







# Think outside the Box:

Expand Model-based Systems Engineering (MBSE) into Model-based Production Engineering (MBPE) to realize a Lego Manufacturing System

**SIEMENS**



Have you ever heard of Model-based Production Engineering?



Go to [www.menti.com](https://www.menti.com)

Enter the code

1443 9492



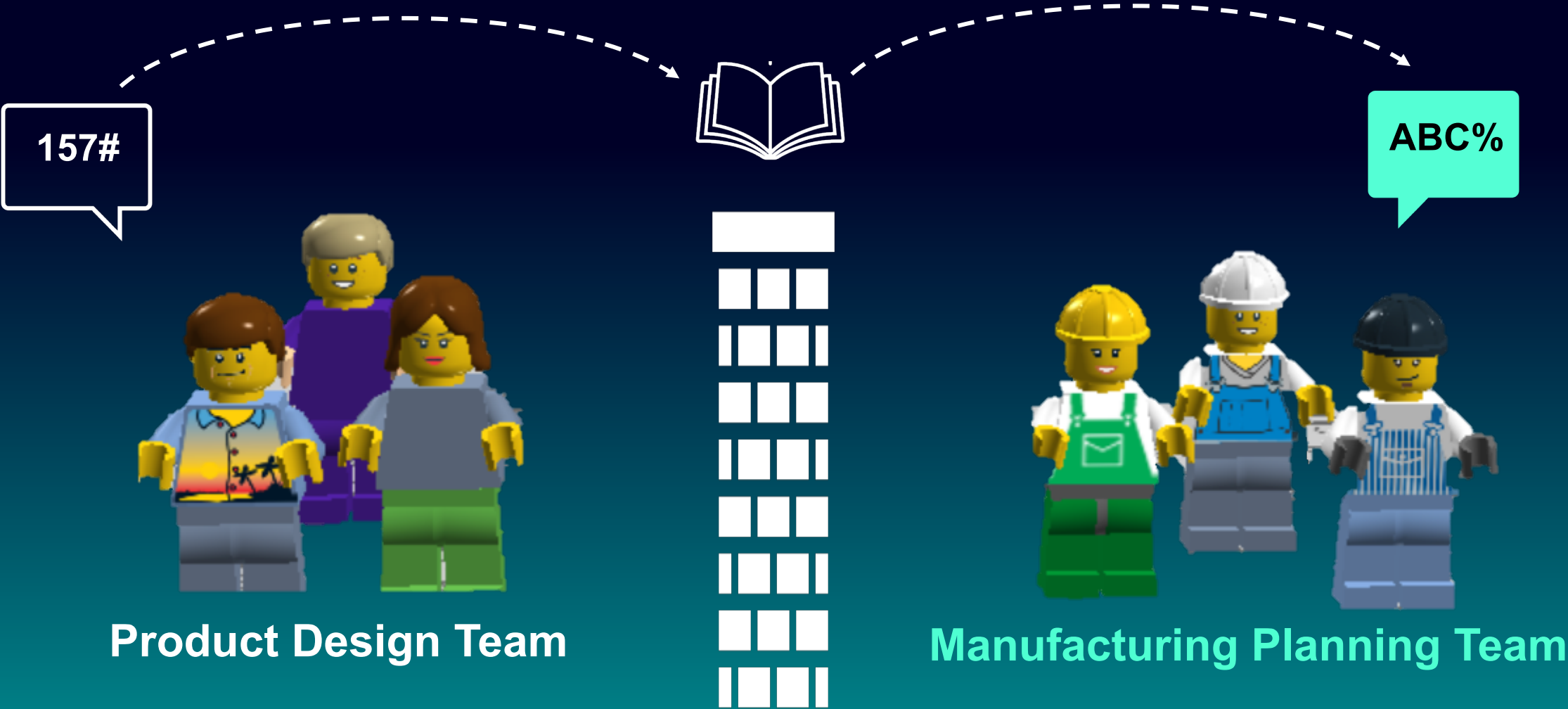


# Amira Head of Factory Planning

Source: LEGO Digital Designer



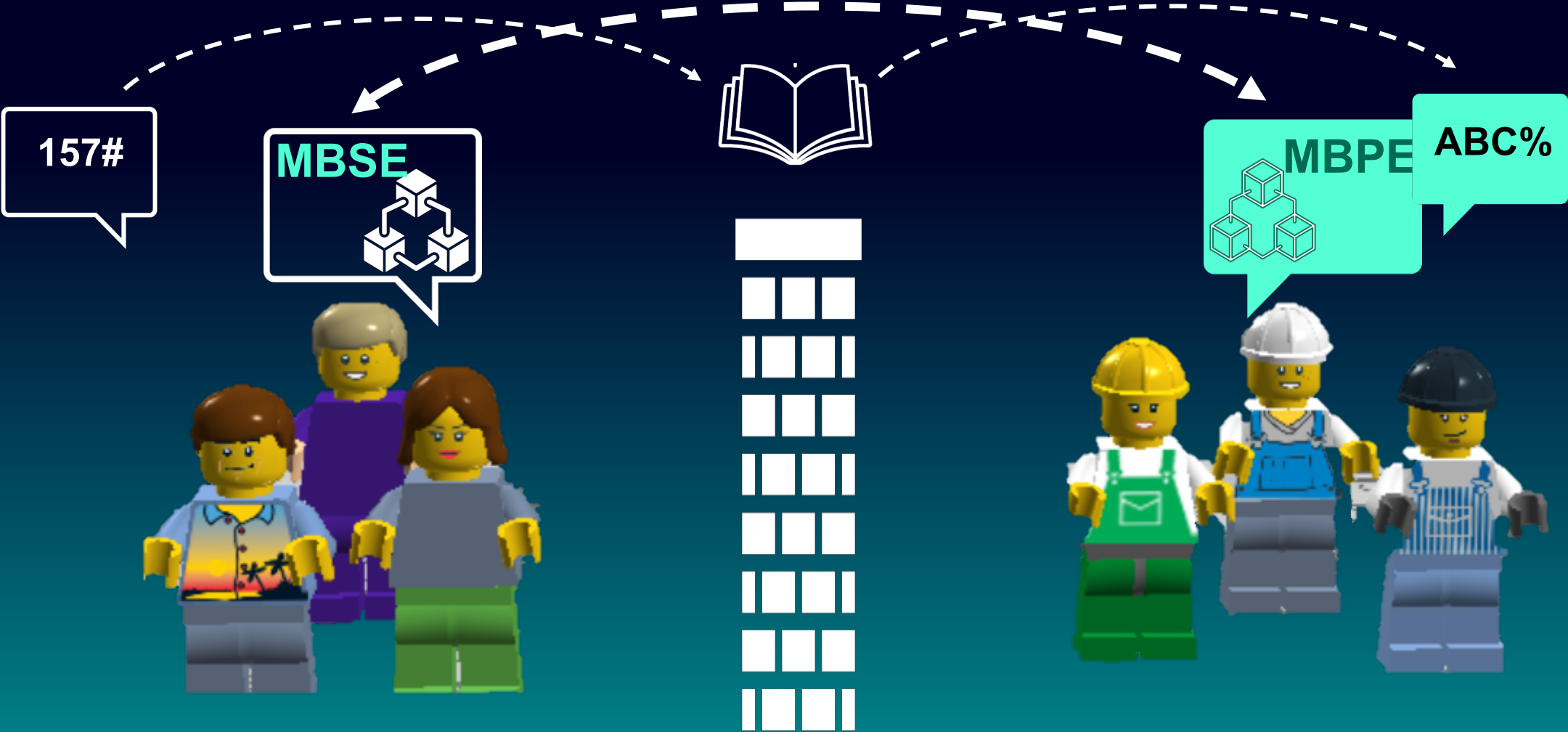
# Mind-Game: Current Status of Amiras team ... ... organized by Classical Collaboration Silos



Source: LEGO Digital Designer



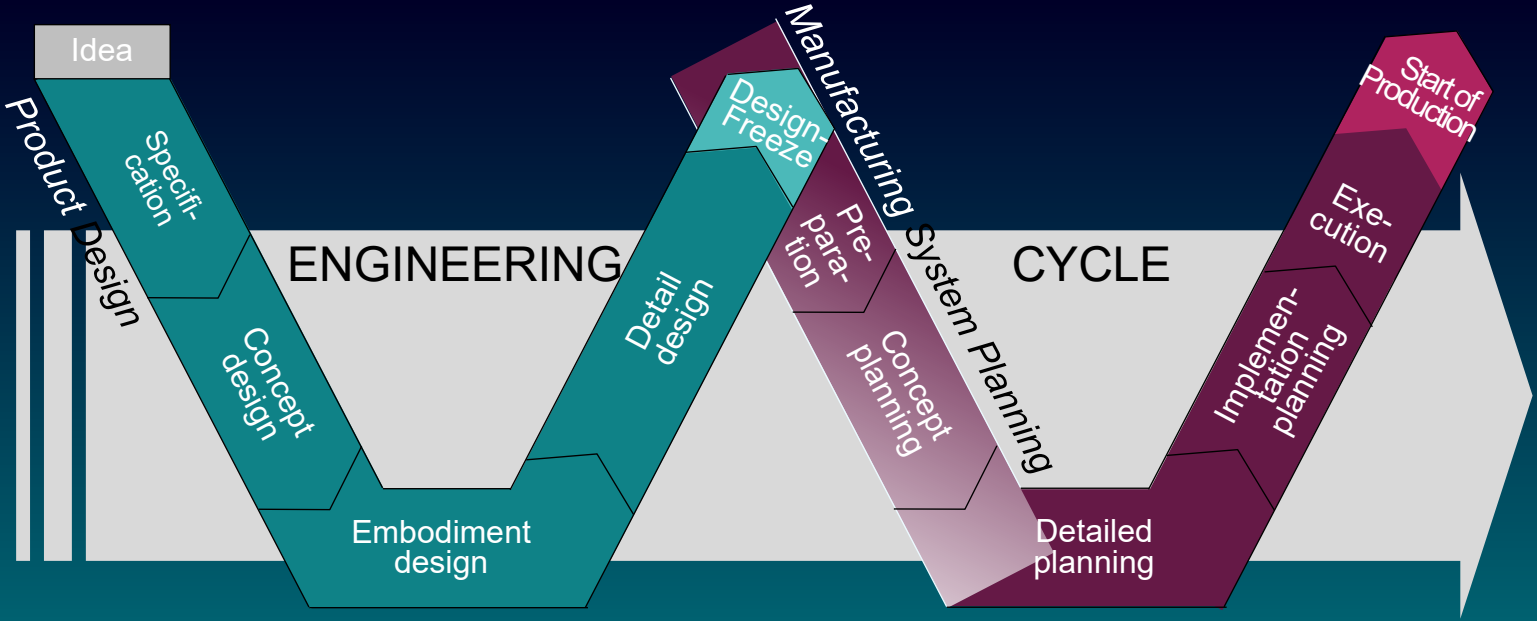
Let's imagine...  
... Amira would have integrated Engineering Teams



Source: LEGO Digital Designer



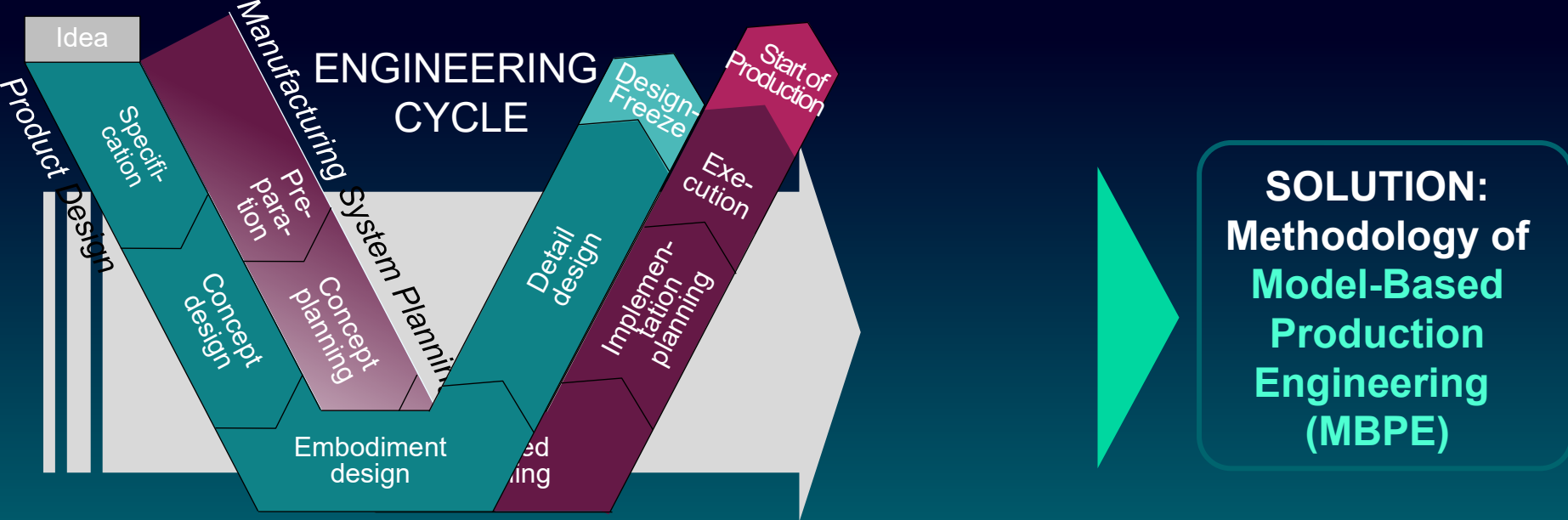
# Why should you think about Manufacturing Engineering in the early phase of engineering? Because product design and manufacturing engineering do not collaborate efficiently!





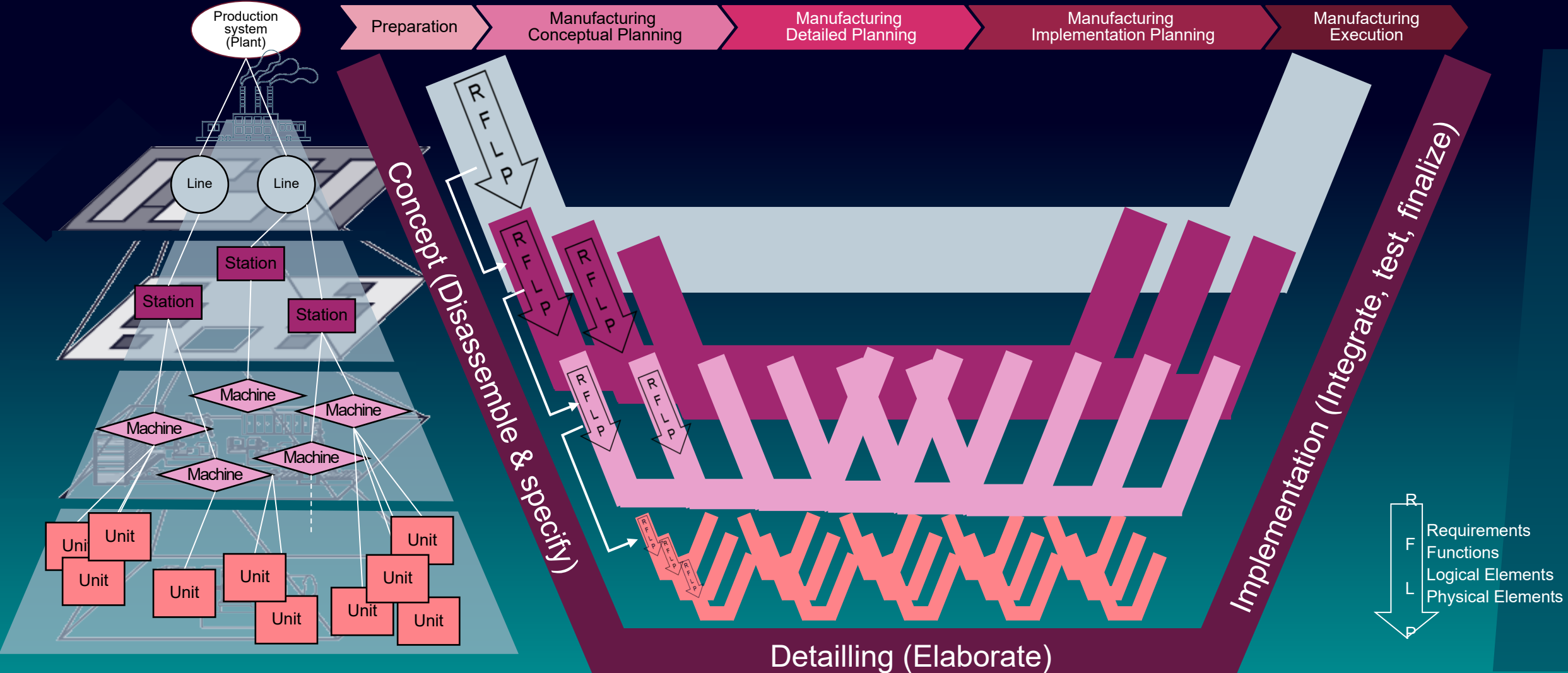
# Traceability through integrated system models during the overall design cycle is the key!

Model-based Production Engineering for better integration back into the engineering



# MBPE means to hierarchically decompose Manufacturing Systems

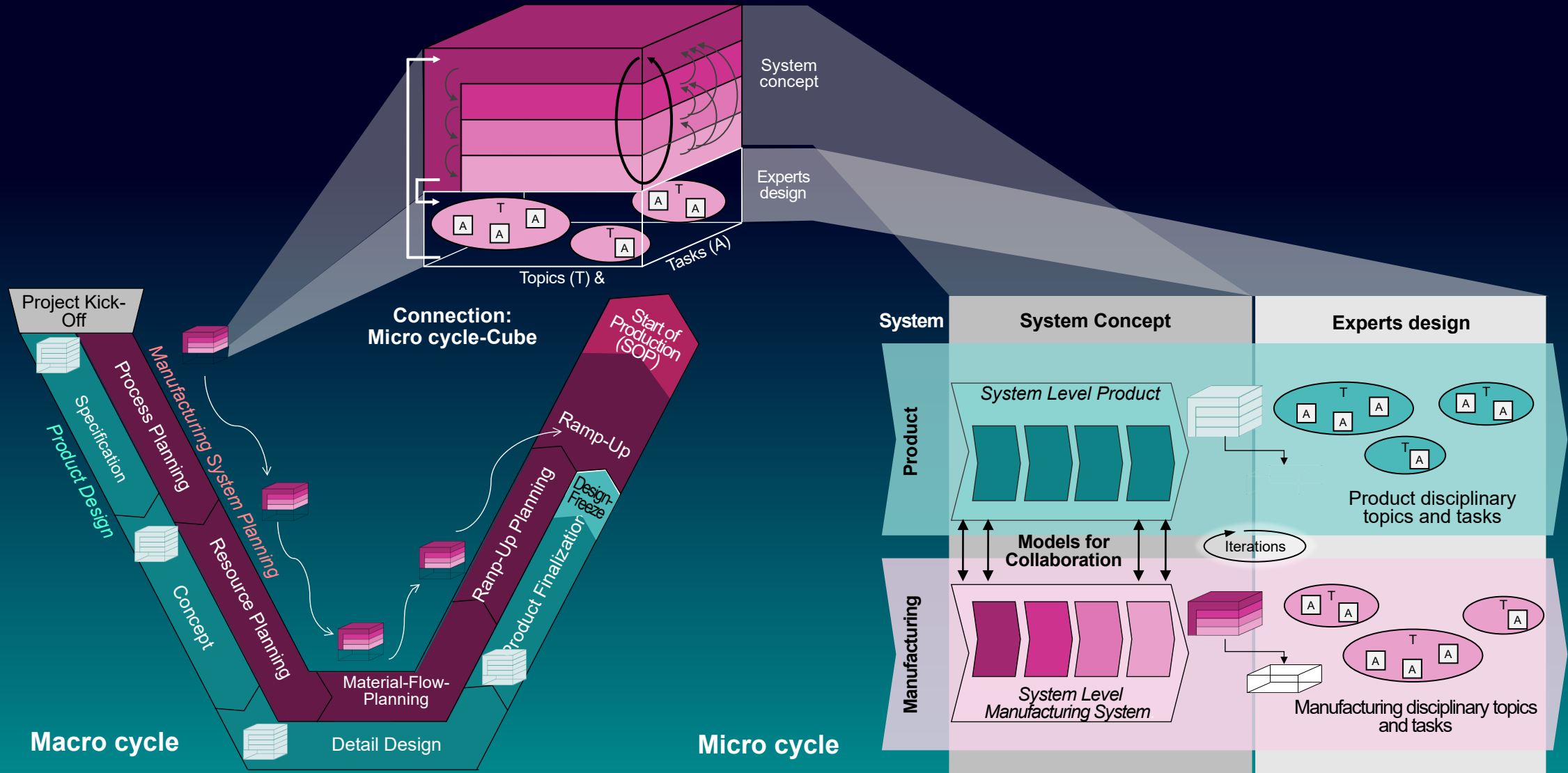
## Handle Complexity and Collaboration aligned with Product Design





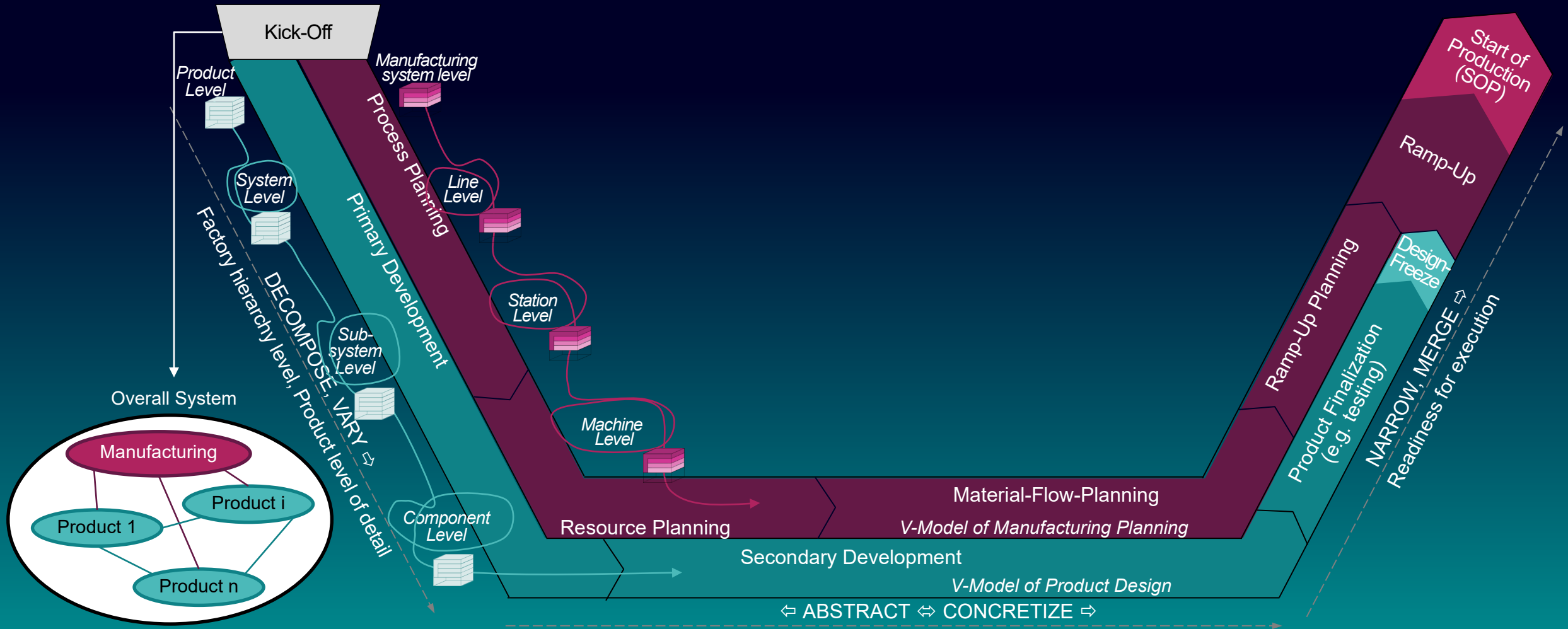
# The 3 parts of MBPE: Process vs. Methodology vs. Modeling

Integrated process model, systematic method for manufacturing concept design & modeling approach



# Part 1: Integrated Process Model for Design and Manufacturing

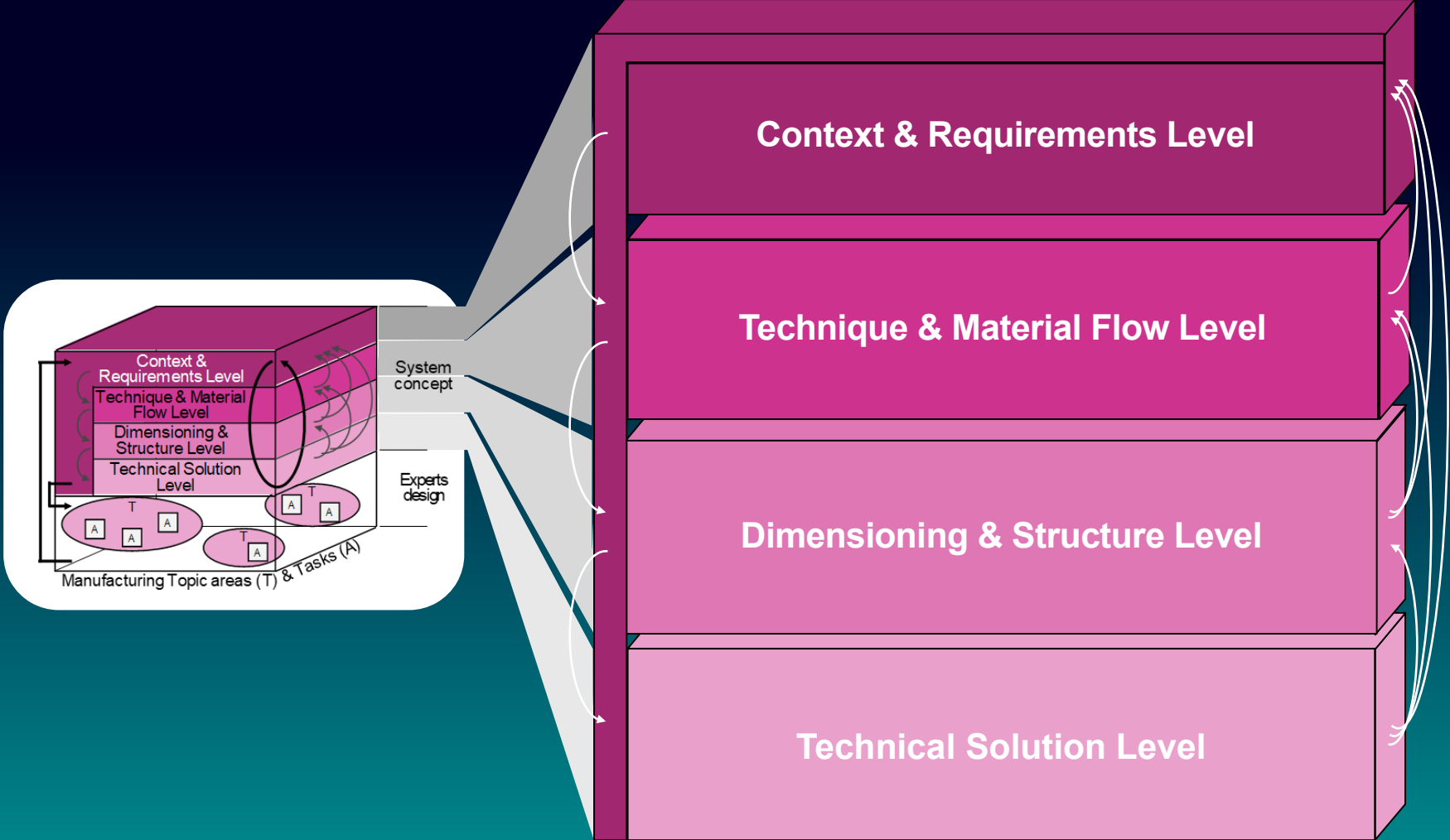
## Control collaboration during the overall Product Engineering Cycle until SOP





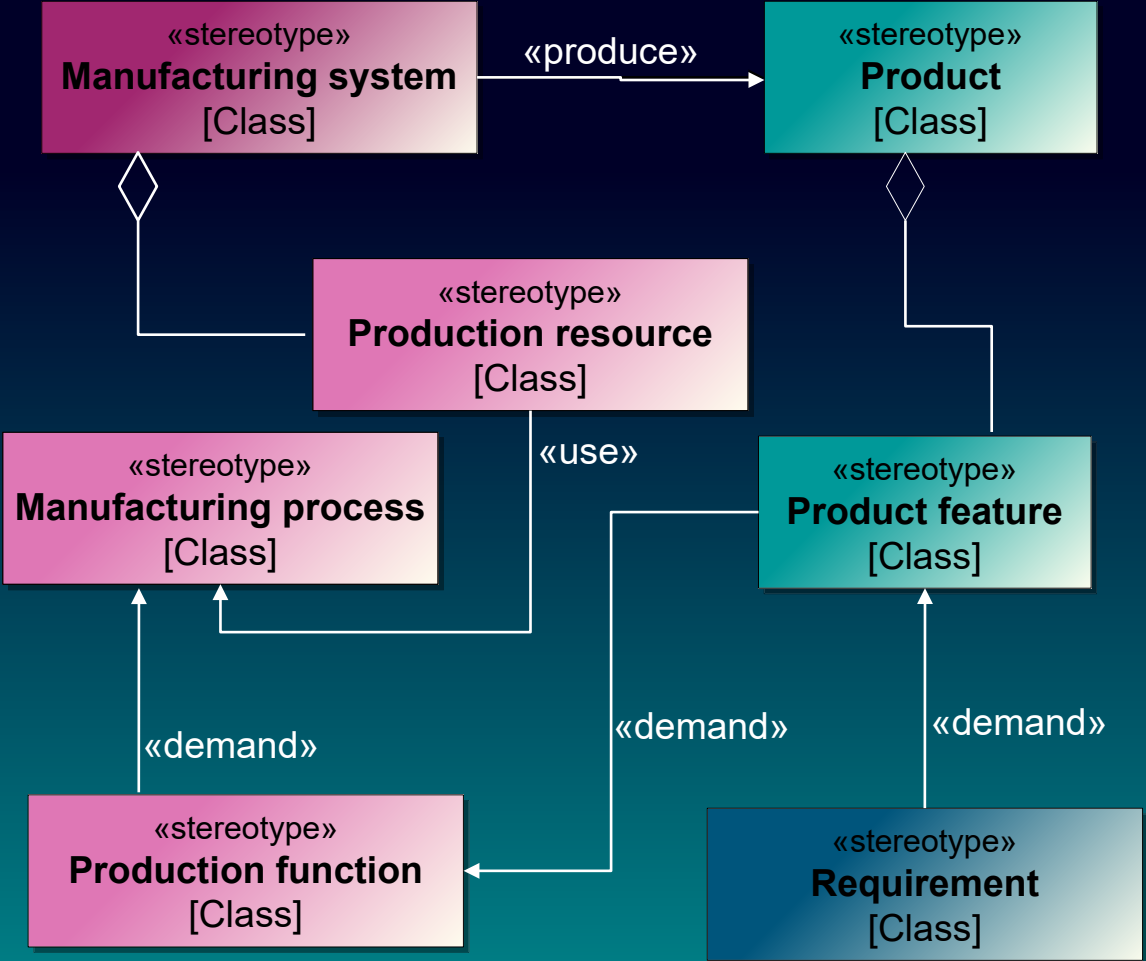
# Part 2: Systematic method for conceptual manufacturing system design

Is defined by its system design levels and a clear methodology



# Part 3: Modeling approach (originally designed for UML2)

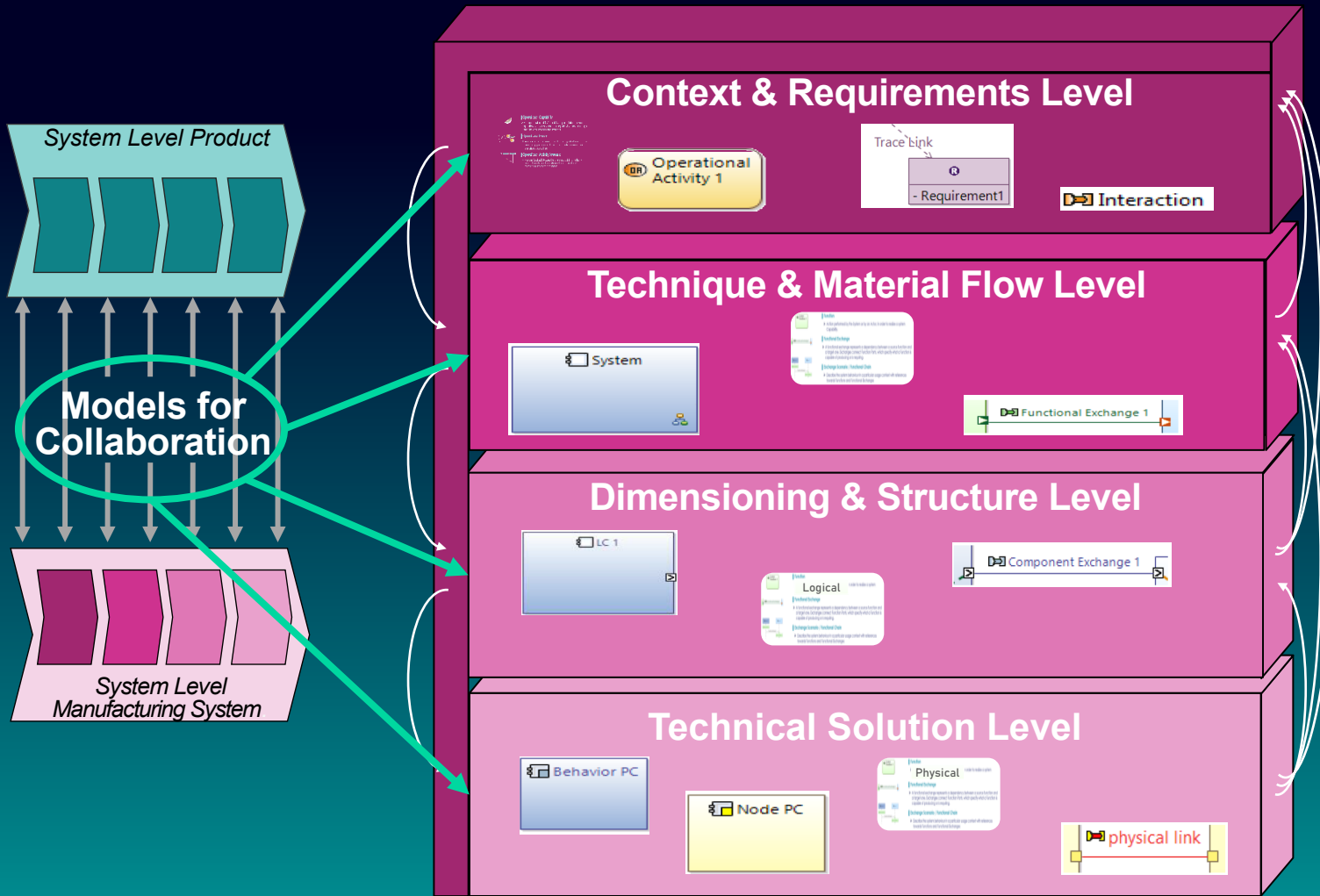
Common design language for design & planning using object-oriented modeling and UML-stereotypes



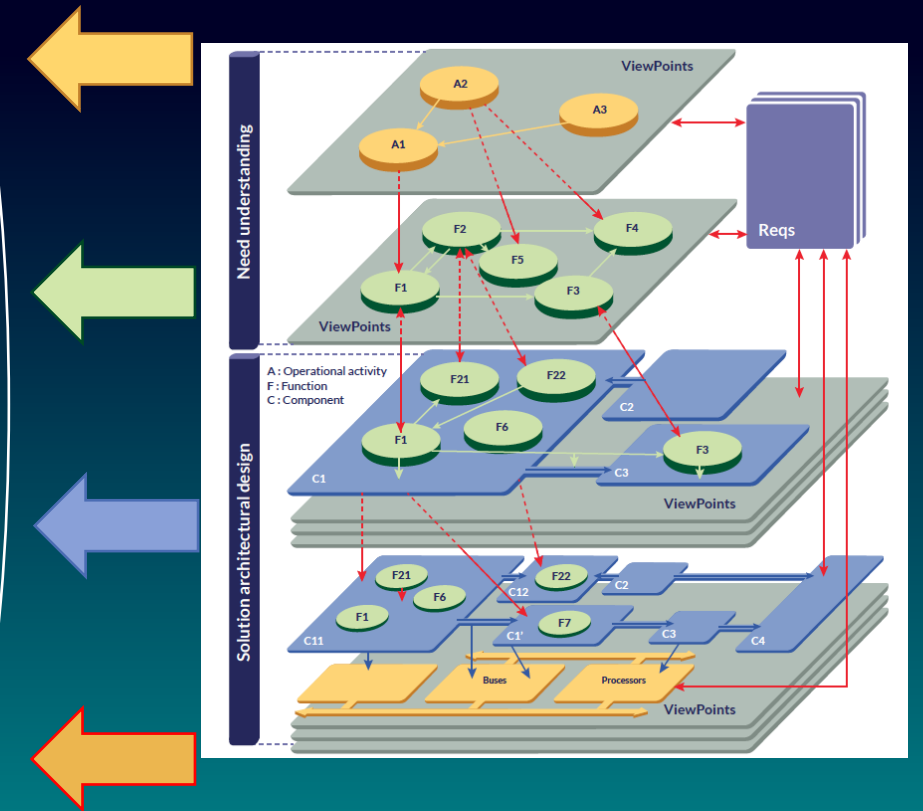
# Part 3: Modeling approach (originally designed for UML2)

Common design language for design & planning adapted for using ARCADIA modeling artefacts

## MBPE Micro Cycle Cube



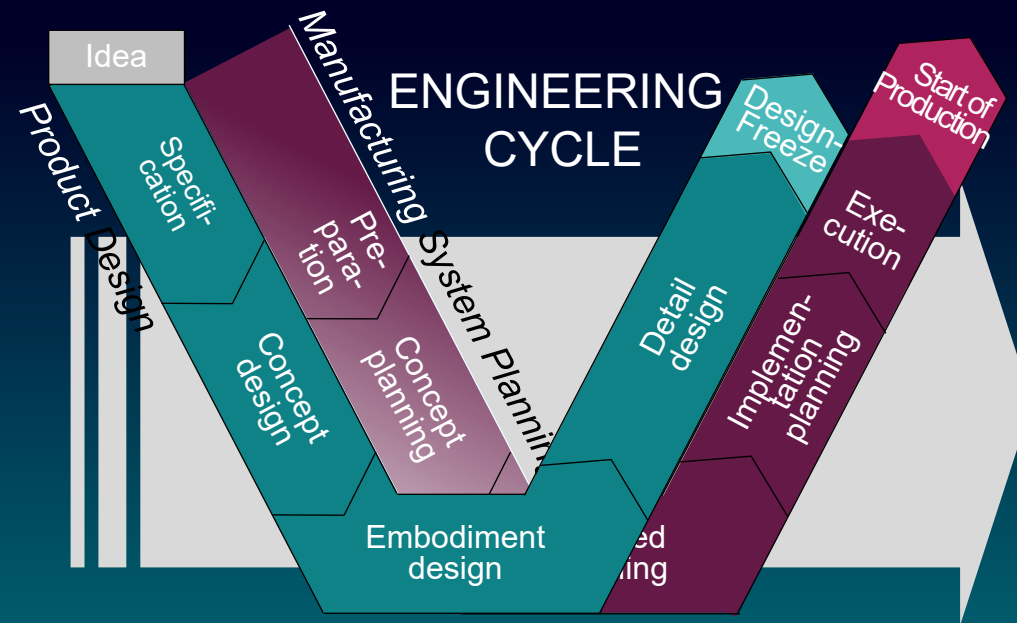
## ARCADIA-Method Framework





# What's behind Model-based Production Engineering?

## MBPE in a nutshell





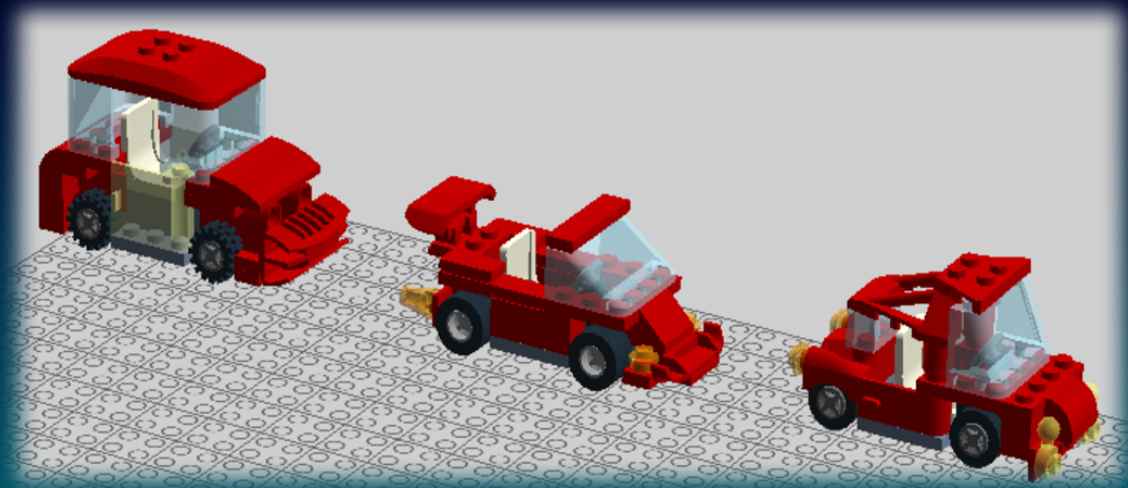
# Amira Head of Factory Planning

Source: LEGO Digital Designer

# UseCase – Develop a Lego toy car product family and automated manufacturing line

Variability of min. 3 & corresponding manufacturing line using a minimum of Lego Mindstorms Bricks

## Product Design



Source: LEGO Digital Designer

## Manufacturing Planning

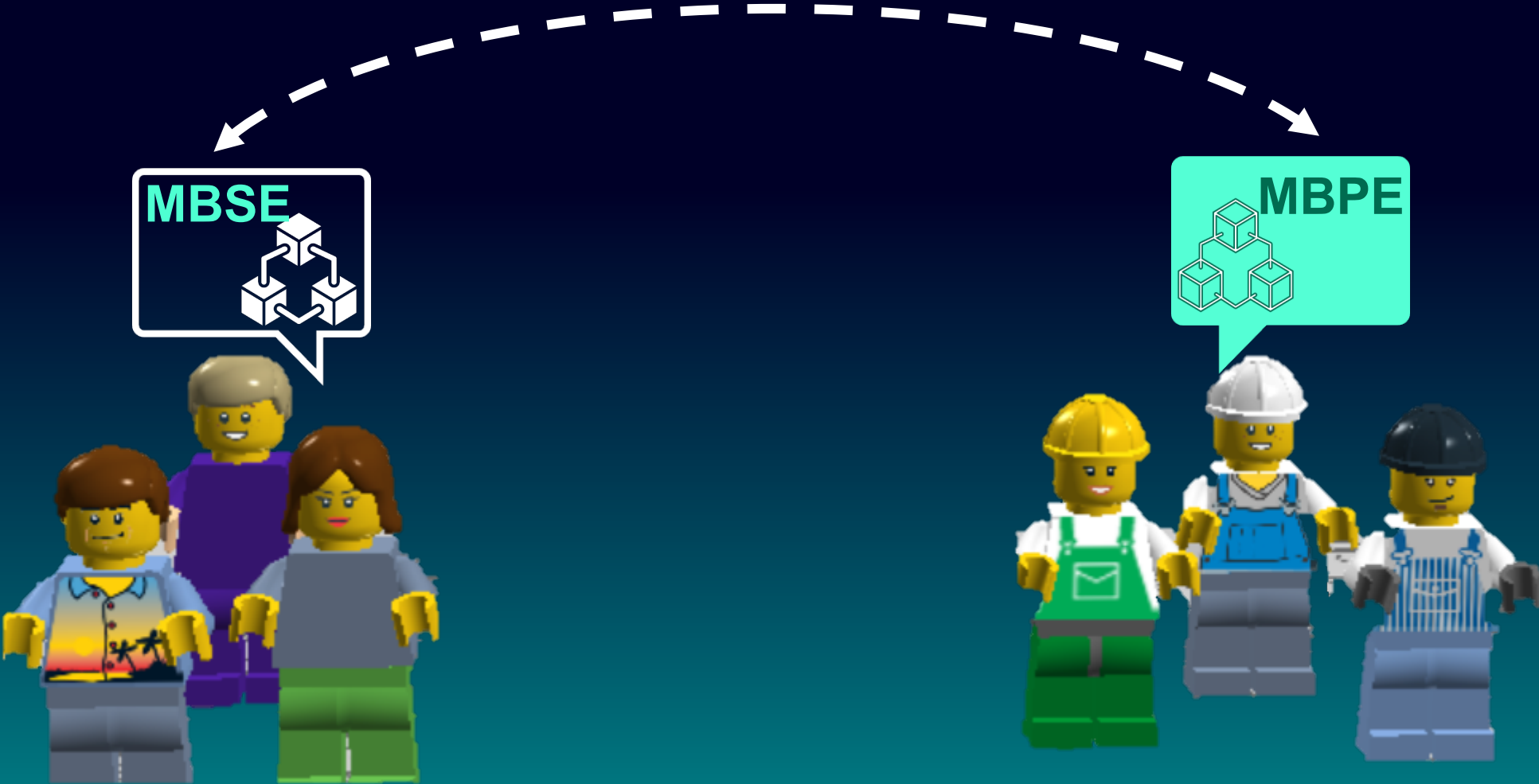


Source: <https://robotics.benedettelli.com/lego-car-factory/>



# MBPE connects Engineering & Manufacturing Teams

ONE Team approach



Source: LEGO Digital Designer

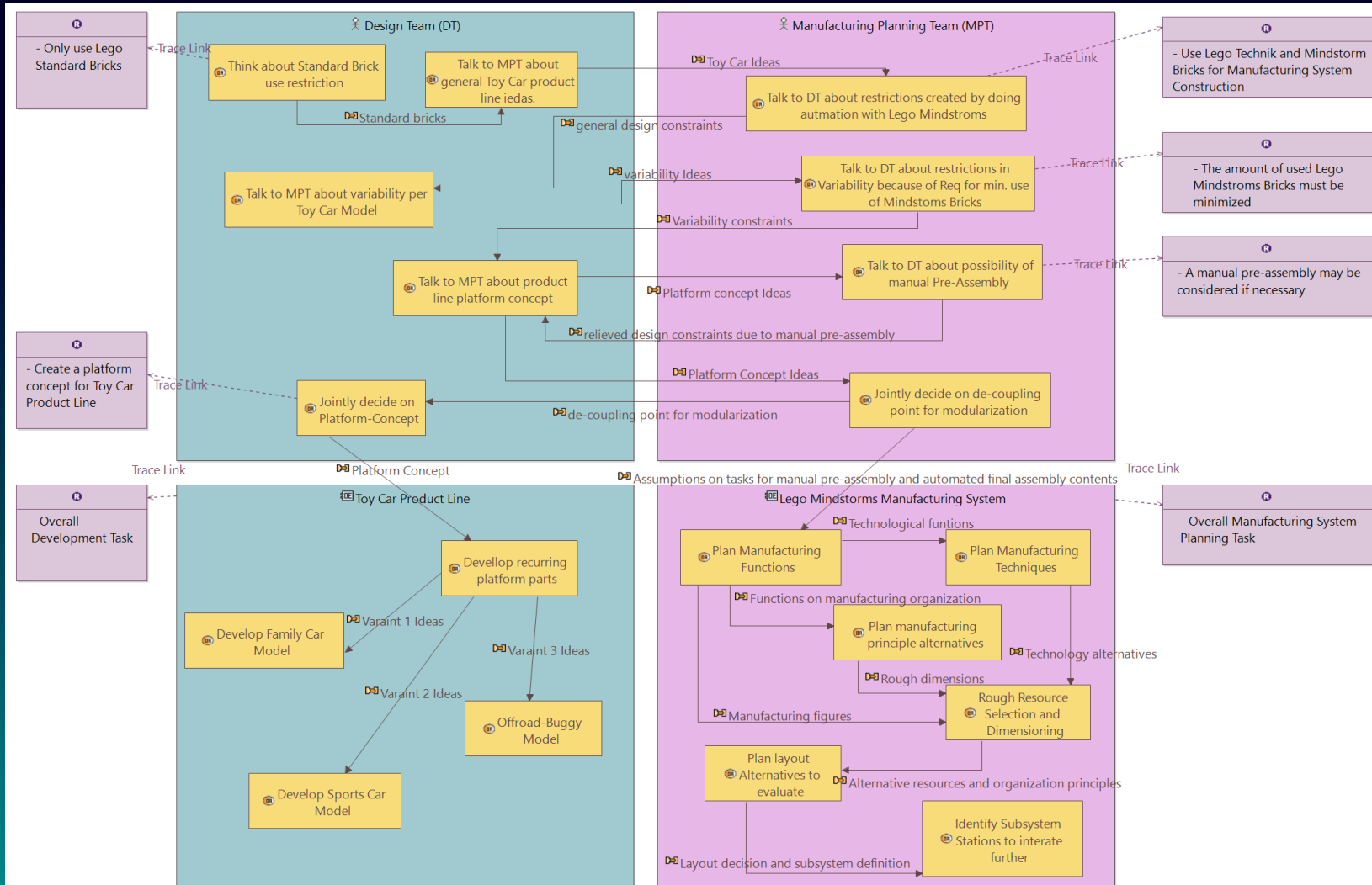
# Operational Analysis

## Manufacturing Purpose on Context and Requirements Level

The LEGO toy car family shall ...



Source: LEGO Digital Designer



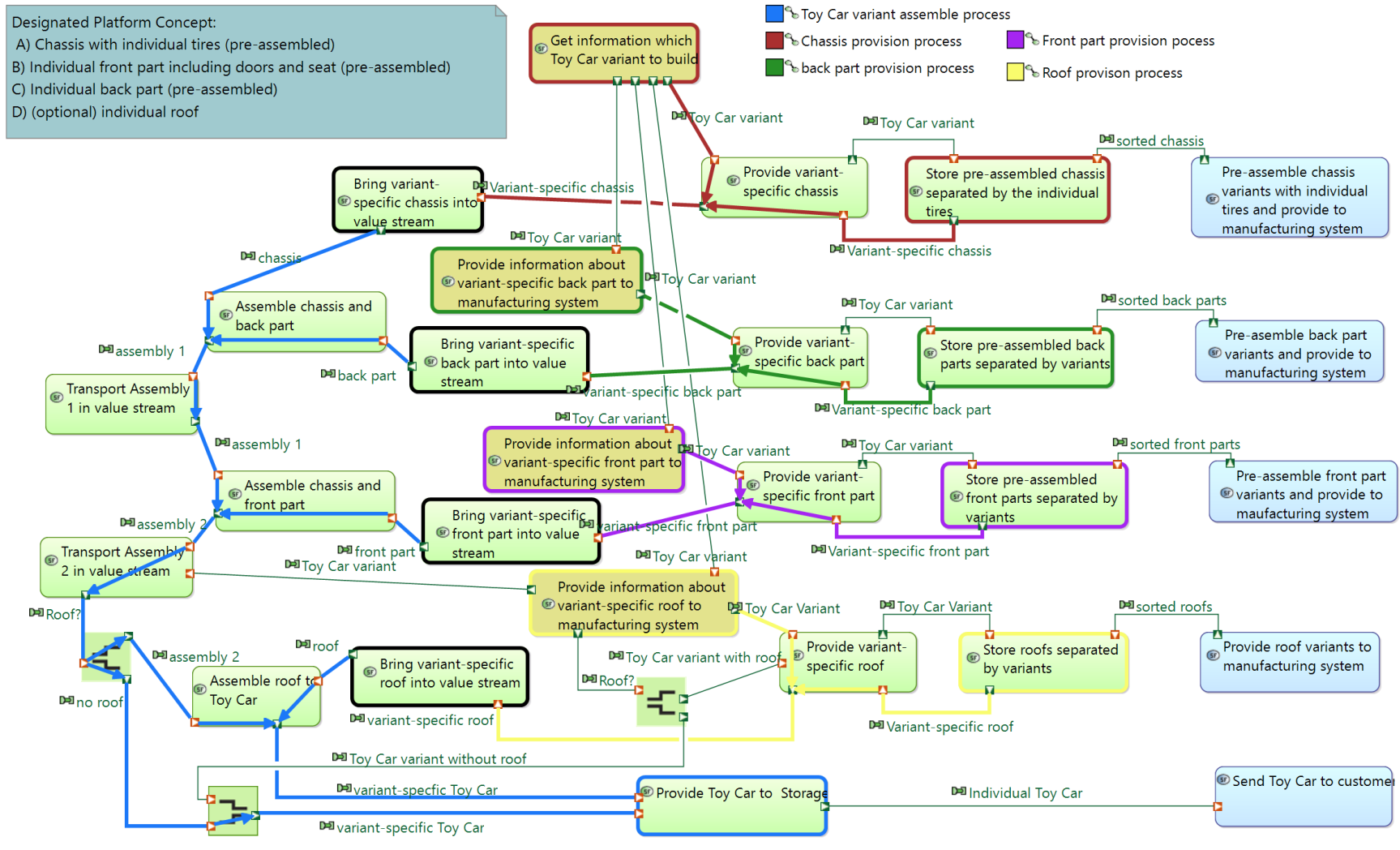
The LEGO manufacturing line shall ...



Source: LEGO Digital Designer

# System Analysis

## Manufacturing Techniques and Material Flows Level



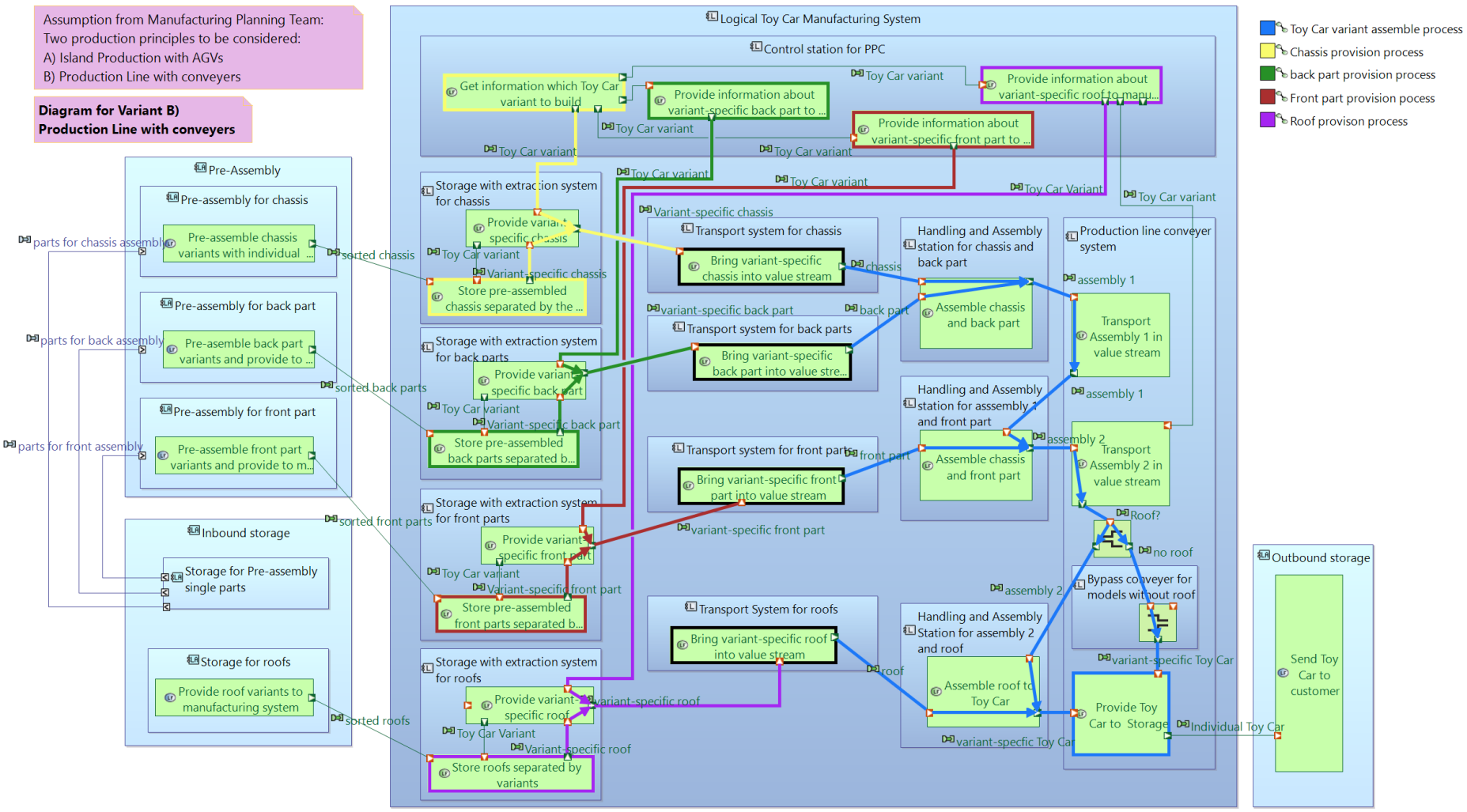
Source: LEGO Digital Designer





# Logical Architecture

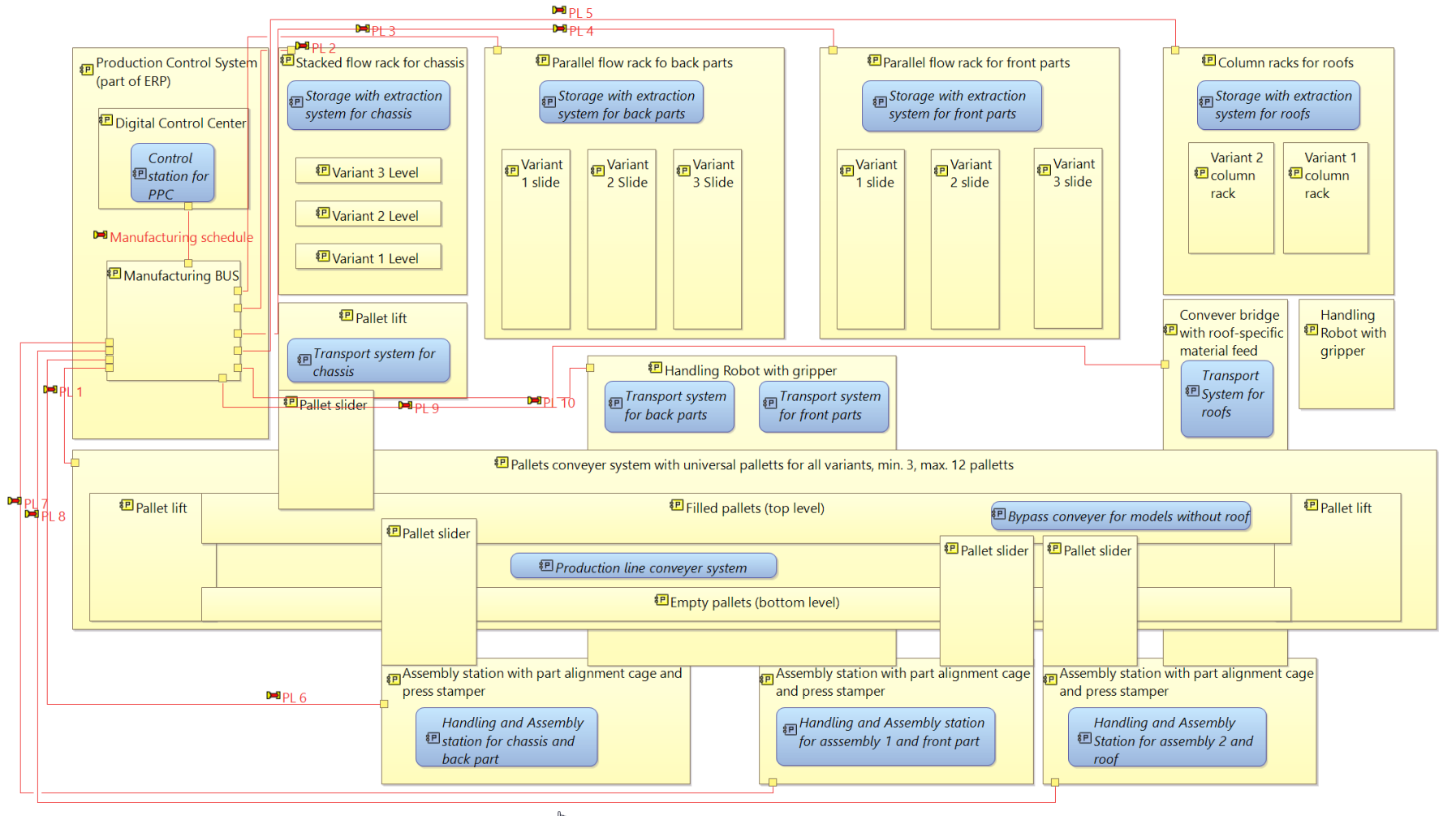
## Manufacturing Dimensioning and Structure Level



Source: LEGO Digital Designer

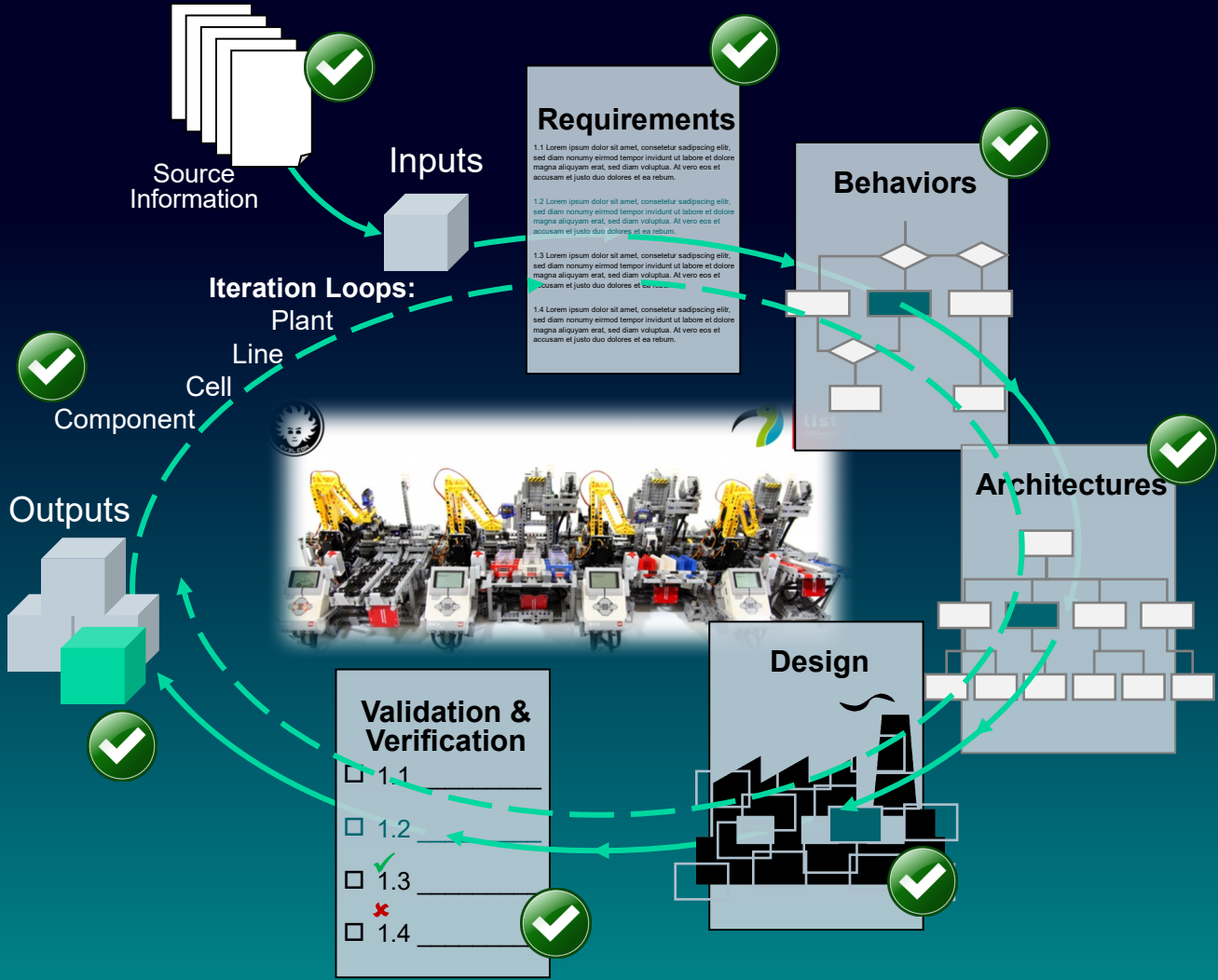
# Physical Architecture

## Manufacturing Resources and Layout on Technical Solution Level



Source: <https://robotics.benedettelli.com/lego-car-factory/>

# MBPE results in the Availability of consistent Information For Design, Manufacturing Engineering, Simulation and Virtual Commissioning



# Q&A

## Want to learn more about MBPE?

Read paper:  
*CIRP Annals 2019 – Conceptual manufacturing system design based on early product information*

The screenshot shows the title page of the paper "Conceptual manufacturing system design based on early product information" by Chantal Sinnwell, Nicole Krenkel, and Jan C. Aurich. It includes the Elsevier logo, the journal name "CIRP Annals - Manufacturing Technology", and the journal homepage URL. The abstract and keywords are also visible.

**Keywords:**  
Conceptual design  
Manufacturing system  
Integrated planning

**1. Motivation**

Product design and manufacturing systems planning traditionally have been processed as subsequent phases in the product engineering cycle. Today, they are still considered as two separate engineering competences which are characterized by highly interdependent tasks but a clear division of labor. Many specific procedural models, methodologies and tools exist for product design and manufacturing systems planning, which generally consider their specific tasks only. This division is also reflected by several approaches for product modeling [1] or manufacturing systems modeling [2]. Current product design methodologies are described in Ref. [3] and [4], the management of manufacturing systems planning in Ref. [5]. Only a few methodologies offer the possibility to do both, most notably axiomatic design [6] and systems engineering [7].

While integration between product detail design and manufacturing systems planning has made significant progress, the early phase of the engineering cycle, in which information is still assumption-based and uncertain, still lacks methods and tools for integration. Interdependencies between the tasks are not addressed using a clear methodology and collaboration and decision-making still need to be improved. In the early phase, product design and manufacturing systems planning consider each other only implicitly. If at all. Existing integration approaches for product detail design and manufacturing systems planning are concurrent engineering [8], co-ordination between product and process definitions [9], digital factory [10] or the 2-cycle model of product engineering [11]. Furthermore, some high-level strategic approaches exist, which tackle similar issues, e.g. collaborative engineering [12], life-cycle engineering [13], or co-evolution of products, processes and production systems [14].

Yet, all integration approaches still have two major shortcomings. First, none of them include the very early phases from the beginning of the engineering cycle. They can only be applied after the conceptual design of products is completed. Therefore, information from early product design phases is not used sufficiently and decision interdependencies are not fully understood [15]. As early product information is neglected, no systematic method for an integrated conceptual design of products and manufacturing systems in the early phase based on this information exists. Second, the collaboration between engineers from product design and manufacturing systems planning is not supported by the use of a common design language. This results in miscommunication due to differing technical languages as well as complicated collaboration based solely on verbal or textual exchange [16]. Particularly in the early phases, a common design language could allow for the systematic illustration of ideas and alternative models of the conceptual system design. Such information has not been systematically recorded before and has consequently not been available for collaboration in existing integration approaches.

The systematic documentation provides the potential to reveal path dependencies of decisions in early phases. Furthermore, using a formal modeling language as common design language enables the support of early phases by IT. Following this approach, digital models of information from early phases also improve the integration between product detail design and manufacturing systems planning in later phases of the engineering cycle.

In conclusion, a new integration approach is needed, which fulfills three main requirements: (1) reach full engineering cycle coverage, starting from the early phases, to integrate product design and manufacturing systems planning, taking into account task interdependencies; (2) provide a new method for manufacturing systems planning; a systematic approach for the conceptual design of manufacturing systems based on early product information that considers the maturity of available information; (3) provide a common design language for collaboration in early phases.

Have a look into PhD-Thesis:  
*Methode zur Produktionssystemkonzipierung auf Basis früherer Produktinformationen – Ein Beitrag zur Integration von Produktionssystemplanung und Produktentwicklung unter Einsatz des MBSE*

The cover of the PhD thesis features the FBK logo (Lehrstuhl für Fertigungstechnik und Betriebsorganisation) and the author's name, Chantal Fiona Desirée Sinnwell. The title and subtitle are prominently displayed. At the bottom, it mentions 'Produktionstechnische Berichte aus dem FBK Band 02/2020' and the publisher 'Technische Universität Kaiserslautern'.

**Produktionstechnische Berichte aus dem FBK  
Band 02/2020**  
Herausgeber: Prof.-Dr. Ing. Jan C. Aurich

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KAISERSLAUTERN

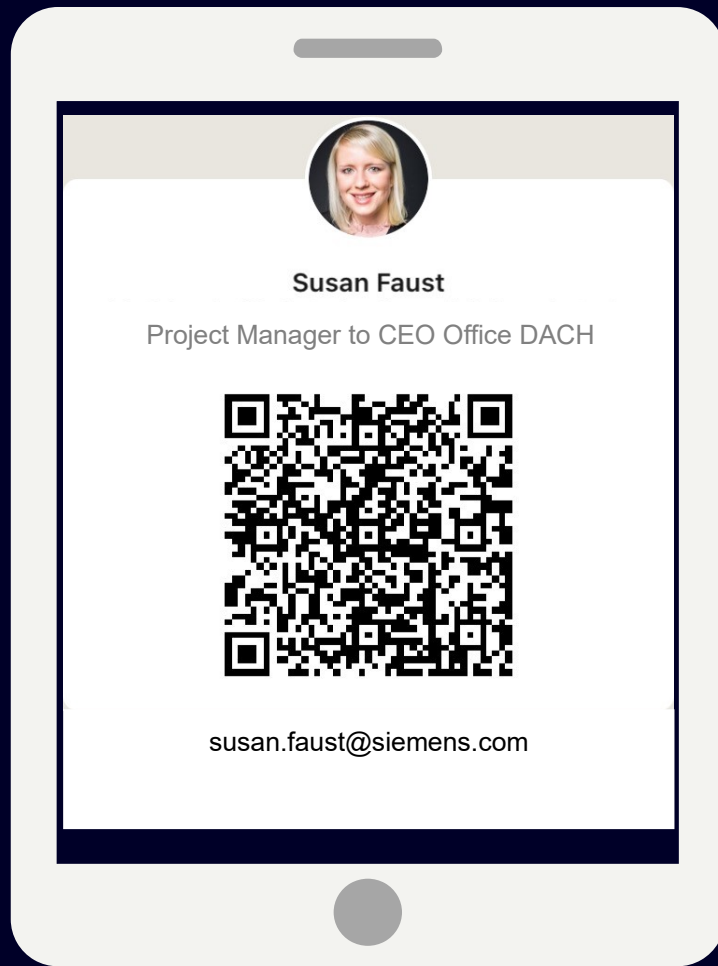




# Amira Head of Factory Planning


- ✓ NO more silos based on integrated MBSE & MBPE approach
- ✓ Aligned language between teams based on ARCADIA
- ✓ Faster processes thanks to interdisciplinary digital twin

Source: LEGO Digital Designer

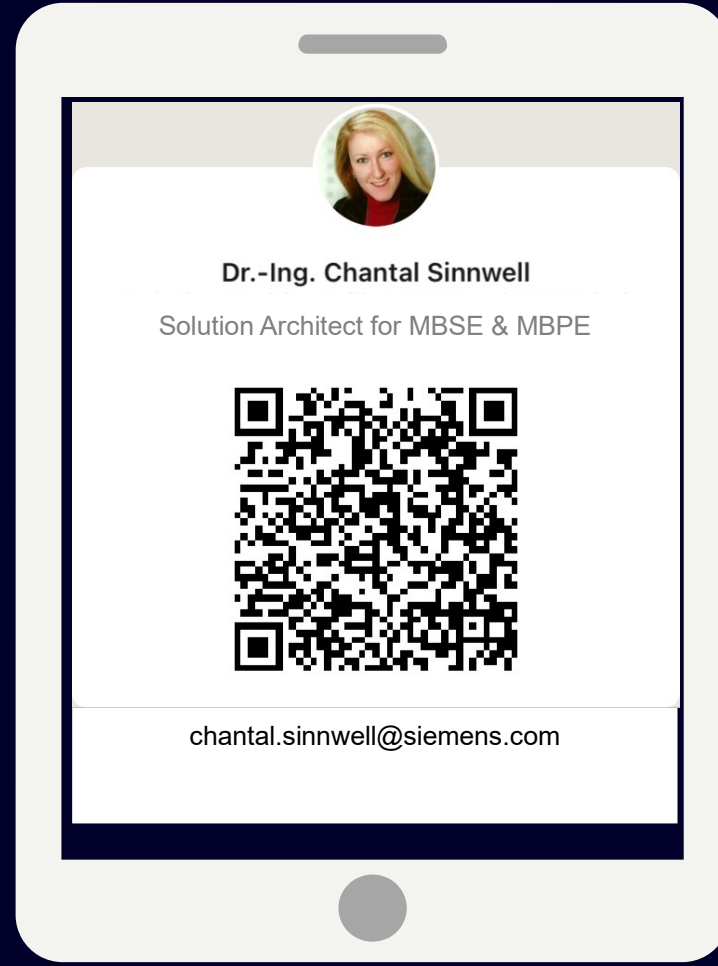


A white smartphone mockup displaying a contact card for Susan Faust. The card features a circular profile picture of a woman with blonde hair. Below the photo, the name "Susan Faust" is written in bold, followed by her title "Project Manager to CEO Office DACH". A large QR code is centered on the card. At the bottom, the email address "susan.faust@siemens.com" is displayed.

**Susan Faust**  
Project Manager to CEO Office DACH




susan.faust@siemens.com



A white smartphone mockup displaying a contact card for Dr.-Ing. Chantal Sinnwell. The card features a circular profile picture of a woman with blonde hair. Below the photo, the name "Dr.-Ing. Chantal Sinnwell" is written in bold, followed by her title "Solution Architect for MBSE & MBPE". A large QR code is centered on the card. At the bottom, the email address "chantal.sinnwell@siemens.com" is displayed.

**Dr.-Ing. Chantal Sinnwell**  
Solution Architect for MBSE & MBPE



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