

Isograph Packages

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

□ Reliability Workbench, modules:

- Prediction (standards,...) ←
- Fault tree (FT) ←
- Reliability Block Diagrams (RBD) ←
- Event tree
- Markov
- Weibull
- FMECA ←

□ Availability Workbench, modules:

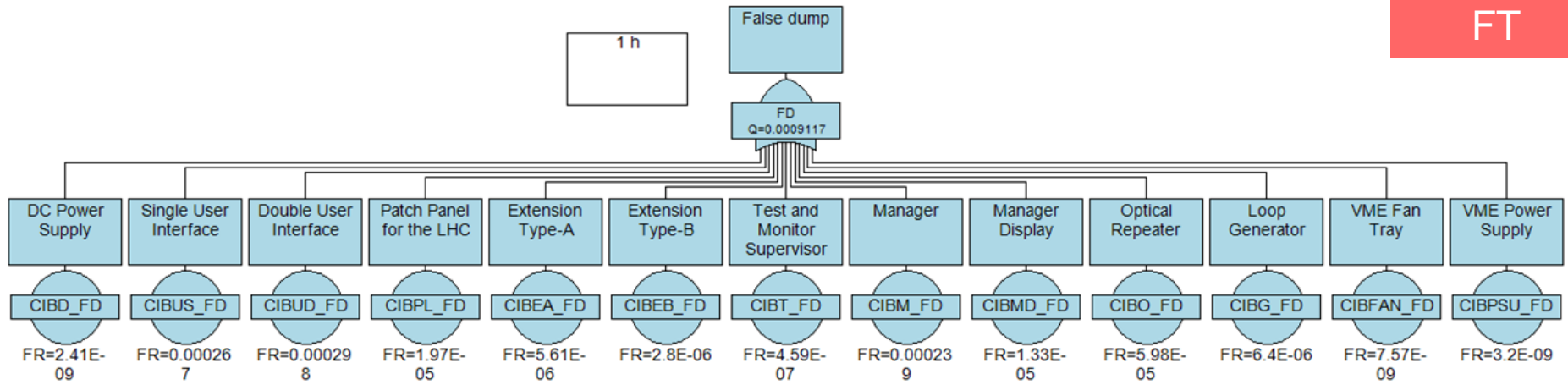
- AvSim ←
- Weibull
- RCM cost

isograph
●●●●



Fault Trees: Example BIS

FT



False Dump rate: 0.0115 / mission
 → 4.6 False Dumps per year

Gate Properties - GT1

General Appearance Notes Hyperlink

ID: GT1

Description:

Type: OR

Vote number:

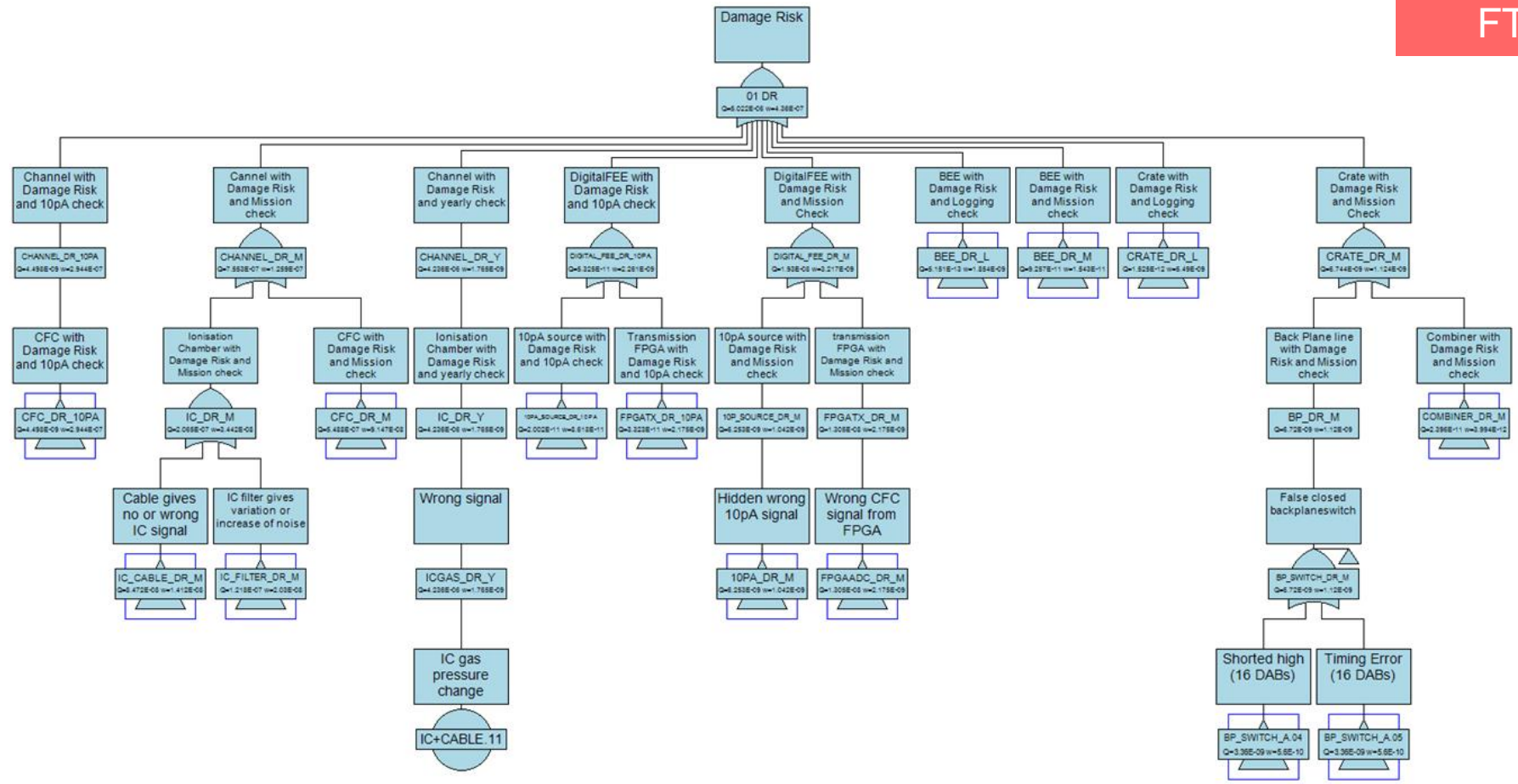
Modularization:

Tag: Automatic

Page

Dependencies...

OK Cancel

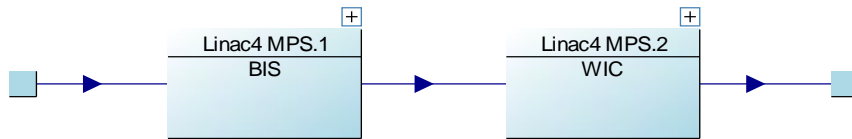


Rate unprotected: $1.26 \cdot 10^{-6}$ / mission
 $\rightarrow 5.02 \cdot 10^{-4}$ per year

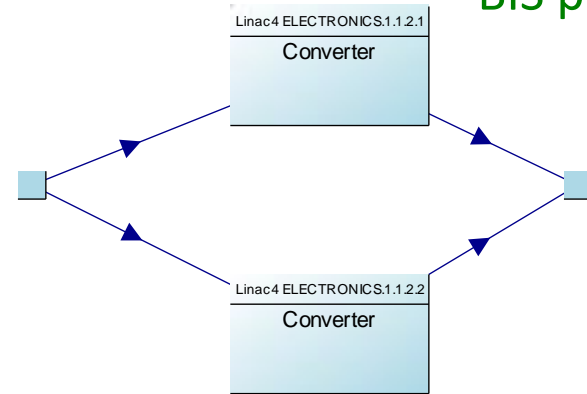
- Manual creation of fault trees and input data insertion
- Copy paste option available (2 different options)
- Option available for importing data from external files (not straightforward)

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

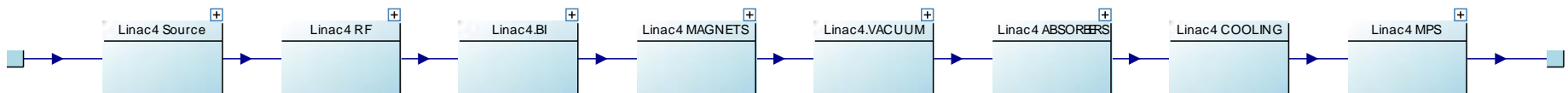
Linac4 MPS



BIS powering



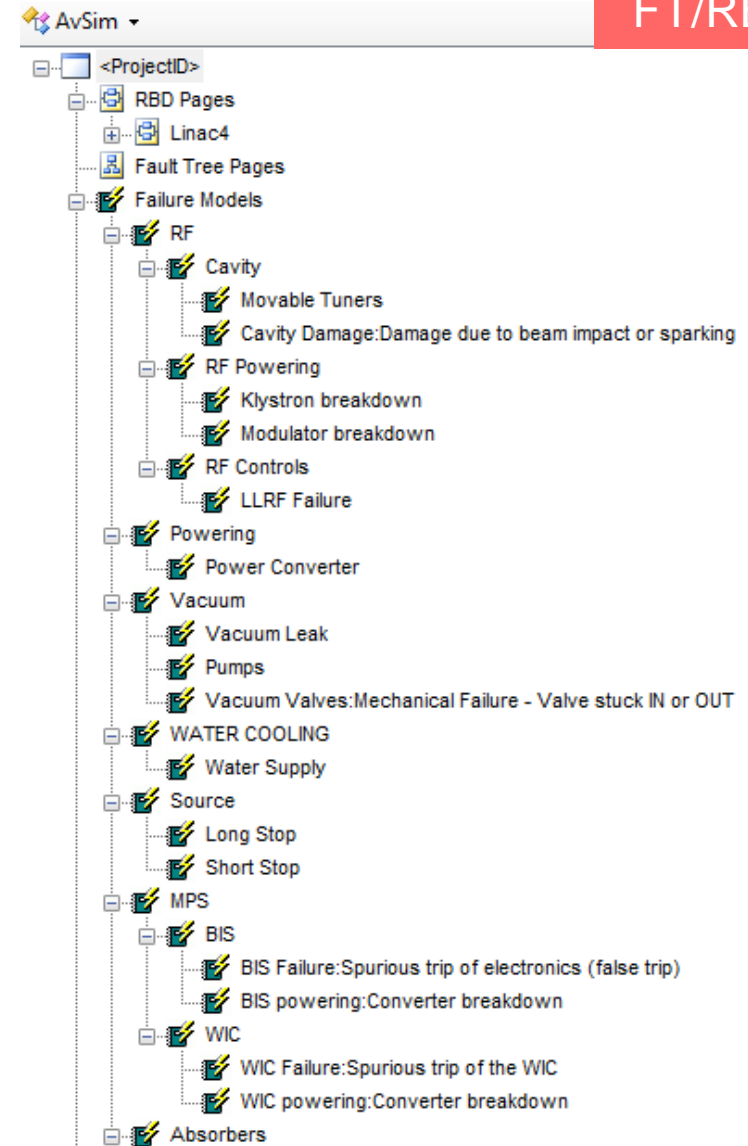
- A hierarchical structure of blocks can be created:

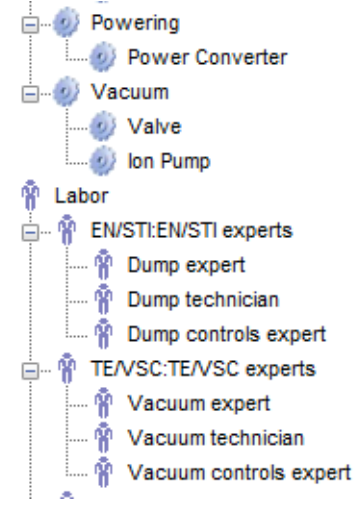


- Same considerations done for FTs apply here

- 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 Model Properties - Vacuum Valves : Mechanical Failure - Valve stuck IN or OUT (6 val... ? X

General Failure Maintenance Alarm Commission Redesign Notes Strategy

Distribution: Exponential Weibull set: Not set

Distribution parameters

Mean time to failure: 21900 Standard deviation: 0

Weibull distribution

Eta-1: 8760	Beta-1: 2	Gamma-1: 0
Eta-2: 8760	Beta-2: 2	Gamma-2: 0
Eta-3: 8760	Beta-3: 2	Gamma-3: 0

Non-operating failure apportionment (%): 50 Dormant failure

Non-operating ageing apportionment (%): 50

Start-up failure probability: 0

OK

Failure Model Properties - Vacuum Valves : Mechanical Failure - Valve stuck IN or OUT (6 val... ? X

General Failure Maintenance Alarm Commission Redesign Notes Strategy

Corrective
└ Valve replacement

Planned
└ Inspection

New... Edit... Remove

Copy Task From Library... Use current project Use task group hierarchy

Task library:

OK Cancel

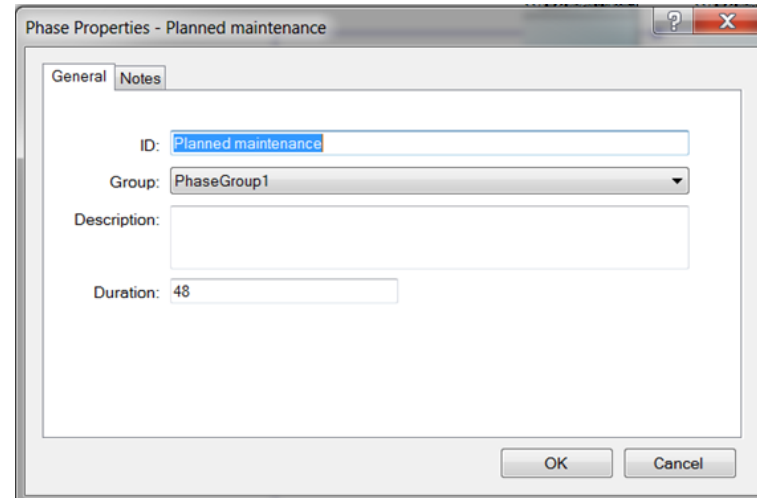
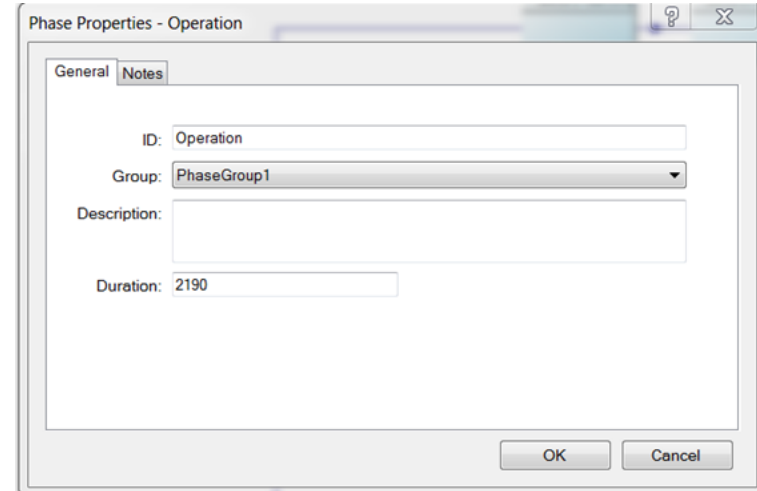
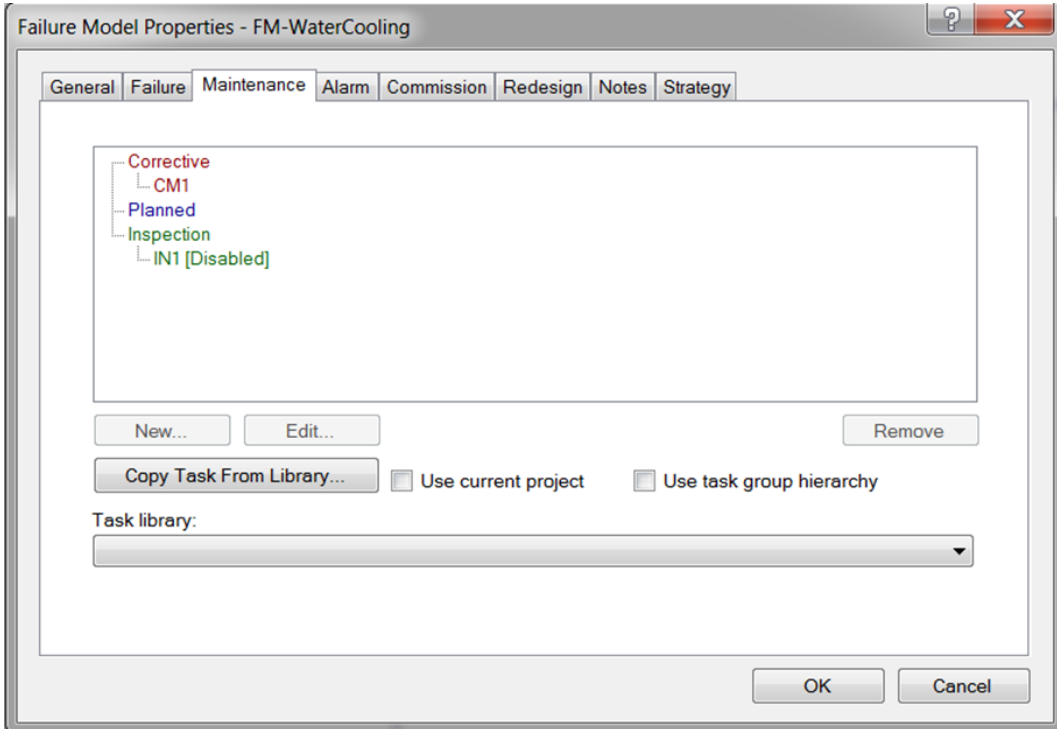
- Resources needed for maintenance are assigned to each task
 - Task duration
 - Personnel required
 - Spare components available

The 'Task Properties - Valve replacement' dialog box has tabs for General, Advanced, Rules, and Notes. The General tab is active. It contains a Description field, a Task ID field with the value 'Valve replacement', a Task duration field with the value '24', an Operational cost field with the value '0', and a Ramp time field with the value '0'. Below these fields is a Resources list containing 'Vacuum technician x 1' and 'Valve x 1'. At the bottom, there are three 'Add...' buttons with icons, an 'Edit...' button, a 'Remove' button, and 'OK' and 'Cancel' buttons.

The 'Labor Properties - Vacuum technician' dialog box has tabs for General and Notes. The General tab is active. It contains an ID field with the value 'Vacuum technician', a Type dropdown menu with 'TE/VSC' selected, and a Description field. Below these are fields for Number available (1), Cost rate (0.06), Corrective logistic delay (0), Corrective call-out cost (0), and Scheduled call-out cost (0). At the bottom are 'OK' and 'Cancel' buttons.

The 'Spare Properties - Valve' dialog box has tabs for General, Level 1, Level 2, Level 3, Repair Shop, Notes, and Optimization. The General tab is active. It contains an ID field with the value 'Valve', a Type dropdown menu with 'Vacuum' selected, and a Description field. Below these are fields for Unit cost (3), Unit volume (0), and Unit weight (0). At the bottom are 'OK' and 'Cancel' buttons.

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



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



Rule Properties

Type: Trigger task by state

State dependency type: RBD Block

Reference block: PSB RF System

Reference block state: Out of service

Minimum elapsed time/age: 1

Rule description:
If block PSB RF System is out of service trigger task if elapsed time/component age ≥ 1

OK Cancel

Rule Properties

Type: Trigger task by phase

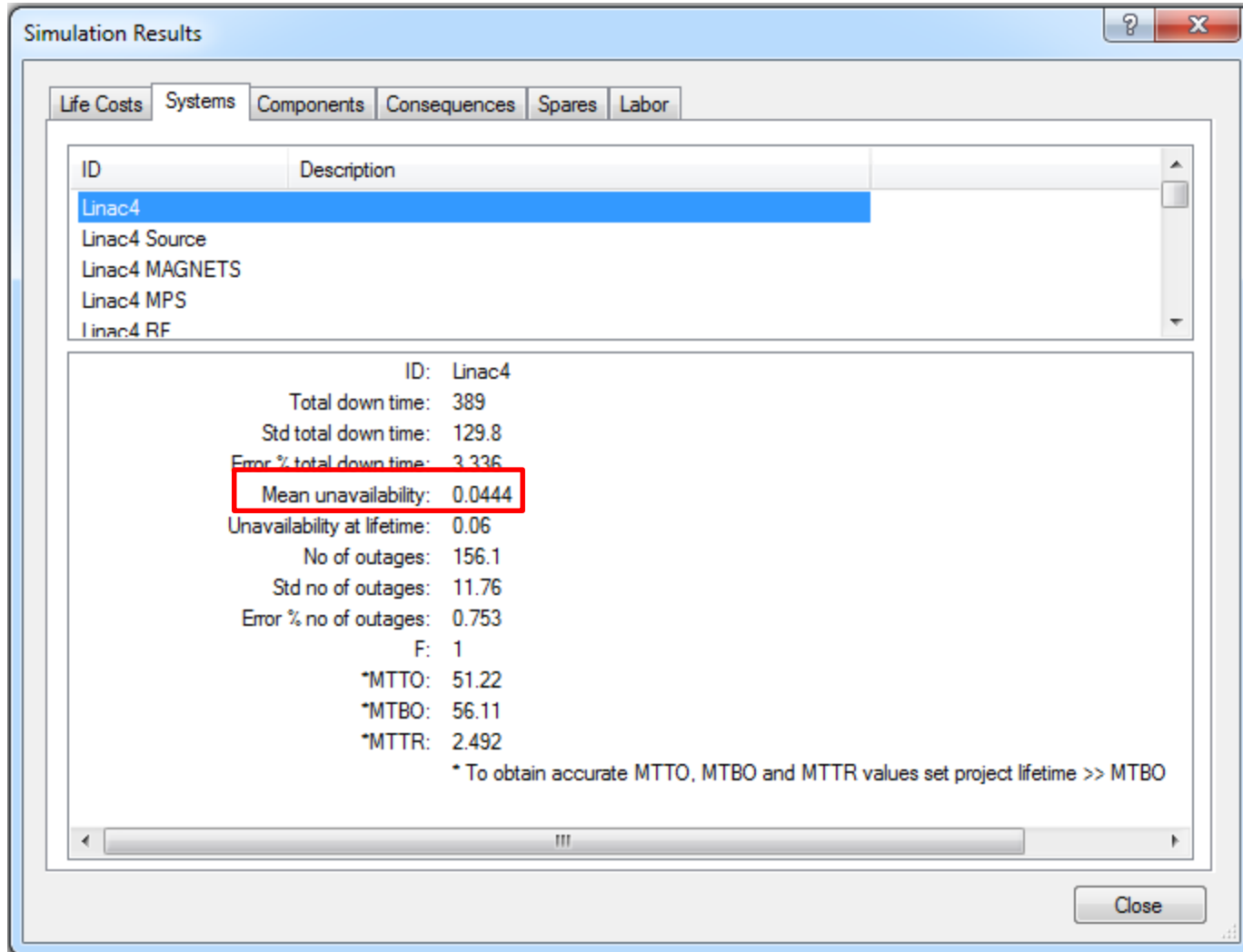
Phase: Planned maintenance

Minimum elapsed time/age: 49

Rule description:
On entering phase Planned maintenance trigger task if elapsed time/component age ≥ 49

OK Cancel

- 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



The screenshot shows a 'Simulation Results' window with a tabbed interface. The 'Systems' tab is selected, displaying a list of components and their associated metrics. The 'Linac4' component is highlighted in blue. Below the list, a detailed view for 'Linac4' is shown, listing various performance indicators. The 'Mean unavailability' value of 0.0444 is highlighted with a red box.

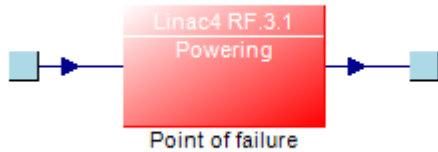
ID	Description
Linac4	
Linac4 Source	
Linac4 MAGNETS	
Linac4 MPS	
Linac4 RF	

ID:	Linac4
Total down time:	389
Std total down time:	129.8
Error % total down time:	3.336
Mean unavailability:	0.0444
Unavailability at lifetime:	0.06
No of outages:	156.1
Std no of outages:	11.76
Error % no of outages:	0.753
F:	1
*MTTO:	51.22
*MTBO:	56.11
*MTTR:	2.492

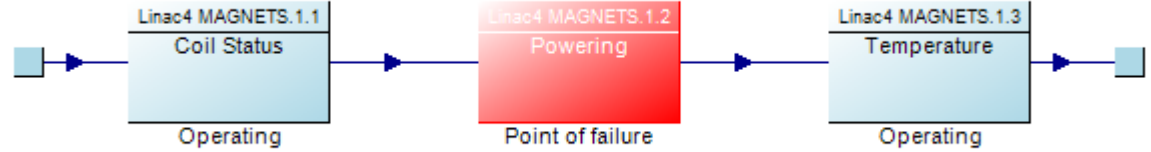
* To obtain accurate MTTO, MTBO and MTTR values set project lifetime >> MTBO

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

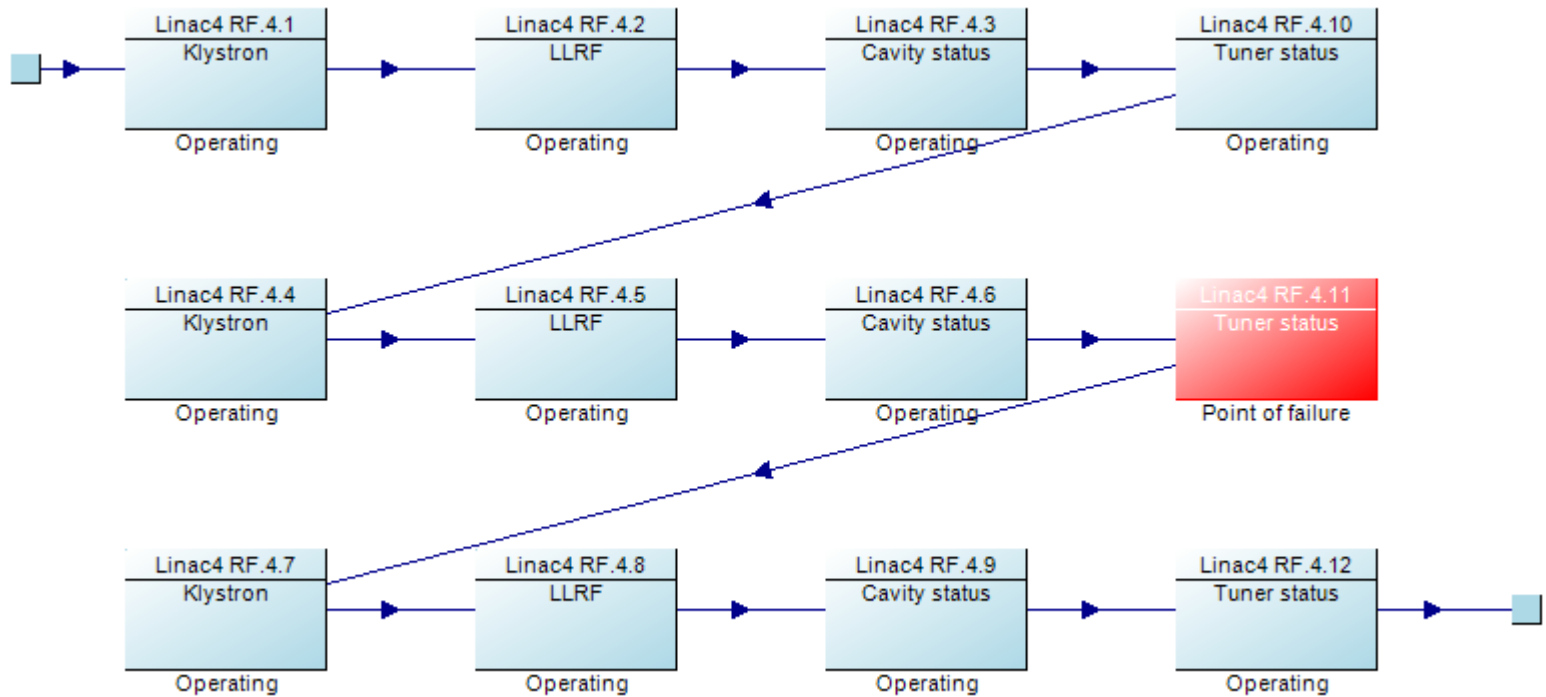
Chopper powering failure

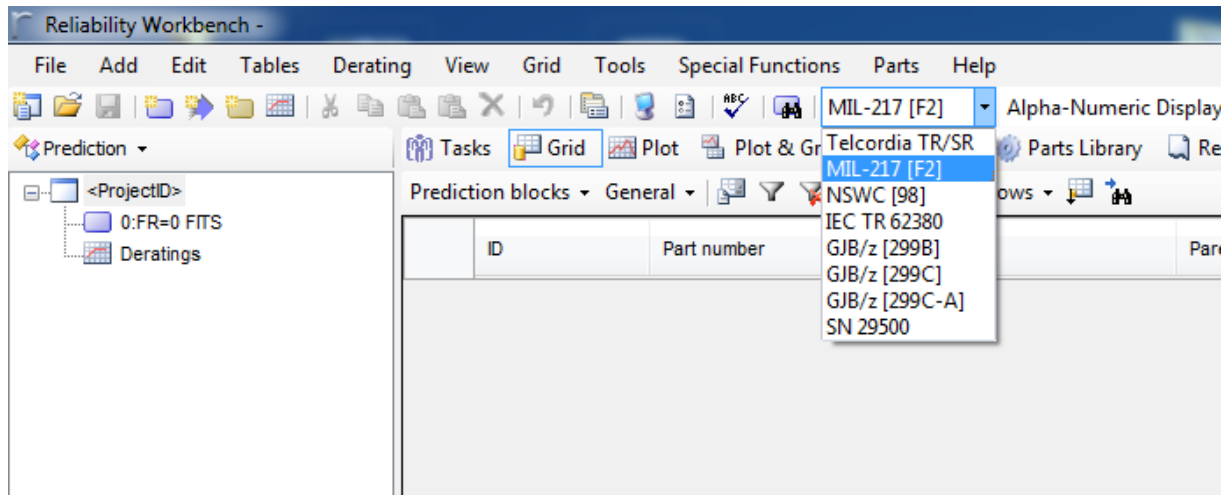


Magnet powering failure

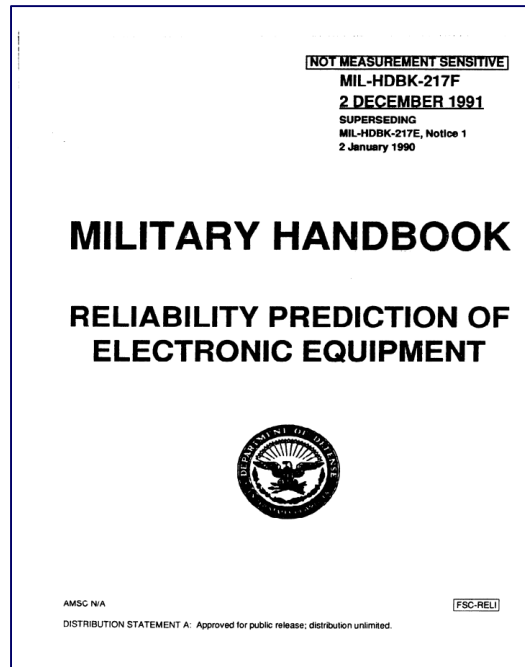


RF Tuner failure



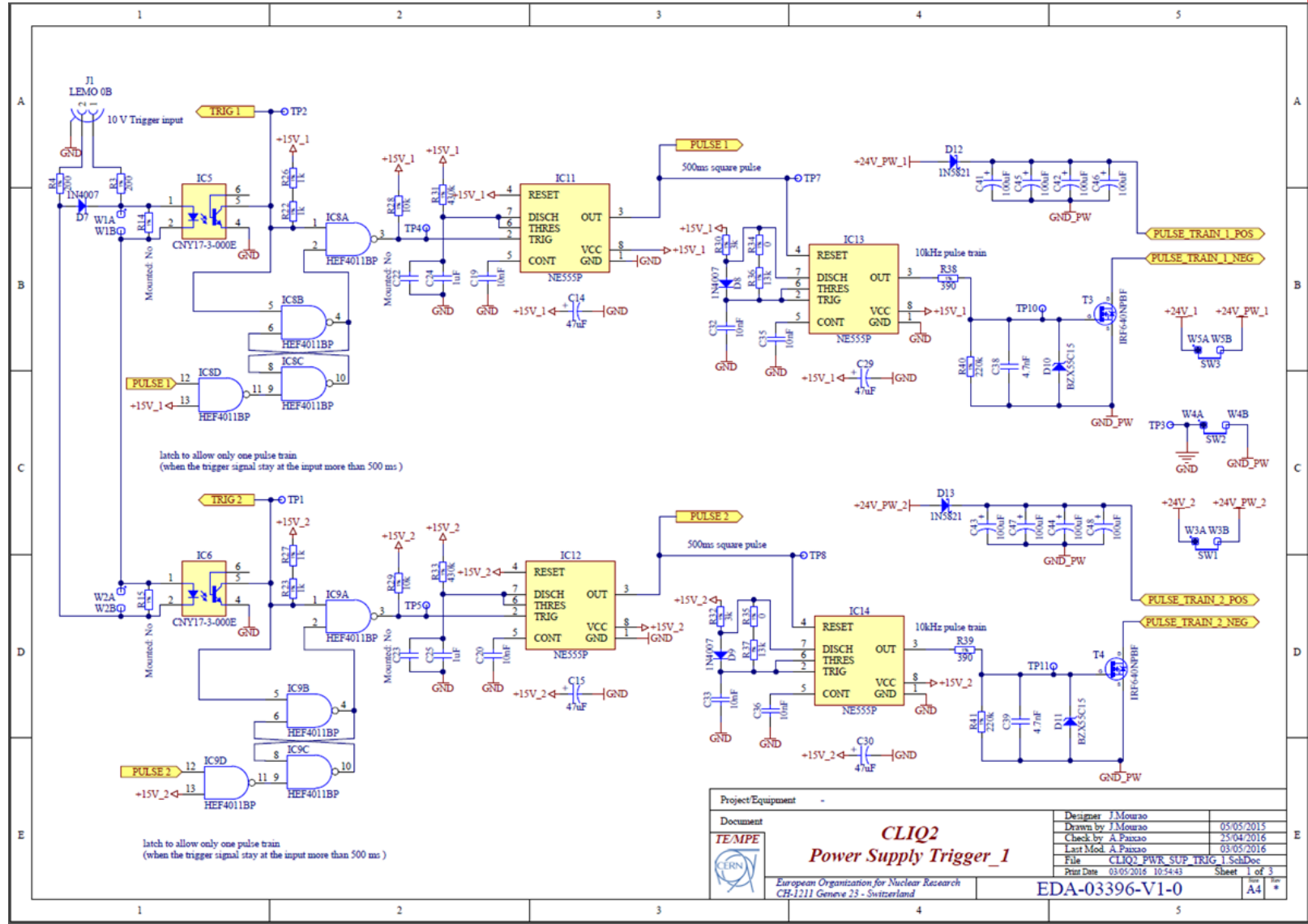


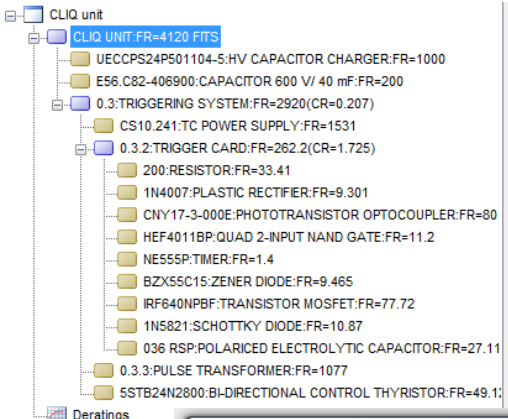
- Calculation of failure rate of standard components from commonly used reliability handbooks



Example of CLIQ Trigger Card

Prediction





Prediction blocks - General - Top 1000 rows

ID	Part number	Description	Parent
UECCPS24P5011...	0-1	HV CAPACITOR CHARGER	
E56.C82-406900	0-2	CAPACITOR 600 V/ 40 mF	
0.3	0-3	TRIGGERING SYSTEM	
CS10.241	0-3-1	TC POWER SUPPLY	
0.3.2	0-3-2	TRIGGER CARD	
1N4007	0-3-2-1	RESISTOR	
1N4007	0-3-2-2	PLASTIC RECTIFIER	
CNY17-3-000E	0-3-2-3	PHOTOTRANSISTOR OPTOCOUPLER	
HEF4011BP	0-3-2-4	QUAD 2-INPUT NAND GATE	
NE555P	0-3-2-5	TIMER	
BZX55C15	0-3-2-6	ZENER DIODE	
IRF640NPBF	0-3-2-7	TRANSISTOR MOSFET	

Block Properties - IRF640NPBF : TRANSISTOR MOSFET MIL-217 [F2] Transistor, LF FET

General Parameters Rate/Pi Factors Tasks Notes Hyperlink

Quantity: 1

Application, LF: Linear

Environment: Ground, benign

Quality, Discrete Semicon: Jan

Junction Temperature: 54.8

Junction Temp Calc Mode: Full Model

Ambient Temperature: 30

Case Temperature: 42.4

Operating Power (W): 0.4

Connection Type: Reflow Solder

Adjustment Factor: 1

Type, FE: MOS FET

No of Pins: 3

Theta Case / Ambient: 31

Theta Junction Case: 31

Stress= Temp= OK Cancel

International Rectifier

IRF640N/S/LPbF

PD - 95046A

IRF640NPbF

IRF640NSPbF

IRF640NLPbF

MOSFET

200V

$r_{DS(on)}$ = 0.15Ω

18A

TO-262 IRF640NLPbF

Units

A

W

W/°C

V

mJ

A

mJ

V/ms

°C

07/23/10

www.irf.com

3

Fig 1. Typical Output Characteristics

Fig 2. Typical Output Characteristics

Fig 3. Typical Transfer Characteristics

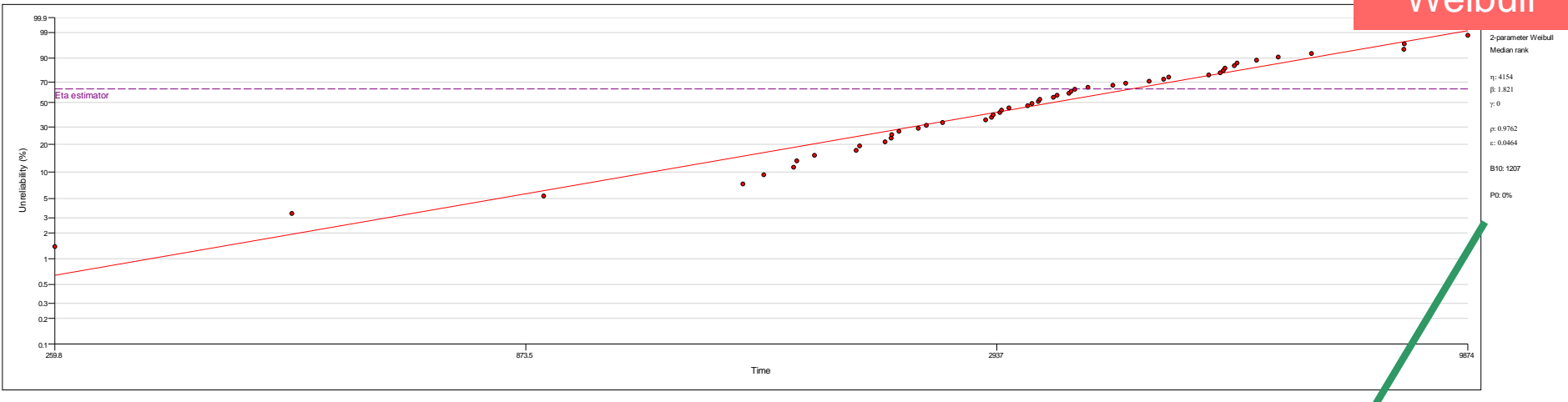
Fig 4. Normalized On-Resistance Vs. Temperature

- Manual procedure, but definition of libraries possible

Weibull Analysis of Historical Data

FANS Cumulative Probability

Weibull



2-parameter Weibull
Median rank
 η : 4154
 β : 1.821
 γ : 0
 ρ : 0.9762
 ϵ : 0.0464
B10: 1207
P0: 0%

	Time	Suspended	Disabled	Quantity
▶	9874.164227	<input type="checkbox"/>	<input type="checkbox"/>	1
	5067.502629	<input type="checkbox"/>	<input type="checkbox"/>	1
	2972.638889	<input type="checkbox"/>	<input type="checkbox"/>	1
	4092.057129	<input type="checkbox"/>	<input type="checkbox"/>	1
	1836.44227	<input type="checkbox"/>	<input type="checkbox"/>	1
	5218.564393	<input type="checkbox"/>	<input type="checkbox"/>	1
	2399.066718	<input type="checkbox"/>	<input type="checkbox"/>	1
	4346.794493	<input type="checkbox"/>	<input type="checkbox"/>	1
	6059.76623	<input type="checkbox"/>	<input type="checkbox"/>	1
	5450.632577	<input type="checkbox"/>	<input type="checkbox"/>	1
	478.216229	<input type="checkbox"/>	<input type="checkbox"/>	1
	5731.037643	<input type="checkbox"/>	<input type="checkbox"/>	1
	8374.289538	<input type="checkbox"/>	<input type="checkbox"/>	1
	3214.247652	<input type="checkbox"/>	<input type="checkbox"/>	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

CERN		Responsible: HSE-RP		CROME - MTF Prediction					Date: 08/06/2016		FMEA		
CERN		Project: CROME							Used standard: MIL-HDBK 217F - Notice 2				
CERN		Version: V1							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 property	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 property	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 property	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 property	Degraded mode CROME	3			1		10	30
1.1.1.6	Inductor with Magnetic Core		L2 - Short	Filter not working property	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 property	Degraded mode CROME	3			5		10	150	

Itm	Designation	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

- ❑ 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!