

# Mental Workload and Situational Awareness Evaluation of APR1400 ESF- CCS Activation Systems using Augmented Reality

Presented by :  
**Mwongeera Murungi**

INSTITUTION: KINGS

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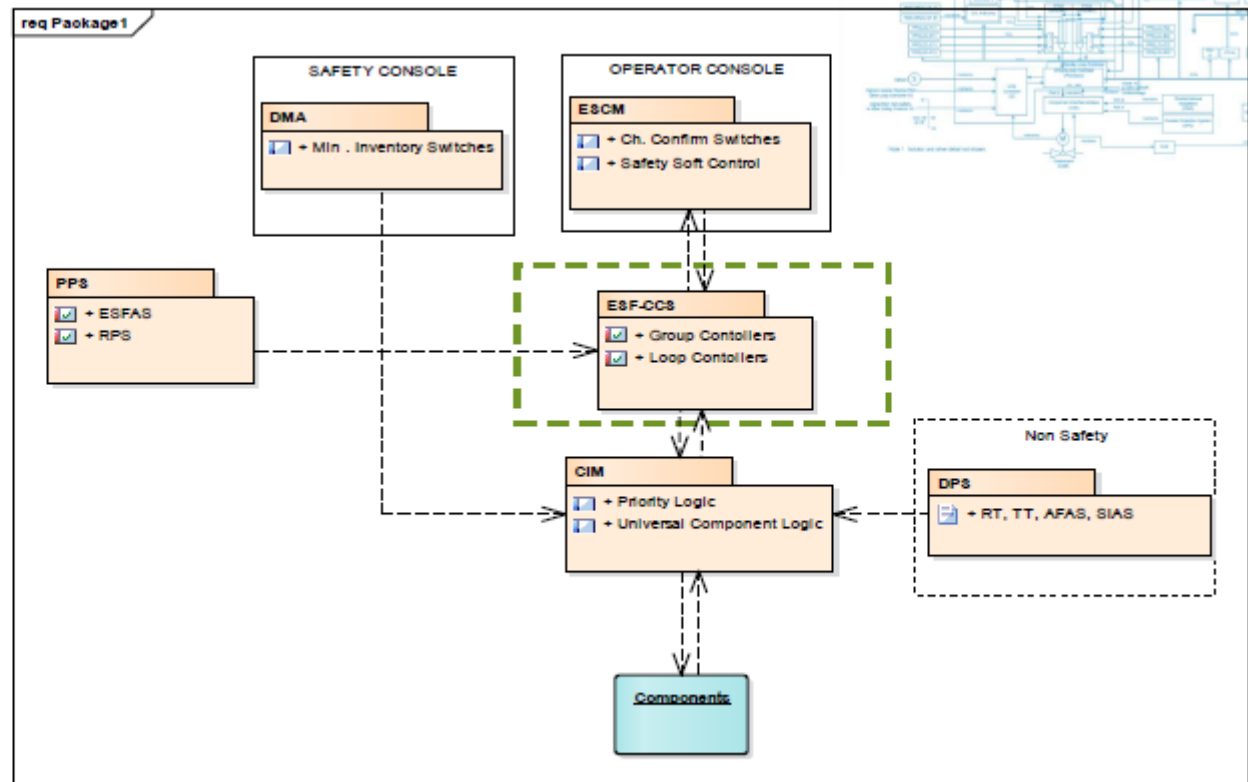
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3. Methods of conducting the study
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# Introduction

## The ESF-CCS

**ESF-CCS:** The interface between the ESFAS portion and the remote actuation devices



# Introduction

## **Situational Awareness and (Mental) Workload**

Situational Awareness put simply is knowing what is going on around you. Tied to this knowledge is an understanding of what is important to know and what isn't.

Workload is a term that represents the cost of accomplishing mission requirements for a human operator.

It can be measured as Mental, Physical, Temporal, Frustration, Effort, and Performance.

# Introduction

## Augmented Virtual Reality

Superimposes a computer-generated image on a user's view of the real world, to provide a composite view.

“Stay in the real world but see simulated objects

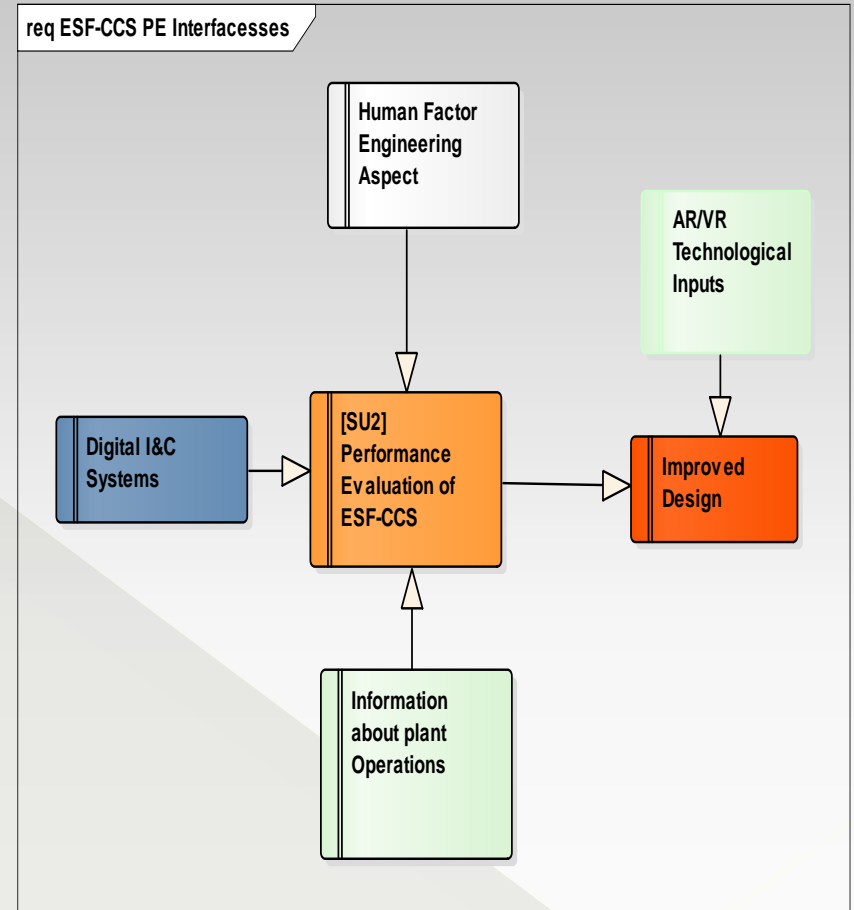


# Objectives - Design

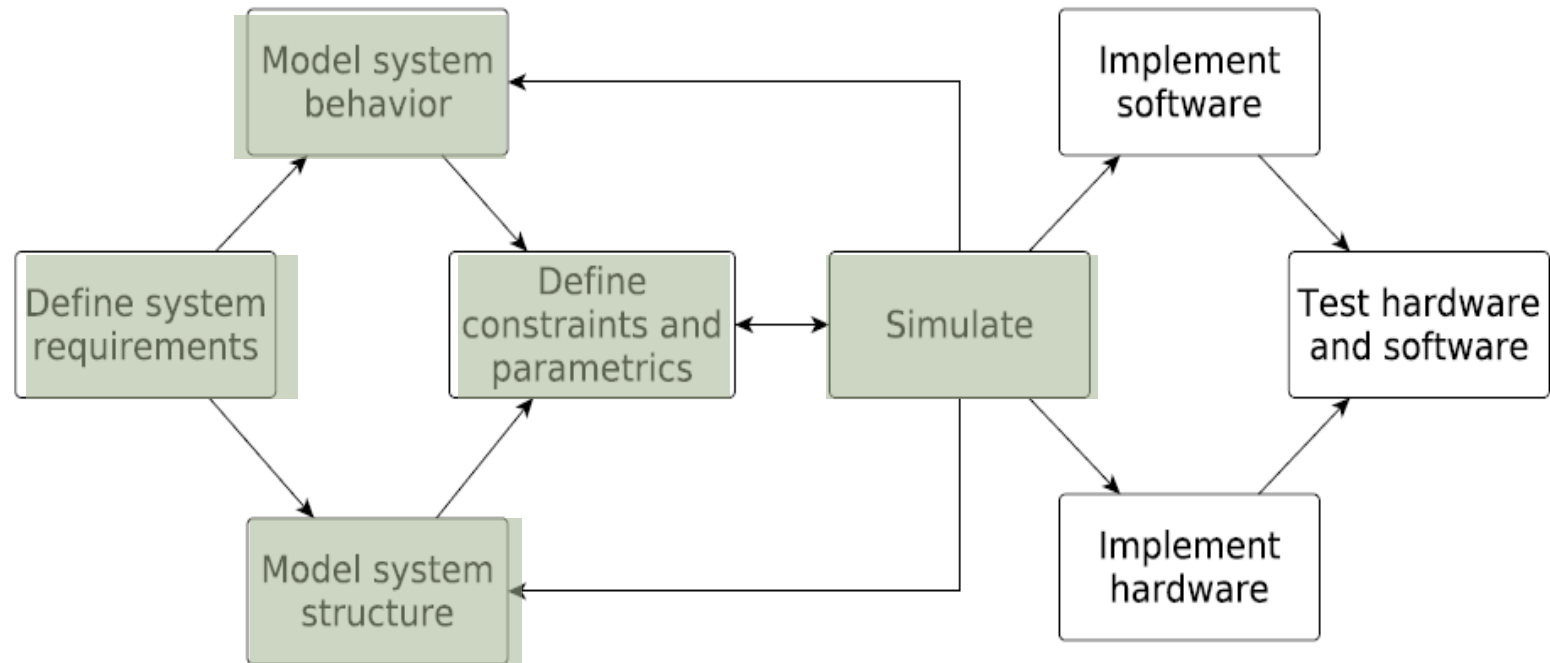
To explore how Augmented Virtual Reality (AVR) can be used in NPP control systems to determine whether:

1.) Operator(s) performance could be enhanced by introduction of an improved cognitive method of monitoring plant information during an Emergency Operating Procedure (EOP) and

2.) In correlation, inform the performance of the diverse safety systems on the basis of human factors.



# Objectives - Scope



# Objectives – Problem Statement

## **Problem statement**

The operating procedures in a power plant provide a measure of the availability of I&C systems.

Availability of the ESF-CCS, being a system that is critical during emergency operations, and its subsystems is largely determined by human operations, behavior and awareness during abnormal plant conditions

**It is therefore sought to consider how HFE can be used to determine the performance of safety critical digital I&C systems in order to ascertain their availability.**



# Objectives – Operation of research

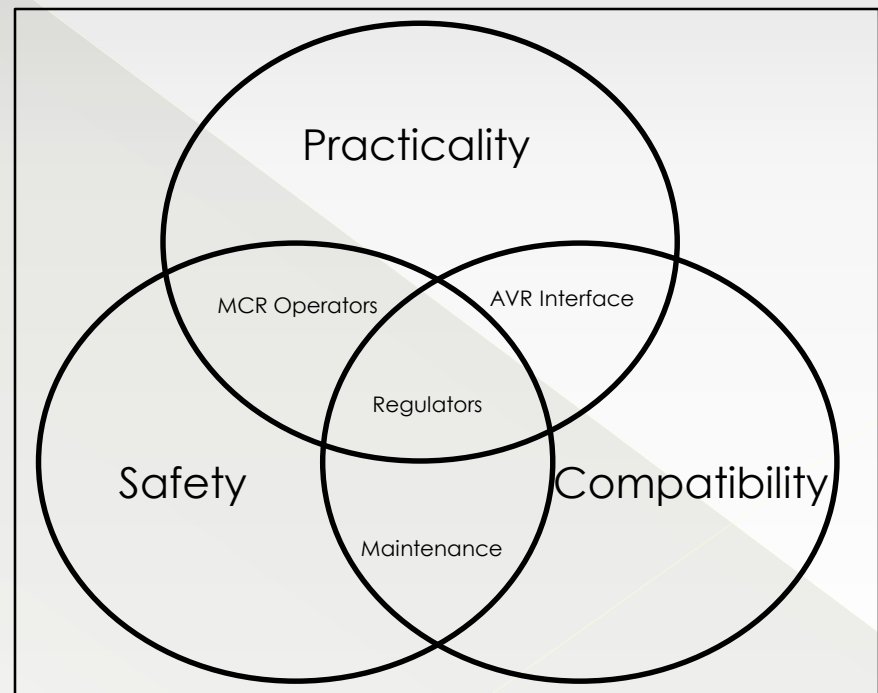
1. Review of ESF-CCS design description
2. Review of HFE program Requirements
3. Development of a Requirements Definition based on systems needs
4. Identification of the workload and Situational Awareness processes required for evaluation
5. Development of performance evaluation tool to gather initial Situational Awareness data

# Solution Methods

## Problem 1: System Requirement Definition

>elicitation was conducted by interviews, conversations and consultations with industry professionals.

Concern	Elaboration
Safety	<b>S1.</b> The AVR system shall be used during EOP-LOCA along with the CPS.
	<b>S2.</b> The AVR system shall provide critical information/data needed by a Senior Reactor Operator (SRO) during an Emergency Operation Procedure (EOP) for his monitoring/ checking/advisory tasks.
	<b>S3.</b> The AVR system shall assure that the correct transition of plant procedures
	<b>S4.</b> The AVR system shall validate the Entry conditions for emergency operation.
	<b>S5.</b> The AVR System shall not affect the normal execution of the current system
Compatibility	<b>C1.</b> The AVR system software shall be integrated with existing system without requiring down time
Practicality	<b>P1.</b> The AVR system shall reduce/release work burden to the STA during the EOP
	<b>P2.</b> The AVR system shall, by introduction of improved situational awareness, be more intuitive to the STA than existing system.
	<b>P3.</b> The AVR system shall reduce the amount of navigation required by STA during EOP execution.
	<b>P4.</b> The AVR system shall seek to find a means of reducing the human factor related operator performance degradation <b>during safety critical operations</b> (EOP)—stemming from human errors, and reduced readability.
	<b>P5.</b> The AVR system shall provide more comprehensive plant status information to the STA to enable him to more effectively keep track of the changing plant conditions



# Solution Methods

- ◎ Problem 2: Choice of Mental Workload and Situational Awareness measurement methods
  - > 1. NASATLX was chosen to assess the mental workload due to its wide acceptance, quick and easy implementation and accuracy.
  - > 2. SART was chosen to assess SA due to accountability for cognitive demand and considerable diagnostic capability.

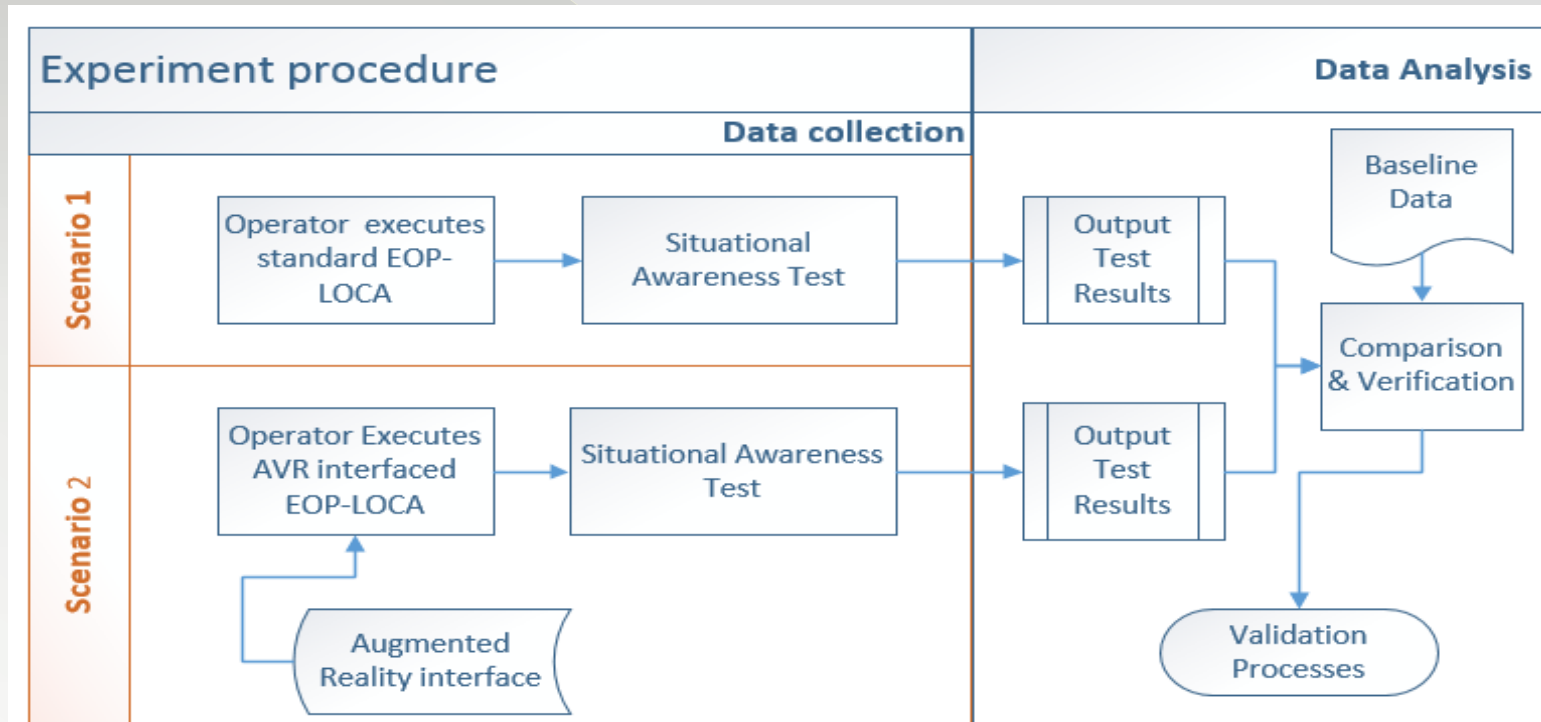
Both methods allow for individual assessment

# Solution Methods

- ◎ Problem 3: Determination of goal of the MW/SA measurement
  - > The EOP was chosen as the scenario for modelling because it is the one of the critical plant conditions that requires human intervention.
  - > The workload and situational awareness evaluation will justify the benefits of the system towards mitigation of human error.
  - > The primary goal of the designed system is to leverage the existing infrastructure and system data sources to implement a method that can reliably measure the efficacy and performance level of the emergency response system using SA measurement analysis

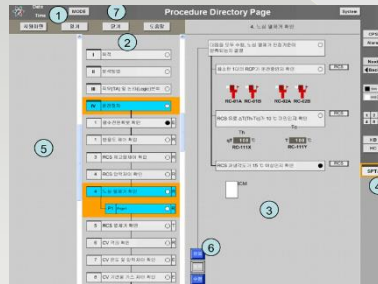
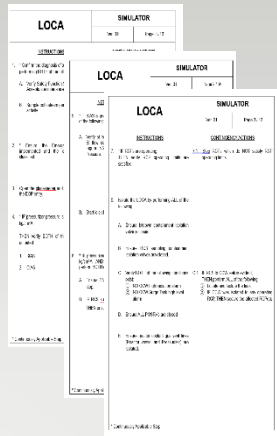
# Solution Methods

- Problem 4: Modelling the existing system to incorporate MW/SA measurement.



# Solution Methods

- Problem 4: Modelling the evaluation tool.



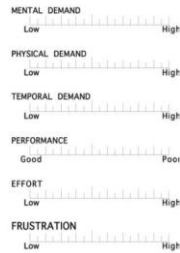
A screenshot of the 'EOP Situational Analysis' software interface. The interface is titled 'KICL KINGS I&C LAB' and 'EOP Situational Analysis'. It features a checklist of 11 emergency procedures, each with a corresponding button or status indicator. The procedures are: 1. Confirmation of LOCA (highlighted in green), 2. Emergency plan implementation, 3. Note Time of EOP entry, 4. System Pressure Check, 5. Minimum Flow Verification, 6. RCP Operation, 7. RCP Operating Limits, 8. LOCA Isolation, 9. Containment Pressure, 10. Cont. Pressure above 110cmH2O, and 11. Cont. Pressure >= 1.421 cmH2O. To the right of the checklist is a detailed view of the '1. Confirmation of LOCA Diagnosis' procedure, which includes sections for 'Verify Safety Functions' (with 'Check PTA status' and 'Confirm DA action' buttons), 'Check Steam Generator Activity' (with 'SG1 Status' and 'SG2 Status' sections, each containing 'Temp', 'Pressure', and 'Level' fields), and 'Contingency Action' (with '1. Perform Rediagnosis' and '2. Go to Recovery Guidelines' steps). A 'Next >>' button is located at the bottom right of the detailed view.

Read from data File

# Solution Methods

## Problem 4: Modelling the existing system to incorporate MW /SA measurement.

RATING SCALE DEFINITIONS		
Title	Endpoint	Description
MENTAL DEMAND	Low/High	How much mental and perceptual activity was required (e.g., thinking, decision-making, calculating, remembering, looking, searching, etc.)? Was the task easy or demanding, simple or complex, exciting or tiring?
PHYSICAL DEMAND	Low/High	How much physical activity was required (e.g., pushing, pulling, leaning, twisting, reaching, etc.)? Was the task easy or demanding, slow or fast, dull or strenuous, monotonous or interesting?
TEMPORAL DEMAND	Low/High	How much time pressure did you feel due to the rate or pace at which the task or task sections occurred? Was the pace slow and leisurely or rapid and frantic?
EFFORT	Low/High	How hard did you have to work (mentally and physically) to complete your level of performance?
PERFORMANCE	Good/Poor	How successful do you think you were in accomplishing the goals of the task or the subtask? Were you with your performance in accomplishing these goals?
FRUSTRATION LEVEL	Low/High	How insecure, discouraged, irritated, stressed and annoyed were you (e.g., frustrated, concerned, upset and annoyed) due to your level during the task?



NASA TLX Website



SITUATION AWARENESS RATING TECHNIQUE (SART) (Taylor, 1986)	
<b>Instability of Situation</b> How changeable is this situation? Is the situation highly unstable and likely to change suddenly (High) or is it very stable and straightforward (Low)?	1 2 3 4 5 6 7
<b>Complexity of Situation</b> How complicated is this situation? Is it complex with many interrelated components (High) or is it simple and straightforward (Low)?	1 2 3 4 5 6 7
<b>Variability of Situation</b> 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)?	1 2 3 4 5 6 7
<b>Arousal</b> How aroused are you in the situation? Are you alert and ready for activity (High) or do you have a low degree of alertness (Low)?	1 2 3 4 5 6 7
<b>Concentration of Attention</b> How much are you concentrating on the situation? Are you concentrating on many aspects of the situation (High) or focused on only one (Low)?	1 2 3 4 5 6 7
<b>Division of Attention</b> How much is your attention divided in the situation? Are you concentrating on many aspects of the situation (High) or focused on only one (Low)?	1 2 3 4 5 6 7
<b>Spare Mental Capacity</b> 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)?	1 2 3 4 5 6 7
<b>Information Quantity</b> How much information have you gained about the situation? Have you received and understood a great deal of knowledge (High) or very little (Low)?	1 2 3 4 5 6 7
<b>Information Quality</b> How much good value does the knowledge obtained contain? Is it useful to the operation (High) or entirely useless to the situation (Low)?	1 2 3 4 5 6 7
<b>Familiarity with Situation</b> How familiar are you with the situation? Do you have a great deal of relevant experience (High) or is it a new situation (Low)?	1 2 3 4 5 6 7

SA Literature [Endsley., 1988]

**SITUATIONAL ANALYSIS EVALUATION**  
NASA Task Load Index

1 Please Select the item that in your opinion

**SITUATIONAL ANALYSIS EVALUATION**  
NASA Task Load Index

Workload  
Mental Demand  
[NASA TLX Web page](#)

**Ratings**

**MENTAL DEMAND** How mentally demanding was the task?  
Low High 6

**PHYSICAL DEMAND** How physically demanding was the task?  
Low High 6

**TEMPORAL DEMAND** How hurried/rushed was the pace of the task?  
Low High 6

**OWN PERFORMANCE** How Successful were you in accomplishing what you were asked to do?  
Low High 6

**EFFORT** How hard did you have to work to accomplish your level of performance?  
Low High 6

**FRUSTRATION** How insecure, discouraged, irritated, stressed, and annoyed were you?  
Low High 16

**CONFIRM**

**SITUATIONAL ANALYSIS EVALUATION**  
SART

**Ratings**

**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)? 6

**Complexity of Situation** How complicated is the situation? Is it complex with many interrelated components (High)? Or is it simple and straightforward (Low)? 6

**Variability of Situation** How many variables are changing within the same situation? Are there a large number of factors varying (High) or are there very few variables changing (Low)? 6

**Arousal** How aroused are you in the situation? Are you alert and ready for activity (High) or do you have a low degree of alertness (Low)? 6

**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)? 6

**Concentration of Attention** How much are you concentrating on the situation? Are you concentrating on many aspects of the situation (High) or focused on only one (Low)? 6

**Division of Attention** How much is your attention divided in the situation? Are you concentrating on many aspects of the situation (High) or focused on only one (Low)? 6

**Information quantity** How much information have you gained about the situation? Have you received and understood a great deal of knowledge (High) or very little (Low)? 6

**Information quality** How much good value does the knowledge obtained contain? Is it useful to the operation (High) or entirely useless to the situation (Low)? 6

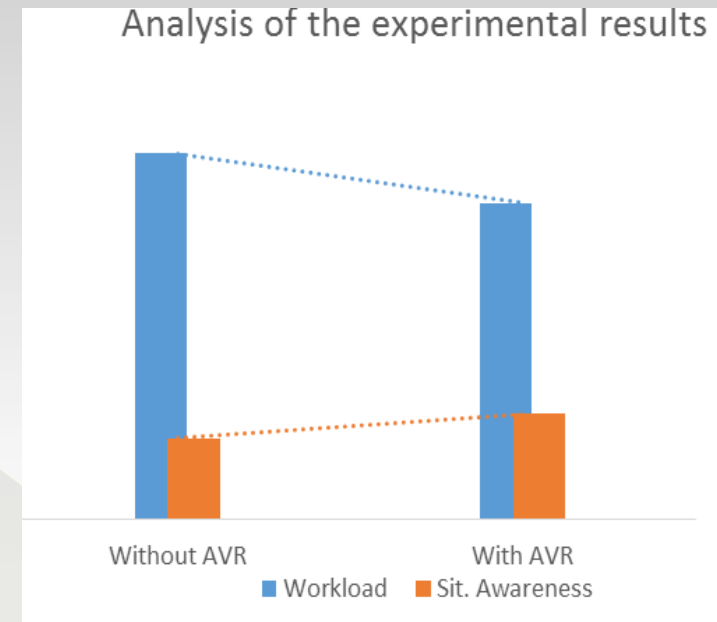
**Familiarity with Situation** How familiar are you with the situation? Do you have a great deal of relevant experience (High) or is it a new situation (Low)? 6

**CONFIRM**

Output data to File

# Solution Methods - Initial Test data results

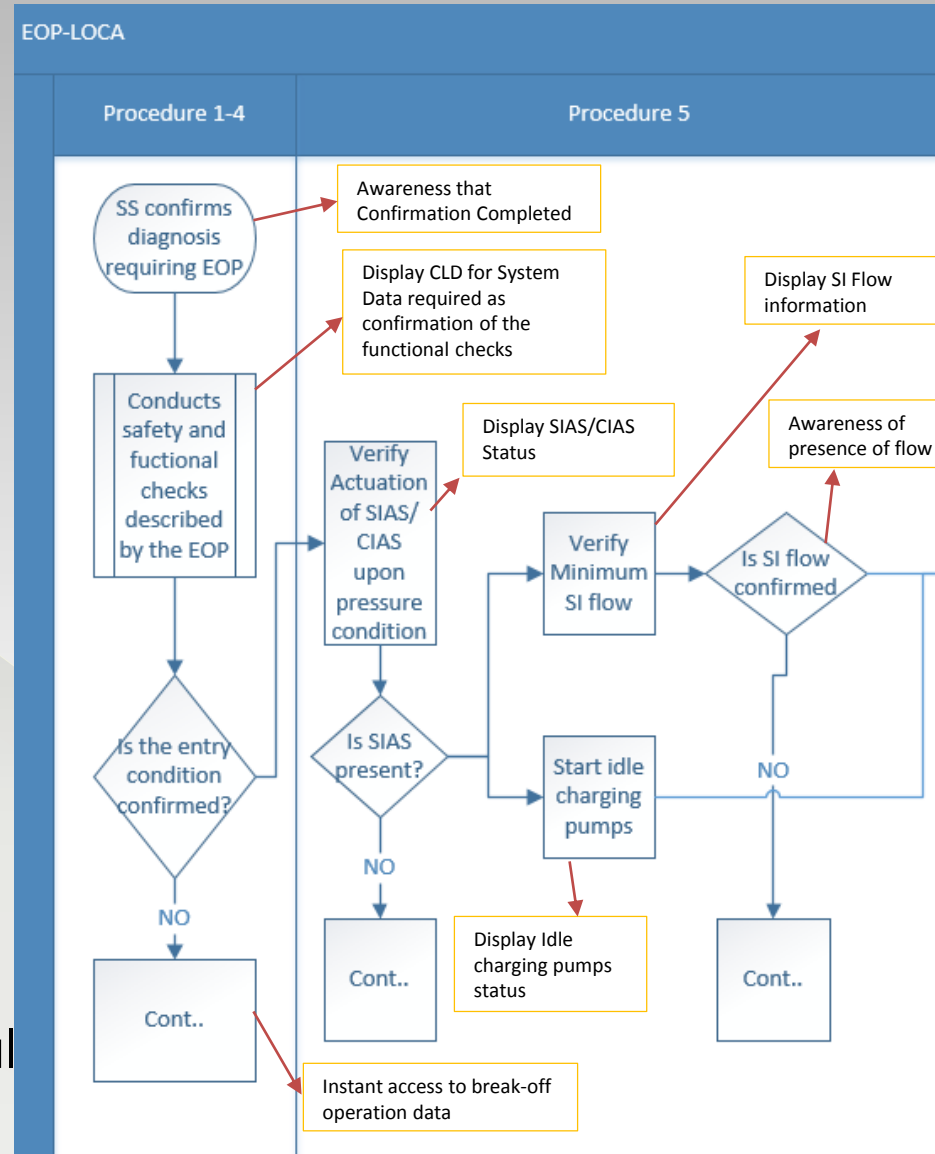
- > Experiments were carried out in order to analyze eleven (11) EOP-LOCA procedures ;using the simulated system verified by standard CPS (computer Based Procedure System) used in the APR1400 MCR





# Solution Methods

- Next phase 5: Modelling the existing system to improve MW/SA.
  - > Will be accomplished by incorporating AR
  - > Complexity analysis will be performed to identify complexity reduction potential.
  - > Functional flow analysis will be used to check functional coherence.



# Conclusion

- After analyzing the current system by examining EOP LOCA, it was discovered that the performance requirements of ESF-CCS could be evaluated from a HFE point of view.
- Critical information/data needed by an operator during an Emergency Operation Procedure (EOP) for his monitoring/ checking/advisory tasks was identified
- By conducting a SA analysis it was determined that the work burden could be reduced/ released from the operators during the selected EOP.
- Further work is needed to develop the improved system that will make operations conducted in the MCR by operators more intuitive through the introduction of improved situational awareness using AR-VR design.

# Q&A

