

Preliminary Analysis Results of SACADA Data for HEPs

Y. James Chang, Ph.D.

U.S. Nuclear Regulatory Commission

James.Chang@nrc.gov

Presented at HRA Data Workshop at US Nuclear Regulatory
Commission

March 12-13, 2020

SACADA Development Background

- Aim to collect operator performance information in simulator training to improve human error probability (HEP) estimates
 - Developed software for nuclear plants to use in operator simulator training
 - Plant-collected information shared with the NRC
- Strength
 - Collect large amount of data points to provide statistical evidence of the relation between context and cognitive performance
- Weakness
 - Data taxonomy needs to accommodate constraints in operator simulator training
- Strength & Weakness
 - Information entered by operation instructors and crews, not researchers
 - Strength: (1) Enable a long-term, continuous data collection; (2) Data are accurate because entered by the instructors and crew in the simulator training and immediate immediately after the training
 - Weakness: data are entered in a time constraint environment

Data of Interest

- Basic human error probability (HEPs) of various macrocognitive functions (MCF)
 - MCFs: Detection (Alarms vs. Indicators), Understanding/Diagnosis, Deciding, and Action
- Effects of individual performance influencing factors (PIFs) and combinations of PIFs
 - MCF-dependent effects
 - PIF combinations having cliff effect
 - How does the PIF combined effect work (multiplication or addition or something else)?
- Effects not captured in the current data taxonomy

Data used in this analysis are partially available to the public in <https://www.nrc.gov/data/>

Performance Influencing Factors of Diagnosis (Partial List)

#	PIF	PIF Attribute
1	Diagnosis Basis	<ul style="list-style-type: none"> ○ Skill-based ○ Procedure-based ○ Knowledge-based
2	Familiarity	<ul style="list-style-type: none"> ○ Standard ○ Novel ○ Anomaly
3	Information Integration	<ul style="list-style-type: none"> <input type="checkbox"/> Timing of information <input type="checkbox"/> Ambiguous information <input type="checkbox"/> Integration required
4	Information specificity	<ul style="list-style-type: none"> ○ Specific ○ Not specific
5	Information quality	<ul style="list-style-type: none"> <input type="checkbox"/> Missing Information <input type="checkbox"/> Misleading Information <input type="checkbox"/> Conflicting Information
6	Workload	<ul style="list-style-type: none"> ○ Normal ○ Concurrent Demands ○ Multiple Concurrent Demands
7	Time Criticality	<ul style="list-style-type: none"> ○ Expansive Time Available ○ Nominal Time Available ○ Barely Adequate Time Available
...	...	

Data Unit: Training Objective Elements

Example of Malfunction of SGTR in 1B SG

#	Training Objective Element	MCF	UNSAT Ratio
1	Diagnose SGTR in B SG	Diagnosis	0/13
2	Direct a reactor trip and safety injection based on increasing RCS leakage.	Diagnosis	0/13
3	Performs Immediate actions of OPOP05-EO-EO00, including RNO actions for Throttle Valve stuck open.	Deciding	0/13
4 -7	...		0/13
8	Transitions to EO30 SGTR	Deciding	0/13
9	Completes isolation of ruptured S/G: (4 isolation tasks)	Action	0/13
10	Properly select and maintain target temperature for cooldown based on the chart provided in EO30.	Diagnosis	0/13
11	Directs/initiates RCS cooldown	Action	0/13
12	Directs/stops RCS cooldown and maintains < target temperature	Action	0/13
13	Depressurize RCS to meet SI termination criteria before either of the following occur: (1) SG PORV or Safety Valve opens (2) SG Narrow Range level goes Off scale high	Action	0/13
14	Terminate SI and control RCS pressure and makeup flow so that RCS pressure is at SG Pressure and stable before the end of the scenario	Deciding	0/13
15	Declares an Alert Based on SGTR greater than the capacity of one CCP (FA1).	Diagnosis	0/13
16	Other items to discuss	None	0/13

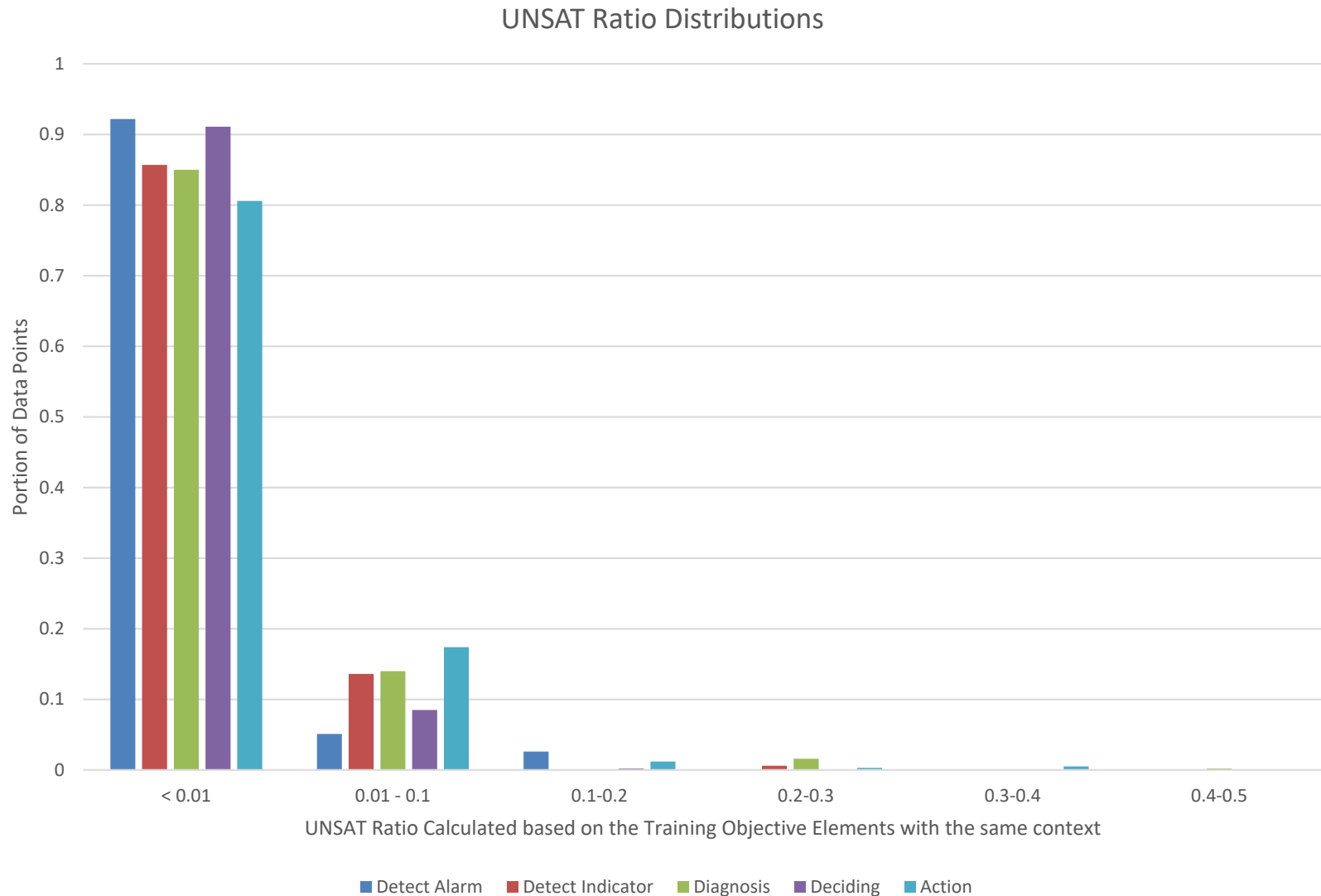
Overview of the Data

(As of 4/2019, available in <https://www.nrc.gov/data/>)

Cognitive Type	Data Points	# of Unique Context Available	# of Possible Unique Context*
Alarm detection	2099	61	~ 60,000
Indicator detection	2198	95	~ 80,000
Diagnosis/ Understanding	2613	116	~ 3,000,000
Deciding	6019	147	~ 60,000
Action	5167	159	~ 3,000,000
TOTAL	18096	578	

*Based on SACADA's data taxonomy

Overview of Operator Performance



Preliminary Analysis Results

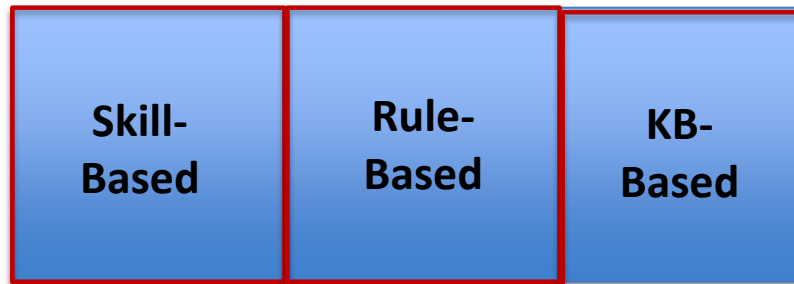
(Grouped Based on Same Context, in <https://www.nrc.gov/data/>)

MCF	UNSAT Ratio		
	Average (All Context)	Highest Value* (A Specific Context)	Highest Value/ Average
Detection (Alarm)	6.2E-3 (13/2099)	0.19 (5/26)	31
Detection (Indicator)	7.7E-3 (17/2198)	0.21 (3/14)	27
Diagnosis	1.1E-2 (28/2613)	0.5 (3/6)	45
Decisionmaking	5.3E-3 (32/8019)	0.13 (2/15)	25
Action	1.1E-2 (59/5167)	0.33 (4/12)	30

*Calculate based on the crew performance of a Training Objective Element of a specific scenario

Single PIF Effects

- Based on available data, the effects were calculated by changing the status of one-and-only-one PIF (before and after)
- The effects may or may not only caused by difference of the PIF's status PIF because the data populations before and after are exclusive to each other.
- Many context groups have zero UNSAT which are not discussed in this analysis.
- The directions of effects are generally as expected.



Single PIF Effects – Alarm Detection

(Change a PIF's status only)

PIF	Status 1 UNSAT Ratio 1		Status 2 (2)/(1)		Status 3 (3)/(1)	
Alarm Board Status	Dark 2.1E-3 (2/953)	1	Busy 5.0E-3 (5/991)	2.4	Overloaded 3.9E-2 (6/155)	18.4
Detection Mode	Self Revealing 2.1E-3 (4/1872)	1	Awareness /Inspect 5.1E-2 (9/177)	23.8		

Note: the other PIFs' statuses are likely different in the above data points.
The effects (UNSAT ratio 2/UNSAT Ratio 1) may include the other factors' effects.

Single PIF Effects – Indicator Detection

(Change a PIF's status only)

PIF	Status 1 UNSAT Ratio 1		Status 2 UNSAT Ratio 2		UNSAT Ratio 2/ UNSAT Ratio 1	
Detection Mode	Procedure Directed Check 3.4E-3 (3/870)	1	Awareness/ Inspection 6.4E-3 (5/782)	1.9	KB-Driven Monitoring 1.9E-2 (8/432)	5.4
Change Degree	Distinct Change 1.0E-2 (13/1291)	1	Slight Change 4.4E-3 (4/907)	0.44		
Meter Type	Meter 2.4E-2 (11/463)	1	Computer 2.9E-3 (3/1019)	0.1		

Note: the other PIFs' statuses are likely different in the above data points.

The effects (UNSAT ratio 2/UNSAT Ratio 1) may include the other factors' effects. 12

Single PIF Effects – Diagnosis Detection (1/2)

(Change a PIF's status only)

PIF	Status 1 UNSAT Ratio 1		Status 2 (2)/(1)		Status 3 (3)/(1)	
Diagnosis Familiarity	Standard 7.6E-3 (13/1718)	1	Novel 8.8E-3 (7/800)	1.2	Anomaly 1.2E-1 (8/69)	15.3
Poor Information Timing	Not Exist 9.5E-3 (24/2524)	1	Exist 4.5E-2 (4/89)	4.7		
Ambiguous Information	Not Exist 8.1E-3 (19/2350)	1	Exist 3.4E-2 (9/263)	4.2		

Note: the other PIFs' statuses are likely different in the above data points.
The effects (UNSAT ratio 2/UNSAT Ratio 1) may include the other factors' effects.

Single PIF Effects – Diagnosis Detection (2/2)

(Change a PIF's status only)

PIF	Status 1 UNSAT Ratio 1		Status 2 UNSAT Ratio 2	
Integration Required	Not Exist 9.5E-3 (23/2429)	1	Exist 2.7E-2 (5/184)	2.9
Information Specificity	Specific 7.7E-3 (10/1293)	1	Not Specific 1.5E-2 (16/1077)	1.9

Note: the other PIFs' statuses are likely different in the above data points.
The effects (UNSAT ratio 2/UNSAT Ratio 1) may include the other factors' effects. 14

Single PIF Effects – Decisionmaking

(Change a PIF's status only)

PIF	Status 1 UNSAT Ratio 1		Status 2 (2)/(1)		Status 3 (3)/(1)	
Decision Familiarity	Standard 5.1E-3 (24/4691)	1	Adaption Required 6.6E-3 (7/1062)	1.3	Anomaly 1.1E-2 (1/92)	2.1
Decision Uncertainty	Clear 4.9E-3 (22/4460)	1	Uncertain 6.3E-3 (4/634)	1.3	Competing Priority 8.7E-3 (6/693)	1.8

Note: the other PIFs' statuses are likely different in the above data points.
The effects (UNSAT ratio 2/UNSAT Ratio 1) may include the other factors' effects. 15

Single PIF Effects – Action

(Change a PIF's status only)

PIF	Status 1 UNSAT Ratio 1		Status 2 (2)/(1)		Status 3 (3)/(1)	
Action Type	Simple and Distinct 1.0E-2 (22/2151)	1	Order 1.1E-2 (21/1876)	1.1	Maintaining 1.5E-2 (12/793)	1.5
Action Guidance	Procedure -Based 1.1E-2 (55/4786)	1	Skill-of-the-Craft 8.9E-3 (2/224)	1.3	STAR(Faulted Hardware) 1.3E-2 (2/157)	3.2
Additional Mental Effort Required	Not Exist 1.0E-2 (52/4960)	1	Exist 3.4E-2 (7/207)	3.2		

Note: the other PIFs' statuses are likely different in the above data points.
The effects (UNSAT ratio 2/UNSAT Ratio 1) may include the other factors' effects.

Workload “Effects” in Various MCFs

	Normal (1)		Concurrent Demands (2)		Multiple Concurrent Demands (3)	
Alarm detection	1.2E-3 (1/801)	1	9.6E-3 (12/1255)	7.7	0 (0/29)	--
Indicator Detection	2.8E-3 (2/711)	1	7.8E-3 (10/1289)	2.8	2.5E-2 (5/198)	9.0
Diagnosis	1.3E-2 (9/674)	1	8.5E-3 (15/1759)	0.6	2.9E-2 (4/138)	2.2
Deciding	3.7E-3 (5/1342)	1	5.9E-3 (23/3899)	1.6	5.2E-3 (4/762)	1.4
Action	9.2E-3 (9/983)	1	9.4E-3 (30/3181)	1.0	2.0E-2 (20/987)	2.2

PIF effects may be MCF-dependent. Need detailed analyses for confirmation.

Note: the other PIFs' statuses are likely different in the above data points.
The effects (UNSAT ratio 2/UNSAT Ratio 1) may include the other factors' effects.

PIF Combined Effects – Alarm Detection

PIF	Base PIF Status		PIF Status 1		PIF Status 2	
Alarm Board Status	Dark 2.1E-3 (2/953)	1	Busy 5.0E-3 (5/991)	2.4	Overloaded 3.9E-2 (6/155)	18.4
Workload – Alarm Detection	Normal 1.2E-3 (1/801)	1	Concurrent Demand 9.3E-2 (12/1255)	7.7	Multiple Concurrent Demands 0 (0/29)	--

Workload	Alarm Board Status					
	Dark		Busy		Overloaded	
Normal	1.5E-3 (1/687)	1	0 (0/111)	--	0 (0/3)	--
Concurrent Demand	4.0E-3 (1/252)	2.7/ 1	5.7E-3 (5/880)	3.9/ 15.8	4.9E-2 (6/123)	33.5/ 12.3
Multiple Concurrent	0 (0/0)	--	0 (0/0)	--	0 (0/29)	--

PIF Combined Effects – Indicator Detection

PIF	Base PIF Status		PIF Status 1		PIF Status 2	
Detection Mode	Procedure-Directed Check 3.4E-3 (3/87)	1	Awareness/Inspection 6.4E-3E-2 (5/782)	1.9	KB-Driven Monitoring 1.9E-2 (8/432)	5.4
Workload – Indicator Detection	Normal 2.8E-3 (2/711)	1	Concurrent Demand 7.8E-3 (10/1298)	2.8	Multiple Concurrent Demands 2.5E-2 (5/198)	9.0

Workload	Indicator Detection Mode					
	Procedure directed Check		Awareness/Inspection		KB-Driven Monitoring	
Normal	0 (0/324)	--	4.3E-3 (1/235)	1.6	0 (0/50)	--
Concurrent Demand	2.7E-3 (1/376)	1	7.5E-3 (4/533)	2.8	1.4E-2 (5/366)	5.1
Multiple Concurrent	1.2E-2 (2/170)	4.4	0 (0/14)	--	0.21 (3/14)	80.6

Are PIFs' Effects Context Independent?

PIF	Poor Info Timing	Ambiguous Info	Require Integration	Info Not Specific
PIF Effect	4.7	4.2	2.9	1.9

Poor Infor Timing			
No		Yes	
Ambiguous Info			
No	Yes	No	Yes
1 (3/1116)	-- (0/24)	31 (3/36)	-- (0/0)
2.7 (6/812)	16 (9/209)	-- (0/13)	-- (0/0)
12.7 (4/117)	-- (0/0)	-- (0/0)	-- (0/0)
(0/0)	(0/0)	(0/0)	(0/0)

Require Integration	No	Info Not Specific	No
			Yes
	Yes		No
	Yes		

Single and Combined PIFs' Effects

- A PIF's effects should be evaluated in the condition when the other factors' statuses remain identical; otherwise, the results may be misleading.
- Based on currently available for analysis, it does not conclude whether the PIFs' combinational effect is addition or multiplication.

Support IDHEAS-ECA Method

- All IDHEAS's base HEPs are less than the average UNSAT ratios of SACADA.
- Ideally, data in optimal operational conditions should be used to inform for base HEPs. Indirect indications may be able to inform base HEPs with limited data.

	UNSAT Ratio	IDHEAS-ECA (2)	
MCF	Average (1)	Base HEP (2)	(1)/(2)
Detection (Alarm)	6.2E-3	1E-4	62
Detection (Indicator)	7.7E-3	1E-4	77
Diagnosis	1.1E-2	1E-3	11
Decisionmaking	5.3E-3	1E-4	53
Action	1.1E-2	1E-3	11

Does task Importance Affect Human Performance

- SACADA data does not support operator performance is affected by task importance
- The table shows statistics of SACADA's TOEs classified in four importance levels
 - Item (1) the scenario-specific TOEs met
 - UNSAT ratio greater than 10%; and
 - ≥ 2 crews dispositioned as UNSATs
 - The higher (1)/(2) value in critical tasks (the most important tasks) is attributed to scenario design
 - Critical tasks are typically appear in the end of scenarios whether the situation is generally more complex).

Importance Level	# of Items (1)	Total # of Items (2)	(1)/(2)
1 (Critical Task)	2	71	2.8%
2 (Safety related)	11	822	1.3%
3 (professional tasks)	20	1619	1.2%
4 (General)	8	559	1.4%

Qualitative Context Related to TOEs with high UNSAT Ratios

General suspects with scenario-system specific information

- Unfamiliarity + Information masking
 - Fail to trip RCPS because tripping criteria were determined not met
 - HHPI is running and indicating flow rate
 - The local valve was closed so the flow did not reach to the targeted location
 - Not a trivia to identify the flow did not reach to the target area
- Multiple concurrent tasks
 - Fail to trip ESF DG manually before its automatic trip
 - Monitor ESF DG's parameters and detect the lube oil temperature was increasing abnormally
 - The crew was tie up to responding a previous malfunction

Ongoing SACADA Work

- Recently completed SACADA-2 tool development (simulator data portion)
- Welcome collaborations on using SACADA to collect operator performance data
- Analyzing SACADA data to improve IDHEAS-ECA
- Welcome collaborations on analyzing SACADA data
- Contact: James.Chang@nrc.gov