Complexity Source Networks in Advanced Nuclear Power Plant Control Rooms

Farzan Sasangohar

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Research Group: **Humans and Automation Laboratory**
Thesis Advisor: **Prof. Mary Cummings** • Committee: **Prof. Yossi Sheffi; Prof. Nancy Leveson**

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Farzan Sasangohar
farzans@mit.edu

Problem

The nuclear power industry in the United States has declined in terms of growth since the Three Mile Island (TMI) incident in 1979. After more than 30 years, there are renewed interests in reviving the U.S. nuclear industry. Future computerized control rooms may challenge the cognitive abilities of human operators by presenting information in complex ways (Figure 1). Without proper understanding and management of the complexity in these control room environments, such unidentified complexity sources may negatively impact human performance and ultimately a system's safety.

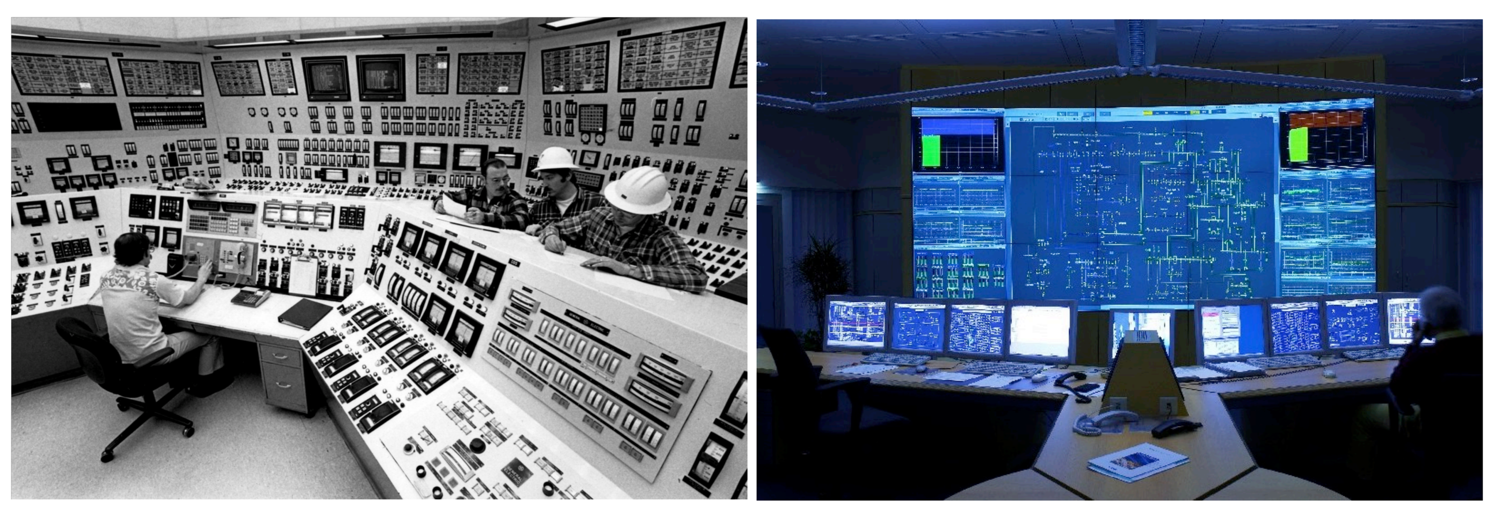

Figure 1. Traditional control room (left) vs. next generation control room (right)

Background

Broadly stated, the effects of complexity in Nuclear Power Plant (NPP) control rooms could be explained both objectively and subjectively. Objective complexity has been defined as the inherent property of a system or the environment surrounding a system. Alternatively, subjective complexity describes complexity as the unique understanding of a phenomenon by a human observer. An historical analysis of complexity literature shows that strategies for studying complexity are not comprehensive enough and complexity distinctions are potentially biased through either the objective or subjective outlook particular researchers adopt regarding complexity. A more systematic approach, which takes into account the interconnections between the observer and the observed, is missing from existing approaches.

Objective vs. Subjective Complexity

An effective evolutionary process for the design and acquisition of new NPP control rooms requires a balance between the objective and subjective views of complexity. The mismatch between the perceptions of operators, control room designers and NRC reviewers regarding complexity, and the actual objective complexity of control rooms (Big Δ in Figure 2) remain problematic. Another important balance that needs to be maintained is between complexity views within different groups of stakeholders, most notably between 1) the control room designers or Original Equipment Manufacturers (OEMs), 2) the NRC regulatory and evaluation team, and 3) the control room operation team, such as operators and supervisors.

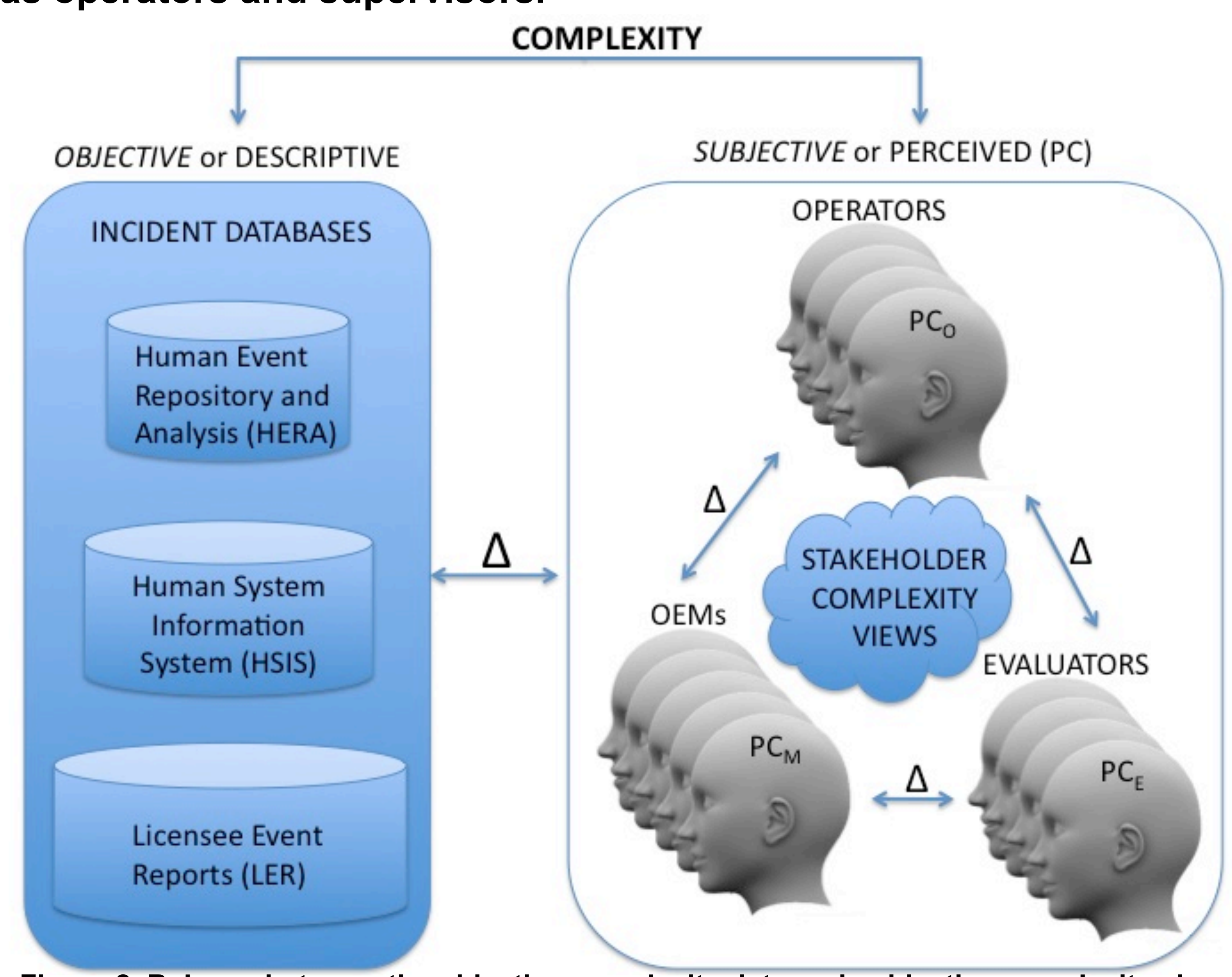

Figure 2. Balance between the objective complexity data and subjective complexity views

Key Questions

1. What aspects of a control room design contribute to its perceived complexity?
2. How can the effects of complexity on human performance be measured both objectively and subjectively?
3. How can the negative effects of complexity in NPP control rooms be mitigated or changed through design, procedures and organizational practices?

Methodology

1. Reviews of previous research, field studies, and Subject Matter Expert (SME) interviews cumulatively led to the initial identification of potential sources of complexity in NPP control rooms in the United States.
2. Objective evidence for the identified sources was gathered from several incident databases: Human Event Repository and Analysis (HERA), Licensee Event Report (LER), and Human Factors Information System (HFIS).
3. A Complexity Source Network (CSN) was used to represent the identified sources of complexity and their interrelations for each incident in HERA (Figure 3).
4. CSN was embedded in a Human Supervisory Control (HSC) complexity chain which is an effort to identify categories of complexity within socio-technical systems.
5. A tool called CXViz was developed to visualize and analyze the CSNs for all the incidents included in the HERA database (Figure 3).

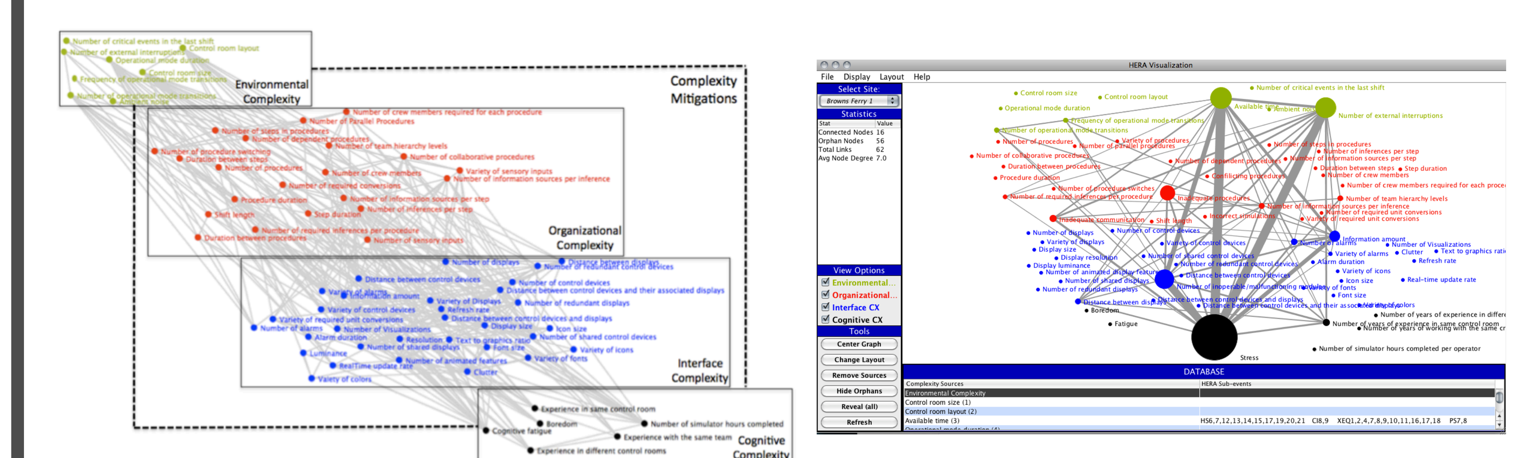

Figure 3. HSC complexity chain (left) and CXViz tool (right)

6. Network theory was utilized to enable the measurement and evaluation of characteristics of the resulting networks for emergent patterns.
7. An interactive iPad® application called CXSurvey was developed to gather subjective complexity data from the stakeholder.
8. The subjective and objective data will be compared and analyzed for disparities.

Acknowledgements

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