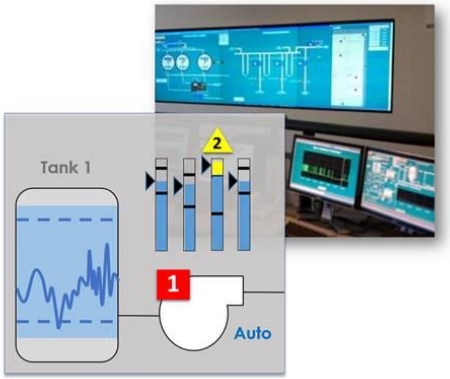

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NEXT-GENERATION SCADA HIGH PERFORMANCE HUMAN MACHINE INTERFACES

Configuring HMIs to Display “Operator-centric” Information

Ryan Kowalski, PE; Ed Kowalski, PE

11 September 2017

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Today's Presenter

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Learning Objectives

- Recognize key components of a plant or facility **Human Machine Interface** (HMI)
- Define **situational awareness** as it relates to SCADA systems and identify common HMI pitfalls working against it
- Describe how High Performance HMI (HPHMI) **concepts** serve to enhance situational awareness
- Identify how **methodologies** such as ANSI/ISA 18.2 alarm management approach support HPHMI and are critical to SCADA system success
- Outline how to **benchmark and measure** the performance of HPHMIs and related alarm management systems

Introduction

Automation and SCADA systems are **fundamental** to water resource plant operations

Operators struggle with **massive amounts** of alarms, increasing screen counts and I/O

Information is presented in ways that may not enhance **situational awareness**

Agenda

1. Background of HMI Engineering
2. Situational Awareness
3. “High Performance” HMI
4. Examples of Implementing HPHMI Engineering
5. Alarm Management – An integral part of HPHMI

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1. BACKGROUND OF HMI ENGINEERING

SCADA Components

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Enterprise Systems

Remote Site Telemetry

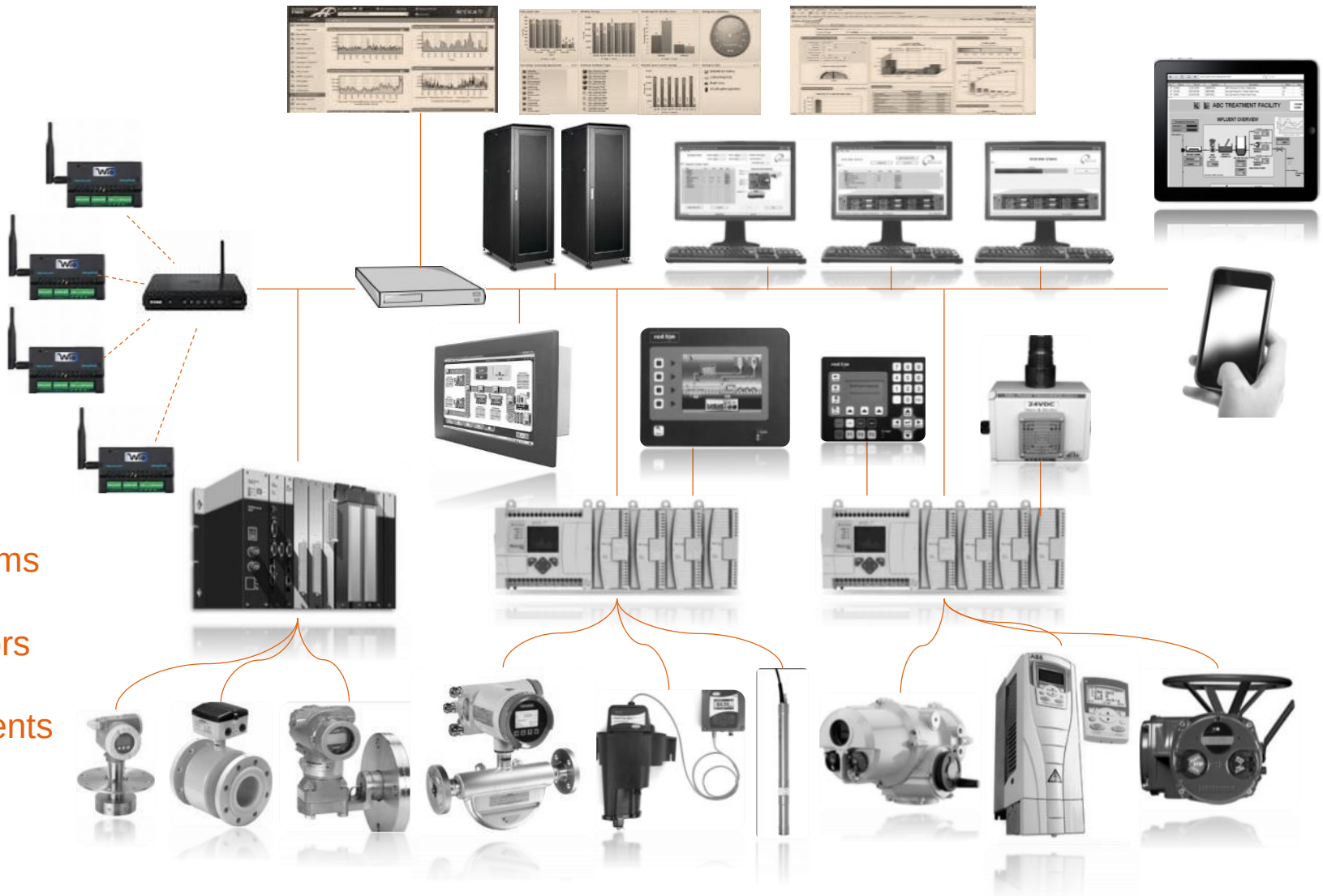
HMI/OIT

Controllers

Packaged Vendor Systems

VFDs/Actuators

Field Instruments



HMI Components

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Enterprise Systems

Remote Site Telemetry

HMI/OIT

Controllers

Packaged Vendor Systems

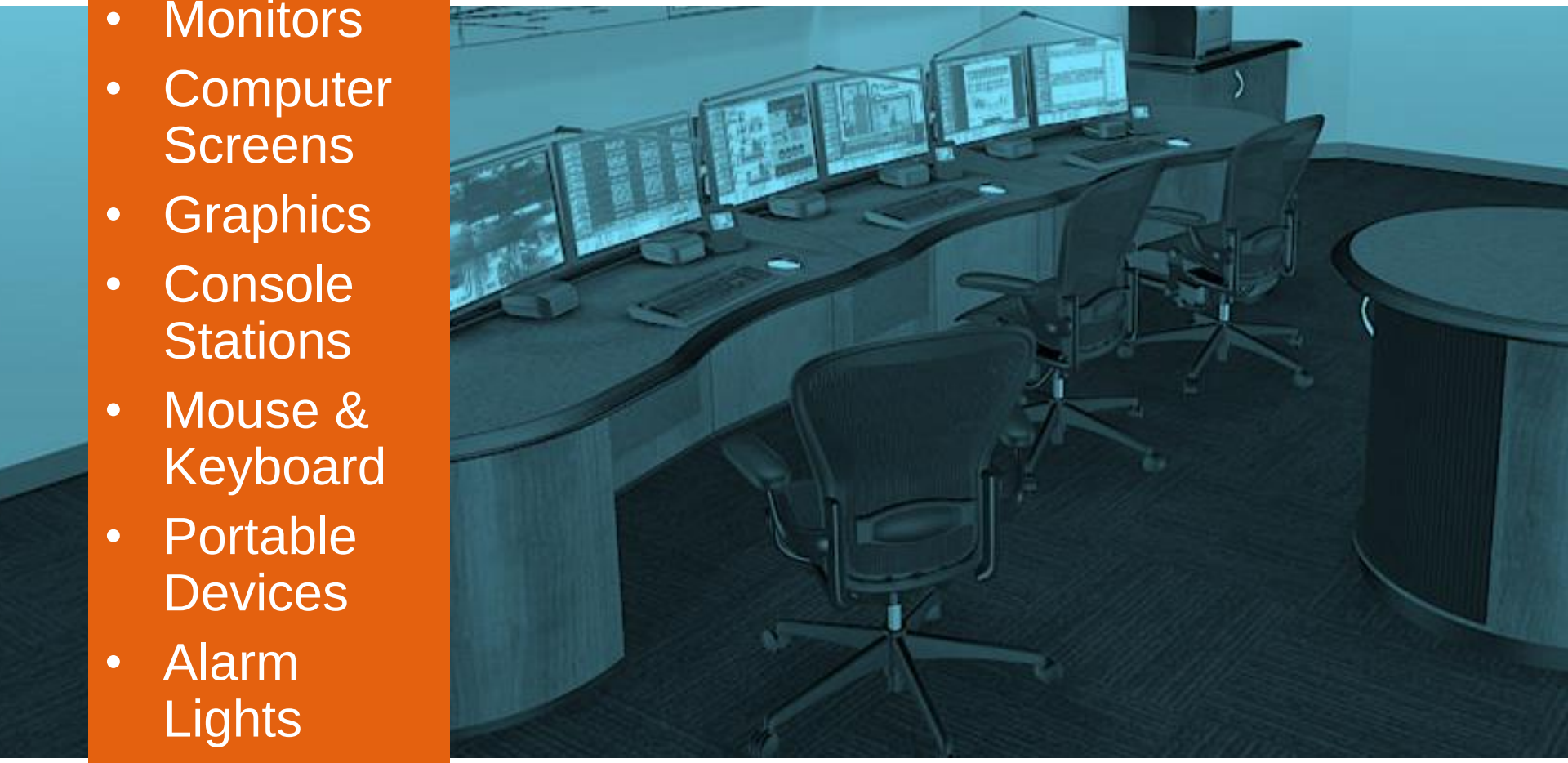
VFDs/Actuators

Field Instruments

HMI - Human Machine Interface – The collection of displays (hardware and software) that allows an operator to “see and hear” the process

The Plant Control Room

- Monitors
- Computer Screens
- Graphics
- Console Stations
- Mouse & Keyboard
- Portable Devices
- Alarm Lights
- Audible Devices



History of HMIs: …80s, early 90s

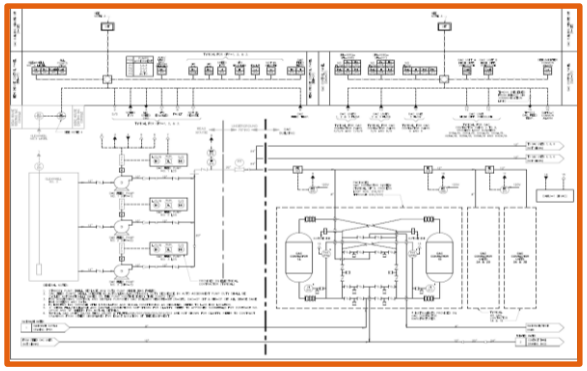
History of HMIs: 90s/00s

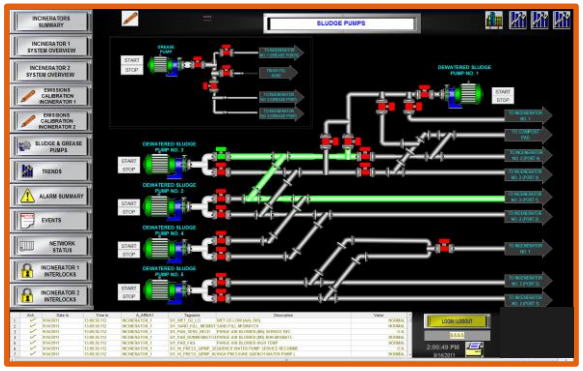
Computerized SCADA systems

Control engineer prepares Process and Instrumentation Diagrams (P&IDs)

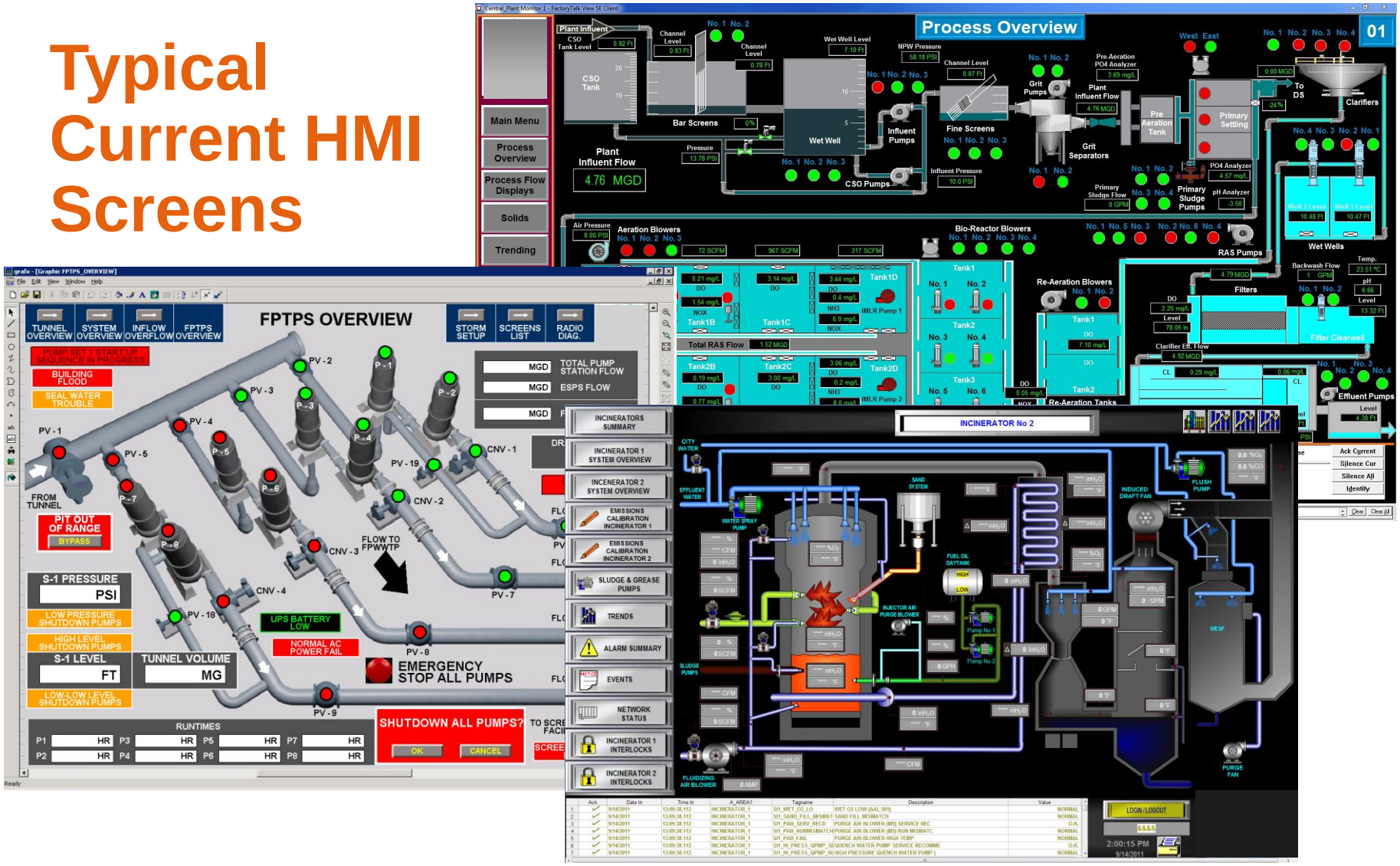
HMI software provides toolkits, features, objects, colors

Contractor/System Integrator configures HMI based on P&IDs and specifications





Typical Current HMI Screens



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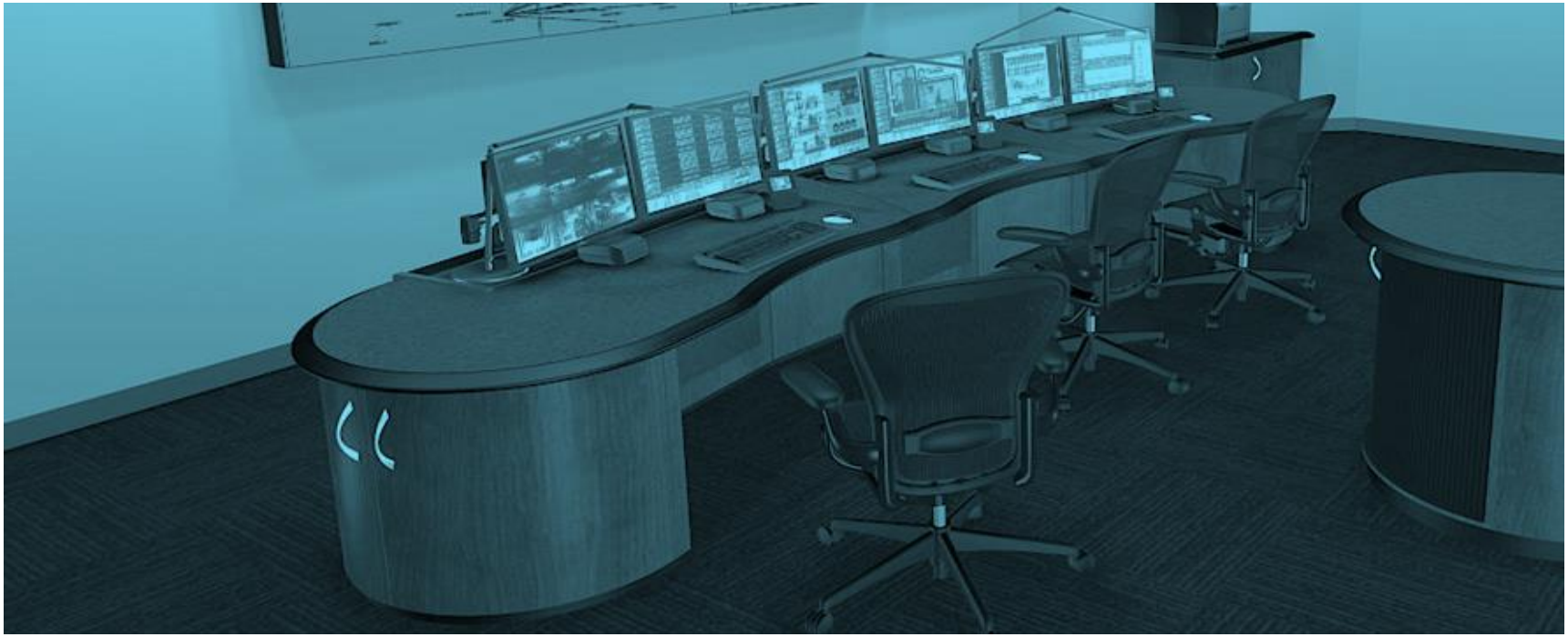
2. SITUATIONAL AWARENESS

Situational Awareness (SA)

Boeing 777 Cockpit

Situational awareness (SA) is the **perception** of environmental elements with respect to time or space, the **comprehension** of their meaning, and the **projection** of their status after some variable has changed, such as time, or some other variable, such as a predetermined event.

Situational Awareness (SA)



“The relationship between the operator's understanding of the plant's condition and its actual condition at any given time”

- (International Society of Automation (ISA)

HMI Impacts to SA

Performance shaping factors:

- "Attention tunneling"
- Reliance on Short-term Memory
- Physical and mental stress
- Too much data
- Misplaced emphasis
- Increasing Complexity
- Improper Mental Model
- Automation, loss of institutional knowledge ("out-of-the-loop") syndrome

Source: Designing for Situational Awareness: An Approach to User-Centered Design, 2nd Edition, Endlsey

“Too much data” “Increasing Complexity”

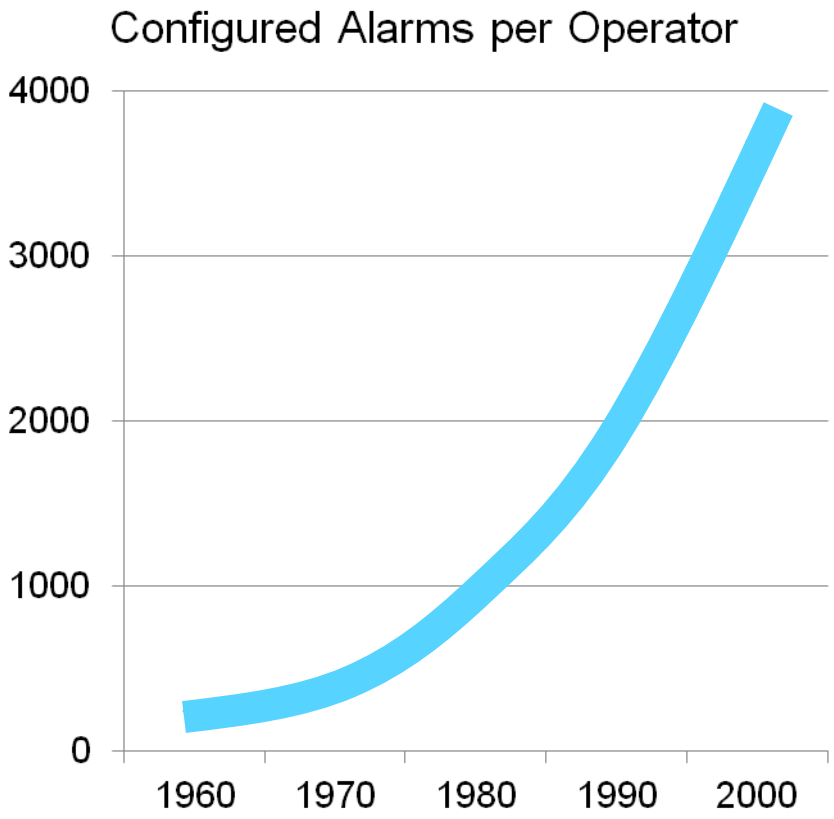
Too many alarms

Too many options

Easy to configure

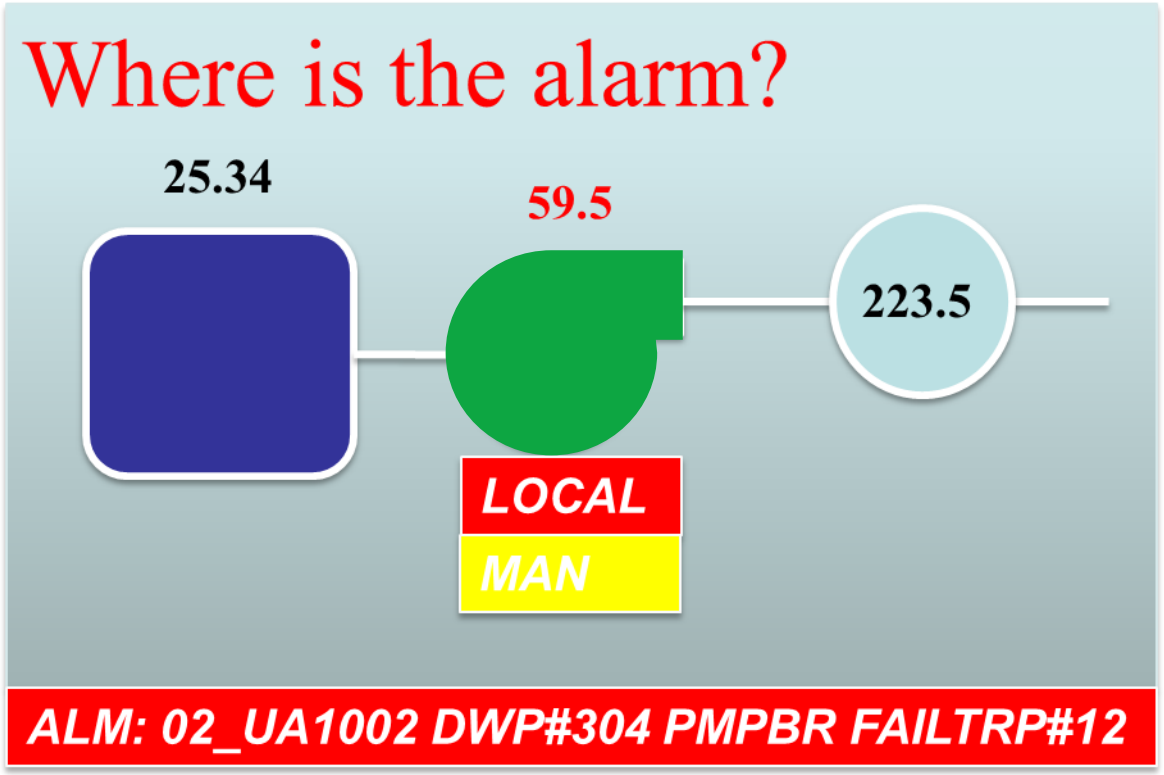
Built-in alarms for analog

Custom graphics development



“Attention Tunneling” “Loss of View”

“Misplaced Emphasis” “Too much data”



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3. “HIGH PERFORMANCE” HMI

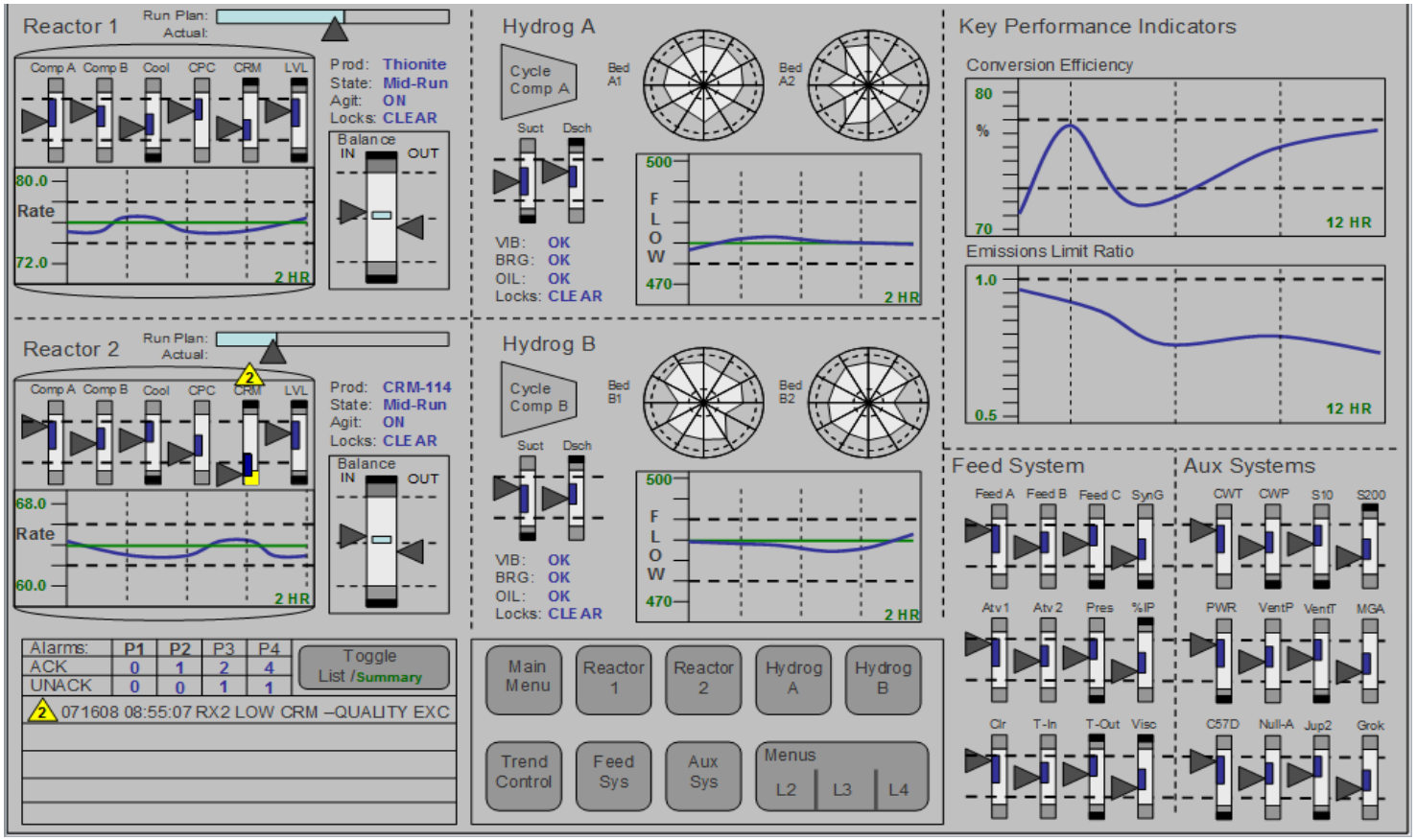
High Performance HMI

Terms:

- “High Performance”
- “High Impact”
- “Next Generation”
- “Situational Awareness”

HPHMI - *Providing an interface to the process that is operator-centric, and focuses on human factors, the operator’s mental model, and enhancing the operator’s situational awareness.*

Vision



Source: HMI Handbook

Vision

Display

- Contrast
- Repetition
- Alignment
- Proximity

Graphic Development

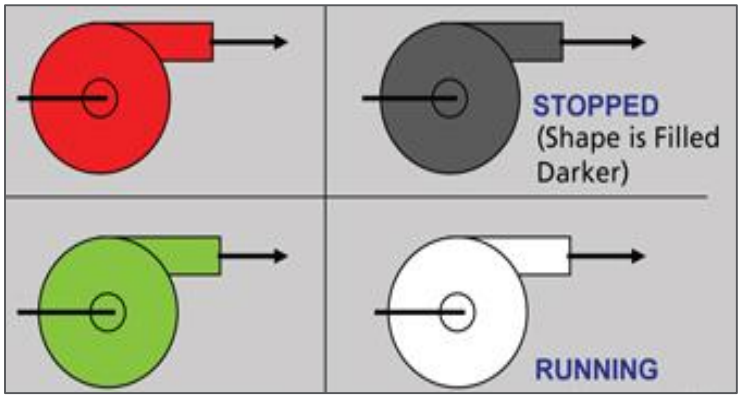
- **Use of Color and Shape**
- **Use of Patterns**
- **Use of Trends**

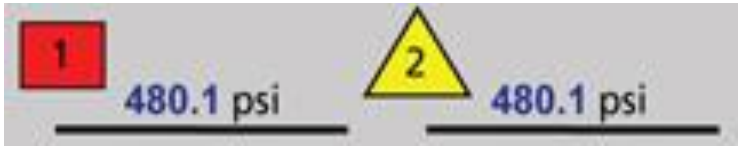
Source: Stock Photo

Use of Color and Shape

Use color and shape to focus attention

- Muted Background (Gray)
- Avoid Run/ Stop/ Open/Close Color, use contrast instead
- Indicate alarms with both color and shape

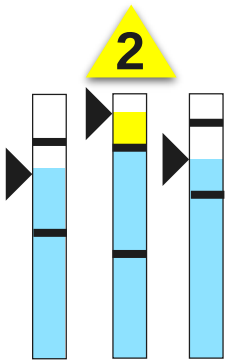


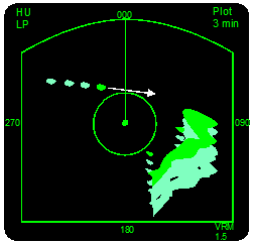


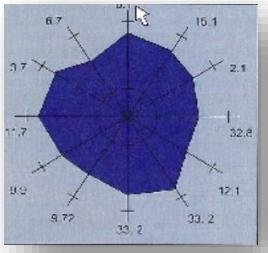
Source: The High Performance HMI Handbook (Hollifield et al., 2008].

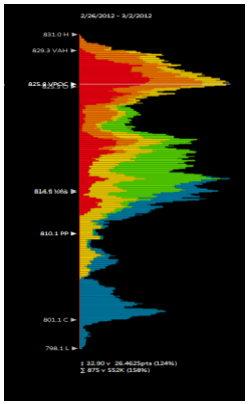
Use of Patterns and Analog Indicators

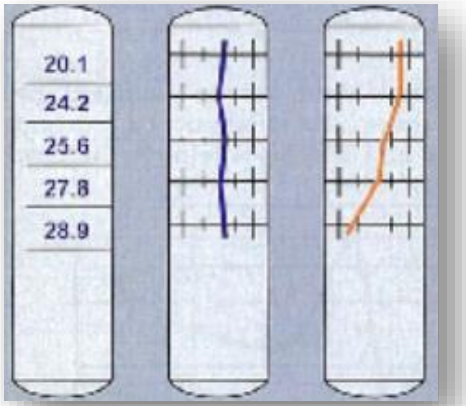
- “At-a-Glance”
- Analog Indicator
- Pattern Recognition Objects (PROs)
  - Profile Displays
  - Radar Plots











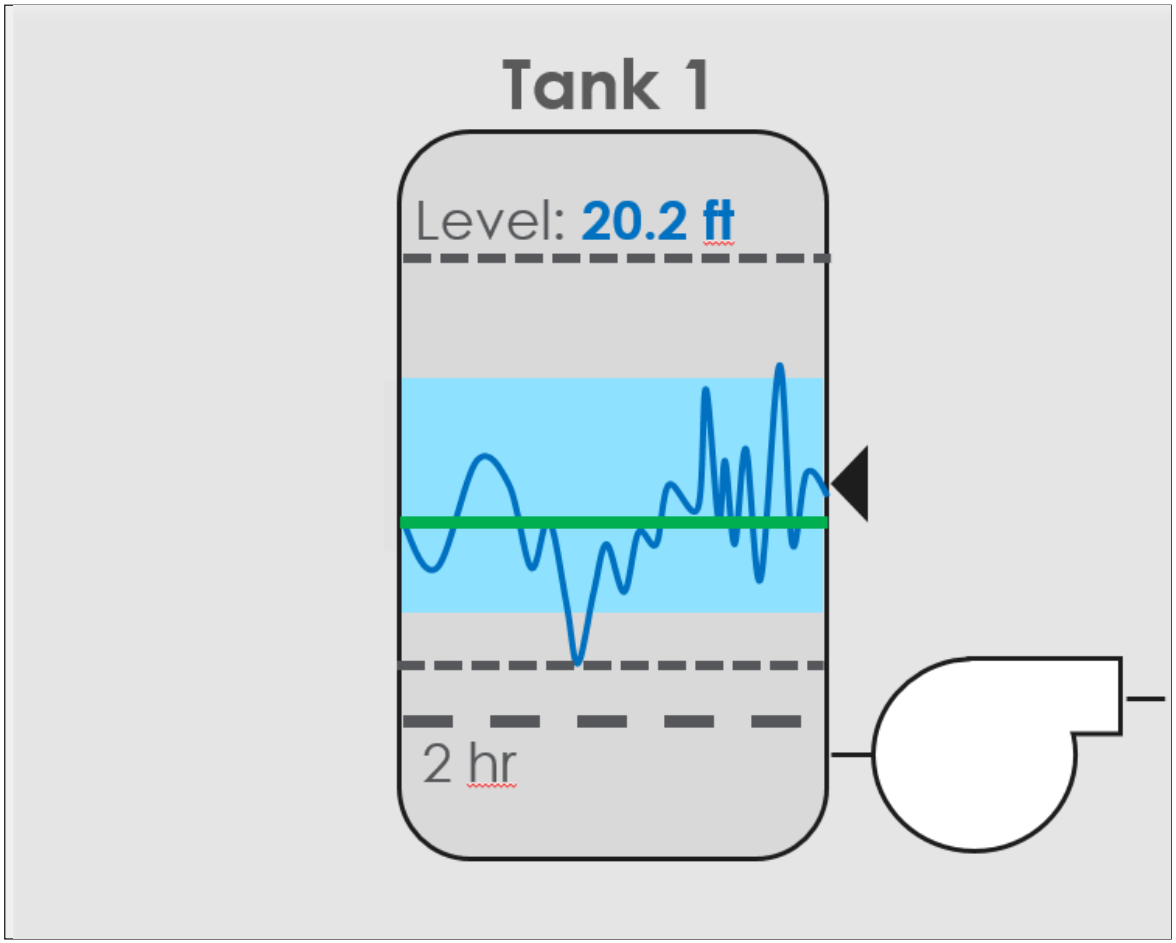
Source: The High Performance HMI Handbook (Hollifield et al., 2008].

Use of Analog – Car HMI Example

Useful to the driver (operator)?

Use of Trends

- Enhanced use of trends
- Embedded “road-map” trending
- Features:
  - Alarm and shutdown levels
  - Setpoints
  - Time interval



Hearing

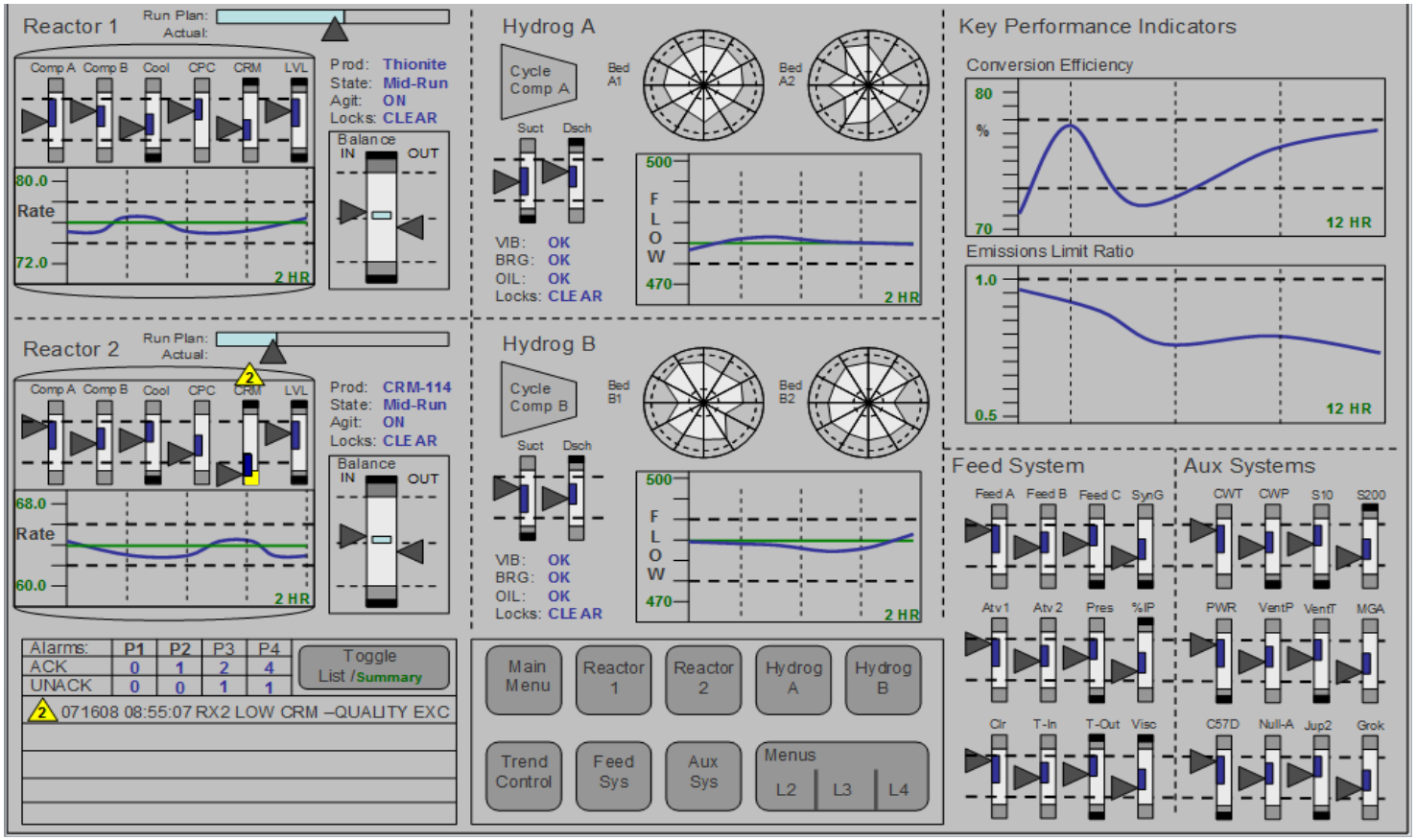
Ability for humans to distinguish sounds is exceptional.

Example: Car HMI unique sounds:

- Driver opens the door with keys in the ignition
- There is low tire pressure
- Outside temperature falls below 3C (37F)
- The windshield washer fluid is low

Source: Stock Photo

High Performance HMI



Source: HMI Handbook

ISA Standard 101 – HMI Lifecycle Model

ANSI/ISA 101 (2015) Human Machine Interfaces for Process Automation Systems

- Builds on and brings together threads from various sources (industry / academic partners)
- Establishes consistent approach to HMI development (process industries)

API 1165 *Recommended Practice for Pipeline SCADA Displays*

ASM Consortium Guidelines Rev 3-2008 *Effective Operator Display Design*

ANSI/HFES 100-2007 *Human Factors Engineering of Computer Workstations*

ANSI/HFES 200-2008 *Human Factors Engineering of Software User Interfaces*

ISO 9241 *Ergonomic requirements for office work with display terminals*

ISO 11064 *Ergonomic design of control centers*

EEMUA 201 *Process plant control desks utilizing human-computer interfaces: a guide to design and human-computer interfaces*

NUREG-0700 Rev. 2-2002 *Human-System Interface Design Review Guidelines*

ISA Standard 101 – Lifecycle Approach

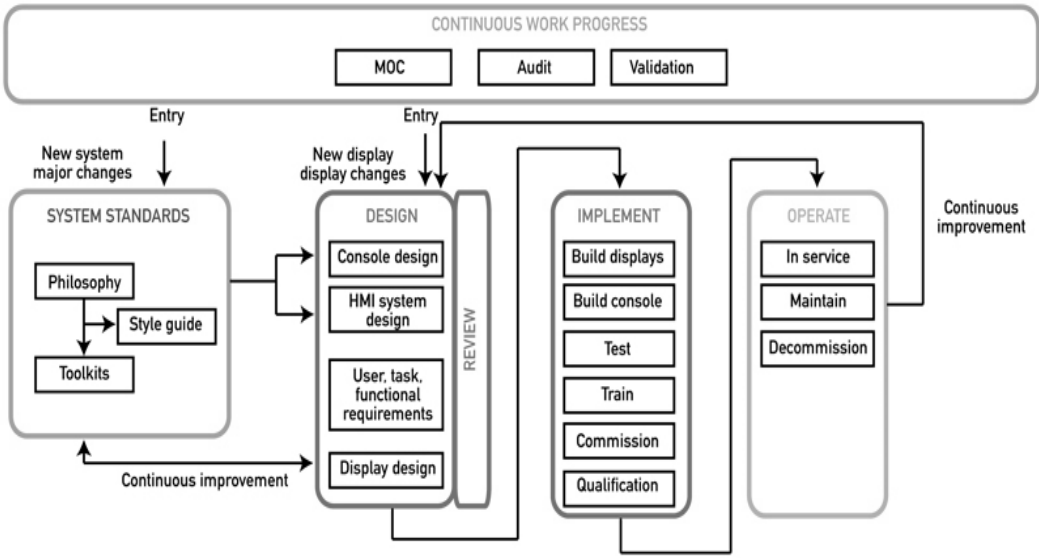
Considerations of sensory and cognitive limits of operators, situational awareness, ergonomics

Focus is on HMI lifecycle

Custom Approach

- HMI Philosophy
- Style Guide

Consistent Documentation	Continuous Work Processes
• HMI Philosophy • Style Guide • Toolkits	• Change Management (MOC) • Audit • Validation

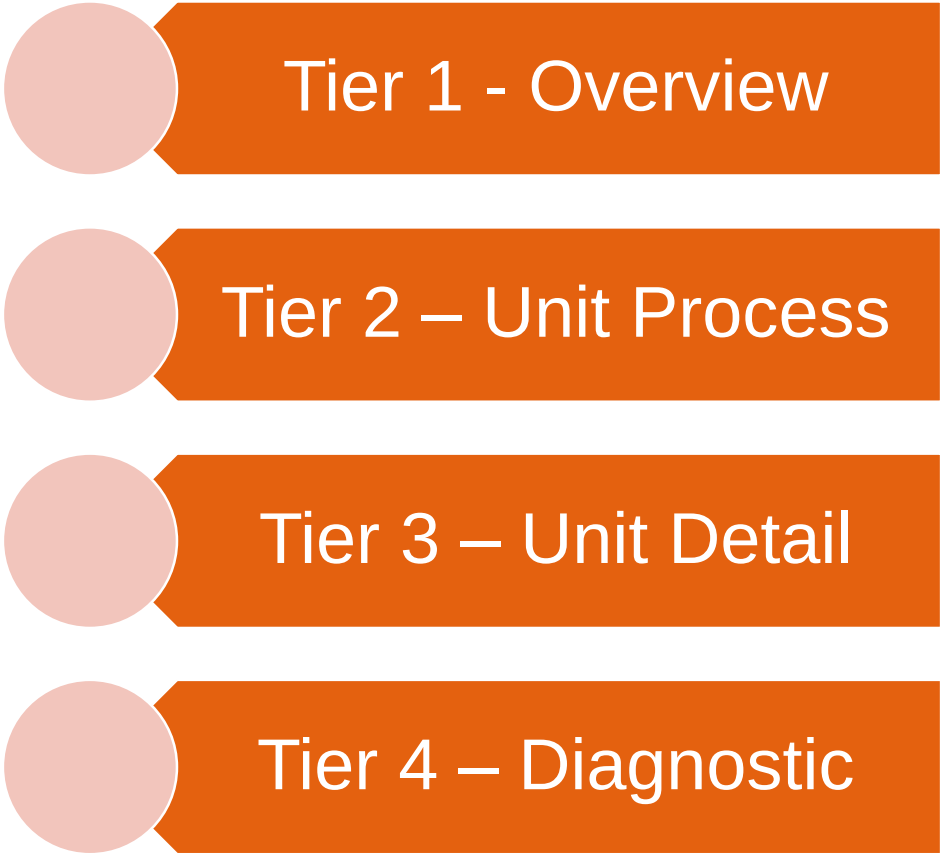


Tiers of HPHMI

Philosophy

Navigation

Style Guide



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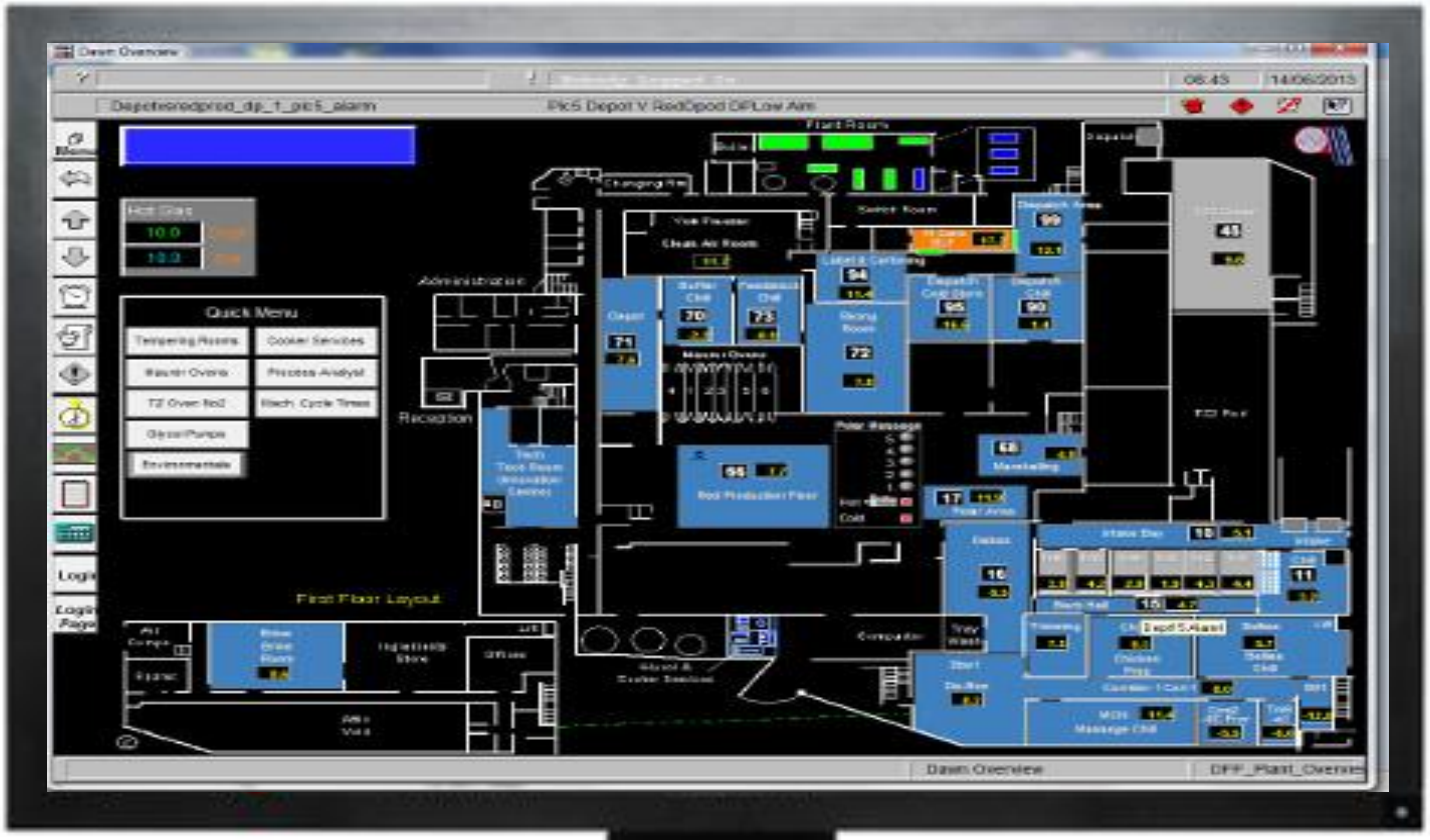
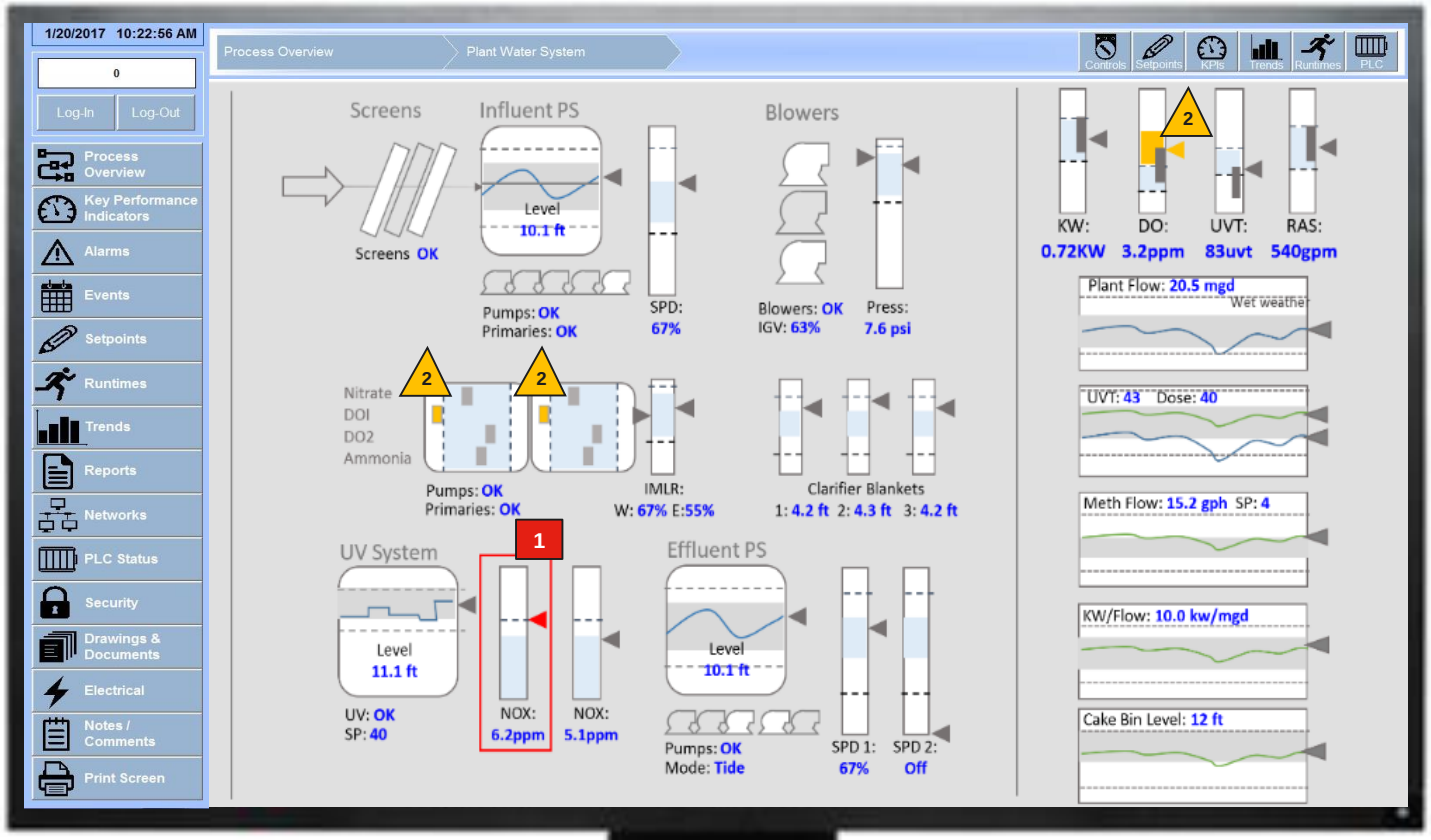
4. EXAMPLES OF HPHMI IMPLEMENTATION

Example – Tier 1 – Plant Overview



Is the plant doing OK?

Example – Tier 1 – Plant Overview



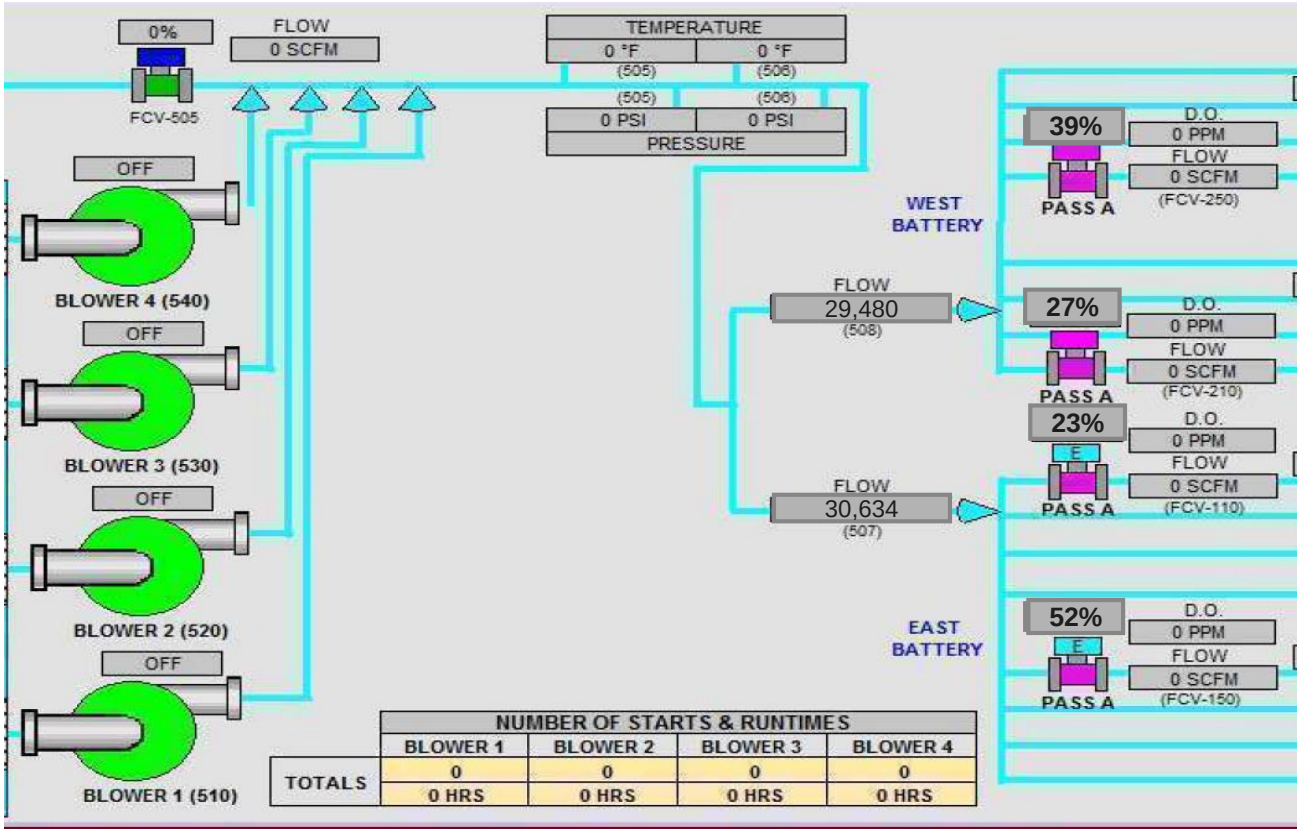
Is the plant doing OK?

Example – Tier 2 – Unit Process

Process Air Unit Process

Header Distribution

MOV Control/ Balance



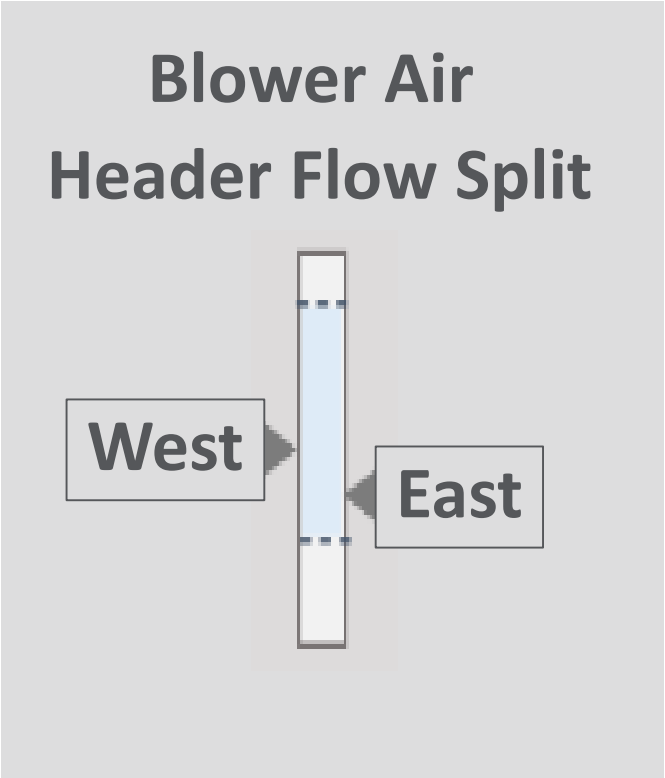
Is flow balanced?

Example – Tier 2 – Unit Process

Process Air
Unit Process

Header Distribution

MOV Control/ Balance



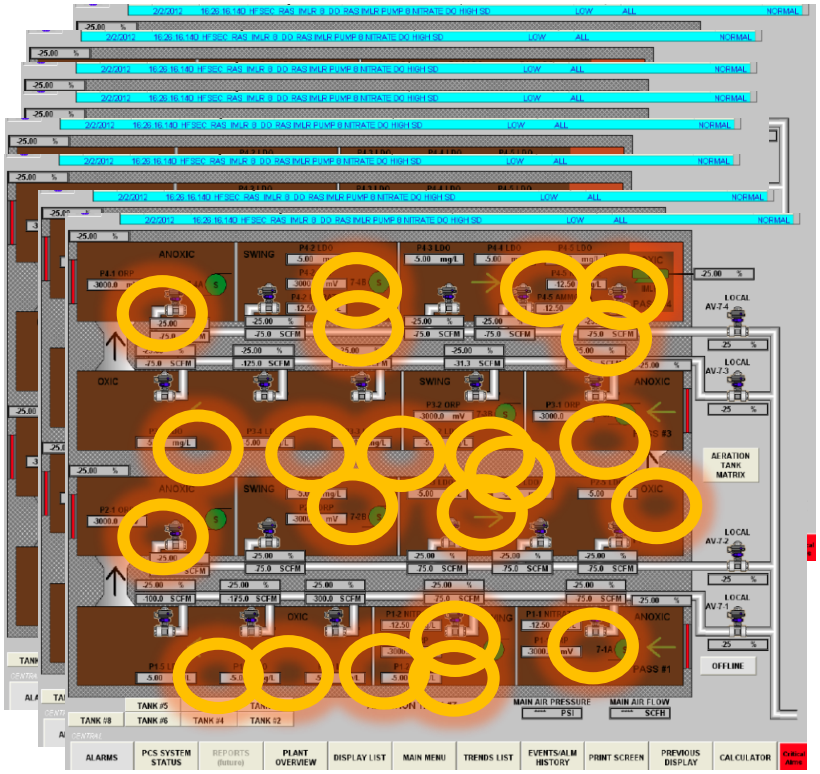
Is flow balanced?

Example – Tier 2 – Unit Process

BNR Unit Process

Nitrogen Removal Process

Multiple Analytical Values to review/ check



Is BNR within range?

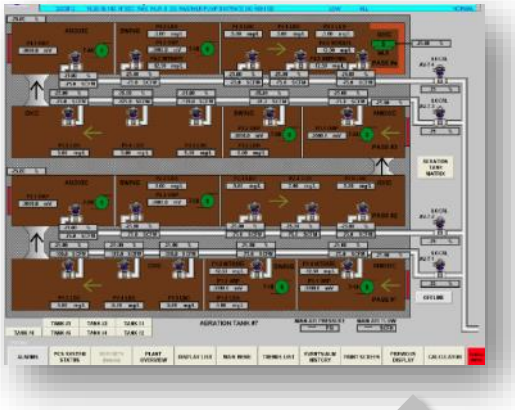
HPHMI Approach

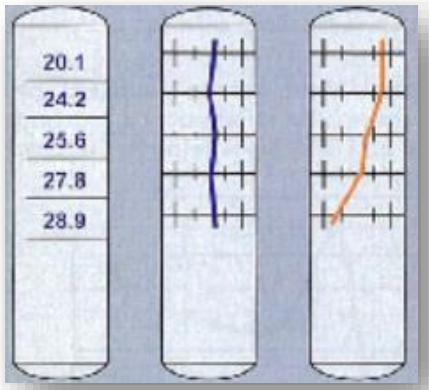
Challenges:

- “Loss of view”
- “Too much data”

Opportunities:

- PRO Object Development
- See “at-a-glance”

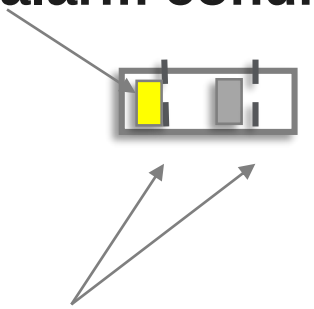




PRO in Practice

Parameter	iFix HMI Range	"Good" Process Range		(FOR HMI CONFIG ONLY) Normalized PRO Object Limits (Horizontal Pos.)	
		Lower	Upper	Lower	Upper
NITRATE (Pass 1-1/ Pass 4-2)	0-20 ppm	0.5 ppm	3 ppm	-0.75	4.25
NITRATE (Pass 4-5)	0-20 ppm	2 ppm	6 ppm	0	8
DO (all locations)	0-5 ppm	1 ppm	2.5 ppm	0.25	3.25
ORP (anoxic)	-2000-+2000mV	-80 mV	+20 mV	-100	100
Ammonia (Pass 4)	0 – 50 ppm	2 ppm	5 ppm	0.5	6.5

Low alarm condition



Normal Process Range

Outside normal process range, yellow indicates alarm condition

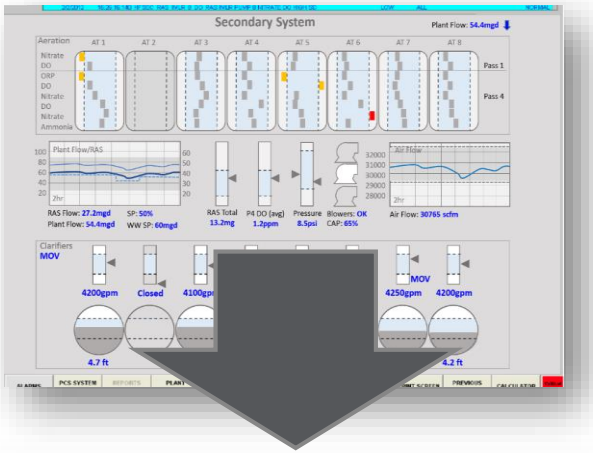
Use red for nitrate/ammonia as higher priority alarm than DO

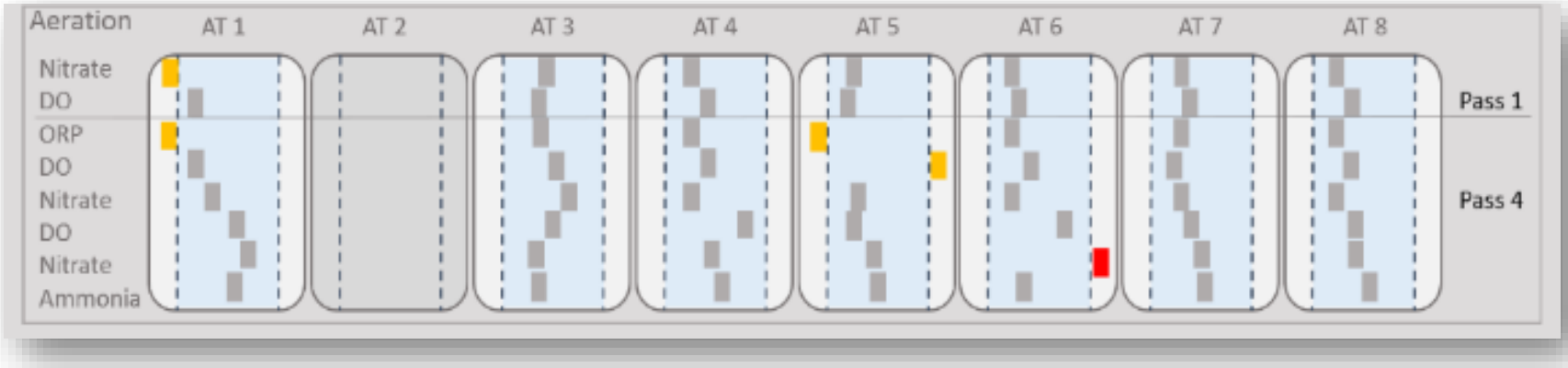
Example – Tier 2 – Unit Process

Entire Secondary

Profile Displays

- DO, Nitrate, Nox
- RAS, etc.





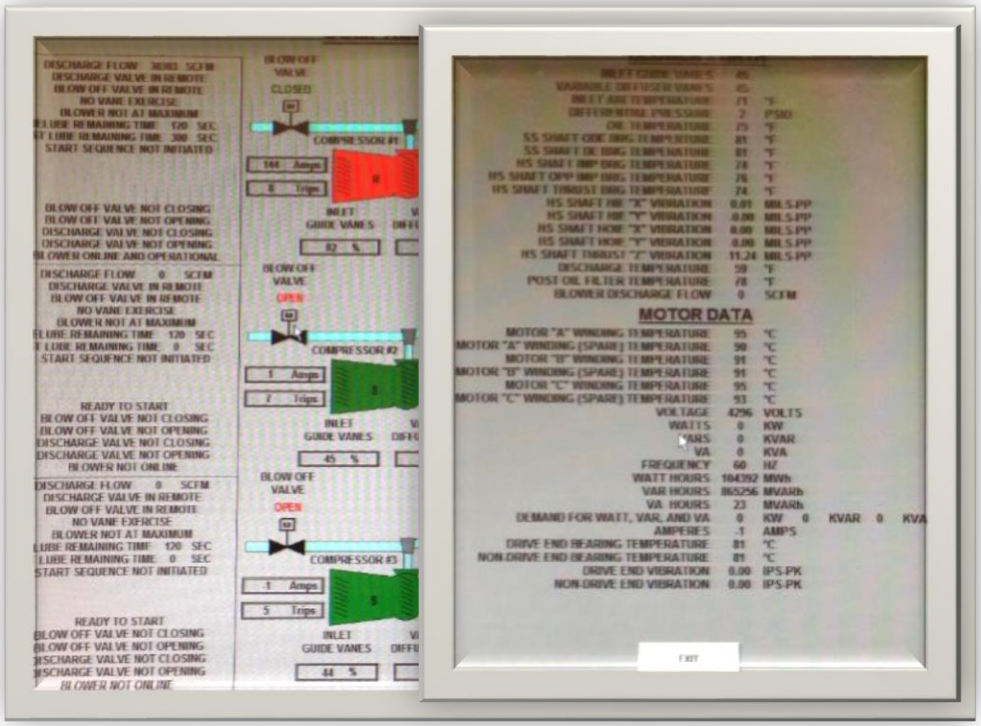
Is BNR within range?

Example – Tier 3

Equipment monitoring

Blower Information:

- Scroll through many screens
- No summary, at-a-glance
- Alarming issues
- Too much information
- Too little information



Is the 1,000 HP Aeration Blower running OK?

Example – Tier 3

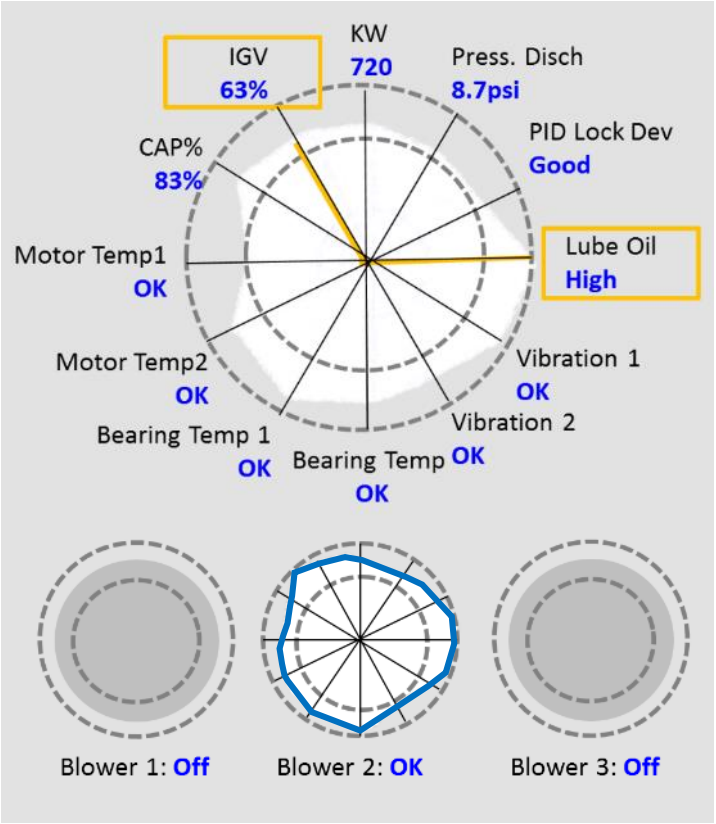
Develop Tier I Screen

Multivariable

At-a-glance, normalize parameters in PRO:

- Capacity
- Temperatures
- Vibrations
- Deviation from SP

From 6 screens with 80+ numbers to….1 screen



Is the 1,000 HP Aeration Blower running OK?

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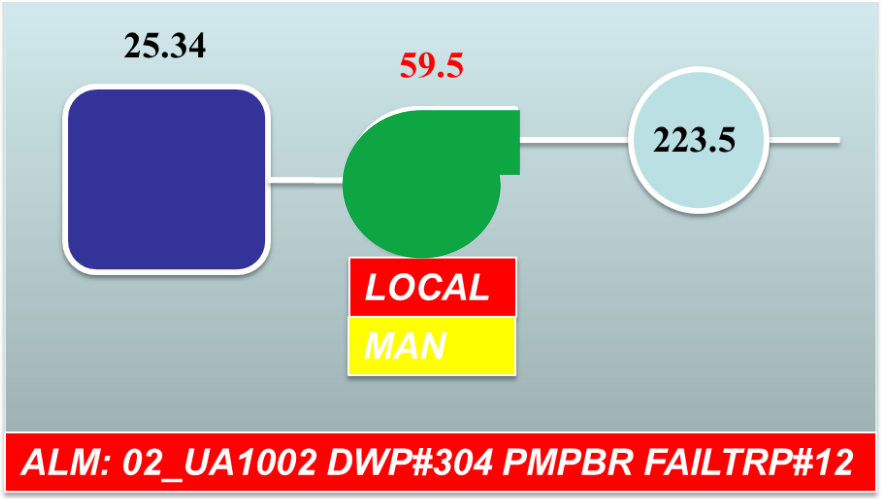
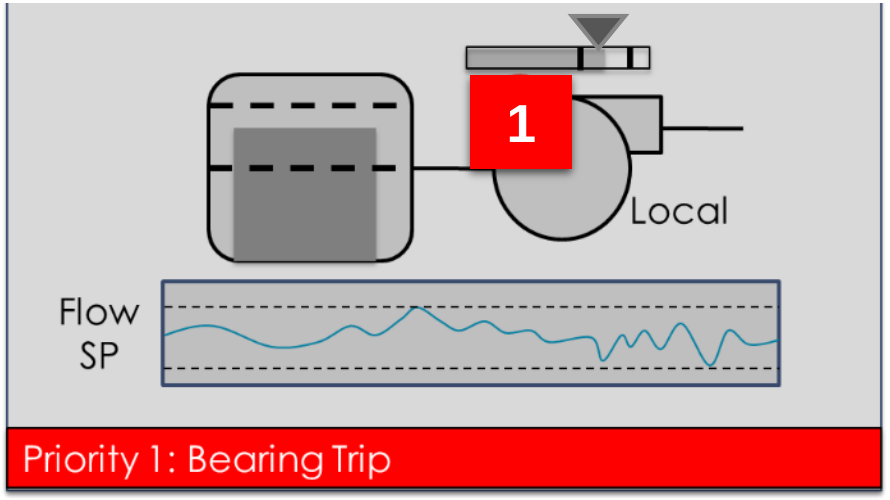
5. ALARM MANAGEMENT – AN INTEGRAL ASPECT OF HPHMI

HMI Design for Alarms

HMI design directly impacts emphasis of abnormal condition. Which HMI is better?



Option 1



Option 2

Alarm defined by number, color, shape, sound.

Definition of an alarm

"An audible and/or visual means of indicating to the **operator** an equipment malfunction, process deviation, or abnormal condition requiring a **response**."

- ANSI/ISA 18.2-2009 Management of Alarm Systems for the Process Industries

HMI Alarm Problems

Typical SCADA Issues:

- Nuisance alarming
- Alarm Floods
- Alarm Chatter
- Stale Alarms
- Suppressed Alarms
- Event “Alarms”

Poor alarm management can contribute to loss of situational awareness

ISA 18.2 Alarm Management Framework

Alarm Philosophy
- Priority
- Distribution

Rationalize
- “Bad Actor” Resolution
- Measure and Benchmark

Audit

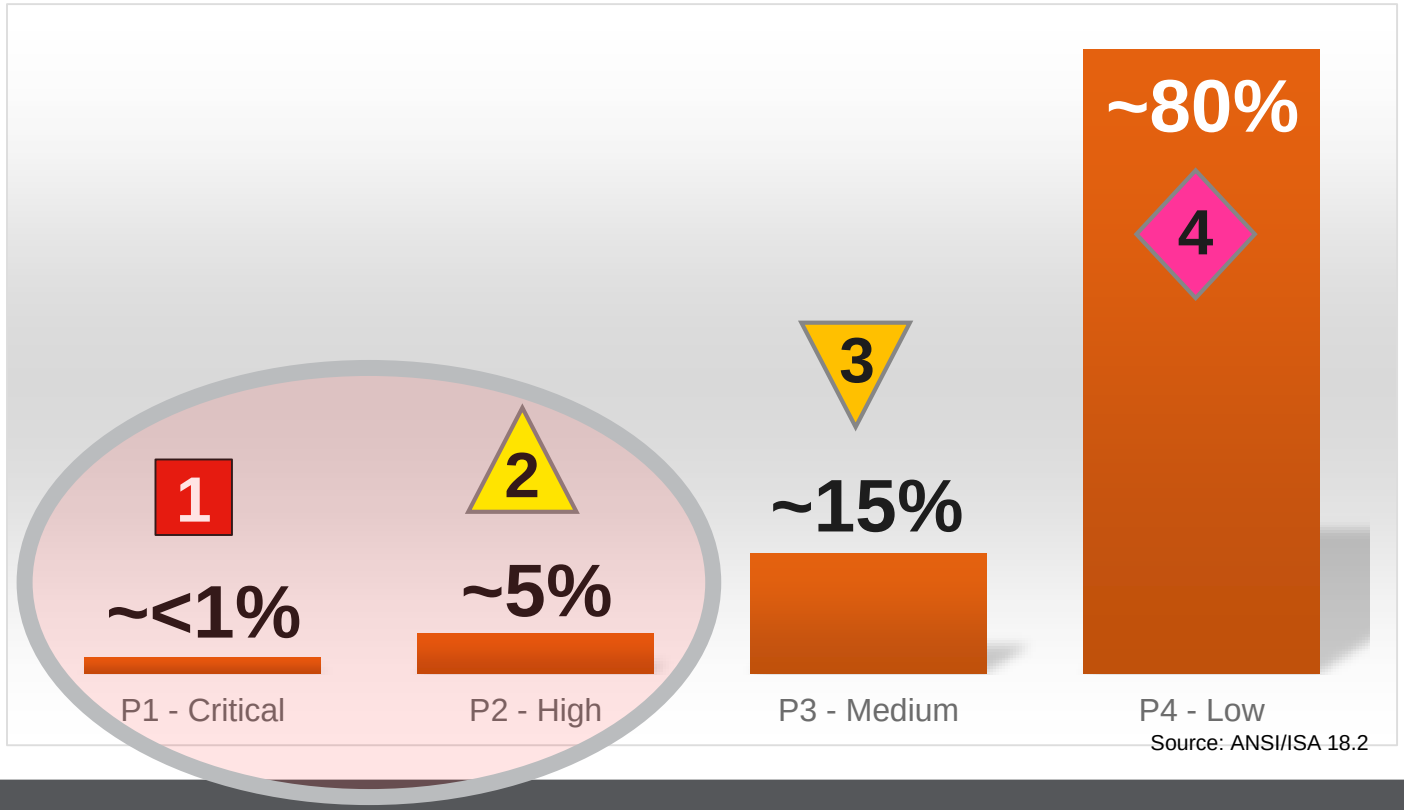
Alarm management life cycle stage		Activities
Stage	Title	
A	Philosophy	Define processes … m management and ASRS*
B	Identificatio	Determine potential a…
C	Rationaliz…	Rationalization, classi… prioritization, and documentation
D	Detailed …	Basic alarm design, HM…gn, and advanced alarming desig…
E	Implement…ion	Install alarms, initial tes… d initial training
F	Opera…	Operator responds to a… refresher training
G	Maintena…	Maintenance repair a… cement and periodic testing
H	Monitoring … essment	Monitoring alarm d… report performance
I	Management o… e	Process to autho… itions, modifications, and deletions … s
J	Audit	Periodic au… arm management proces…

Not just during startup and commissioning of a SCADA system….but continuously update.

Source: ANSI/ISA 18.2

HMI alarm priorities

ISA 18.2-2009 suggests 3 (or 4) priorities. Distribution shown below:



Source: ANSI/ISA 18.2

Critical alarms should comprise ~5% of total alarms.

HMI Alarm Metrics and Benchmarking

Alarms **"acceptable"** ~1/10 min (150/day)

Alarms **"maximum manageable"** ~2/10 min (300/day)

Alarm **Floods:** No more than 10 alarms / 10 min

Priority **Distribution:** ~5% or less, Highest Priority

Stale and **Chattering** Alarms: Zero

Alarm performance metrics Based on at least 30 days of data		
Metric	**Target value**	
Annunciated alarms per operating position	Target value: very likely to be acceptable	Target value: maximum manageable
Annunciated alarms per day per operating position	~150 alarms per day	~300 alarms per day
Annunciated alarms per hour per operating position	~6 (average)	~12 (average)
Annunciated alarms per 10 minutes per operating position	~1 (average)	~2 (average)
Metric	**Target value**	
Percentage of hours containing more than 30 alarms	~<1%	
Percentage of 10-minute periods containing more than 10 alarms	~<1%	
Maximum number of alarms in a 10-minute period	≤10	
Percentage of time the alarm system is in a flood condition	~<1%	
Percentage contribution of the top 10 most frequent alarms to the overall alarm load	~<1 to 5% maximum, with action plans to address deficiencies	
Quantity of chattering and fleeting alarms	Zero, action plans to correct any that occur	
Stale alarms	Less than 5 present on any day, with action plans to address	
Annunciated priority distribution	3 priorities: ~80% low, ~15% medium, ~5% high or 4 priorities: ~80% low, ~15% medium, ~5% high, ~<1% "highest" Other special purpose priorities excluded from the calculations	
Unauthorized alarm suppression	Zero alarms suppressed outside of controlled or approved methodologies	
Unauthorized alarm attribute changes	Zero-alarm attribute changes outside of approved methodologies or management of change	

Source: ANSI/ISA 18.2

Conclusions: Benefits of HPHMI

Before

- Engineer and software features drives design
- Ineffective overview of processes
- Emphasis on numerical displays
- Little use of embedded trending
- Poor use of color
- Too many alarms to handle

After

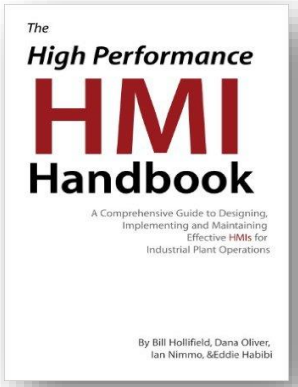
- Design driven by operator mental model
- Effective “at-a-glance” process overviews
- Emphasis on analog displays and patterns
- Effective use of roadmap trending
- Appropriate use of color
- Alarms properly rationalized

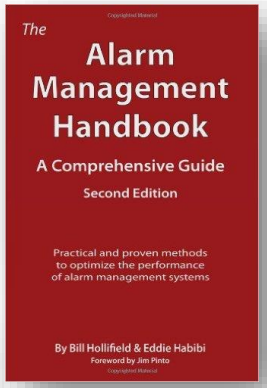
Increasing situational awareness & effectiveness of HMI

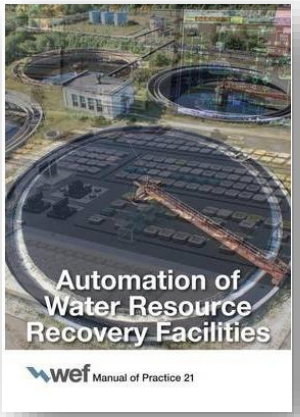
Revisit Learning Objectives

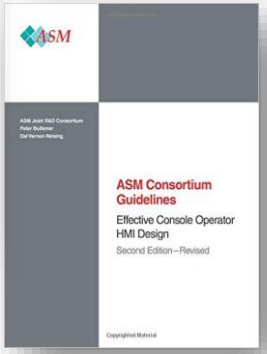
- Recognize key components of a plant or facility **Human Machine Interface** (HMI)
- Define **situational awareness** as it relates to SCADA systems and identify common HMI pitfalls working against it
- Describe how High Performance HMI (HPHMI) **concepts** serve to enhance situational awareness
- Identify how **methodologies** such as ANSI/ISA 18.2 alarm management approach support HPHMI and are critical to SCADA system success
- Outline how to **benchmark and measure** the performance of HPHMIs and related alarm management systems

References









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Q&A

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