CONWIP

(A pull alternative to kanban principle)

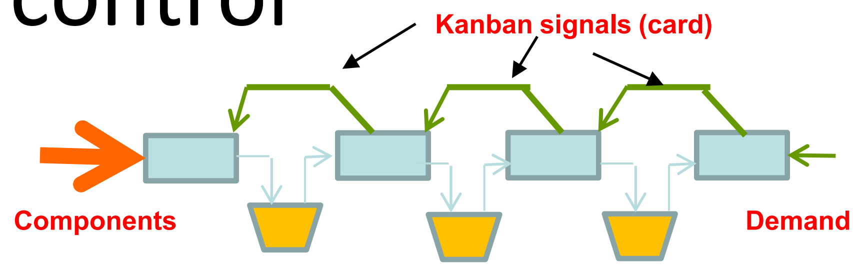
Main resources : Mark Spearman, David Woodruff and Wallace Hopp
Northwestern University,
Evanson, Illinois, USA

Diagrams, modifications, structures and editing (J.Skorkovský,KPH)
CONWIP diagrams: EuroLean+

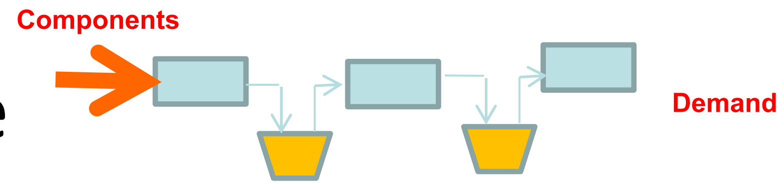
Methodologies used for effective production control

- Based on PULL principle
  - JIT
  - Kanban (tool to support JIT)
  - Zero inventory
    - Kanban is used mostly for repetitive manufacturing)

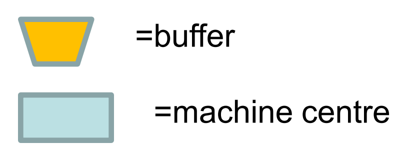
→ greatly reduced inventory levels and production lead times



- Based on PUSH principle
  - MRP (MRP-II)

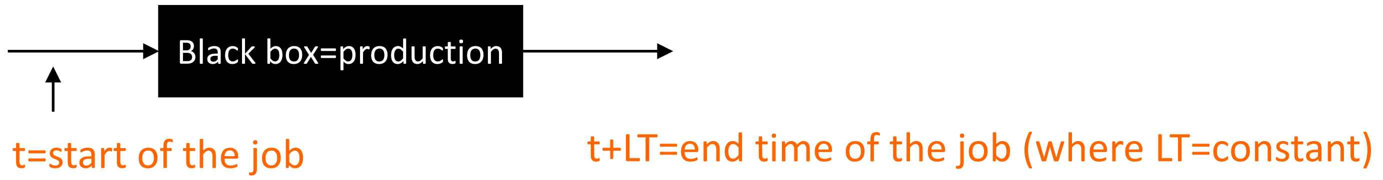


- Based on both principles (push and pull)
  - CONWIP (Constant Work-In-Process)



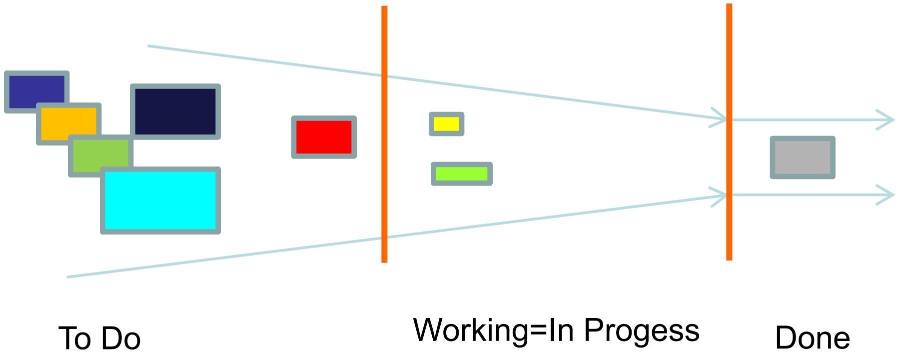
PUSH and PULL

- **PUSH** : production jobs (production orders) are scheduled (MRP and MRP-II)
  - often **not feasible plans** are generated and problems are often detected too late
  - used fixed lead times=**LT** (see next slide) does not depend on capacity utilization
  - Mind you, that **production is a random process** and estimation of LT is very pessimistic

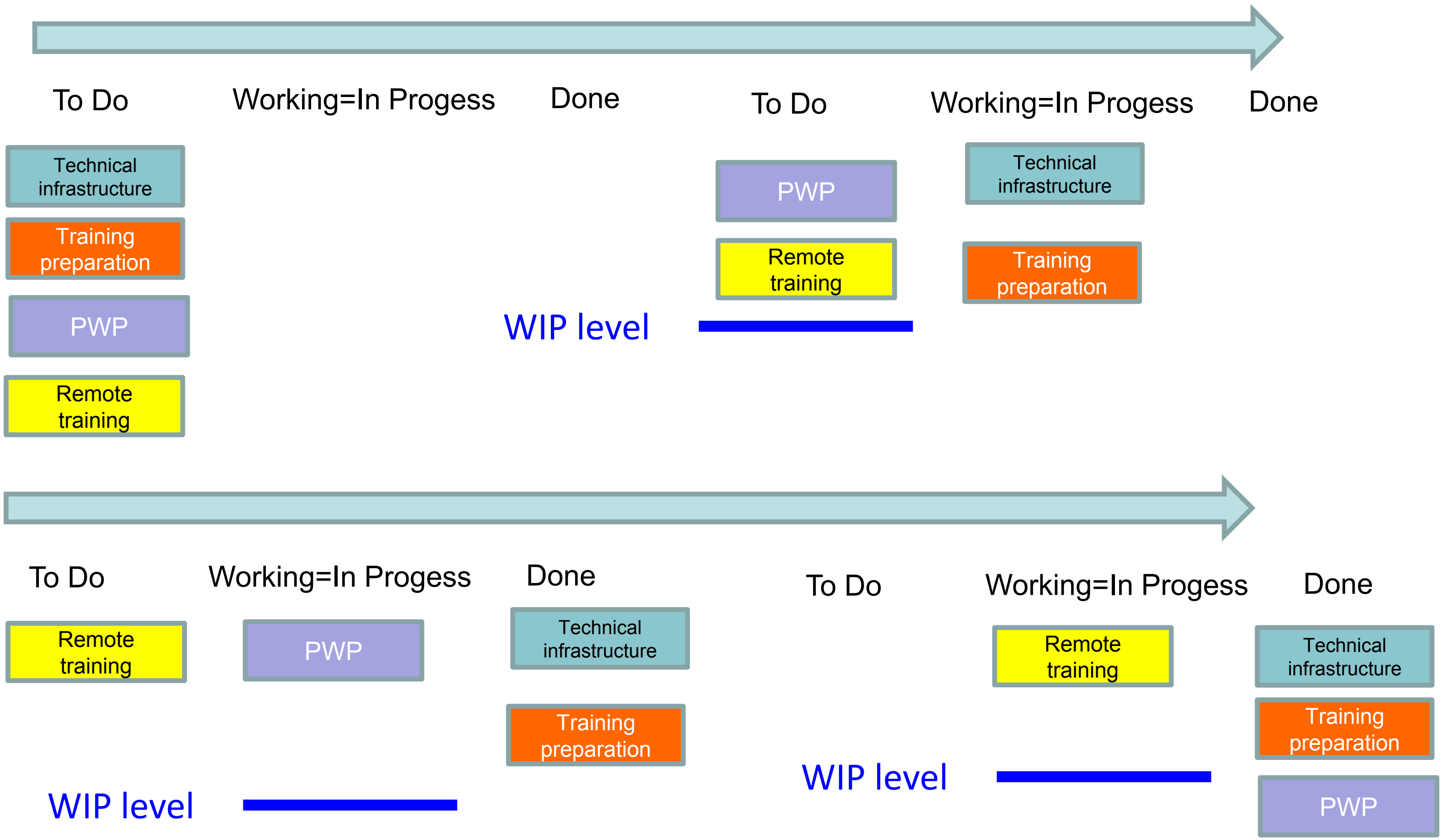


- **PULL** : production jobs (production orders) starts are triggered by the completion of another job.
- **In other words : It authorizes releases of the jobs)**

Kanban rules



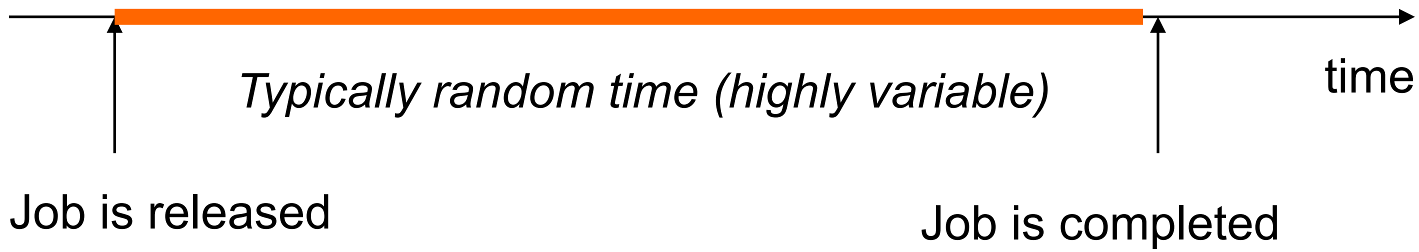
Kanban rules (signal card)



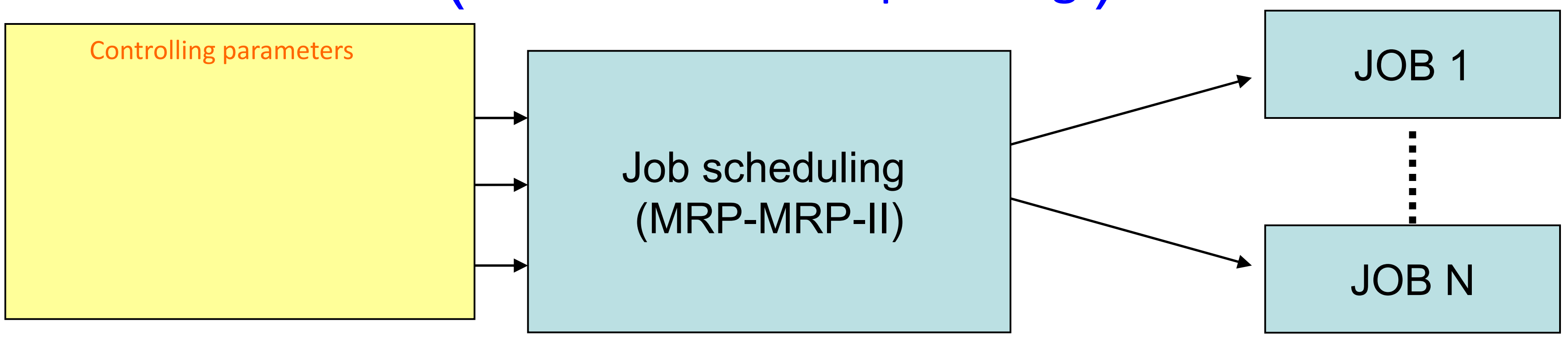
Too high a WIP setting leads to poor multitasking
and increasing the value of the lead time (reduction of Throughput)

Flow time and Lead time

- Flow time (known also as a „**Cycle time**")



- Lead time (constant used for planning)



FGI – finished good inventory

KANBAN

Components for Job 3 needed…

1 (kanban = card)

Operation 1 (Job1)

Operation 2 (Job1)

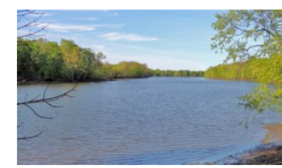
2

Operation 3 (Job1)

Components for Op 3 produced by Op 2 and supplied to Op 2 successor *(pulled)*

UPSTREAM

DOWNSTREAM



Authorization to start Op 22

1 =kanban (production card)

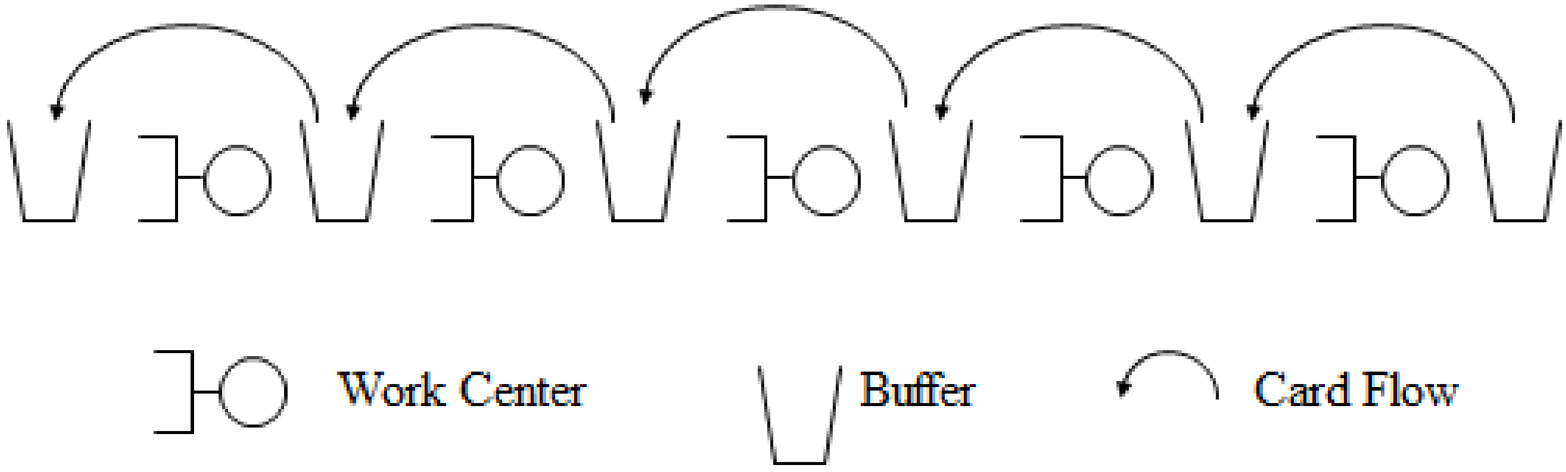
Controlling parameter

Job=Work order=Production order

Production

The number of cards in the system determines the WIP levels in the plant

KANBAN



Trade-offs

- Too many Kanban cards-> To much WIP and long Cycle times

- Too few Kanban cards->lower throughput and vulnerability to demand

Little´s low – not for AOMA

- Little´s law : Cycle Time=WIP/Throughput
  - see basic explanation further ahead
  - more detailed explanantion : **Factory Physics** (W.J.Hopp and M.L.Spearman)

JIT

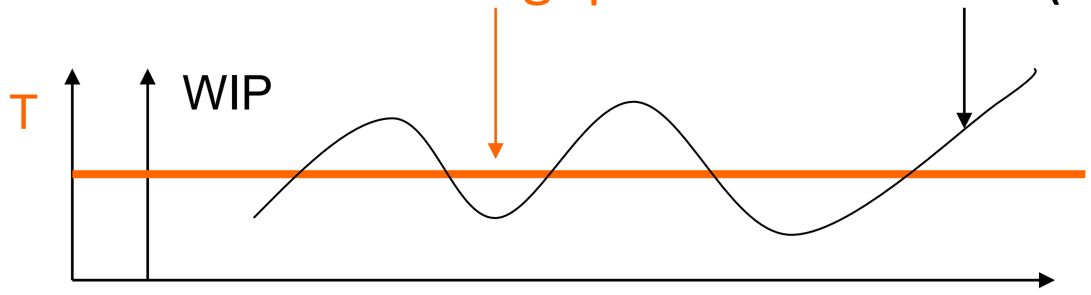
- Kanban is not JIT (JIT is a manufacturing philosophy)
- JIT encompasses :
  - Kanban (card system transferring singnals)
  - total quality control (TQM) – e.g. scrap loss not tolerated….
  - setup time reduction
  - worker participation !!!!
  - lean production (low level of waste)
- Advantages of JIT philosophy :
  - reduced WIP (Work In Process)
  - shorter flow times (cycle times)
  - lower production costs
  - greater customer responsiveness
  - reduces setup times

PUSH and **PULL** are not mutually exclusive approaches and other statements…

- **Push** and **Pull** can be combined
- MRP is considered to be more applicable than kanban
- MRP is in almost any discrete part production
- Kanban(JIT,pull) – superior results if applicable
- Kanban(JIT,pull) – is difficult to use if :
  - Jobs with short production runs
  - Significant setup times (numerically controlled machines)
  - Remarkable Scrap losses
  - Unpredictable fluctuation in demand

PUSH and PULL and the types of the queueing networks

- **Push** : open queueing network
- **Pull** : closed queueing network
- **Push** : schedule Throughput and measure (observe) WIP



- **PULL :** setup WIP and measure (observe) Throughput

Advantage of PULL over PUSH (home study not for MPH-AOMA)

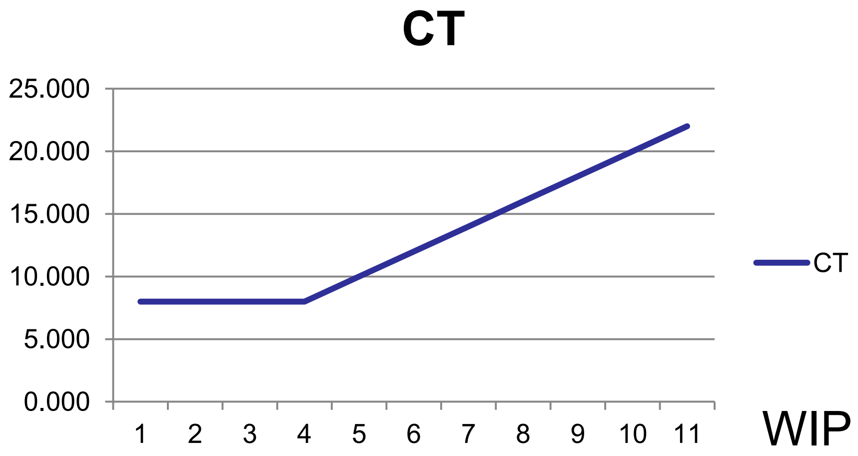
- **PUSH** : WIP and Throughput fluctuations – result in violation of the assumption, that CycleTimes (**CT**) and therefore Lead Times (**LT**) are constant !
- WIP is easier to optimize than Throughput (**T**)
- **Little´s low :**

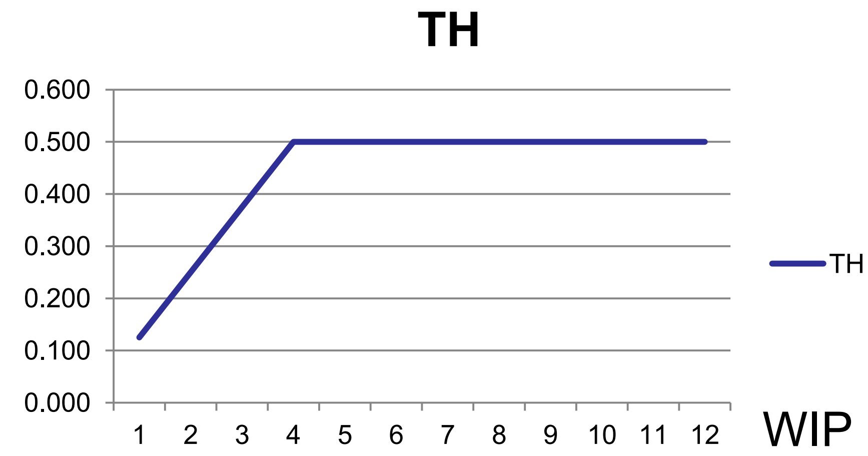
  Average **CT**=Average **WIP**/Average **T** – meaning that **CT** cannot be constant but vary with **WIP** and **T .**

- **Pull is easy to manage :** why ? -> **WIP** is easier to control than **capacities** needed to appropriately release work in **push** system . The problem is estimation of these capacities as exact as possible,

Little´s Law (home study- not for MPH_AOMA)

WIP	CT	TH
1	8	0,125
2	8	0,250
3	8	0,375
4	8	0,500
5	10	0,500
6	12	0,500
7	14	0,500
8	16	0,500
9	18	0,500
10	20	0,500
11	22	0,500
12	24	0,500





CONstant Work In Process = CONWIP

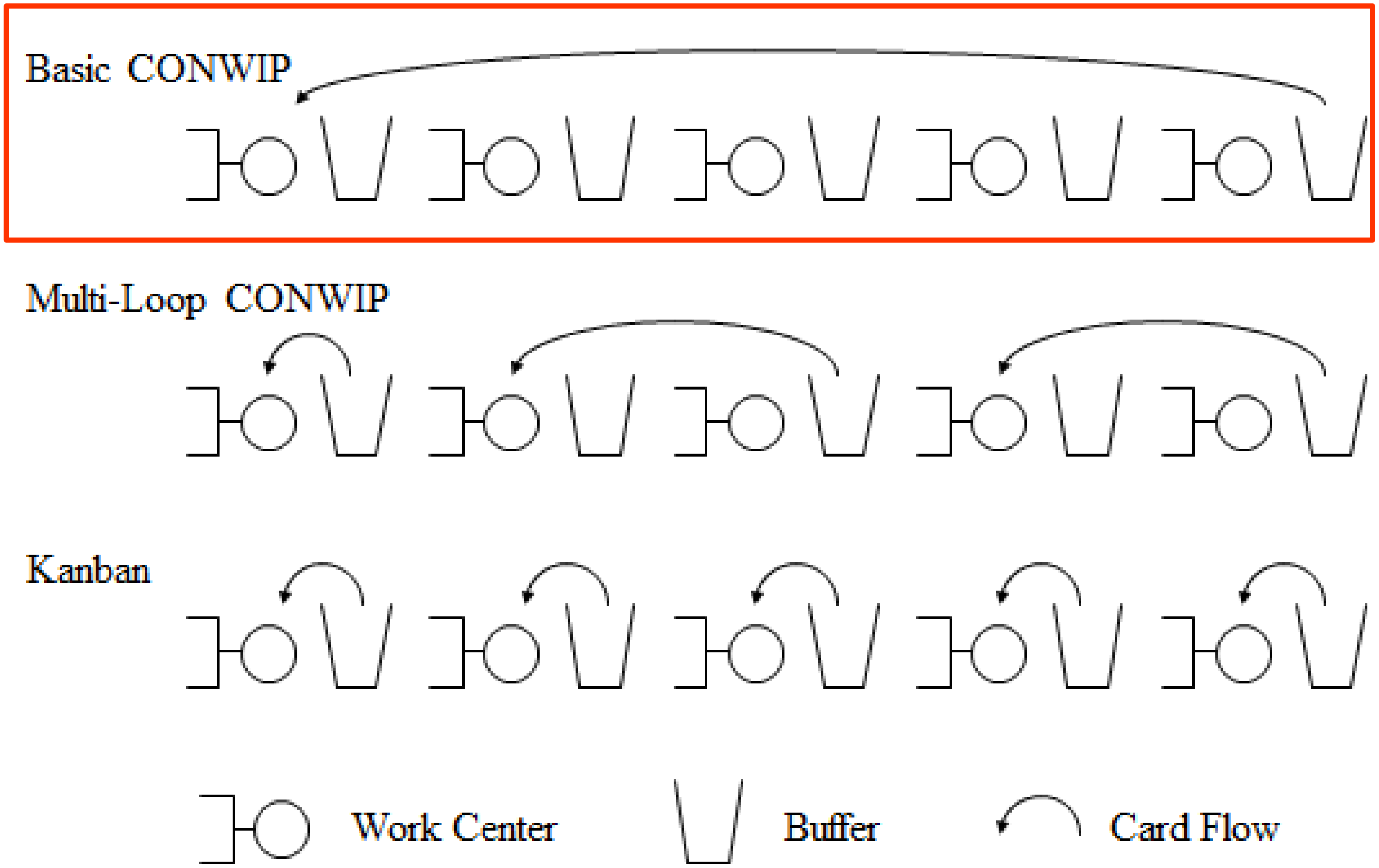
- System having benefits of a PULL and can be used in variety of manufacturing environment
- CONWIP : generalized form of Kanban
- CONWIP relies on signals (electronic, paper cards...)

CONstant Work In Process = CONWIP

- **Kanban:** card is used to signal production of a specific part

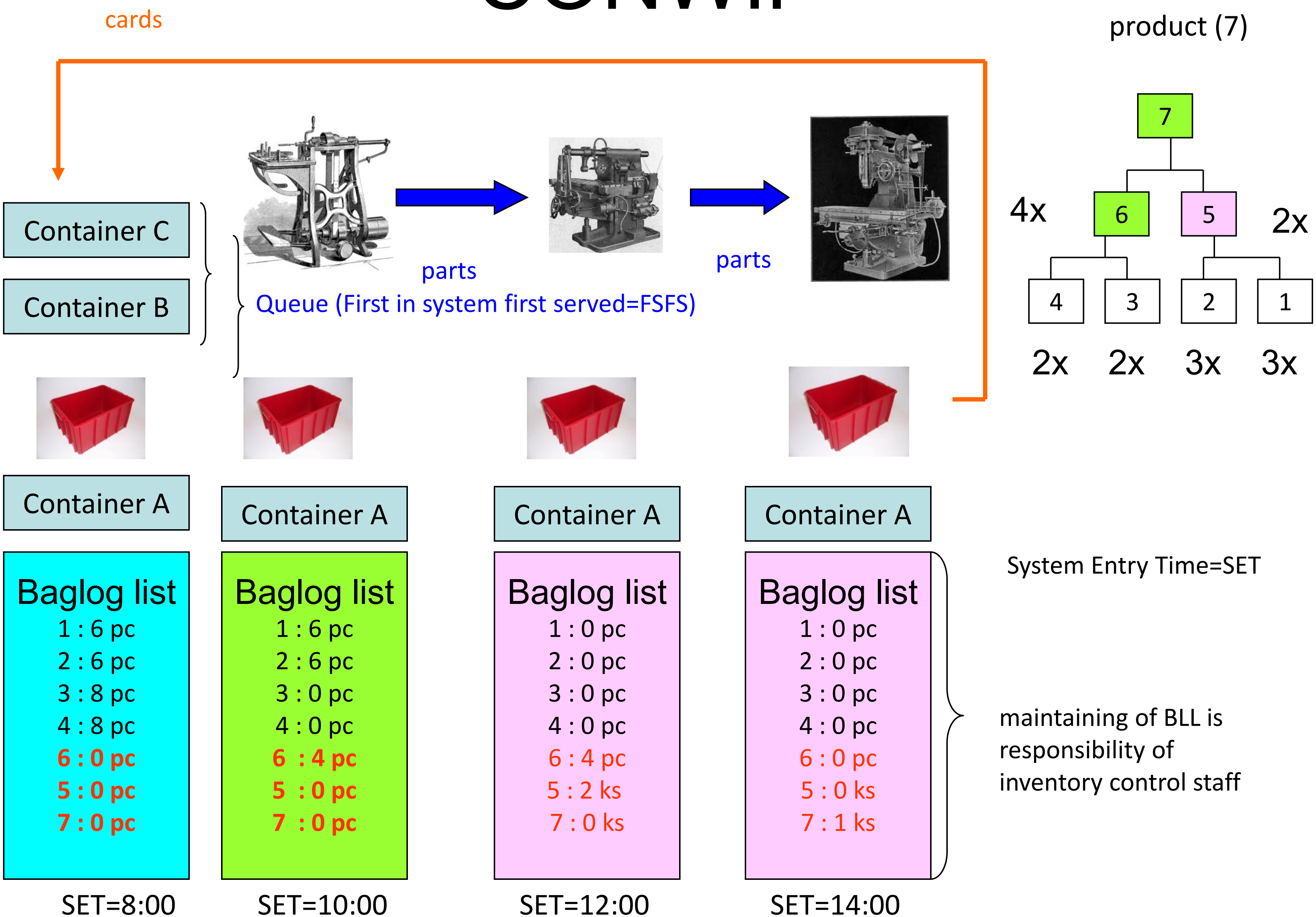
- **CONWIP :** card is assigned to production line and are not part number specific

CONWIP Configuration



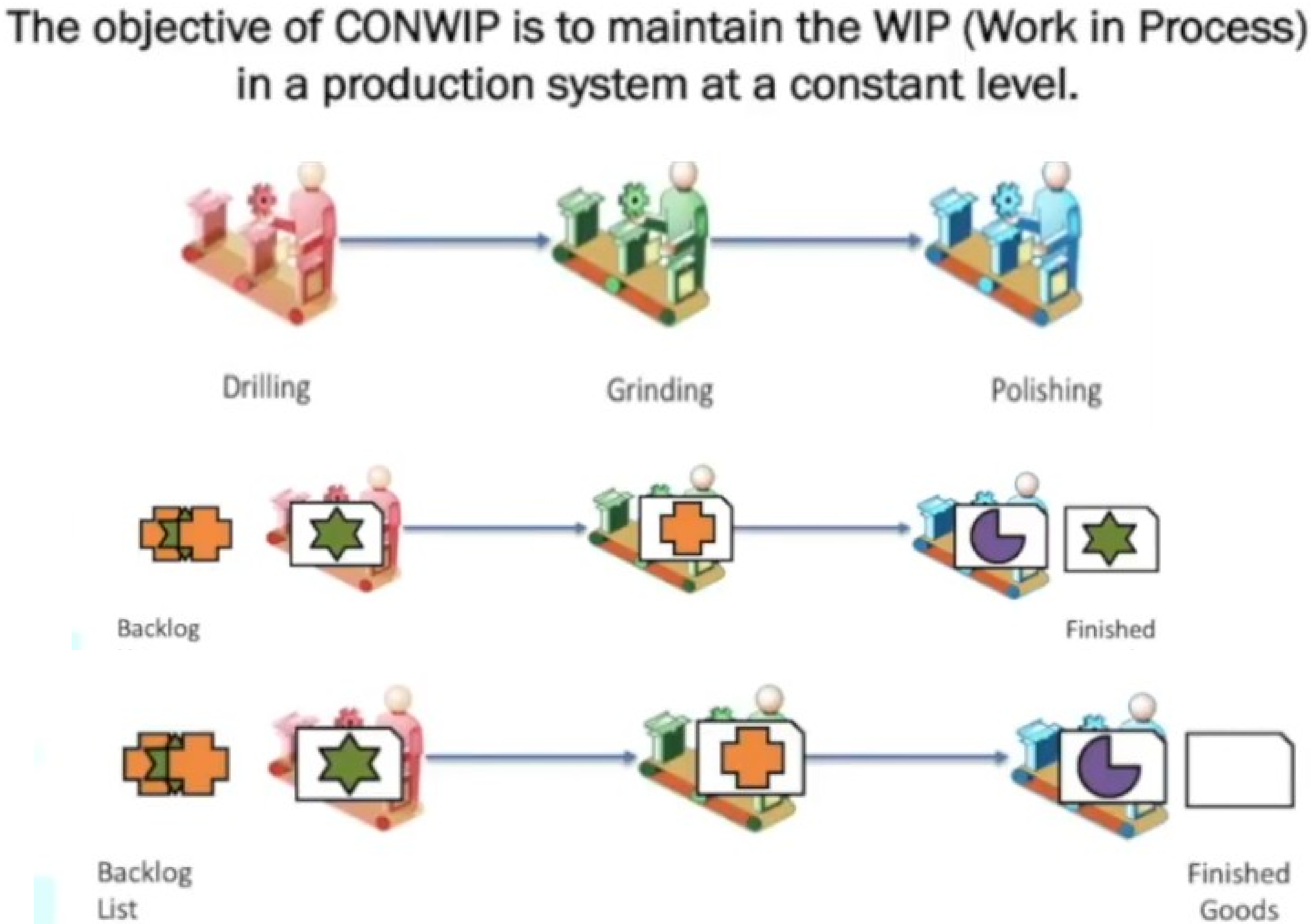
For this course only **red framed** scenario will be considered.
It is a system controoled by one loop (feedback)

CONWIP



cards
BOM of the final product (7)
Container C
Container B
parts
parts
Queue (First in system first served=FSFS)
7
4x
6
5
2x
4
3
2
1
2x
2x
3x
3x
Container A
Container A
Container A
Container A
Baglog list
1 : 6 pc
2 : 6 pc
3 : 8 pc
4 : 8 pc
6 : 0 pc
5 : 0 pc
7 : 0 pc
Baglog list
1 : 6 pc
2 : 6 pc
3 : 0 pc
4 : 0 pc
6 : 4 pc
5 : 0 pc
7 : 0 pc
Baglog list
1 : 0 pc
2 : 0 pc
3 : 0 pc
4 : 0 pc
6 : 4 pc
5 : 2 ks
7 : 0 ks
Baglog list
1 : 0 pc
2 : 0 pc
3 : 0 pc
4 : 0 pc
6 : 0 pc
5 : 0 ks
7 : 1 ks
System Entry Time=SET
maintaining of BLL is responsibility of inventory control staff
SET=8:00
SET=10:00
SET=12:00
SET=14:00

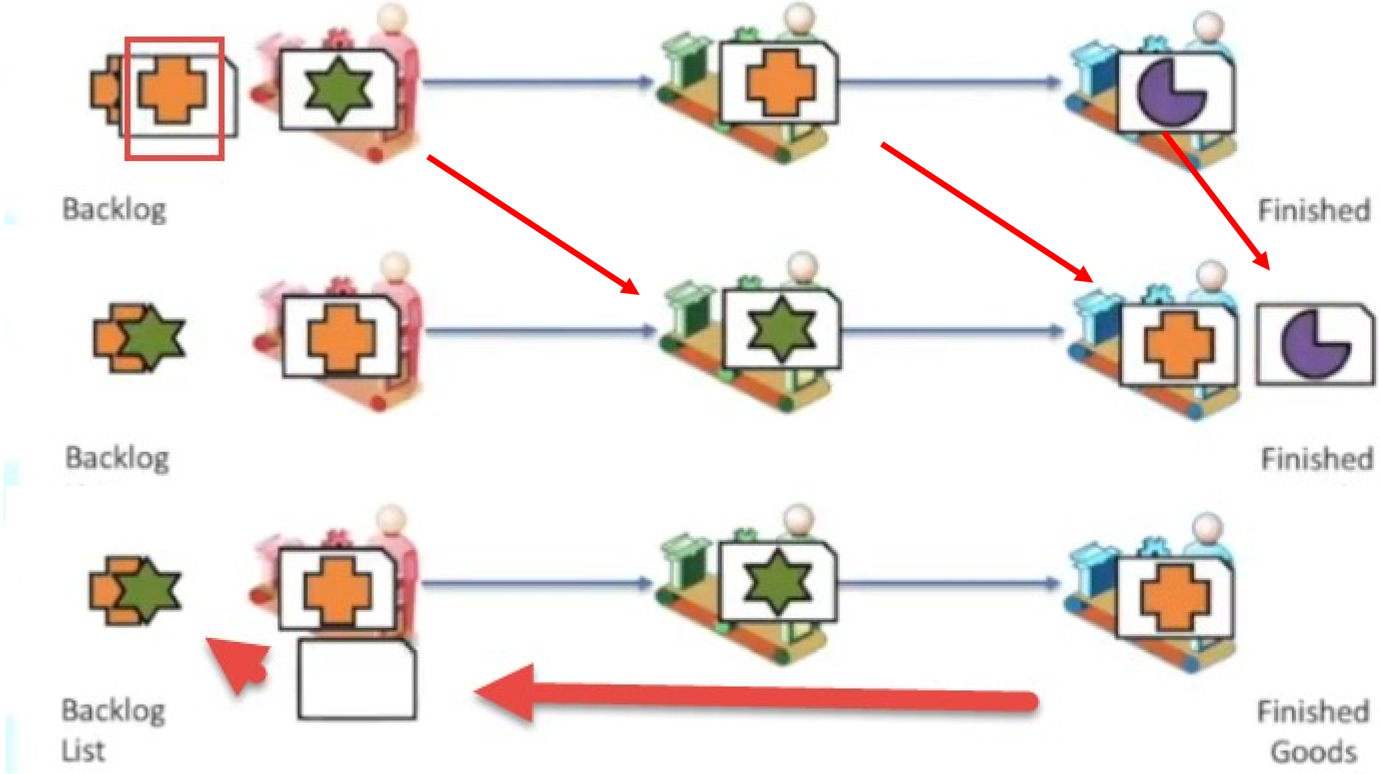
One loop (card based-pull based) I.



We have in our production line all in all 4 kanban cards
When FG is consumed one card is free

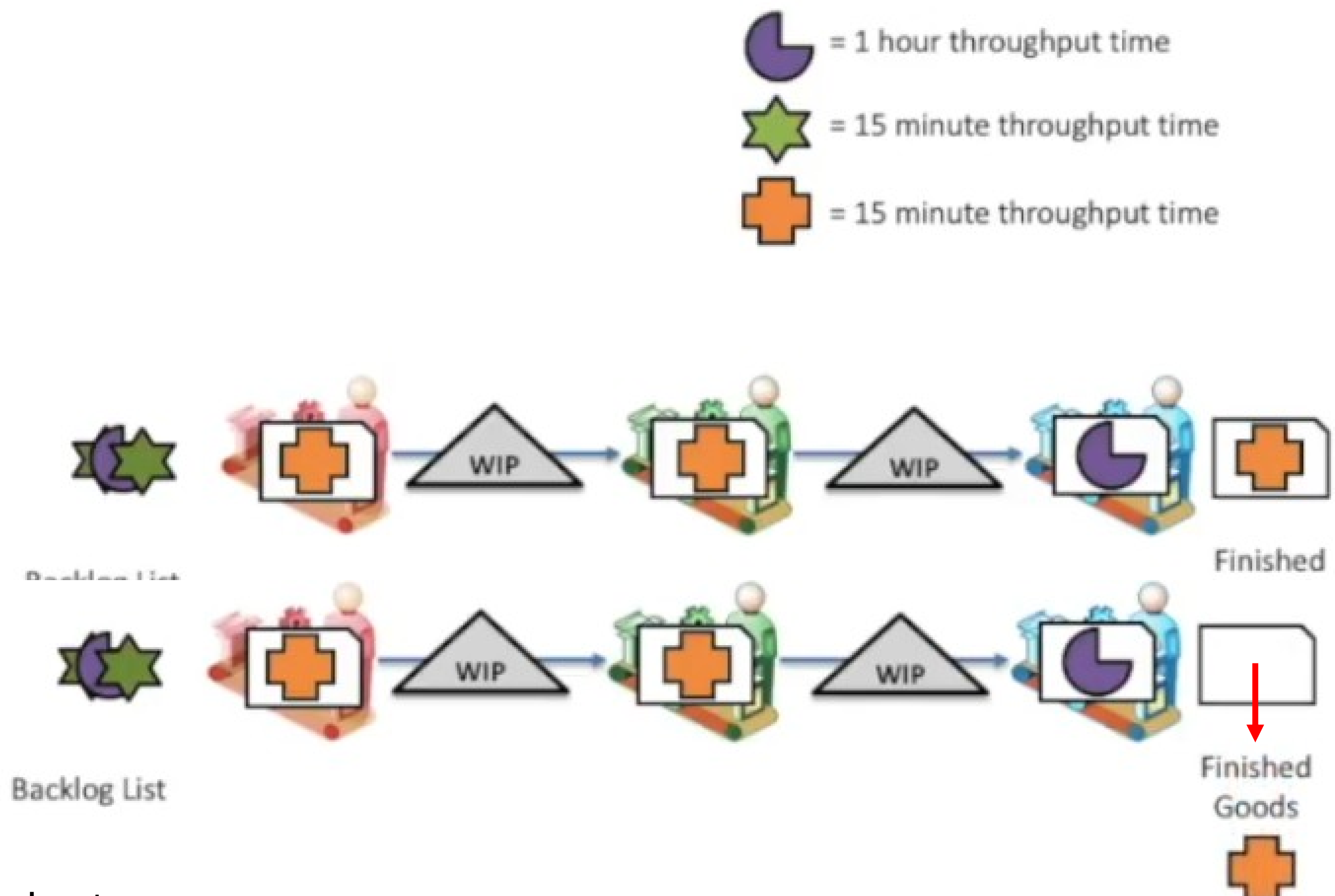
Resource: EuroLean+

One loop (card based – pull based) II.



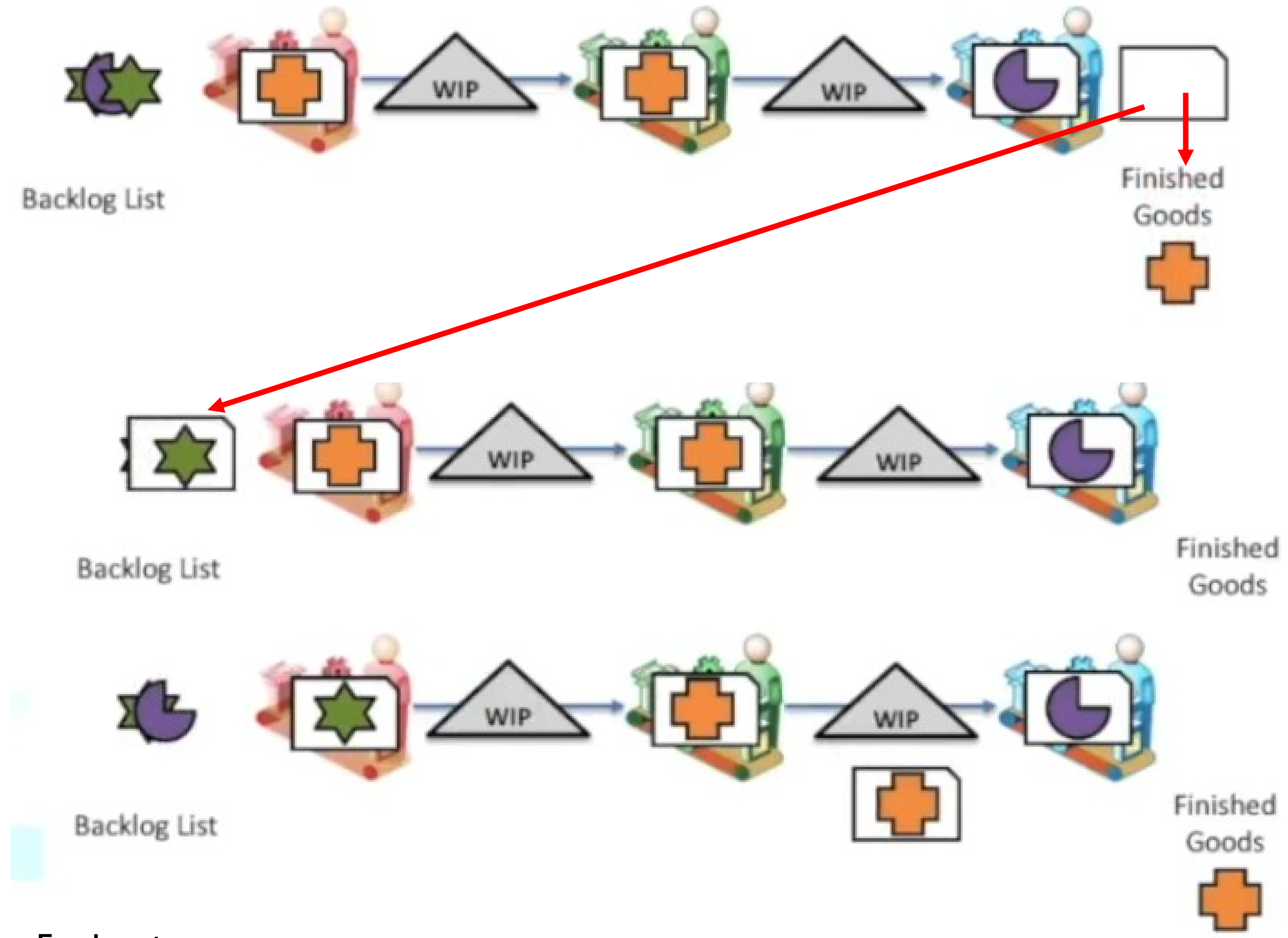
Resource: EuroLean+

CONWIP –different throughput times I



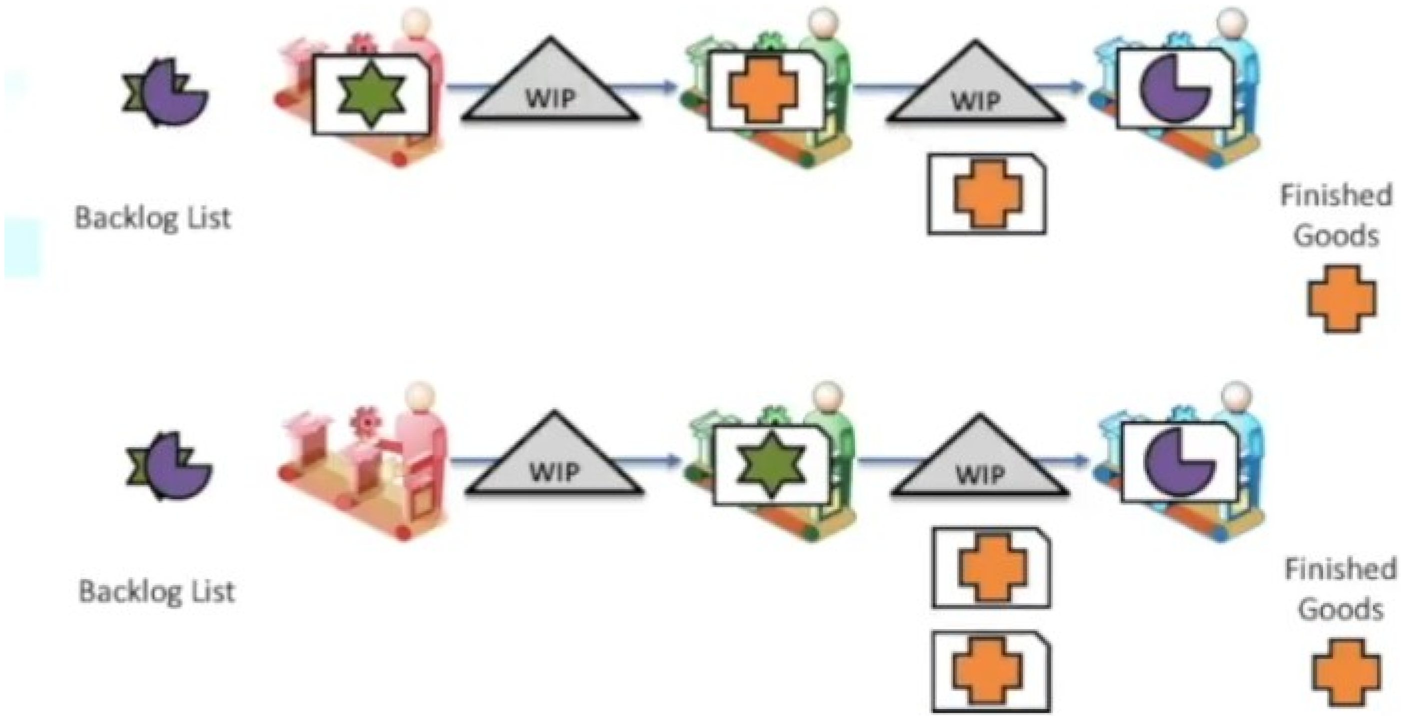
Resource: EuroLean+

CONWIP –different throughput times II.



Resource: EuroLean+

CONWIP –different throughput times III.



Resource: EuroLean+

CONWIP characteritics

- **Order release** is based on a **backlog list**
- The backlog list is not defined by the CONWIP system
  - **Relies on personnel to set priorities!**
- Queue discipline within the production system is **FSFS** (first in system first served)
- The number of cards can be calculated similar to Kanban, although it requires adjustment and fine-tuning

Resource: EuroLean+

CONWIP-air traffic control

Originating airport

Destination airport
(air above airport)

If heavy air traffic, departing planes should be held on the ground at the originating airport rather than control flying aircrafts in the air above destination airport as a holding pattern

The results : greater safety and lower fuel consumption

CONWIP-Theory of Constraints

- Balance the flow and not the capacity
- Operation of the CONWIP line is regulated by the bottleneck resource
- If we have sufficient demand, the correct number of the cards will maintain just enough WIP to keep bottleneck busy

Thanks for your attention

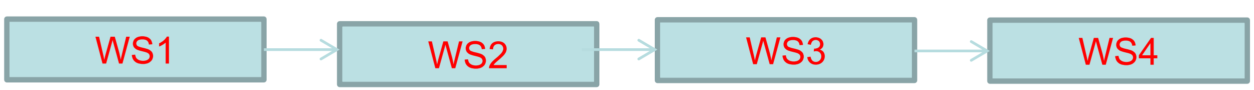
(next few slides are not part of this course)

Utilization, Bottleneck rate and Raw process time (cycle time)

- Arrival rate to the machine (working centre) = AR
- Effective Production Rate (maximum average rate at which workstation can process parts, considering effects of failures, setups and other detractors that are relevant over the planning period) =EPR
- Utilization = AR/EPR = U
- $r_b = parts\ per\ time\ unit\ of\ the\ workstation with\ highest$ long-term utilization (U)
- T_0 = raw process time of the line = $\sum_1^N PT_i$,where N= number of workstations
- **Critical WIP** =$W_0 = r_b \times T_0$,where T_0 =minimum cycle time and r_b= maximum throughput

Example

- Capacity of 4 machines is equal
- Thus every machine is bottleneck
- Line is balanced
- r_b=0,5 product/hour
- Daily line produces 12 products = 0,5 x24
- T_0 =8 hours=2 hours (product on one machine) x 4 machines in the line
- **Critical WIP** =W_0= $r_b \times T_0$ =0,5 x 8 =4 product
- S



Little´s Law

- WIP=TH x CT ,where TH=throughput and CT=cycle time

Little´s Law

WIP	CT	TH
1	8	0,125
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3	8	0,375
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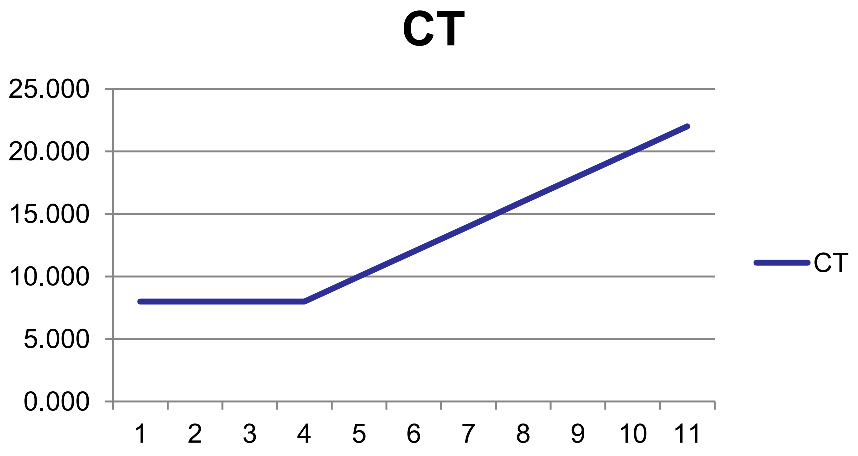

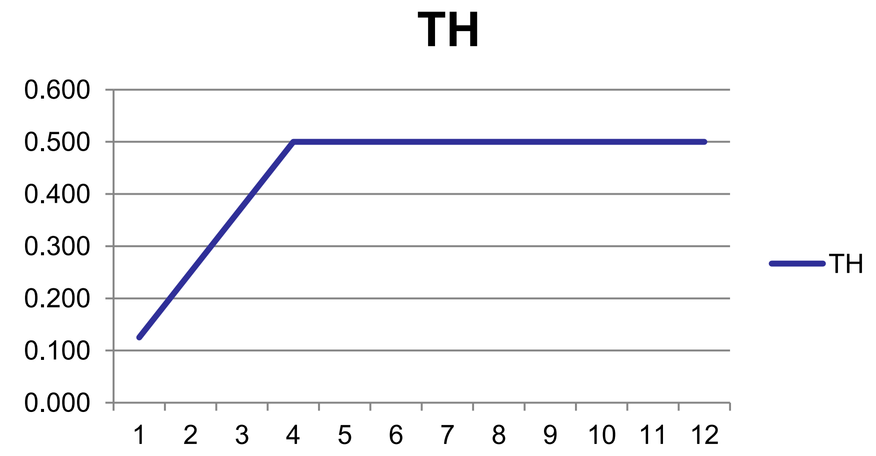

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