Human System Interfaces and Resilience Interaction

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First: Dr. Boring is my
real name. It’s not my
supervillain name. It’s
also not a name given to me
by Witness Protection
Services.

One Big Happy Family: Boring is derived from same surname as Boeing

What is human factors and ergonomics?

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What is human factors and ergonomics?

Study of humans interacting with technology

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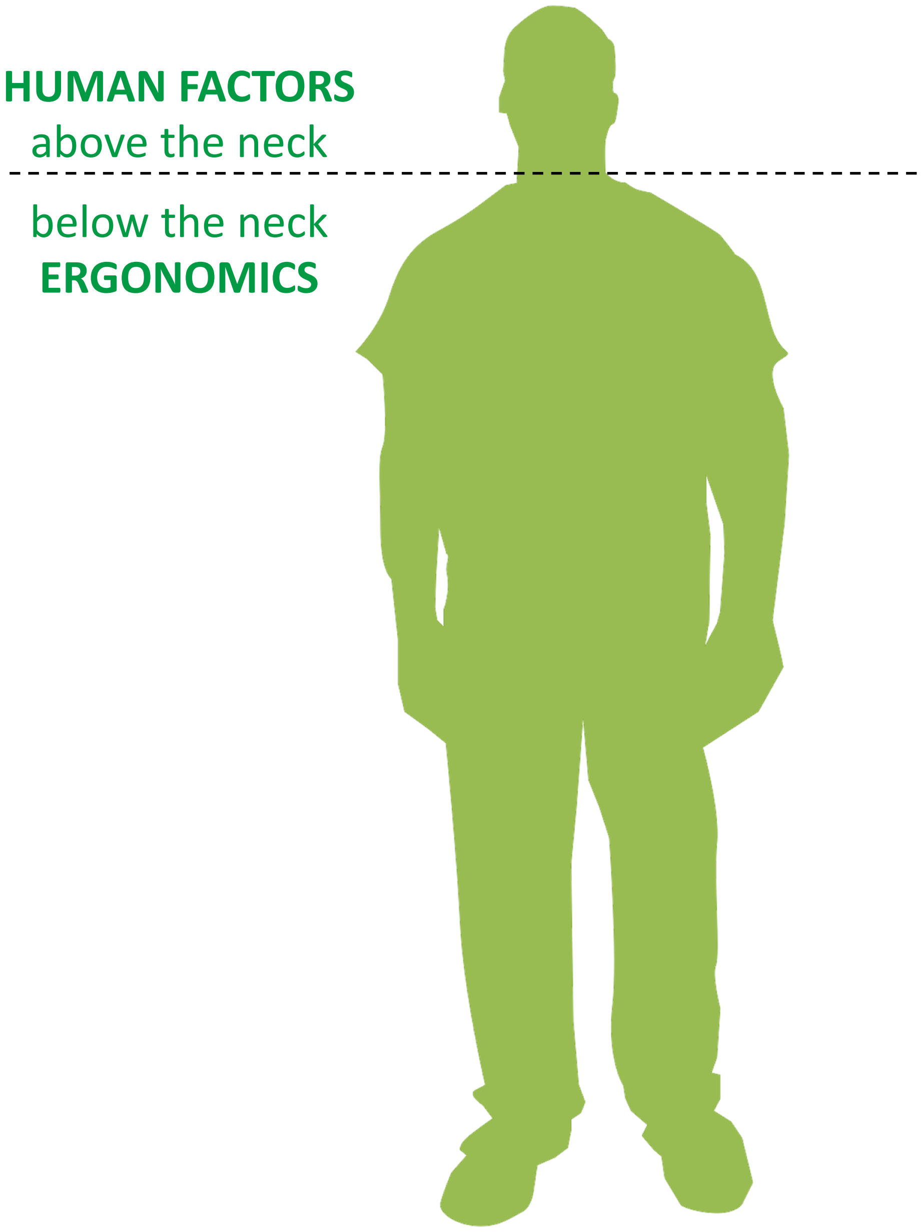

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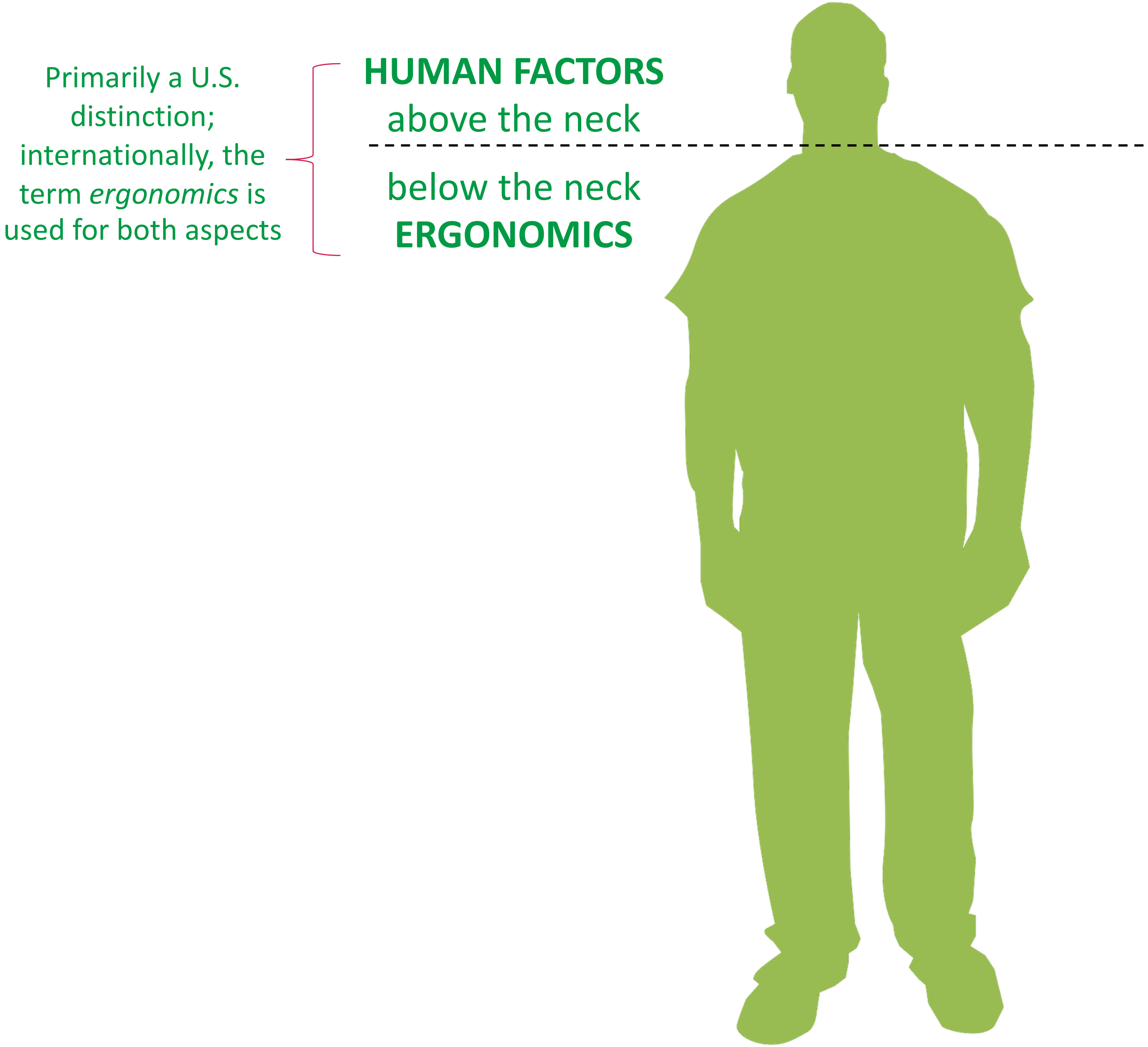

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What are the Human Factors?

The Operator
Mental & physical abilities and limitations, motivations, enjoyment, satisfaction, personality, experience level…

Performance
Productivity, quality, accuracy, speed, reduced errors, situation awareness…

Task
Ease, complexity, novelty, task allocation, skills, knowledge, repetitive, monitoring, control, mitigation…

Interface
Input & output devices, dialogue structures, display objects, navigation, color, icons, commands, graphics, natural language, 3D, touch, haptics, user support, multimedia…

Environmental
Noise, heating, lighting, ventilation, radiation, accessibility, habitability…

Organizational
Regulatory, training, job, design, politics, roles, shift work…

Health
Stress, headaches, musculo-skeletal disorders…

Comfort
Seating, equipment, layout…

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Birth of Human Factors in the U.S.

- **During WWII psychologists were enlisted to help in war effort**
  - Screening aptitudes to determine where conscripted soldiers should go
    - E.g., someone with particularly good spatial aptitude might be assigned to the emerging air force
  - Enhancing training
    - Need to train people very quickly to fill the wartime roles
  - Counseling and clinical needs
    - Help allay the severity of post-traumatic stress (know at the time as being shell-shocked)

National Museum of the U.S. Air Force

- **New technologies were tricky**
  - No amount of training seemed to help master emerging technologies
    - B-17 bomber featured newfangled landing gear
    - Upon landing, pilots kept confusing flaps and landing gear, crashing the planes

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Birth of Human Factors in the U.S.

- **Alphonse Chapanis, psychologist from Johns Hopkins University, realized that placement of landing gear and flaps was confusing**
  - The human factors:
    - Levers were behind pilots and not visible
    - Pilots had high workload while landing
    - Plane movement while landing was considerable
  - Chapanis realized that humans could not be adapted to the design—the design needed to be adapted to the human
    - It was nearly impossible to change the engineering (e.g., reposition the levers) of the plane at this stage
    - Would it be possible to make the function of the two levers **intuitive**?
      - The pilots were not confused about what they wanted to do = *they had a pretty clear mental model*
      - The pilots simply couldn't easily distinguish the levers in those circumstances = *limits of human performance*

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Birth of Human Factors in the U.S.

- **Wrong mental model**
  - Training can often reinforce the right way to do something and change mental model if needed
- **Limits of human performance**
  - Humans can show improvement through training, but only to a point
  - There are limits on what humans can do
- **Chapanis addressed this problem by making the lever handles intuitive**
  - Flat horizonal handle = *the shape of a wing or flap*
  - Round handle = *the shape of a wheel*
  - Easy fix that could be retrofitted without major engineering efforts
  - Bonus! No more crashes of planes due to flap/ landing gear confusion!
- **Human factors is about designing for the capabilities of the user**

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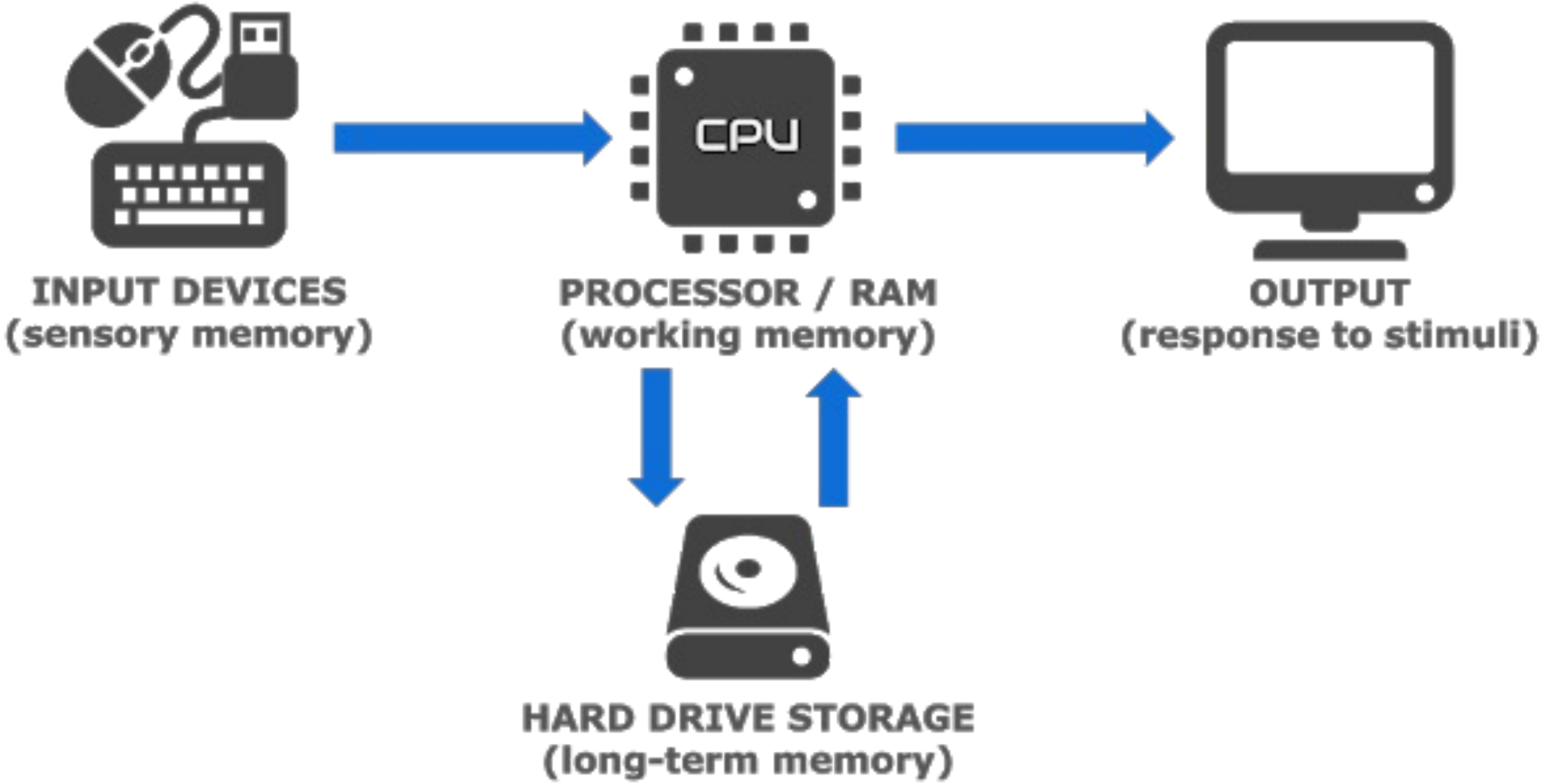
Information Processing

Information Processing in Computers



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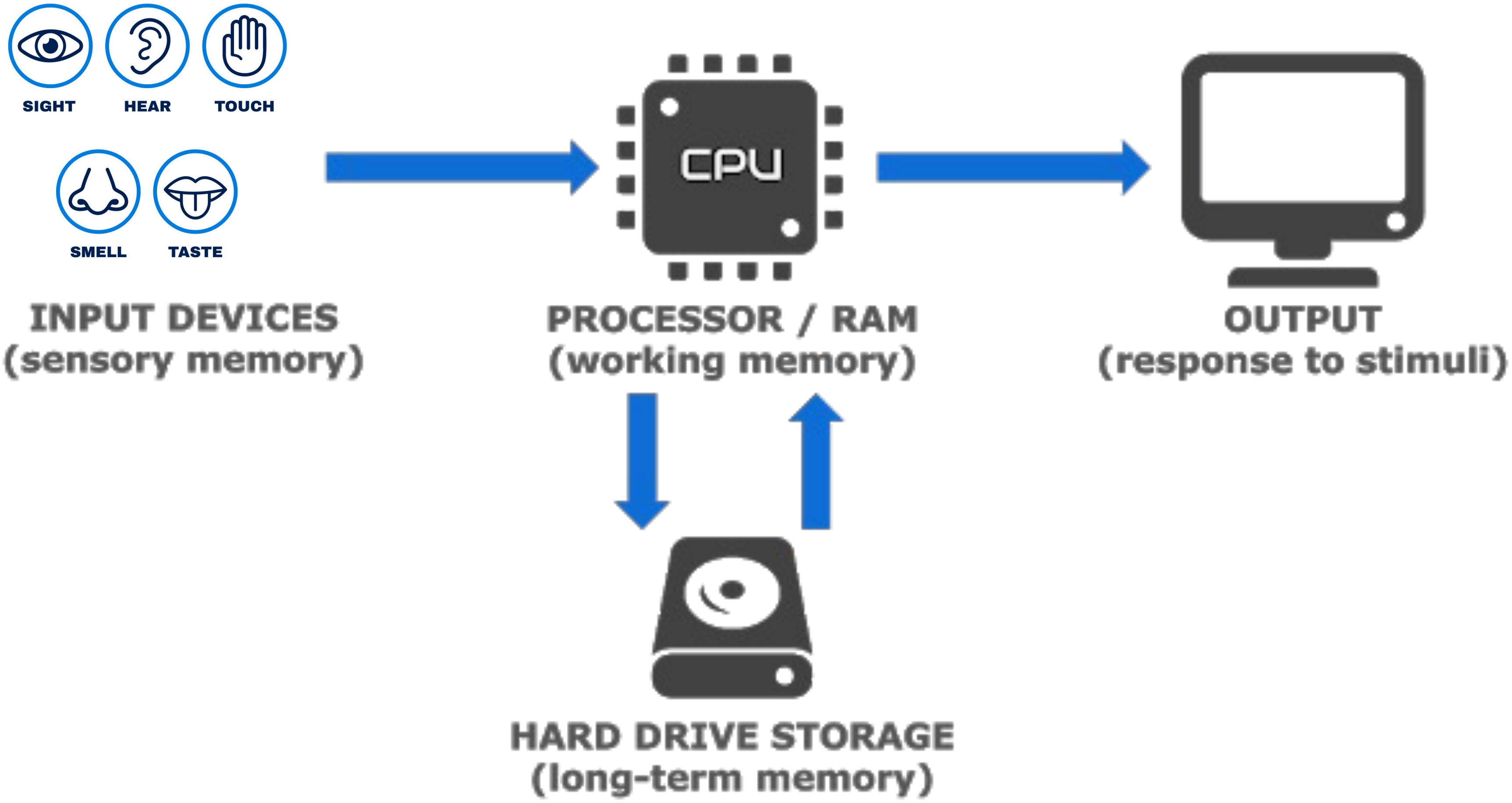
Information Processing in Humans



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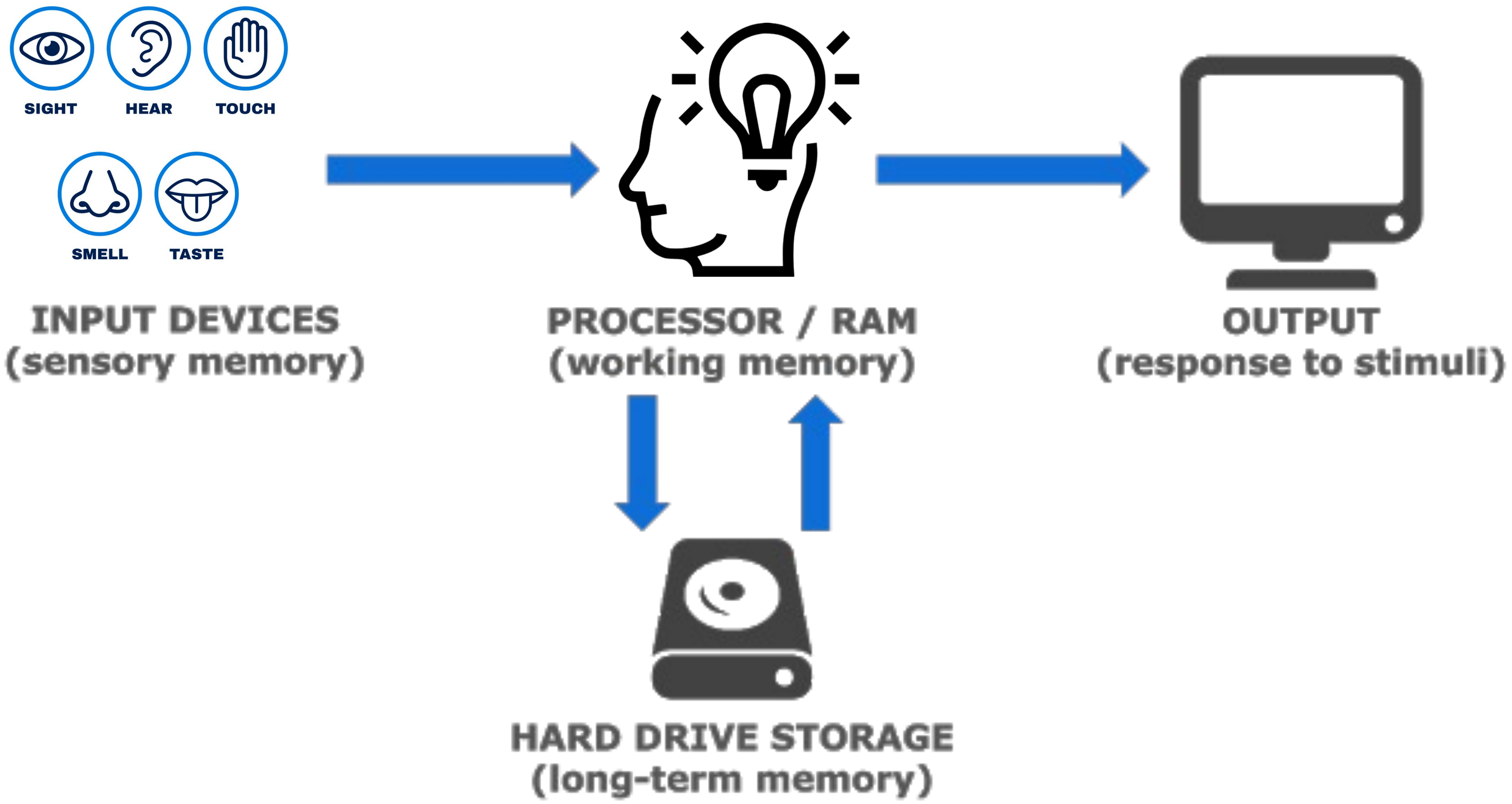

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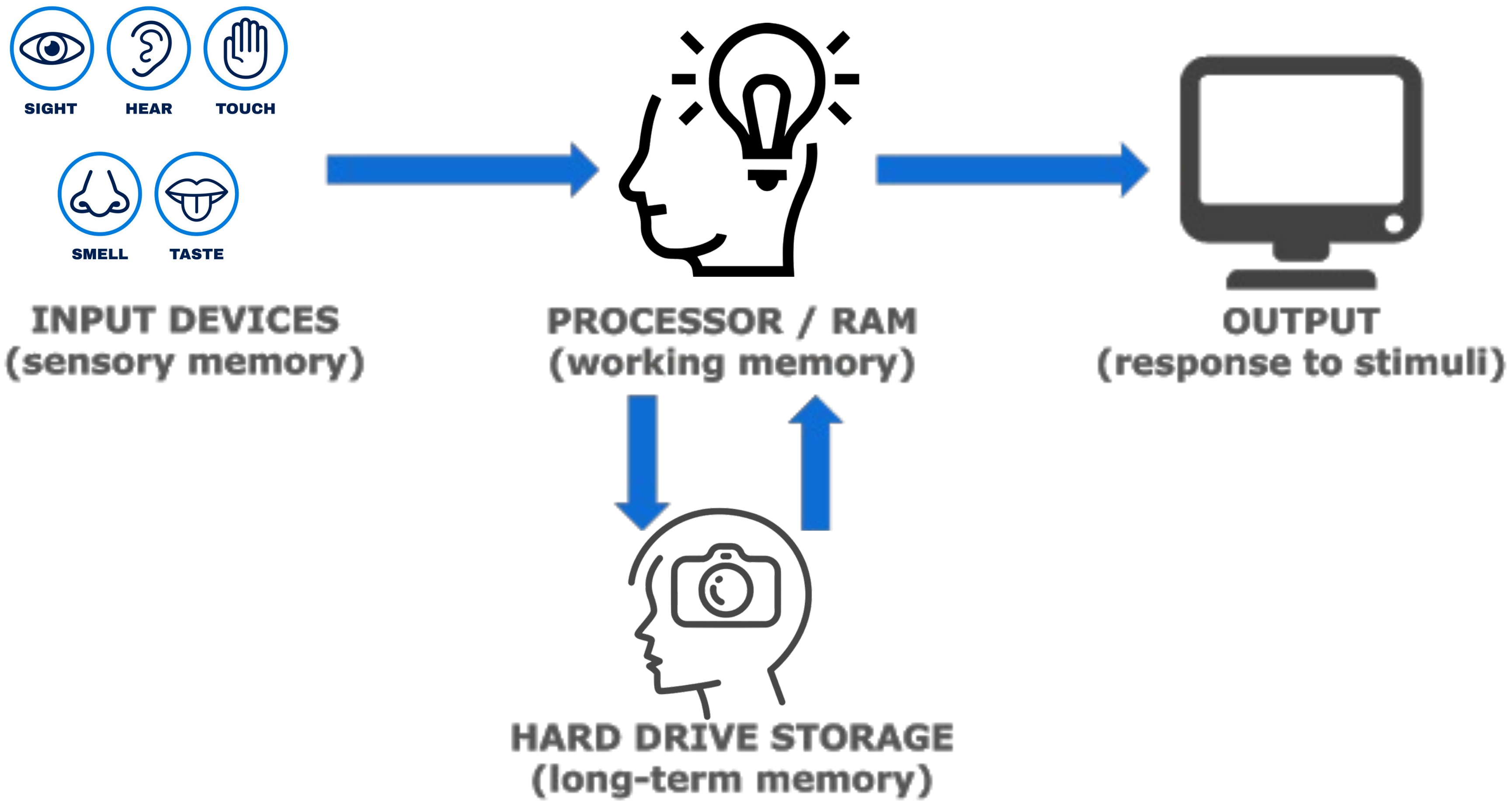

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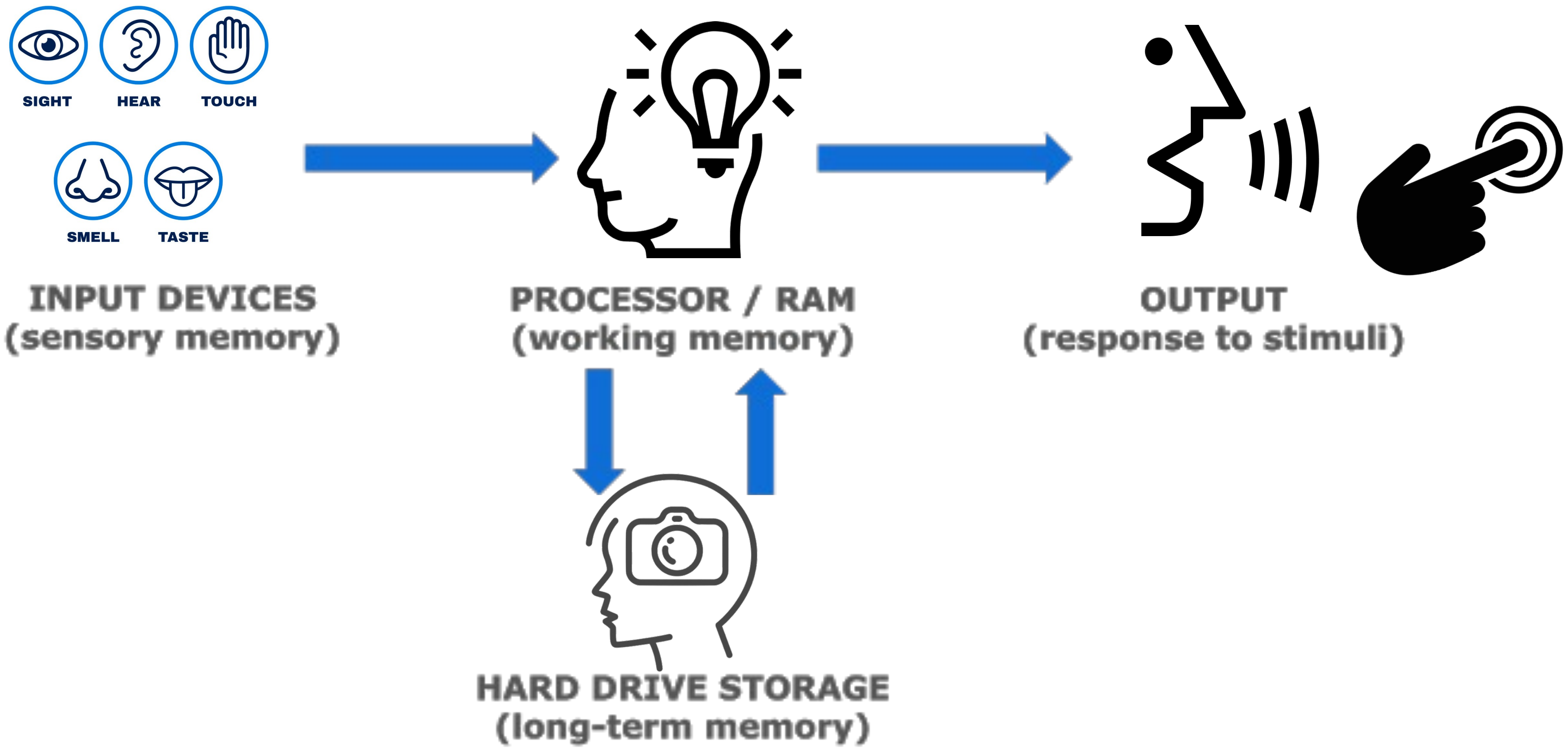

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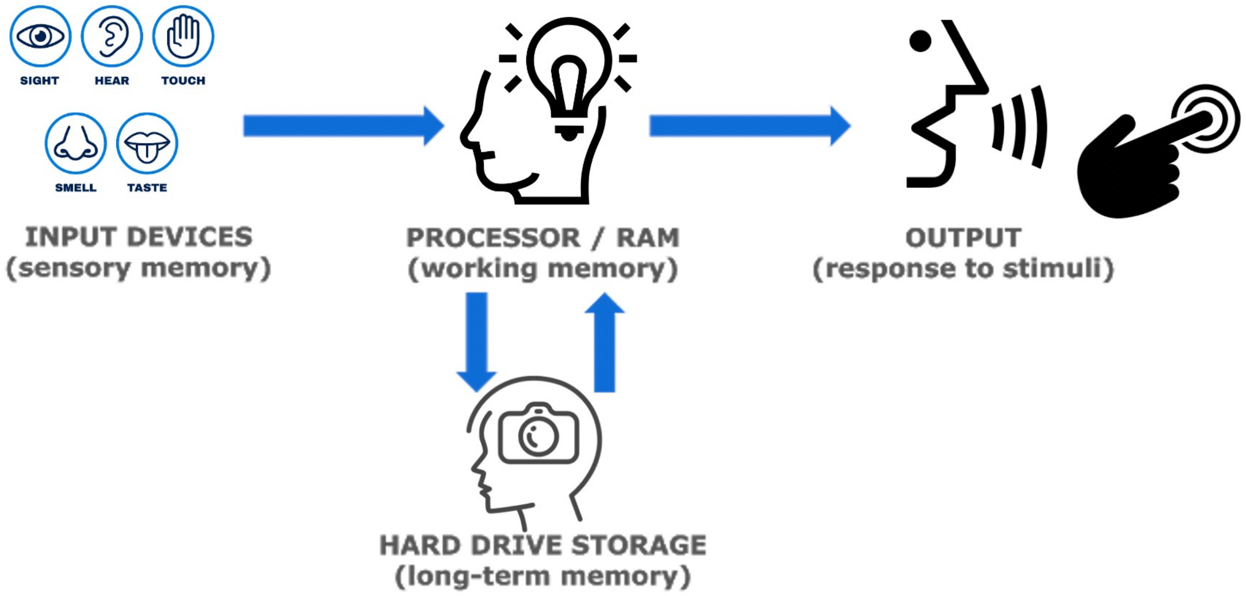


In Simplest Terms

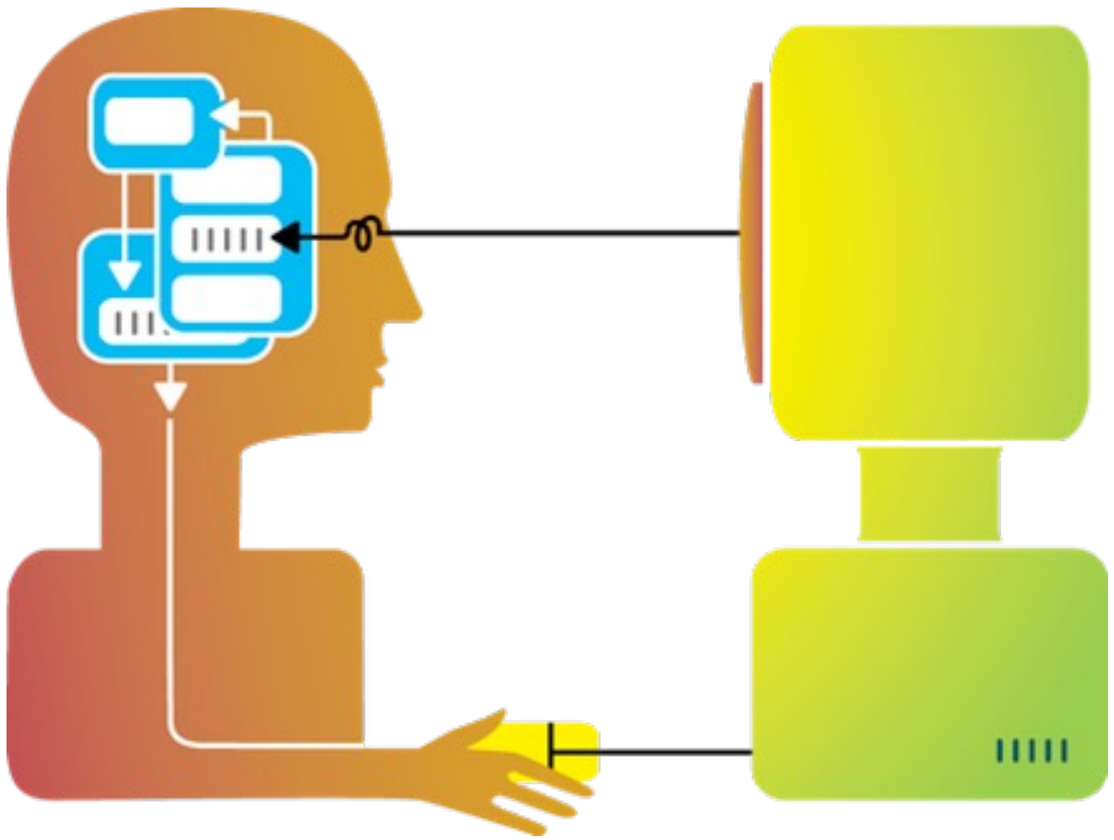
- Each of these functions of human cognition presents an opportunity for error
  - *Input:* Didn't see a brake light
  - *Decision Making:* Got distracted
  - *Memory:* Got confused about right-of-way rules
  - *Action:* Hit the gas instead of the brake
- Each also presents a way for human to adapt or be resilient

We have to design systems around human cognition

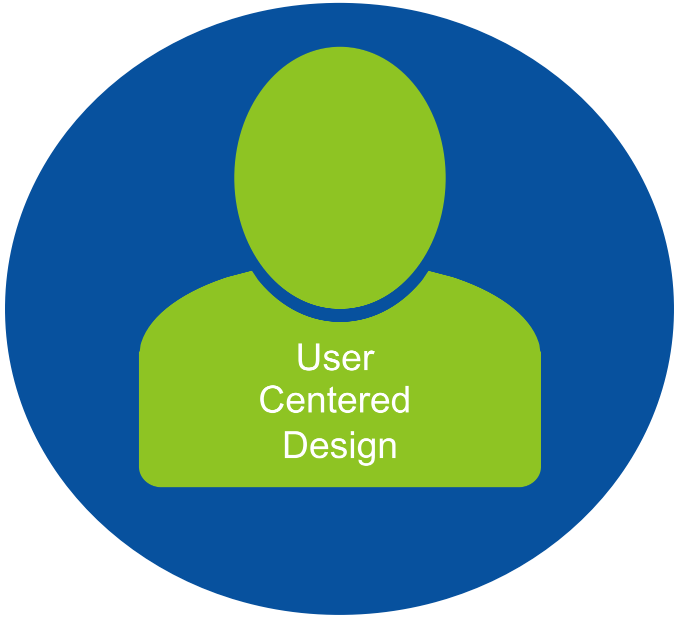
Big Picture in Information Processing

Human-Computer Interface (HCI)

- Computer output = human sensation and perception
- Human action = computer input
- It’s a feedback loop



Human Factors Design Philosophy



It’s not enough to merely design a product. A designer must identify the user and consider the respective abilities, needs, and limitations. Considering the user enhances **safety, efficiency, accuracy, and effectiveness** of a design. It also increases the **resilience** of the user.

What Does Human Factors Do?

Most commonly, human factors helps design and validate technologies for human use

- Combination of applying knowledge and gathering knowledge

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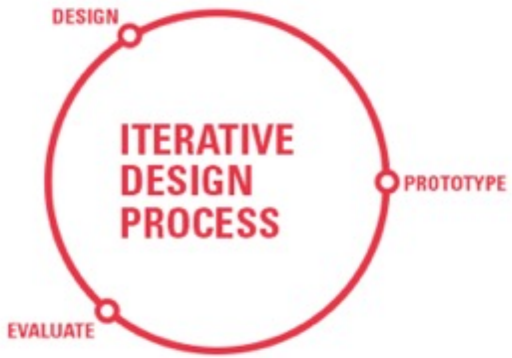

- Combination of **applying knowledge** and gathering knowledge
  - Known good practices for what makes a design work
    - e.g., properties of good human-computer interface (HCI) such as layout, legibility, colors, navigation, etc.
  - Fed into design process as design requirements

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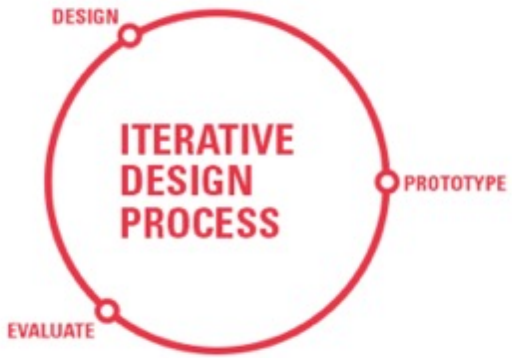

- Combination of applying knowledge and **gathering knowledge**
  - Each human-system interface application is different
  - Necessary to evaluate the human use of that specific technology
  - Mockups, prototypes, or beta versions run through scenarios with users
  - Performance data collected to determine if it works

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APPLY KNOWLEDGE

take what you know that works for human interactions with technology and use it to design system

GATHER KNOWLEDGE

run a user study to learn about how human interacts with that technology

Methods vs. Measures

Human factors as a science and practice has thousands of methods

- ***Methods*** outline *how* to apply or gather knowledge
- The techniques human factors experts use = the process of human factors

Human factors has thousands of measures

- ***Measures*** outline *what* the resultant knowledge is
- We measure some aspect of the human performance with the technology and use that to determine if the technology works or not for human use

Methods vs. Measures: Thinking Human Factors

Problem: What is the ideal input device for a digital display on a control board—mouse, trackpad, or touchscreen?

- ***Applying knowledge:*** What do we know from what's been done before?
  - Many digital systems currently in nuclear plants predate current input device technologies—*not applicable to generalize current systems*
  - Surrogate systems like aviation decided against touchscreens because of turbulence—*not applicable, because we have minimal turbulence in control rooms*
  - "Gorilla arm syndrome" that arms get fatigued using vertical touchscreen—*applicable finding but not conclusive enough to make design decision*

Methods vs. Measures: Thinking Human Factors

Problem: What is the ideal input device for a digital display on a control board—mouse, trackpad, or touchscreen?

- ***Gathering knowledge:*** Let's find out from actual operators
  - Put a prototype digital control system in front of operators and see
  - Each operator tries out simple task using mouse, trackpad, and touchscreen
  - Ask them what they liked best—touchscreen
  - See how they performed best—mouse (accidental activations with touchscreen)
- ***Applying knowledge:*** Design recommendation is for mouse because operator performance was best and that's most important factor for nuclear operations

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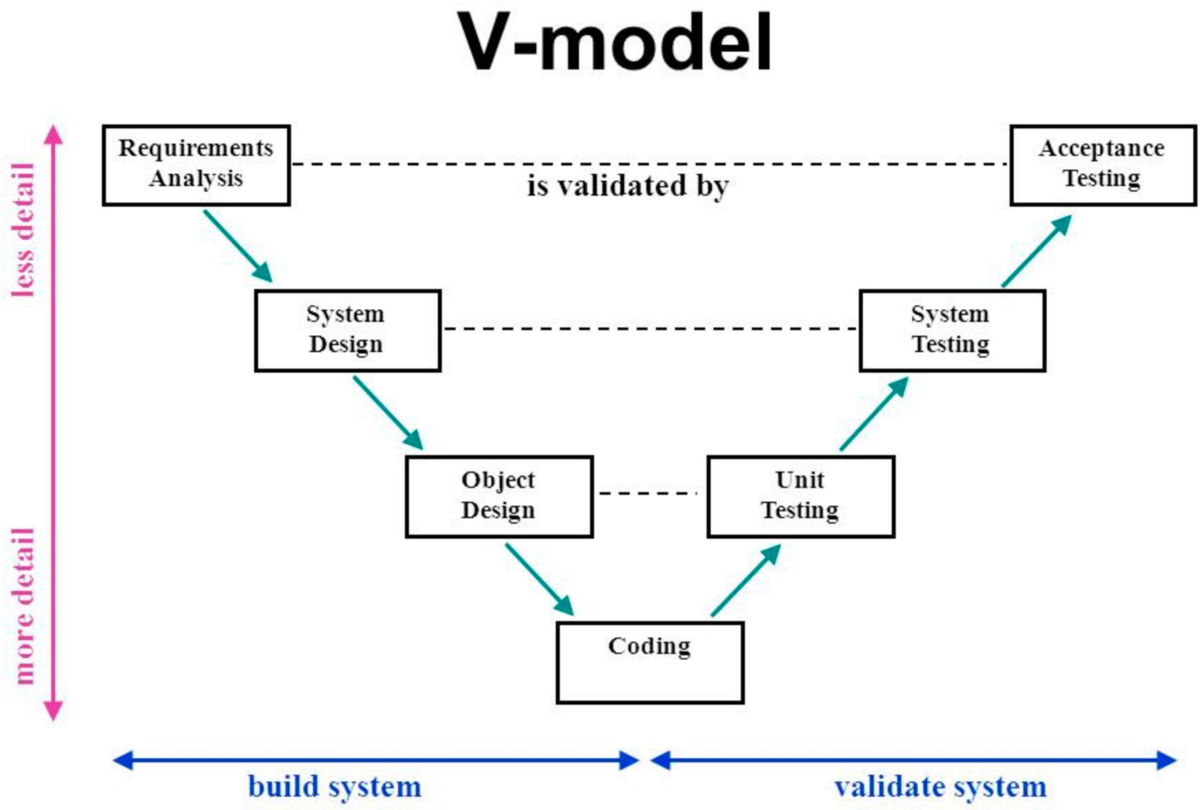
Human Factors and System Engineering

Applying and gathering knowledge are part of system engineering approach



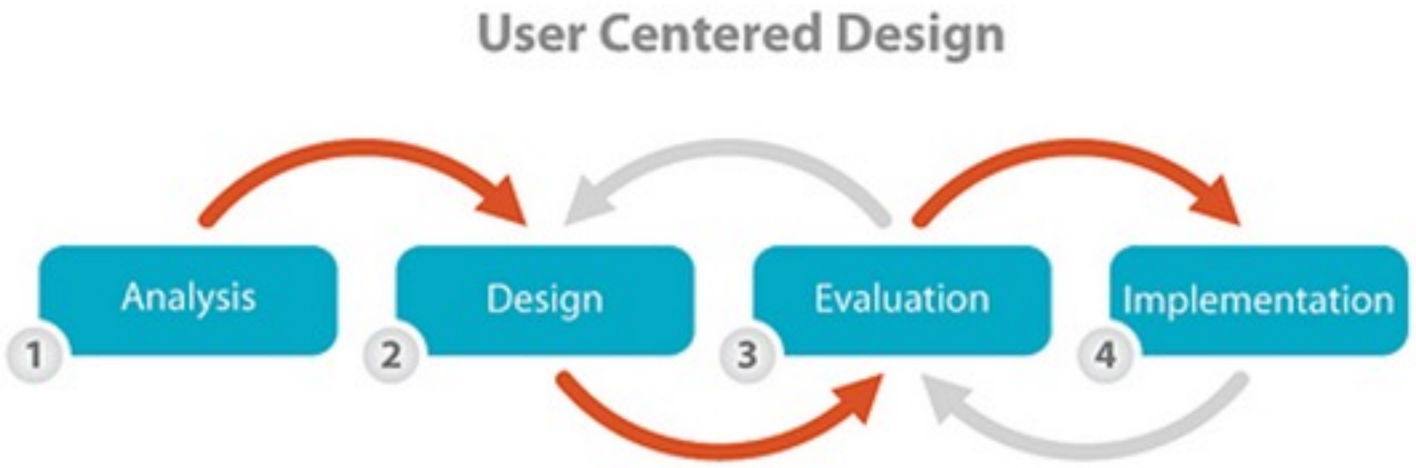
Source: International Council On Systems Engineering (INCOSE)

- Applying knowledge helps build the system *(left side)*
- Gathering knowledge helps validate the system *(right side)*

Iterative Design

Often system engineering is done iteratively and called *user centered design*

- Early analysis done to gather knowledge to inform design
- System is designed
- Early designs are tested
- Design improved and implemented
- New design tested
- Repeat



Source: Usabilia

Key Human Factors Nuclear Regulatory Guides (NUREGs)

Applying knowledge

- NUREG-0700: *Human-System Interface Design Review Guidelines*
- Provides a compendium of principles of human factors that should be considered for good design

Gathering knowledge

- NUREG-0711: *Human Factors Engineering Program Review Model*
- Provides a process model for gathering knowledge as part of design and implementation

Note: Similar guidelines found in most industries

Human Factors Methods per NUREG-0711

Planning and Analysis	Design	Verification and Validation	Implementation and Operation
HFE Program Management	Human-System Interface Design	Human Factors Verification and Validation	Design Implementation
Operating Experience Review	Procedure Development		Human Performance Monitoring
Function Analysis & Allocation	Training Program Development		
Task Analysis			
Staffing & Qualification			
Treatment of Important Human Actions			

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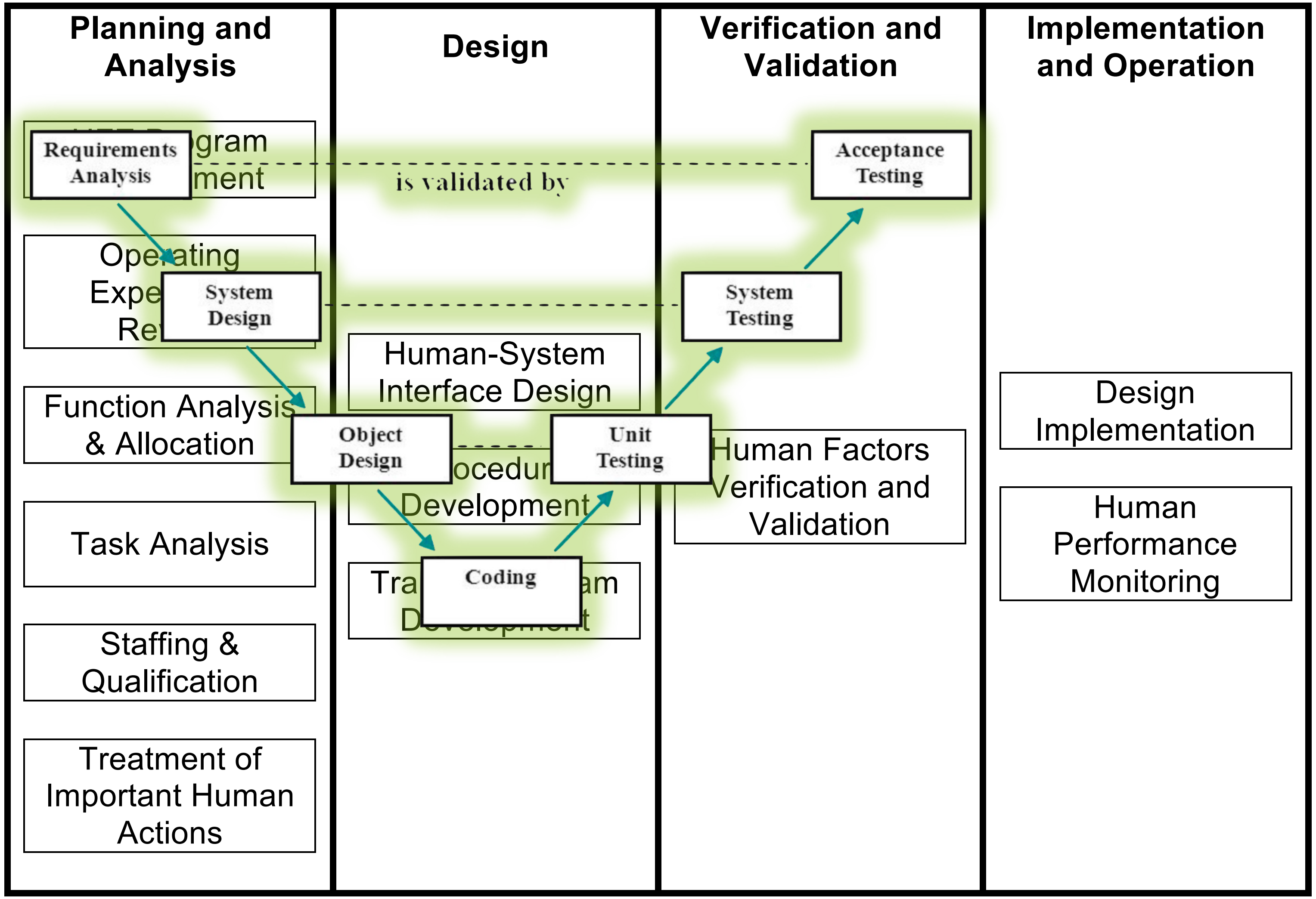
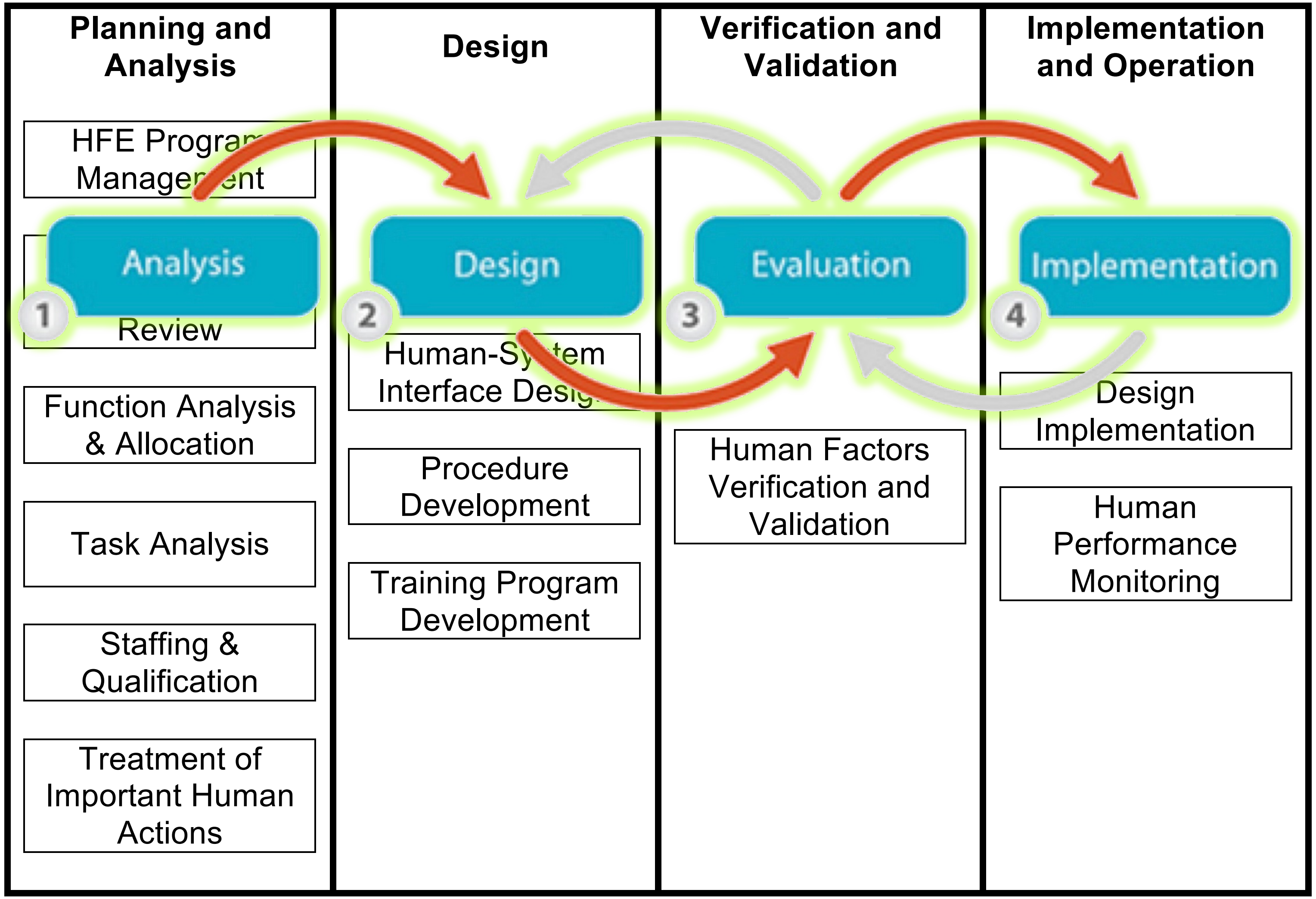
Human Factors Methods per NUREG-0711



Look familiar?

- The general system engineering "V" Model overlays on the major elements

Human Factors Methods per NUREG-0711



Look familiar?

- This is the "user centered design" process mapped to nuclear power applications

Methods and Measured Revisited

In reality, you use specific methods to gather specific results/measures

- Guided by where you are in the design process, especially when iterative
  - ***Formative:*** The design is still being formed = early design stage
  - ***Summative:*** The design is complete and being summarized or validated = late design stage

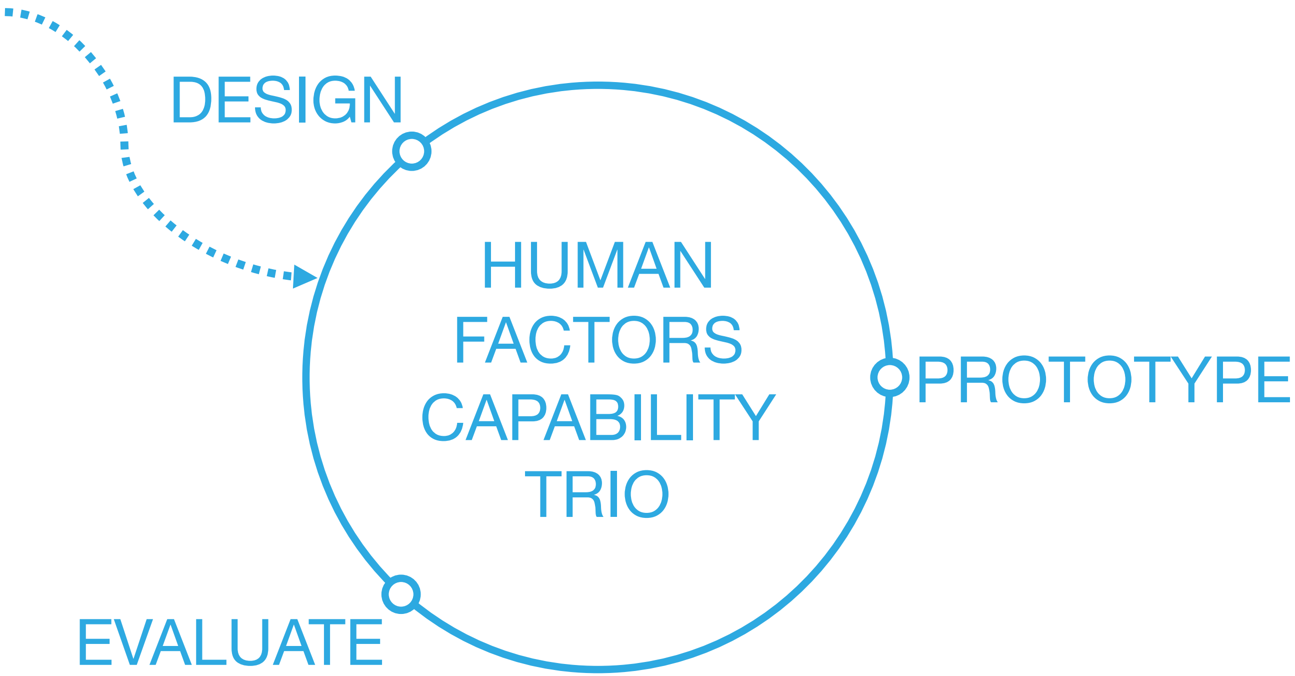
Early (formative)

Late (summative)

- Usability informing design
- More qualitative emphasis

- Acceptance testing of final design
- More quantitative emphasis

What We Do in Human Factors at INL



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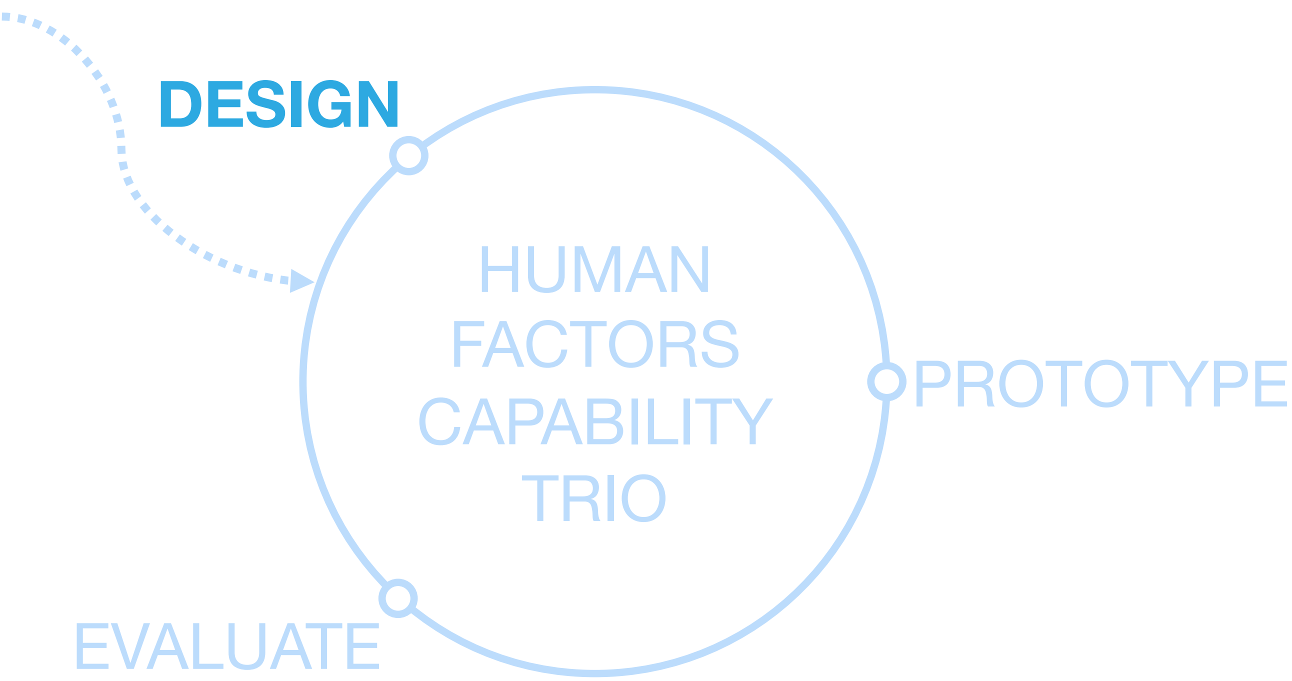

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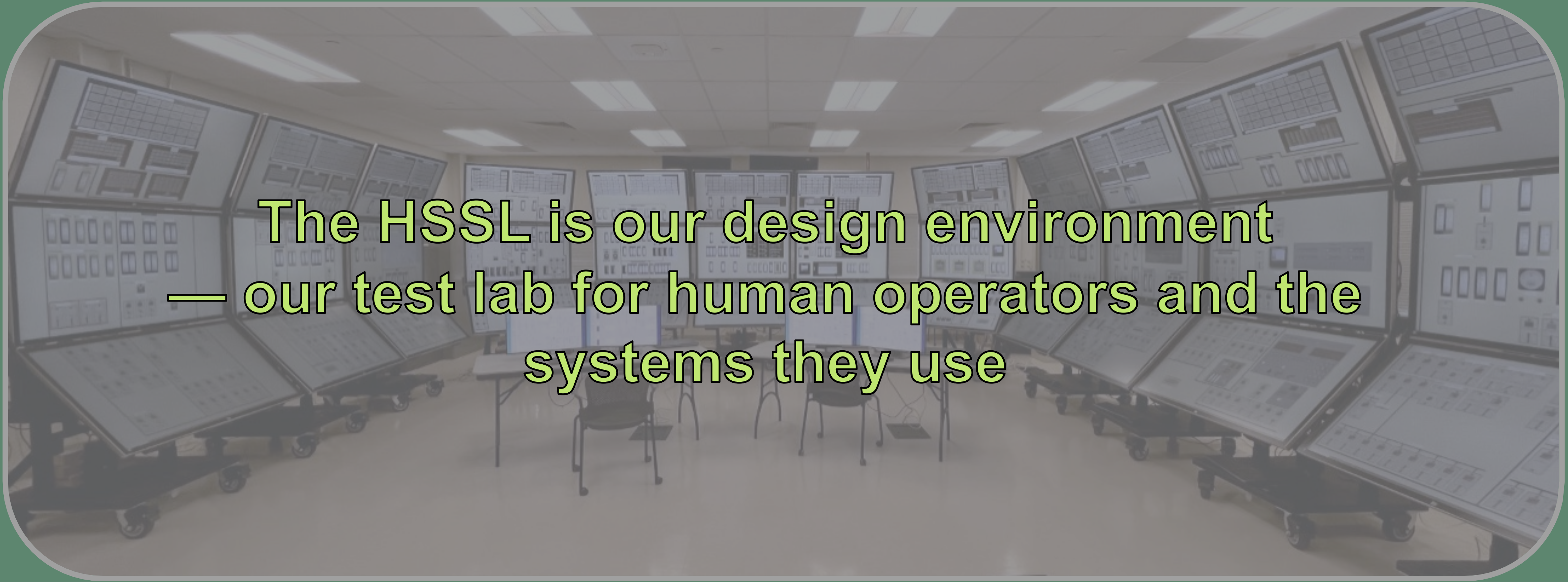
Human Systems Simulation Laboratory

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

Human Systems Simulation Laboratory



The HSSL is our design environment — our test lab for human operators and the systems they use

reconfigurable,
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Our Design Testbeds Aren’t Just Nuclear Power

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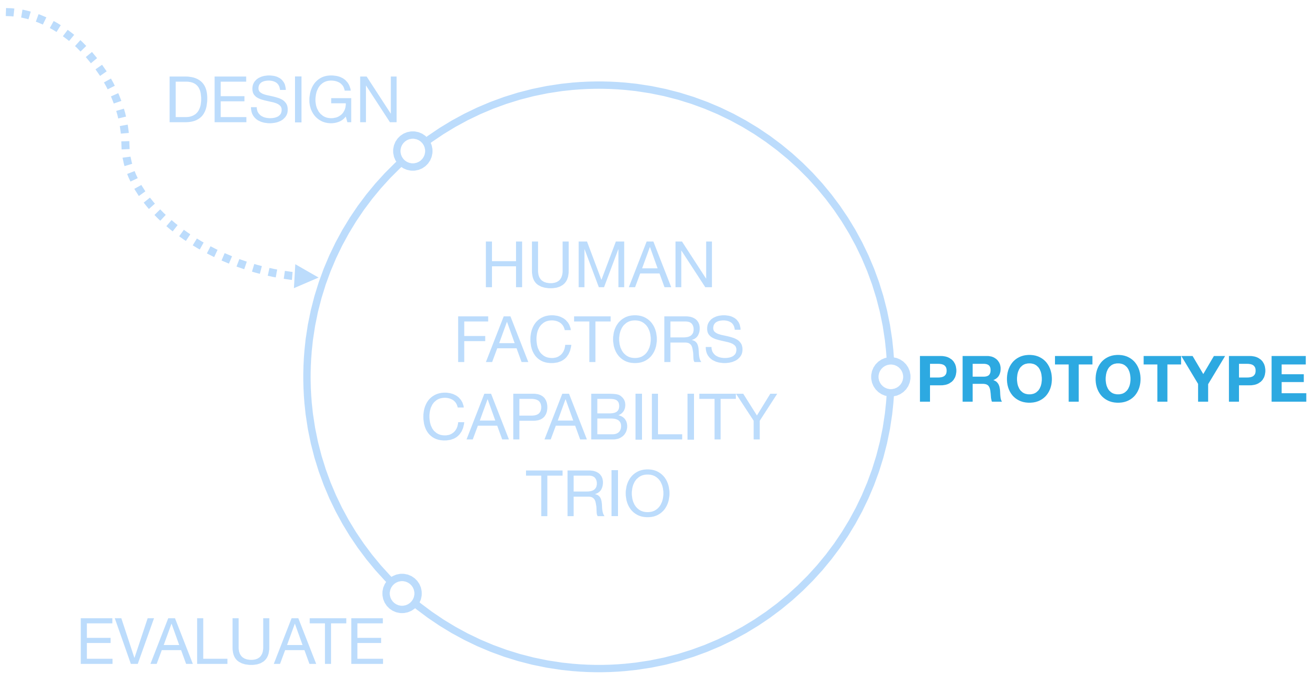

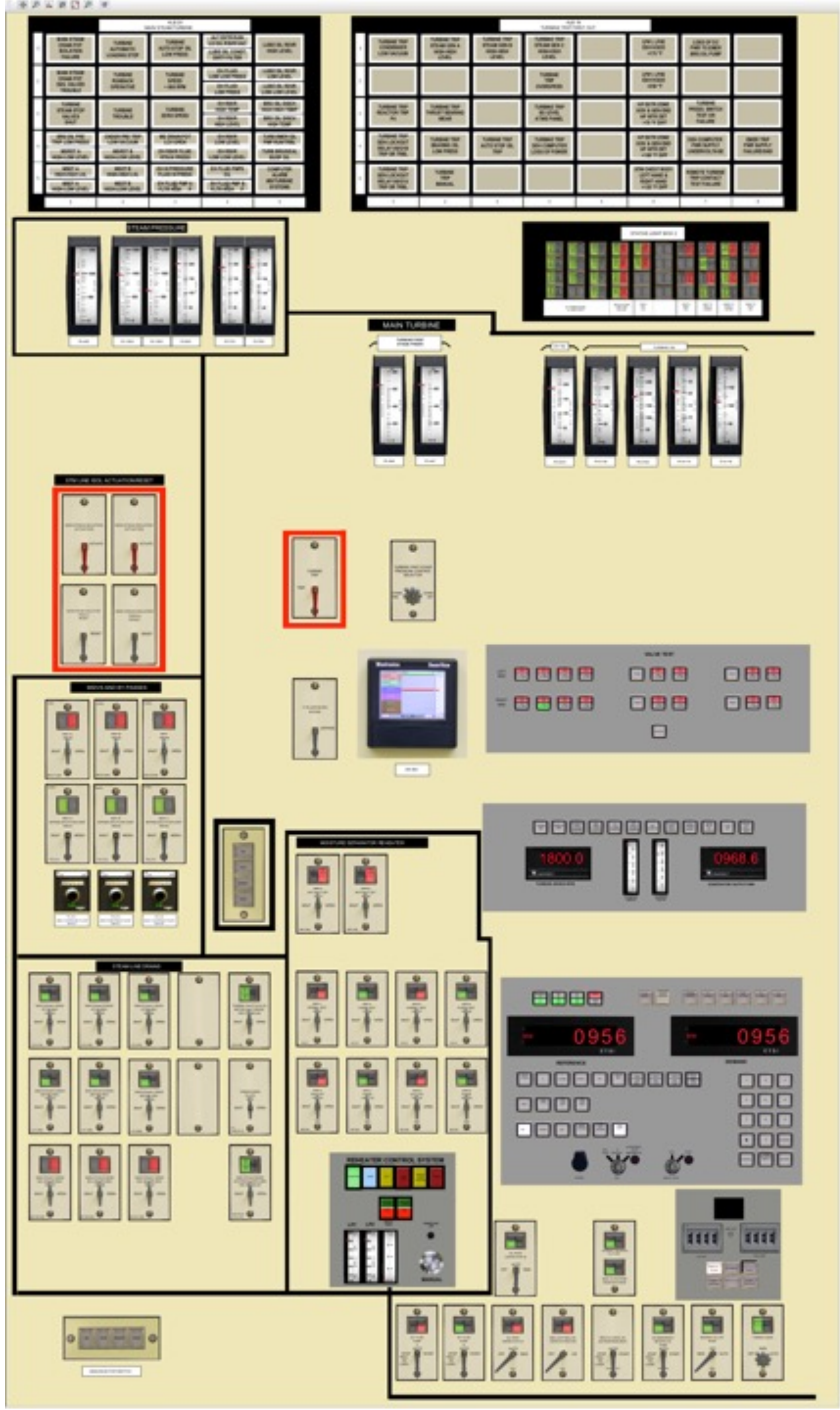

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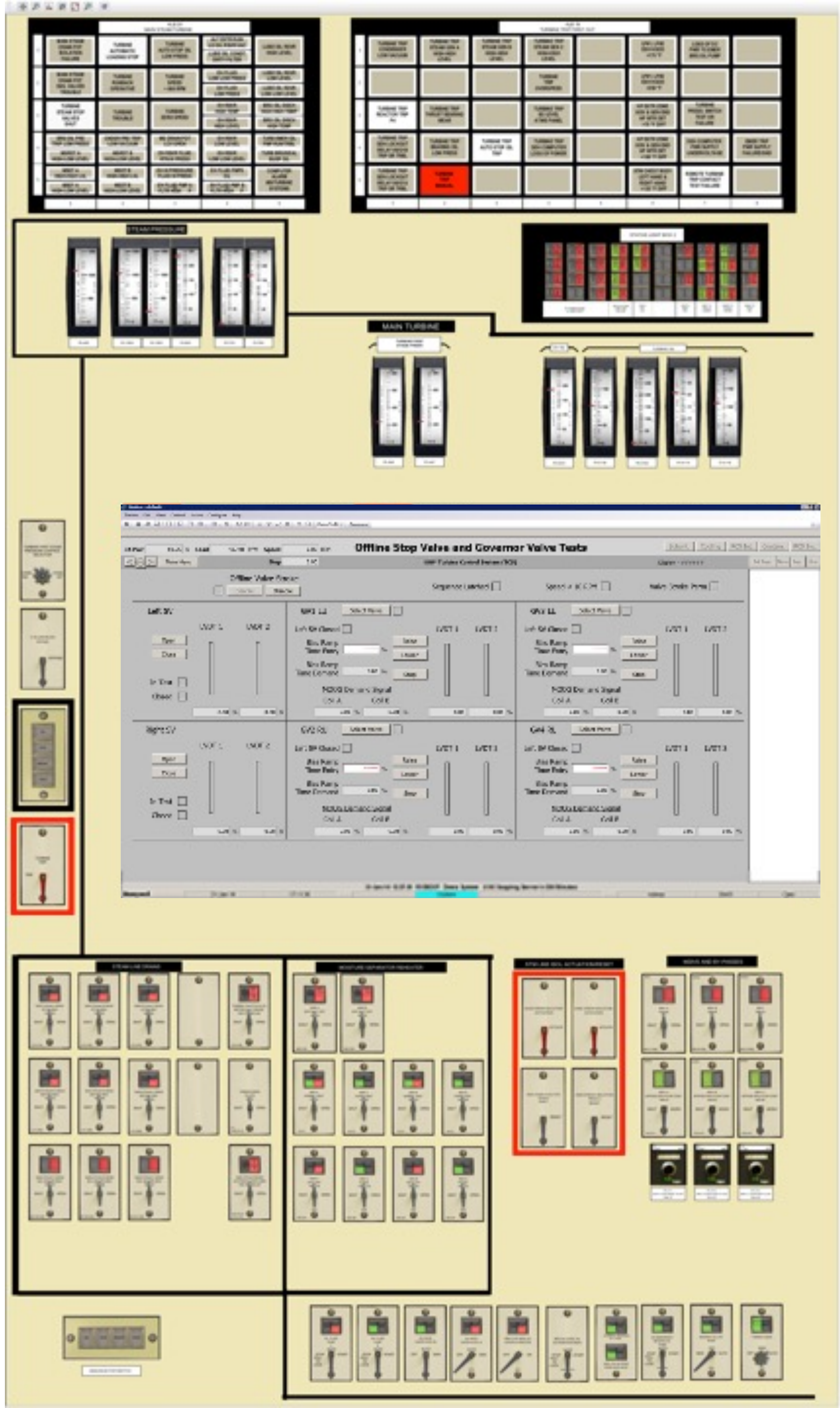
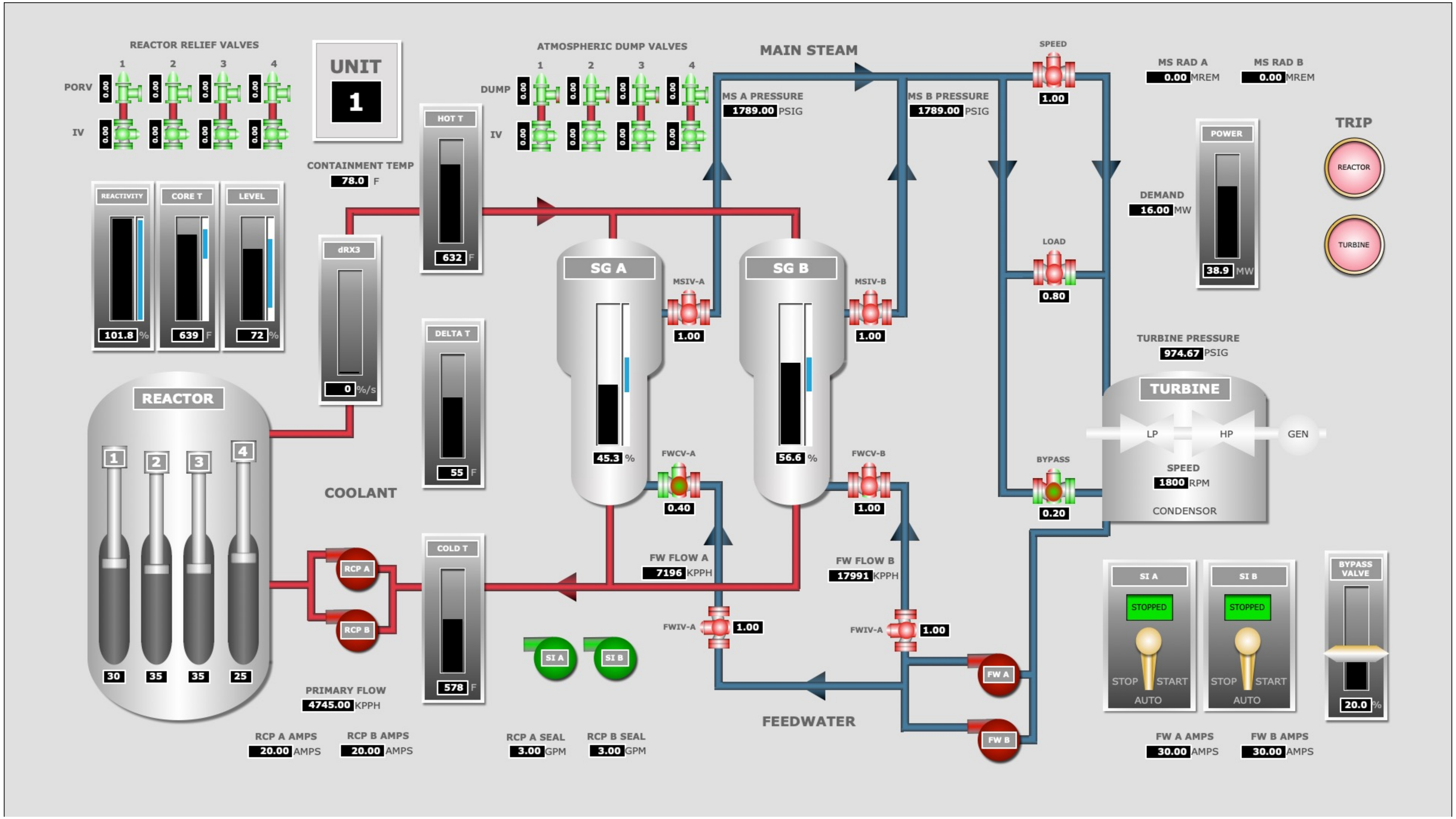


How About Different Interfaces for the Same Systems?



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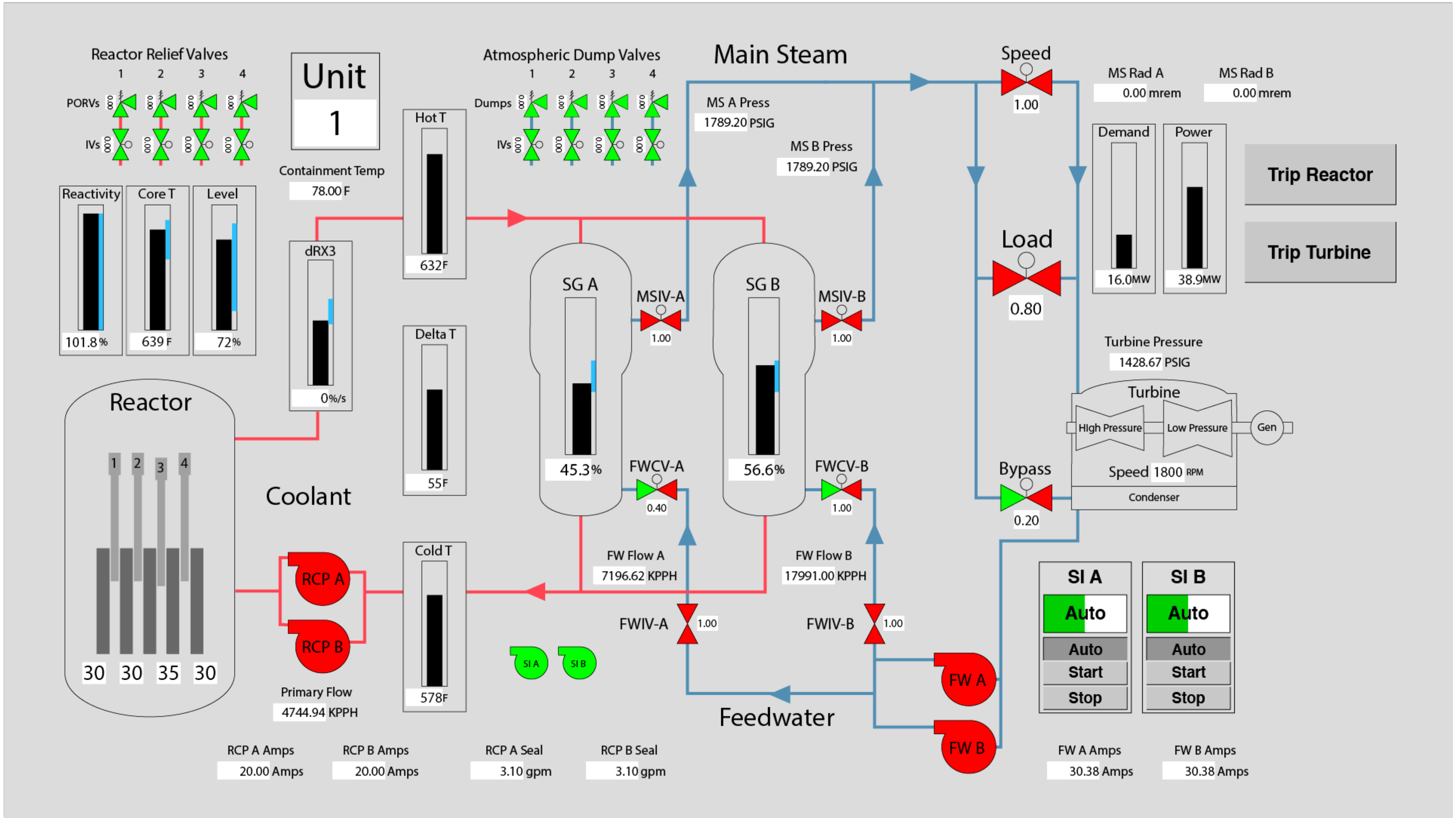

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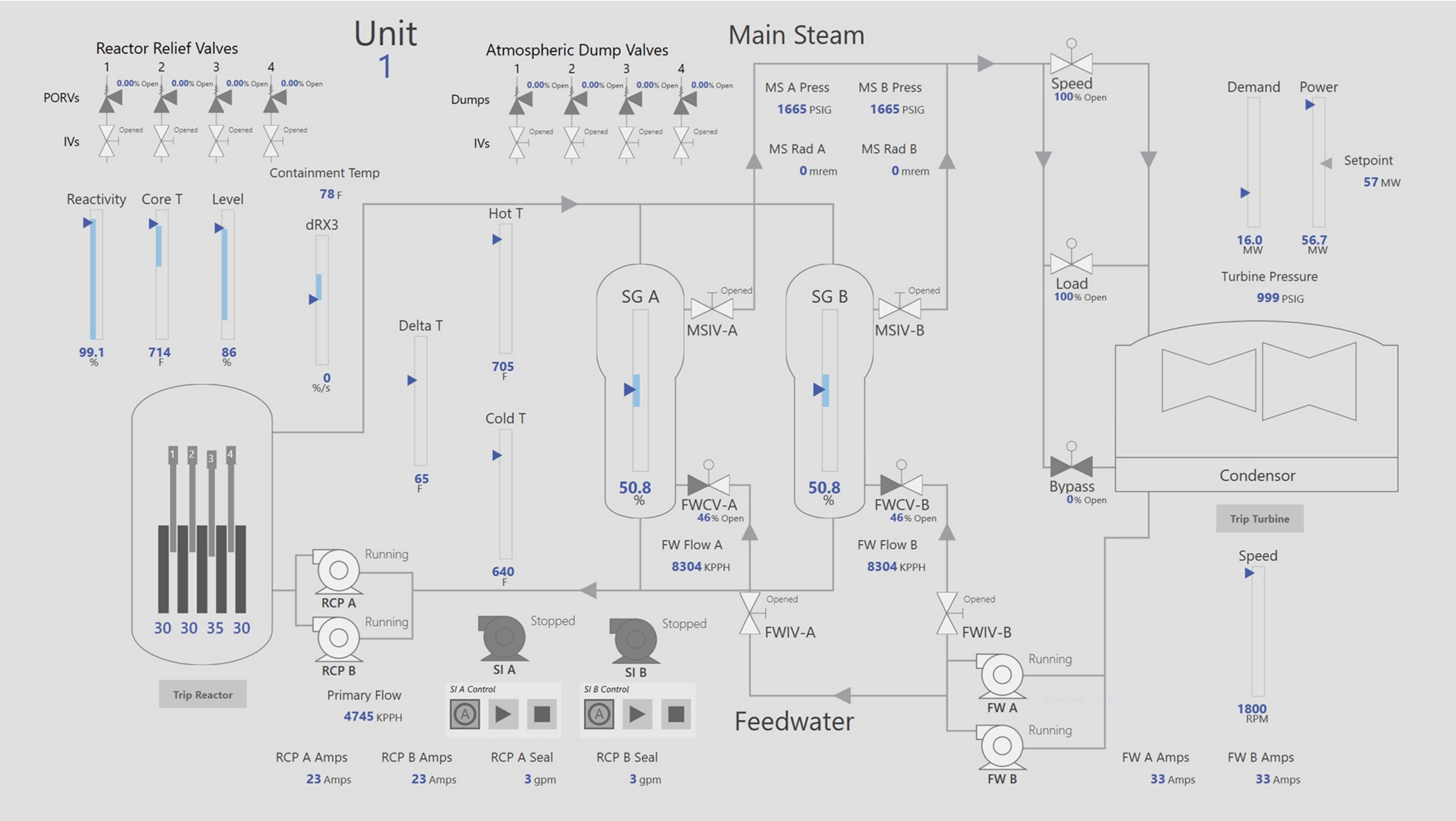

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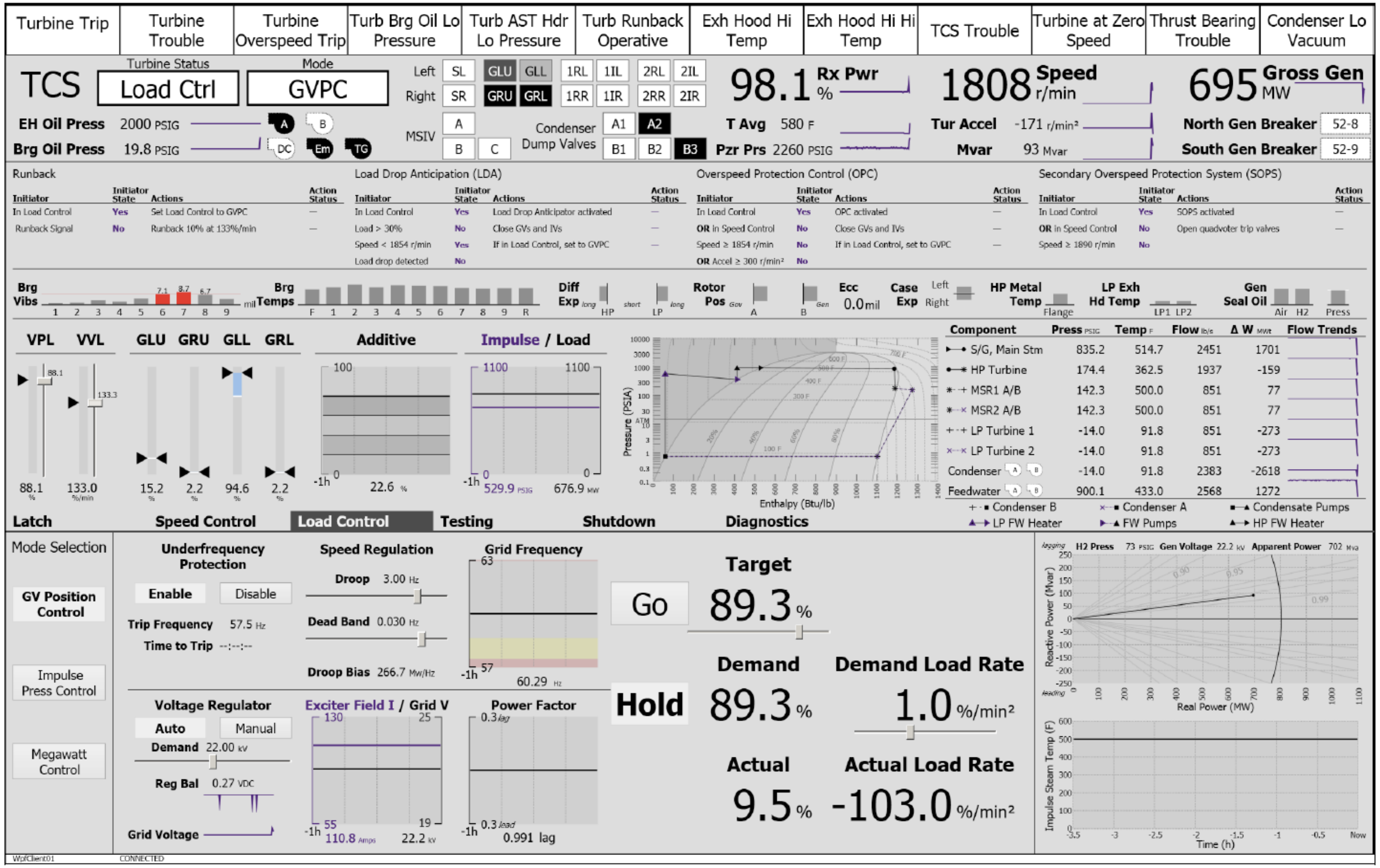
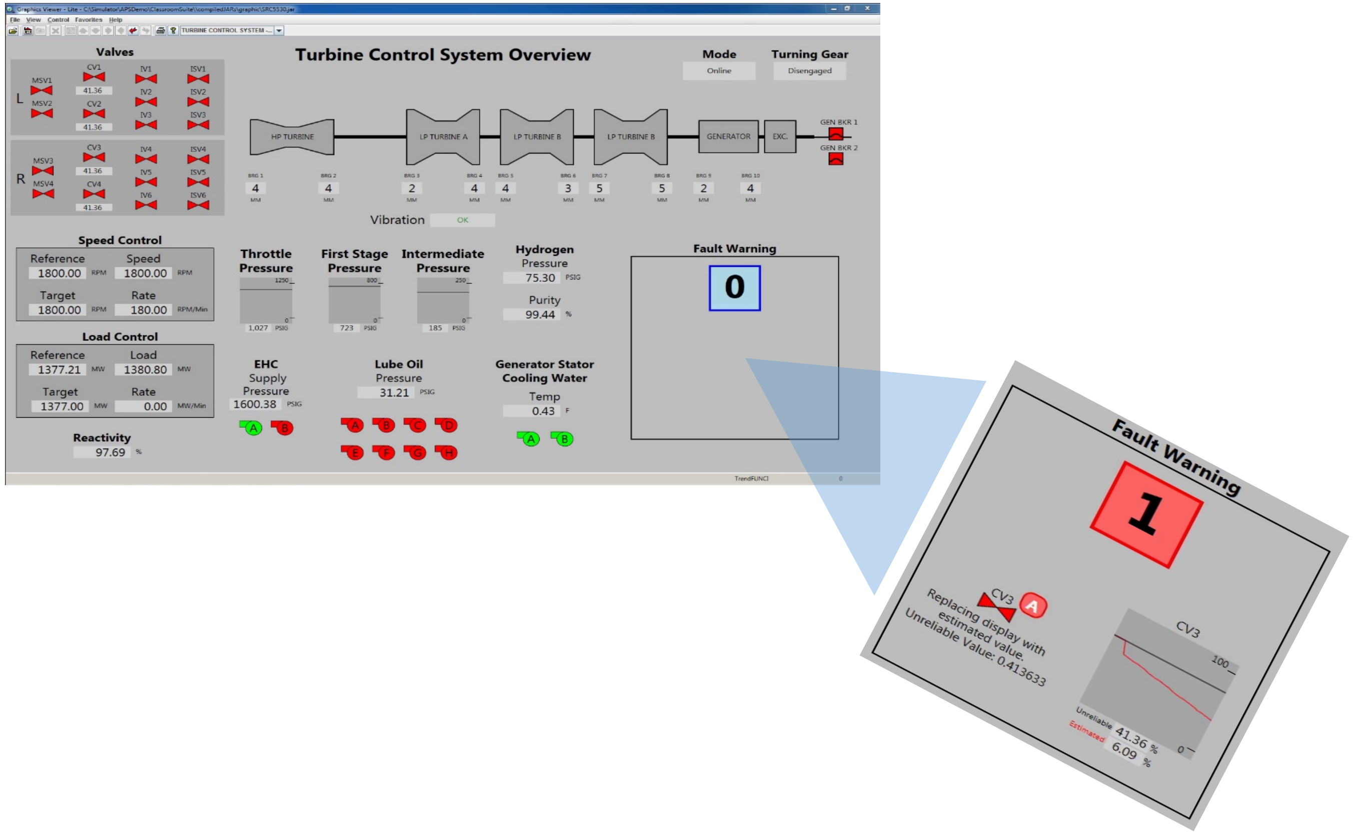
Advanced Visualizations



Advanced Features Like Intelligent Operator Aides



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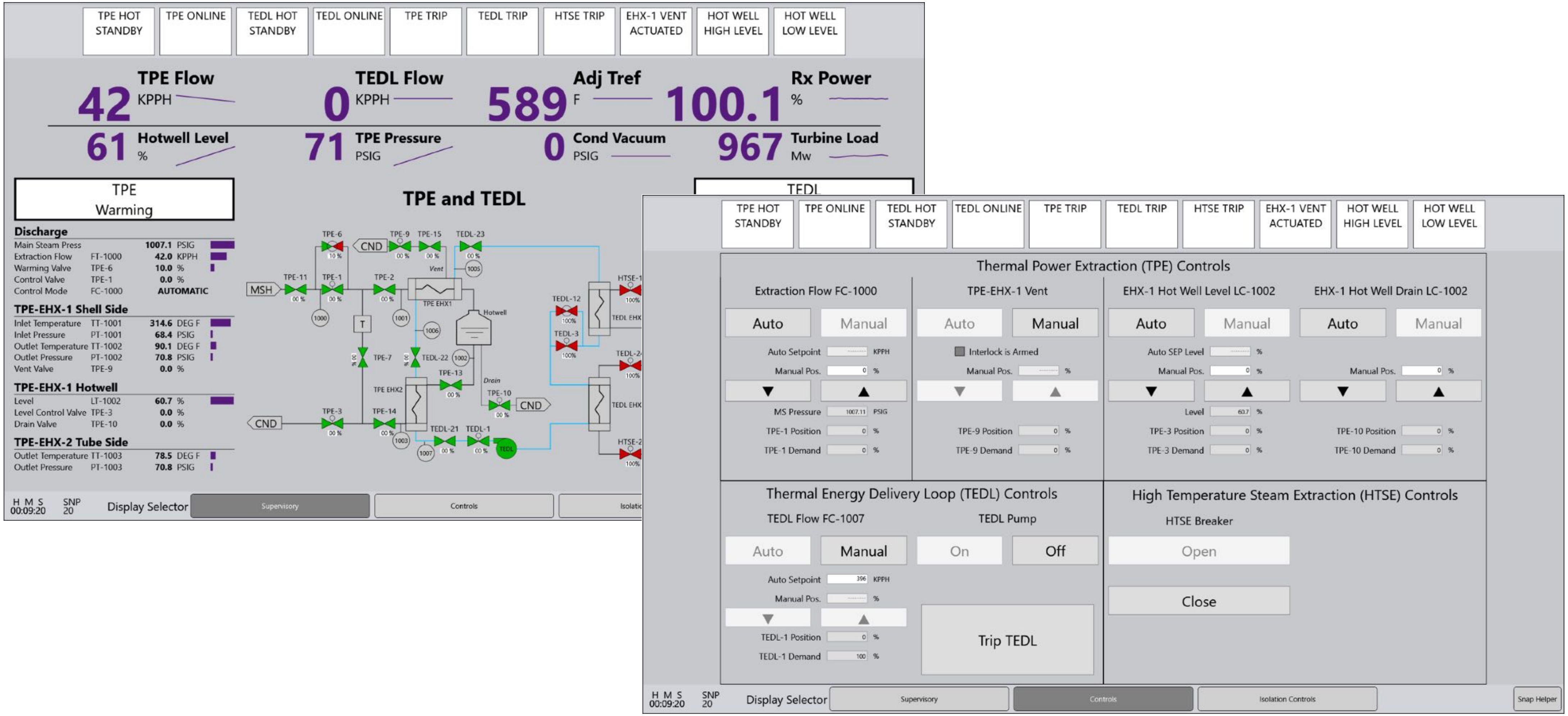
Advanced Applications Like Hydrogen Production



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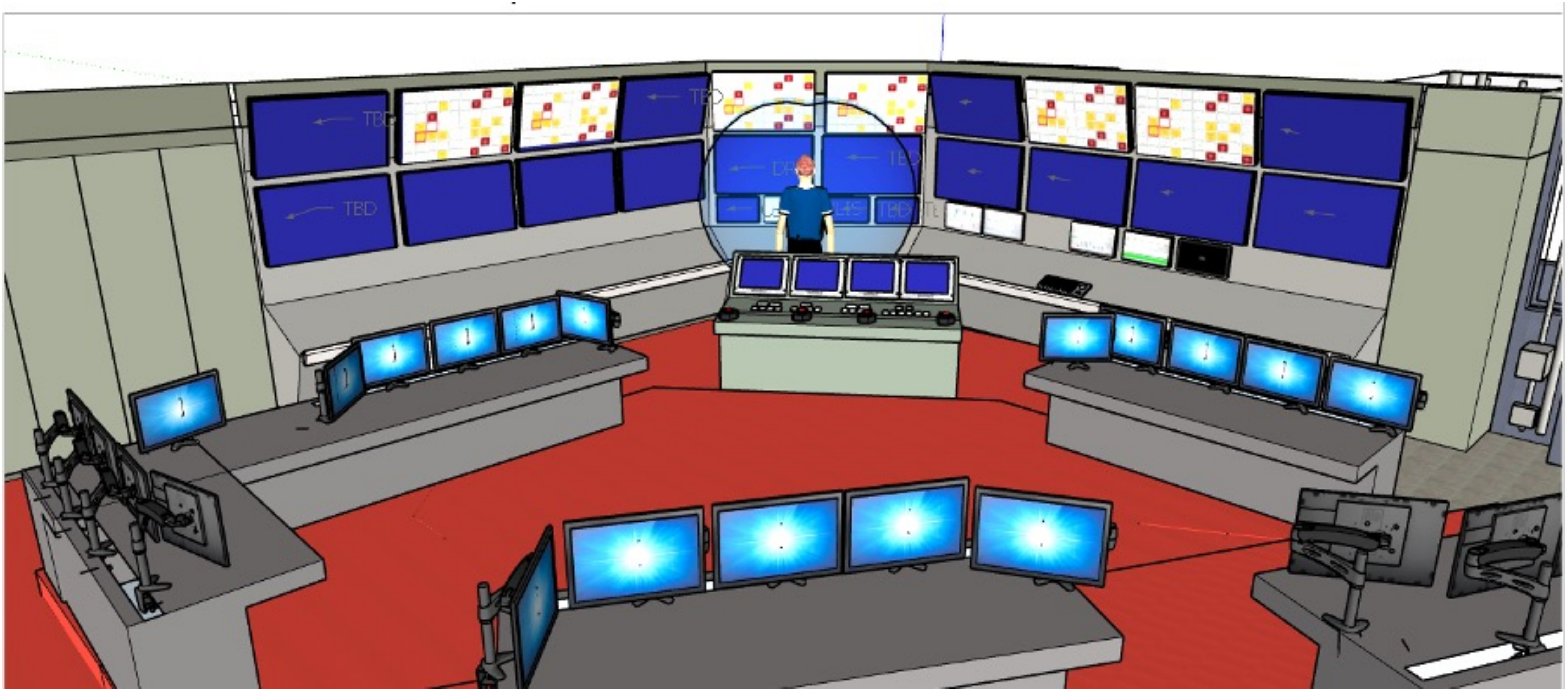
Advanced Control Room Mockups



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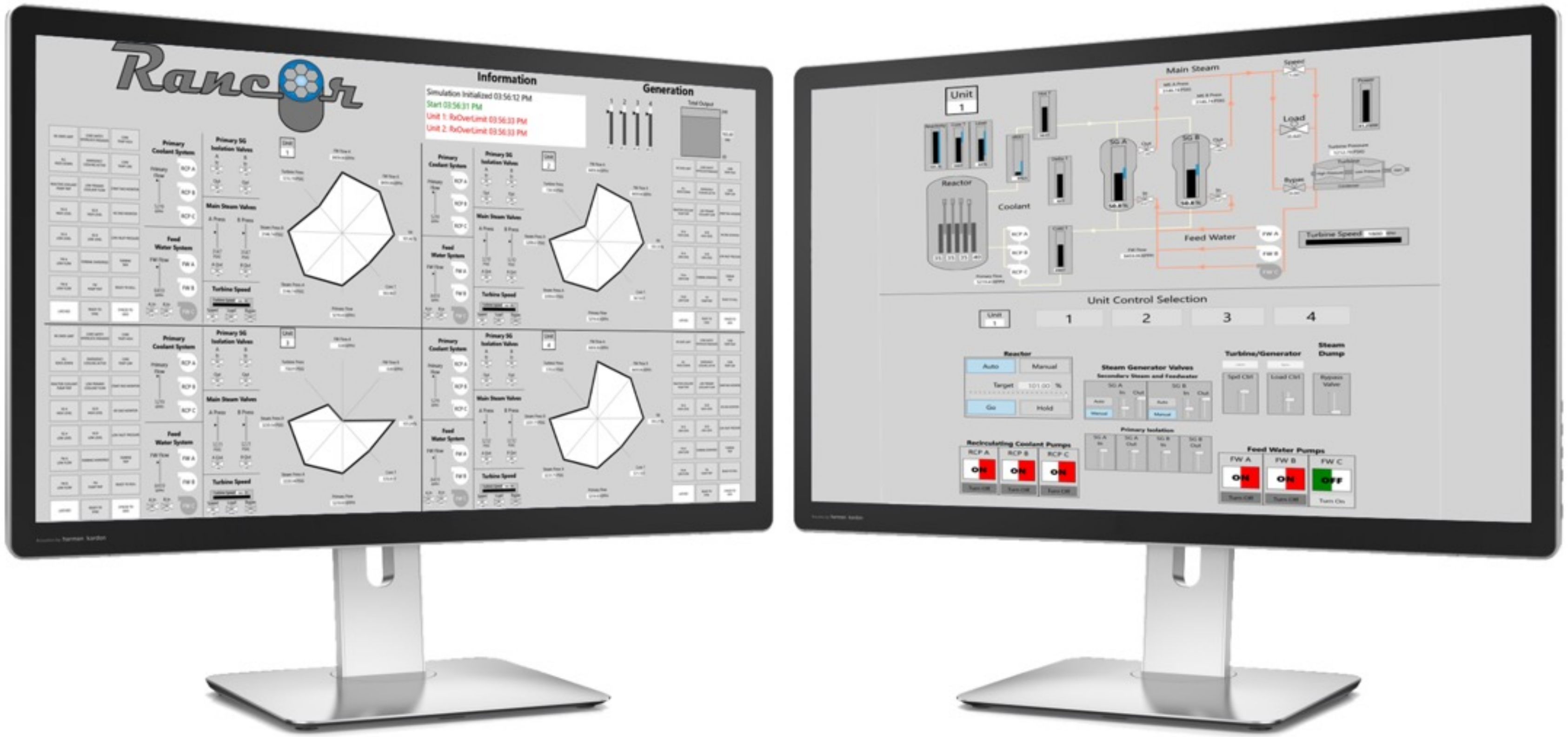
Simplified Simulator for Advanced Control Rooms



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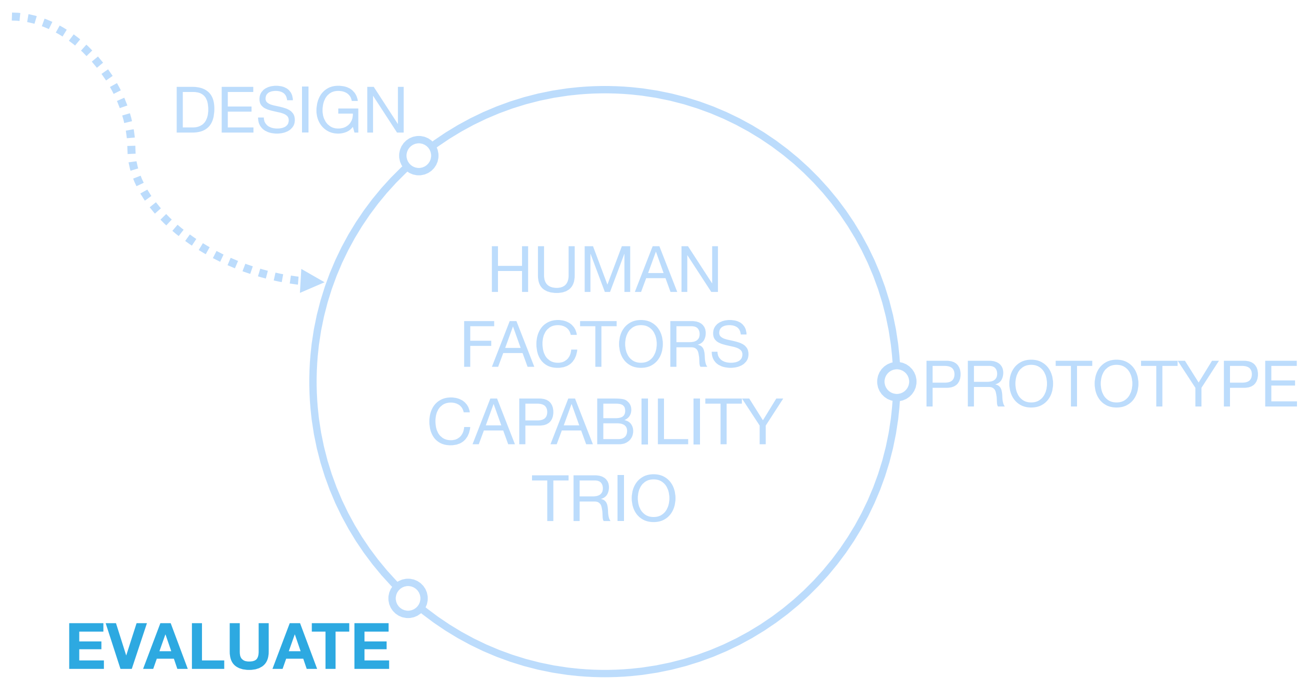

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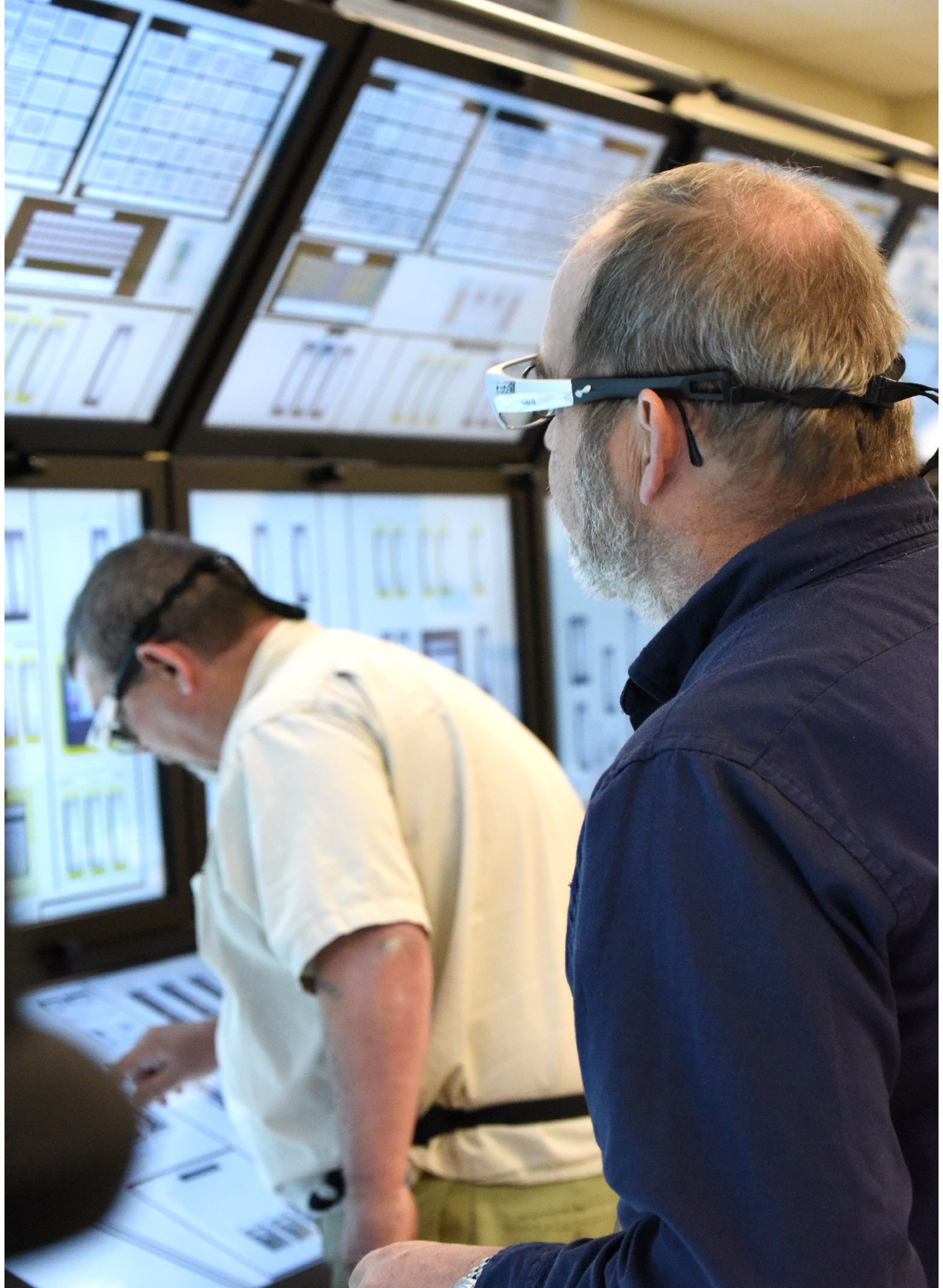
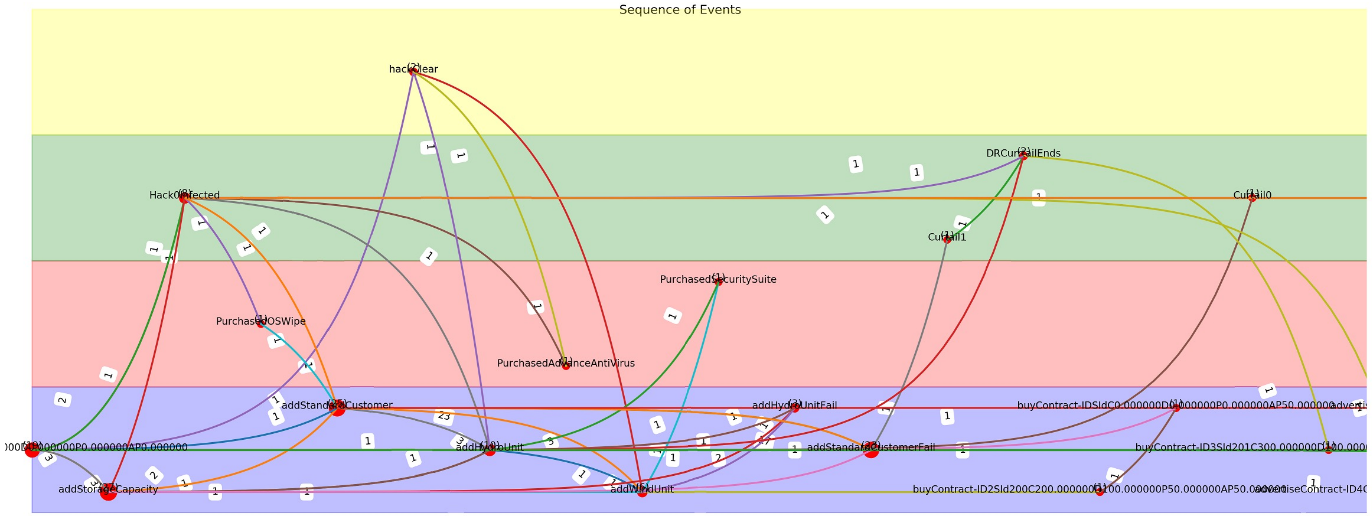
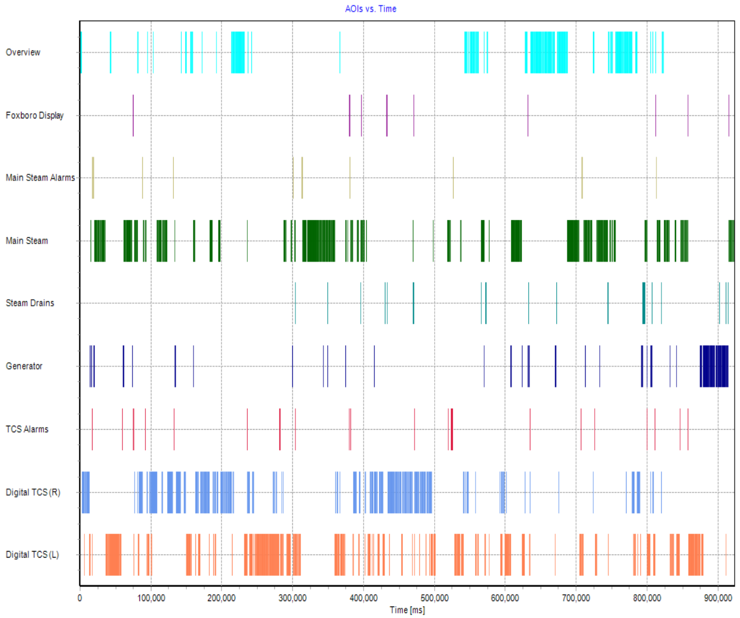
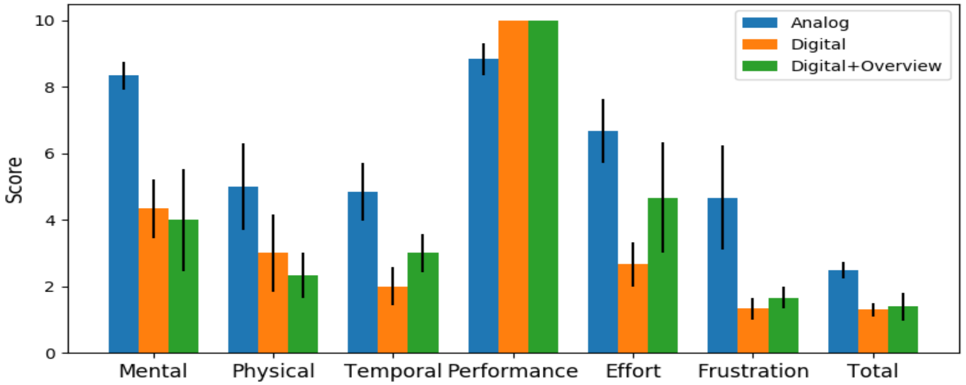
GSE SYSTEMS



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







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)

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Typical utility/ regulatory emphasis

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That ignores a lot of chances to get the interface right

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home
work

exam

In education, we test learning continuously and cumulatively

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Evaluation Phase

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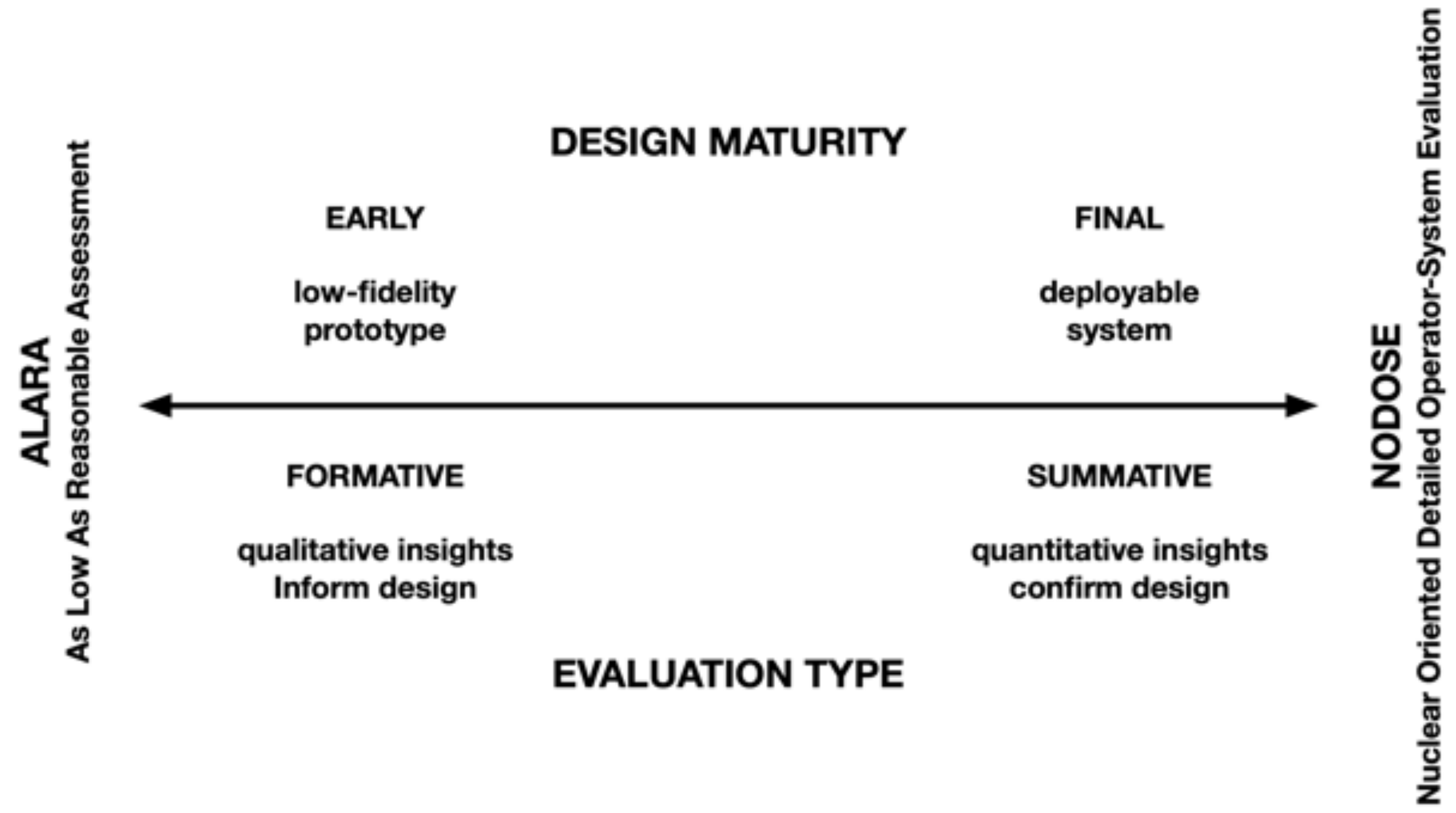
Epistemiation: Capturing Expert Operator Knowledge to Design New System

Bridging Design, Prototyping, and Evaluation



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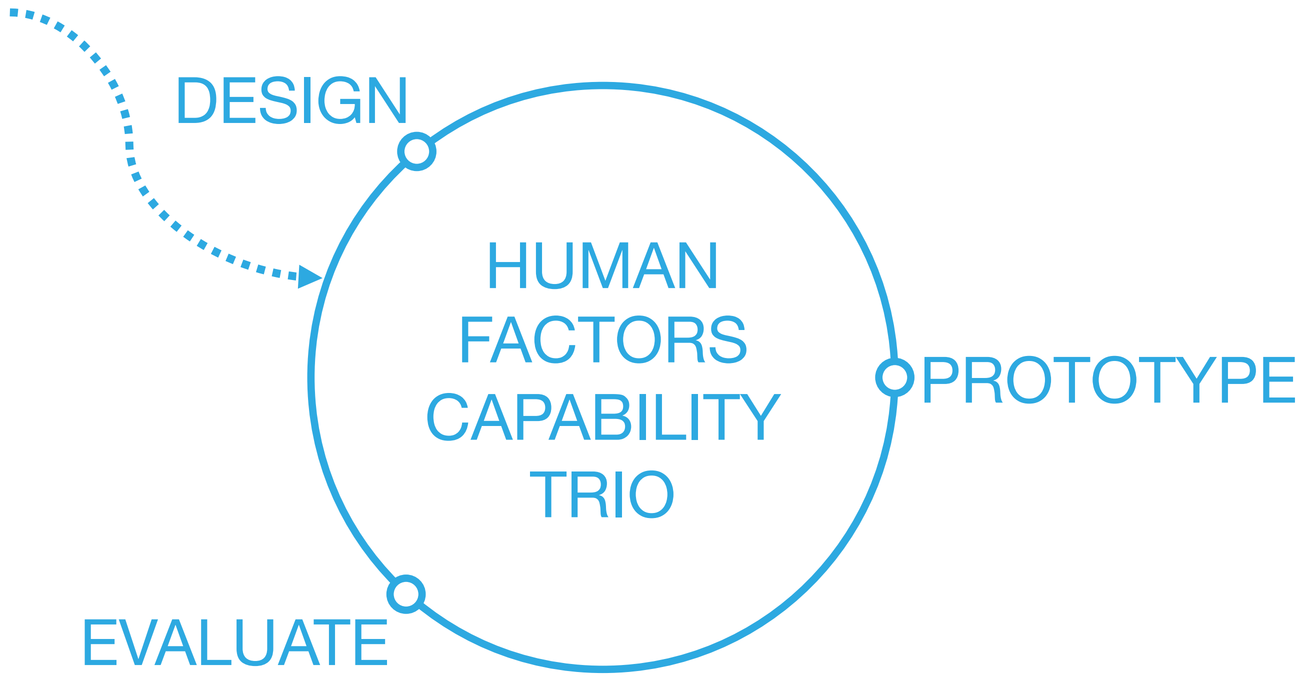

methods

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

measures

Methods and Measures Revisited

Why would you use different methods and measures depending on where you are the design phase?

- Early on, it may be as important to know *why* they didn't do well or didn't like an interface
    - Qualitative feedback from operators helps refine design
    - e.g., "I didn't understand the dialog box and clicked the wrong button" is more useful to design improvement than "2 out of 3 operators clicked wrong button"
- Later on, it is important to know *how* they did to pass the design
    - Quantitative feedback gives objective measures of performance
    - e.g., operators completed task using interface within the tech spec time limit
    - e.g., operators completed task with no critical errors

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In Sum: Designing for Human Resilience

1. Understand human limitations

2. Understand what humans are good at
   - Automating the human out of the system may not be the best solution

3. Prototype your system and test actual human performance

4. Identify opportunities for preventing and recovering from error traps

Questions?

ronald.boring@inl.gov

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