PV Manufacturing Lines Planning and Optimisation with InFrame Synapse Simulation Library and AnyLogic

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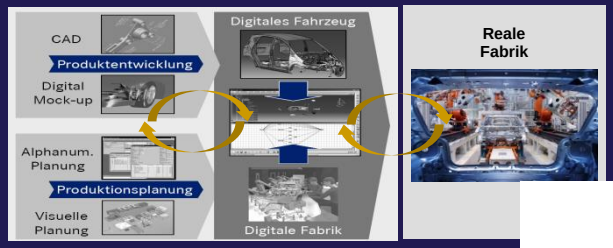
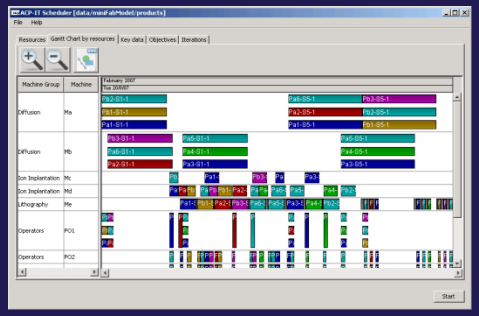
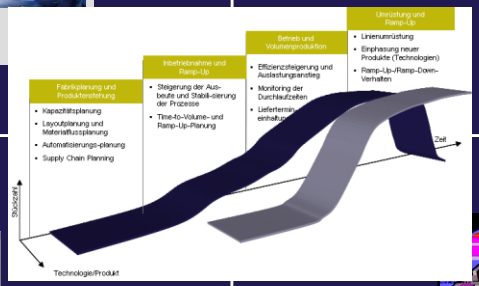
acp-IT's Expertise in Logistics & Digital Factory IT

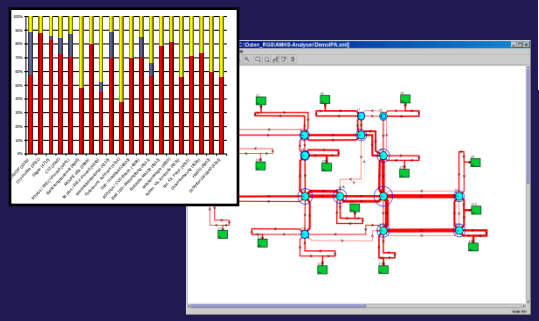
Product Data Management (PDM) Factory Life Cycle Management IT Integration

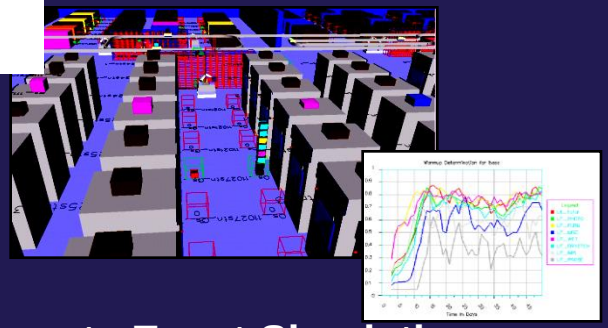


Advanced Planning, Scheduling, Dispatching







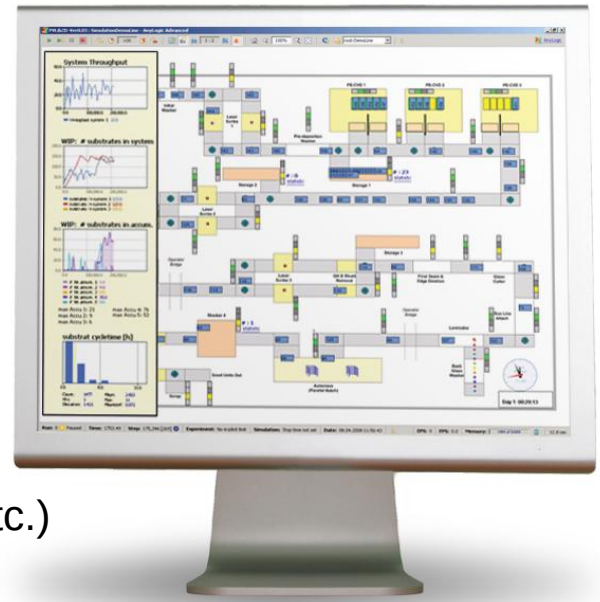


Capacity, Material Flow and Layout Planning

Discrete Event Simulation, Performance Evaluation

Simulation Services

Simulation based planning of manufacturing lines

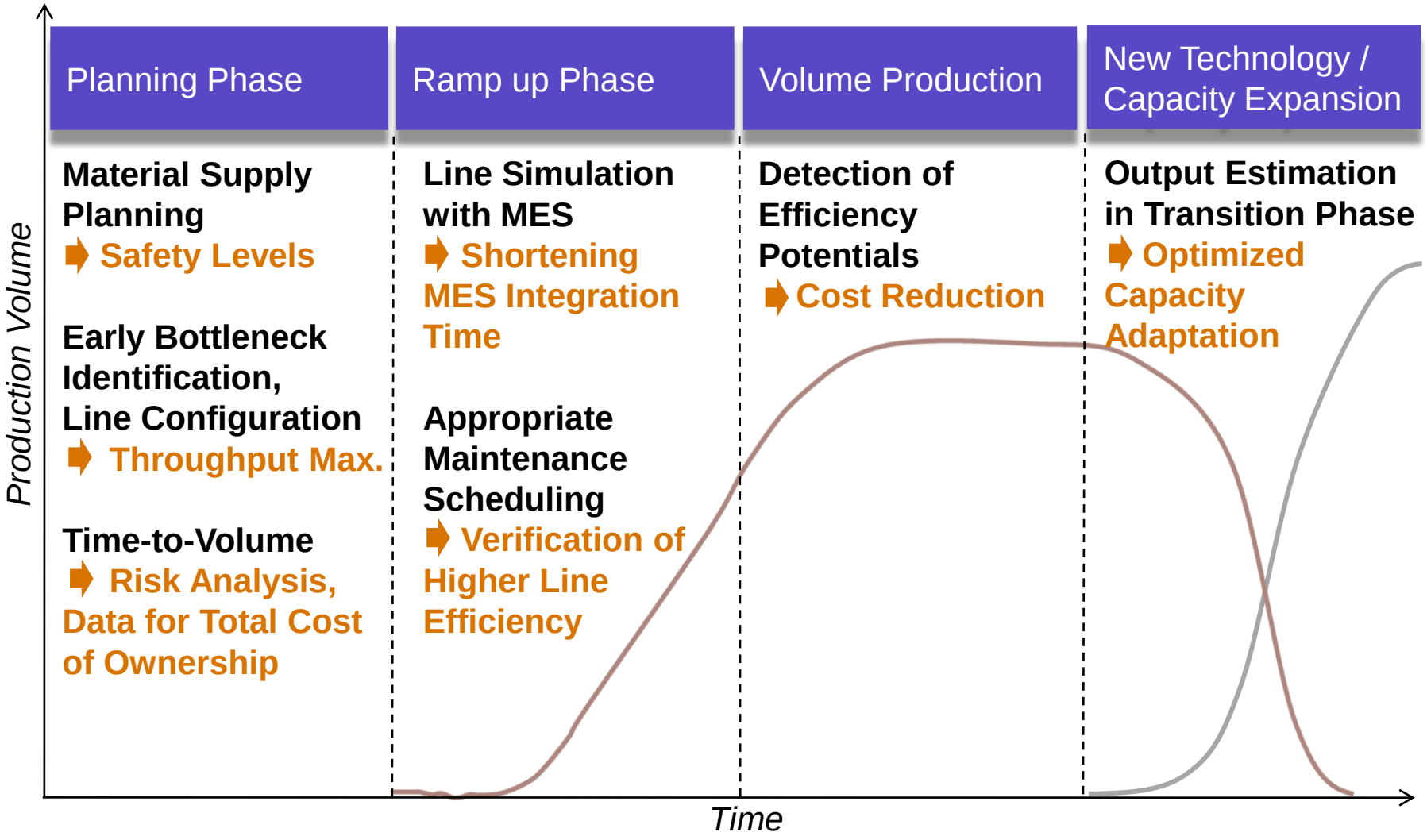


- resource capacity planning
- material flow analysis & layout planning
- planning of storage and transportation processes
- emulation of lines for the testing of factory control software
- ramp-up simulation
- development of modular components for equipment & material handling
- inbound and outbound logistics with infrastructure, warehouse (raw material, finished goods, handling of glass etc.)

Simulation based optimization of existing manufacturing lines

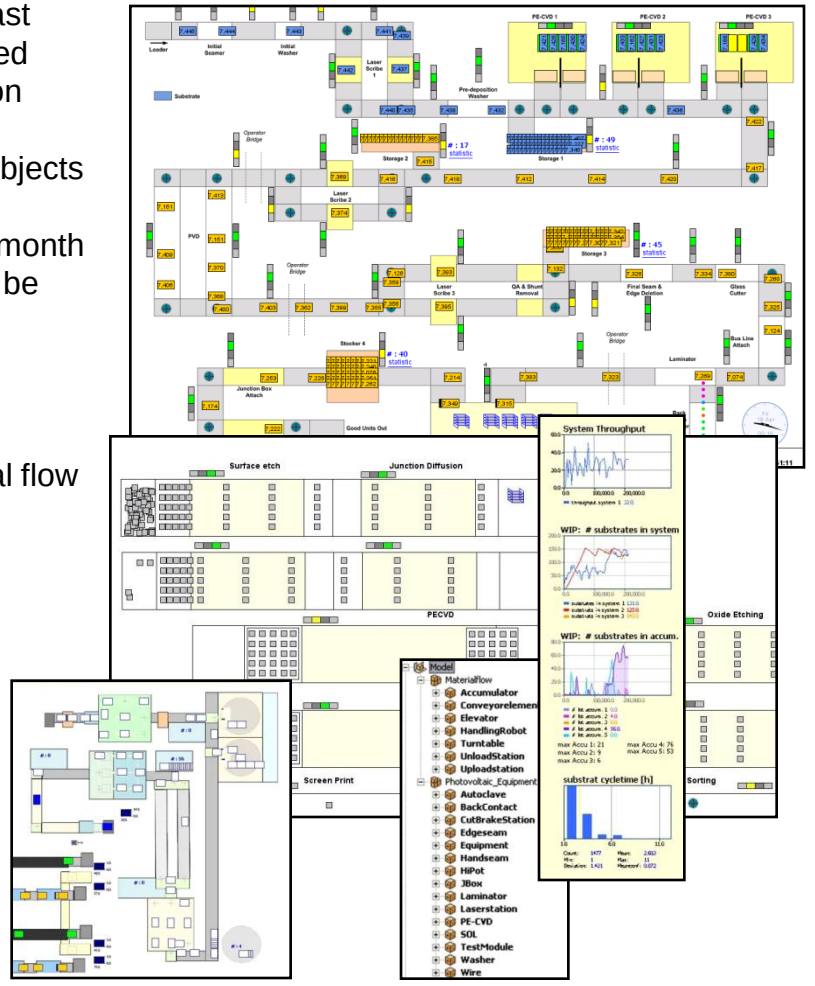
- performance evaluation based on log data
- development and continuous measurement of key performance indicators such as overall equipment efficiency (OEE)
- bottleneck detection
- optimization of material flow policies

Potential Benefits of Manufacturing Simulation



Application of the InFrame Synapse Simulation Library based on AnyLogic Ver. 6

acp-IT disposes of a simulation library with specific components for the fast setup of PV production simulation models. This library has been developed and executed within numerous projects for the simulation of PV production lines (thin film and wafer based).
Layouts can be modelled with the drag&drop functionality and the used objects can be adapted via parameter input. The simulation execution time is extremely short (only few minutes computing time for the simulation of 1 month of a typical production scenario with a normal CPU). Simulation runs can be executed via Java applet in a web browser.



The library includes:

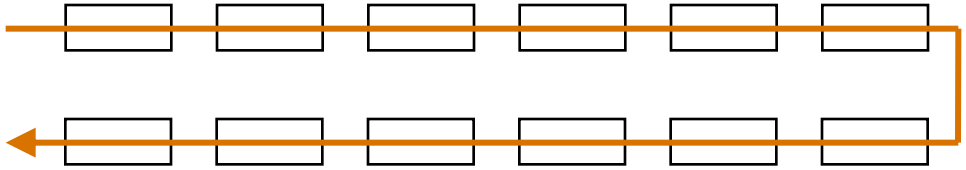
- process equipment and material handling equipment library
- routing and dispatching logic components for building the material flow
- optimisation algorithms for job shop material flow
- equipment specific state models for process equipment and material handling elements
- online graphics and reports for the line and equipment performance monitoring
- offline statistics for scenario runs comparison
- interface for the communication with control systems (MES)

At the moment, the library is extended with material flow components used for warehouse simulation:

- additional material handling for warehouse such as forklifts
- automated storage systems for glass
- warehouse disposition strategies

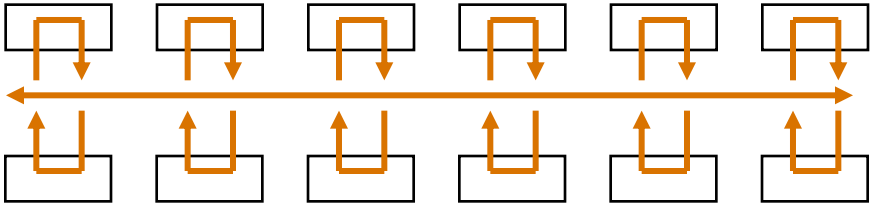
Layout Planning for Thin Film Manufacturing Lines

Flow line with conveyor transport



- Substrate queuing in front of critical process steps
  (→ need for several buffering elements)
+ high transport throughput possible

Job shop layout with central transport (handling unit)

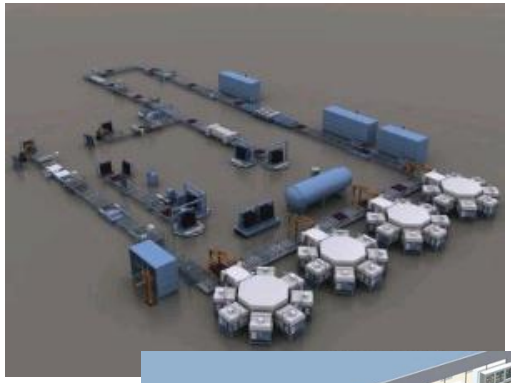


- Central transportation can become the bottleneck
+ More process flexibility & process capacity extension easier

Analysis of flow dynamics requires simulation!

Example layouts from equip. suppliers

Sunfab
(Applied Materials)



Turnkey solar factory
(Centrotherm)

The Way to the Base Model … for a Thin Film Mfg. Model

1 Process Step Modeling

Seam, wash, laser scribe, PECVD, Laser scribe, PVD, …

- **Model all process steps & times for each product.**

→ Capture all throughput dynamics from the equip.

2 Capacity Check

Simulate with factory load (substrate start rate)

→Enough equipment capacity?

→Number of equip. for each equip.-group

Seam → 1 Equip.
Wash → 1 Equip.
Laser Scribe → 3 Equip.
PECVD → 2 Equip. (7 chambers)
…

3 Mat. Handling Modeling

Model material flow between process steps

→Equip. for execution of transport & mat.handling steps

→Buffering elements

→Configuration of complex material flow policies

Conveyor and robots, transport speeds, spacing, transport capacity, location of buffers, substrate routing policies (look ahead), queuing behavior …

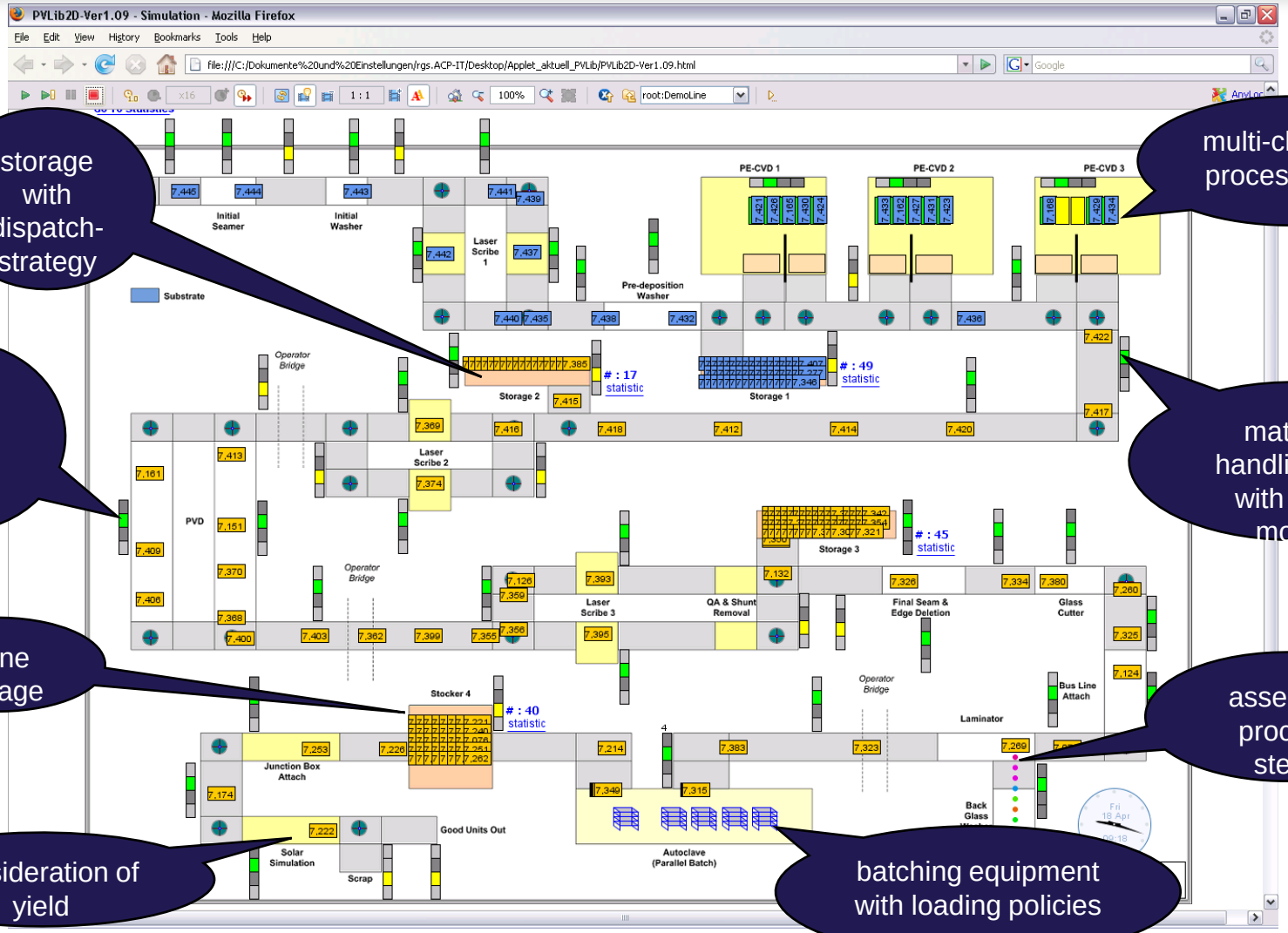
gridlock free substrate routing

4 Throughput Check

Verify overall throughput
→ process & transport & material handling

cycle time, throughput, equipment utilization, max. buffer WIP, …

Modelling of Thin-Film Manufacturing Line based on InFrame Synapse Simulation Library and AnyLogic



storage with dispatch-strategy

multi-chamber process steps

state-model and light tower

material handling unit with state model

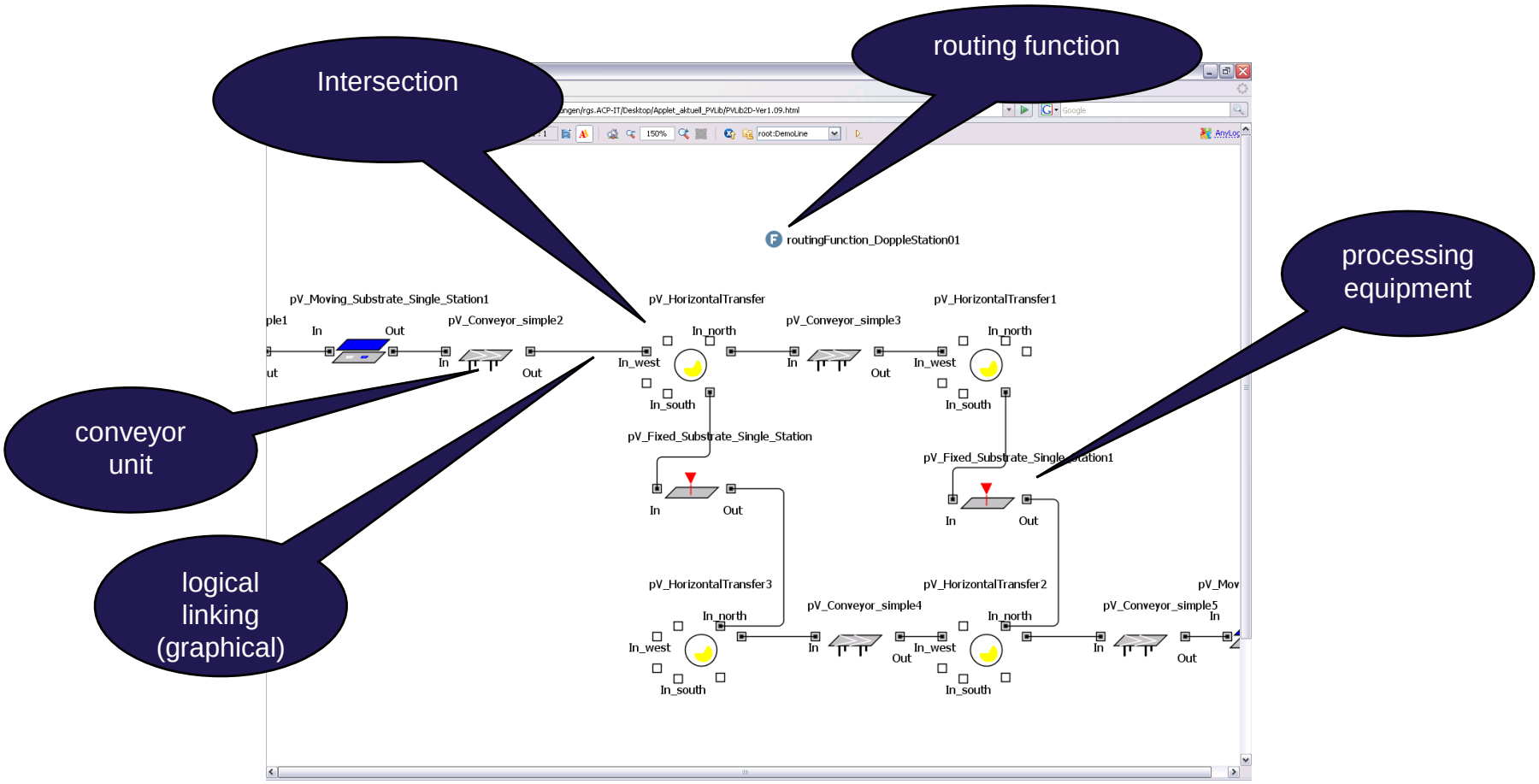
inline storage

assembly process steps

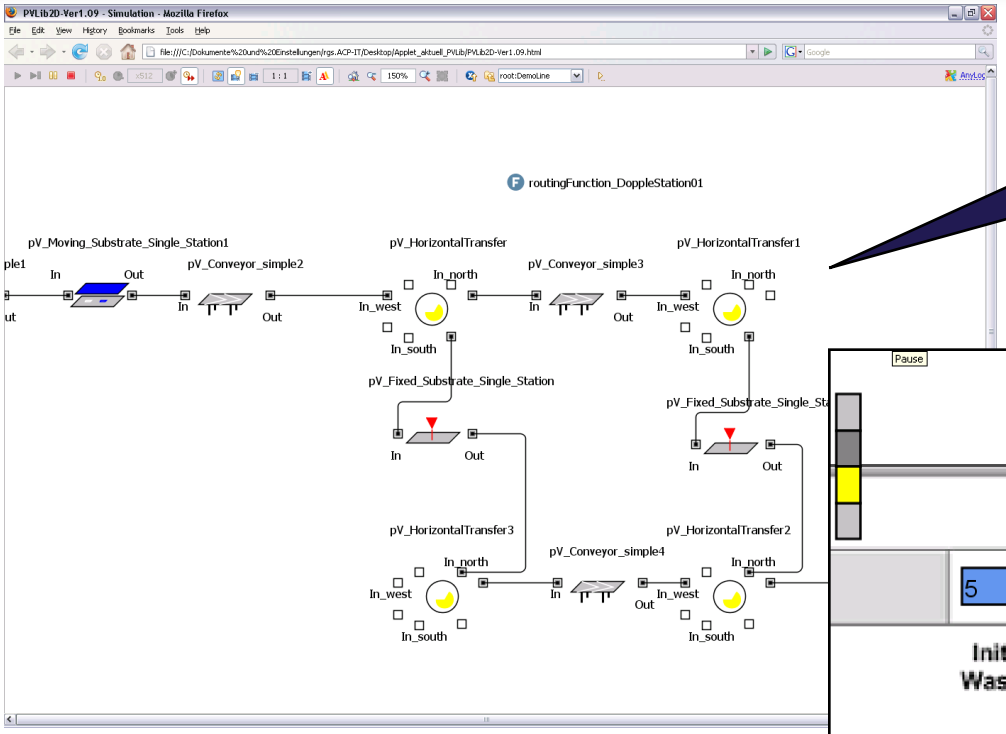
consideration of yield

batching equipment with loading policies

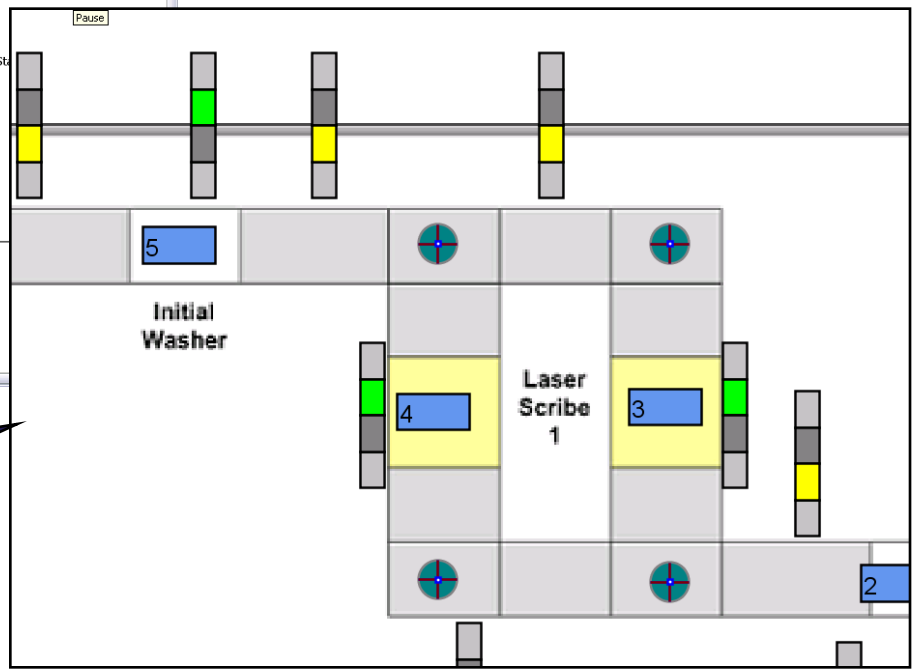
Drag & Drop Modelling and Easy Linking of Library Objects



Drag & Drop Modelling of Logical Library Objects and Drag & Drop Positioning in Factory Layout

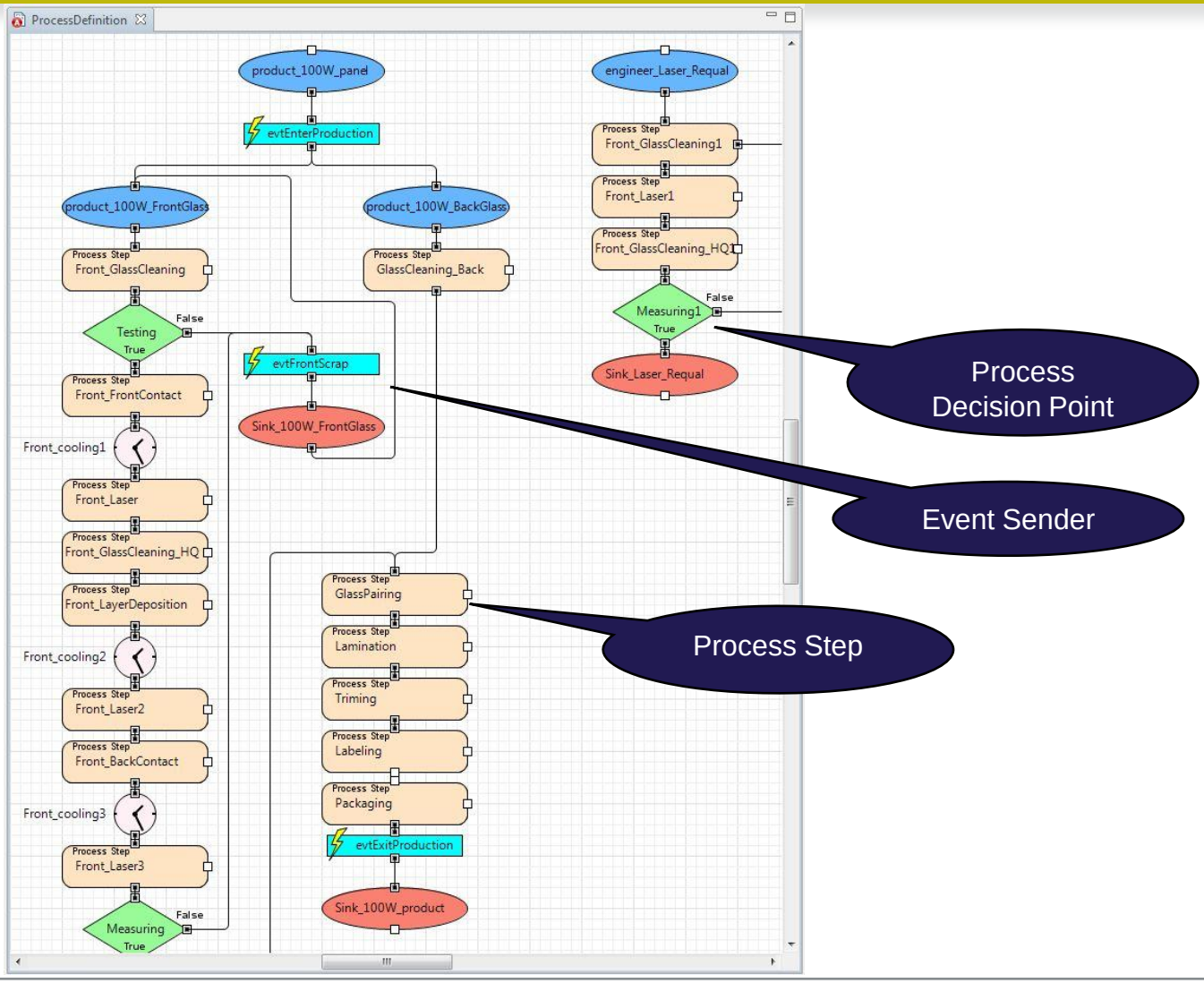


logical modelling in block diagram

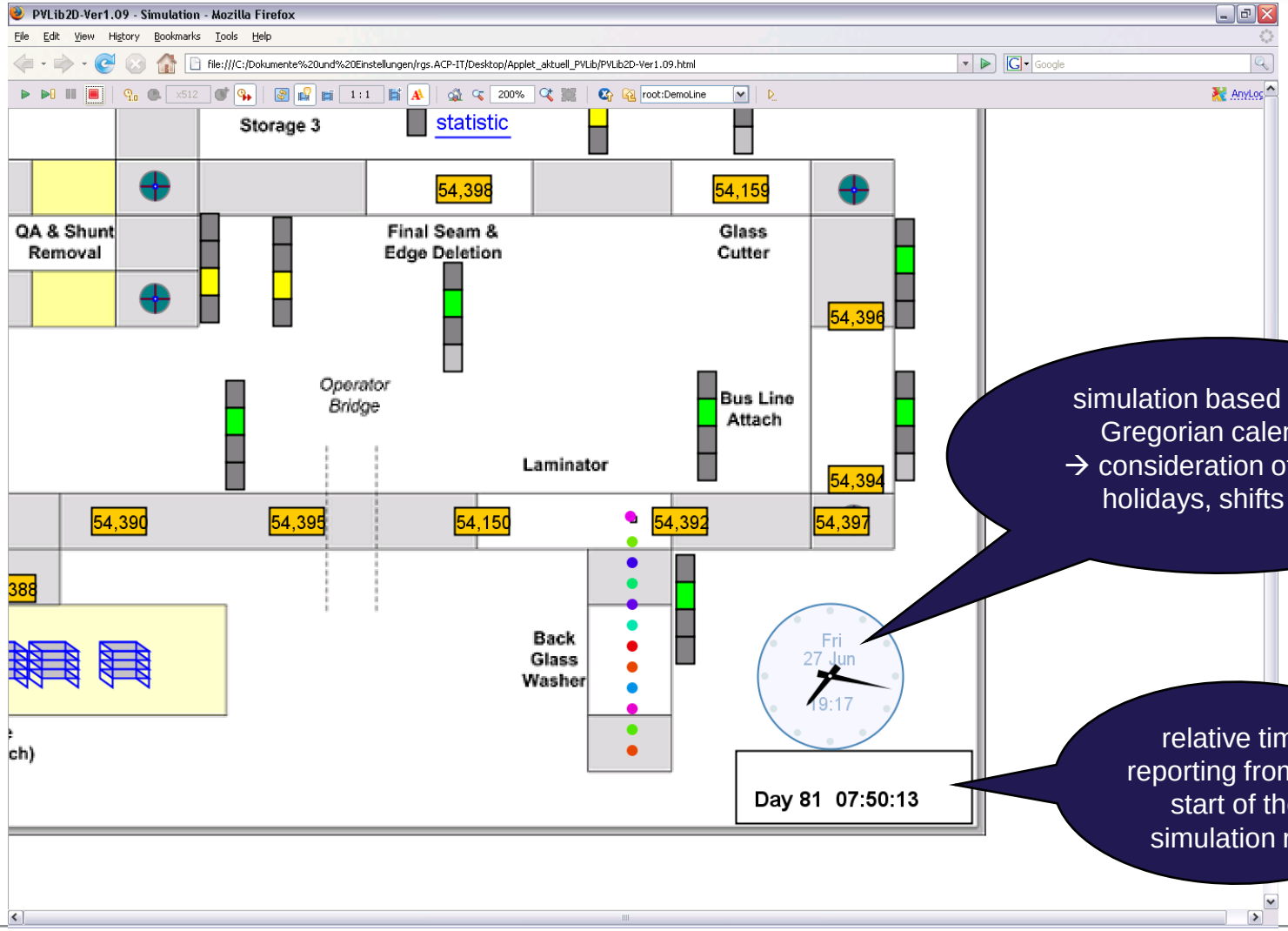


animation of material flow and relocation in layout independently of the flow logic – adaptable built-in-animation for the library objects

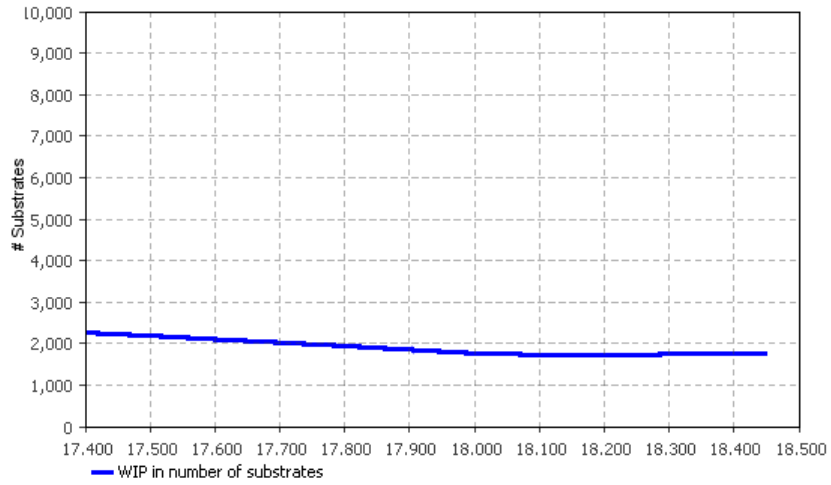
Drag & Drop Modelling of Complex Process Flows

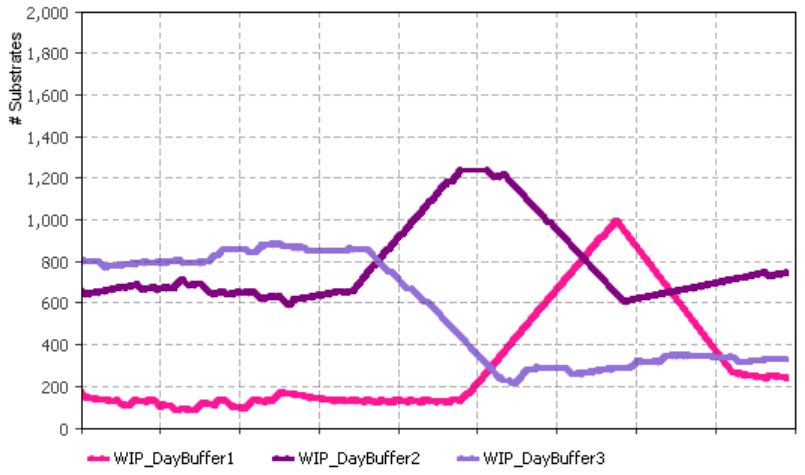


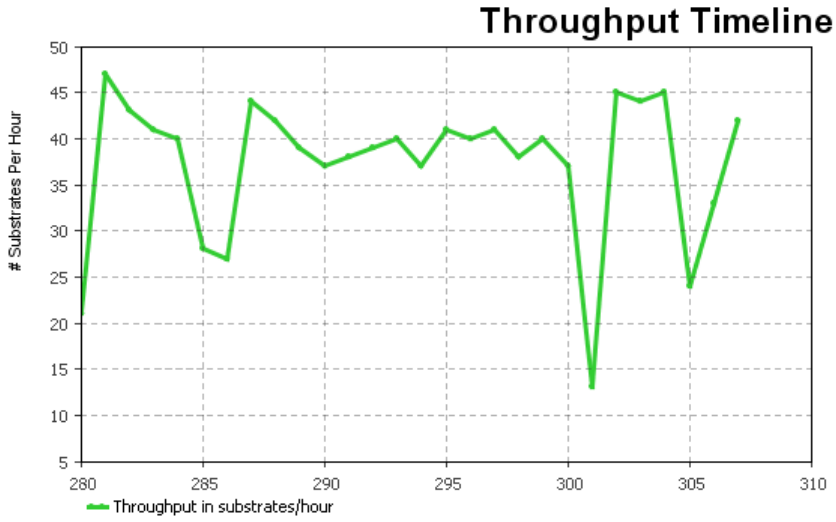
Simulation Clock – Relative and Absolute Time with the Consideration of Shift and Work Calendars

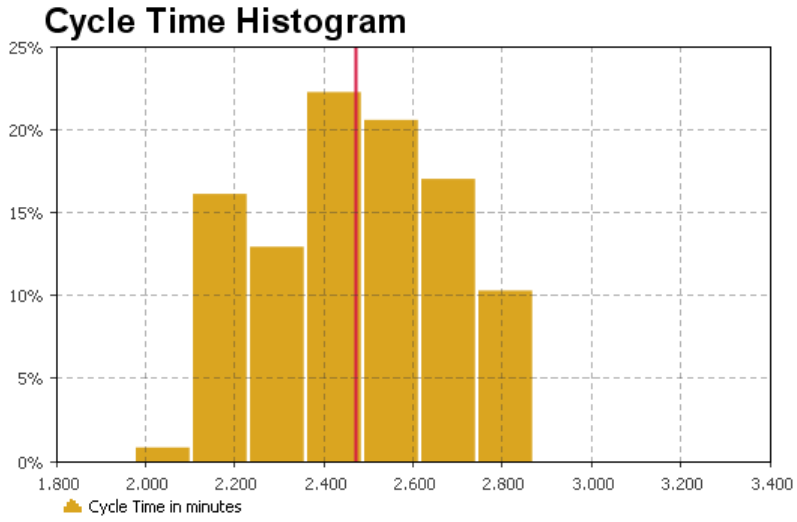


Online Charts for the Monitoring of Line Performance Metrics

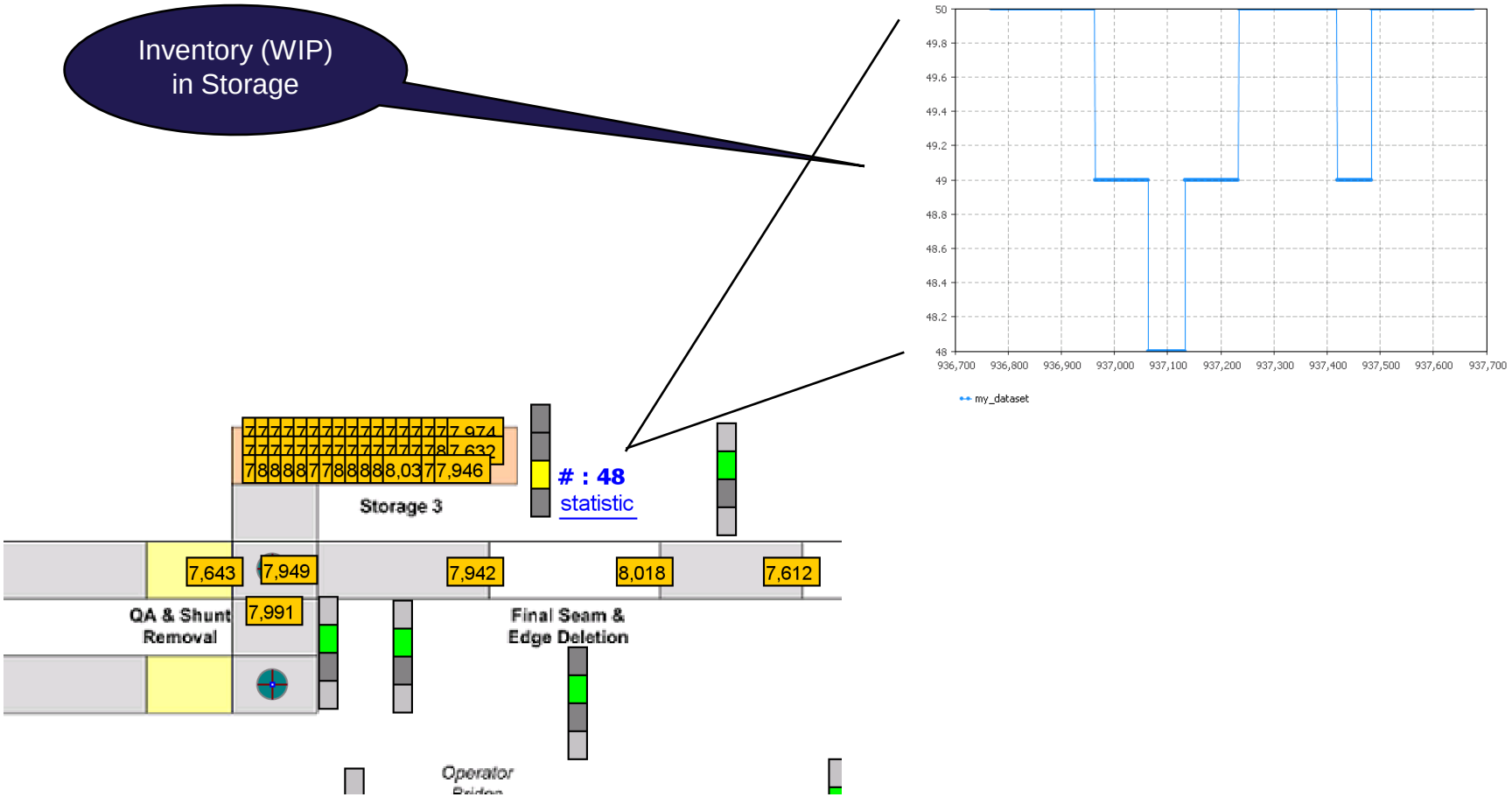




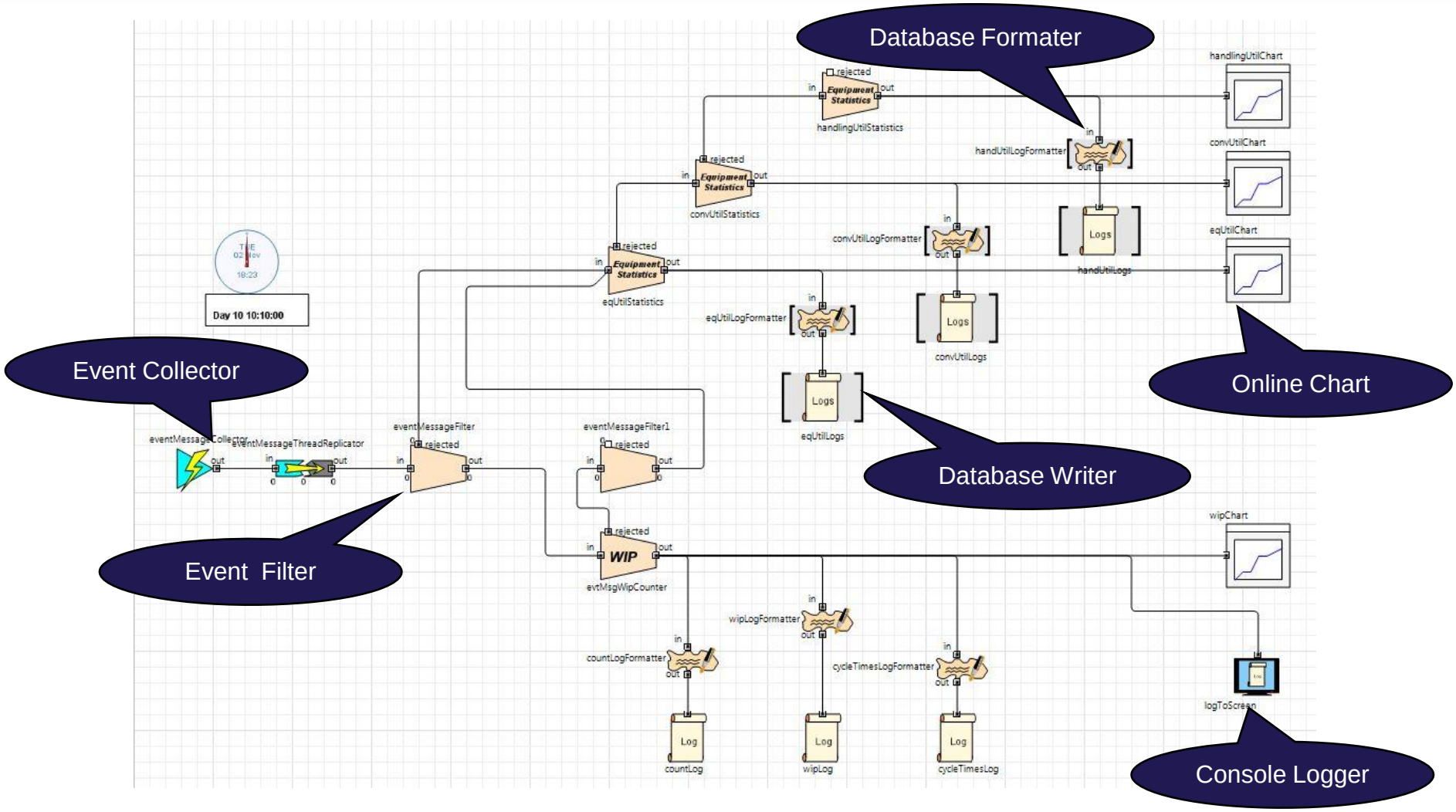




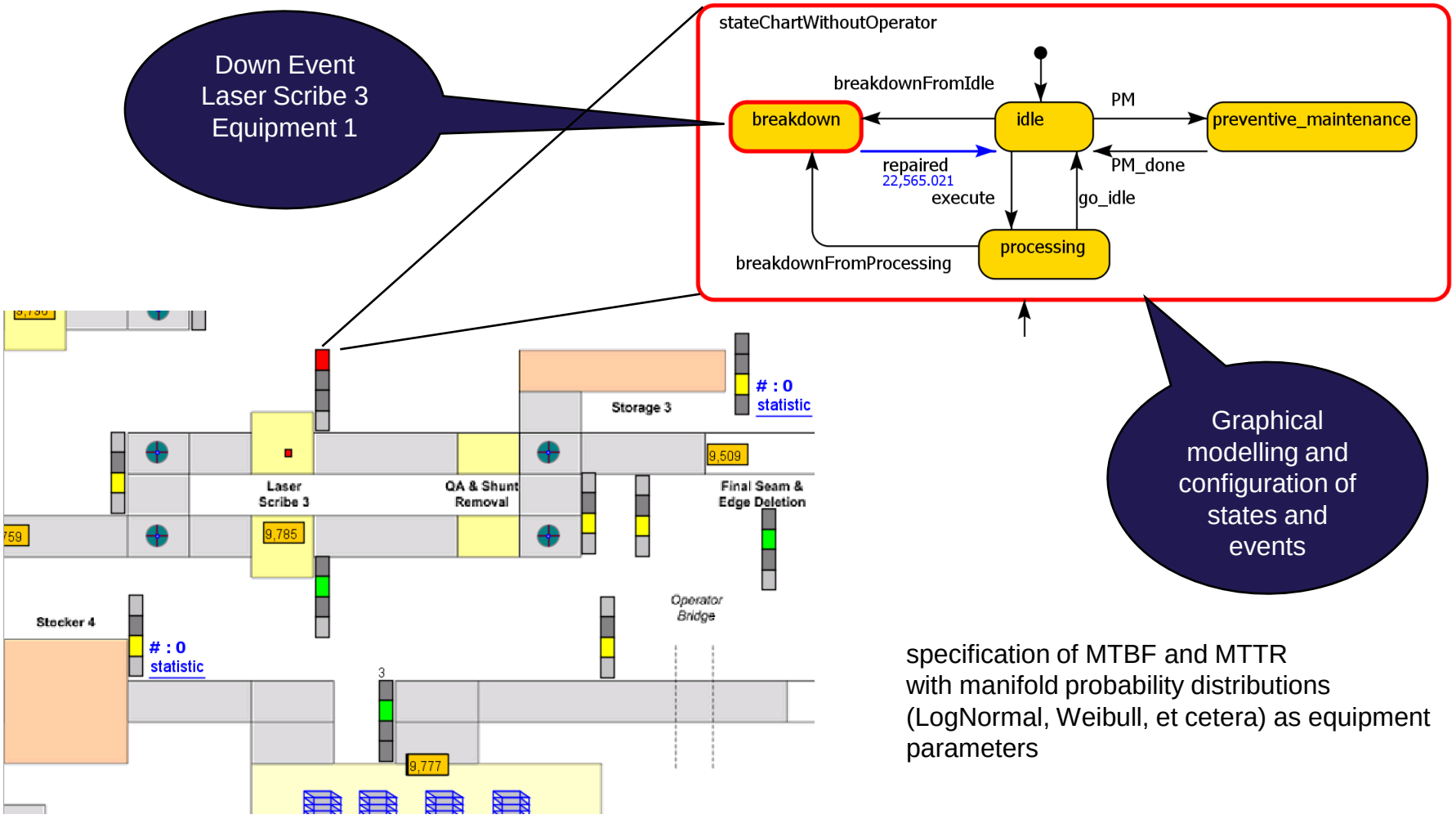
Online Charts for the Analysis of Single Components
here: Charts and Reports for the Dimensioning of Storage Systems



Drag & Drop Configuration of Statistics and Reports

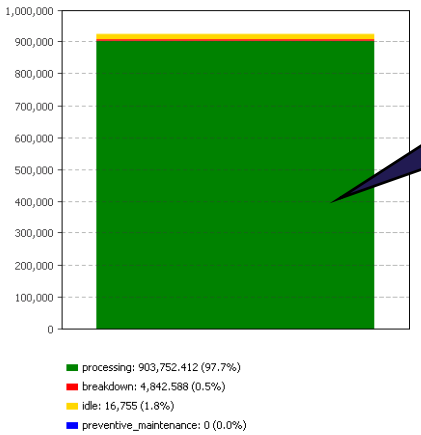


Specific Resource State Models
here: State and Event Model for a Laser Scribe Equipment



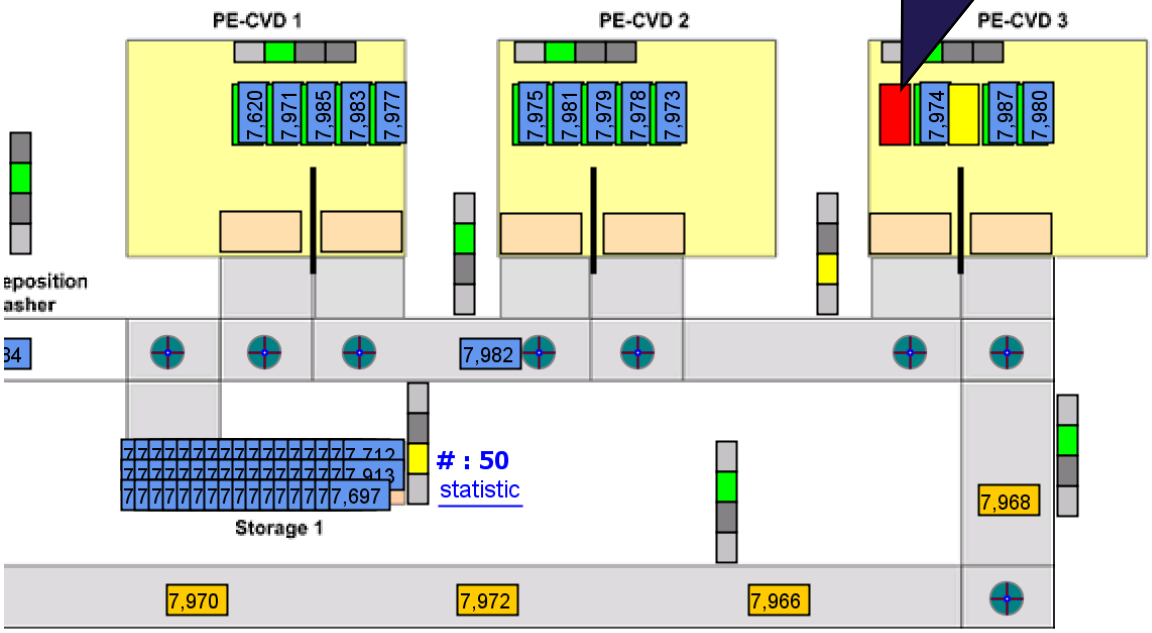
specification of MTBF and MTTR
with manifold probability distributions
(LogNormal, Weibull, et cetera) as equipment parameters

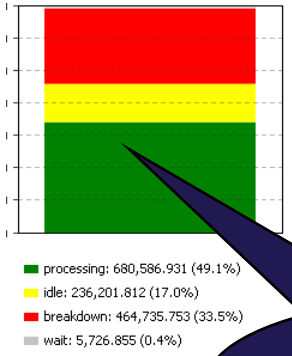
Detailed Modelling of Timing Behaviour
Unscheduled Down Specification for Equipment and Chamber Level



utilisation of equipment

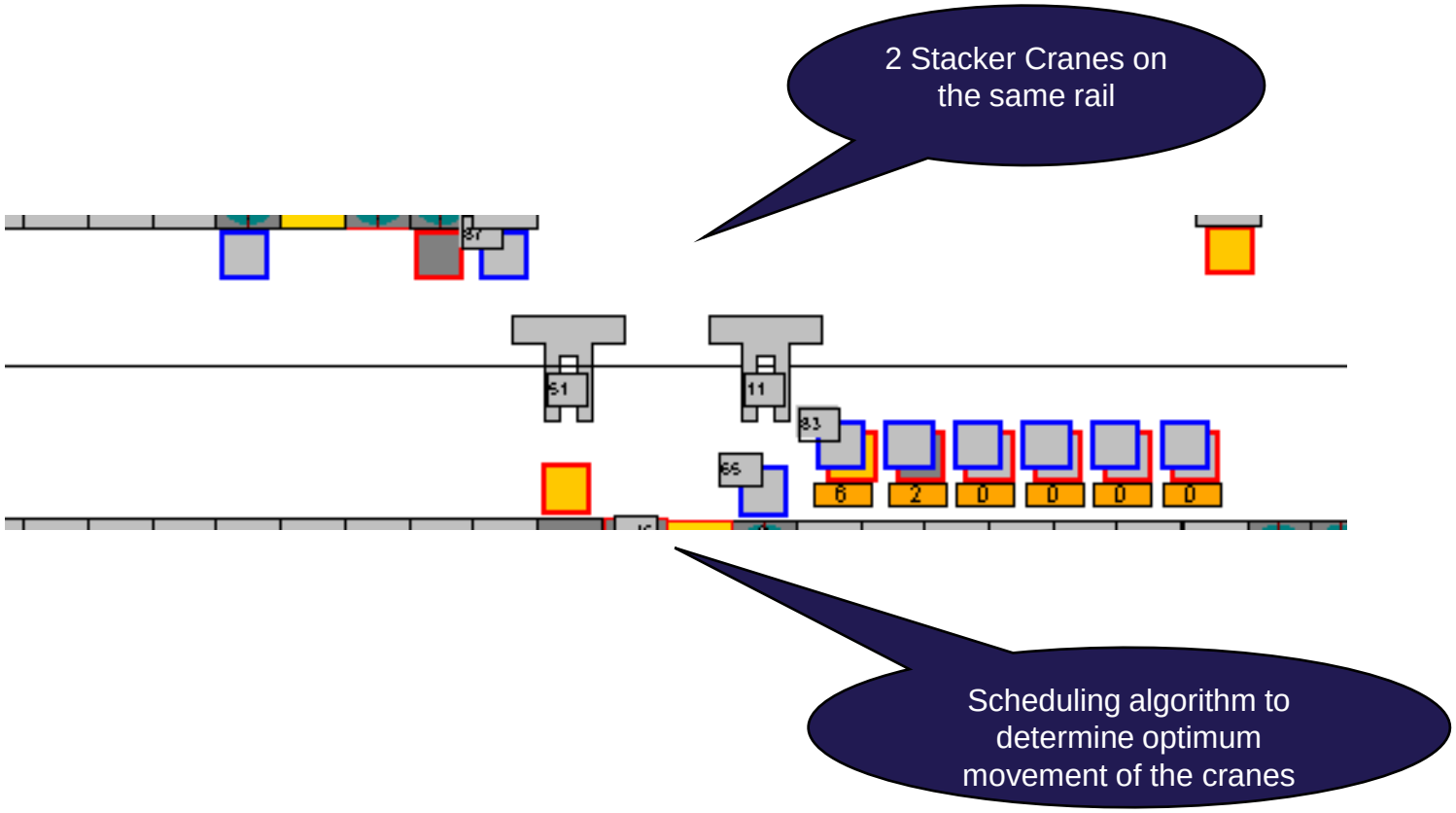
down event for process chamber



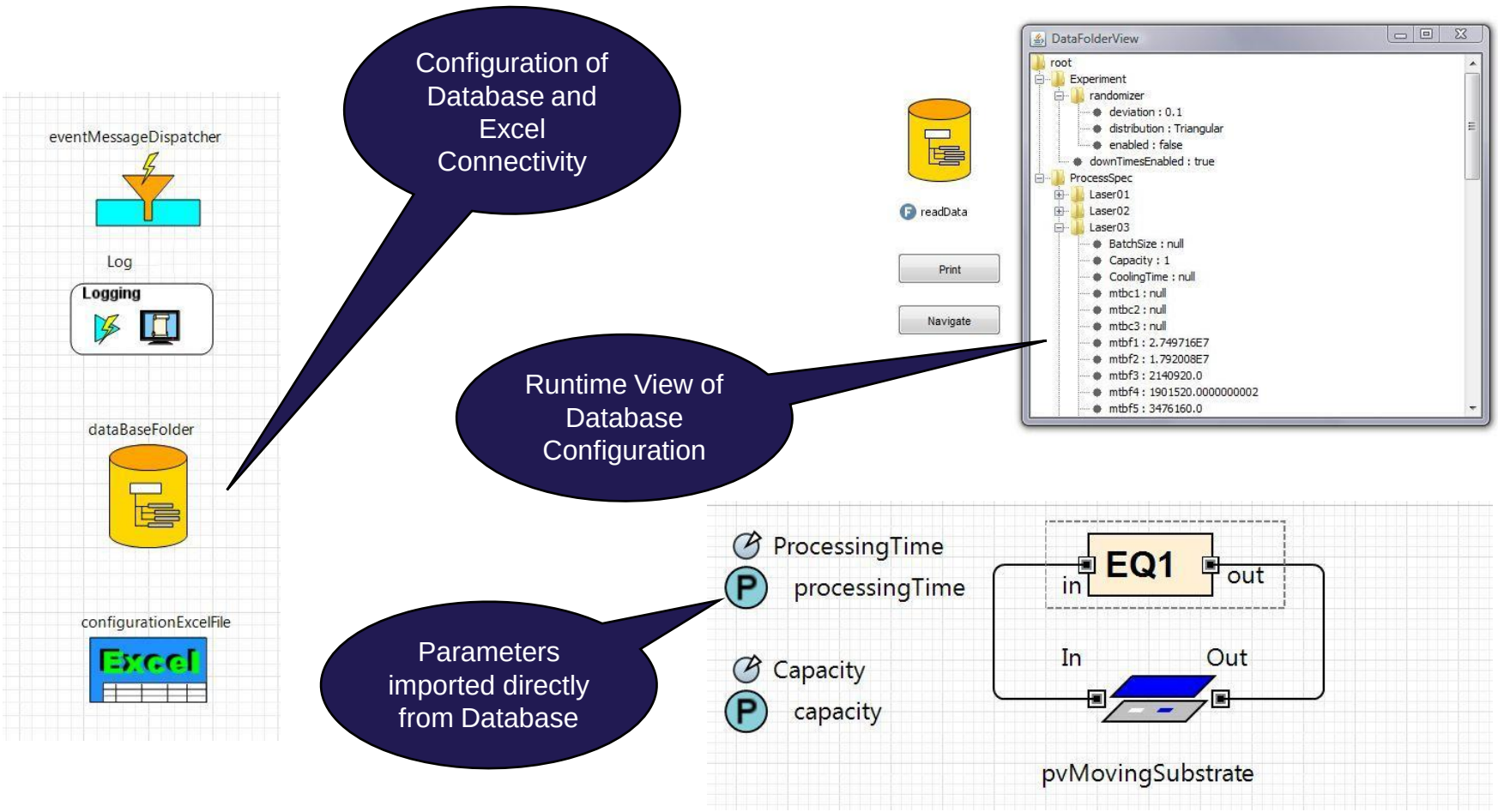


utilisation per chamber

Complex Material Handling Systems
here: Simulation of Central Handler with multiple Stacker Cranes



Equipment Parameters Imported Directly from Databases



Using Simulation Results for a TCO Analysis

- **Variability in Material Supply & Safety Levels**
- **WIP Timeline, Inventory Statistics**
- **Buffer Capacity**
- **Required Equipment Capacity**
- **Product Cycle Time Statistics**
- **Line Throughput as Timeline**
- **Overall Line Yield**
- **Equipment & Line Utilization**

TCO: Total Cost of Ownership
FC: Fixed Cost
RC. Running Cost
YC: Yield Cost
L: Lifetime
T: Throughput
Y: Yield
U: Utilization

$$TCO = \frac{FC + RC + YC}{L * T * Y * U}$$

Enabling Factors for a Successful Simulation Project

Systematic Input Data Acquisition

- Fab Layout
- Equipment Key Data (Timing Behavior, Availability)
- Constraints of Processes

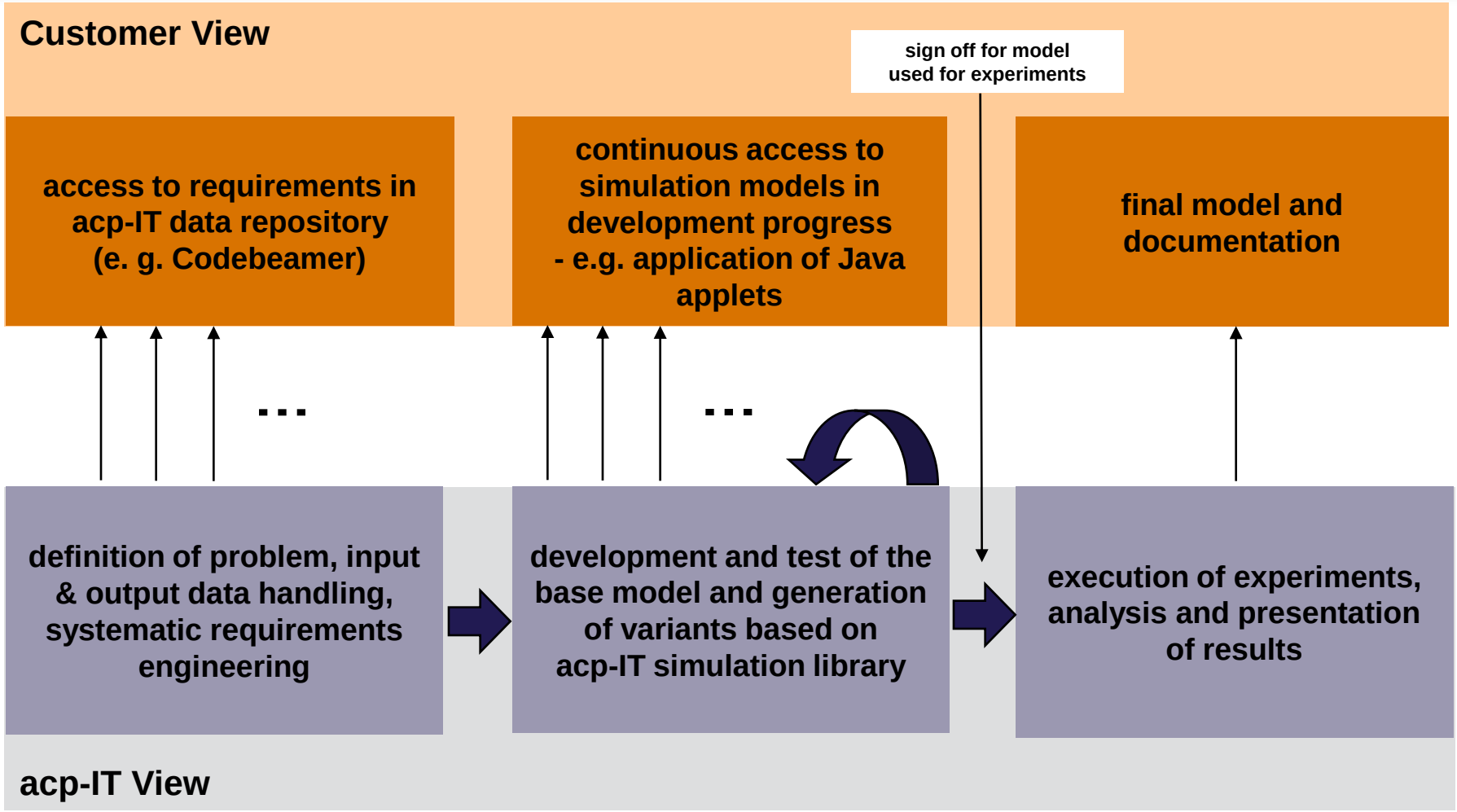
Short Build-up Time of First Model

- Library-based EQ Components
- Standardized Interfaces of the EQ Components
- Flexibility to Add Features to EQ Components

Fast Model Execution and Flexible Output Generation

- Fast Simulation Execution
- Time Measurement between any Points in the Manufacturing Process
- Powerful Online-Statistics

Successful Project Work Enabled by a Common Repository and a Systematic Requirements Tracking for Simulation Project Team



Why AnyLogic?
Advantages Compared with other Simulation Software Packages

- **Object-oriented modelling approach** – allows for a detailed modelling of manufacturing scenarios, the exact timing and state behaviour of processing and material handling equipment aligned with the equipment and line control software
- **Well proven simulation library** from acp-IT which is tailored to the needs of modelling a solar manufacturing line and therefore small effort for the generation of models based on this library
- Short time for the execution of simulation experiments – **outstanding run time performance**
- **Simulation runs in Java Applets** – Model sharing for users without simulation package license and without comprehensive simulation expertise
- **Complete decoupling of animation and control logic** in the simulator
- **Linking of control software** based on **free configurable control events** and therefore easy application of simulation models as emulators for factory control applications
- **Online charts and reports (data sets)** for the monitoring of performance metrics during simulation runs without significant impact to the run time performance
- **Small license costs** – also for industrial and commercial application of the simulation package
- Interface for CAD layout data import

For further information, please contact:

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Thank you for your attention.

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