Information Complexity and Appropriate Interface Design in Nuclear Power Plant Control Rooms

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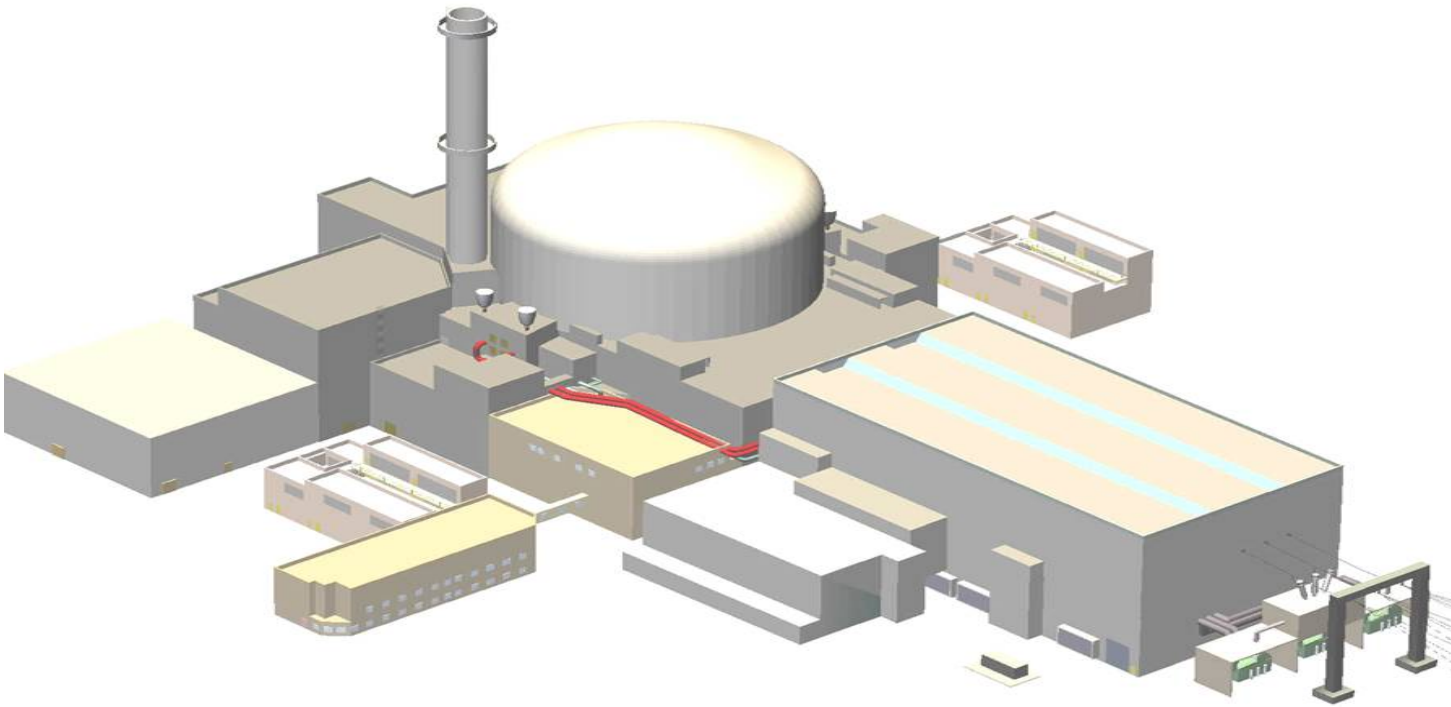


Objective

- A multi-year project to address Human Factors Engineering of U.S. EPR to support Human System Interface and screen design and evaluation
- This paper focuses on measures of information complexity for screen design

Introduction

- Digital I&C and advanced interface technology is being applied in NPP control rooms
- Factors may cause information complexity in NPPs, including:
  - Complicated control system
  - Improper automation design
  - Ill-designed human computer user interface

- It is important to know how to measure the information complexity of interface in NPP CR

Our Approach

- Consider how to use the HSI screens developed for our predecessor plants
- Analyze I&C architecture/platform
- Integrated system validation will late in the design process, but we recognize that it may reveal that some displays and controls are very complex
  - Helps us to re-focus training issues

Example of OL3 Interface Design

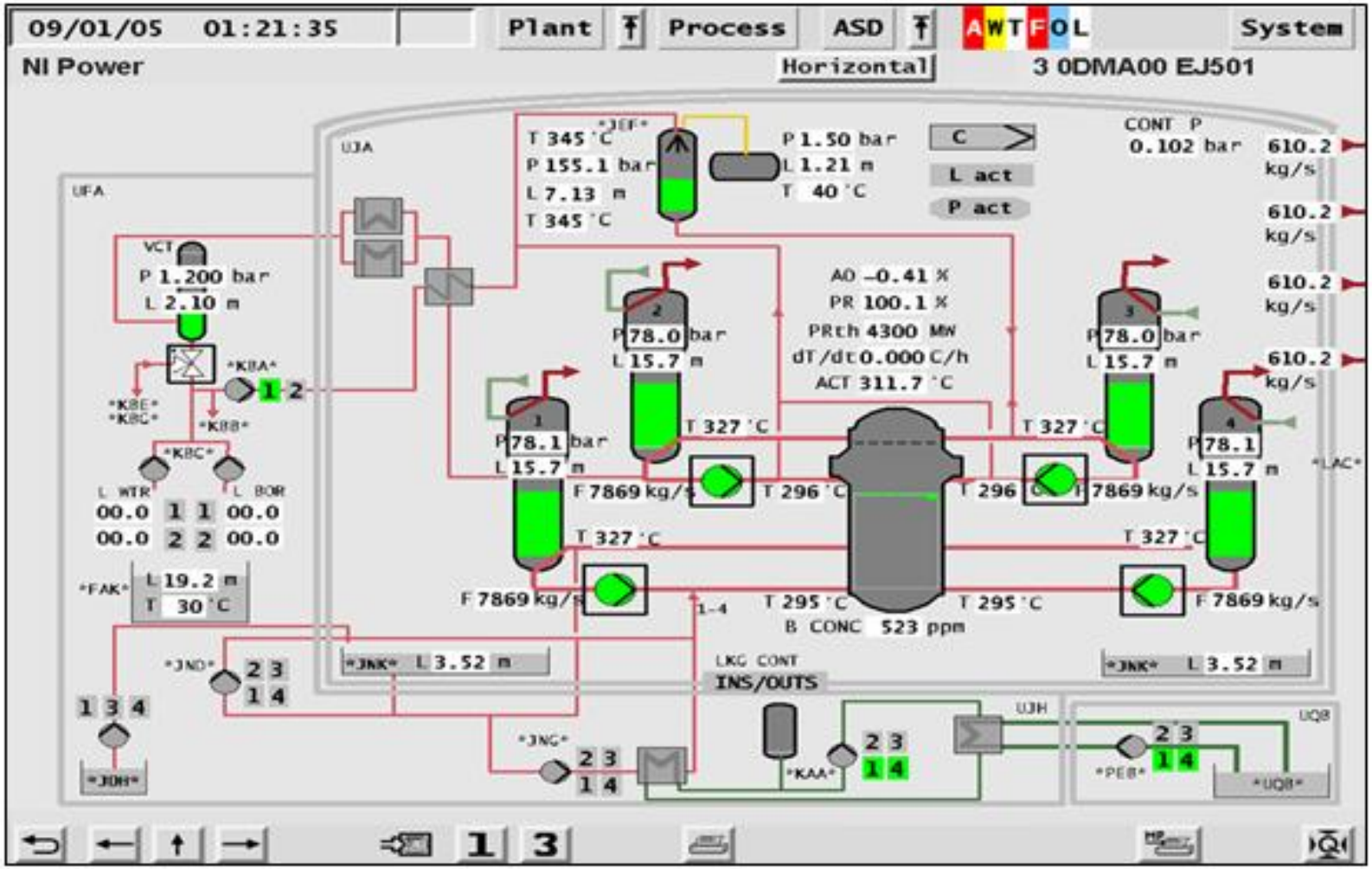


Figure 2. Example of information display interface

Overview of I&C System

- U.S. EPR is a mature design based on construction and operating experience at existing plants
- U.S. EPR utilizes same basic control of system functions and I&C concepts as predecessor plants
  - Level 0 – process interface
  - Level 1 – system-level automation system
  - Level 2 – operator interface
- HSI will be next generation of platform

I&C Systems Architecture

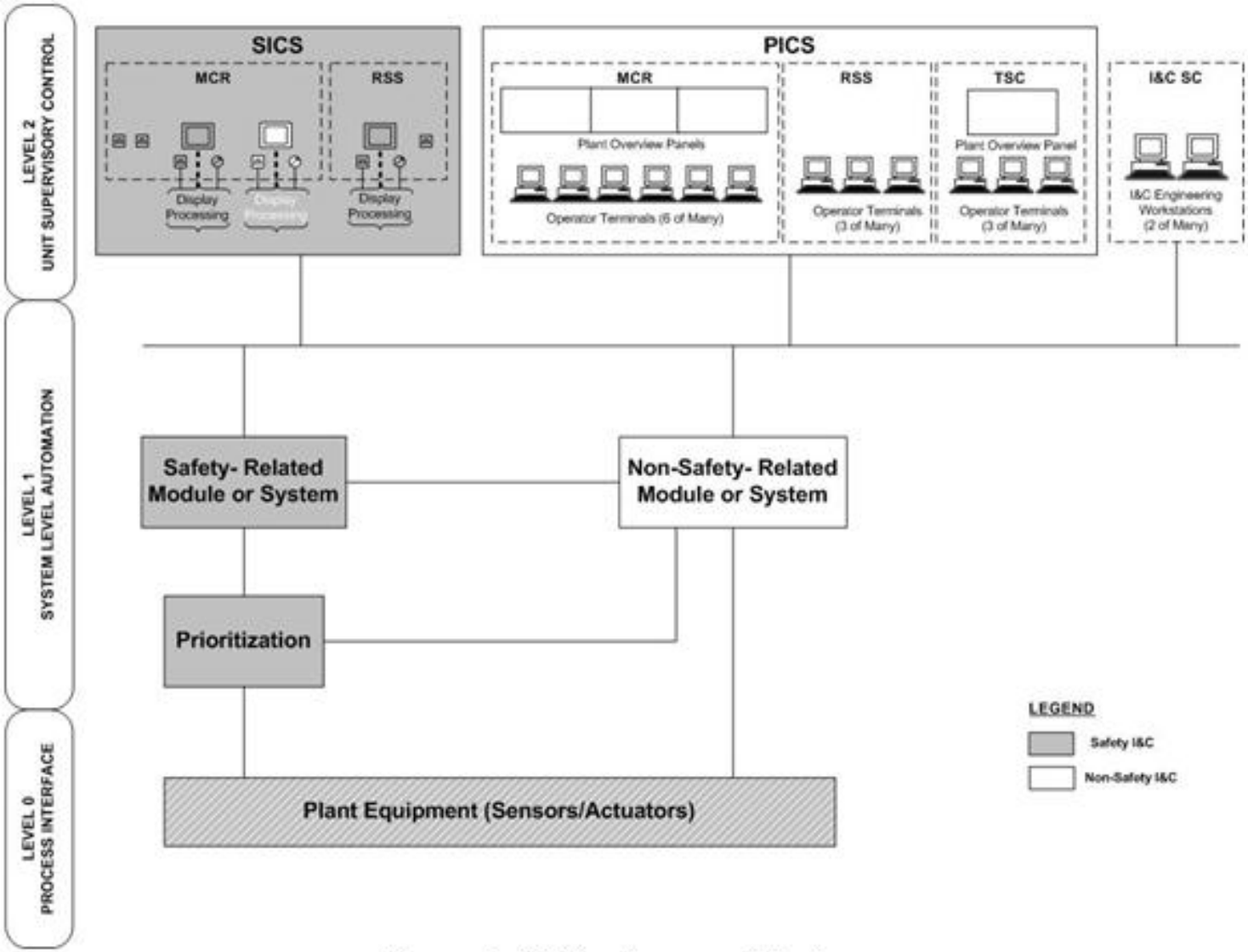


Figure 1: I&C systems architecture

Measure of Information Complexity: NASA-TLX

- **NASA-TLX is used to capture operators' workload along six dimensions:**
  - **Mental demand**
  - **Physical demand**
  - **Temporal demand**
  - **Effort**
  - **Frustration**
  - **Performance**

Measure of Information Complexity: TACOM

- **Task COMplexity (TACOM) is used to measure emergency procedure (Park and Jung, 2006) including five sub-measures:**
  - **Step Information Complexity (SIC) that represents the complexity due to the amount of information to be processed by operators**
  - **Step Logic Complexity (SLC) that denotes the complexity due to the execution logic of the required actions to be sequenced by operators**
  - **Step Size Complexity (SSC) that indicates the complexity due to the amount of the required actions to be performed by operators**
  - **Abstraction Hierarchy Complexity (AHC) that expresses the complexity due to the amount of system knowledge that is necessary to identify the problem space of the required actions**
  - **Engineering Decision Complexity (EDC) that manifests the complexity due to the amount of cognitive resources that is necessary to establish the proper decision criteria of the required actions**

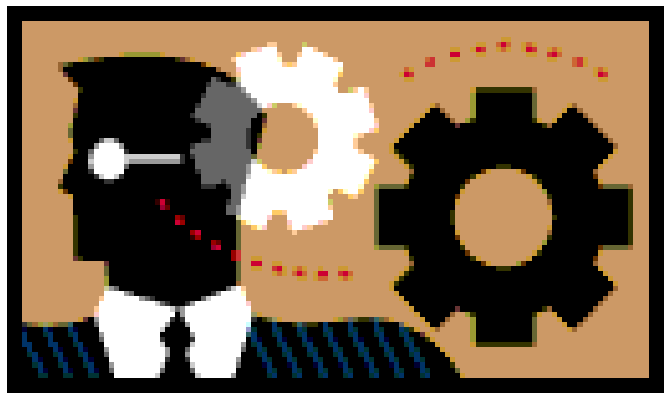
TACOM Equation

$$TACOM = \left[\begin{array}{l} (\alpha \times SIC)^2 + (\beta \times SLC)^2 + (\gamma \times SSC)^2 \\ + (\delta \times AHC)^2 + (\varepsilon \times EDC)^2 \end{array} \right]^{\frac{1}{2}}$$

- SIC, SLC, SSC, AHC, and EDC have been defined above
- The α, β, γ, δ, ε are relative weightings for five sub-measures, which will be decided by procedure experts

Design Interface to Reduce Information Complexity

- Two principles to direct interface design of U.S. EPR:
  - Provide information in a satisfactory manner
  - Provide adequate information
- HSI evaluation
  - Heuristic review
  - NUREG-0700
  - Other principles, e.g., Nielson 10 principles
  - U.S. EPR style guide



Conclusion

- Present U.S. EPR I&C system and associated information complexity
- Present measures of information complexity
- Discuss the HSI design and evaluation to reduce information complexity