Activities of HRA Data Collection for Nuclear Power Plants in SNERDI

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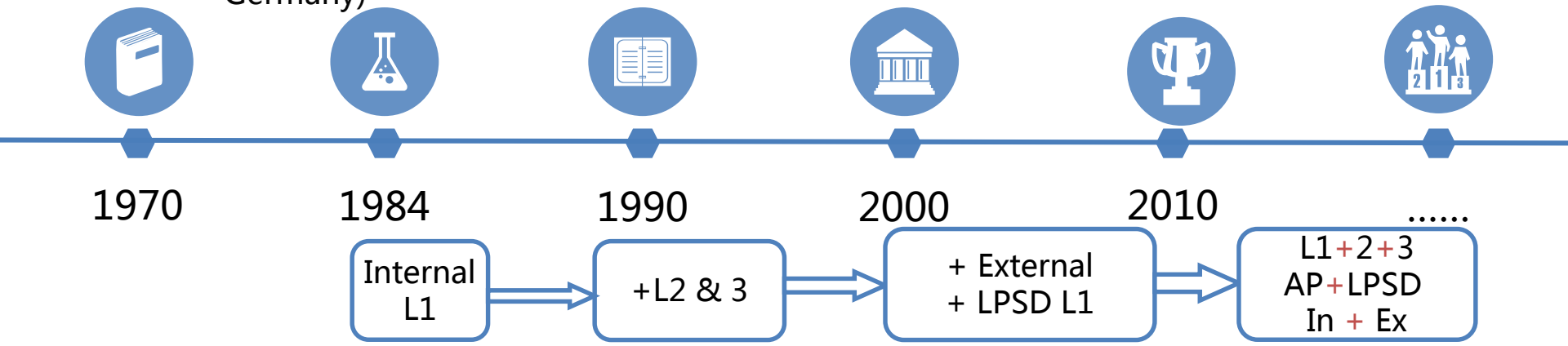
1. Background

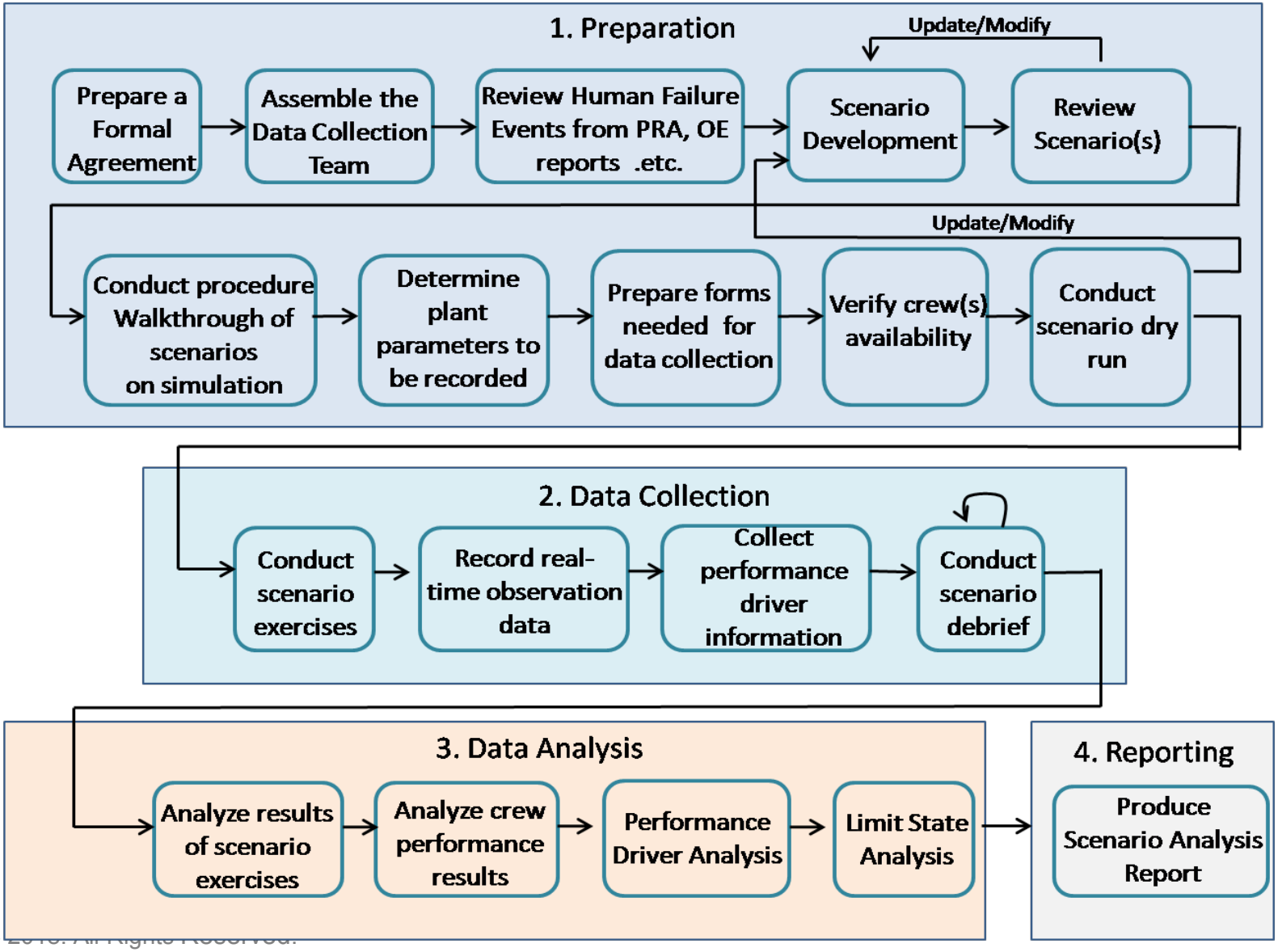
Evolution of SNERDI’s PSA/HRA



HRA Data Collection Activities

- HRA data collection for Tianwan NPP
- HRA data collection and analysis for two digital NPPs with Tsinghua University
  - Operators as participants came from two digital full-scope simulators
  - Actions were observed during their training and EOP validation and verification.
- HRA data collection for CHASHMA nuclear power plant unit 2 (C-2)
  - The simulator exercises, data collection and operator interviews were carried out to support the C-2 human reliability analysis

HRA simulator data collection process recommended in NUREG/CR-7163



2. Data Collection for Digital NPPs

2.1 Preparation

Participants

Operators as participants came from two digital full-scope simulators **(Simulators A and B)**

The crews were trained to follow emergency operating procedures (EOPs) and mitigate the simulated accident emergencies.

Actions were observed during their training and EOP validation and verification.

2.1 Preparation

➢ Example of log sheet

Scenario #____ Crew #____ Date _____ Recorded by _____

Description of the scenario: _____

The operator responses following the accident:

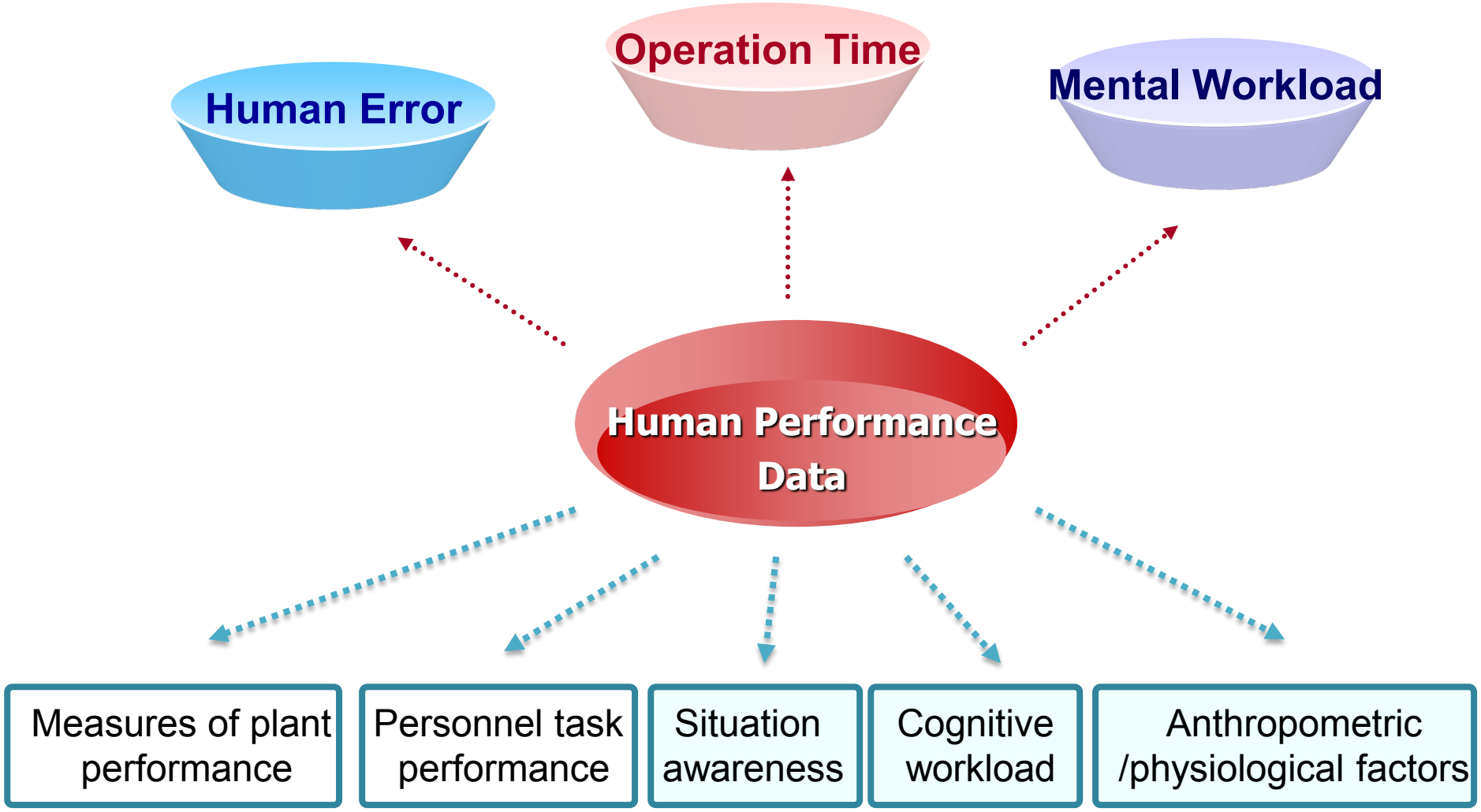
Time	Operator Actions (including the step No. of the procedure used)	Note

2.1 Preparation

- Example of operator interview form

HRA operator interviews (part of the content)
Interviewer： time： interviewee： job title： work experience:
HFE description: CIB-MAN00+CIB-MAN01：During SGTR event with CVS failure, the crew failed to identify the accident and isolate the faulted SG.
1. What procedures are used to address this scenario?
A：
2. Do the operators receive training on this type of scenario? If so, what type of training (classroom, simulator, other)? If training is received, how often is it conducted? What is your experience specifically to this evolution or set of initial conditions?
A：
4. What cues and indications are available for this condition in the plant? Where can they be observed by operators?
A：
5. How much time is needed for the operator to see the cue and then diagnose the cue?
A：

Human Performance Metrics



2.2 Analysis Results——*Human Error*

Selected Operator Errors in Simulator A

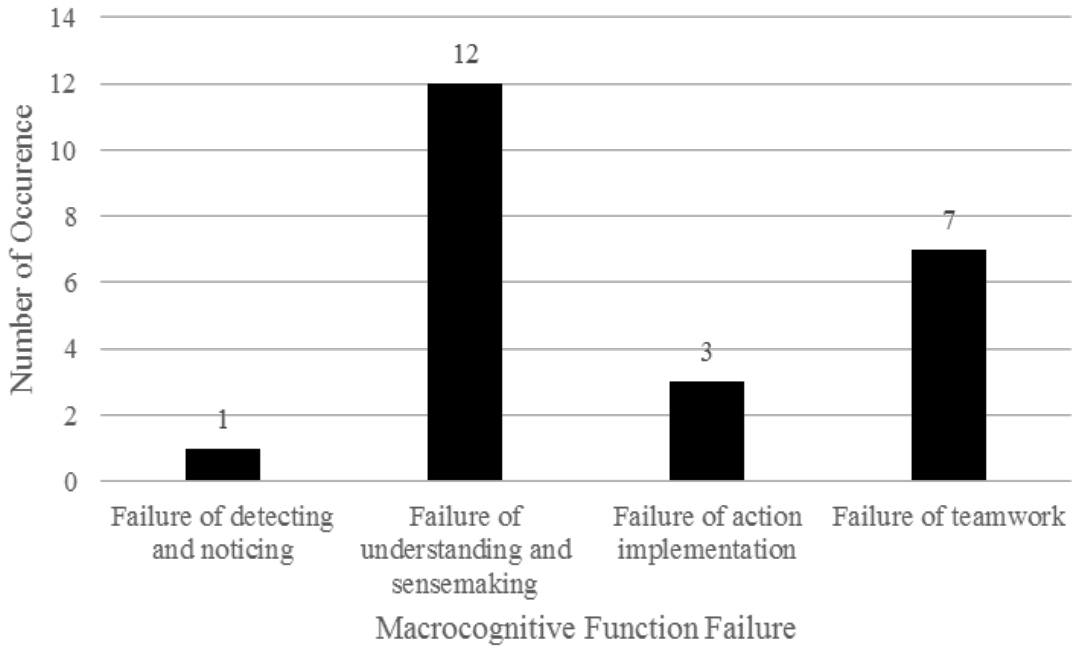
Error	Description	Macrocognition Failure	Proximate Cause
1	During SGTR event with SG#2 tube rupture, the crew failed to identify the condition of SG#1 and assumed that SG#1 also ruptured.	Failure of understanding and sensemaking	Uncertain
2	Failure of control room supervisor (CRS) to arrange operators to monitor one continuous step	Failure of teamwork	Failure of team coordination
3	Operator failed to monitor the actuation signals of the fourth stage ADS valves during execution of ES-1.3 (ADS Stage 1-3 Actuation Response) procedure	Failure of action implementation	Error of omission

2.2 Analysis Results——*Human Error*

Selected Operator Errors in Simulator B

Error	Description	Macrocognition Failure	Proximate Cause
1	Following loss of main feedwater with ATWS (anticipated transient without scram) occurred afterwards, operator followed Step 19 (Check for reactivity insertion from uncontrolled RCS cooldown) in FR-S.1 and failed to perform the RNO (response not obtained) steps due to his wrong judgment of relevant parameters (RCS temperature or SG pressure)	Failure of understanding and sensemaking	Uncertain
2	Following loss of main feedwater and startup feedwater, operator failed to follow the RNO (response not obtained) column of Step 8.a in ES-0.1 (Reactor Trip Response) and continued to perform Step 8.b.	Failure of action implementation	Errors of commission
3	Following a station blackout, when the RNO column of Step 4 in E-0 (reactor trip or safeguards actuation) was performed, operator failed to follow RNO 4c “go to ES-0.1” and continued to perform Step 5.	Failure of understanding and sensemaking	Uncertain

2.2 Analysis Results——*Human Error*

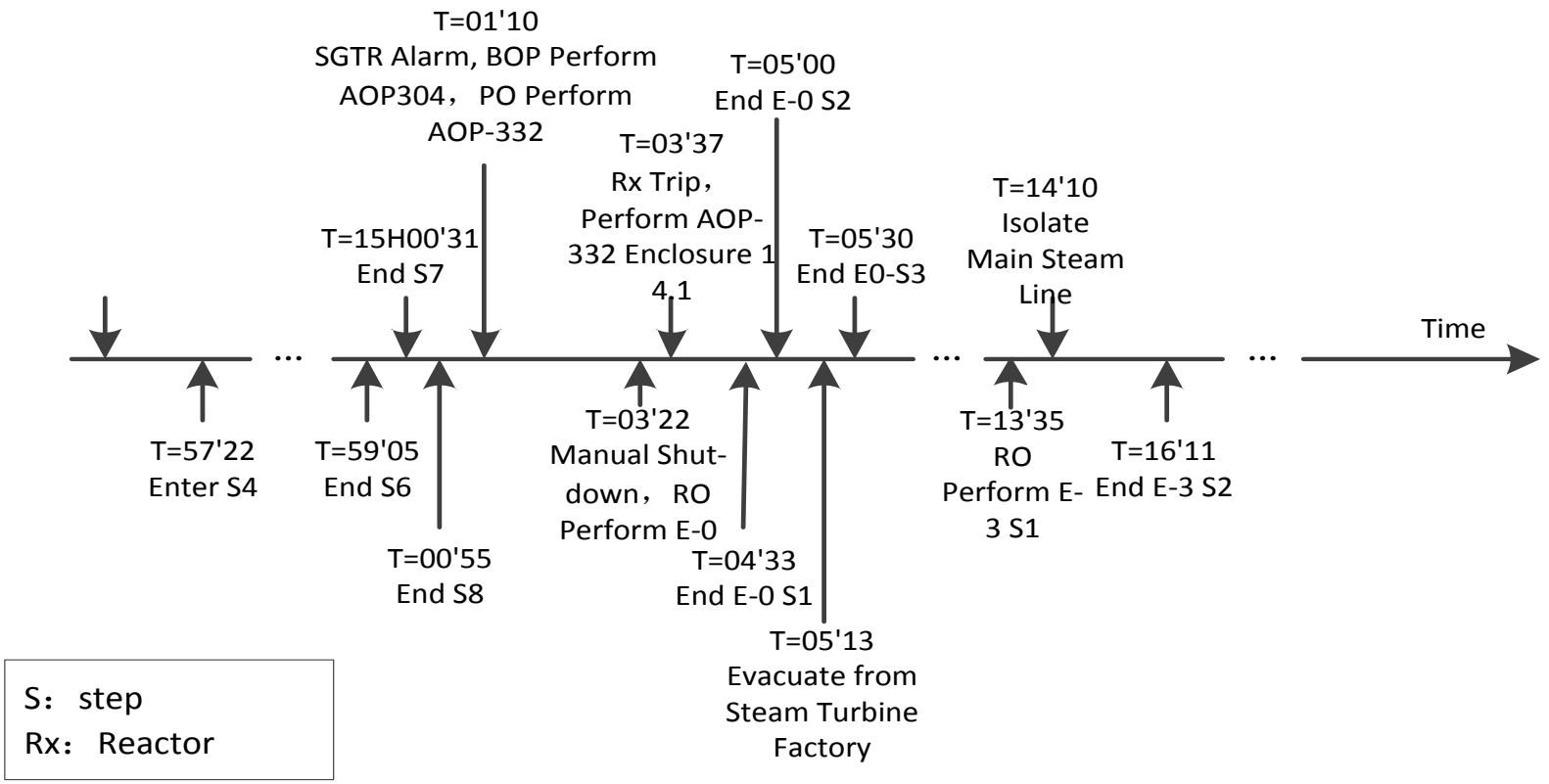


◆A total of ***23*** operator error events were observed in our observation.

◆Failure of understanding and sensemaking in the observed operator error events was predominant that ***52%*** of (12 out of 23) operator error events were related to this macrocognition failure.

◆Failure of teamwork was also a significant macrocognitive failure and it was associated with ***30%*** of (7 out of 23) operator error events.

2.2 Analysis Results——*Operation Time*



Demonstration of Time-Line Analysis

✓The time data may be used to update time-related PIF information or time-reliability curve based HRA.

2.2 Analysis Results——*Mental Workload*

Operator Mental Workload

Num	Operator Type	Mental Demand	Physical Demand	Temporal Demand	Performance	Effort	Frustration	Overall Workload
1	CRS	4	3	4	7	8	7	33
2	RO	4	2	3	9	8	2	28
3	STA	5	1	4	4	7	2	23
4	PO	5	4	4	9	8	8	38
5	BOP	5	3	7	8	6	3	32
6	CRS	9	1	7	8	8	2	35
7		4	4	6	5	9	1	29
Mean		5.1	2.6	5.0	7.1	7.7	3.6	31.1

✓Qualitative arguments
✓Operators reported relatively high workload on the dimensions of performance (Mean = 7.1) and effort (Mean = 7.7).
✓Two CRS operators reported relatively high workload (Overall Workload = 33 and 35, respectively).

3. Data Collection for C-2 NPP

3.1 Preparation

- Human failure events and scenarios were mainly selected based on the plant's PSA.
- Example of selected Human Failure Events & scenarios of C-2 NPP

No	Simulator Initial Condition	Initiators and Definition	Success Function	Insert Malfunction	Expected Human Action	Expected Response of the Accident	Associated Human Failure Event in PSA
1	100% rated power operation	Steam Generator A Tube Rupture (a complete double ended rupture in a single steam generator tube)	Reactor trip, Auxiliary Feedwater Success, High Pressure Safety Injection, Valves on Fault SG reset	PRZR auxiliary spray valve SCV-V006 malfunction (the PRZR auxiliary spray failure); The condenser malfunction (could not dump steam to condenser from SG)	Open one of the two relief valves（SSR-V005B/D) on intact SG to cool down SRC; Open pressurizer relief valves （SRC-V02A/B) to depressurize SRC. Terminate SI to stop primary to secondary leakage.	E-0 step 1→step22→E-3 step 1→step 6 (cool down SRC) →step 17 (depressurize SRC) →step 20 (stop SHI pump)	SPRO-RV02--HEO2 SSRO-RV05BDHEO1 SHI-TRIP-HEO
2	100% rated power operation	loss of the offsite grid power (failures of equipment that tie the plant to the grid)	Reactor Trip	House load operation failure, both emergency diesel generators failure (DGA and DGB)	Actuate the AAC (EAG-801DG)	E-0 step 1→step 4→ECA-0.0 step 1→step 7(actuate the AAC)	EMG--AAC---HEO
3	100% rated power operation	Loss of main feedwater (SMF-V002A and SMF-V002B malfunction)	Turbine Trip, PORVs Open and Safety Valves Open, Auxiliary Feedwater Success, PRZR PORV Reset	Reactor Trip Failure	Check at least one centrifugal charging pump running, and then start boric acid pumps, and open valves V133/134 or V220/222, and regulate the charging flow to maximum	E-0 step 1→FR-S.1 step 1→step 5	SCV--ATWS--HEO

3.1 Preparation

- All forms were prepared and sent to the relevant plant staff (PSA leader and simulator trainer) one month before the plant visit to confirm the acceptance of the scenario exercises.

➢ Example of log sheet

Scenario 1

Description of the scenario: After the initiating event SGTR (assume SG A tube rupture), and assume that the PRZR auxiliary spray fails, operator needs to recognize the need and open the relief valves on intact SG to cool down SRC, and open pressurizer relief valves（SRC-V02A/B) to depressurize SRC.

The operator responses following the accident:

Time	Operator Actions (including the step No. of the procedure used)	Note

3.1 Preparation

Example of C-2 data collection form

Questionnaire for the Simulation of Simulator Scenarios (Scenario 1)
Description of the Scenario/Event： After the initiating event of SGTR (assume SG A tube rupture), operator needs to recognize the need and open the relief valves on intact SG to cool down SRC.
Human Failure Event ID： SSRO-RV05BDHEO1 (part of the table is shown as follows)

PSF	Accident Diagnosis		Action Implementation	
	PSF level	select（tick）	PSF level	select（tick）
Stress/ stressors	Extreme		Extreme	
	High		High	
	Nominal		Nominal	
Complexity	Highly complex		Highly complex	
	Moderately complex		Moderately complex	
	Nominal		Nominal	
	Obvious diagnosis		——	
Experience/ Training	Low		Low	
	Nominal		Nominal	
	High		High	
Procedures	Not available		Not available	
	Incomplete		Incomplete	
	Available, but poor		Available, but poor	
	Nominal		Nominal	
	Diagnostic/symptom oriented procedure		——	

3.2 Data collection

- Prior to the start of each simulator scenario run, the detailed scenario process and the inserted malfunction in simulator were discussed with the simulator instructor to ensure the simulator exercises running smoothly.
- The prepared scenarios were exercised on the simulator and the required data and information were recorded and collected.
- Following each simulator scenario run, the crew were debriefed and asked the predetermined questions regarding their performance.
- The video of the accident response process, log files of the instructors and operators, the completed questionnaires, etc. are obtained.

Example of recorded forms

Scenario 1

Description of the scenario: After the initiating event of SGTR(assume SG A tube rupture), and assume that the PRZR auxiliary spray fails, operator needs to recognize the need and open one of the two relief valves on intact SG to cooldown SRC. And open one pressurizer relief valves（SRC-V02A/B) to depressurize SRC.

Date: 15-05-17 Crew (2)

The response following the accident:

Time	Content(include the step No. of the procedure used)	Note
14:12:00	Plant is in normal operation	
14:13:30	N-16 alarm appear. activity high on secondary side	
14:14:36	SG-A level is increasing	
14:14:48	Stand by SCV pump is started	
14:15:17	Manual Reactor is tripped by operator	
14:15:58	SI actuated manually	
14:16:13	SEOP E-0 Step1, Verify Reactor trip	
14:18:59	SEOP E-0 Step 9, Verify CTMT Isolation	
14:20:00	SEOP E-0 Step10, Check if Main Steam line should be isolated	
14:22:01	SEOP E-0 Step13, Verify SI flow	
14:24:56	SEOP E-0 Step18, Check PRZR PORVs, Block and Spray valves	
14:25:09	SEOP E-0 Step19, Check if RCPs should be stopped	
14:25:42	SEOP E-0 Step 20, initiate monitoring of CSF status tree using F-0	
14:26:28	SEOP E-0 Step 22, Check if SG tubes are not Ruptured, now shifted to E-3	
14:28:30	SEOP E-3 Step 3, Isolate flow from ruptured SG	

Example of recorded forms

Questionnaire of C-2 HRA for the Internal Event PSA

Description of the accident and human action: After the initiating event of SLOCA, and assume that the AFW fails, operator needs to recognize the need and open one pressurizer relief valves (SRC-V02A/B) to carrying out the "bleed action" of "SRC feed-bleed cooling".

Human Failure Event ID: SPRO-RV02--HEO1

1. The response following the accident

Diagnosis process: Operator initiates E-0 when the reactor trip signal occurs, when the SAF fails and SG narrow level less than 9.3m, operator would initiate FR-H.1 by the RED PATH of Lossing HEAK SINK according to the foldout of procedure. in step 19, open one pressurizer relief valves to carrying out the "bleed action" of "SRC feed-bleed cooling".

Action implement process and the place: open one pressurizer relief valves (SRC-V02A/B)

2. The time needed to recognize the need of the expected action: 20 min

The time needed to execute the expected action: 10 min

PSF	Accident Diagnosis		Action Implement	
	PSF level	select(tick)	PSF level	select (tick)
Stress/ stressors	Extreme		Extreme	
	High	✓	High	✓
	Nominal		Nominal	
Complexity	Highly complex		Highly complex	
	Moderately complex		Moderately complex	
	Nominal	✓	Nominal	✓
	Obvious diagnosis		——	
Experience/ Training	Low		Low	
	Nominal		Nominal	
	High	✓	High	✓
Procedures	Not available		Not available	
	Incomplete		Incomplete	
	Available, but poor		Available, but poor	
	Nominal	✓	Nominal	✓
	Diagnostic/symptom oriented procedure		——	

3.3 Data Analysis

- The accident progressions were confirmed and the parameters and data information required in C-2 HRA were obtained based on the simulator exercises records, log files and operator interview forms.

4. Conclusion

Conclusion

- Collecting and accumulating operator performance data for HRA, operator error prevention program, and human factor review program are paid close attention during these years.
- We visited and observed two full-scope digital simulators, collected human performance data in terms of operator errors, operation time, and workload.
- The parameters and data information required in C-2 HRA were obtained with plant simulator exercises, data collection tools, log files and operator interviews.
- More work of data collection will be carried out both for the new plant and operating plants to support the HRA database development and HRA in PSA.

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