Material Flow Simulation of TF Production Lines – Results & Benefits (Example based on CIGS Turnkey)

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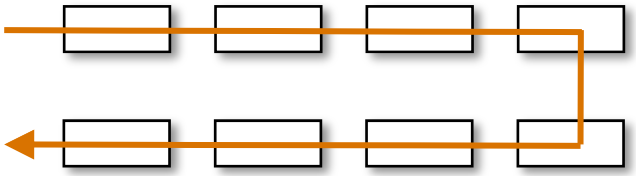
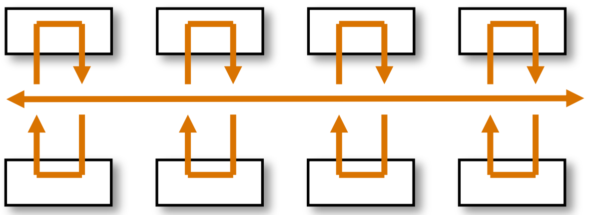
Contents

Material Flow Simulation of TF Manufacturing Lines

- **TF manufacturing lines**
  ➧ high degree of automation for transport & material handling
- **Layout:** flow line, job shop or mix of both



Flow line with tact



Job shop layout with central transport

- Typically a **tact time drives a flow line.**
- Substrates **MOVE, STOP, WAIT, ACCUMULATE**
  Tact is often interrupted. → There is no flow of material!
- **Simulation clarifies the timing dynamics** in the manufacturing line.

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

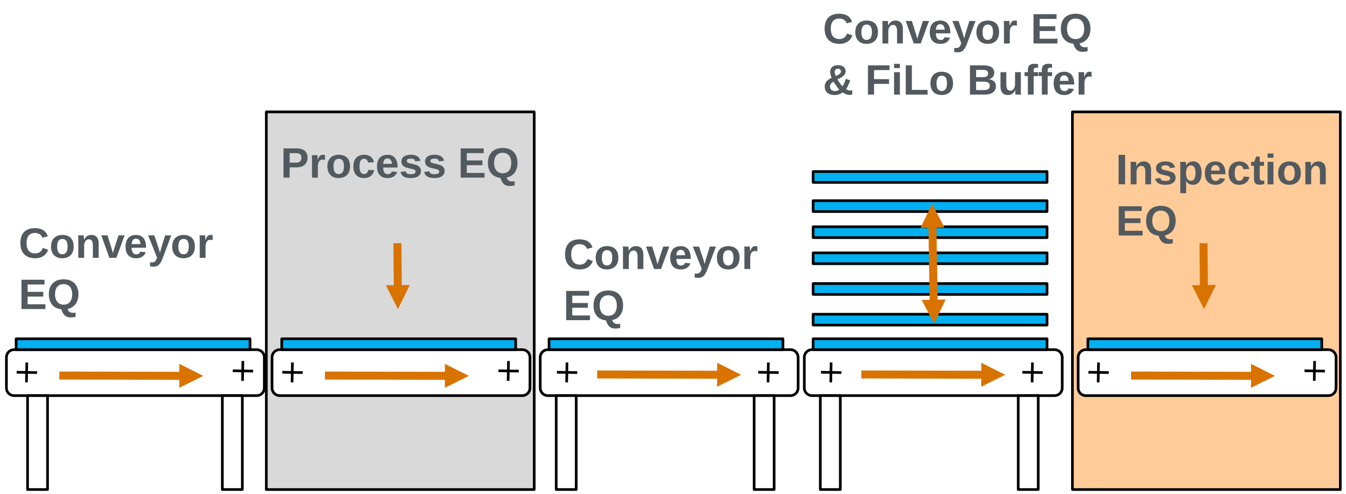
- Library-based EQ Components
- Standardized Interfaces of the EQ Components
- Flexibility to Add Features to EQ Components

Fast Model Execution and Flexible Output Generation

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

Building-up the Model – Think in Components!

- Model conception: **Separation** of the line **in components**.
- Each line component to be modeled with specific **timing behavior** including **unscheduled** & **scheduled down** time.
- Consideration of **total system availability** in a flow line.



Single Point Failures in a Flow Line

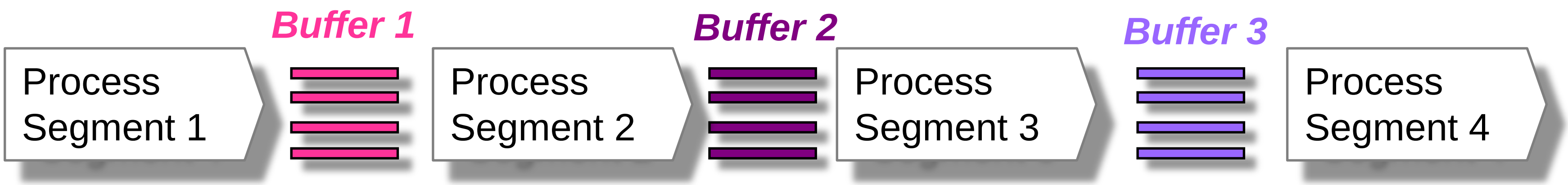
EXAMPLE CALCULATION

		Processing EQ	Material Handling & Transport EQ
	Availability in %	96%	99%
	Unscheduled Down Time per year in days	14,6	3,65
Repair Time Distr.	1 h	80	20
	2 h	40	15
	4 h	20	9
	8 h	10	
	24 h	5	

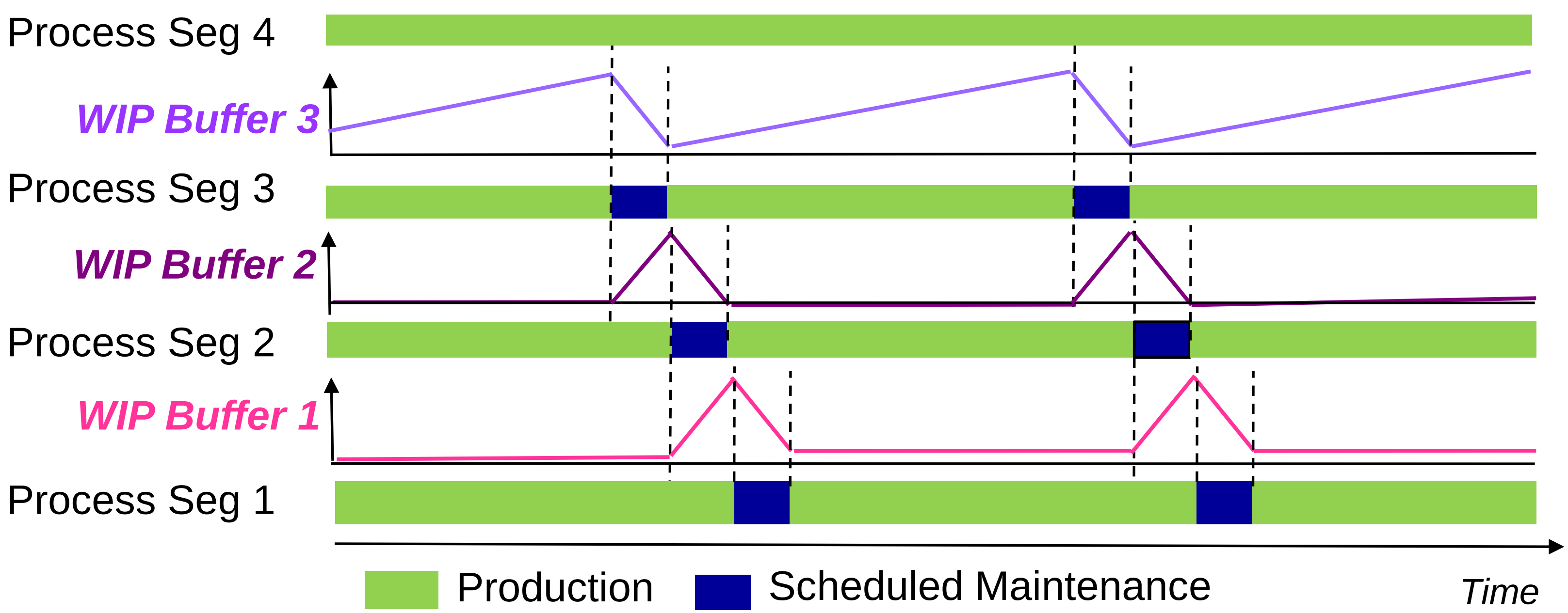
MTTR in hours	**3,61**	**1,95**
MTBF in hours	**86,7**	**193,5**
Number of EQ in the Line	33	140

Average Number of EQ in Down State at One Specific Time	**1,38**	**1,41**

Maintenance Scheduling & Buffer Management

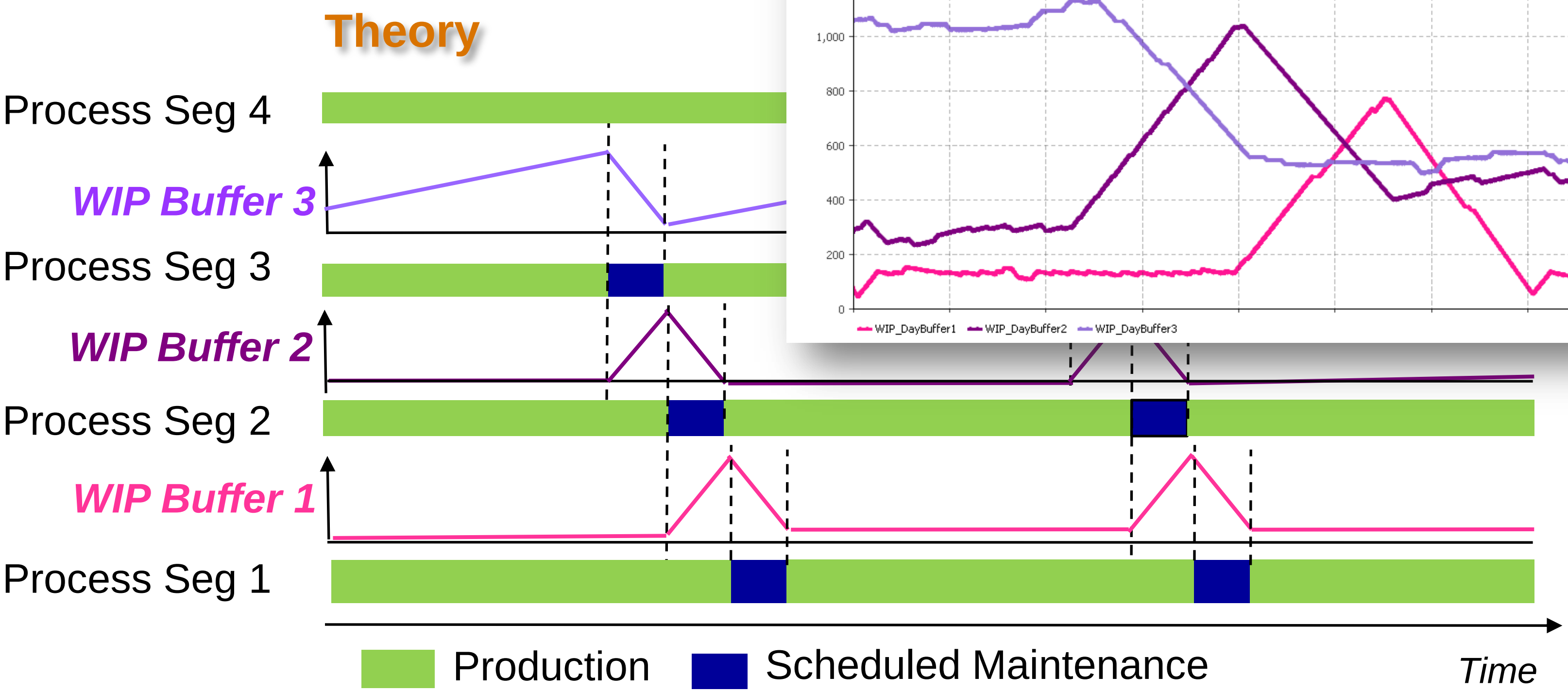


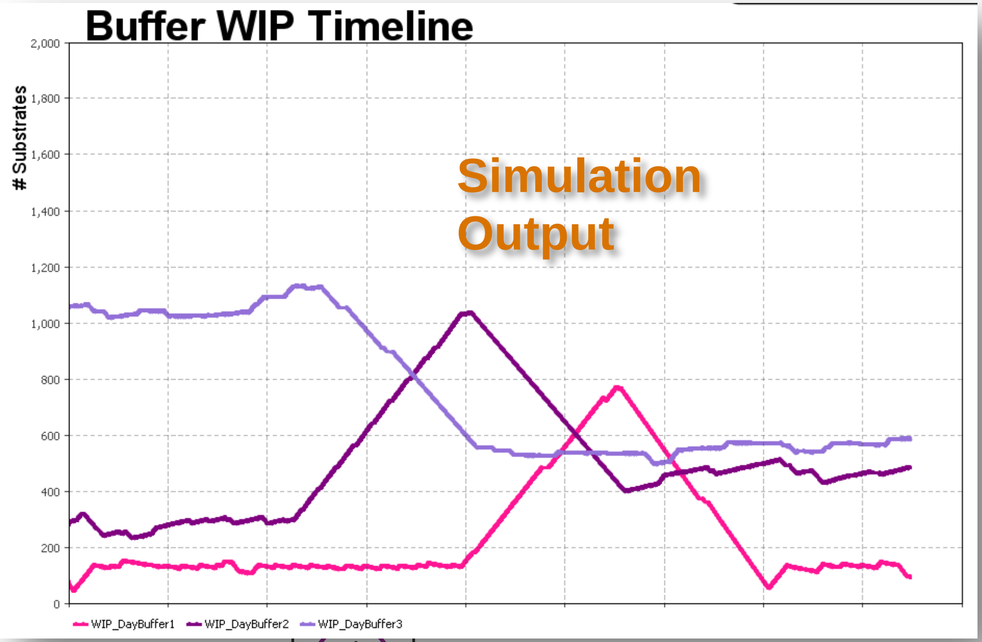
EXAMPLE CONFIGURATION



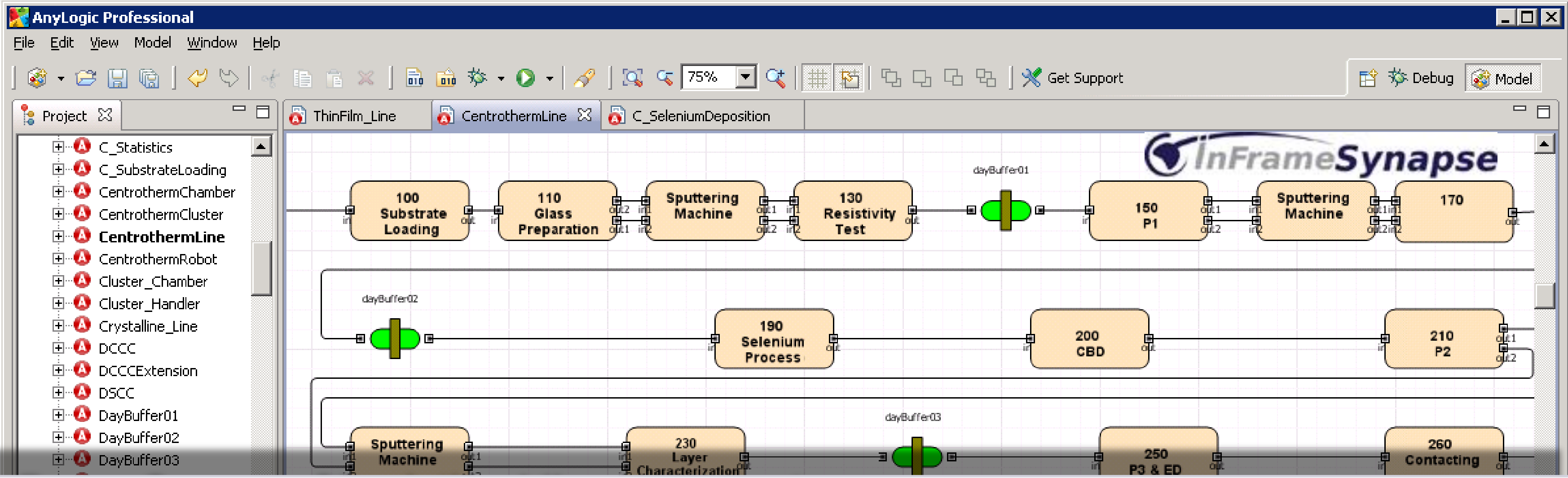
Buffer WIP – Theory vs. Simulation

EXAMPLE CONFIGURATION





InFrame Synapse Simulation Library
- Rapid Simulation Model Building



InFrame Synapse Simulation Library Contents:

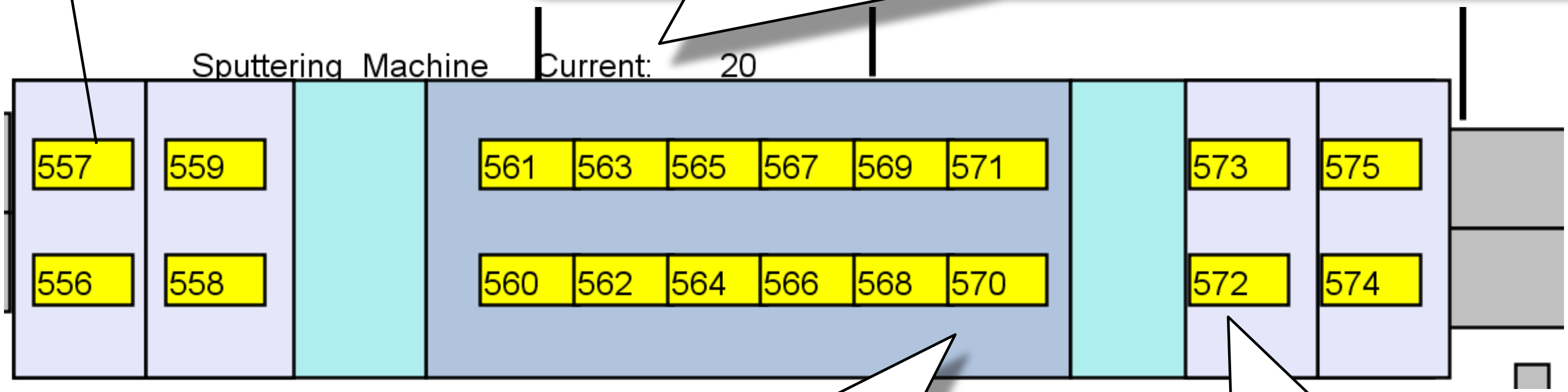
- **Processing & Material Handling EQ for PV Manufacturing**
- **Routing and Dispatching Functions**
- **EQ State Models (processing, loading/unloading, maintenance, breakdown)**
- **Reports for Line Performance Monitoring & Online Statistics**
- **Optional: Interfaces for Communication with Control Systems (MES)**

Systematic Input Data Acquisition

- **Example: Sputter Process EQ**

- **Substrate with SubstrateID & Size**

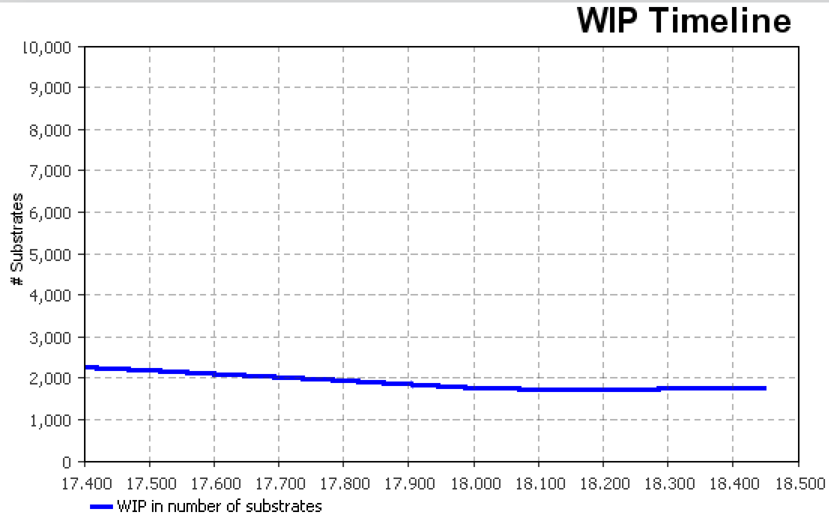
- **Capacity: Number of Substrates in the Equipment**
- **MTBF, MTTR**
- **Maintenance Cycle**
- **Yield Rate**

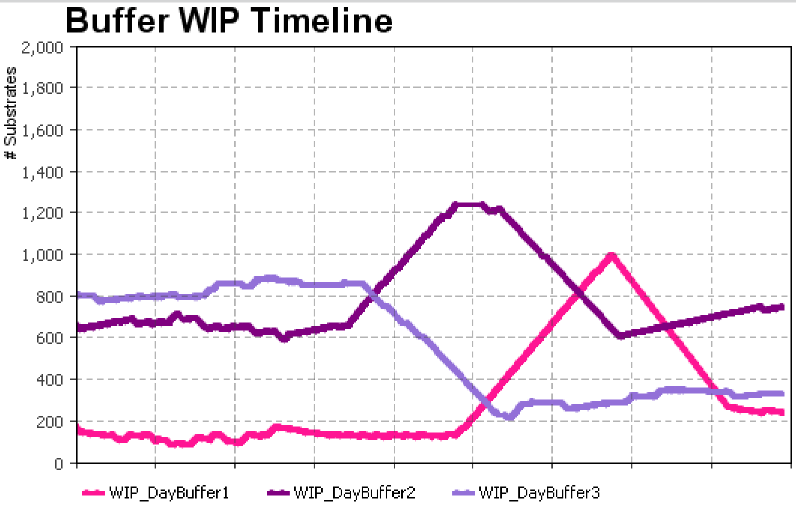


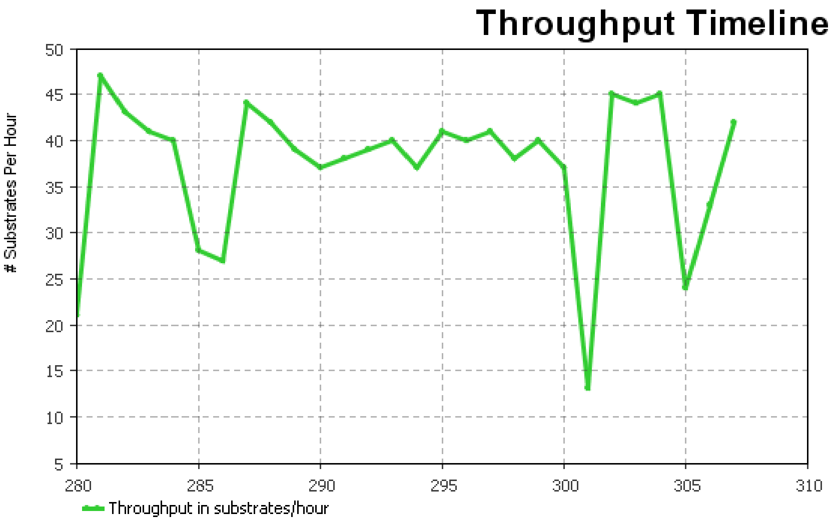
- **Speed of Sputter Process**
- **Constraint: Closed Carpet in the Process Chamber**

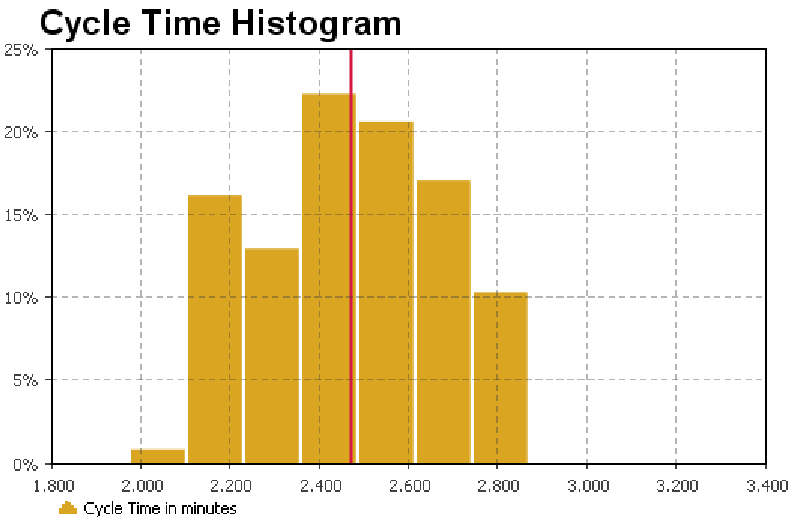
Pumping Chambers:
- **Capacity**
- **Pump Time → Tact**

Timeline Reports & Cycle Time Histogram









Simulation Results & Input Data for TCO

- **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**

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

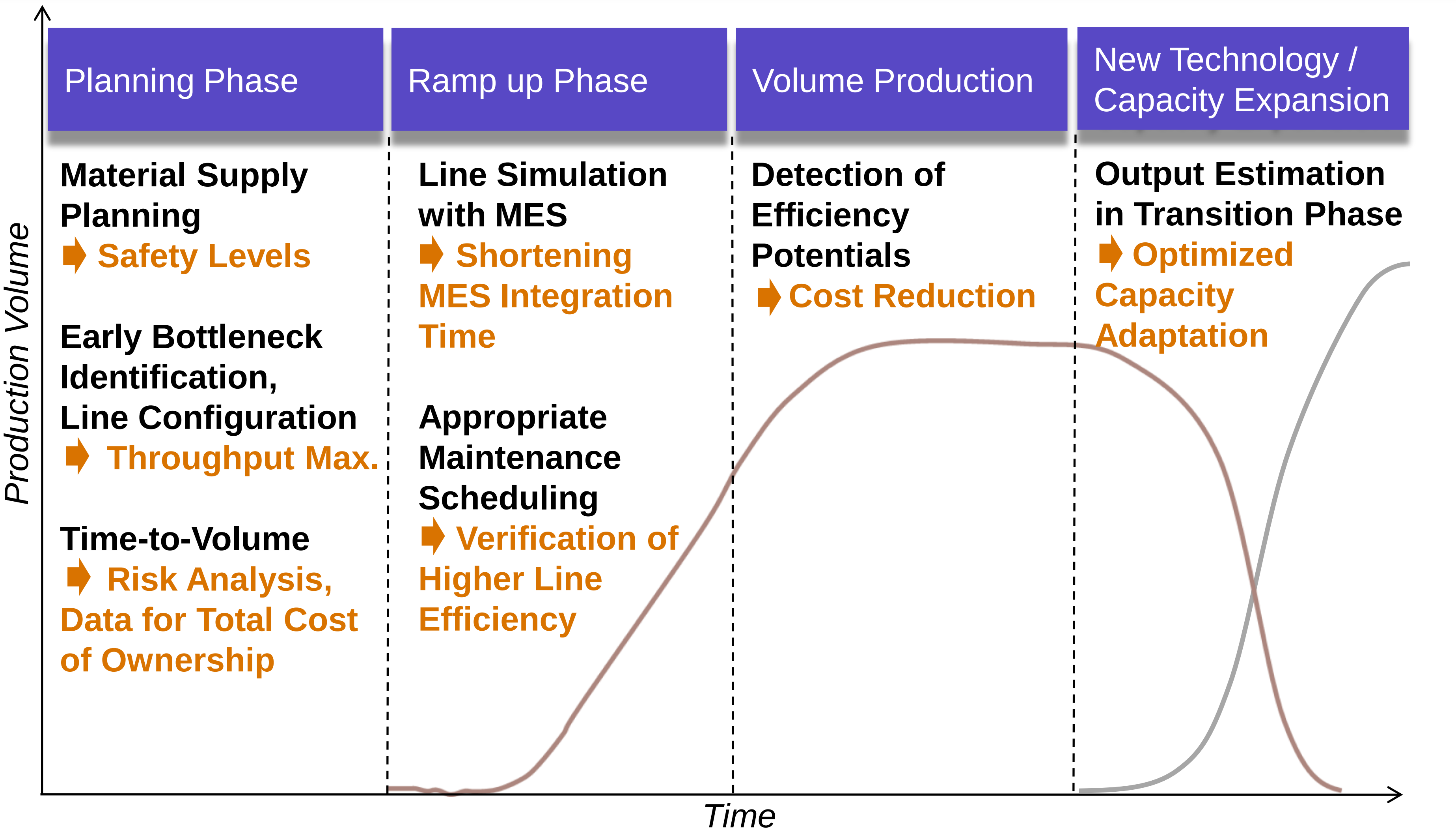
TCO: Total Cost of Ownership
FC: Fixed Cost
RC. Running Cost
YC: Yield Cost
L: Lifetime
T: Throughput
Y: Yield
U: Utilization

Line Simulation – Benefits for TF Manufacturers

- Systematic **input data collection** for engineering team
- Proof of **line control policies** → MES & line controller
  - Ramp-up, maintenance scheduling, buffer management
  - PUSH and PULL analysis
- **Transparency for factory dynamics**
  - Effect of single point failures
  - Verification of buffer capacities → investment!
- Proof of **capacity profile**
  - "De-Bottlenecking"
  - Required redundancy to guarantee output targets
- **Feeding TCO analysis** with dynamic data
  - Utilization and throughput considering dynamic yield and line dynamics

Benefits of Manufacturing Simulation

Planning Phase	Ramp up Phase	Volume Production	New Technology / Capacity Expansion
Material Supply Planning ➧ Safety Levels **Early Bottleneck Identification, Line Configuration** ➧ Throughput Max. **Time-to-Volume** ➧ Risk Analysis, Data for Total Cost of Ownership	**Line Simulation with MES** ➧ Shortening MES Integration Time **Appropriate Maintenance Scheduling** ➧ Verification of Higher Line Efficiency	**Detection of Efficiency Potentials** ➧ Cost Reduction	**Output Estimation in Transition Phase** ➧ Optimized Capacity Adaptation



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