg assy.

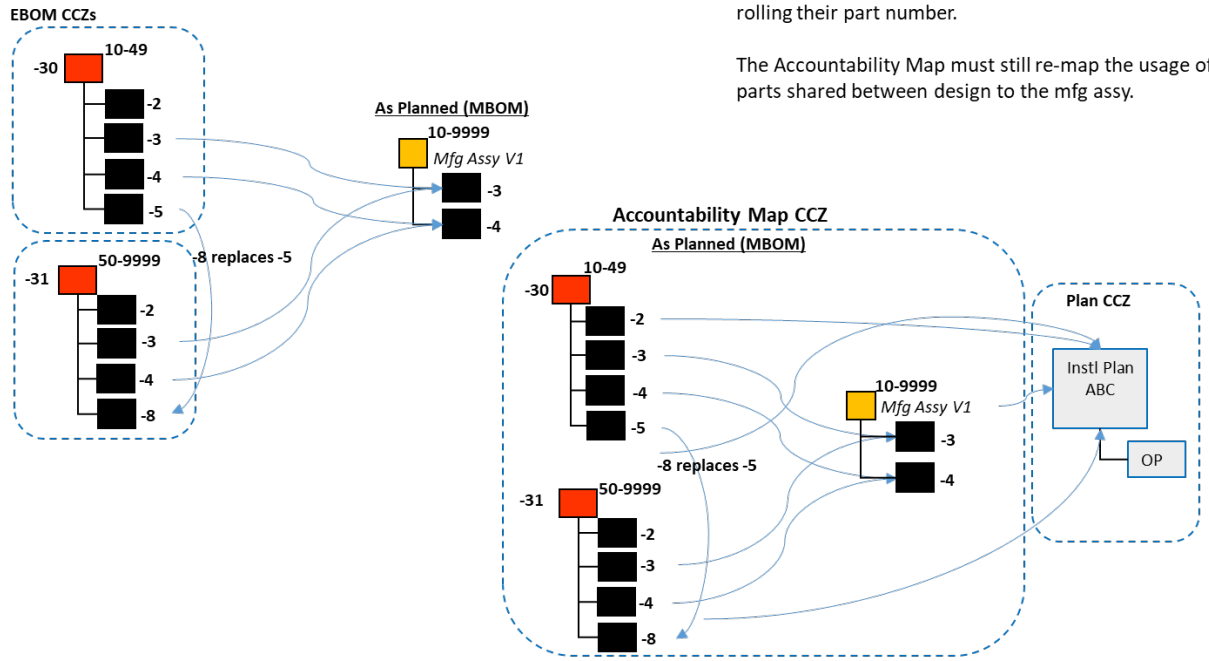


Figure 29 – Reuse of Existing Manufacturing Assembly

Design Evolution Requires Manufacturing Assembly Part Number Roll

The expanding Accountability Map CCZ accounts for the all mfg configurations in both the -30 and -31.

The idea being that each company can create their own system enforced business rules that are owned by the Accountability Map that enforce MBOM and Effectivity alignment to engineering prior to approval (or state change).

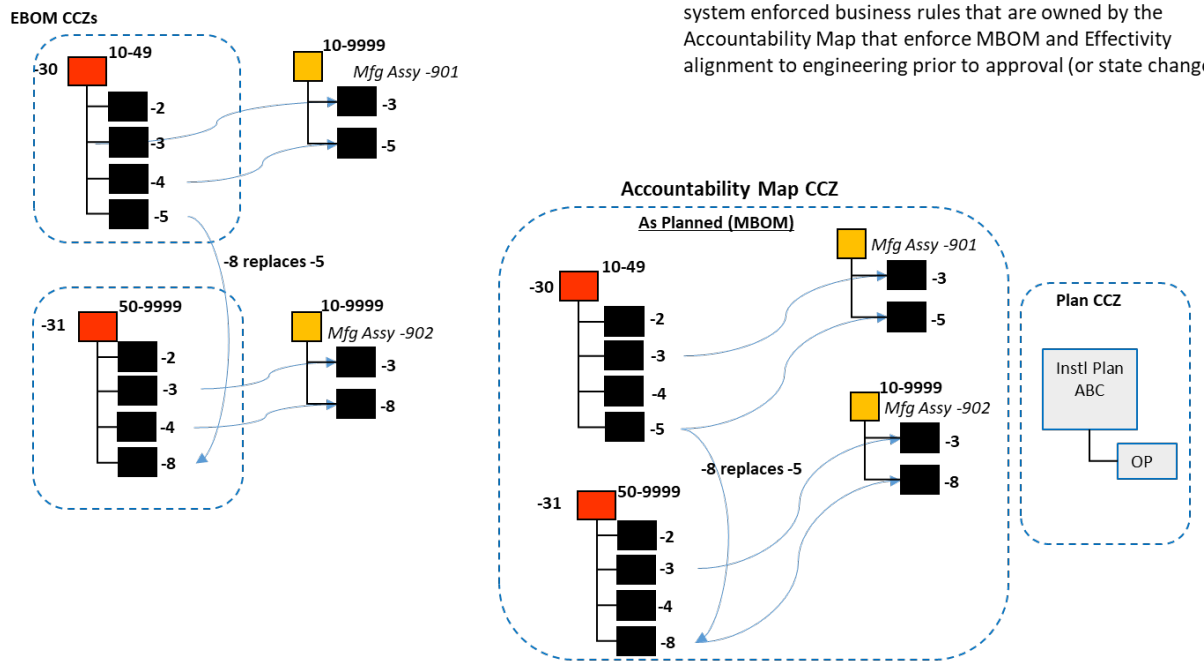


Figure 30 – Manufacturing Assembly Part Number Roll

Manufacturing Superset Assemblies

As noted in the body of the *Multiple View Bill of Materials (BOM)* position paper, superset assemblies can contain elements originating from separate engineering definitions. The superset becomes particularly complex to manage when the engineering definitions containing the components have different effectivity.

Two Separate Designs, Most Likely from Two Separate Functional Design Groups

The following accountability map figure illustrates the connection of two separate designs with a superset manufacturing assembly.

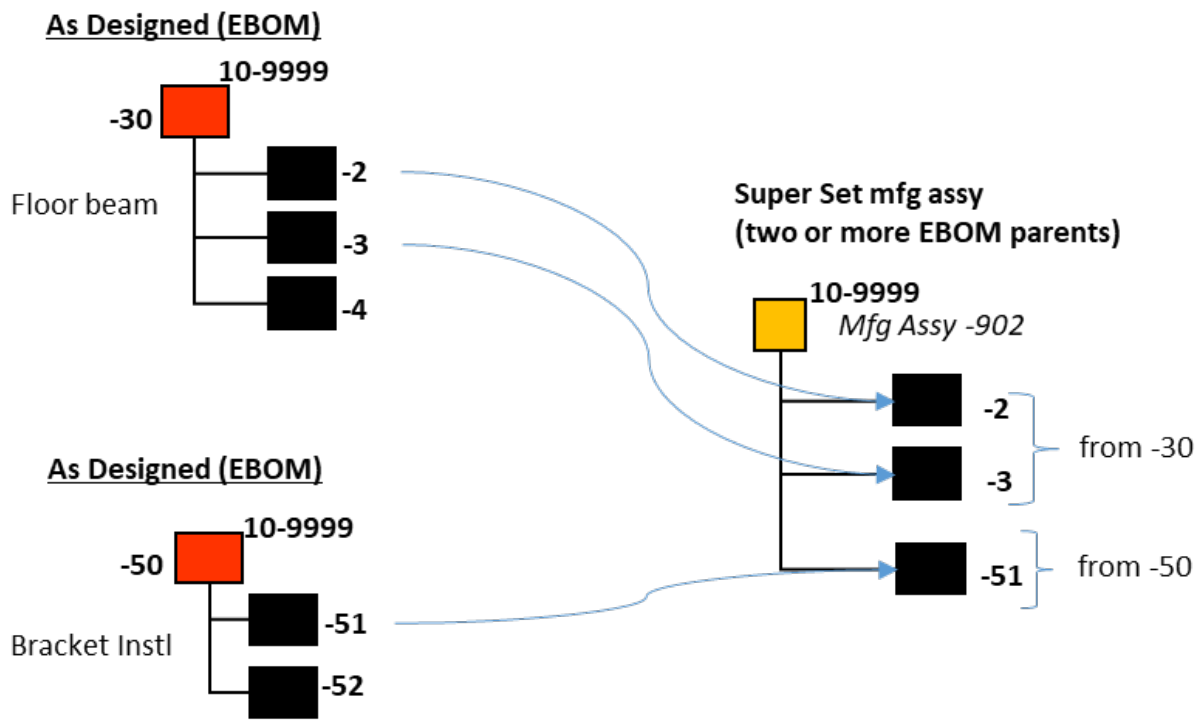


Figure 31 – Two Separate Designs

The Boeing experience with part number-controlled superset assemblies uncovered many complex issues. This is especially true when options and variants are used. In most cases creating part number-controlled superset manufacturing assemblies is avoided. The preferred approach is to create unitized assemblies that facilitate different configurations by unit number with a single manufacturing assembly definition (NOT part number-controlled). See later examples.

More Than One EBOM Parent

The following figure illustrates multiple designs with more than one EBOM parent.

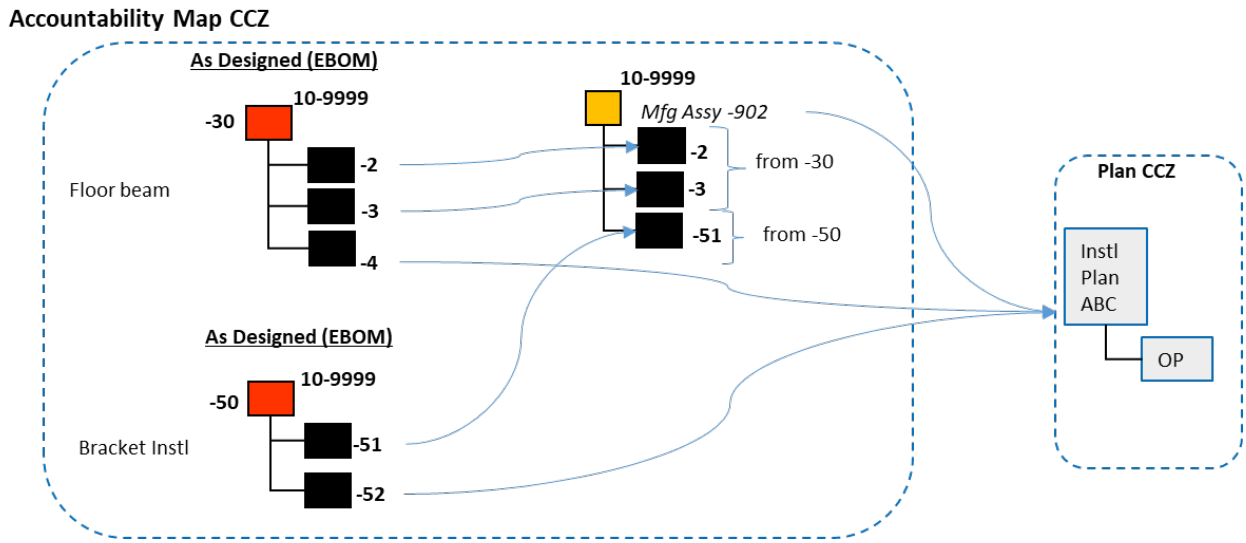


Figure 32 – Multiple EBOM Parents

In the examples so far, the accountability maps have only shown expansion to include more than one EBOM when design evolution originates from a single design.

The superset condition requires all designs that create the condition to be contained in the same CCZ of the accountability map. If all designs in the superset are applicable for the same options and effectivity, the superset condition is much easier to manage.

Three Separate Designs with Option Variability

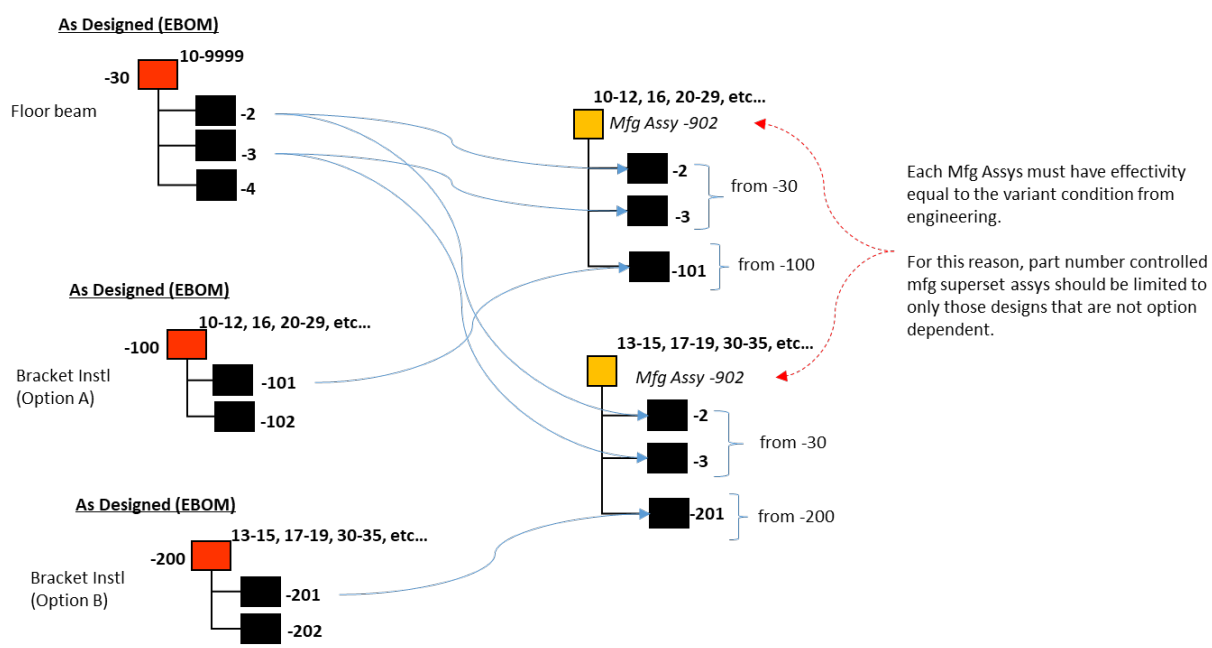


Figure 33 – Three Designs with Option Variability

Effectivity Not Common Between Designs

The following figure illustrates assembly when effectivity is not common between designs.

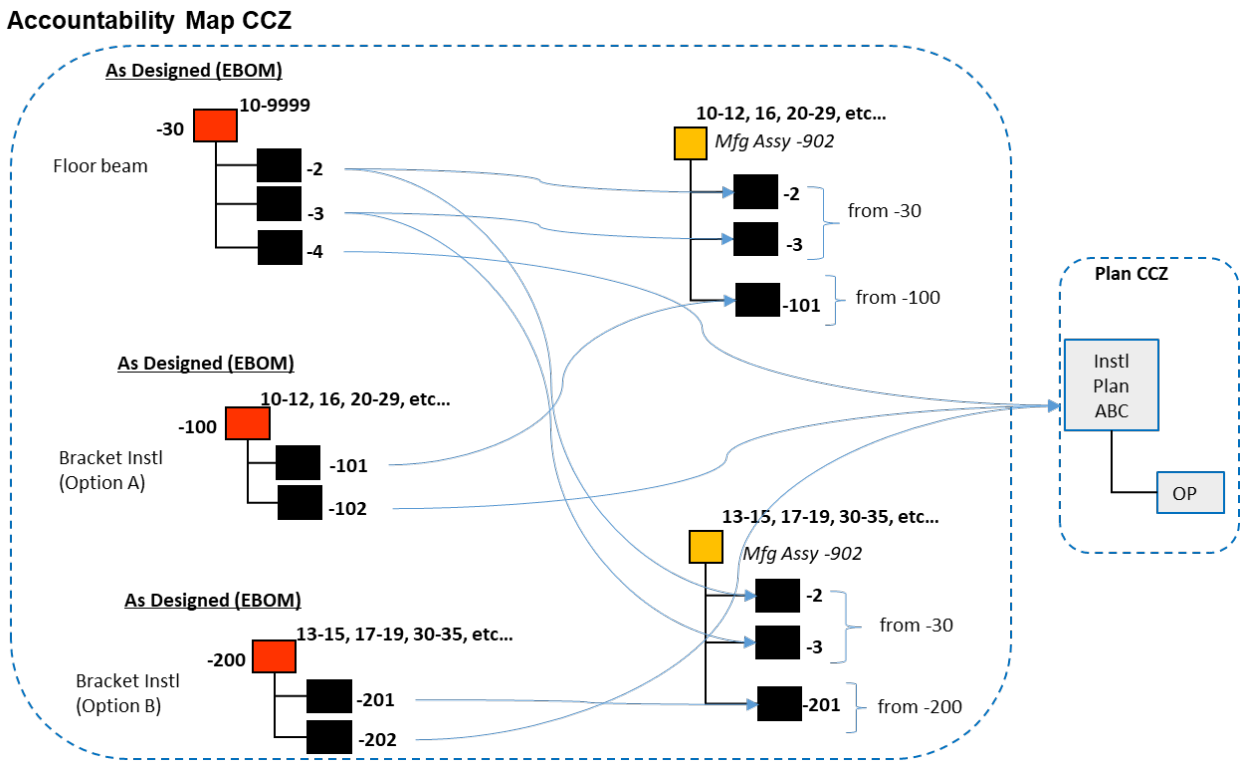
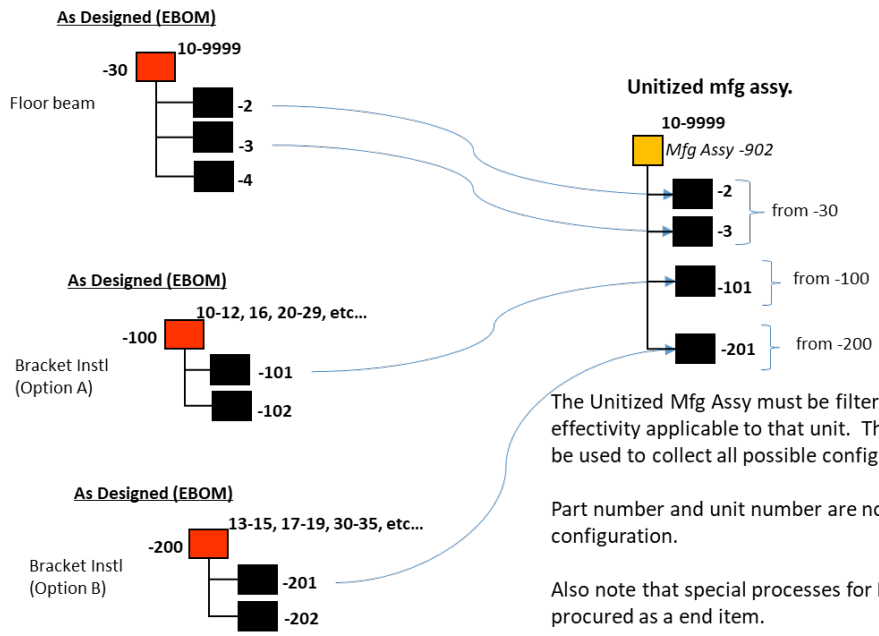


Figure 34 – Effectivity Not Common between Designs

Manufacturing Utilized Assemblies

Three Separate Designs with Option Variability

- Assy is NOT part number controlled.
- Effectivity is NOT common between designs.



The Unitized Mfg Assy must be filtered for each build unit based upon the effectivity applicable to that unit. This allows a stable mfg assy number to be used to collect all possible configurations from engineering.

Part number and unit number are now required to understand each build configuration.

Also note that special processes for ERP and suppliers are required when procured as a end item.

Figure 35 – Three Designs with Option Variability

Detailed Use Cases

This section describes all the use cases that shall be considered in the EBOM and MBOM restructuring scenarios. The first section describes EBOM and MBOM restructuring use cases from a static point of view; in other words, they describe how items are restructured without any consideration of effectivity management. The second section describes EBOM and MBOM restructuring from a dynamic point of view, taking effectivity management into consideration.

Static View – No Effectivity Applied

This section describes EBOM and MBOM restructuring uses cases without any consideration of effectivity management.

EBOM and MBOM > 1 to 1 Restructuring

This use case describes how an EBOM is restructured into an MBOM that has the same structure (items and quantities) than the original EBOM.

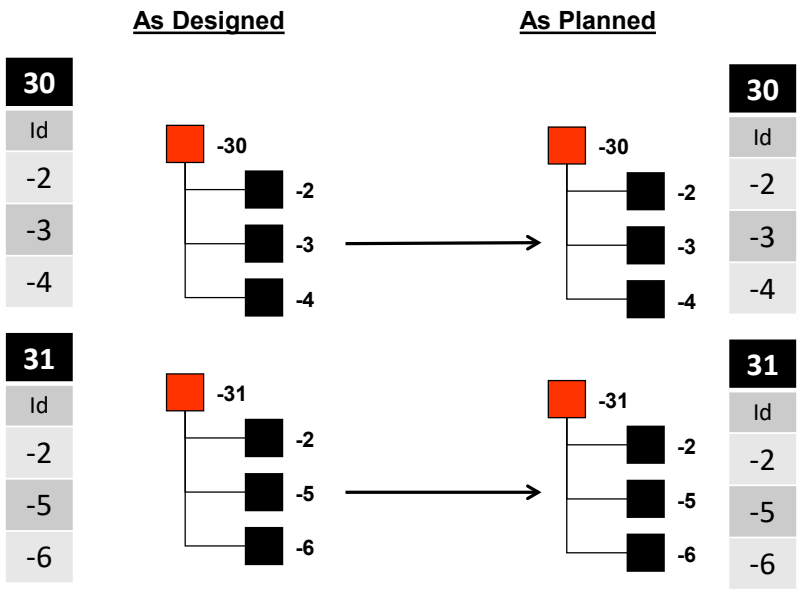


Figure 36 – EBOM and MBOM > 1 to 1 restructuring

EBOM and MBOM > 1 to N Restructuring

This use case describes how an EBOM is restructured into two or more MBOM. In other words, EBOM items are arranged differently in two or more MBOM

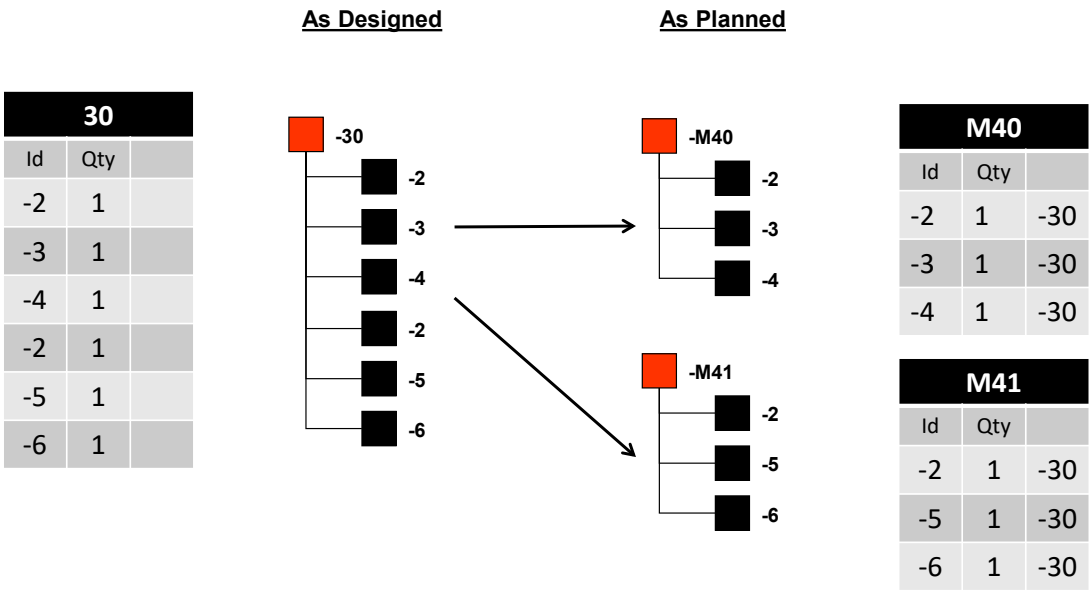


Figure 37 – EBOM and MBOM > 1 to N restructuring

EBOM and MBOM > N to 1 Restructuring

This use case describes how two or more EBOM are restructured into one MBOM. In other words, two or more EBOM items are arranged differently in one single MBOM.

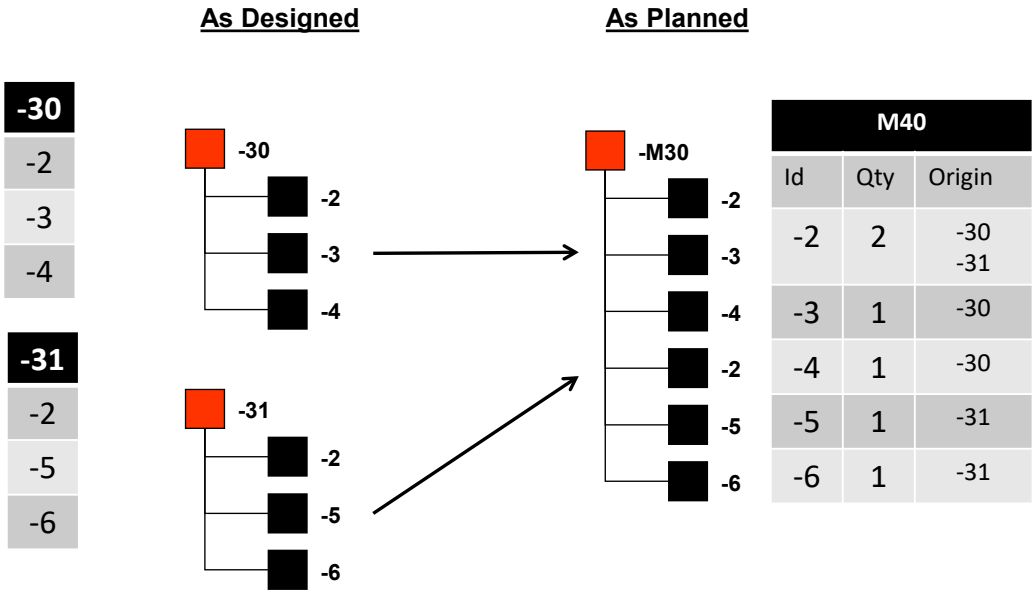


Figure 38 – EBOM and MBOM > N to 1 restructuring

EBOM and MBOM > N to M Restructuring

This use case describes how N number of EBOM are restructured into M number of MBOM, being N different from M.

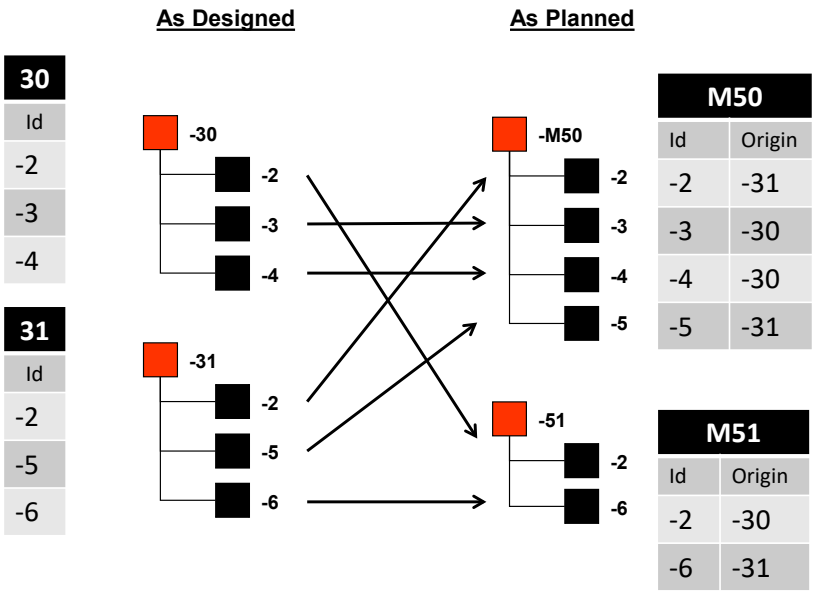


Figure 39 – EBOM and MBOM > N to M restructuring

EBOM and MBOM > Engineering Assembly Executed as Make On Assembly

This use case describes how individual items of an EBOM Assembly (-40) are restructured and linked to an MBOM as individual items. In other words, the EBOM Assembly is not installed "as it is designed" in the MBOM.

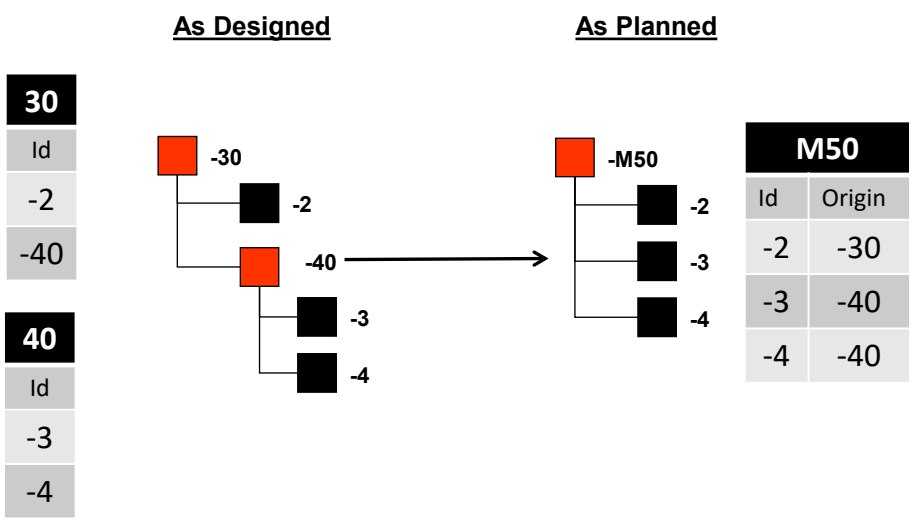


Figure 40 – EBOM and MBOM > Engineering Assembly Executed as Make on Assembly

EBOM and MBOM > Parts Executed as Manufacturing Only Assembly

This use case describes how several individual items (-2, -3, -2, -6) belonging to an EBOM are restructured and linked "as a manufacturing assembly" to one or more MBOM. In other words, the EBOM items are installed together as "manufacturing assemblies" that do not belong to the "as designed" view.

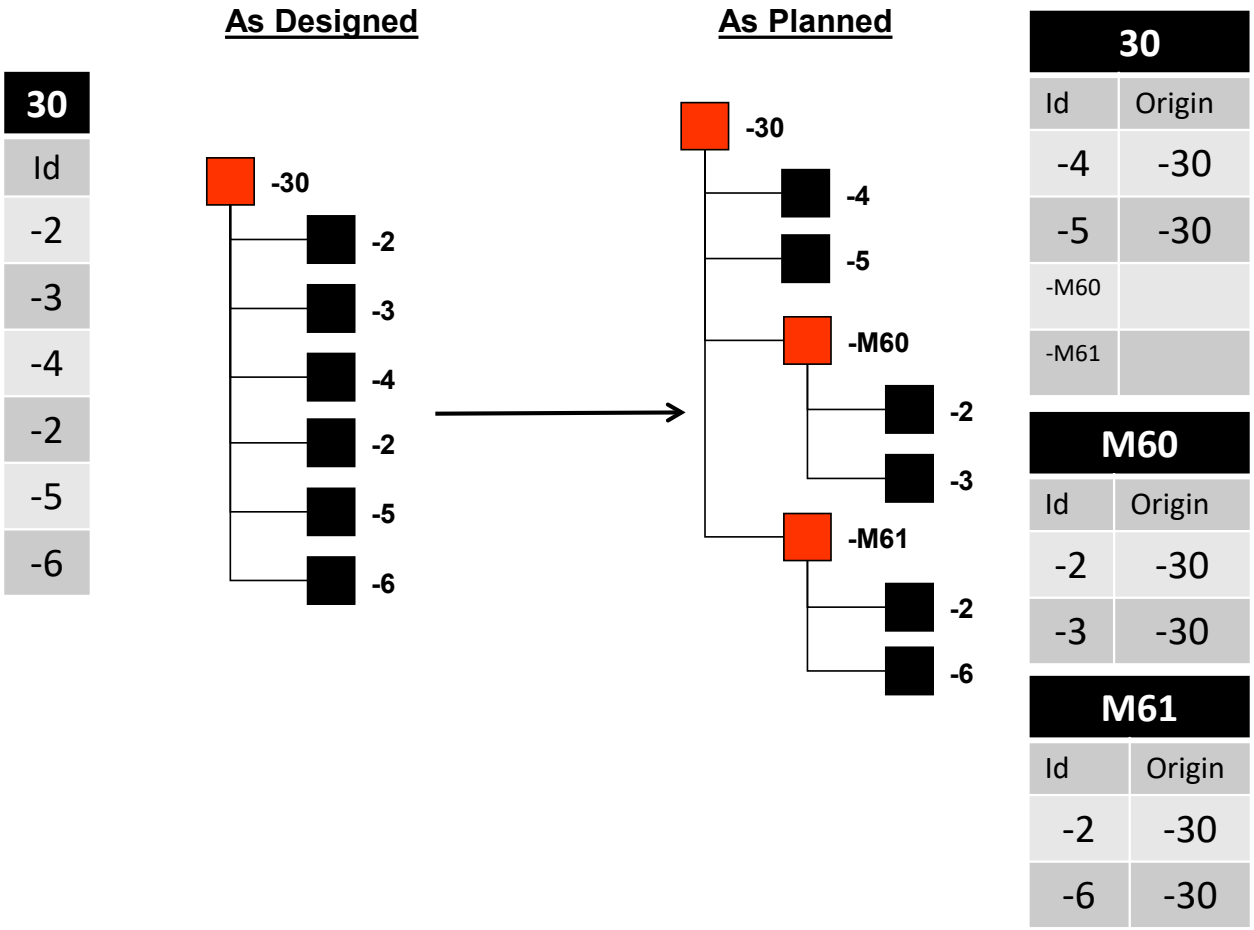


Figure 41 – EBOM and MBOM > Parts Executed as Manufacturing Only Assembly

EBOM and MBOM > 1 to 1 Restructuring with Conditions of Supply or Manufacturing Part

This use case describes how several individual items (-3, -5) belonging to one or several EBOM are not linked to an MBOM as they are designed. In other words, these EBOM items are subject to some production changes, such as holes omitting, that force the creation new Part Number references to differentiate the "As-Designed" product from the "Manufactured" product.

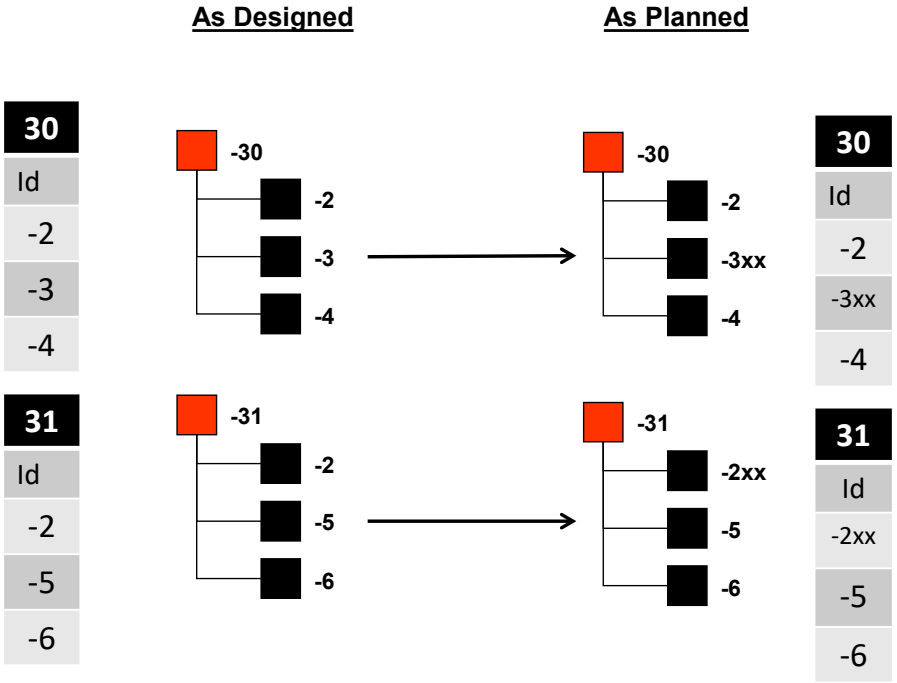


Figure 42 – EBOM and MBOM > 1 to 1 Restructuring with Conditions of Supply or Manufacturing Part

EBOM and MBOM > Quantity References for Products

This use case describes a specific behavior for products, such as glue or paint. Contrary to parts or assemblies count, the products quantity cannot be measured with cardinal numbers. For example, they may be expressed as a weight or volume.

If a product is restructured, its count shall be the same after EBOM-to-MBOM restructuring.

This use case may apply to 1 to N, N to 1, and N to M EBOM-to-MBOM restructuring cases if the restructuring involves a product.

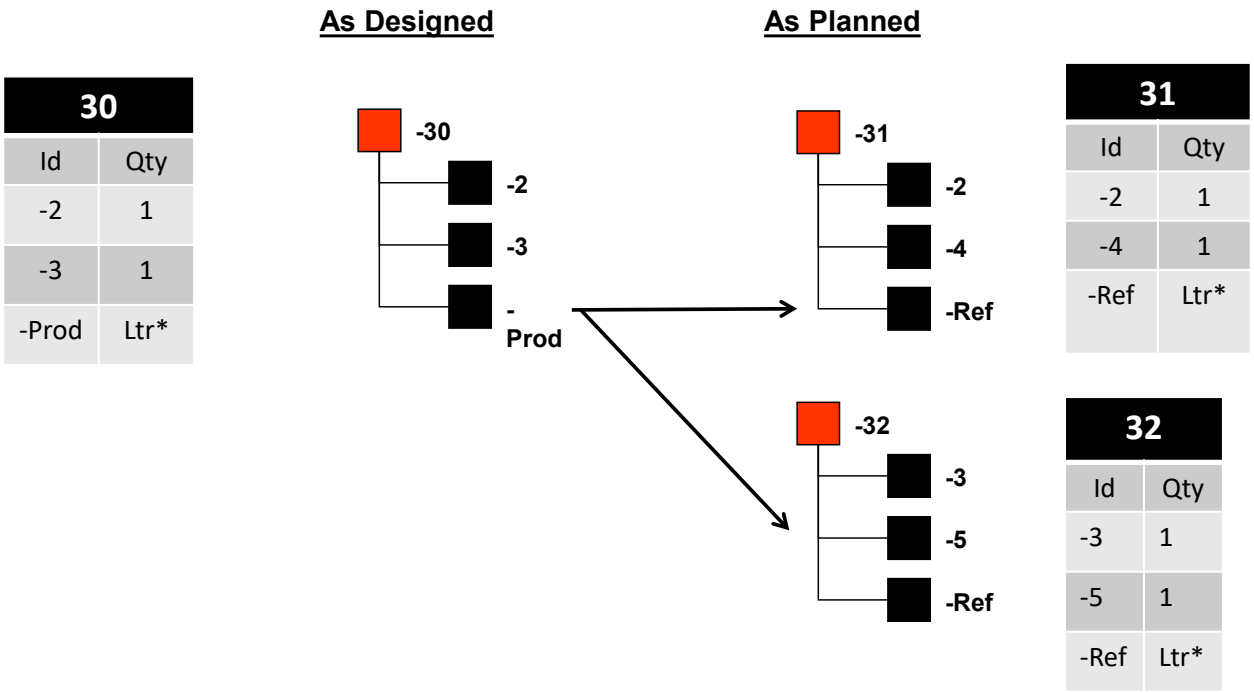


Figure 43 – EBOM and MBOM > Quantity References for Products

EBOM and MBOM > Specific Alternate – Simple Version

This use case describes individual items (-3, -4) that are alternate in an EBOM and can be used interchangeably in the MBOM.

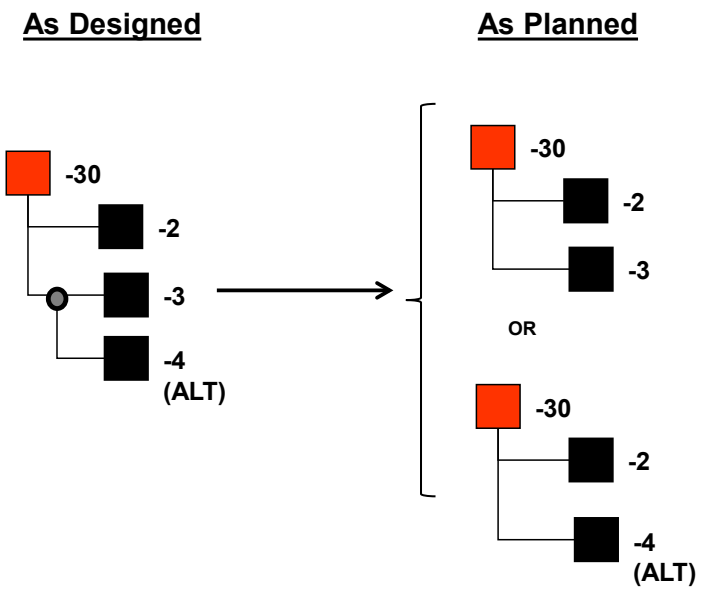


Figure 44 – EBOM and MBOM > Specific Alternate – Simple Version

EBOM and MBOM > Specific Alternate – Complex Version

This use case describes items (XYZ rivet) that are alternate with other (-4, -5, -6) in an EBOM and can be used interchangeably in the MBOM.

The complexity in this use case, compared to the previous one, is that cardinality of (XYZ rivet) and (-4, -5, -6) are different: three items are the alternate of one item.

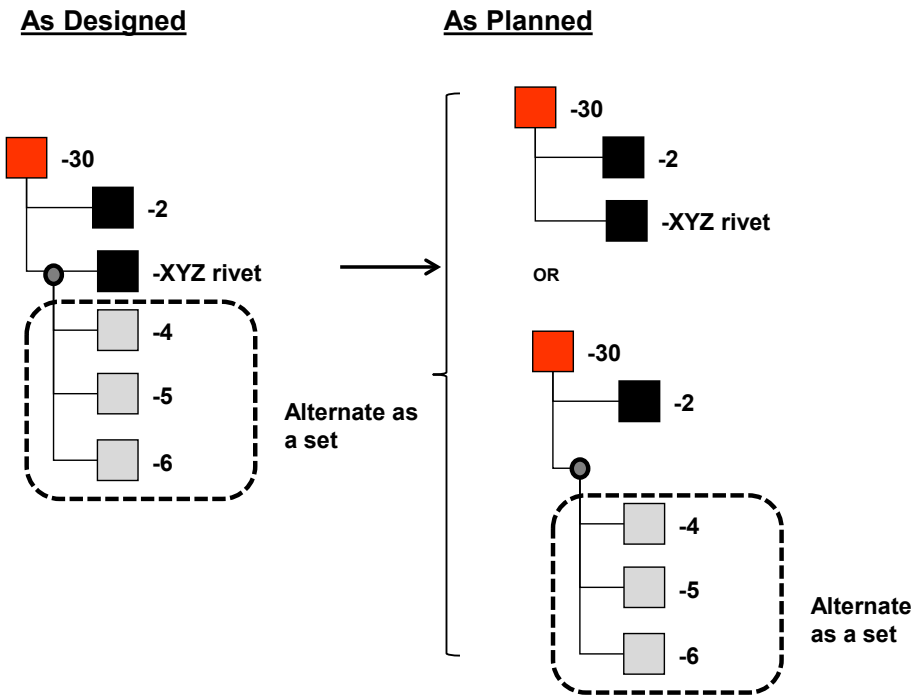


Figure 45 – EBOM and MBOM > Specific Alternate – Complex Version

Dynamic View – Effectivity Applied

This section describes EBOM and MBOM restructuring from a dynamic point of view, taking effectivity management into consideration.

EBOM Effectivity Change

This use case describes how engineering effectivity change works in a restructuring scenario. The example uses a 1 to N restructuring scenario; however, this EBOM effectivity change may apply to any other use case already described.

In Step 1, (-30) EBOM effectivity range 1-999 is stablished for the EBOM, and consequently propagated to the (-M40) and (-M41) MBOM.

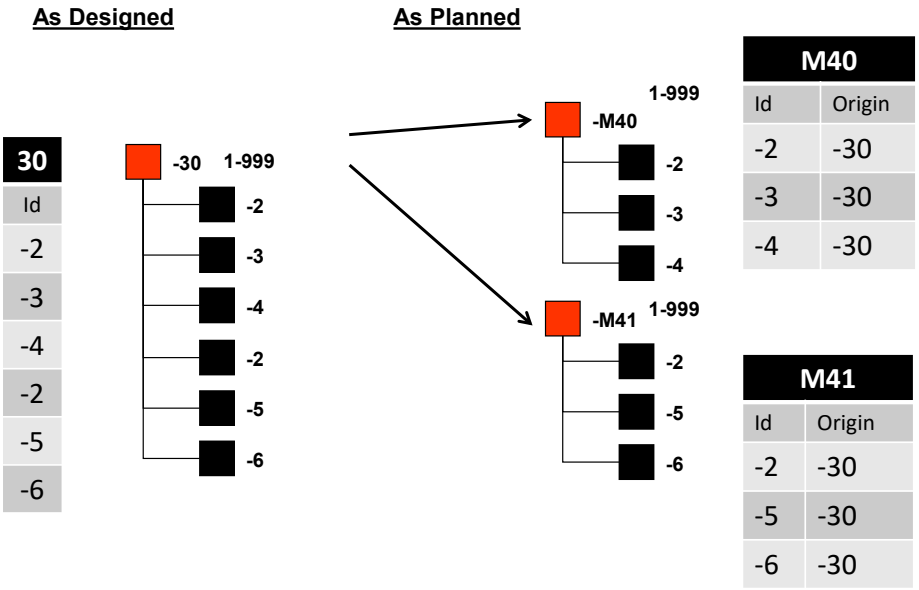


Figure 46 – EBOM Change, EBOM and MBOM > 1 to N Restructuring – 1 of 2

In Step 2, an engineering change starting in 17 restricts (-30) EBOM effectivity range to 1-16. Consequently, that effectivity shall be propagated to the (-M40) MBOM, while (M41) MBOM effectivity is unaffected.

A new EBOM engineering baseline (-31) is established starting in 17. Due to the restructuring (-M41), MBOM remains unaffected, while a new (-M42) MBOM is created from 17 onwards.

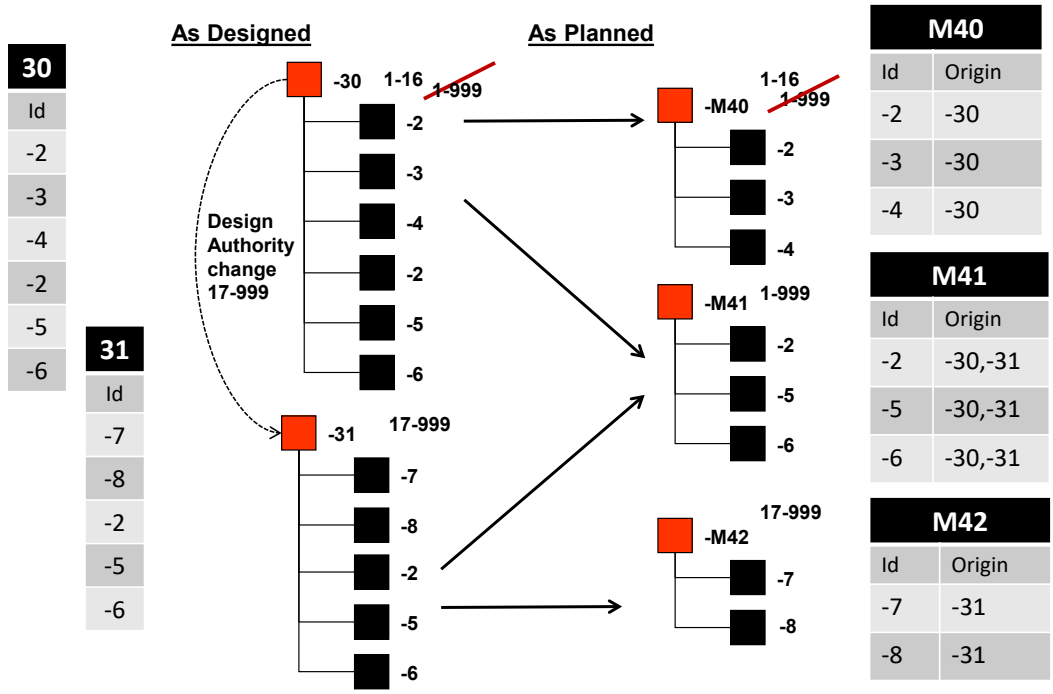


Figure 47 – EBOM Change, EBOM and MBOM > 1 to N Restructuring – 2 of 2

MBOM Effectivity Change, EBOM and MBOM > 1 to N Restructuring

This use case describes how manufacturing effectivity change works in a restructuring scenario. The example uses a 1 to N restructuring scenario; however, this MBOM effectivity change may apply to any other use case already described.

In Step 1, (-30) EBOM effectivity range 1-999 is established for the EBOM and consequently propagated to the (-M40) and (-M41) MBOM.

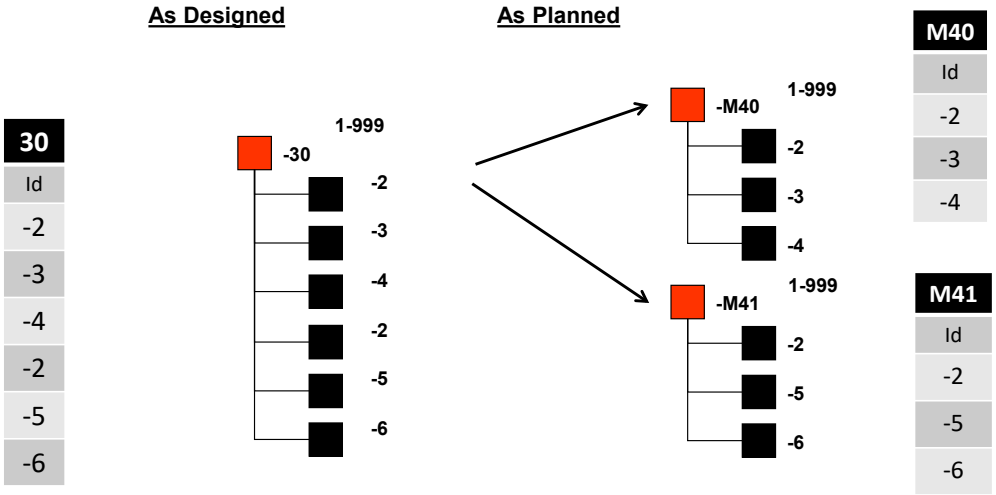
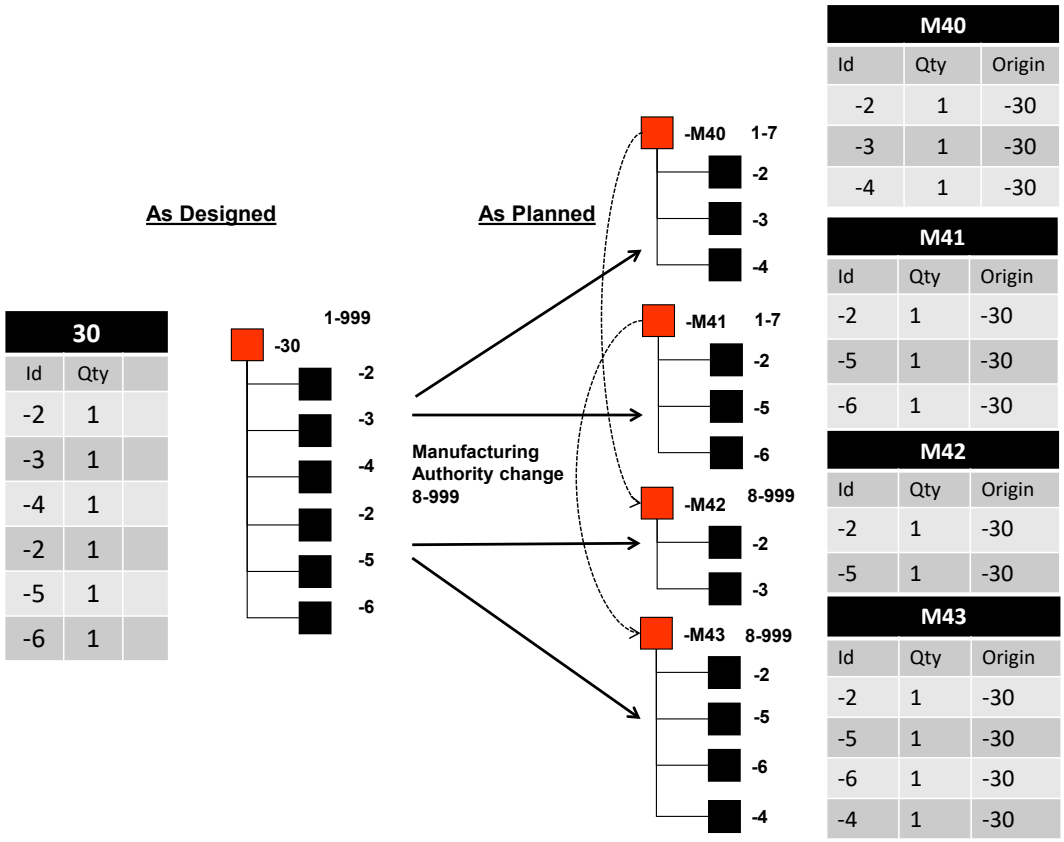


Figure 48 – MBOM Change, EBOM and MBOM > 1 to N Restructuring – 1 of 2

In Step 2, a manufacturing change starting in 8 replaces (-M40) and (-M41) MBOM by (-M42) and (-M43) MBOM for 8 onwards. However, (-30) EBOM remains strictly unaffected by the MBOM change.



30		
Id	Qty	
-2	1	
-3	1	
-4	1	
-2	1	
-5	1	
-6	1	

M40		
Id	Qty	Origin
-2	1	-30
-3	1	-30
-4	1	-30

M41		
Id	Qty	Origin
-2	1	-30
-5	1	-30
-6	1	-30

M42		
Id	Qty	Origin
-2	1	-30
-5	1	-30

M43		
Id	Qty	Origin
-2	1	-30
-5	1	-30
-6	1	-30
-4	1	-30

Figure 49 – MBOM Change, EBOM and MBOM > 1 to N Restructuring – 2 of 2

About AD PLM Action Group

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

- Set the direction for the aerospace & defense (A&D) 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.

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