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Design. Analyze. Optimize.

ELMAS Screen Captures

Availability Modelling Tools and Synergies for Collaboration Workshop

CERN 7.7.2016

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Outline

1. Brief Background: Ramentor Inc., ELMAS acronym
2. Basic Fault Tree – General User Interface
   - Tree structure, Root Failure/Restoration, Simulation, Risks
3. Larger Fault Tree – Data Interface
   - Results Overview, HTML Reports, Table Summary, Excel Reports
4. Advanced Features
   - Block Diagram, Data Import, Maintenance Actions
   - Dynamic Simulation, Debug Log Window
   - LHC Dynamic Model

Ramentor Inc.

- Founded in 2006 and based in Tampere, Finland
  - Personnel ~10 (Dr. & M.Sc. – Mech. & aut. eng. / Applied math. / Software dev.)
  - Privately owned and independent software and expertise company
- Background: Tampere University of Technology (TUT)
  - Finnish Technology Agency (TEKES) Competitive Reliability Programme 1996-2000
  - Probabilistic approach in reliability and maintenance management 2001-2003
  - RAM Products 2003-2005, RAM Solutions 2006-2008, RAM Efficiency 2008-2010
- Please visit for more information: *www.ramentor.com*

Ramentor – Experience in Industry Sectors

- Energy Industry:
  - Nuclear Power Plants, District Cooling, …
- Process Industry :
  - Pulp & Paper Mills, Steel Industry, Mineral Processing, Medical, …
- IT Industry:
  - Data Centers, Telecommunication, Broadband connections, …
- Equipment Manufacturers:
  - Cranes, Elevators, Thruster Units, …
- Education and Research Organizations:
  - Universities (technology / applied sciences), CERN, …

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Ramentor – ELMAS Users / Co-developers

Industry Service	Design for Reliability	Quality & Risk mgmt
Caverion, YIT, ALGOL, EMPOWER, ABB, maint partner, Efora	KONECRANES, FINGRID, Fortum, KONE, ABB, PÖYRY, TeliaSonera, CARGOTEC, CERN, POSIVA, VACON, Google, metso, elisa, NOKIA	
Operation & Maintenance	**After Sales Support Service & Warranty**	**Research & Education**
UPM, TVO, POHJOLAN VOIMA, Fortum, OUTOKUMPU, Outotec, ruukki, nokian RENKAAT	Rolls-Royce, KONE, KONECRANES, Valmet, CARGOTEC, VACON	TAMPERE UNIVERSITY OF TECHNOLOGY, LAPIN AMK Lapland University of Applied Sciences, Jyväskylän AMK, SOLTEQ, HAMK HÄMEEN AMMATTIKORKEAKOULU

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ELMAS – An Acronym

Event

- Time to Failure, Distribution
- Time to Repair, Distribution
- Maintenance actions
- Break and downtime loss
- Repair Costs
- Hazards
- Usage and stress profile
- External events

Logic

- OR
- AND
- K/N-Voting
- XOR-Exclusive
- Limits
- Conditional probability
- Delays
- Throughput, fuzzy logic
- Dynamic coding

Modeling

- Fault tree
- Event tree
- Cause-consequence-tree
- Reliability block diagram
- Process diagram
- Waiting and redundancy
- Buffers
- Failure modes, RCA

Analysis

- Simulation
- Reliability, Availability
- Risk Analysis
- Importance measures
- Conditional probabilities
- Spare part consumption
- Resources
- FMEA, Classification, RCM, Decision tree, Criticality

Software

- Graphical user interface
- Excel export and import
- HTML report
- Table summary
- ERP interface
- Project versioning
- Template library
- Search
- Web start

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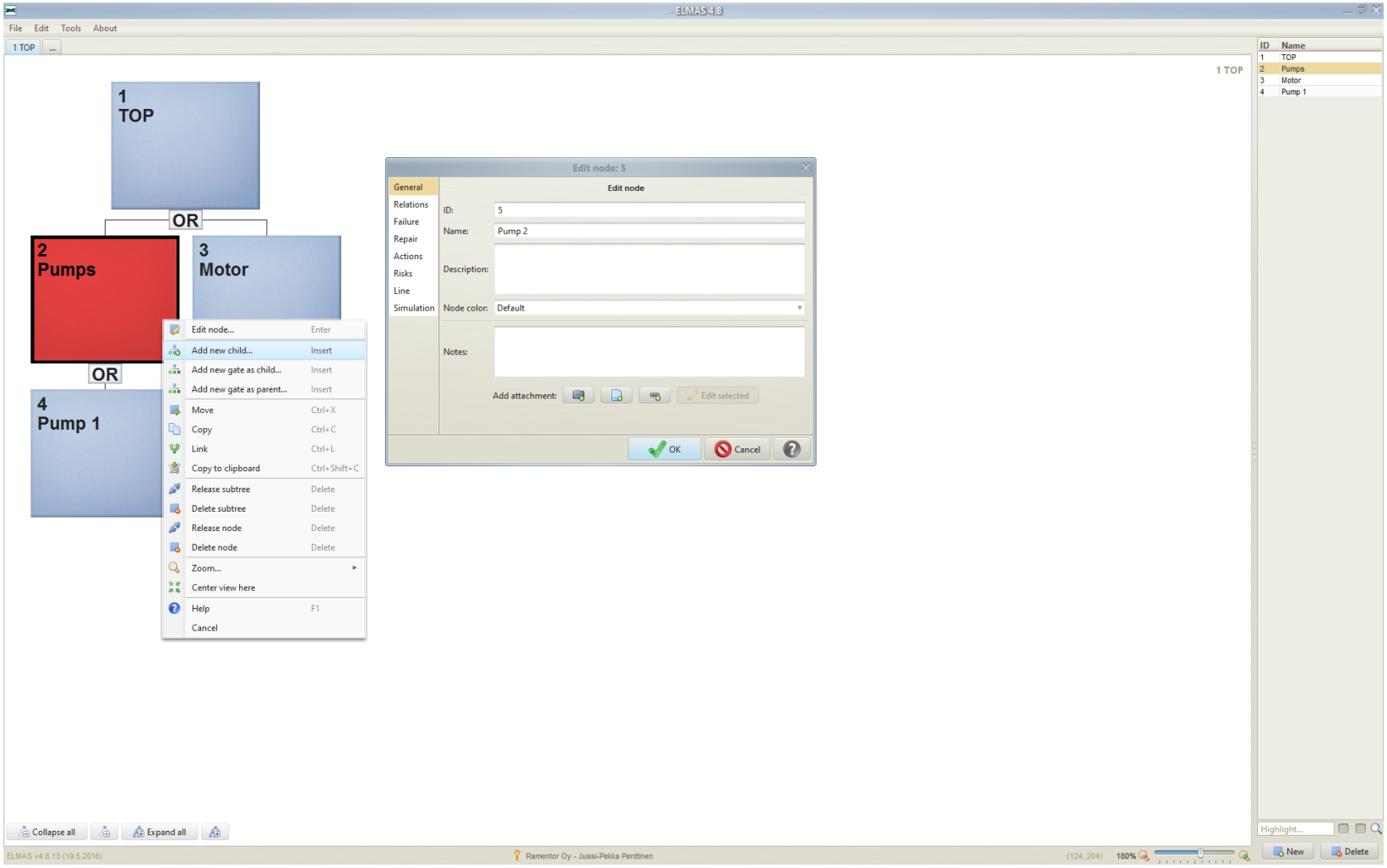
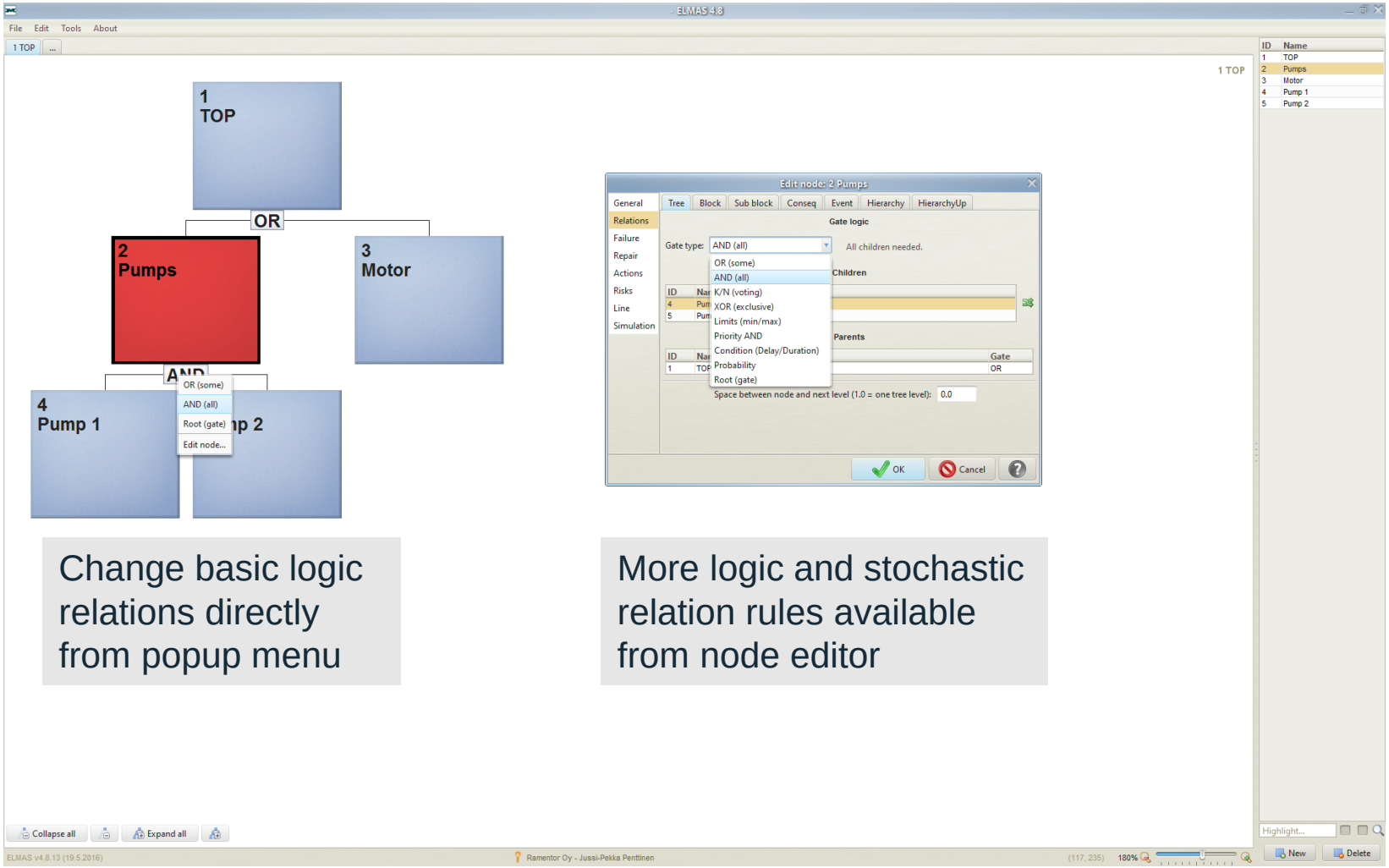
Basic Fault Tree – General User Interface

Basic Fault Tree: Structure + Node Info



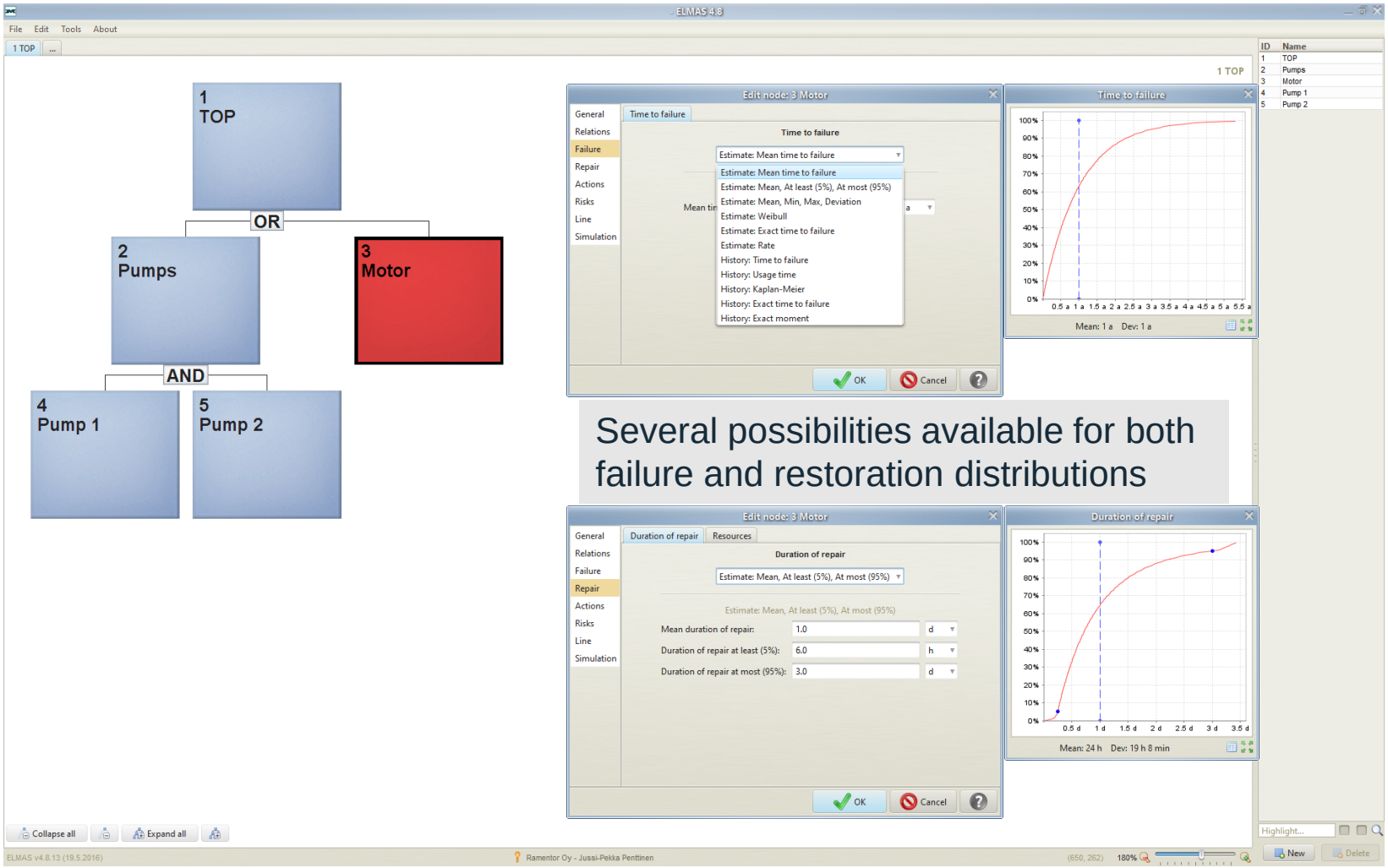
Basic Fault Tree: Gate Relation



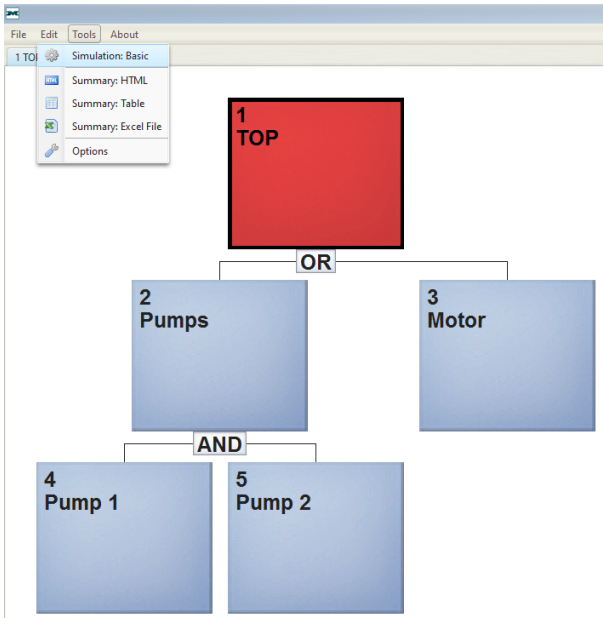
Change basic logic relations directly from popup menu

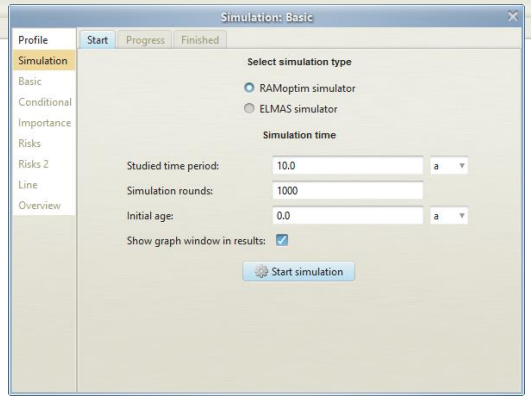
More logic and stochastic relation rules available from node editor

Basic Fault Tree: Root Failure/Restoration

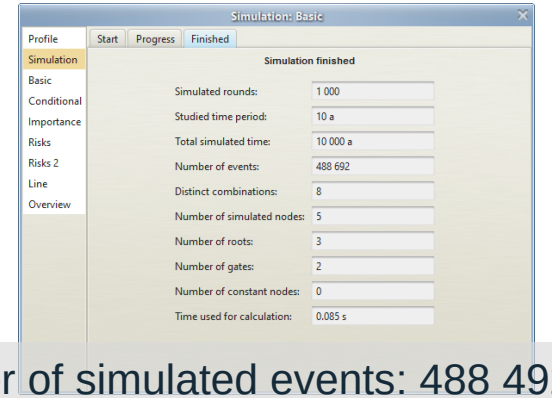


Basic Fault Tree: Stochastic Simulation



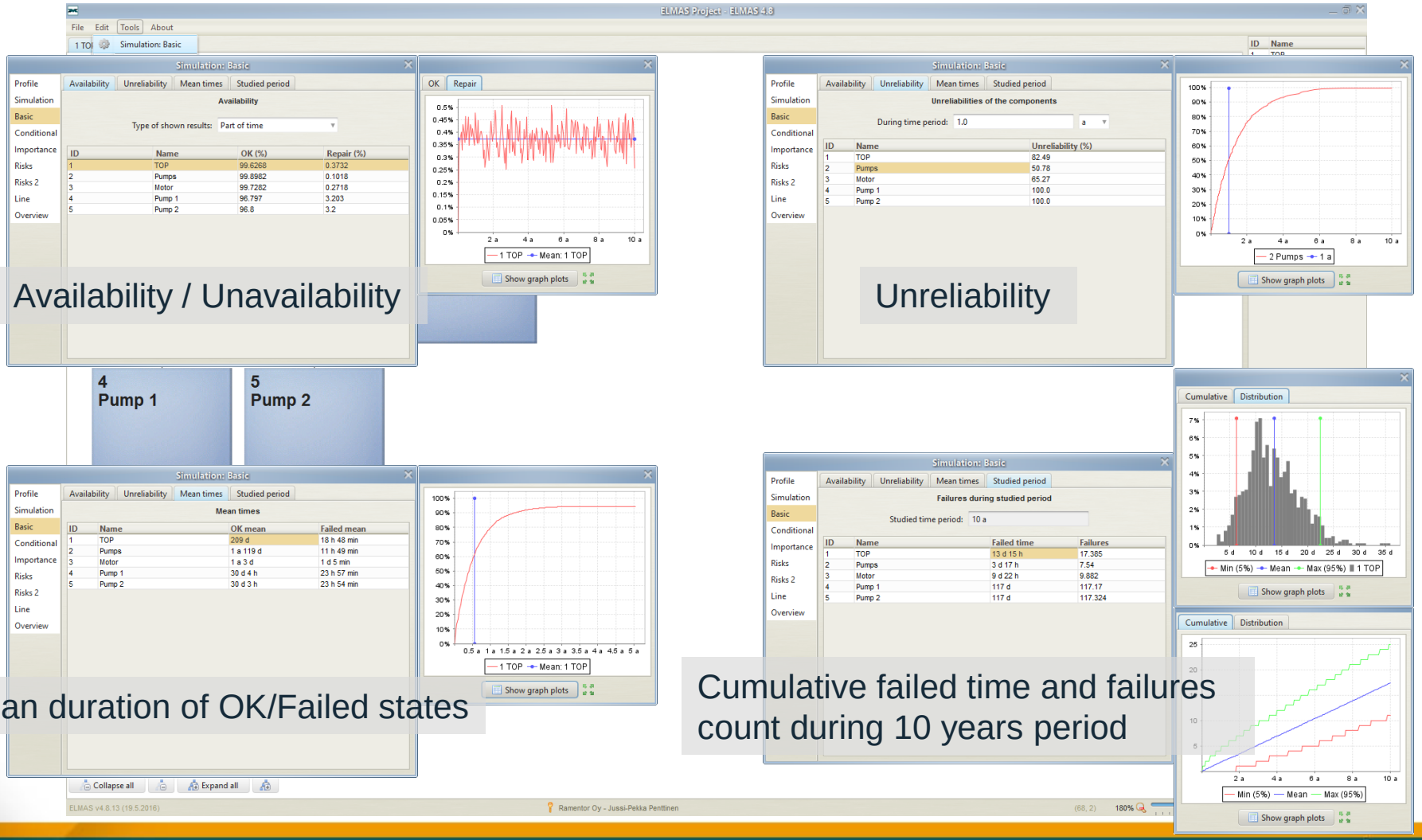


Simulation of 10 years period 1000 rounds

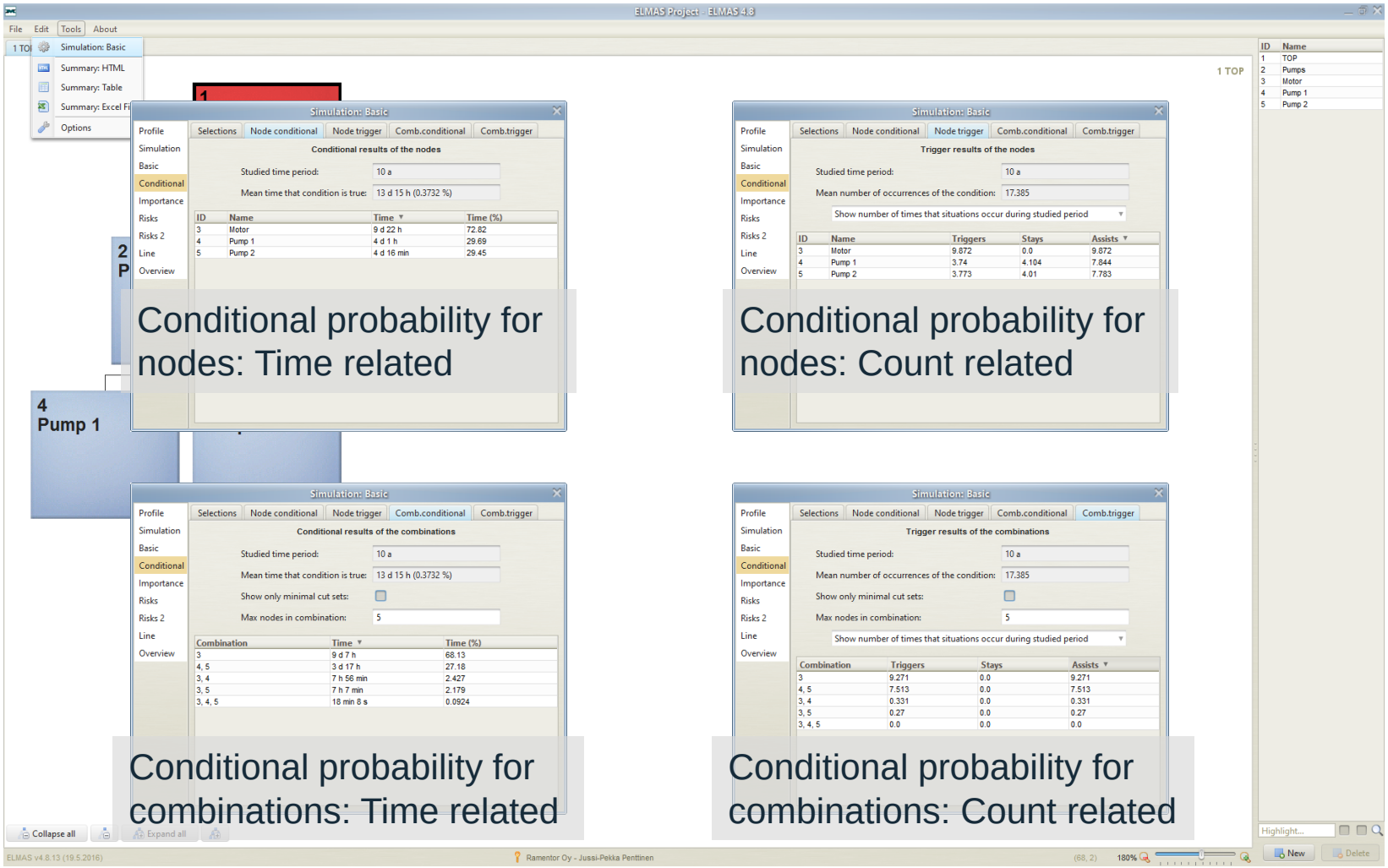


Number of simulated events: 488 492
Calculation time: < 0.1s

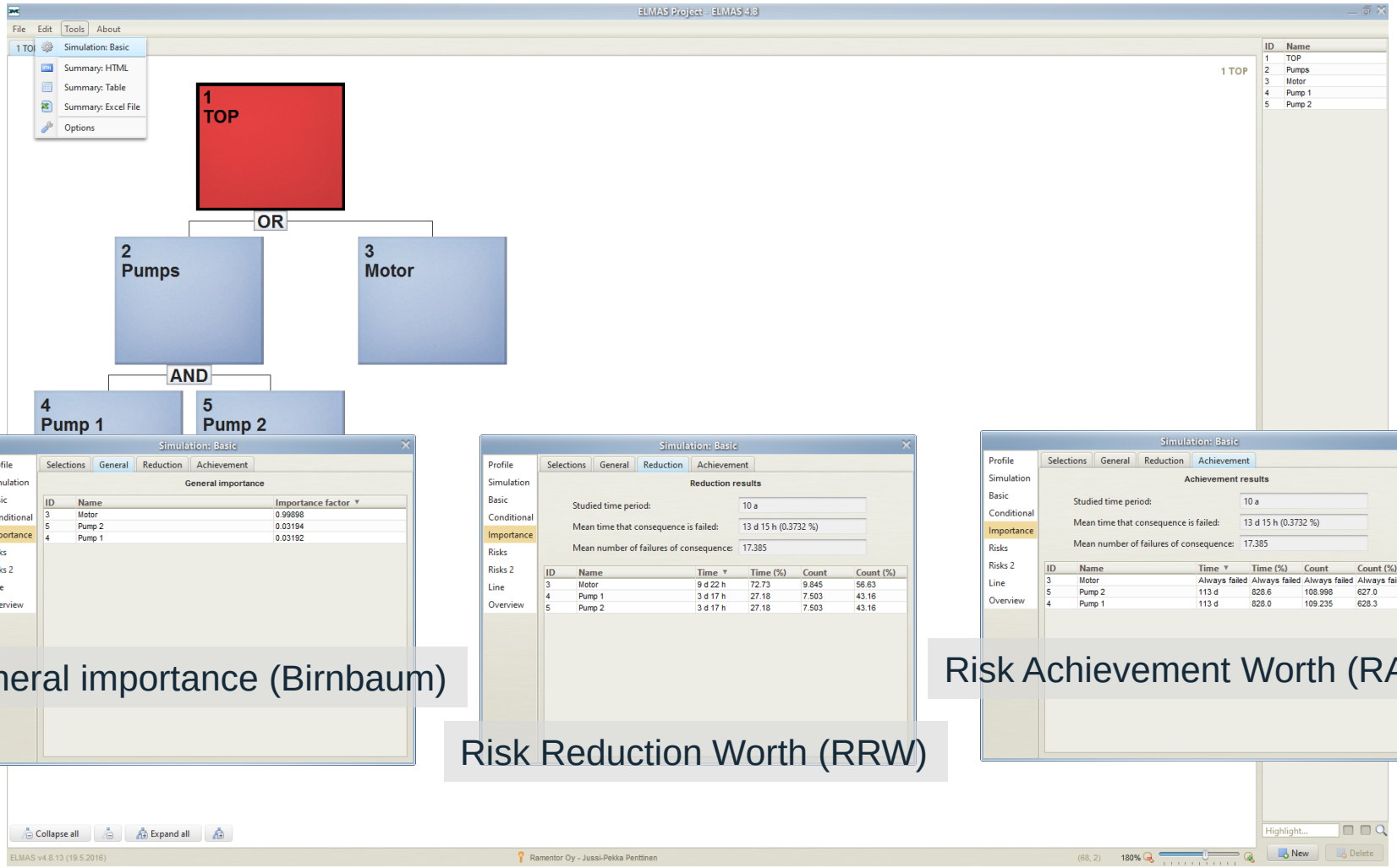
Basic Fault Tree: Basic Analysis Results



Basic Fault Tree: Conditional Results



Basic Fault Tree: Importance Measures

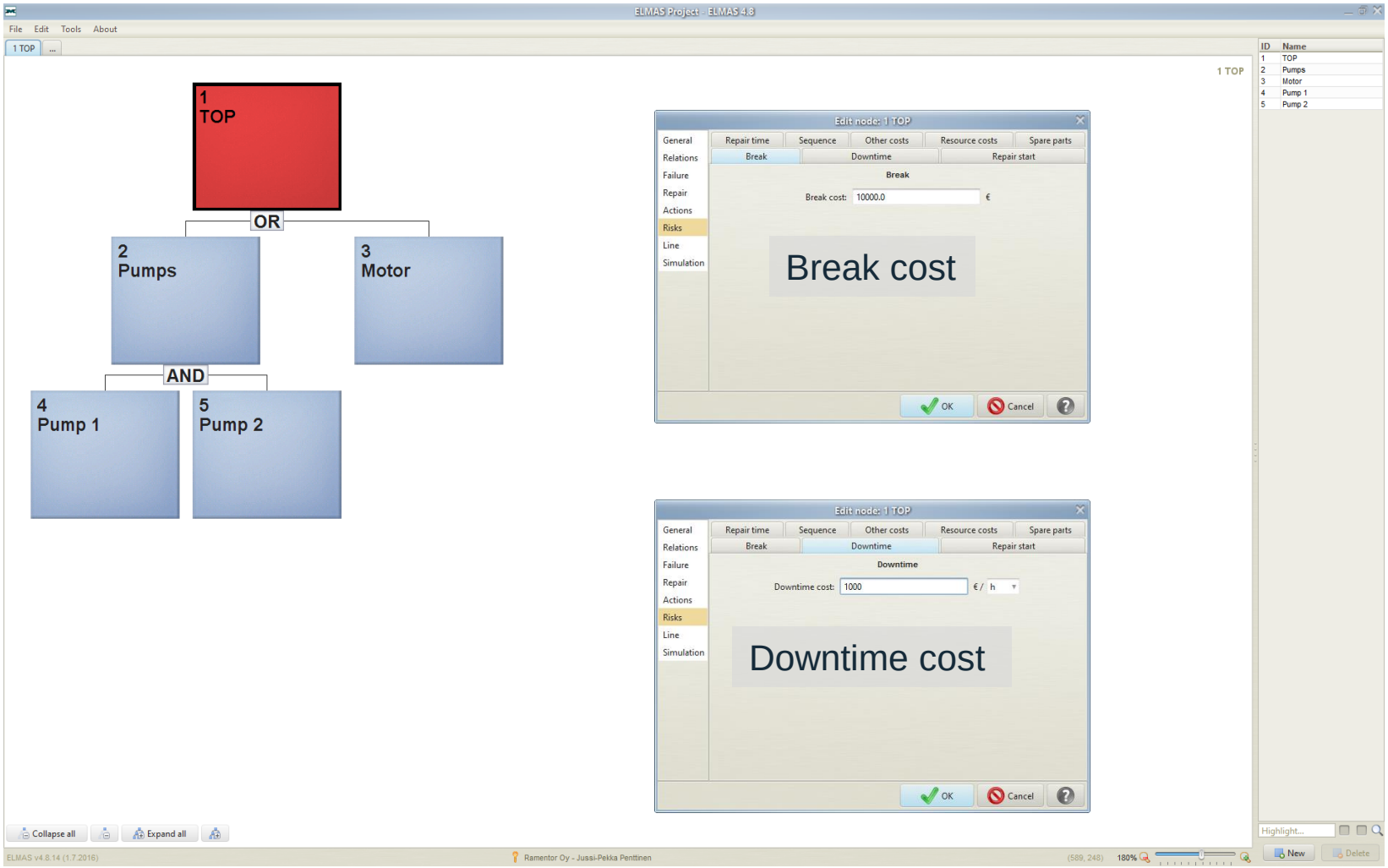


General importance (Birnbaum)

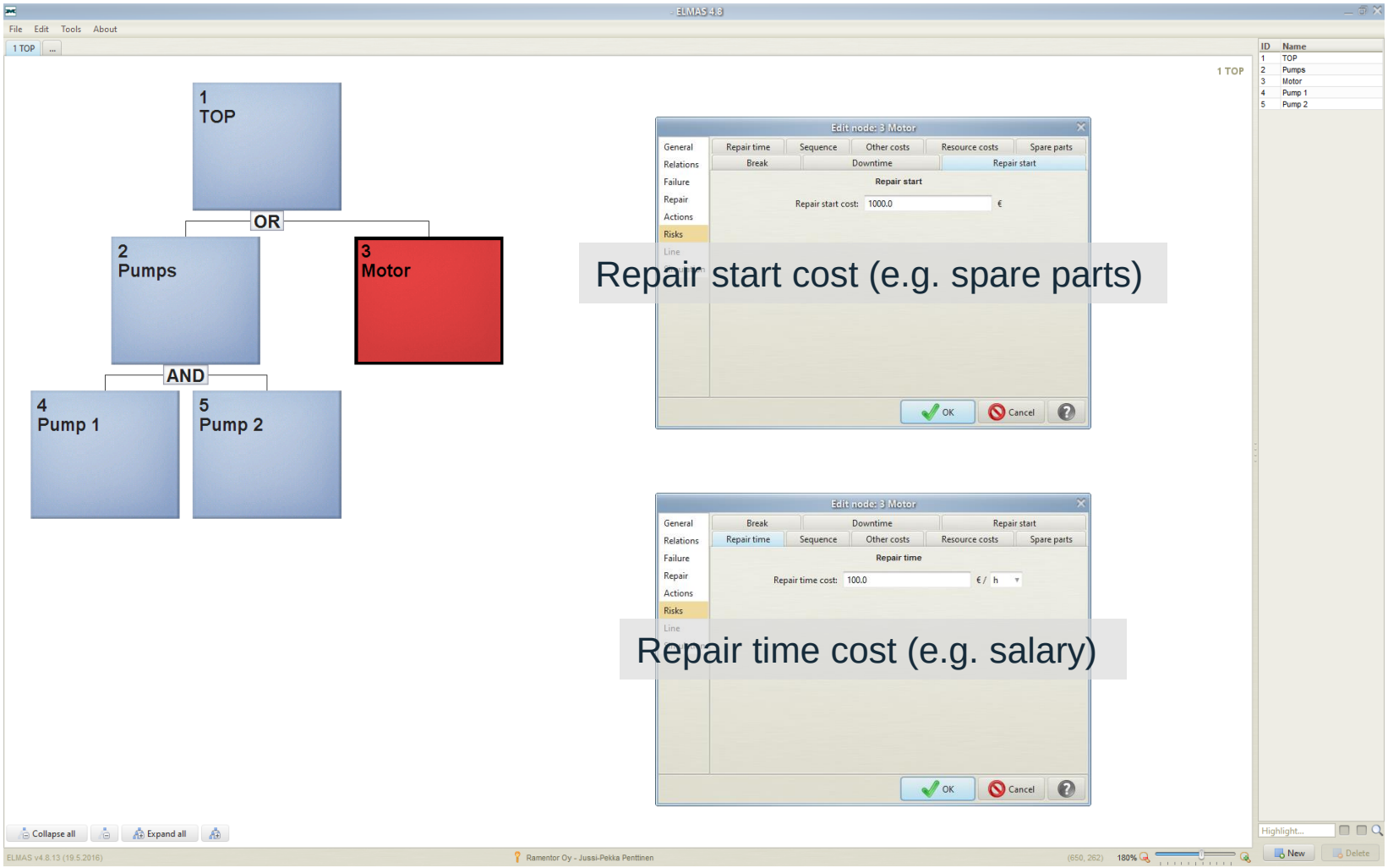
Risk Reduction Worth (RRW)

Risk Achievement Worth (RAW)

Basic Fault Tree: Break and Downtime Cost



Basic Fault Tree: Repair Start and Time



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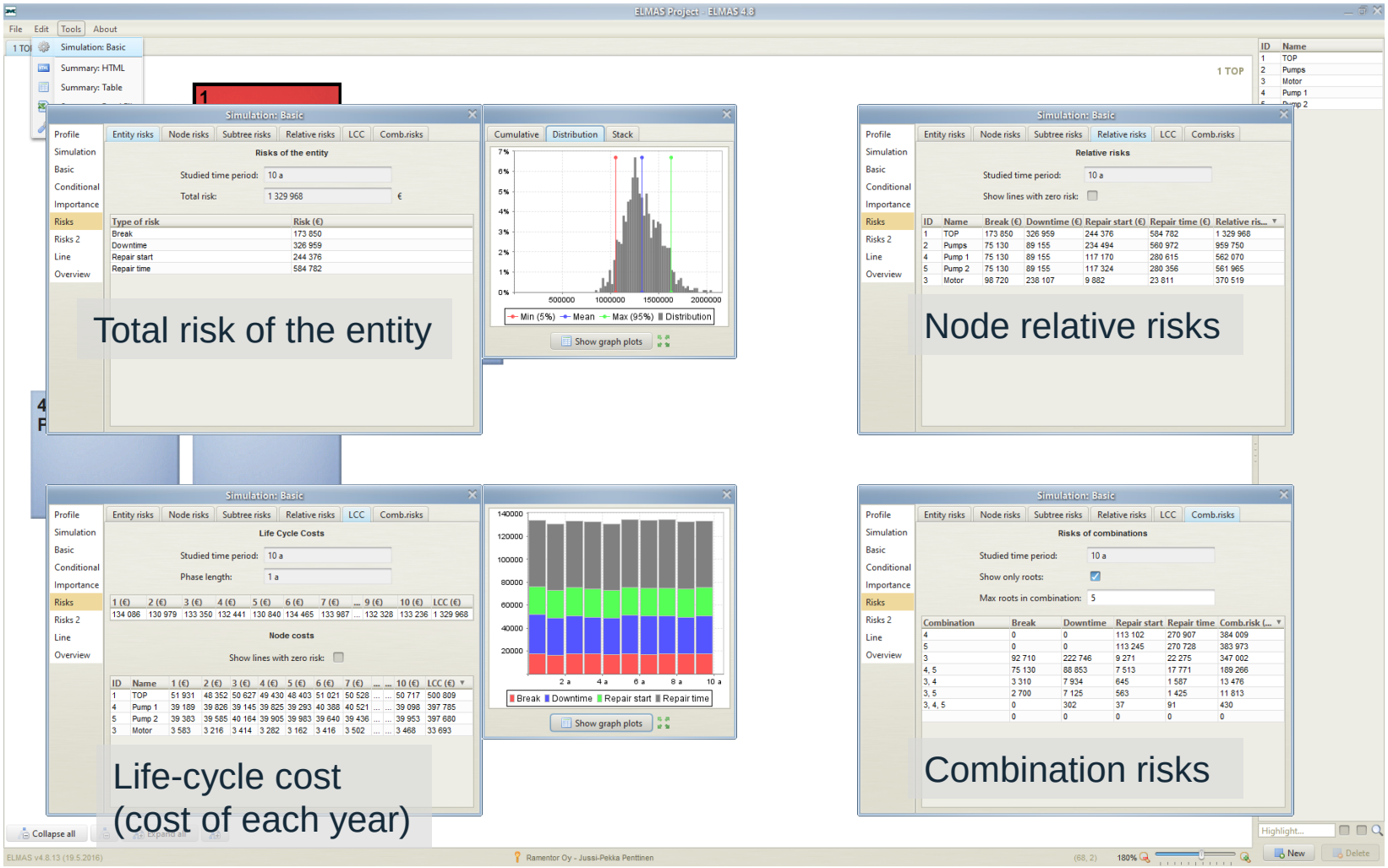
Basic Fault Tree: Risk Results



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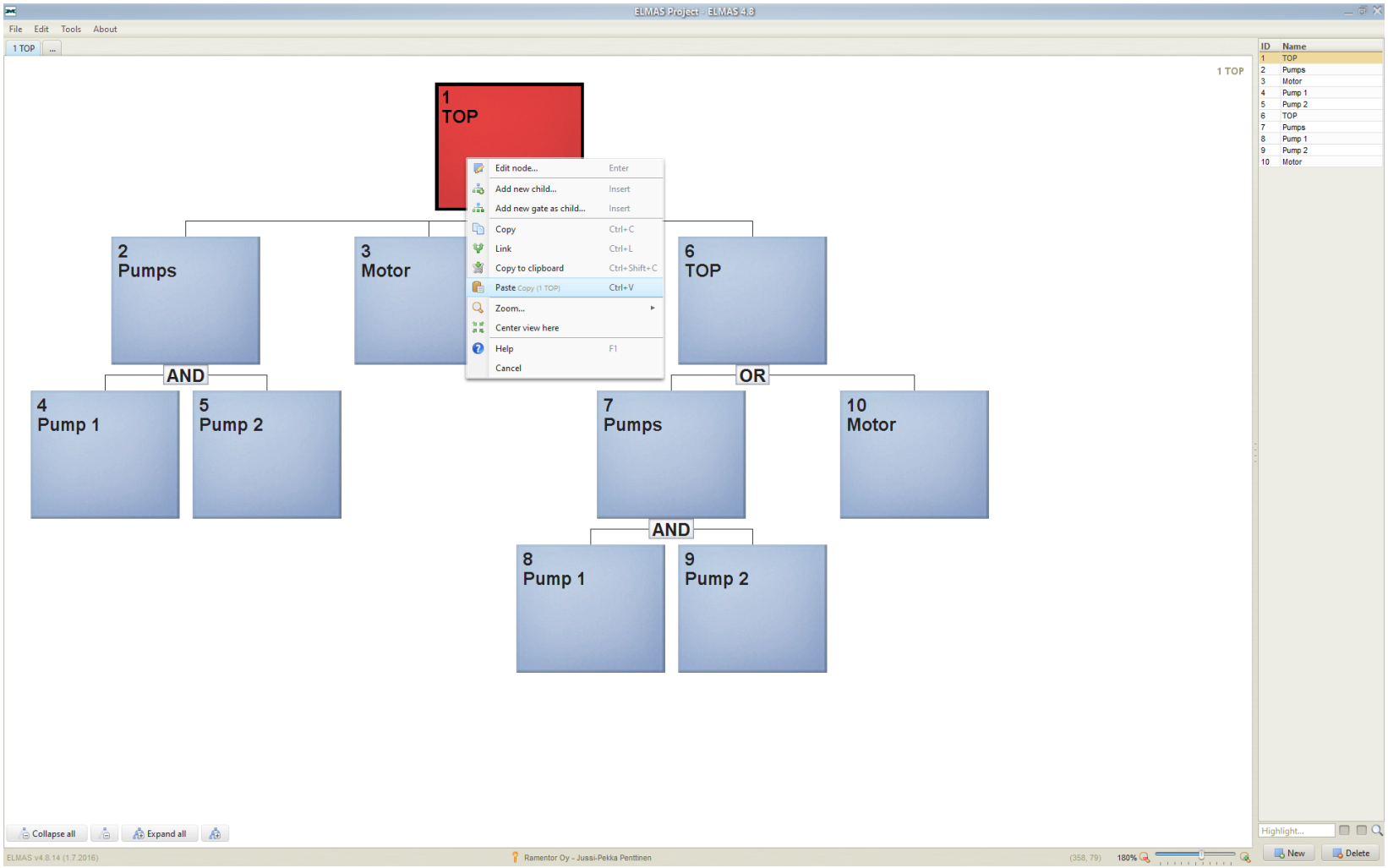
Larger fault tree – Data Interface

Larger Fault Tree: Copy-Paste Subtree



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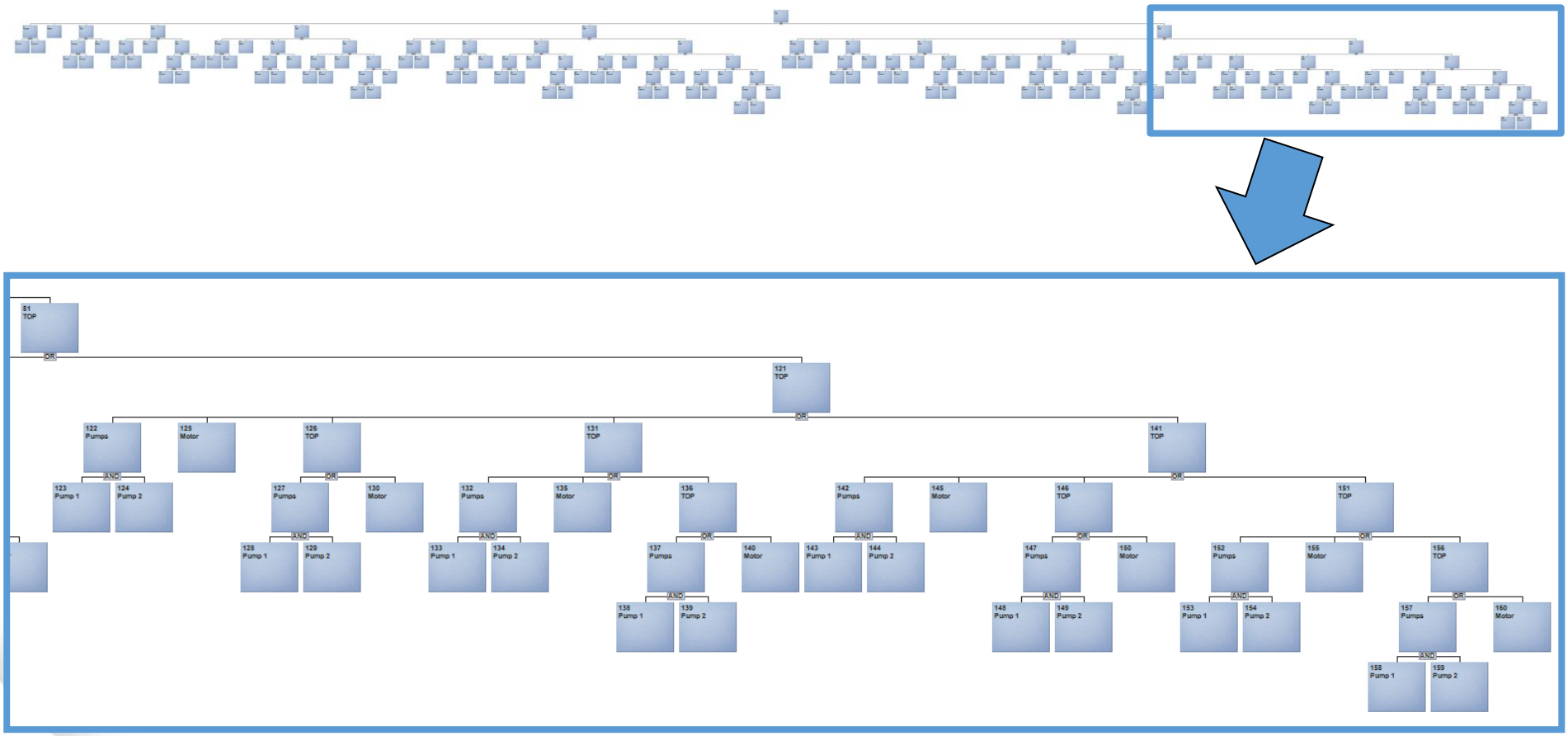
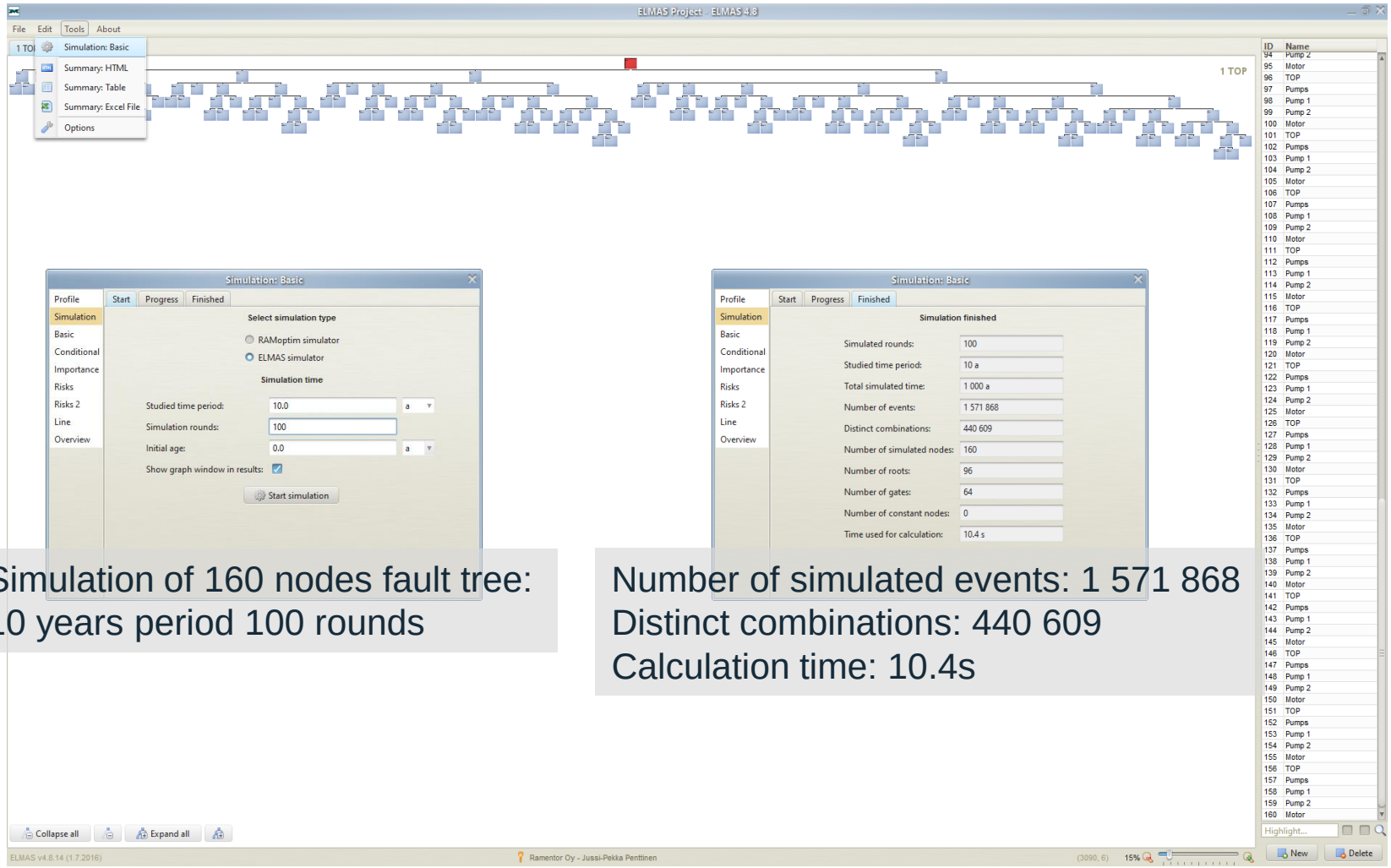
Larger Fault Tree: Repeat Until 160 Nodes



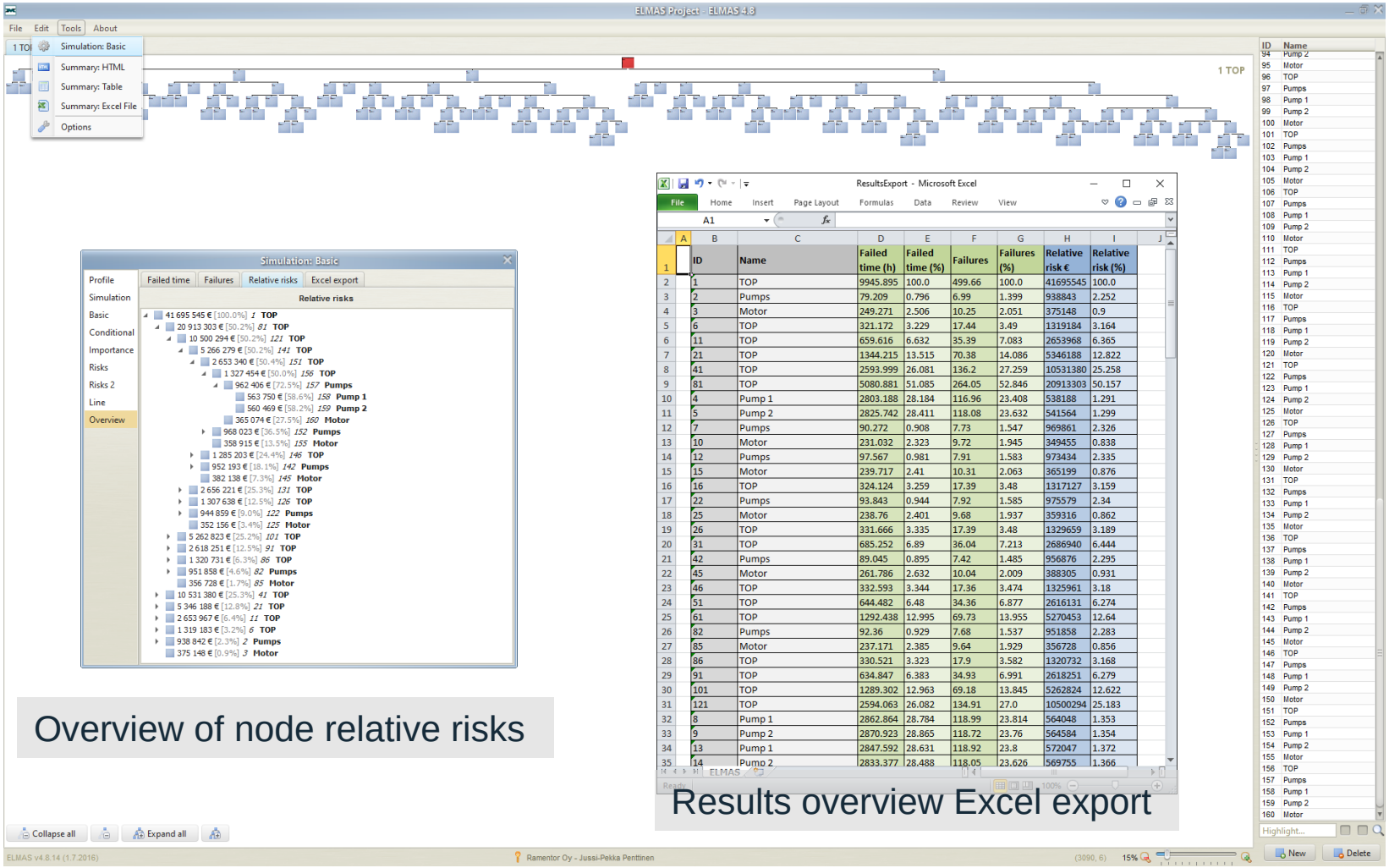
Larger Fault Tree: Simulation



Simulation of 160 nodes fault tree:
10 years period 100 rounds

Number of simulated events: 1 571 868
Distinct combinations: 440 609
Calculation time: 10.4s

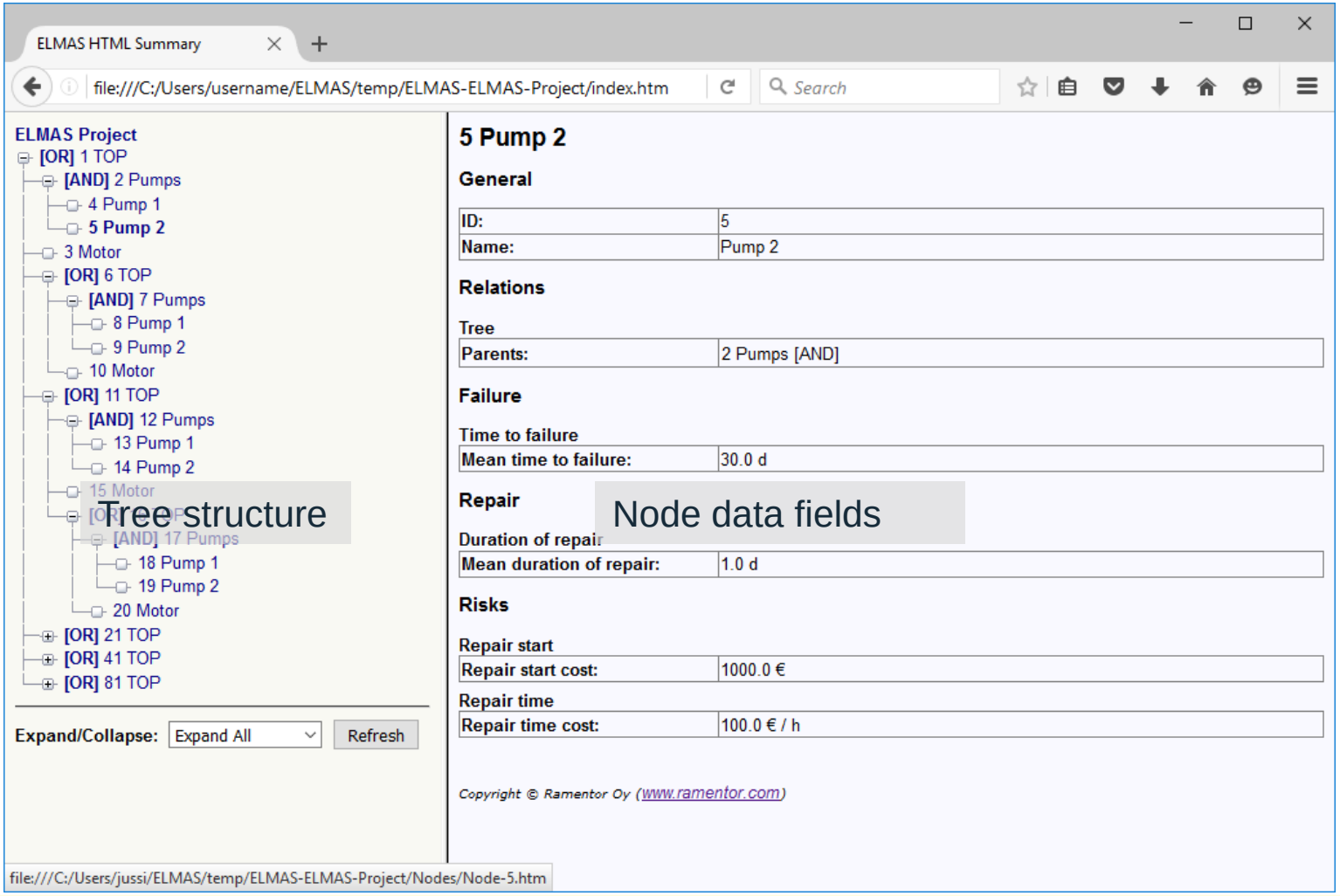
Larger Fault Tree: Results Overview



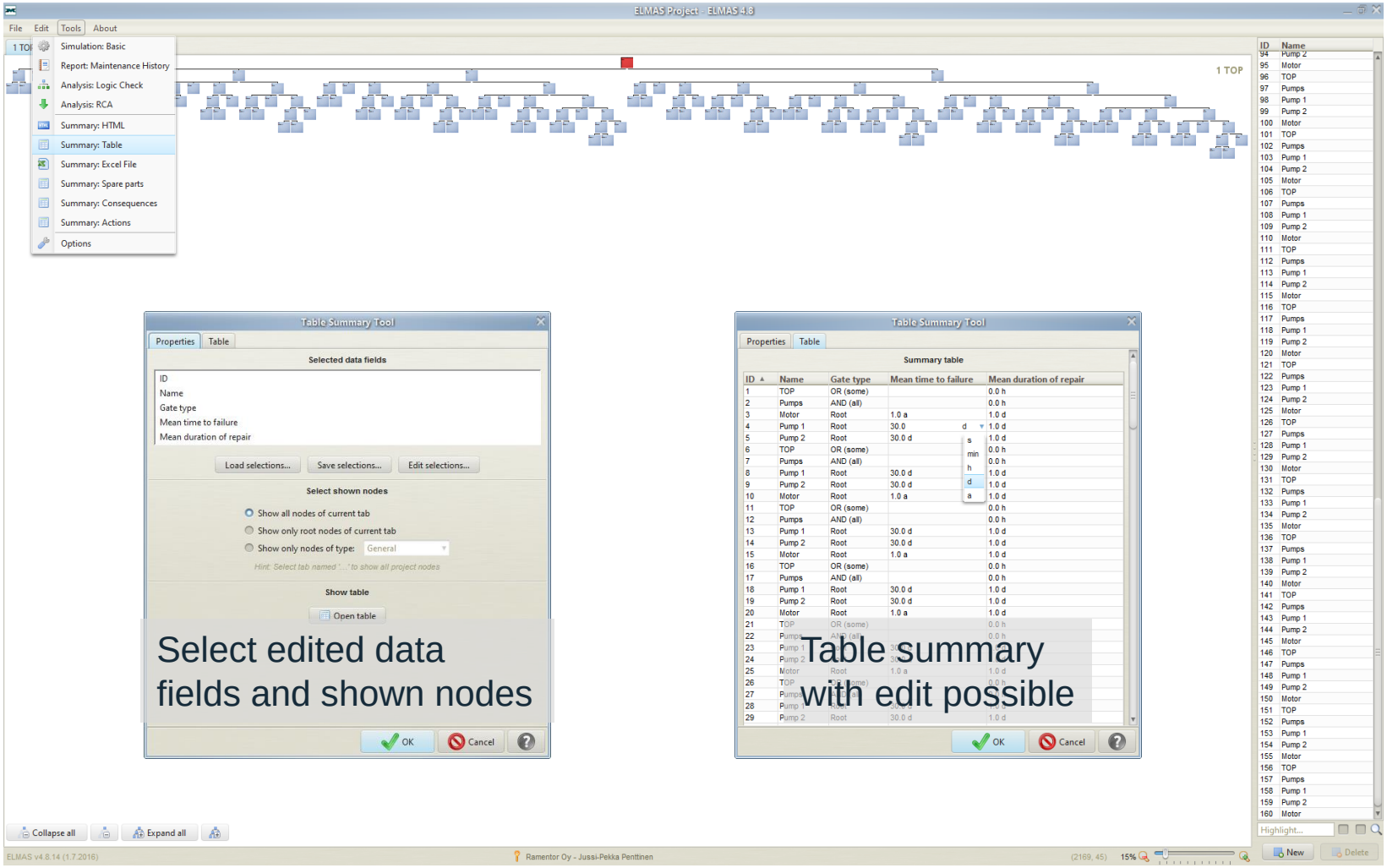
Overview of node relative risks

Results overview Excel export

Larger Fault Tree: HTML Summary



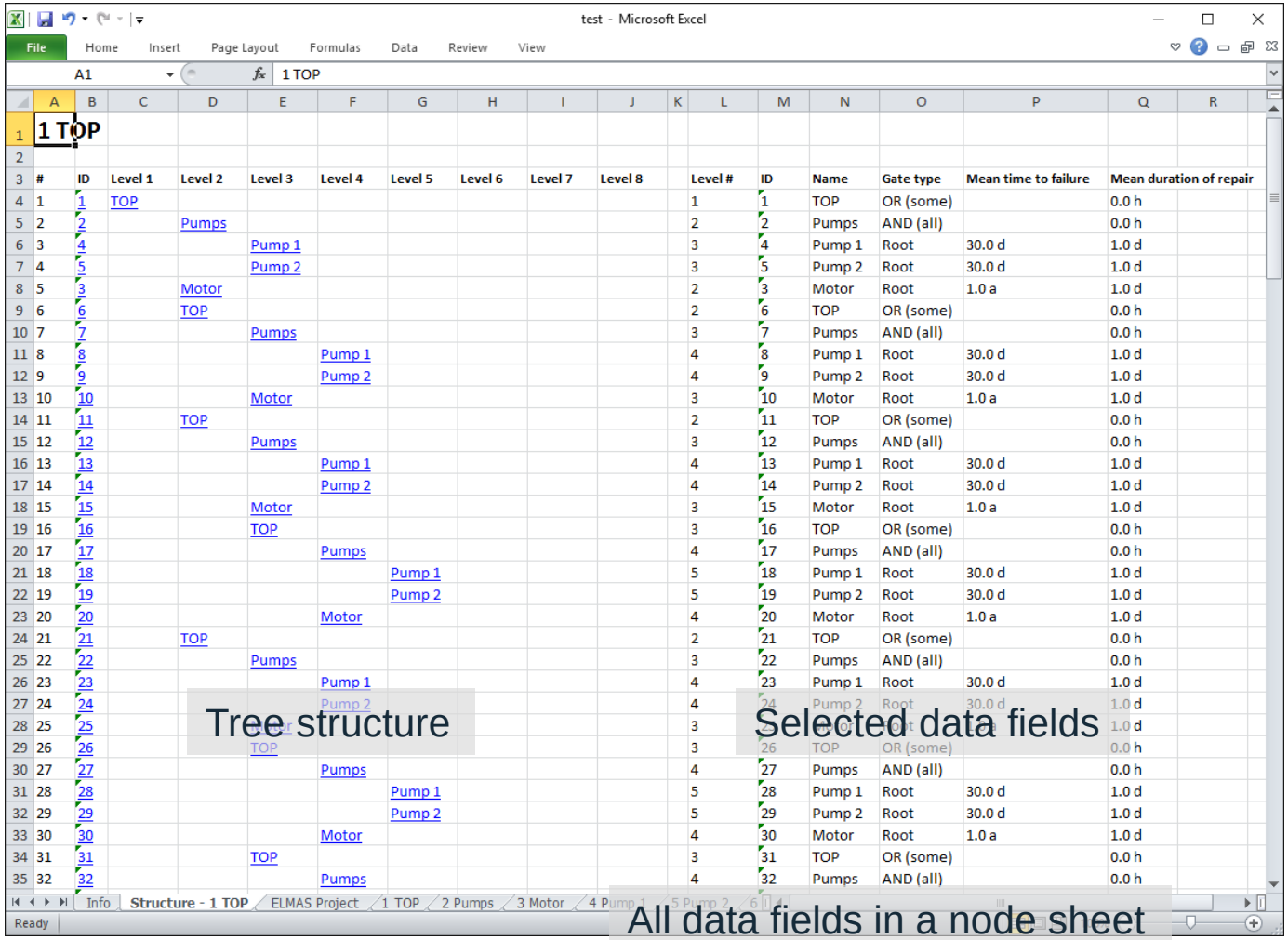
Larger Fault Tree: Table Summary



Select edited data fields and shown nodes

Table summary with edit possible

Larger Fault Tree: Excel Summary



#	ID	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8	Level #	ID	Name	Gate type	Mean time to failure	Mean duration of repair
1	1	TOP								1	1	TOP	OR (some)		0.0 h
2	2		Pumps							2	2	Pumps	AND (all)		0.0 h
3	4			Pump 1						3	4	Pump 1	Root	30.0 d	1.0 d
4	5			Pump 2						3	5	Pump 2	Root	30.0 d	1.0 d
5	3		Motor							2	3	Motor	Root	1.0 a	1.0 d
6	6		TOP							2	6	TOP	OR (some)		0.0 h
7	7			Pumps						3	7	Pumps	AND (all)		0.0 h
8	8				Pump 1					4	8	Pump 1	Root	30.0 d	1.0 d
9	9				Pump 2					4	9	Pump 2	Root	30.0 d	1.0 d
10	10			Motor						3	10	Motor	Root	1.0 a	1.0 d
11	11		TOP							2	11	TOP	OR (some)		0.0 h
12	12			Pumps						3	12	Pumps	AND (all)		0.0 h
13	13				Pump 1					4	13	Pump 1	Root	30.0 d	1.0 d
14	14				Pump 2					4	14	Pump 2	Root	30.0 d	1.0 d
15	15			Motor						3	15	Motor	Root	1.0 a	1.0 d
16	16			TOP						3	16	TOP	OR (some)		0.0 h
17	17				Pumps					4	17	Pumps	AND (all)		0.0 h
18	18					Pump 1				5	18	Pump 1	Root	30.0 d	1.0 d
19	19					Pump 2				5	19	Pump 2	Root	30.0 d	1.0 d
20	20				Motor					4	20	Motor	Root	1.0 a	1.0 d
21	21		TOP							2	21	TOP	OR (some)		0.0 h
22	22			Pumps						3	22	Pumps	AND (all)		0.0 h
23	23				Pump 1					4	23	Pump 1	Root	30.0 d	1.0 d
24	24				Pump 2					4	24	Pump 2	Root	30.0 d	1.0 d
25	25			Motor						3	25	Motor	Root	1.0 a	1.0 d
26	26			TOP						3	26	TOP	OR (some)		0.0 h
27	27				Pumps					4	27	Pumps	AND (all)		0.0 h
28	28					Pump 1				5	28	Pump 1	Root	30.0 d	1.0 d
29	29					Pump 2				5	29	Pump 2	Root	30.0 d	1.0 d
30	30				Motor					4	30	Motor	Root	1.0 a	1.0 d
31	31			TOP						3	31	TOP	OR (some)		0.0 h
32	32				Pumps					4	32	Pumps	AND (all)		0.0 h

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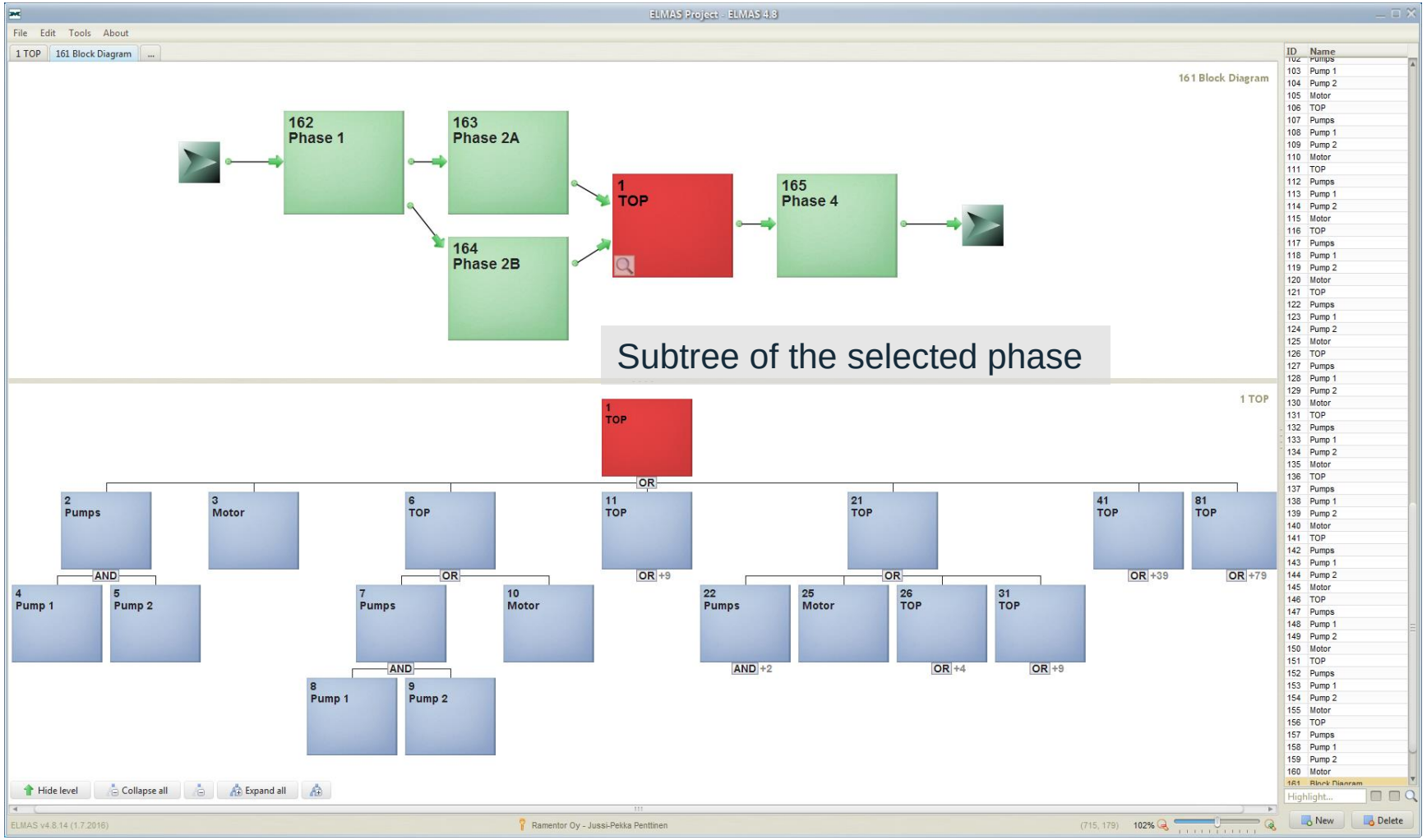
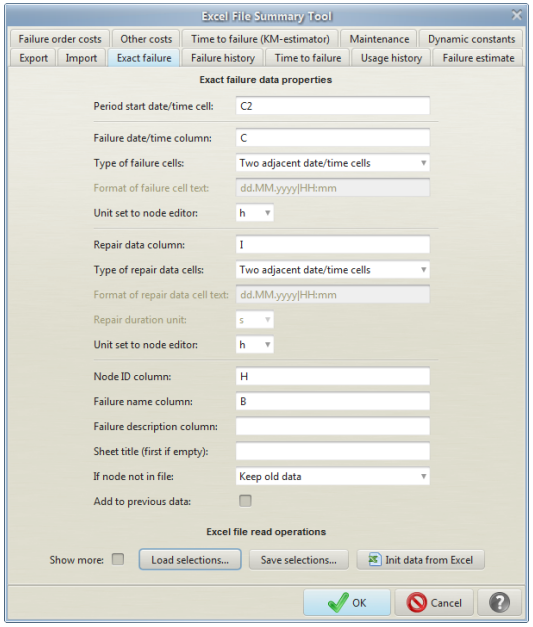
Advanced Features

Advanced Features: Block Diagram



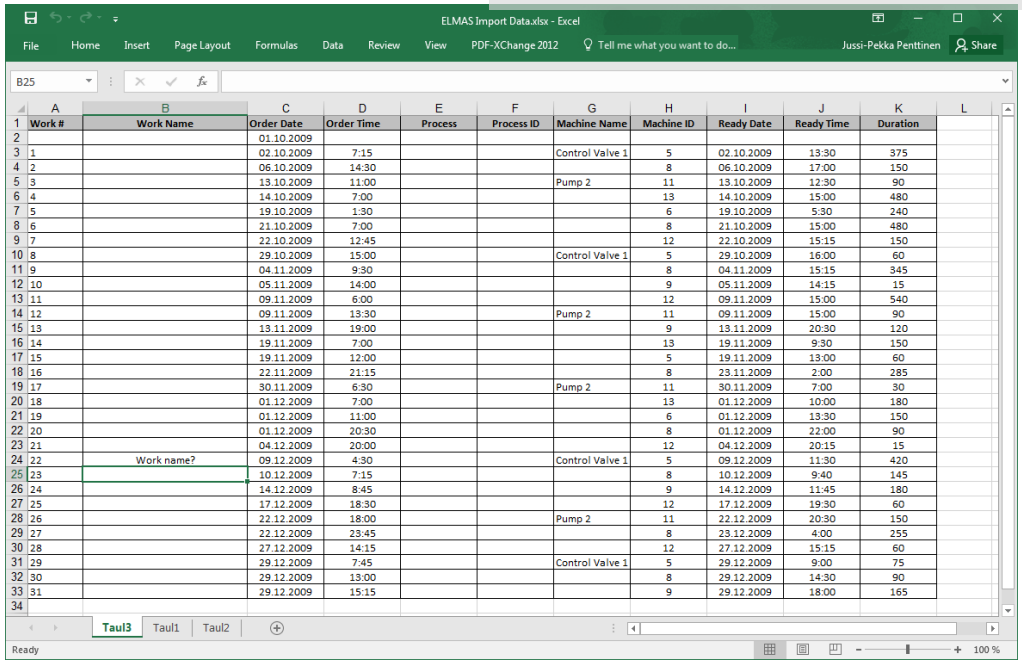
Advanced Features: Data Import

Several import types in own tabs



Select from ELMAS which type of Excel is imported and the format used in ELMAS

Machine ID is used to find correct ELMAS model node



Work #	Work Name	Order Date	Order Time	Process	Process ID	Machine Name	Machine ID	Ready Date	Ready Time	Duration
		01.10.2009								
1		02.10.2009	7:15			Control Valve 1	5	02.10.2009	13:30	375
2		06.10.2009	14:30				8	06.10.2009	17:00	150
3		13.10.2009	11:00			Pump 2	11	13.10.2009	12:30	90
4		14.10.2009	7:00				13	14.10.2009	15:00	480
5		19.10.2009	1:30				6	19.10.2009	5:30	240
6		21.10.2009	7:00				8	21.10.2009	15:00	480
7		22.10.2009	12:45				12	22.10.2009	15:15	150
8		29.10.2009	15:00			Control Valve 1	5	29.10.2009	16:00	60
9		04.11.2009	9:30				8	04.11.2009	15:15	345
10		05.11.2009	14:00				9	05.11.2009	14:15	15
11		09.11.2009	6:00				12	09.11.2009	15:00	540
12		09.11.2009	13:30			Pump 2	11	09.11.2009	15:00	90
13		13.11.2009	19:00				9	13.11.2009	20:30	120
14		19.11.2009	7:00				13	19.11.2009	9:30	150
15		19.11.2009	12:00				5	19.11.2009	13:00	60
16		22.11.2009	21:15				8	23.11.2009	2:00	285
17		30.11.2009	6:30			Pump 2	11	30.11.2009	7:00	30
18		01.12.2009	7:00				13	01.12.2009	10:00	180
19		01.12.2009	11:00				6	01.12.2009	13:30	150
20		01.12.2009	20:30				8	01.12.2009	22:00	90
21		04.12.2009	20:00				12	04.12.2009	20:15	15
22	Work name?	09.12.2009	4:30			Control Valve 1	5	09.12.2009	11:30	420
23		10.12.2009	7:15				8	10.12.2009	9:40	145
24		14.12.2009	8:45				9	14.12.2009	11:45	180
25		17.12.2009	18:30				12	17.12.2009	19:30	60
26		22.12.2009	18:00			Pump 2	11	22.12.2009	20:30	150
27		22.12.2009	23:45				8	23.12.2009	4:00	255
28		27.12.2009	14:15				12	27.12.2009	15:15	60
29		29.12.2009	7:45			Control Valve 1	5	29.12.2009	9:00	75
30		29.12.2009	13:00				8	29.12.2009	14:30	90
31		29.12.2009	15:15				9	29.12.2009	18:00	165

Example Excel sheet with work orders as rows

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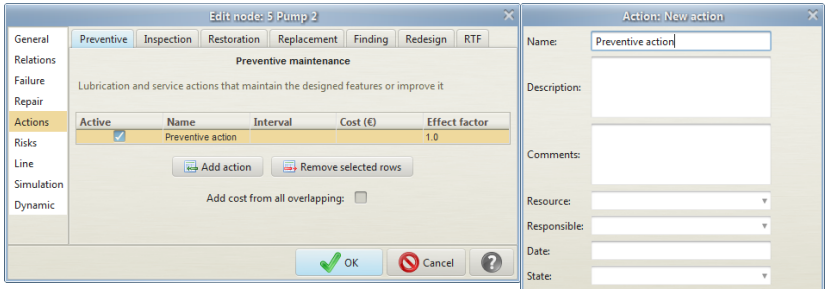
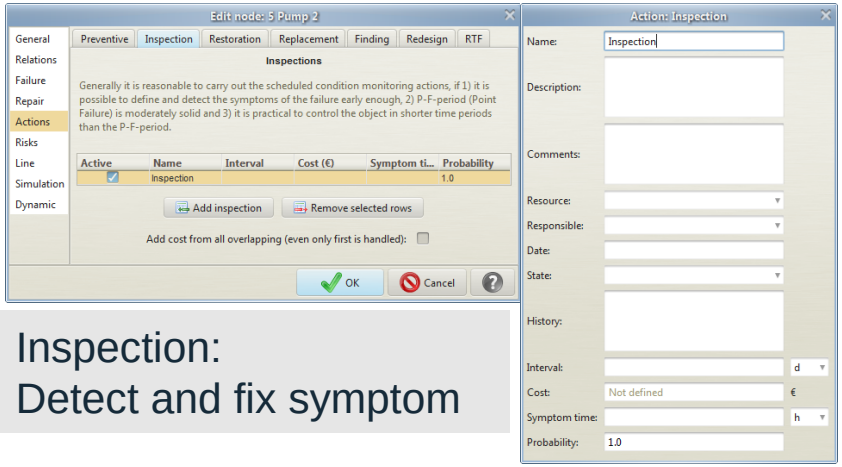
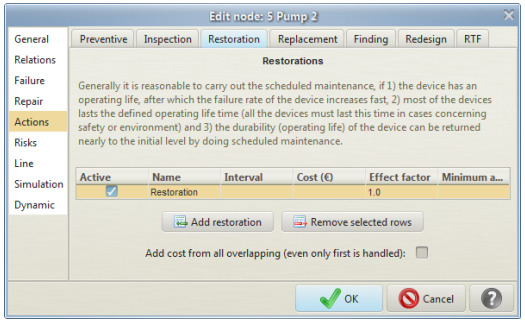
Advanced Features: Maintenance Actions



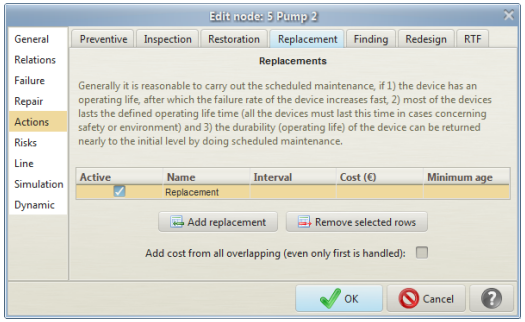
Preventive maintenance:
Improve condition by effect factor



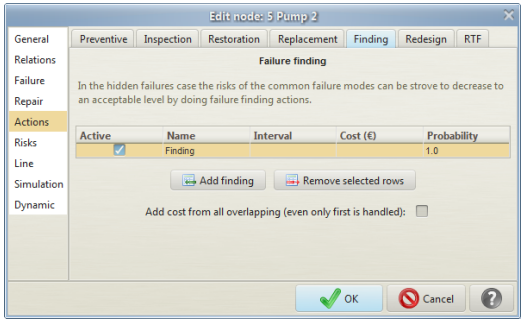
Inspection:
Detect and fix symptom



Restoration:
Improve age by effect factor

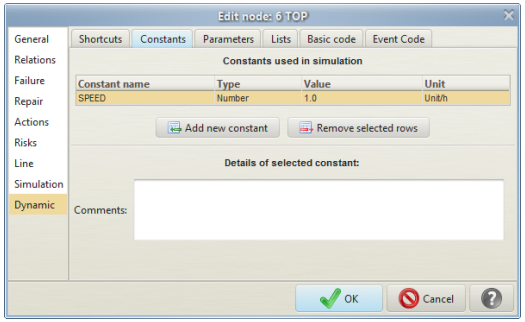


Replacement:
Improve as good as new

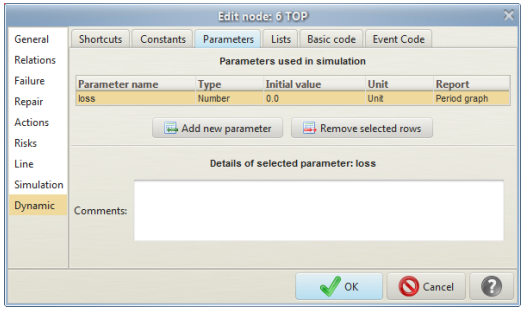


Finding:
Find and fix hidden failure

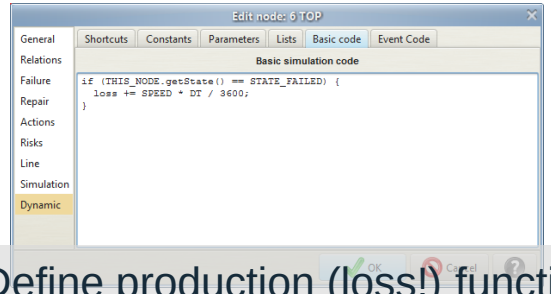
Advanced Features: Dynamic simulation



Define constant: SPEED (production speed units/h)



Define parameter: loss (cumulative value added when component is failed)

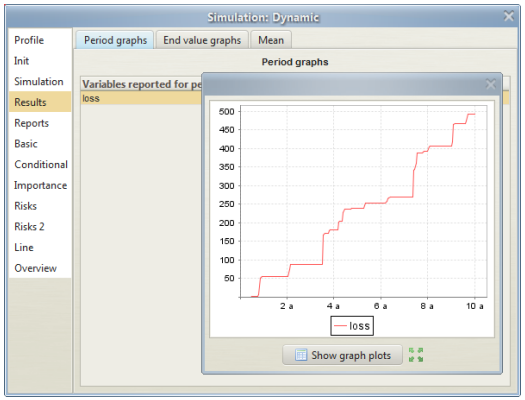


In addition to each simulation step it is also possible to add code for each simulation event

Define production (loss!) function:

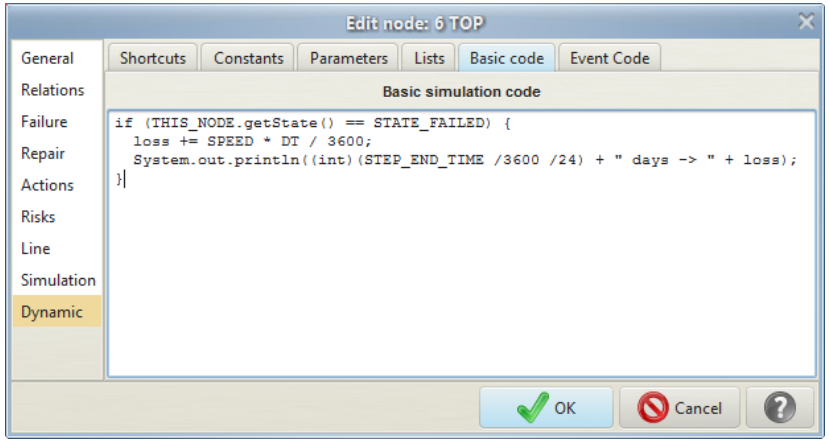
```
if (THIS_NODE.getState() == STATE_FAILED) {
  loss += SPEED * DT / 3600;
}
```

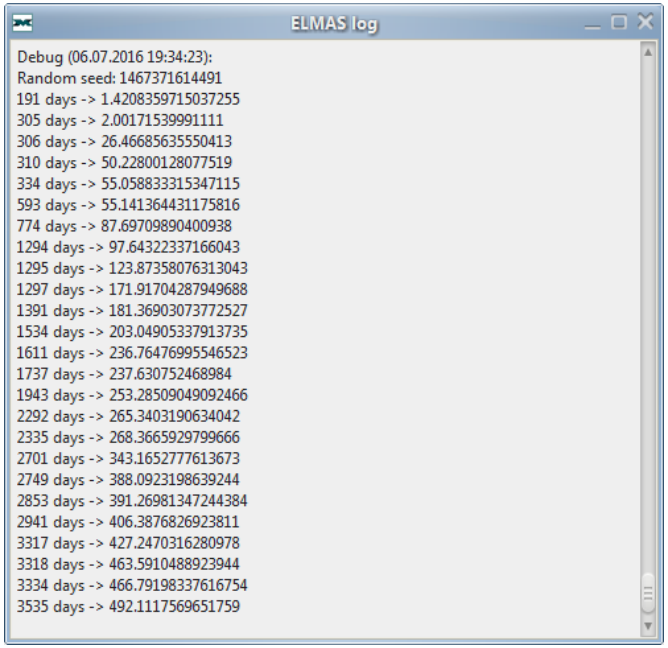
(DT = simulation step length in seconds)



Dynamic simulation results for the parameter

Advanced Features: Debug Log Window





Print debug log for example after each event (current time in days + current loss):

```
(int)(STEP_END_TIME /3600 /24) + " days -> " + loss
```

(STEP_END_TIME = simulation step end time in seconds)

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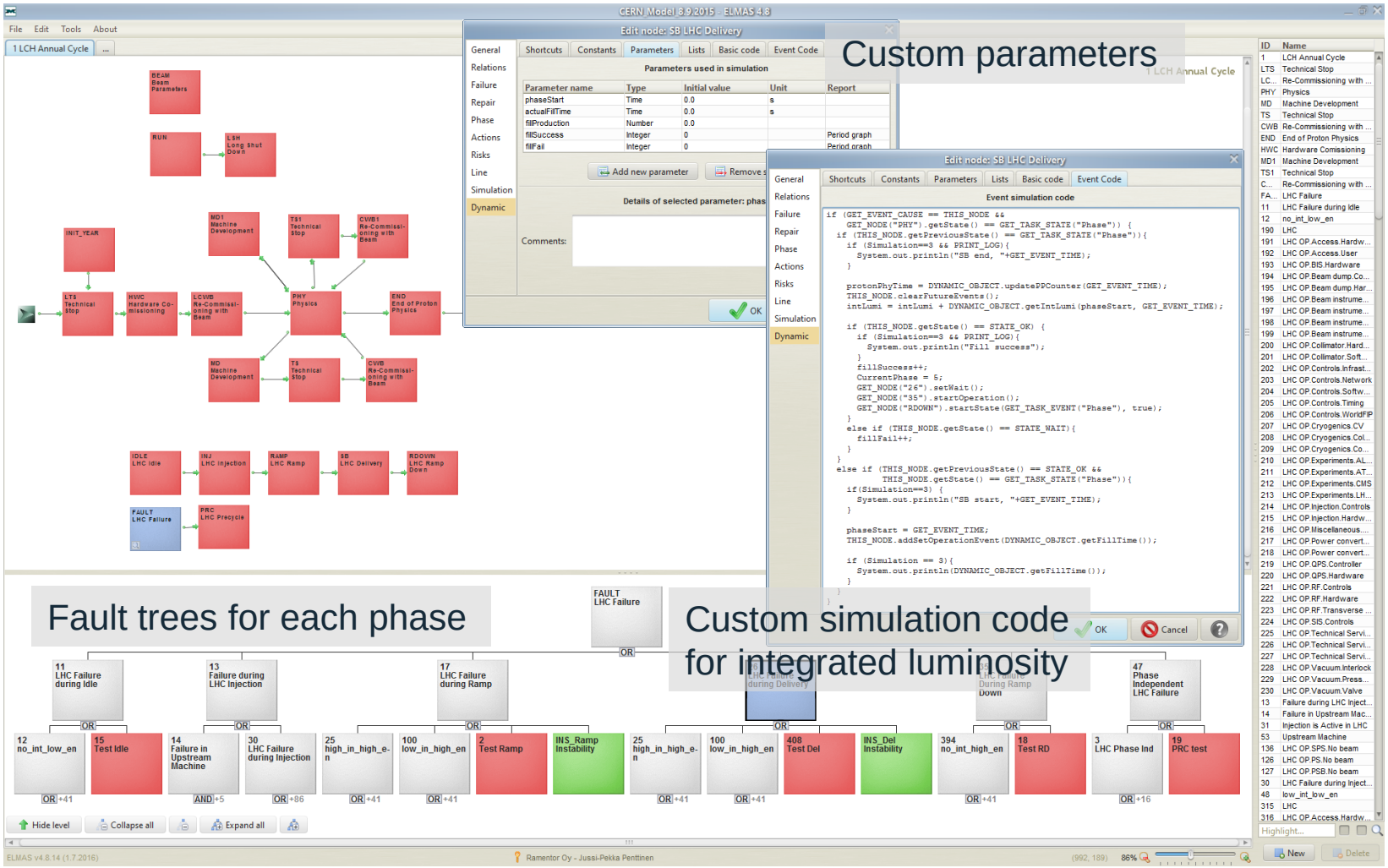
Advanced Features: LHC Dynamic Model



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Design. Analyze. Optimize.

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