You Have to Build It to Evaluate It: Prototyping and Evaluating Advanced Control Rooms

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Manager & Distinguished Scientist
Human Factors and Reliability Department

Idaho National Laboratory (INL)

Idaho National Laboratory

One of 9 large U.S. Department of Energy (DOE) multi-program Labs

DOE's Lead Lab for Nuclear Energy

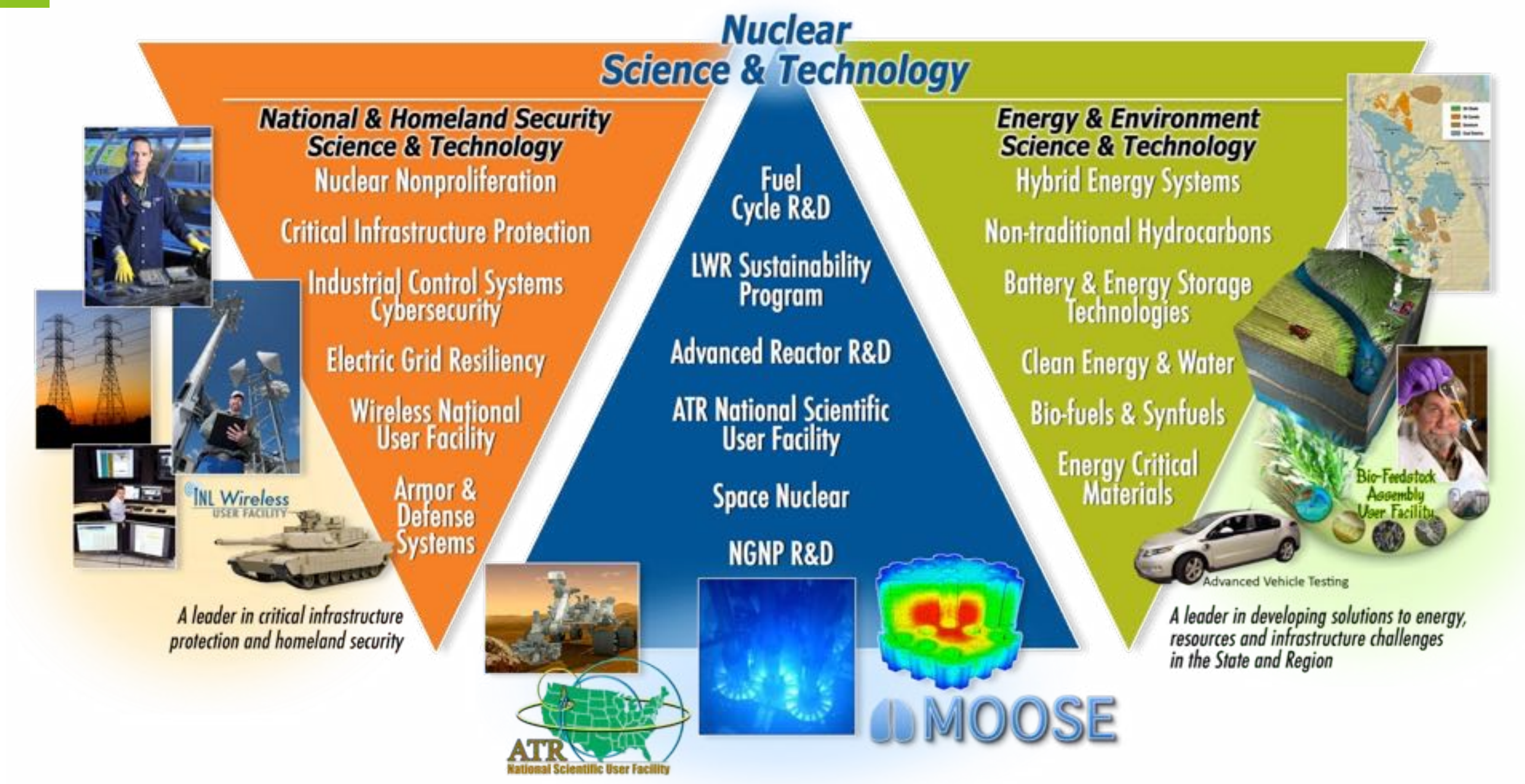
- *Site of 52 historic prototype or test reactors*
- *4 reactors currently being developed*

5,500 full-time researchers and staff

Nearly $2bn annual budget

890miles² (2300km²) of research facilities across ca. 600 buildings

Our Programs of National Importance



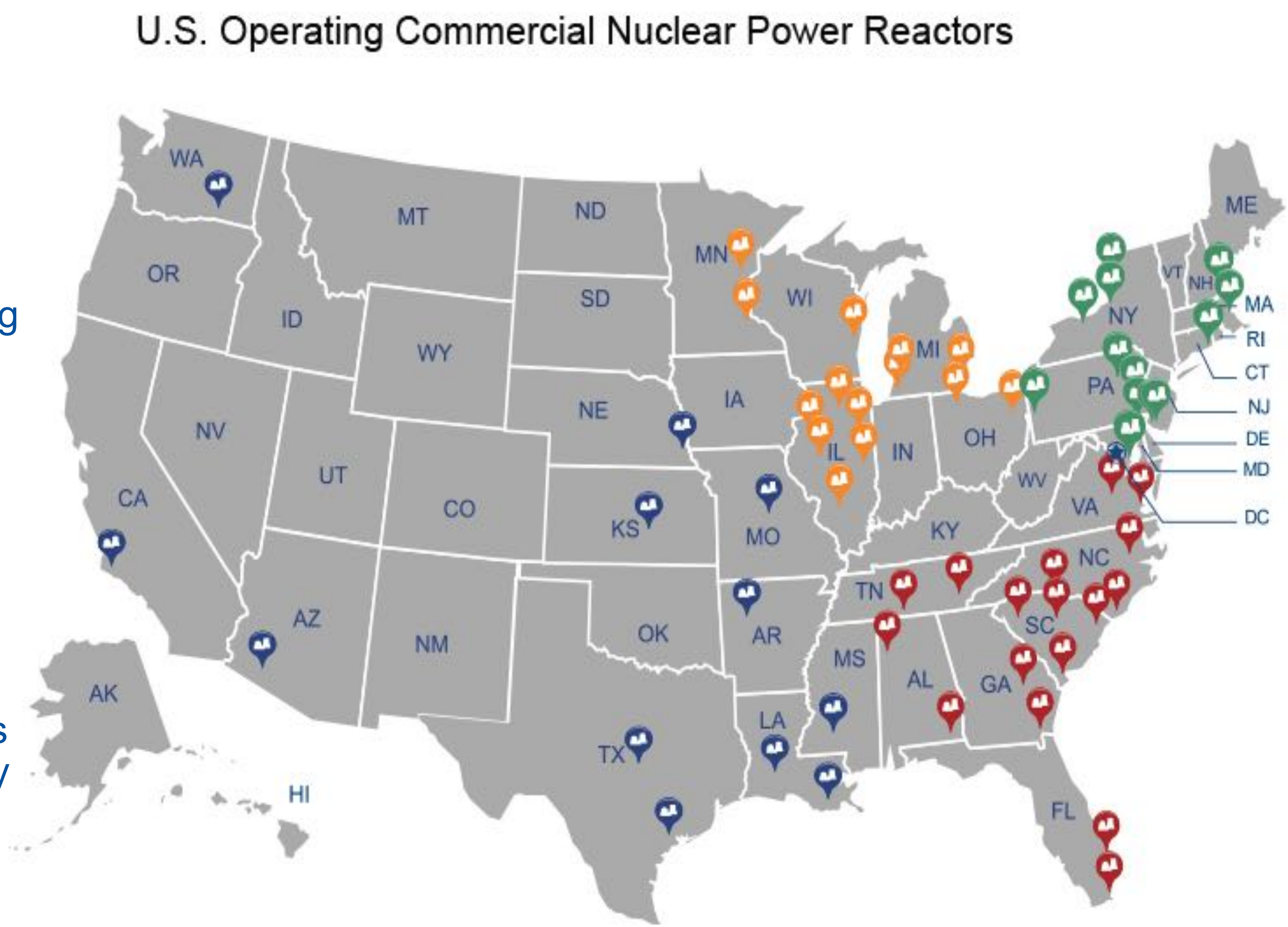
Research – Development – **Demonstration** – Deployment

Why It Matters: Nuclear Power Plants in U.S.

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

October 2021

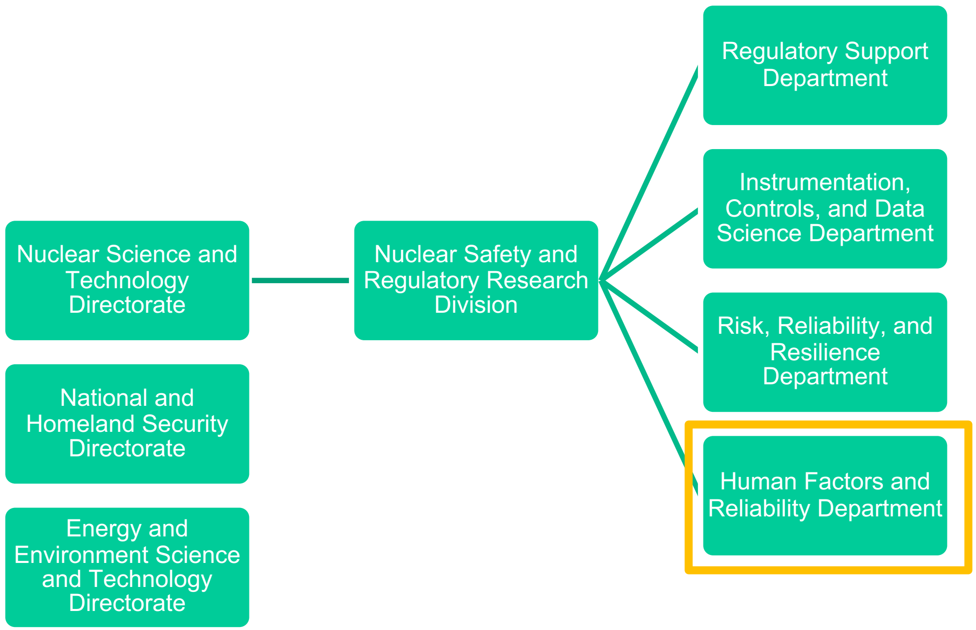
- 93 operating commercial reactors generating about 20% of U.S. electric supply
- 12 reactors shut down over past 10 years, reducing nuclear proportion of U.S. electricity generation by 5%
- Shutdown reactors largely replaced by natural gas plants
- Emissions have gone up!



Human Factors at INL

Human Factors and Reliability Department

INL Research Organizations

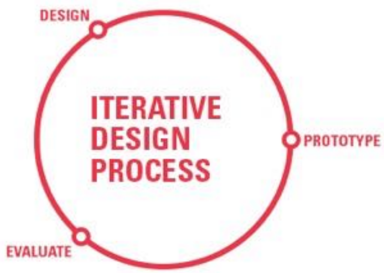


- Human factors employs design and evaluation methods to determine the optimal human-system interface
- Human reliability is the study of how to model and predict human performance to minimize human error and the contribution to overall risk
- These two capabilities are combined in the **Human Factors and Reliability Department** at INL
- Our mission is to ensure the safety of humans and the usability of systems they operate

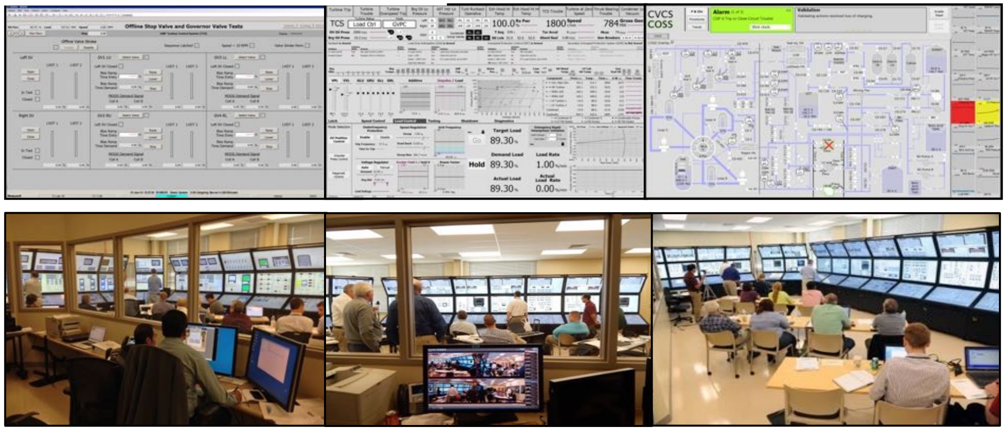
Human Factors and Reliability Department

- **16 human factors staff and 2 support staff**
  - Primarily engineering psychologists involved in design and evaluation of control rooms
- **Practitioners**
  - Apply standards, guidance and principles within a regulatory framework
  - e.g., Help utilities apply with control room modernization using established tools and methods
- **Researchers**
  - Develop new tools and methods for human factors and reliability
  - e.g., Develop new computer-based procedure software

What Do We as Psychologists Do?



my team and I **build prototypes** of control rooms for nuclear power plants that we then **evaluate** through operator-in-the-loop studies



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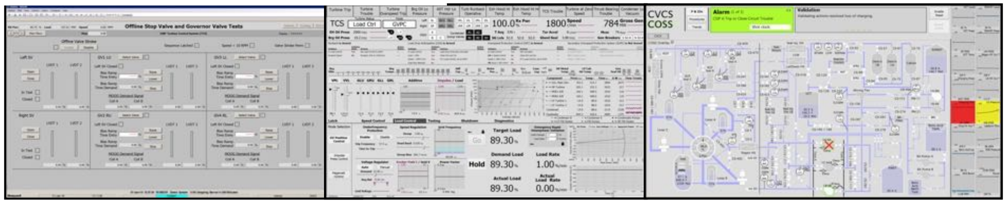
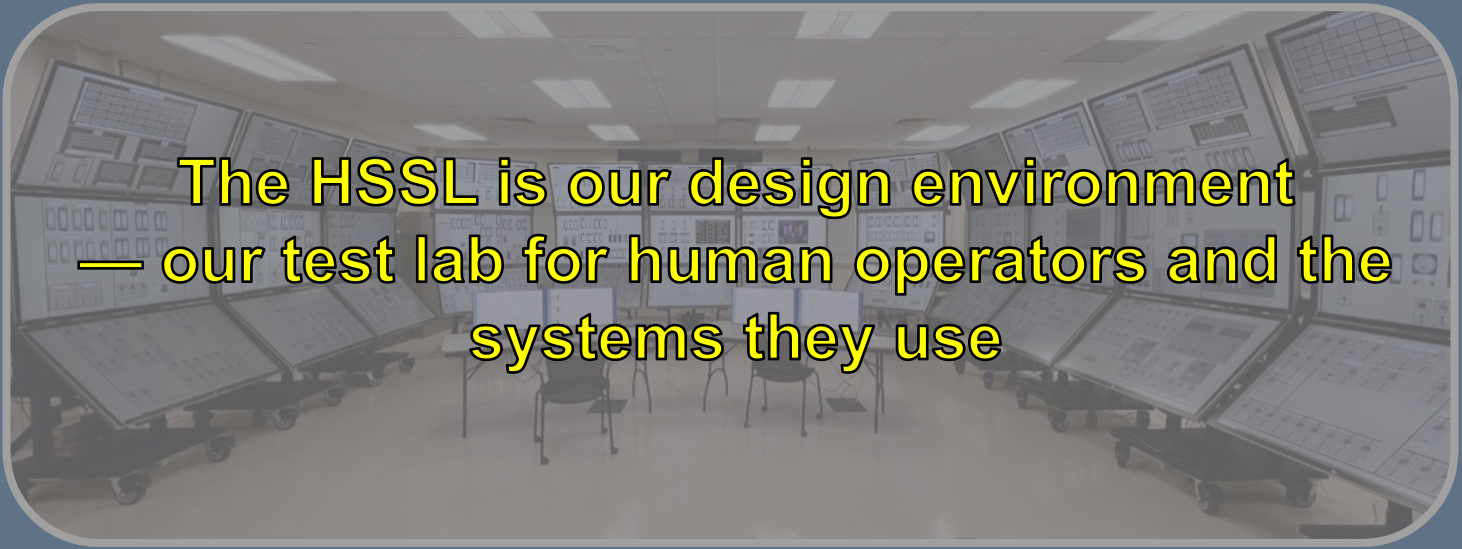


Human System Simulation Laboratory

reconfigurable,
full-scale,
full-scope,
research simulator

Human System Simulation Laboratory



reconfigurable,
full-scale,
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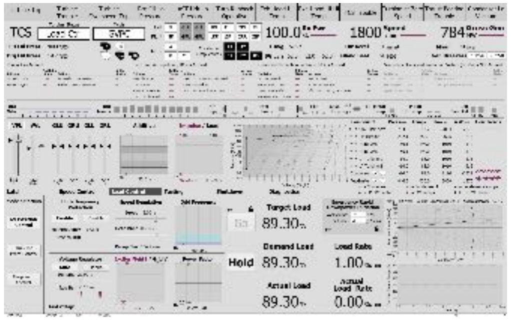
ANIME

advanced nuclear interface
modeling environment

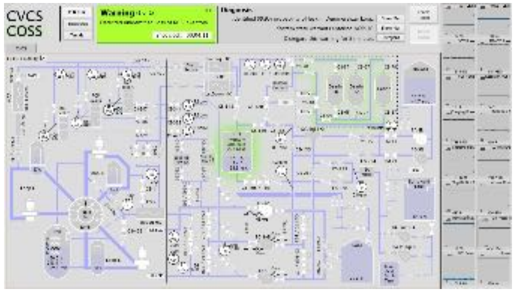
a development framework and sample
code library for process control

ANIME Continuum

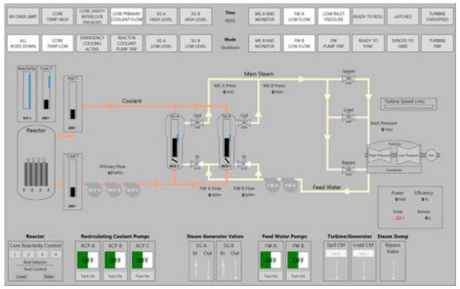
Emulation of Conventional Distributed Control System HMI



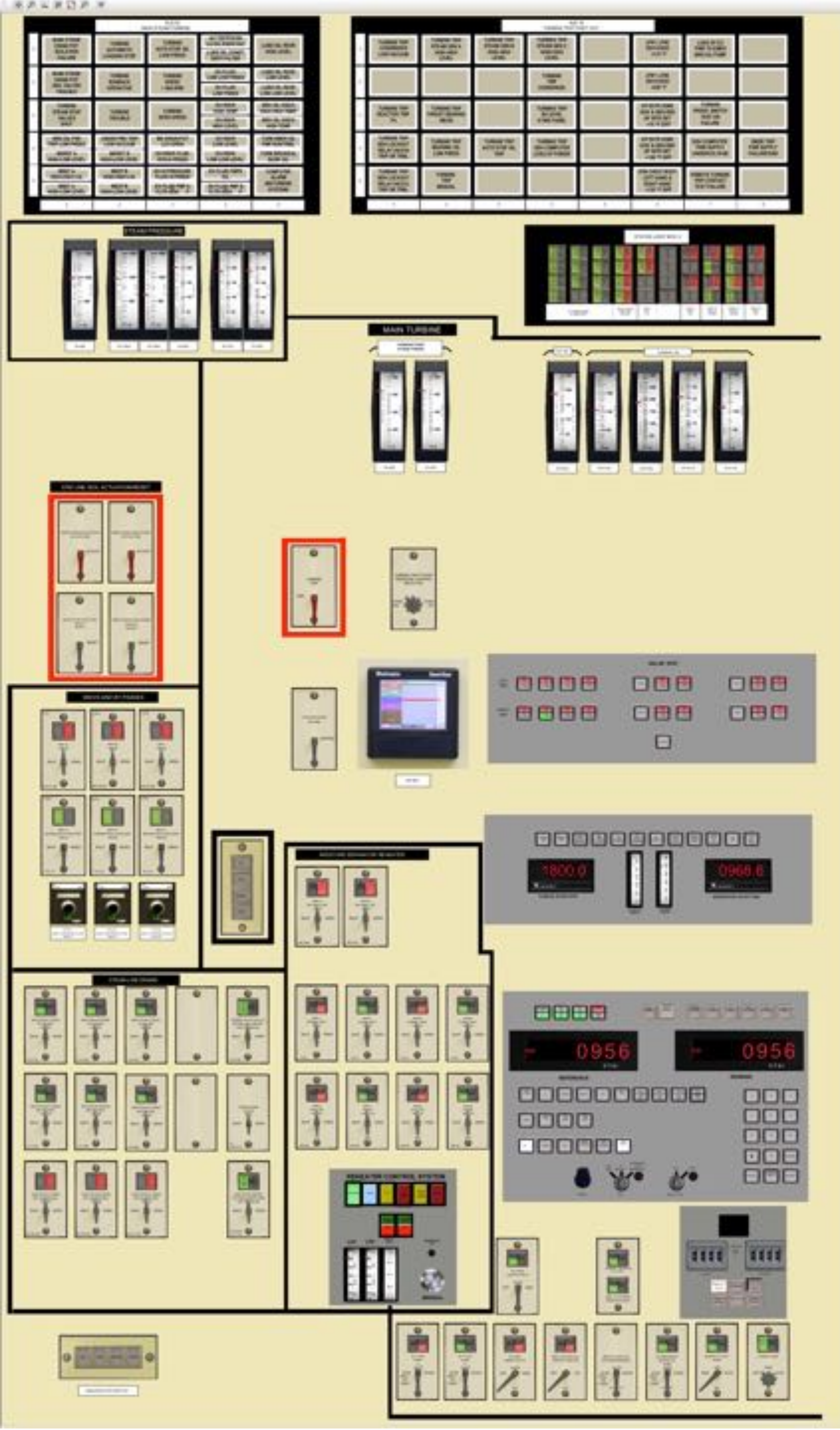
Conceptual Distributed Control System Prototype



Computerized Operator Support System



Standalone Microworld for Human Factors and Automation Research



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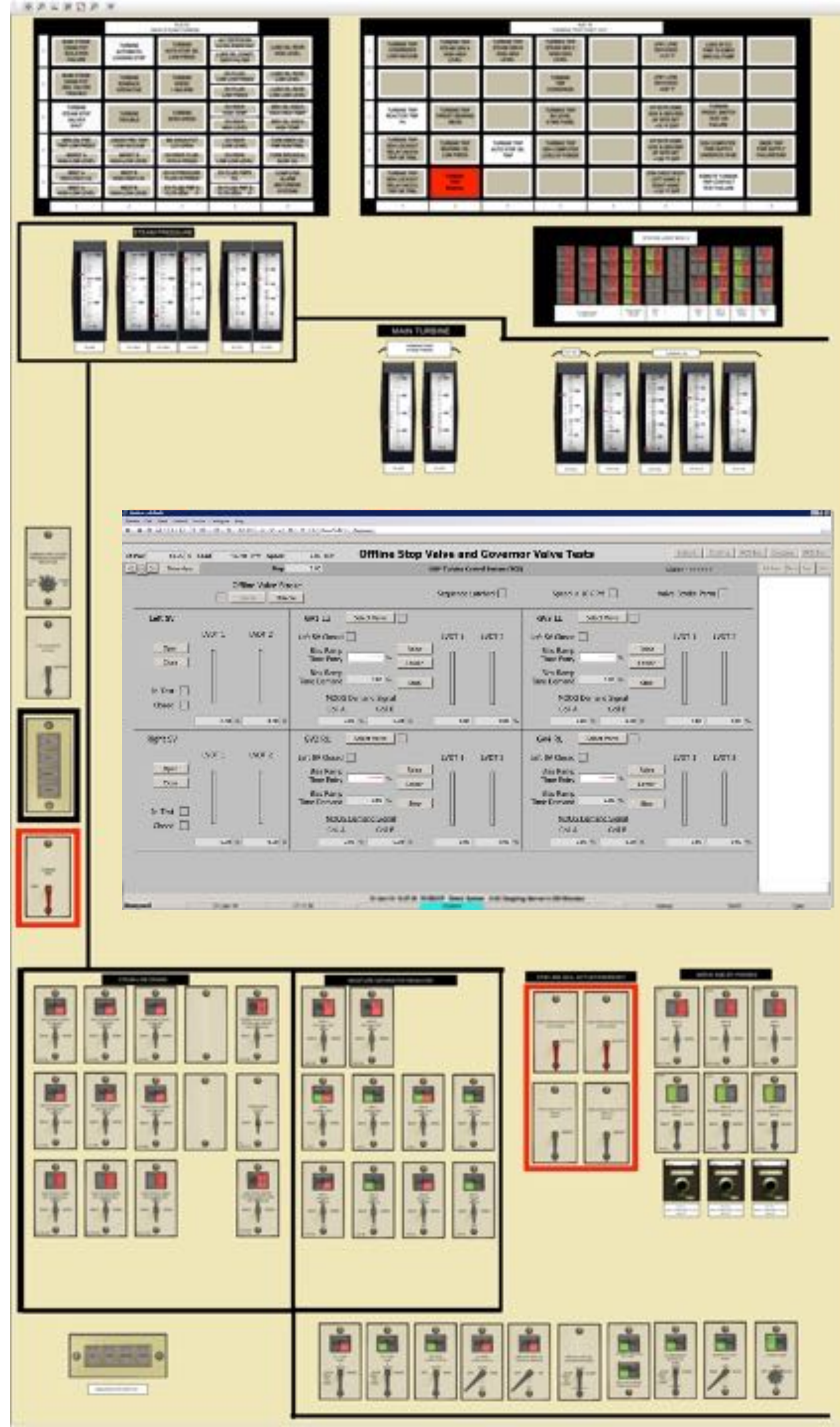
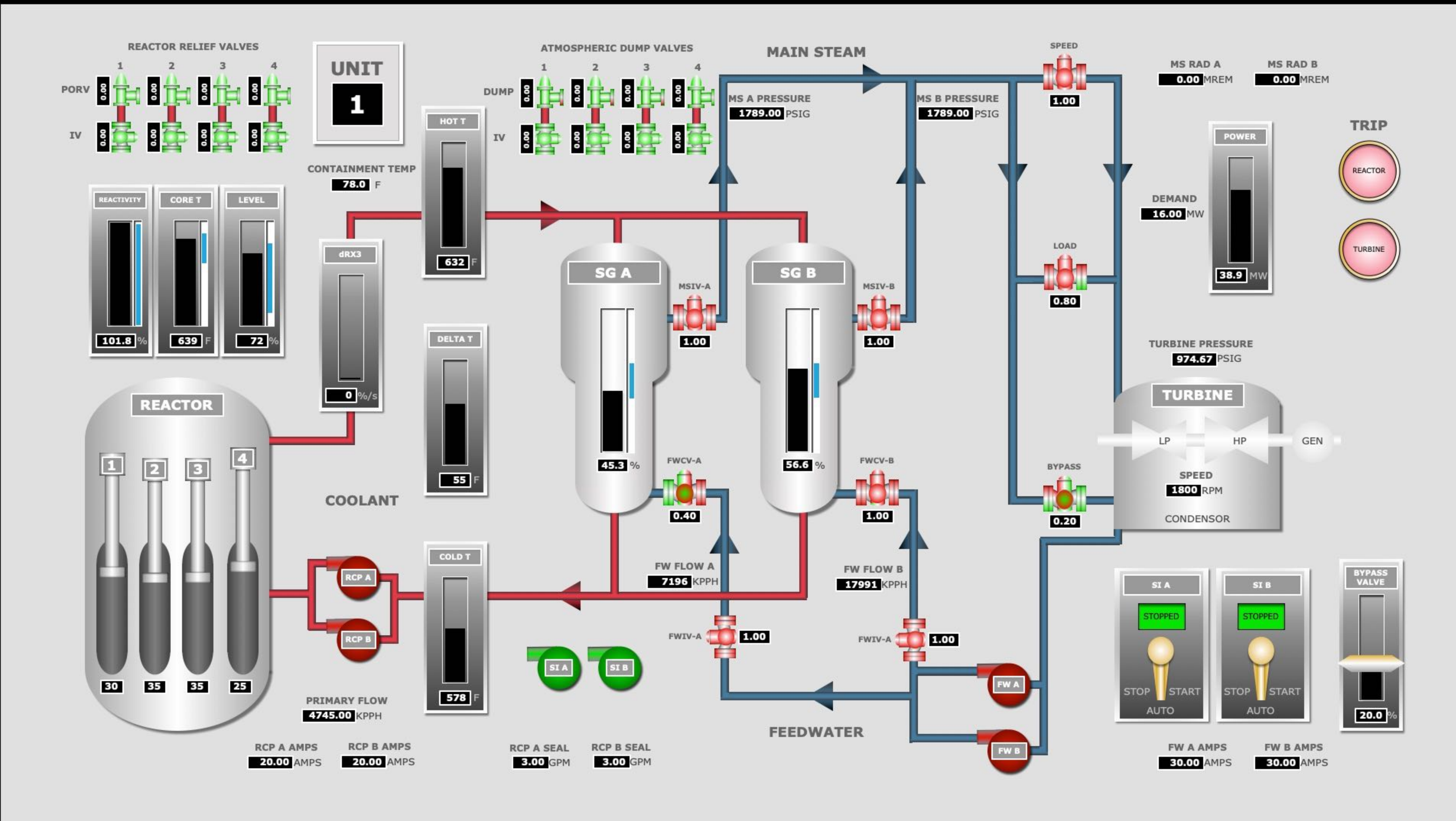


How about trying out different interfaces for same systems?



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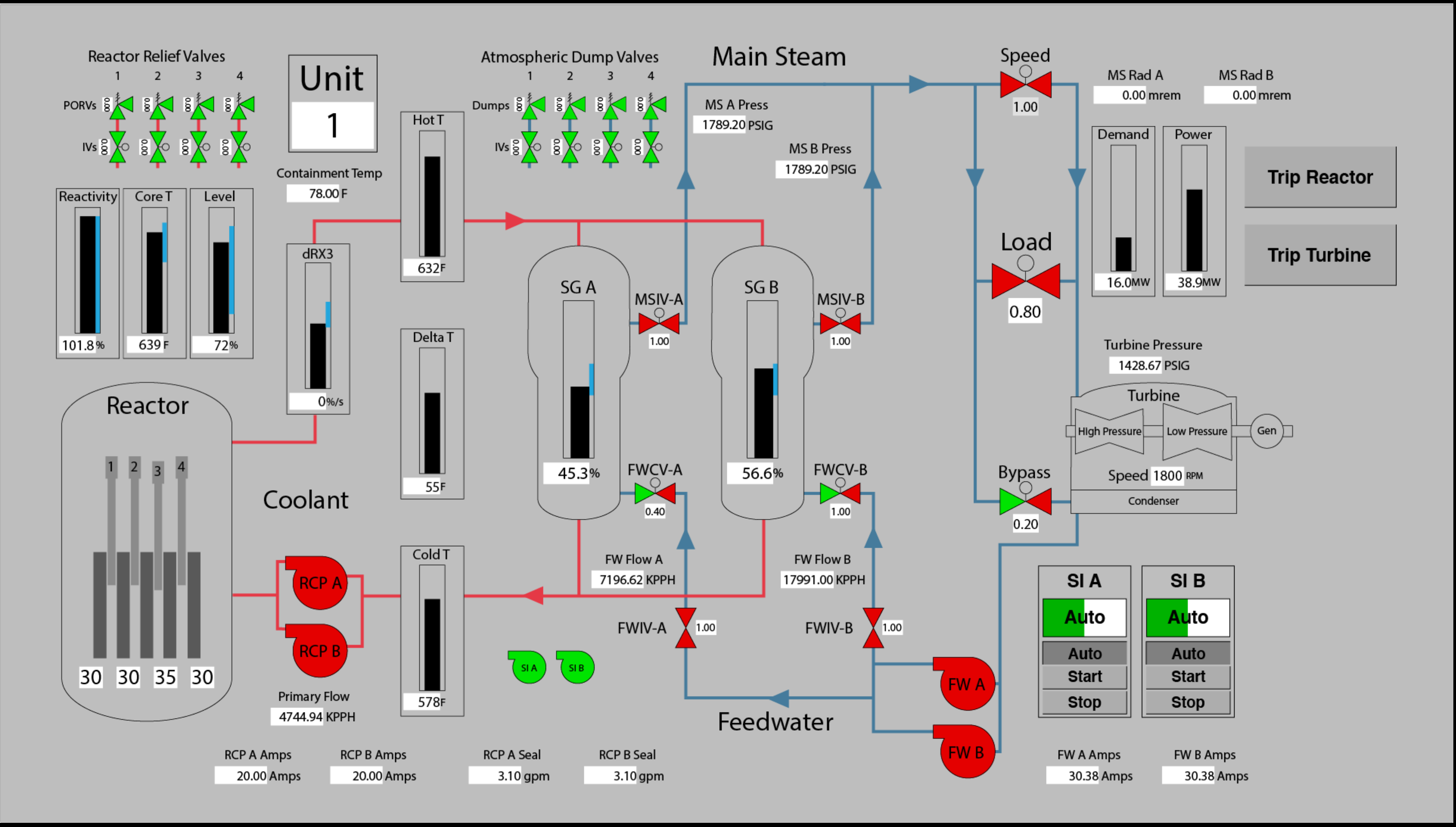

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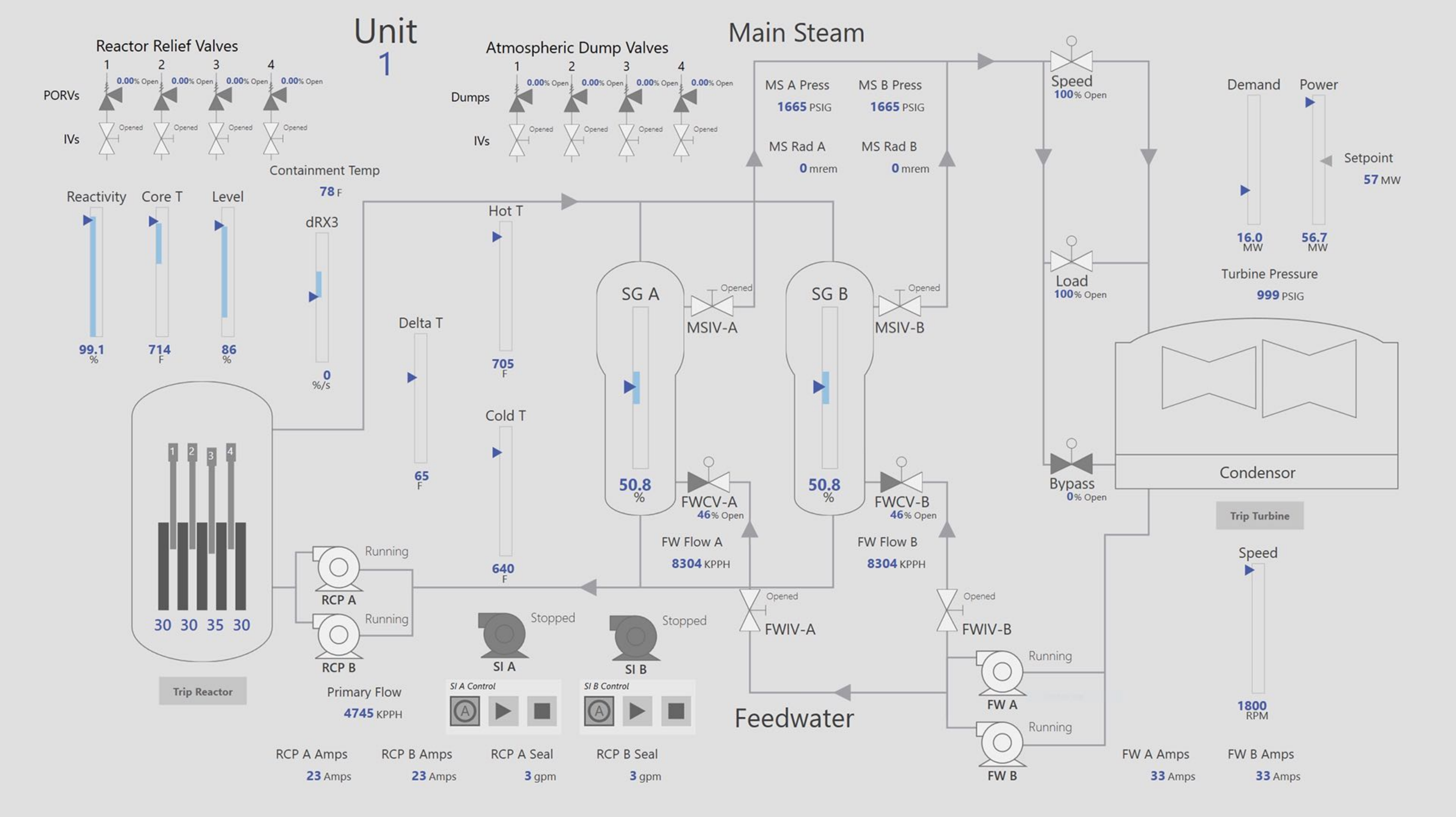

ANIME Continuum

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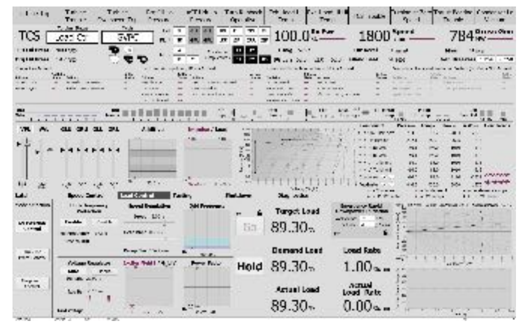
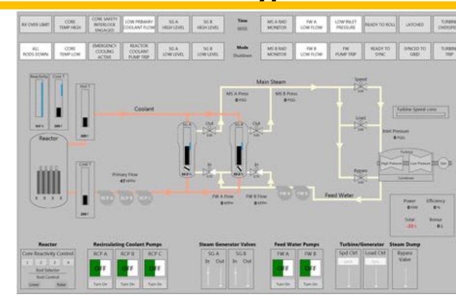


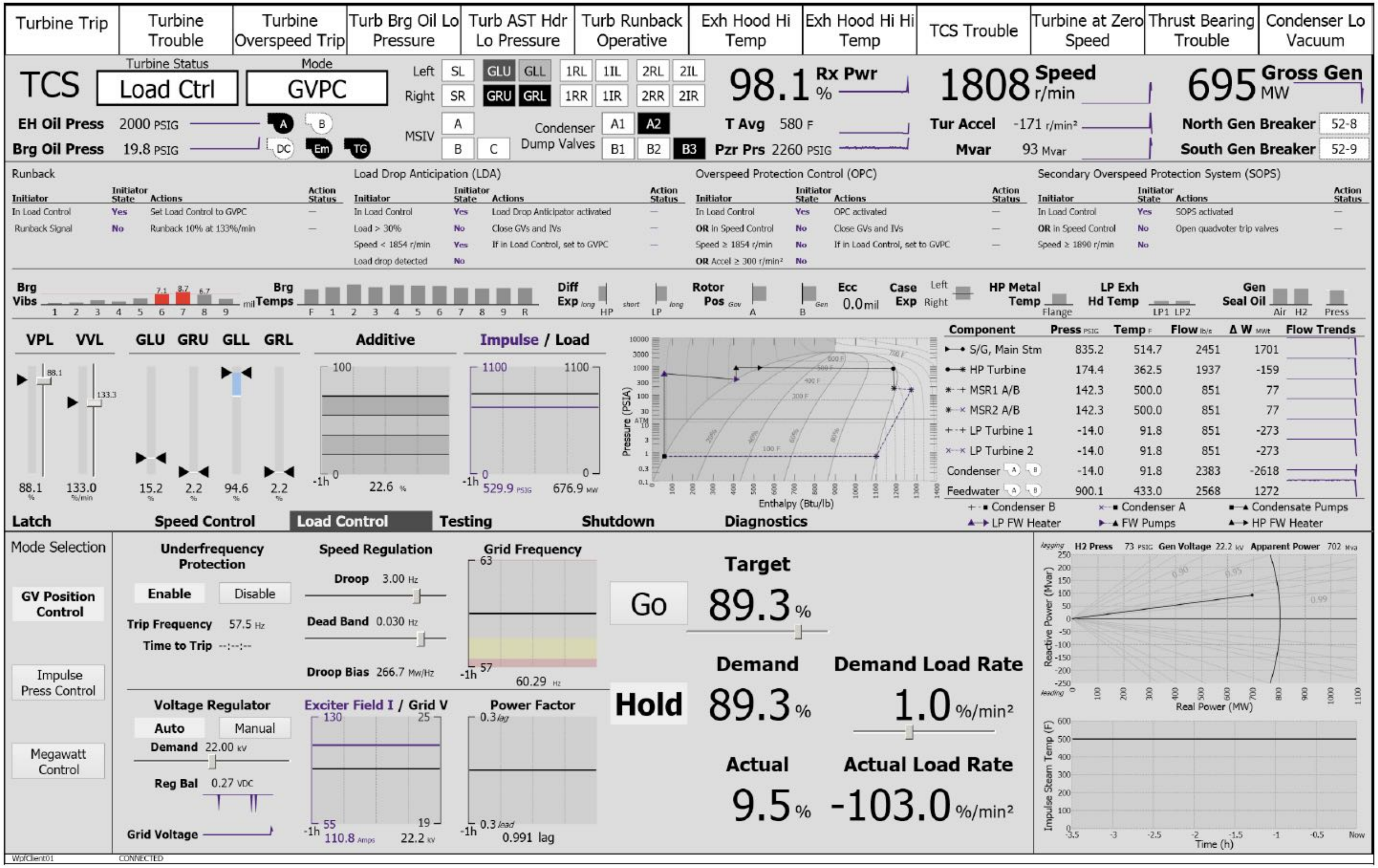
Conceptual Distributed Control System Prototype

Computerized Operator Support System

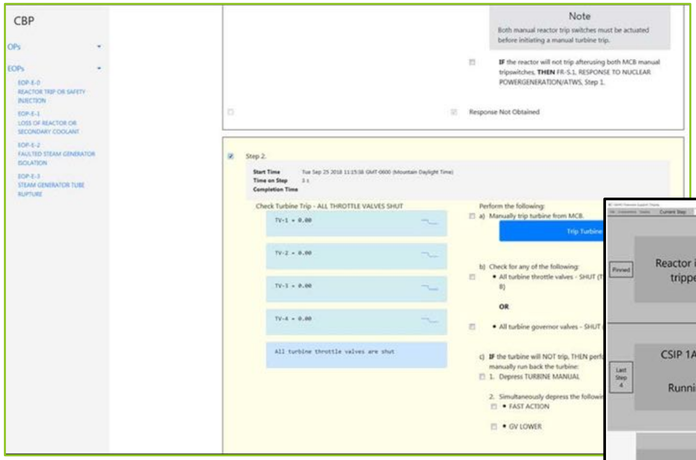


Standalone Microworld for Human Factors and Automation Research

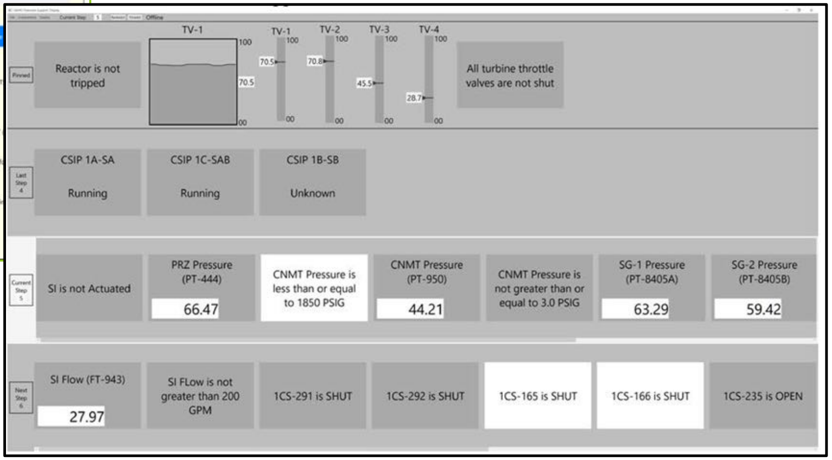
Advanced Turbine Control System Prototype



The Two-Screen Plant Control System Concept



Task Engine for Job and User Notification (TEJUN): A Tool for Building Computerized Procedures

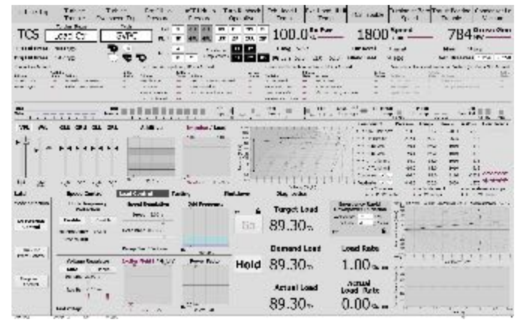


Graphical Augmentation Interface for Yoked Overviews (GAIYO): A Tool for Building Overview Screens for Main Control Rooms

GAIN
Gateway for Accelerated Innovation in Nuclear

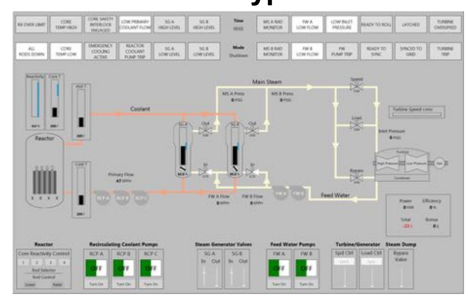
ANIME Continuum

Emulation of Conventional Distributed Control System HMI



Conceptual Distributed Control System Prototype

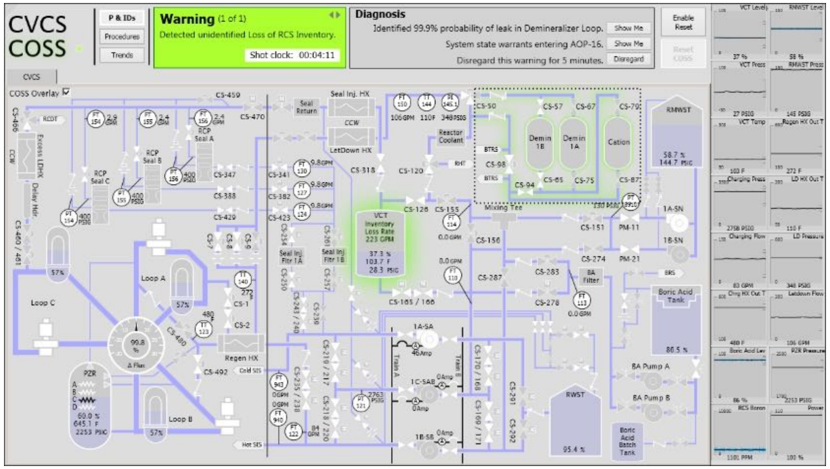
Computerized Operator Support System

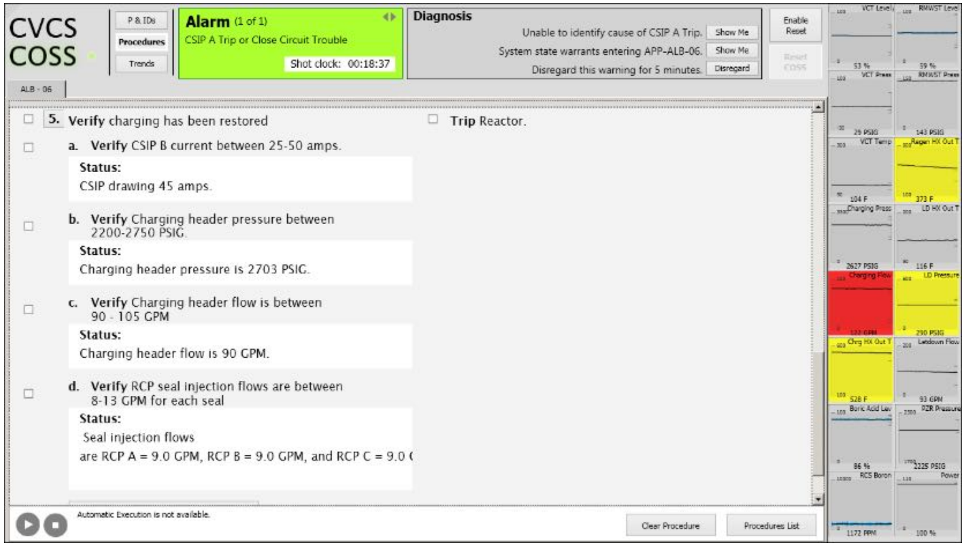


Standalone Microworld for Human Factors and Automation Research

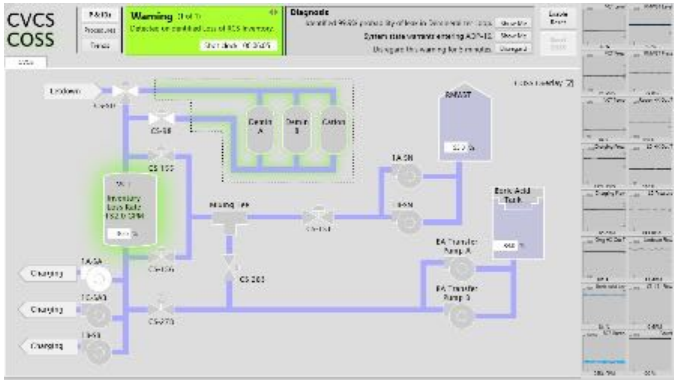
Computerized Operator Support System (COSS)

- Collection of technologies to assist operators in monitoring the plant and making timely, informed decisions

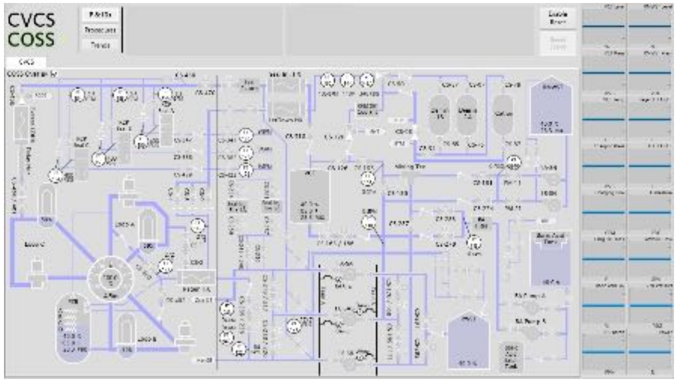




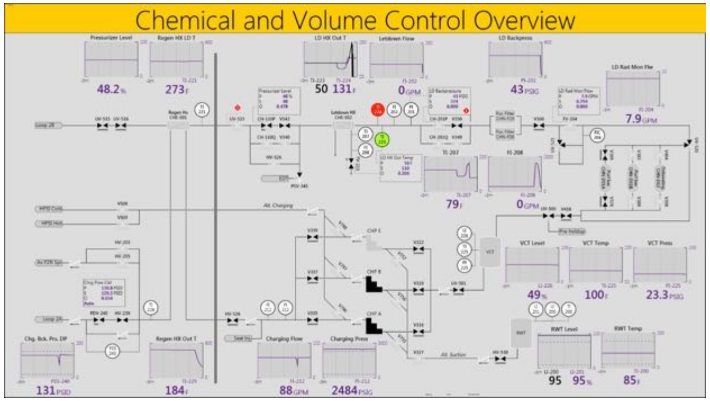
Iteration 1

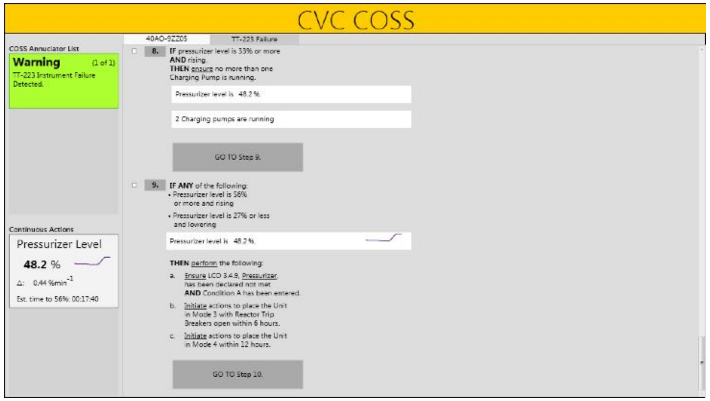


Iteration 2

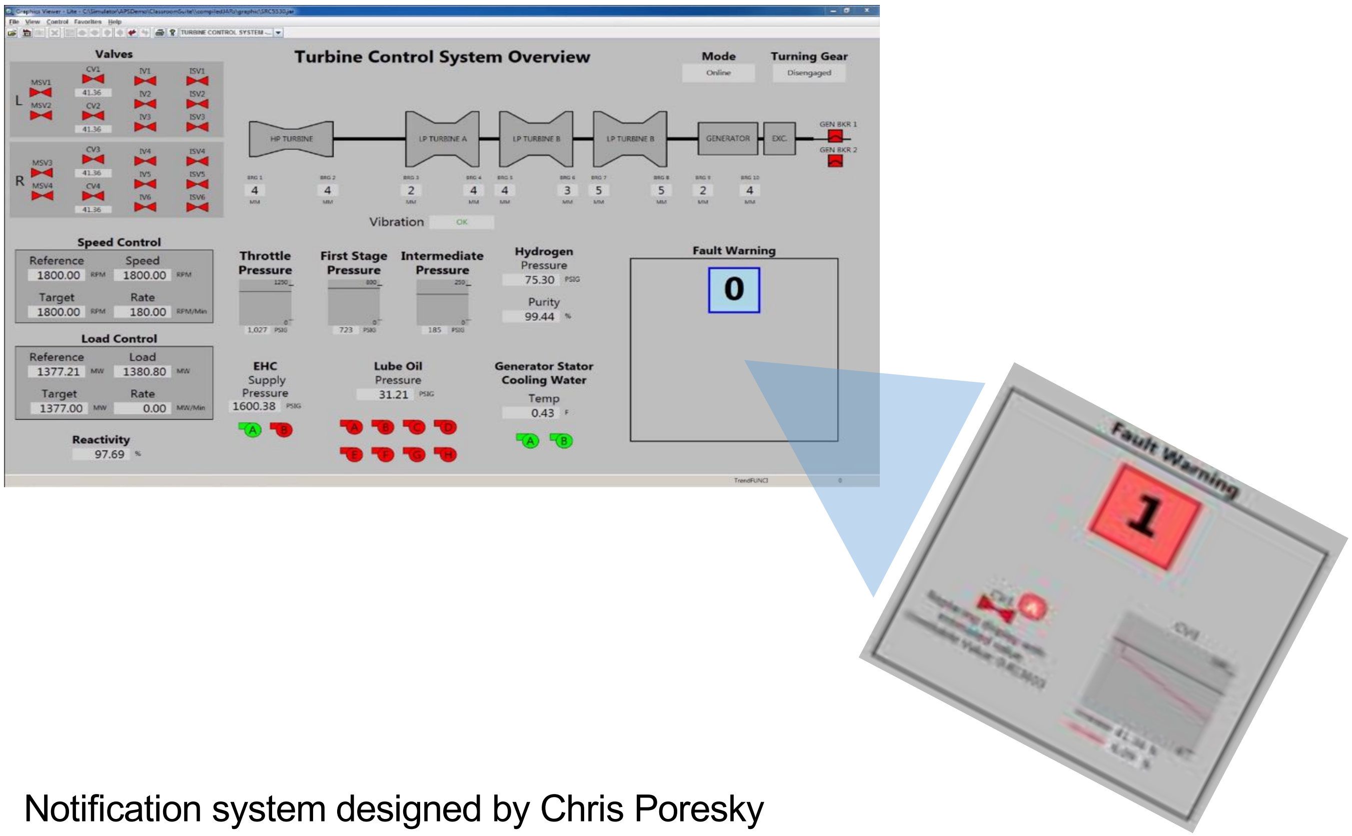


Iteration 3





COSS: System Overview Display for Turbine



Notification system designed by Chris Poresky

ANIME Continuum

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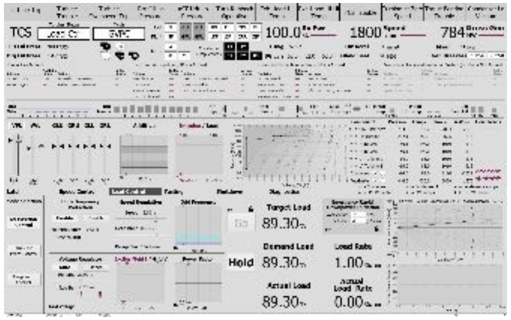

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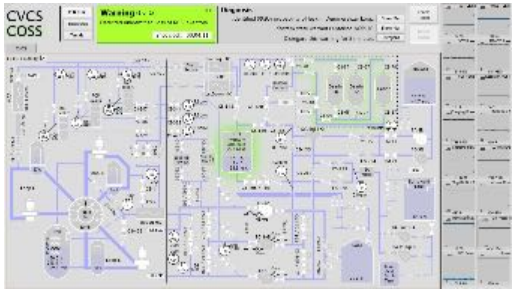

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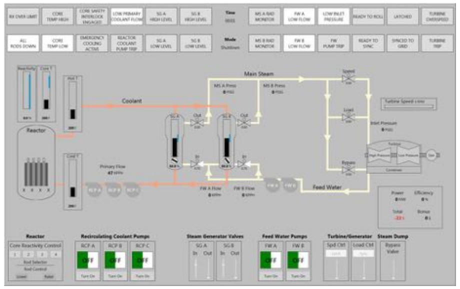
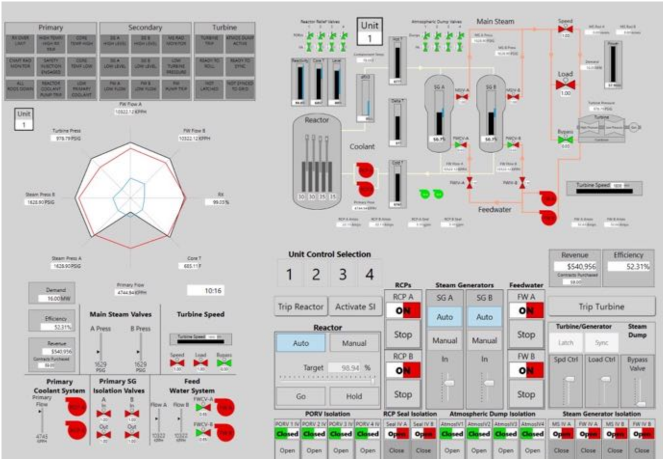


Standalone Microworld for Human Factors and Automation Research

Standalone Microworld for Research



- Microworld = simplified simulator
  - Use reduced order physics model as backend instead of full-scope simulator
- Use for research
  - Human factors using students instead of operators
    - Optimal alarms
  - Prototyping advanced features and reactors not yet available in full-scope versions

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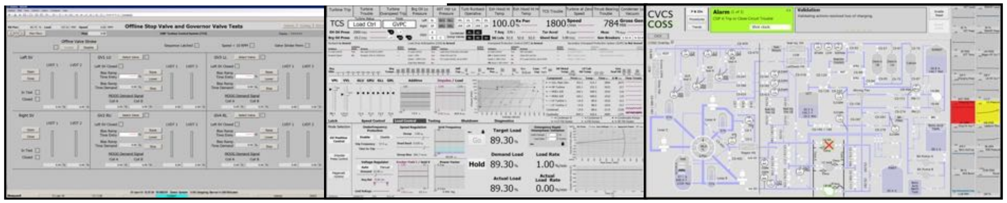


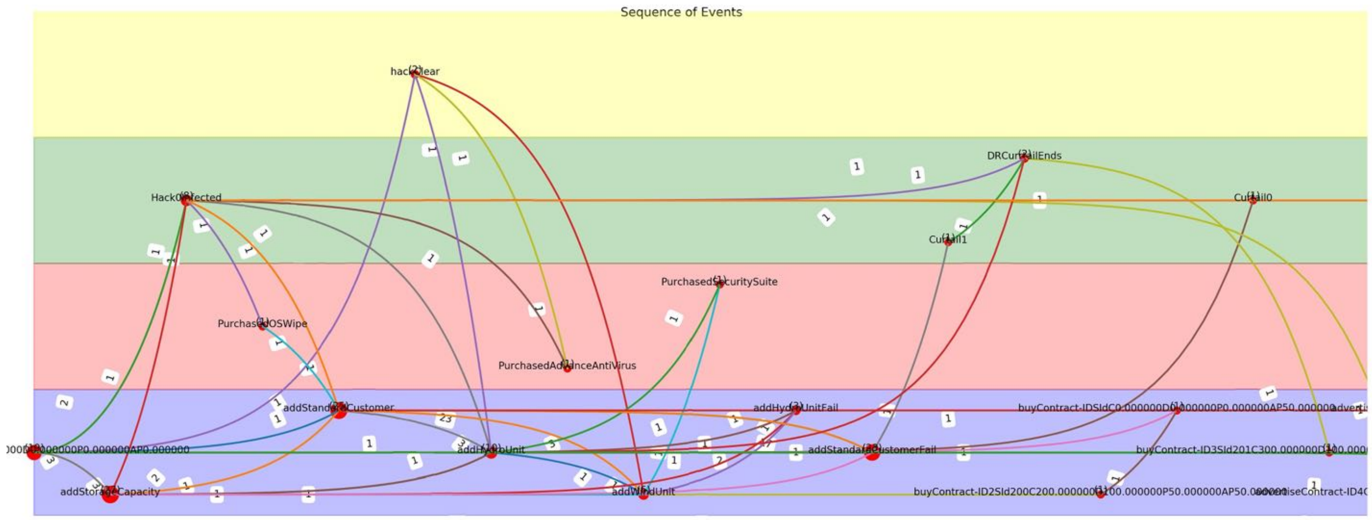
humans as sources of data

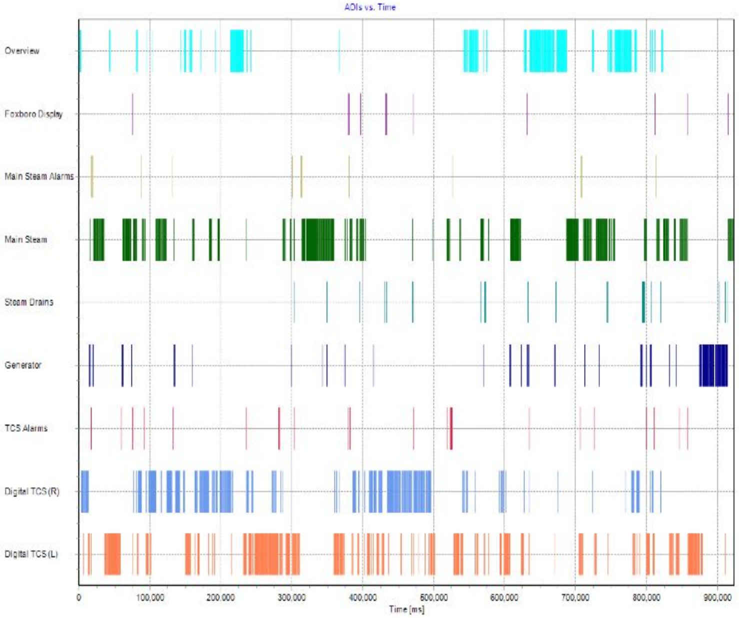

GSE SYSTEMS

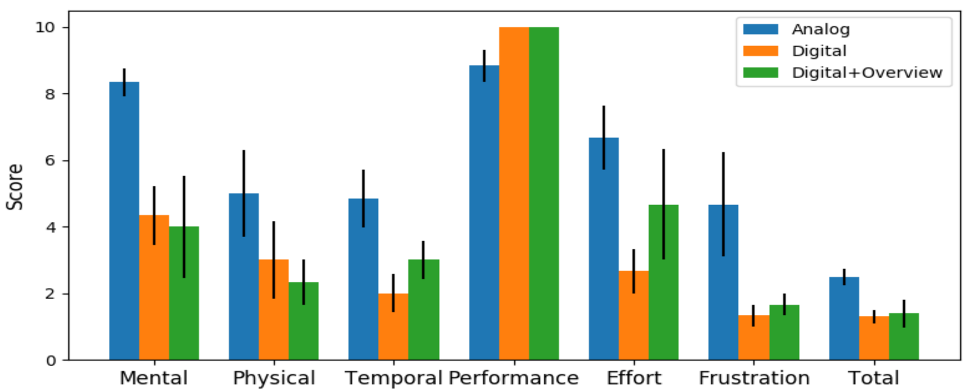
Operators Leave Traces

Procedure				Failure Events			Time		
Procedure	Step	Substep	TLP	LOOP	LODG	LOB	5th	Expected	95th
PTA	1	-	-	1	0	0	-	-	-
PTA	1	a	Rc	1	0	0	3.08	9.81	21.9
PTA	1	b	Rc	1	0	0	3.08	9.81	21.9
PTA	1	c	Rc	1	0	0	3.08	9.81	21.9
PTA	2	-	-	1	0	0	-	-	-
PTA	2	a	Cc	1	0	0	2.44	11.41	29.88
PTA	2	b	Cc	1	0	0	2.44	11.41	29.88
PTA	2	c	Cc	1	0	0	2.44	11.41	29.88
PTA	3	-	-	1	0	0	-	-	-
PTA	3	a	Rc	1	0	0	3.08	9.81	21.9
PTA	3	b	Rc	1	0	0	3.08	9.81	21.9
PTA	4	-	Rc	1	0	0	3.08	9.81	21.9
PTA	5	-	-	1	0	0	-	-	-
PTA	5	a	Cc	1	0	0	2.44	11.41	29.88
PTA	5	b	Rc	1	0	0	3.08	9.81	21.9
PTA	5	c	Rc	1	0	0	3.08	9.81	21.9
PTA	6	-	-	1	0	0	-	-	-
PTA	6	a	Rc	1	0	0	3.08	9.81	21.9
PTA	6	b	Rc	1	0	0	3.08	9.81	21.9
PTA	6	c	Rc	1	0	0	3.08	9.81	21.9
PTA	7	-	-	1	0	0	-	-	-
PTA	7	a	Rc	1	0	0	3.08	9.81	21.9
PTA	7	b	Cc	1	0	0	2.44	11.41	29.88
PTA	7	c	Cc	1	0	0	2.44	11.41	29.88
PTA	8	-	-	1	0	0	-	-	-
PTA	8	a	Rc	1	0	0	3.08	9.81	21.9
PTA	8	b	Rc	1	0	0	3.08	9.81	21.9
PTA	9	-	-	1	0	0	-	-	-
PTA	9	a	Rc	1	0	0	3.08	9.81	21.9
PTA	9	b	Rc	1	0	0	3.08	9.81	21.9
SBO	3	-	Rc	1	1	0	3.08	9.81	21.9
SBO	4	-	-	1	1	0	-	-	-
SBO	4	a	Cc	1	1	0	2.44	11.41	29.88
SBO			Ac	1	1	0	1.32	18.75	65.26
SBO	4	b	Cc	1	1	0	2.44	11.41	29.88
SBO			Ac	1	1	0	1.32	18.75	65.26
SBO	4	c	Cc	1	1	0	2.44	11.41	29.88
SBO			Ac	1	1	0	1.32	18.75	65.26
SBO	5	-	-	1	1	0	-	-	-
SBO	5	a	Cc	1	1	0	2.44	11.41	29.88
SBO			Ac	1	1	0	1.32	18.75	65.26
SBO	5	b	Cc	1	1	0	2.44	11.41	29.88
SBO	5	c	Cc	1	1	0	2.44	11.41	29.88
SBO	6	-	Rc	1	1	0	3.08	9.81	21.9
SBO			Sc	1	1	0	3.01	34.48	115.57
SBO	7	-	Rc	1	1	0	3.08	9.81	21.9
SBO			Sc	1	1	0	3.01	34.48	115.57
SBO	8	-	Cc	1	1	0	2.44	11.41	29.88
SBO			Ac	1	1	0	1.32	18.75	65.26
SBO	9	-	Ac	1	1	0	1.32	18.75	65.26

Operators Leave Traces







Guideline for Operator Nuclear Usability and Knowledge Elicitation (GONUKE)

Evaluation Phase

Evaluation Type

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

[1]Corresponding Phases in NUREG-0711.

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Guideline for Operator Nuclear Usability and Knowledge Elicitation (GONUKE)

What the regulator requires

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Guideline for Operator Nuclear Usability and Knowledge Elicitation (GONUKE)

Typical usability evaluation

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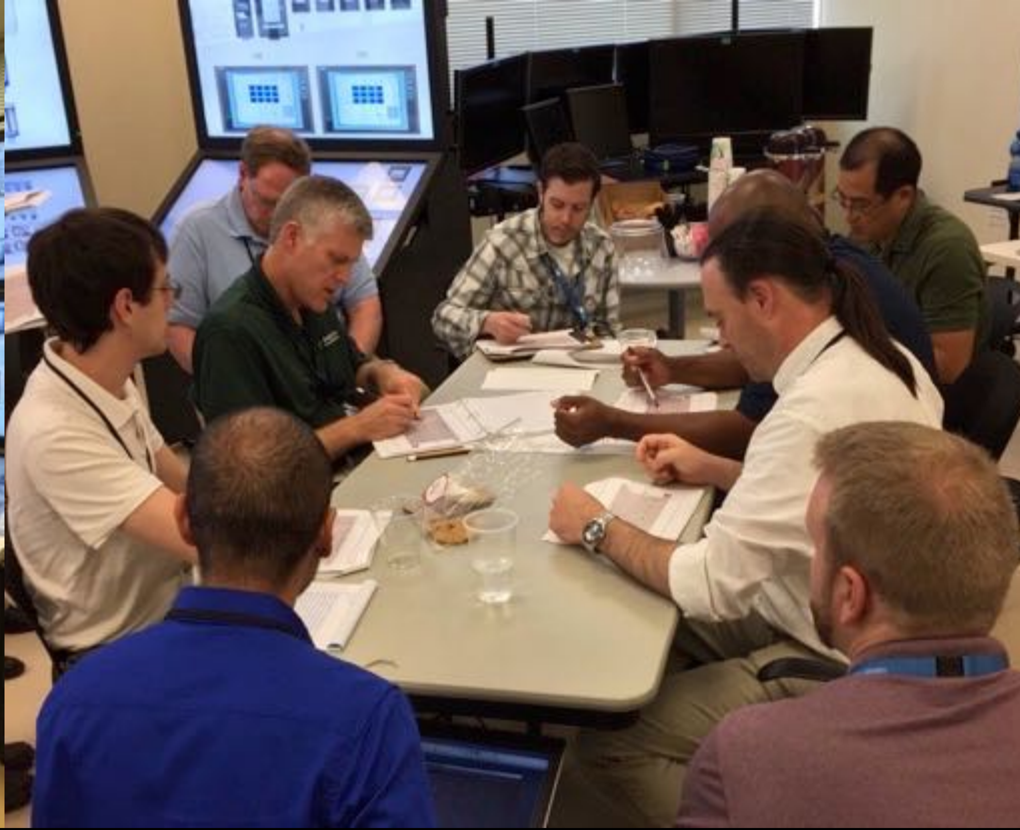
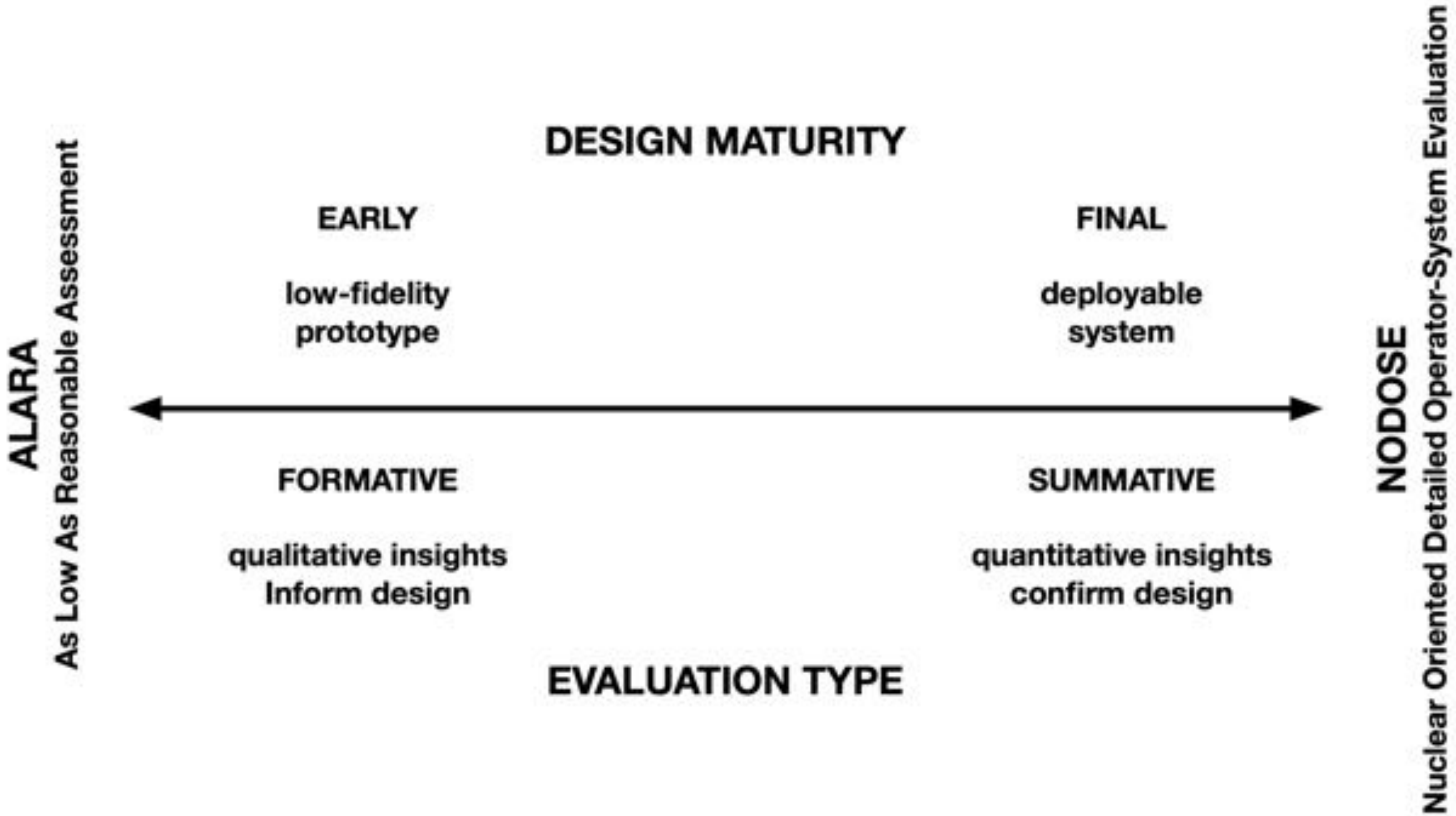
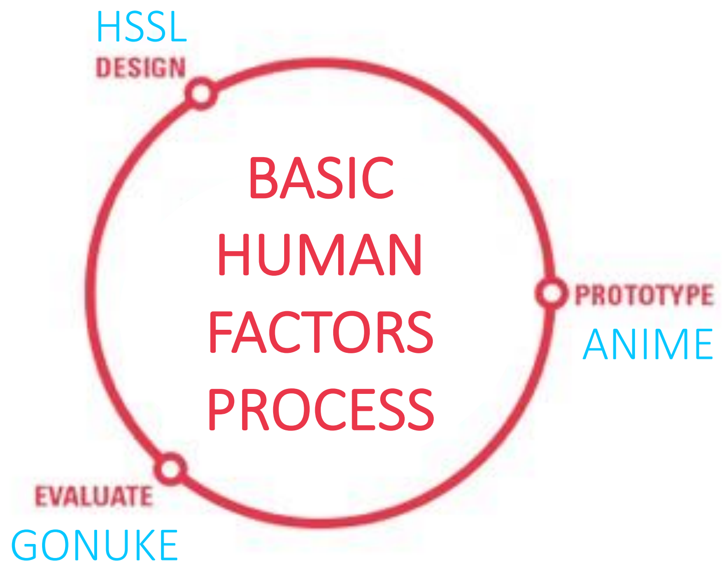


Epistemiation: Capturing Expert Operator Knowledge to Design New System


DESIGN MATURITY
EARLY
low-fidelity prototype
FINAL
deployable system
ALARA
As Low As Reasonable Assessment
NODOSE
Nuclear Oriented Detailed Operator-System Evaluation
FORMATIVE
qualitative insights Inform design
SUMMATIVE
quantitative insights confirm design
EVALUATION TYPE


HSSL
DESIGN
BASIC HUMAN FACTORS PROCESS
PROTOTYPE
ANIME
EVALUATE
GONUKE

IDAHO NATIONAL LABORATORY

70th Anniversary

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