

Visualizing PMU Data for the End-User: A Human Factors Approach

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05 APR 2023

20 YEAR SBIR/STTR DATA RIGHTS (2019)

Funding Agreement No: DE-SC0020819

Award Date: 06/23/2020

SBIR/STTR Protection Period: Twenty years from Award Date

SBIR/STTR Awardee: Pacific Science & Engineering Group, Inc



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Agenda



- Review what Human Factors is and its value in Energy
- Review PSE's unique user-centered design (UCD) process
- Explore application of HF and UCD to support PMU data visualization
- Discuss anticipated impacts of UCD PMU data visualization

What is Human Factors? Human Machine Interfaces?



Applied science field started in WWII

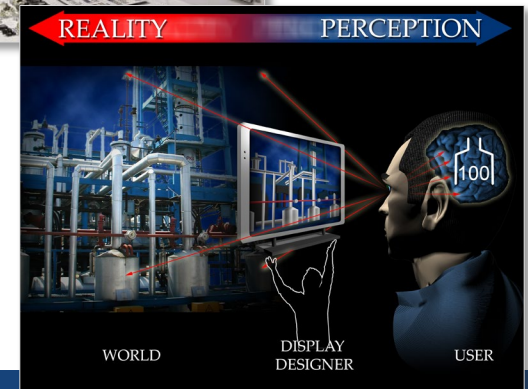
Human Factors is a scientific discipline concerned with the interactions of humans with systems. It addresses human capabilities and limitations in system design, development, and use.

History: Originating to address aviation training accidents in WWII, and then nuclear power control room design after the Three Mile Island accident in the 1970s, Human Factors is now a large field with multiple subdisciplines and specialties, from physical to cognitive ergonomics.

Human factors engineering applies this science to the design of tools, displays and processes to improve overall system performance by enhancing user task performance and reducing error.

Human Machine Interfaces (HMIs) are the critical bridges between human users and the systems they oversee, control, and make decisions about.

HMI design is a key area where Human Factors Engineering can be applied to improve user and system performance.



1940s

1970s

Today

Systems must be engineered for human capabilities in order to perform well and safely

Why is Human Factors relevant to the Energy domain?



Utilities have multiple complex systems involving humans...

- Grid Operations, Cyber Security, Emergency Risk Management, Repair services, Customer Support, Aviation Services, and many more...

...in different contexts

- Inside: Control rooms, individual offices
- Outside: Pole laying, line repair, remote sensing
- Large Scale: Extended co-located or distributed teams
- Small Scale: Individual or small teams

...performing different tasks

- Monitoring, supervisory control, decision making, forecasting, training, maintenance, software development, installation, and repair

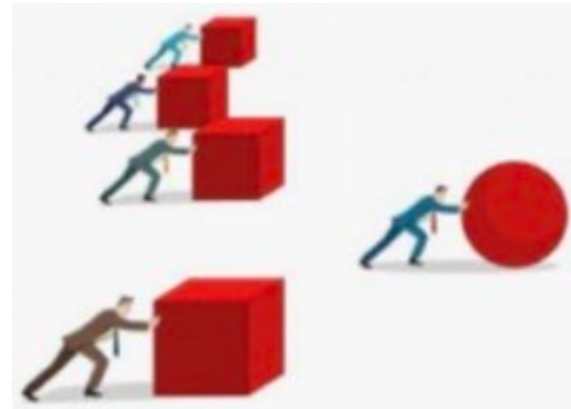


Human Factors issues are ubiquitous across utility operations

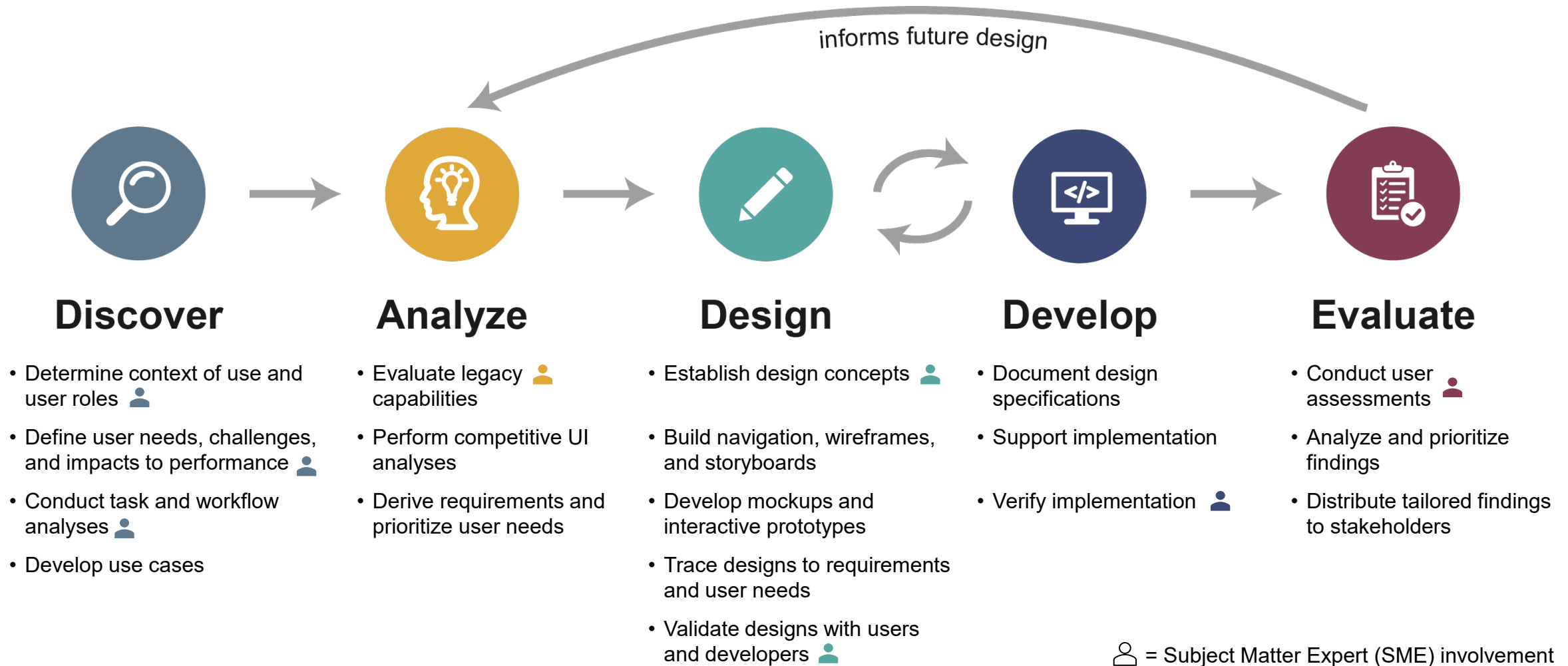
Human Factors Design Principles



- Physical ergonomics
- Consistency
- Familiarity
- Sense of control
- Efficiency
- Error management



PSE's User-Centered Design (UCD) approach

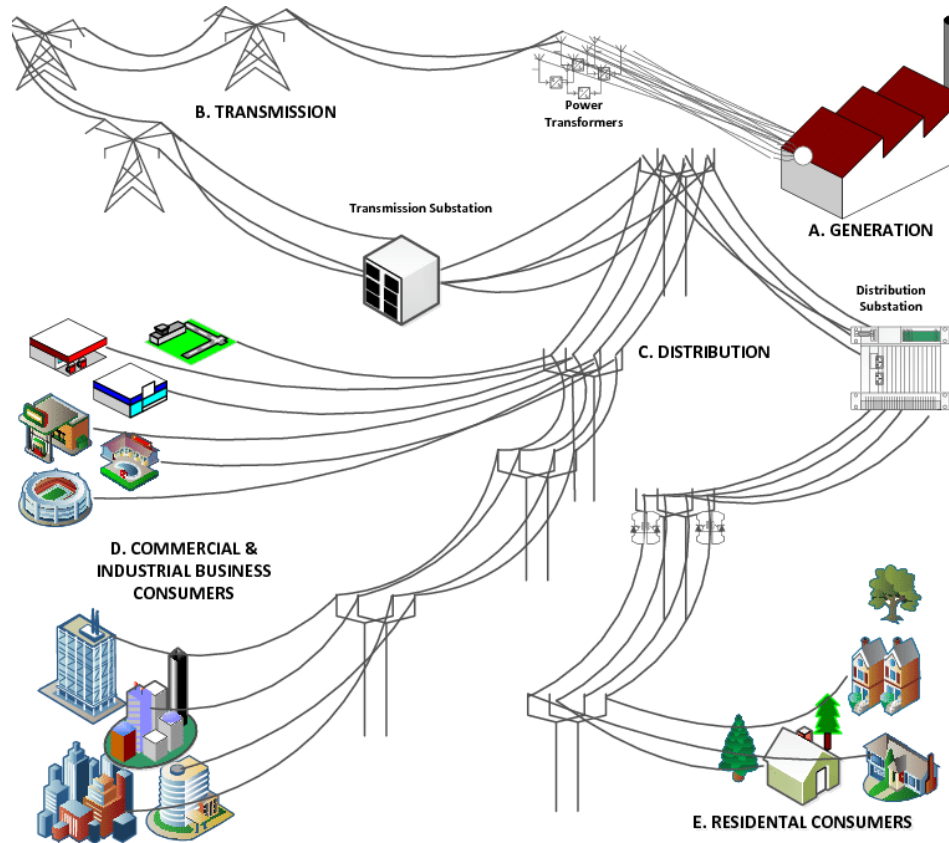


Engaging with end users at key points along the process ensures their goals, tasks, and information needs are met

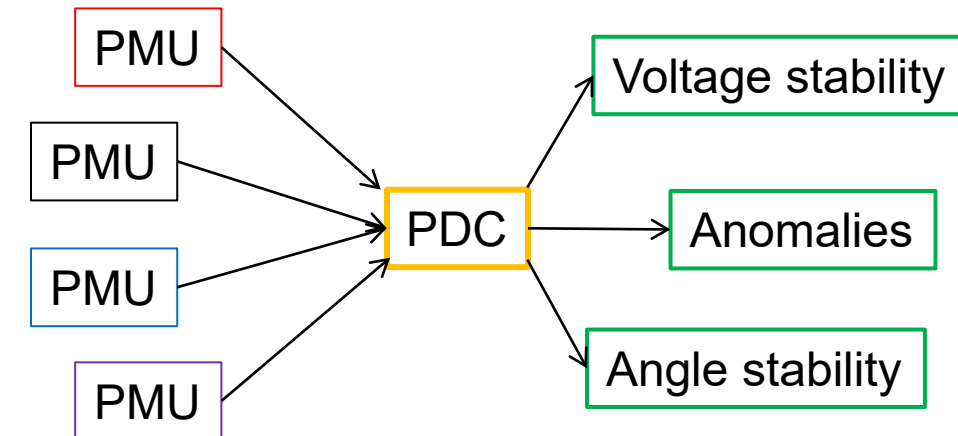
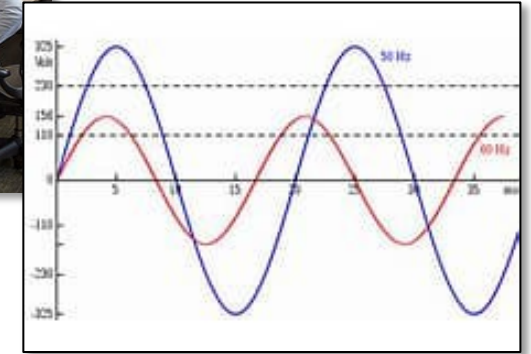
Applying the UCD process to PMU HMIs



Discover



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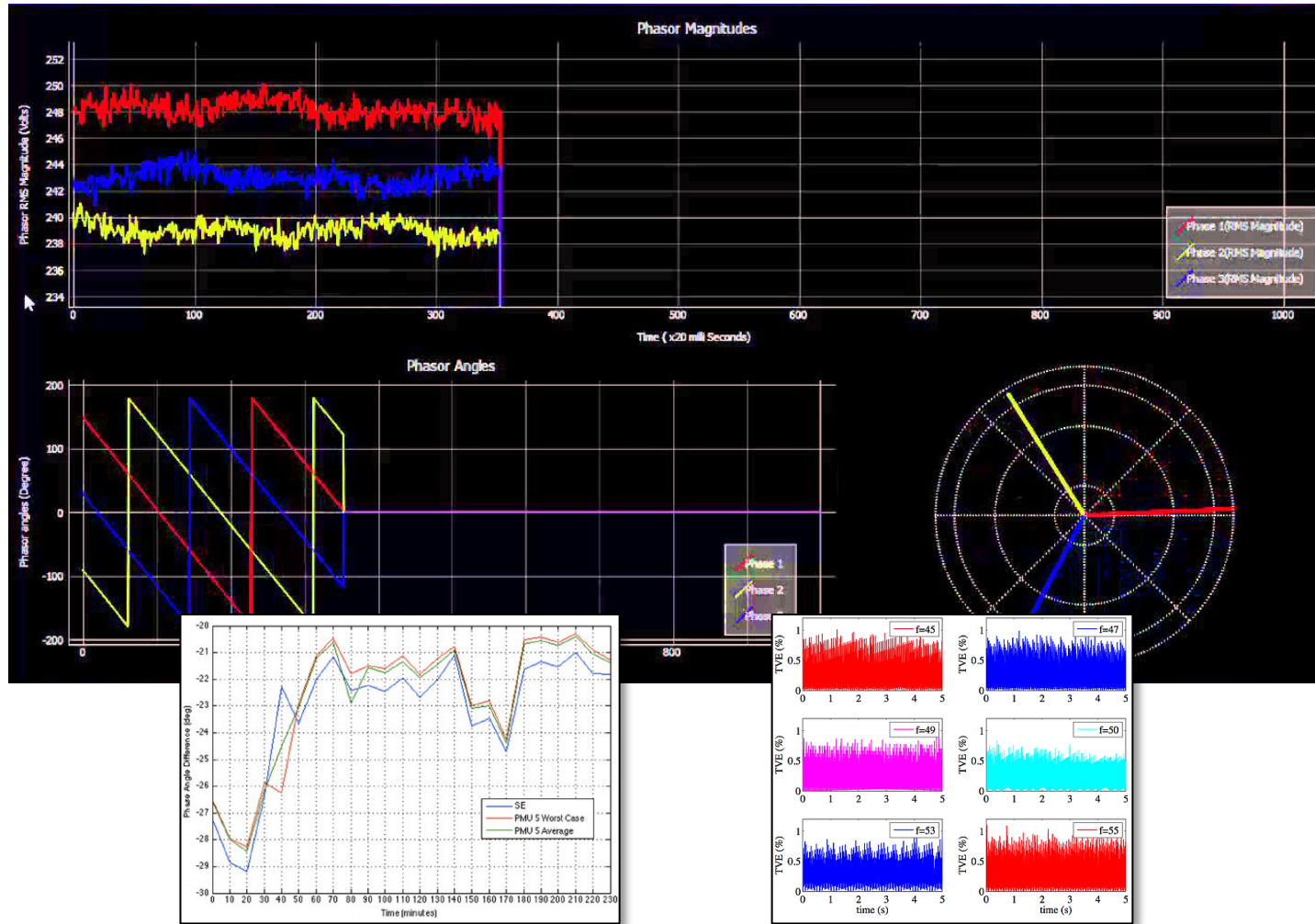


Who are the users, how are they using the data, in what situational context?

Applying the UCD process to PMU HMIs



Analyze



Real-time plotting
metaphors and raw data
visualizations



Overwhelming, unusable
Data rich, information poor



The system shall...

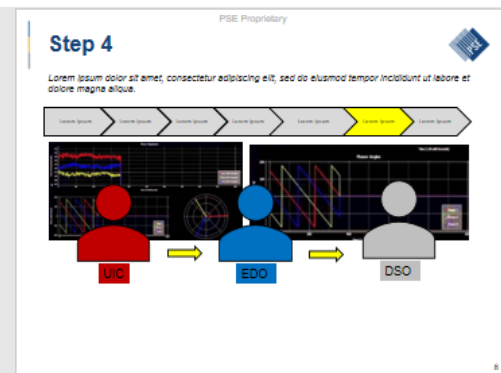
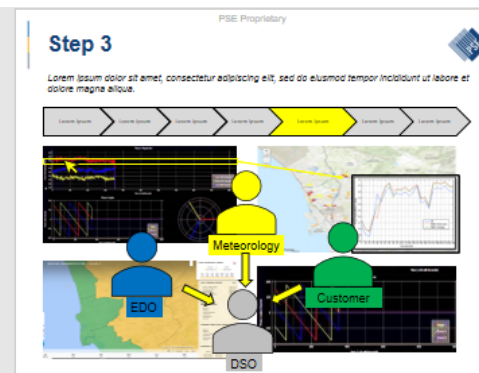
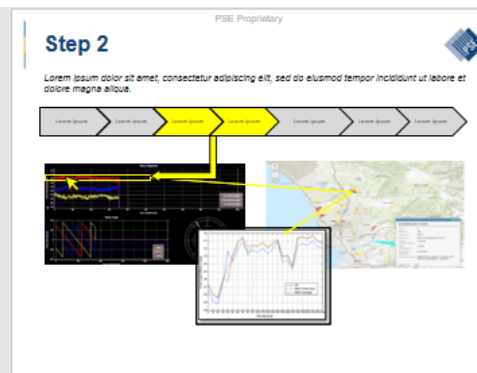
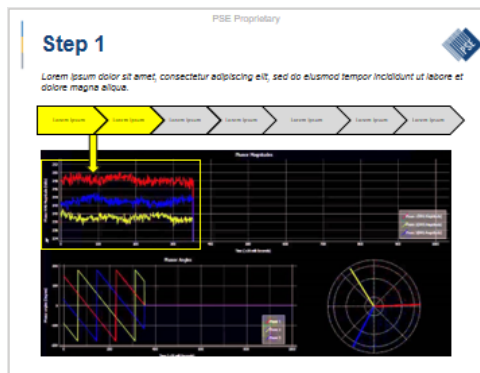
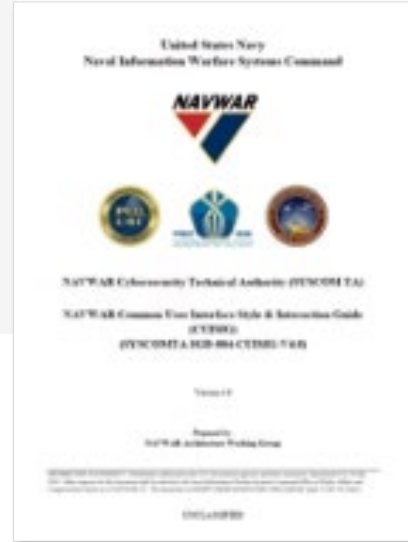
The HMI should...

How are these data currently represented? What do users need to make better use of the data?

Applying the UCD process to PMU HMIs



Design



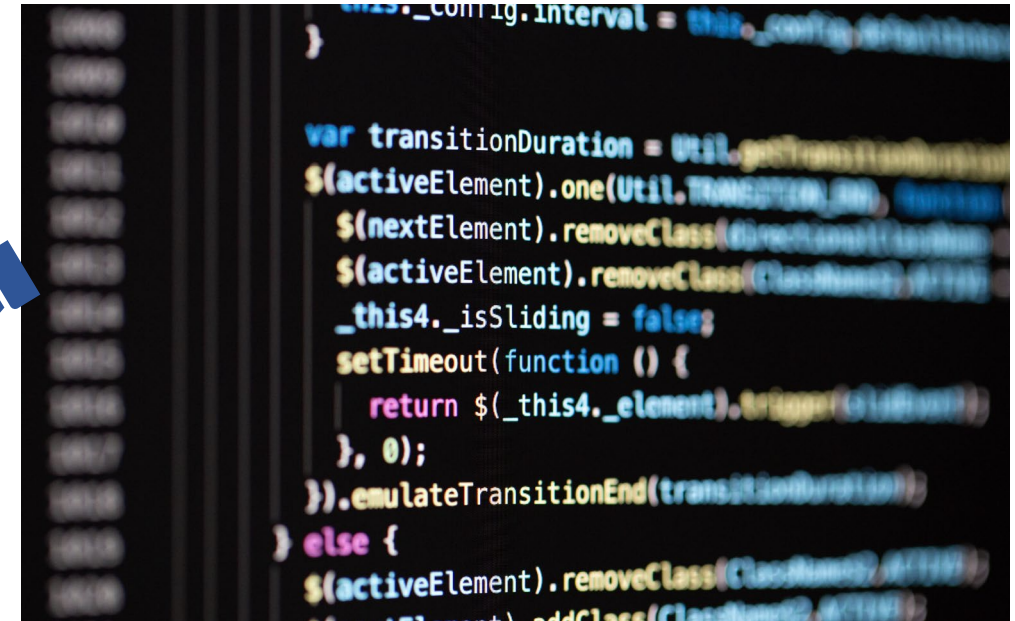
Apply standards and best practices from HF, cognitive science, and UX/UI, while working within domain constraints to iterate on designs to meet user needs

Applying the UC4D process to PMU HMIs



Develop

Requirement #	Priority	Functional Requirement	Impacted NMS Container(s)	UC4D Design Recommendation	Additional Description/Detail	Link to model
1	High	NMS shall enable user to add PPSI handoff forms to devices that have been will be de-energized "to protect public safety" from the Work Agenda view.	Work Agenda	NMS shall display a "Handoff Form" column in the Work Agenda view. NMS shall enable users to right-click in a Handoff Form cell to access a right-click menu with the option to "Add/Edit Form." This Handoff Form cell shall serve as the handoff status indicator for each device viewed from the Work Agenda. Alternatively, NMS shall enable users to select the appropriate Handoff Form cell, select the Actions dropdown in the Work Agenda toolbar, and then select the option to "Add/Edit Form."	Adding a handoff form from Work Agenda opens up the digital handoff form model.	
2	High	NMS shall indicate handoff form status in the Work Agenda.	Work Agenda	From the Work Agenda, NMS shall display a "Handoff Form" column that contains a readout of current handoff form status for each device. This Form column should be one of the first five columns that appear in the Work Agenda view by default. For users that do not yet have any forms associated with them, the Form column should appear empty. Handoff form status includes: 3 possible status: 1. Orange: Agreed 2. Orange: Tag Pending 3. Orange: Tag Verified 4. Panel: Agreed 5. Panel: Disputed 6. Panel: Completed 7. Red/Orange: Agreed 8. Red/Orange: Clear 9. Red/Orange: Placed	Handoff form status is based on logic built into the fields of digital handoff forms. The fields set to stage gates that return specific handoff form status values after checking whether valid data has been entered into certain form fields. 1. Orange: Agreed should be displayed after valid data is entered in the OIC Authorization field and the form has been sent to the EDO Manager 2. Orange: Tag Pending should be displayed after valid data is entered in the Verified Green Tag dropdown and the Orange Control form has been submitted for completion 3. Orange: Tag Verified should be displayed after valid data is entered in the OIC and DOC-E Authorization fields and the form has been sent to the EDO Manager 4. Panel: Agreed should be displayed after valid data is entered in the OIC and DOC-E Authorization fields and the form has been sent to the EDO Manager 5. Panel: Disputed should be displayed after valid data is entered in the Panel start date and time fields and the DSD has been sent to the EDO Manager 6. Panel: Completed should be displayed after valid data is entered in all of the fields and the Panel form has been submitted for completion 7. Red/Orange: Agreed should be displayed after valid data is entered in the OIC, DOC-E and DPUC Authorization fields and the form has been sent to the EDO Manager 8. Red/Orange: Clear should be displayed after valid data is entered in the relevant question and the form has been sent to the DSD 9. Red/Orange: Placed should be displayed after valid data is entered in all of the fields and the Red/Orange form has been submitted for completion	AI
3	High	NMS shall enable users to add PPSI handoff forms to devices that have been will be de-energized "to protect public safety" from the Switching Plan List view.	Switching Plan List	NMS shall display a "Handoff Form" column in the Switching Plan List view. NMS shall enable users to right-click in a Handoff Form cell to access a right-click menu with the option to "Add/Edit Form." This Handoff Form cell shall serve as the handoff status indicator for each device viewed from the Switching Plan List. Alternatively, NMS shall enable users to select the appropriate Handoff Form cell, select the Actions dropdown in the Switching Plan List toolbar, and then select the option to "Add/Edit Form."	Adding a handoff form from the Switching Plan List opens up the digital handoff form model.	AI
4	High	NMS shall indicate handoff form status in the Switching Plan List.	Switching Plan List	From the Switching Plan List, NMS shall display a "Handoff Form" column that contains a readout of current handoff form status for each device. This Handoff Form column should be one of the first five columns that appear in the Switching Plan List view by default. For switching plans that do not yet have any forms associated with them, the Form column should appear empty. NMS shall display the option to "Add/Edit Form" in the Control Tool for each device that can be accessed from the NMS Viewer.		AI
5	High	NMS shall enable users to add PPSI handoff forms to devices that have been will be de-energized "to protect public safety" from the NMS Viewer.	NMS Viewer	NMS shall display a tag that contains a readout of current handoff form status attached to the relevant device in the NMS Viewer. The handoff form tag shall serve as the handoff status indicator for each device viewed from the NMS Viewer. If no handoff form has been submitted for a device, no handoff form tag shall appear attached to the device.	Adding a handoff form from the NMS Viewer opens up the digital handoff form model.	AI
6	High	NMS shall automatically add a handoff form tag to the selected device in the NMS Viewer commensurate with handoff form status.	NMS Viewer	NMS shall display a tag that contains a readout of current handoff form status attached to the relevant device in the NMS Viewer. The handoff form tag shall serve as the handoff status indicator for each device viewed from the NMS Viewer. If no handoff form has been submitted for a device, no handoff form tag shall appear attached to the device.		AI
7	High	NMS shall indicate handoff form status in the NMS Viewer.	NMS Viewer	From the NMS Viewer, NMS shall display handoff form tags that contain a readout of current handoff form status attached to relevant devices. If no handoff form has been submitted for a device, no handoff form tag shall appear attached to the device.		AI
8	High	NMS shall enable users to add PPSI handoff forms to devices that have been will be de-energized "to protect public safety" from the Stage tab of a selected switching plan.	Stage tab	NMS shall enable users to right-click on a row in a device's switching plan to access a right-click menu with the option to "Add/Edit Form" as a step in the switching plan. Upon selection of the "Add/Edit Form" step, a new row for a handoff form step shall be added below the selected row. NMS shall display a readout of current handoff form status in the automatically added handoff form step of a device's switching plan.	Adding a handoff form from the Stage tab opens up the digital handoff form model and adds a row to the device's switch plan.	AI
9	High	NMS shall automatically add a handoff form step to a de-energized device's switching plan commensurate with handoff form status.	Stage tab	From the Stage tab inside a switching plan, NMS shall display rows for handoff form steps that contain readouts of current handoff form status where NMS shall enable users to access current handoff forms by double-clicking on any handoff form status indicator. Upon right-clicking of a handoff form		AI
10	High	NMS shall indicate handoff form status in the Stage tab.	Stage tab			AI
11	High	NMS shall provide users with access to current and historical PPSI Handoff forms.	History Document tab Handoff form	Alternatively, NMS shall enable users to access current handoff forms by right-clicking on any handoff status indicator. Upon right-clicking of a handoff status		AI



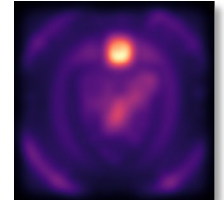
Work directly with IT team to ensure designs are implemented as intended

Applying the UCD process to PMU HMIs

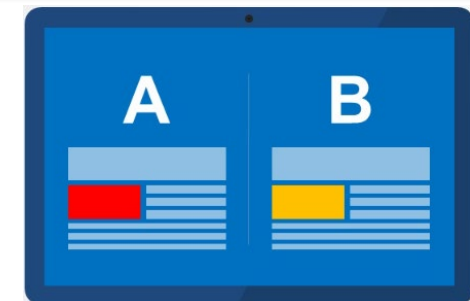


Evaluate

- Computational models simulate human visual/attention
 - Clutter models produces a “feature congestion” score that tracks time needed to find info on display (i.e., more congested, longer to find information) (Rosenholtz and Nakano, 2006)
 - Saliency models indicates which area(s) would pull visual attention (i.e., brighter areas) (Harel, Koch, and Perona, 2007)
- Human information processor models capture interactions with HMIs
- Human performance experiments validate anticipated outcomes



ID	Task Description	Tool	Key Description	Subtask	Subtask	Score	Score	Score
1	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
2	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
3	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
4	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
5	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
6	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
7	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
8	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
9	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
10	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
11	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
12	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
13	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
14	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
15	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
16	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
17	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
18	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
19	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
20	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
21	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
22	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
23	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
24	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
25	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
26	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
27	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
28	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
29	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
30	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
31	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
32	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
33	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
34	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
35	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
36	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
37	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
38	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
39	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
40	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
41	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
42	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
43	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
44	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
45	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
46	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
47	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
48	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
49	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
50	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
51	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
52	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
53	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
54	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
55	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
56	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
57	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
58	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
59	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
60	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4
61	OK	Phen	More load to phase	More load to phase	More load to phase	1	0.4	0.4



Benefits of HMI concepts can be explored before and after implementation

Anticipated impacts



- UCD HMI address critical issue of PMU data adoption
- Utilities see ROI on PMU investments and experience more reliable energy transmission & distribution through reduced outages
- Scientific community gains topical, relevant visualizations to empirically validate research on PMUs
- Operators make use of PMU data and experience improved, proactive monitoring, data management, and faster, more reliable anomaly detection

Thank you!



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