

# Human System Interface Test for Elastic Tile Alarm Display of SMART Alarm and Indication System

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# 01 Introduction

## » Conventional MCR vs Digital MCR



- Paper based Procedure System
- Dedicated Control
- **Tile Alarm System on Control Panel**



- Computerized Procedure System
- Soft Control
- **Advanced Alarm System**

# 01 Introduction

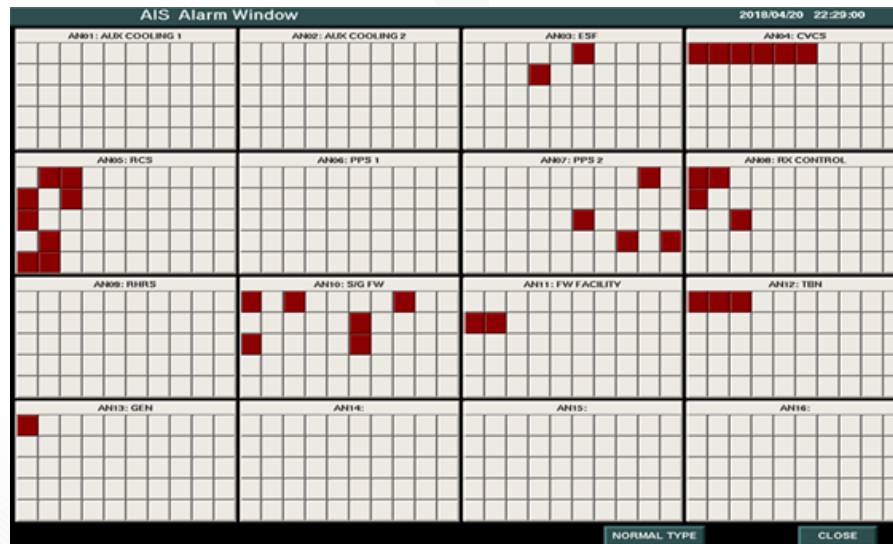
## » Alarm and Indication System of SMART (digital) MCR

- The SMART main control room (MCR) is a digital control room adopting the computer-based technologies.
- While existing **analog-based control rooms** include **a thousand of alarm tiles, indicators, and controllers**, the **SMART MCR** is the compact and digital control room with the adoption of **visual display unit (VDU)-based** monitoring and control equipment.
- This digital control room has **the limitation that the display space is not sufficient** for displaying all the indication and alarm information.
- The **SMART alarm and indication system (AIS)** adopted the **advanced alarm processing techniques** such as the alarm filtration and suppression, called an **elastic tile alarm display (ETD)** which is a new interface and specific for the SMART.
- In this paper, since the ETD method is the unique concept for the SMART and is not validated, the human factors engineering (HFE) **evaluation for ETD human system interface (HSI) features is performed to validate its effectiveness.**

# 02 Elastic Tile Alarm Display

## » Design Features

- The Elastic Tile Alarm Display (ETD) basically adopts the tile-type alarm displays of a conventional control room
- In addition, the ETD **displays all alarms on a page** to take advantage of **operators' alarm pattern recognition**.
- In order to display all alarms on dedicated one screen, both alarm filtration , suppression techniques, and **display expanding and reducing technique** are applied to the ETD.

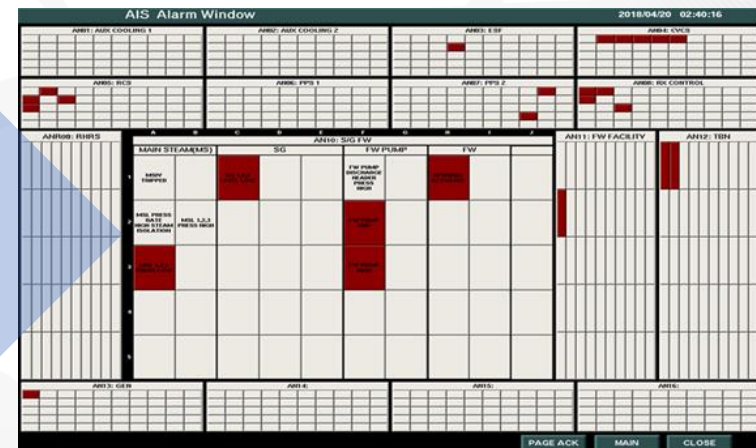
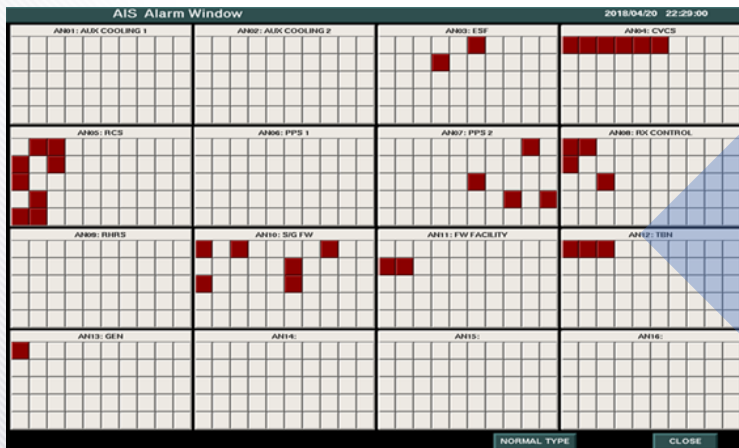


<Initial displays of the ETD>

# 02 Elastic Tile Alarm Display

## » Structure of ETD

- Four layers of alarm windows (4x4), for reactor operator (RO) and assistant operator (AO) separately, is displayed on the ETD. Each alarm window consists of 50 (10x5) alarm tiles.
- The initial display of the ETD is composed of an alarm window consisting of 50 alarm tiles and does not display the alarm descriptions of the alarm tiles.
- When an alarm is activated, the alarm flashes on the ETD. To recognize the flashing alarm, the operator has to click the flashing alarm window.
- Once clicked, the alarm window expands as shown in the figure below within 1 second.
- When an alarm window is expanded, the adjacent alarm windows are reduced while the clicked alarm window is sufficiently enlarged for the operator to read and recognize the alarm description.



<Configuration of ETD>

# 03 Human System Interface Test for ETD

## » Test Purpose

- As explained in the introduction, since the ETD method is not validated, the **HFE evaluation for ETD HSI features** is performed to validate its **effectiveness**.

## » Test Methodology

### ■ Constraints

- In this study, although the comparison usability test is considered as a kind of objective method, the comparison usability test such as the usability comparison between the commercial NPP alarm display and the SMART alarm display is not performed since the results of this comparison may be sensitive.
- For this reason, the **HSI usability test** in this study is performed by **comparing the instructor's performance and subjects' performance** in terms of performance time dimension when using ETD display method.

# 03 Human System Interface Test for ETD

## » Test Methodology

### ■ Performance measurement

- Accuracy and completeness:
  - 1) Accuracy of alarm tile acknowledgement
  - 2) Accuracy of alarm window acknowledgement
- Performance time:
  - 1) Time to find the designated alarm tiles and alarm windows
  - 2) Time to finish all tasks in the scenario

### ■ Validation Criteria

- Accuracy and completeness:
  - Subject's alarm recognition accuracy should be accomplished as **100% accuracy**
- Performance time
  - Subject's performance time should be within the reference performance time (the baseline performance time), which is average task performance time performed by the instructor, subtracted by the time for its standard deviation.

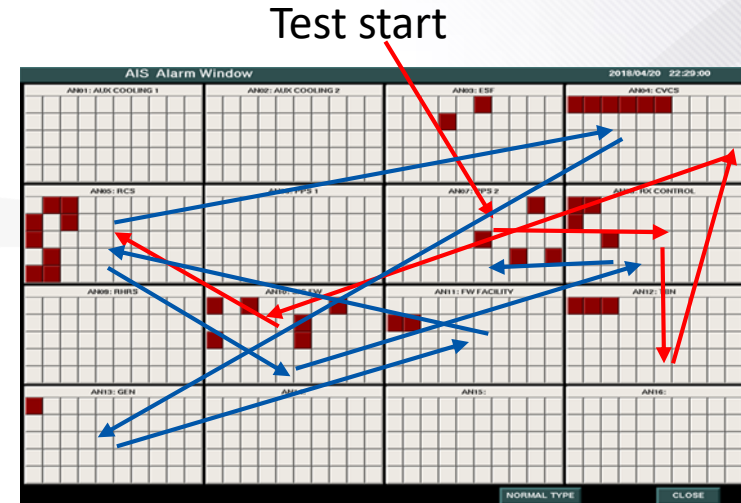


# 03 Human System Interface Test for ETD

## » Test Scenario

The brief explanation of the scenario and the associated alarms/alarm windows are as follows.

- Verify the reactor trip
  - PRZ LOW PRESS & P-7 RX TRIP alarm at AN07 window
  - CONTROK BANK LOW-LOW LIMIT alarm at AN08 window
- Verify the turbine trip
  - TBN TRIP P-4 alarm at AN12 window
- Verify the ESF actuation
  - PRZ PRESS LO SI alarm at AN03 window
- Verify the status of secondary system/steam generators
  - SG 1,2,3 LEVEL LOW alarm at AN10 window
  - FW PUMP TRIP alarm at AN10 window
- Verify the status of primary system/pressurizer
  - PRZ PRESS LOW alarm at AN05 window
- ETD alarm window navigation tasks
  - AN04 window (CVCS) to AN13 window (GEN) → AN13 window (GEN) to AN11 window (FW FACILITY) → AN11 window (FW FACILITY) to AN05 window (RCS) → AN05 window (RCS) to AN10 window (S/G FW) → AN10 window (S/G FW) to AN08 window (RX CONTROL) → AN08 window (RX CONTROL) to AN07 window (PPS2)



<ETD Interface movement>

- ➔ Alarm recognition tasks
- ➔ Alarm window navigation tasks

# 03 Human System Interface Test for ETD

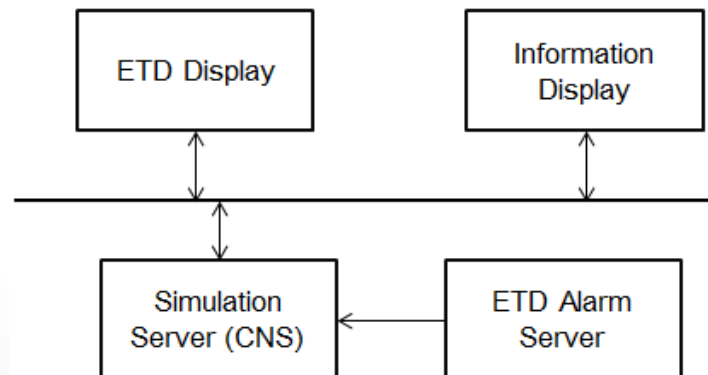
## » Test Implementation

### ■ Subjects

- The number of subjects participated in this test is nine. All subjects consist of male and have knowledge about overall NNP systems. The average age of the subject is 29.78 ( $\pm 3.71$ ).

### ■ Instruction

- According to the instruction of the information display, the **subjects navigate alarm windows and acknowledges specific alarm** by focusing on the activated alarms on the ETD. In the information display, the information of the **alarm window navigation and the specific alarm** that the subjects should acknowledge **are provided**.



<Configuration of the Test-Bed>

# 04 Test Results

## » Accuracy and Completeness

### ■ Subject's alarm recognition log (part)

Scenario	Task (Ideal Path)	S1(1)	S1(2)	S2(1)	S2(2)	S3(1)	S3(2)	S4(1)	S4(2)	S5(1)	S5(2)	S6(1)	S6(2)	S7(1)	S7(2)	S8(1)	S8(2)	S9(1)	S9(2)
Verify the reactor trip.		..																	
Verify PRZ LOW PRESS & P-7 RX TRIP alarm at AN07 window.	Screen Navigation to AN07 (PPS 2).	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.
	Alarm Tile Acknowledgement of PRZ LOW PRESS & P-7 RX TRIP.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.
Verify CONTROK BANK LOW-LOW LIMIT alarm at AN08 window.	Screen Navigation to AN08 (RX CONTROL).	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.
	Alarm Tile Acknowledgement of CONTROK BANK LOW-LOW LIMIT.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.
Verify the turbine trip.		..																	
Verify TBN TRIP P-4 alarm at AN12 window.	Screen Navigation to AN12 (TBN).	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.
	Alarm Tile Acknowledgement of TBN TRIP P-4.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.
Verify the ESF actuation.		..																	
Verify PRZ PRESS LO SI alarm at AN03 window.	Screen Navigation to AN03 (ESF).	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.
	Alarm Tile Acknowledgement of PRZ PRESS LO SI.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.
Verify the status of secondary system/steam generators.		..																	
Verify SG 1,2,3 LEVEL LOW alarm at AN10 window.	Screen Navigation to AN10 (S/G FW).	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.
	Alarm Tile Acknowledgement of SG 1,2,3 LEVEL LOW.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.
Verify FW PUMP TRIP alarm at AN10 window.	Alarm Tile Acknowledgement of FW PUMP TRIP.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.
Verify the status of primary system/pressurizer.		..																	
Verify PRZ PRESS LOW alarm at AN05 window.	Screen Navigation to AN05 (RCS).	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.
	Alarm Tile Acknowledgement of PRZ PRESS LOW.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.
ETD alarm window navigation tasks.		..																	
Main window to AN04 window (CVCS).	Screen Navigation to AN04 (CVCS).	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.
	Alarm Window Acknowledgement of AN04 (CVCS).	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.
AN04 window (CVCS) to AN13 window (GEN).	Screen Navigation to AN13 (GEN).	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.
	Alarm Window Acknowledgement of AN13 (GEN).	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.	V.

# 04 Test Results

## » Accuracy and Completeness

Task (Ideal Path) of Scenario	Total Number of Task Given	Total Number of Task Performed
Screen Navigation to AN07 (PPS 2)	18	18
Alarm Tile Acknowledgement of PRZ LOW PRESS & P-7 RX TRIP	18	18
Screen Navigation to AN08 (RX CONTROL)	18	18
Alarm Tile Acknowledgement of CONTROK BANK LOW-LOW LIMIT	18	18
Screen Navigation to AN12 (TBN)	18	18
Alarm Tile Acknowledgement of TBN TRIP P-4	18	18
Screen Navigation to AN03 (ESF)	18	18
Alarm Tile Acknowledgement of PRZ PRESS LO SI	18	18
Screen Navigation to AN10 (S/G FW)	18	18
Alarm Tile Acknowledgement of SG 1,2,3 LEVEL LOW	18	18
Alarm Tile Acknowledgement of FW PUMP TRIP	18	18
Screen Navigation to AN05 (RCS)	18	18
Alarm Tile Acknowledgement of PRZ PRESS LOW	18	18
Screen Navigation to AN04 (CVCS)	18	18
Alarm Window Acknowledgement of AN04 (CVCS)	18	18
Screen Navigation to AN13 (GEN)	18	18
Alarm Window Acknowledgement of AN13 (GEN)	18	18
Screen Navigation to AN11 (FW FACILITY)	18	18
Alarm Window Acknowledgement of AN11 (FW FACILITY)	18	18
Screen Navigation to AN05 (RCS)	18	18
Alarm Window Acknowledgement of AN05 (RCS)	18	18
Screen Navigation to AN10 (S/G FW)	18	18
Alarm Window Acknowledgement of AN10 (S/G FW)	18	18
Screen Navigation to AN08 (RX CONTROL)	18	18
Alarm Window Acknowledgement of AN08 (RX CONTROL)	18	18
Screen Navigation to AN07 (PPS2)	18	18
Alarm Window Acknowledgement of AN07 (PPS2)	18	18
<b>Total</b>	<b>486</b>	<b>486</b>

- The subjects performed **all 486 tasks successfully without any difficulty** which means that the subjects accomplished **100% accuracy in performing the task within the scenario.**
- This result implies that the **ETD display feature that expands and reduces the alarm windows does not have negative effects on selecting what the subjects want and performing the given tasks.** Moreover, it is obvious that the subject performance is **good enough in terms of the accuracy performance dimension.**

# 04 Test Results

## » Performance Time

### ■ Reference Performance Time

- The **reference performance time** was measure to evaluate that the subject performance times are satisfied with the **performance time validation criteria**.

Scenario	Task (Ideal Path)	I1(1)	I1(2)	I1(3)	I1(4)	I1(5)	Iavg	Istd	Iavg-Istd
Verify the reactor trip									
Verify PRZ LOW PRESS & P-7 RX TRIP alarm at AN07 window	Screen Navigation to AN07 (PPS 2)	00:00	00:00	00:00	00:00	00:00			
	Alarm Tile Acknowledgement of PRZ LOW PRESS & P-7 RX TRIP	00:09	00:05	00:04	00:03	00:08			
Verify CONTROK BANK LOW-LOW LIMIT alarm at AN08 window	Screen Navigation to AN08 (RX CONTROL)	00:05	00:09	00:08	00:12	00:09			
	Alarm Tile Acknowledgement of CONTROK BANK LOW-LOW LIMIT	00:09	00:06	00:03	00:02	00:03			
Verify the turbine trip									
Verify TBN TRIP P-4 alarm at AN12 window	Screen Navigation to AN12 (TBN)	00:08	00:09	00:08	00:08	00:09			
	Alarm Tile Acknowledgement of TBN TRIP P-4	00:05	00:01	00:03	00:02	00:03			
Verify the ESF actuation									
Verify PRZ PRESS LO SI alarm at AN03 window	Screen Navigation to AN03 (ESF)	00:08	00:09	00:12	00:07	00:10			
	Alarm Tile Acknowledgement of PRZ PRESS LO SI	00:03	00:03	00:01	00:04	00:03			
Verify the status of secondary system/steam generators									
Verify SG 1,2,3 LEVEL LOW alarm at AN10 window	Screen Navigation to AN10 (S/G FW)	00:08	00:12	00:07	00:13	00:09			
	Alarm Tile Acknowledgement of SG 1,2,3 LEVEL LOW	00:08	00:03	00:04	00:03	00:04			
Verify FW PUMP TRIP alarm at AN10 window	Alarm Tile Acknowledgement of FW PUMP TRIP	00:03	00:04	00:01	00:02	00:03			
Verify the status of primary system/pressurizer									
Verify PRZ PRESS LOW alarm at AN05 window	Screen Navigation to AN05 (RCS)	00:11	00:08	00:09	00:08	00:10			
	Alarm Tile Acknowledgement of PRZ PRESS LOW	00:08	00:04	00:09	00:06	00:09			
• Total Time to find the designated alarm tiles (A), (mm:ss)		01:25	01:13	01:09	01:10	01:20	01:15	00:06	01:09

- Total time to find the designated alarm tiles: 01:09 (mm:ss)
- Total time to find the designated alarm windows: 00:41 (mm:ss)
- Time to finish all tasks in the scenario: 01:54 (mm:ss)

# 04 Test Results

## » Performance Time

### ■ Subject Performance Time

Scenario	Task (Ideal Path)	S1(1)	S1(2)	S2(1)	S2(2)	S3(1)	S3(2)	S4(1)	S4(2)	S5(1)	S5(2)	S6(1)	S6(2)	S7(1)	S7(2)	S8(1)	S8(2)	S9(1)	S9(2)	
<b>Verify the reactor trip.</b>																				
Verify PRZ LOW PRESS & P-7 RX TRIP alarm at AN07 window.	Screen Navigation to AN07 (PPS 2).	00:00	00:00	00:00	00:00	00:00	00:00	00:00	00:00	00:00	00:00	00:00	00:00	00:00	00:00	00:00	00:00	00:00	00:00	
	Alarm Tile Acknowledgement of PRZ LOW PRESS & P-7 RX TRIP.	00:04	00:05	00:02	00:05	00:07	00:05	00:05	00:02	00:06	00:03	00:06	00:06	00:04	00:03	00:04	00:04	00:03	00:03	00:02
Verify CONTROK BANK LOW-LOW LIMIT alarm at AN08 window.	Screen Navigation to AN08 (RX CONTROL).	00:04	00:04	00:04	00:02	00:09	00:03	00:06	00:03	00:07	00:03	00:04	00:03	00:05	00:03	00:05	00:03	00:03	00:03	00:02
	Alarm Tile Acknowledgement of CONTROK BANK LOW-LOW LIMIT.	00:08	00:05	00:02	00:04	00:05	00:05	00:07	00:05	00:05	00:04	00:05	00:05	00:05	00:03	00:06	00:04	00:03	00:03	00:03
<b>Verify the turbine trip.</b>																				
Verify TBN TRIP P-4 alarm at AN12 window.	Screen Navigation to AN12 (TBN).	00:04	00:04	00:05	00:04	00:04	00:03	00:05	00:03	00:04	00:03	00:03	00:02	00:06	00:03	00:03	00:02	00:03	00:03	00:03
	Alarm Tile Acknowledgement of TBN TRIP P-4.	00:03	00:02	00:03	00:03	00:03	00:03	00:05	00:03	00:03	00:02	00:04	00:02	00:03	00:03	00:03	00:02	00:03	00:01	00:01
<b>Verify the ESF actuation.</b>																				
Verify PRZ PRESS LO SI alarm at AN03 window.	Screen Navigation to AN03 (ESF).	00:05	00:04	00:03	00:04	00:04	00:03	00:04	00:03	00:04	00:03	00:02	00:02	00:05	00:03	00:03	00:02	00:04	00:03	00:03
	Alarm Tile Acknowledgement of PRZ PRESS LO SI.	00:02	00:02	00:03	00:02	00:03	00:02	00:02	00:03	00:03	00:03	00:02	00:02	00:03	00:03	00:04	00:03	00:02	00:02	00:02
<b>Verify the status of secondary system/steam generators.</b>																				
Verify SG 1,2,3 LEVEL LOW alarm at AN10 window.	Screen Navigation to AN10 (S/G FW).	00:05	00:05	00:03	00:06	00:04	00:03	00:05	00:04	00:05	00:03	00:06	00:03	00:05	00:03	00:04	00:02	00:05	00:03	00:03
	Alarm Tile Acknowledgement of SG 1,2,3 LEVEL LOW.	00:03	00:03	00:05	00:02	00:05	00:02	00:05	00:03	00:06	00:04	00:03	00:03	00:05	00:04	00:04	00:02	00:03	00:02	00:02
Verify FW PUMP TRIP alarm at AN10 window.	Alarm Tile Acknowledgement of FW PUMP TRIP.	00:04	00:03	00:01	00:02	00:04	00:03	00:03	00:02	00:02	00:01	00:03	00:02	00:03	00:02	00:02	00:02	00:02	00:03	00:03
<b>Verify the status of primary system/pressurizer.</b>																				
Verify PRZ PRESS LOW alarm at AN05 window.	Screen Navigation to AN05 (RCS).	00:05	00:04	00:03	00:05	00:04	00:04	00:05	00:03	00:04	00:03	00:05	00:03	00:04	00:04	00:04	00:03	00:04	00:03	00:03
	Alarm Tile Acknowledgement of PRZ PRESS LOW.	00:05	00:06	00:03	00:03	00:06	00:04	00:05	00:04	00:05	00:03	00:03	00:03	00:05	00:04	00:04	00:03	00:05	00:02	00:02
• Total Time to find the designated alarm tiles (A), (mm:ss).		00:52	00:47	00:37	00:42	00:58	00:40	00:57	00:38	00:54	00:35	00:46	00:36	00:53	00:38	00:46	00:32	00:40	00:29	00:29

• • • • •

• Total Time to find the designated alarm windows (B), (mm:ss).	00:35	00:30	00:24	00:24	00:34	00:25	00:38	00:28	00:31	00:24	00:31	00:20	00:36	00:30	00:25	00:20	00:26	00:23	00:23
• Time to finish all tasks in the scenario (C=A+B), (mm:ss).	01:27	01:17	01:01	01:06	01:32	01:05	01:35	01:06	01:25	00:59	01:17	00:56	01:29	01:08	01:11	00:52	01:06	00:52	00:52

# 04 Test Results

## » Performance Time

### ■ T-test

- In order to verify that the subject performance times are satisfied with the validation criteria (subject's performance time should be within the reference performance time), t-test were performed.

T-test results of total time to find the designated alarm tiles (AT)

	Reference Performance Time = 69					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval	
					Lower	Upper
AT	-12.501	17	.000	-25.66667	-29.9986	-21.3348

T-test results of total time to find the designated alarm windows (AW)

	Reference Performance Time = 41					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval	
					Lower	Upper
AW	-10.190	17	.000	-13.00000	-15.6915	-10.3085

T-test results of total time to finish all tasks

	Reference Performance Time = 114					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval	
					Lower	Upper
Total time	-13.248	17	.000	-42.66667	-49.4616	-35.8717

- The subject performance times such as total time to find the designated alarm tiles, the designated alarm windows, and finish all tasks in the scenario were satisfied with the performance time criteria with statistical significance ( $p=0.00$ ).

# 05 Conclusions

- From the results of Accuracy and Completeness Test
  - The **ETD display** feature that expands and reduces the alarm windows **does not have negative effects on selecting what the subjects want and performing the given tasks.**
  - Moreover, it is obvious that the subject performance is **good enough in terms of the accuracy performance dimension.**
- From the results of Performance Time Test
  - The **ETD display** feature does not have negative effects on **performing the given tasks with in the required times.**
  - Moreover, it is obvious that the subject performance is **good enough in terms of the performance time dimension.**
- Discussion Point
  - Since the subjects' performance time was compared with the reference performance time based on the instructor performance time, and this **result would be largely affected by the reference performance time, much more studies** should be performed to support the **result of performance time** when using the ETD method



# THANK YOU

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