Potentials of Petri nets for Availability Modeling and Analysis

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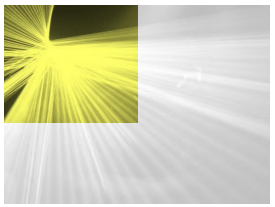
Workshop: Machine Availability and Dependability for post LS1 LHC
28 November 2013
Geneva, Switzerland

Outline

- Introduction
- Availability Modeling
- Analysis and Prediction
- Software Tool: REALIST
- Large and Complex Systems
- Application Example
- Summary & Conclusions

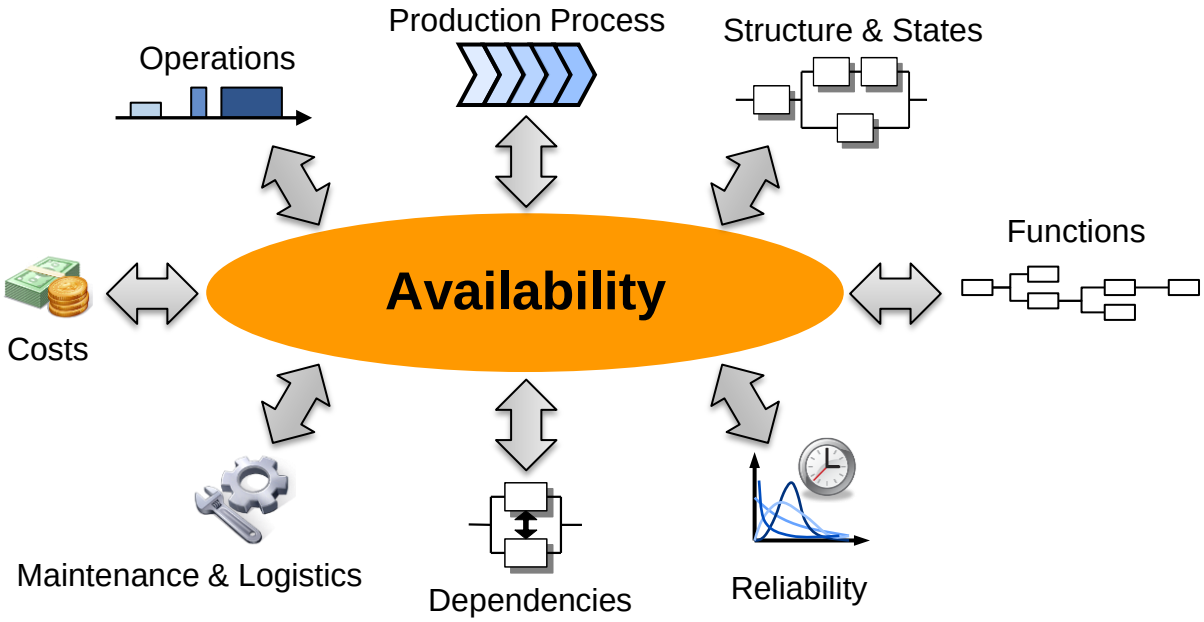


Introduction

Motivation

Availability Modeling and Analysis



Numerous interactions, extremely complex system description

Motivation

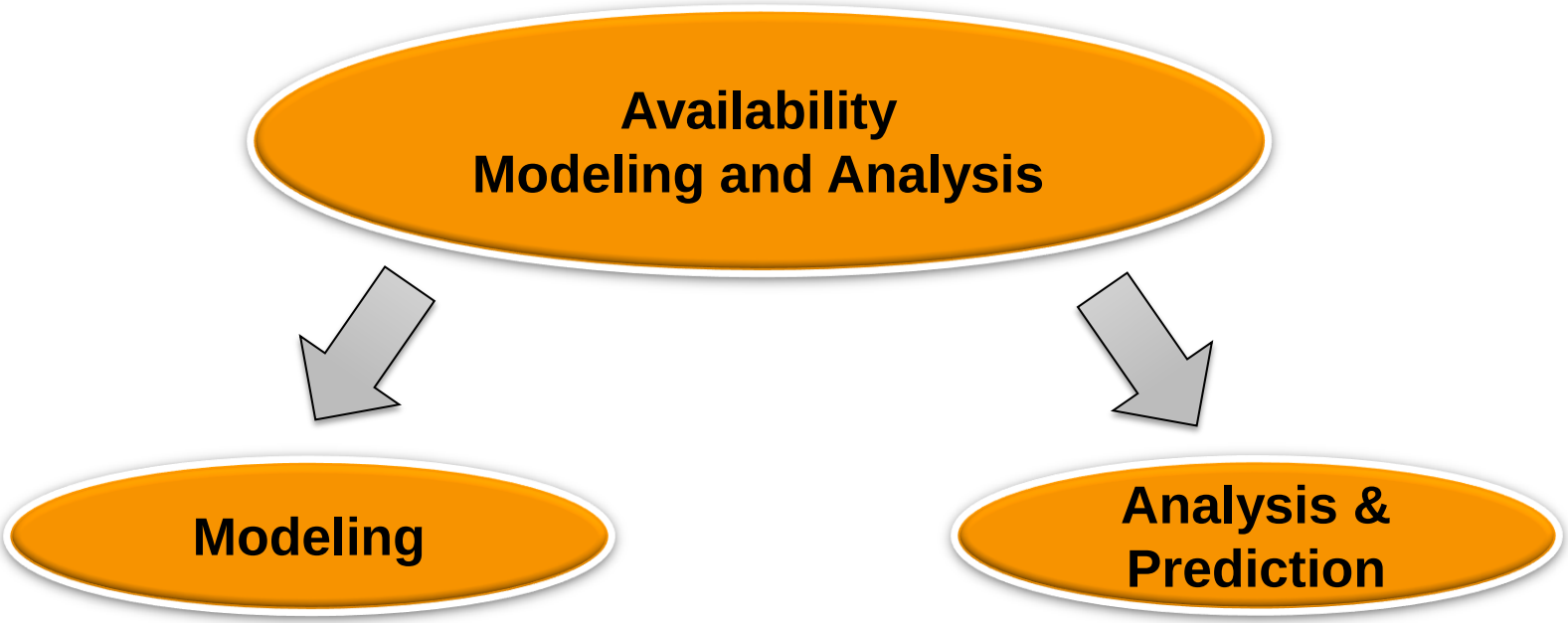
- **Prediction** of operational availability

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

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

Availability Modeling

Availability Modeling and Analysis

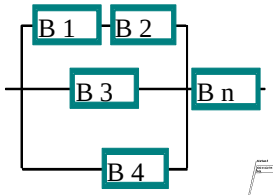


Overview and Comparison of Modeling Methods

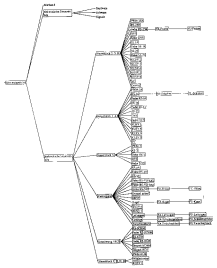
Modeling methods

Combinatorial models

- Reliability block diagram

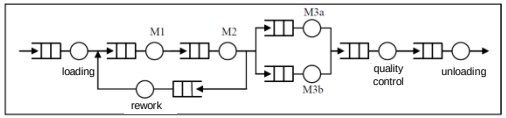


- Fault tree



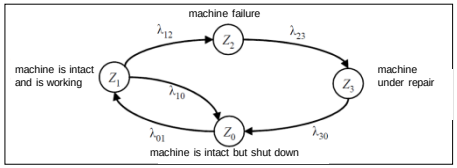
Queue oriented models

- Queues

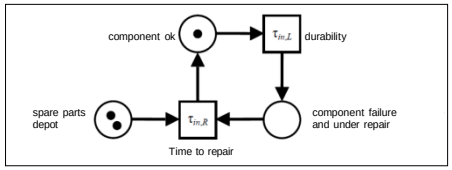


State-space oriented models

- Markov state graphs

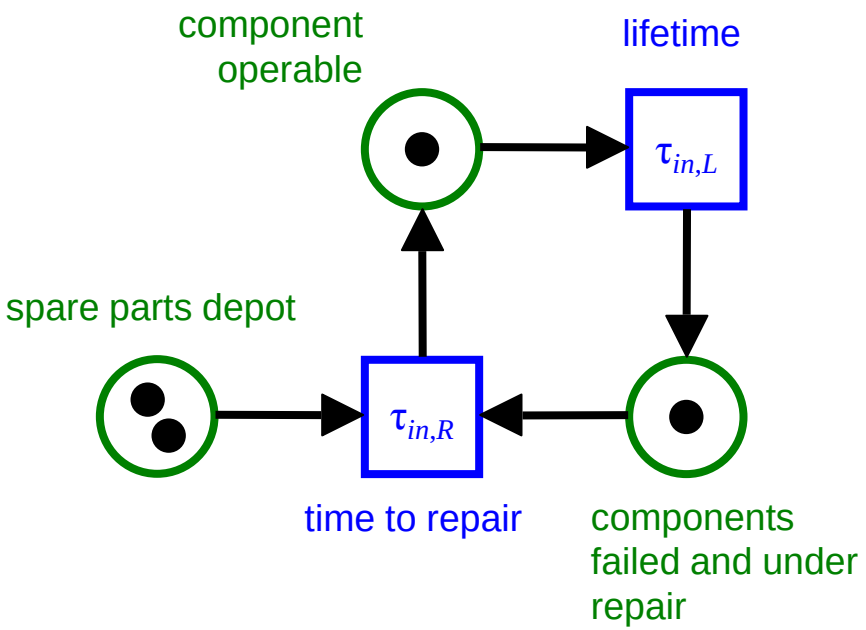


- Petri nets



Extended Stochastic Petri Net (ESPN)

- Statical 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

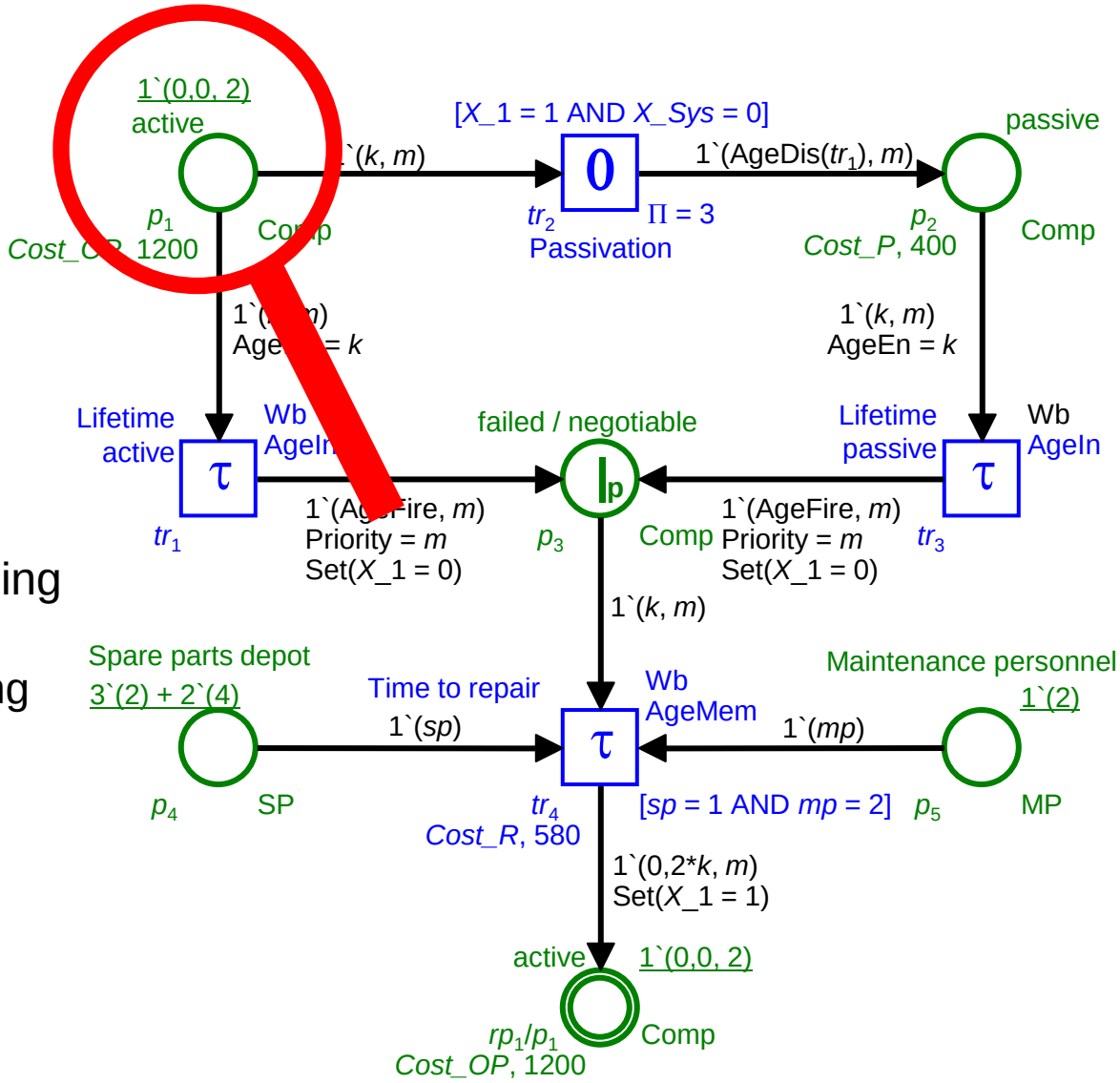


Few basic elements: great flexibility in modeling

Extended Coloured Stochastic Petri Net (ECSPN)

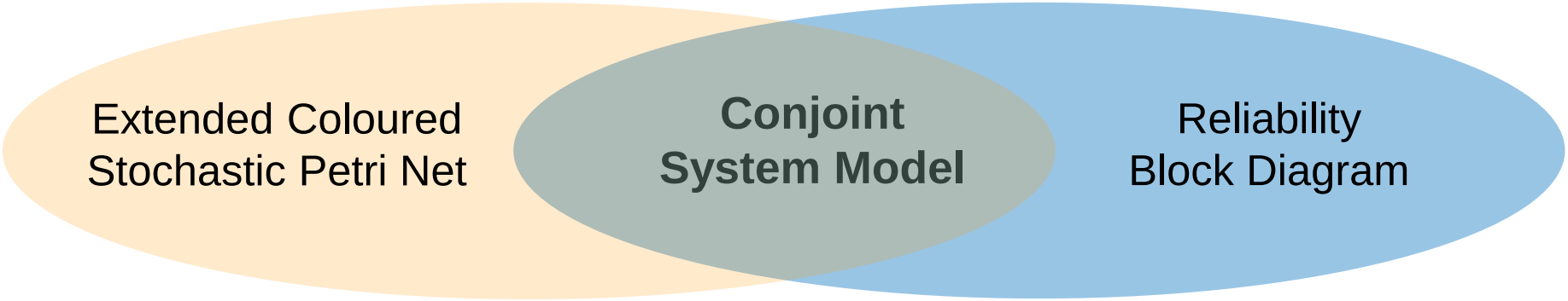
Extensions

- 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



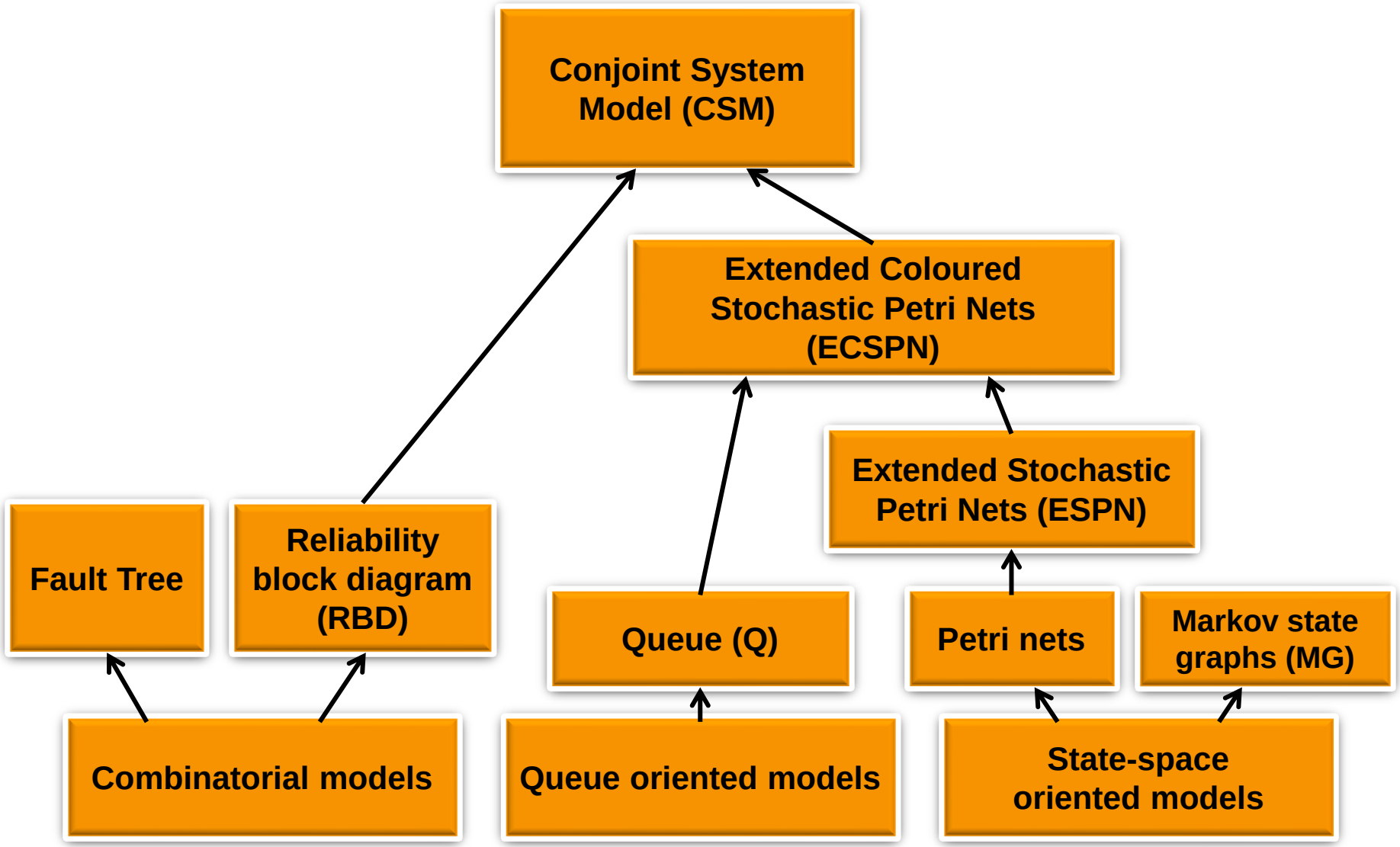
Conjoint System Modeling (CSM)

- 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 dependencies

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

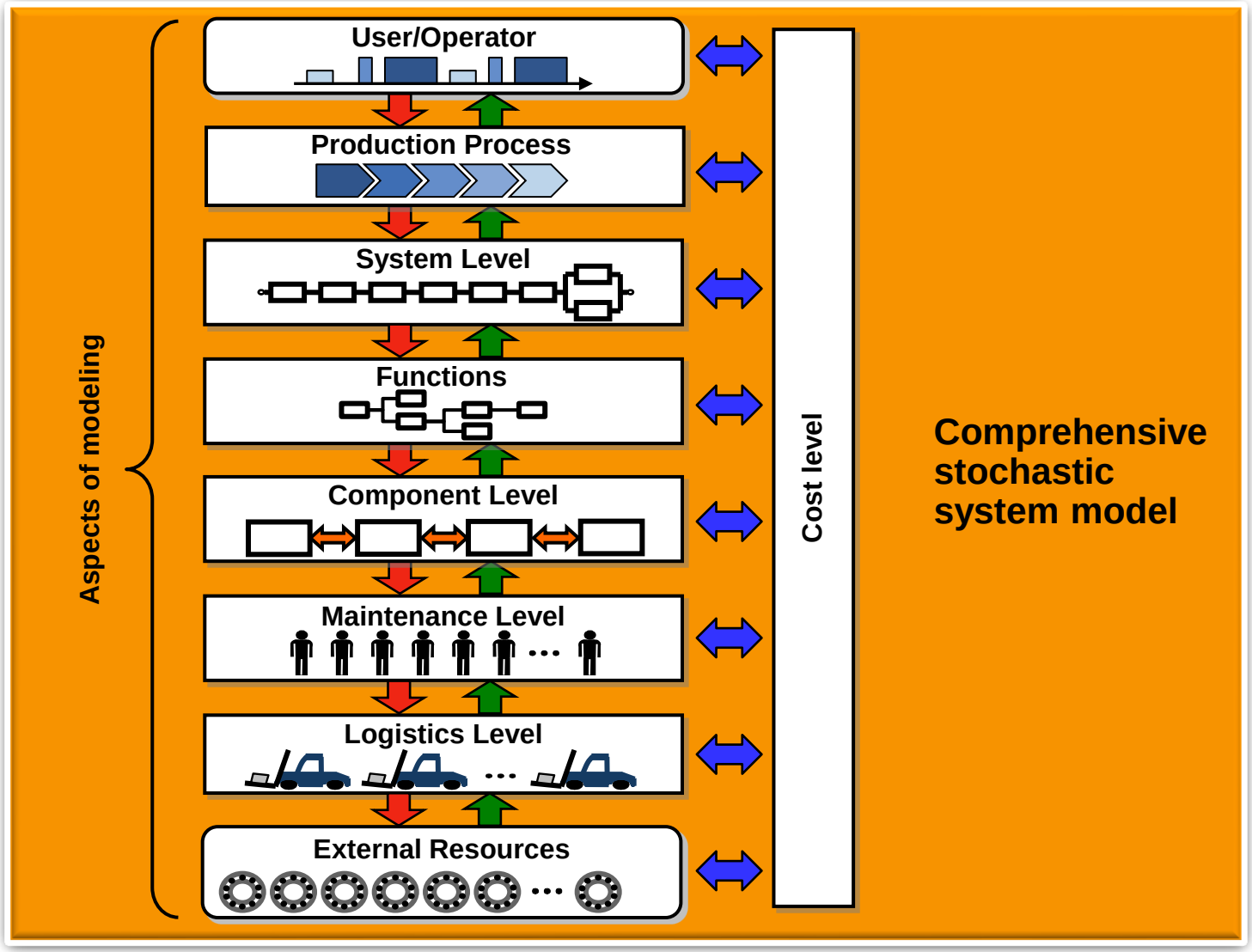
- Corrective and preventive maintenance
- Inspections and sensor-based condition monitoring
- Time-dependent transition rates
- Degree of renewal*
- Spare part logistics
- Limited maintenance capacities
- Maintenance dependencies

Costs

- Duration-based costs
- Number-based costs
- Variable Costs/Revenues

* with time-dependent failure or transition rates

System Model - Close to Reality



Analysis and Prediction

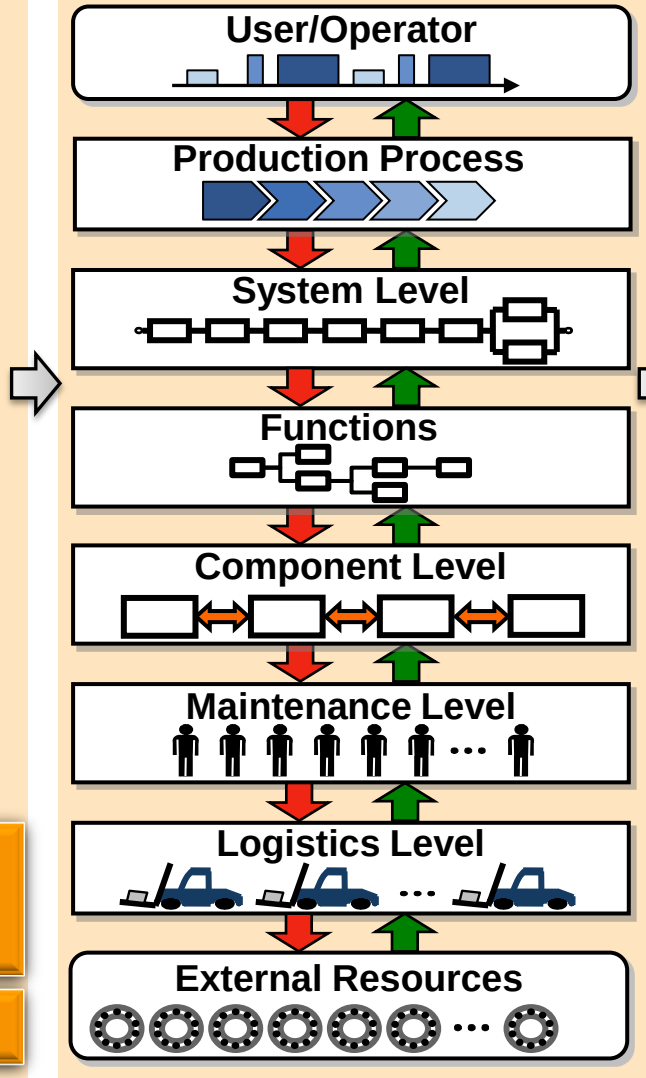
Dependability Characteristics

Inherent Characteristics

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

Independent processes, structures, components and states

Input Information



Operational Characteristics

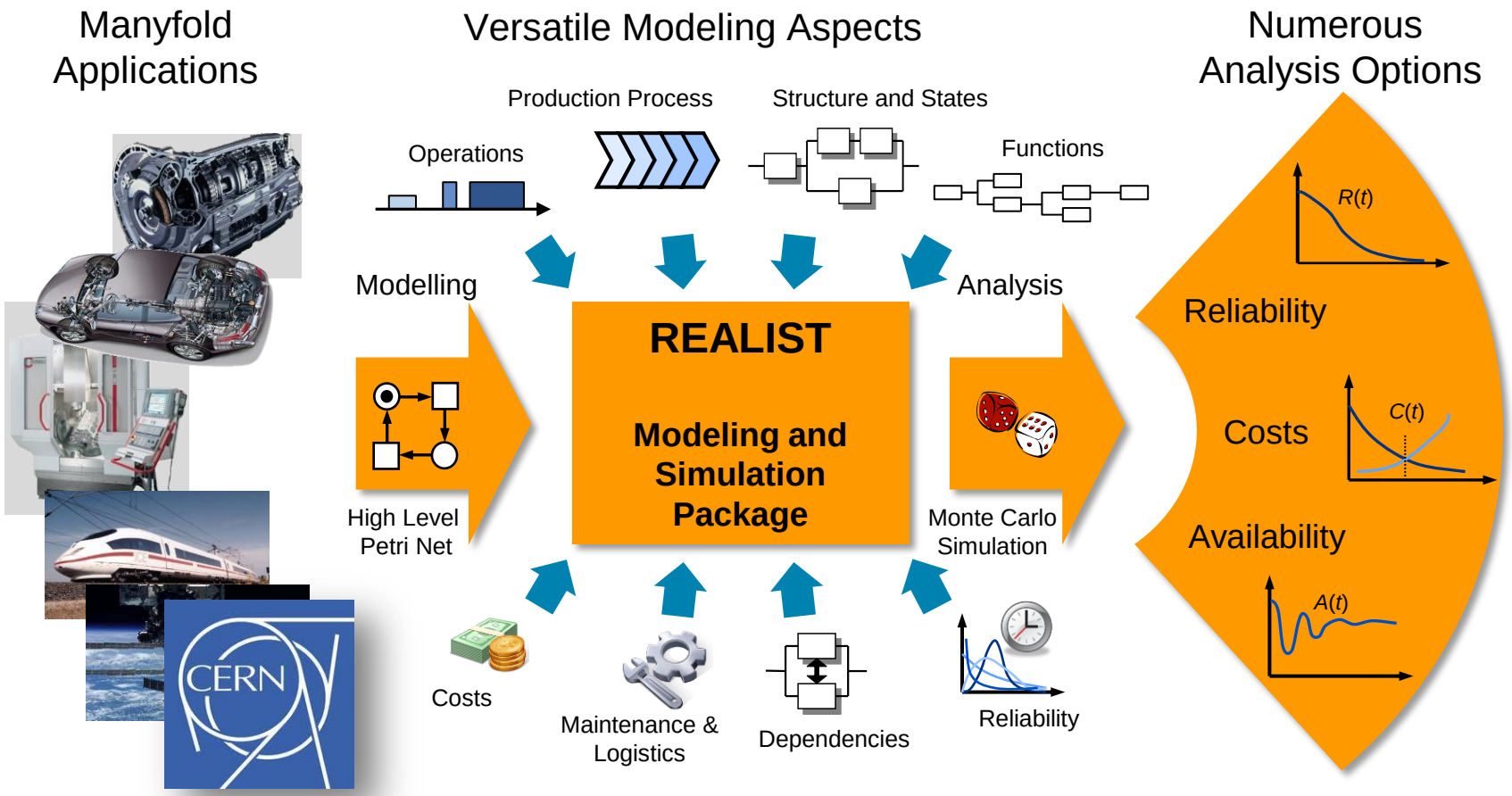
- Operability
- Productivity
- Availability
- Reliability
- Functionality
- Reparability/Maintainability
- Inspectability
- Maintenance Delay Time
- Logistic Delay Time
- Level of Service

Evaluation under operating conditions (with dependencies)

Output Information

Software Tool: REALIST

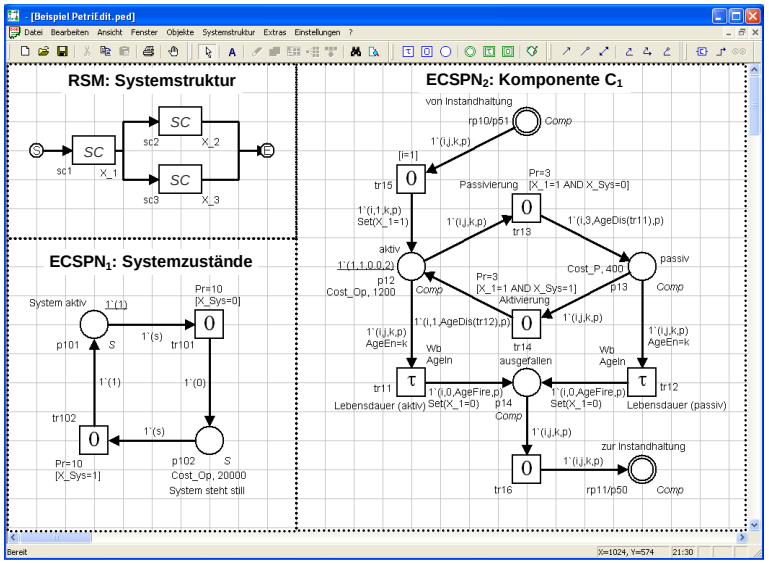
Modelling and Simulation Package REALIST*

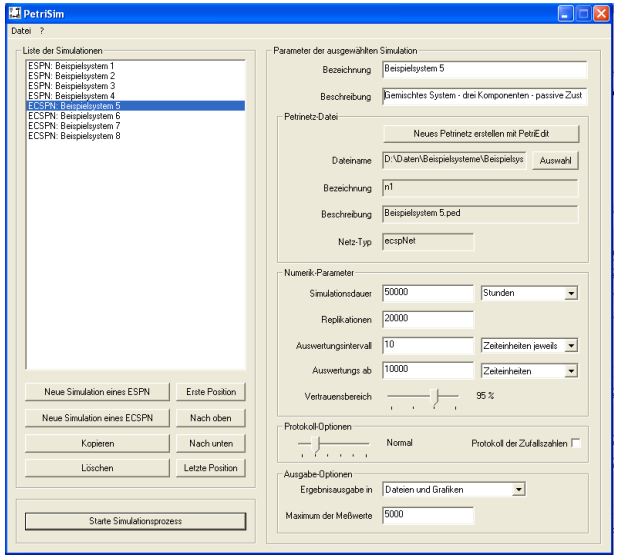


Modeling and Analysis of complex technical systems "without" limitations!

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

Modeling and Simulation Package REALIST





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

Comfortable development and efficient analysis of a system model

Large and Complex Systems

Complexity of the Model

Measures to support modeling:

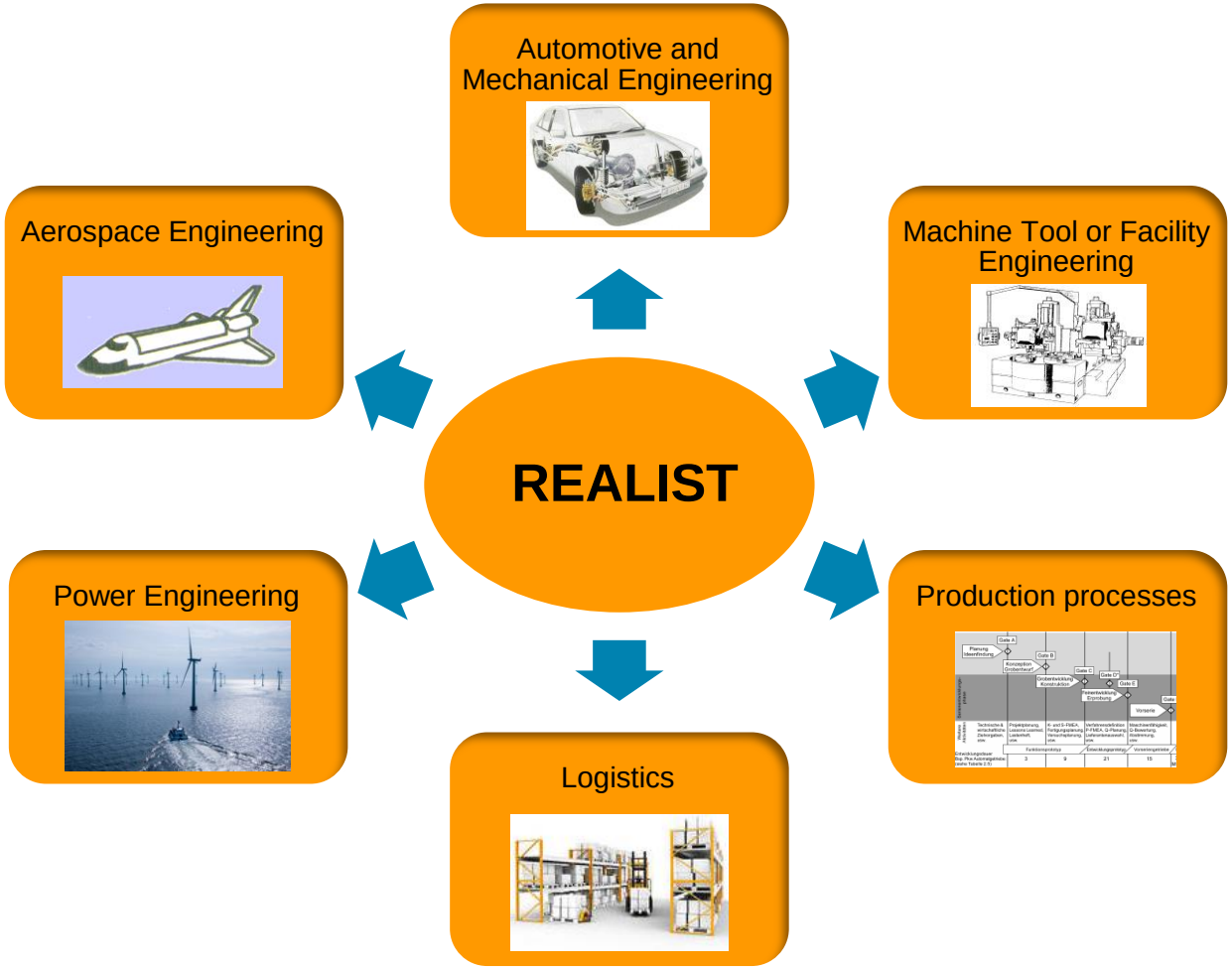
- Decomposition
- Application of sub-models
- Application of extended sub-models
- Conjoint modeling
- Generic model design (automatic generation)

Measures to reduce simulation time:

- Parallelization
- Focusing

Application Examples

Range of Application

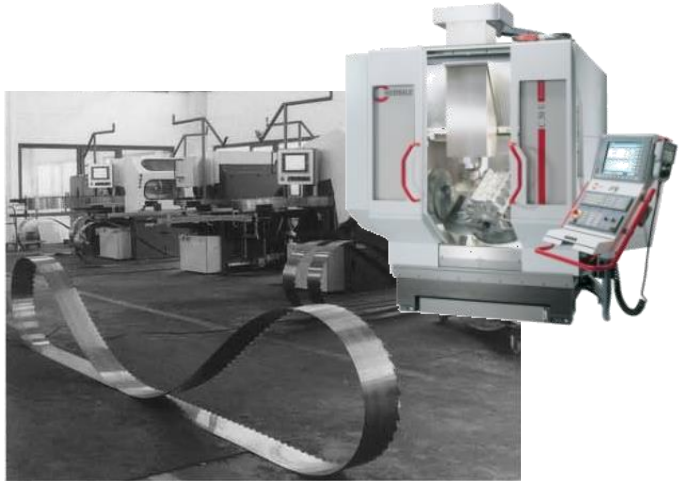


From single component up to comprehensive system

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, …



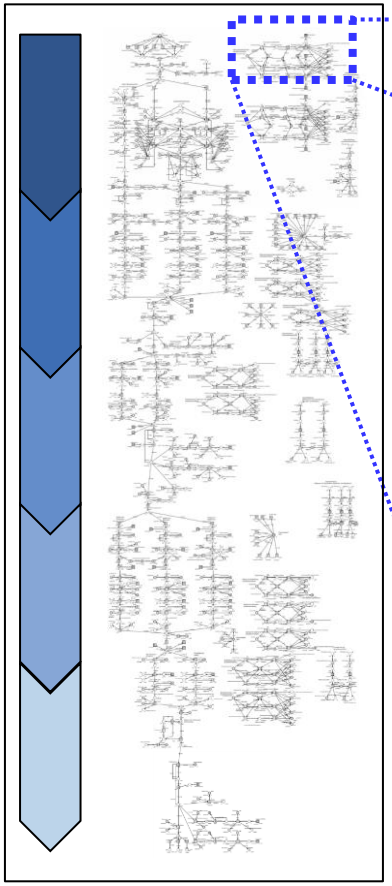
Production system: band saw blade fabrication

Main analysis objectives:

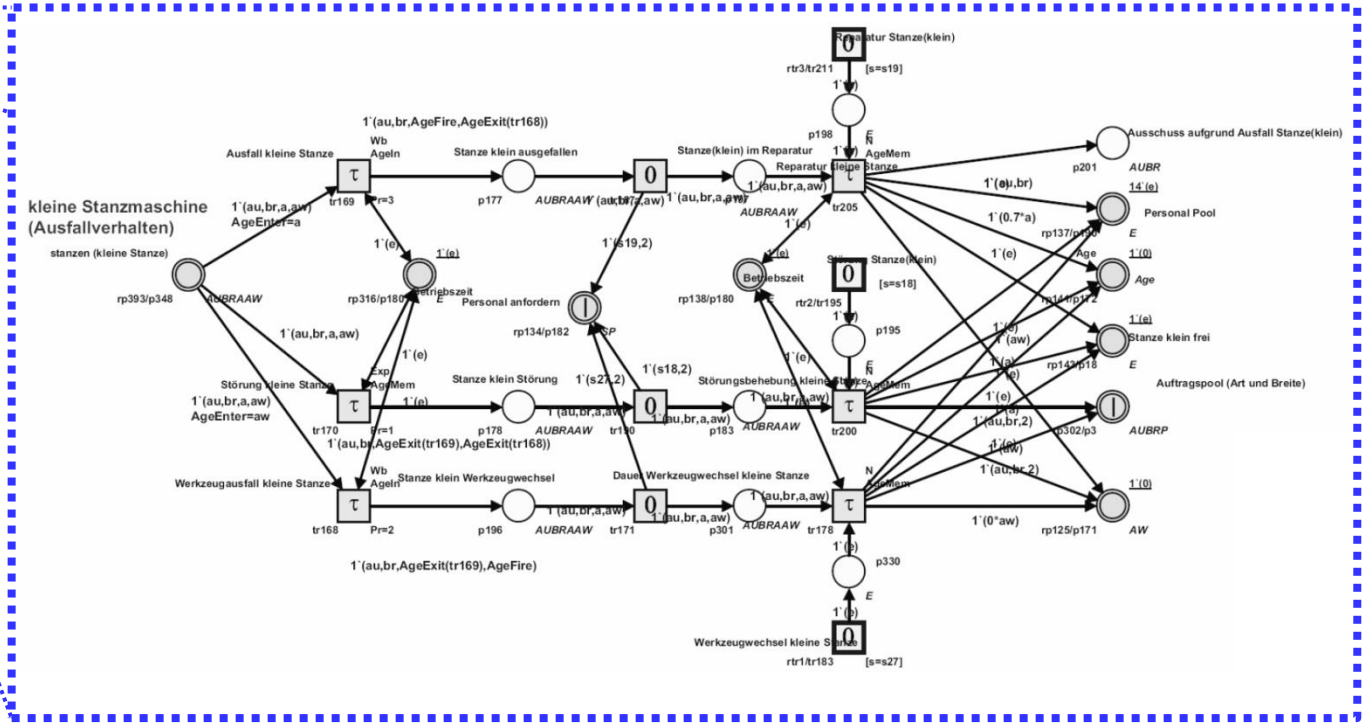
- Different maintenance strategies and costs
- Probability of shortfall for the production unit target (based on **availability**)

System Model – Production system

Entire model



Reliability model of machine A



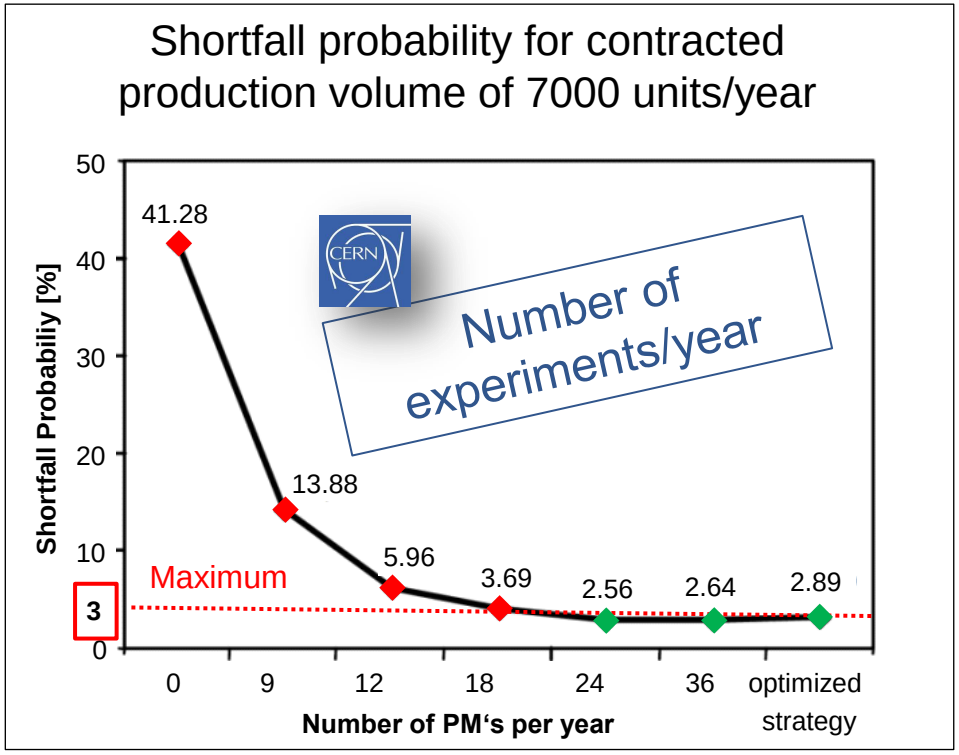
- 3 concurrent failure modes
- Initiation/administration of repair process

Results – Production system

Main analysis results:

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

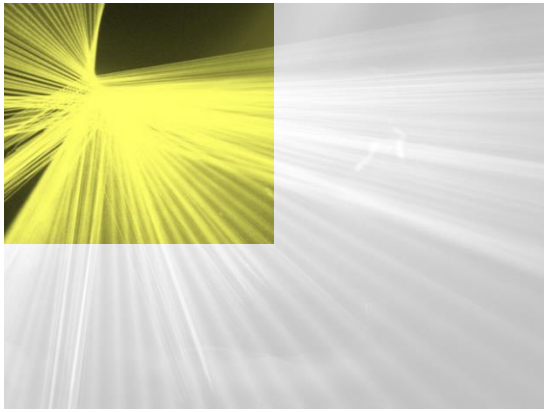
Production system: band saw blade fabrication



Maintenance strategy and costs:

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

CERN Budget constraints



Summary & Conclusions

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!