HRA data Workshop
- March 15~16, 2018, NRC -

HuREX – Human Reliability data Extraction

A Framework for Simulator Data Collection and Analysis to Generate Human Error Probability

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Contents

HRA Issues in Korea

- Quality of HRA
  - PSA has become a part of licensing documents for an NPP
  - Technical quality of PSA/HRA should be ensured against ASME PRA requirements
- HRA of a digital MCR
  - Urgent issue in Korea due to the APR1400
  - HRA method/data reflecting the design features of a digital MCR

Objectives

- To develop a framework of HRA data collection in simulators
- To generate HRA data (e.g., HEP, PSF multiplier) using the framework

HEP: Human Error Probability
PSF: Performance Shaping Factors

Previous Studies

- HRA data source
  - Expert judgement based on multiple sources: THERP, NUCLARR, CORE
  - Operating experience: CAHR, HEP from German NPP
  - Simulator experiment: HCR/ORE
- Simulator data collection for HRA purpose
  - HCR/ORE (EPRI) – EPRI simulator study
  - Int' HRA empirical study (HRP/NRC) - HAMMLAB simulator experiment
  - Others (EDF, NUBIKI, NRI, KAERI, etc.)
- But, still "a lack of HEP data"
  - Most of simulator studies were performed to support specific HRA methods
  - Limited scope and data points with different perspectives
  - Focus on qualitative analysis of human behavior under emergencies

Using Simulators for HEP

- Can we generate HEP data from simulators?
- How do we collect data from simulators to generate HEP?

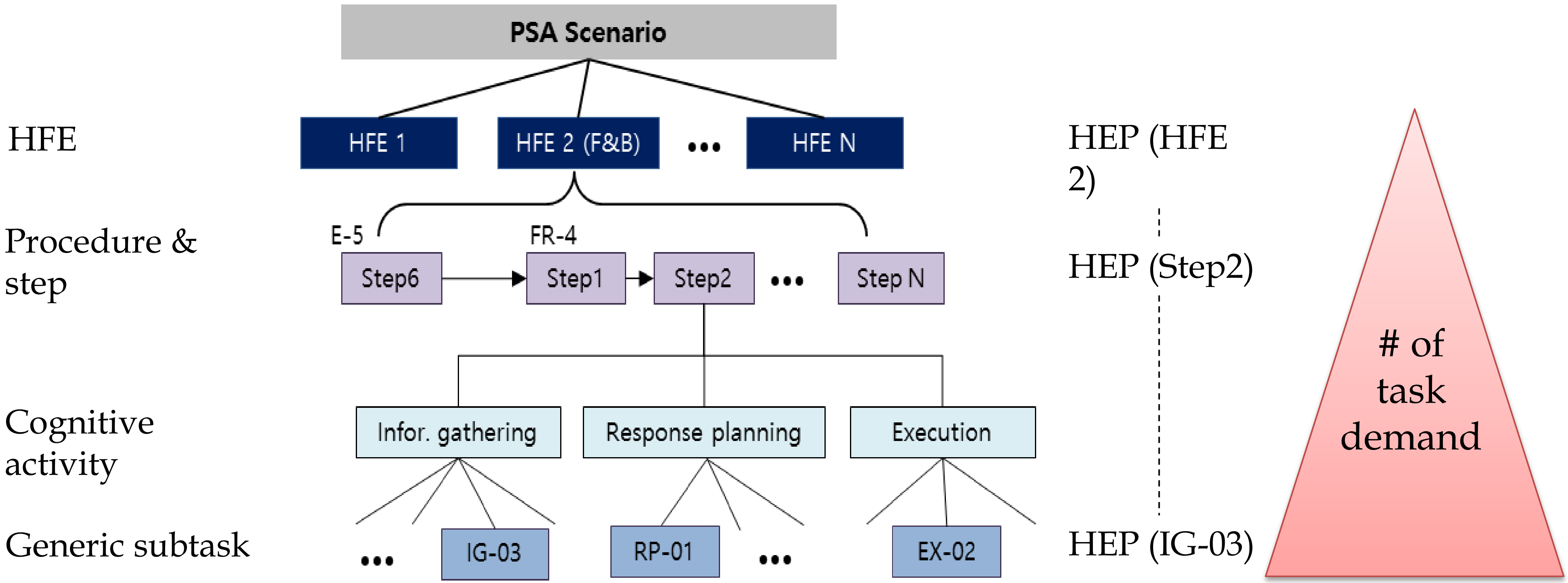
Challenge (1)

- Can we generate HEP data from simulators?

- HEP = Observation/Demand
  - O: the number of an observed human error
  - D: the number of task demand

* Key challenges are "how to secure sufficient task demand" and "how to count them"

Key Concept



PSA Scenario
HFE
HFE 1
HFE 2 (F&B)
•••
HFE N
HEP (HFE 2)
Procedure & step
E-5
FR-4
Step6
Step1
Step2
•••
Step N
HEP (Step2)
Cognitive activity
Infor. gathering
Response planning
Execution
Generic subtask
•••
IG-03
RP-01
•••
EX-02
HEP (IG-03)
# of task demand

Challenge (2)

- How do we collect data from simulators to generate HEP?

Simulation preparation → **Data collection** → **Data analysis** → **Data reporting**

Simulation preparation:
- What kinds of preparations should be considered?
- How we can prepare them?

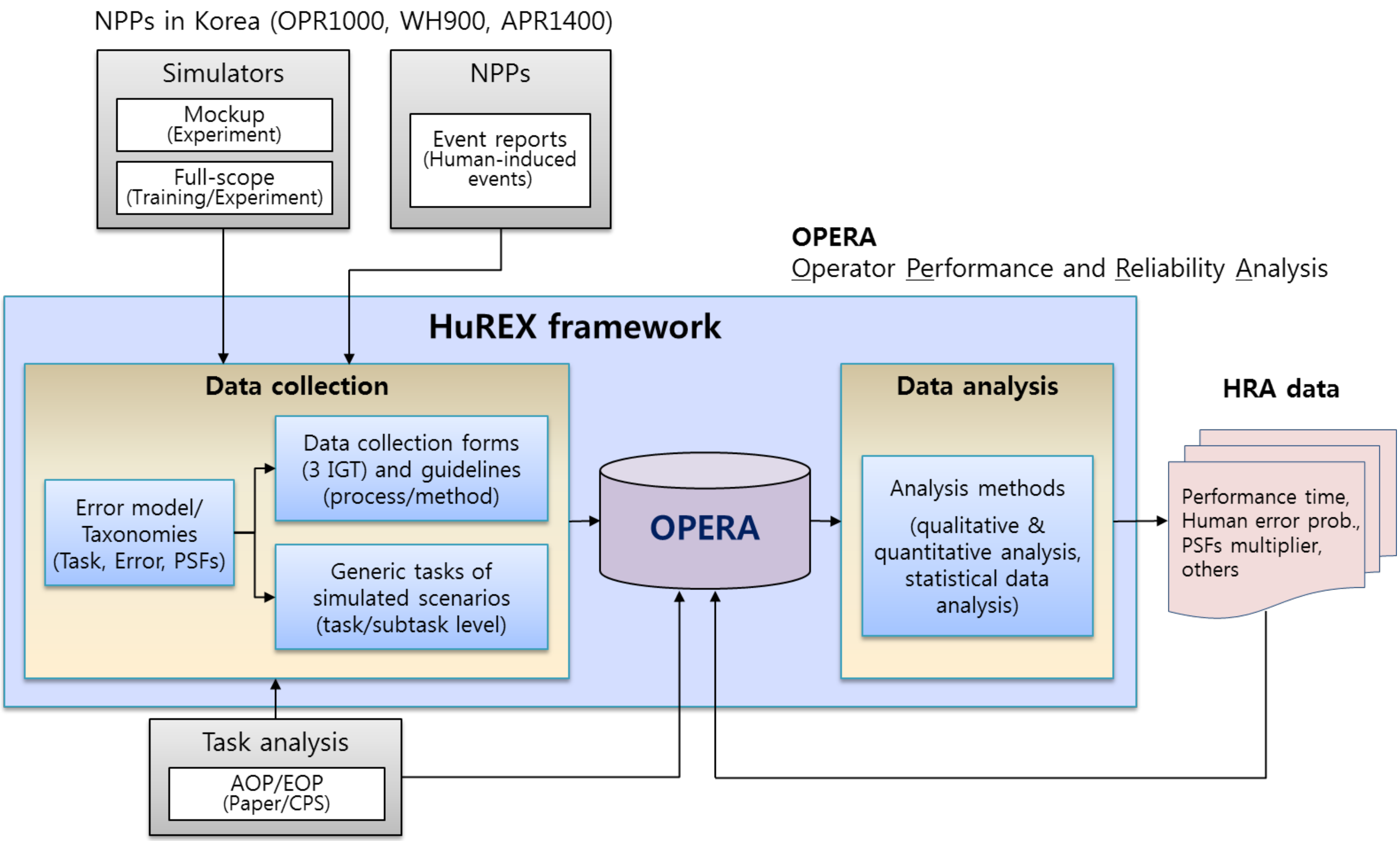
Data collection:
- What kinds of (qualitative) data should be gathered?
- How we can collect them?

Data analysis:
- What kinds of HRA data should be extracted from (qualitative) data?
- How we can extract/analyze them?

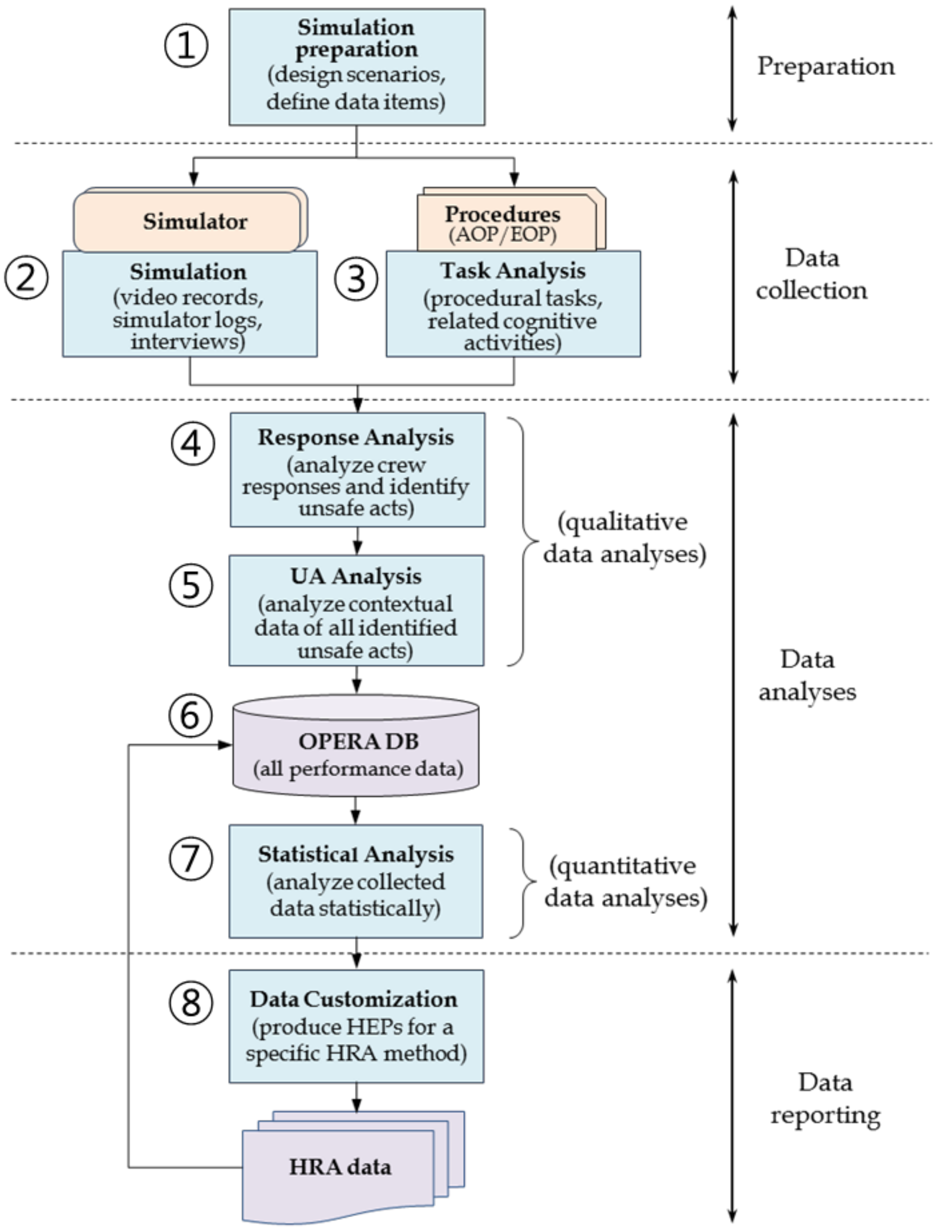
Data reporting:
- What kinds of HRA data should be reported?
- How we can share them with others?

- Need a systematic approach to collect data
  - Framework to collect data from simulators and procedures
  - Taxonomy of task and error

HuREX (Human Reliability data Extraction)



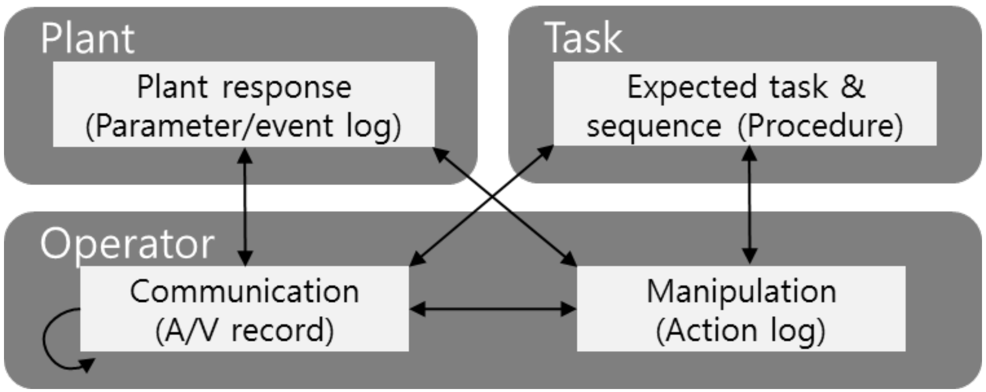
Process of HuREX



No	HuREX Process
①	Design a scenario, and define expected procedural path & key operator tasks
②	Perform simulation, observation & interview
③	Identify generic subtasks & cognitive activities
④	Analyze observed operator responses & performance
⑤	Analyze unsafe act & related context information
⑥	Store collected data in OPERA DB
⑦	Analyze data statistically to generate HRA data
⑧	Customizing HRA data

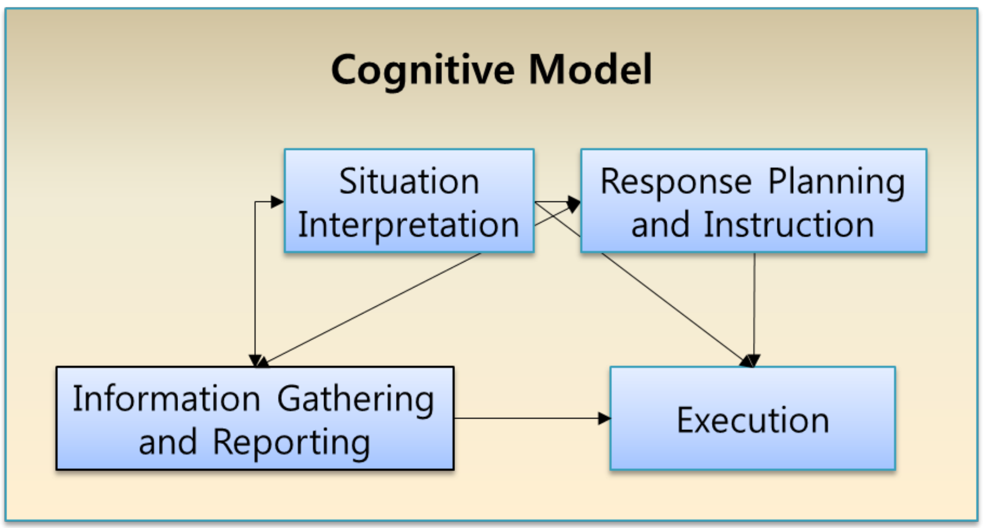
Unsafe Act

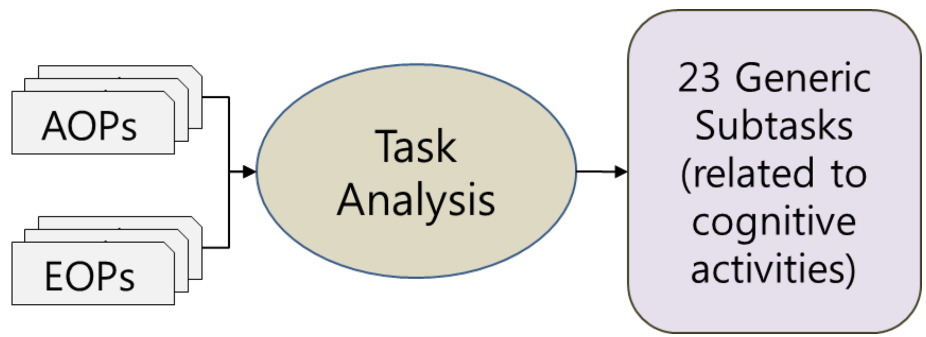
- Definition of Unsafe Act (UA)
  - An erroneous behavior that negatively affects the safety of a plant (= human error + a part of routine violation)
- Identification of UA
  - First, identify all UA candidates (any kind of deviation from an expected procedural path)
  - Second, select UA from UA candidates based on their consequences.
    - 17 rules are available to distinguish UAs from UA candidates



Cognitive Task Type

- Task analysis of AOPs/EOPs
  - A simplified cognitive model with four cognitive activities
  - A detailed task analysis of all EOPs of OPR1000, WH900, and APR1400
    - Identified 23 types of generic cognitive task related to all procedural steps in abnormal or emergency situations





Taxonomy of HuREX

Cognitive activity	Task type	Abbreviation	Error mode*
Information gathering and reporting	Checking discrete state – Verifying alarm occurrence	IG–alarm	EOO, EOC
	Checking discrete state – Verifying state of indicator	IG–indicator	EOO, EOC
	Checking discrete state – Synthetically verifying information	IG –synthesis	EOO, EOC
	Measuring parameter – Reading simple value	IG–value	EOO, EOC
	Measuring parameter – Comparing parameter	IG–comparison	EOO, EOC
	Measuring parameter – Comparing in graph constraint	IG–graph	EOO, EOC
	Measuring parameter – Comparing for abnormality	IG–abnormality	EOO, EOC
	Measuring parameter – Evaluating trend	IG–trend	EOO, EOC
Response planning and instruction	Entering step in procedure	RP–entry	EOO
	Transferring procedure	RP–procedure	EOO, EOC
	Transferring step in procedure	RP–step	EOO, EOC
	Directing information gathering	RP–information	EOO, EOC
	Directing manipulation	RP–manipulation	EOO, EOC
	Directing notification/request	RP–notification	EOO, EOC
Situation interpreting	Diagnosing	SI–diagnosis	EOO, EOC
	Identifying overall status	SI–identification	EOO, EOC
	Predicting	SI–prediction	EOO, EOC
Execution	Manipulation – Simple (discrete) control	EX–discrete	EOO, WDEV, WDIR
	Manipulation – Simple (continuous) control	EX–continuous	EOO, WDEV, WDIR, WQTY
	Manipulation – Dynamic manipulation	EX–dynamic	EOO, WDEV, WDIR, WQTY
	Notifying/requesting to MCR outside	EX–notification	EOO, EOC
Other	Unauthorized control – Unguided response planning and instruction	OT–planning	EOC
	Unauthorized control – Unguided manipulation	OT–manipulation	EOC
	–		Timing error (too fast/too late)

*EOO (Error of Omission); EOC (Error of Commission); WDEV (Wrong Device); WDIR (Wrong Direction); WQTY (Wrong Quantity)

Information Gathering Template (IGTs)

- Design IGTs
  - Define 84 data fields fo
  - Design three IGTs: Ov

Overview IGT

1. Plant/Simulation Overview
2. Crew
3. Training & Education
4. Environment
5. Observed Response
6. Scenario
7. Crew characteristics & Dynamics

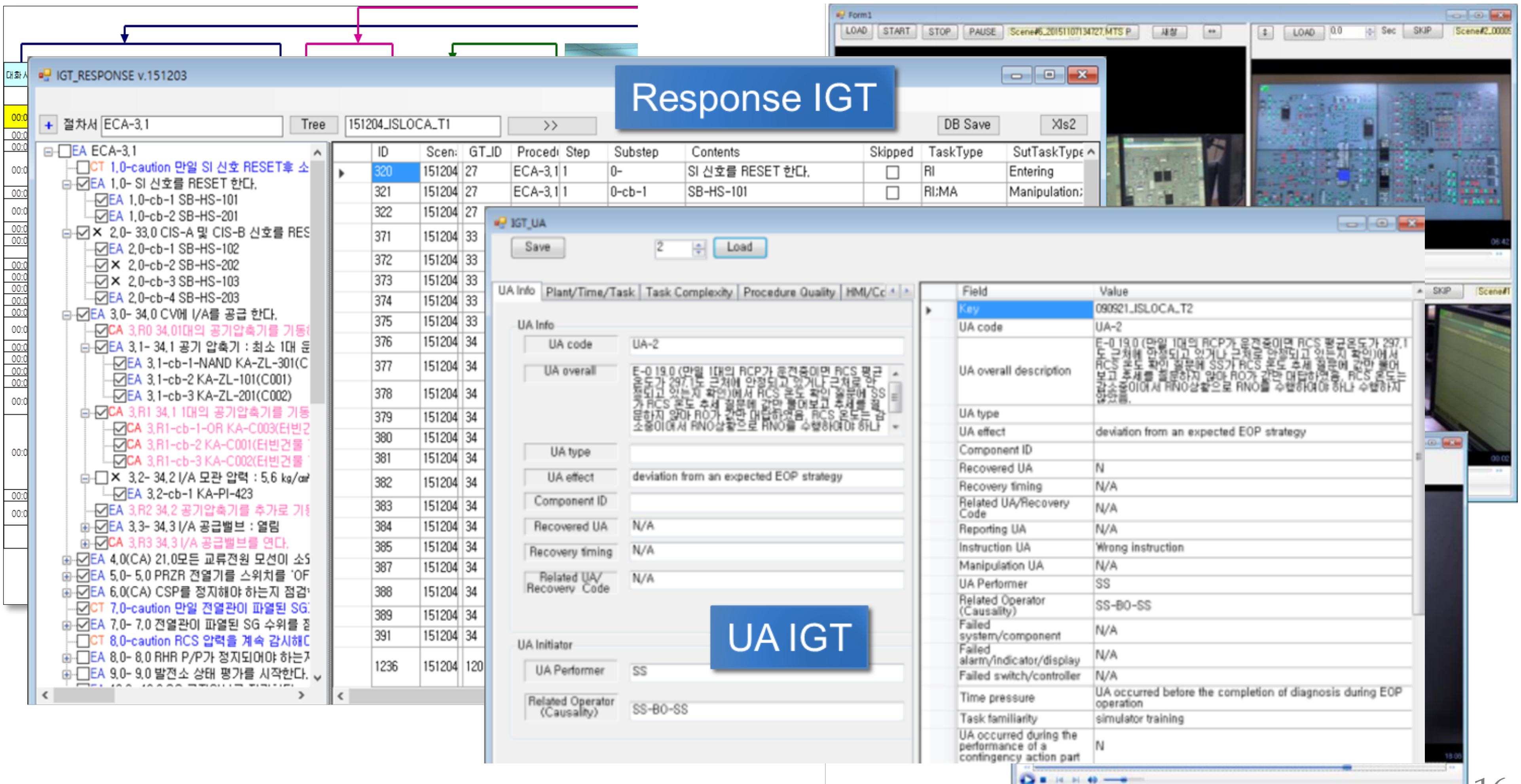
Response IGT

1. Conducted T
   - Time
   - Procedure / S
   - Contents
   - Task Type
   - Number of D
   - Number of Su
   - Operator
   - Component T
   - System Type
2. UA Analysis
   - UA Candidate
   - UA Code
   - EOO / EOC
   - Description

IGT	Category	Data field
Overview IGT	Plant & simulation overview	Plant/simulator name
		Plant type
		Operating mode
		Simulation date
		Ingress/injection time of initiating event
		Simulation completion time
		Crew/shift/team name
	Crew (SS/RO/TO/EO/ STA)	Age
		Work experience of plant operation (yr)
		Work experience in current position/role (yr)
		Certified License
		Work experience in current team (yr)
	Training & education	Simulator training frequency
		Training experience on the scenario
	Environment	Simulation environment
	Observed response	Observed procedural path
	Scenario & expected response	Simulation mode
		Initiating event
		Multiple initiating events
		Failed system or component
		Failed/masked alarm or indicator
		Scenario/event summary
		Expected procedural path
		Allowable time
	Crew characteristics and dynamics	Leadership of SS
		Cooperative attitude
		Supervising level of STA
		Independent checker
		Procedure compliance
		Communication level

Aiding Systems of HuREX

- Develop aiding systems for the data collection/analysis



Application Study

- Simulation records used in the preliminary analysis

Plant type	Event category	Scenario (# of simulation)	Supplementary information	Remark
OPR1000 (2-loop PWR)	Abnormal event	Diverse abnormal scenarios (205)	• Communication logs • Process parameter logs • Event logs • Action logs	• Collected from 2008 to 2011
WH900 (3-loop PWR)	DBA	• ISLOCA (10) • Multiple events (MSLB * SGTR) (8)	• Communication logs • Process parameter logs • Event logs • Action logs	• Collected from 2009 to 2010

- From 223 simulations, 141 UAs (83 EOOs, 58 EOCs) were identified.

Preliminary Results

- Estimated HEPs (KAERI/TR-6649)

Cognitive Activity	Abb. of Task Type	# of UA opp.	# of UA (EOO)	Pr (EOO)			# of UA (EOC)	Pr (EOC)		
				5%	50%	95%		5%	50%	95%
Information gathering and reporting	IG-alarm	453	1	3.0E-04	2.6E-03	8.6E-03	0	3.0E-04	2.6E-03	8.6E-03
	IG-indicator	2282	2	2.0E-04	9.0E-04	2.4E-03	0	1.0E-04	5.0E-04	1.7E-03
	IG-synthesis	120	0	1.4E-03	9.8E-03	3.3E-02	0	1.4E-03	9.8E-03	3.7E-02
	IG-value	121	0	1.4E-03	9.8E-03	3.2E-02	1	1.4E-03	9.8E-03	3.2E-02
	IG-comparison	395	0	4.0E-04	2.9E-03	9.8E-03	6	7.5E-03	1.6E-02	2.8E-02
	IG-graph	20	0	8.8E-03	5.8E-02	1.8E-01	0	8.8E-03	5.8E-02	1.8E-01
	IG-abnormality	371	0	4.0E-04	3.1E-03	1.1E-02	0	4.0E-04	3.1E-03	1.1E-02
	IG-trend	391	0	4.0E-04	3.0E-03	9.9E-03	7	9.3E-03	1.8E-02	3.2E-02
Response planning and instruction	RP-entry	624	2	9.0E-04	3.5E-03	8.9E-03	-	-	-	-
	RP-procedure	253	1	6.0E-04	4.6E-03	1.5E-02	0	6.0E-04	4.6E-03	1.5E-02
	RP-step	71	4	2.4E-02	5.9E-02	1.2E-01	0	2.4E-03	1.7E-02	5.4E-02
	RP-information	2885	10	2.0E-03	3.5E-03	5.7E-03	4	6.0E-04	1.4E-03	2.9E-03
	RP-manipulation	830	40	3.7E-02	4.8E-02	6.2E-02	13	9.7E-03	1.6E-02	2.4E-02
	RP-notification	523	9	9.7E-03	1.8E-02	2.9E-02	1	3.0E-04	2.2E-03	7.4E-03
Situation interpreting	SI-diagnosis	30	0	5.8E-03	3.9E-02	1.2E-01	8	1.5E-01	2.7E-01	4.1E-01
Execution	EX-discrete	712	11	9.2E-03	1.6E-02	2.5E-02	2	8.0E-04	3.0E-03	7.8E-03
	EX-continuous	25	0	7.0E-03	4.7E-02	1.5E-01	0	7.0E-03	4.7E-02	1.5E-01
	EX-dynamic	150	0	1.1E-03	7.9E-03	2.6E-02	1	1.1E-03	7.9E-03	2.6E-02
	EX-notification	512	3	2.1E-03	6.2E-03	1.4E-02	3	2.1E-03	6.2E-03	1.4E-02
Other	OT-manipulation	-	-	-	-	-	12	-	-	-

Preliminary Results

- Estimated recovery HEPs (KAERI/TR-6649)

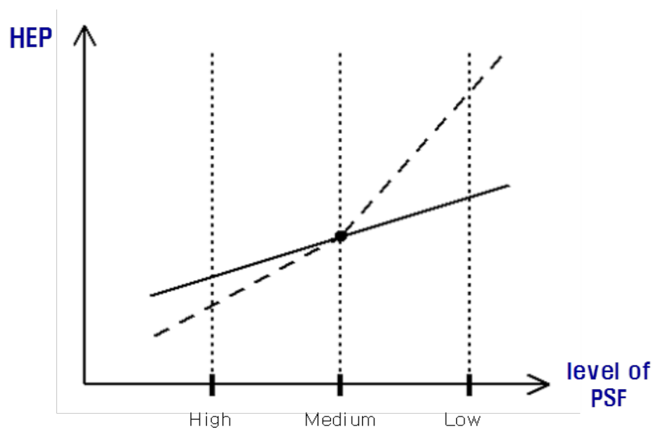
Cognitive Activity	Abb. of Task Type	Recovery from UA (EOO)			Recovery from UA (EOC)		
		Self-review	Peer-check	Not recovered	Self-review	Peer-check	Not recovered
Information gathering and reporting	IG-alarm	0 (0%)	1 (100%)	0 (0%)	-	-	-
	IG-indicator	0 (0%)	2 (100%)	0 (0%)	-	-	-
	IG-synthesis	-	-	-	-	-	-
	IG-value	-	-	-	0 (0%)	0 (0%)	1 (100%)
	IG-comparison	-	-	-	1 (17%)	1 (17%)	4 (67%)
	IG-graph	-	-	-	-	-	-
	IG-abnormality	-	-	-	-	-	-
	IG-trend	-	-	-	0 (0%)	1 (14%)	6 (86%)
Response planning and instruction	RP-entry	0 (0%)	0 (0%)	2 (100%)	-	-	-
	RP-procedure	0 (0%)	0 (0%)	1 (100%)	-	-	-
	RP-step	0 (0%)	0 (0%)	4 (100%)	-	-	-
	RP-information	0 (0%)	2 (20%)	8 (80%)	0 (0%)	0 (0%)	4 (100%)
	RP-manipulation	2 (5%)	13 (33%)	25 (63%)	4 (31%)	2 (15%)	7 (54%)
	RP-notification	0 (0%)	1 (11%)	8 (89%)	0 (0%)	0 (0%)	1 (100%)
Situation interpreting	SI-diagnosis	-	-	-	2 (25%)	0 (0%)	6 (75%)
Execution	EX-discrete	0 (0%)	8 (73%)	3 (27%)	0 (0%)	0 (0%)	2 (100%)
	EX-continuous	-	-	-	-	-	-
	EX-dynamic	-	-	-	0 (0%)	0 (0%)	1 (100%)
	EX-notification	0 (0%)	0 (0%)	3 (100%)	0 (0%)	1 (33%)	2 (67%)
Other	OT-manipulation	-	-	-	6 (50%)	1 (8%)	5 (42%)

Preliminary Results

- PSFs effects on HEP
  - logistic regression model

$$Y = \ln\frac{p(x)}{1-p(x)} = \beta_0 + \beta_1 x_1 + \cdots + \beta_n x_n \qquad p(x) = \frac{exp^{\beta_0+\beta_1 x_1+\cdots+\beta_n x_n}}{1+exp^{\beta_0+\beta_1 x_1+\cdots+\beta_n x_n}}$$

Here, $p(x)$ is the conditional probability of human error under the certain conditions of independent variables, $x_1,\ldots x_i,\ldots,x_n$, and $\beta_0, \ldots, \beta_n$ are regression coefficients indicating the effects of each variables on the $p(x)$.



PSF effect on HEP

Wrong mode conversion

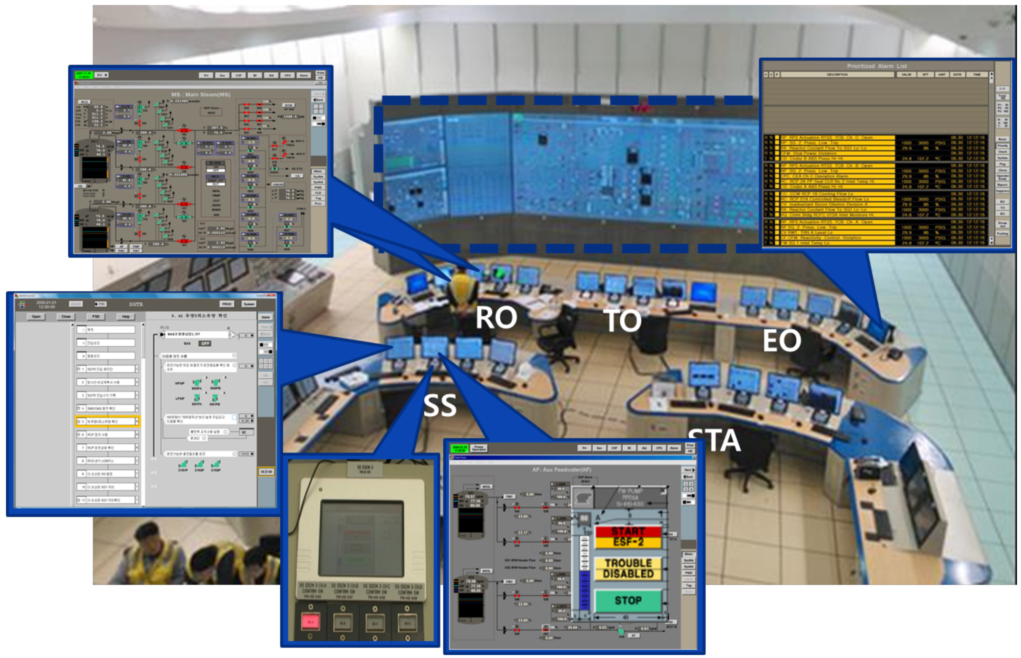
EOP description	Control Type	Experience Level	HEP
Detail	Discrete	Practiced	0.0108
		Unpracticed	0.0108
	Continuous	Practiced	0.0108
		Unpracticed	0.0363
Simple	Discrete	Practiced	0.0558
		Unpracticed	0.0558
	Continuous	Practiced	0.0558
		Unpracticed	0.169

x5

x3.5

Data Collection from APR1400

- A project is being conducted to develop HRA database to support the HRA of APR1400
  - Jan. 1, 2017 ~ July 31, 2019 (2.5 years)
- Digitalized MCR of the APR1400
  - Large Display Panel
  - Advanced Alarm System
  - Computerized Procedure System
  - Soft Control
  - Integrated Graphic Display
  - Etc.



Data Collection from APR1400

- Revise IGTs to reflect new characteristics of a digital MCR
  - Add 11 data fields
- Two sets of simulator training have been collected so far
  - Data gathering from two cycles of simulator training
    - Total 8 scenarios and 12 crew teams
  - Data analysis to produce HRA data such as HEPs, PSFs multipliers, recovery HEPs, performance times, etc.

Conclusion

- Simulator is an importance source for HRA data
- KAERI has developed HuREX as a framework of simulator data collection
  - To generate the HEPs of generic task types
  - To provide a technical basis for the HRA in Korea
- A project is now underway
  - To collect data from a full-scope simulator of APR1400 NPP
  - To develop HRA database and technical basis for the HRA of a digital MCR

Thank you for your attention!

Q&A