# Potentials of REALIST for Availability Modeling and Analysis

**Availability Modelling Tools and Synergies for Collaboration Workshop**
CERN

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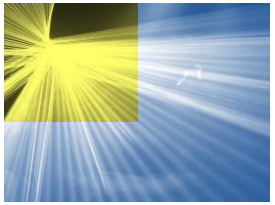
# Outline

- Application Example
- REALIST: Range of Application
- Motivation for REALIST
- Software Performance
- User Interface
- Modeling Methods and Capability
- Features
- Summary & Conclusions



# Application Example – Production system

Boundary conditions:

- 9 different product variants
- Entire manufacturing process (15 process steps) including quality control and rework
- Reliability based on concurrent failure modes
- Maintenance process including preventive and corrective actions
- Several cost drivers e.g. material, energy, personnel, …

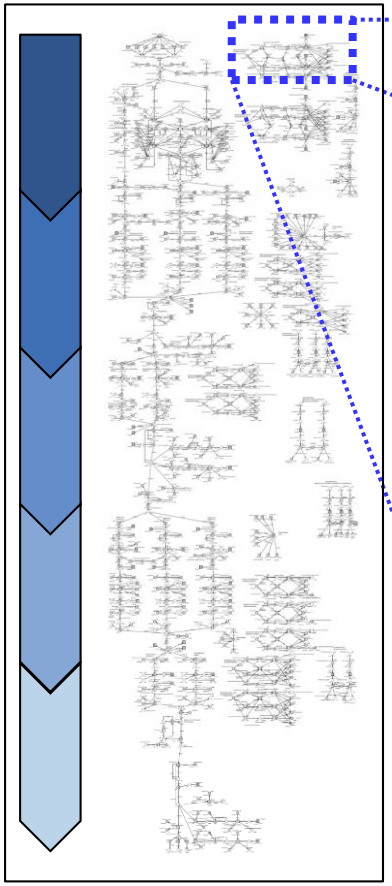
Production system: band saw blade fabrication

Main analysis objectives:

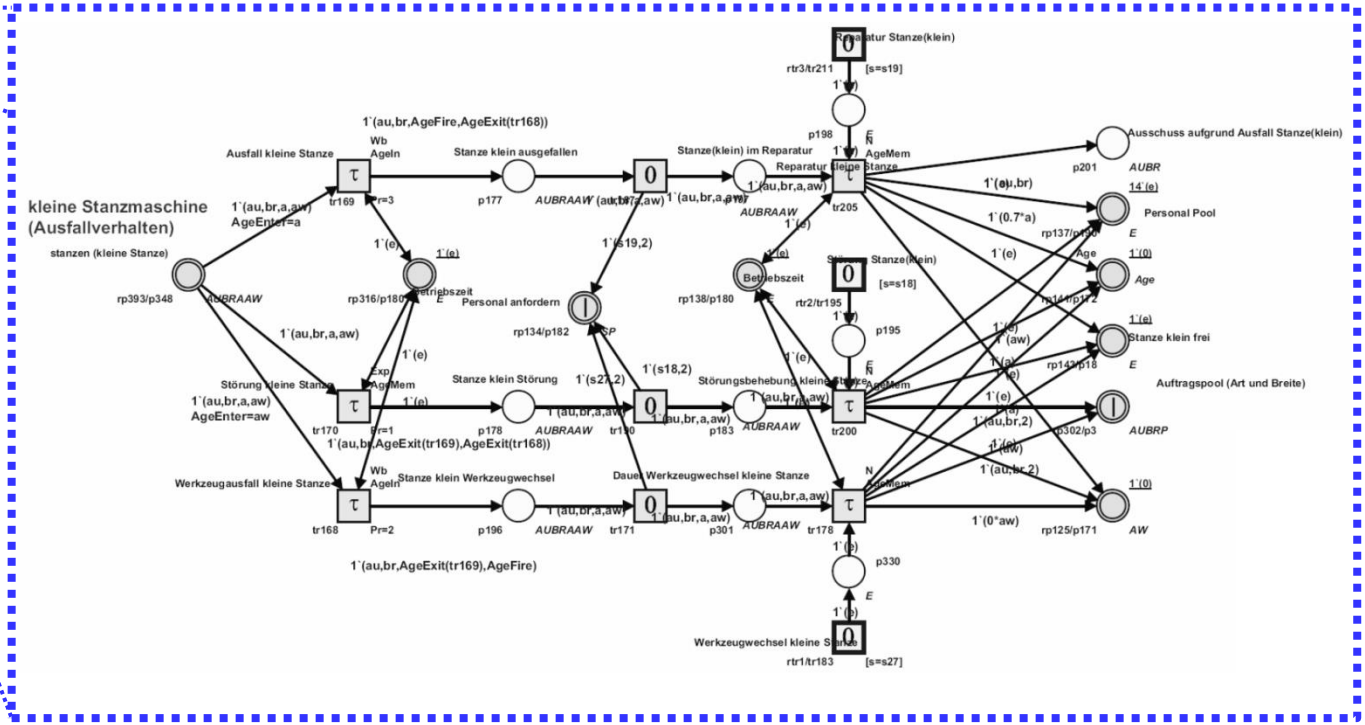
- Different maintenance strategies and costs
- Probability of shortfall for the production unit target (based on **availability**)

# System Model – Production system

## Entire model



## Reliability model of machine A



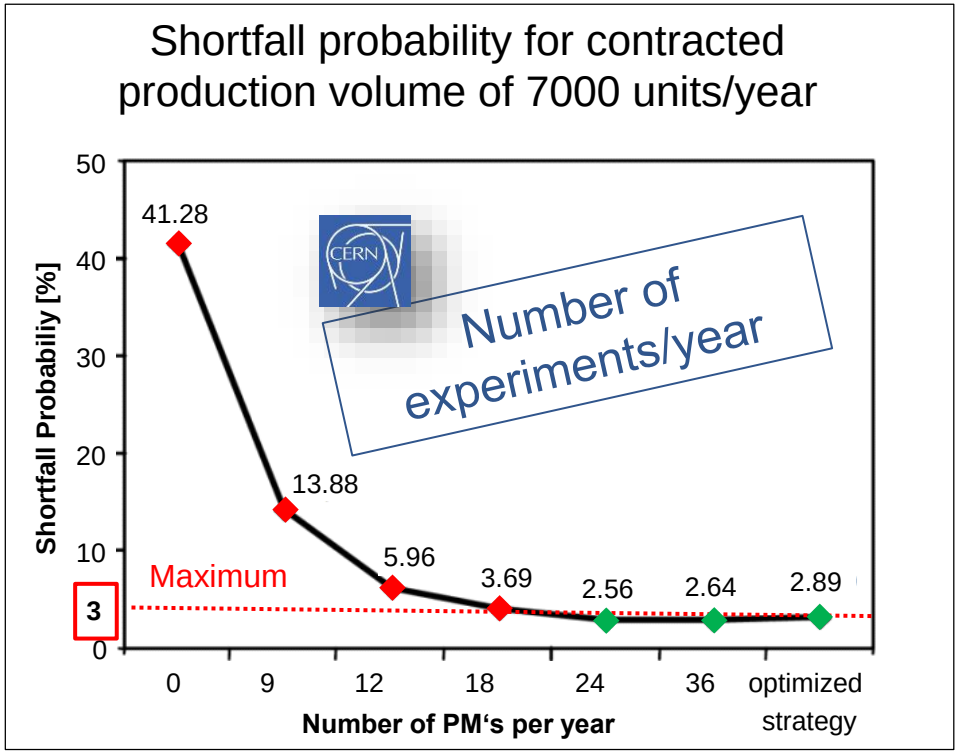

- 3 concurrent failure modes
- Initiation/administration of repair process

# Results – Production system

Main analysis results:

- Maintenance strategy
- Probability of shortfall for the production unit target (based on **availability**)

Production system: band saw blade fabrication

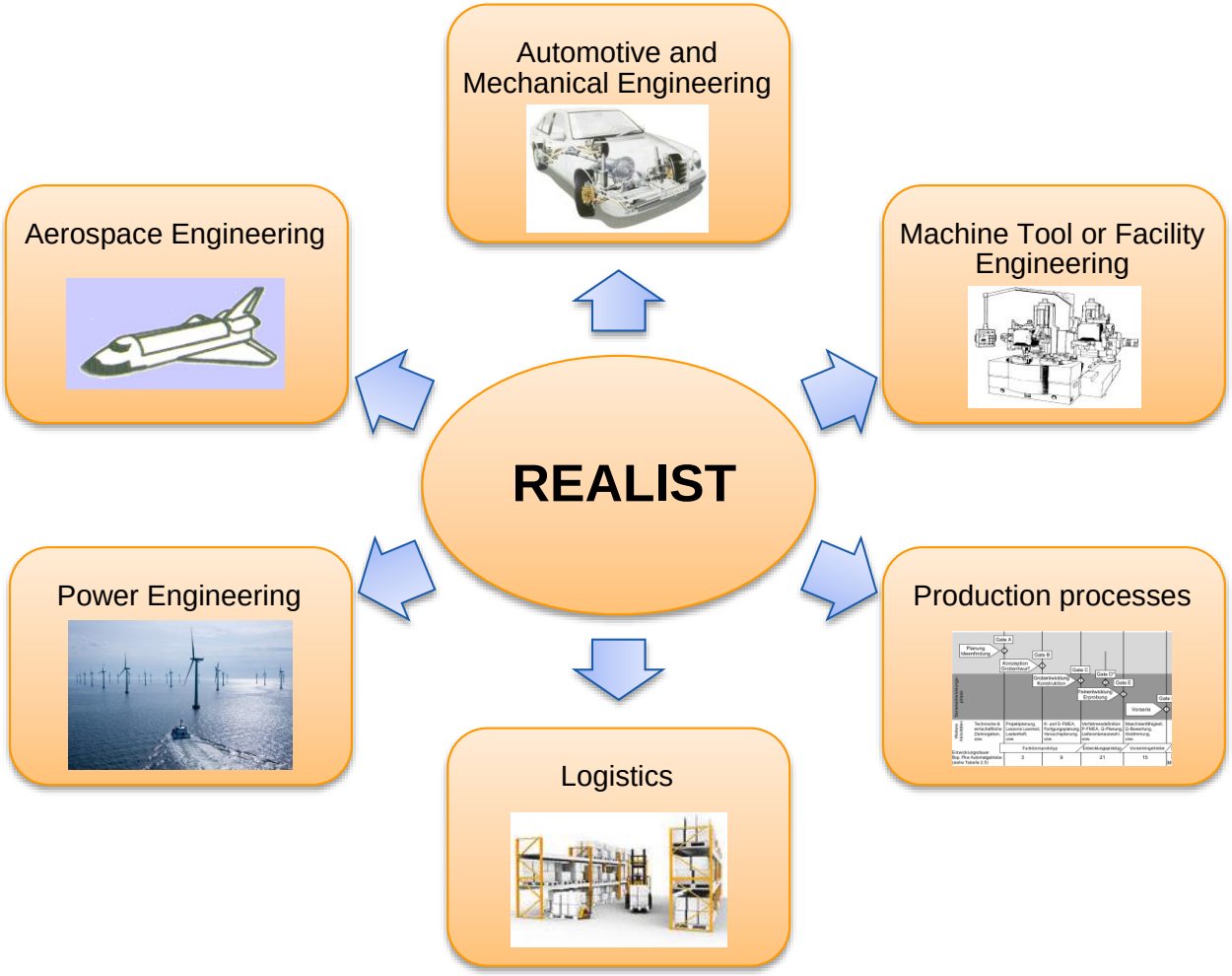



Maintenance strategy and costs:

- Strategy "24" PMs: 562,170 €/year
- Strategy "36" PMs: 567,910 €/year
- *"Optimized Strategy": 557,200 €/year*

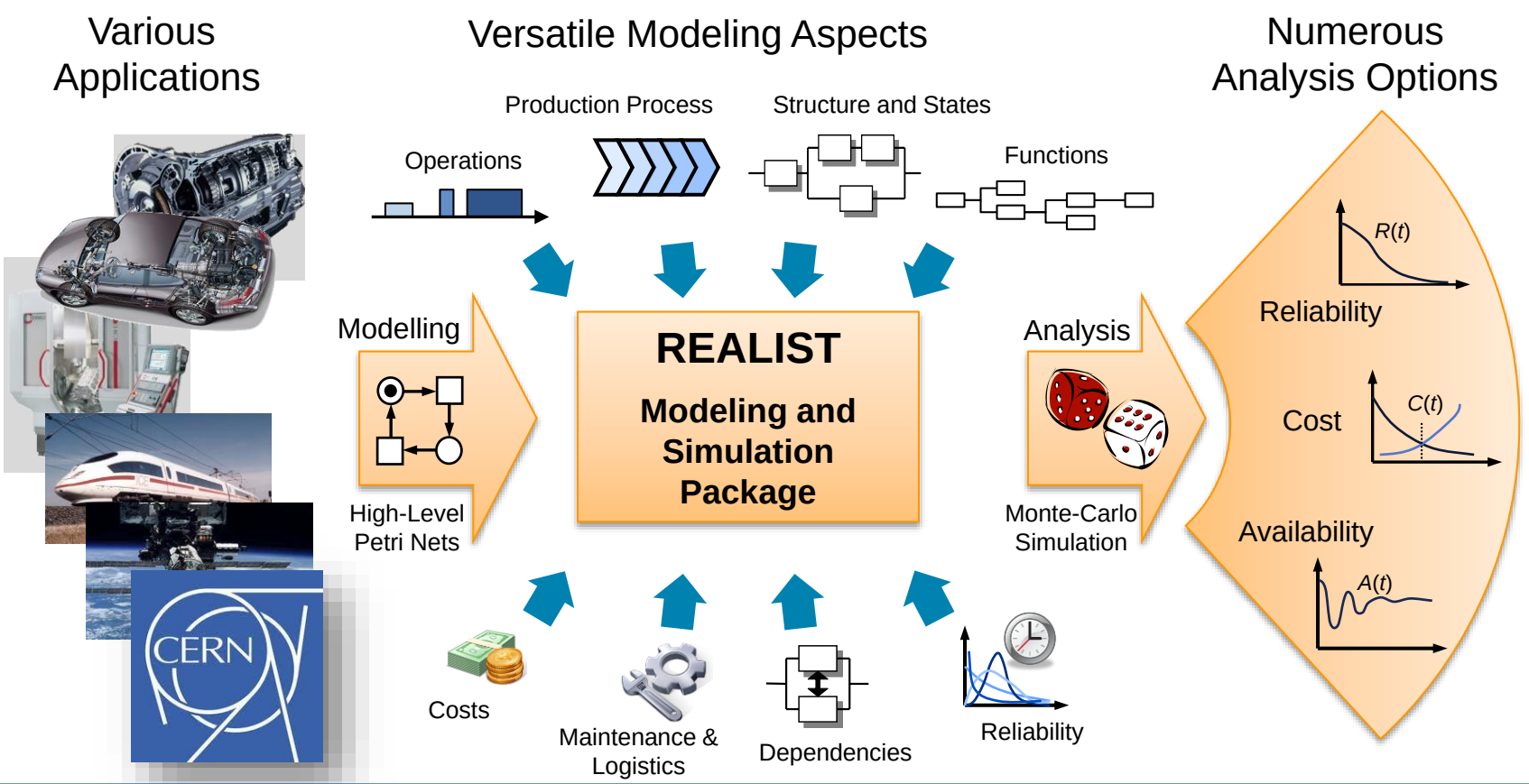
CERN Budget constraints

# Range of Application




From single components and process steps up to entire systems and overall processes

# Motivation for REALIST*




**Modeling and Analysis of Reliability and Availabililty of complex technical systems "without" any limitations!**

*) REALIST = Reliability, Availability, Logistics and Inventory Simulation Tool

# Motivation for REALIST

- Prediction of operational availability
- Reduce the system downtimes by applying the optimal maintenance strategy and therefore reducing life cycle costs
- Close-to-Reality representation of a production system's behavior

- Decision between alternatives:
  - Operation strategy
  - Production process
  - System configurations
  - Reliability demands
  - Maintenance strategy
  - Logistics concepts

- **Necessary: Powerful methods for availability analysis and prediction**

# Performance

Measures to support modeling:

- Decomposition
- Application of submodels
- Conjoint modeling

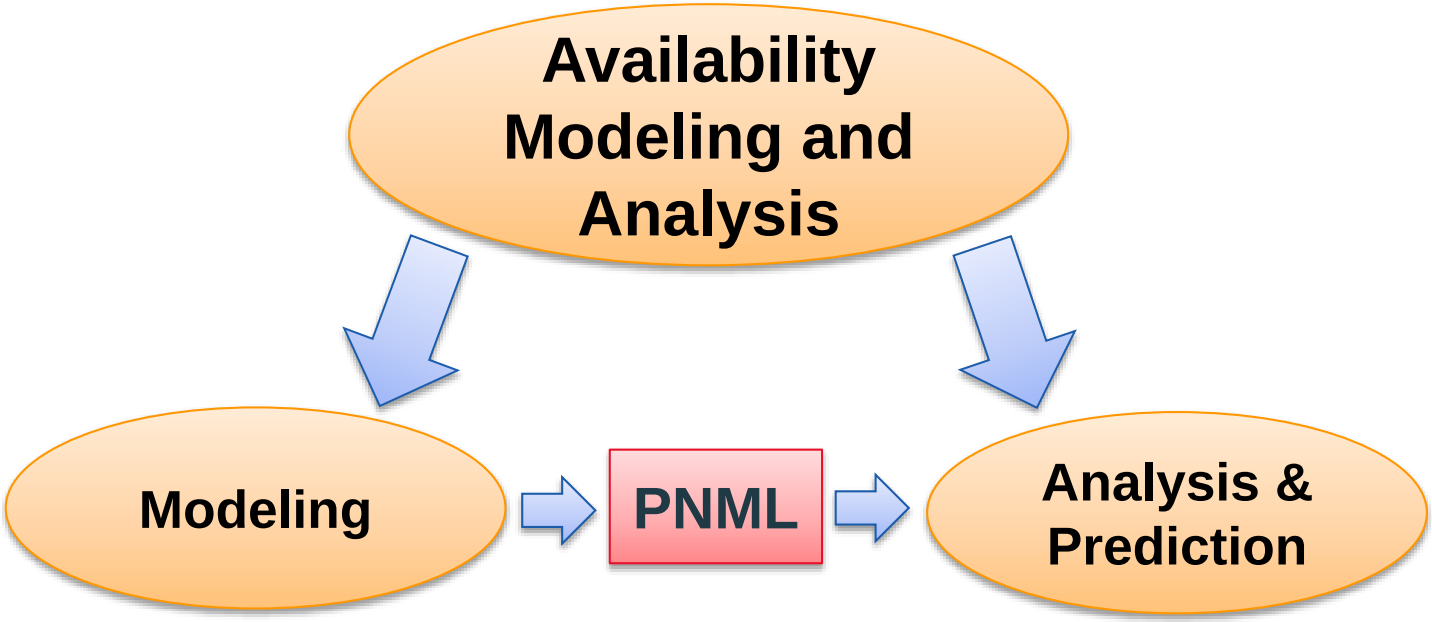
Measures to reduce simulation time:

- Parallelization
- Focusing

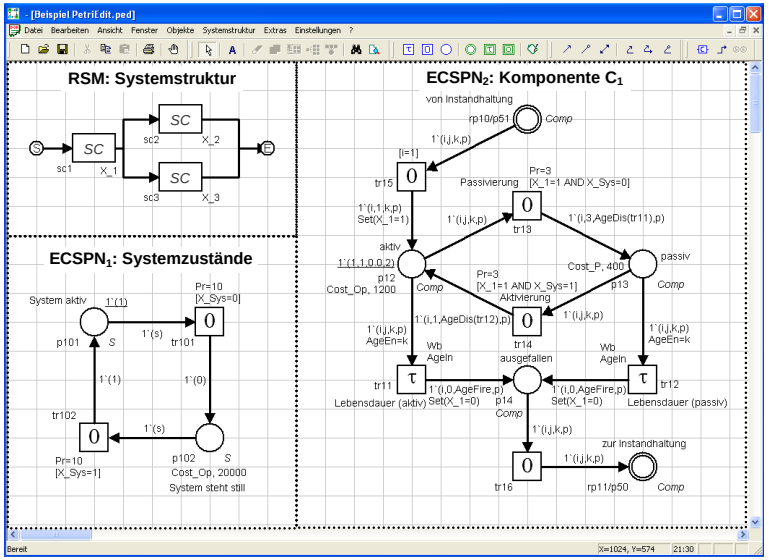
Future Topics:

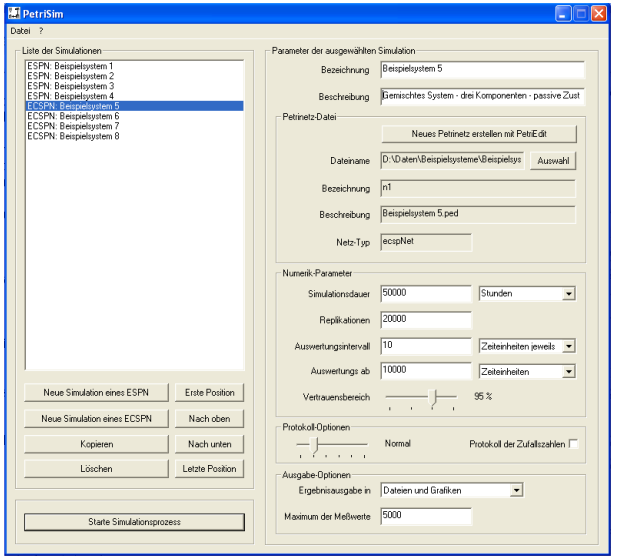
- Application of extended submodels
- Generic model design (automatic generation)
- Rare Event Simulation Speed-Up for ECSPN:
  - much more simulation runs for satisfying result -> significantly increasing computing time
  - RESTART algorithm: use structural information of RBD to automatically set thresholds

# Modeling and Simulation



# Modeling and Simulation Package REALIST: User Interface




- Creation of the system model as ESPN, ECSPN or CSM
- Modularization
- Management of simulation projects
- Automated implementation of simulation projects
- Analysis and processing of result data

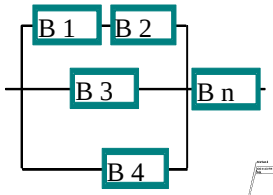
**Comfortable development and efficient analysis of a system model**

# Overview and Comparison of Modeling Methods

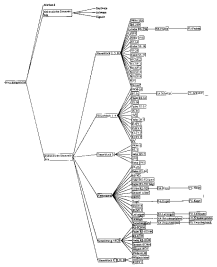
## Modeling methods

### Combinatorial Models

- Reliability Block Diagram

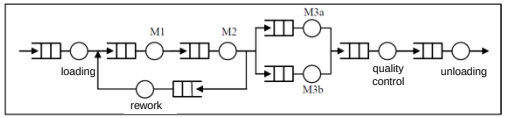



- Fault Tree



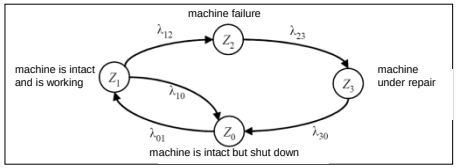
### Queue Oriented Models

- Queues

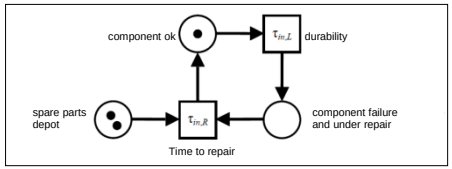



### State-Space Oriented Models

- Markov State Graphs

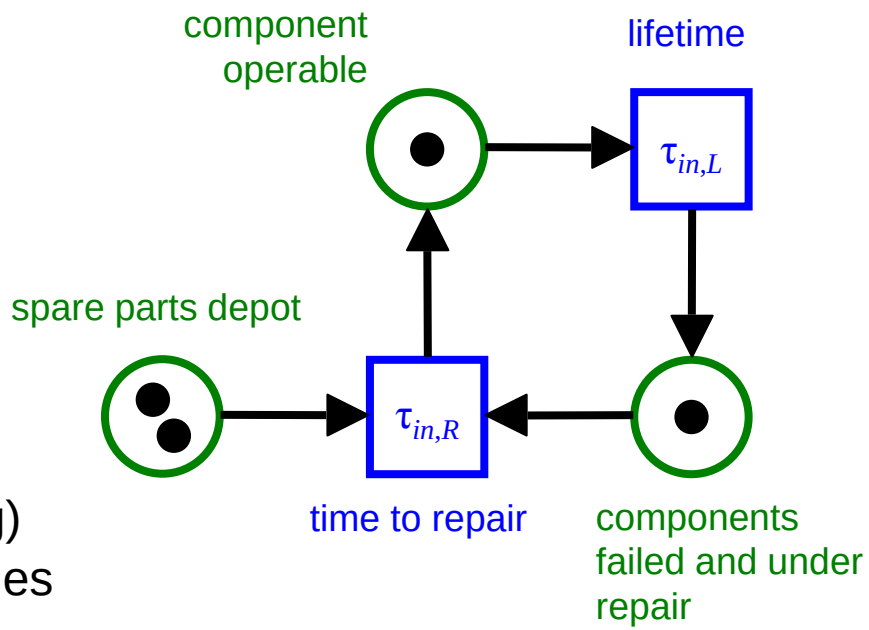



- Petri Nets



# Extended Stochastic Petri Pet (ESPN)

- Static elements
  - Places (States, Objects)
  - Transitions (Time & Logic)
  - Arcs (Relations, Structure)
- Dynamical description
  - Marking
  - Activation (or deactivation)
  - Switching
- Initial marking
- Sequence of activating (or deactivating) and switching results in marking changes

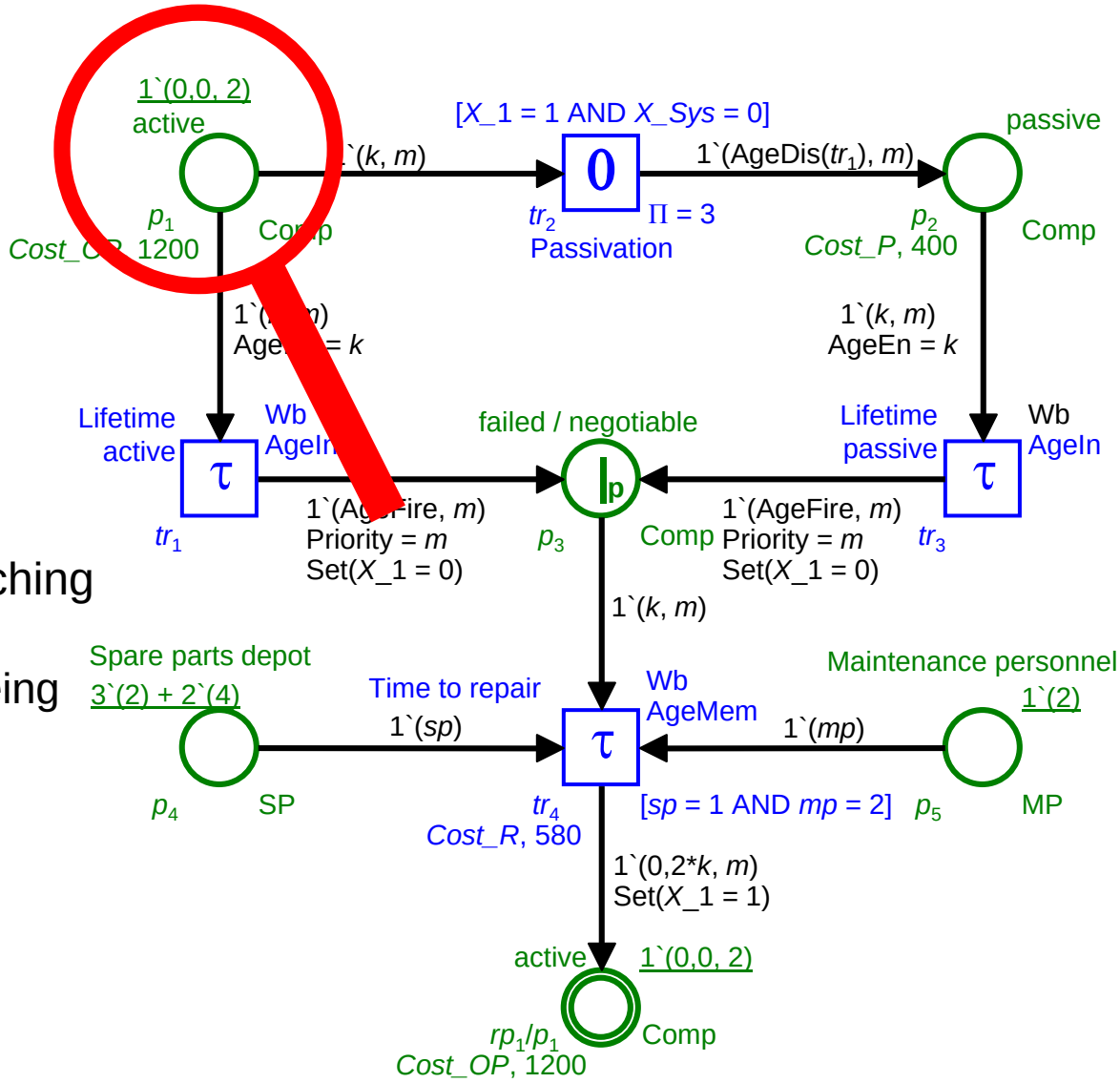



**Few basic elements: great flexibility in modeling**

# Extended Coloured Stochastic Petri Net (ECSPN)

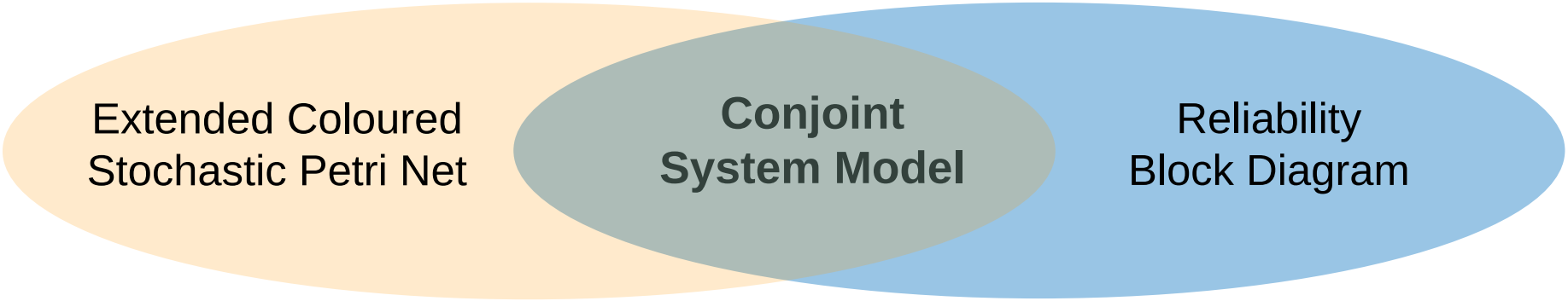
## Extensions

- Markings with complex information („Colour“ = Data type)
- Activation condition and switching rule are colour dependent
- Special elements and switching processes
  - State behaviour with ageing
  - Queuing discipline
  - Degree of renewal
  - Operational costs



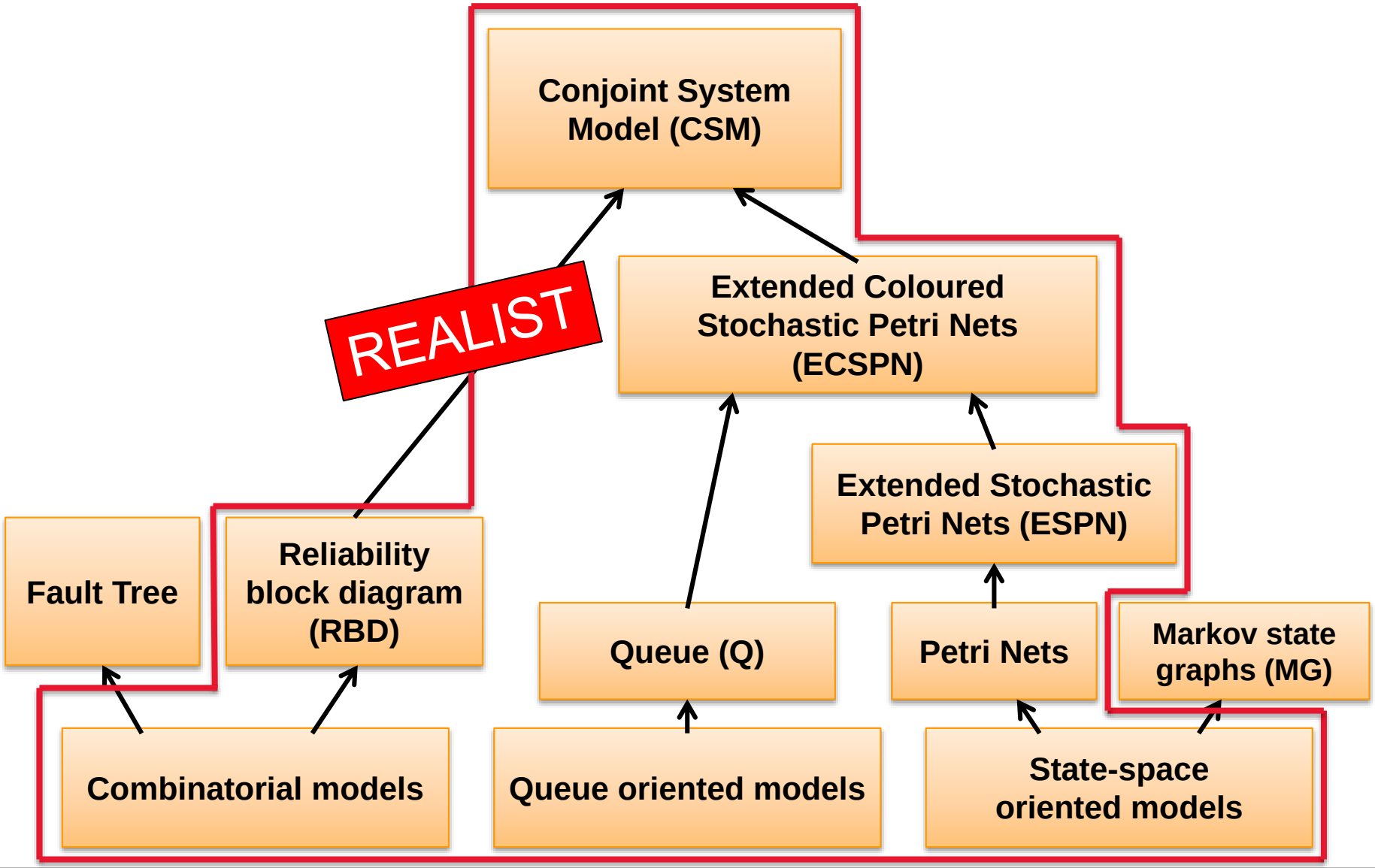
# Conjoint System Modeling (CSM)

- Hybrid system model
- ECSPN state space oriented
  - Reliability structure is not directly representable
  - System state complex
- Reliability Block Diagram (RBD) favorable for reliability structure




**Presentation of various aspects using the optimal modeling technique in each case**

# Hierarchy of Modeling Methods



# CSM/ECSPN – Modeling capability

General

- Concurrency/Synchronization
- Chronological sequences
- Competition
- Logic conditions
- Queuing behavior
- Timed/Stochastic system behavior
- Dynamic changing system behavior
- Fuzzy input data

# CSM/ECSPN – Modeling capability

**Operation**

- Operation schedule
- Mission profile

LHC-Operation

**Production**

- Material flow
- Information flow
- Production structure
- Queuing behavior
- Priorities
- Production dependencies

Beam Generation & Experiments

**System & Reliability**

- Reliability structure
- System and component states
- Constant failure rates
- Time-dependent failure rates
- Dynamic changing failure behavior
- Aging
- Several operative states*
- Failure propagation
- Failure dependencies
- Confidence Intervals

LHC systems & components

* with time-dependent failure or transition rates

# CSM/ECSPN – Modeling capability

**Functions**

- Functional states
- Functional sequences
- Functional logics
- Functional dependencies


**Maintenance & Logistics**

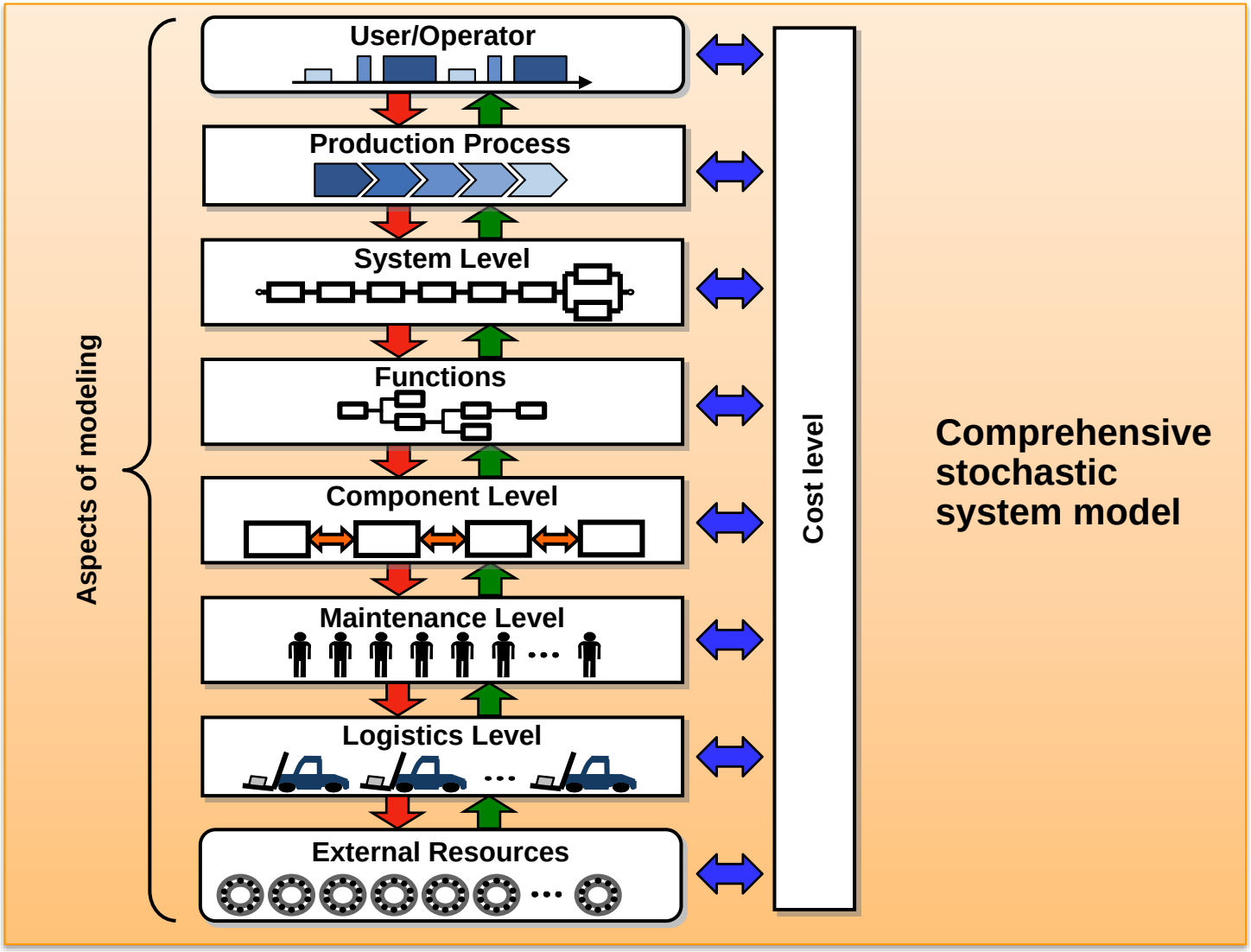
- Corrective and preventive maintenance
- Inspections and sensor-based condition monitoring
- Dynamic grouping of maintenance actions
- Time-dependent transition rates
- Degree of renewal*
- Spare part logistics, purchasing procedure
- Limited maintenance capacities
- Complex maintenance dependencies
- Maintenance priorities


**Costs**

- Duration-based costs
- Number-based costs
- Variable Costs/Revenues
- Cost for storage


* with time-dependent failure or transition rates

# System Model - Close to Reality



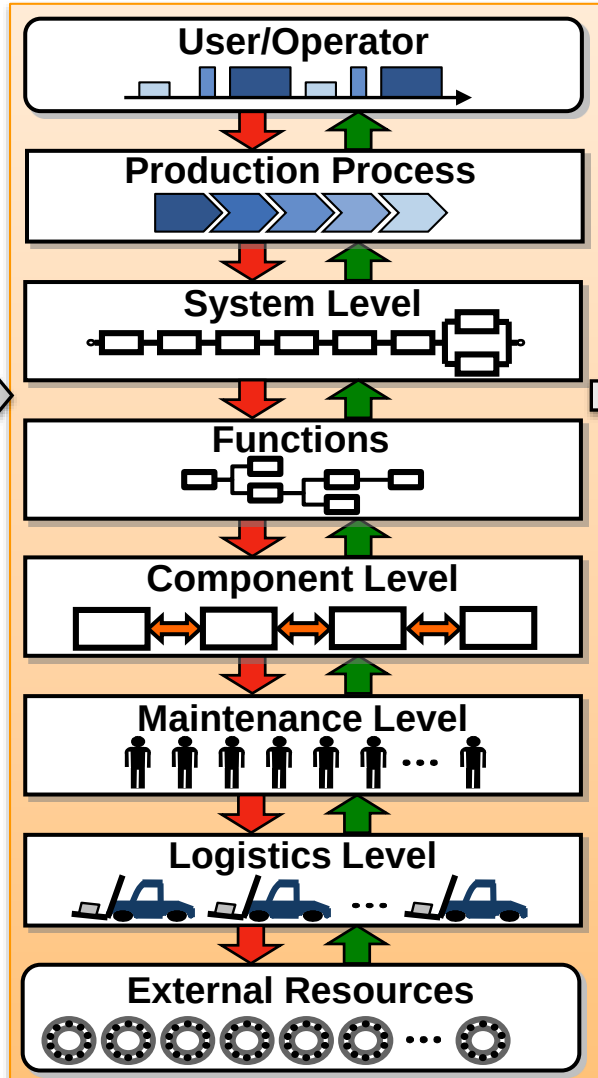
# Dependability Characteristics

## Inherent Characteristics

- Operation schedule
- Production process
- Reliability structure
- Functions
- Availability
- Reliability
- Reparability/Maintainability
- Inspectability

**Independent processes, structures, components and states**

**Input Information**




## Operational Characteristics

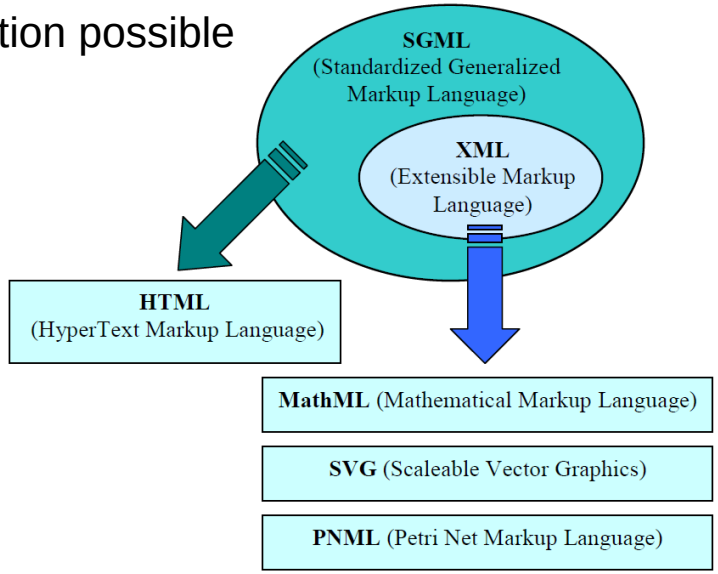
- Operability
- Productivity
- Availability
- Reliability
- Functionality
- Reparability/Maintainability
- Inspectability
- Maintenance Delay Time
- Logistic Delay Time
- Level of Service

**Evaluation under operating conditions (with dependencies)**

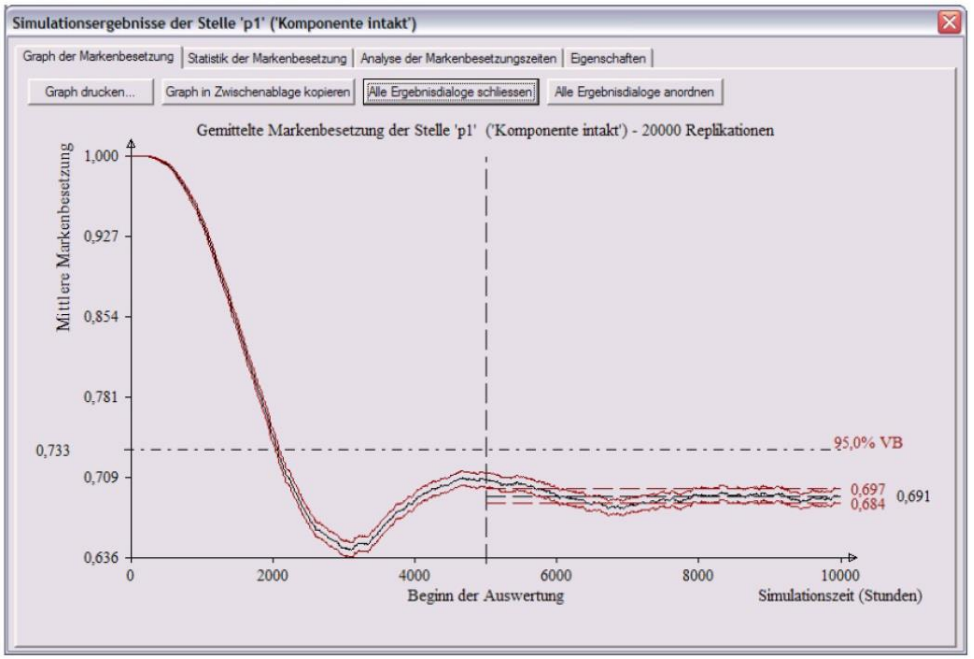
**Output Information**

# Basic features

- Windows application
- Visual C++
- data interface
  - .pnml-Files (Petri Net Markup Language)
  - versatile and mostly standardized format for graphical modeling and analysis of processes
  - input of model without any graphical representation possible
- Monte-Carlo for analysis



# Features




Input data format:

- distribution functions
- .pnml files

Output data format:

- .txt
- .pst – software specific

Data analysis:

- raw simulation data for all model elements
- statistical processed data
- distribution types and parameters (e.g. mean values, standard deviations)
- confidence intervals
- ASCII files for post processing tools (e.g. Excel)
- graphical plots

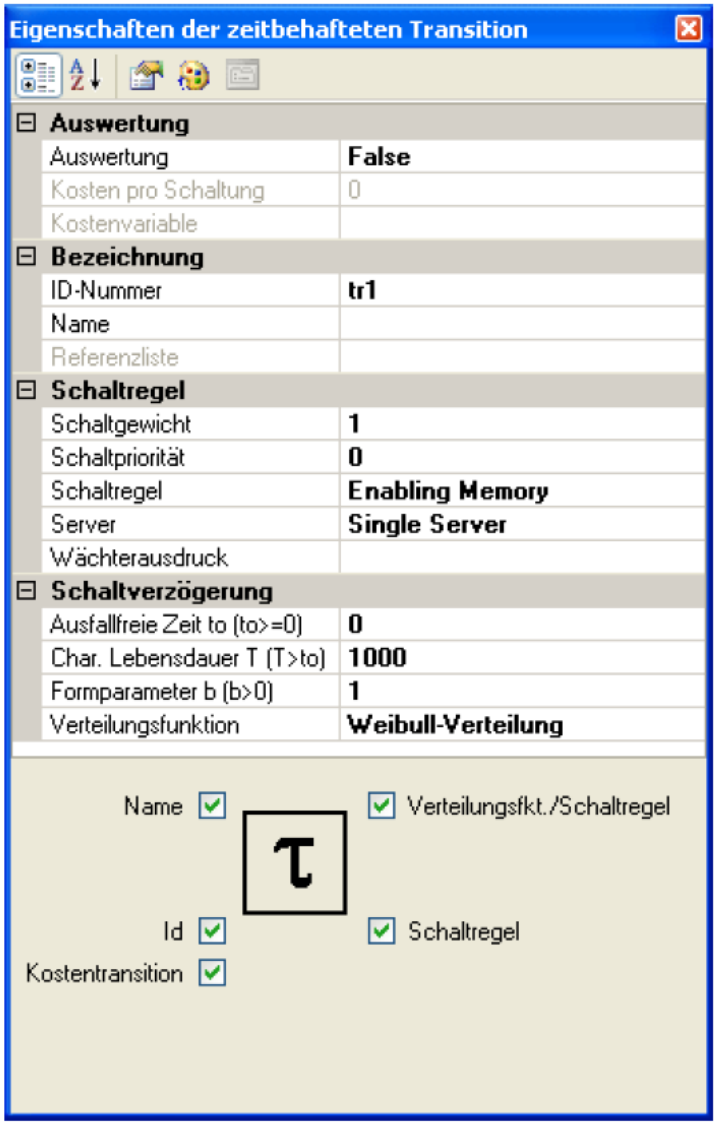
# Features

Debugging features:

- automatic check of model
- model animation
- customizable protocol files

Plotting features:

- markings of places to derive
  - reliability
  - availability
  - maintainability
  - delay times
  - logistics
  - …



# Summary & Conclusions

- Presented powerful modeling methods are able to consider various modeling aspects
- Conjoint system model based on Petri Net yields the maximum modeling power and is able to consider manifold dependencies and reciprocal effects
- Analyzed operational parameters are an integral base for the development of availability (predictions, comparisons, optimizations, …)
- Large systems require support in modeling and analysis

Availability modeling and analysis based on Petri Nets offers a great potential for CERN

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# Thank you for your attention!