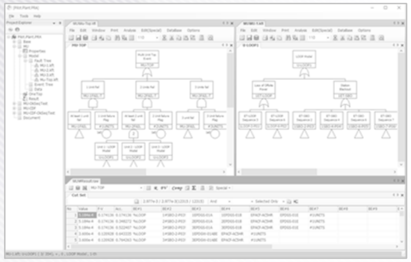
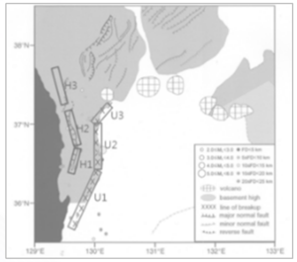
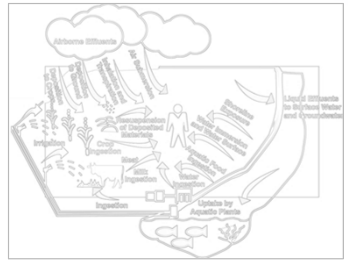
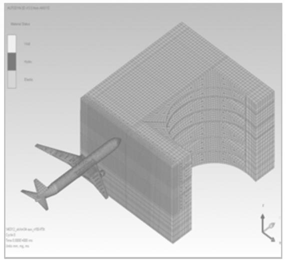
www.kaeri.re.kr

Toward a novel SA measure for a digital main control room*

Jinkyun Park, Yochan Kim and Wondea Jung

Korea Atomic Energy Research Institute

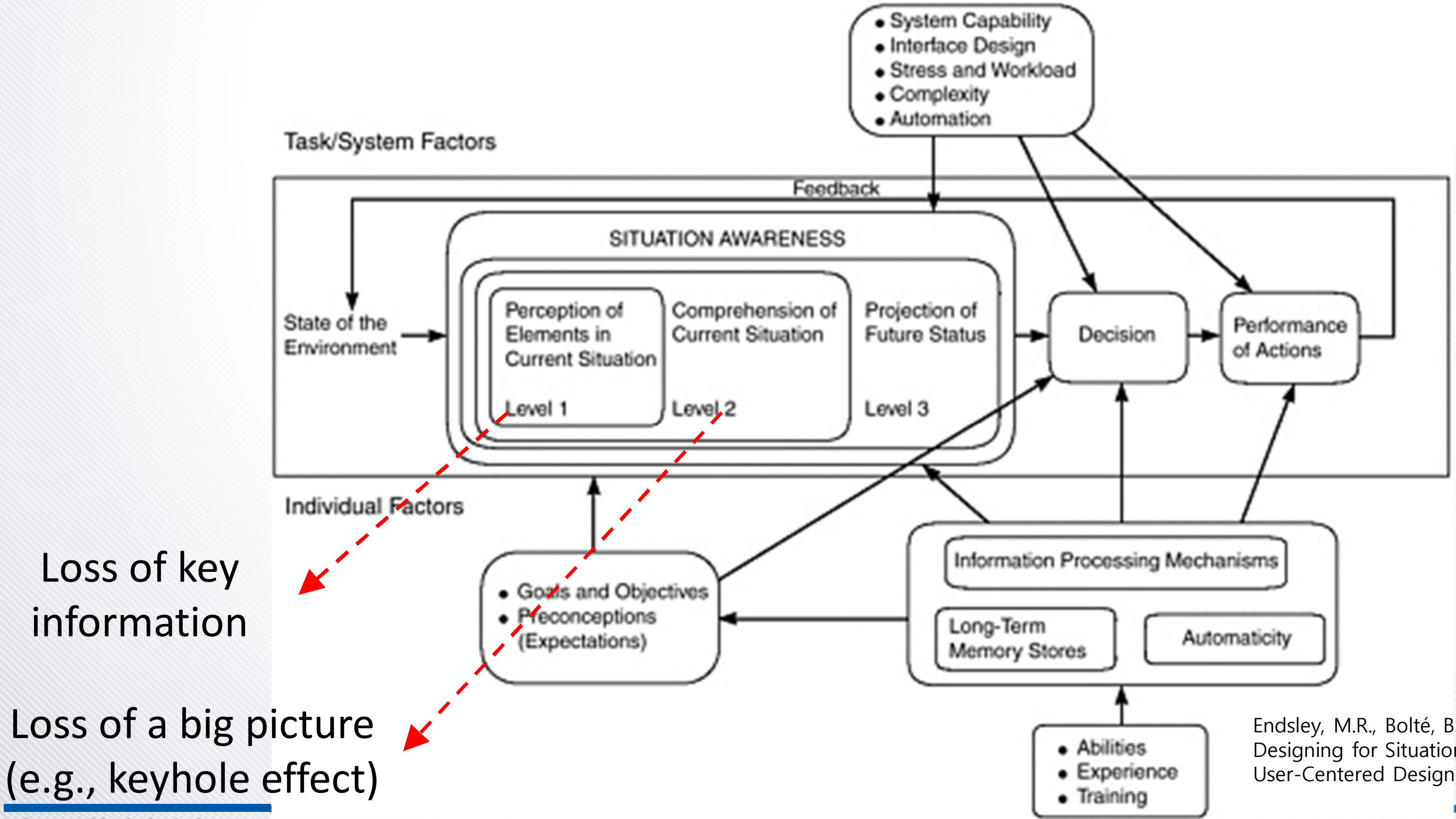
PSAM 14, Los Angeles, CA, September 16-21, 2018

*More detailed information about this presentation can be found from:
Ronald L. Boring, Thomas Ulrich, and Bruce P. Hallbert, Jinkyun Park, Yochan Kim, and Wondea Jung (KAERI), INL/EXT-17-43719 (KAERI/TR-6968/2017), Evaluation of the sustainability and effectiveness of proposed methods and measures for operator performance in control rooms.

CONTENTS

Introduction

- **Situation awareness (SA) is one of the critical factors affecting the performance of human operators who are responsible for a complicated socio-technical systems; e.g., nuclear power plants (NPPs)**



Endsley, M.R., Bolté, B., and Jones, D.G. (2003). Designing for Situation Awareness: An Approach to User-Centered Design. Taylor & Francis: London.

Limitations of existing methods

- **Most of representative methods based on questionnaires have several limitations:**
  - Expecting **HIGH** interference with human operators
  - Requiring **HIGH** effort to collect raw data
  - Requiring **HIGH** expertise to interpret collected data

Questionnaire-based evaluation

Representative method
Cognition as a Network of Tasks (COGNET)
Situation Awareness for SHAPE (SASHA)
Situation Awareness Verification and Analysis Tool (SAVANT)
Goal-Directed Task Analysis (GDTA)
Situation Awareness Global Assessment Technique (SAGAT)
Situation Awareness of en-route air traffic controllers in the context of automation (SALSA)
Situation Awareness Rating Technique (SART)
Situation Present Assessment Method (SPAM)
Situational Awareness Linked Indicators Adapted to Novel Tasks (SALIANT)

- **A novel SA measure is strongly need, which requires less interference, effort, and expertise.**

SA measurement: SART example

$$SART\ Score: [-14, 46]$$

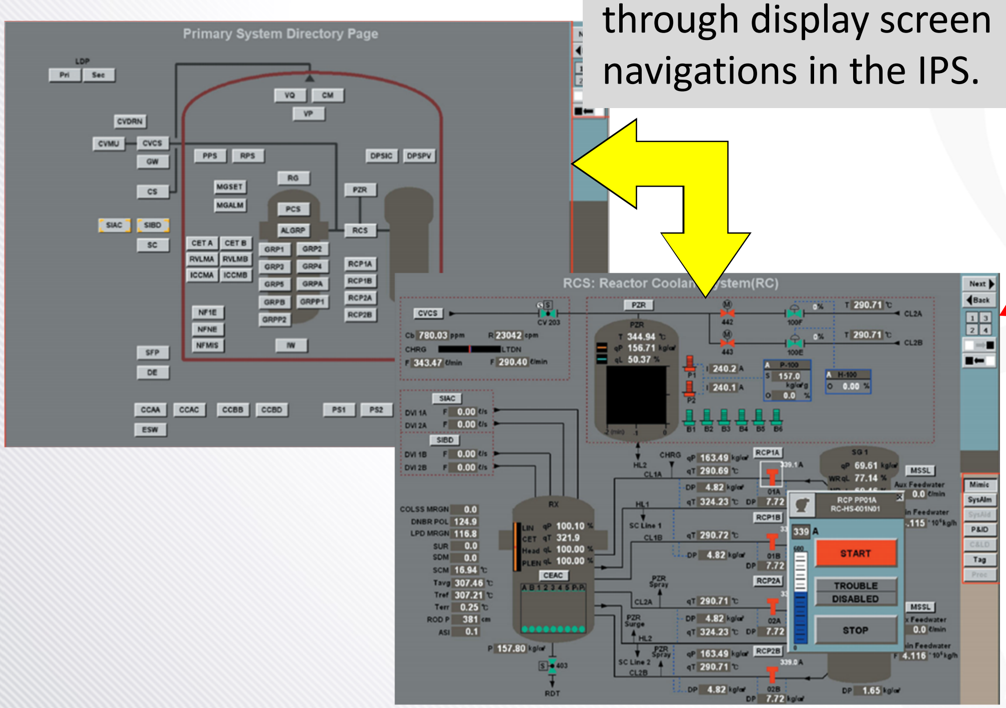
$$= \sum(Q_4 + Q_5 + Q_6 + Q_7) + \sum(Q_8 + Q_9 + Q_{10}) - \sum(Q_1 + Q_2 + Q_3)$$

	ID	Dimension	Description (Rated by 7-point Likert scale, High=7, Low=1)
Demand	Q_1	Instability of situation	How changeable is the situation? Is the situation highly unstable and likely to change suddenly (High) or is it very stable and straightforward (Low)?
	Q_2	Variability of situation	How many variables are changing within the situation? Are there a large number of factors varying (High) or are there very few variables changing (Low)?
	Q_3	Complexity of situation	How complicated is the situation? Is it complex with many interrelated components (High) or is it simple and straightforward (Low)?
Supply (resources)	Q_4	Arousal	How around are you in the situation? Are you alert and ready for activity (High) or do you have a low degree of alertness (Low)?
	Q_5	Spare mental capacity	How much mental capacity do you have to spare in the situation? Do you have sufficient to attend to many variables (High) or nothing to spare at all (Low)?
	Q_6	Concentration	How much are you concentrating on the situation? Are you concentrating on many aspects of the situation (High) or focused on only one (Low)?
	Q_7	Division of attention	How much is your attention divided in the situation? Are you concentrating many aspect of the situation (High) or focused on only one (Low)?
Understanding	Q_8	Information quantity	How much information have you gained about this situation? Have you received and understood a great deal of knowledge (High) or very little (Low)?
	Q_9	Information quality	How much information have you gained about this situation? Have you received high degree of goodness of knowledge (High) or do you have a low degree of goodness (Low)?
	Q_{10}	Familiarity	How familiar are you with the situation? Do you have a great deal of relevant experience (High) or is it a new situation (Low)?

New SA measure – underlying idea (1/3)

- It should be emphasized that human operators working in a digital main control room (MCR) have to use centralized information processing system (IPS).

Human operators can reach all kinds of information sources and control devices through display screen navigations in the IPS.



New SA measure – underlying idea (2/3)

- In the IPS, each and every screen navigation activity is recorded in the form of a text file (i.e., action log file).
- Display pages visited by human operators can be subdivided into three categories based on the contents of required tasks.
  - Key display screen: containing necessary information for conducting required tasks;
  - Neutral display screen: providing task neutral information such as directory pages or common information display pages;
  - Less meaningful display screen: others
- High SA score is expected if human operators visited key display screens that contain necessary information for conducting required tasks.

Identifying key display screens

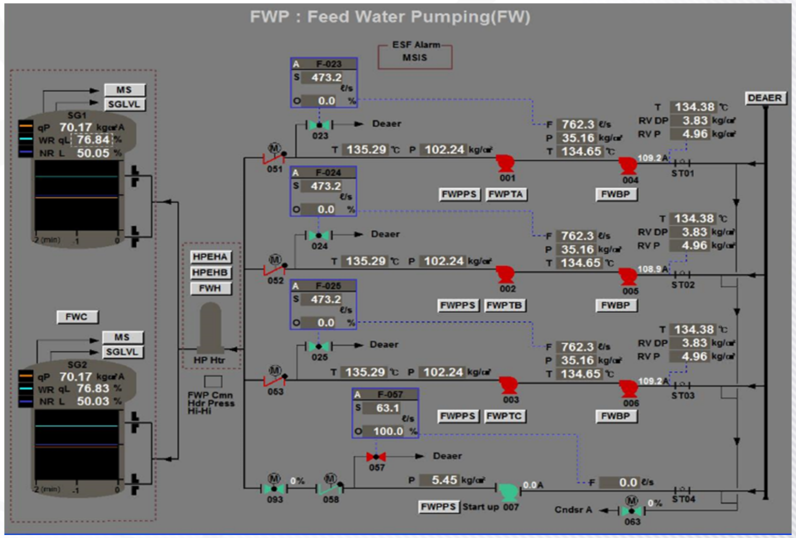
- **Task analysis**
  - When a steam generator tube rupture (SGTR) occurred, a turbine operator's (TO) role is vital for coping with it.
  - The catalog of critical tasks to be done by TOs can be identified from detailed task analysis.
  - Detailed information display screens were distinguished based on critical tasks (**key display screens**).

Critical tasks for an SGTR

- Initial cooling down the hot-leg temperature of RCS (Reactor Coolant System)
- Identifying and isolating a faulty SG (Steam Generator)

…

One of key display screens for this task



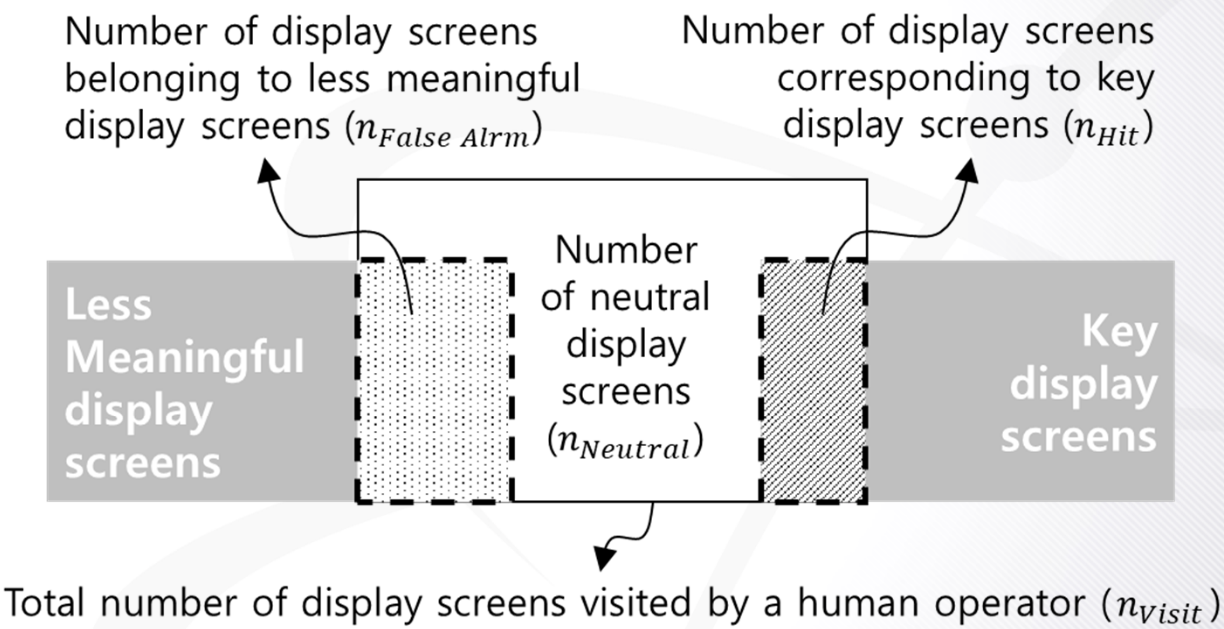
New SA measure – underlying idea (3/3)

- **Originated from signal detection theory (SDT)**

$$\text{Sensitivity} = \frac{p(Hit) - p(False\ Alarm)}{1 - p(Hit)}$$

- **High sensitivity** value
~ **high SA** score

- Low sensitivity value
~ low SA score



$$n_{Visit} = n_{Hit} + n_{False\ Alarm} + n_{Neutral}$$

$$p(False\ Alarm) = \frac{n_{False\ Alarm}}{n_{Visit}} \qquad p(Hit) = \frac{n_{Hit}}{n_{Visit}}$$

Novel SA measure validation – overall process

Recruiting subjects

Six MCR crews working in domestic NPPs with diverse operating experience

Exposing to simulated SGTR condition

Collecting action log files

Identifying key display screens for SGTR

Calculating sensitivity scores

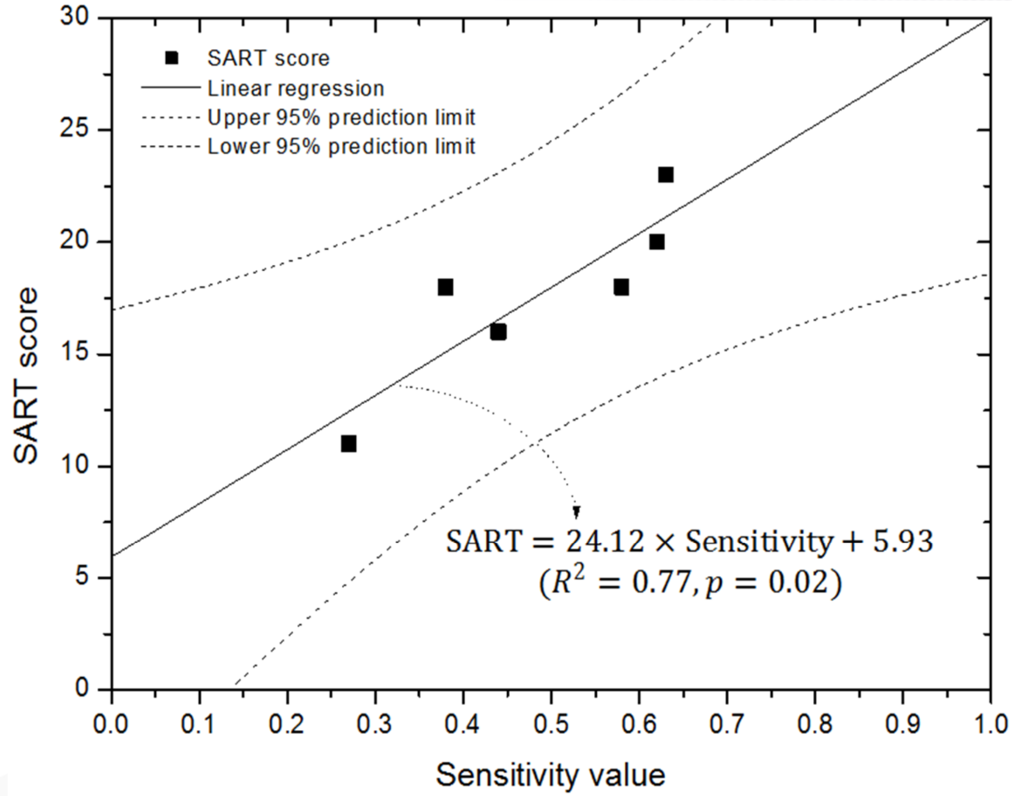
Collecting SART scores from human operators

Each human operator was asked to fill out SART questionnaires after the simulation.

Comparing SART and sensitivity scores

Comparison result (w.r.t Turbine operator)

Crew ID	Operator	SART score
1	SS (Shift supervisor)	19
	RO (Reactor operator)	19
	TO (Turbine operator)	16
2	SS	17
	RO	17
	TO	20
3	SS	16
	RO	23
	TO	18
4	SS	15
	RO	18
	TO	11
5	SS	20
	RO	12
	TO	18
6	SS	16
	RO	14
	TO	23



ANOVA (Analysis Of Variance) result

$\text{SART} = 24.12 \times \text{Sensitivity} + 5.93\ (R^2 = 0.77, p = 0.02)$

Item	Degree of freedom	Sum of squares	Mean square	F statistics
Model	1	62.54	62.54	13.31
Error	4	18.79	4.70	-
Total	5	81.33	-	-

Concluding remark and future works

- **This study proposed a novel SA measure based on SDT.**
  - SA scores calculated by the proposed SA measure showed a good correlation with the associated SART scores.
  - It seems that the proposed SA measure is advantageous rather than existing methods because:
    - It require less intervention of human operators with low effort/expertise.
    - On-line SA scores can be automatically calculated based on action log files;
    - SA score for individual human operator can be separately calculated → Technical basis for visualizing **Team SA** or **Shared SA**

- **The proposed SA measure can be used to quantify human operators' Level 1 and 2 SA**
  - Catalog of key display screens for Level 1 SA
  - Catalog of key display screens for Level 2 SA
- **It is required to extend the proposed SA measure for representing SA Level 3.**
- **Further validation study is necessary based on additional SART scores collected from other off-normal scenarios.**

THANK YOU