
CERN

Lesson learnt from the Isograph Training Course

Winterthur 24th to 26th of July 2017

Miriam Blumenschein, Saskia Hurst and Estrella Vergara

- RAS Working Group Meeting -

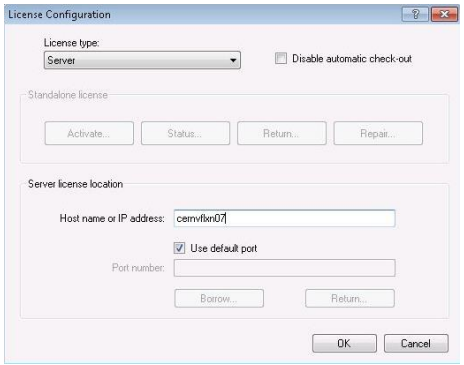
31st of August 2017

1. Isograph for beginners

Estrella Vergara

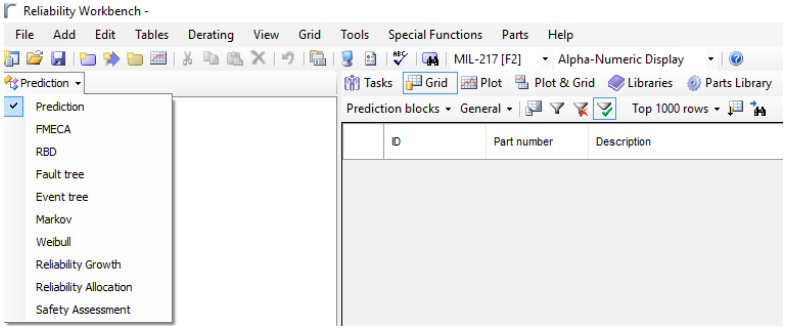
Reliability Workbench

During installation…



Password needed for installation: *cernvflxn07*

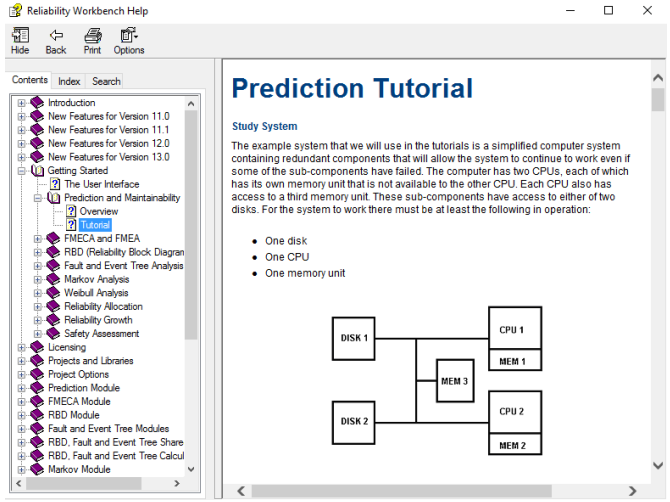
Available in CMF Packages: *Isograph – RelWorkbench 13.01*



Modules available

CERN licenses

- Prediction Methods
- Failure Mode Effect and Criticality Analysis (FMECA)
- Reliability Block Diagrams (RBD)
- Fault Tree Analysis (FTA)
- Event Tree Analysis (ETA)
- Markov Analysis
- Weibull
- Reliability Growth
- Reliability Allocation

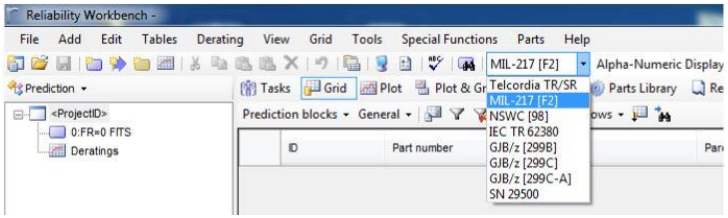


Tutorials for each module:

Help → Getting Started → Tutorial

Prediction module

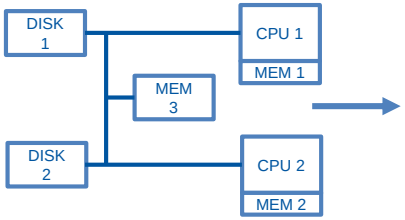
Provide consistent methods of estimating **failure rates** using **Handbooks and standards**



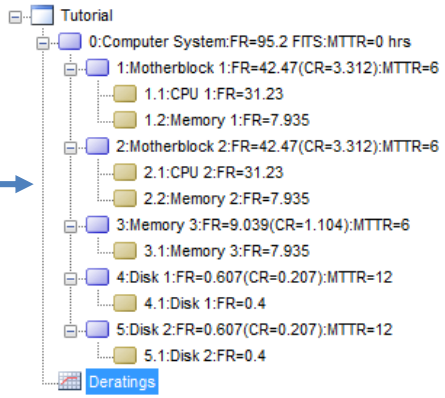
CERN license:
- Telecordia TR/SR
- MIL-217 Prediction
- NSWC Prediction

Only 1 license:
- 217 Plus Prediction
- FIDES Prediction

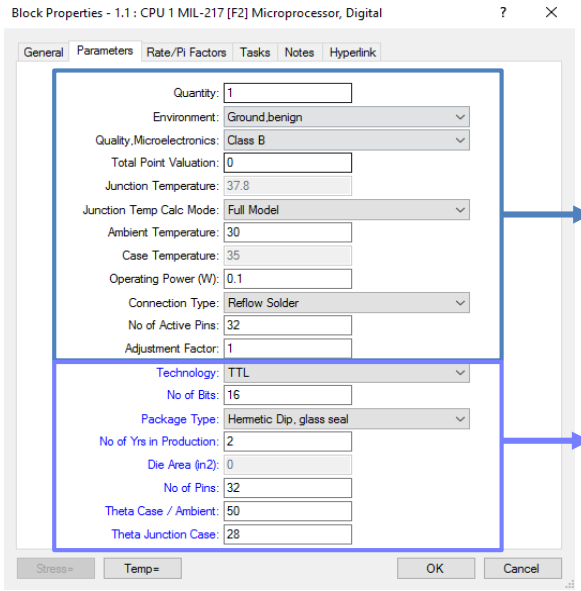
Project Hierarchy Diagram



Simplified Computer System Schematic



Block Systems and Components Properties

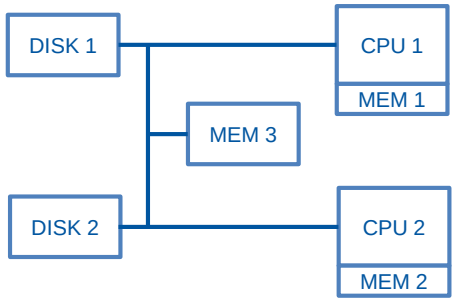


Environmental Properties

Parameters for the component type (defined by Handbook or Standard)
- External Category: entering data manually

- Entering prediction data manually or using **libraries** (Project and Library must follow the same Standard or Handbook)
- Possibility to associate **maintenance** tasks in the prediction hierarchy
- Option to specify the **phases** if the ambient conditions change during the lifetime of the system

Prediction module

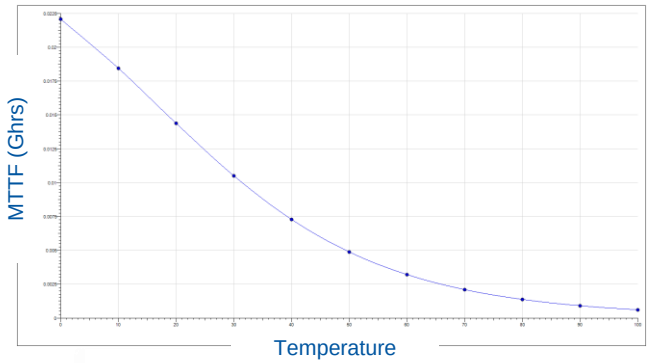


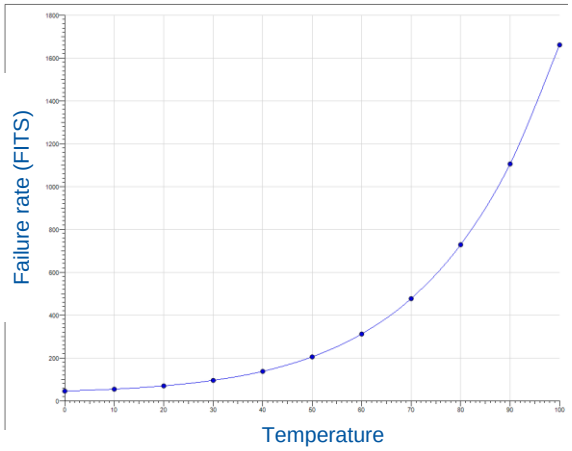
Simplified Computer System Schematic

Results

ID	Part number	Description	Parent	Category	Sub category	Failure rate	MTTF	MTTR
1	0-1	Motherblock 1		System Block		42.47	0.02354	6
1.1	0-1-1	CPU 1	1	Microprocessor, ...	TTL	31.23	0.03202	0
1.2	0-1-2	Memory 1	1	Micro, Not EEPROM	ROM	7.935	0.126	0
2	0-2	Motherblock 2		System Block		42.47	0.02354	6
2.1	0-1-1	CPU 2	2	Microprocessor, ...	TTL	31.23	0.03202	0
2.2	0-1-2	Memory 2	2	Micro, Not EEPROM	ROM	7.935	0.126	0
3	0-3	Memory 3		System Block		9.039	0.1106	6
3.1	0-1-2	Memory 3	3	Micro, Not EEPROM	ROM	7.935	0.126	0
4	0-4	Disk 1		System Block		0.607	1.647	12
4.1	0-4-1	Disk 1	4	External		0.4	2.5	0
5	0-5	Disk 2		System Block		0.607	1.647	12
5.1	0-5-1	Disk 2	5	External		0.4	2.5	0

Plots





Fault Tree Analysis (FTA)

- Show interaction to failures
- Creation of fault trees manually

GATES TYPES

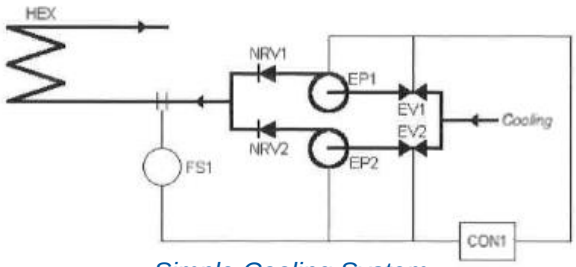
Symbol	Name	Meaning	Inputs
	OR	TRUE if any input is TRUE	≥2
	AND	TRUE if all inputs are TRUE	≥2
	VOTE	TRUE if *m* inputs are TRUE	≥3
	EXCLUSIVE OR	TRUE if one and only one inputs is TRUE	2
	INHIBIT GATE	TRUE if all inputs are TRUE; one input is conditional	≥2
	PRIORITY AND	TRUE if inputs occur in left to right order	≥2
	NOT	TRUE if inputs is FALSE	1
	Transfer In	Inputs appear elsewhere on same page or on another page	
	Transfer Out	Output appears elsewhere on same page or another page	

EVENT TYPES

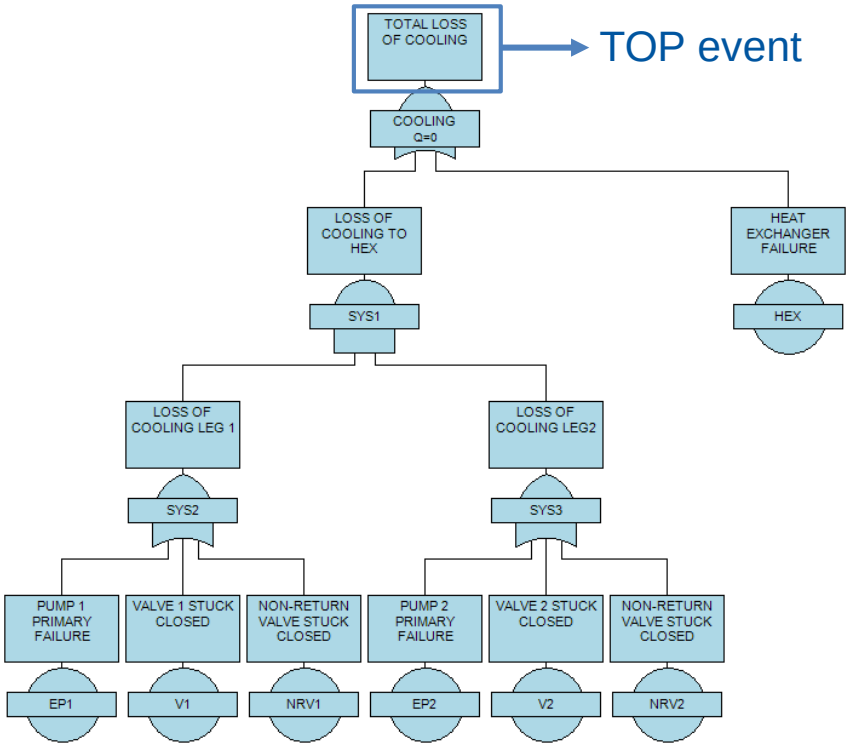
Symbol	Name	Meaning
	BASIC	Basic event
	UNDEVELOPED	A system event which is yet to be developed
	CONDITIONAL	Conditional event connected to an inhibit gate
	HOUSE	Definitely operating or definitely not operating
	DORMANT	Failure not immediately revealed; latent/ hidden failure

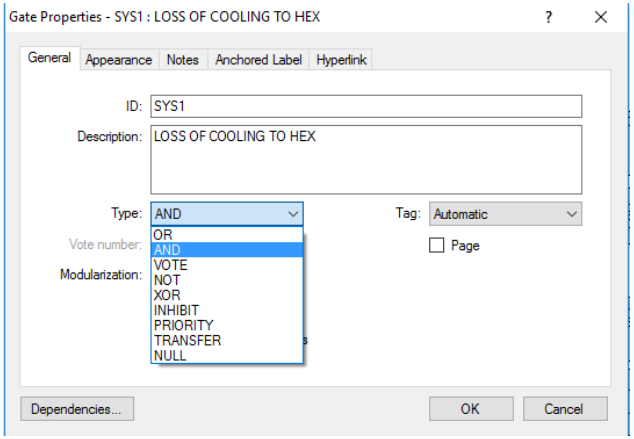
Fault Tree Analysis (FTA)

- Show interaction to failures
- Creation of fault trees manually thought gates



Simple Cooling System

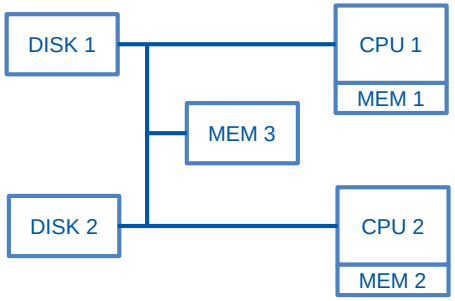




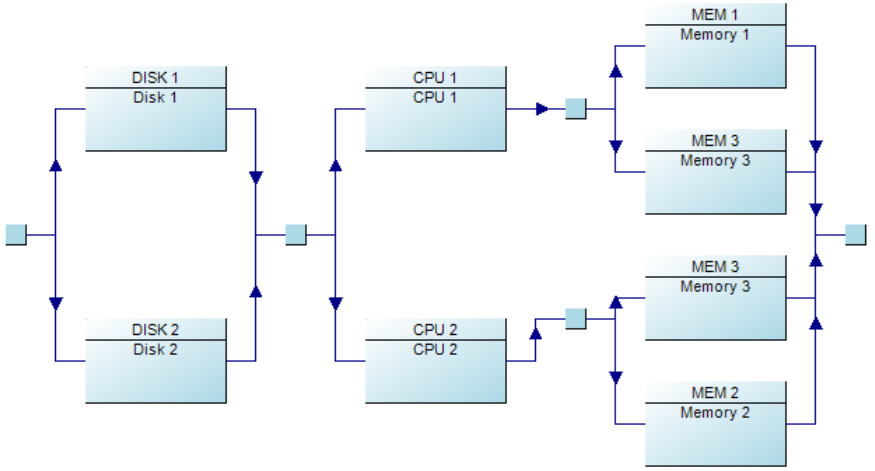
- No limit of gates or events (“Page” checkbox)
- Special Function: Multiple Project option:
  - ID must be coherent
  - Connection between gates (no events)
- **Minimal Cut Set**:
  - Minimum combination of events which cause TOP event
  - First step of Analysis
  - Produced using Boolean algebra

Reliability Block Diagram (RBD)

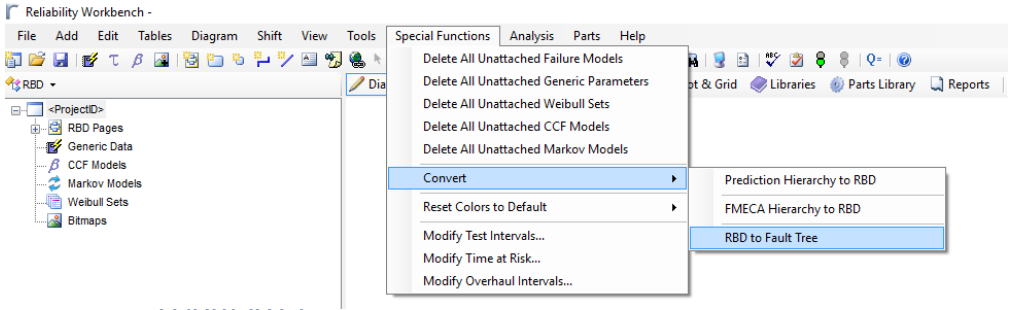
- Used to predict the **reliability** of entire systems
- Similar to FTA:
  - RBD → Process (availability) / FTA → Hazards



Simplified Computer System Schematic



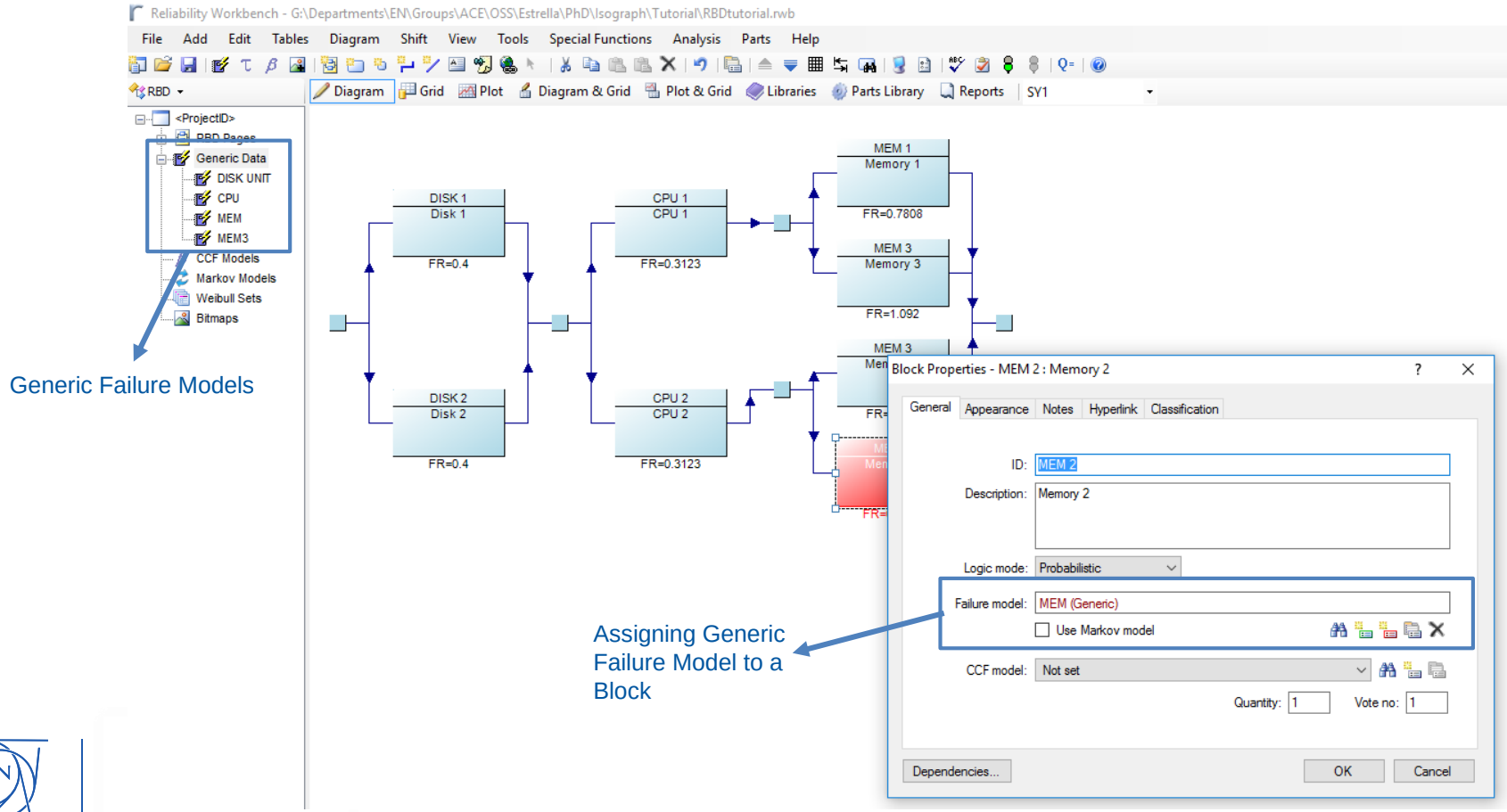
- Flow from left to right – easy to read
- Blocks connected in series/ parallel
- Option to Copy-Paste to duplicate a block (e.g. “MEM 3”)
- Special functions: RBD to FTA, Prediction to RBD and FMECA to RBD



Reliability Block Diagram (RBD)

ASSIGNING FAILURE MODELS TO BLOCKS

- Failure and repair date is entered in a failure model
  - Local Failure Model: attached to one block only
  - Generic Failure Model: can be attached to multiple blocks
- Applicable for FTA as well



Reliability Block Diagram (RBD)

PERFORMING AN ANALYSIS - Results

Summary

Results for block SY1

(●) Summary ( ) Importance ( ) Cut sets ( ) Appearance

Parameter	Point Value
Unavailability	2.861E-12
Frequency	1.717E-06
CFI	1.717E-06
Number expected fail...	1.717E-06
Unreliability	1.717E-06
MTTF	Not calculated
MTTR	Not calculated
Total down time	2.861E-12
Mean unavailability	2.861E-12
Risk reduction factor	3.495E+11
Q/T	2.861E-12
Used method	Cross product
Number of compact s...	5

Cut Sets: Combination of component block failures that will cause system failure

( ) Summary ( ) Importance (●) Cut sets ( ) Appearance

No.	Q	Minimal cut set
1	1.778E-12	DISK 1.DISK 2
2	1.084E-12	CPU 1.CPU 2
3	9.862E-18	CPU 1.MEM 3.MEM 2
4	2.466E-17	MEM 1.MEM 3.MEM 2
5	9.862E-18	MEM 1.CPU 2.MEM 3

Importance: Block's contribution to the unavailability of the system

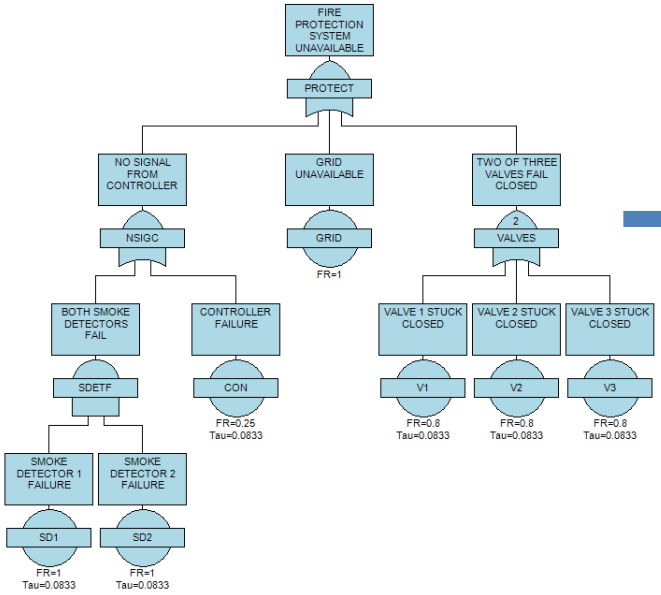
( ) Summary (●) Importance ( ) Cut sets ( ) Appearance

Event ID	Fussell-Vesely	Bimbaum	Barlow-Proschan	Sequential	Risk Reduction Worth	Risk Achievement ...
DISK 2	0.6213	1.333E-06	0.3106	0.3106	2.64	4.66E+05
DISK 1	0.6213	1.333E-06	0.3106	0.3106	2.64	4.66E+05
CPU 1	0.3787	1.041E-06	0.1894	0.1894	1.61	3.638E+05
CPU 2	0.3787	1.041E-06	0.1894	0.1894	1.61	3.638E+05
MEM 3	1.551E-05	1.219E-11	7.755E-06	1.551E-05	1	5.261
MEM 2	1.206E-05	1.326E-11	6.032E-06	1.206E-05	1	5.635
MEM 1	1.206E-05	1.326E-11	6.032E-06	1.206E-05	1	5.635

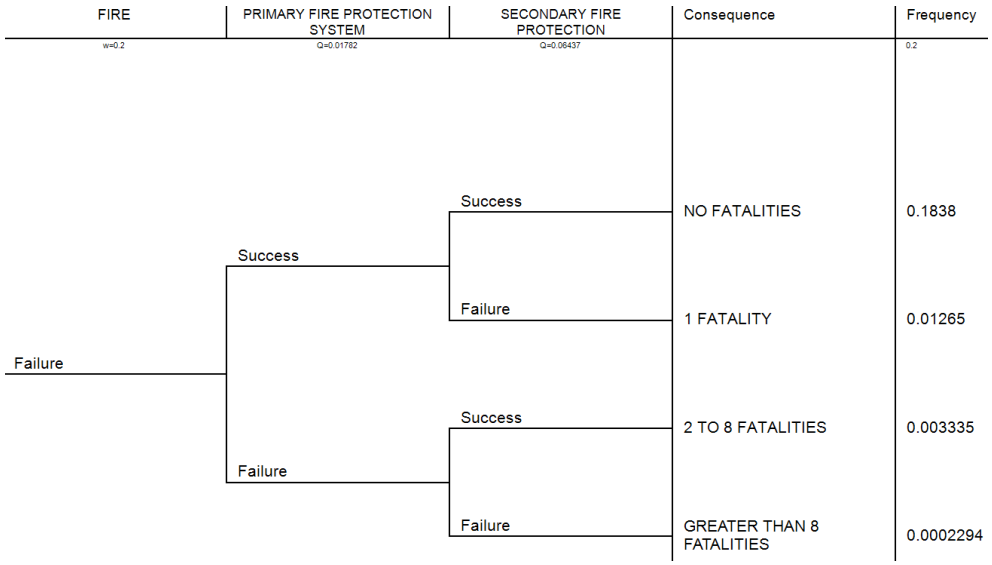
Event Tree Analysis (ETA)

- Identifies outcomes of initiating event
- ETA & FTA closely linked:
  - FTA can be used to quantify events in ETA sequence
  - Use cut sets and same quantitative methodology

Fault Tree created in FTA module



Event Tree Analysis



Failure Mode Effect and Criticality Analysis (FMECA)

- Rates failure modes by danger

Date: 05/07/2017 — **FMEA CIBDS: Failure chain all levels** — Page 1 of 38

Id	Component	Component FM	Effect immidiate	Effects +1	Effects +2	Effects +3	Effects on LBDS
1.1.1.1	P1	not considered	Not considered				
1.1.1.2	P2	not considered	Not considered				
1.1.1.3	IC26	Input open	Incorrect transfer of CIBDS monitoring data from Monitoring_FPGA to MenA20 processor	1.1.3 Incorrect monitoring information	1.16 Incorrect monitoring information	7 Incorrect monitoring information CIBDS	Incorrect monitoring information CIBDS
		Output open	Incorrect transfer of CIBDS monitoring data from Monitoring_FPGA to MenA20 processor	1.1.3 Incorrect monitoring information	1.16 Incorrect monitoring information	7 Incorrect monitoring information CIBDS	Incorrect monitoring information CIBDS
		Supply open	Incorrect transfer of CIBDS monitoring data from Monitoring_FPGA to MenA20 processor	1.1.3 Incorrect monitoring information	1.16 Incorrect monitoring information	7 Incorrect monitoring information CIBDS	Incorrect monitoring information CIBDS
		Output stuck low	Incorrect transfer of CIBDS monitoring data from Monitoring_FPGA to MenA20 processor	1.1.3 Incorrect monitoring information	1.16 Incorrect monitoring information	7 Incorrect monitoring information CIBDS	Incorrect monitoring information CIBDS
		Output stuck high	Incorrect transfer of CIBDS monitoring data from Monitoring_FPGA to MenA20 processor	1.1.3 Incorrect monitoring information	1.16 Incorrect monitoring information	7 Incorrect monitoring information CIBDS	Incorrect monitoring information CIBDS
1.1.1.4	IC22	Input open	Incorrect transfer of CIBDS monitoring data from Monitoring_FPGA to MenA20 processor + No transfer of CIBDS rearm controlling data from MenA20 processor to Monitoring_FPGA	1.1.3 Incorrect monitoring information 1.1.11 Remote + BIS freq: no effect 1.1.21 Remote + no Bis freq: no effect 1.1.42 Remote + Transition to BIS freq: arming is blocked 1.1.51 Local + no BIS freq: no effect 1.1.31 Remote + Transition to no BIS freq: no effect	1.16 Incorrect monitoring information 1.17 No effect 1.13 Arming procedure blocked	7 Incorrect monitoring information CIBDS 8 No effect 10 Arming procedure blocked	Incorrect monitoring information CIBDS No effect Arming procedure blocked
		Output open	Incorrect transfer of CIBDS monitoring data from Monitoring_FPGA to MenA20 processor + No transfer of CIBDS rearm controlling data from MenA20 processor to Monitoring_FPGA	1.1.3 Incorrect monitoring information 1.1.11 Remote + BIS freq: no effect 1.1.21 Remote + no Bis freq: no effect 1.1.42 Remote + Transition to BIS freq: arming is blocked 1.1.51 Local + no BIS freq: no effect 1.1.31 Remote + Transition to no BIS freq: no effect	1.16 Incorrect monitoring information 1.17 No effect 1.13 Arming procedure blocked	7 Incorrect monitoring information CIBDS 8 No effect 10 Arming procedure blocked	Incorrect monitoring information CIBDS No effect Arming procedure blocked

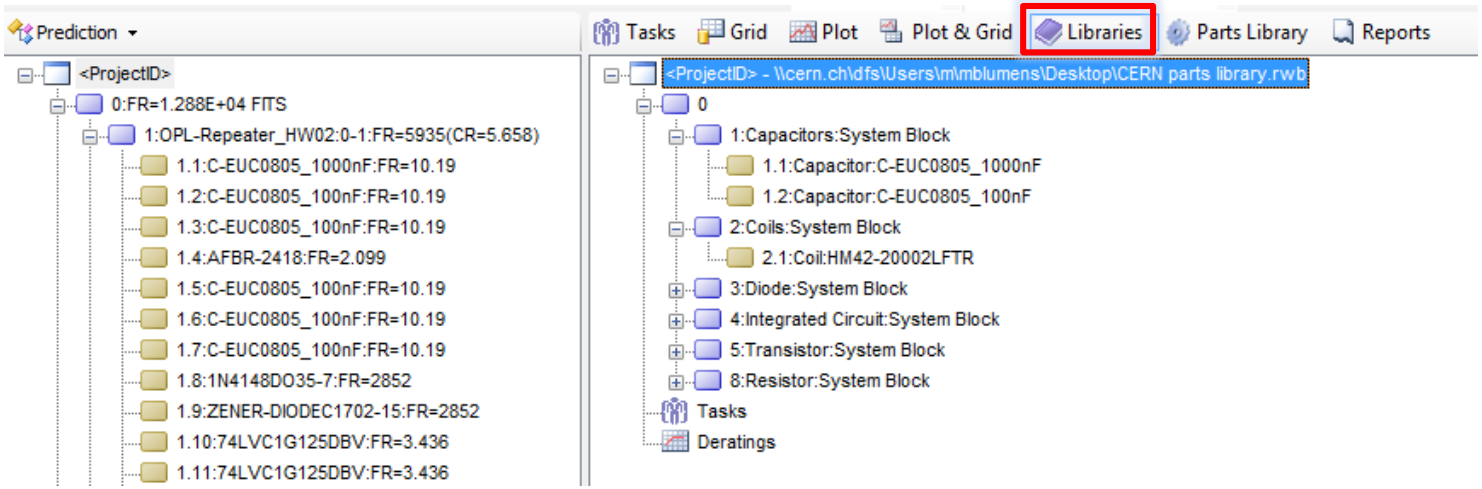
2. Compendium of useful features

Miriam Blumenschein

Prediction – FMECA – Fault Tree

Prediction

1. **Component library**
   - Construct a project from a library:
     - *File ►Attach Library*
     - Drag and drop parts or structures to system structure
     - No automatic update if library is modified
   - Build a library: create components in prediction (blue fields)
   - Common CERN library?

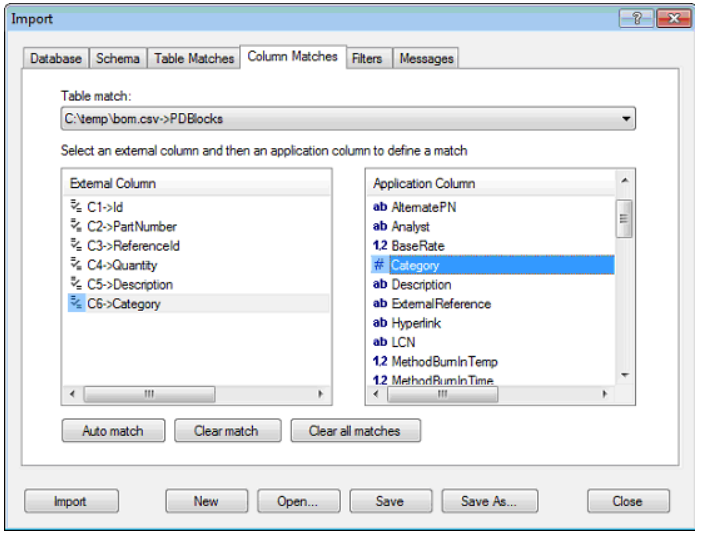


Prediction

2. Import of bill of material:

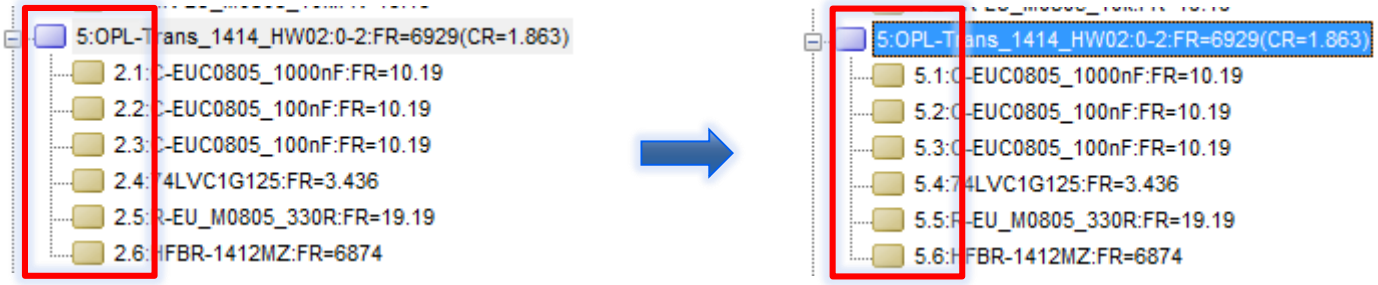
- Easy to import: blue fields (component properties) part number, ID, quantity, description and category
- ► *Manual chapter "Importing a Bill of Materials"*
- Not (yet) easy to import: black fields (operating environment), filled in manually
- Common Excel format of BOM ?

Id	PartNumber	Quantity	Description	Category
1	0-1	1	OPL-Repeater_HW02	MIL-BK
2	0-2	1	OPL-Trans_1414_HW02	MIL-BK
3	0-3	1	OPL-REC-2418_HW02	MIL-BK
1.1	C-EUC0805_1000nF	1		MIL-CR
1.2	C-EUC0805_100nF	1		MIL-CR
1.3	C-EUC0805_100nF	1		MIL-CR
1.4	AFBR-2418	1		MIL-LB
1.5	C-EUC0805_100nF	1		MIL-CR

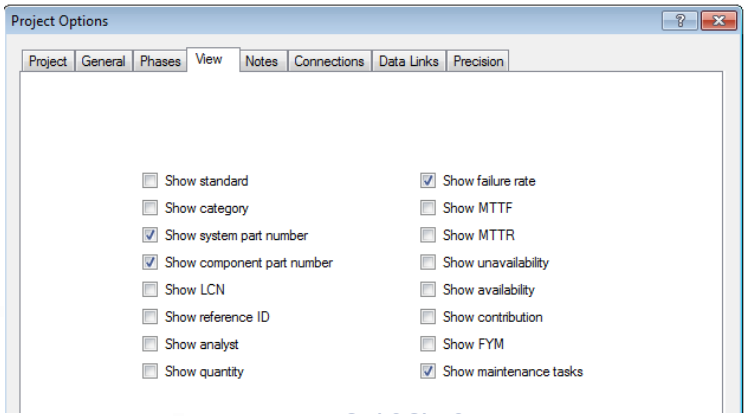


Prediction

3. **Rename option**
   - Objects under the current tree control selection will be renamed based on the name of their parent
   - *Select parent block ► Tools ► Rename ► Blocks under selection*



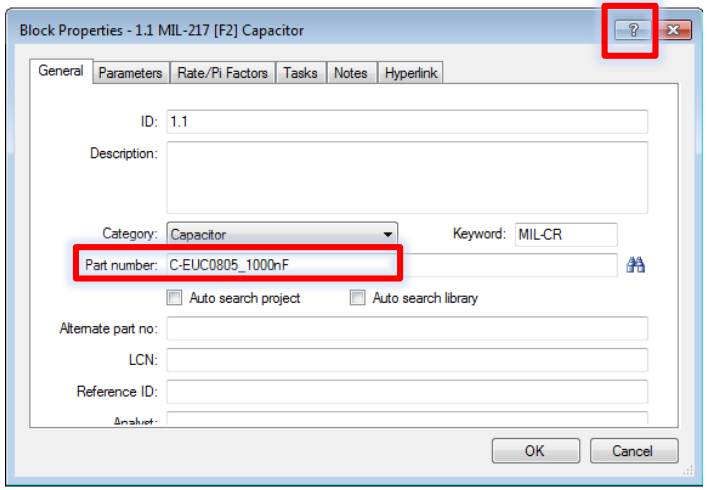
4. **View option:**
   - Determination of the data which is displayed in the project tree control
   - *Project Options ► View ► check "Show category"; "Show component part; … number"*

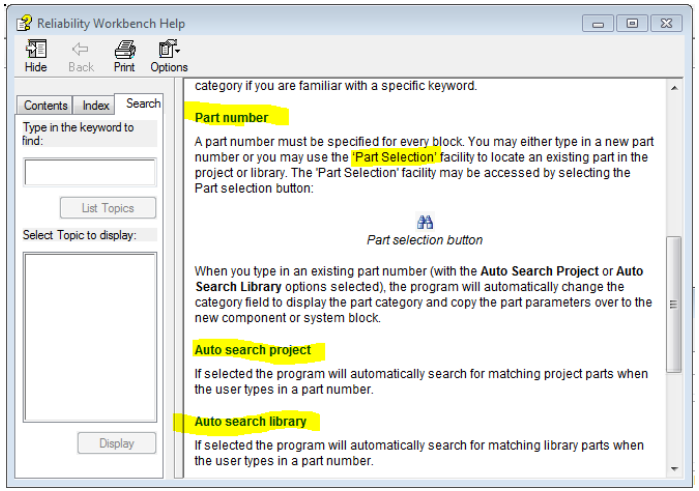


Prediction

5. Help option in dialog boxes

- "?" on the top right in each dialog opens corresponding chapter of the manual





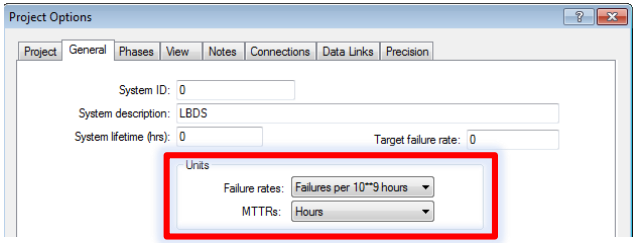
6. Part number

Several Functions are linked to the part number

- Blue fields = component properties: same properties for same part number
- Black fields = operating environment: independent of part number
- Part Selection facility, Auto search project, auto search library, Auto Add Apportioned Failure Modes, Linked block, …

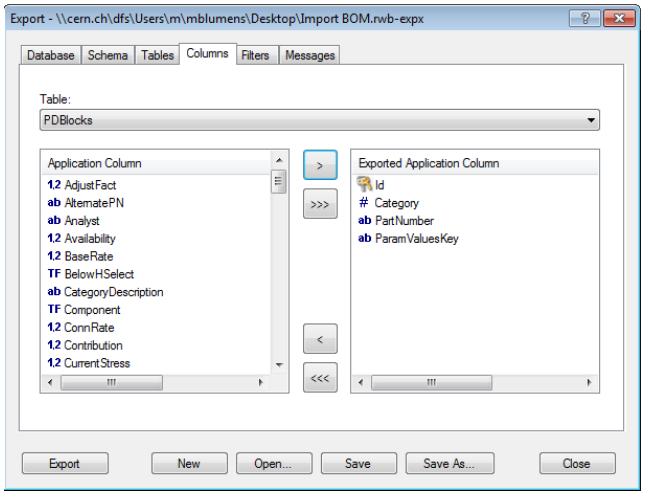
Prediction

7. **Unit of failure rate**
   - *Project Options ► General ► Units*



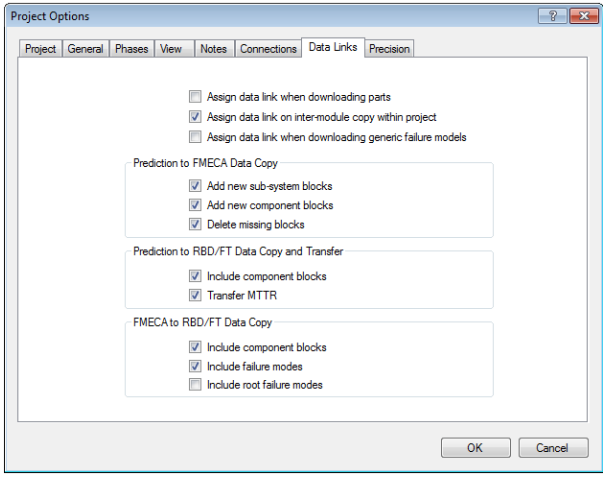
8. **Change component parameters**
   - Temperature, Environment, …
   - *Select section in tree control ► Special Functions ► change temperature/ MIL-217 environment*

   OR
   - Export block properties to Excel (table PDBlocks; columns PartNumber, ParamValuesKey), find and replace properties in Excel, import Excel file



9. **Project Options, Special Functions and Tools change from one module to the other, always worth having a look at**
10. **Recommendation: Always create system structure in the prediction module, even if no prediction is performed**

From one module to another

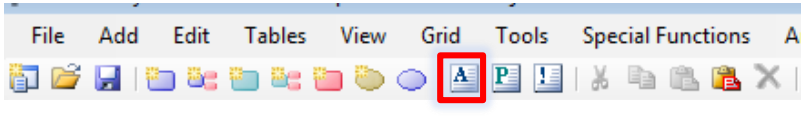


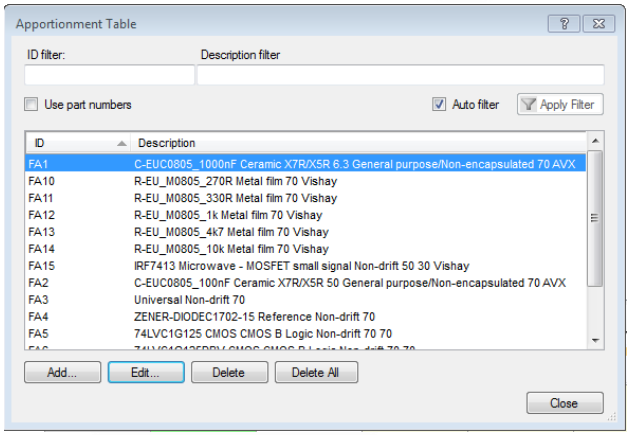
1. **Data conversion**
   - prediction hierarchy to FMECA, RBD, fault tree
   - FMECA hierarchy to RBD, fault tree
   - RBD to fault tree
   - Common way: Prediction to FMECA to Fault Tree
   - *Special Functions ►Convert pull-down menu*
2. **Data links**
   - Needs to be defined before the data conversion!
   - Data links will be automatically created between objects when copying between modules
   - Customize data conversion: *Project options ► Data links ► check " Assign data link on inter-module copy within project"*
   - Prediction to FMECA: Edit ►*Transfer linked data* ►*run the FMECA simulation*
   - *FMECA to Fault Tree: Run the FMECA simulation* Edit ►*Transfer linked data* ►*run the Fault Tree simulation*
3. **Update of system structure**
   - Failure modes remain
   - Prediction to FMECA: *Special Functions ►Convert pull-down menu*

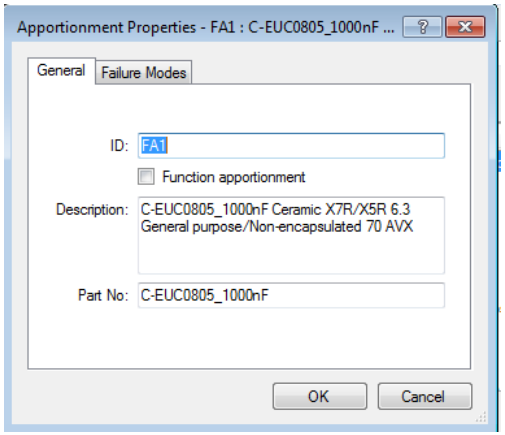
FMECA-module

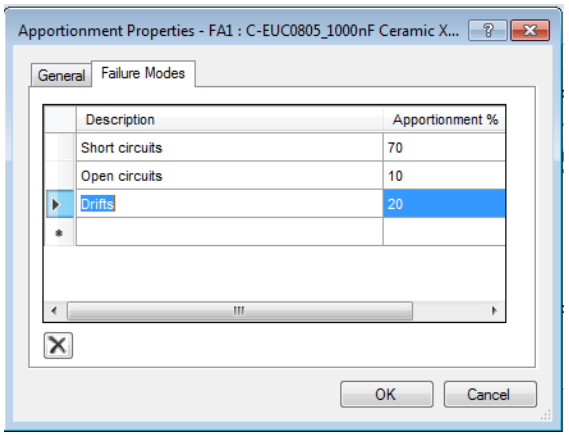
1. **Apportionment table**
   - Lists a component type (defined by the part number) and its failure modes and %
   - Apportionment table can be imported from excel
   - Add failure modes to existing blocks: Add ► Auto Add Apportioned Failure Modes

     OR
   - Add apportioned block
   - Common CERN apportionment table?









FMECA-module

2. **Severity matrix**
   - Tabulates the number of failure mode contributors in each severity category for each block in the system
   - Exported as excel file
   - If severity categories are defined as system failure modes: number of root contributors per system failure mode
   - *Special Functions ► Export ► Severity Matrix*
3. **Criticality matrix**
   - Tabulates the severity category and criticality for each failure mode
   - *Special Functions ► Export ► Criticality Matrix*

Block Name	Block Description	I	II	III	IV
1	POWER SUPPLY	0	0	7	11
1.1	CAPACITOR, FIXED CK	0	0	1	3
1.2	CAPACITOR, FIXED CB	0	0	2	2
1.3	CAPACITOR, FIXED CK	0	0	2	2
1.4	RESISTOR, FIXED RCR	0	0	0	2
1.5	RESISTOR, FIXED RC	0	0	0	2
1.6	I.C., DIGITAL	0	0	2	0
2	CPU BOARD	3	0	3	8
2.1	I.C., DIGITAL	0	0	0	1
2.2	CAPACITOR, FIXED CK	2	0	1	1

Block and Mode ID	Component Block Description	Failure Mode Description	Severity Category	Criticality
1.1.1	CAPACITOR, FIXED CK	Shorted (Electrical)	IV	0.069375
1.1.2	CAPACITOR, FIXED CK	Change of Value	IV	0.0555
1.1.3	CAPACITOR, FIXED CK	Open (Electrical)	III	0.006938
1.1.4	CAPACITOR, FIXED CK	Other	IV	0.006938
1.2.1	CAPACITOR, FIXED CB	Shorted (Electrical)	III	3.40543
1.2.2	CAPACITOR, FIXED CB	Open (Electrical)	III	0.729735
1.2.3	CAPACITOR, FIXED CB	Change of Value	IV	0.48649
1.2.4	CAPACITOR, FIXED CB	Other	IV	0.243245
1.3.1	CAPACITOR, FIXED CK	Shorted (Electrical)	III	0.055985
1.3.2	CAPACITOR, FIXED CK	Change of Value	IV	0.044788

Fault Tree

1. **System lifetime**
   - Unit of system lifetime corresponds to unit of failure
   - *Project Options* ► *Calculation*
2. **Failure and repair models**
   - 17 model types with different failure and repair characteristics
   - Rate models: Constant failure and repair rate
     - Input Rate Model: failure rate λ and repair rate μ

       μ = 0: non-repairable components
     - Input Rate/MTTR: failure rate λ and MTTR

       MTTR = 0: failures are immediately repaired
   - Dormant failure model: non repairable components between inspections
     - Three methods: mean (default), max (worst case), IEC 61508
   - Local failure model (for one event): Primary Event Properties ► Local Failure Model ► Failure Model Properties
   - Generic failure model (for any event): Add ► Failure model ► Failure Model Properties

Fault Tree

3. **Calculation methods:**
   - Cross Product, Esary-Proschan (Bertsche), Rare, Optimum Upper Bound (default), Lower Bound
   - *Project Options* ► *Set Generations* ► *Custom Options*

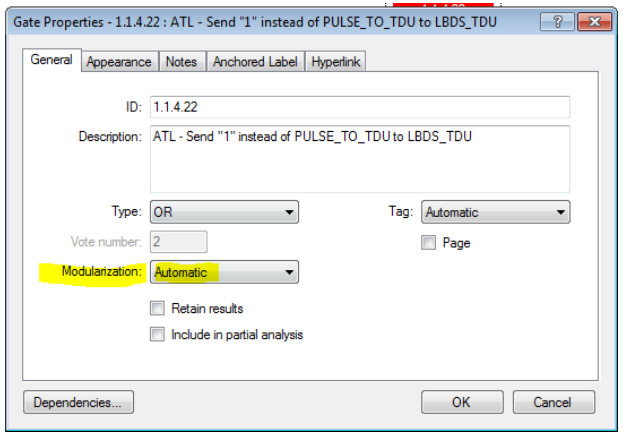
	% Difference			
Event Q	**Cross Product**	**Esary-Proschan**	**Rare**	**Lower Bound**
0.5	0%	4.5%	45%	9.1%
0.1	0%	0.69%	2.5%	0.085%
0.01	0%	0.0096%	0.029%	0.000098%

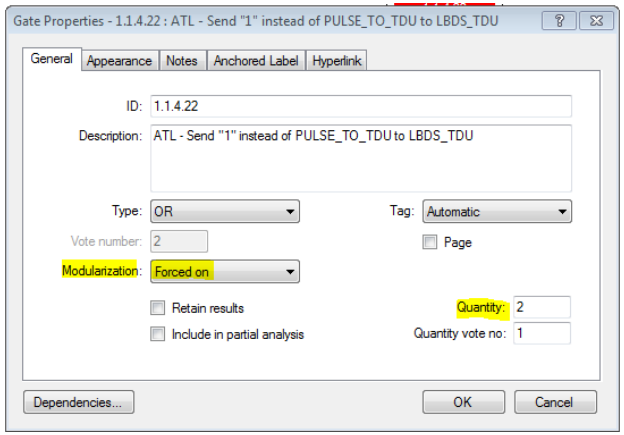
4. **Result Summary**
   - CFI: Conditional Failure Intensity corresponds to λ (t) (Bertsche):
     - **probability per unit time** that the component or system experiences **a failure at time t**, (operating, or was repaired to be as good as new, at time zero and operating at time t).
   - Unconditional Failure Intensity or Failure Frequency ω(t) Frequency:
     - **probability per unit time** that the component or system experiences **a failure at time t**, (operating at time zero).
   - ➢ **CFI-λ(t), ω(t) Difference:** the CFI has an additional condition that the component or **system has survived to time t.**

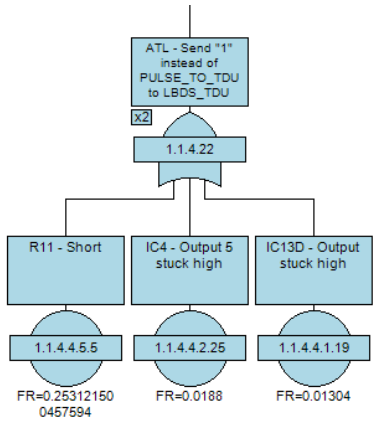
Fault Tree

5. Quantity of gates

- Specifying a quantity of *n* is equivalent to including *n* identical gates underneath an gate, with no common cause failures, in the fault tree diagram.
- Quantity values may only be specified for gates that have Modularization set to “Forced on” (default = automatic).

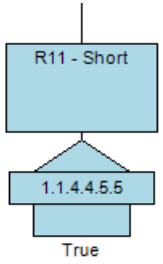






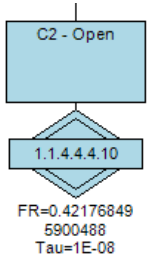
6. House event

- Used for “what if”: switches branches on (Q = 1) and off (Q = 0)
- *Primary event properties ► Type ► House; logic mode True or False*



Fault Tree

7. **Event symbols dormant**
   - Option to visualize the failure model
   - *Primary event properties* ► *Type* ► *Dormant*



8. **Append facility**
   - Alternative to library
   - Batch append: transfer all the fault tree structures from a group of projects in one go
   - Partial append: append parts of a single project by selecting individual gates
   - If branches need to be combined in different fault trees and the event ID needs to remain
   - *Special Functions* ► *Append*

9. **MTTF**
   - By default not calculated
   - Calculation requires numerical integration methods to be employed and may be time consuming for large numbers of minimal cut sets
   - *Project Options* ► *Calculation* ► *MTTF/MTBF/MTTR calculations* ► *Method* ► *Standard*

Fault Tree

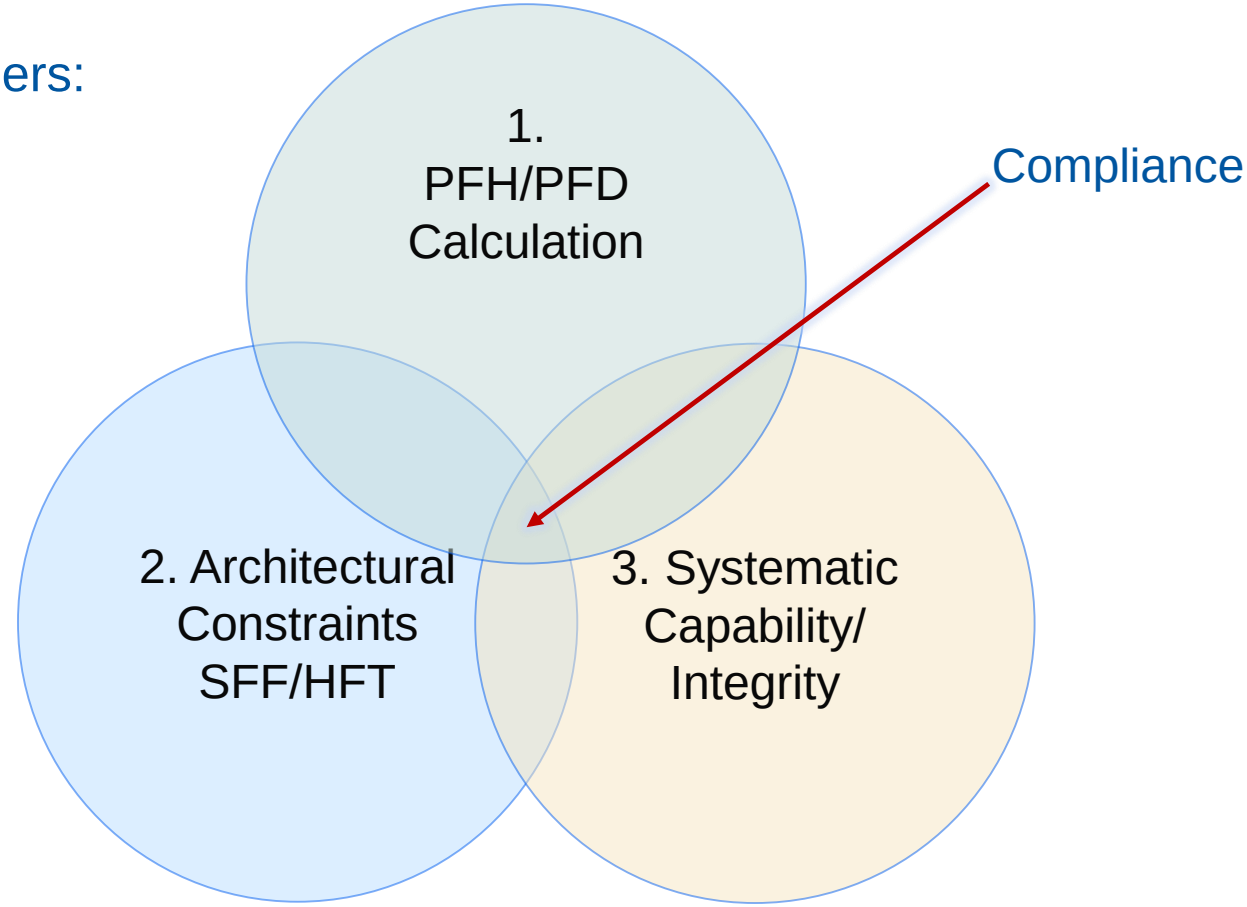
10. **Importance analysis**
    - Helps determine:
        - Event contribution to TOP event
        - TOP event sensitivity to event changes
        - Weak areas in the system
    - 6 different importance measures, most useful (?) Fussell-Vesely Importance (contribution to system Q)
11. **Confidence analysis**
    - Introduces uncertainty in component Q
    - *Project Options ▸ Confidence*

3. Isograph and the IEC 61508 Standard

Saskia Hurst

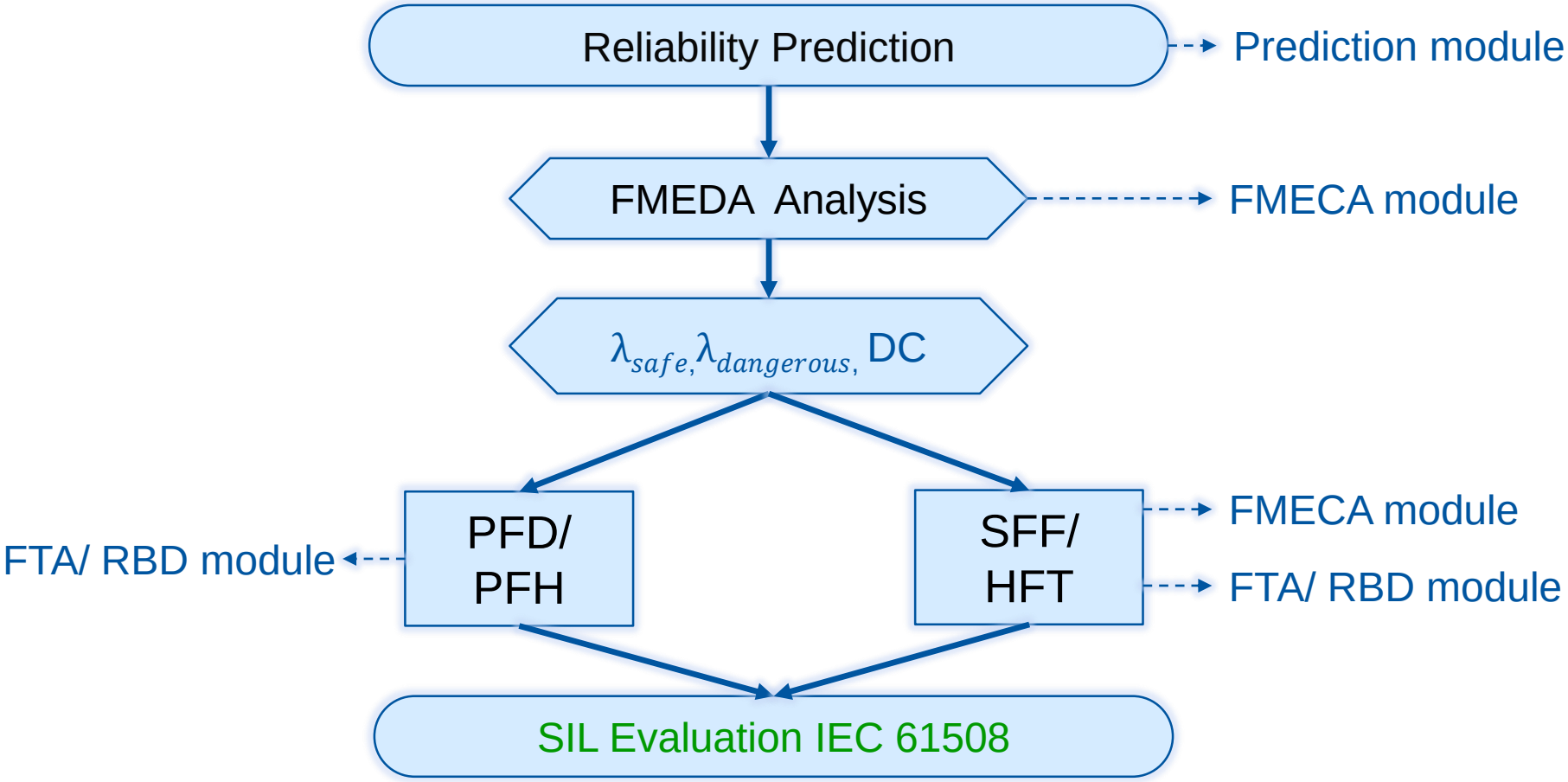
IEC 61508 - General SIL Verification

Three Barriers:



→ Barrier 1 and barrier 2 can be calculated in Isograph

IEC 61508 - SIL Quantitative Calculation



FMEDA (Failure Modes, Effects and Detectability Analysis)

- Takes into account:
  - Failure rates of components,
  - Failure mode probabilities,
  - Failure effect of each failure mode,
  - Diagnostic coverage:

$$SC(Safe\ Coverage) = \frac{\lambda_{SD}}{\lambda_{SD}+\lambda_{SU}}; DC\ (Dangerous\ Coverage) = \frac{\lambda_{DD}}{\lambda_{DD}+\lambda_{DU}},$$

  - Division into safe λ_S and dangerous λ_D and detectable and undetectable failure rates ($\lambda_{SD}, \lambda_{SU}, \lambda_{DD}, \lambda_{DU}$)

ID	Description	Effects defined	Contributors defined	Effects (immediate)	Effects (higher level)	Alpha	Beta	Detectable	Dangerous failure %	Dangerous coverage %	Safe coverage %	Detected safe failure rate	Undetected safe failure rate	Detected dangerous failure rate	Undetected dangerous failure rate	Safe failure fraction
2.1.2.7.1	(CC) C80 - short	Yes	N/A	No 24V	1 No alert CROME 2.1 No measurement	49	1	Yes	100	50	0	0	0	0.000949133	0.000949133	0.5
2.1.2.7.2	(CC) C80 - change in value	Yes	N/A	No effect CB	16 No effect CROME 2.16 No effect CMPU	29	1	No	0	0	0	0	0.00112346	0	0	1
2.1.2.7.3	(CC) C80 - open	Yes	N/A	No effect CB	16 No effect CROME 2.16 No effect CMPU	22	1	No	0	0	0	0	0.000852283	0	0	1

IEC 61508 - SFF Calculation

- Calculation in the FMECA module of Isograph by doing a FMEDA
- SFF is the ratio of safe and dangerous detected failures to the total failure rate
- Safe Failure Fraction (SFF) for a component:

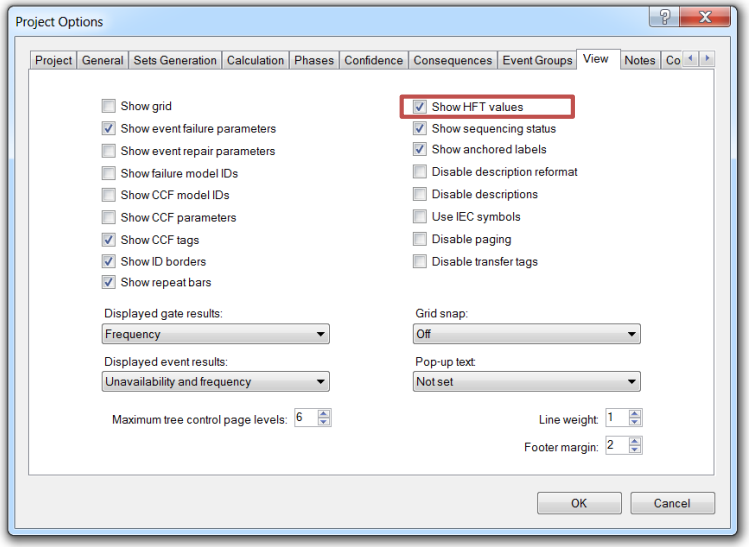
$$SFF = \frac{\lambda_{SD} + \lambda_{SU} + \lambda_{DD}}{\lambda_{SD} + \lambda_{SU} + \lambda_{DD} + \lambda_{DU}}$$

- Safe Failure Fraction (SFF) for a subsystem (safety function):

$$SFF = \frac{\sum \lambda_{SD} + \sum \lambda_{SU} + \sum \lambda_{DD}}{\sum \lambda_{SD} + \sum \lambda_{SU} + \sum \lambda_{DD} + \sum \lambda_{DU}}$$

IEC 61508 - HFT Calculation

- Calculation in the Fault Tree module of Isograph



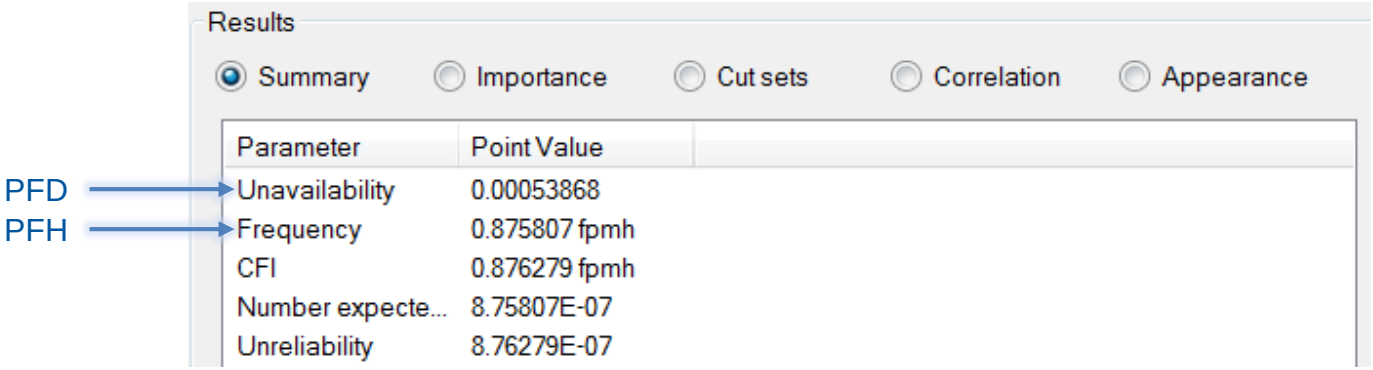
- Hardware Fault Tolerance (HFT) is the maximum number of faults that can be tolerated before the loss of the safety function
- i.e. HFT = N means that N + 1 faults will cause a loss of the function
- Isograph selects HFT by calculating SFF and cross referencing it against the SIL target for the gate (tables 2 and 3 from IEC 61508-2)

IEC 61508 - PFH/PFD Calculation

- Calculation in the Fault Tree module or RBD module in Isograph
- Probability of dangerous Failure per Hour PFH (continuous or high demand mode)

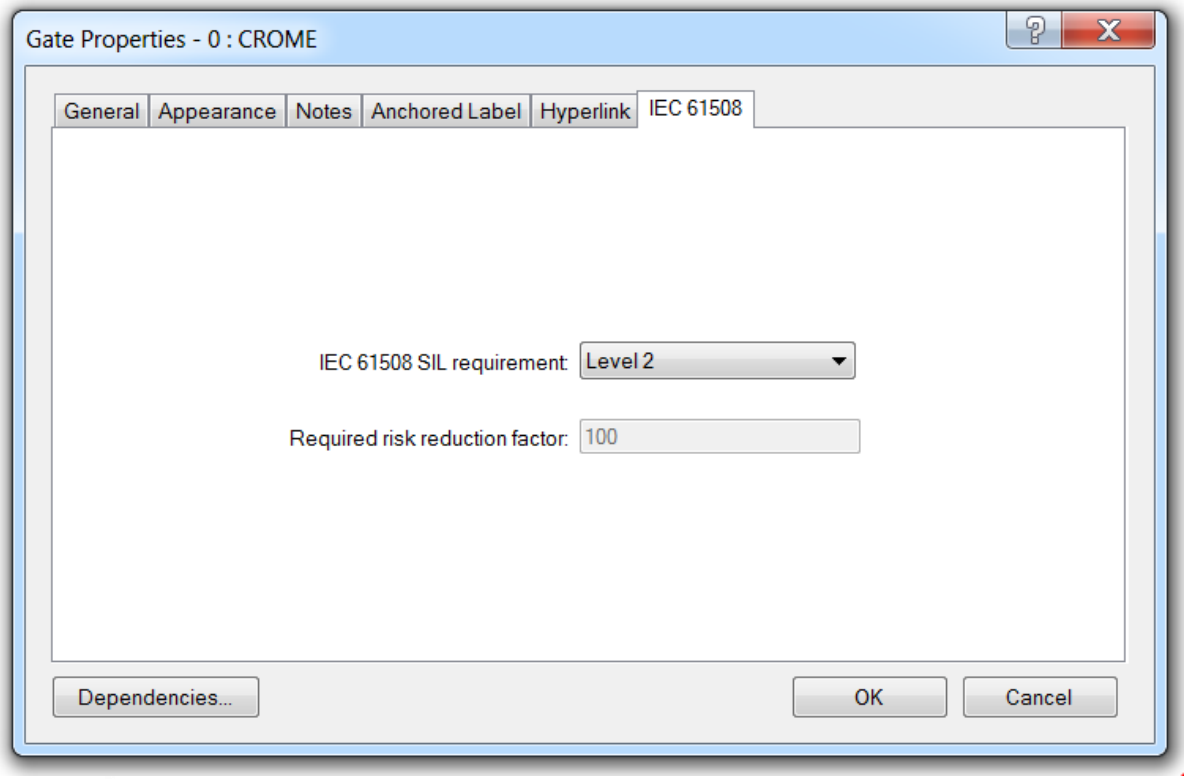
  → Frequency ω in Isograph
- Probability of dangerous Failure on Demand PFD (low demand mode)

  → Unavailability Q in Isograph



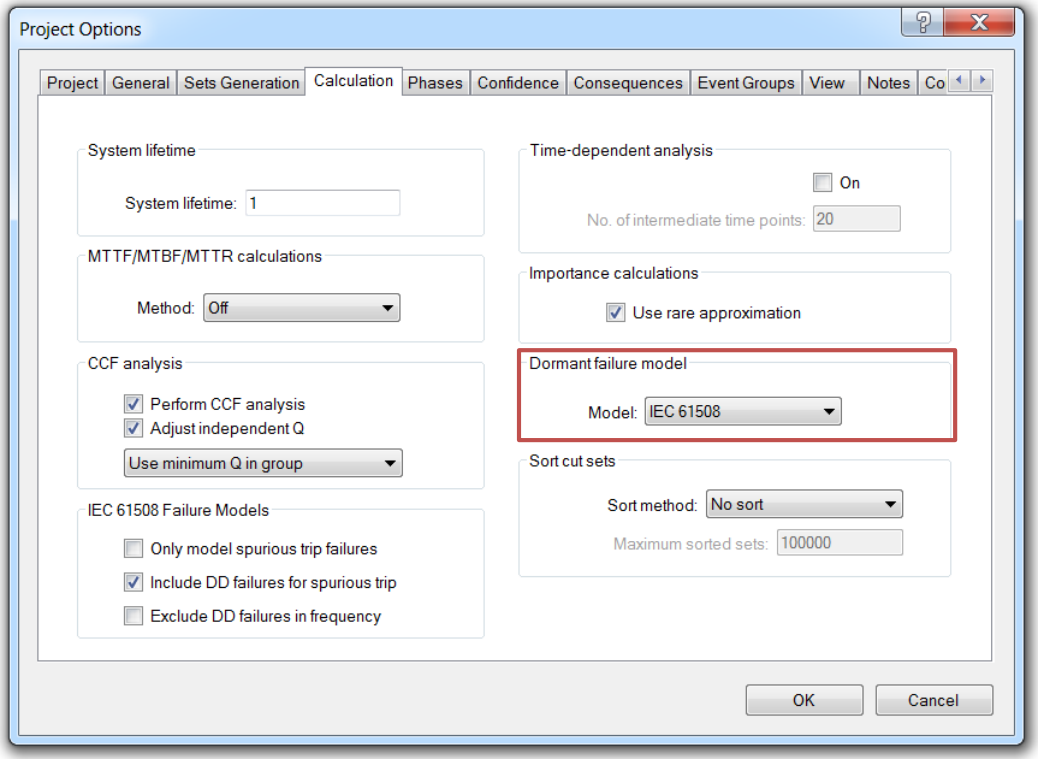
Important Settings in Isograph

- Set IEC 61508 requirement by either defining
  - Required SIL or
  - Required risk reduction factor



Important Settings in Isograph

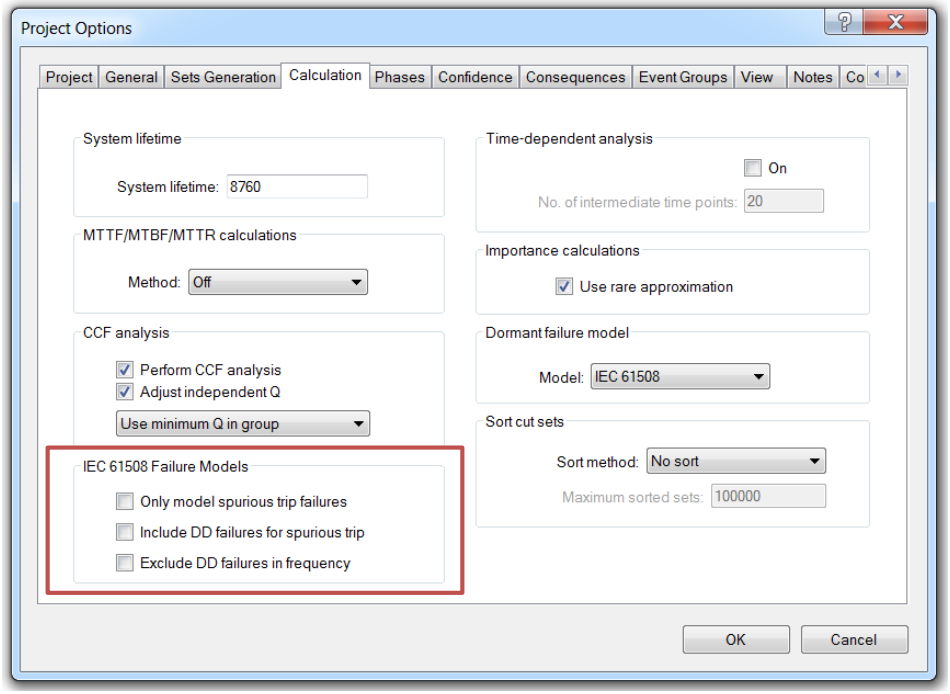
- Dormant failure model → IEC 61508



- Logic for average: 1. Product of the function (Fault Tree Logic)
  2. Average of the result

Important Settings in Isograph

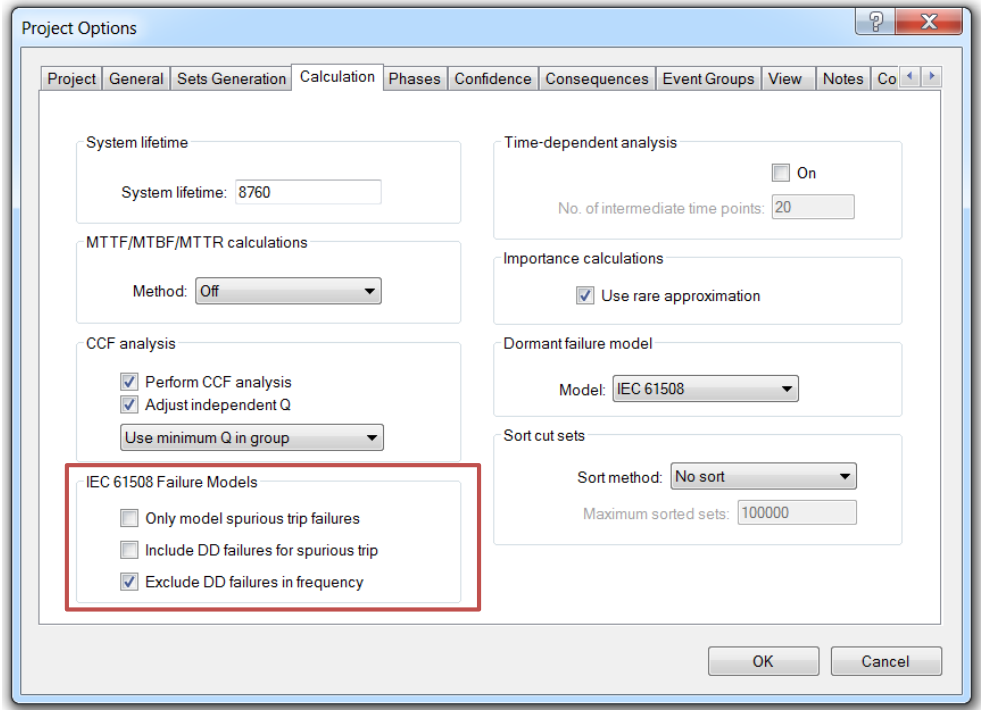
- Default setting: calculation of PFD/PFH with dangerous failure rate λ_{DU}



- *"Only model spurious trip failure"*: calculation of PFH/PFD with λ_S
- *"Only model spurious trip failure"* and "*Include DD failures for spurious trip*": calculation of PFH/PFD with λ_S and λ_{DD}

Important Settings in Isograph

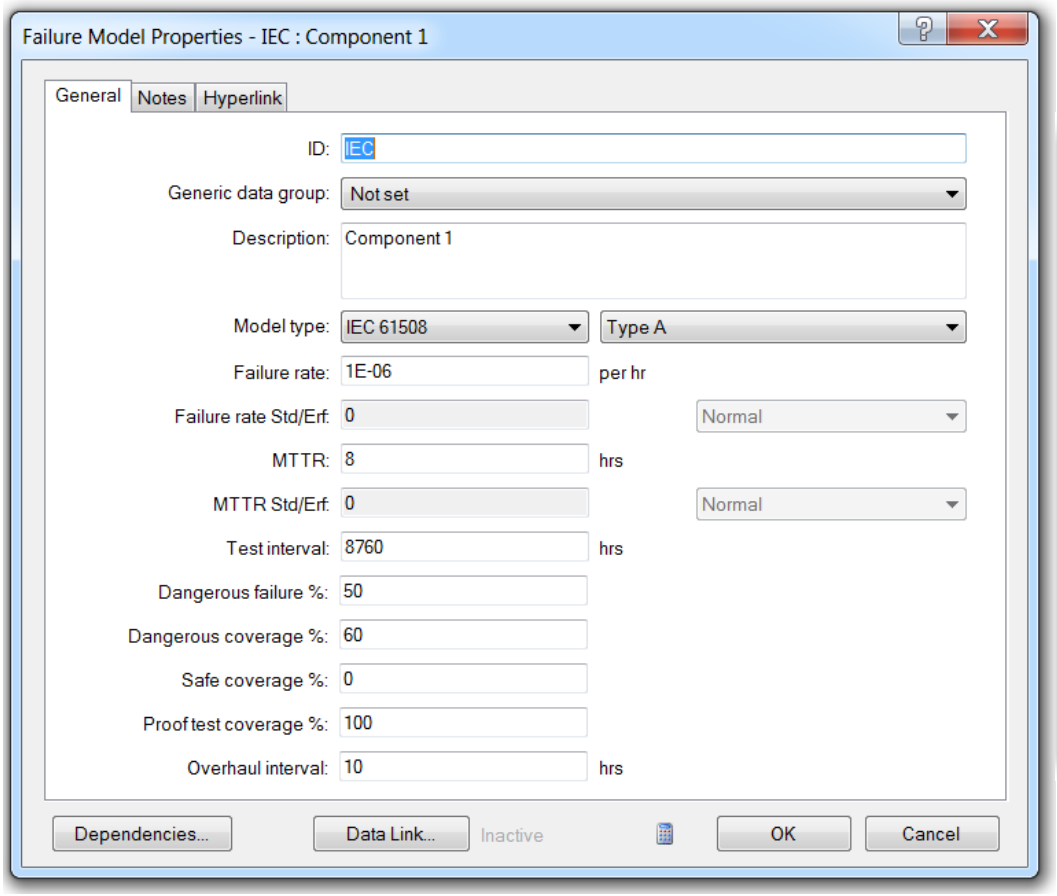
- For continuous or high demand functions (PFH): "E*xclude DD failures in frequency*"

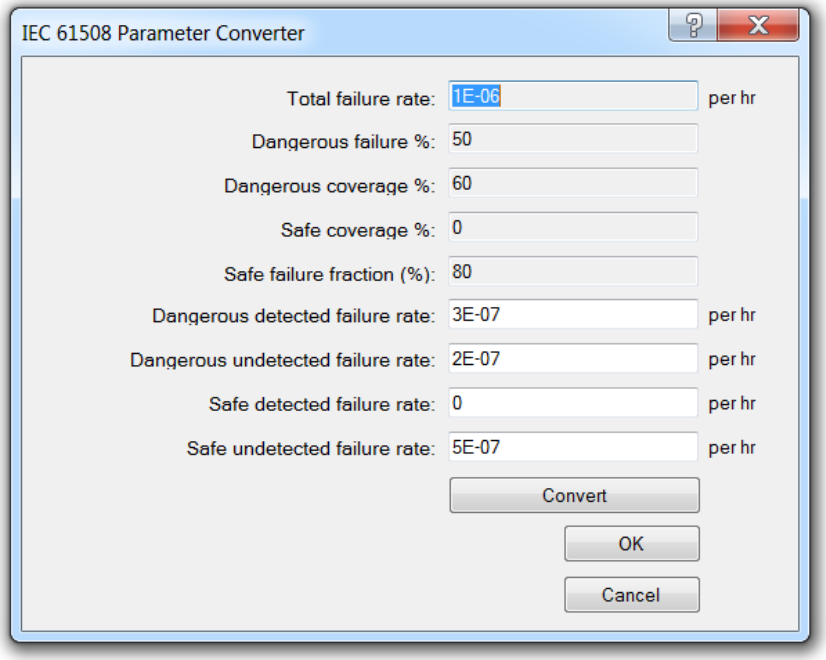


→ Calculation of the frequency (PFH) with only dangerous undetectable failures λ_{DU} according to IEC 61508 standard

Important Settings in Isograph

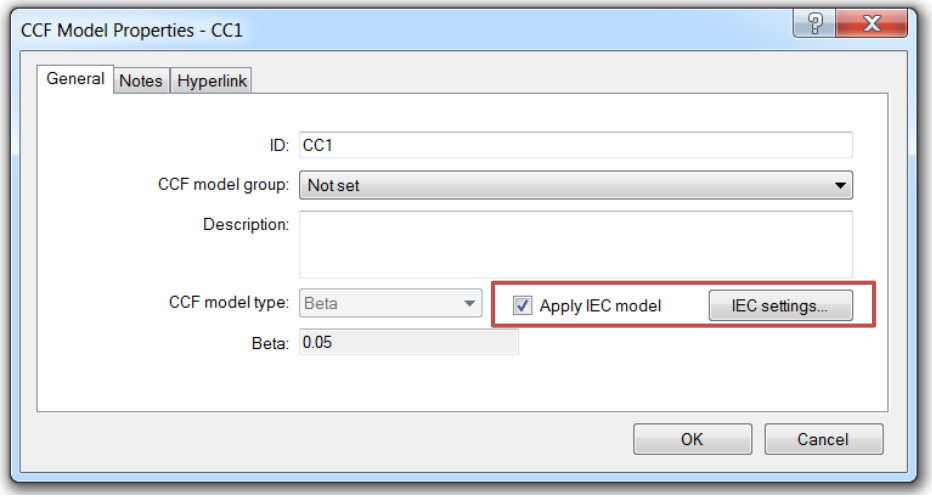
- Model type: IEC 61508

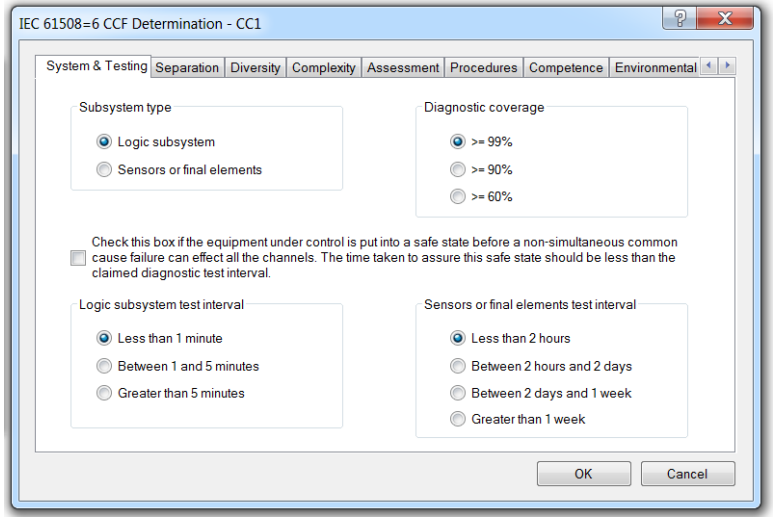




Common Cause Failures

- β Factor Model (used in IEC 61508)





- Calculates the proportion of event failures due to common cause

$$Q_1 = (1 - \beta) \cdot Q_T; \qquad \mathrm{QCCF} = \beta \cdot Q_T$$

Q_1: Q due to independant failure, Q_T: Total Q, Q_{CCF}: Q due to common cause failure

- β-factor can be determined by "A*pply IEC model"* with a questionnaire which is implemented in Isograph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