Product assembly and effective manual workplace design

Smart Factory Assembly: Unlock the potential of your assembly process

What is assembly, assembly process, assembly system?

The product structure, components, subassemblies and product.

Assembly tasks, operations.

What is product (definition)?

What is product structure, the function of product structure?

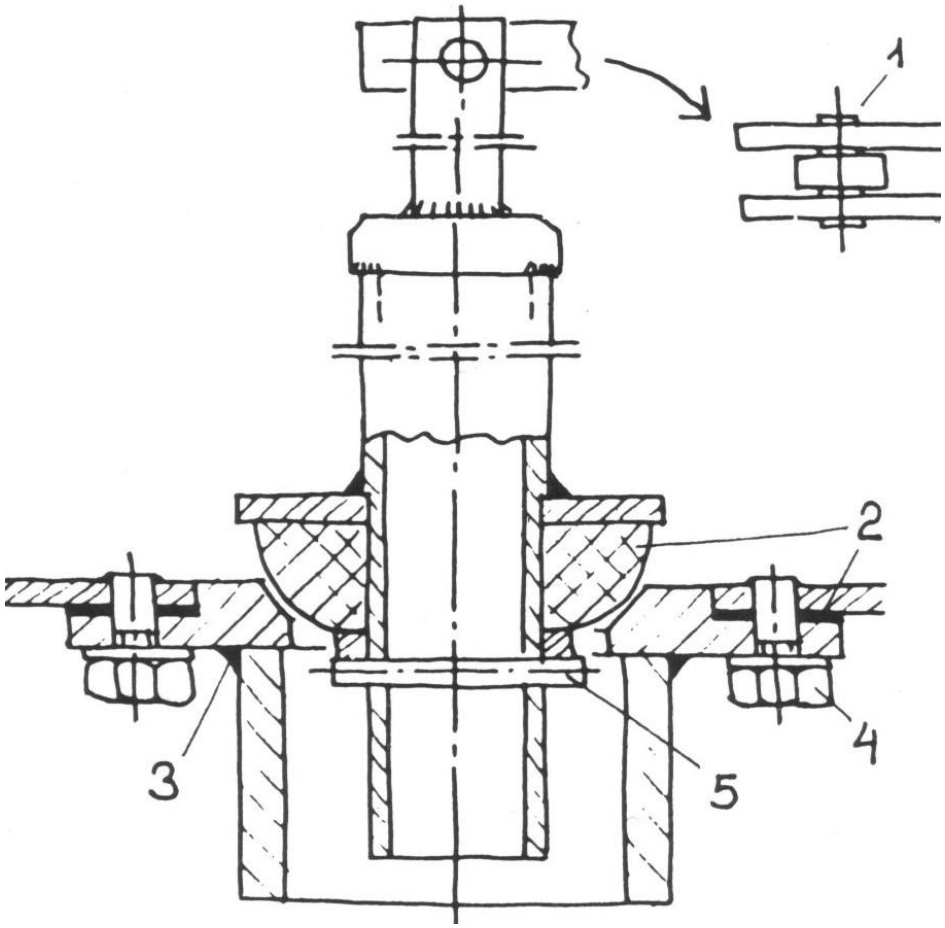
Description of product structure in different way.

Base part, component.

Digital support for complex products and assembly processes.

Total time, cycle time, decreasing the cycle time, balancing.

Why the product needs to be assembled?



1-moving parts
2-different functions
3-different materials
4-disassembly, replacement
5-positiioning

6-manufacturing of parts
7-recycling

IMPORTANT

What we mean by the term »ASSEMBLY«

Assembly is:

The sum of all the processes by which the various components and subassemblies of a product are assembled together to form a complete, geometrically designed assembly or product (device, machine, electronic circuit, etc.) as part of an individual, batch or continuous process.

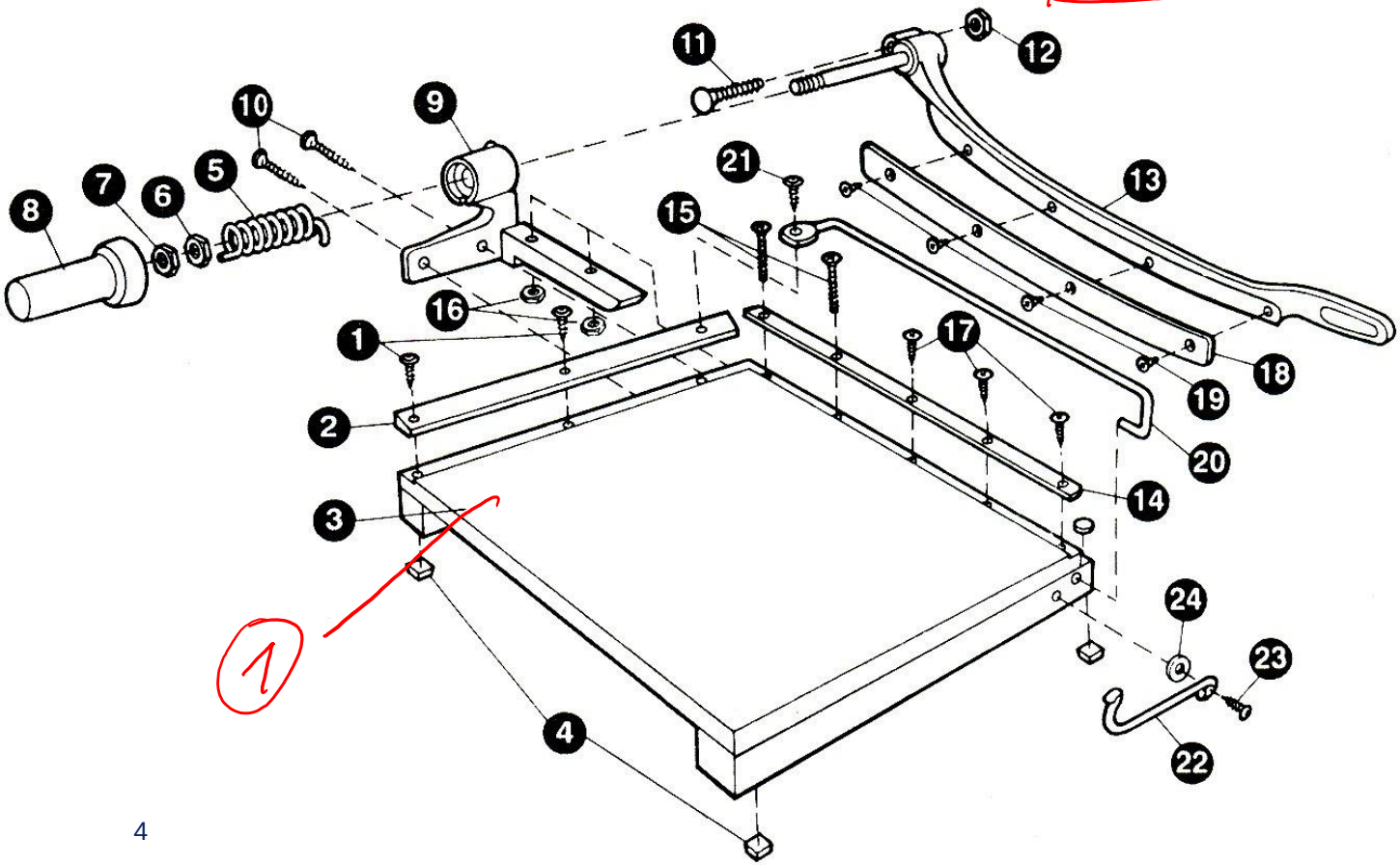
Assembly is part of the production process and system *(integral approach: product, process, systems)*.

IMPORTANT

Example of a product

Brainstorming about the presented product:
Write down a questions related to the assembly process, system.
What do you want to know before beginning?

The complexity of the product?
How many parts?
Parts relations?
Special requirements, tooling?
Do we need any other instructions?
What is the base part?
How to organise the assembly (parts, sequence, subassemblies)?



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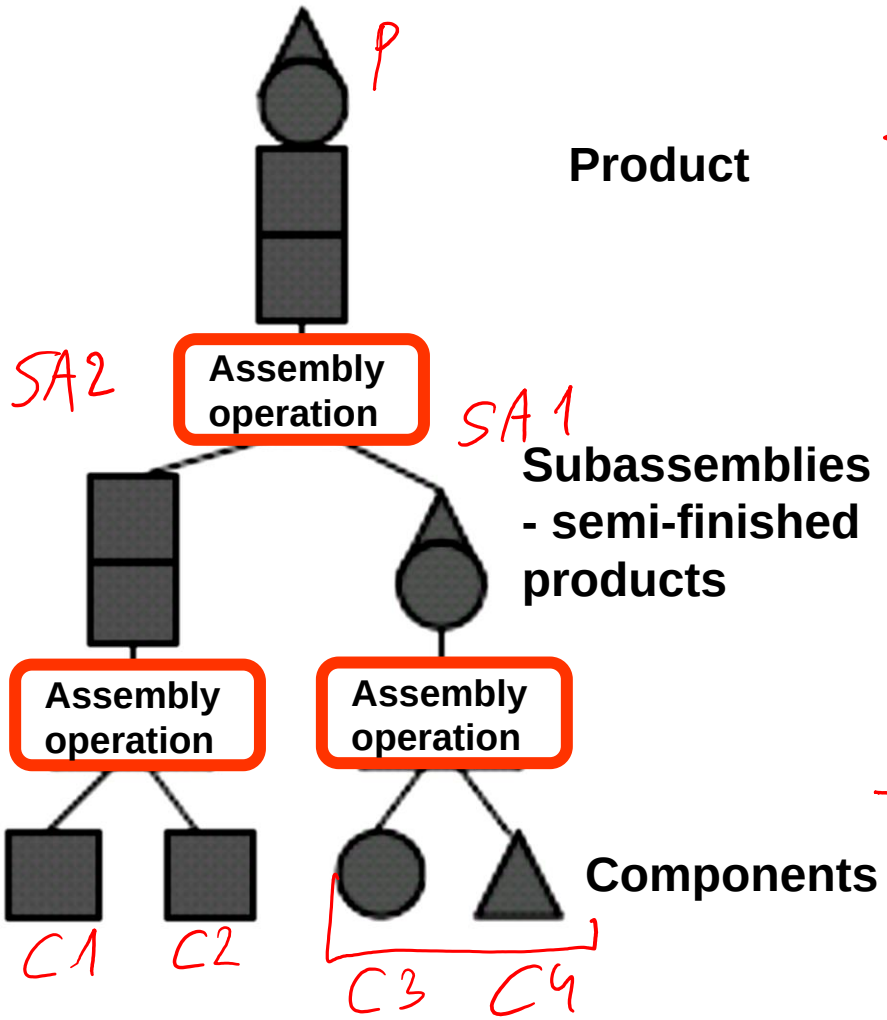
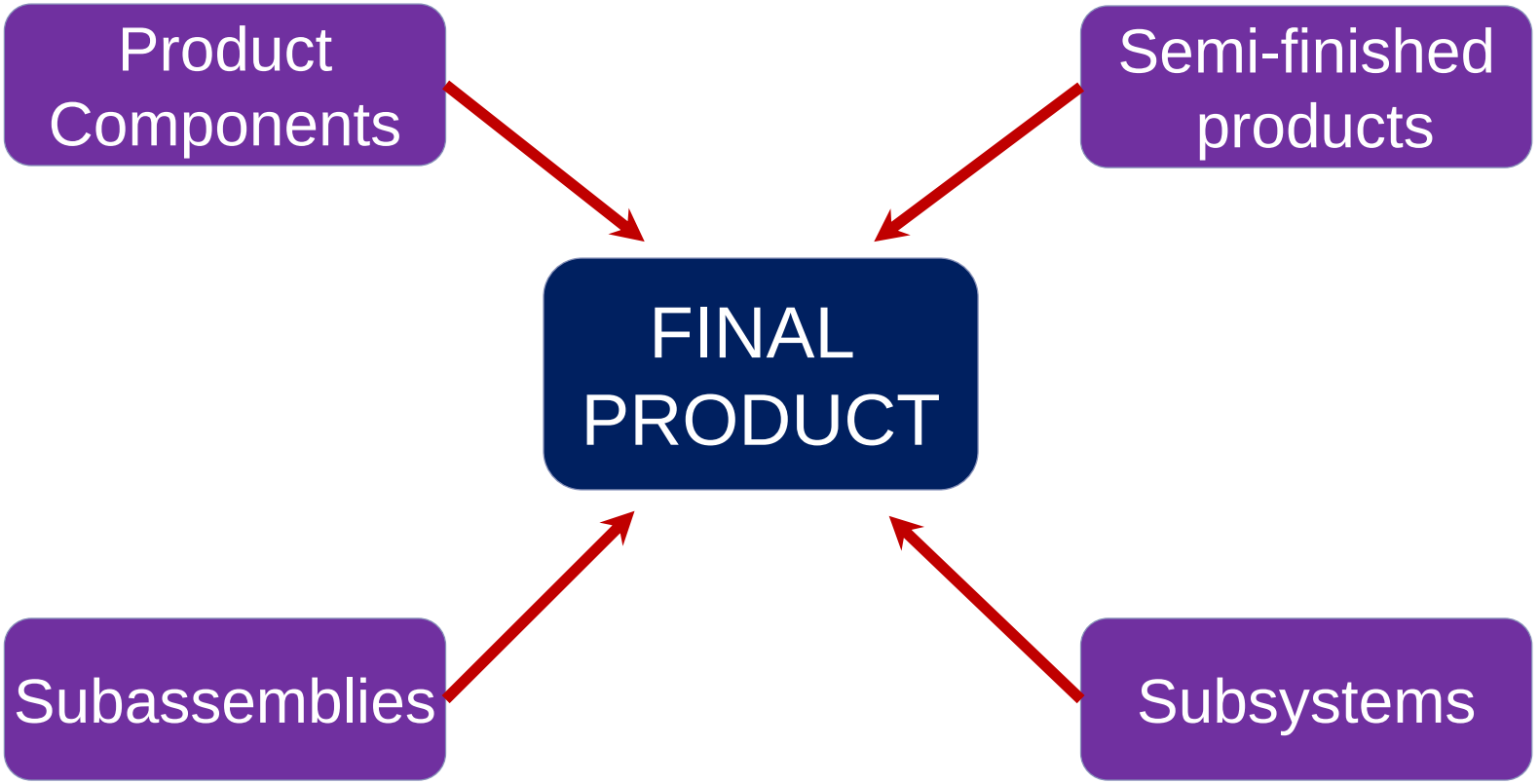
Assembly task

The job of the assembly is to build a system of higher complexity, using a predefined amount of components and subassemblies, within a limited time.



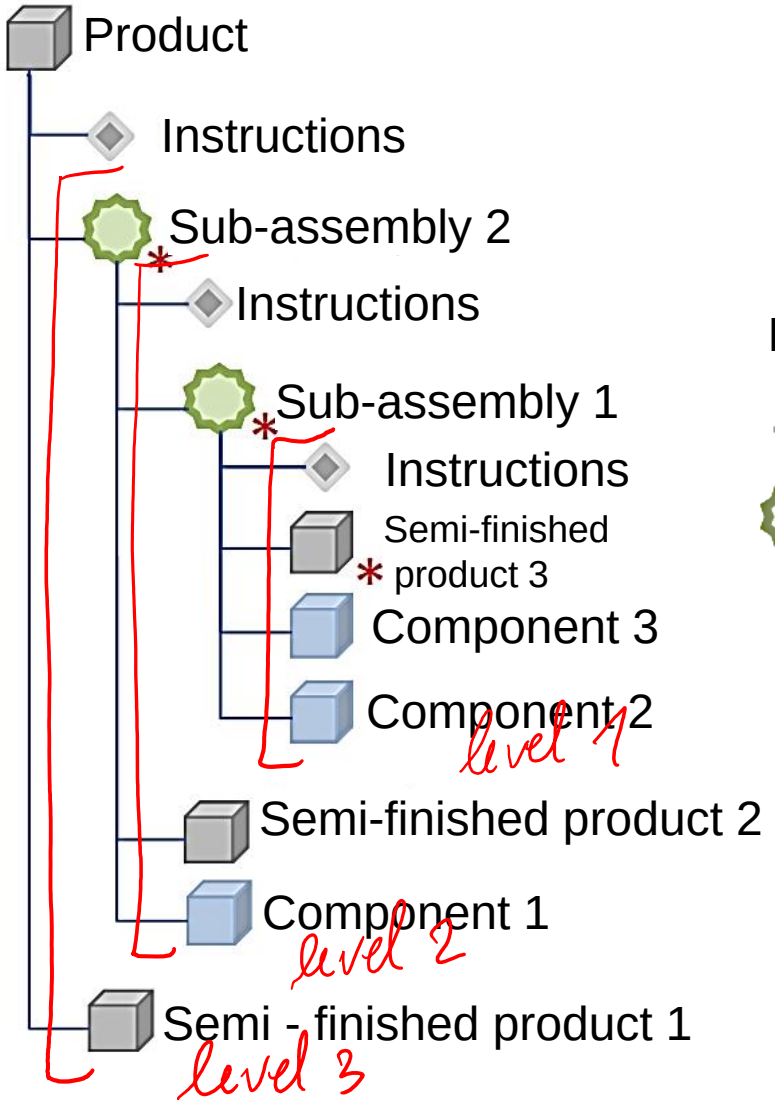
IMPORTANT

Product definition



Product structure

Tree structure

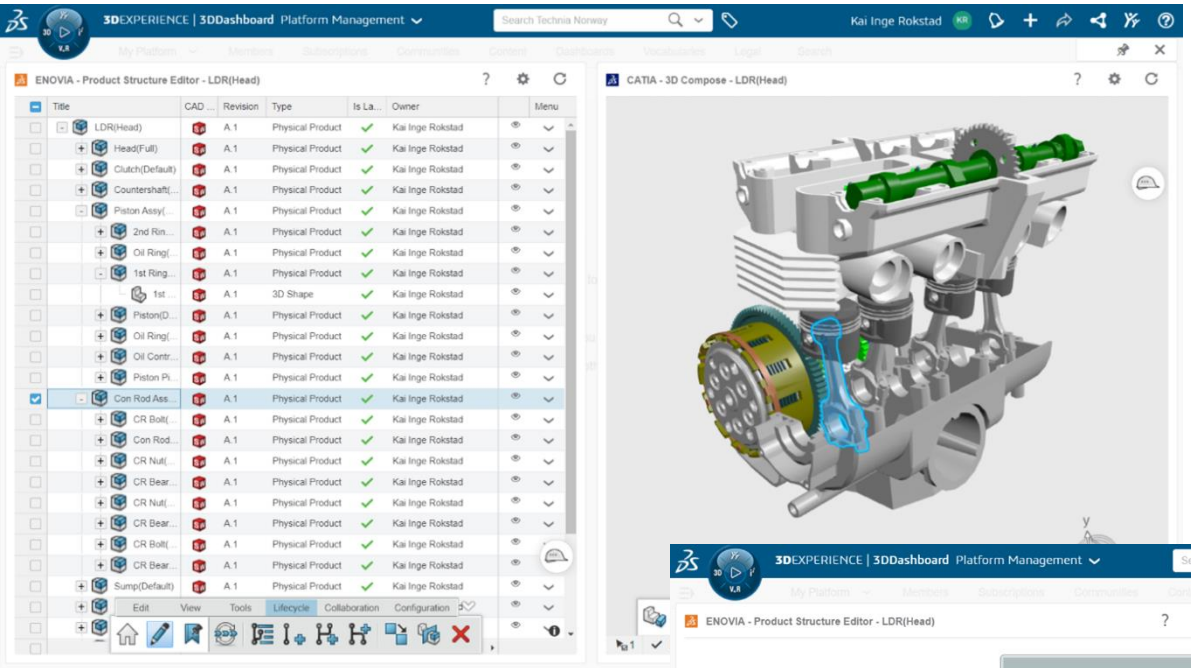


Legend:

- Instructions
- Sub-assembly
- * Base part

Instructions?
-special requirements
-material properties
-joining methods
-special tooling, accessories
-other resources
-worker skills requirement

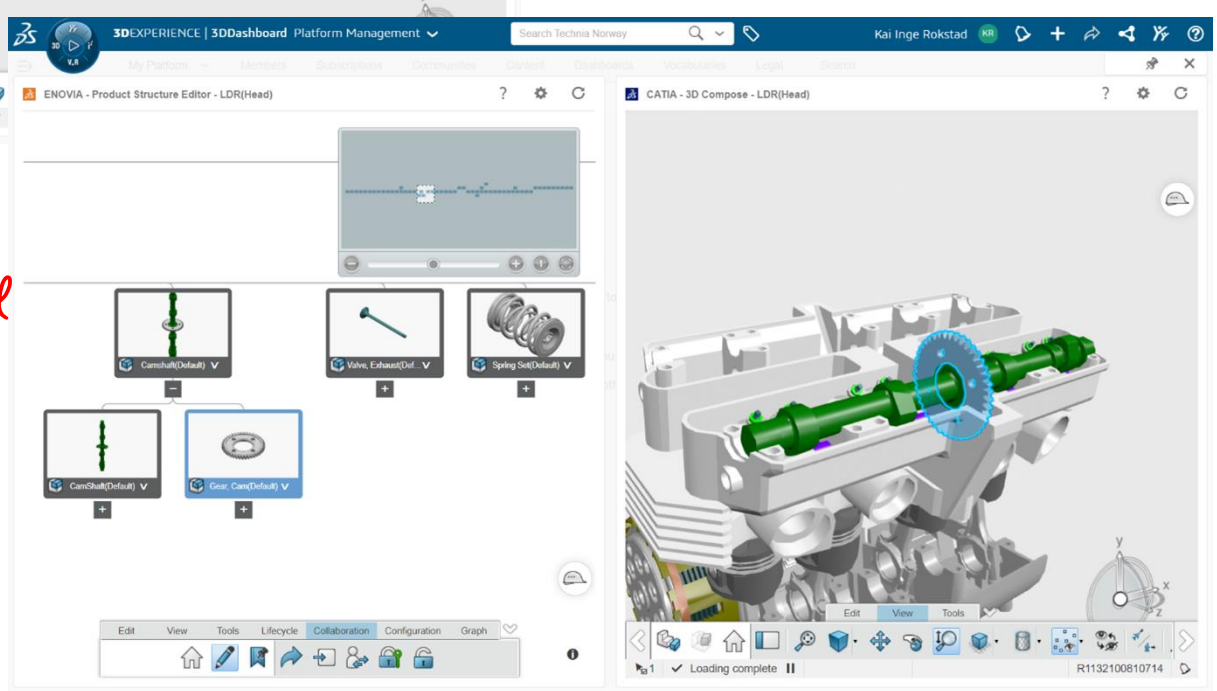
Product structure – ENOVIA Product Structure Editor



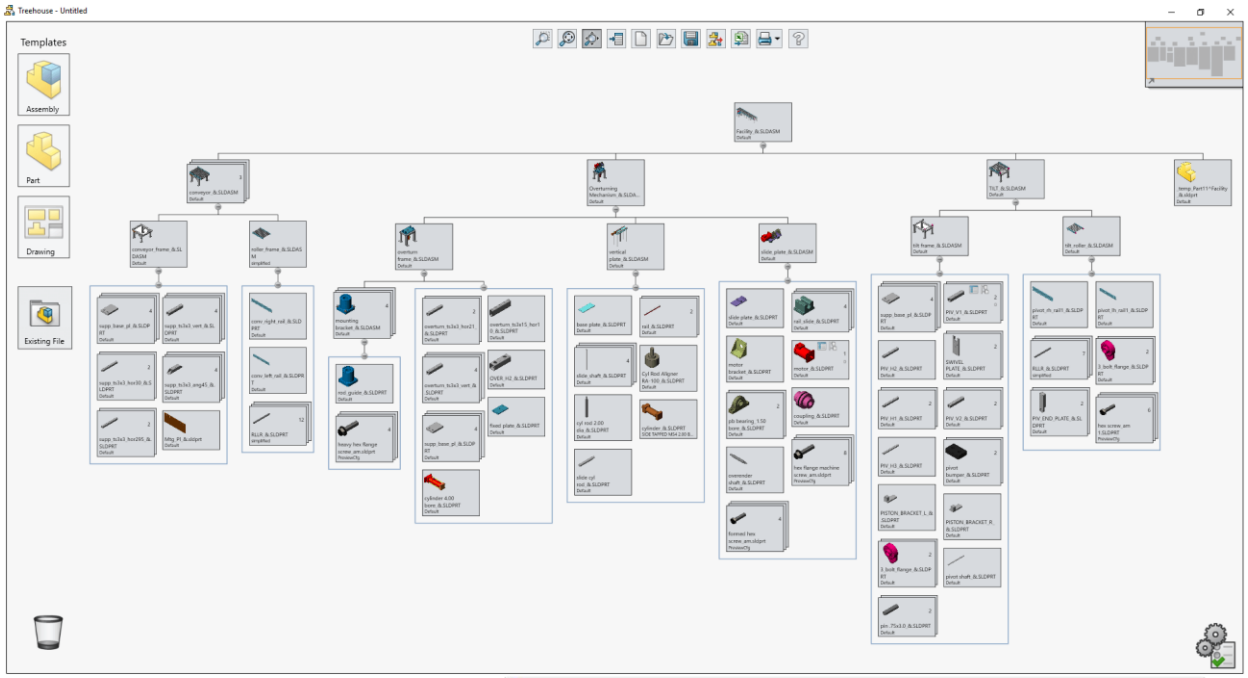
PLM system

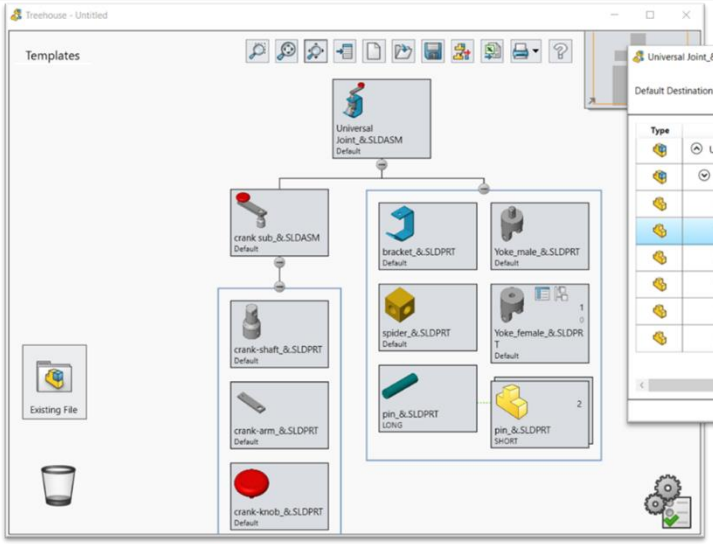
Tree structure

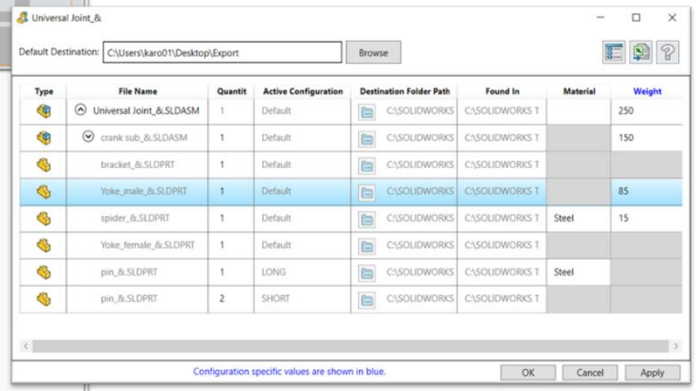
=)



Product structure – SOLIDWORKS Treehouse







Product structure

- **The product structure** describes the relationship between components, subassemblies and material (DIN 6789).
- The product structure shows how and in what way components and material are combined into sub-assemblies and further into the finished product.
- The structure of the product dictates the assembly method and enables the production of variant products, while well-structured products also provide the possibility of automation.

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The product structure can be defined in different ways

1. Structural Bill of Materials

STRUKTURNA KOSOVNA LISTA
Stran 1
DEL: Elektromotor, Štev. dela: E10

Raven	Štev. dela	Naziv dela	unit Mer.enota	Količina
1	901	Ohišje (komplet)	kos	1
*2	891	Ohišje s paketom statorjeve pločevine	kos	1
**3	870	Blok ohišja (ALU)	kos	1
***4	130	Aluminijeve palice	kg	0,5
**3	790	Paket statorjeve pločevine	kos	1
***4	700	Lamela statorjeve pločevine	kos	34
****5	110	Zvitek elektropločevine 200 mm	m	0,02
***4	400	Kovica 4x150 mm	kos	6
*2	740	Statorjevo navitje	kos	1
**3	120	Bakrena žica premera 0,5 mm	m	38
1	830	Os kompletna	kos	1
*2	770	Podnožje 30x40 cm	kos	1
**3	780	Lamela rotorjeve pločevine	kos	34
***4	110	Zvitek elektropločevine 200 mm	m	0,02

Level, number of parts

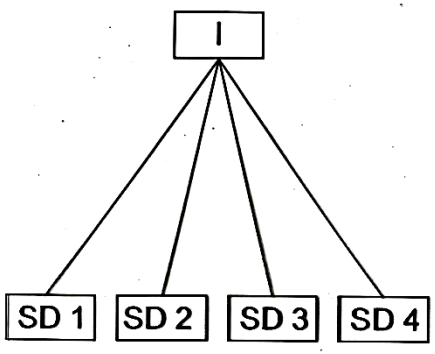
Id number of part

Name of component

2. Table

Serial num.	Name of component	Product variant (number of components)	
		B1	B2
1	Sticker	1	1
2	External lock ring	1	2
3	Screw	3	2
4	Radial seal 1	1	2
5	Radial seal 2	2	1

3. Tree structure



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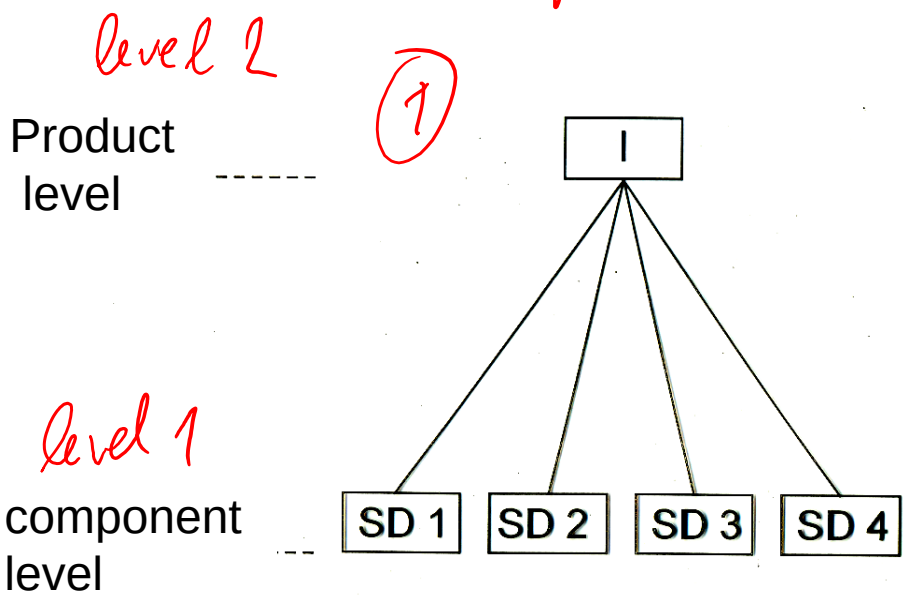
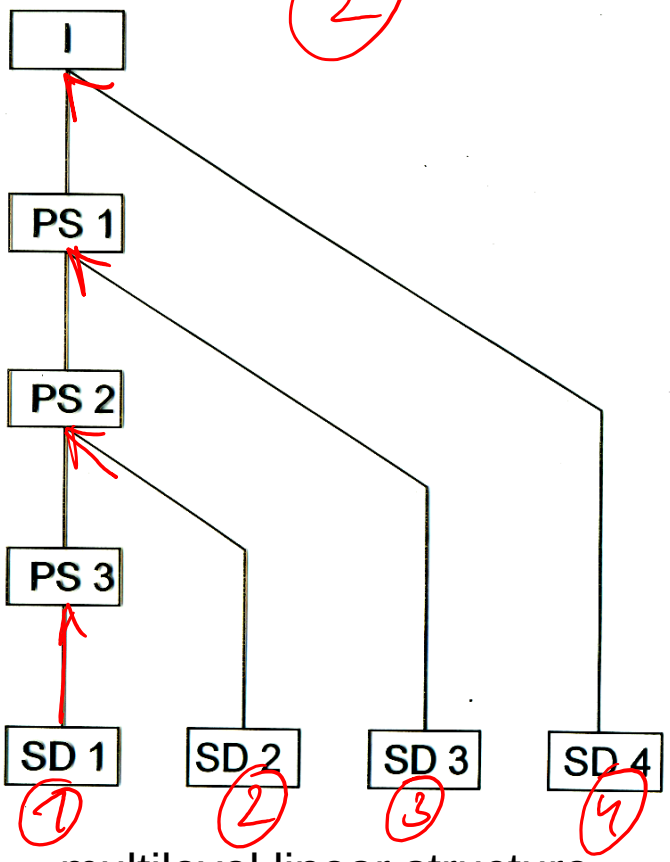
SD – Assembly part (AP)

Tree structure - 1



simple two-level structure



multilevel linear structure

Legend:
I - product
PS - subassembly
SD – assembly part, component

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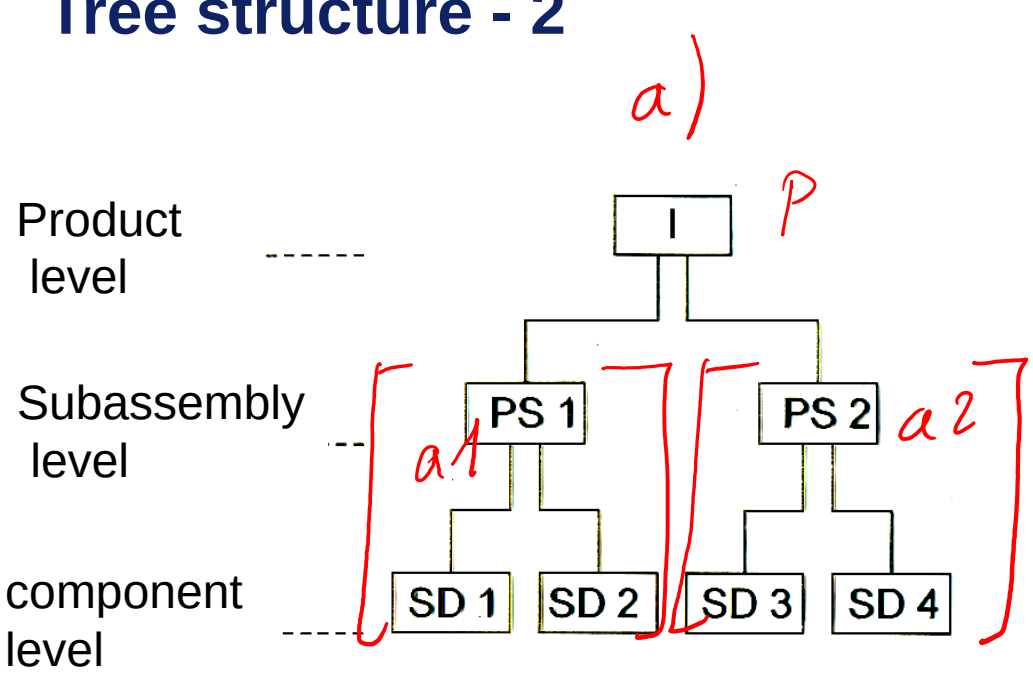
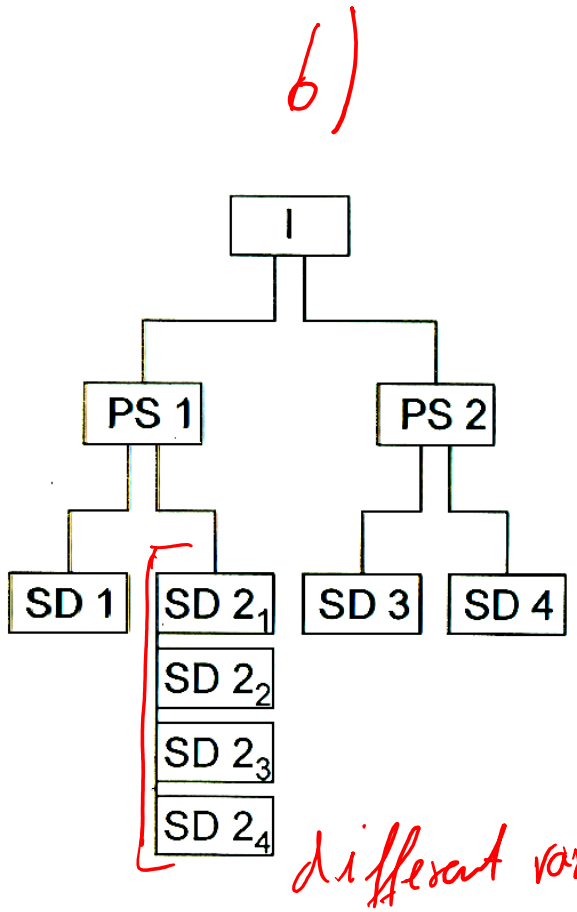
Tree structure - 2



multilevel branched structure



product structure with variant components

Legend:
I - product
PS - subassembly
SD – assembly part, component

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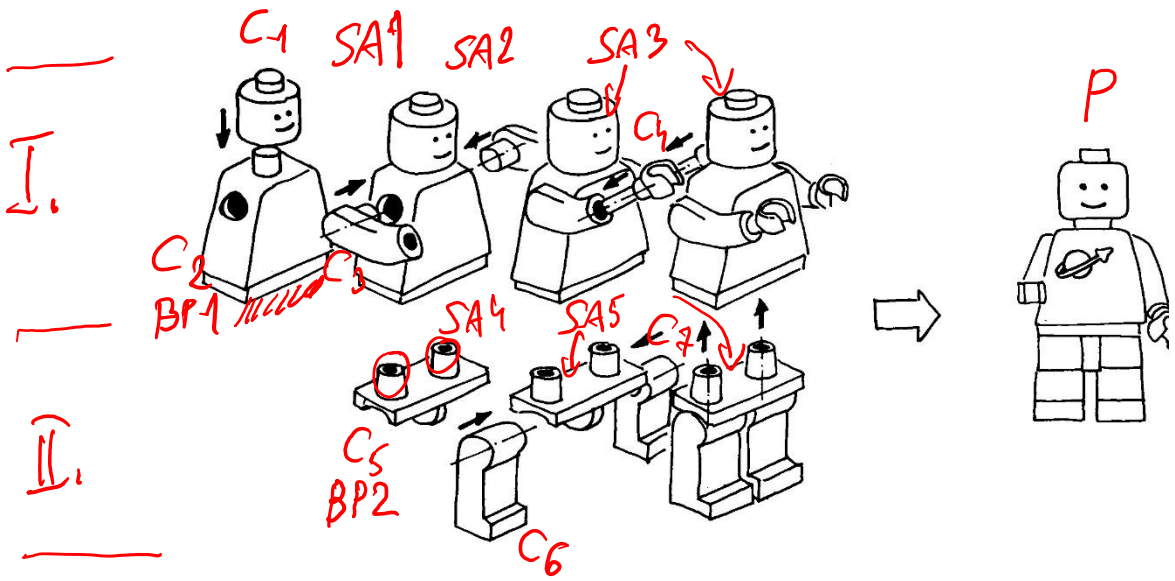
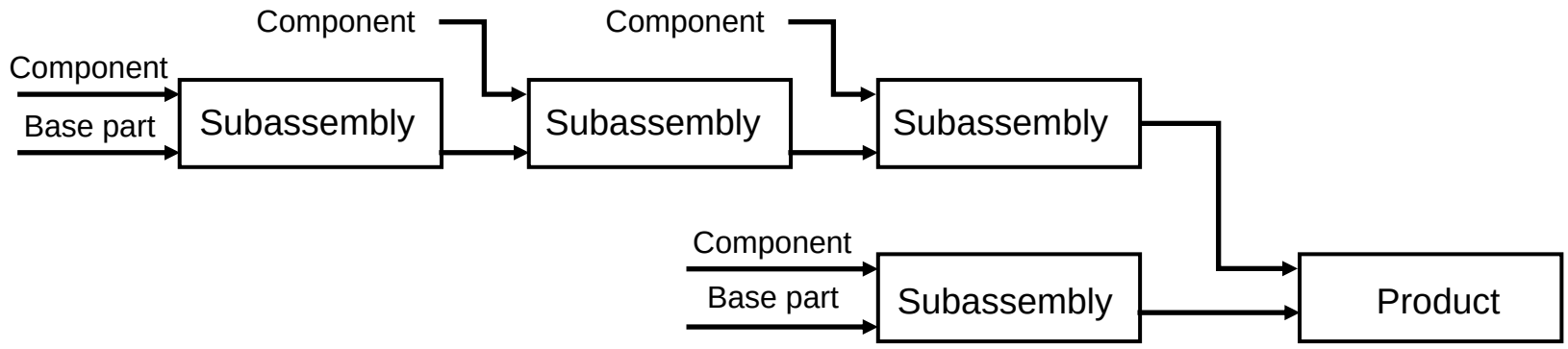
An example of a product tree structure



- Components?
- Base parts?
- Subassemblies?
- Products?

TEAM WORK



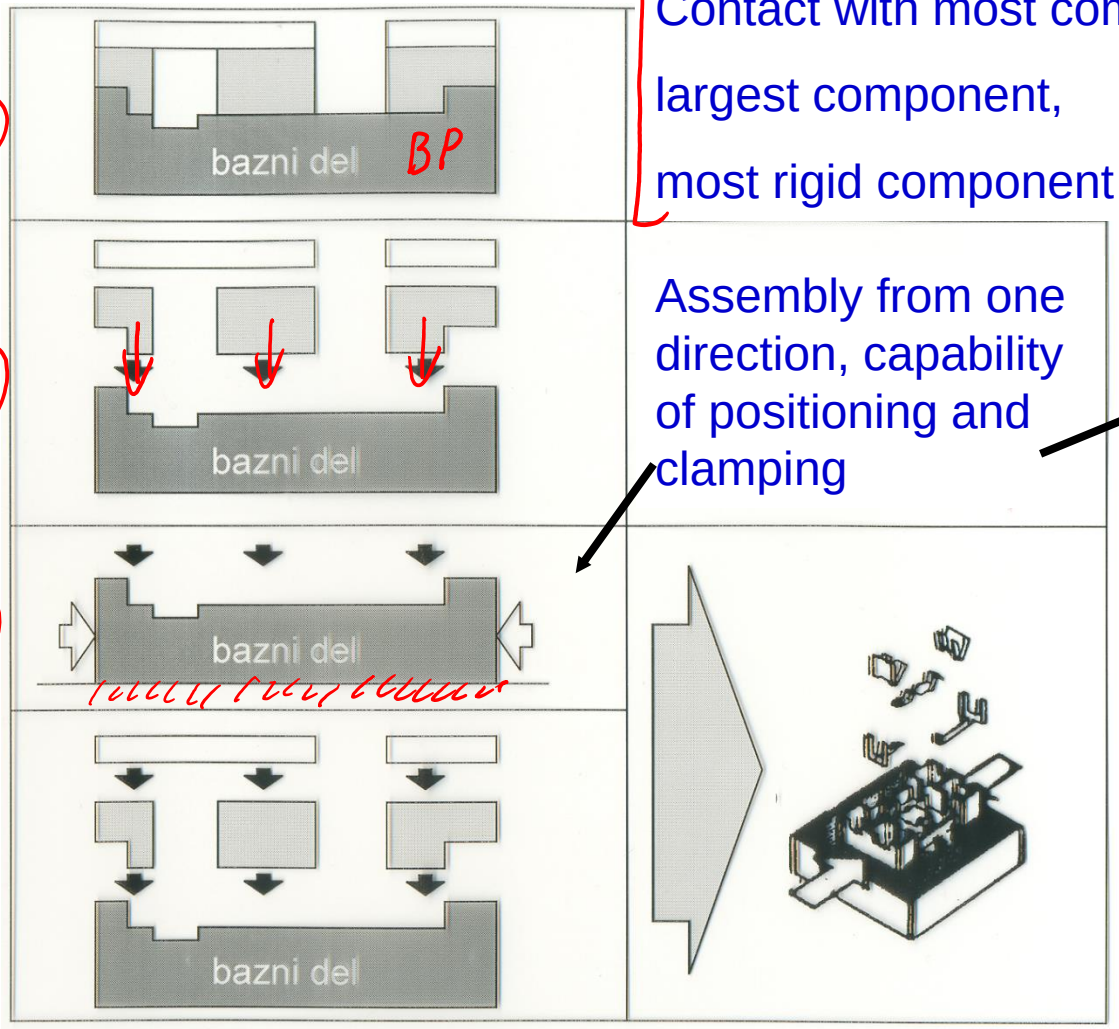
Base part - 1

How to define the base part?

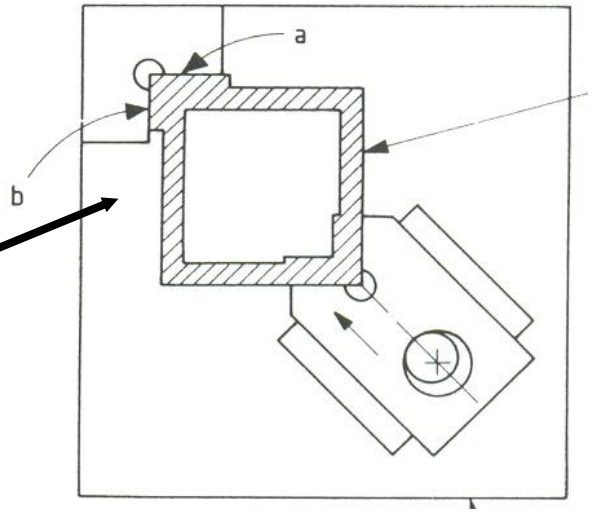
Contact with most components,

largest component,

most rigid component



Assembly from one direction, capability of positioning and clamping



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Base part - 2

IMPORTANT

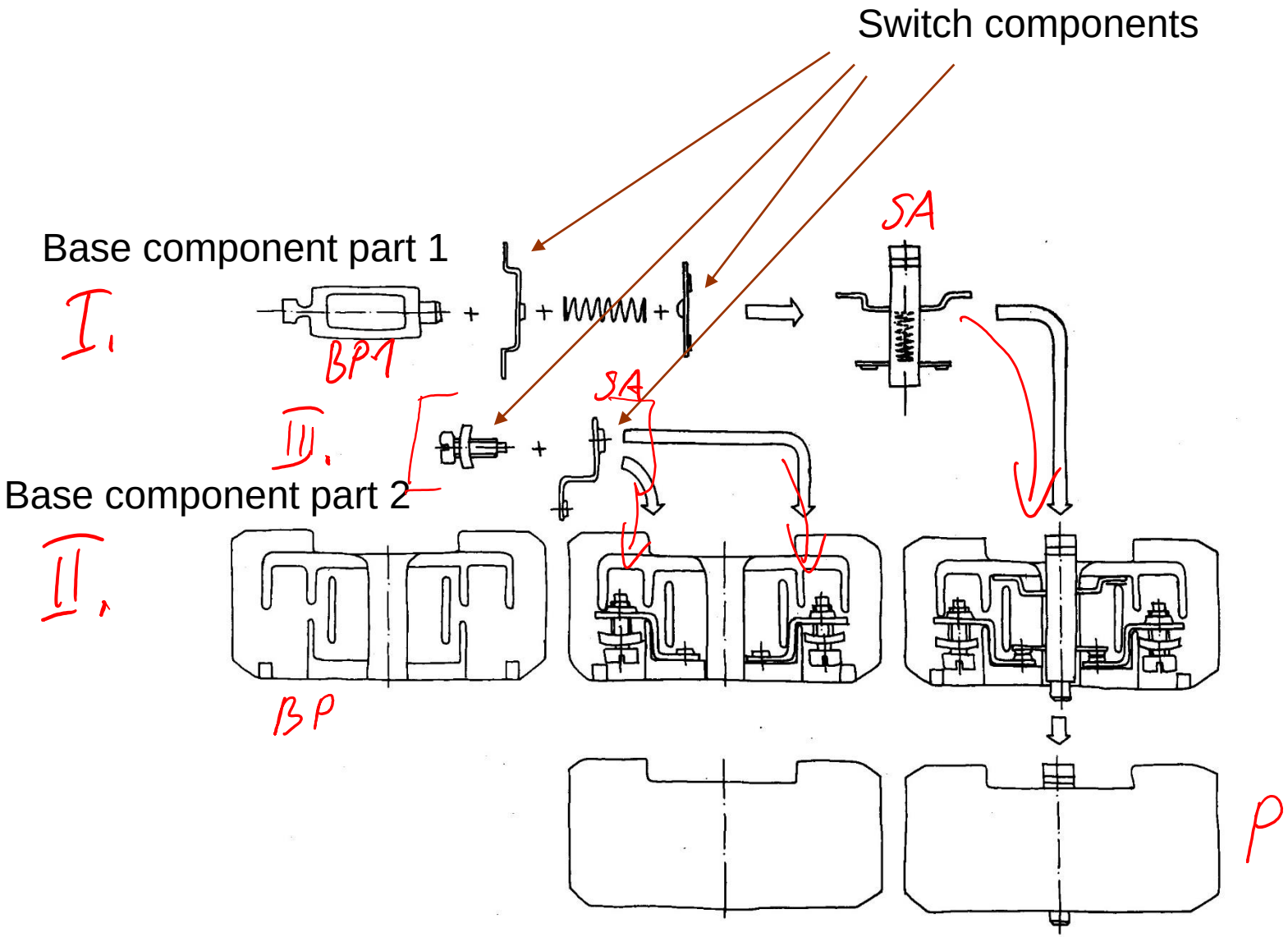
Base component: is one of the components or sub-assemblies of a product to which other components and sub-assemblies are added.

Properties of the base component:

- has appropriate positioning and clamping surfaces,
- many points of contact with other components,
- it is usually the largest and sufficiently rigid and/or has the highest mass,
- components are added to it from the least directions possible, from one direction if possible.

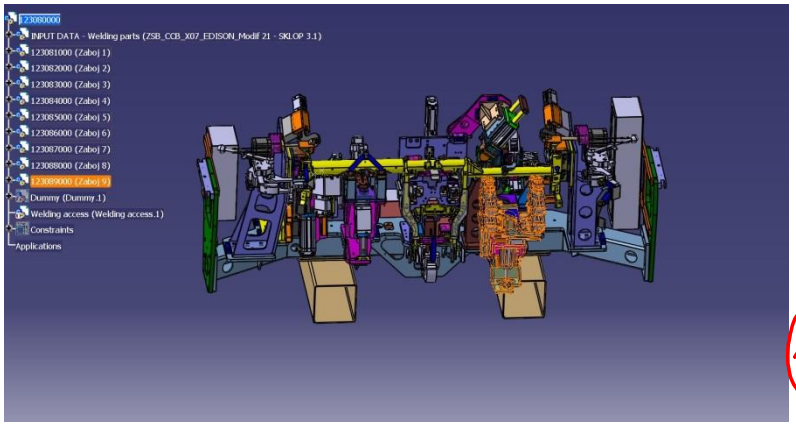
We usually begin the assembly process by securing the base component to the assembly nest.

Switch – an example of product structure



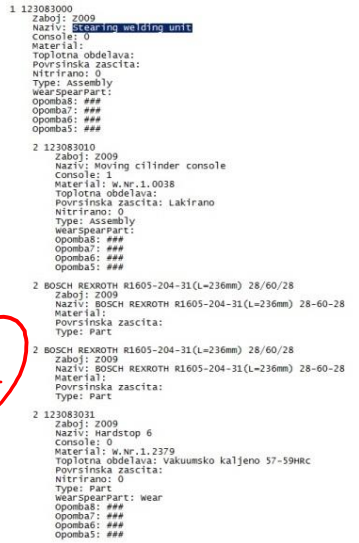
Software package developed to visually display the structure of the assembly product

The product structure is defined in the modeler (CATIA, SOLIDWORKS, etc.) by the constructor and the technologist of assembly.



1

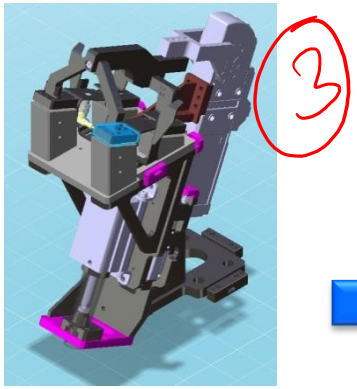
Export of product structure from CATIA to a * .txt file



```
1 123083000
    Zaboj: Z009
    Naziv: Stearing welding unit
    Console: 0
    Material:
    Toplotna obdelava:
    Povrsinska zascita:
    Nitrirano: 0
    Type: Assembly
    WearSpearPart:
    Opomba8: ###
    Opomba7: ###
    Opomba6: ###
    Opomba5: ###

    2 123083010
        Zaboj: Z009
        Naziv: Moving cilinder console
        Console: 1
        Material: W.Nr.1.0038
        Toplotna obdelava:
        Povrsinska zascita: Lakirano
        Nitrirano: 0
        Type: Assembly
        WearSpearPart:
        Opomba8: ###
        Opomba7: ###
        Opomba6: ###
        Opomba5: ###

    2 BOSCH REXROTH R1605-204-31(L=236mm) 28/60/28
        Zaboj: Z009
        Naziv: BOSCH REXROTH R1605-204-31(L=236mm) 28-60-28
        Material:
        Povrsinska zascita:
        Type: Part

    2 BOSCH REXROTH R1605-204-31(L=236mm) 28/60/28
        Zaboj: Z009
        Naziv: BOSCH REXROTH R1605-204-31(L=236mm) 28-60-28
        Material:
        Povrsinska zascita:
        Type: Part

    2 123083031
        Zaboj: Z009
        Naziv: Hardstop 6
        Console: 0
        Material: W.Nr.1.2379
        Toplotna obdelava: Vakuumsko kaljeno 57-59HRc
        Povrsinska zascita:
        Nitrirano: 0
        Type: Part
        WearSpearPart: Wear
        Opomba8: ###
        Opomba7: ###
        Opomba6: ###
        Opomba5: ###
```

2

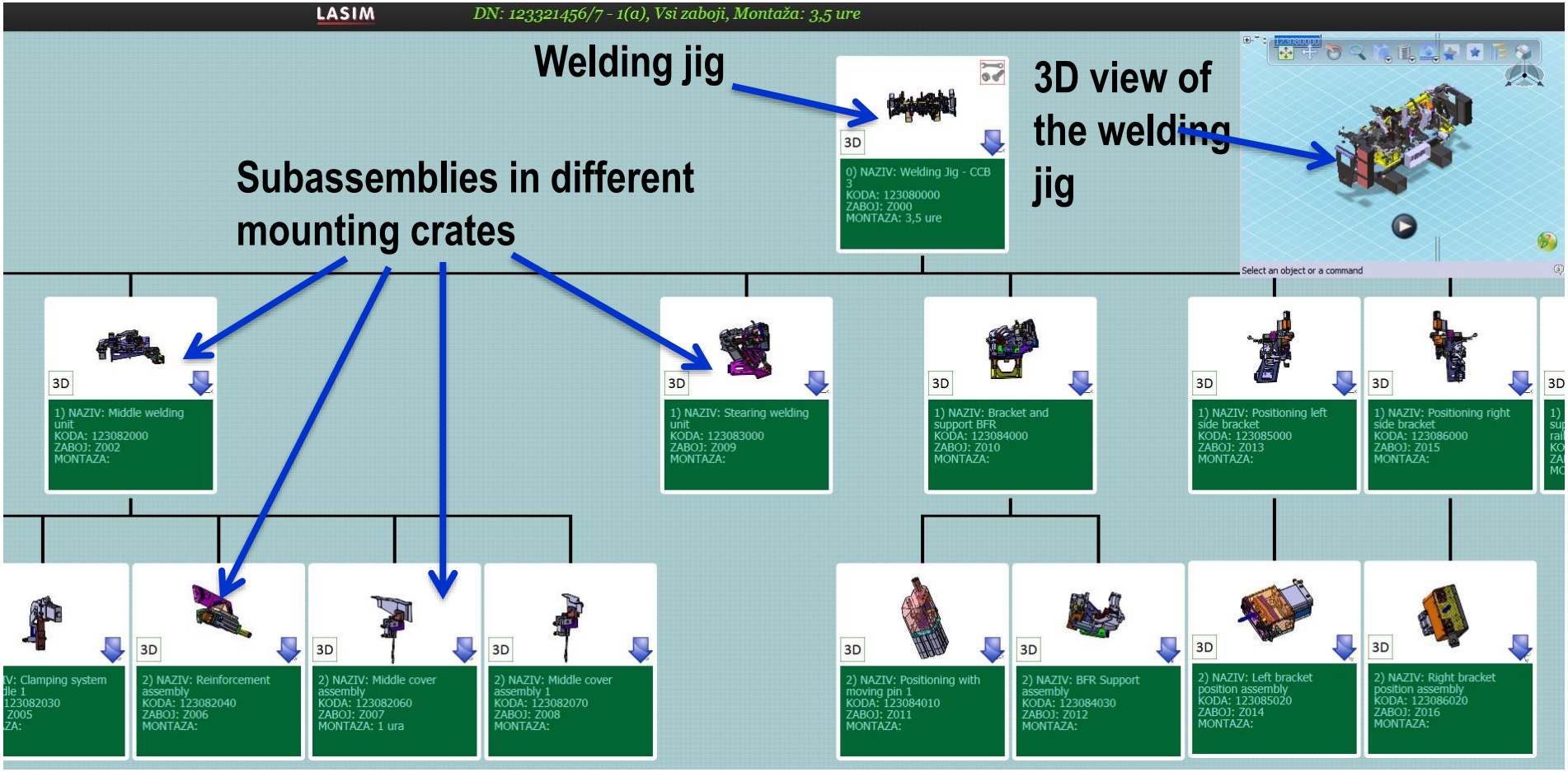
Generation of images, 3D models and * .pdf documentation



3

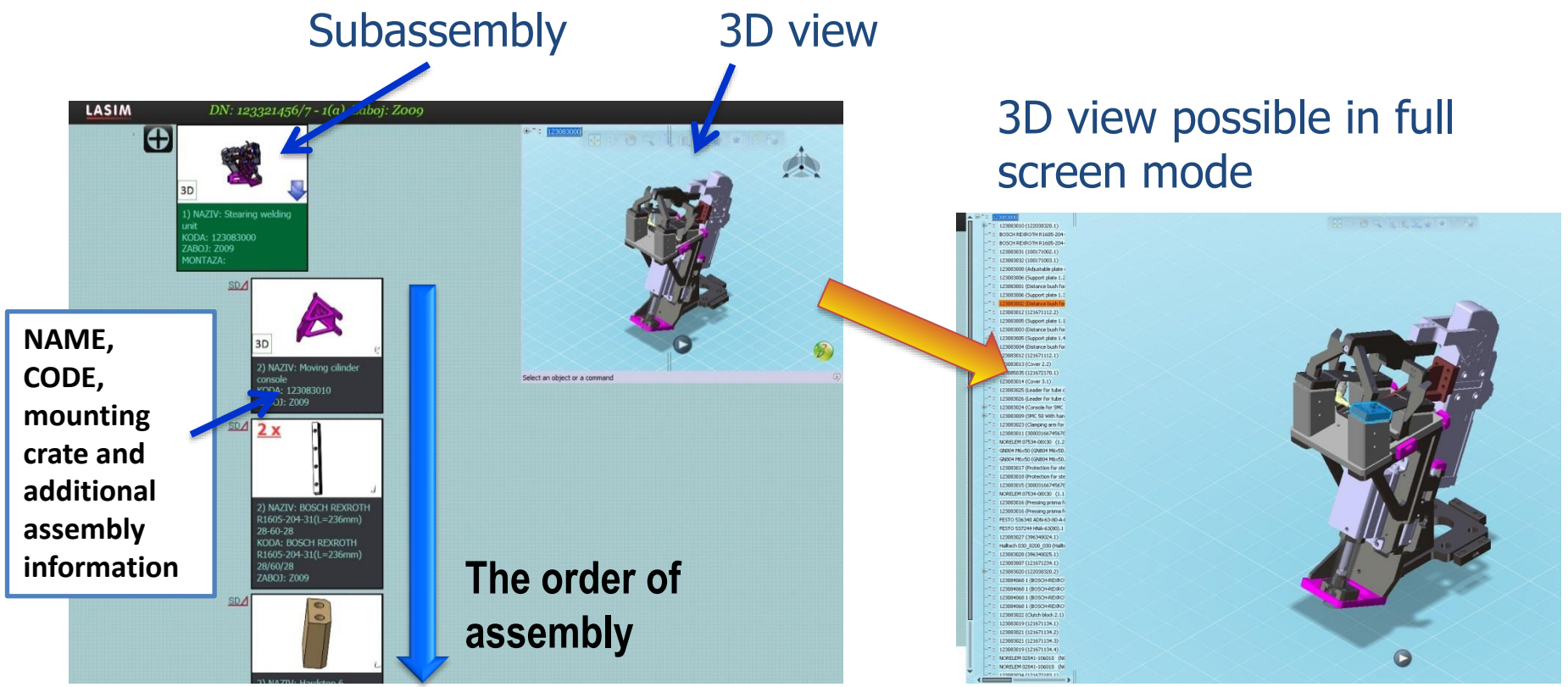
Generation of product structure for assembly

- View of the entire welding jig with all the subassemblies sorted in different mounting crates.
- 3D view of the finished product and all sub-assemblies.

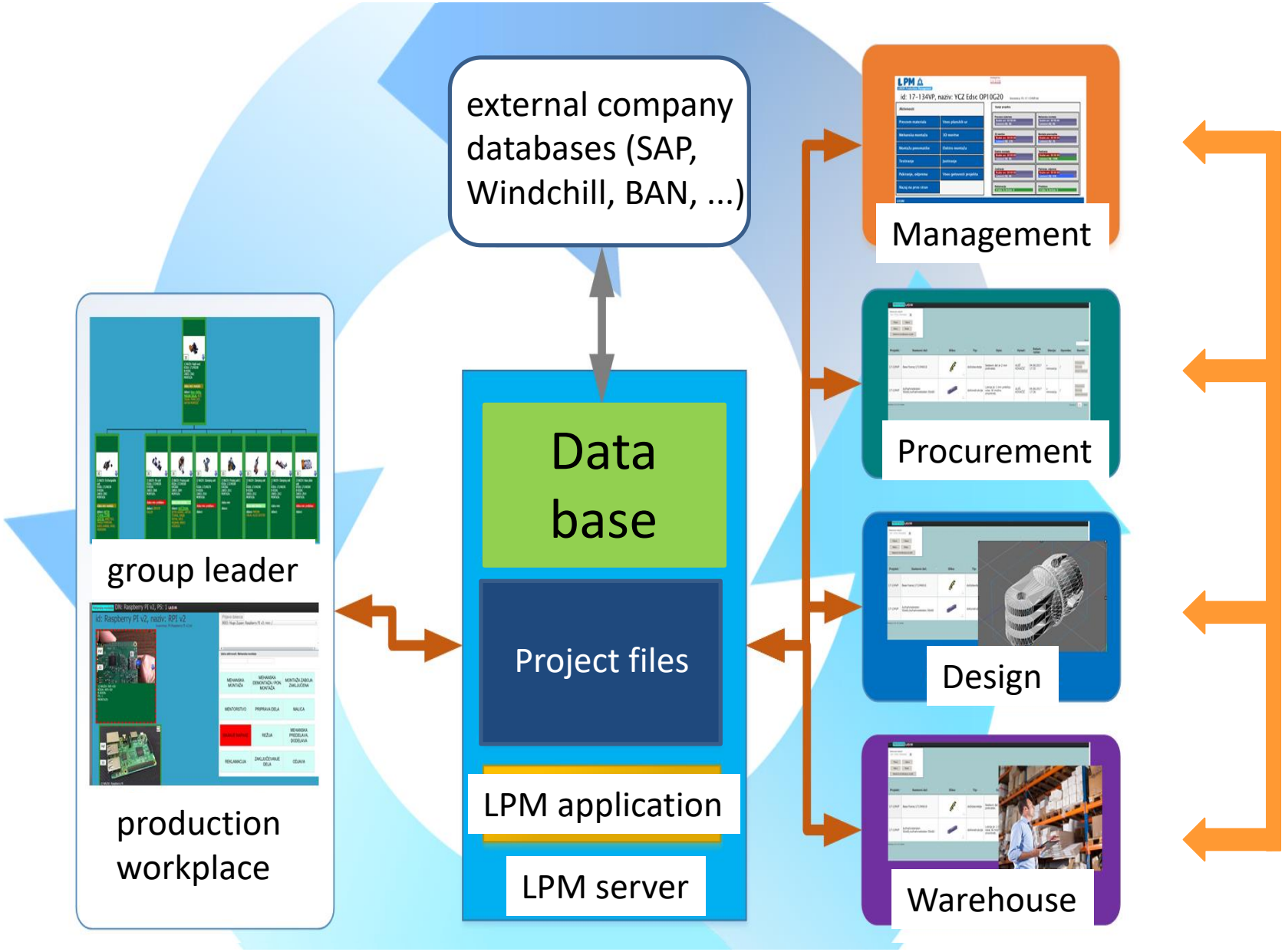


- Clicking on an individual subassembly opens the product structure.

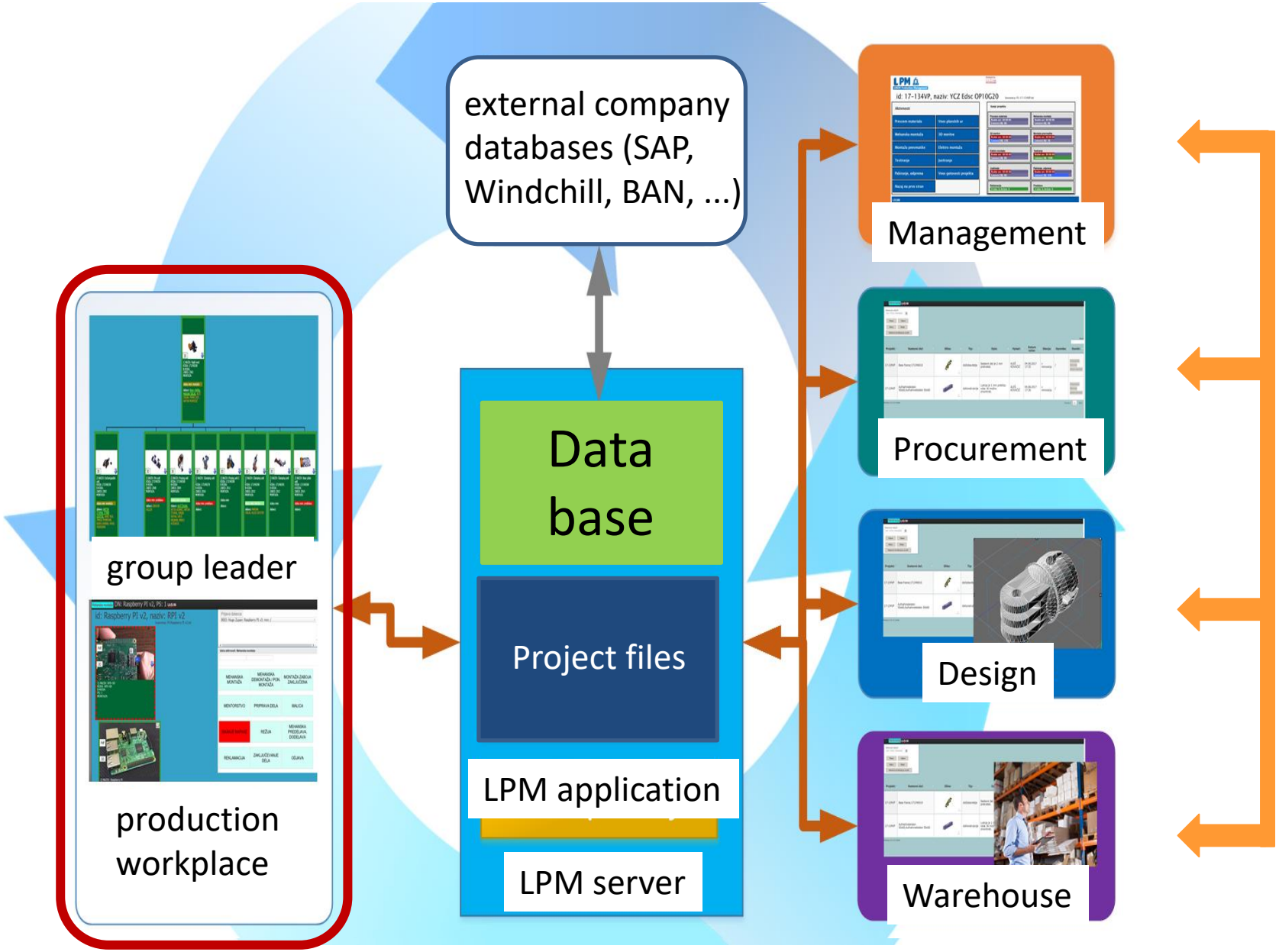
- Sub-assembly of all components in the order of assembly
- All parts have unique Id number (marker)
- 2D view of the product and all subassemblies
- Additional information for assembly (list of screws and nuts, tightening torques and other data)



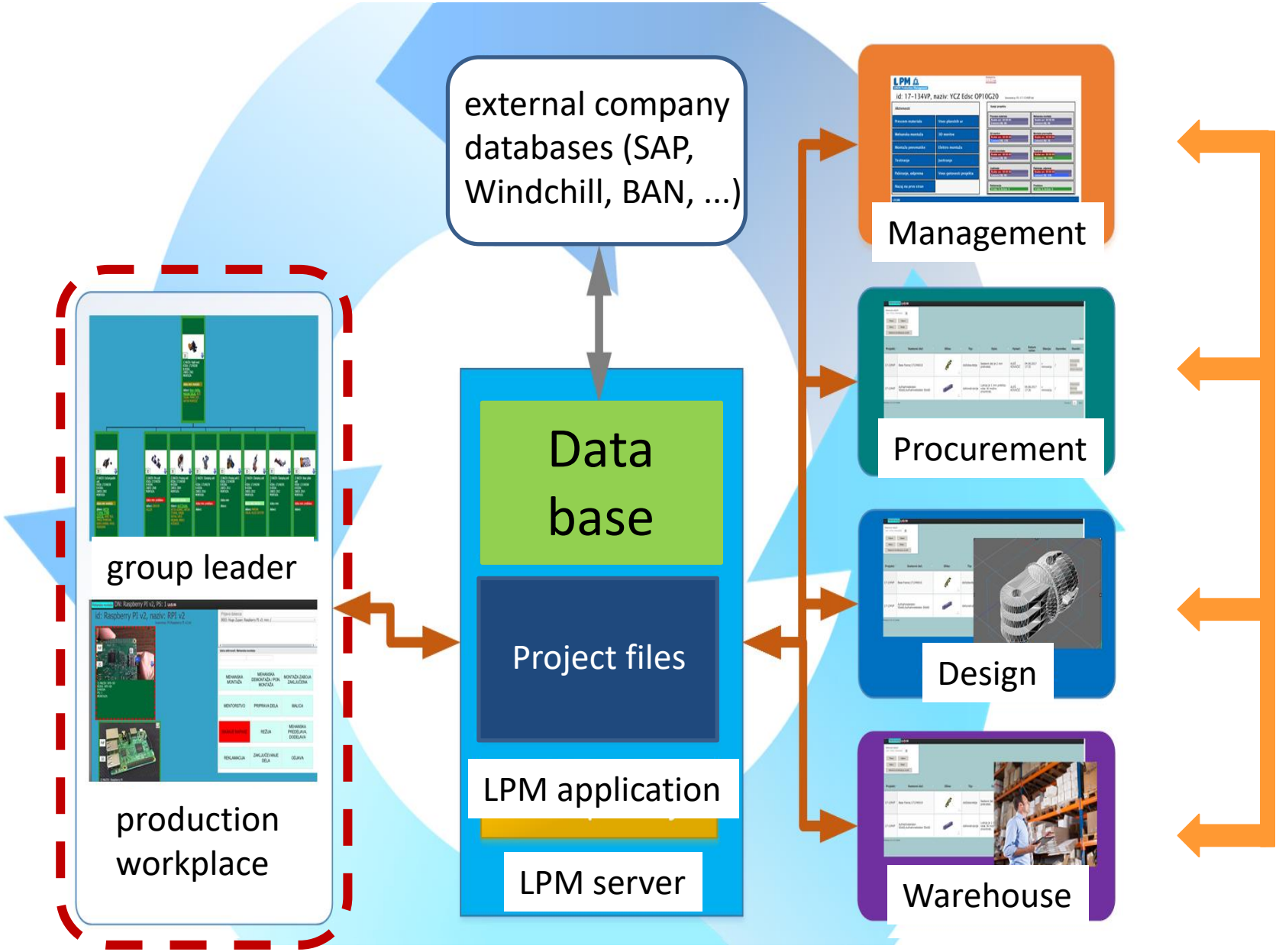
LPM Software Tool - From the Design to Supply Chain



LPM Software Tool - From the Design to Supply Chain



LPM Software Tool - From the Design to Supply Chain



LPM Software Tool - From the Design to Supply Chain

What is the main purpose to apply such approach

IMPORTANT

external company databases (SAP, Windchill, BAN, ...)

Management

Procurement

Design

Warehouse

Data base

Project files

LPM application

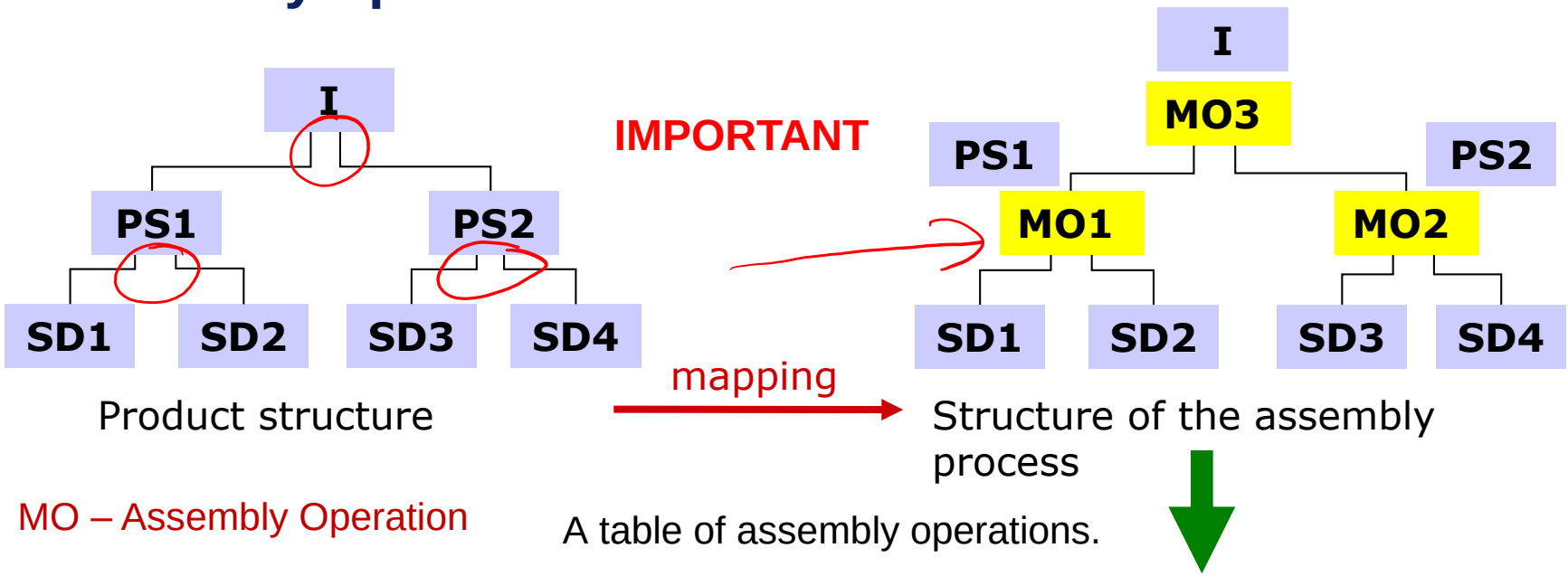
LPM server

group leader

production workplace

Visualization for everyone - TRANSPARENCY

Product structure and assembly structure, sequence of assembly operations

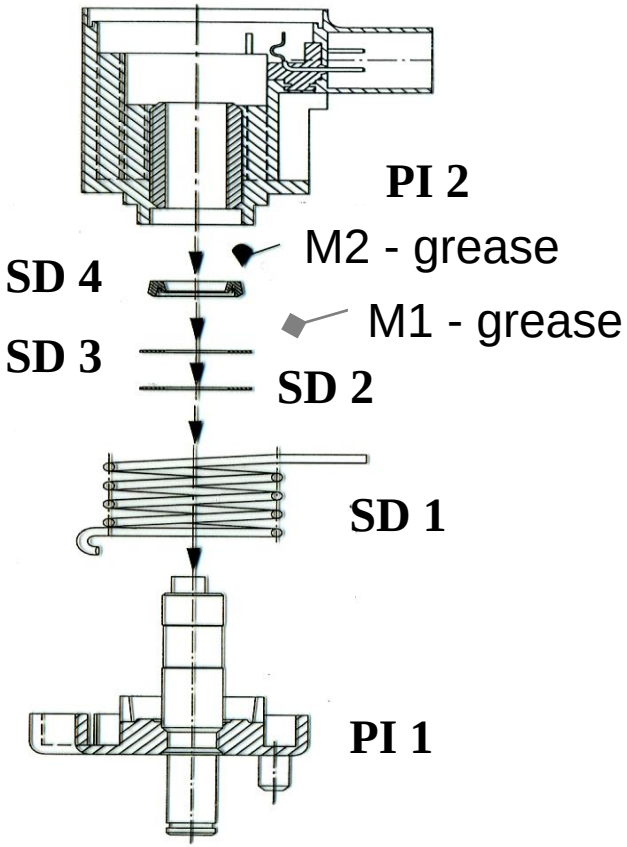


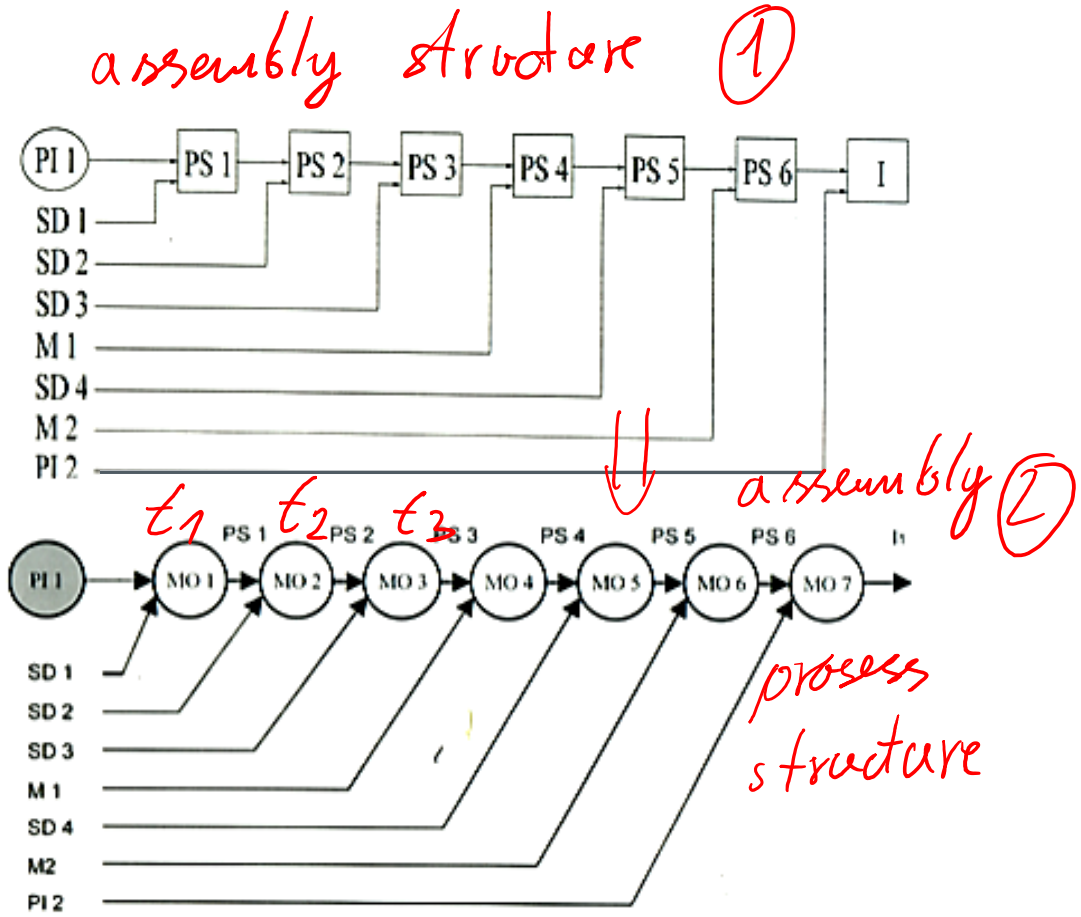
MO – Assembly Operation

A table of assembly operations.

Serial number	Assembly operations	Previous assembly operation (MO)	Next assembly operation (MO)	Time [s]
MO1	Assembly of SD1 and SD2	-	MO3	3
MO2	Assembly of SD3 and SD4	-	MO3	5
MO3	Assembly of PS1 and PS2	MO1&MO2	-	11

Example



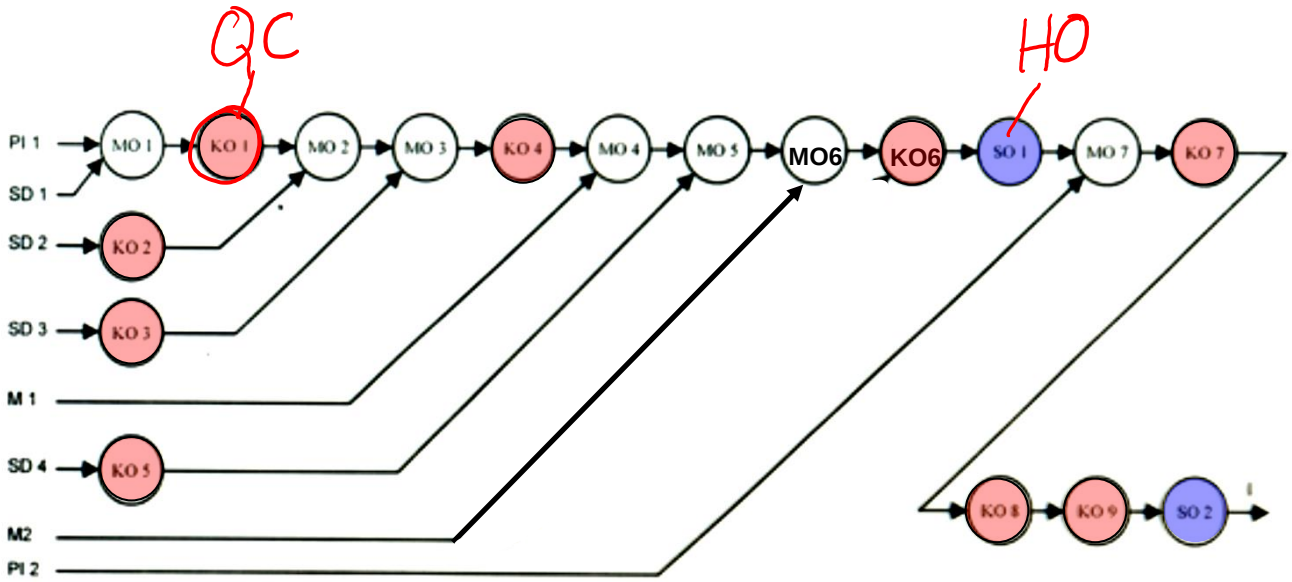


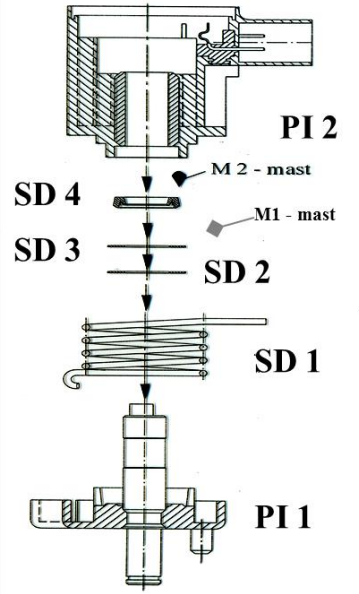
MO 1 - Assembly of axles and springs
MO 2 – Attachment of Teflon washer 1
MO 3 - Attachment of Teflon washer 2
MO 4 - grease application
MO 5 - Seal fitting
MO 6 - grease application
MO 7 - Housing installation

The product has a multi-level line structure where „PI“ are semi-finished products, „PS“ are subassemblies as a result of performing individual assembly operations – „MO“ and I is a product.

Adding control and handling operations

IMPORTANT





KO 1 - control of presence of PS1 after assembly operation
KO 2 - Teflon foil thickness control before cutting before assembly operation
KO 3 - Teflon foil thickness control before cutting before assembly operation
KO 4 - control after insertion of Teflon washers
KO 5 - Inspection of seals before insertion
KO 6 - Check the position of seals after insertion
KO 7 - spring position control
KO 8 - spring torque control
KO 9 - contact control
SO 1 - removal of incorrect subassembly after KO 6
SO 2 - removal of incorrect product after KO 9

All of the following assembly operations, which are yet to be defined, are specified with the assembly system and specific customer requirements (for example packaging)

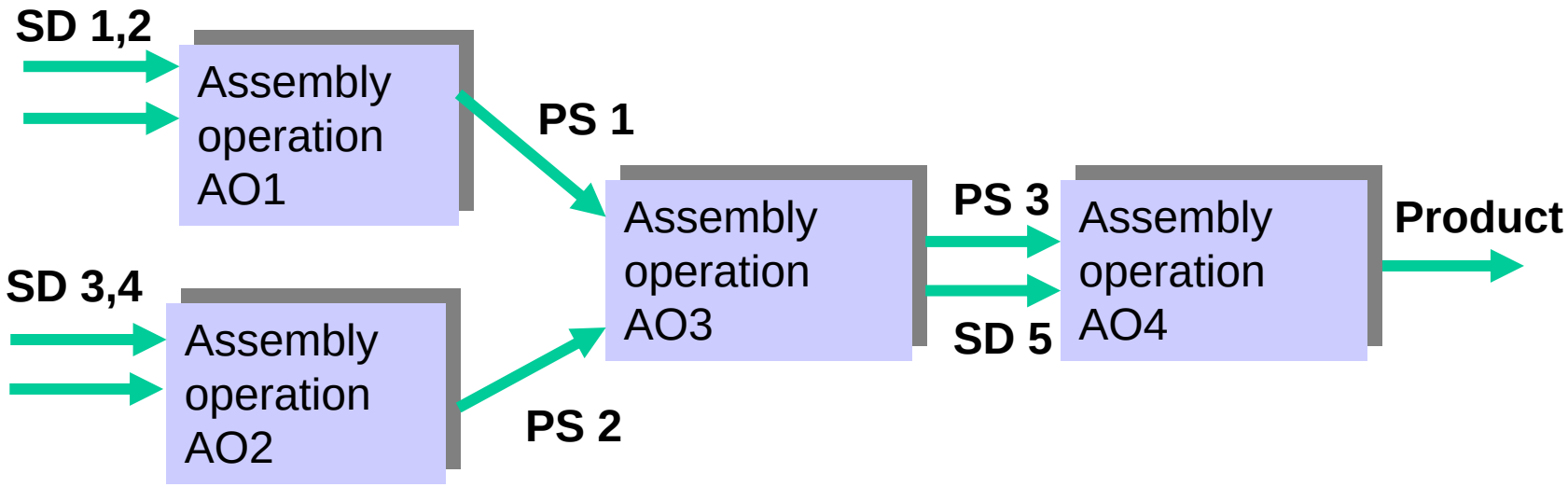
Control and handling operations are defined on the basis of the specified requirements.

Assembly operations - definition

IMPORTANT

Assembly operation (MO or AO): is the elementary activity of the assembly process, defined by the type of AO, the mode of execution, the movements of execution (duty cycle), the duration of movements, the total time of the AO and the price. Each AO performed represents an increase in the value of the product.

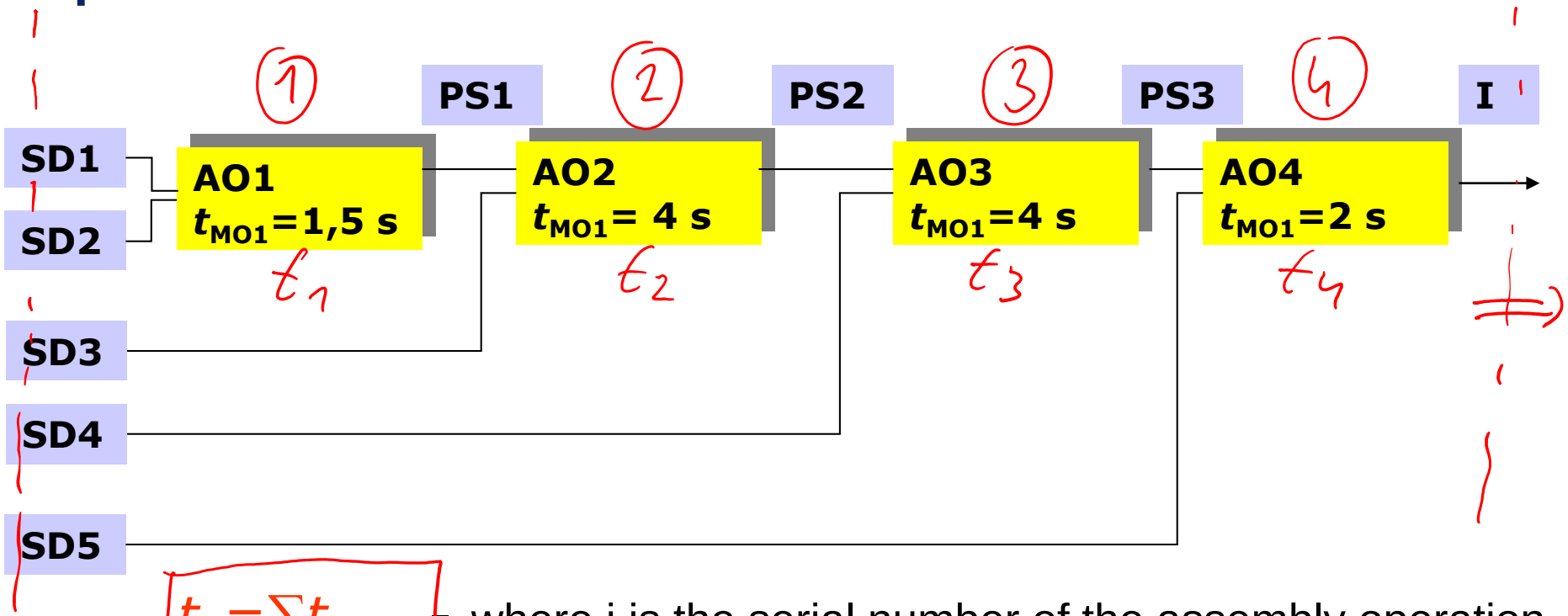
t - time



Each MO (AO) requires assembly resources and time!

IMPORTANT

Structure, total time and cycle time of the assembly process - 1



- where i is the serial number of the assembly operation

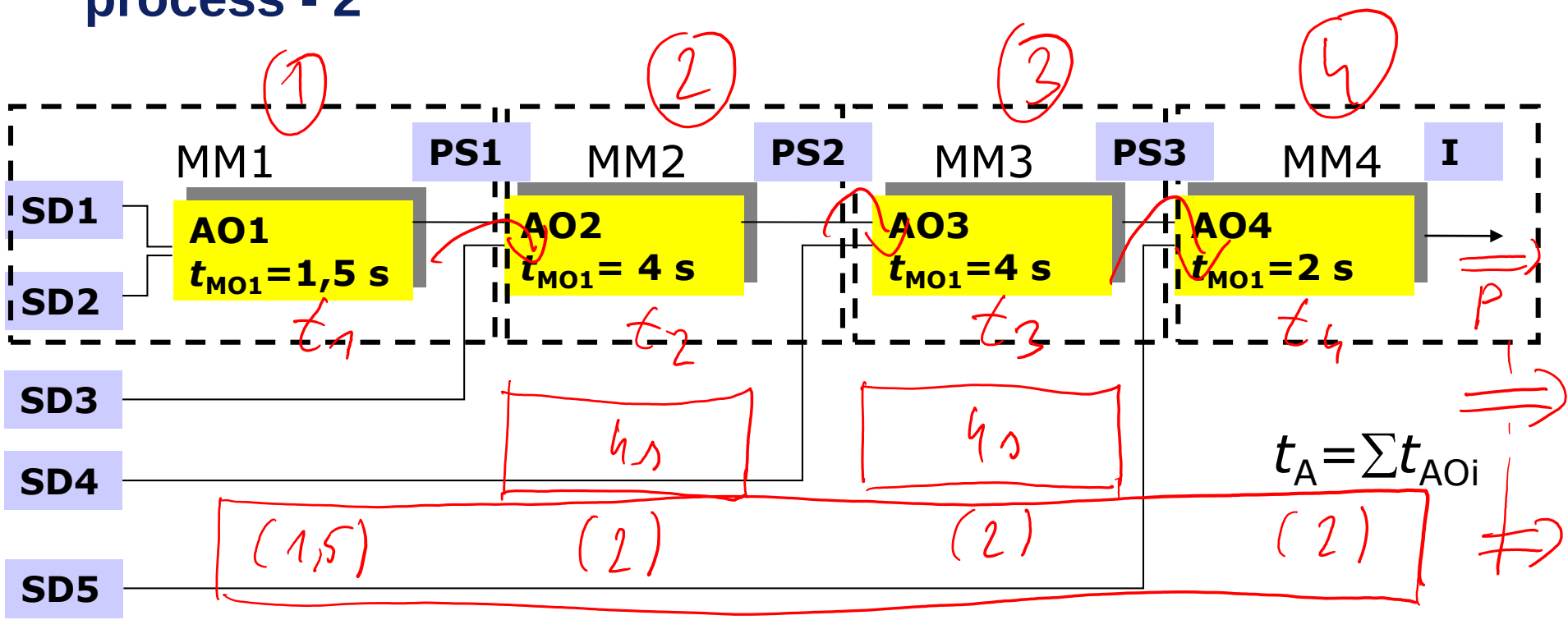
$t_A=\sum t_{AOi}$ = 1,5 + 4 + 4 + 2 = 11,5 s * total time

* **Assembly cycle time: time in which the product is assembled - in this case 11.5 s**

(one assembly station)

IMPORTANT

Structure, total time and cycle time of the assembly process - 2



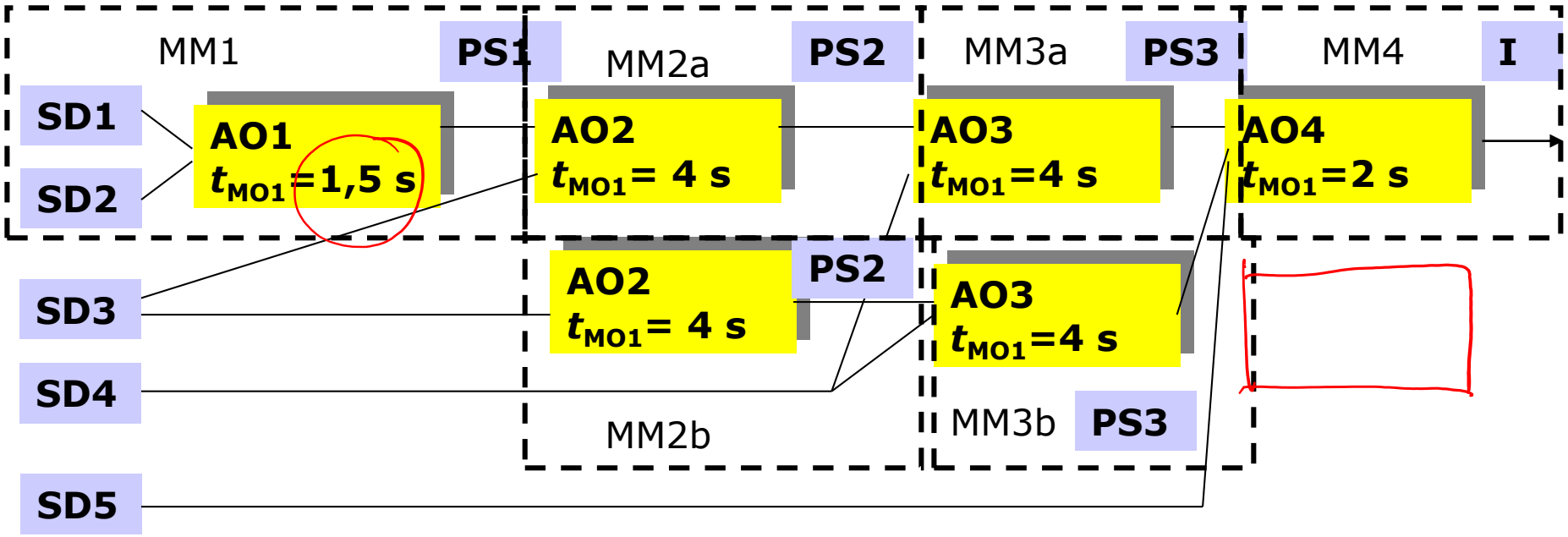
$t_A=\Sigma t_{AOi}$ = 1,5 + 4 + 4 + 2 = 11,5 s

Assembly cycle time: time in which the product is assembled - in this case 4 s

(multiple assembly stations)

IMPORTANT

Decreasing the cycle time of the assembly process



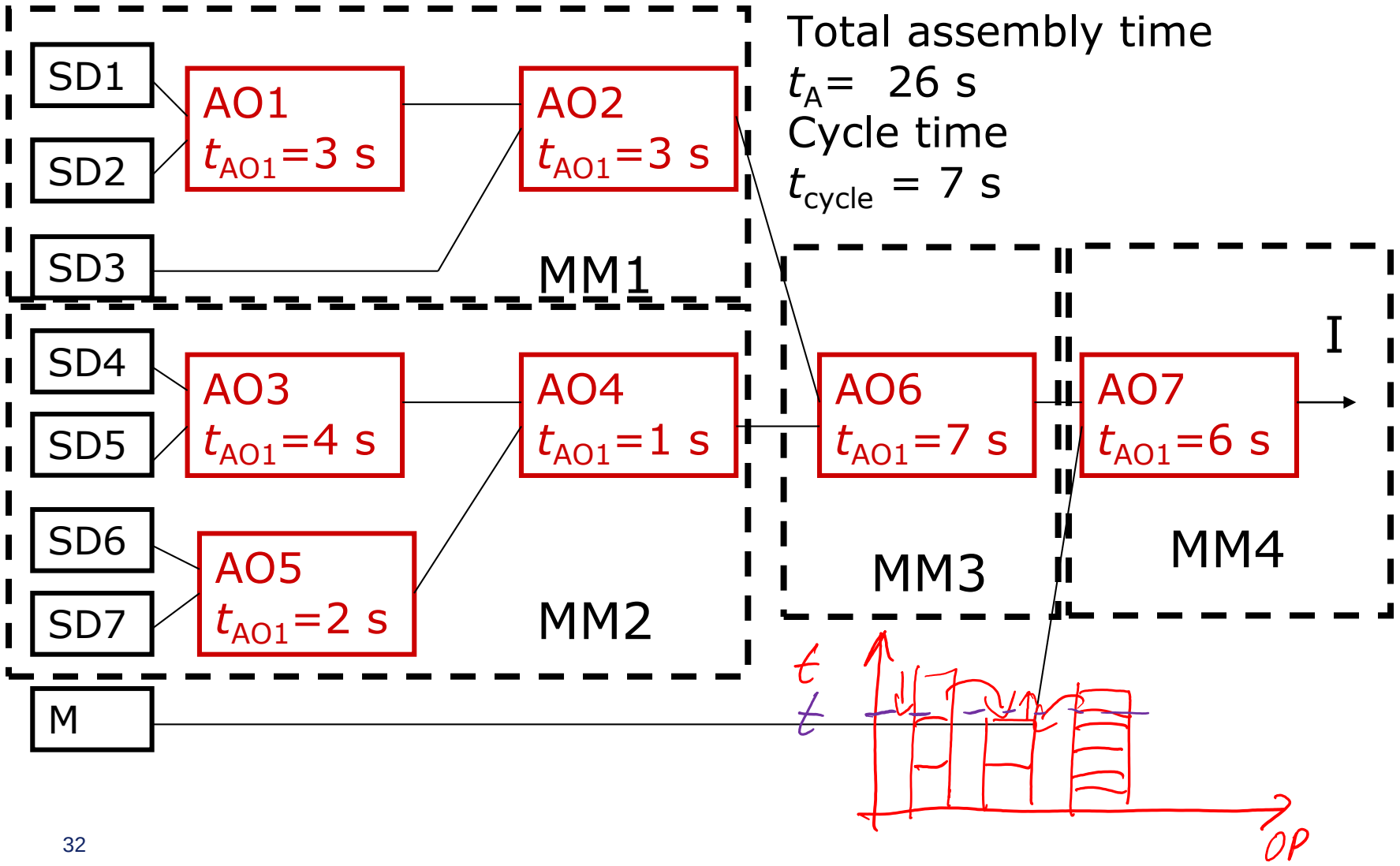
$$t_A = \sum t_{AOi} = 1{,}5 + 4 + 4 + 2 = 11{,}5 \text{ s}$$

Assembly cycle time: time in which the product is assembled - in this case 2 s

(implementation of parallel assembly stations)

IMPORTANT

Combining of assembly operations - Balancing the assembly process



IMPORTANT

The time of the assembly operation

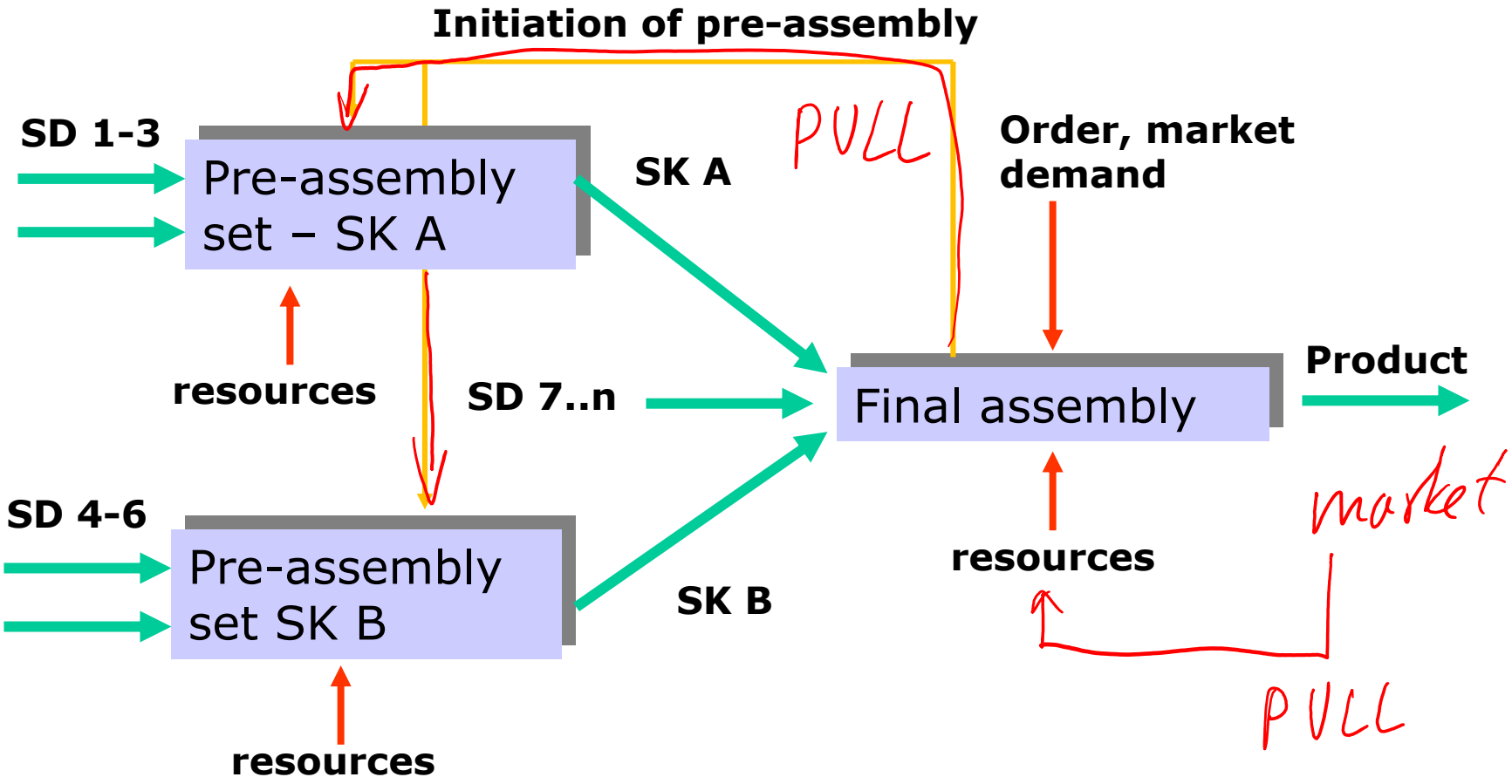
How we can define the time

- The time of the assembly operation is calculated on the basis of the duration of the individual motions of the duty cycle.
- The assembly time is directly related to the assembly device, to the type of assembly operation and working movements of the selected assembly unit or to manual assembly with the movements of the worker.

Different methods are used to determine the time of the assembly operation:

- Intuitive method – the planner's experience in planning similar cases
- Database based on previously recorded measurements and solutions
- Calculation of manual assembly times by methods Work Factor, MTM (Methods-Time Measurement)
- Time calculation of automated systems based on known stroke lengths and velocities.

Dividing (distributing) the assembly process into final assembly and pre-assembly



IMPORTANT

Reasons for dividing (distributing) the assembly process into final assembly and pre-assembly

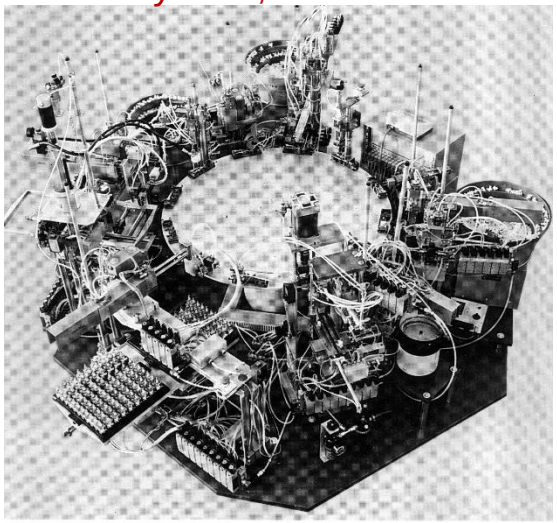
- number of components,
- branched multi-level product structure
- possibility of automation of subassemblies,
- required number of products (decreasing the cycle time),
- variant products, modular construction,
- manufacturing and assembly technology,
- control and testing,
- reliability and availability,
- space,
- outsourcing of pre-assembly to suppliers,
- costs, etc.

Modes of assembly processes

Manual assembly, flexible cells with configuration capabilities.

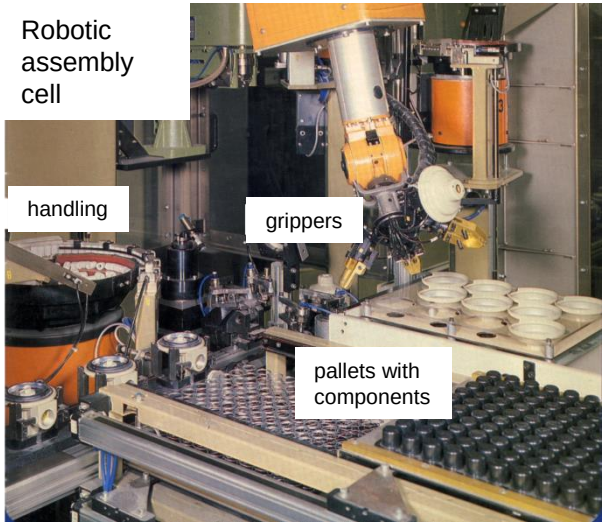
Automated line, automated transport, manual assembly work places

Dedicated automatic assembly cells, machines



Dedicated automatic assembly lines

Robotic assembly cell



Assembly activities