Using Microworlds to Support Dynamic Human Reliability Analysis

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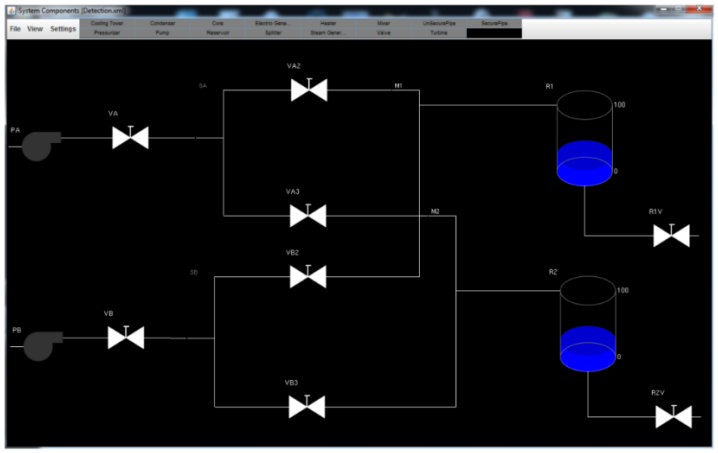
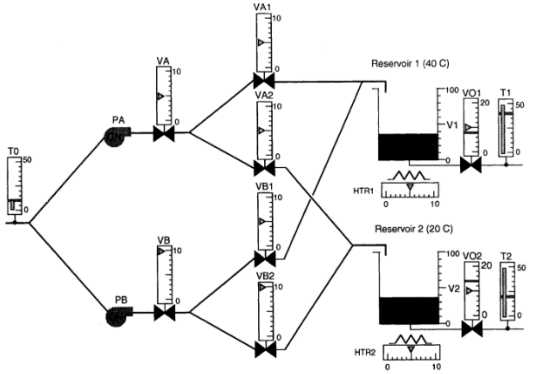
The Challenge – Studying Operators

- NPP **control room** studies are typically large scale endeavors (Ulrich, Werner, & Boring, 2016)
  - Performed at the plant or in a **full-scope simulator** (HSSL)
    - At INL we focus on control room modernization
  - **Expensive** – require SMEs and technical expertise to run simulator
  - Fast-paced due to limited time operators are available
  - Highly **applied** due to collaboration with utilities
  - Challenging to get sufficient operator **sample sizes**
  - **Complex and confounded** environment that limits experimental control
- **Microworlds** offer an alternative approach to gather human performance data

Microworlds

- Microworlds "…reproduce important characteristics of real situations while leaving open the possibility of manipulation and experimental control" (Funke, 1993)
  - Simplified simulator of a process like nuclear power control
- Current nuclear-related microworlds
  - DURESS II (Vicente et al., 1995; Vicente et al., 1996)
  - Microsimulator (Dyre et al., 2013)

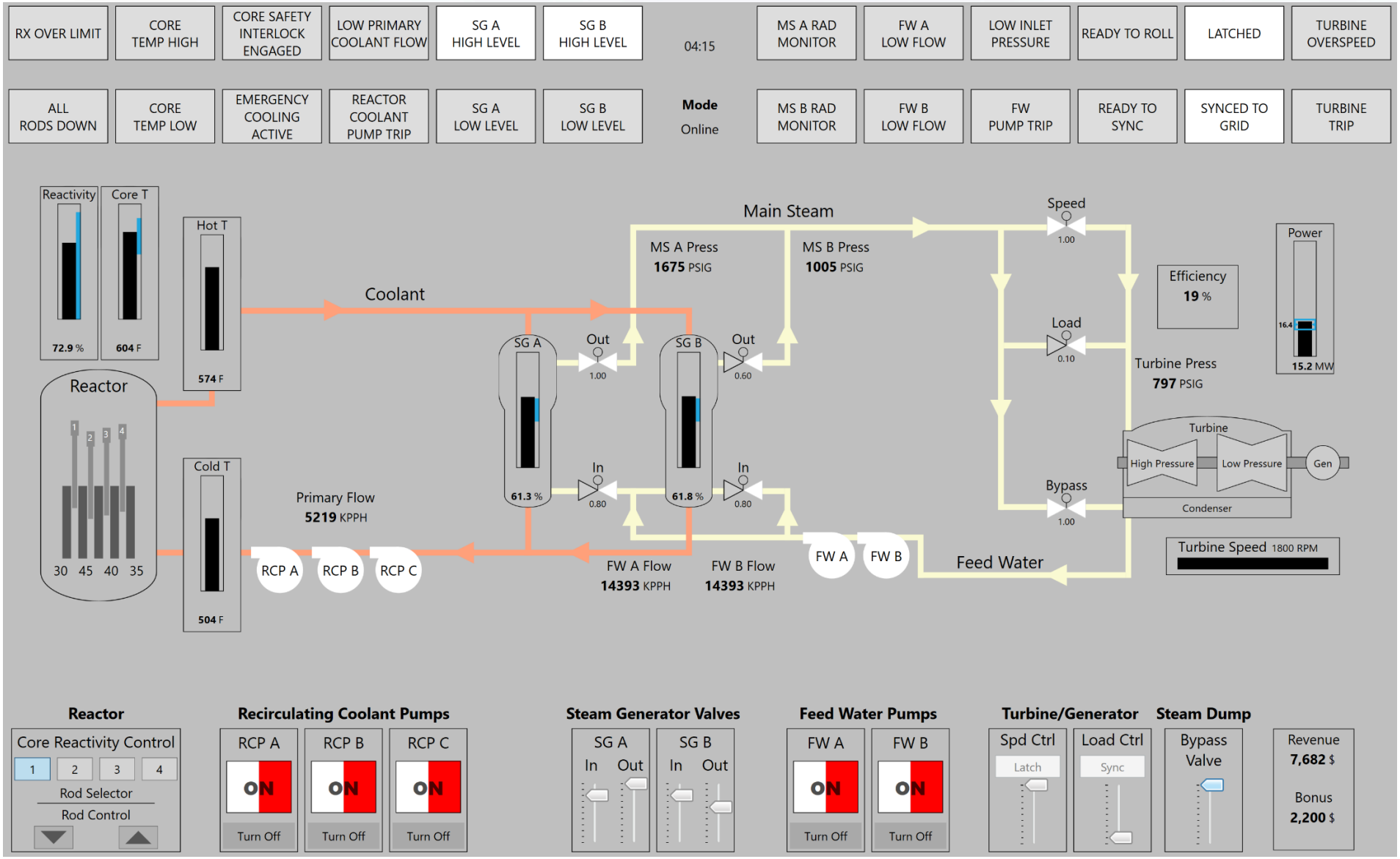




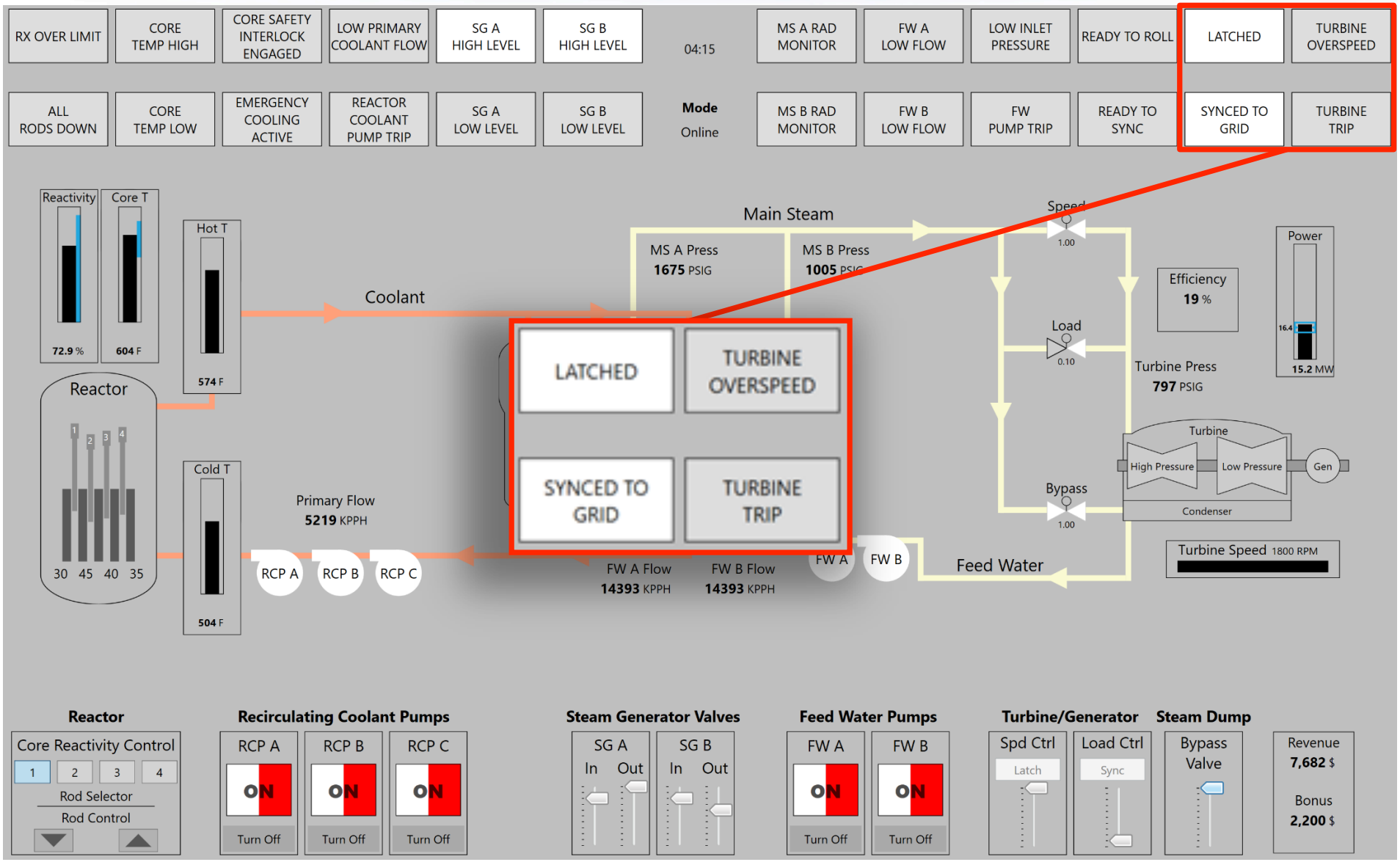
New INL Microworld: Rancor

- **Overall Task** – Transition the plant from shutdown to online electrical power production
  - Several subtasks required to achieve goal
  - Gamified – revenue generation
  - Designed to be easy for students to learn and use
  - Model – simplified process control (Rankine Cycle) simulation
- **Rationale** – Reduced complexity affords
  - Using less experienced participants
  - Quick administration – shorter task durations
  - Experimental control
- **Data Sources**
  - Parameter logging
  - Event coding (modes operations = tasks)
  - Human actions
  - Integrated with eye tracking for time synchronization

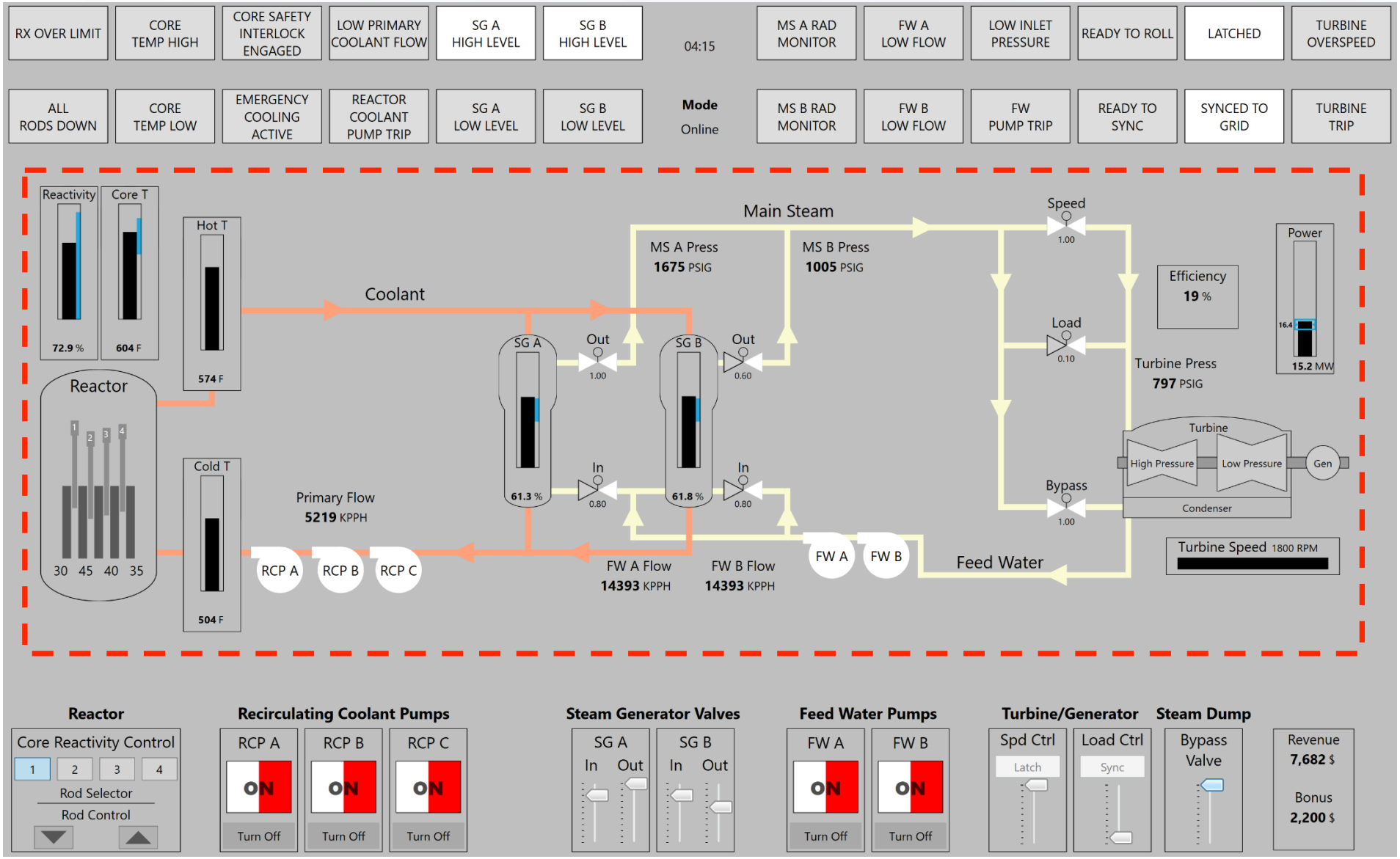
Rancor Microworld Interface



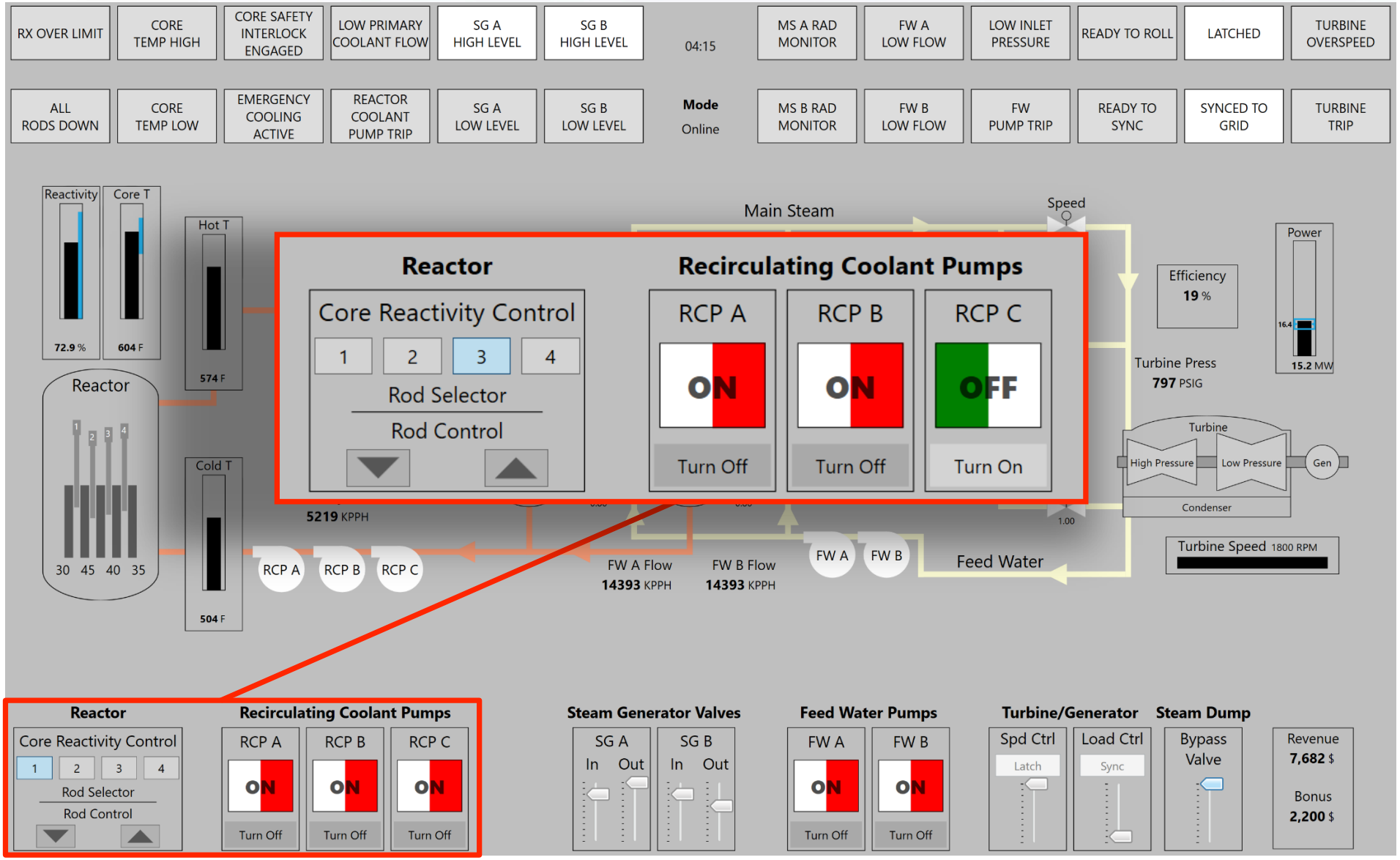
Rancor Microworld – Alarm Region



Rancor Microworld – Graphical System Depiction

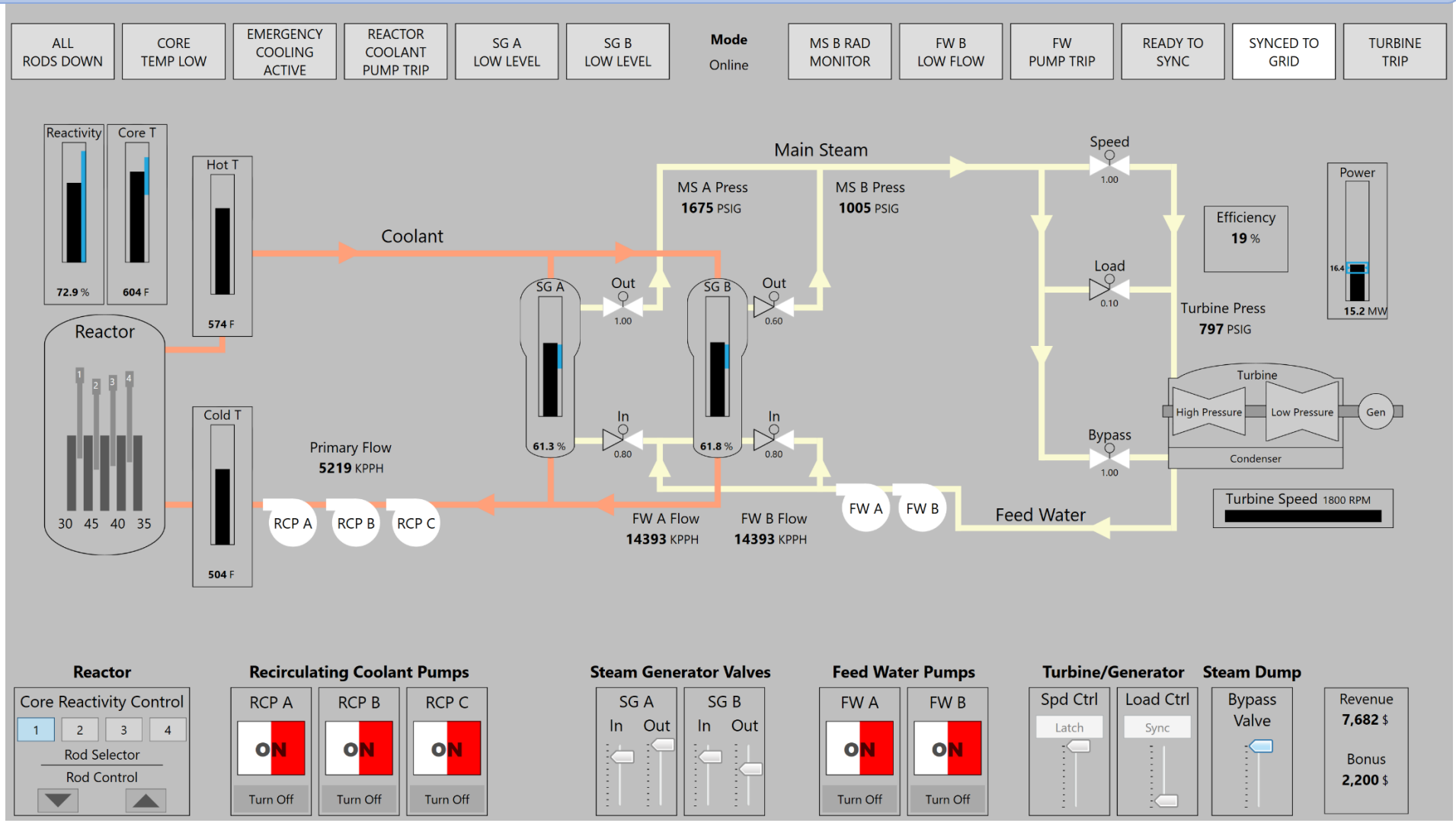


Rancor Microworld - Controls



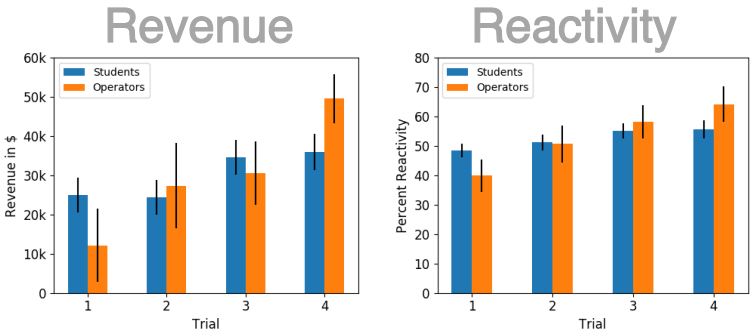
Rancor Microworld - Modes

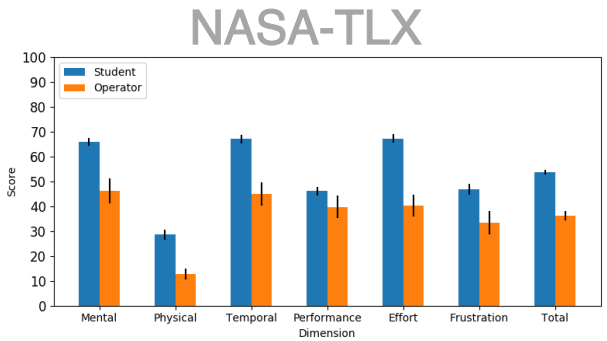
Modes | Startup | Ready To Roll | Rollup | Ready to Sync | Online

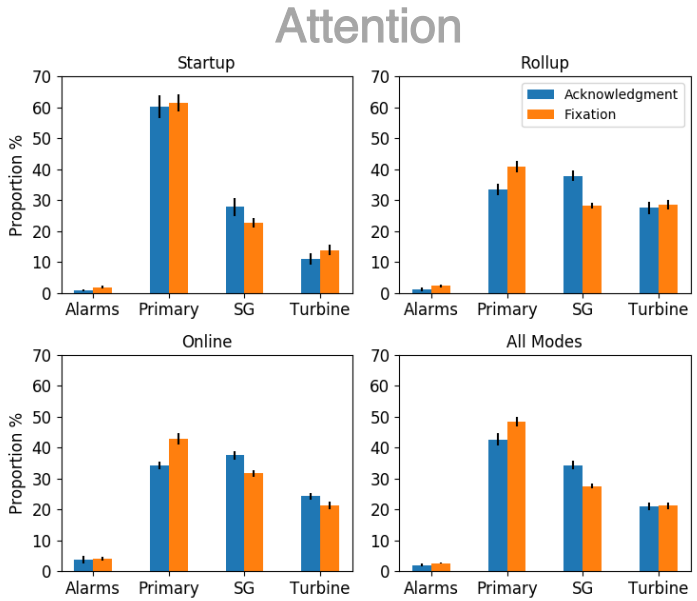


Prior Research Efforts

- Can students use the microworld?
  - Performance → **Yes**
- Does domain specific knowledge affects performance? → **Yes**
  - Students versus Steam Plant Operators
- Are meaningful results generated for cognitive constructs? → **Yes**
  - Attention
  - Situation Awareness
  - Workload







Active Research Efforts

How do we generalize microworld human performance data to the nuclear industry?

- Can student data inform research on operators and control rooms?
- More specific – can we investigate HRA concepts such as the PSF experience/training?

Goals

- Validate the simulation with operators to determine face validity
  - **Hypothesis** – the microworld is representative
- Examine how students and operators compare (experience/training)
  - **Hypothesis** – Operators will demonstrate better performance
  - Examined a number of variables:
    - **Performance (process values)**
    - Subjective ratings
    - Attention
    - Situation Awareness

Experience/Training Comparison

- **Participants**
  - Six licensed operators participating in an operator-in-the-loop study on a new Turbine Control System
  - Each operator completed two-year-full-time licensing classes from the same U.S. NPP

- **Protocol**
  - 4 trials (2 training, 2 experimental*)
  - Each 8 minute trial required the operators to transition the NPP from a shutdown to electrical power production state
  - After completing the experimental trials, the operators were debriefed and completed a short questionnaire aimed at gathering their impressions of the simulation

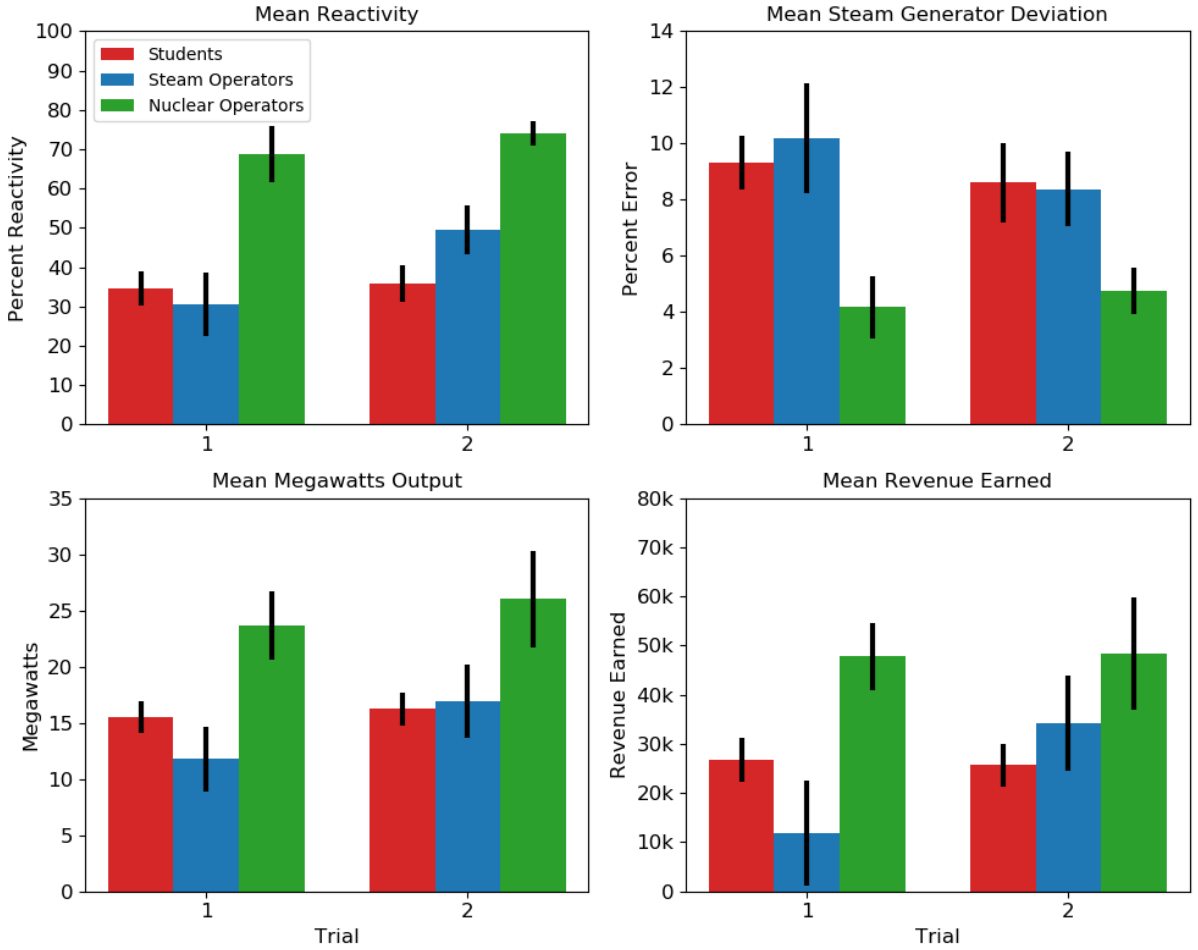
*Prior experiments used 6 experimental, but time constraints for operators allow for only 2

Qualitative Results

- Operators reported the microworld was representative of the process
  - "General theory is good, operationally need procedures and all the other stuff that goes on behind the scenes"
  - "Secondary plant was well designed as far as feed flow, steam gen level and secondary pressure response"
  - "…involves applying a heat source, have to feed flow, and have steam generators – its pretty good and it is like a simulator"
- Noted some differences from the actual process
  - "…the numbers for Thot, so there are some extra things you don't need. Megawatts, efficiency, and reactivity themselves don't help me meet the goal"

Performance Data Results

- Operators consistently demonstrated better performance over 2 experimental trials
  - In line with extensive prior HRA research on experience/training PSF



Preliminary Conclusions

- **Promising preliminary results**
  - The operators performed better than students as expected
  - The operator reported the microworld was representative
  - Still **not enough data** to make any concrete conclusions
    - Data collection is ongoing
      - Last month two more operators were sampled

- **Limitations**
  - Limited number of trials and measures (no eye tracking)

Future Directions

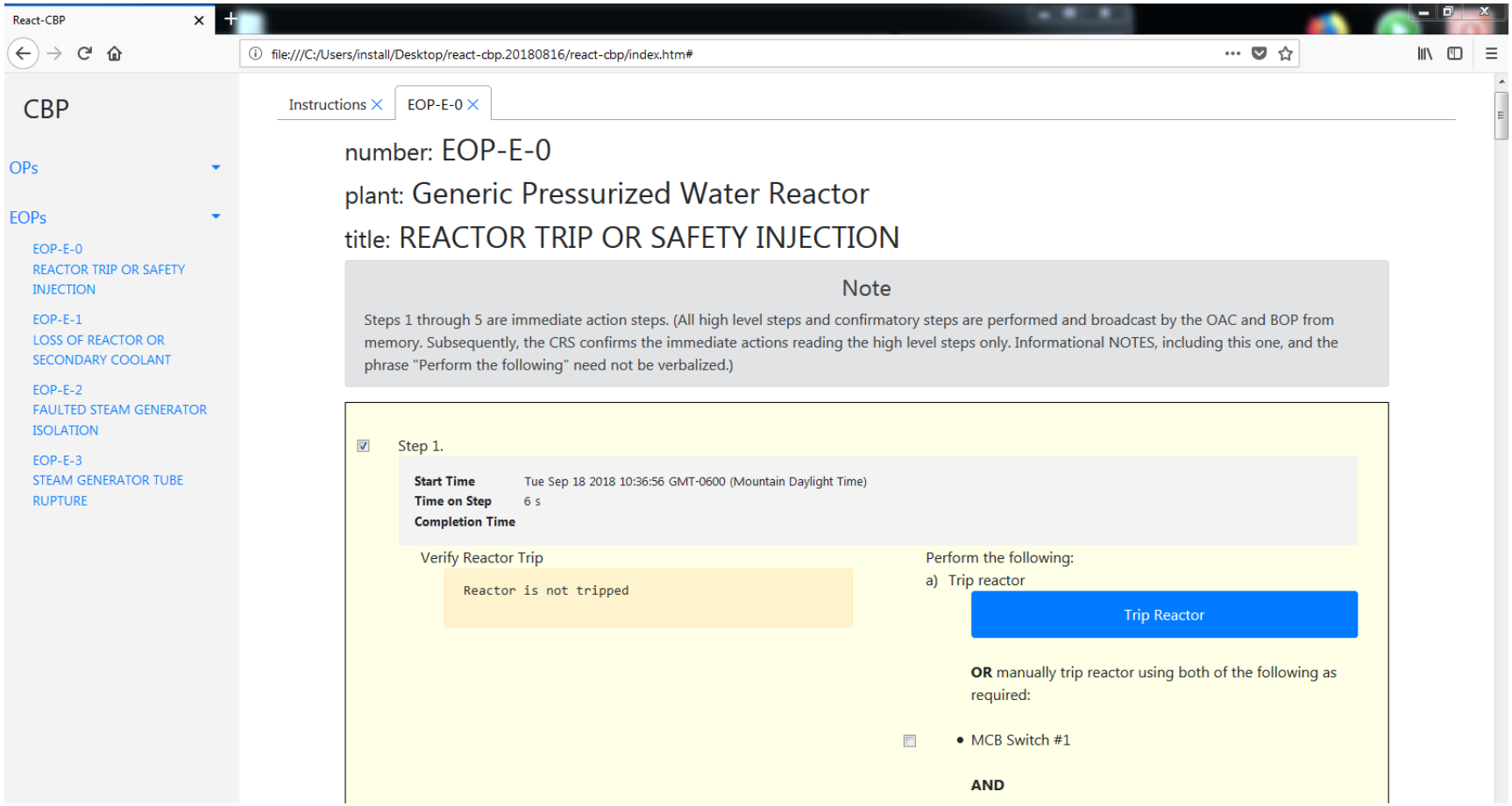
- **Future Directions**
  - Gather data to support
    - HEP estimates
    - Performance timing data (see yesterday's talk on GOMS-HRA)
    - Compare analog and digital formats
    - Support Dynamic HRA
      - Detailed data gathering to support subtask modeling and decision making
  - Sampling other areas of expertise
    - Oil and gas
    - Adapting system to other models
  - Integrate with other ANIME tools → Test analog and digital human-machine interfaces
    - TEJUN
    - GAIYO

TEJUN-GAIYO Comparing Analog and Digital

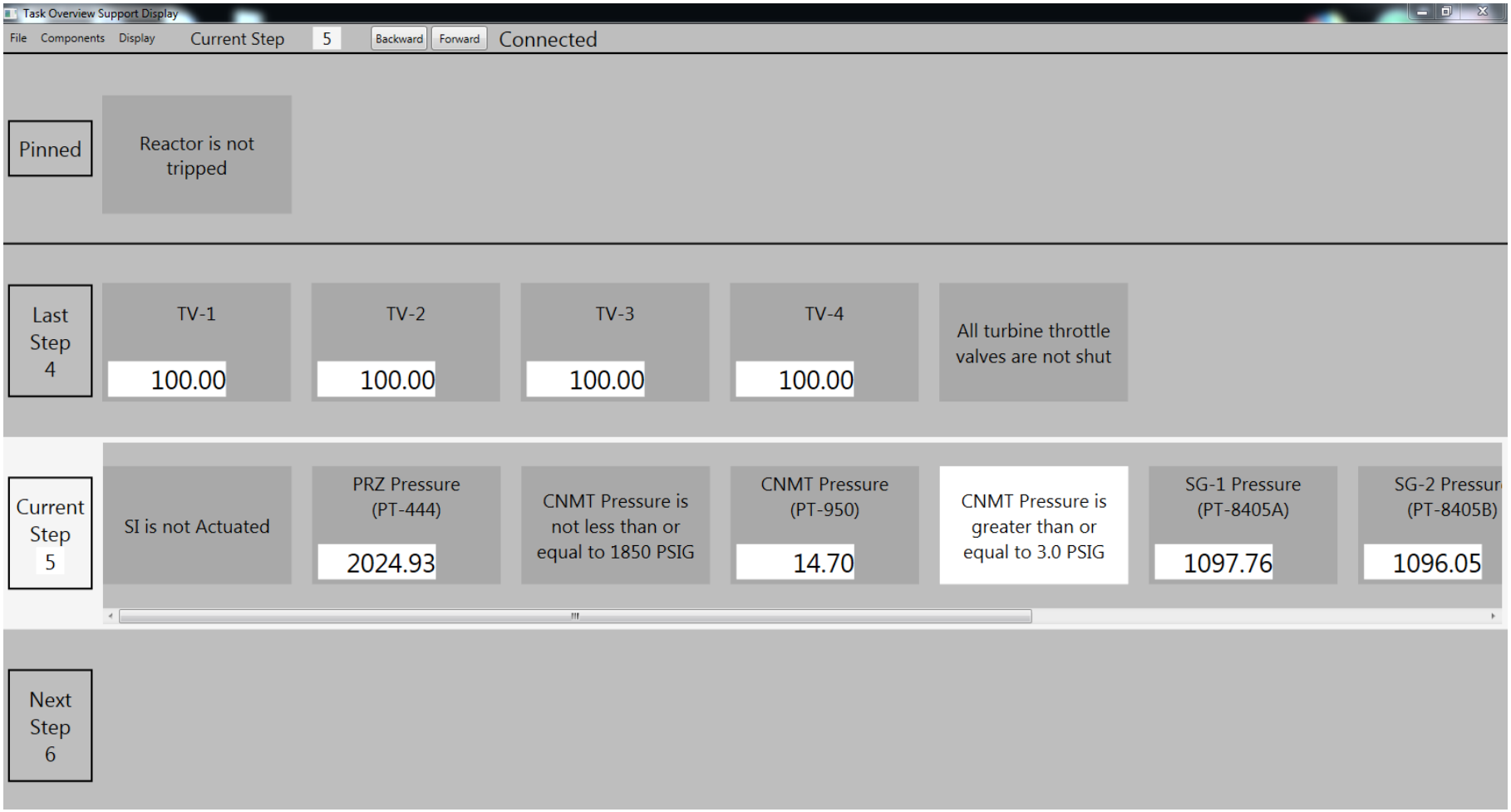
- Advanced Nuclear Interface Modelling Environment (**ANIME, アニメ**)
  - Windows (Visual Studio and WPF) based interface prototyping environment
  - Collection of library and controls
  - Can couple to simulator vendor models (various GSE and WSC simulators) or run in standalone mode (Rancor)

- Next step: Compare operator performance using all digital controls
  - Task Engine for Job and User Notification (**TEJUN, 手順**)
    - Computer-based procedure authoring system
    - Markdown based procedure input in native 2 column format
  - Graphical Augmentation Interface for Yoked Overviews (**GAIYO, 概要**)
    - Dynamic Task based overview display
    - Tracks procedure completion to dynamically display current digital indication and controls

TEJUN


React-CBP
file:///C:/Users/install/Desktop/react-cbp.20180816/react-cbp/index.htm#
CBP
OPs
EOPs
EOP-E-0
REACTOR TRIP OR SAFETY INJECTION
EOP-E-1
LOSS OF REACTOR OR SECONDARY COOLANT
EOP-E-2
FAULTED STEAM GENERATOR ISOLATION
EOP-E-3
STEAM GENERATOR TUBE RUPTURE
Instructions
EOP-E-0
number: EOP-E-0
plant: Generic Pressurized Water Reactor
title: REACTOR TRIP OR SAFETY INJECTION
Note
Steps 1 through 5 are immediate action steps. (All high level steps and confirmatory steps are performed and broadcast by the OAC and BOP from memory. Subsequently, the CRS confirms the immediate actions reading the high level steps only. Informational NOTES, including this one, and the phrase "Perform the following" need not be verbalized.)
Step 1.
Start Time Tue Sep 18 2018 10:36:56 GMT-0600 (Mountain Daylight Time)
Time on Step 6 s
Completion Time
Verify Reactor Trip
Reactor is not tripped
Perform the following:
a) Trip reactor
Trip Reactor
OR manually trip reactor using both of the following as required:
MCB Switch #1
AND

GAIYO


Task Overview Support Display
File
Components
Display
Current Step
5
Backward
Forward
Connected
Pinned
Reactor is not tripped
Last Step 4
TV-1
100.00
TV-2
100.00
TV-3
100.00
TV-4
100.00
All turbine throttle valves are not shut
Current Step 5
SI is not Actuated
PRZ Pressure (PT-444)
2024.93
CNMT Pressure is not less than or equal to 1850 PSIG
CNMT Pressure (PT-950)
14.70
CNMT Pressure is greater than or equal to 3.0 PSIG
SG-1 Pressure (PT-8405A)
1097.76
SG-2 Pressur (PT-8405B)
1096.05
Next Step 6

Conclusions

Rancor microworld holds great utility for gathering operator performance data to inform HRA

- Complements large data gathering efforts like SACADA and HuREX by allowing first principles research
  - Allows more precise control of scenarios and interfaces than is possible in full-scope simulator
- Possible to gather large samples of student operators
  - More conclusive statistical findings than small sample operator-in-the-loop studies possible at INL
  - Flag areas of interest for subsequent full-scope simulator studies with actual operators
- Results show promise in generalizing results from less experienced operators
- As new microworlds are developed, they provide a much-needed platform to investigate human performance outside nuclear

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