

# Methodology for Supporting the Determination of Human Error Probabilities from Simulator Sourced Data

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**SACADA HRA Methodology –  
A Game Changer for HRA Methodologies ?**

## SACADA (The Scenario Authoring, Characterization, and Debriefing Application)

- NPP simulators provide empirical data on control room processes and actions
- Licensed simulator instructor and licensed Operator input
- A significant amount of simulator data has been acquired from pilot efforts
- SACADA process provides a robust data source
- Accompanying methodology produces a significant improvement in HRA methodology

## SACADA (The Scenario Authoring, Characterization, and Debriefing Application)

- The SACADA data structure can be used to inform IDHEAS and other HRA methodologies

# Objective

- Demonstrate HEPs can be calculated from SACADA process
- Demonstrate reduction in HEP uncertainty

# Data Development & Processing

- SACADA data is structured by Macroognitive Functions (Mcog)
  - Monitoring/Detecting
  - Diagnosis
  - Response Planning
  - Manipulation
  - Communication (excluded from the study)
- Human actions in simulator scenarios are defined as Training Objective Elements (TOEs)
- Each TOE is characterized by a set of Situational Factor (SF) states referred to as the “Context”
  - TOEs and SF states are defined by licensed simulator instructors
  - TOEs with the same Context represent the same human action

# SACADA Concept: A Game Changer for HRA Methodologies?

Traditional HRA	SACADA HRA
Expert judgment driven	Data driven
HFEs based on possible failures in scenarios	HFEs are sum of TOEs; actual human actions in the procedures
PSFs or PIFs are assigned using expert judgment	SFs are assigned by instructors and verified by licensed operators. PIFs are assigned by operators and verified by instructors.

# Pro's and Con's of SACADA Methodology

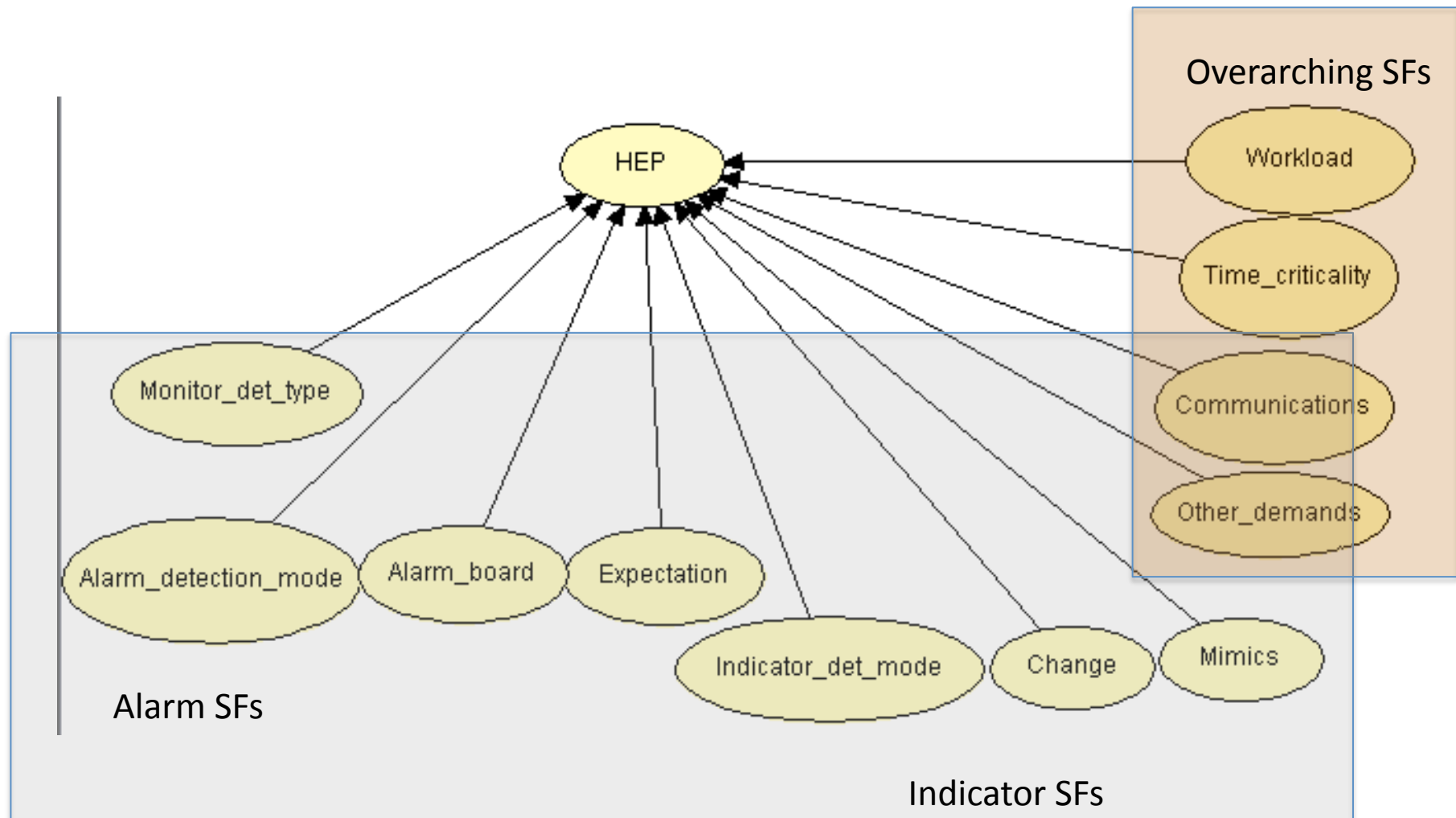
Pro	Con
TOEs are actual procedural steps, identified by instructors	Not in the Control Room
TOEs are graded by importance by instructors	TOEs may be more severe than actual HFEs (That the failure may not actually lead to Core melt, rather is an instructor defined failure)
TOEs are evaluated by the crew after the scenario exercise (error modes and error causes PIFs)	SF context grouping should result in same generic action. If not, could be a source of uncertainty and SF coding should be reviewed.



# Bayesian Network Approach

- Able to incorporate expert opinion and empirical data
- Graphical and visual
- Human actions are functions of SFs
- Updatable
  - Learning algorithm to include experience
- Hugin software program was chosen

# Detection / Monitoring: MCog1



# BN Model Parameters

- The probabilities of the SF states based on plant operating experience or expert judgment
- Prior probabilities for each context input
  - Expert judgment
  - HRA method (e.g., SPAR-h)
  - Other approach (weight factors developed from SACADA data, currently underway)
  - Over time, priors will come from SACADA data
- The number of trials and failures for each context
  - HUGIN uses counting-learning algorithm to update the prior from the SACADA input file

Example 1: Feed and bleed

# SFs from TOEs

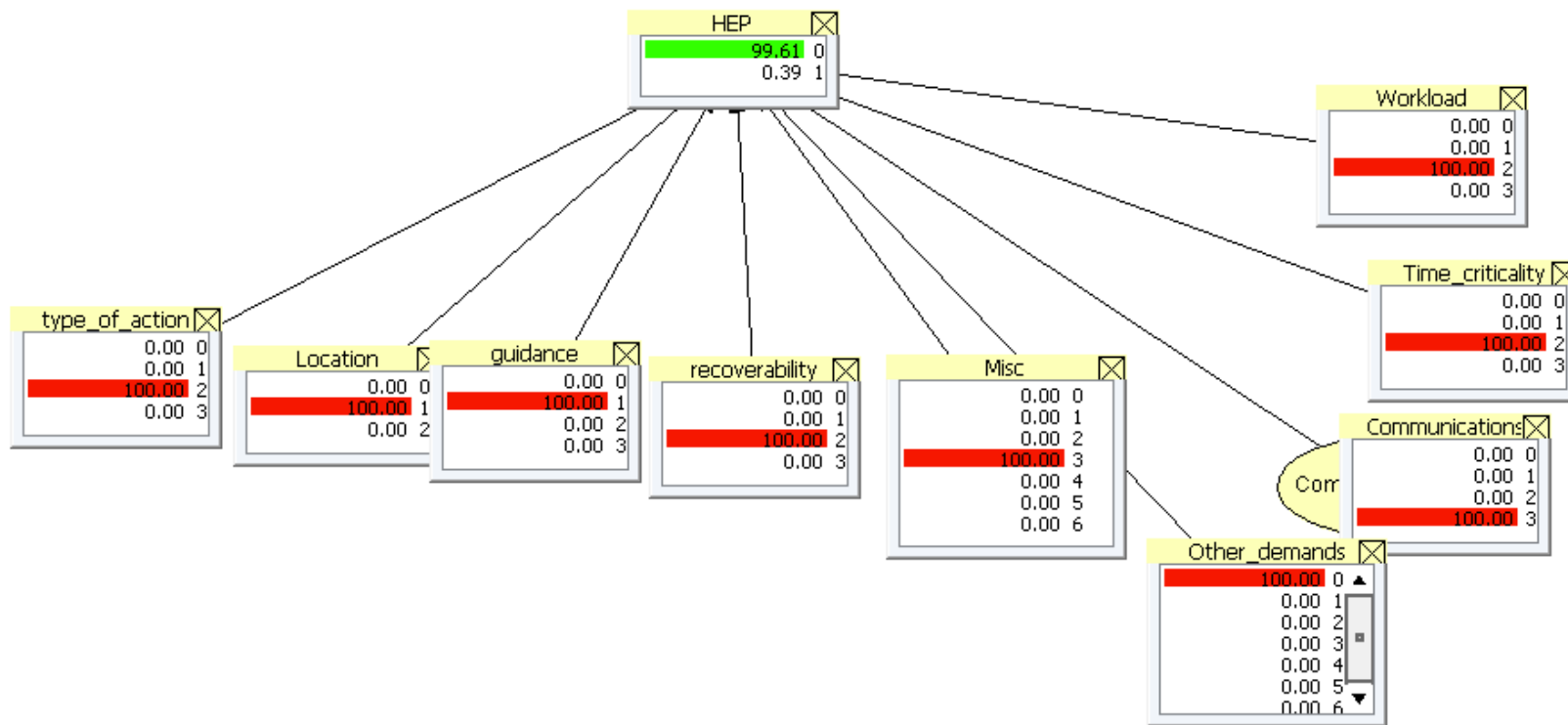
TOE	MCog	SF1	SF2	SF3	SF4	SF5	SF6	SF7	SF8
Commences monitoring Critical Safety Functions. (Recognizes and informs US of red path on Heat Sink.)	1	6	0	0	0	3	2	0	0
Transitions to OPOP05-EO-FRH1, Response to Loss Of Secondary Heat Sink when addendum 5 is complete.	2	0	0	0	0	0	0	0	2
Trip RCPs per FRH1 CIP or step 2 due to inadequate WR S/G level. (<50% on 2 or more SG)	3	0	0	0	0	0	0	0	0
Initiate RCS bleed and feed so that the RCS depressurizes sufficiently for HHSI pump injection to occur	3	0	0	0	0	0	0	0	0

Embedded in these steps is the action to open PORVs, but should be separated and considered as another human action.

# Identify SFs

TOE & Description		SACADA PSFs			
TOE	Description	Detection Macroognitive Function	Diagnosis & Planning Response Macroognitive Function	Manipulation Macroognitive Function	Overarching Contexts
1249	Commences monitoring Critical Safety Functions. (Recognizes and informs US of red path on Heat Sink.)	<b>Detection Type:</b> Computer  <b>Detection Mode:</b> Procedure Directed  <b>Individual Indicator:</b> Slight Change			
1250	Transitions to OPOP05-EO-FRH1, Response to Loss Of Secondary Heat Sink when addendum 5 is complete.		<b>Diagnosis and Response Planning: Diagnosis or Response Planning</b>  Primarily Response Planning/Decision Making  <b>Response Planning /Decision Making Basis</b> Knowledge  <b>Response Planning /Decision Making Uncertainty</b> Clear		

# Feed& Bleed:MCog3=.0039

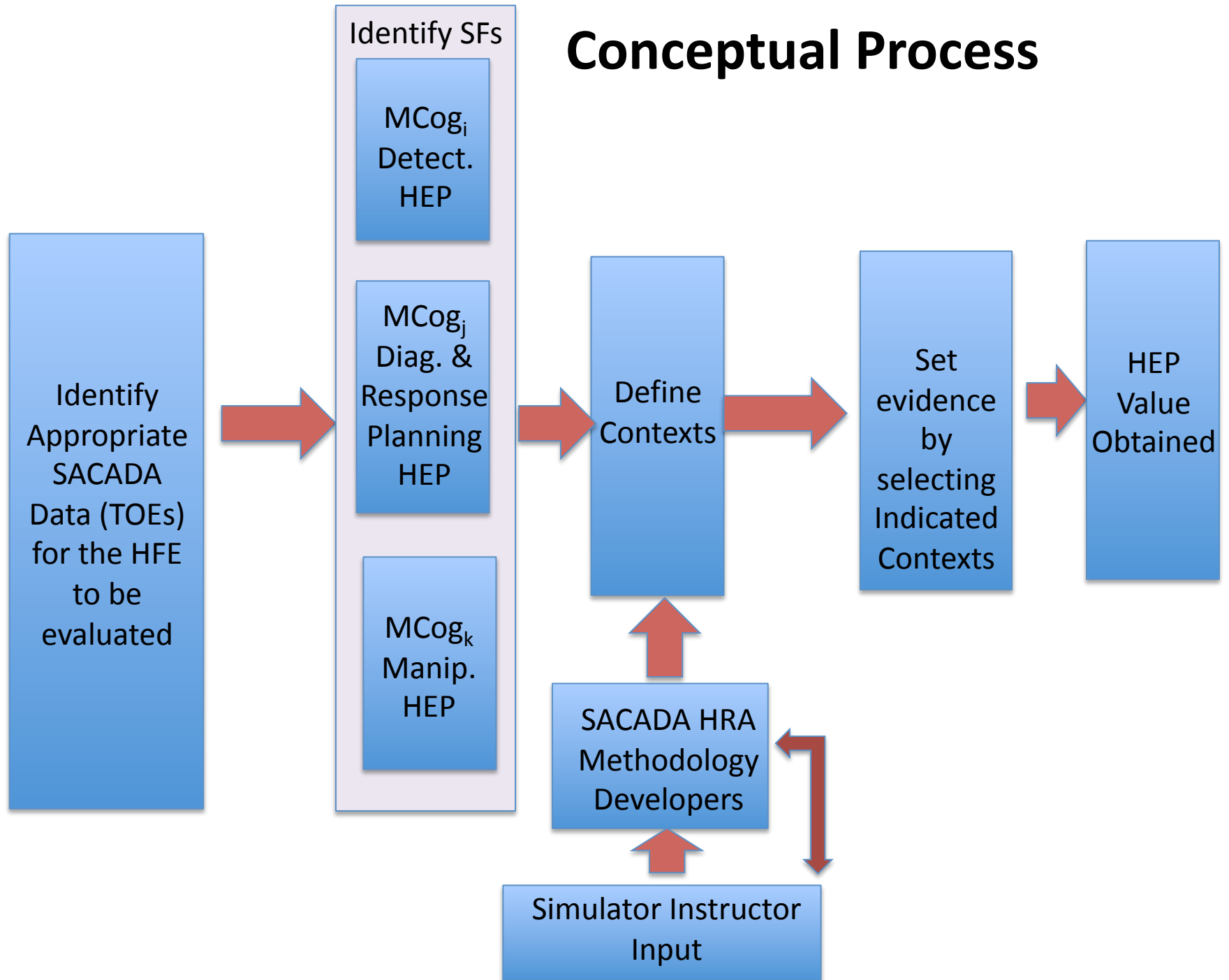


# Feed & Bleed HFE Results

- MCog1 0.0033
- MCog2a 0
- MCog2b 0.053
- MCog3 0.0039
  
- HFE HEP = .0602



# Conceptual Process



# Conclusions

- The SACADA data has been shown to be useful for developing HEPs
- Meets the requirements from the ASME/ANS PRA standard
- Realistic
- Over time can grow to provide generic HEPs that are updatable with plant specific HEPs
- Can be used to improve plant performance

Thank you

Backup slides

# Factor Analysis for Manipulation

SF	Factor 1	Factor 2
Type of action	0.024	-0.019
Location	-0.140	-0.653
Guidance	-0.077	1.003
Recoverability	0.291	0.063
Miscellaneous	0.081	0.149
Workload	0.805	0.004
Time criticality	0.839	0.124
Communication	0.476	-0.197
Other	0.177	0.136

Factor 1, we could call it "Crew dynamics."

Factor 2 "Human-machine interface."

# Part of Alarm\_Issue Conditional Probability Table

Other_dem...															6								
Communica...															3								
Time_criti...															3								
Workload															3								
Expectation															3								
Alarm_board															3								
Alarm_dete...	2						3							4									
Monitor_de...	1	2	3	4	5	6	7	0	1	2	3	4	5	6	7	0	1	2	3	4	5	6	7
0	0.9943	0.9943	0.9943	0.9943	0.9943	0.9943	0.999999	0.9943	0.923082	0.9943	0.9943	0.9943	0.9943	0.916673	0.9943	0.9943	0.900009	0.9943	0.9943	0.9943	0.9943	0.999999	0.846165
1	0.0057	0.0057	0.0057	0.0057	0.0057	0.0057	1.4246...	0.0057	0.076918	0.0057	0.0057	0.0057	0.0057	0.083327	0.0057	0.0057	0.099991	0.0057	0.0057	0.0057	0.0057	1.1397...	0.153835
Experience	0.001	0.001	0.001	0.001	0.001	0.001	4.001	0.001	13.001	0.001	0.001	0.001	0.001	12.001	0.001	0.001	10.001	0.001	0.001	0.001	0.001	5.001	13.001

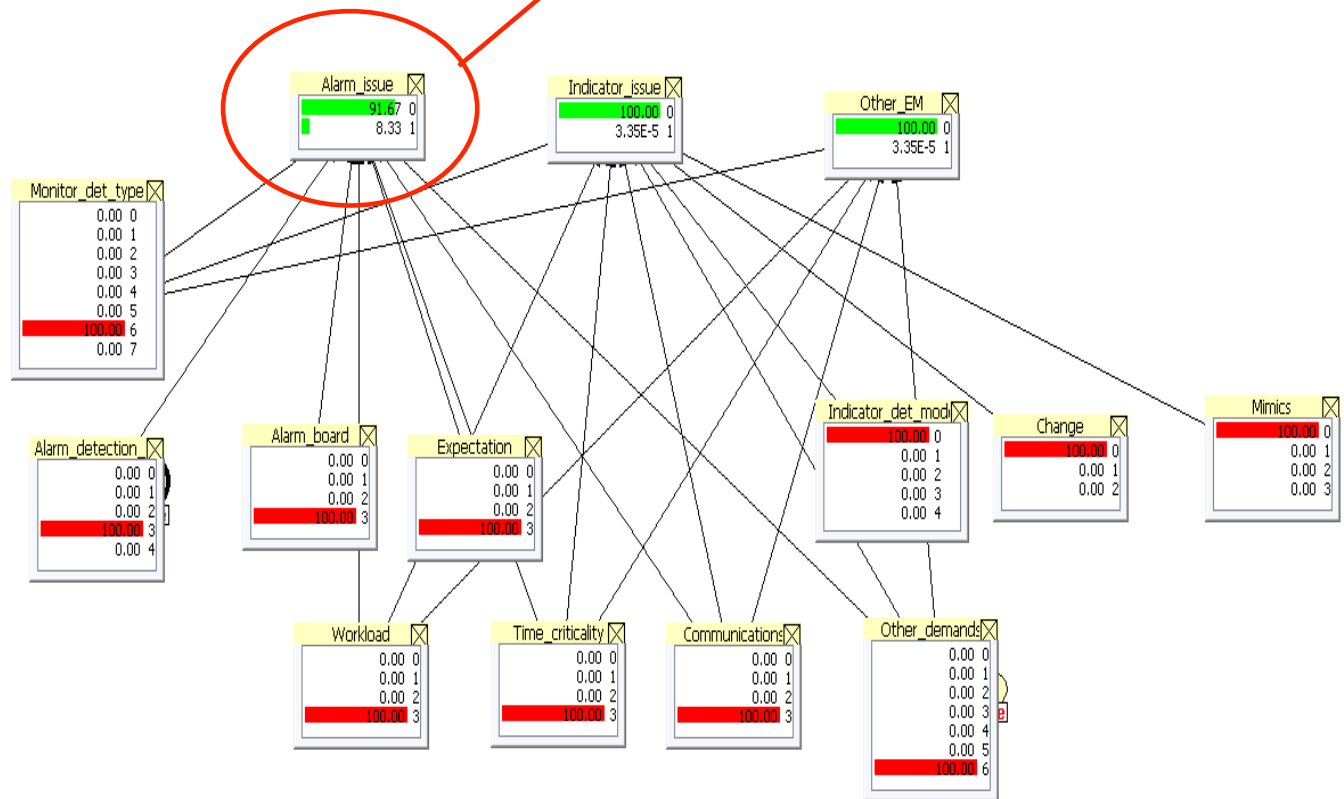
• No evidence in these cases

- Red Arrows point to existing contexts in the data base.
- Experience is 0.001 plus total number of trials for that context.
- Posterior failure probability converges to UNSAT ratio value.

Other_dem...																						6	
Communica...																						3	
Time_critica...																						3	
Workload																						3	
Expectation																						3	
Alarm_board																						3	
Alarm_dete...	2							3							4								
Monitor_de...	1	2	3	4	5	6	7	0	1	2	3	4	5	6	7	0	1	2	3	4	5	6	7
0	0.9943	0.9943	0.9943	0.9943	0.9943	0.9943	0.999999	0.9943	0.923082	0.9943	0.9943	0.9943	0.9943	0.916673	.9943	0.9943	0.900009	0.9943	0.9943	0.9943	0.9943	0.999999	0.846165
1	0.0057	0.0057	0.0057	0.0057	0.0057	0.0057	1.4246...	0.0057	0.076918	0.0057	0.0057	0.0057	0.0057	0.083327	.0057	0.0057	0.099991	0.0057	0.0057	0.0057	0.0057	1.1397...	0.153835
Experience	0.001	0.001	0.001	0.001	0.001	0.001	4.001	0.001	13.001	0.001	0.001	0.001	0.001	12.001	.001	0.001	10.001	0.001	0.001	0.001	0.001	5.001	13.001

Extract from data input

6,3,3,3,0,0,0,3,3,3,6,0,0,0  
6,3,3,3,0,0,0,3,3,3,6,0,0,0  
6,3,3,3,0,0,0,3,3,3,6,0,0,0  
6,3,3,3,0,0,0,3,3,3,6,0,0,0  
6,3,3,3,0,0,0,3,3,3,6,0,0,0  
6,3,3,3,0,0,0,3,3,3,6,0,0,0  
6,3,3,3,0,0,0,3,3,3,6,0,0,0  
6,3,3,3,0,0,0,3,3,3,6,0,0,0  
6,3,3,3,0,0,0,3,3,3,6,0,0,0  
6,3,3,3,0,0,0,3,3,3,6,0,0,0  
6,3,3,3,0,0,0,3,3,3,6,0,0,0  
6,3,3,3,0,0,0,3,3,3,6,0,0,0  
6,3,3,3,0,0,0,3,3,3,6,0,0,0  
6,3,3,3,0,0,0,3,3,3,6,0,0,0  
6,3,3,3,0,0,0,3,3,3,6,1,0,0



1 unsat, 12 trials:  $1/12=0.08333...= 8.33\%$

# Prior probability and its significance

- If there are 0 failures in a number of trials, the probability will become small
- If there are 1 or more failures in a number of trials, the probability will trend toward the failure rate observed, independent of the prior probability.
- If there are no trials, the prior remains the same, thus prior becomes important for those human actions where no SACADA trials have occurred.



# Context Counting

## (Number of trials per context)

Cognitive Type: 1																
(including overarching)																
Monitoring/Detection Detection Type	Alarms/Stat us Tile Detection Mode	Alarms/Sta tus Tile Status of Alarm Board	Alarms/Stat us Tile Expectation of Alarm/Indic ation Change	Meter/Light /Flag Detection Mode	Meter/Light /Flag Individual Indicator	Meter/Light /Flag Mimics/Di splay etc.	Overarching Issues Workload	Overarching Issues Time Criticality	Overarching Issues Extent of Communicat ions Required	Overarching Issues Other Demands/F actors	Quantity (with Overarching)	Quantity with UNSAT	Quantity with SAT Δ	Total UNSAT	Total SAT Δ	Total Trials
0:NULL	0:NULL	0:NULL	0:NULL	0:NULL	0:NULL	0:NULL	0:NULL	0:NULL	0:NULL	0:NULL						
1:Alarm	1:Self- Revealing	1:Dark	1:Expected	1:Procedure Directed	1:Slight Change	1:No Mimics	1:Normal	1:Expansive Time Available	1:Nominal Communicat ion	1:Non- Standard 2:Noisy Background						
2:Status Tile	2:Procedure Directed	2:Busy	2:Not Expected Applicable	2:Knowledg e-Driven	2:Distinct Change	2:Small Indications	2:Concurren t Demands	2:Nominal Time	2:Extensive Onsite	2:Coordinati on						
3:Meter	3:Procedure Directed	3:Overload	3:Not Applicable	3:Procedure- Directed Monitoring	3:Procedure- Directed Monitoring	3:Similar Displays	3:Multiple Concurrent Demands	3:Barely Adequate Time Available	3:Extensive Communicat ion Within the Control Room	3:Communicator Unavailable 5:Multiple Demands 6:Memory Demands						
4:Indication Light	4:Awareness /Inspection			4:Awareness /Inspection												
5:Flag																
6:Computer																
7:Other																
	1	1	1	0	0	0	1	1	1	0	6	0	0	0	0	78
	1	1	1	0	0	0	2	1	1	0	1	0	0	0	0	16
	1	1	1	0	0	0	2	2	1	5	1	0	0	0	0	15
	1	1	1	0	0	0	2	2	2	0	1	0	1	0	1	9
	1	1	1	0	0	0	2	2	3	0	1	0	0	0	0	14
	1	1	1	0	0	0	2	3	1	5	1	0	0	0	0	14
	1	1	1	2	0	0	1	1	0	0	1	0	0	0	0	12
	1	1	1	2	0	0	1	1	1	0	13	1	1	1	1	157
	1	1	1	2	0	0	1	1	1	1	1	0	0	0	0	14
	1	1	1	2	0	0	1	1	2	0	1	0	0	0	0	15
	1	1	1	2	0	0	1	1	3	1	1	0	0	0	0	5
	1	1	1	2	0	0	1	2	1	0	8	0	0	0	0	107
	1	1	1	2	0	0	1	3	1	0	1	0	1	0	1	14
	1	1	1	2	0	0	1	3	2	1	1	0	0	0	0	14
	1	1	1	2	0	0	2	1	1	0	1	0	0	0	0	3
	1	1	1	2	0	0	2	2	1	0	1	0	0	0	0	15
	1	1	1	2	0	0	2	2	1	6	1	0	0	0	0	12

# Char worksheet sorted by context

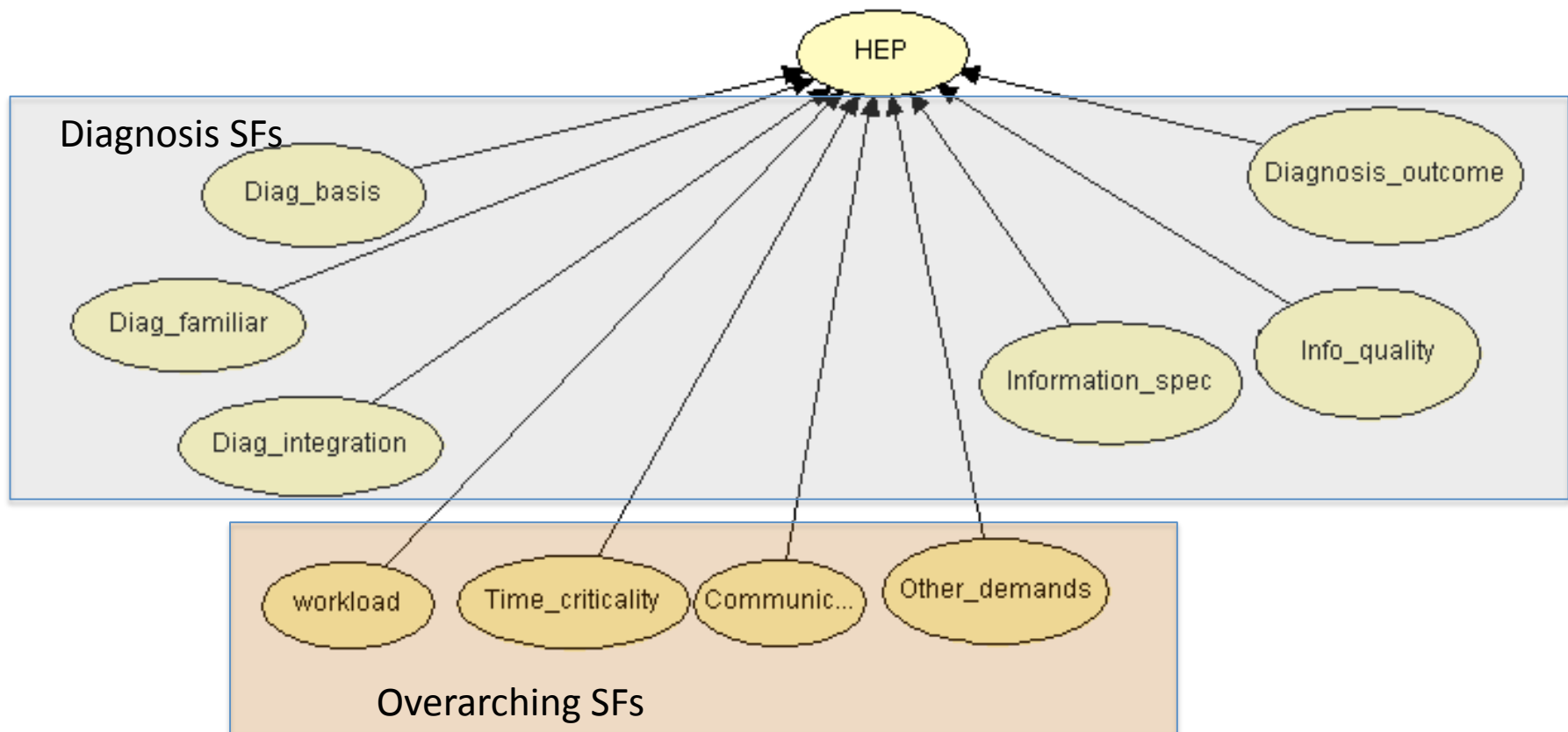
	A	B	C	L	M	N	O	P	Q	R	S	AL	AM	AN	AO	AP	AQ	AR	AS	AT	AU
1	TOE (training objective element)	+ Scen	Orig	itive	Moni	Alar	Alar	Alar	Mete	Mete	Mete	Over	Over	Over	Over	Aggregate Totals					
2			Orde	0:NU	0:NU	0:NU	0:NU	0:NU	0:NU	0:NU	0:NU	0:NU	0:NU	0:NU	0:NU	UNSA	SAT	SAT Δ	SAT+	Total	JNSA
3	Evaluate and Respond to alarms IAW	Evalua	319	1	1	1	1	0	0	0	0	1	1	1	0	0	12	0	0	12	0
7	Evaluate and Respond to alarms IAW	Evalua	323	1	1	1	1	0	0	0	0	1	1	1	0	0	12	0	0	12	0
11	Report No. 12 Condensate Pump Trip annunciator.	Report	618	1	1	1	1	0	0	0	0	1	1	1	0	0	15	0	0	15	0
17	Determines 12 ACW pump has tripped	Determ	1019	1	1	1	1	0	0	0	0	1	1	1	0	0	13	0	0	13	0
28	Determines LC 1N has lost Power, uses	Determ	1078	1	1	1	1	0	0	0	0	1	1	1	0	0	12	0	0	12	0
36	Note the ICS alarm	Note t	1190	1	1	1	1	0	0	0	0	1	1	1	0	0	14	0	0	14	0
126	Responds to alarm 10M01 B/6	Respor	680	1	1	1	1	0	0	0	0	2	1	1	0	0	16	0	0	16	0
142	Report SGFPPT 12 TRIP annunciator and verify Main Feed Pump #12 has tripped.	Report	626	1	1	1	1	0	0	0	0	2	2	1	5	0	15	0	0	15	0
150	Determines a Reactor Trip signal is present with NO Reactor Trip	Determ	430	1	1	1	1	0	0	0	0	2	2	2	0	0	8	1	0	9	0
165	Enters OPOP09-AN-02M4 and	Enters	549	1	1	1	1	0	0	0	0	2	2	3	0	0	14	0	0	14	0
190	Determines that PT-0557 failed low	Determ	516	1	1	1	1	0	0	0	0	2	3	1	5	0	14	0	0	14	0
195	Enters OPOP09 and Ensures the Standby OL-ACW pump starts and is maintaining	Enters	698	1	1	1	1	2	0	0	0	1	1	0	0	0	12	0	0	12	0
202	Identifies failure (Respond to alarms)	Identif	1	1	1	1	1	2	0	0	0	1	1	1	0	0	3	0	0	3	0
210	Respond to SDG 12 trouble alarm per the alarm response procedure	Respor	124	1	1	1	1	2	0	0	0	1	1	1	0	0	13	0	1	14	0
221	Responds to changes in indicated letdown flow (alarm response)	Respor	188	1	1	1	1	2	0	0	0	1	1	1	0	0	11	1	0	12	0

78

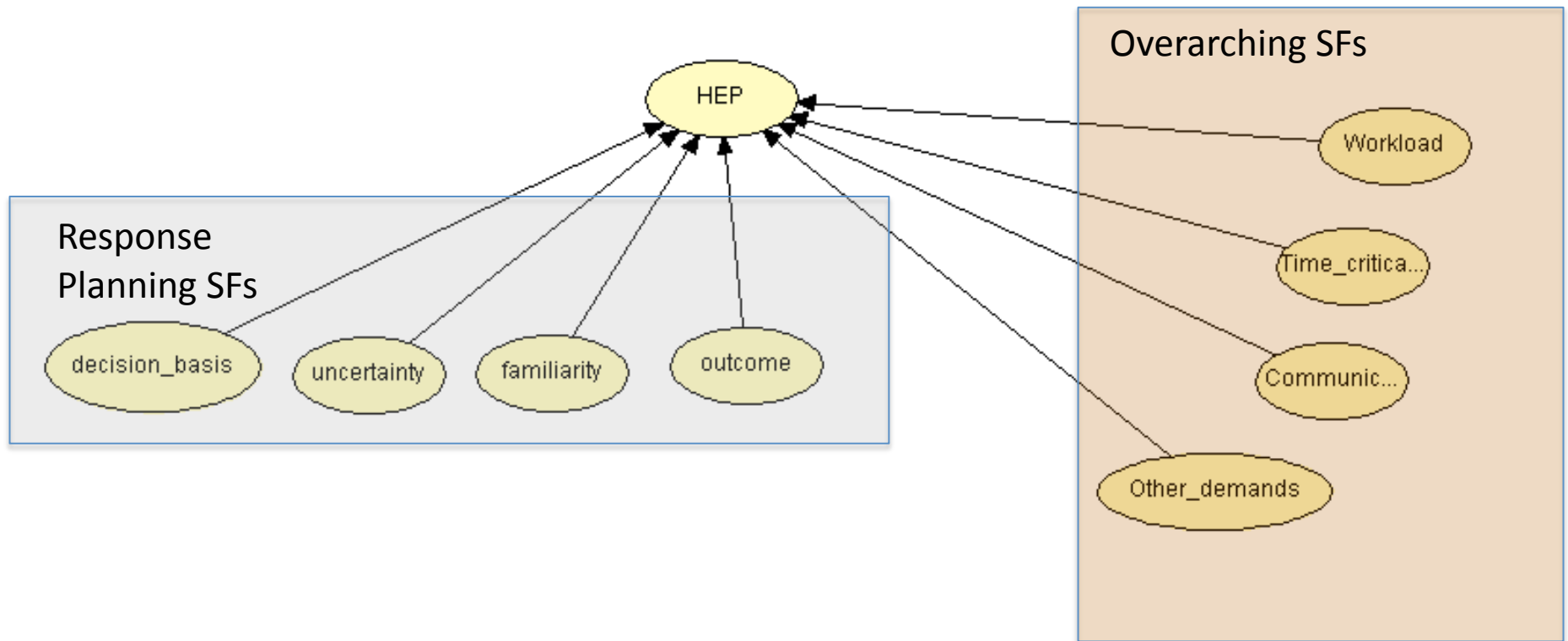
Note that several TOEs have the same context.



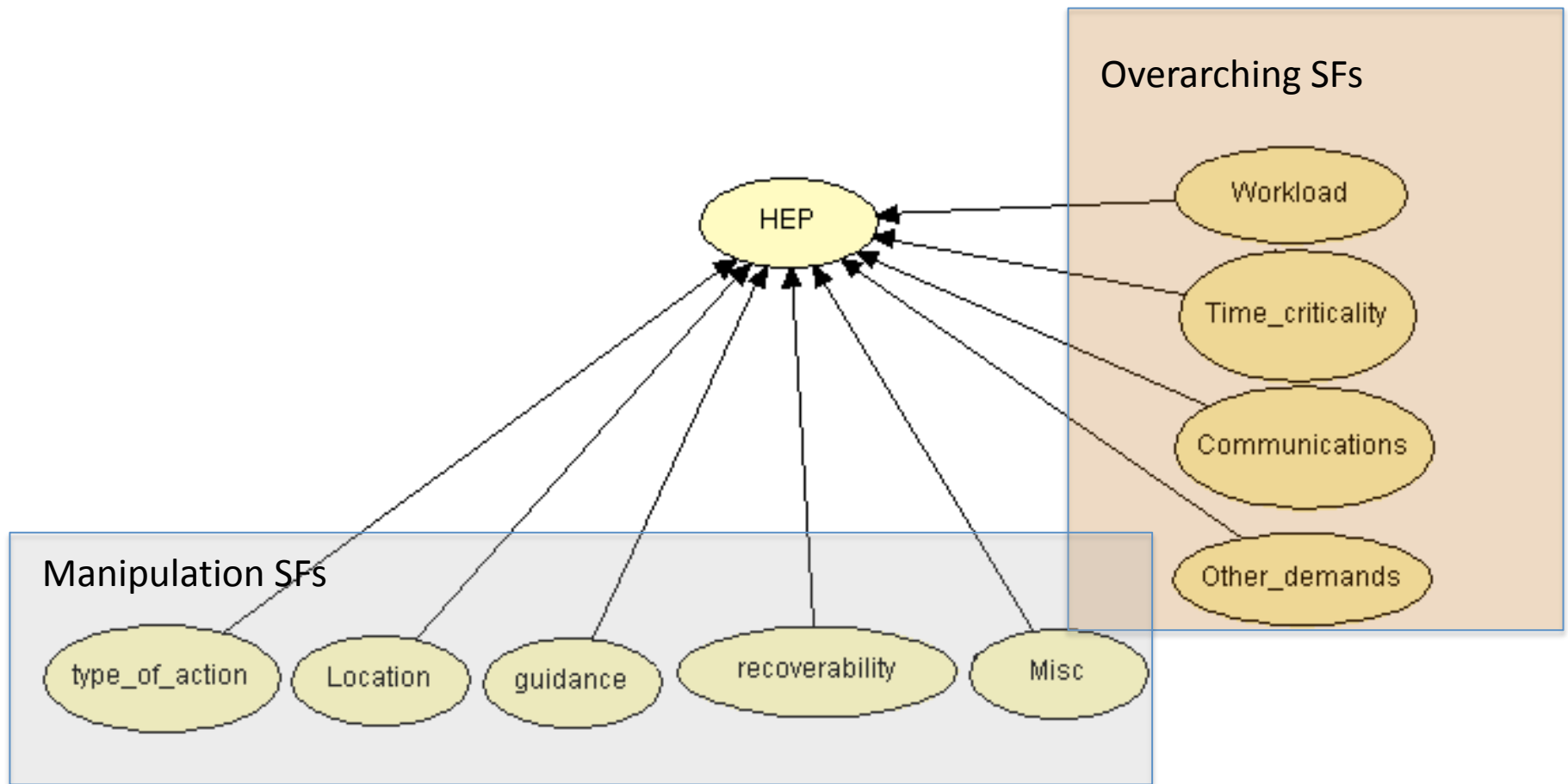
# Diagnosis: MCog2a



# Response Planning: MCog2b



# Manipulation: MCog3



# Input field observations

- Learning algorithm:

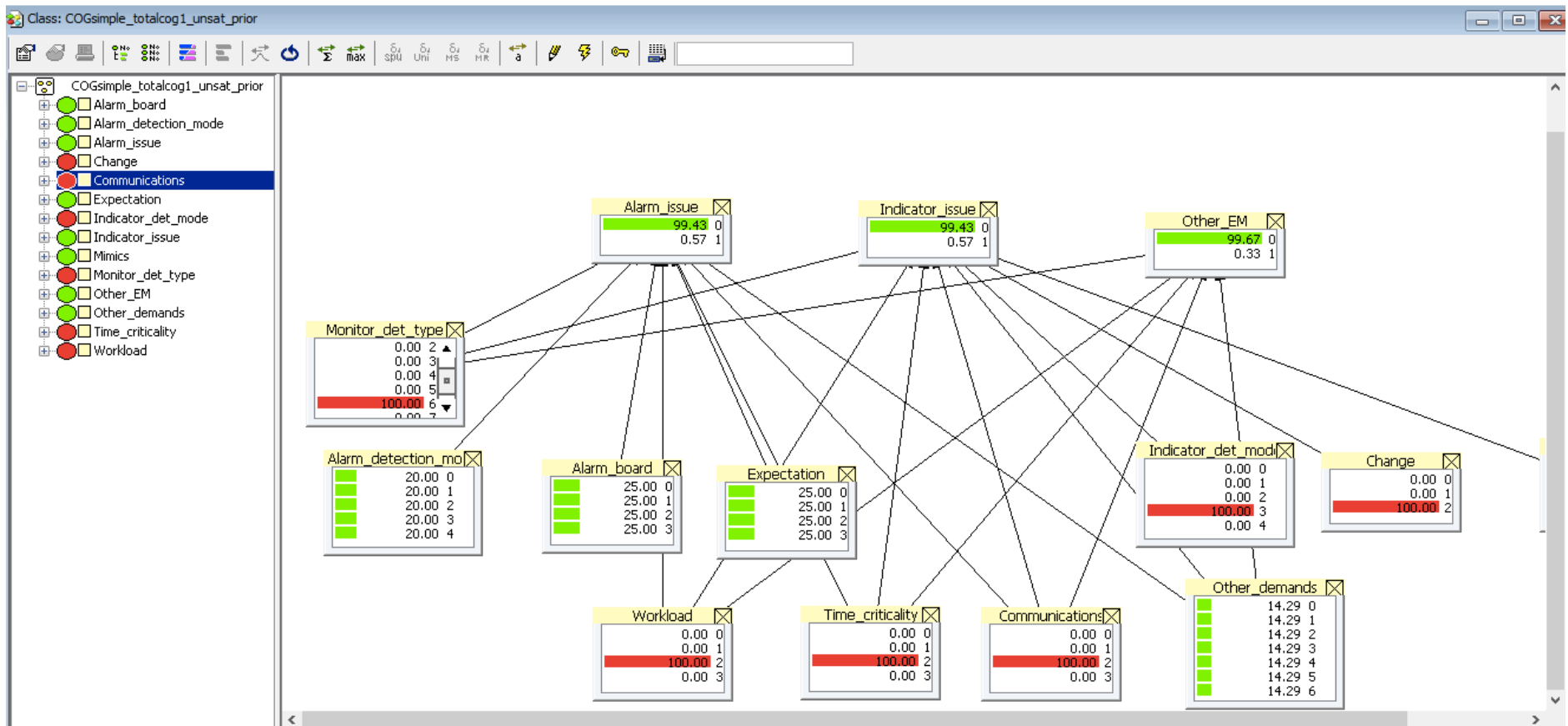
$$\frac{((\text{Prior probability} * \text{prior experience}) + \text{failures})}{(\text{prior experience} + \text{no. of trials})}$$

$$\frac{((0.5 \times 1) + 1)}{(1 + 29)} = .05$$

- Thus, the probability of this cell went from 0.5 to .05

All 29 observations were in one cell of the CPT and one of those had a failure.

# Feed & Bleed - MCog1=.0033

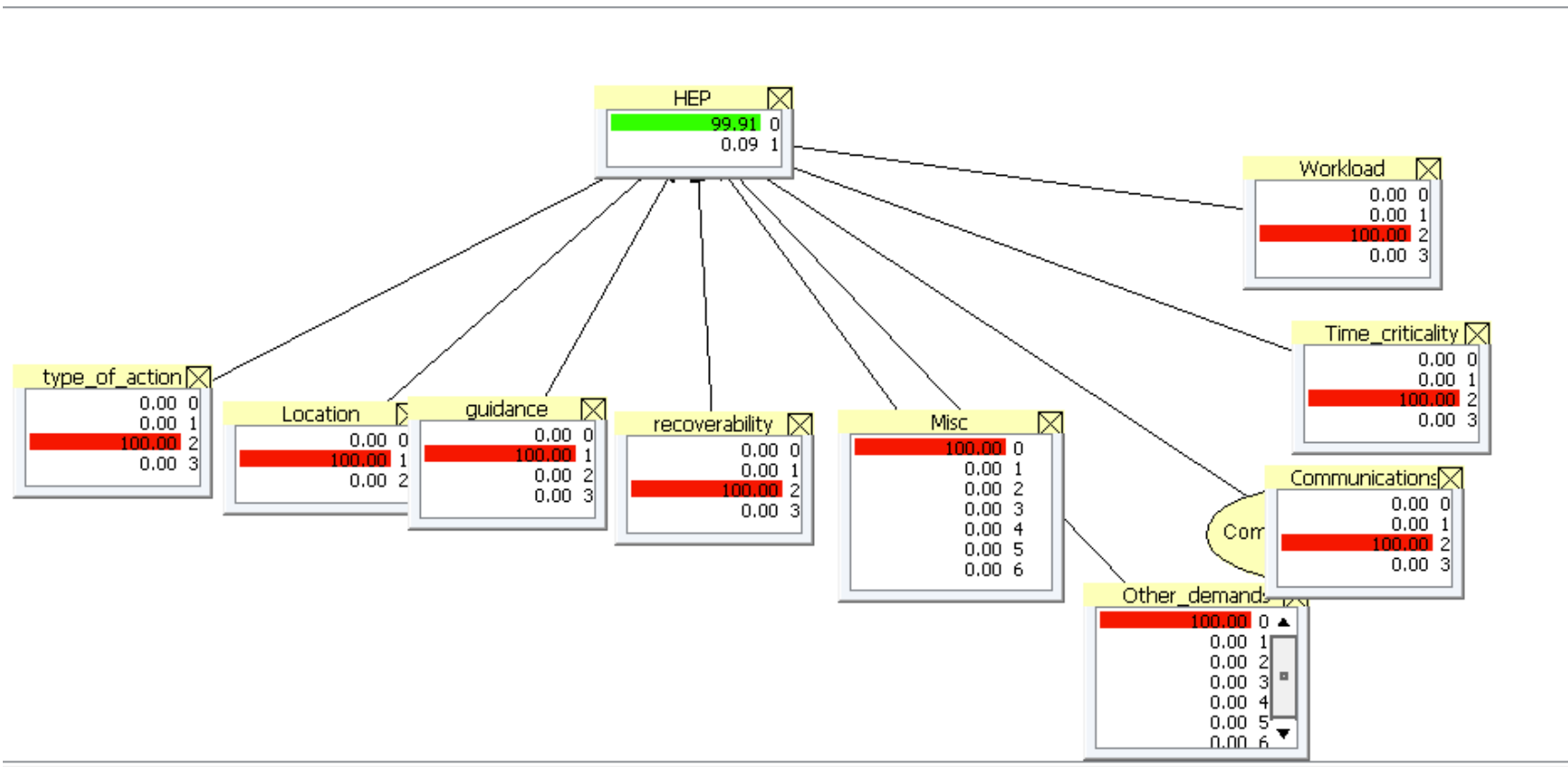




## RHR cut in results

- MCog1 .0041
  - MCog2a 0
  - MCog2b .01
  - MCog3 .0009
- 
- HFE HEP = 0.015

# RHR cut in: MCog3 = .00009



# Model With Error Modes and Error Causes

