# ALTERNATIVE HUMAN-MACHINE INTERFACES FOR COPING WITH TEAM ERRORS IN THE DIGITALIZED CONTROL ROOM OF NUCLEAR POWER PLANTS

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*This study aims to propose alternative human-machine interfaces (HMI) in terms of team errors in the digitalized control room of nuclear power plants. Especially a group-view display and computer-based procedure system have deep relationships with team errors in terms of team communication, shared situation awareness, and decision making. We proposed alternative HMIs to improve team communication, shared situation awareness, and decision making using a group-view display and computer-based procedure system.*

*To develop alternative HMIs we found team error hazards in digitalized control room based on team error model; proposed countermeasures against team error hazards in terms of HMI; reviewed the derived countermeasures with operational experts; determined alternative HMIs according to review criteria for selecting new and advanced interfaces; finally, validated each interfaces in terms of recovery rates against team errors.*

*We found that the developed HMIs are effective to reduce team errors in digitalized control room. We also found that an alternative group-view display interface supported team communication and decision making and an alternative computer-based procedure system supported shared situation awareness among team members. Digitalized control rooms have many advantages in terms of information configuration and visualization. However, each team member is easy to turn loose other person's situations so that team performance could be turn down. We hope that the developed alternative HMIs could be a role to reduce team errors in digitalized control room in nuclear power plants.*

*Keywords: team errors, human-machine interfaces, group-view display, computer-based procedure, control room, nuclear power plant*

## I. BACKGROUND

Tenerife airport disaster in 1977, Chernobyl disaster in 1986, and USS Vincennes disaster in 1988 are well-known disasters in the world. A representative common cause of those disasters is deficiency of shared situation awareness, which is one of the root causes of team errors. Team is defined as two or more people who are appropriately interacting with each other, and the team is a dependent aggregate, which accomplishes a valuable common goal (Ref. 5). Teamwork can detect and recover errors; however, it can also create errors (Ref. 4). Team error is one form of human error; however, team error considers how a group of people made human errors when they worked in a team or a group (Ref. 4). Sasou and Reason defined the team error as human error made in team processes. They also explained team error process in terms of individual and shared errors. Their model for team error process is described in Fig. 1.

In general, there are three perspectives for human errors; individual, team, and organizational perspectives. According to the each human error perspective, different countermeasures are needed for reducing human errors because different factors accordance with those perspectives affect human errors as Fig. 2 (Ref. 2). So that the team errors should be considered with team perspective such as team decision-making, leadership & followership, shared situational awareness, shared mental model, team communication, team coordination, team spirit, etc.

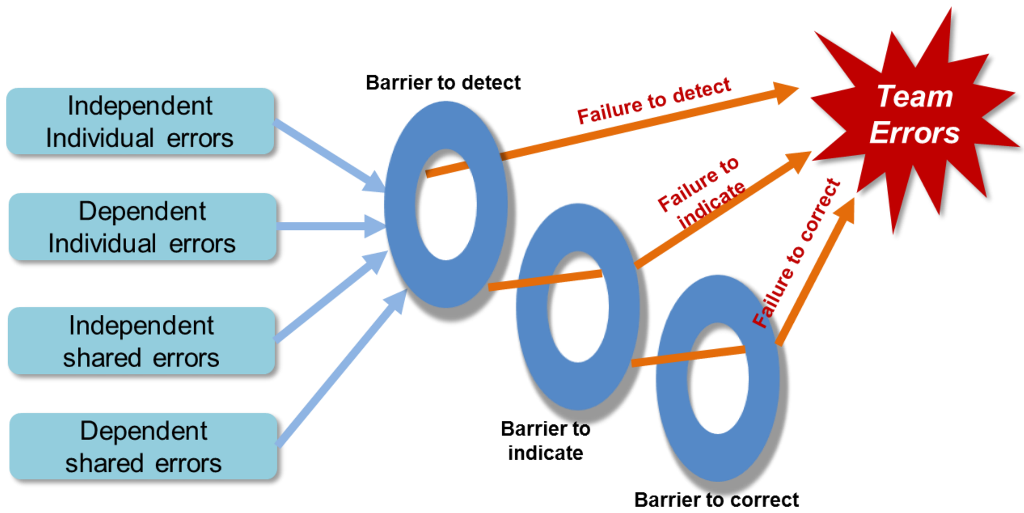


Fig 1. Team error process by Sasou and Reason (1999)

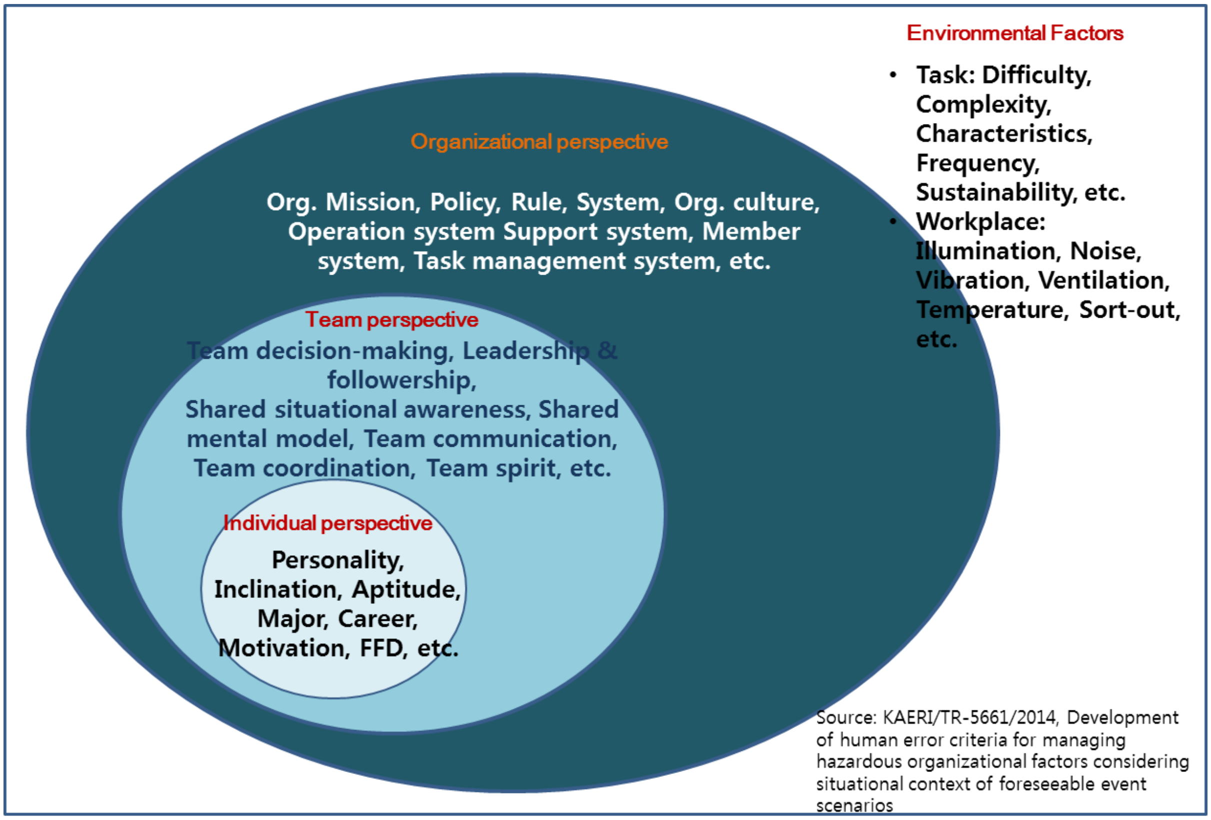


Fig. 2. Three perspectives for human errors

In the team perspective, team performance and effectiveness are the main topics to improve productivity and safety. However, team error has been dealt with one of the causes or performance shaping factors. Team error is recognized as a typical type of human errors also. Team performance is influenced by factors occurring not only at the team level but also at levels above and below such as culture, climate, individual performance, which can make it difficult to determine the root cause of a team failure (Ref. 3). Also, errors within teams can originate and manifest at both the individual and collective levels of analysis (Ref. 1). Bell and Kozlowski studied about the moderating influence of task interdependence on the relationship between individual and team error.

In nuclear industry, team error is a challengeable topic because most of human errors have been dealt as an individual failure or organizational failure. Recently as digitalized techniques are adopted in control room of nuclear power plants, new digital interfaces make new concerns relevance with team communication, shared situational awareness, etc. The new team error issues related with digital control room are following:

- Shared situational awareness among team members - Individual situational awareness could be better. However, shared situational awareness could be worse;
- Sensitive team stability - Fluctuating change in a team could make problems such as poor leadership, declined team learning;
- Shared mental model - Different mental models could be coexisting in a team due to multi-generations;
- Team communication - Low frequent communication among team members owing to difficult of the ‘Face to Face’ communication and change of operational concept;
- Shared task procedures - Team members could perceive different task procedure each other in case of using computer-based procedures;
- Leader’s mental workload - Leader should obtain much more information in his or her workstation in order to confirm the plant situations, which are reported by team members.

In this study, we proposed countermeasures against team errors in terms of human-machine interfaces (HMI). Especially a group-view display and computer-based procedure are dealt with important digital interfaces in main control room of nuclear power plants. Because a group-view display and computer-based procedure are the representative digital interfaces in the advanced control room and are deeply related with team activities, those interfaces was chosen.

## II. ALTERNATIVE INTERFACES

### II.A. Strategic Countermeasures Coping with Team Errors

To cope with the current issues, we determined the following strategic countermeasures through experts’ brain storming;

- Shared situational awareness among team members: A group-view display is determined as a vital coping tool. One of the strategic countermeasures is to provide common cues in a group-view display to share the situational awareness among operators. For example, providing a temporal pop-up in the group-view display whenever someone controls a component or system or providing a temporal mark-up function to leader in the group-view display using such as air writing technology or laser pointing marking technology are the representative countermeasures.

- Sensitive team stability: A crew resource management (CRM) training program is determined as a vital coping tool. Providing a CRM training program is to enhance adaptation ability against team instability such as a team error management program, team-customized training program, or leadership paired followership training program.

- Shared mental model: A crew resource management (CRM) training program is determined as a vital coping tool. Providing a CRM training program is to enhance shared mental model and shared understanding such as making a shared space through team seminar and dialogue and role playing. Also, providing a joint CRM training program is to enhance each understanding.

- Team communication: A computer-based procedure system is determined as a vital coping tool. Providing communication steps in the computer-based procedure system is to facilitate team members' communication via essential steps to communicate with each other or confirming function into the communication steps. Also, providing a supervision display to team leader using web-camera is to make more complete communication among team members.

- Shared task procedures: A computer-based procedure system is determined as a vital coping tool. Providing confirmed or be active information in a computer-based procedure system is one of the countermeasures.

- Leader's mental workload: To reduce the leader's mental workload in the digital control room, a new staffing is necessary. Providing vice-leader to share the leader's mental workload is a vital resolution. A new vice-leader as a safety technical assistant is one of the countermeasures. Also, providing a supporting system to help critical decision-makings is one of the other resolutions.

### II.B. Countermeasures using a Group-view Display

In terms of the Human-System Interface (HSI) of a group-view display, we proposed a modified HSI through the modification process of group-view display as described in Fig. 3.

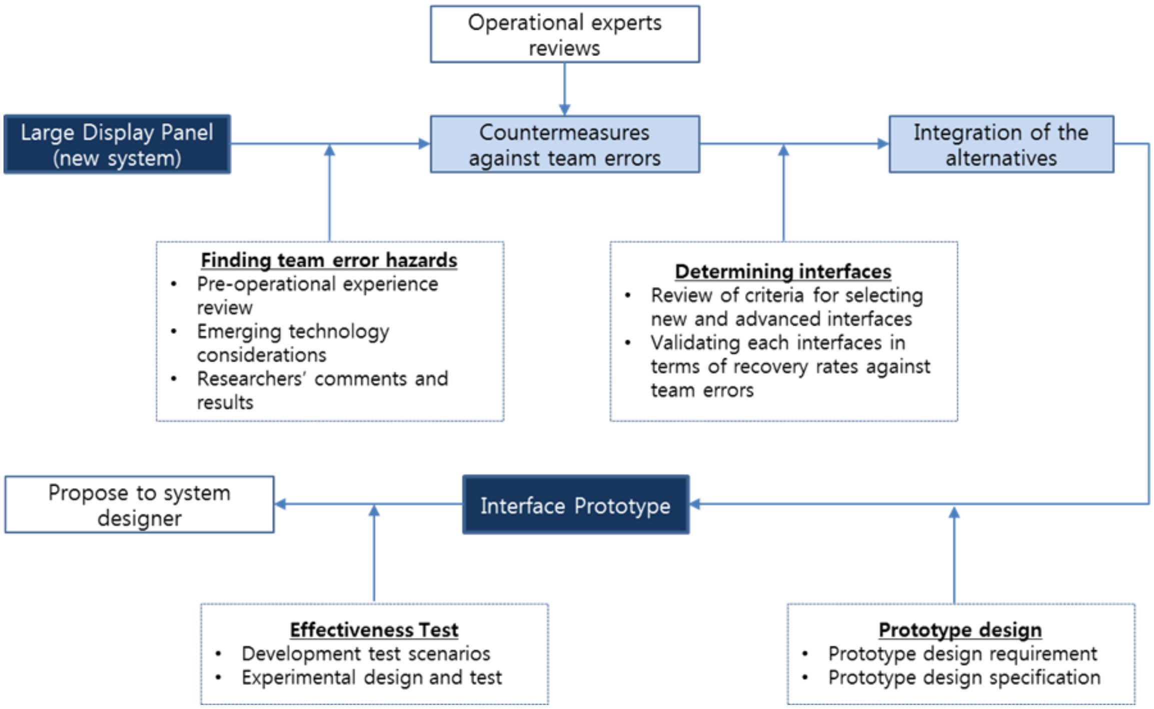

Fig. 3. HSI modification process

Firstly, we found team error hazards through reviewing pre-operational experiences, considering emerging HSI technology in digital control room, and comparing researchers' comments and research results. As described in section II.A, six strategic countermeasures are the determined alternatives. To determine those countermeasures, we reviewed the criteria for selecting new and advanced interfaces and validated each interfaces in terms of recovery rates against team errors through an event tree analysis of unsafe scenarios, which are deployed by our research team such as Fig 4.

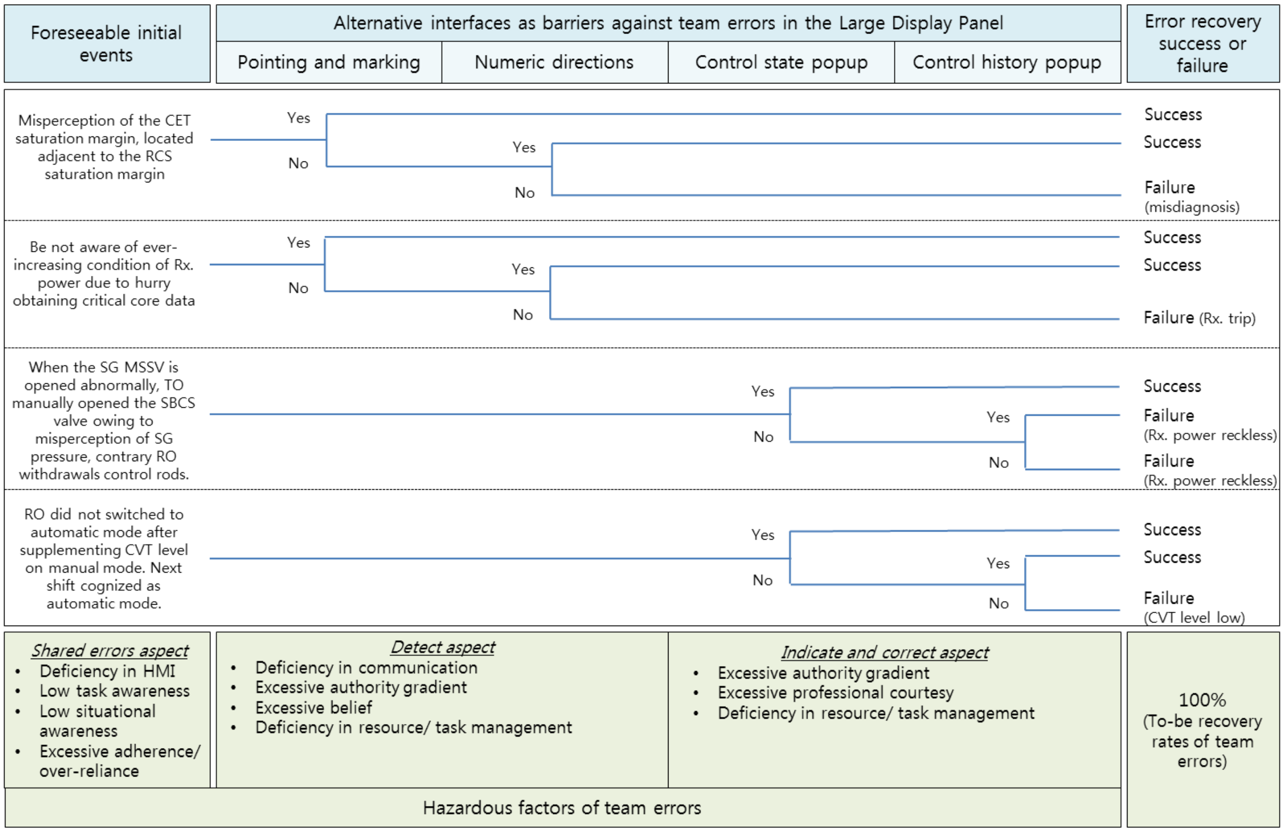


Fig. 4. Example of an event analysis of unsafe scenarios

The developed unsafe scenarios were used for analyzing team error hazards and barriers. The alternative interfaces as barriers against team errors in a group-view display are following:

- Pointing and marking: On the group-view display, team leader can point an object and mark a line, circle, or text using a developed pointing and marking tool. Fig. 5 shows how to point and mark on a group-view display.

- Numeric directions: In case of a numeric value has a direction such as left, right, up, down, or right circulation, etc., the interface has a dynamic direction.

- Control state pop-up: Whenever someone controls a component or system, the control state will be displayed on the group-view display.

- Control history pop-up: In case someone wants to know what controls were performed, he or she can see the control history by pop-up display on the group-view display.

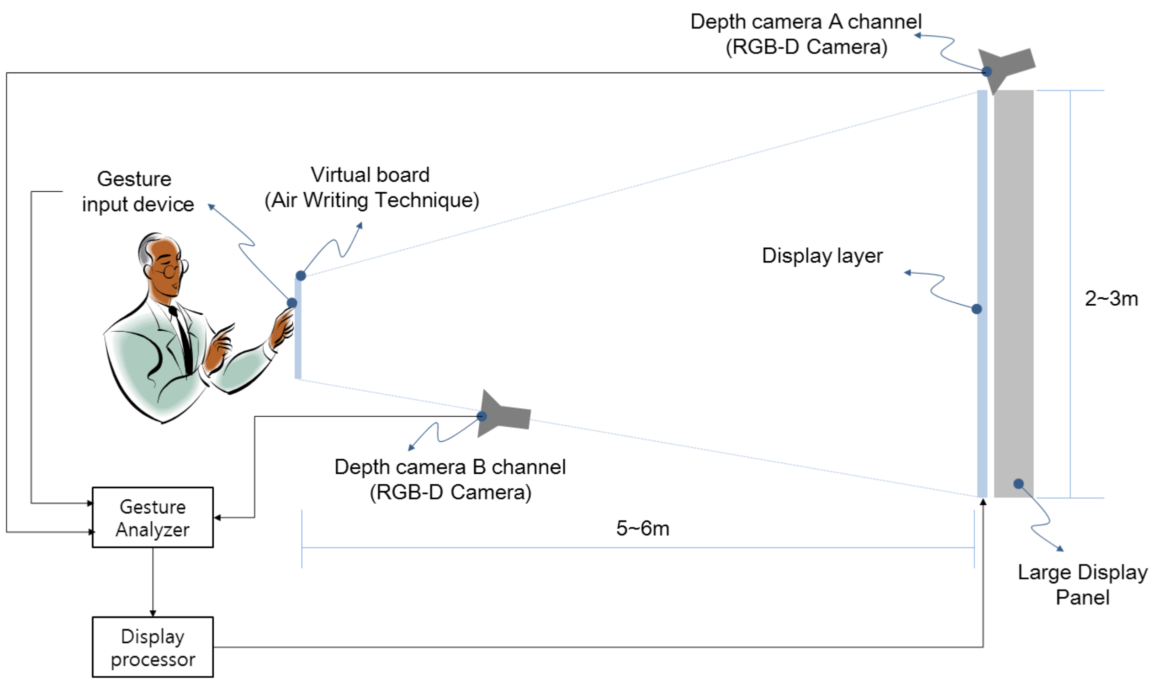


Fig. 5. Pointing and marking function on a group-view display

## III. EFFECTS OF THE ALTERNATIVE INTERFACES

In this study, we confirmed the effects of team error reduction using the proposed HSI alternatives. An effectiveness test was performed. The effectiveness test aims to validate that the proposed HSI supports the shared situational awareness of operation team. We used a dynamic mockup which could partially simulate a nuclear power plant. The details about the test will be introduced on the conference in Seoul.

## IV. CONCLUSIONS

We are on the way to develop alternative interfaces against team error in a condition of using large display panel in main control room of APR-1400. Currently, we are progress on the test. We will present the results of the test on the conference in Seoul. The APR-1400 is a new plant adapted to advanced digital technology in main control room. The large display panel is a representative feature of digitalized control room. As a group-view display, the large display panel provides plant overview to the operators. However, in terms of team performance and team errors, the large display panel is on a discussion board still because the large display panel was designed just a concept of passive display. In this study, we will propose revised large display panel which is integrated with several alternative interfaces against feasible team errors. We are on the phase of analyzing foreseeable team errors and feasible scenarios. After validating the effectiveness through the experimental way, we will propose a revised large display panel. Of cause, the adoption and application are the other business.

## ACKNOWLEDGMENTS

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIP). The project number is 2012M2A8A-4004256.

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