



**KTH Industrial Engineering  
and Management**

# **INTEGRATED PROCESS PLANNING AND FLOW SIMULATION**

via feature-based process feedback

MAGNUS LUNDGREN – KTH  
BJÖRN JOHANSSON – CHALMERS



Framtidens maskinverkstäder - Katrineholm, June 2, 2010



# Magnus Lundgren

Ph.D Student

KTH – Production Engineering



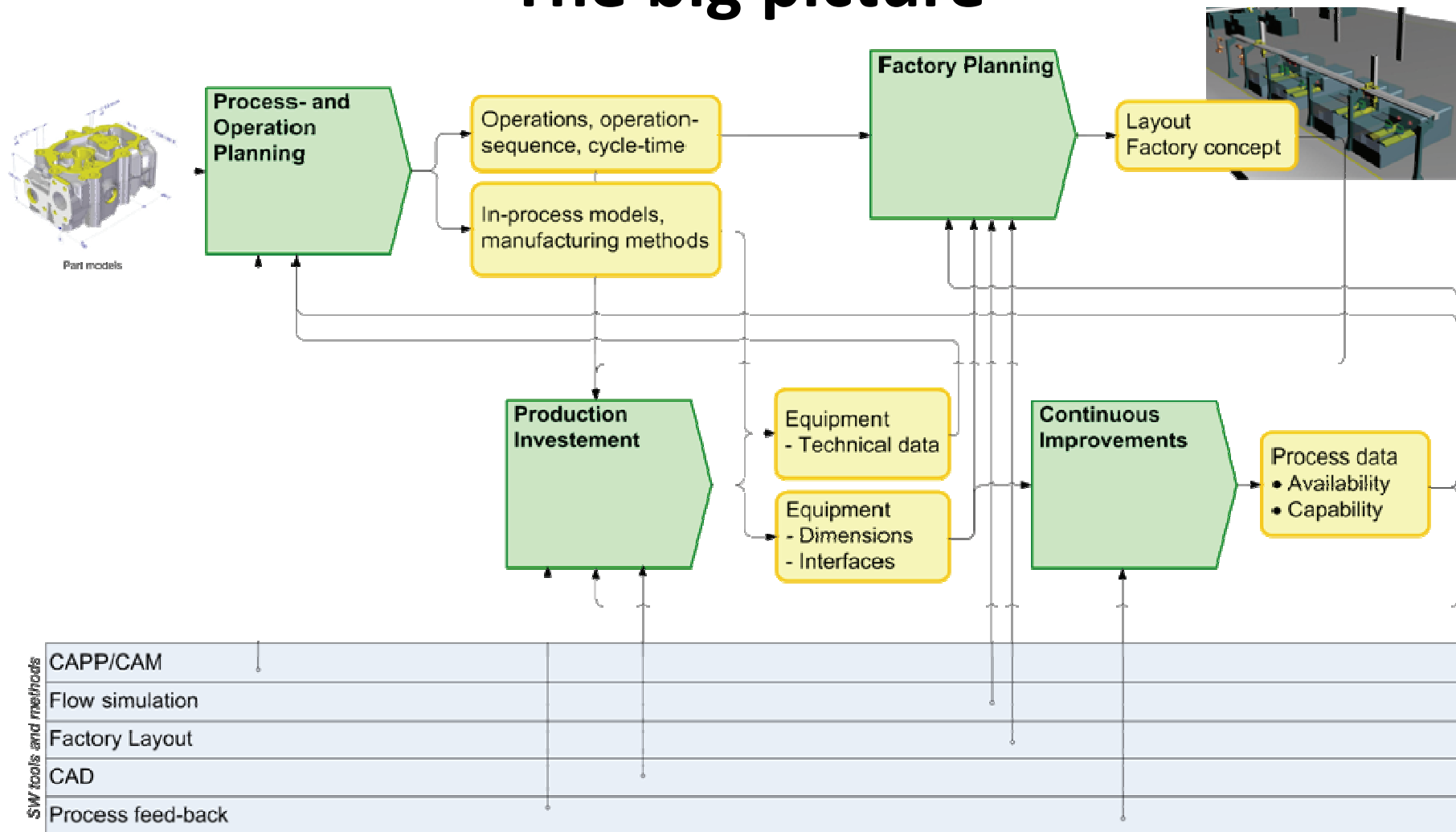
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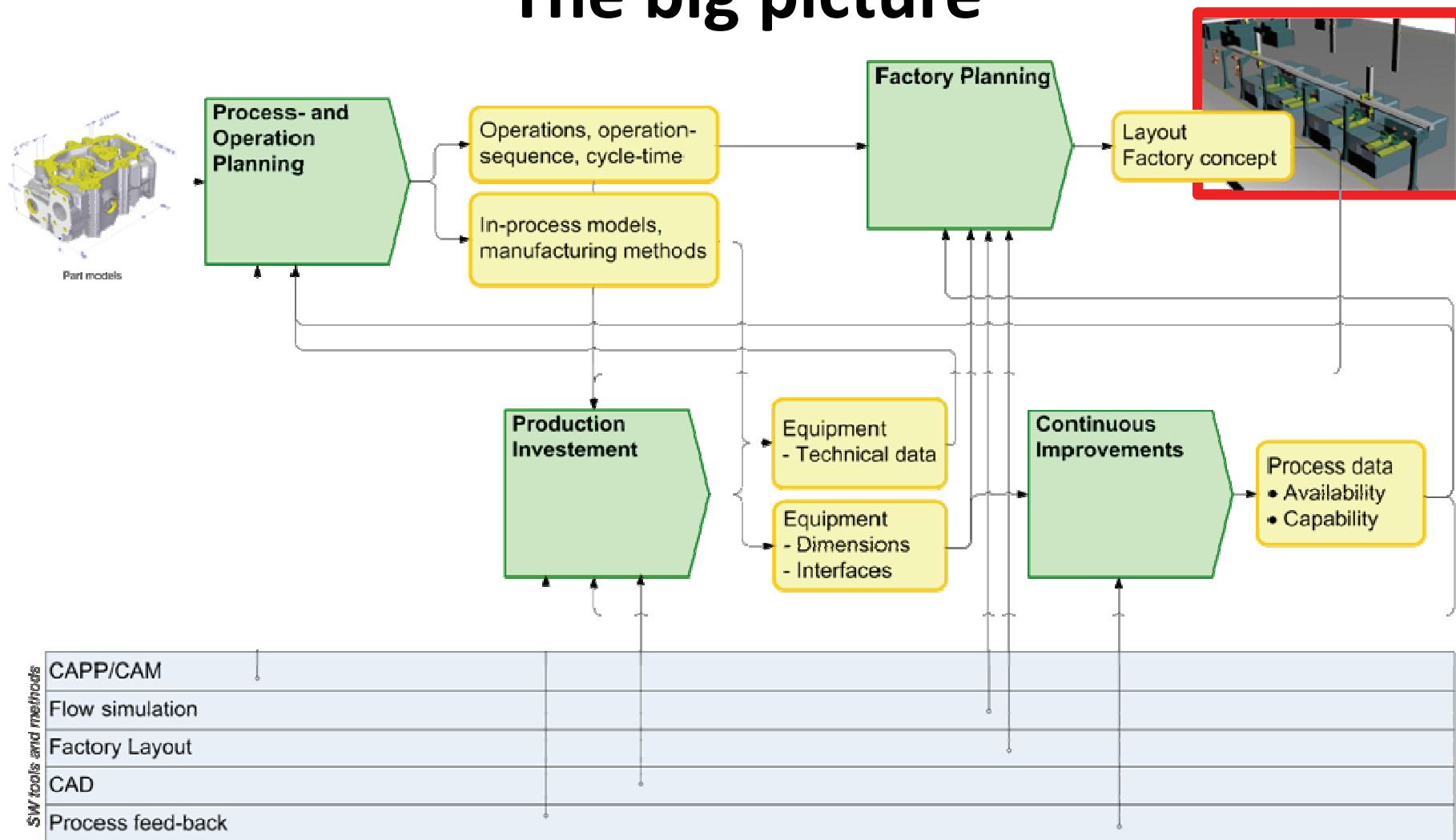
# Björn Johansson

Assistant professor  
Chalmers –Production Systems

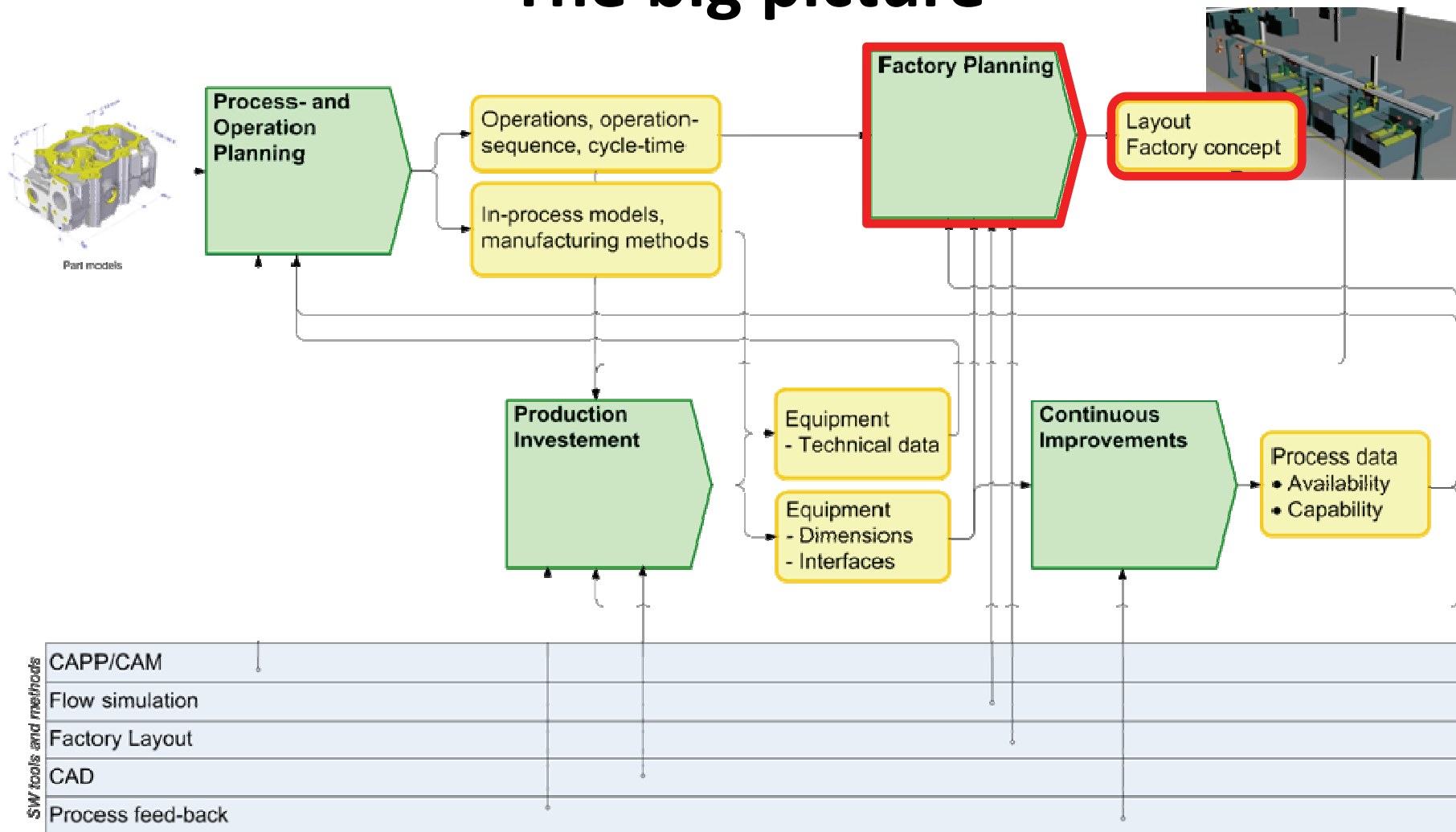
# The big picture



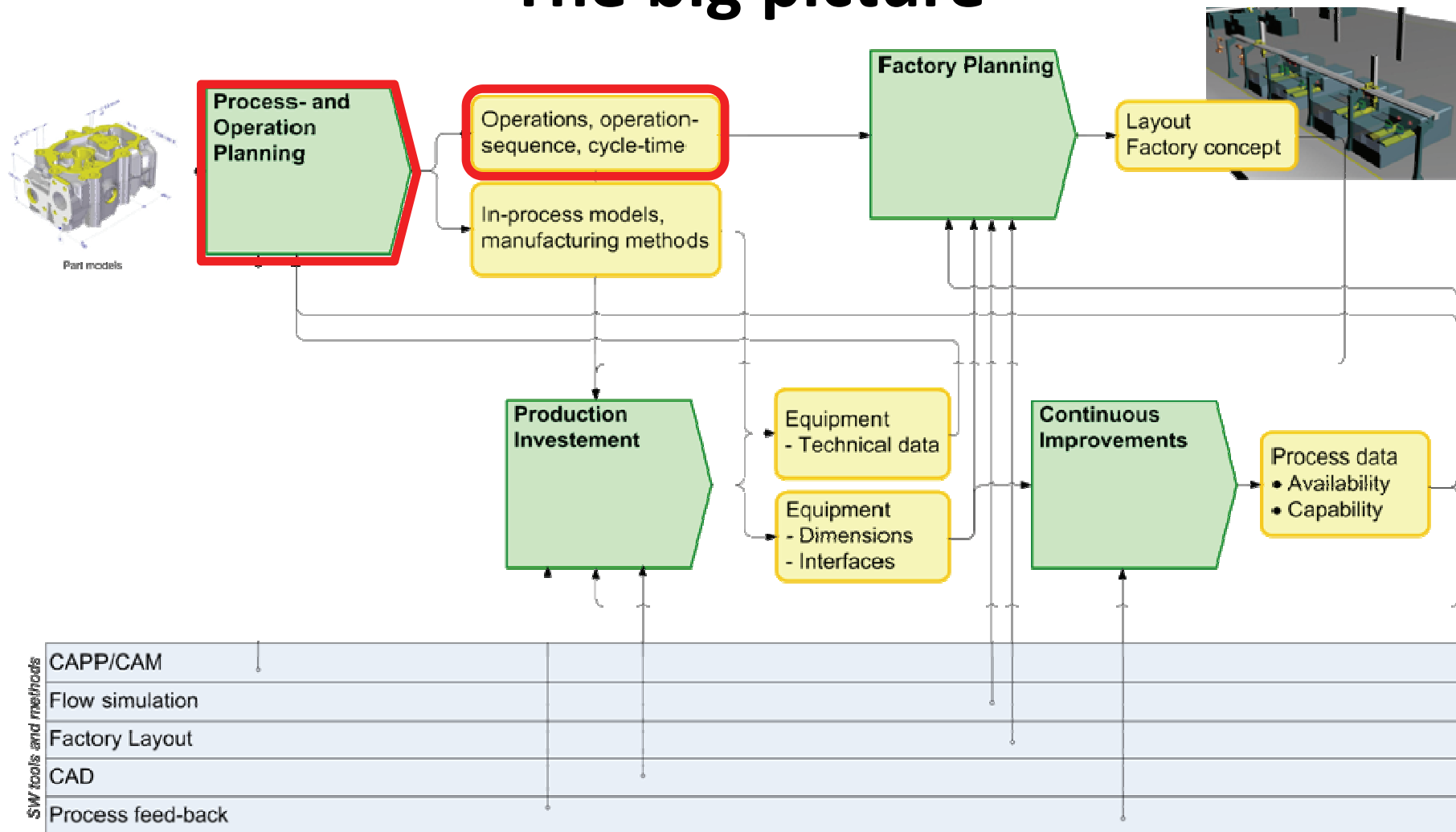
# The big picture



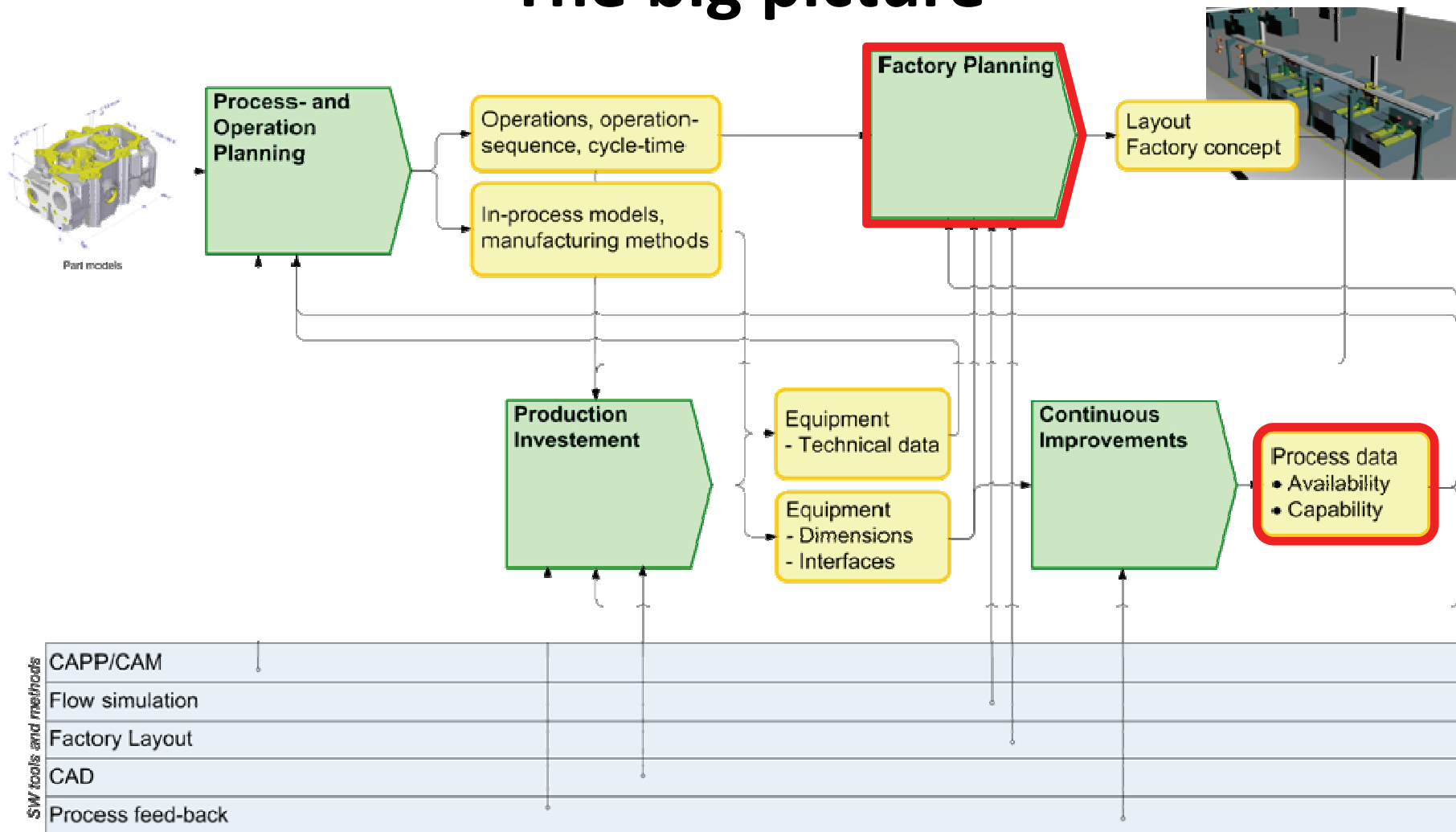
# The big picture



# The big picture

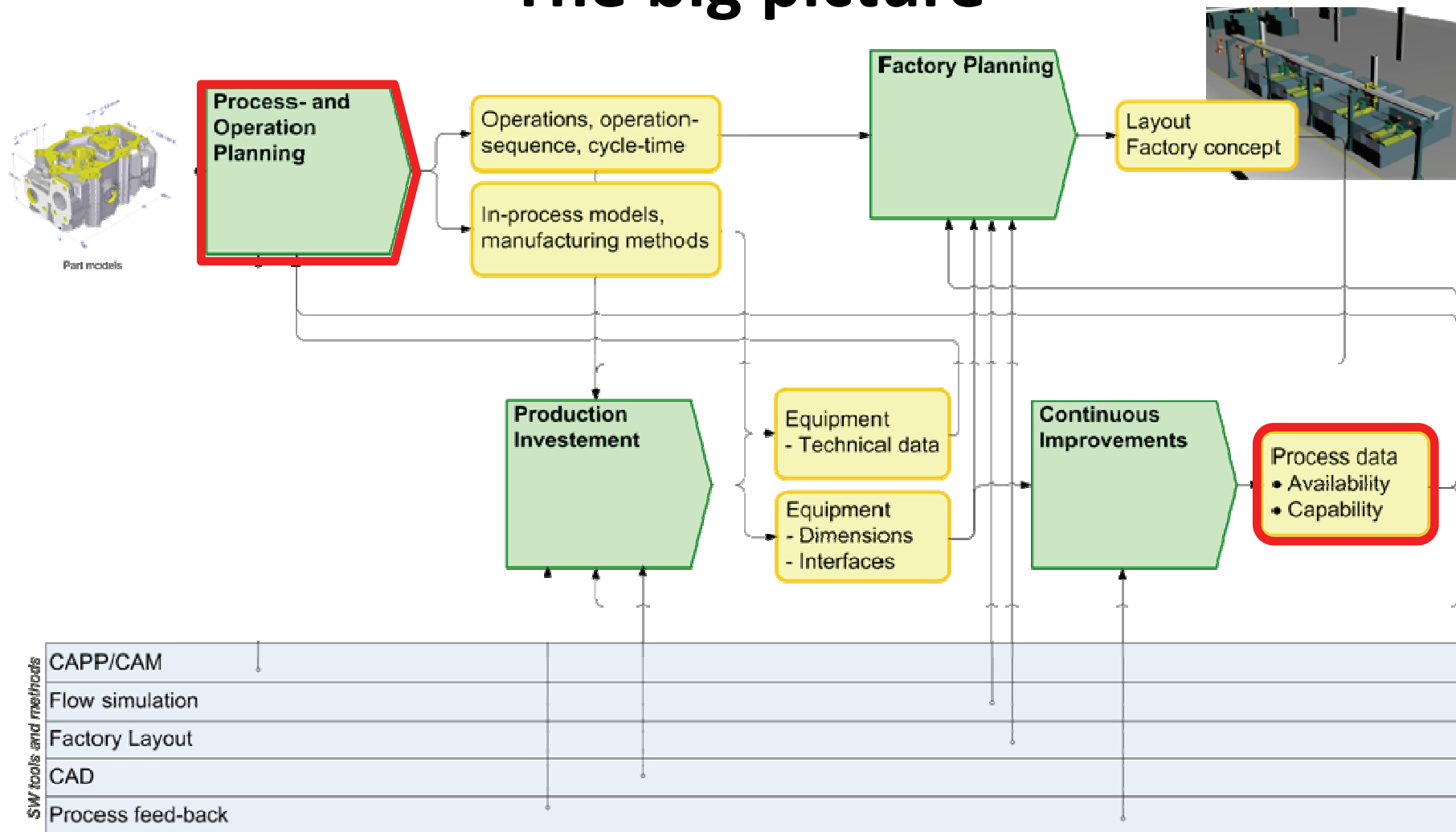


# The big picture

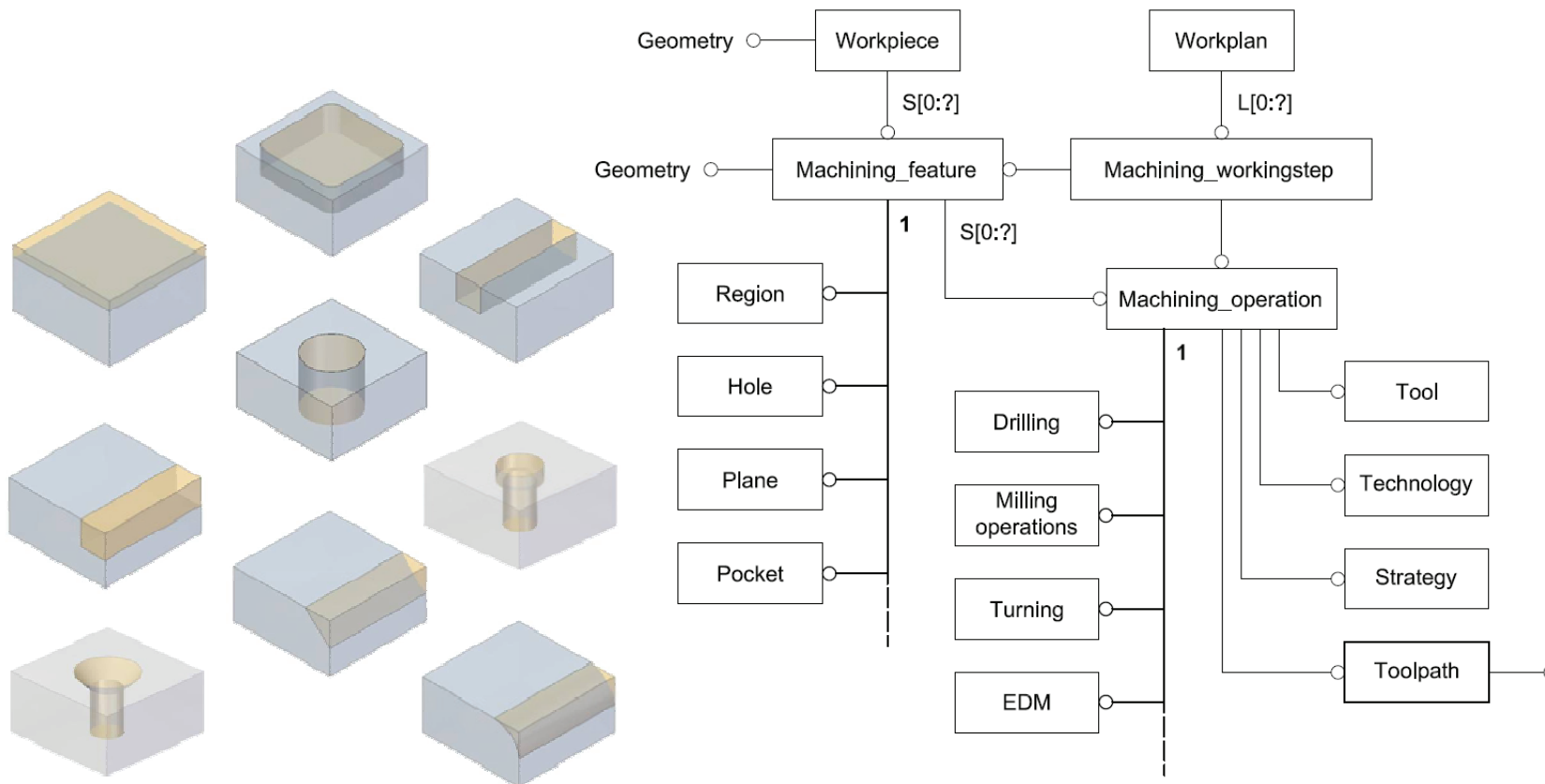




# The big picture

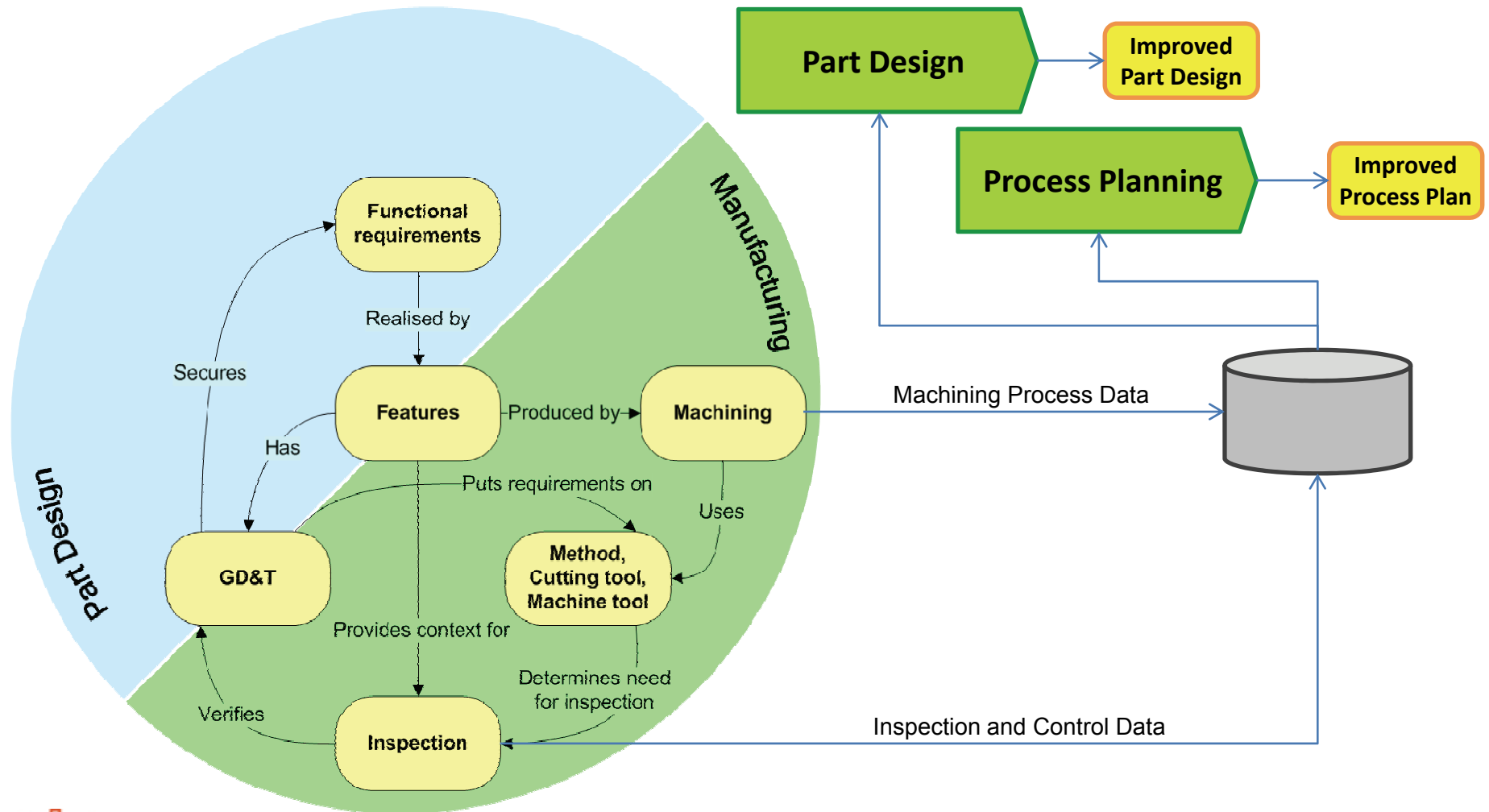


# STEP-NC: A standard for feature-based Process Planning and NC

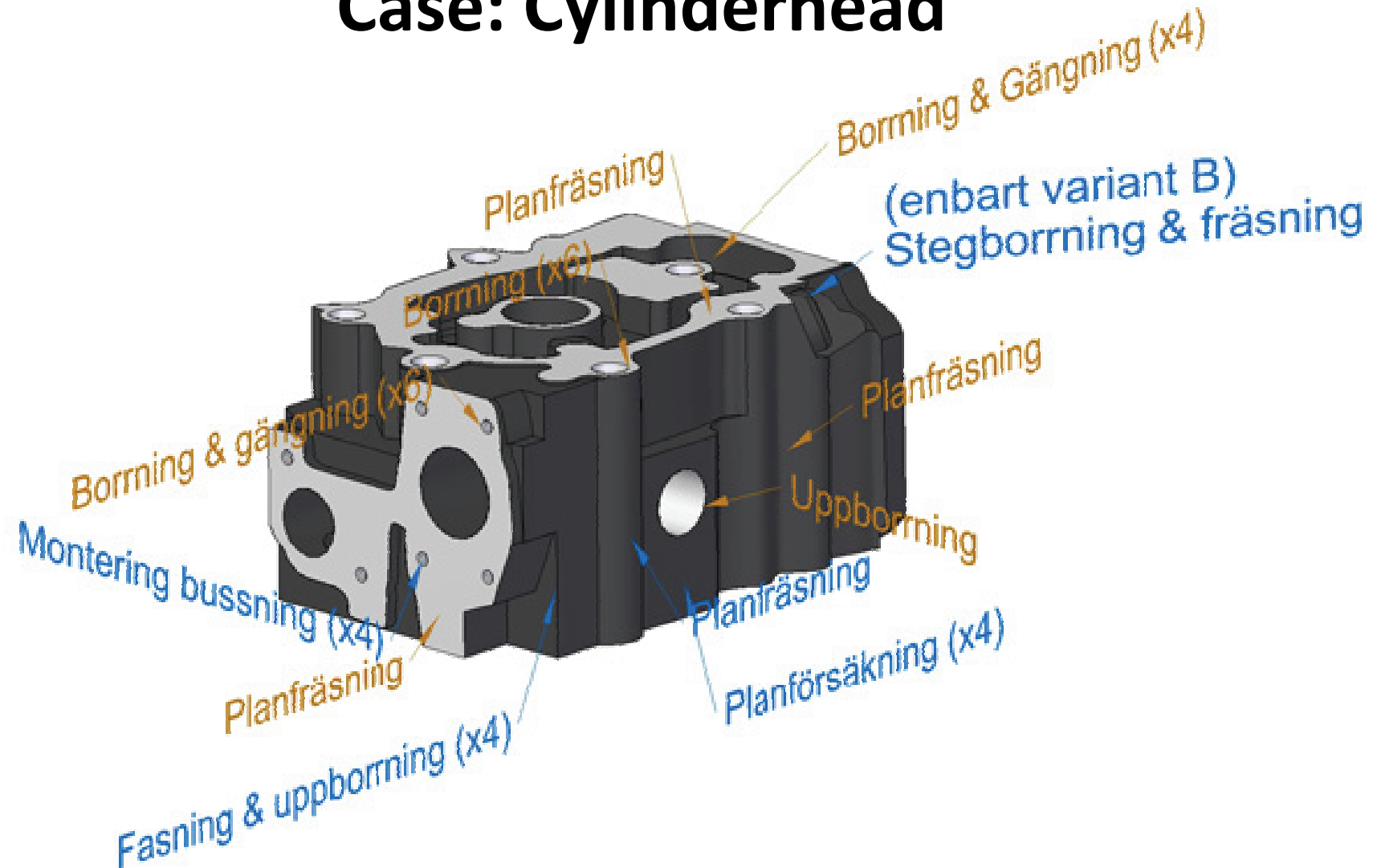


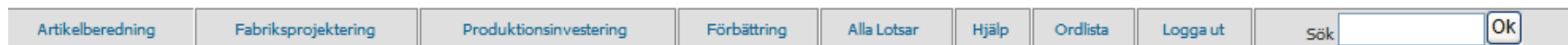
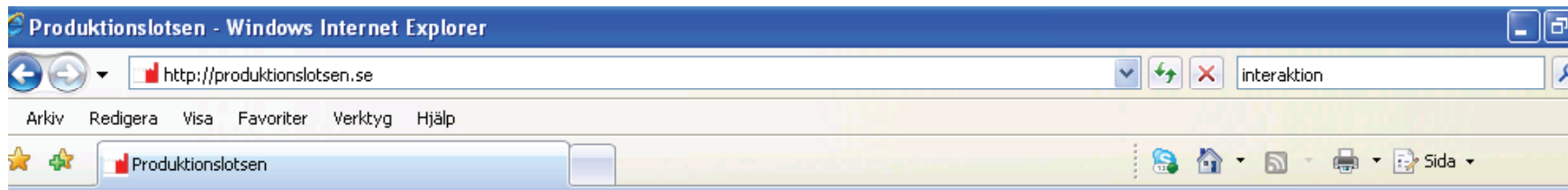
[ISO 10303-238:2007 ARM / ISO 14649-1]

# Machining features

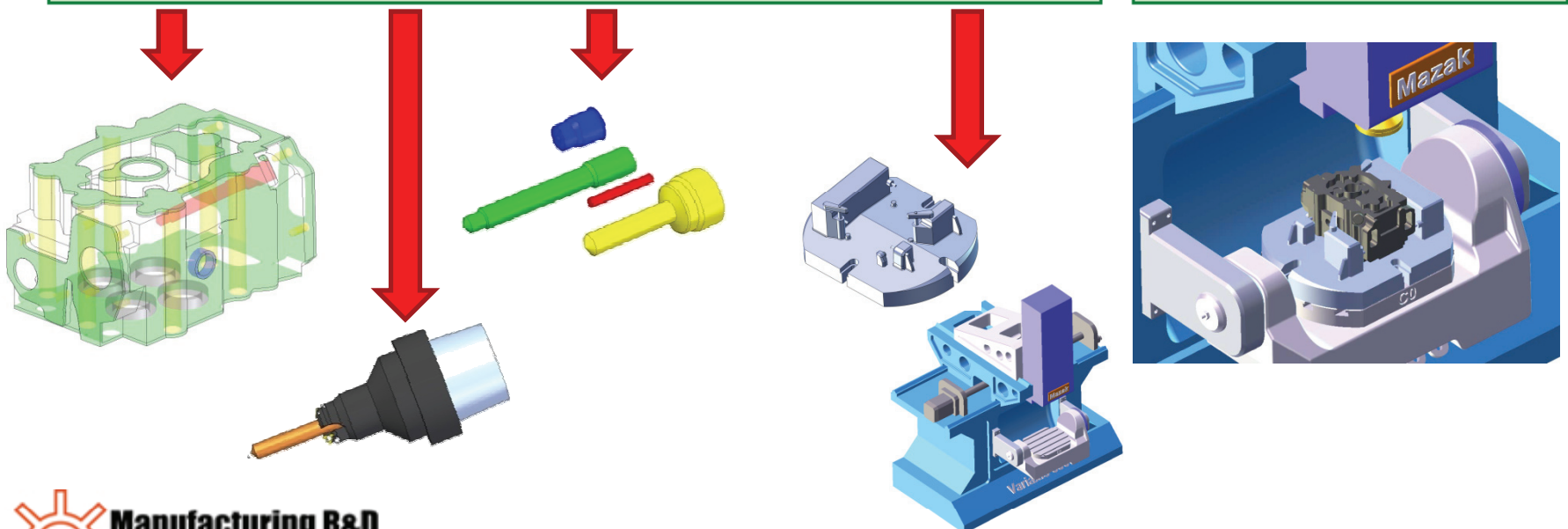
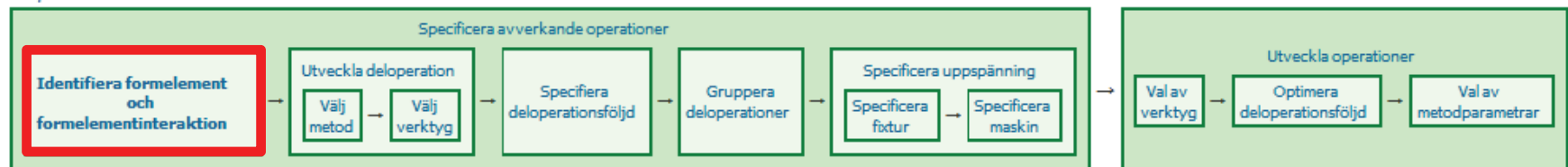


# Case: Cylinderhead



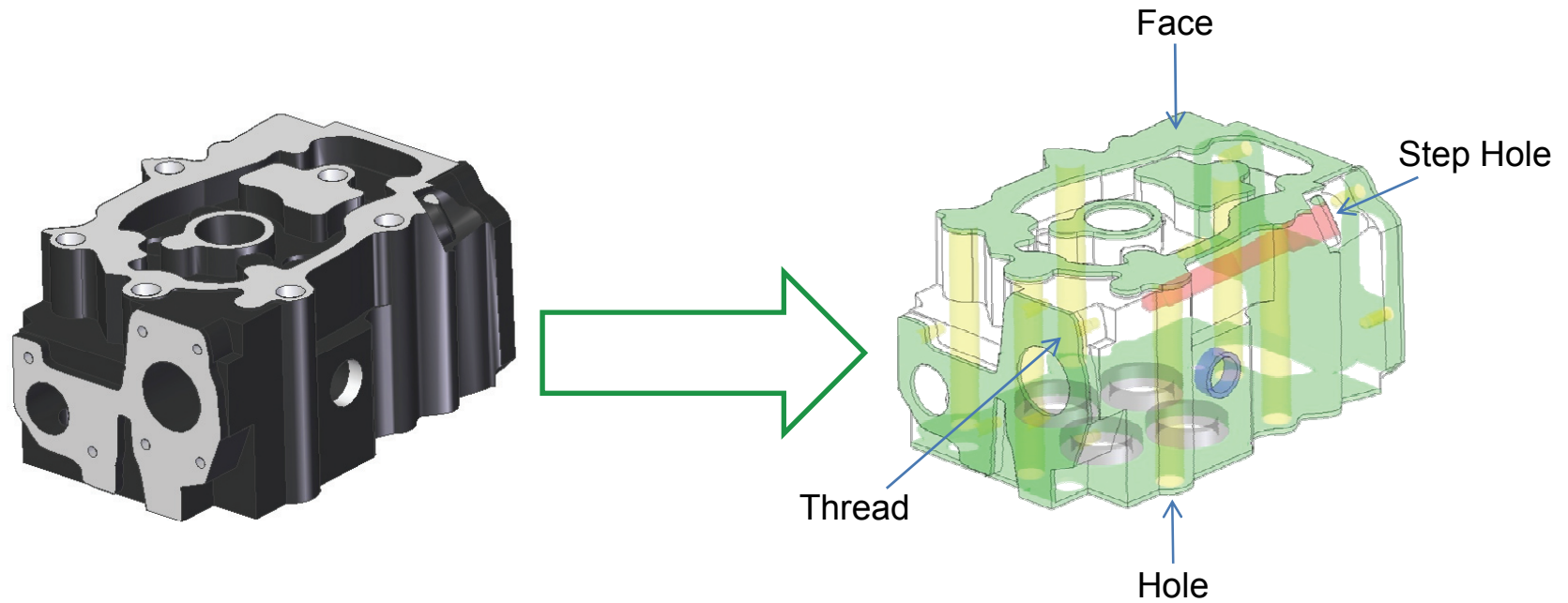


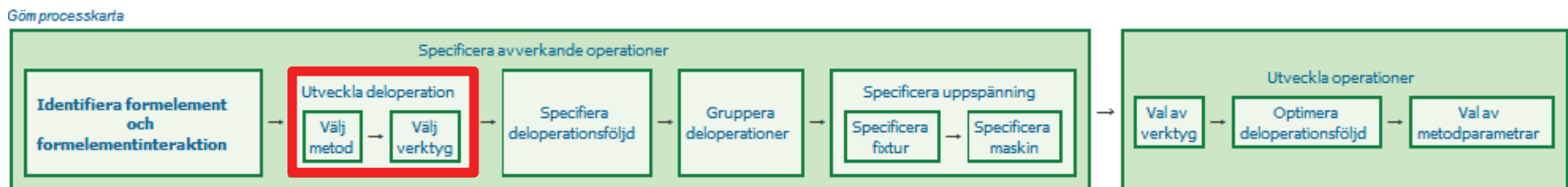
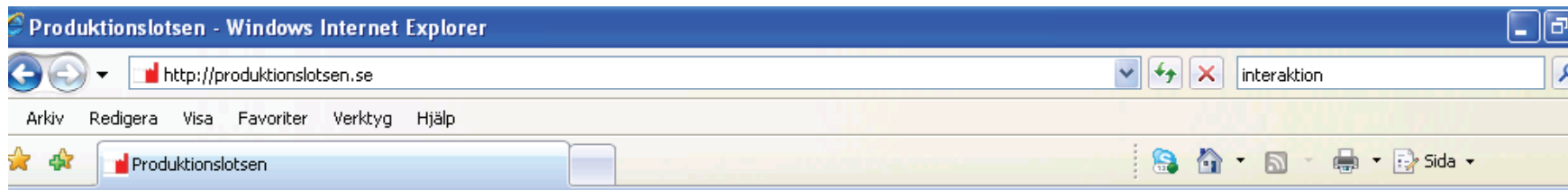
Göm processkarta



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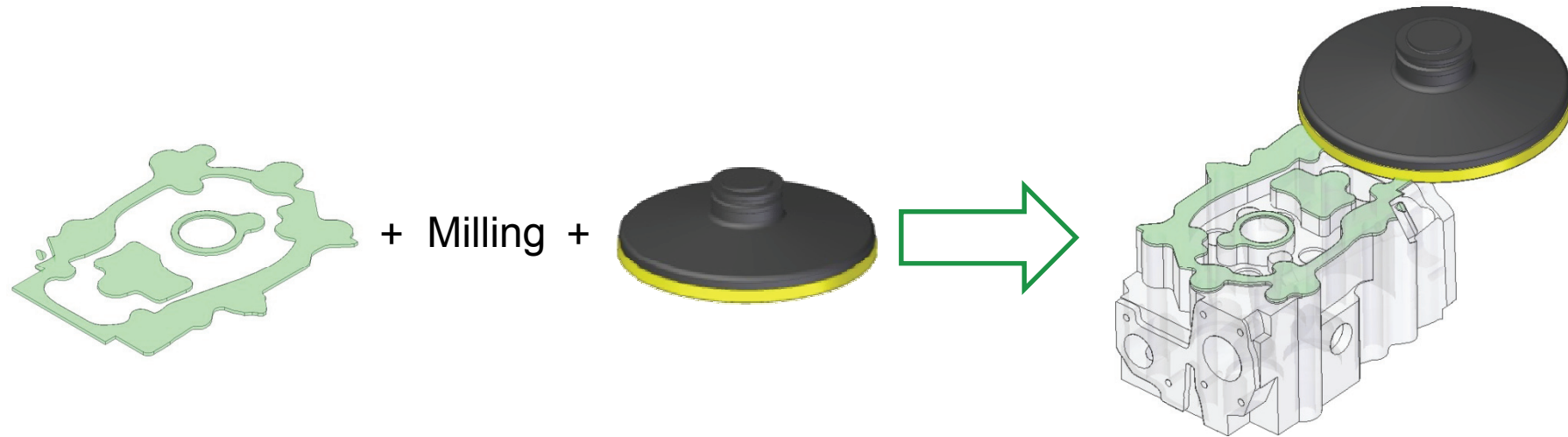
# Identify features



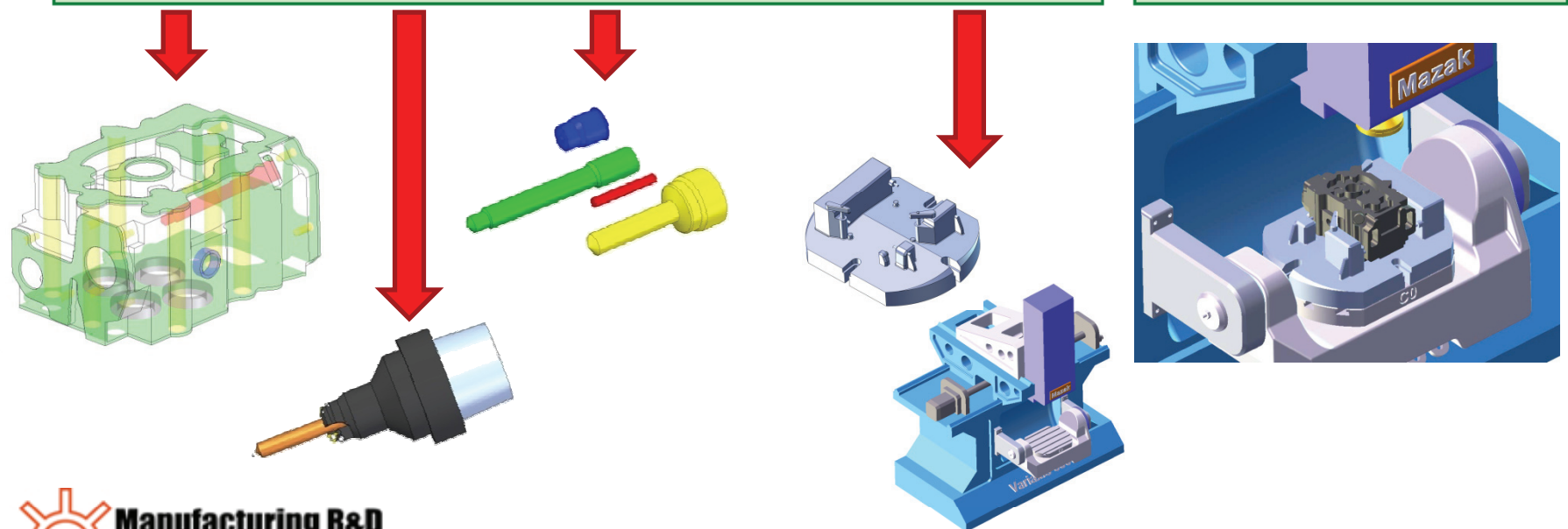
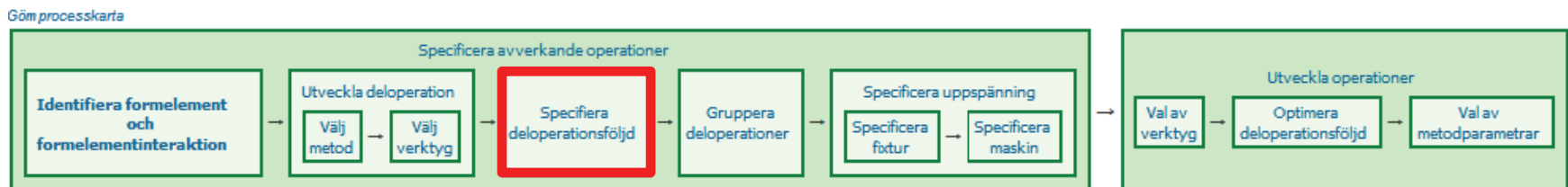
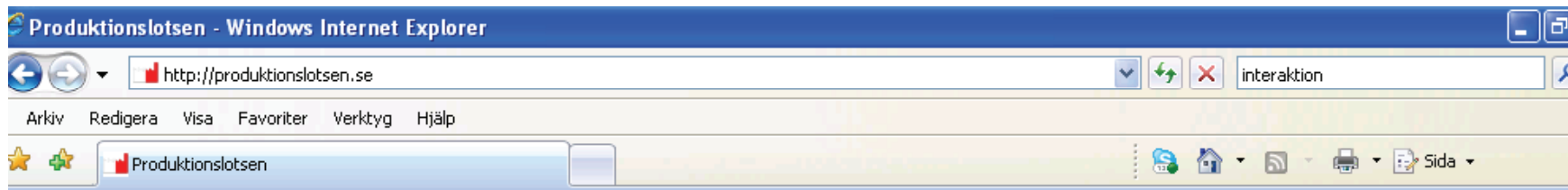


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# Develop machining operation

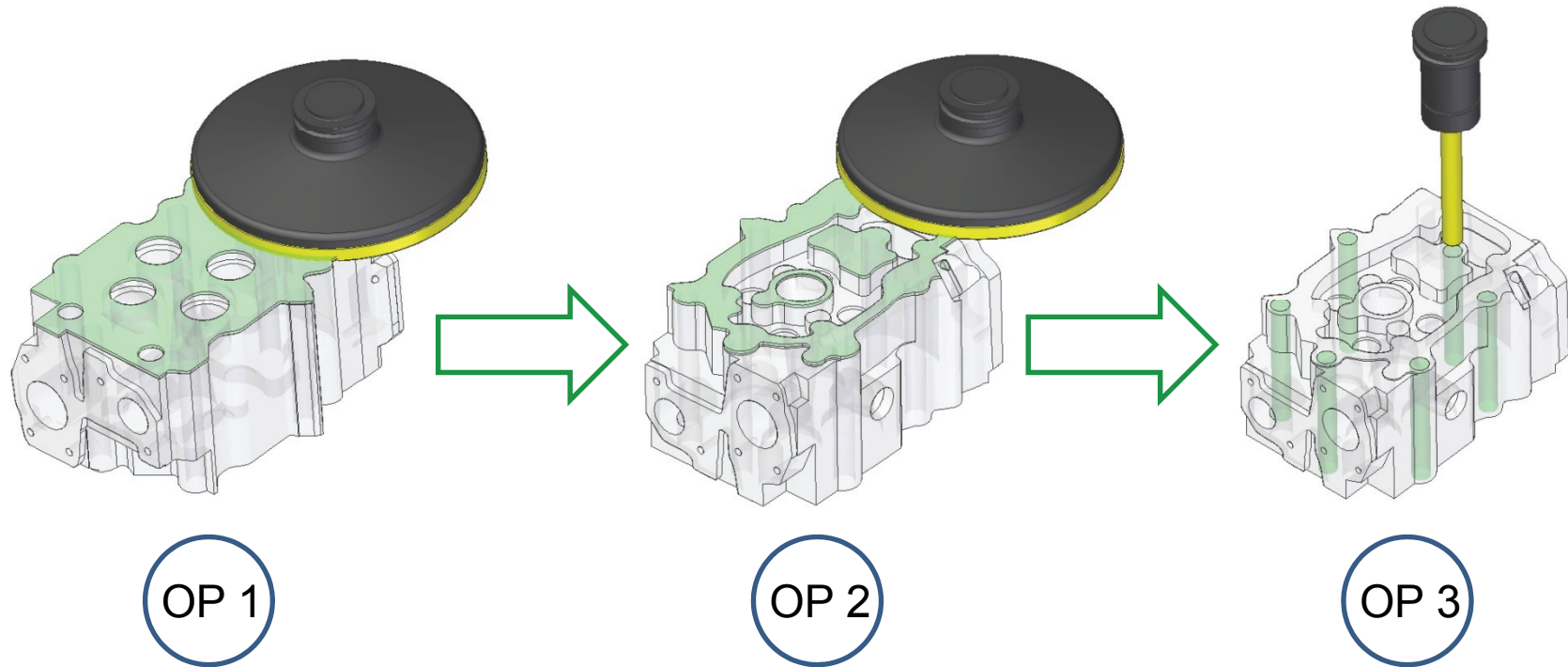


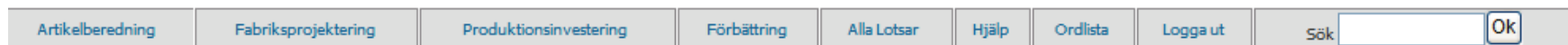
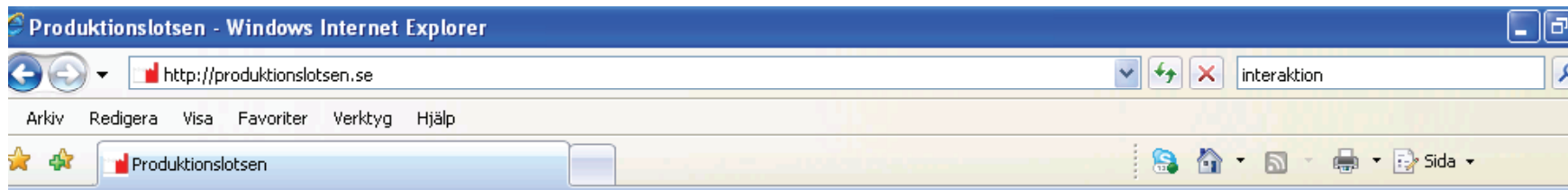




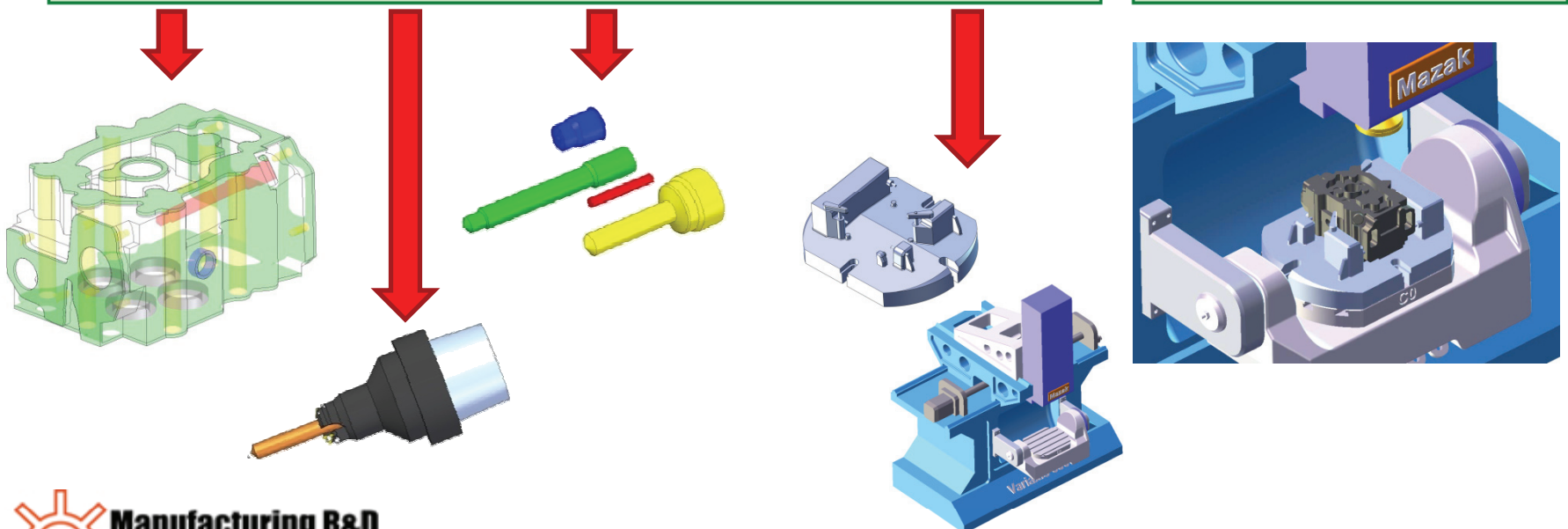
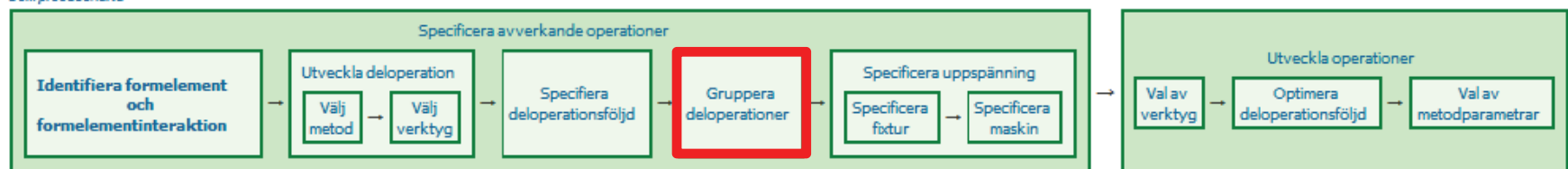
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# Machine operation sequencing



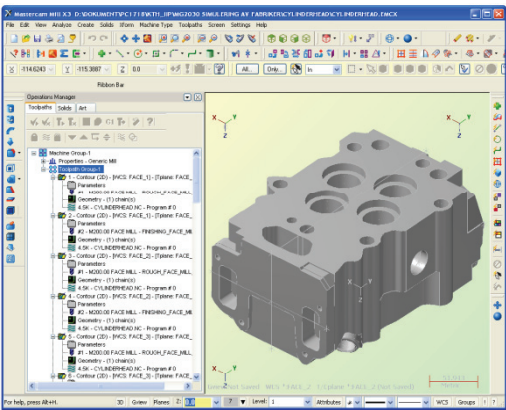
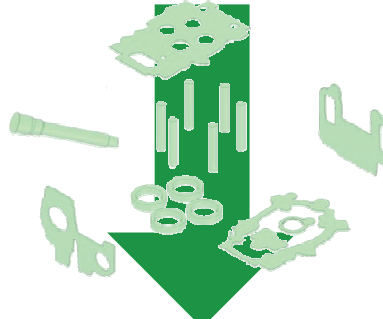


Göm processkarta

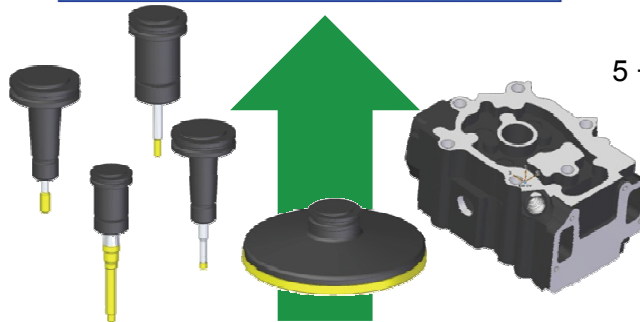
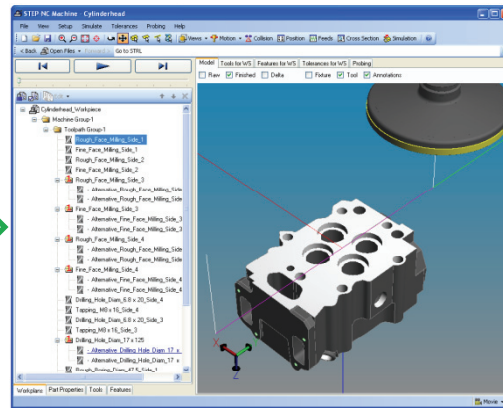


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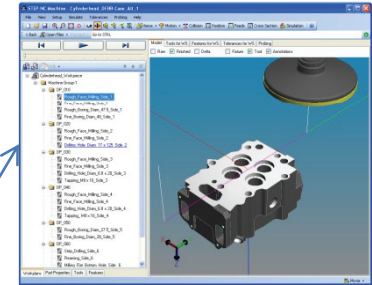
# What we have done and how



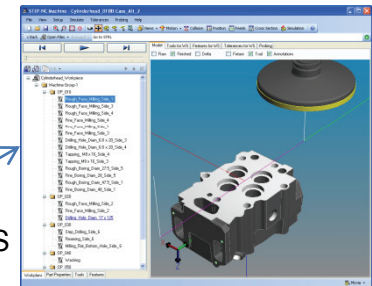
ISO10303-238



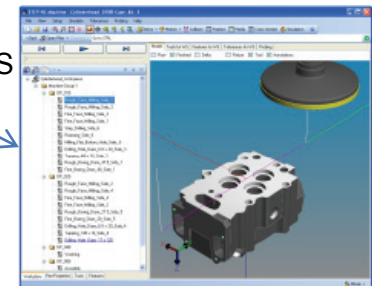
7 + 2 MACHINES



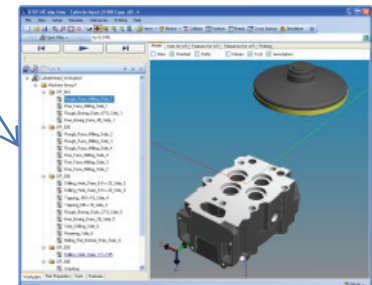
4 + 2 MACHINES



3 + 2 MACHINES



5 + 2 MACHINES



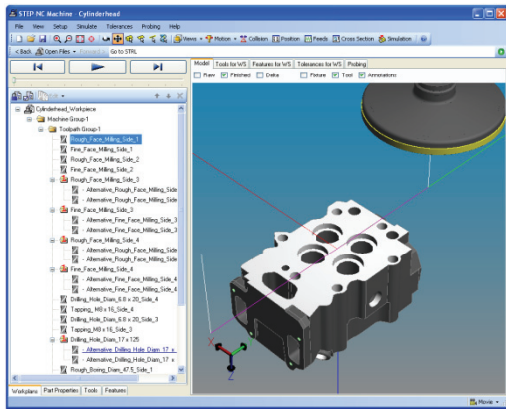
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The screenshot displays the STEP-NC Machine software interface for a cylinder head part. The 'Setup' menu is open, showing options like 'Setup Sheet'. The 'DlgTextView' window shows the following data:

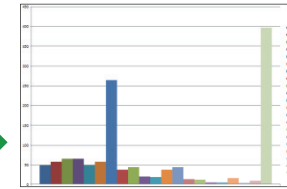
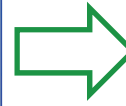
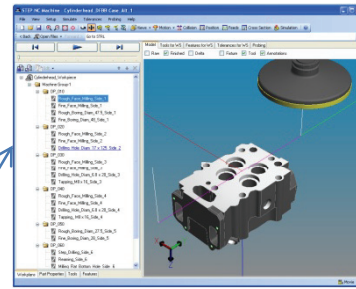
Workplan	Total Workplan Time	Total Workplan Distance
WORKPLAN MAIN	1272,2 second	20788,33 mm
WORKPLAN 1	238,44 second	3993,23 mm
1-1 Rough Face Milling Side 1	48,85 second	765,5 mm

Callouts in the image point to these values:

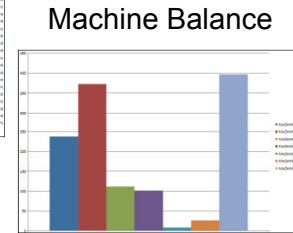
- Machining time for all setups:** 1272,2 second
- Machining time for one setup:** 238,44 second
- Machining time for one operation:** 48,85 second



7 + 2 MACHINES

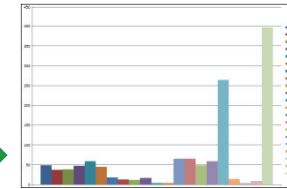
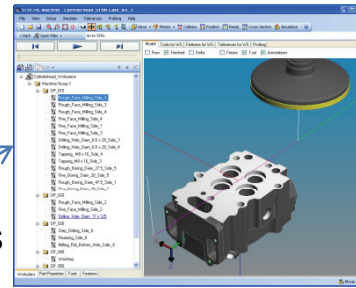


Operation Balance

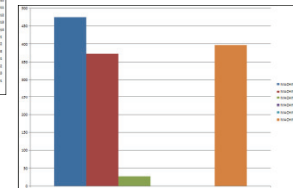


Machine Balance

4 + 2 MACHINES

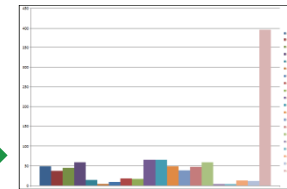
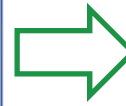
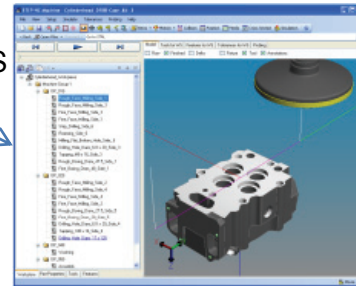


Operation Balance

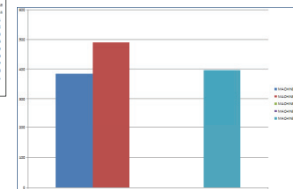


Machine Balance

3 + 2 MACHINES

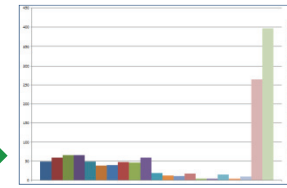
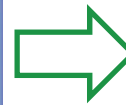
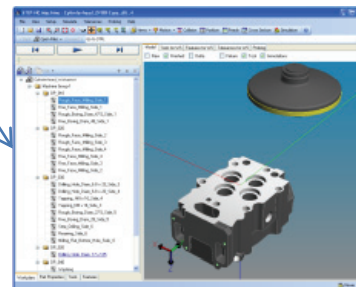


Operation Balance

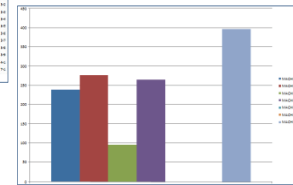


Machine Balance

5 + 2 MACHINES



Operation Balance

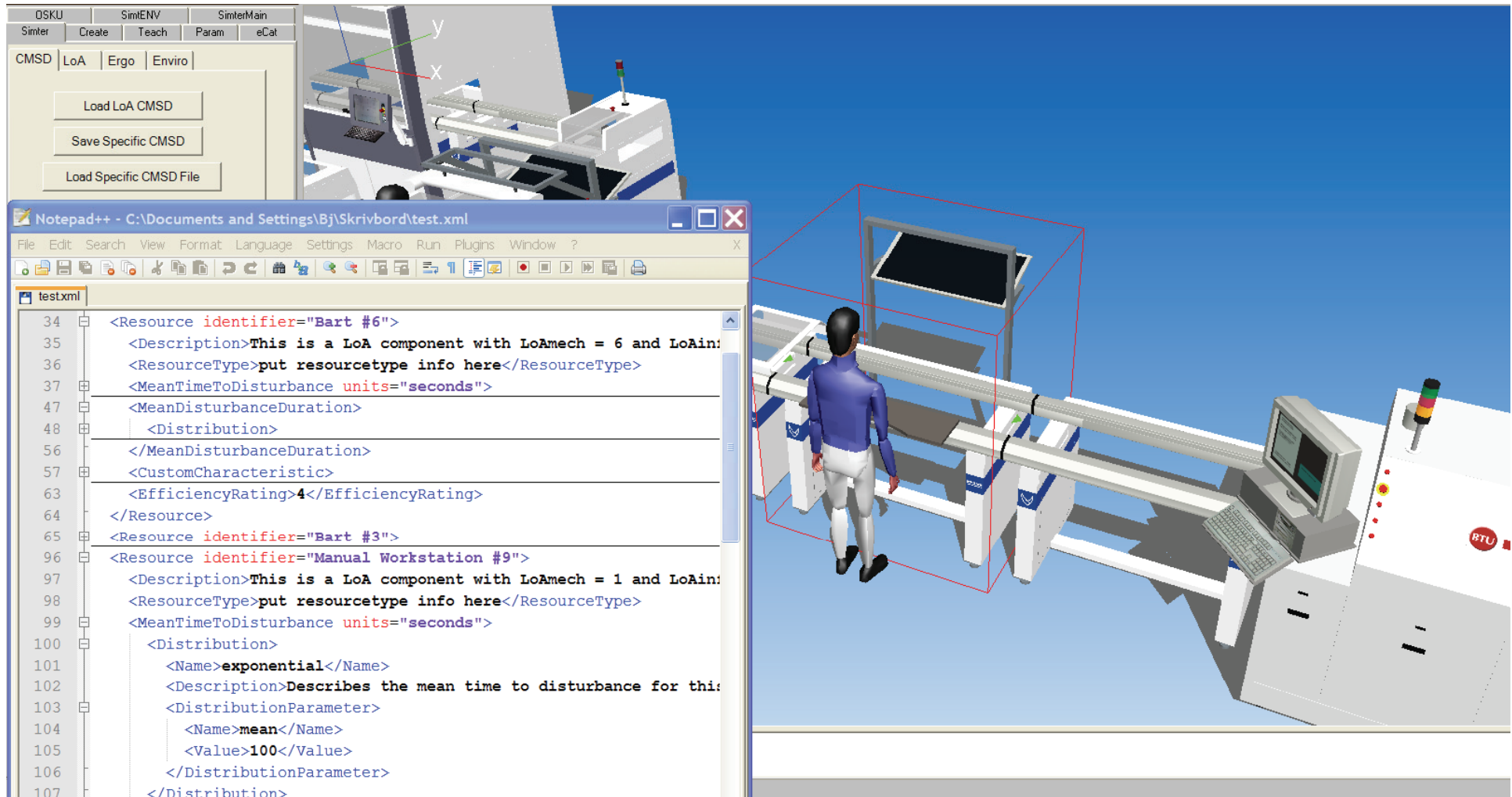


Machine Balance

# Discrete event simulation

- **Input data from Process Planning**
- **Variations over time**
- **Captures needs for buffers and shows if the system is well balanced**
- **Can calculate uncertainty in output and lead times**
- **Can be used to give Feedback to Process Planner**

# Core Manufacturing Simulation Data -Standard



The image displays a software interface for manufacturing simulation. On the left, a control panel includes buttons for 'Load LoA CMSD', 'Save Specific CMSD', and 'Load Specific CMSD File'. The main area shows a 3D model of a workstation with a person figure. A Notepad++ window is open, showing XML data for two resources:

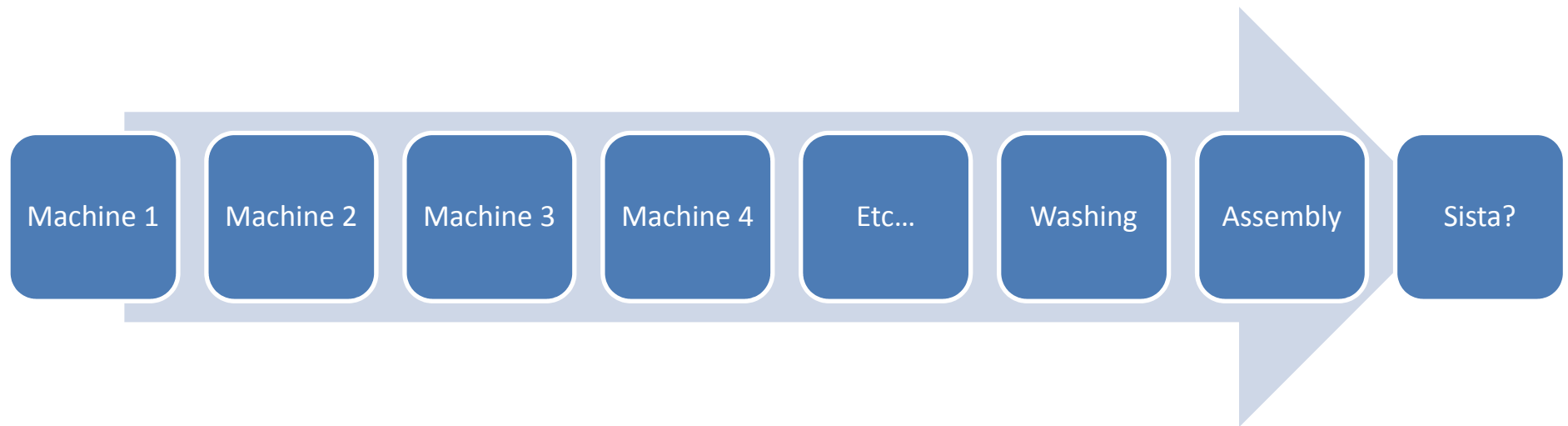
```
34 <Resource identifier="Bart #6">
35 <Description>This is a LoA component with LoAmech = 6 and LoAin:
36 <ResourceType>put resourcetype info here</ResourceType>
37 <MeanTimeToDisturbance units="seconds">
47 <MeanDisturbanceDuration>
48 <Distribution>
56 </MeanDisturbanceDuration>
57 <CustomCharacteristic>
63 <EfficiencyRating>4</EfficiencyRating>
64 </Resource>
65 <Resource identifier="Bart #3">
96 <Resource identifier="Manual Workstation #9">
97 <Description>This is a LoA component with LoAmech = 1 and LoAin:
98 <ResourceType>put resourcetype info here</ResourceType>
99 <MeanTimeToDisturbance units="seconds">
100 <Distribution>
101 <Name>exponential</Name>
102 <Description>Describes the mean time to disturbance for this:
103 <DistributionParameter>
104 <Name>mean</Name>
105 <Value>100</Value>
106 </DistributionParameter>
107 </Distribution>
```



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# Flow in example system



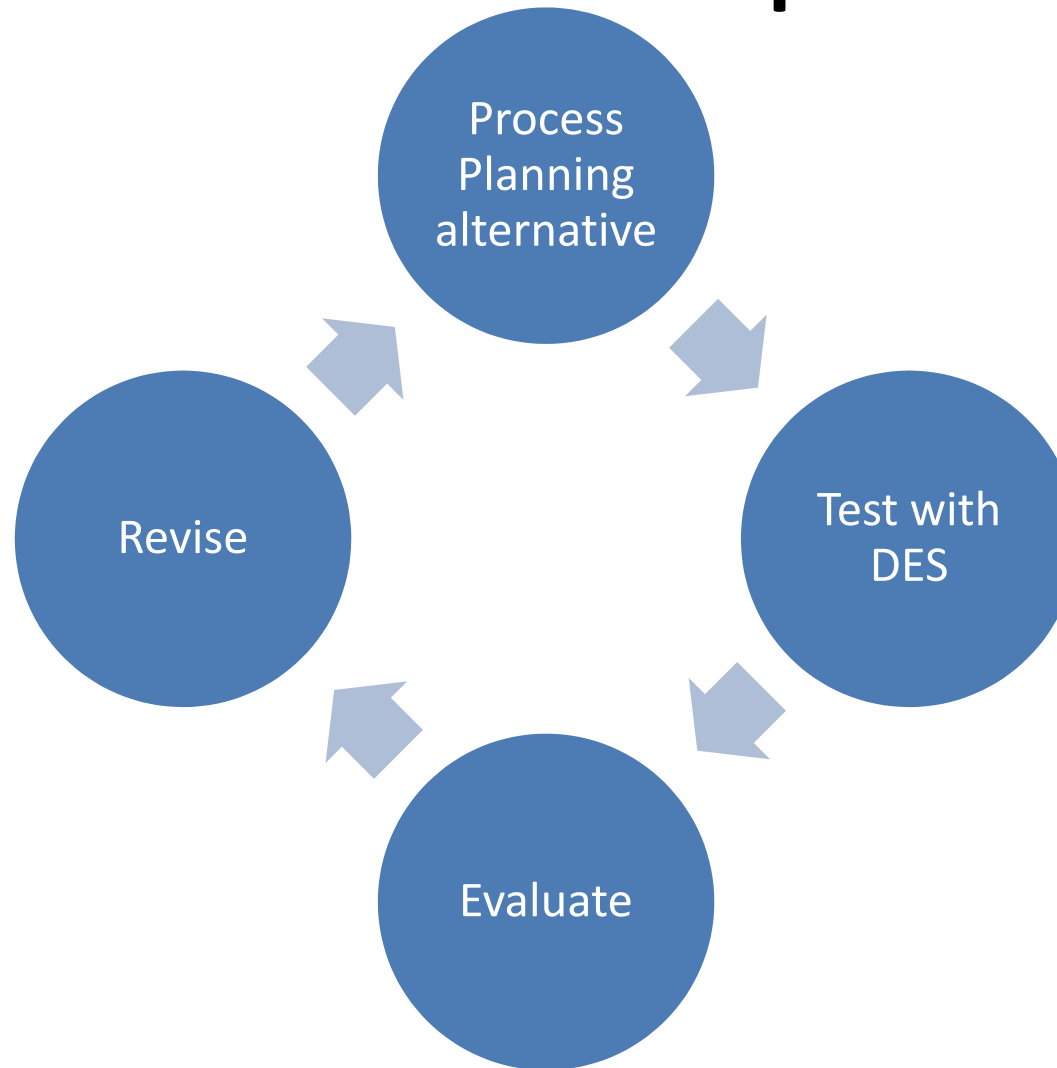
# System test

	3-Axis	3-Axis	3-Axis	3-Axis	3-Axis	5-Axis	Washing	Assembly	
MACHINE	1	2	3	4	5	6	7	8	9
Alt 1 cycletime (seconds)	238.44	372.39	112.36	101.22	8.42	27.11	180	90	397.06
Alt2 cycletime (seconds)	475.63	372.39	27.11	0	0	0	180	90	397.06
Alt3 cycletime (seconds)	384.37	490.77	0	0	0	0	180	90	397.06
Alt4 cycletime (seconds)	238.44	276.81	95.02	264.87	0	0	180	90	397.06
	5-Axis	5-Axis	5-Axis	5-Axis					
MTBF (minutes)	90	70	59	82	64	57	76	56	87
MTTR (minutes)	15	13	21	10	9	14	12	15	5

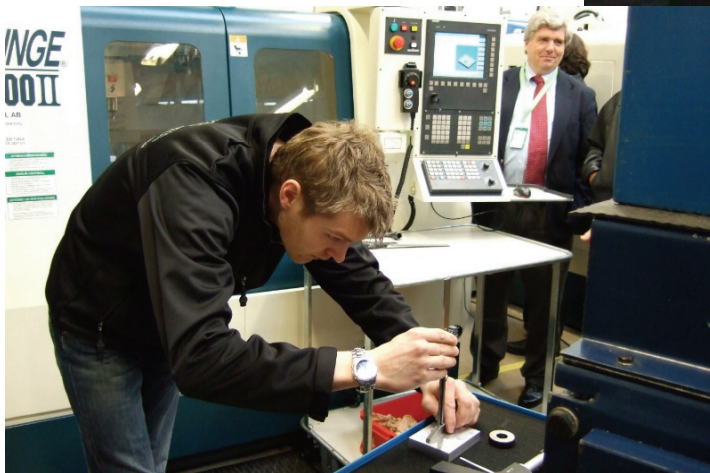
# Results from experiment

Experiment	Buffer sizes	Output for 100 hours	Standard deviation	Buffer influence
Alt 1	1	620	24.9	Index
Alt 2	100	802	19.4	29.2 %
Alt 3	1	544	17.1	Index
Alt 4	100	624	14.1	14.6 %
Alt 5	1	517	16.9	Index
Alt 6	100	614	14.0	18.8 %
Alt 7	1	673	24.1	Index
Alt 8	100	841	9.8	24.9 %

# Feedback loop



# ISO TC184 SC4 Demonstration, March 2008 @ Scania



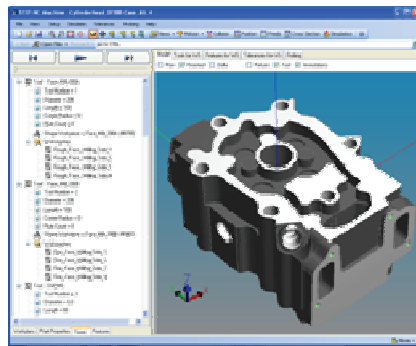
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# ISO TC184 SC4 Demonstration, March 2008 @ Scania

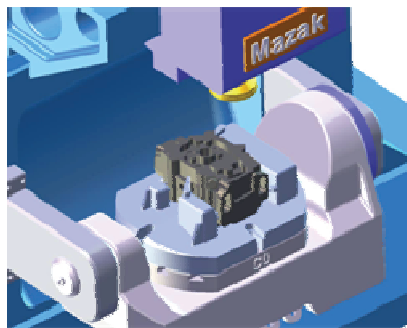
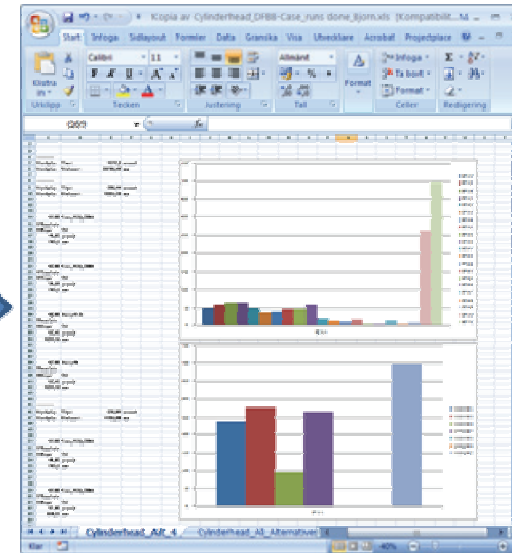
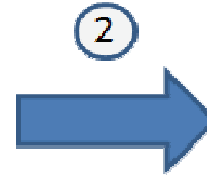
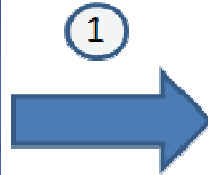
```
KTH_Part_3.mpf - Anteckningar
Arkiv Redigera Format Visa Hjälp
; AP-238 STEP-NC PROGRAM
; Generated: 2008-03-04T18:47:29+01:00
DEF INT LOG
DELETE(LOG,"MLM")
$AC_TIMER[1]=0
G17 G40 G90
N1 G54 ; use work offset 1
N2 G71
; workingstep: mill ws 1
WRITE(LOG,"MLM","MILL WS 1@"<<$AC_TIMER[1])
N3 T1M6
N4 M3S2400
N5 G0X-55Y40Z100
N6 Z3
N7 G1Z-0.025F5000
N8 X155F2900
N9 G0Z100
; workingstep: drill ws 2
WRITE(LOG,"MLM","DRILL WS 2@"<<$AC_TIMER[1])
N10 M5
N11 T2M6
N12 M3S8000
N13 G0X50Y25Z100
N14 Z15
N15 G1Z-22F640
N16 G0Z100
; workingstep: mill ws 3
WRITE(LOG,"MLM","MILL WS 3@"<<$AC_TIMER[1])
N17 M5
N18 T3M6
N19 M3S8000
N20 G0X-5Y82.851Z100
N21 Z10
N22 G1Z-5.02F1910
N23 G41 X-8Y77.654
```



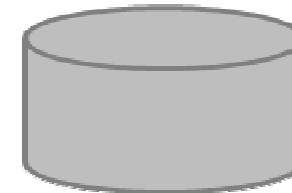
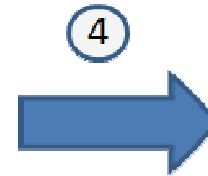
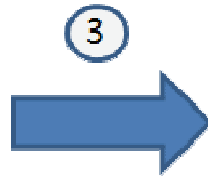
```
MLM.MPF - Anteckningar
Arkiv Redigera Format Visa Hjälp
WS 1=6.12
WS 2=12.285
WS 3=34.285
```



Setups and operation sequence with estimated machining time from Process planning



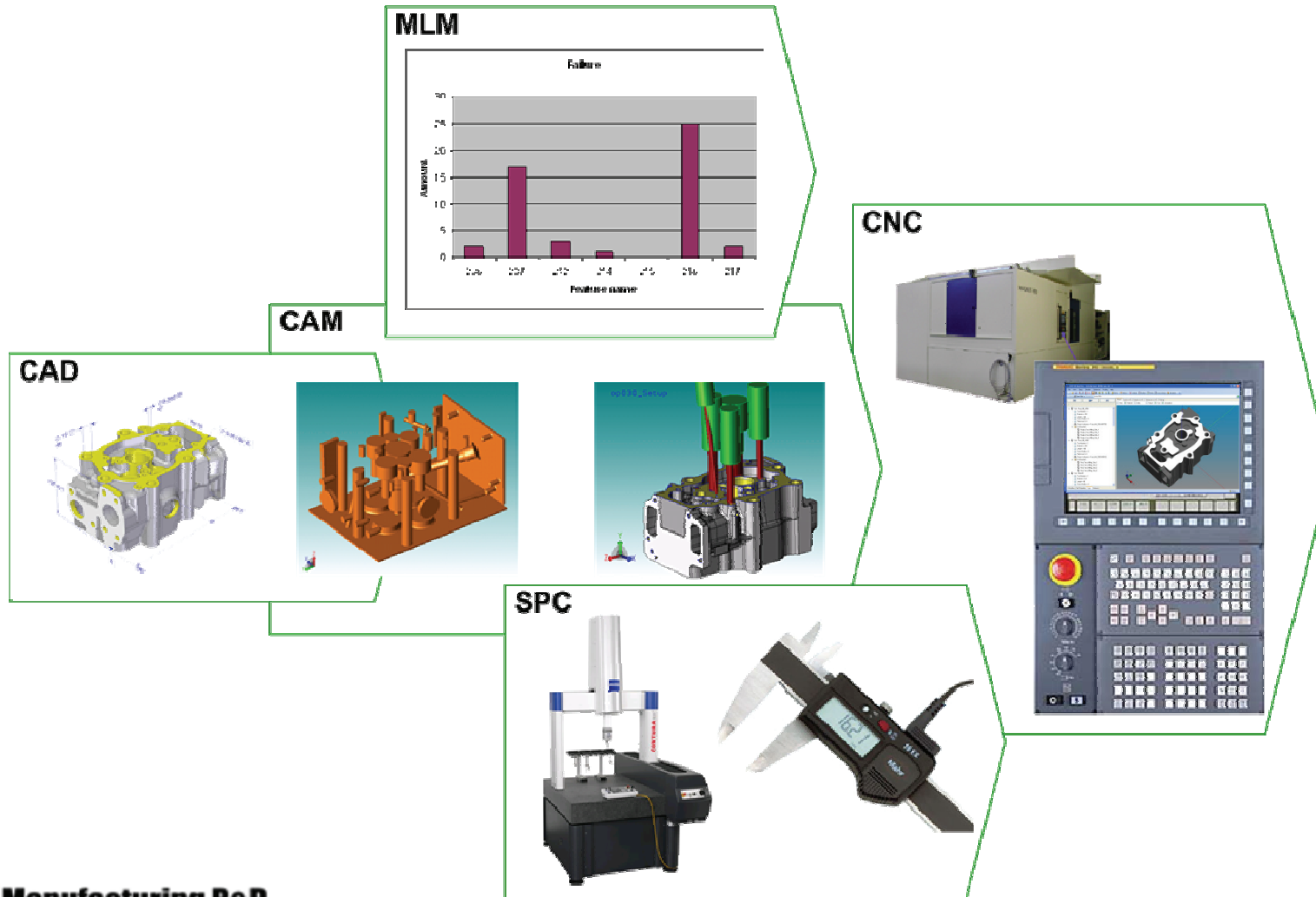
Each machine run becomes a record:  
 - Timestamp  
 - Machine tool  
 - Workingstep etc.



Statistical distribution, MTBF etc. for machines and operations



# Contextualized process feed back





# Questions?