

## Informática Industrial 2022/23

# MES

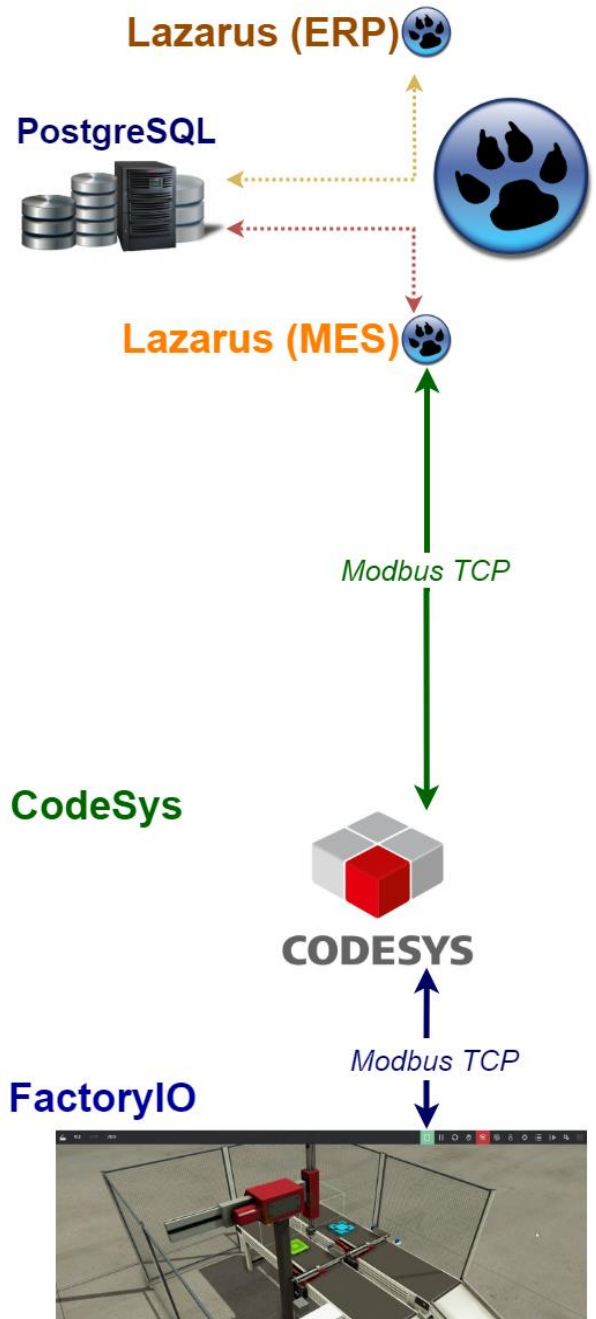
Andry Pinto, José Faria

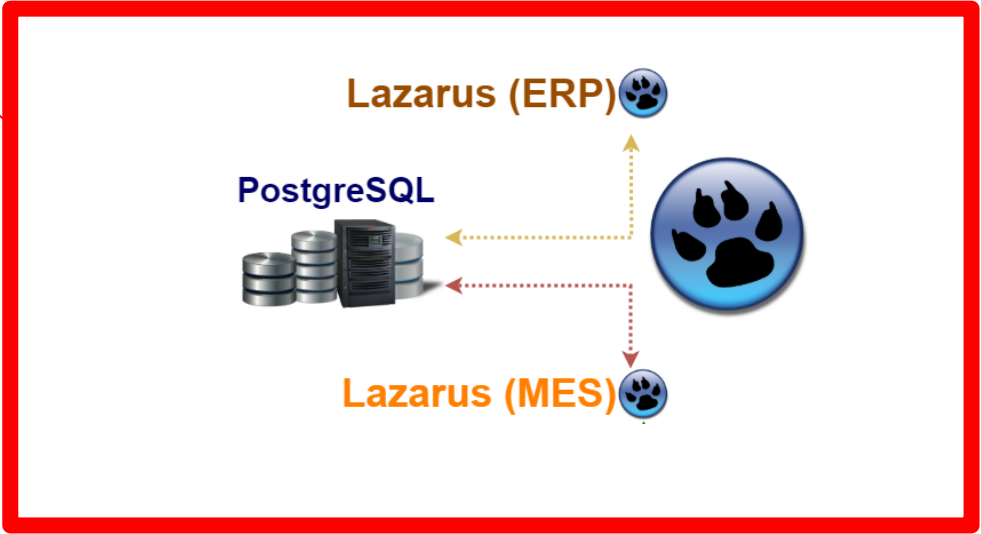
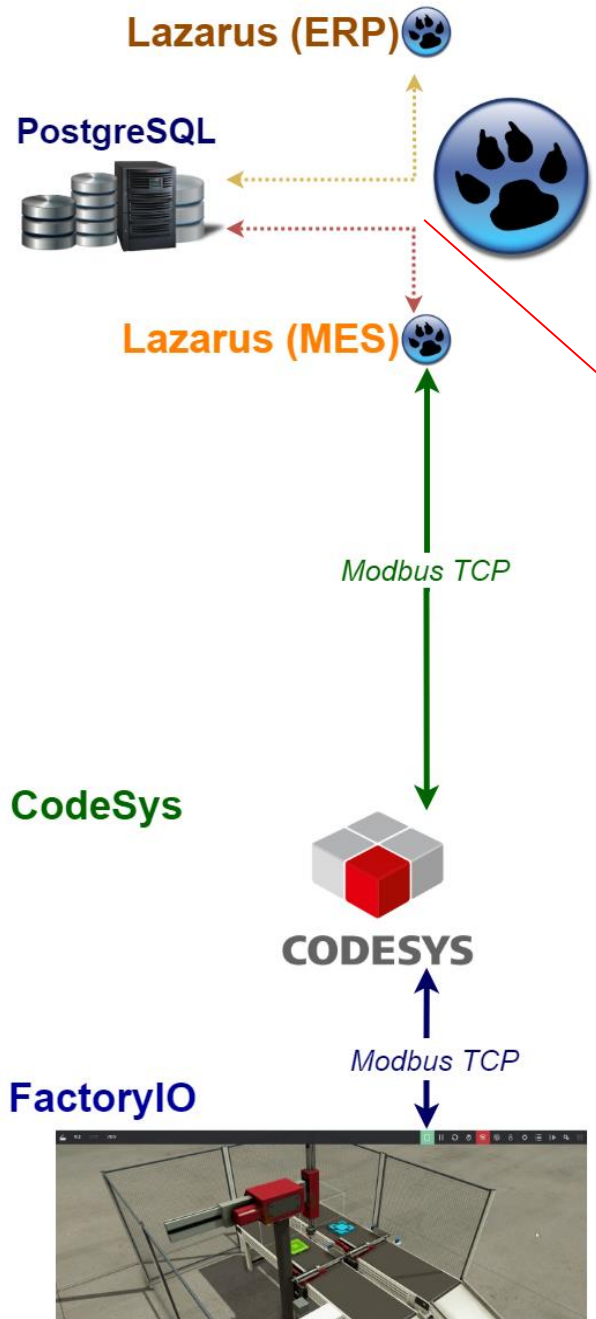
# Summary

1. Introduction
2. Factory Operation and Restrictions
3. Scheduler
4. Implementation

# 1. Introduction

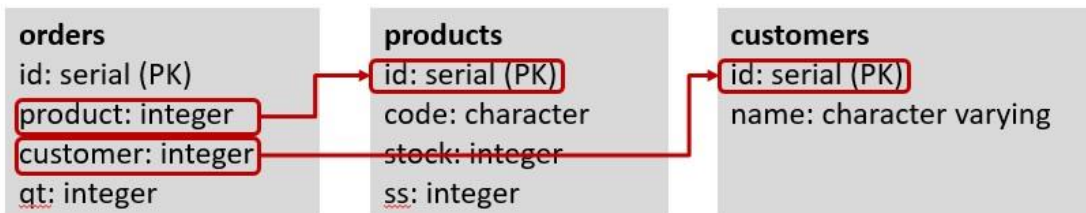






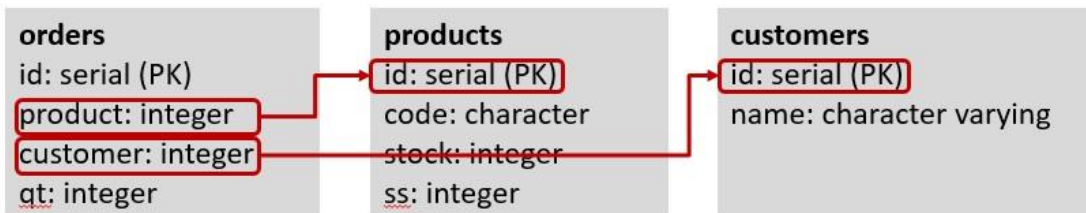
# Enterprise Resource Planning (ERP)

- Receipt of Orders
- Customer Management
- Product/stock management
- Production planning
- Delivery/Expedition planning
- Purchases from suppliers



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Let's assume the  
Production  
Planning!





# Manufacturing execution system (MES)

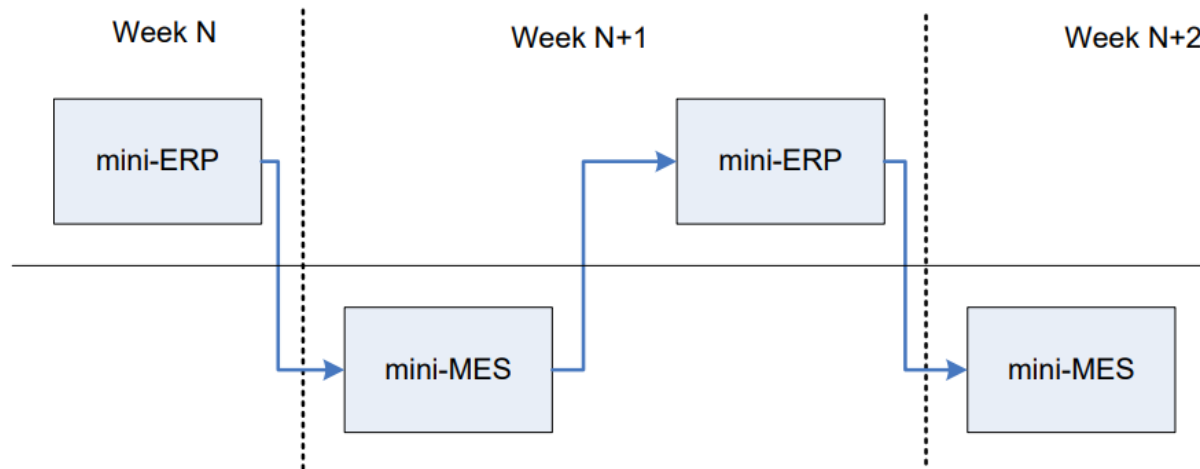
- Production planning
- Controlling and monitoring production
- Interaction with equipments

...



# Manufacturing execution system (MES)

- The MES (mini-MES) starts its execution after the ERP (mini-ERP) finishes the planning for the next week.



1. At the beginning of each week, the MES receives the orders planned in the previous week by the ERP.
2. It starts its execution until it finishes all the orders.
3. When all orders are finalized, it send the results to the ERP and stop their execution.
4. The ERP starts planning the next week.

# Manufacturing execution system (MES)

- Assuming the **Production Plan**, **Expedition Plan** and **Purchase Plan**:

## Otimize the production

- Schedulability Analysis:

Optimization goals	Restrictions
<i>Minimize</i> the <b>time</b> necessary to complete the orders	Physical resources (ex. machines, warehouse, other equipment's, etc.): <ul style="list-style-type: none"><li>• Setup time, capacity, sharing, availability, maximum working hours, etc</li></ul>
<i>Maximize</i> <b>productivity</b>	Plant layout
<i>Minimize</i> production <b>costs</b>	Time required to: produce, receive, ship a part.
<i>Minimize</i> warehouse <b>stock</b>	Production sequence
...	Human resources

# Manufacturing execution system (MES)

- The **objective** is:
- To define an **operation sequence** for the production:

- inbound,
- production,
- expedition.



- **Knowing:**

- The performance indicators
- The restrictions

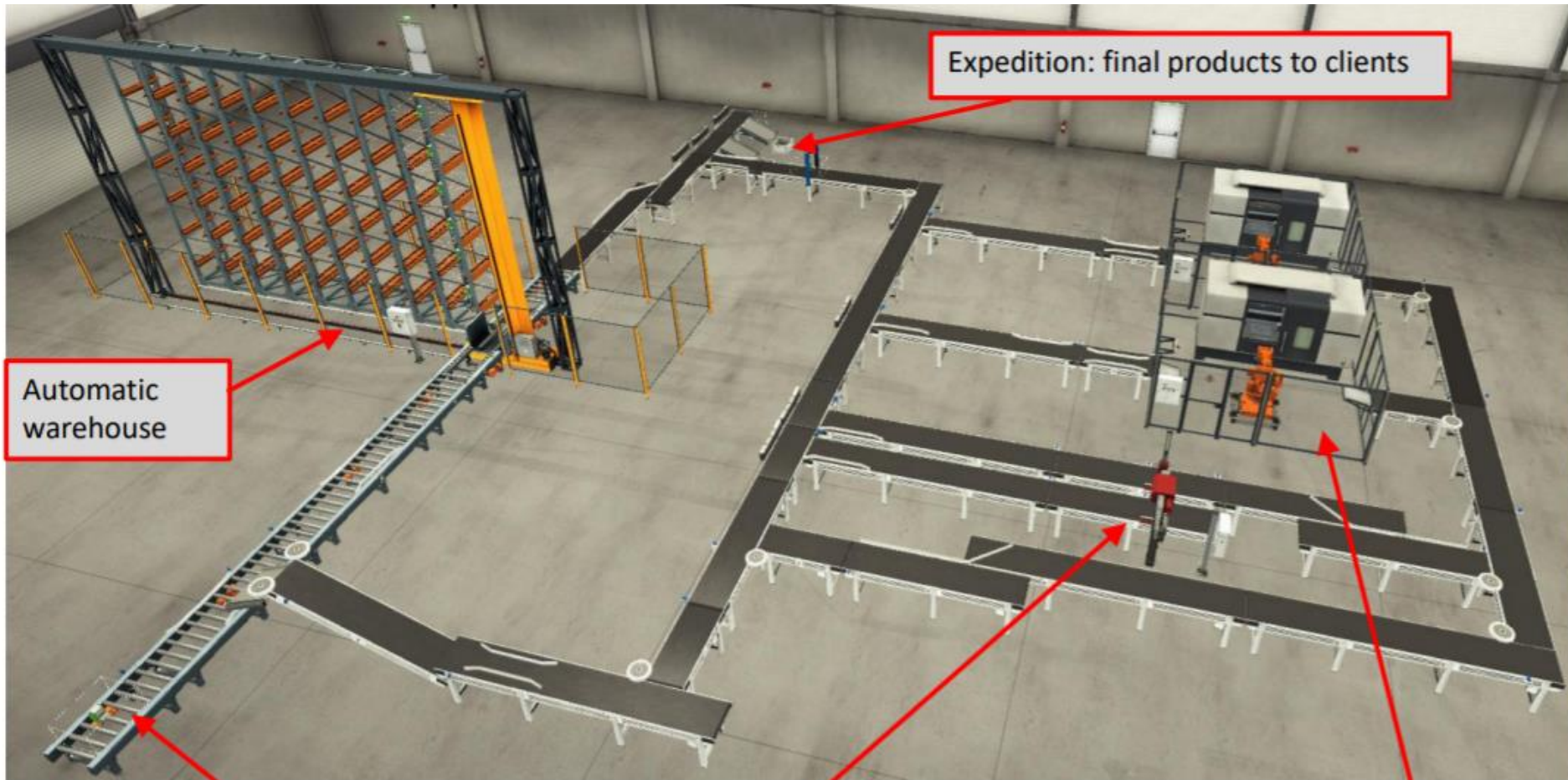
# Manufacturing execution system (MES)



- The main responsibilities of the MES:
- **Scheduling orders:** define the **sequence of orders**, received from enterprise resource planning (ERP), to **meet the production goals**, making **optimal use of local resources**.
- **Dispatching orders:** decide which order must be **executed at each moment** and adjust orders to unanticipated conditions.
- **Execution of orders:** inform other systems about the **progress of the orders** and performing checks on resources.
- **Collection of data:** collection, storage and exchange of process data, equipment status, material information and production logs.

## **2. Factory Operation and Restrictions**

# Factory Layout



Automatic warehouse

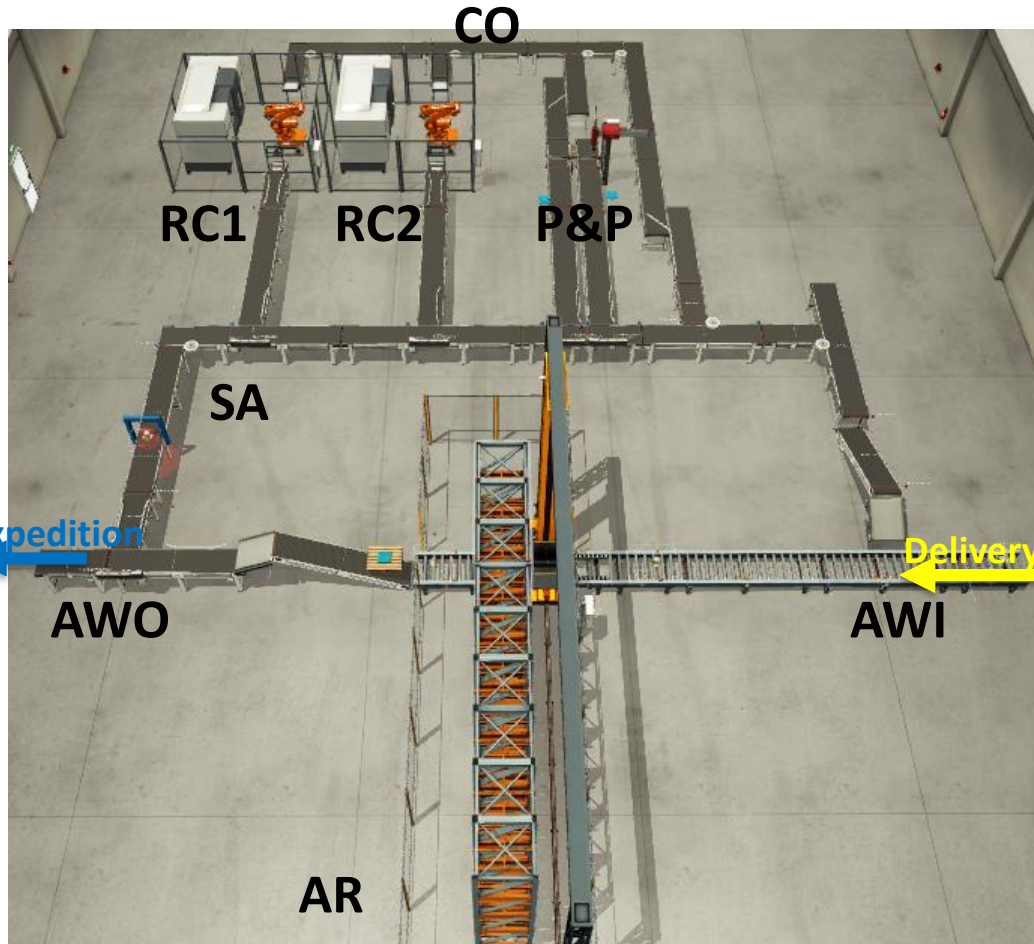
Expedition: final products to clients

Inbound: raw materials from suppliers

2-axis Pick & Place: part assembly

Machining Centers : production

# Factory Layout

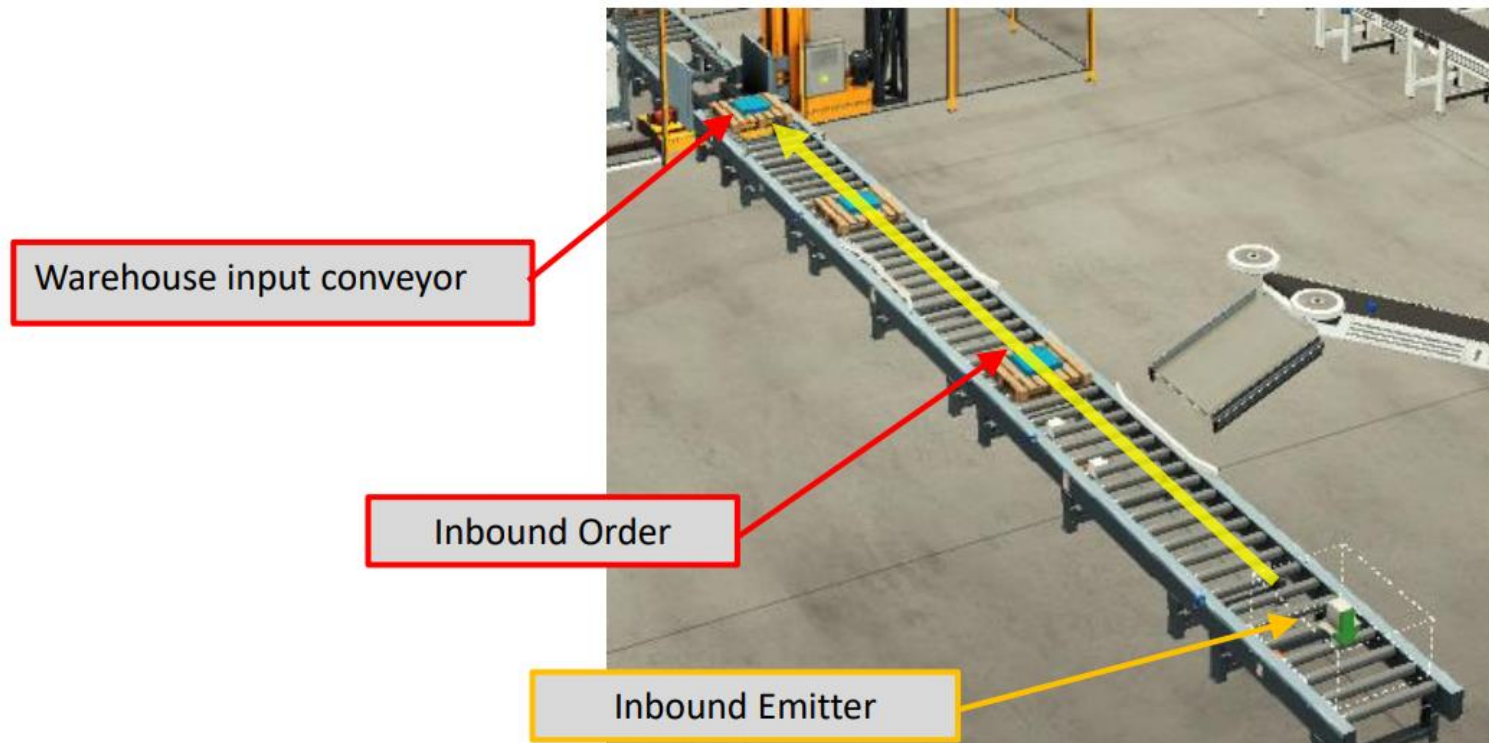


- AR** – Automatic Warehouse
- AWI** – Warehouse Input
- AWO** – Warehouse Output
- SA** – Sorting System
- RC1** – Robot Cell (Bases)
- RC2** – Robot Cell (Lids)
- P&P** – Pick and Place
- CO** – Conveyor Output System



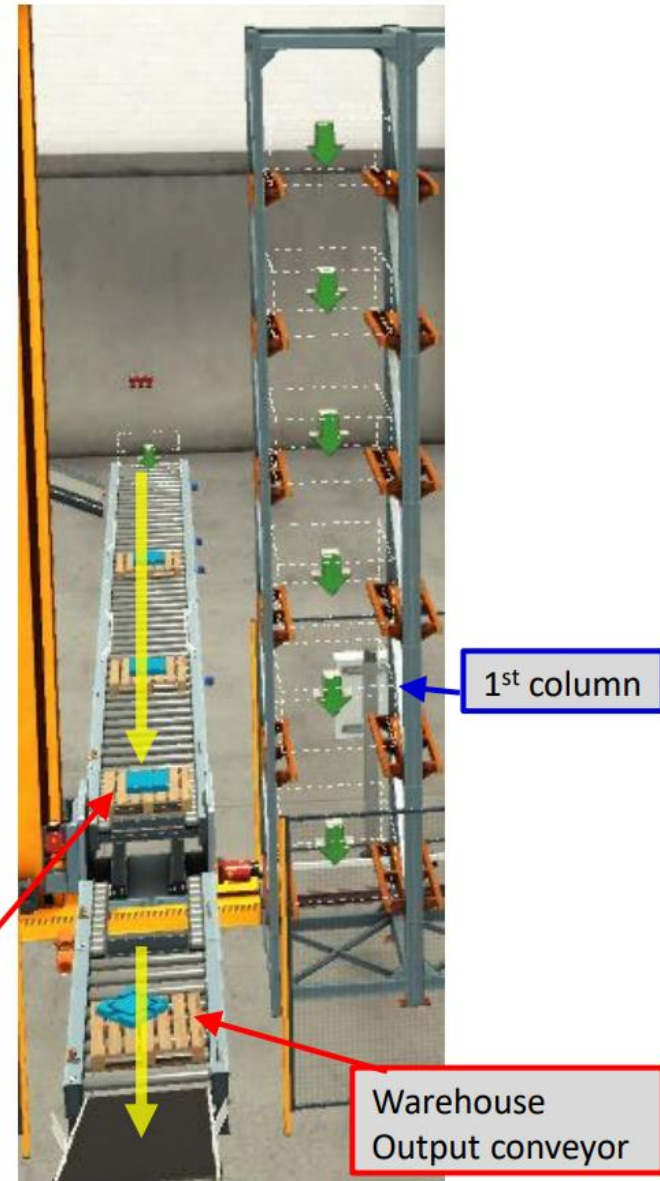
# Inbound area

- It can only receive **1 part at a time** (raw material), i.e. an Inbound order.
- After issuing the order, it takes a few seconds for the order to start (to 'appear' in the factory).
- Inbound orders are transported automatically to the Warehouse Input conveyor.
- Several parts can be queued at the Inbound zone.



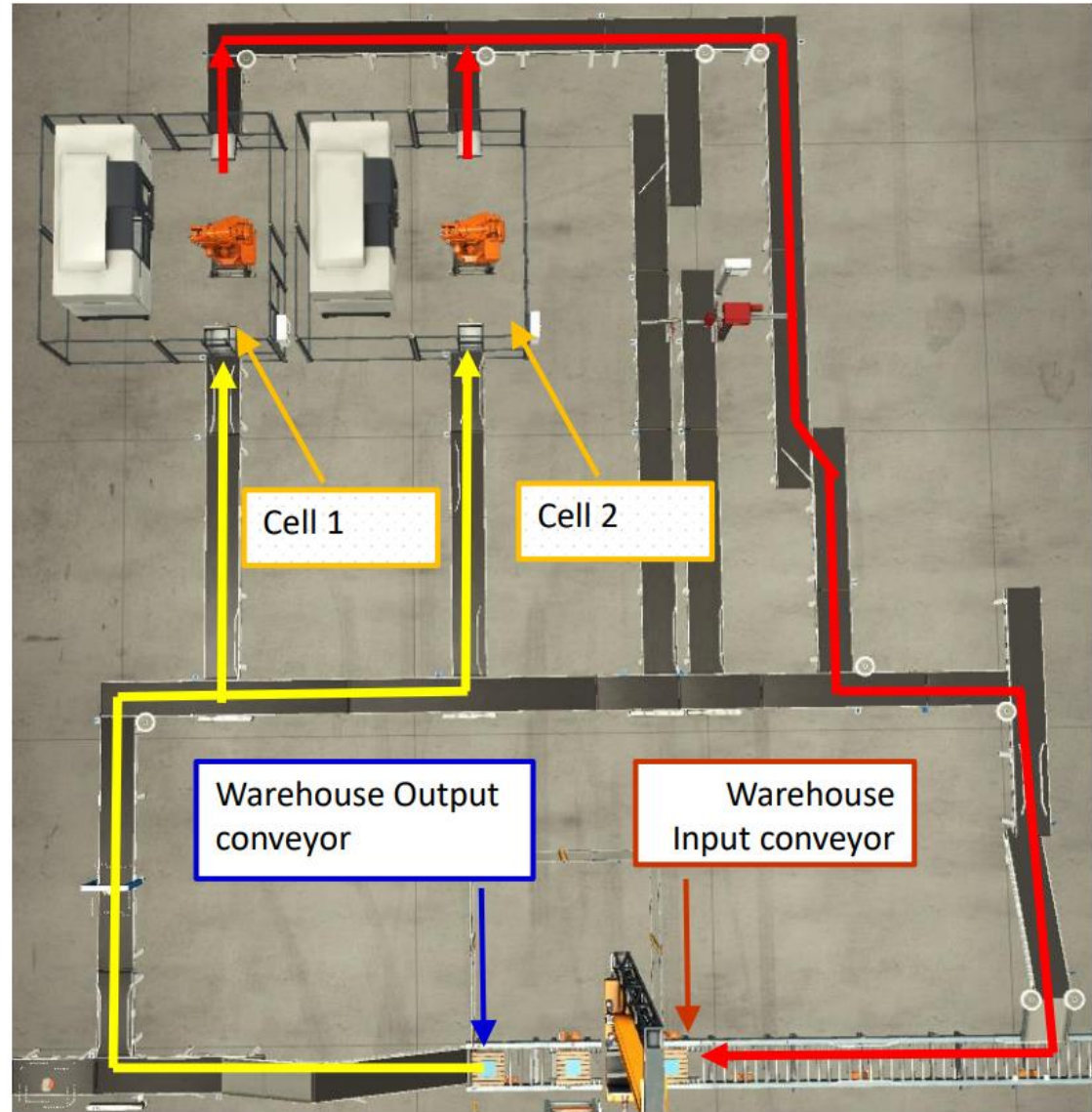
# Warehouse

- It has a capacity of 54 positions.
- It can only execute **1 operation at a time**: Load Part, Unload Part, etc.,
- While executing an operation, it is unavailable for other requests.
- The first column (6 positions) can be initialized with different parts (raw materials or final products) without using Inbound orders (stock initialization).
- Parts arrive at the Input conveyor and leave by the Output conveyor.
- Several parts can be queued at the Inbound zone.
- Only 1 part can be on the Output conveyor at a time.



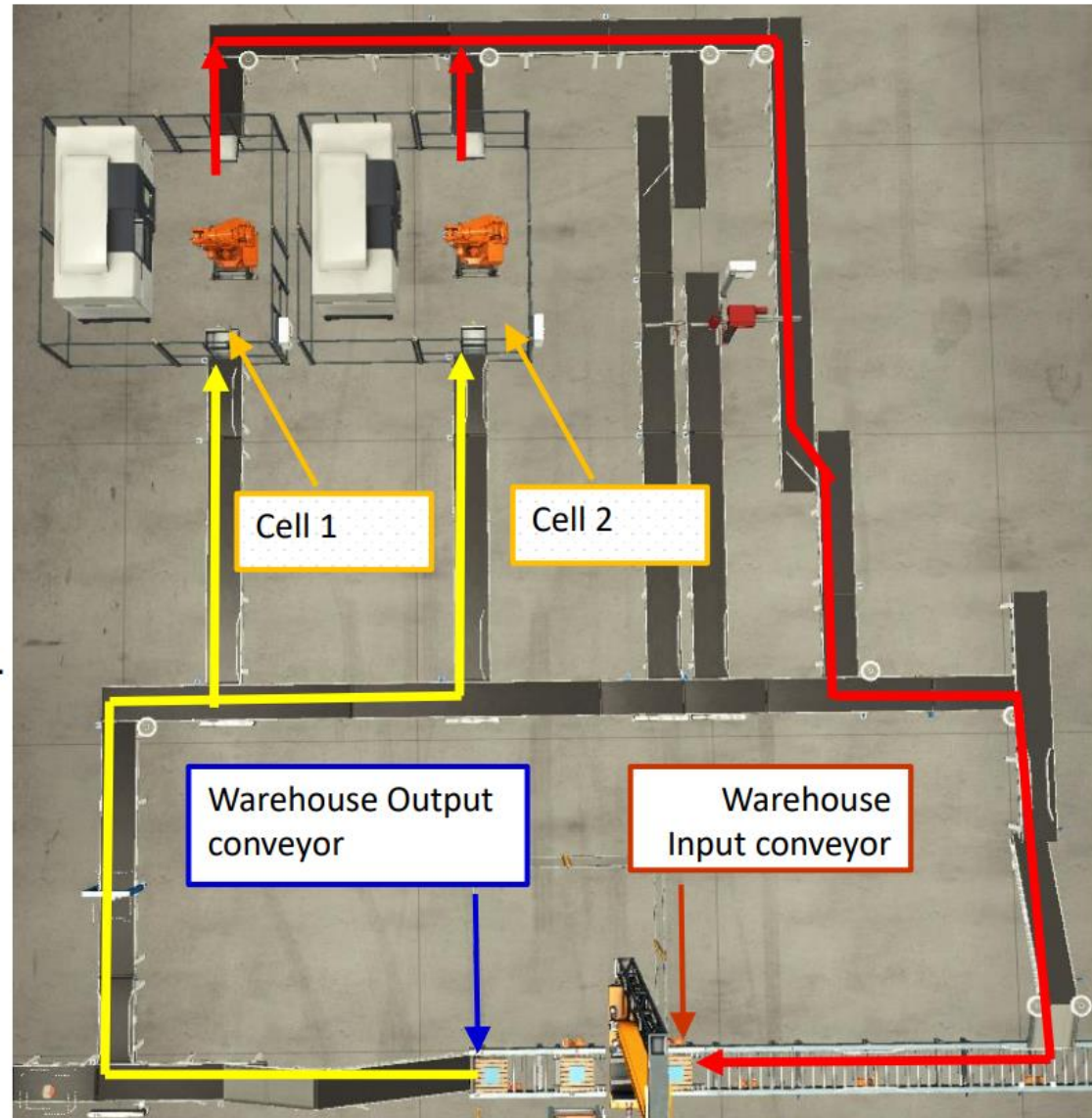
## Manufacturing area – parts flow

- Final products are manufactured from raw materials in Cell 1 and Cell 2.
- Raw materials leave from the Warehouse Output conveyor.
- Final products leave the Cell from the Cell Output conveyor and are transported to the Warehouse Input conveyor.
- An automatic system (the PLC) routes raw materials from the Warehouse to the Cells and final products from the Cells to the Warehouse.



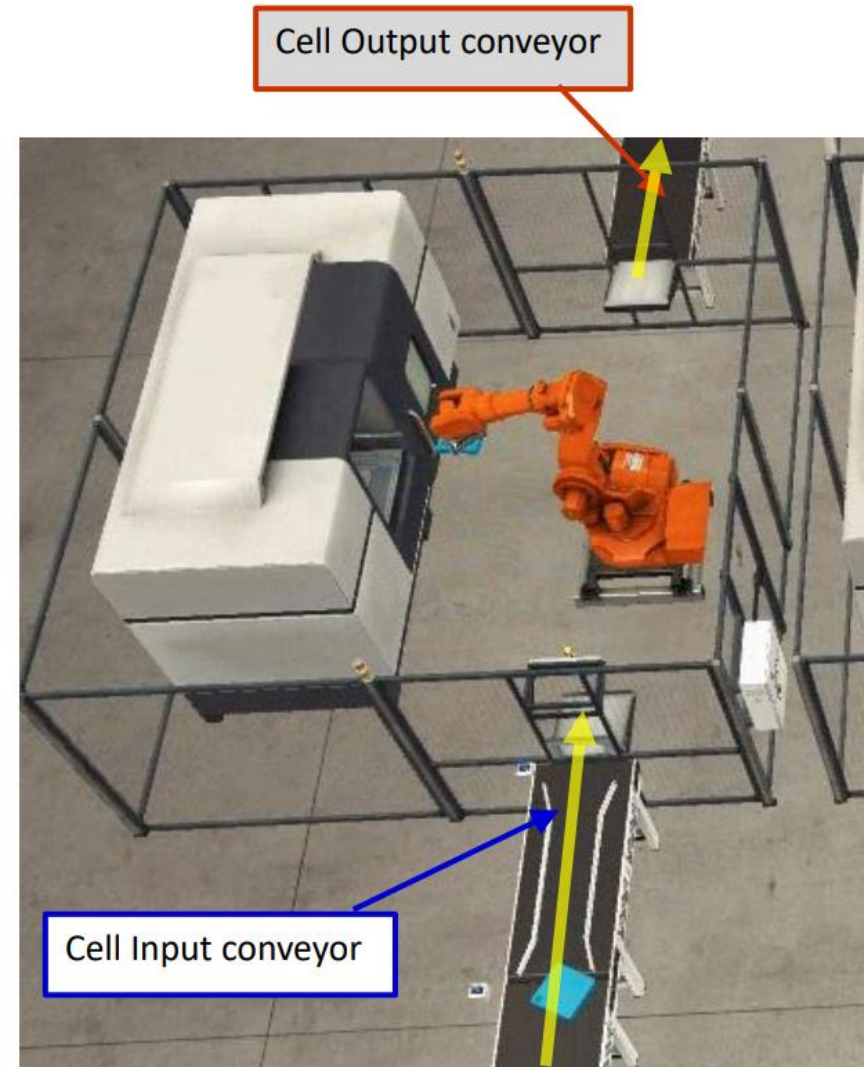
## Manufacturing area – parts flow

- At any time, there is only 1 part on each conveyer.
- In each conveyer, parts cannot surpass others.
- The routing system ensures that there are no collisions between parts.
- A part can only 'enter' into a conveyer if that conveyer is free. Otherwise, it waits at the entrance. When the conveyer becomes free, the part starts moving to the destination.
- The control system avoids 'collisions' of parts in the Inbound area (note that this area receives raw materials and final products).



# Manufacturing area – Cells

- A Cell (Machining Center) can only produce **1 type of final product**.
  - Cell 1 : **Bases**
  - Cell 2 : **Lids**
- Each Cell has different setup times:
  - Cell 1
    - » Production time : 5 seconds
    - » Changing tool : 10 seconds
  - Cell 2
    - » Production time : 3 seconds
    - » Changing tool : 10 seconds
- While is producing a final product, a raw material can wait at the Cell Input conveyor.
- Final products leave the Cell by the Cell Output conveyor.



# Part type evolution across the factory

None	0
Blue Raw Material	1
Green Raw Material	2
Metal Raw Material	3
Blue Product Base	4
Green Product Base	5
Metal Product Base	6
Blue Product Lid	7
Green Product Lid	8
Metal Product Lid	9

## RC1 – Robot Cell (Bases)

Blue Raw Material	1
Green Raw Material	2
Metal Raw Material	3



Production Time: 5 seconds  
Changing tool: 10 seconds



Blue Product Base	4
Green Product Base	5
Metal Product Base	6

## RC2 – Robot Cell (Lids)

Blue Raw Material	1
Green Raw Material	2
Metal Raw Material	3



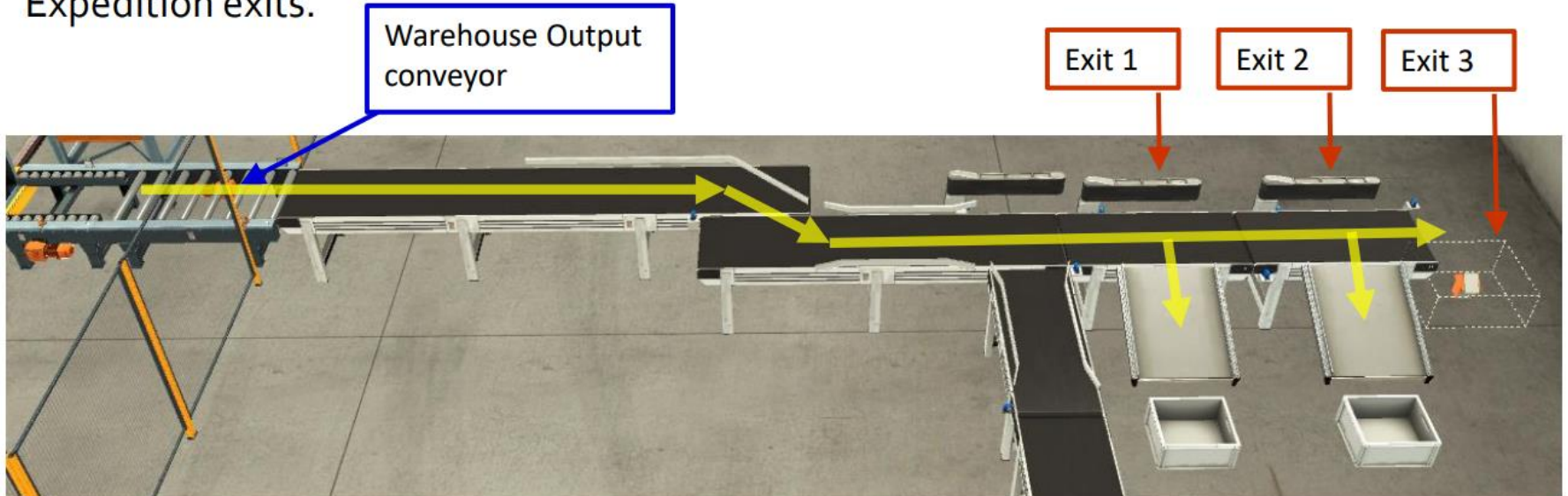
Production Time: 3 seconds  
Changing tool: 10 seconds



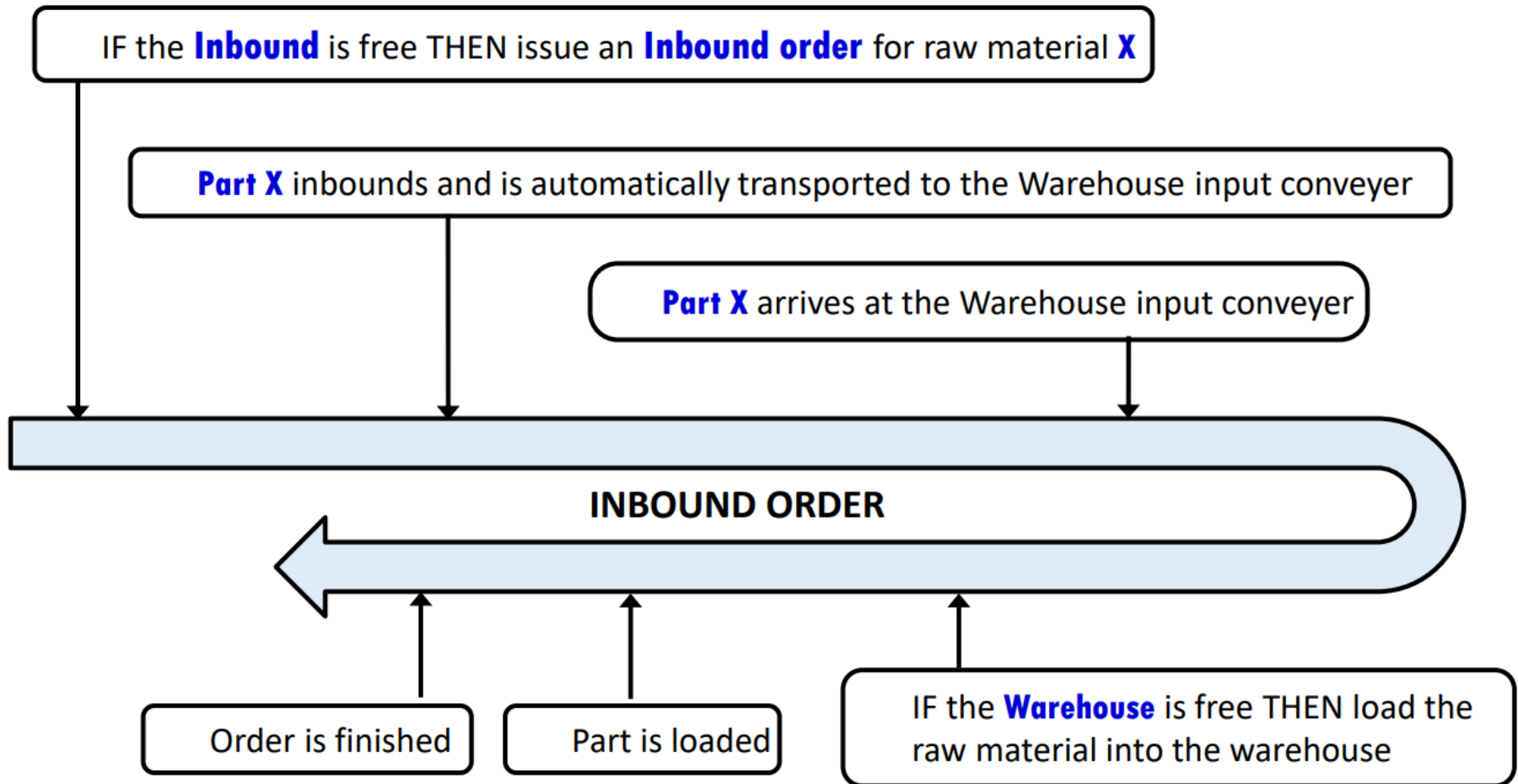
Blue Product Lid	7
Green Product Lid	8
Metal Product Lid	9

# Expedition area

- There are 3 Expedition exits:
  - Exit 1: for **Bases**
  - Exit 2: for **Lids**
  - Exit 3: parts with defects
- Final products for Expedition leave from the Warehouse Output conveyor
- An automatic system routes final products from the Warehouse Output conveyor to the Expedition exits.

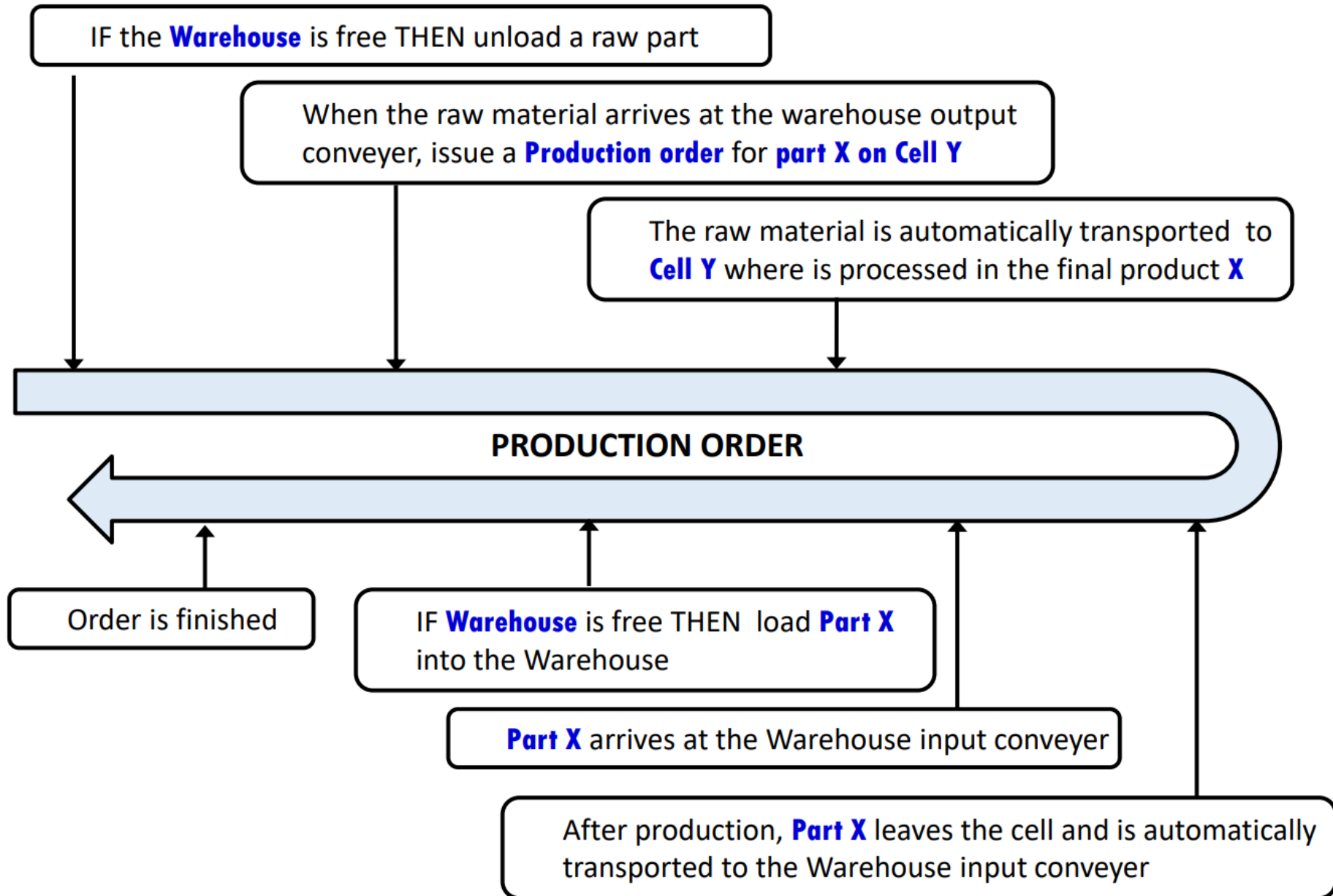


## Inbound order flow

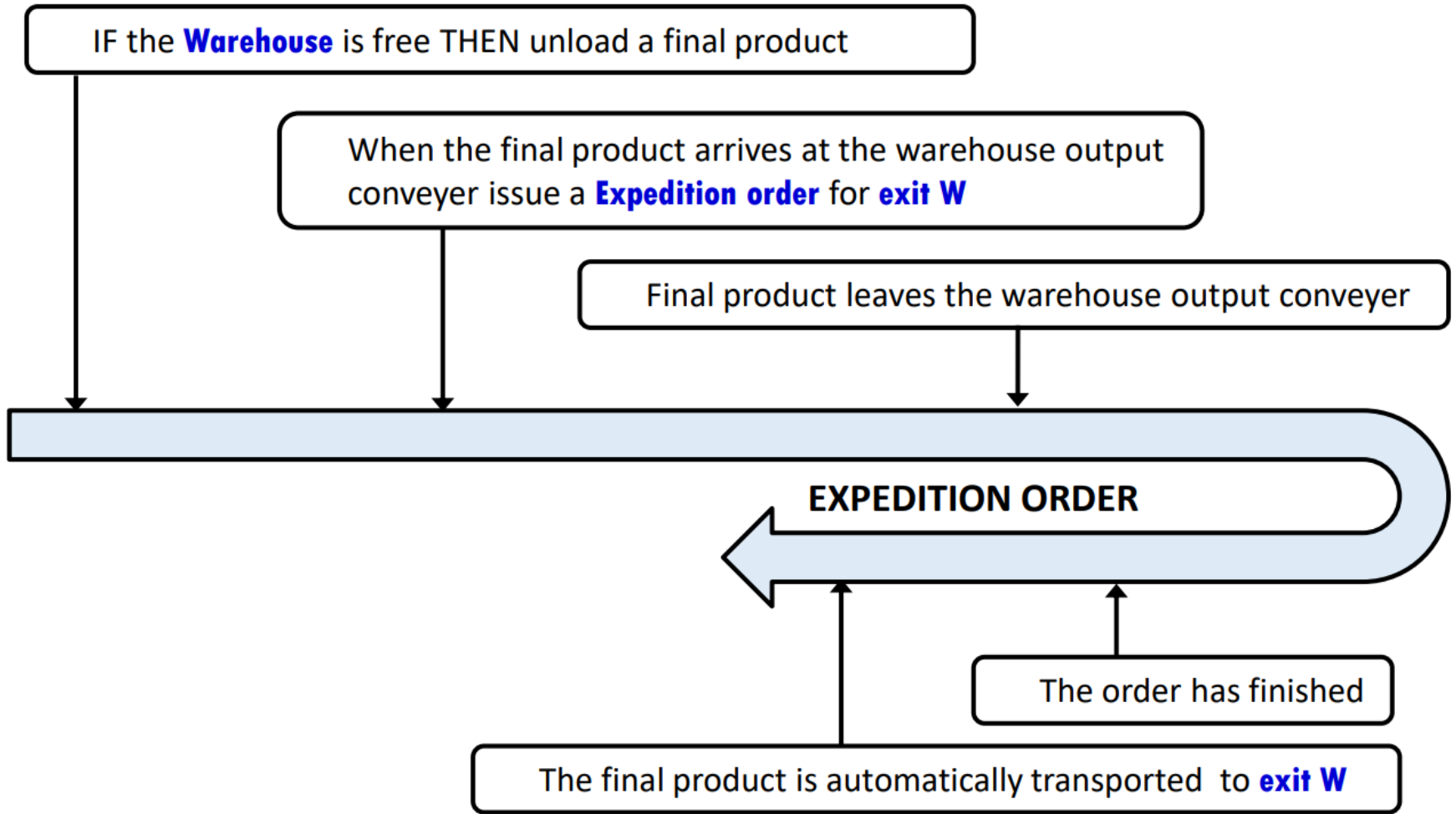




# Production order flow



# Expedition order flow



# 3. Scheduler

# Scheduler



- **Type** of schedulers:
- **Static (offline)**: decide the sequence before the production starts and it is not changed afterwards.
- **Dynamic (online)**: reschedules the production after occurring an event.

The KISS approach is recommended !!

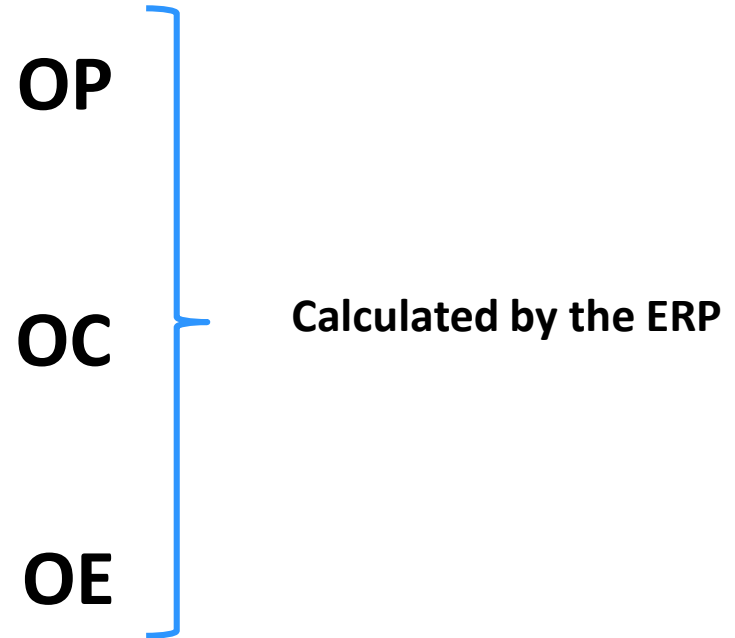
A simple example is ...

# Simple Scheduler

- **Production orders**      **OP**
- **Purchase order**      **OC**
- **Expedition order**      **OE**

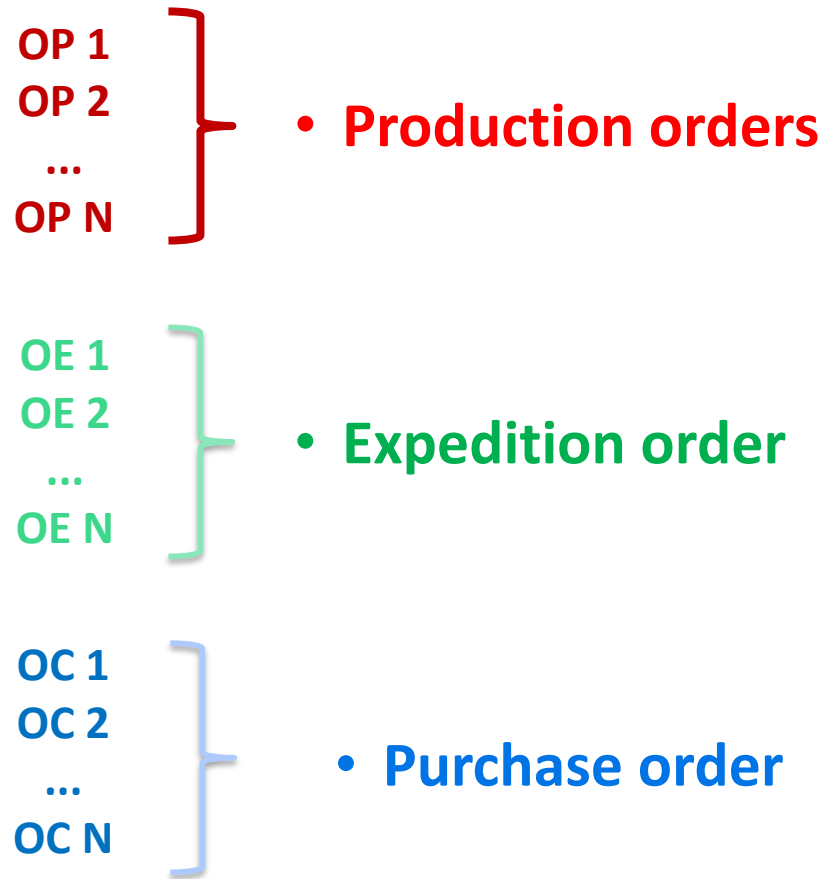
# Simple Scheduler

- **Production orders**
- **Purchase order**
- **Expedition order \***

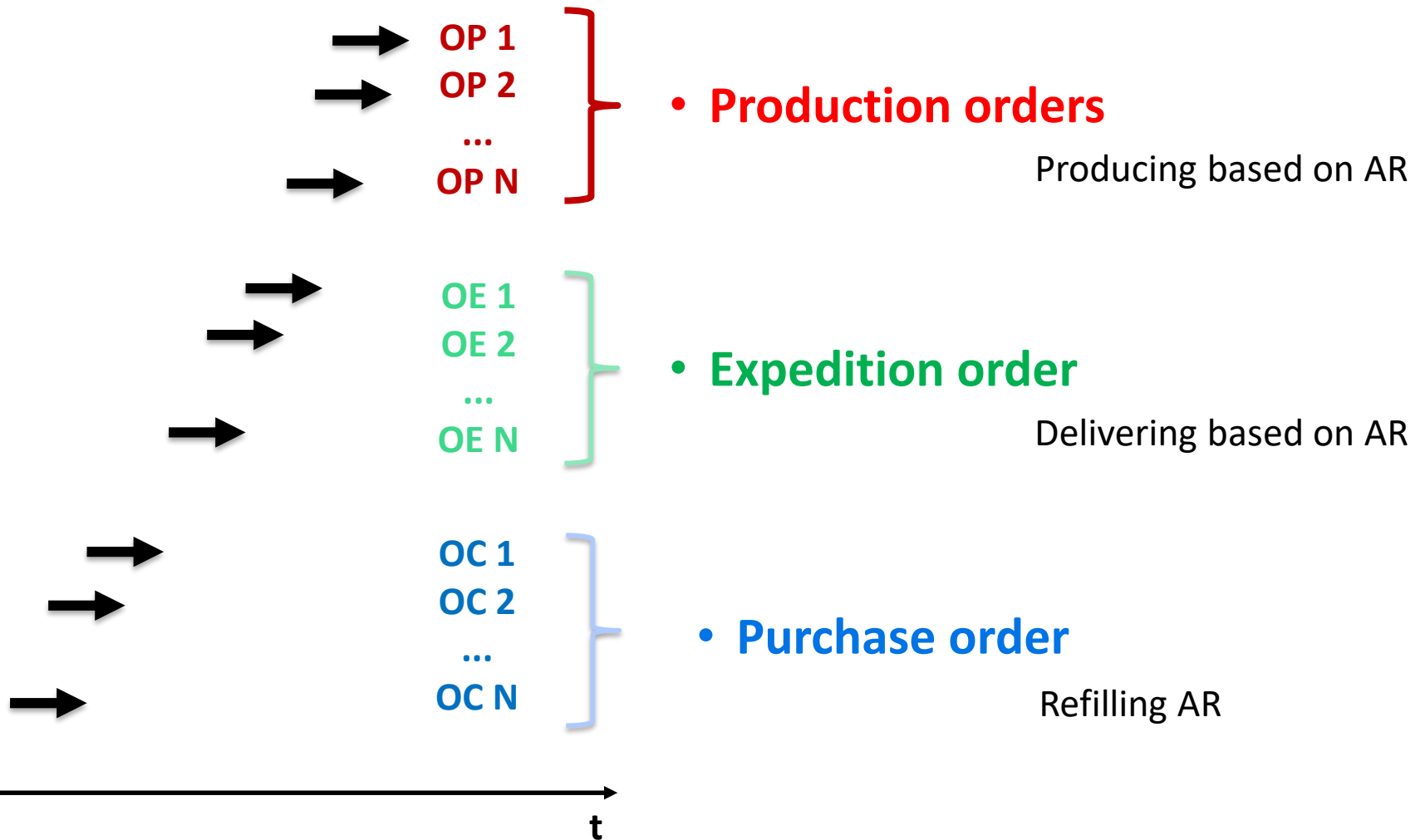


\* Stock that must be delivered to clients

# Simple Scheduler



# Simple Scheduler





# Simple Scheduler

- Expedition order

Type	#Q
BA	2
BV	0
TA	3

- Purchase order

Type	#
MA = BA + TA	2
MV = BV + TV	3

- Production orders

Type	#Q
BA	2
BV	3
TA	0

# Simple Scheduler

- Expedition order

Type	#Q
BA	2
BV	0
TA	3

- Purchase order

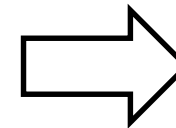
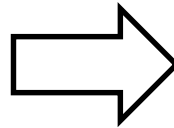
Type	#
MA = BA + TA	2
MV = BV + TV	3

- Production orders

Type	#Q
BA	2
BV	3
TA	0

Sequence generation:

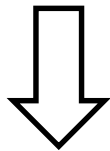
OP 1 (BA)  
OP 2 (BA)  
OP 3 (BV)  
OP 4 (BV)  
OP 5 (BV)  
OE 1 (BA)  
OE 2 (BA)  
OE 3 (TA)  
OE 4 (TA)  
OE 5 (TA)  
OC 1 (MA)  
OC 2 (MA)  
OC 3 (MV)  
OC 4 (MV)  
OC 5 (MV)



Dispatcher

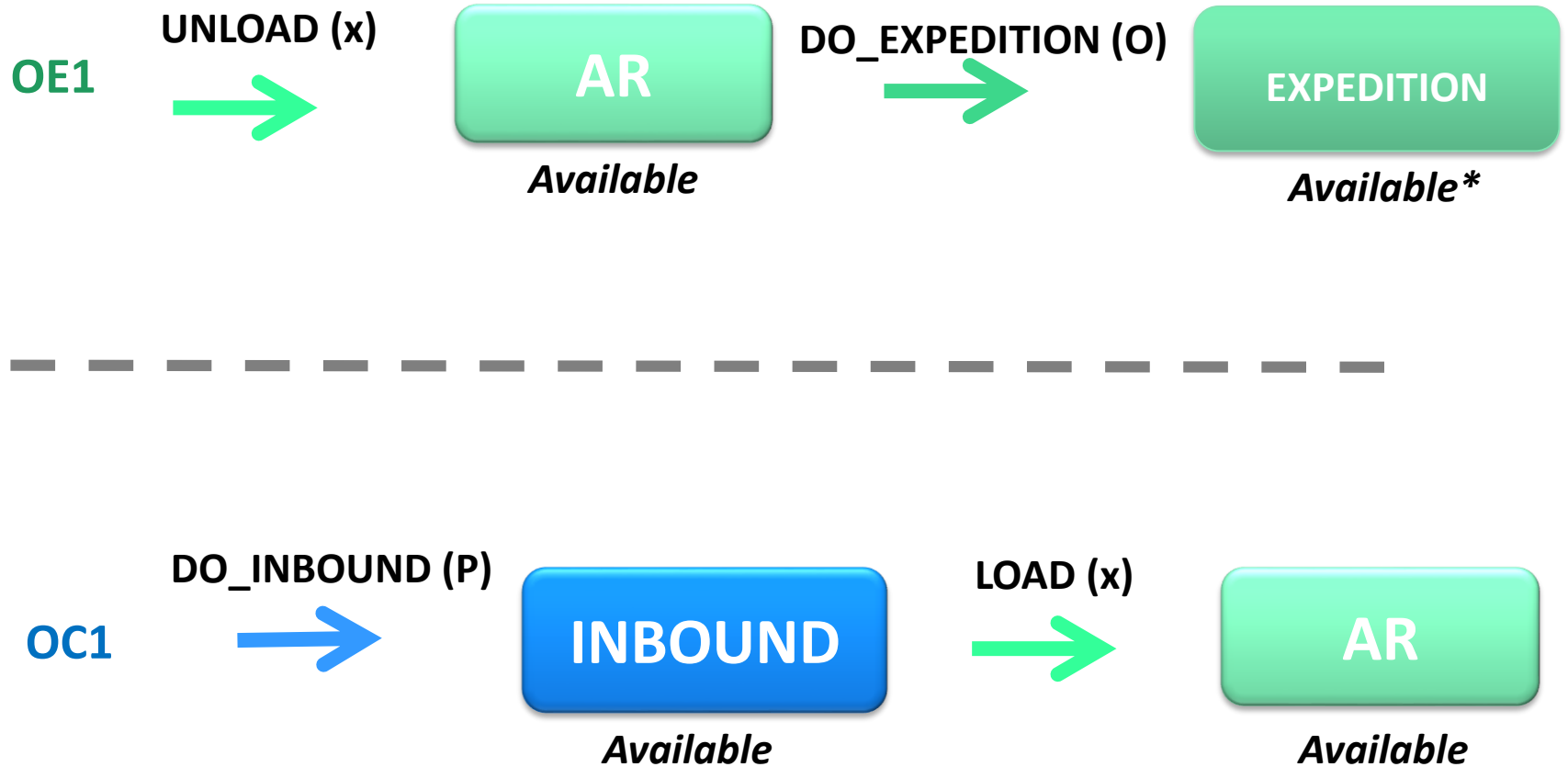
# Dispatcher

- Managing production
  - Number of orders that is being produced
  - Status of each order
  
- Controlling production:
  - Parts localization
  - Availability of AR
  - Availability of RC1 and RC2
  - Availability of Transportation System

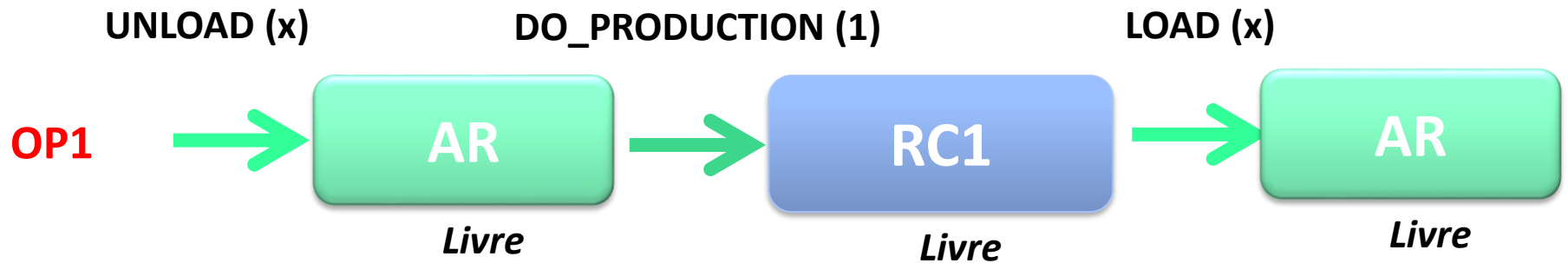


**MODBUS** commands (to PLC)

# Dispatcher - modbus

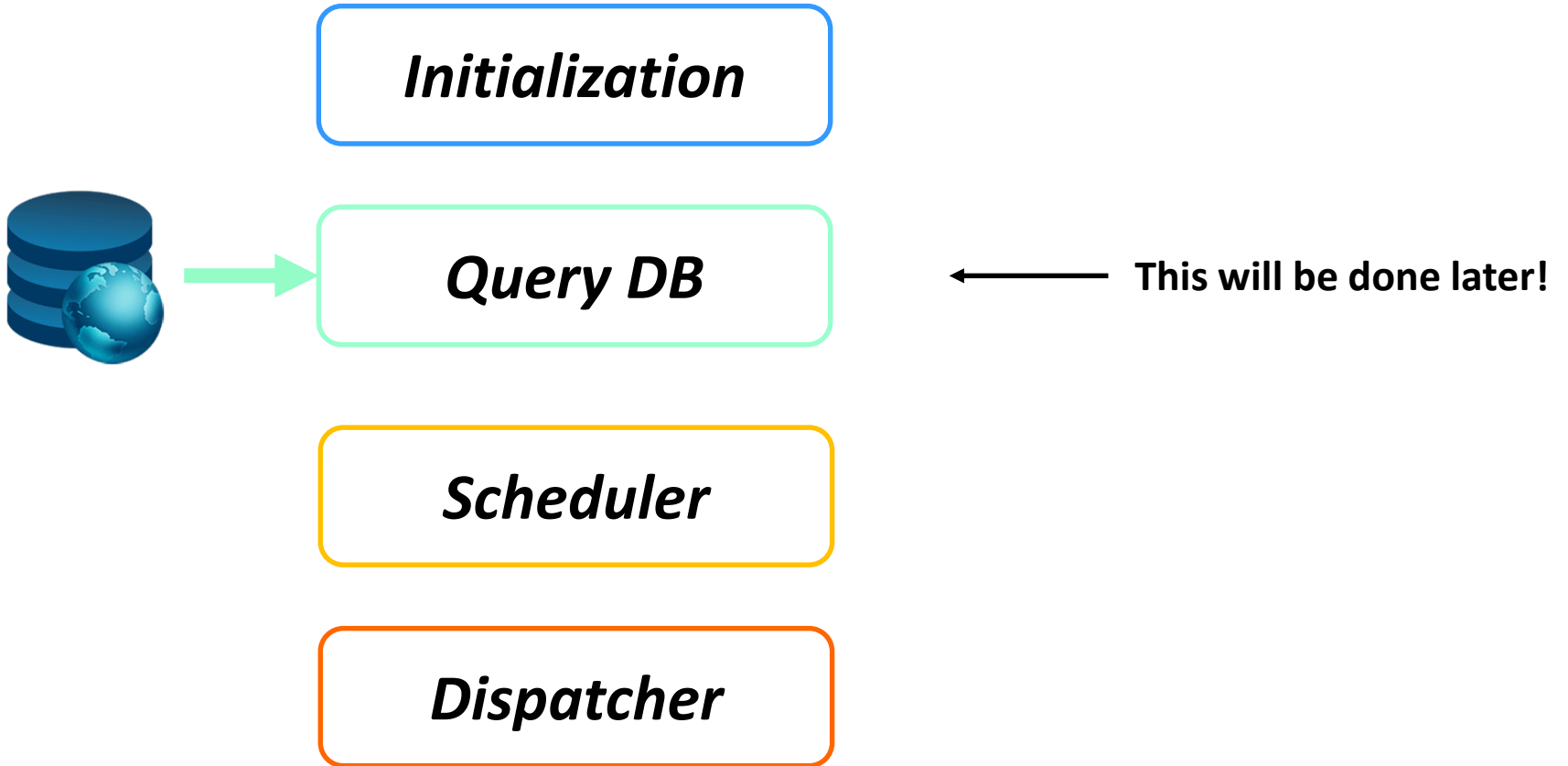


# Dispatcher - modbus

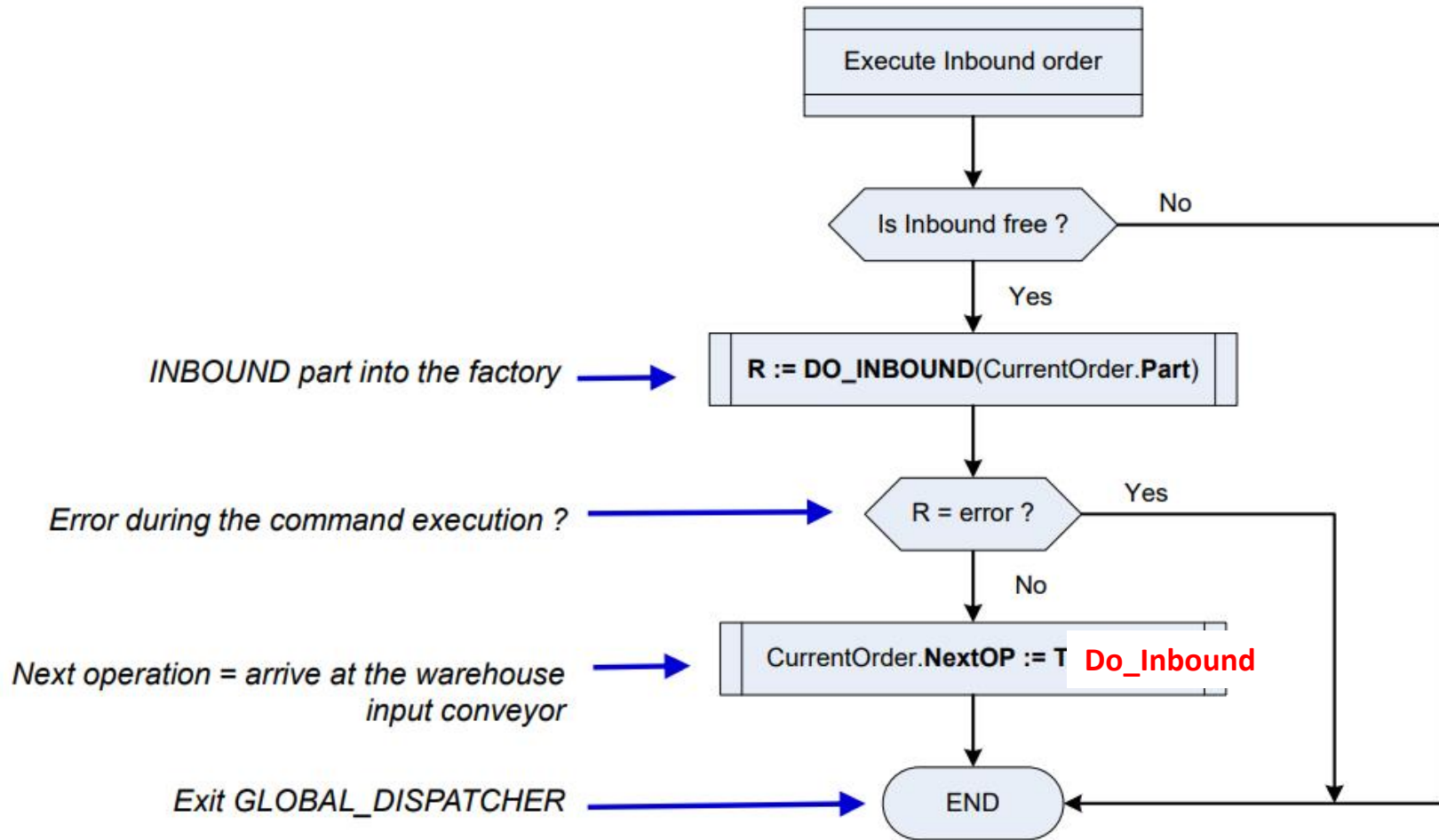


# 4. Implementation

# Dispatcher - modbus

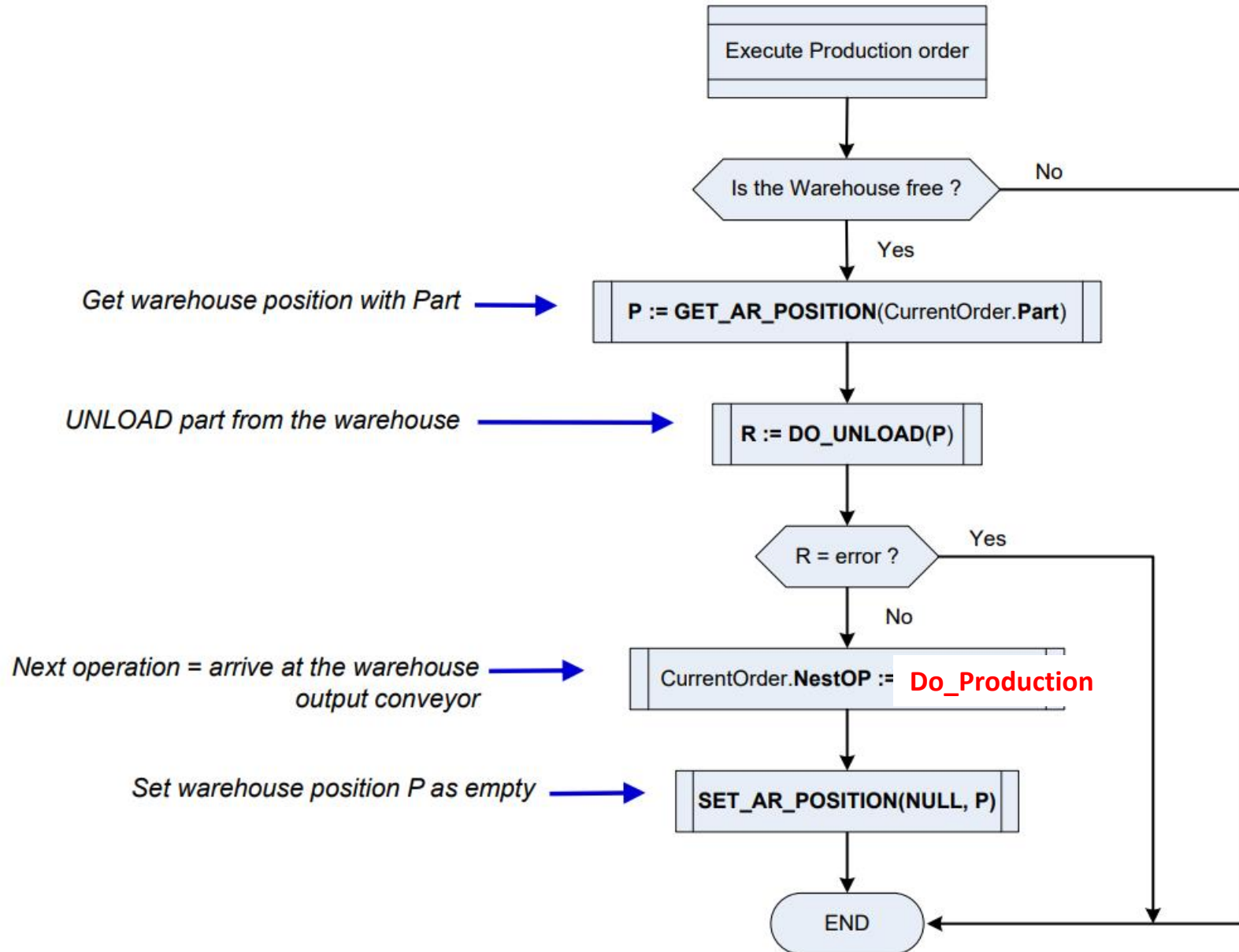


# Dispatcher – Inbound Order

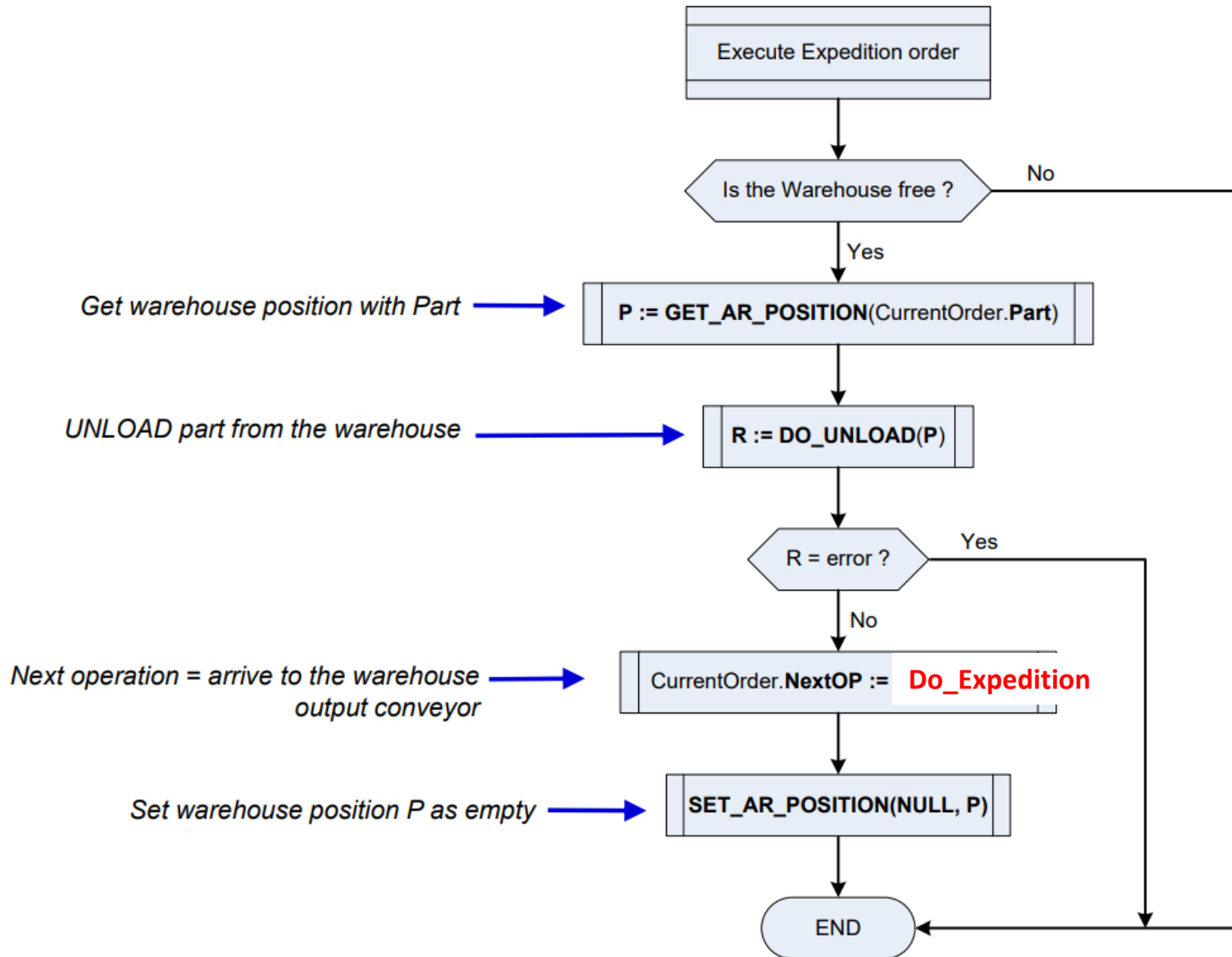




# Dispatcher – Production Order



# Dispatcher – Expedition Order



# Dispatcher – Expedition Order

**Hands on...**

**obrigado !**