Project „Flexible Assembly Processes for the Car of the Third Millennium (MyCar)“

Methodology Description (High Level)

Integrated Methodology towards PoD (Production-oriented Validation) supported by a PoD Validation Tool

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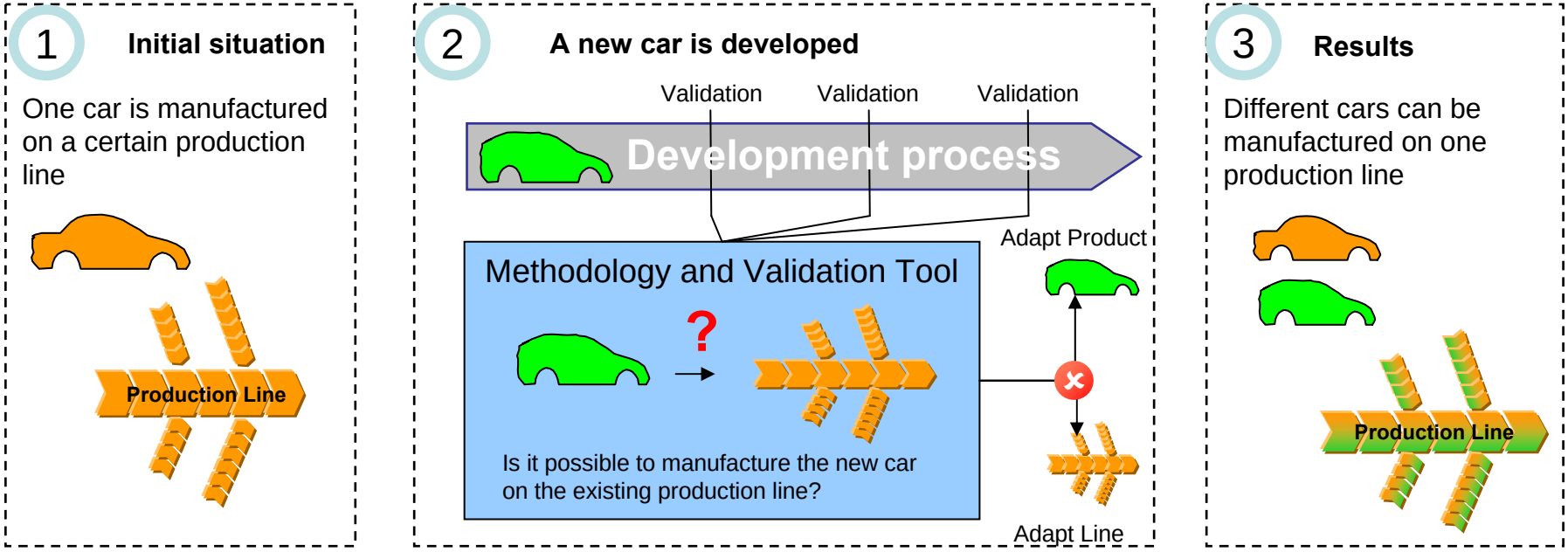
Methodology Description (High Level)

… How can we integrate new developed products
on an existing production line ?

High level methodology description of Production-oriented Validation Framework

The goal is the integration of new developed products on existing production lines while extending the flexibility of the according production facilities supported by a methodology and web based tool



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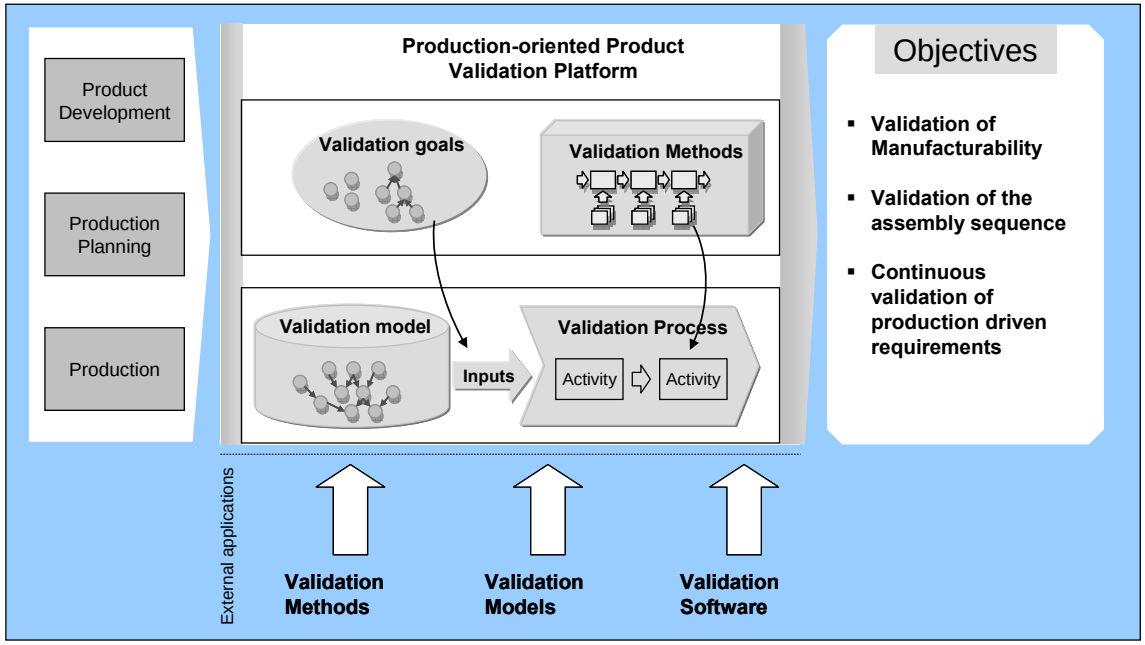
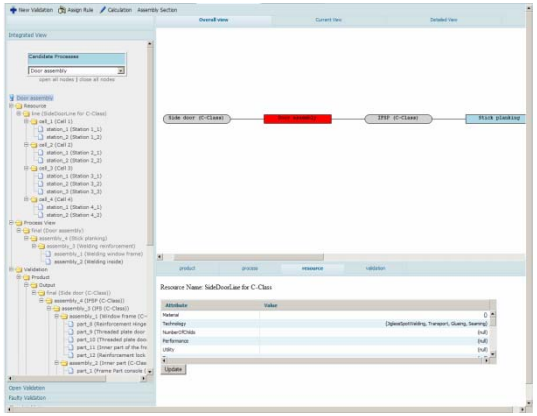
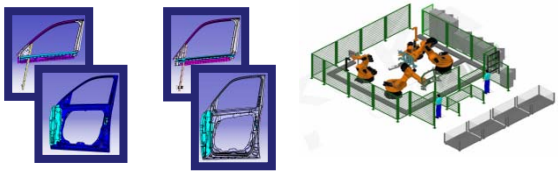
Key components of Production-oriented Validation Framework

1. **Methodology** to support the **product development process**
2. **Software** to support the **product and production engineers**

…in validating the new product against available production resources







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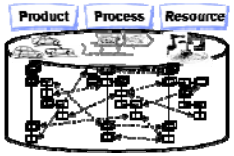
Process overview of Production-oriented Validation Framework

Product / Production Engineer:
Reuse of production equipment ?

1. **Define Product Process Resource (PPR) data**



Via AutomationML interface

2. **Assign validation model**

Validation model configuration

Generation of **PPR-Validation** Tree

3. **Execute validation procedure**

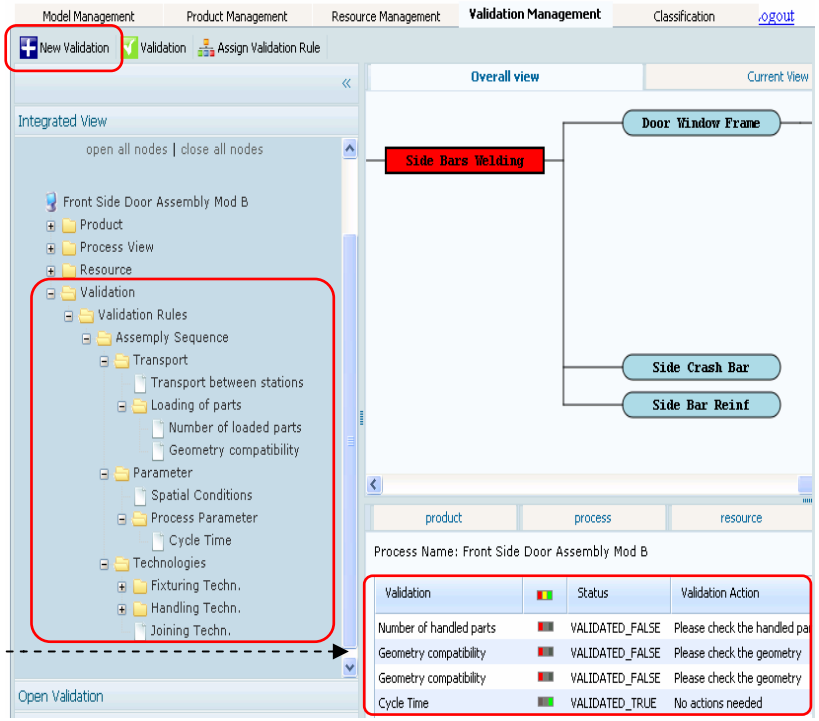
Rule & constraint based validation of PPR-attributes

Aggregation & visualization of validation results

Identification of possible problems

4. **Identification of alternative solutions**

Production-oriented design graphical interface



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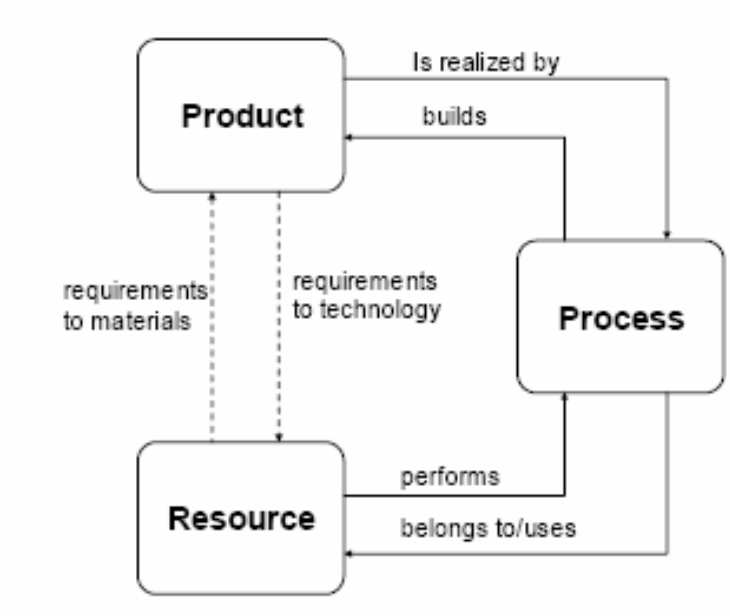
Interrelation between Validation Model and product, process, resource description



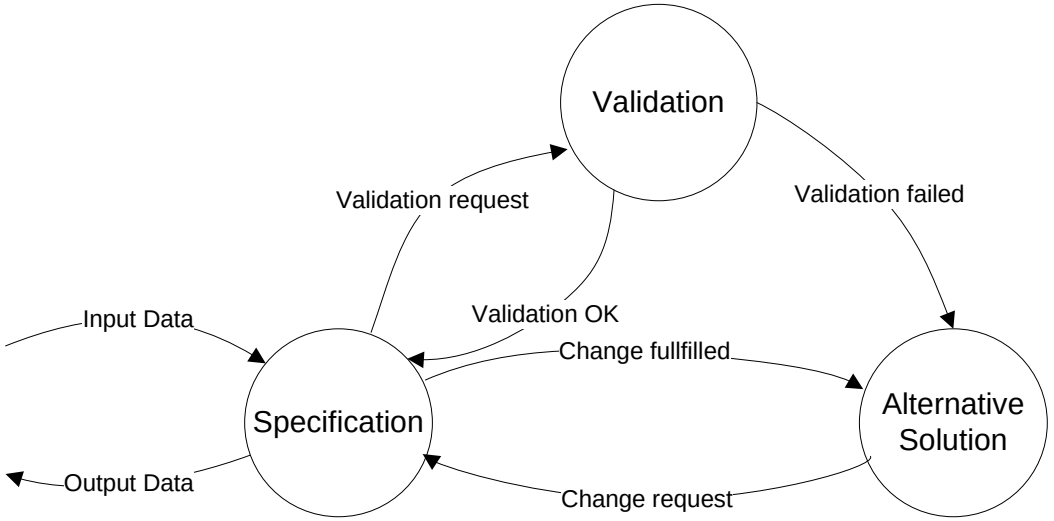
- The **product** is the central entity that must be produced by a **resource** (machine, robot, tool, etc.)
- The **process** description links the particular product to distinct production **resources** and is characterized by attributes
- **Validation Model**: rules and constraints on the set of attributes of the **product, processes and resources**

Formalization of the Validation model using Backward Chaining inference

- On the set of product-, process- and resource attributes (PPR attributes), **logical terms** in form of **IF pre_condition THEN post_condition** are build.
- A logical term may consist of multiple logical terms or using mathematical calculations.
- For the **validation process**, these terms are **evaluated using backward chaining algorithms**

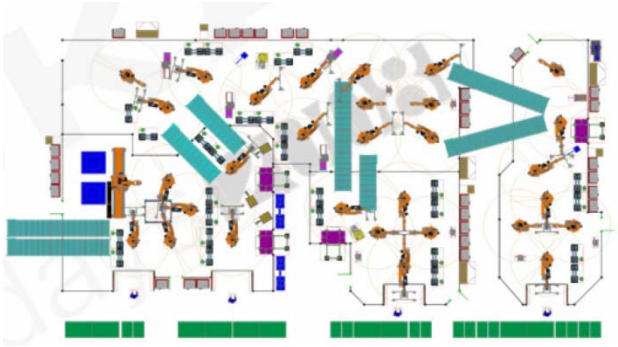
Rule 1	IF	Conditions to Rule 1
	THEN	Manufacturing sequence is compatible
Rule 2	IF	Conditions to Rule 2
	THEN	Manufacturing method is applicable
Rule 3	IF	Conditions to Rule 3
	THEN	Flow of material is consistent
Rule Final	IF	Manufacturing sequence is compatible Manufacturing method is applicable Flow of material is consistent
	THEN	Manufacturing sequence is correct

Composition of the validation procedure

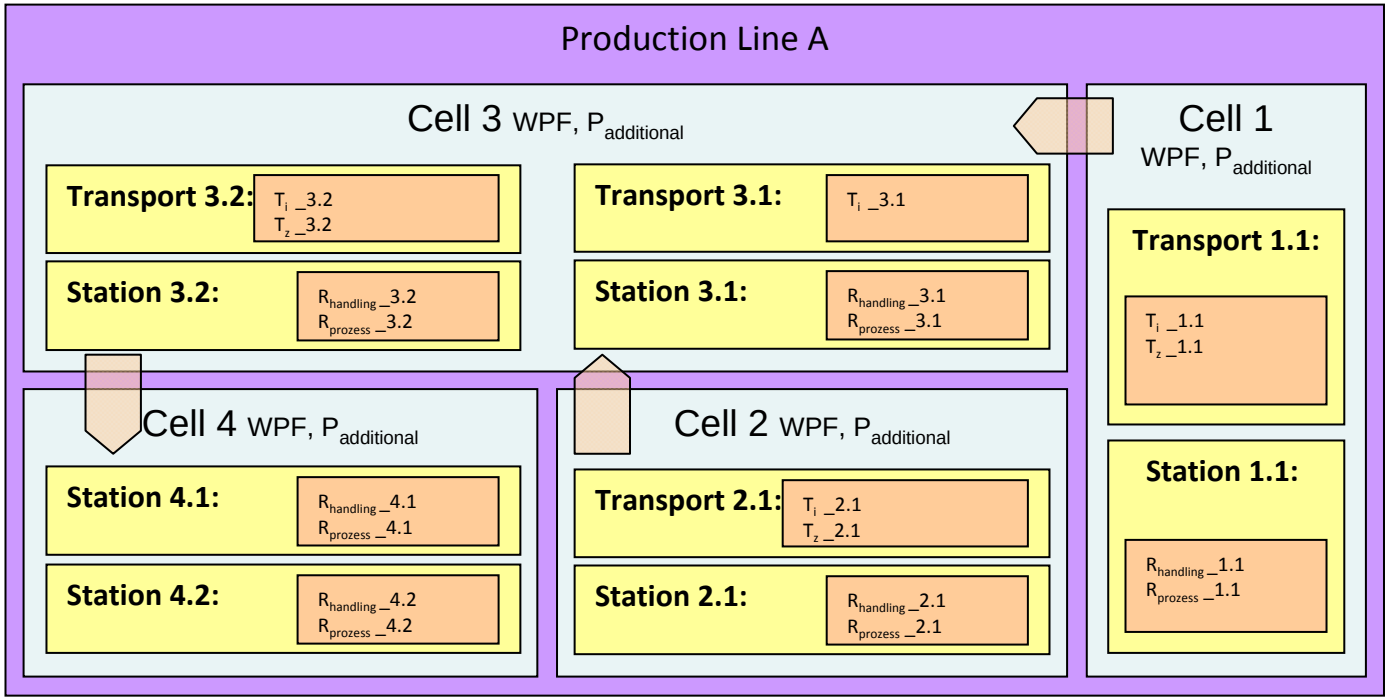


- **Iterative validation procedure**
- The validation goals become more and more detailed and specified as the product data matures over the product development process
- According to the **specification** of product development, a **validation** request may be carried out. If the validation fails, **alternative solutions** have to be deducted in order to satisfy to validation criteria

Exemplary composition of a production line



Exemplary production line:
- Graphical assemby on the left
- Schematic assembly with relationships on the bottom



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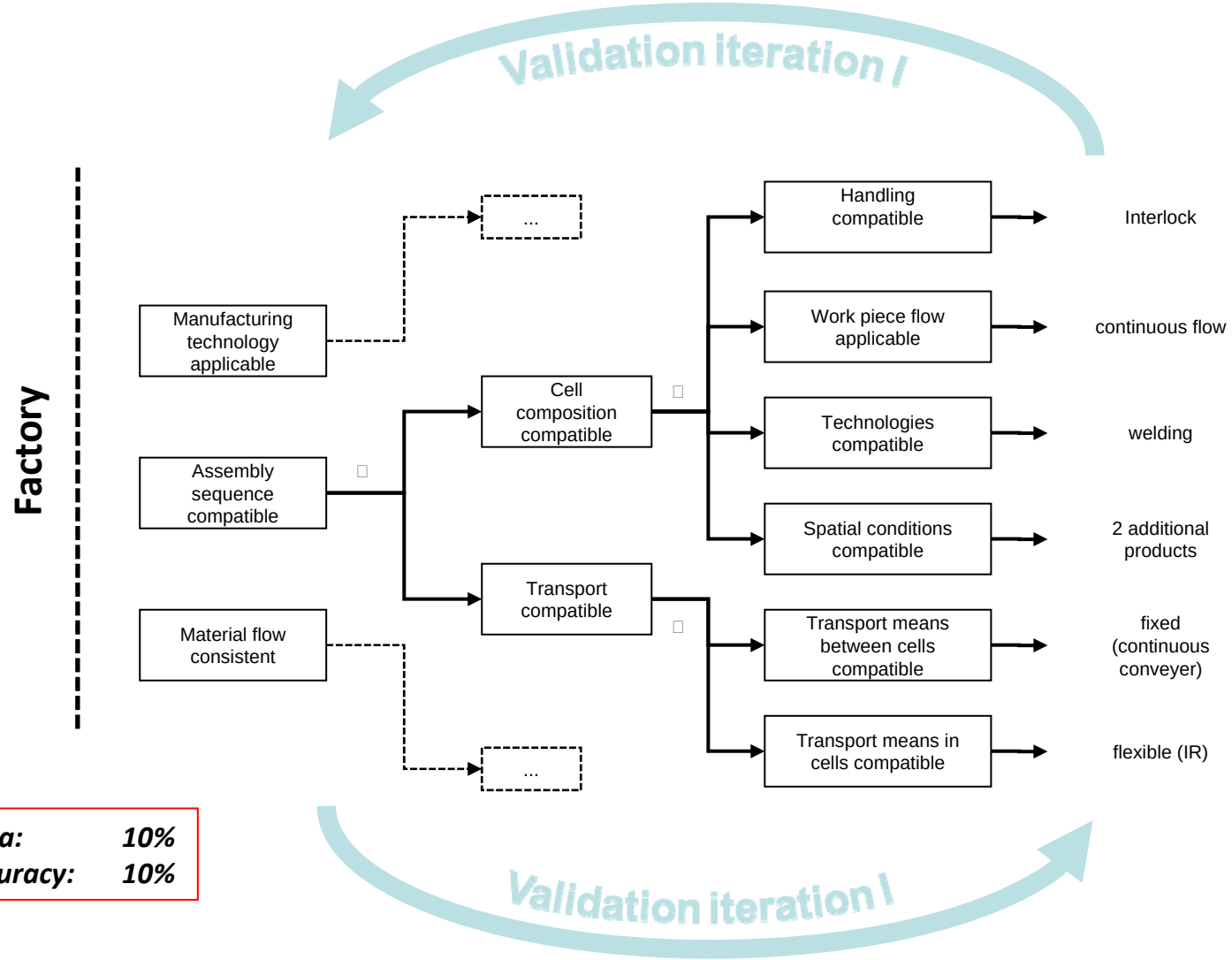
Validation iteration I – Available specification data at an early stage



Data:	***10%***
Accuracy:	***10%***

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Validation iteration I – Attribute catalogue at an early stage

Handling	Friction lock	interlock	flexible glue bonding	vacuum bonding	electrostatic	
Work piece flow	Single-piece	continuous production	continuous flow	bacth flow		
Technologies	welding	gluing	folding	bolting	soldering	
Spatial conditions	*- # of additional products that can be integrated in existing production line or cell, here: „2“ -*					
Transport means between cells	fixed (continuous conveyer, belt conveyer, chain conveyer, assembly conveyer)	loose (buffer, Skid)	flexibel (forklift, telpher, FTS)	Handling tool or machine (e.g. IR)		
Transport means between cells	fixed (continous conveyer, belt conveyer, chain conveyer, assembly conveyer)	loose (buffer, Skid)	flexibel (forklift, telpher, FTS)	Handling tool or machine		

Handling compatible

Work piece flow applicable

Technologies compatible

Spatial conditions compatible

Transport means between cells compatible

Transport means in cells compatible

By selecting the right attributes, potential production lines can be characterized

interlock

continuous flow

welding

2 additional products

Fixed (continuous conveyer)

flexible (IR)

Legend

- The table displays all relevant attributes which a production resource can offer.
- The green marked field identifies those attributes, a particular production resource provides.

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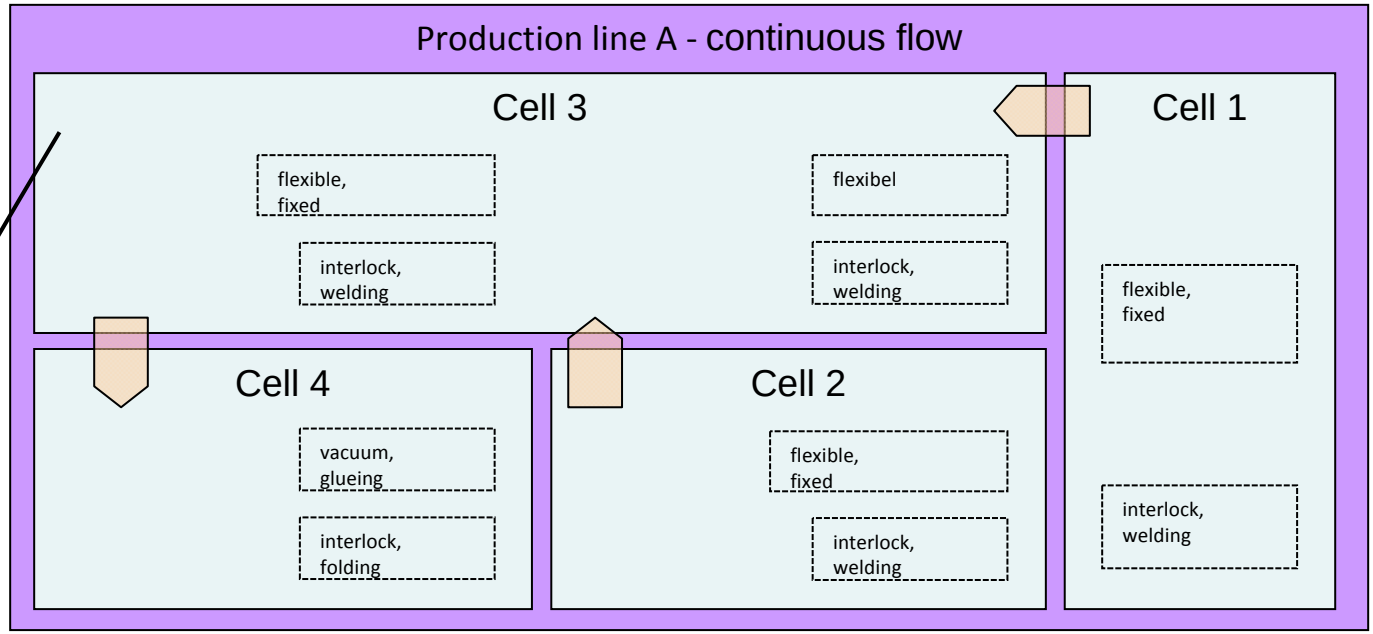
Validation iteration I – Validated configuration of the production line

→ Attribute configuration possible **on cell level** only



Exemplary attribute configuration of cell 3 at time t

A.Z3.T_i.type	=	flexible	(transport means in cell 3)
A.Z3.T_b. type	=	Fixed	(transport means between cell 3 and 4)
A.Z3.$R_{handling}$. type	=	Interlock	(mechanical principle for fixing a work piece)
A.Z3.$P_{additional}$	=	2	(number of additional products that could be integrated in cell 3)
A.Z3.$R_{process}$. type	=	Welding	(joining technology in cell 3)
A.Z3.WPF. type	=	Continous flow	(type of work piece flow in cell 3)

Attributes to be validated at time t

Attribute value at time t

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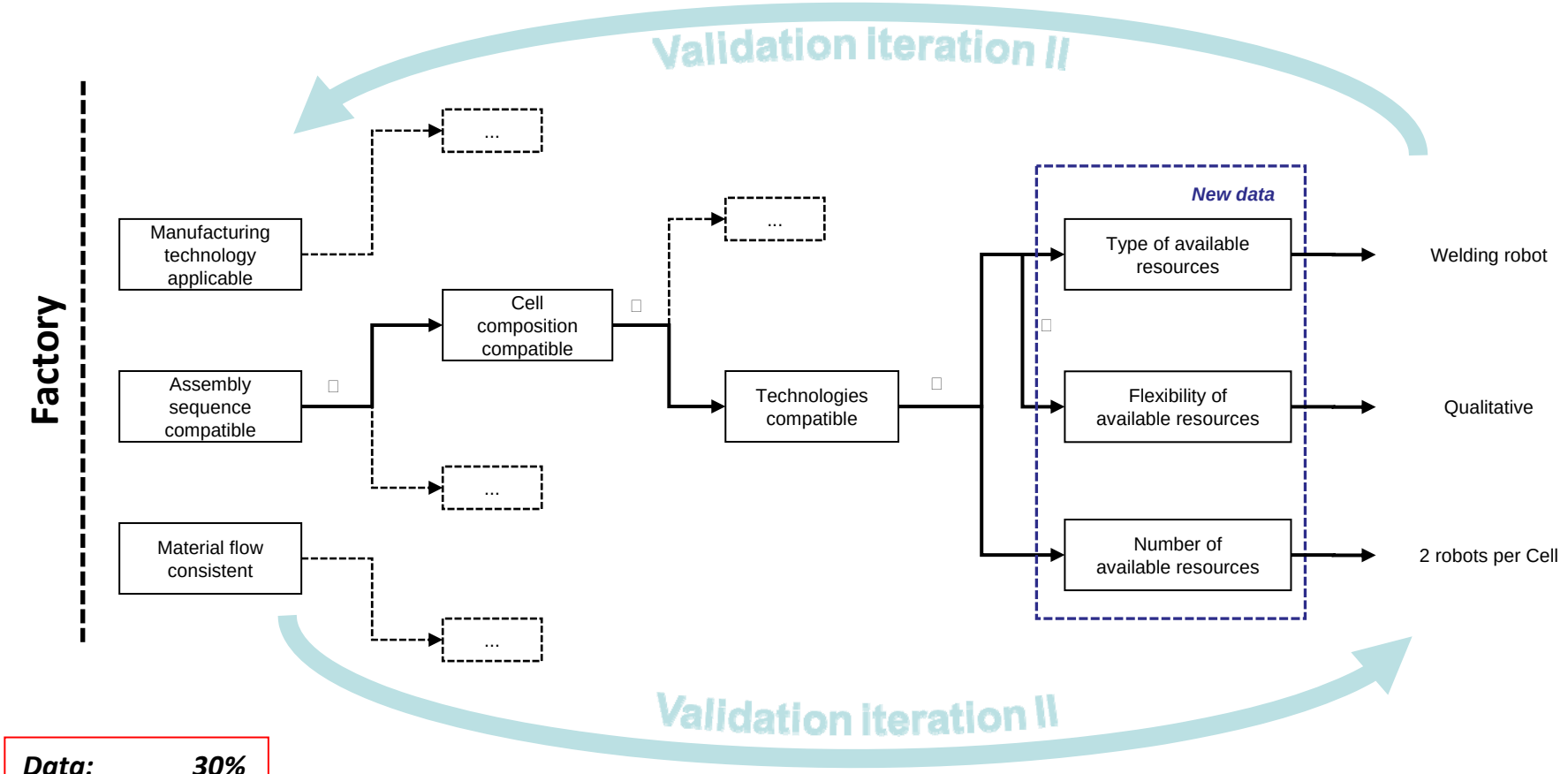
Validation iteration II – Matured specification data



Data:	***30%***
Accuracy:	***30%***

→ After an advanced and matured product development process, a 2nd validation iteration is carried out.

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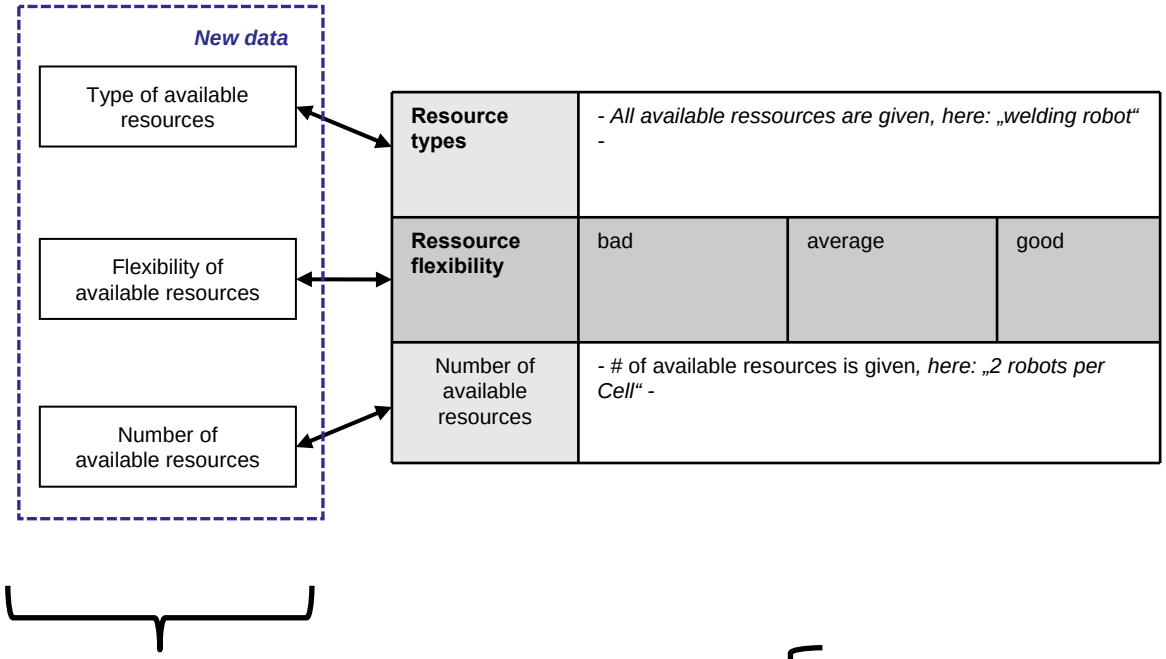
Validation iteration II – Matured specification data



With every new data set the detail level and accuray of the validation method increases.

Welding robot

qualitative

2 robots per Cell

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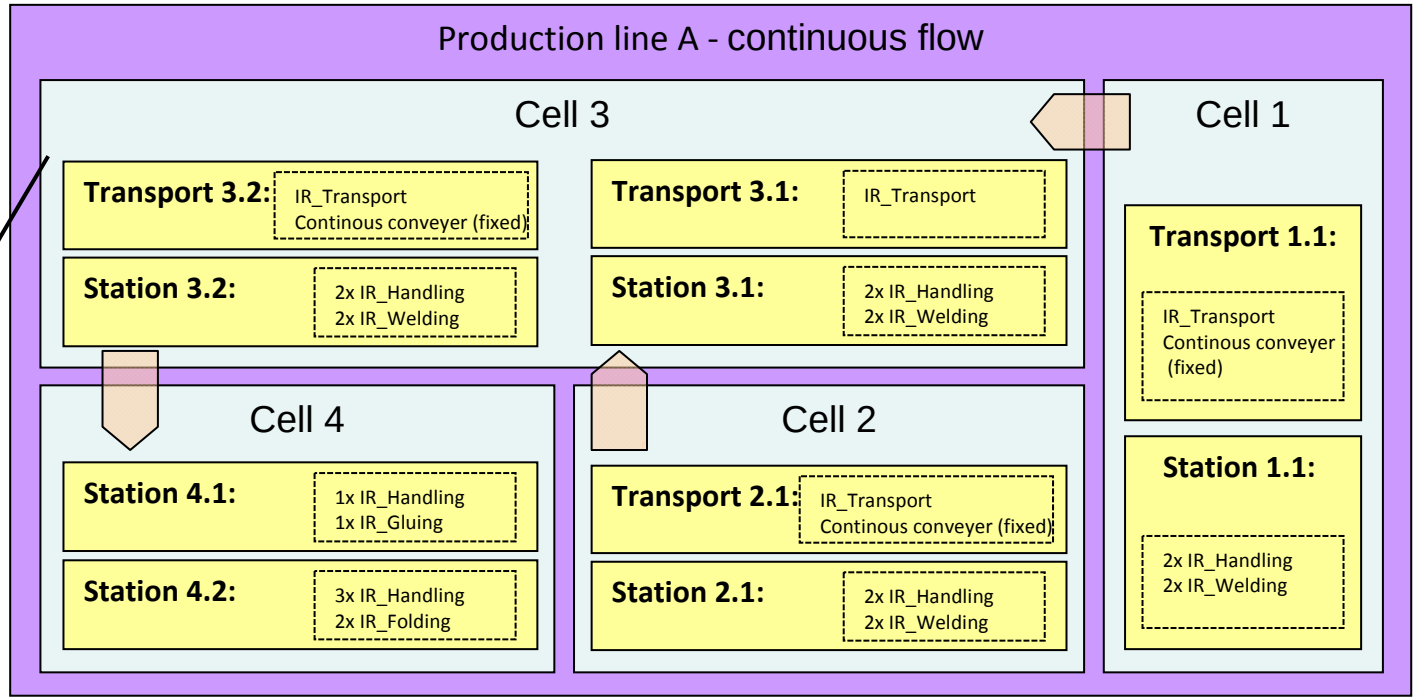
Validation iteration II – Validated configuration of the production line

→ Attribute configuration possible **on station level**



$A.Z3.S1.R_{process}.type$	=	welding robot	(Type of available resources in cell 3)
$A.Z3.S1.R_{process}.\#$	=	4	(Number of available resources in cell 3)
$A.Z3.S1.R_{prozess}.Flex.$	=	unknown	(Flexibility of available resources in cell 3)

Attributes to be validated at time t+1

Attribute value at time t+1

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Innovative aspects and benefits of the Production-oriented Validation Framework

- **Innovative aspects:**
  - Focus on workflow and validation method dependencies
  - Early and systematic application of validation methods
  - Consideration of impact of the design decisions on production process already during the product development process
  - Validation of production process regarding flexible production lines

- **Benefits:**
  - Avoidance of costly design modifications or improvement iterations
  - Reduction of product design process time
  - Suppression of the gap (or one of the gaps) between product design and production planning
  - Contribution to production cost and time reduction

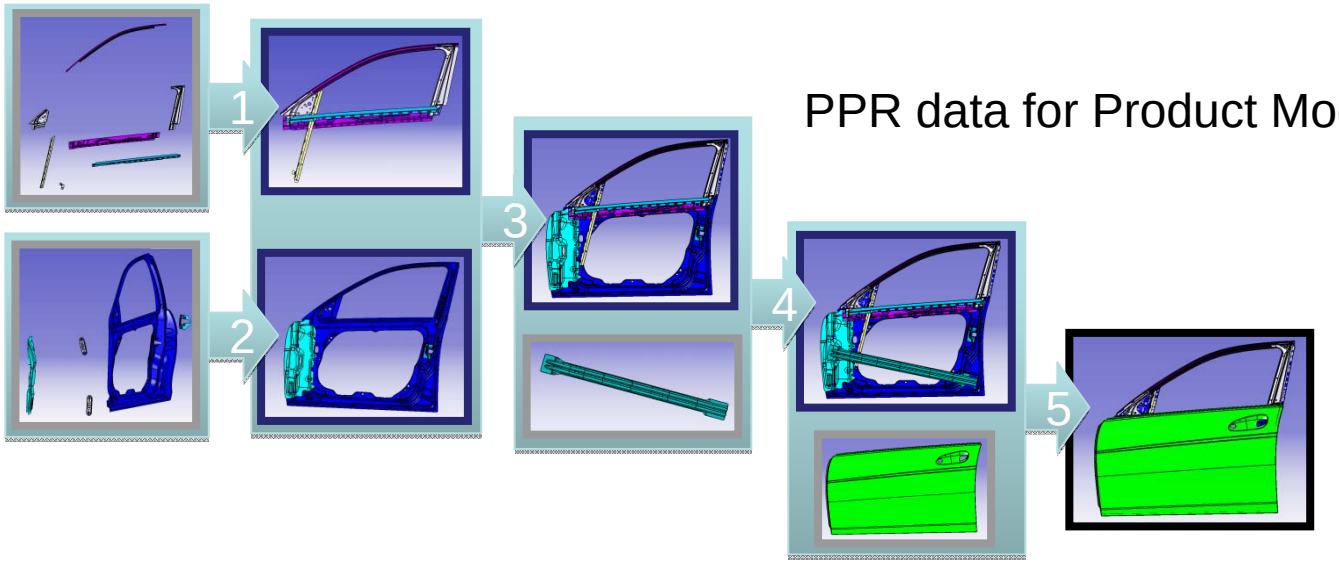
Examples for Production-oriented Validation Framework

In the following, two examples for the use of the Production-oriented Validation Framework are shown

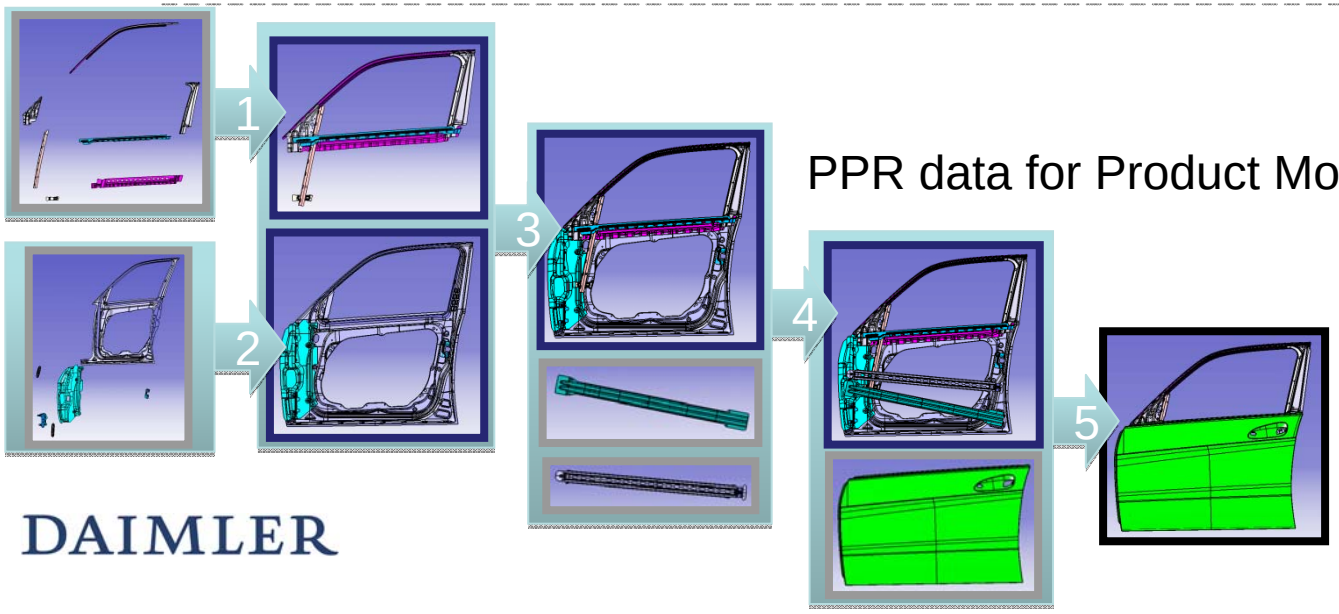
Example 1 Validation of a welding process on multiple cells with a given cycle time. A check, if all processing steps may be carried out within the given cycle time, is carried out.

Example 2 Validation of a new product variant (side door) to be manufactured on an existing line. The framework checks, if the production line is able to handle additional parts and additional processing steps needed to manufacture the product variant.

Definition of Product Process Resource (PPR) data for both examples



PPR data for Product Model A



PPR data for Product Model B

Legend:

3 Responsible production cell

Part

Assembly

Product

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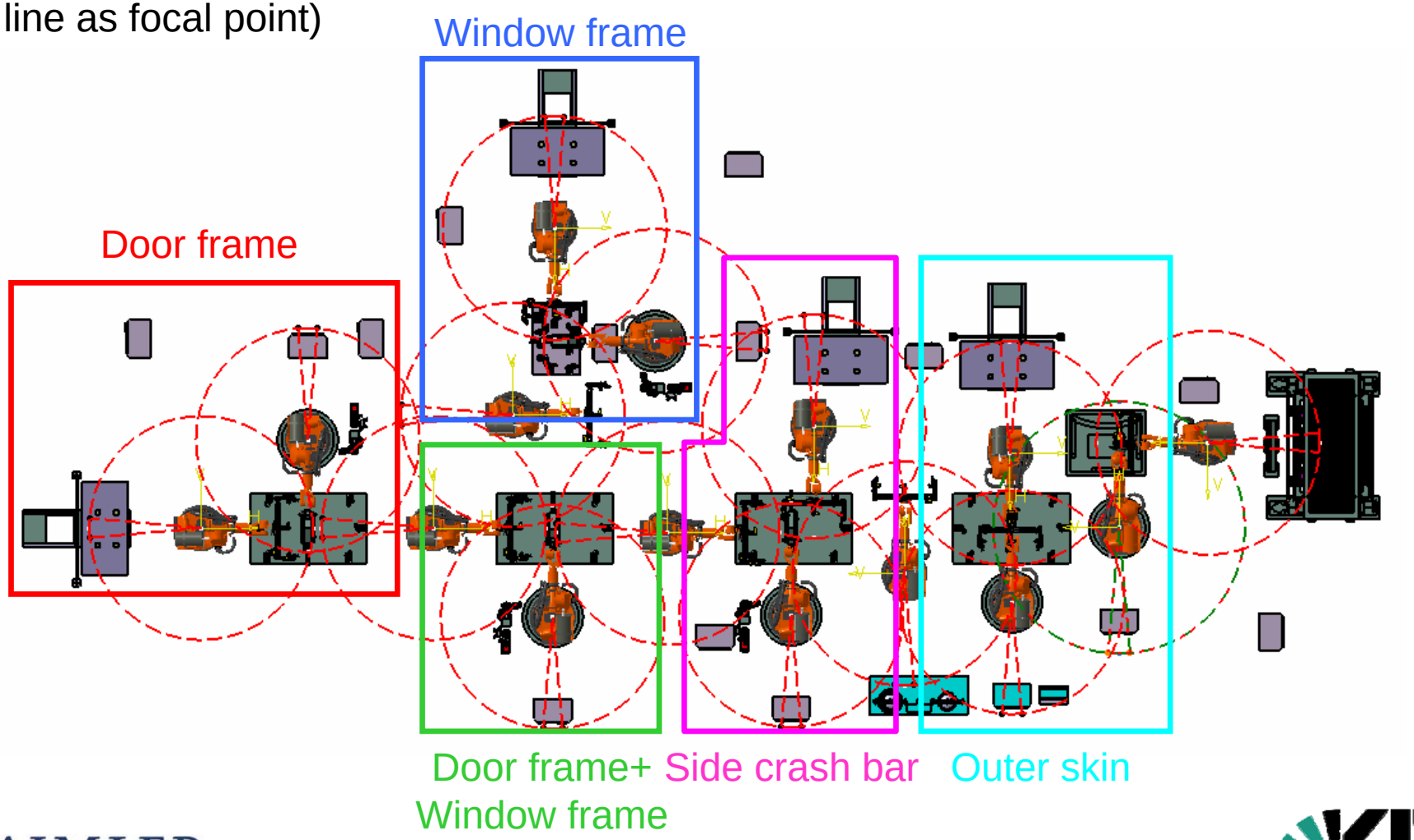
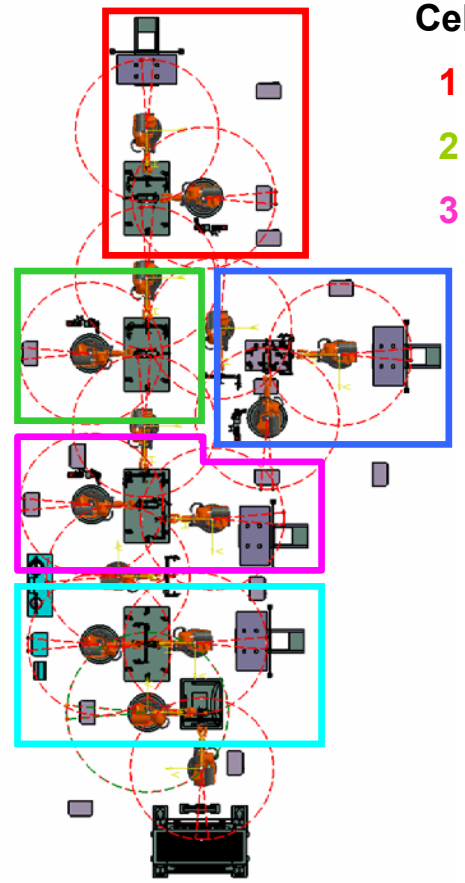
Definition of Product Process Resource (PPR) data for both examples

PPR data shown from production line view (same data as before, but production line as focal point)

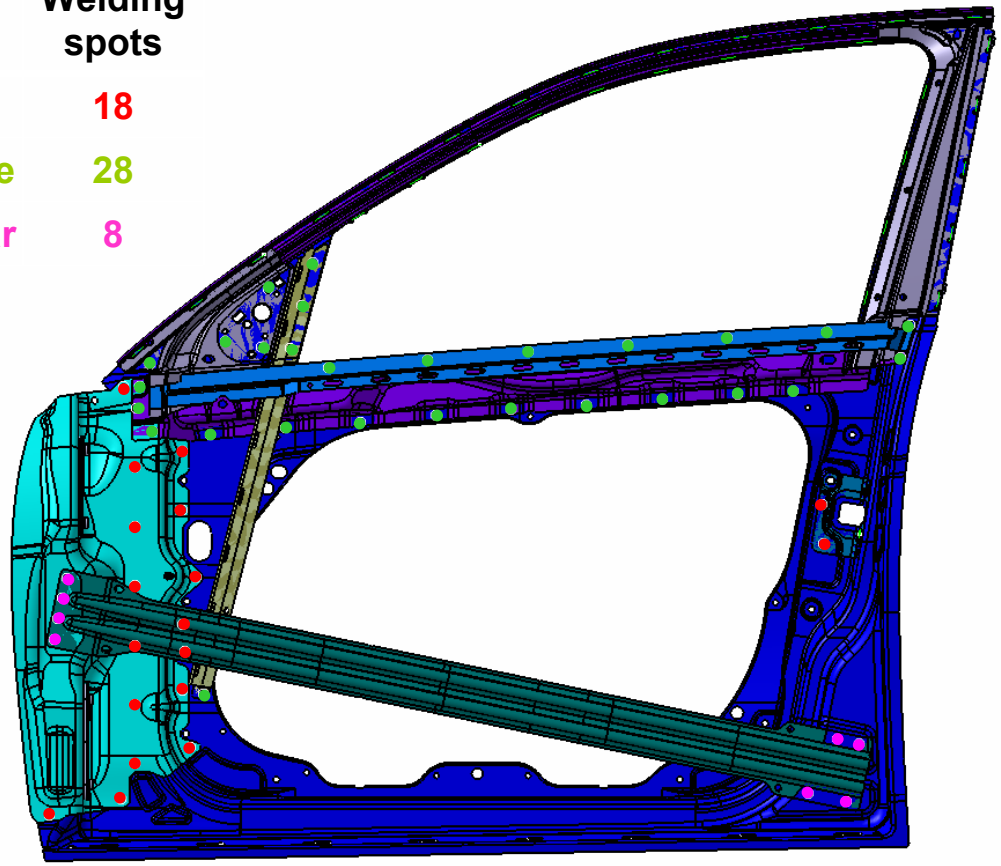


Example 1: Validation of a welding process – Initial Situation

Unbalanced allocation of welding process steps for three different cells
→ **Unbalanced processing times**



Cell	Model part	Welding spots
1	Door frame	18
2	Window frame	28
3	Side crash bar	8



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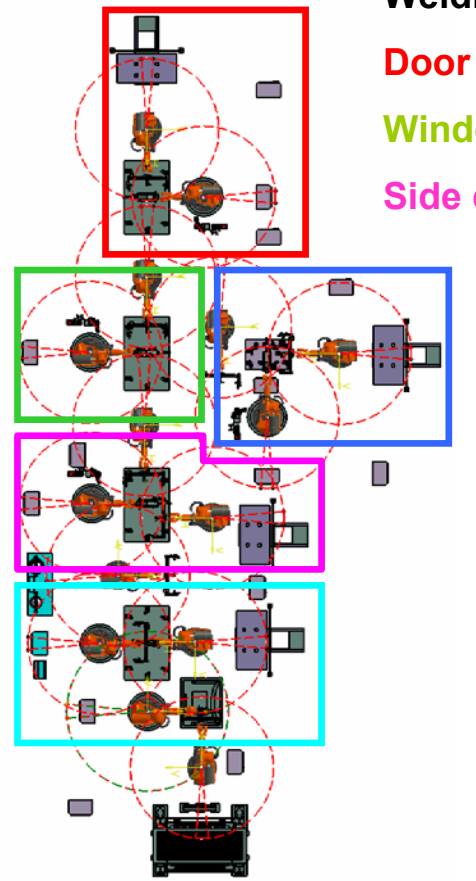
Example 1: Validation of a welding process – Executing Validation Process

Due to unbalanced allocation of welding spots on the three cells, the validation for the second cell (responsible for window frame) fails!



Welding Spots:

Door frame: 18

Window frame: 28

Side crash bar: 8

Validation Constraints:

Cycle time 125 s

Processing time: 125s – 12s (Handling) = 113s

Initial Situation:

Inner Part: 18 => 18 * 6s = 108s

Window frame: 28 => 28 * 6s = 168s

Side Impact Protection: 8 => 8 * 6s = 48s

Solution: move welding spot

Possible solution:

Inner Part: 18 => 18 * 6s = 108s

Window frame: 28 => 18 * 6s = 108s

Side Impact Protection: 8 => 18 * 6s = 108s

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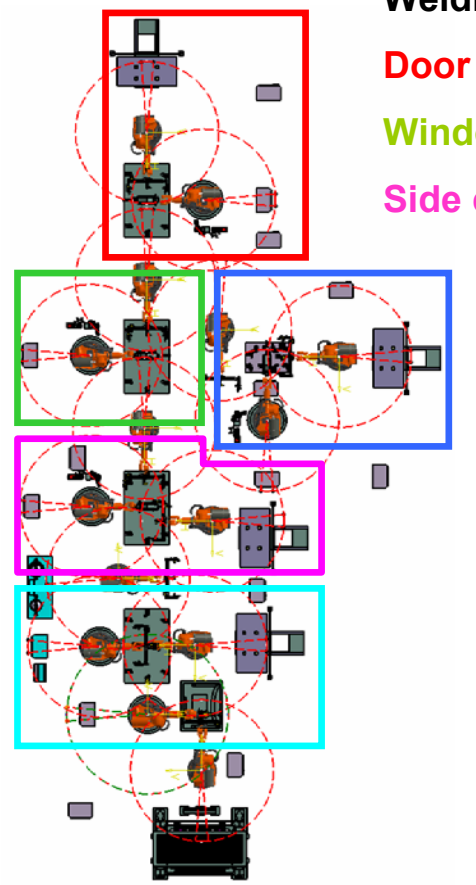
Example 1: Validation of a welding process – Identification of alternative solutions

Engineer identifies possible alternative solution that fixes the validation error.

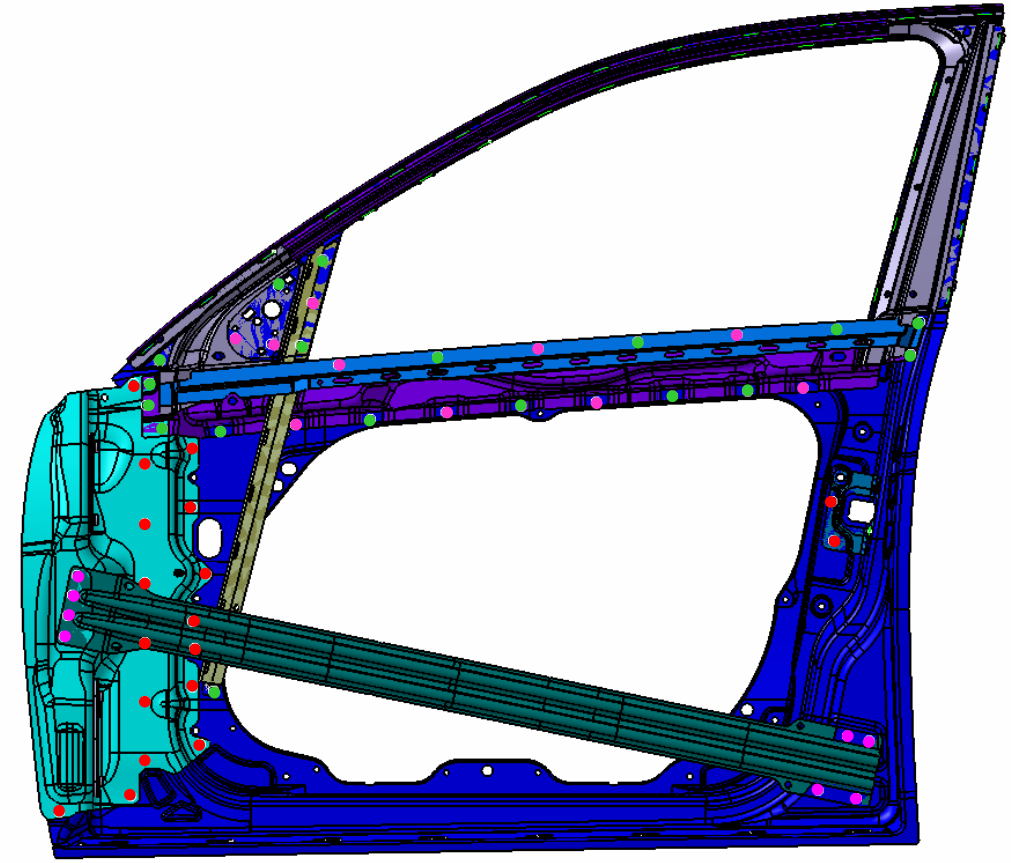


Welding Spots:

Door frame: 18

Window frame: 18

Side crash bar: 18



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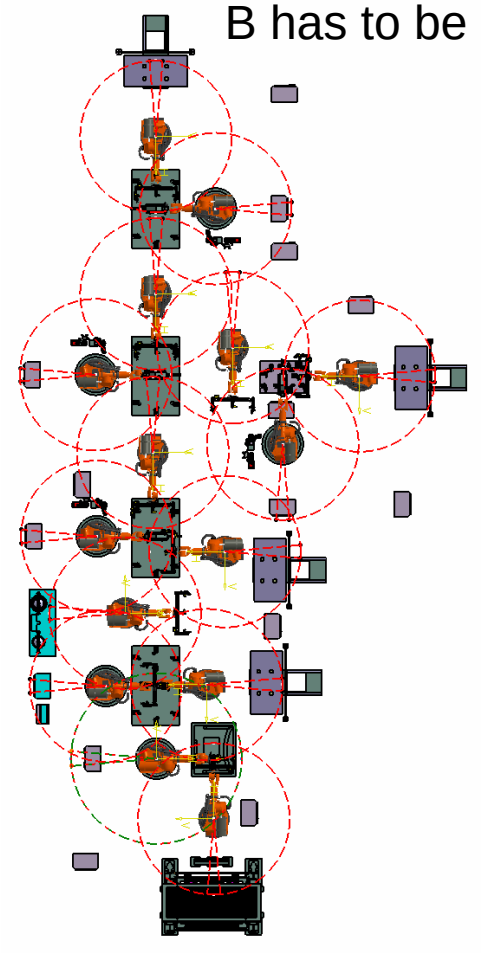
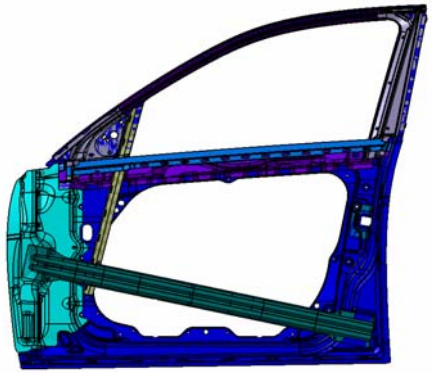
Example 2: Validation of new product variant on existing production line – Initial situation

Door A is manufactured on this production line. What has to be changed if Door B has to be integrated on this production line?

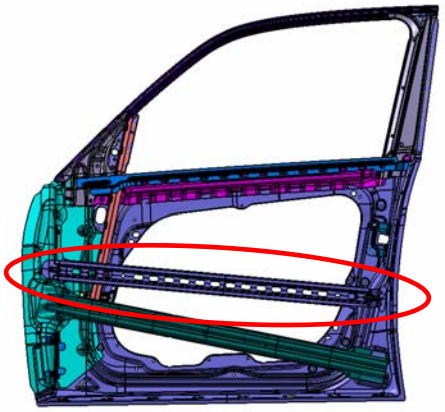


Door A



Door B

Additional part



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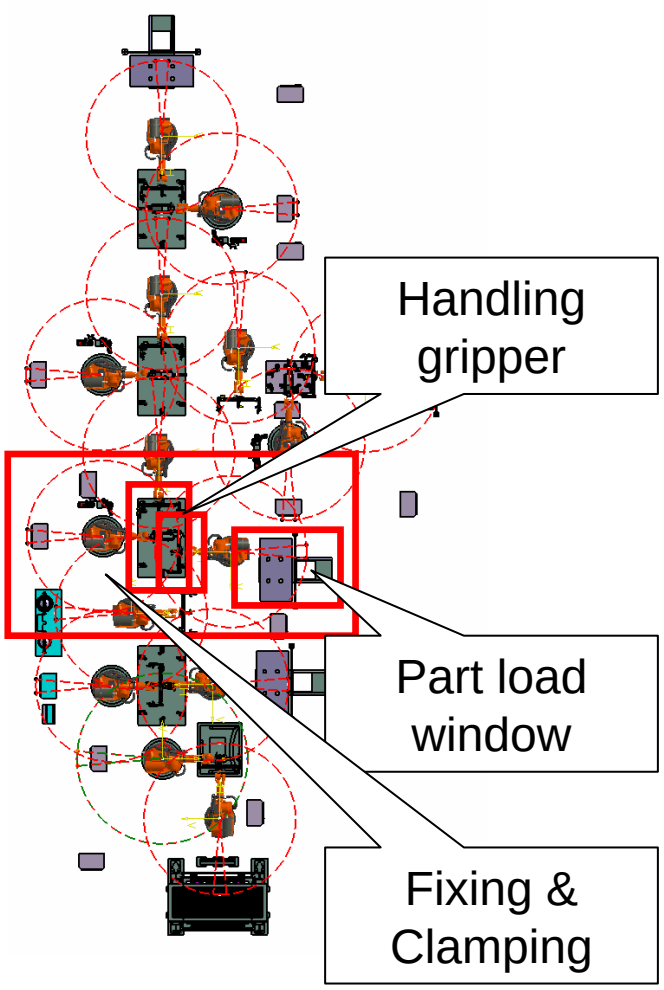
Example 2: Validation of new product variant on existing production line – Execute validation procedure



Validation Constraints:

Handling one side crash bar
Loading 2 sub-assembly/parts
Fixing and Clamping for one particular product geometry
Cycle time 125 s

Need for action

Handling of additional part needs to be verified

Loading of additional part needs to be verified

The equipment related to the product geometry should be checked

→ identify the equipment to be verified

→ External Tool

Cycle time needs to be verified

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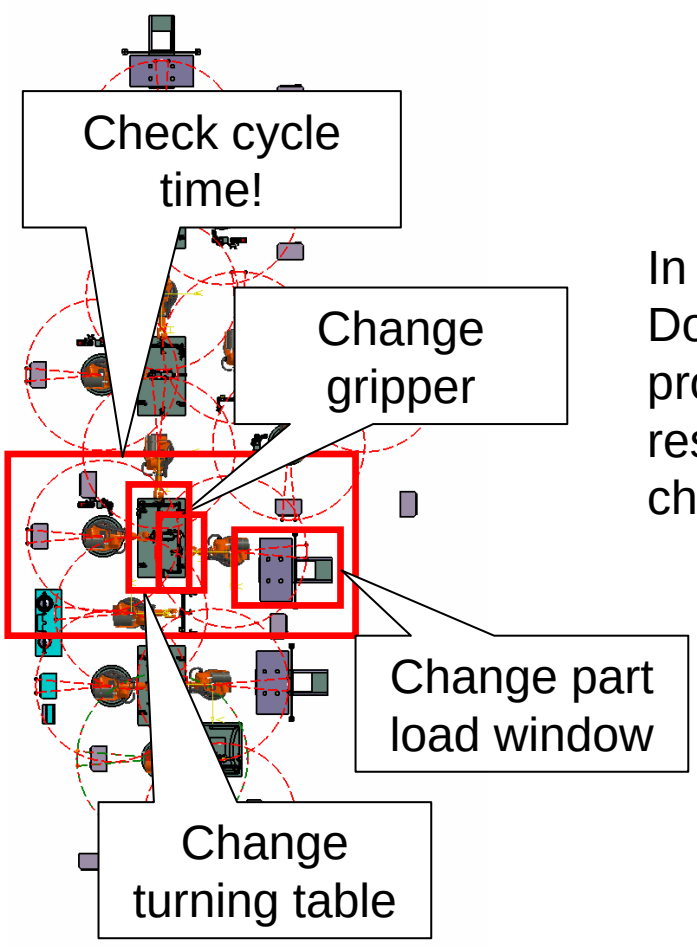
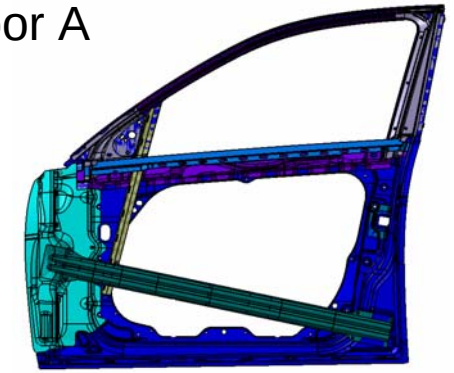
Example 2: Validation of new product variant on existing production line – Identification of solution alternatives

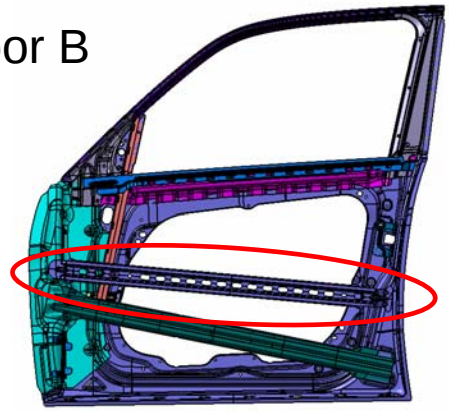


In order to produce the Door B on the existing production line some resources have to be changed!

Door A



Door B



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Thank You