

***Performance Shaping Factors
as Operator Performance
Measures for Validation and
the Need for Robust Usability
in Human Reliability Analysis***

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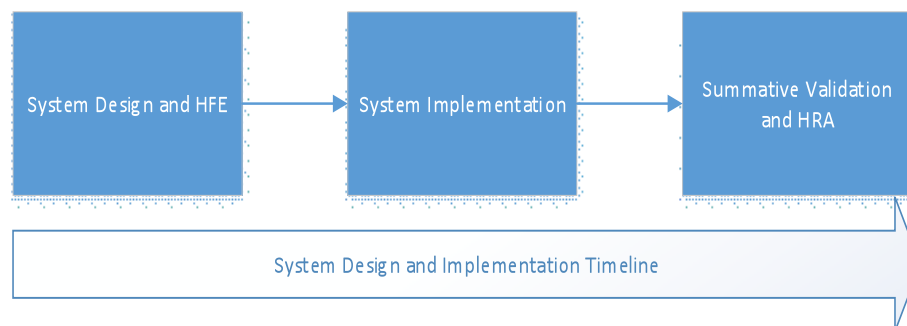
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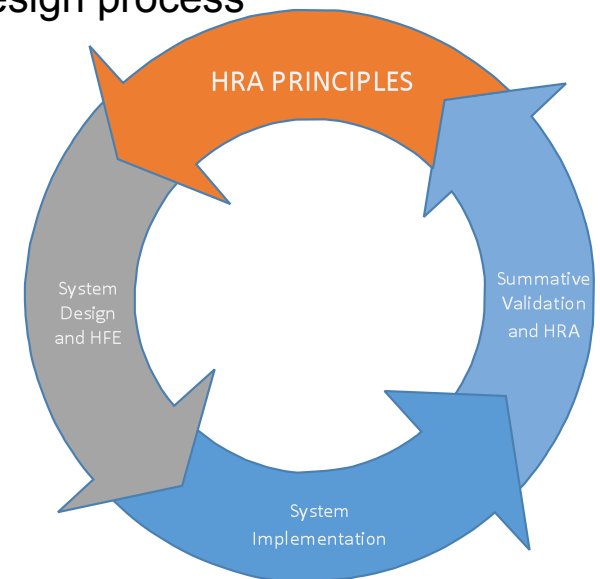
HRA in Design

- HRA is not often considered alongside human factors design activities
- Validation is ultimately a measure of success conditions of a design
- HRA principles can help inform a design to ultimately mitigate conditions that are identified in the HRA assessment

Previous Design Model with HRA at the end of the design process



Proposed iterative work flow that brings HRA to the initial step in the design process



Validation – Now and the Future

- Validation can be used beyond its current applications
- The end goal of validation is to define, measure and quantify the **success conditions** related to plant operations
- Aside from risk assessment, HRA has great potential to inform design processes

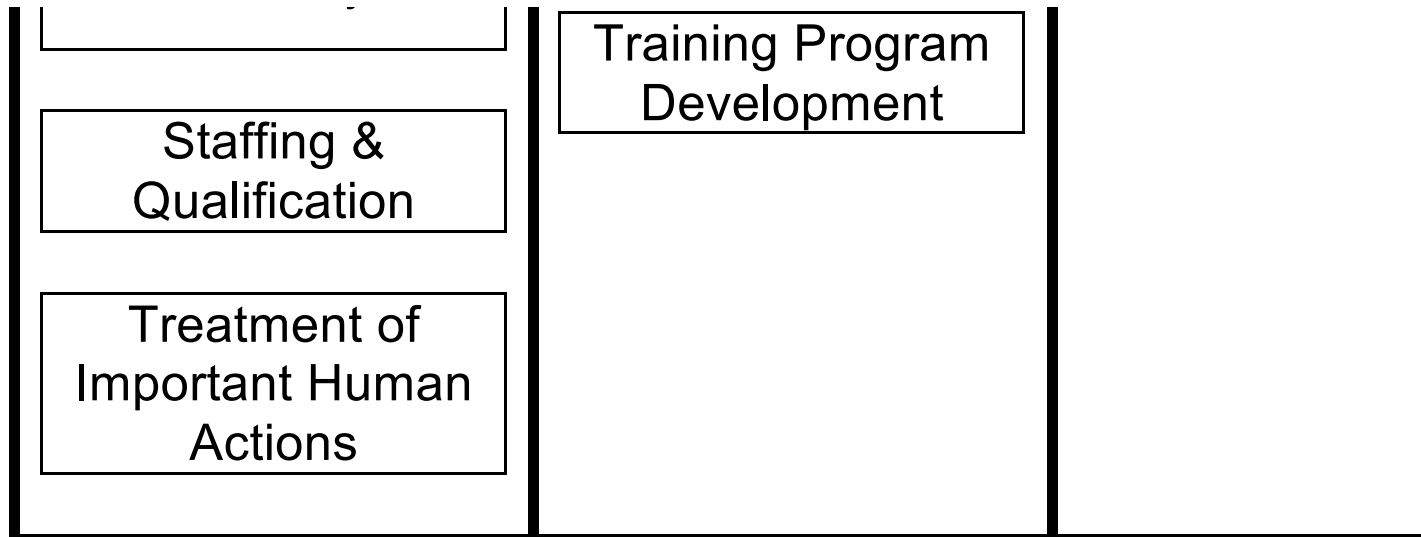
Current State	Proposed Change
Summative - Performed at the end of design lifecycle or for as-built system	Formative – Initial application of HRA principles to design processes to maximize success
Documenting what the human adds to overall risk	Extend HRA to broader success conditions
Assessing safety basis of complex systems	Design with HRA to minimize error rates
Typically expert assessment	Usability testing and insight



Control rooms are hugely complex, old systems

How can we ultimately ensure they are safe as we modernize?

Current Human Factors Process



We conducted a survey of U.S. utilities (Joe et al., 2012) and determined they are likely to go about a partially modernized control room process, resulting in a mix of legacy analog I&C and newer digital HMIs. Systems are likely to be upgraded in stages, resulting in the gradual stepwise modernization of the main control room. Under NUREG-0711, this process of gradually introducing new HMIs to the control room, while maintaining safety systems, is an approach that ensures operators are comfortable with the new systems as they are upgraded.

NUREG-0711 is the *Human Factors Engineering Program Review Model* for the U.S. Nuclear Regulatory Commission.

What is the HSSL?



Human Systems Simulation Laboratory
*a reconfigurable,
full-scale,
full-scope
research simulator
to support NUREG-0711 activities*

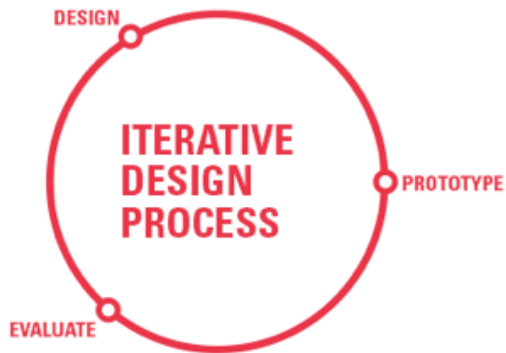
What is the HSSL?

Without good methods
and measures

it's just
eye candy!

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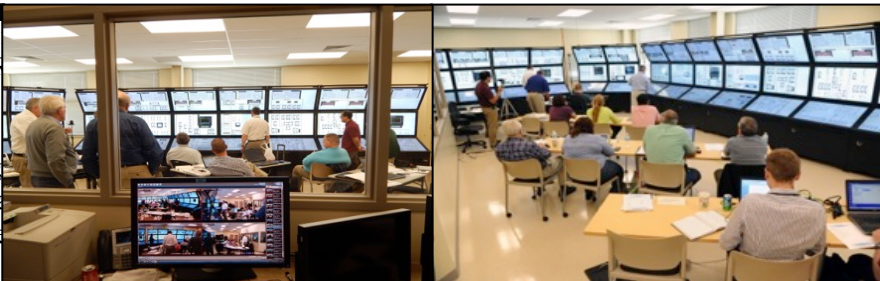
HSSL: Operator-in-the-Loop Design Studies



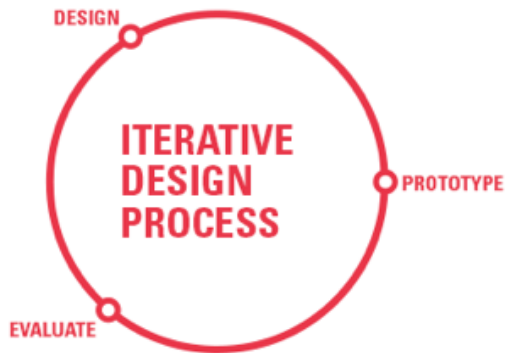
our team builds prototypes of control room upgrades that we then evaluate through operator-in-the-loop studies



Running a Scenario on Day 1 with Observers from the Simulator Instructor Station (R1) were introduced to the new Tricon TCS and the new Avid TCS interface by design engineers who walked through the same four scenarios of the new digital control system placed in place (see Figure 4). The mockup DCS screens were



HSSL: Operator-in-the-Loop Design Studies



methods

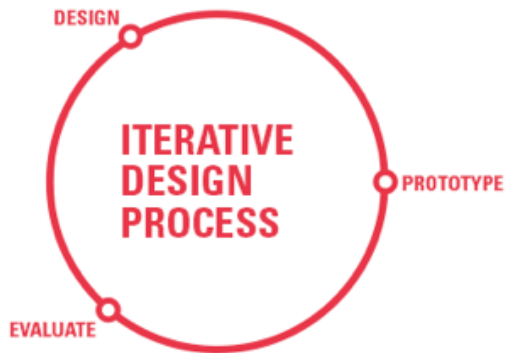
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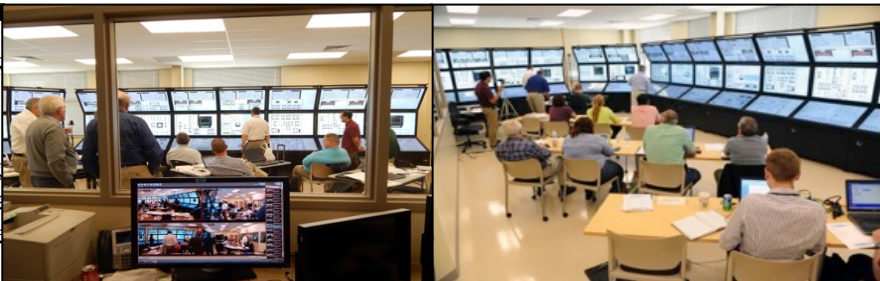


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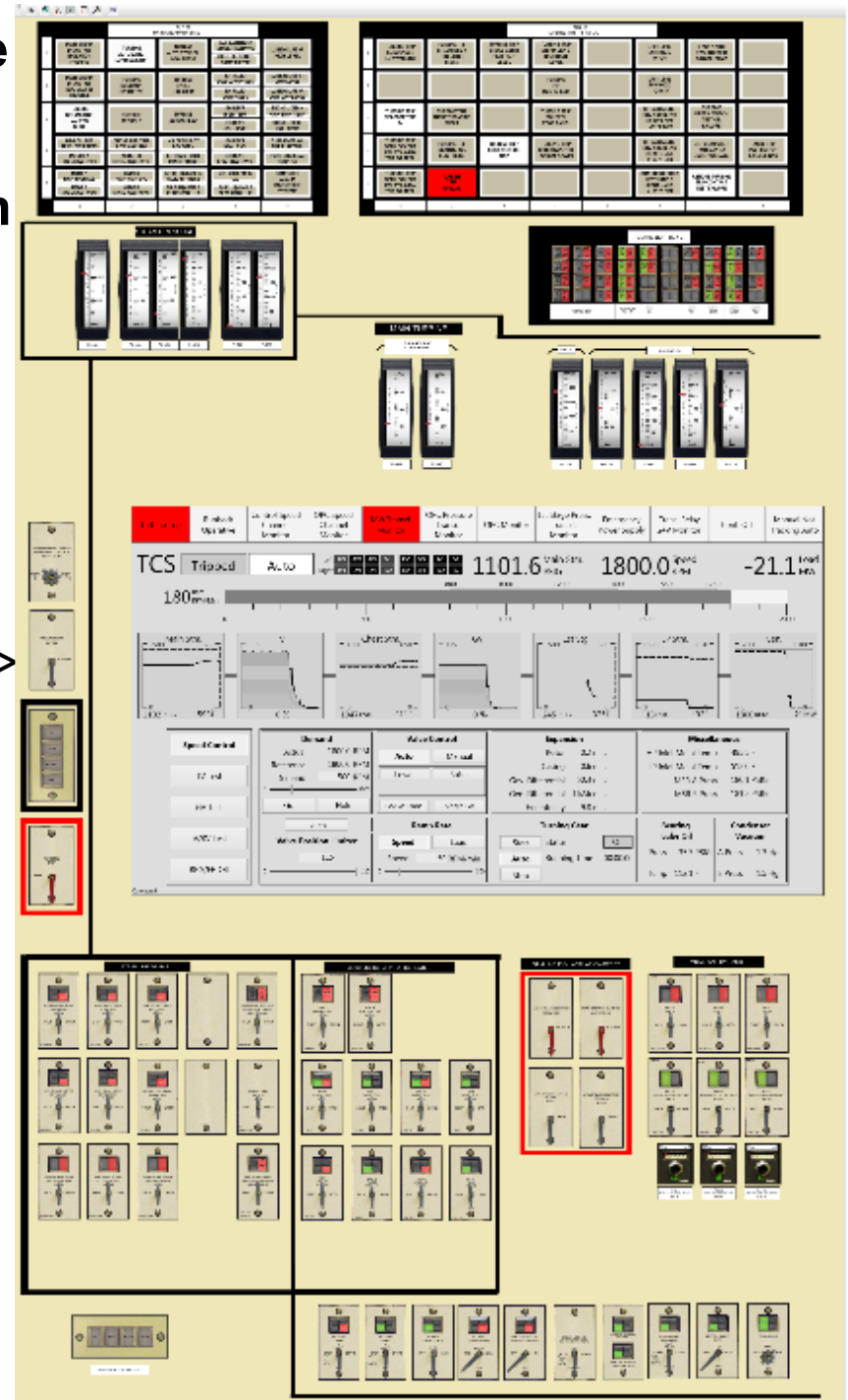
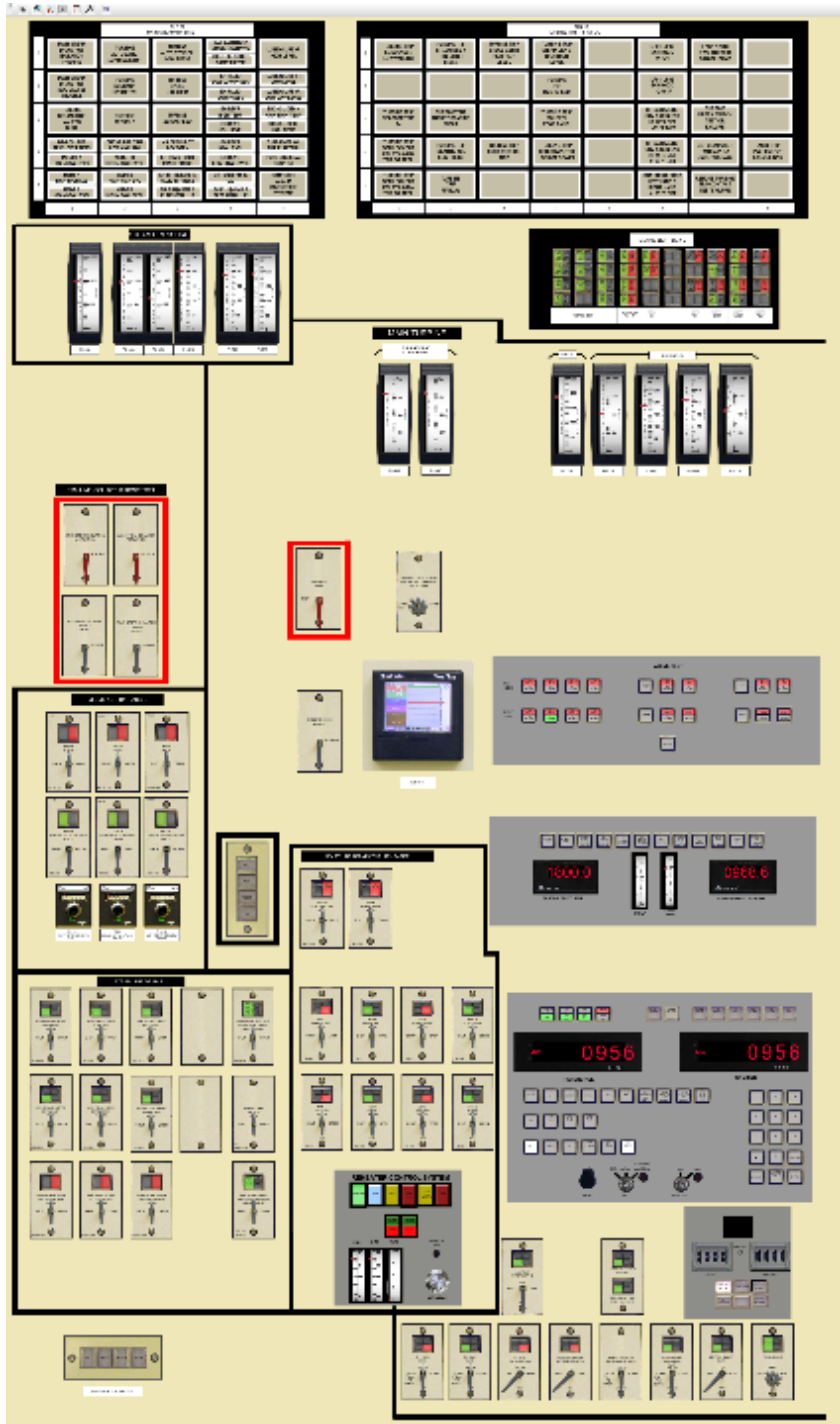


ANIME: Advanced Nuclear Interface Modeling Environment

Stepwise Upgrade is the Reality in the US

< Original

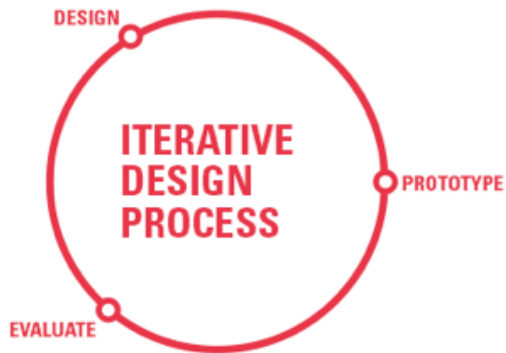
New >



a graded approach means phases of implementation



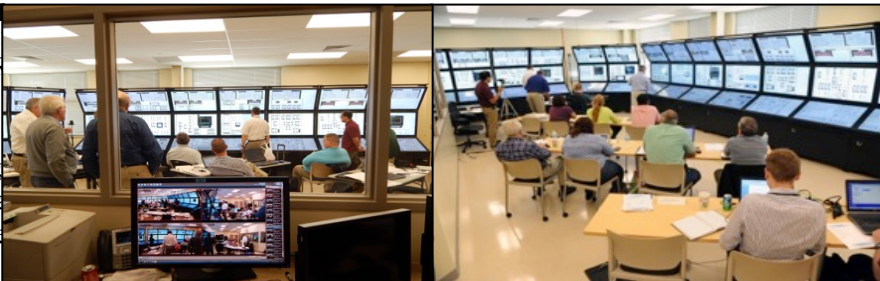
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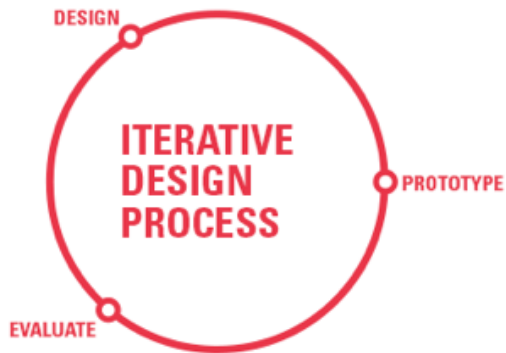
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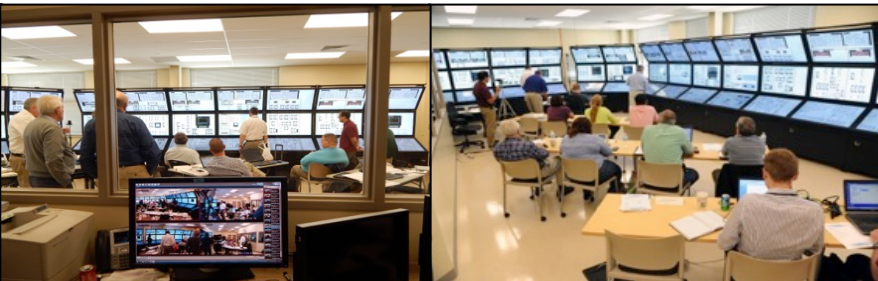
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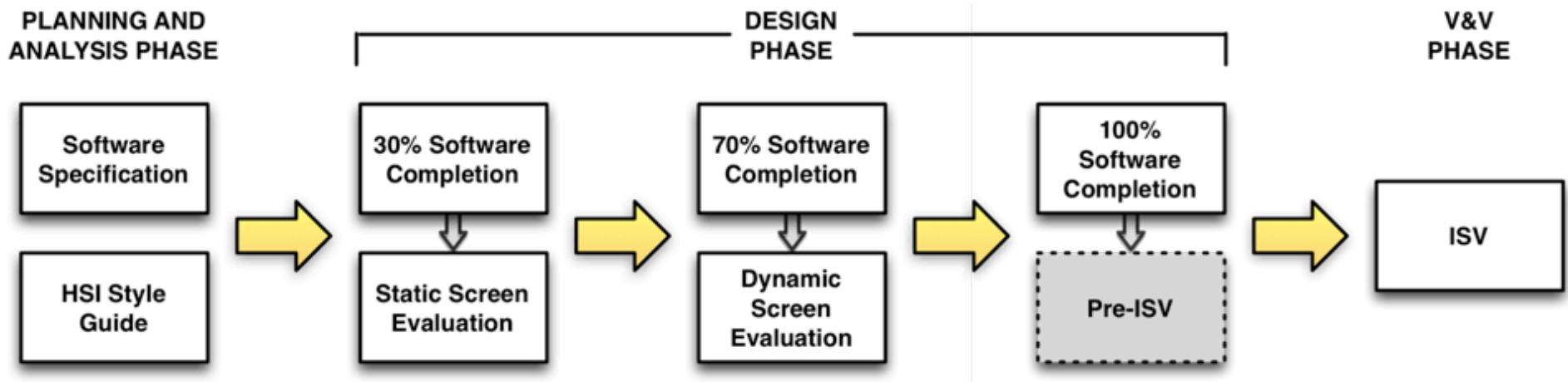


ALARA: As Low As Reasonable Assessment

usability testing across design life cycle

Design and Evaluation Across Several Stages

- conducting a series of progressive operator studies built into the design process
- operators walk through normal and abnormal operating scenarios using existing and new systems
- emphasis is on practical measures and fast results
 - **As Low As Reasonable Assessment (ALARA):**
discount usability for safety systems



Guideline for Operator Nuclear Usability and Knowledge Elicitation (GONUKE)

Evaluation Type

Expert Review (<i>Verification</i>)	[1] Design Requirements Review	[2] Heuristic Evaluation	,
User Study (<i>Validation</i>)	[5] Baseline Evaluation	[6] Usability Testing	
Knowledge Elicitation (<i>Epistemiatio</i>n)	[9] Cognitive Walkthrough (Task Analysis)	[10] Operator Feedback on Design	I I

¹Corresponding Phases in NUREG-0711.

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(Verification)

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[9]
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Typical usability evaluation

Evaluation Type

Expert Review
(*Verification*)

[1]
Design
Requirements
Review

[2]
Heuristic
Evaluation

User Study
(*Validation*)

[5]
Baseline
Evaluation

[6]
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Guideline for Operator Nuclear Usability and Knowledge Elicitation (GONUKE)

Typical utility/
regulatory emphasis

Evaluation Type

**Expert Review
(Verification)**

**[1]
Design
Requirements
Review**

**[2]
Heuristic
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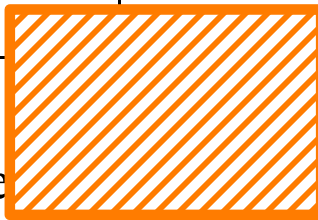
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Guideline for Operator Nuclear Usability and Knowledge Elicitation (GONUKE)

That ignores a lot of chances to get the interface right

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home
work

In education, we test learning continuously and cumulatively

exam

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Epistemiation: Capturing Expert Operator Knowledge to Design New System



Getting There

1) We must stop thinking the final exam is the best test

- ISV can never be all-encompassing—it's only a snapshot
- There is value in formative, systematic design and evaluation
 - Demonstrates a trajectory toward good design
 - Builds a “safety case” of multiple evidences
- Utilities are reluctant to share in-progress findings
 - Yes, the operators maybe didn't do well on an early stage design
 - This is not a weakness or a deficiency in operator performance
 - Early design foibles that are overcome are the hallmark of an effective human factors process

Getting There

2) We must find the right measures

- We are throwing textbooks of measures at the problem
 - State-of-the-art does not mean it's best for the job
 - Some measures like workload are actually pretty insensitive to expert reactor operators
 - Are we actually measuring what we need to perform V&V?
 - We are putting ourselves out of jobs by not being able to offer effective and cost-efficient measurement
- Need to revisit discount usability methods
 - ALARA: graded approach to measurement
 - The right measure for the right phase of design
 - Gradual shift from qualitative to quantitative measures
 - Qualitative informs design
 - Quantitative informs final acceptance of design

PSF-Based Validation

PSFs are Measures of Human Performance

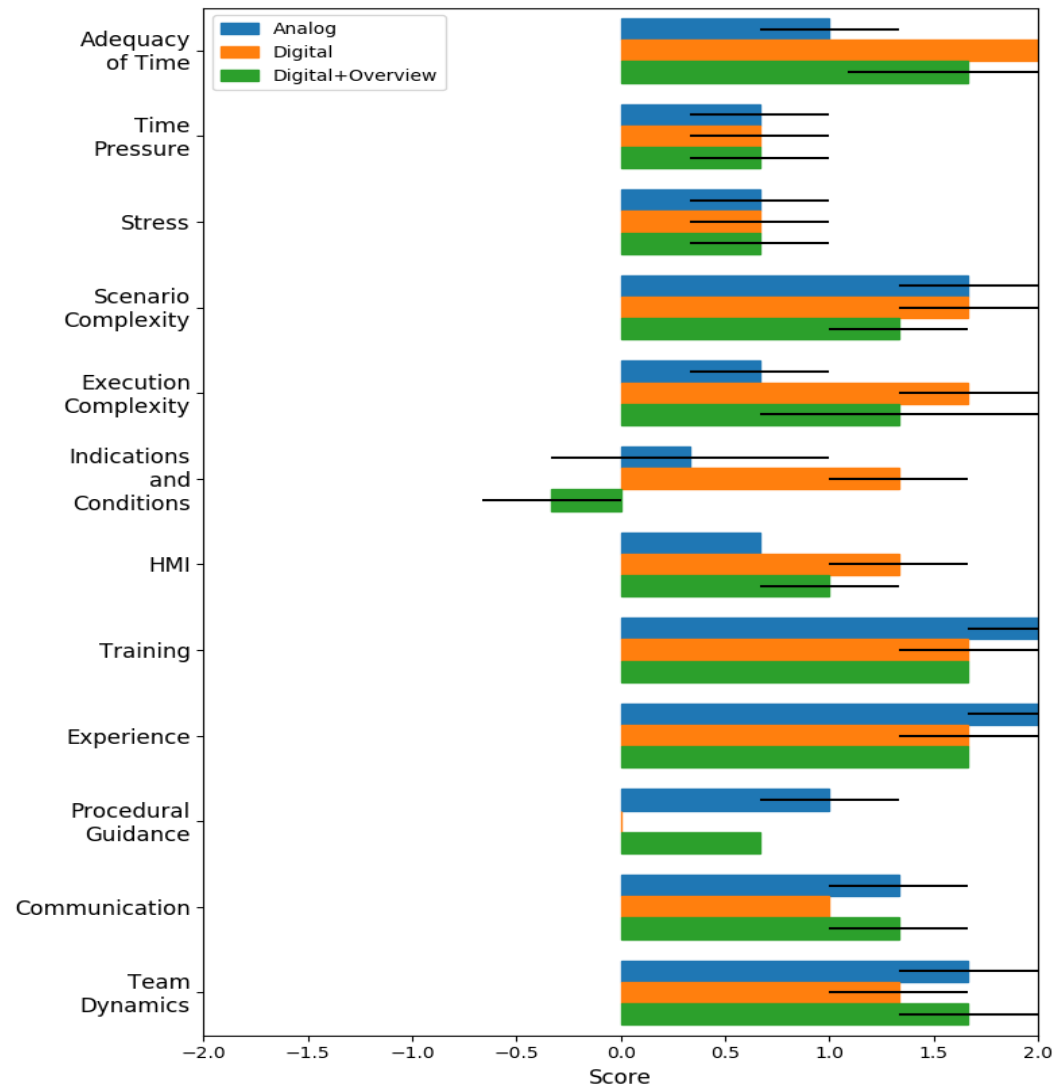
- By definition, these predict human performance
 - We have dozens of methods that purport a relationship between specific PSFs and operator performance
- Why aren't these included in the standard suite of validation/evaluation tools?

PSFs are also Methods for Human Performance

- Independent variables cause dependent variables
 - We control or manipulate independent variables
 - We measure dependent variables
- It's not about measuring PSFs, it's about controlling them
- Shouldn't PSFs be driving the design of validation studies?
 - If PSFs did drive design, couldn't the results inform HRA

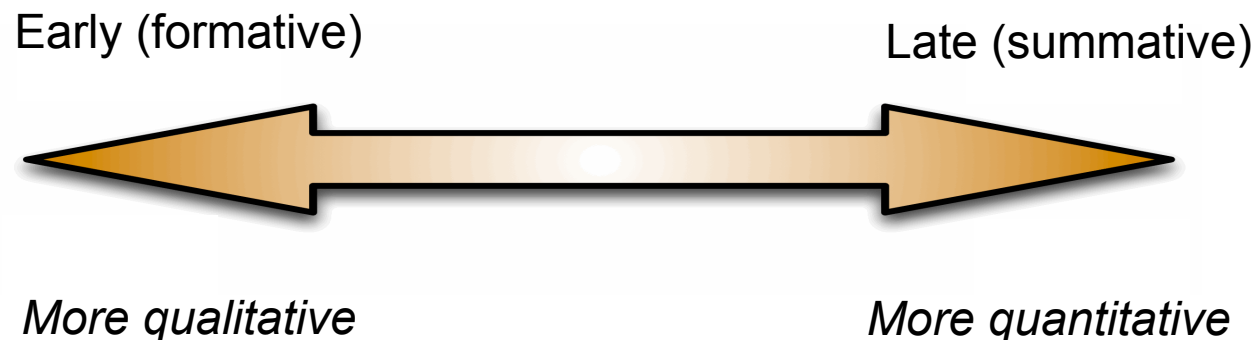
Example PSFs as Measures During Design

- Comparing three interfaces
 1. Existing analog control boards
 2. Control boards with new digital control system
 3. Control boards with new digital control system and supporting system overview display



Evaluation Across Design Lifecycle

- Progressive operator studies built into the design process
 - Operators walk through normal and abnormal operating scenarios using existing and new systems
 - Emphasis is on practical measures and quick but scrutable results
- Design activities may benefit from more *qualitative* measures to shape the design (= PSFs)
- Acceptance activities benefit from more *quantitative* measures to validate performance (= HEPs)



[1]

if we incorporate PSFs into validation studies, we gain greater sensitivity to operator performance

[2]

there is value in measuring performance early

[3]

PSFs are both measures and methods

[4]

if we treat PSFs as independent variables (methods) to shape the scenarios in validation, we may actually collect the HRA data we need

The evolution of control rooms in the first 60 years is less than what will happen in the next 10 years

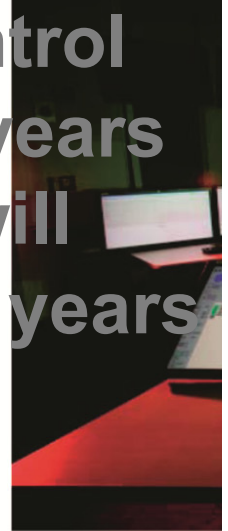


Fig. 1. Three generations of nuclear power plant control rooms: re
nuclear power plant with an all analog control room; re
Nuclear Generating Station, with a hybrid analog-digital c
Reactor Project, a fully digital advanced control room conc
measures and

methods to validate

2 safe performance? **The Need for New Visualization in Co**



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