# Isograph Packages

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Acknowledgements: M. Blumenschein, A. Fernandez Navarro, S. Hurst, O. Rey Orozco

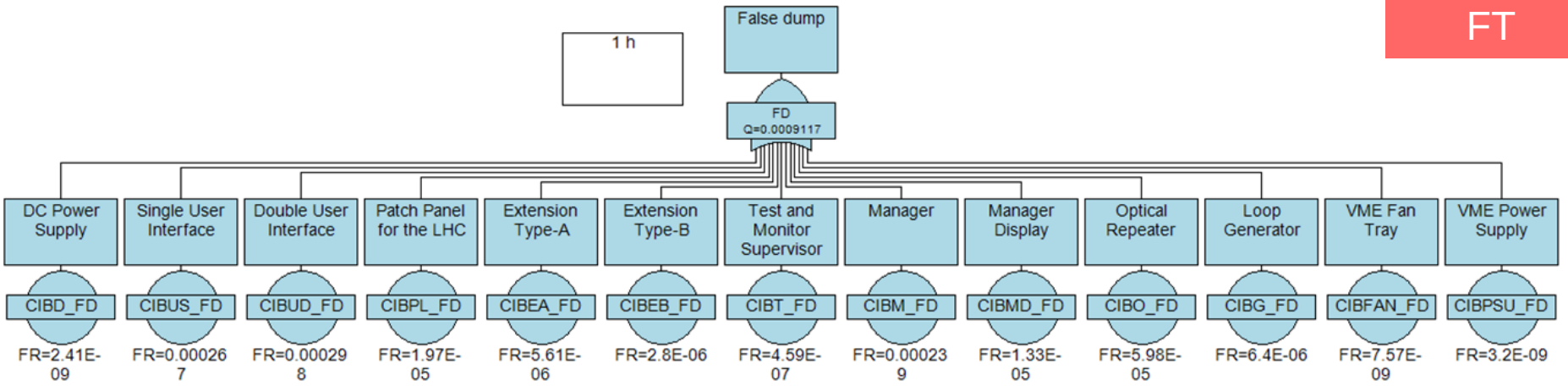
# ISOGRAPH – Overview

- Reliability Workbench, modules:
  - Prediction (standards,…) ←
  - Fault tree (FT) ←
  - Reliability Block Diagrams (RBD) ←
  - Event tree
  - Markov
  - Weibull
  - FMECA ←


- Availability Workbench, modules:
  - AvSim ←
  - Weibull
  - RCM cost

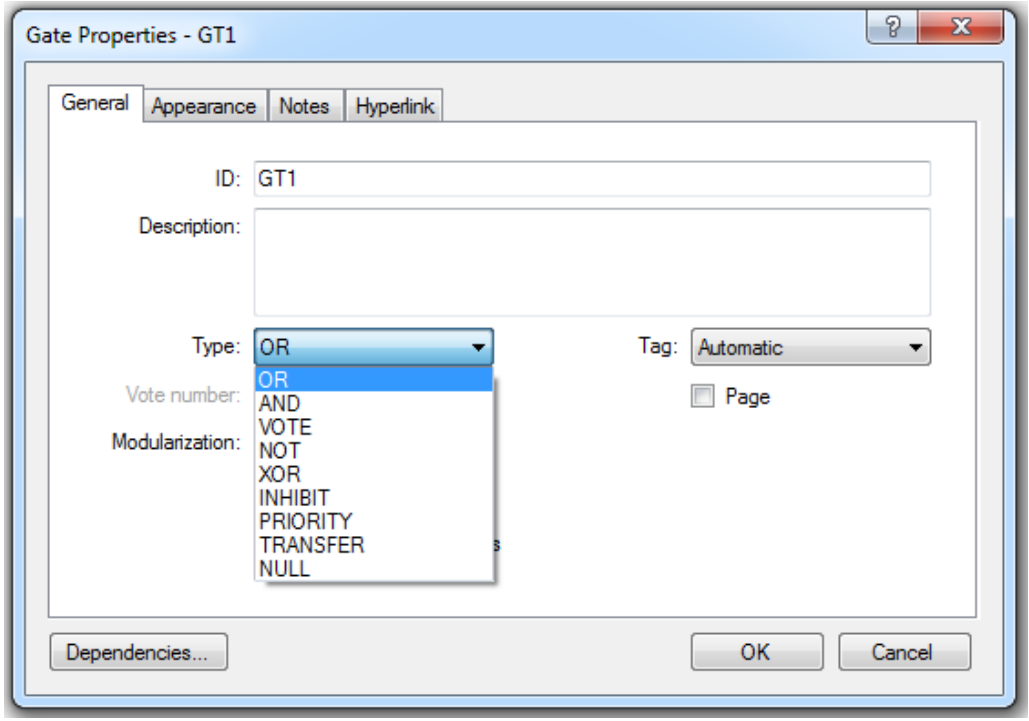
# Fault Trees: Example BIS

FT



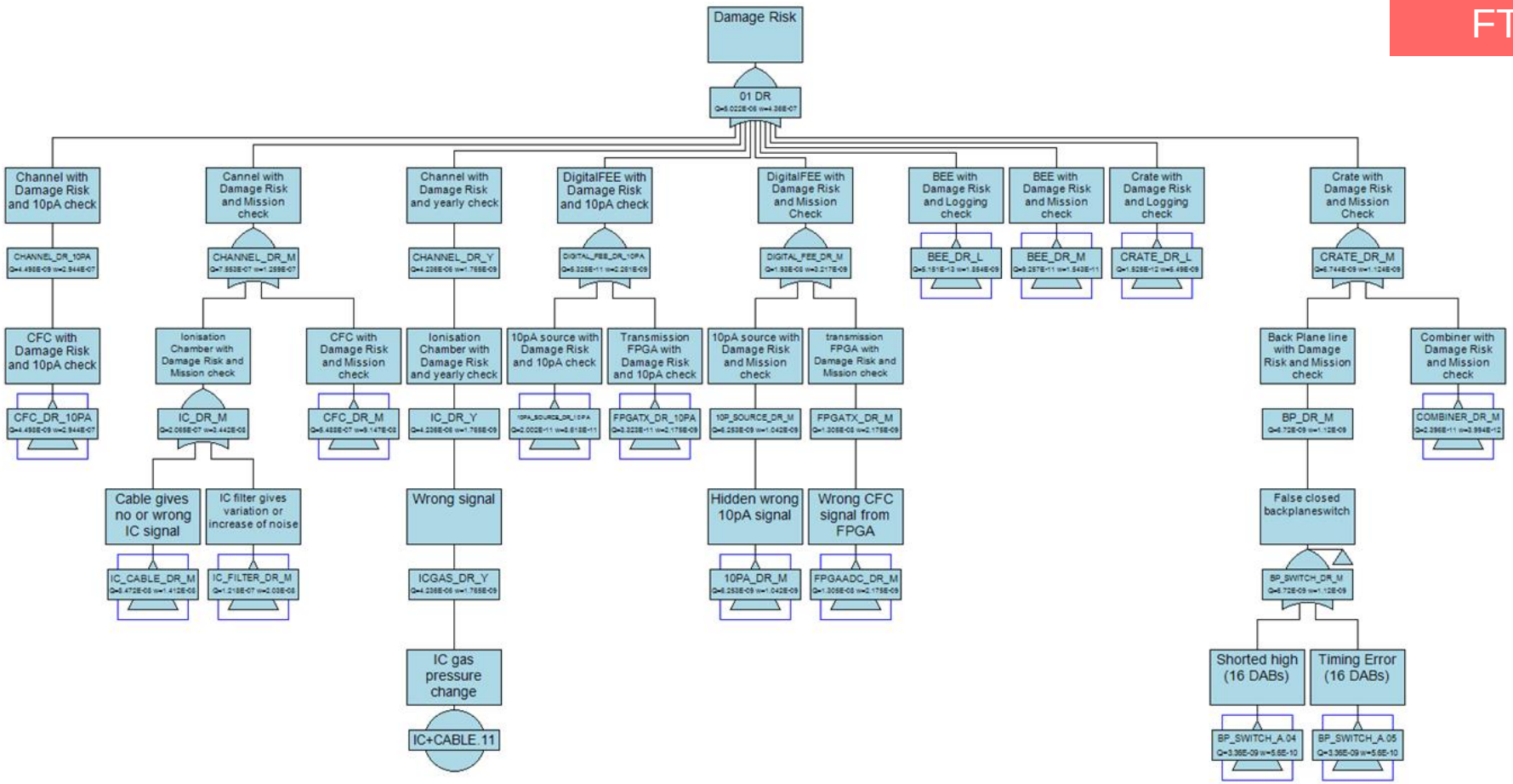

False Dump rate: 0.0115 / mission

→ 4.6 False Dumps per year



# Fault Trees: More Complex Example BLMs

FT




Rate unprotected: $1.26 \cdot 10^{-6}$ / mission

→ $5.02 \cdot 10^{-4}$ per year

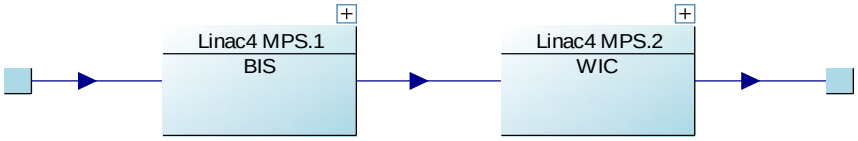
- Manual creation of fault trees and input data insertion
- Copy paste option available (2 different options)
- Option available for importing data from external files (not straightforward)

# Reliability Block Diagrams

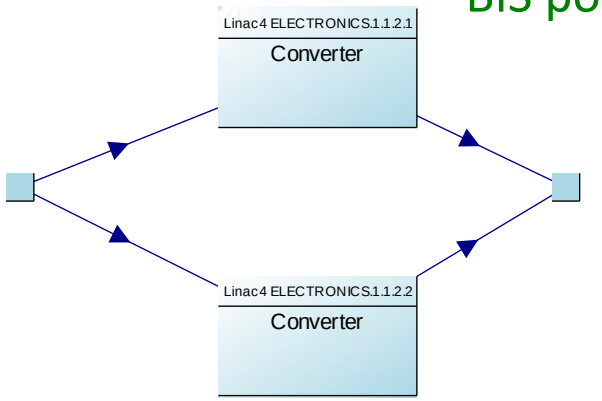
RBD

- ‘Blocks’ connected in series/parallel (voting) depending on the functionality of the system

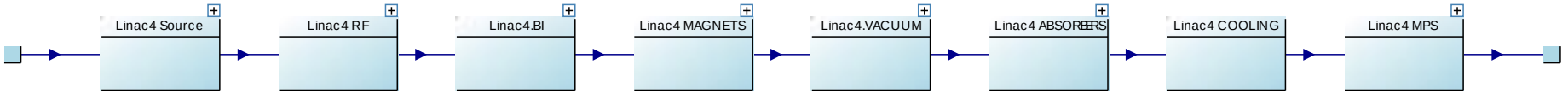
Linac4 MPS




BIS powering




- A hierarchical structure of blocks can be created:

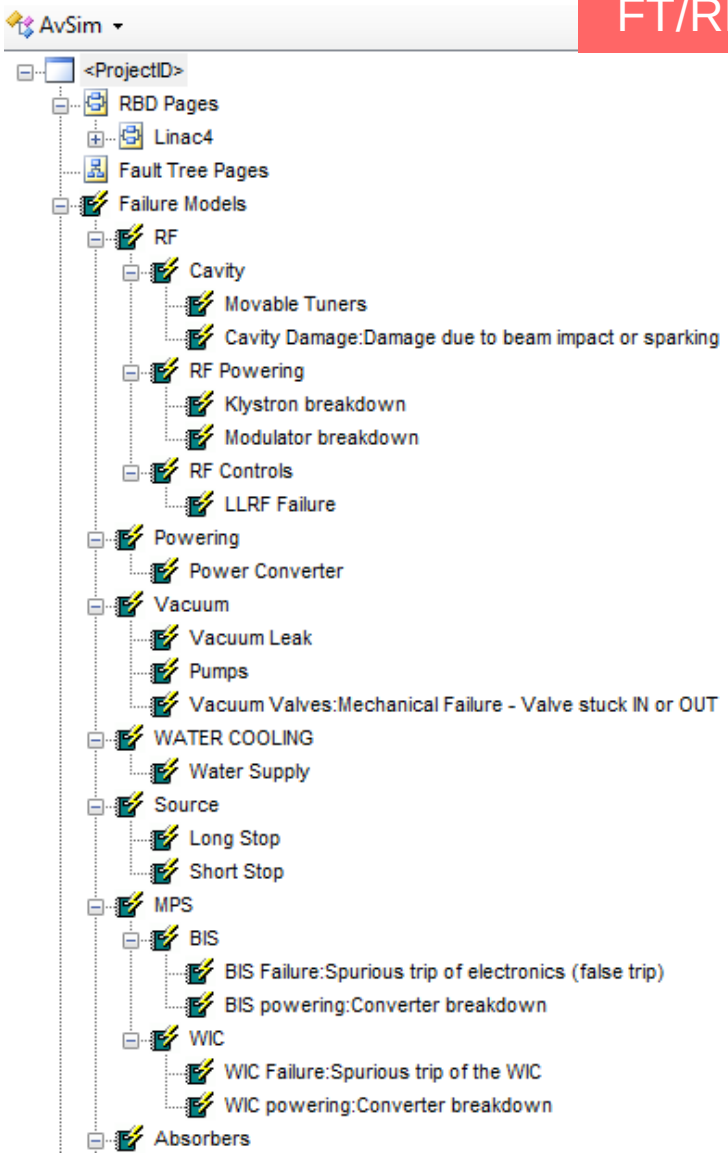



- Same considerations done for FTs apply here

# Definition of Failure Modes

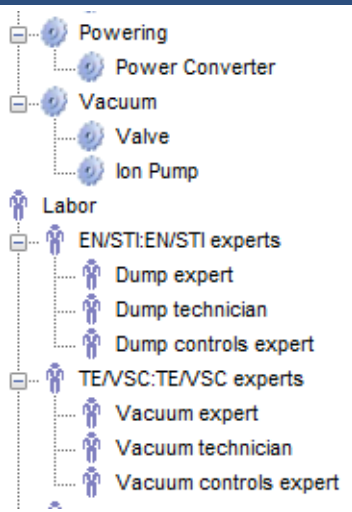
FT/RBD

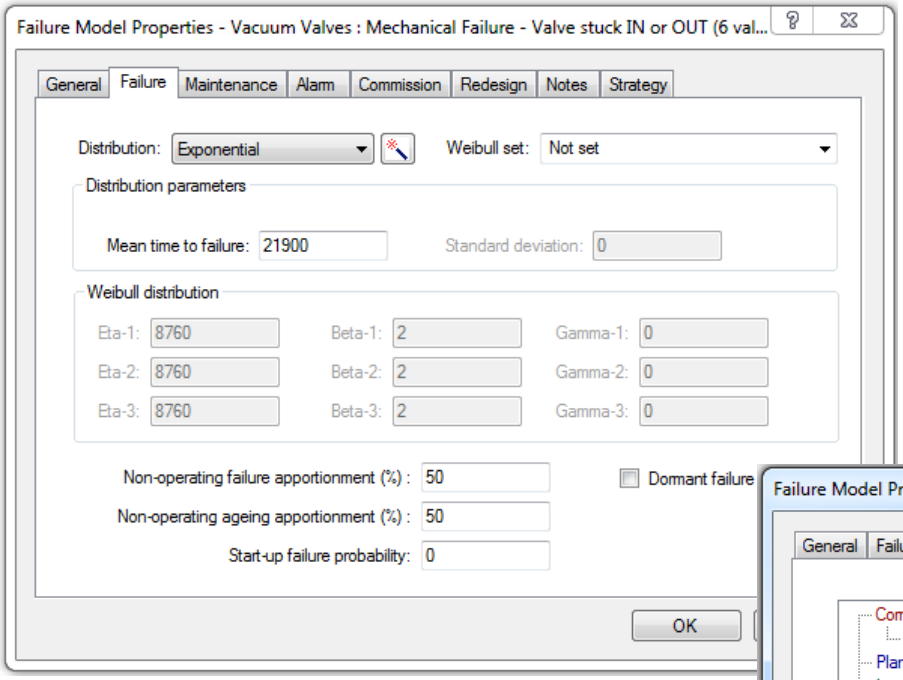
- Each block/fault tree event can be assigned a failure mode manually…
  - Failure density function
  - Failure recovery function
  - Consequences
- …and a maintenance strategy
  - Corrective
  - Inspection
  - Planned

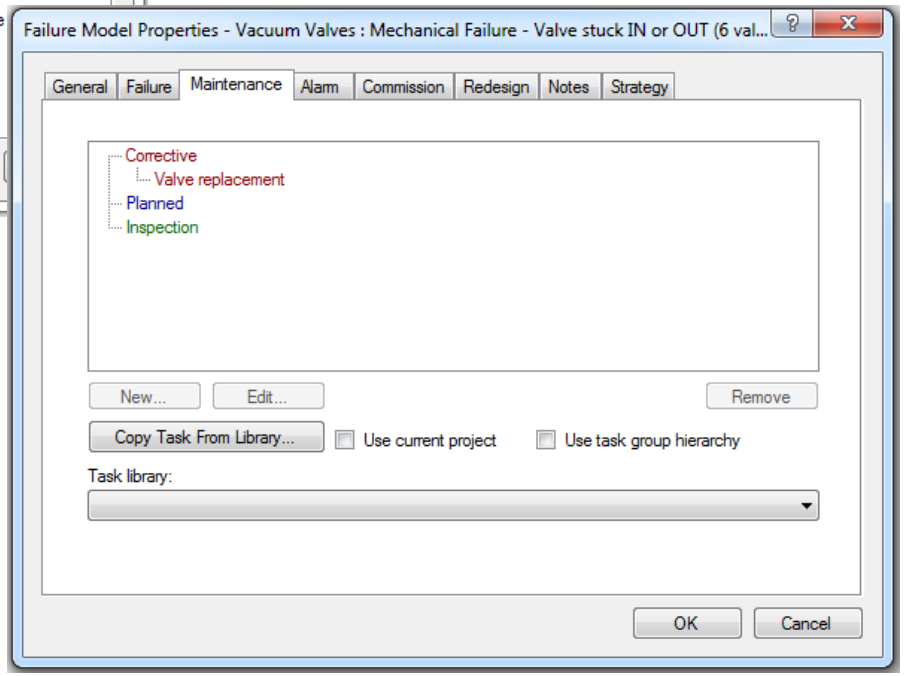


# Failure modes, effects and maintenance

RBD



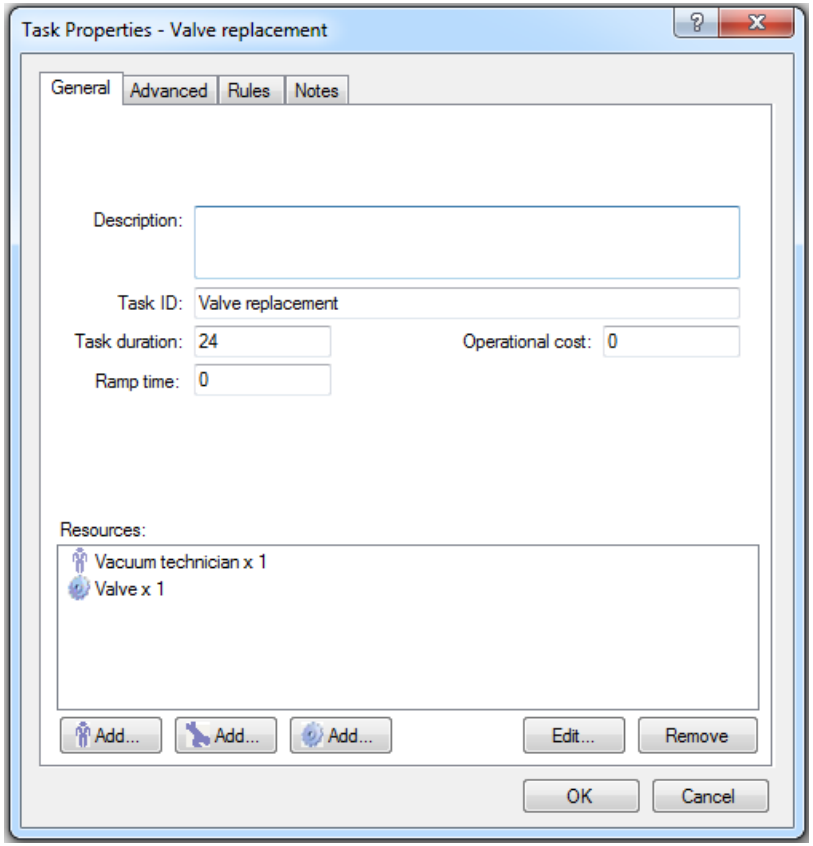



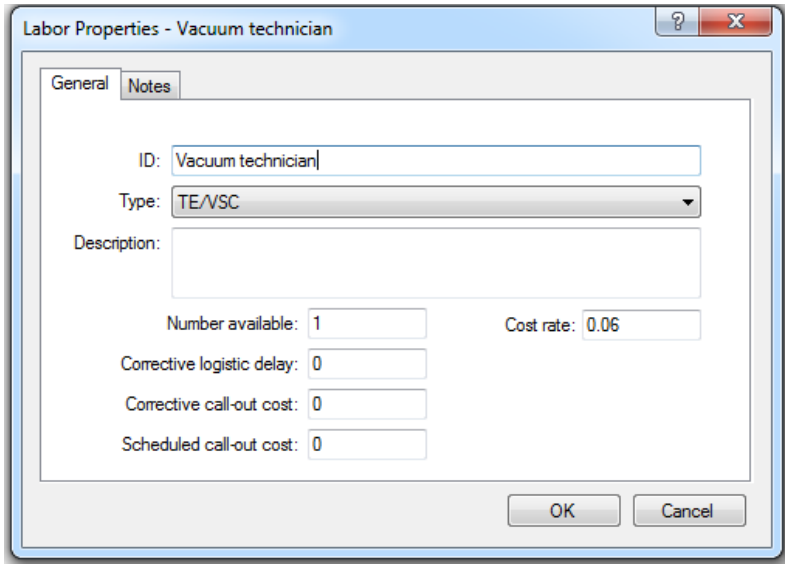



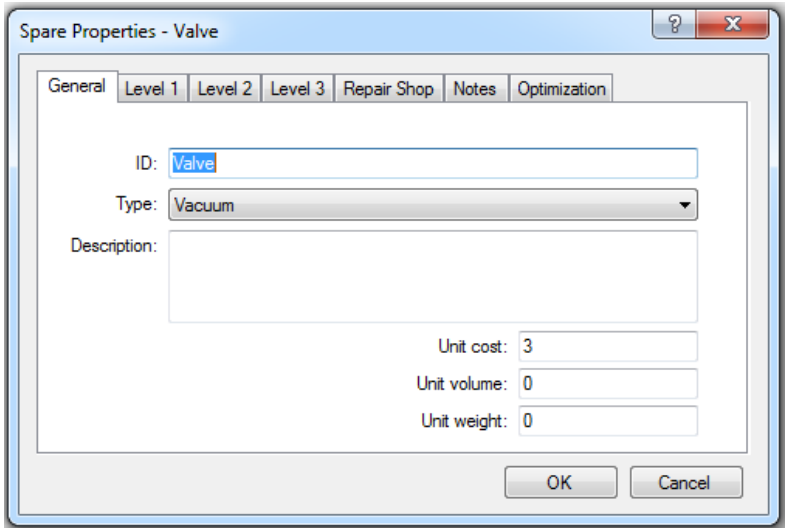
# Resources Definition

RBD

- Resources needed for maintenance are assigned to each task
  - Task duration
  - Personnel required
  - Spare components available



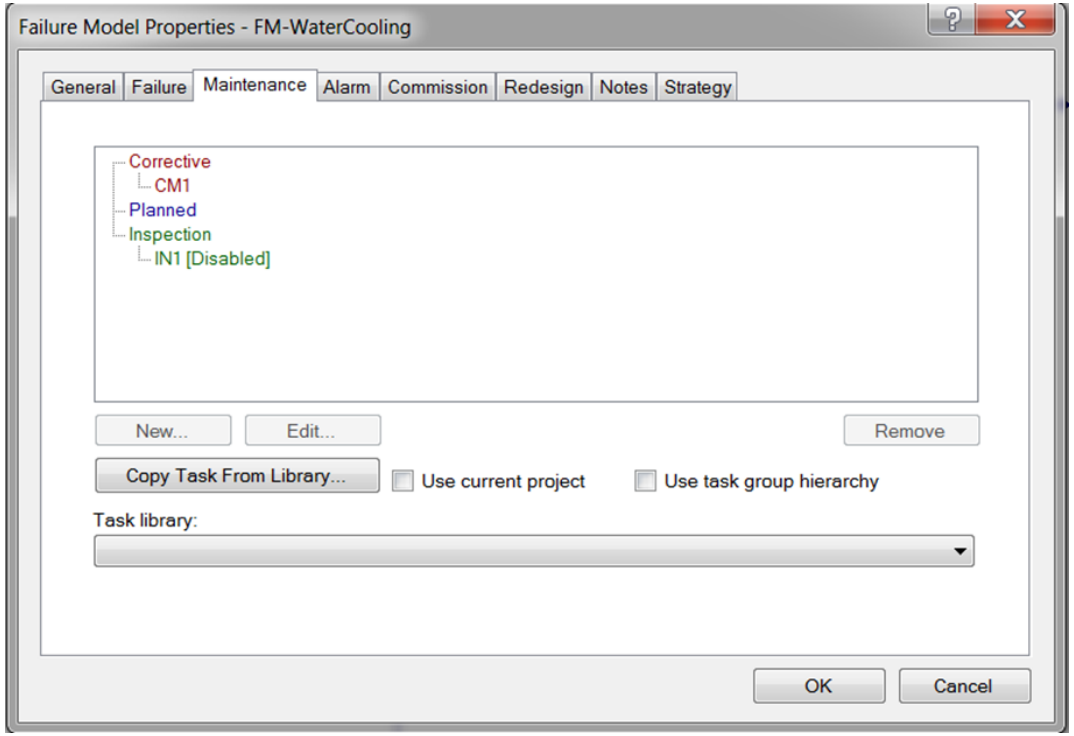



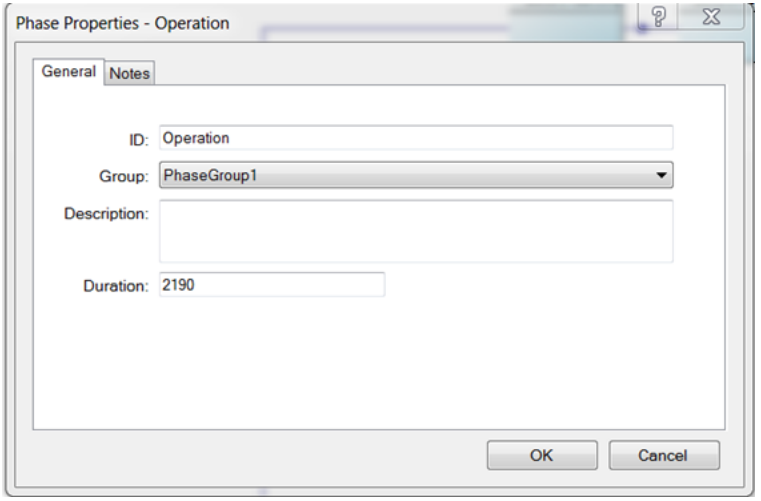



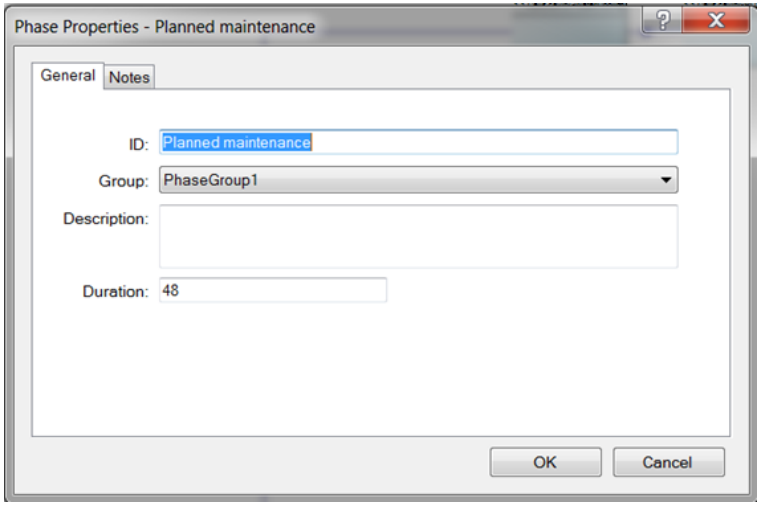
# Maintenance: Scheduled Technical Stops

RBD

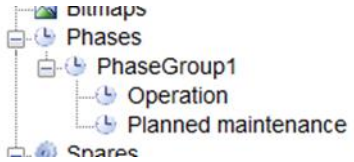
- Requires the definition of 2 phases:
  - Operation, planned maintenance



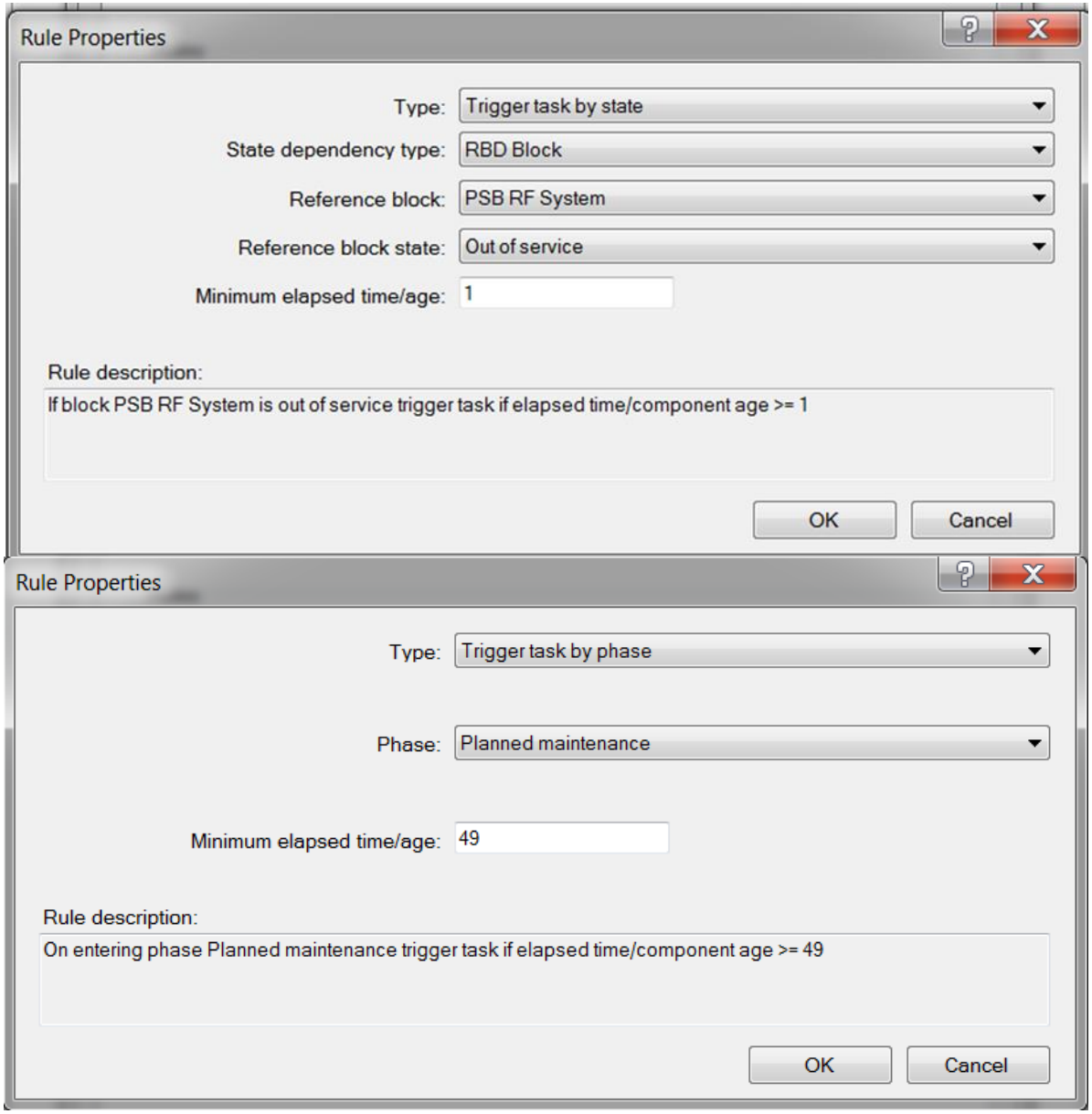




- Planned maintenance in Isograph: fix all components at a predefined time



# Rules for Performing Maintenance

RBD



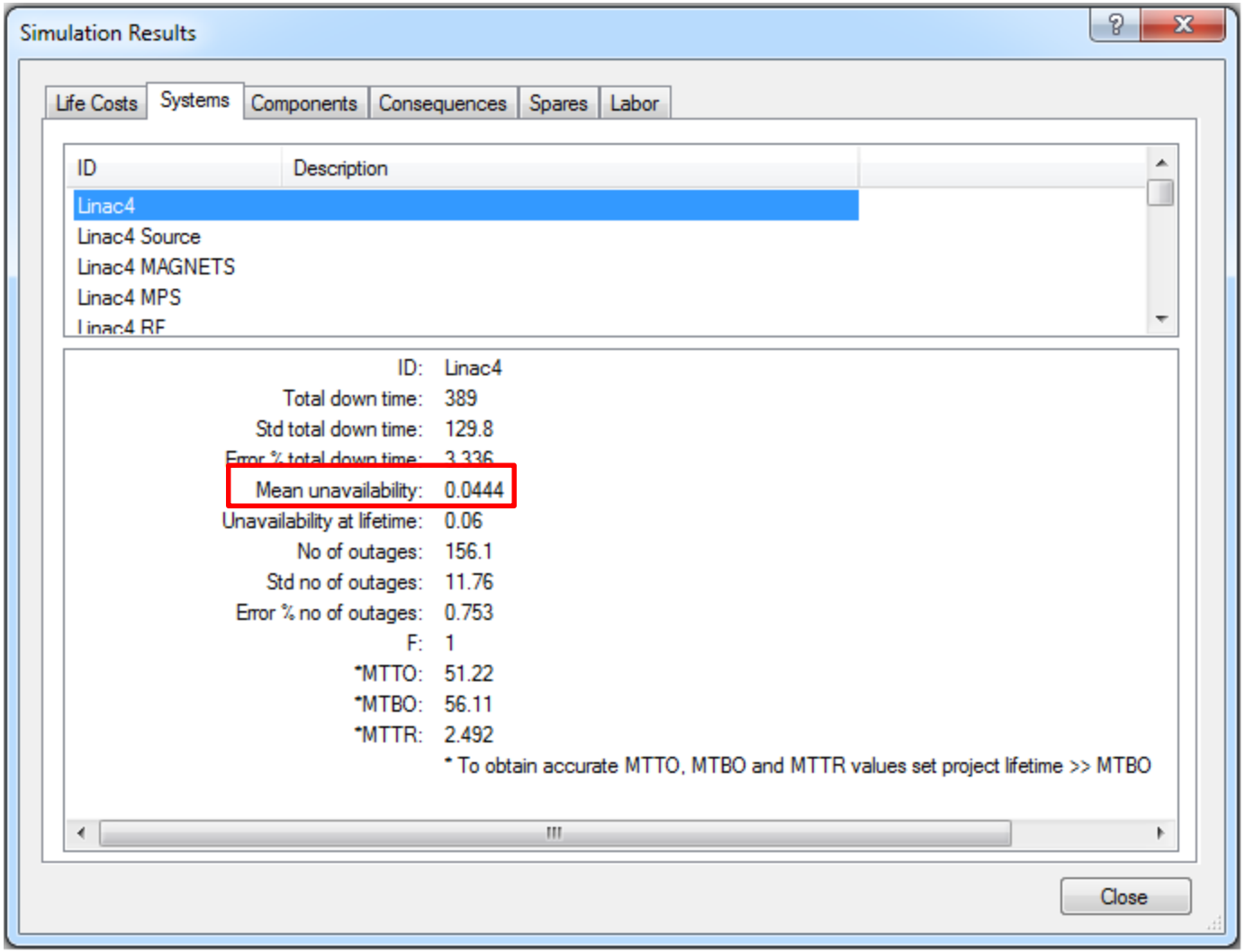
# Simulations

RBD

- Many details can be defined in Isograph, some examples:
  - Storage cost for spares, capacity, etc.
  - Logistic delays and costs
  - …
- Once all parameters related to the blocks are defined, the simulation options are selected:
  - Lifetime
  - Number of simulations (Monte Carlo)
- Results are then presented in terms of:
  - Mean (Un)Availability (system and sub-systems)
  - Required resources
  - Consequences of outages

# Results

RBD

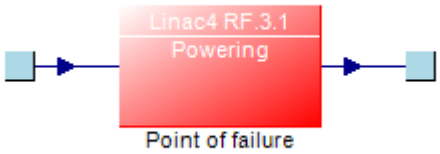



- Options available to export results to text files
- Customization of reports possible but not straightforward

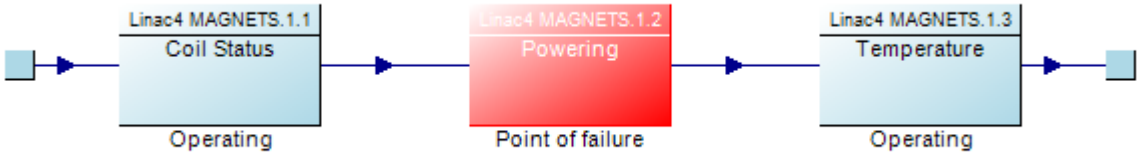
# ISOGRAPH – Simulation Watch

RBD

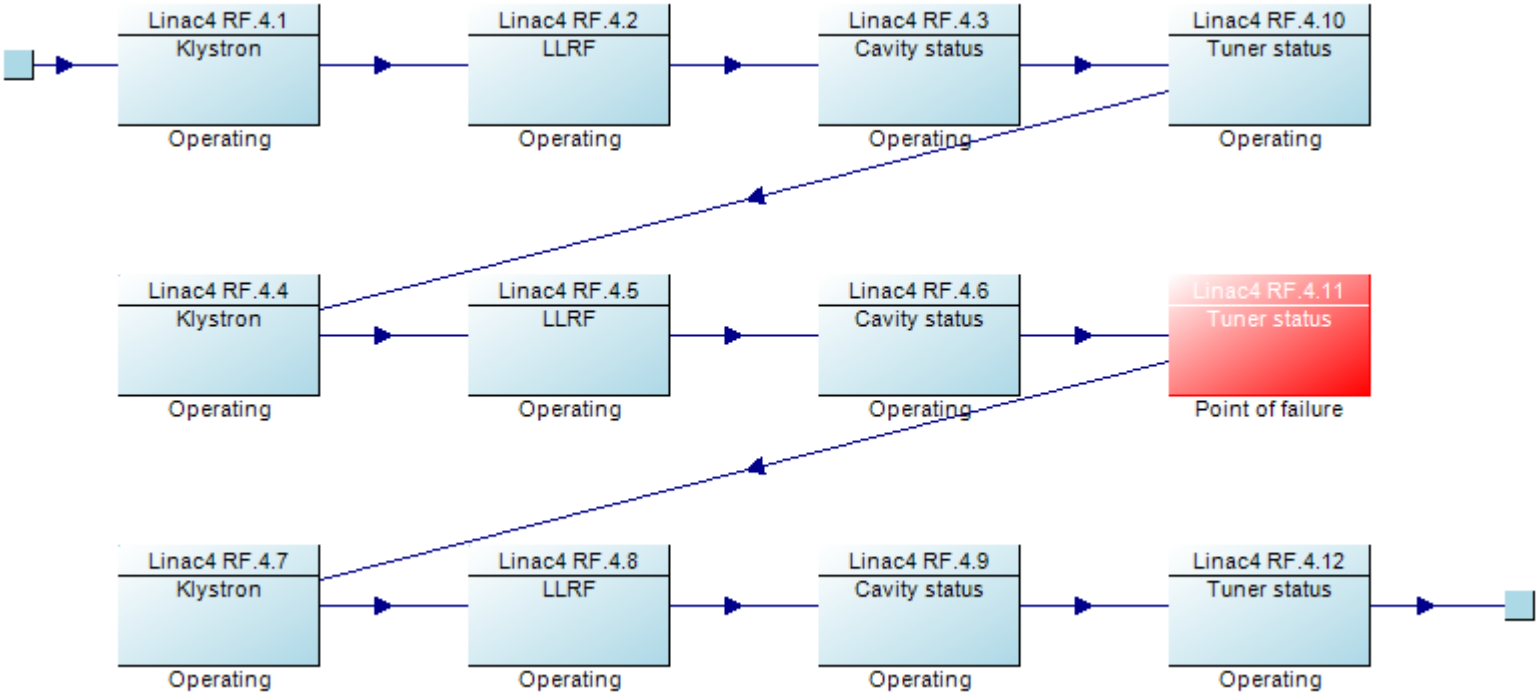
## Chopper powering failure




## Magnet powering failure

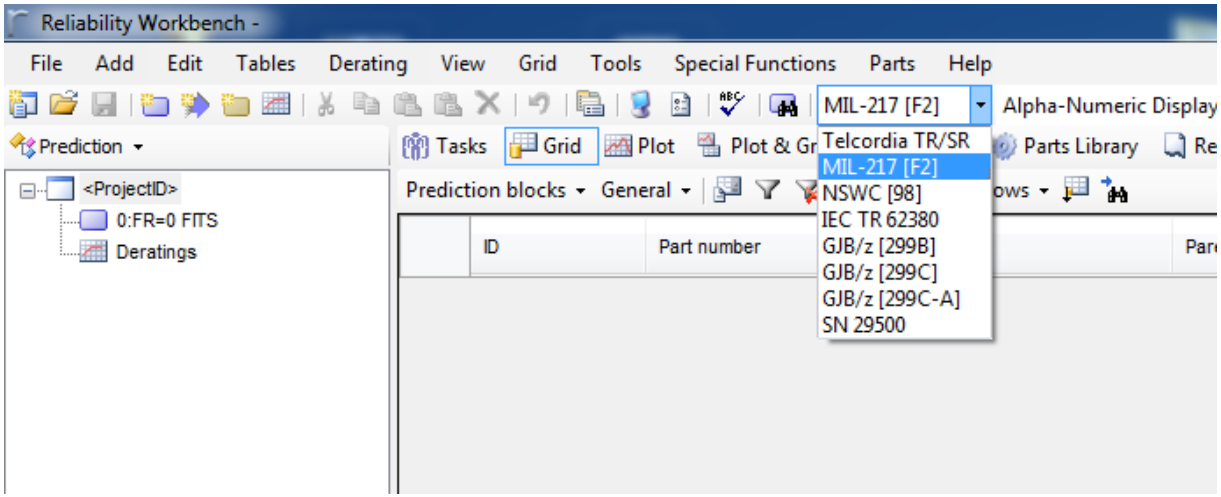



## RF Tuner failure

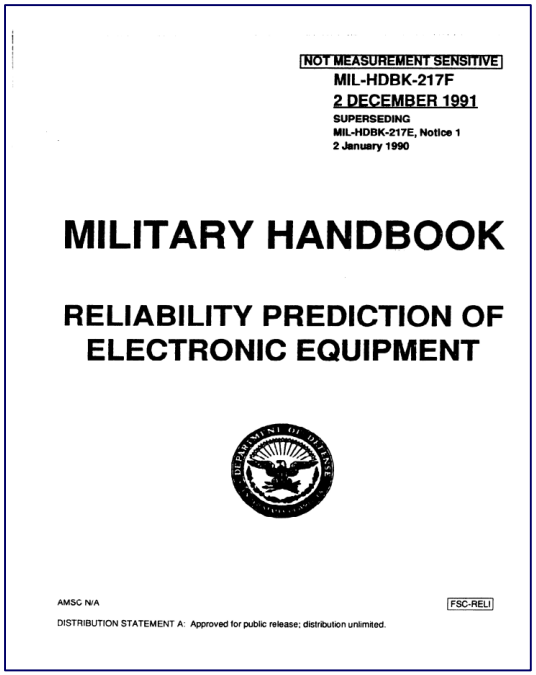


# Failure Rate Predictions - Standards

Prediction




- Calculation of failure rate of standard components from commonly used reliability handbooks


NOT MEASUREMENT SENSITIVE
MIL-HDBK-217F
2 DECEMBER 1991
SUPERSEDING
MIL-HDBK-217E, Notice 1
2 January 1990

MILITARY HANDBOOK

RELIABILITY PREDICTION OF ELECTRONIC EQUIPMENT

AMSC N/A

FSC-RELI

DISTRIBUTION STATEMENT A: Approved for public release; distribution unlimited.


NSWC Naval Surface Warfare Center Carderock Division
Naval Surface Warfare Center
CARDEROCK DIVISION
West Bethesda, Maryland 20817-5700

Handbook
of
Reliability Prediction Procedures
for
Mechanical Equipment

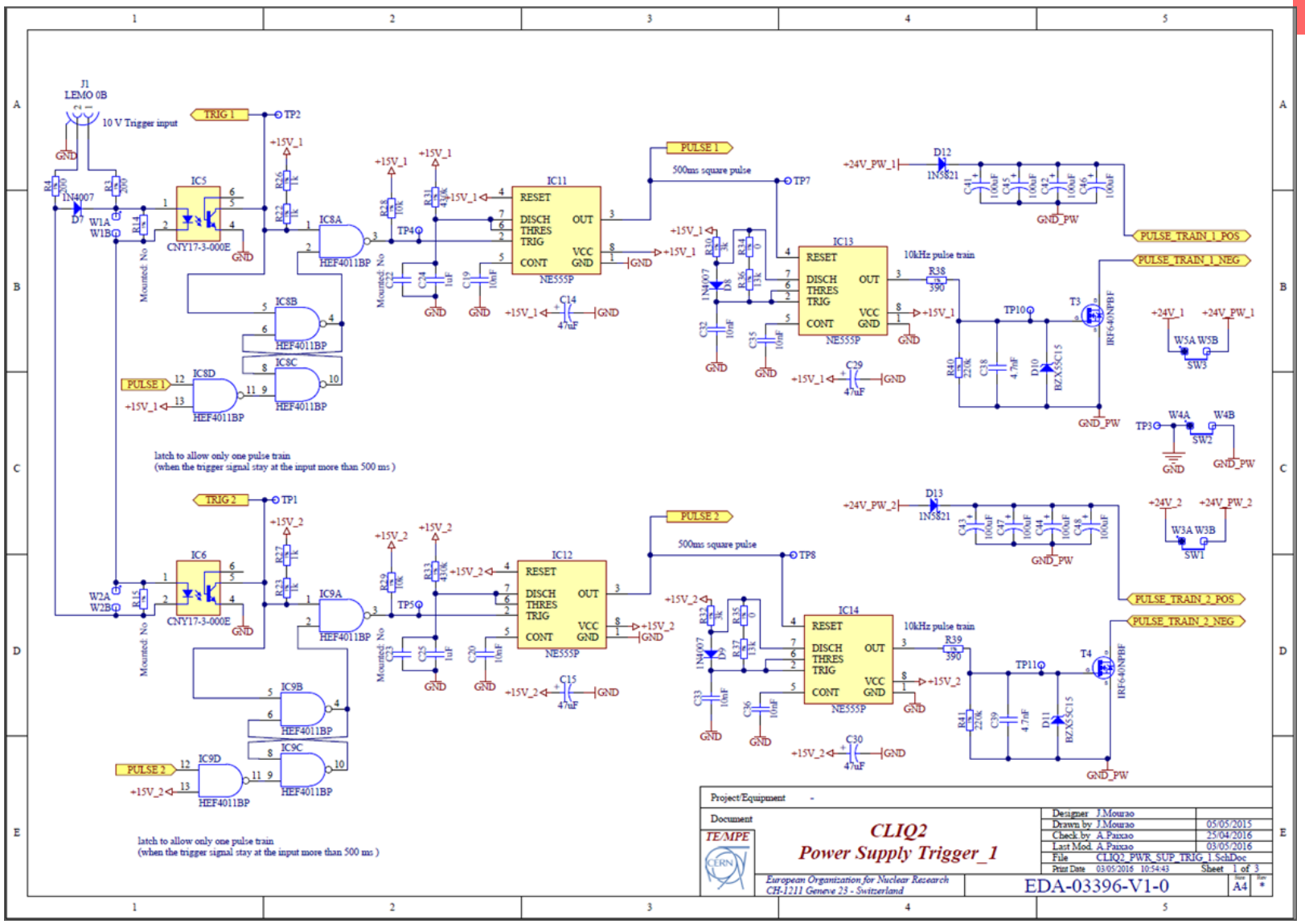
Logistics Technology Support

CARDEROCKDIV, NSWC-11
May 2011

Approved for Public Release; Distribution is Unlimited

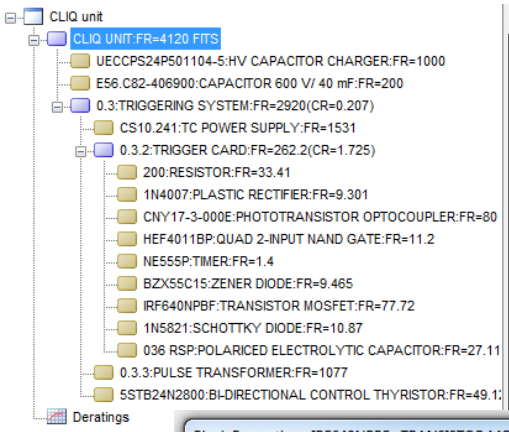
# Example of CLIQ Trigger Card

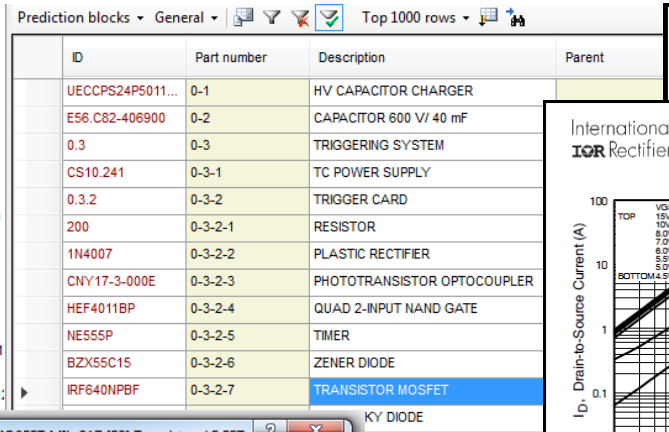
Prediction

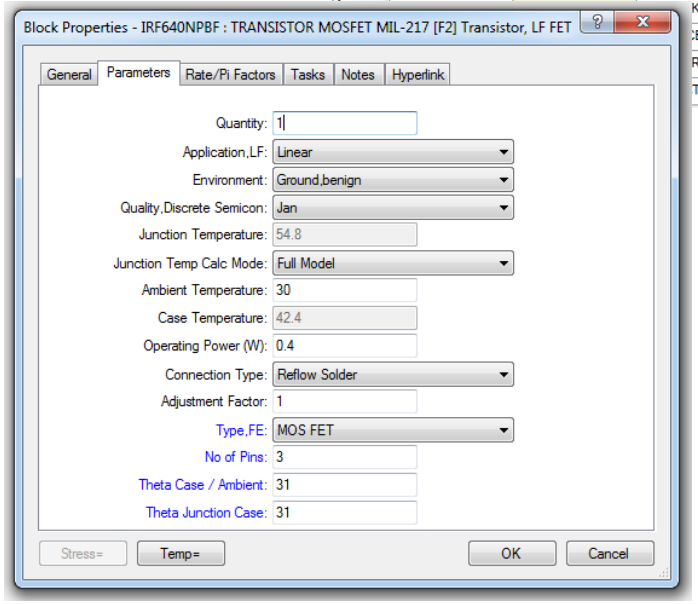


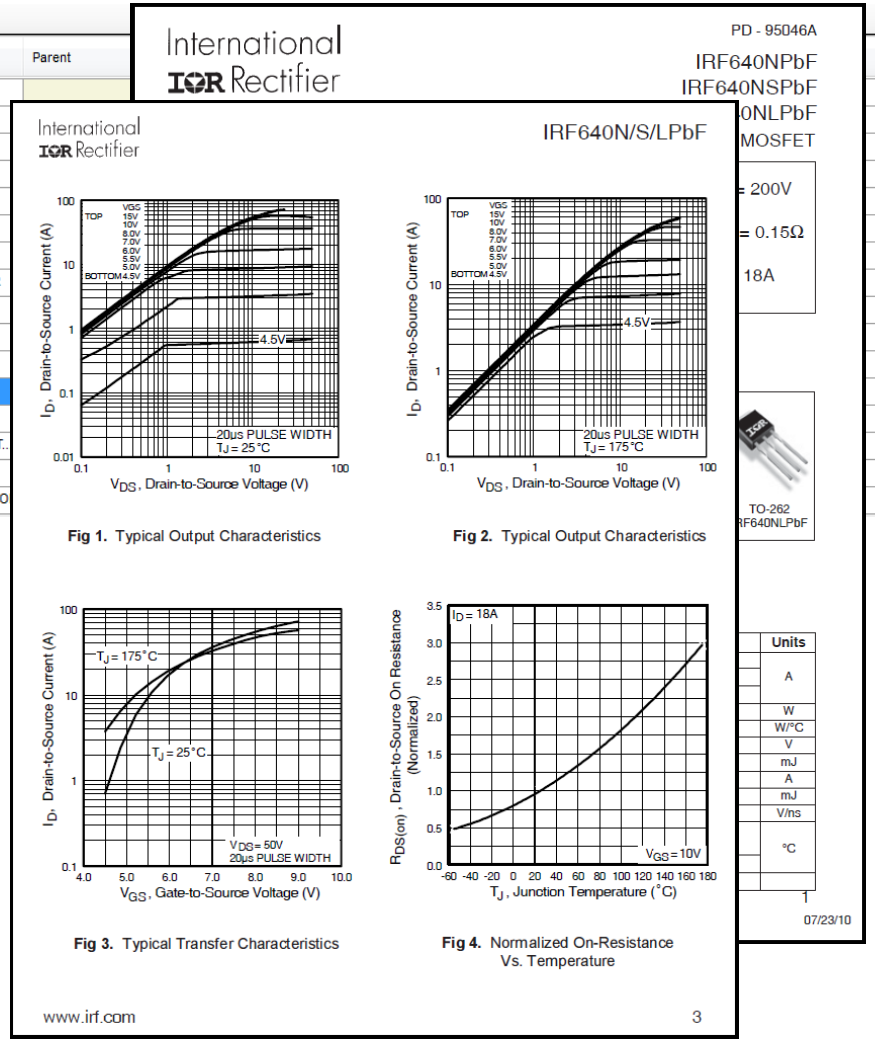
# Failure Rate Predictions

Prediction



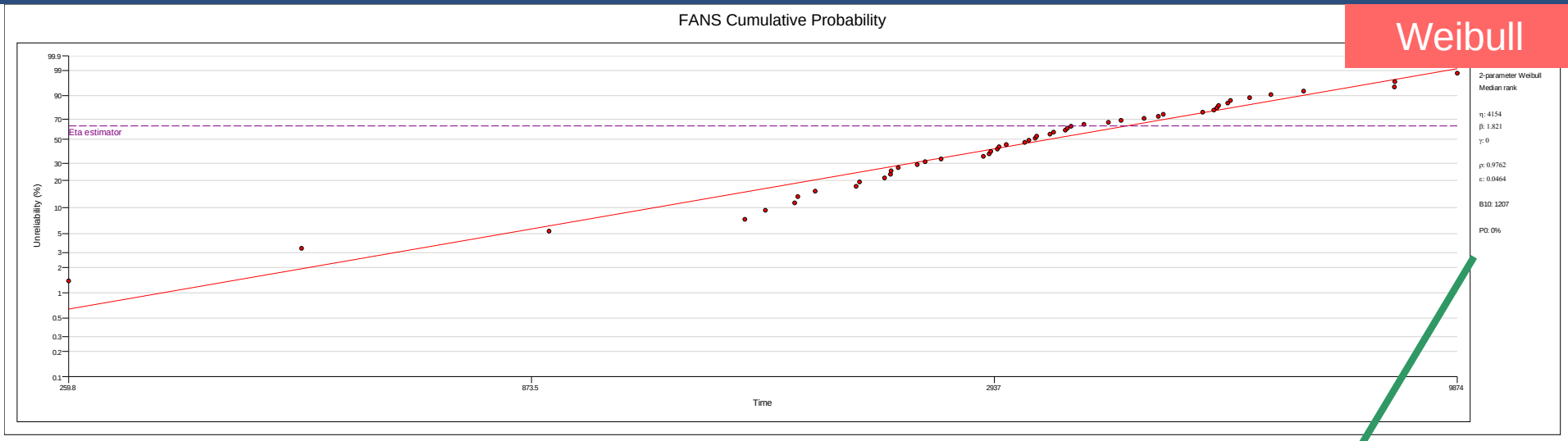




- Manual procedure, but definition of libraries possible

# Weibull Analysis of Historical Data

Weibull




| | Time | Suspended | Disabled | Quantity |
|---|---|---|---|---|
| ▶ | 9874.164227 | ☐ | ☐ | 1 |
| | 5067.502629 | ☐ | ☐ | 1 |
| | 2972.638889 | ☐ | ☐ | 1 |
| | 4092.057129 | ☐ | ☐ | 1 |
| | 1836.44227 | ☐ | ☐ | 1 |
| | 5218.564393 | ☐ | ☐ | 1 |
| | 2399.066718 | ☐ | ☐ | 1 |
| | 4346.794493 | ☐ | ☐ | 1 |
| | 6059.76623 | ☐ | ☐ | 1 |
| | 5450.632577 | ☐ | ☐ | 1 |
| | 478.216229 | ☐ | ☐ | 1 |
| | 5731.037643 | ☐ | ☐ | 1 |
| | 8374.289538 | ☐ | ☐ | 1 |
| | 3214.247652 | ☐ | ☐ | 1 |

2-parameter Weibull

Median rank

η: 4154

β: 1.821

γ: 0

ρ: 0.9762

ε: 0.0464

B10: 1207

P0: 0%

- Importing data from e.g. excel files possible

# FMEA Template

FMEA

| Responsible: HSE-RP | CROME - MTTF Prediction | Date: 08/06/2016 |
|---|---|---|
| Project: CROME | | |
| Version: V1 | Used standard: MIL-HDBK 217F - Notice 2 | Prepared by: Saskia Hurst |

| Indenture level | No | Description | Functions | Failure modes | Higher effect | End effect | S | Contributors | Preventive actions | O | Detection Method | D | RPN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | 1.1.1.1 | Non-polarised Capacitor 10uF | | C7, C12 - Short | No power_in | No alert CROME and no alert next CAU | 10 | | | 4 | | 1 | 40 |
| | | | | C7, C12 - Change in value | Filter not working properly | Degraded mode CROME | 3 | | | 4 | | 5 | 60 |
| | | | | C7, C12 - Open | No filtering | Degraded mode CROME | 3 | | | 4 | | 5 | 60 |
| | 1.1.1.2 | Non-polarised Capacitor 470pF | | C4, C9 - Short | No 24V | No alert CROME | 10 | | | 2 | | 1 | 20 |
| | | | | C4, C9 - Change in value | Filter not working properly | Degraded mode CROME | 3 | | | 2 | | 5 | 30 |
| | | | | C4, C9 - Open | No filtering | Degraded mode CROME | 3 | | | 2 | | 1 | 6 |
| | 1.1.1.3 | Polarised Capacitor 47uF | | C6 - Short | No 24V | No alert CROME | 10 | | | 4 | | 1 | 40 |
| | | | | C6 - Change in value | Filter not working | No alert CROME | 10 | | | 4 | | 1 | 40 |
| | | | | C6 - Open | No 24V | No alert CROME | 10 | | | 4 | | 1 | 40 |
| | 1.1.1.4 | Non-polarised Capacitor 1uF | | C8 - Short | No 24V | No alert CROME | 10 | | | 3 | | 1 | 30 |
| | | | | C8 - Change in value | Filter not working | No alert CROME | 10 | | | 3 | | 8 | 240 |
| | | | | C8 - Open | No 24V | No alert CROME | 10 | | | 3 | | 1 | 30 |
| | 1.1.1.5 | Inductor Common Mode | | L1 - Short | Filter not working properly | Degraded mode CROME | 3 | | | 1 | | 10 | 30 |
| | | | | L1 - Open | No 24V | No alert CROME | 10 | | | 1 | | 1 | 10 |
| | | | | L1 - Change in value | Filter not working properly | Degraded mode CROME | 3 | | | 1 | | 10 | 30 |
| | 1.1.1.6 | Inductor with Magnetic Core | | L2 - Short | Filter not working properly | Degraded mode CROME | 3 | | | 5 | | 10 | 150 |
| | | | | L2 - Open | No 24V optocoupler | Wrong alert CROME an no alert next CAU | 10 | | | 5 | | 1 | 50 |
| | | | | L2 - Change in value | Filter not working properly | Degraded mode CROME | 3 | | | 5 | | 10 | 150 |

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# Costs

| Itm | Designation<br>Delivery date | Unit | Qty orde | Unit price | Discnt./Incr. | Total |
|---|---|---|---|---|---|---|
| 1 | Hazop+ Maintenance (reinstatement and valid for one year from date of PO), 5 licenses | PC | 5 | 189.00 | | 945.00 |
| 2 | AvSim+ Maintenance (reinstatement and valid for one year from date of PO), 5 licenses | PC | 5 | 630.00 | | 3,150.00 |
| 3 | RCMCost Maintenance (reinstatement and valid for one year from date of PO), 5 licenses | PC | 5 | 630.00 | | 3,150.00 |
| 4 | FaultTree+ Maintenance (reinstatement and valid for one year from date of PO), 5 licenses | PC | 5 | 630.00 | | 3,150.00 |
| 5 | Reliability Workbench (FMECA, FaultTree+, MIL217, MTTR, NSWC, RBD and Telcordia) Maintenance (reinstatement and valid for one year from date of PO), 5 licenses | PC | 5 | 1,117.20 | | 5,586.00 |
| | | | | | Total net price | 15,981.00 |
| | | | | | Total price: EUR | 15,981.00 |

# Summary

- Rather good experience with Isograph so far
- At CERN, especially used for:
  - Fault tree modelling
  - Failure rate predictions
  - Availability modelling with RBD
- Some manual work required when:
  - Creating models with a high number of components
  - Defining maintenance strategies common for accelerator applications
  - Retrieving useful information from the available results (strange terminology)
  - Importing of input data (not intuitive)
- Good interaction with the support

# THANKS A LOT FOR YOUR ATTENTION!