

# Advanced Instrumentation, Information, and Control Systems Technologies



Control Room Modernization  
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Light Water Reactor Sustainability R&D Program



# A Programmatic Solution to Aging Plants

## DOE Light Water Reactor Sustainability Program Charter

- Assist utilities with safely extending the life of currently operating plants
- Original licenses were for 40 years
- Extensions up to 60 or 80 years
- Broad area focus, including human factors
  
- Dr. Bruce Hallbert is pathway lead for four pilot projects relevant to human factors in control rooms
  - Control room modernization (PI: Ron Boring)
  - Control room benefits (PI: Katya Le Blanc)
  - Computer based procedures (PI: Johanna Oxstrand)
  - Advanced outage control centers (PI: Shawn St. Germain)
  - Numerous other projects exist beyond control rooms



# Human Systems Simulation Laboratory (HSSL)



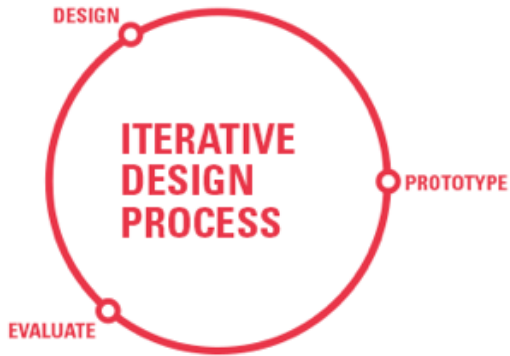
**Plant Models Installed:** SONGS, Robinson, Harris, gPWR, Brunswick

**Prototypes Built:** TCS, CVCS, CBP, LOD

**Crew Studies Run:** 9



# 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



# Developing a Modernization Framework

## Helping Utilities Meet Regulatory Requirements for Modernization

- *Human Factors Engineering Program Review Model, NUREG-0711*

| Planning and Analysis                | Design                               | Verification and Validation               | Implementation and Operation |
|--------------------------------------|--------------------------------------|-------------------------------------------|------------------------------|
| HFE Program Management               |                                      |                                           |                              |
| Operating Experience Review          | New Control Panel Layout*            |                                           |                              |
| Baseline Usability Evaluation*       | Human-Machine Interface Style Guide* | Human Factors Verification and Validation | Design Implementation        |
| Baseline Ergonomic Assessment*       | Human-System Interface Design        | Summative Benchmark Evaluation*           | Human Performance Monitoring |
| Staffing & Qualification             | Formative Evaluation*                |                                           |                              |
| Treatment of Important Human Actions | Training Program Development         |                                           |                              |

\*New Process Articulated by INL



# Utility Challenges with NUREG-0711

## It's a Regulatory Document

- It covers what the regulator needs to see as final proof that the design works
- It is not a prescriptive process for the utility
  - It is *summative*, not *formative*
  - Some key steps for utilities are not explicated

## It Primarily Covers New Builds

- Same process applies to upgrades, but many of the steps are already done at existing plants
- Utilities want a graded approach—the *delta*—for upgrades
- Transitioning to digital HSIs from analog I&C may require rethinking existing assumptions

## INL is Gathering and Documenting Modernization Experience

- Help utility conform to effective human factors process
- Help regulator to refine its guidance for efficient and safe upgrades

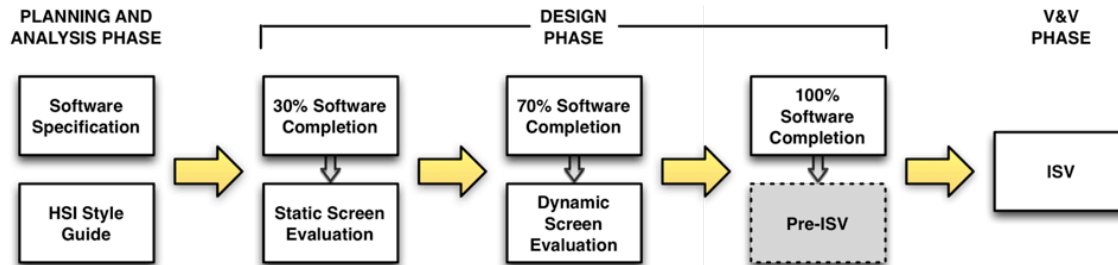


# Impacts: Develop First-of-a-Kind Design and Evaluation Processes for Control Rooms

Evaluation Type

|                                                 |                                              | <u>Evaluation Phase</u>                                      |                                           |                                                                |                                                                      |
|-------------------------------------------------|----------------------------------------------|--------------------------------------------------------------|-------------------------------------------|----------------------------------------------------------------|----------------------------------------------------------------------|
|                                                 |                                              | <b>Pre-Formative<br/>(Planning and Analysis<sup>1</sup>)</b> | <b>Formative<br/>(Design<sup>1</sup>)</b> | <b>Summative<br/>(Verification and Validation<sup>1</sup>)</b> | <b>Post-Summative<br/>(Implementation and Operation<sup>1</sup>)</b> |
| <b>Expert Review<br/>(Verification)</b>         | [1]<br>Design Requirements Review            | [2]<br>Heuristic Evaluation                                  | [3]<br>System Validation                  | [4]<br>Requalification against New Standards                   |                                                                      |
| <b>User Study<br/>(Validation)</b>              | [5]<br>Baseline Evaluation                   | [6]<br>Usability Testing                                     | [7]<br>Integrated System Validation       | [8]<br>Operator Training                                       |                                                                      |
| <b>Knowledge Elicitation<br/>(Epistemation)</b> | [9]<br>Cognitive Walkthrough (Task Analysis) | [10]<br>Operator Feedback on Design                          | [11]<br>Operator Feedback on Performance  | [12]<br>Operator Experience Reviews                            |                                                                      |

<sup>1</sup>Corresponding Phases in NUREG-0711.



# Modernization Processes That Work

## Harris SRO, Bob Stephenson, in His Own Words

- “This simulator allows us to evaluate our new turbine control system and train operators before we modify the plant. This is the only opportunity to work with the new system on this scale and see how it will integrate with other plant control systems. Based on what we learn here, we can modify the design to further improve plant safety and efficiency prior to implementation.”



## Getting the Word Out

- Published 18 DOE milestone reports on various processes for and findings from control room modernization
- Published 35 peer-reviewed publications on control room modernization
  - One paper recognized by Human Factors and Ergonomics Society as runner up for best paper among 891 conference submissions
- Research incorporated into recent EPRI 3002002770, *Guidance for Developing a Human Factors Engineering Program for an Operating Nuclear Power Plant*





# HSSL in Summary

## Accomplishments

- Developed the HSSL into a fully functional research facility in less than 3 years
- Developed a solid customer base
  - Ongoing work with Duke Energy, Southern Nuclear, Arizona Public Services, and Pacific Gas and Electric on control room projects
    - Cooperative Research and Development Agreements (CRADAs) with these parties, including significant funds-in work for Duke Energy
  - Joint work with EPRI on guidance development
- Developed a unique human factors capability
  - Documenting and developing a process and guidance to help U.S. nuclear industry with human factors aspects of modernization
  - Developing a prototyping platform to test upgrades prior to implementation
  - Building critical human factors research competence
- Developed international collaboration on modernization
  - Joint development efforts with Halden Reactor Project and Korea Atomic Energy Research Institute

