ISA 101 and HMI Workshop

Bridget A. Fitzpatrick
Wood Group Mustang

MESA KNOWS
SUSTAINABILITY & ECO-EFFICIENCY - LEAN - METRICS & PERFORMANCE MANAGEMENT
INFORMATION INTEGRATION - SAFETY - ASSET PERFORMANCE MANAGEMENT - B2MML
QUALITY & COMPLIANCE - PRODUCT LIFECYCLE MANAGEMENT - AUTOMATION

Do you know MESA?
Topics

• Industry Guidelines and Standards
• ISA 101 Status, Purpose, Scope
• ISA 101 Lifecycle
• Key Human Factors Issues
• Display Types
• User Interaction
• Performance
• Training
• Questions
Bridget’s background

• Wood Group Mustang, ~9 years
  – Practice Lead for HMI, Abnormal Condition Management and Human Factors Engineering
  – Responsible for Quality on all HMI (5-15k displays per year)

• Celanese AG, ~15 years
  – Optimization Engineer
  – Energy Team Lead
  – Control Section Lead
  – Control Engineer
  – Process Design Engineer

• ISA Volunteer, >20 years
  – ISA 101 Voting Member, Clause Leader (2 clauses)
  – ISA 18 Voting Member, WG6 Co-chair
  – ISA 84 and 106, Information Member
Guidelines/Standards on HMI

- ISA 101 Human Machine Interfaces for Process Automation Systems (draft)
- 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 visual display terminals
- ISO 11064 Ergonomic design of control centres
- EEMUA 201 Process plant control desks utilising human-computer interfaces: a guide to design, operational and human-computer interface issues
- NUREG-0700 Rev. 2-2002 Human-System Interface Design Review Guidelines
The current co-chairs of ISA101 HMI Committee are:

- **Dr. Maurice Wilkins** *(Yokagawa)* and **Greg Lehmann** *(URS)*

<table>
<thead>
<tr>
<th>Clause</th>
<th>Title</th>
<th>Leaders</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>General</td>
<td>Maurice Wilkins, <em>Yokagawa</em></td>
</tr>
<tr>
<td>1</td>
<td>Scope</td>
<td>Maurice Wilkins, <em>Yokagawa</em></td>
</tr>
<tr>
<td>2</td>
<td>Normative References</td>
<td>Nick Sands, <em>Dupont</em> &amp; Dale Reed, <em>Rockwell</em></td>
</tr>
<tr>
<td>3</td>
<td>Definition of Terms and Acronyms</td>
<td>Nick Sands, <em>Dupont</em> &amp; Dale Reed, <em>Rockwell</em></td>
</tr>
<tr>
<td>5</td>
<td>Human Factors/Ergonomics</td>
<td>Beth Vail, <em>URS</em> &amp; Traci Laabs, <em>Pfizer</em></td>
</tr>
<tr>
<td>6</td>
<td>Display Types</td>
<td>Dave Lee, <em>UCDS, Inc.</em> &amp; John Benitz, <em>Applied Control Engineering</em></td>
</tr>
<tr>
<td>8</td>
<td>Performance</td>
<td>Mark Nixon, <em>Emerson</em></td>
</tr>
<tr>
<td>9</td>
<td>Documentation and Training</td>
<td>Dawn Schweitzer, <em>Eastman Kodak</em></td>
</tr>
</tbody>
</table>
Status of ISA 101 Standard

• Editors reviewing and resolving comments from Draft 3\(^1\).
• Committee consensus that this will be a “Standard”.
• Technical Reports and Recommended Practices will be developed as warranted.
Purpose of the Standard

• Address the design, implementation, and maintenance of human machine interfaces (HMIs) for process automation systems.

• Use of this standard should:
  – Provide guidance to design, build, operate, and maintain effective HMIs which result in safer, more effective, and efficient control of the process, in both normal and abnormal situations.
  – Improve the user’s abilities to detect, diagnose, and properly respond to abnormal situations.
Scope of the Standard

• This standard addresses HMIs for equipment and automated processes.
• If the standard, recommended practices, and methodology are followed, the result should enable the users to be more effective in yielding:
  – improved safety,
  – quality,
  – production and
  – reliability.
• The practices in this standard are applicable to continuous, batch, discrete processes, and any process using an HMI for interfacing to a controlled system.
Intended Audience

• Users
  – Responsible for safe and productive operation of equipment and facility

• Integrators, Designers, Engineers
  – Design and build the HMI applications

• Vendors
  – Develop the software tools needed to build the HMI application
  – Develop the interfaces / drivers needed for an HMI to transfer data and information to and from multiple sources
Benefits of Standards

• Consistency in execution
  – Easier to implement new applications
  – Easier to hand off to third party developers

• Less time to train users

• Less operator error as a result of consistent effective design

• Easier to move between platforms or versions of an HMI

• Saves time and money!
Why the Concern about HMIs?

The power of knowing what MESA KNOWS
HMI in the News

• BP Texas City 3/23/05
  – “The control board display did not provide adequate information on the imbalance of flows in and out of the tower to alert the operators to the dangerously high level.”

• Texaco, Milford Haven, UK 7/24/94
  – “Control panel graphics did not provide necessary process overviews.”

• Best to keep the HMI out of the news!

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HMI Basic Definitions

- Definitions include:
  - Console,
  - Station,
  - Pointing Device,
  - Keyboard,
  - Display,
  - Pop-up,
  - Graphic Symbols,
  - Graphic Elements.
Potential Compliance Requirements

• Documents required
  – HMI Philosophy
  – HMI Style Guide
  – HMI Toolkit
  – HMI Design Documentation
  – HMI Training Materials

• Work practices that align with the life cycle stages defined in the standard
  – Testing, Commissioning, Training
  – Management of Change
ISA 101 Life Cycle for HMI
Life Cycle Concept - Stages

- **System Standards**
  - Documents that set the foundation for all HMI design decisions
- **Design**
  - All hardware and software aspects of the HMI (review)
- **Implement**
  - Creation of the HMI in the target platform and hardware from building through test, train, commission and qualify
- **Operate**
  - Includes the normal operation and maintenance, as well as decommissioning
- **Continuous**
  - Management of change, Audit and Validation
Key “Documents” in System Standards

- HMI Philosophy
- HMI Style Guide
- HMI Toolkit (Documentation)
What is an HMI Philosophy?

• The HMI Philosophy is a strategic document addressing the guiding principles that govern the design structure of the HMI.
• Defines the alignment with:
  – human factors,
  – user, task and functional requirements for all modes of operation that require HMI support,
  – design standards, and
  – work practices for the development and management of the HMI.
• Provide a foundation of concepts such that new developers and users can grasp the underlying principles and technical rationales.
Why All Modes?

- CATASTROPHIC LOSS
  - ESD Fails
    - Unit Shutdown
      - Emergency Shutdown System (ESD) Acts
    - Emergency Operations
      - Significant efficiency and quality issues
      - Significant equipment damage
      - Injuries, environmental damage
      - Significant loss of production
    - Upset Operations
      - Large efficiency and quality issues
      - Minor equipment damage
  - Catastrophic loss
    - Equipment damage
    - Environmental damage
    - Significant loss of production
- Normal Operations
  - Some efficiency losses in raw materials and energy
  - Some off spec or lower quality product
- Optimal Operations
  - Peak efficiency and quality
- Emergency Operations
  - Significant efficiency and quality issues
  - Significant equipment damage
  - Injuries, environmental damage
  - Significant loss of production
- Upset Operations
  - Large efficiency and quality issues
  - Minor equipment damage
- Normal Operations
  - Some efficiency losses in raw materials and energy
  - Some off spec or lower quality product
- Optimal Operations
  - Peak efficiency and quality

The power of knowing what MESA KNOWS
Consider What to Show Carefully³

- Real-time Optimization and Manufacturing Execution Systems (RTO/MES)
- Knowledge-based Control
- Multi-variable Control
- Neural Networks or Others Models
- Multi-variable Control (DMC)
- Feed forward Control
- Code Control
- Logic Blocks
- Enhanced Control
- Basic Loop Control
- Loop Tuning
- Control Scheme Monitoring
- Basic Control
- Field Indication
- DCS Indication
- Field (Local) Controllers
- Field Control

The power of knowing what MESA KNOWS

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What is an HMI Style Guide?

- A Style Guide will include general design principles for the displays and implementation standards.
- Should reinforce the guiding principles from the Philosophy, including support for:
  - human factors,
  - users, task and functional requirements, and
  - design standards.
- Also includes:
  - Work practices recommended to manage the HMI,
  - Guidance on display types and their preferred use,
  - Guidance on expected HMI performance targets.
HMI Toolkit

• Typically platform dependent
  – So may have more than one Toolkit...

• May be vendor supplied, custom developed, or a combination of the two

• Includes templates and examples of all necessary graphic symbols and elements to implement an HMI application that meets the Style Guide requirements
## System Standards Stage

<table>
<thead>
<tr>
<th>Activity</th>
<th>Objectives</th>
<th>Inputs</th>
<th>Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>HMI Style Guide</td>
<td>Turns the guiding principles and concepts of the HMI Philosophy and turns them into implementation examples and guidance. (This does not include all technical details, though the style guide needs to be feasible in all target platforms).</td>
<td>HMI Philosophy, Platform experience and expertise (to confirm feasibility; develop early proof of concept designs).</td>
<td>HMI Style Guide Document</td>
</tr>
<tr>
<td>HMI Toolkit</td>
<td>Generate all requirement graphical symbols and other supporting elements as required to implement the Style Guide.</td>
<td>HMI Style Guide Document, Platform experience and expertise, Conceptual User, Task, Functional Requirements.</td>
<td>HMI Toolkit (Platform-specific).</td>
</tr>
</tbody>
</table>
• Console Design
  – What hardware and software will be in use (this is iterative with requirements)

• HMI System Design
  – User accounts, operating systems, toolkits, network, etc.

• User, Task, Functional Requirements
  – Once the basic user roles and requirements are defined, the actual tasks to be performed by the users are captured, reviewed and potentially optimized.

• Display Design
  – Finally, the actual displays...
User, Task, Functional Requirements

• A variety of simple and more complex techniques can be used:
  – Hierarchical Task Analysis
    • A comprehensive list of the tasks that make up a job or function are clustered / grouped to show the relationships for decision making.
  – Timeline Analysis
    • Tasks are broken down into events and shown on a chart over the time horizon.
  – Link Analysis
    • Demonstrates the frequency of linkage between tasks. Useful for streamlining tasks and optimizing display content.
  – Other more advanced techniques such Abstraction Hierarchical Analysis, Cognitive Work Analysis and Ecological Analysis exist but may require Human Factors Engineering (HFE) expertise to complete.
## Design Stage

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>User, Task and Functional</td>
<td>Identify primary and secondary requirements that <strong>must</strong> be supported in the HMI.</td>
<td>HMI Philosophy, HMI Style Guide, Console Design, User, Task and Functional Requirements Analysis.</td>
<td>Requirements document(s).</td>
</tr>
<tr>
<td>Functional Requirements</td>
<td></td>
<td>User, Task, Functional Requirements; Control System Design Standards, Network Design Standards, Preliminary Network Design.</td>
<td>HMI system design documents.</td>
</tr>
<tr>
<td>HMI System Design</td>
<td>Identify design basis for the HMI system.</td>
<td>User, Task, Functional Requirements; Control System Design Standards, Network Design Standards, Preliminary Network Design.</td>
<td></td>
</tr>
<tr>
<td>Console Design</td>
<td>To provide hardware and software design for the Console. This includes furniture and supporting systems (phone, radio, LAN PC, cameras, etc.).</td>
<td>.User, Task, Functional Requirements; Vendor Specifications, Human Factors Engineering Design Standards.</td>
<td>.Console design documents.</td>
</tr>
<tr>
<td>Display Design</td>
<td>Identifies conceptual design for displays and the navigation hierarchy. (This <strong>may</strong> include some prototype displays on complex applications or processes).</td>
<td>HMI Philosophy, HMI Style Guide, User, Task, Functional Requirements document(s), User Input in Review(s).</td>
<td>Display design document(s).</td>
</tr>
</tbody>
</table>
Implement Steps

- Build Displays
  - Yes, really, finally
- Build Console
  - The system to run them on...
- Test
  - Does it work?
- Train
  - Make sure it really works...
- Commission
  - Put it to work.
- Qualification
  - Extra paperwork in some industries.
## Implement Stage

<table>
<thead>
<tr>
<th>Activity</th>
<th>Objectives</th>
<th>Inputs</th>
<th>Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Build Displays</td>
<td>Complete construction of displays and supporting items.</td>
<td>Display design documents.</td>
<td>Displays.</td>
</tr>
<tr>
<td>Build Console</td>
<td>Complete construction of console hardware and software.</td>
<td>Console design documents.</td>
<td>Console</td>
</tr>
<tr>
<td>Commission</td>
<td>Final testing of HMI in Production Environment.</td>
<td>Console, Displays, User Manuals and Online Help (as required).</td>
<td>HMI Ready to Qualify (as required), Commissioning documents.</td>
</tr>
<tr>
<td>Qualification</td>
<td>Verify HMI Ready to Operate.</td>
<td>Qualification Plan, Commissioning documents.</td>
<td>Qualification documents, HMI Ready to Operate.</td>
</tr>
</tbody>
</table>
Operate Steps

• In Service
  – Finally!

• Maintain
  – Error fixes, tweaking after patches to maintain functionality

• Decommission
  – Partial decommissioning probably the most risky
  – BUT, we generally find ~30% abandoned in place0
## Operate Stage

<table>
<thead>
<tr>
<th>Activity</th>
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<th>Inputs</th>
<th>Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>In Service</td>
<td>HMI In Service.</td>
<td>Commissioning/Qualification Approval, User Manuals and Online Help.</td>
<td>HMI in Service.</td>
</tr>
<tr>
<td>Maintain</td>
<td>Ensure HMI is Valid and Reflects Current Process Conditions.</td>
<td>Approved Change Management requests to fix errors or to add enhancements or updates to reflect changes in the process.</td>
<td>Management of Change Logs, Updated HMI, User Manuals, Training Materials and Online Help.</td>
</tr>
<tr>
<td>Decommission</td>
<td>HMI Removed from Service (End of Life).</td>
<td>Change Management Change Requests.</td>
<td>HMI (or part of HMI) removed from use, archived for approved records period.</td>
</tr>
</tbody>
</table>
Continuous Work Processes

- MOC
  - Management of change (mainly outside the scope)
- Audit
  - No kidding, this should happen
- Validation
  - Formal steps required in some industries
## Continuous Work Processes

<table>
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<tr>
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<th>Inputs</th>
<th>Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Management of Change (MOC)</td>
<td>Manage change, ensuring consideration of all impacts.</td>
<td>Changes in process or User, Task and Functional Requirements</td>
<td>Change completed following the approved work practices</td>
</tr>
<tr>
<td>Audit</td>
<td>Verify that the HMI is being managed under the approved work practices</td>
<td>HMI Philosophy, HMI Style Guide, Related Documents</td>
<td>Audit Records, Change requests to Correct any Deviations, Updates (as needed) to HMI Philosophy, HMI Style Guide, HMI Toolkits and Related Documents</td>
</tr>
<tr>
<td>Validation</td>
<td>Verify HMI meets User, Task and Functional Requirements</td>
<td>Validation Plan</td>
<td>Validation System, Validation Records</td>
</tr>
</tbody>
</table>
What else is in the Standard?

• Human Factors Engineering & Ergonomics,
• Display Types,
• User Interaction,
• Performance,
• Training.
Human Factors Engineering

• General principles
• Operator-process interaction model
• User sensory limits
• User cognitive limits
• HMI operation should be intuitive to the user.
  – Relationship of each display and its functionality should be clear to the user.
• The HMI should support tasks related to all commonly expected modes of operation.
  – No unnecessary information or controls.
  – Use separate displays for information required only intermittently
  – For complex tasks requiring HMI interaction, follow the normal work flow in display operation as much as is possible.
• Present information in forms or formats that are appropriate to the user’s goals.

• Control options should include the commonly expected range of user actions.
  – Support for all potential actions should be provided, though non-routine actions can be supported on separate displays.

• Items supporting the most frequent tasks should be readily available to the user.
  – Procedures and instructions used to start up a piece of equipment, or start a batch process.
Situation Awareness

• Situation awareness is defined as:
  – “The relationship between the operator's understanding of the plant's condition and its actual condition at any given time”.

• There are a number of common factors that undermine situation awareness, such as:
  – Attention tunneling.
  – Short term memory trap.
  – Workload, anxiety, fatigue, and other stressors.
  – Data overload. Overwhelming amounts of data can reduce SA.
  – Misplaced salience.
  – Complexity creep.
Operator – Process Model

- Remember that the operator has to Detect – Diagnose – Respond.
- Then Assess if the action has addressed the issue!
Performance Shaping Factors

• Detect
  – Operator’s experience
  – Training and experience
  – Fatigue
  – Redundant coding (e.g. color, shape & location)
  – Alarm effectiveness
  – Detection mechanisms
  – Display effectiveness (how well information is being presented)
  – Console, station, and screen layout
  – Environmental factors
  – Display density
Performance Shaping Factors

• Diagnose
  – Console, station, and screen layout
  – Display organization and navigation
  – Display levels
  – Training and experience
  – Direction process is trending
  – Reliance on short-term memory
  – How well the operator’s mental model maps to the process
  – Display call-up times
  – Environmental factors
  – Fatigue
  – Display change time
Performance Shaping Factors

- Respond
  - Operating Procedures
  - Training
  - Fatigue
  - Operator messaging
  - Help Display
  - Expert systems
  - System Responsiveness
  - Crew
  - Environmental factors
Performance Shaping Factors

• Assess
  – Write time
  – Write refresh time
  – Control Strategy
  – Operator’s mental model
  – Process response time
User Sensory Limits

• Visual considerations
  – Ambient lighting and screen luminance
  – Color
  – Information density
  – Visual dynamics (animation)

• Auditory considerations
  – Design basics
  – Consideration of partial hearing impairment and local conditions
A Word on Color

• The chosen colors should be distinguishable from each other, generally involving usability testing.
• As a general rule, color should be used for emphasizing key information such as alarms and abnormal conditions.
  – Colors used for display design should be consistent with the facility’s alarm philosophy.
  – Colors used for alarm presentation should be reserved and not used for any other purpose in order to strengthen their cognitive meaning and speed up operator response to alarms.
• The salience of colors used on a display should reflect the importance of the information being presented.
More Words on Color

• Color can be used for emphasis and clarity; however, color alone should not be relied upon to convey meaning.
  – Color gradients should not be used for static or non-dynamic elements on the display, but may be used to highlight a dynamic element.
• Color should be used conservatively and consistently.
• Color perception deficiencies and color combinations should be considered during design.
• Color and/or flashing of symbols should direct the operator’s attention to newly developing situations.
Colorblindness

- **Significant Issue**
  - One of the drivers for less color
  - Other, of course, is using color sparingly to make it actually MEAN something
  - In North American Operator population can be as high as 30%

- **Easy to Design Around**
  - Need to run the analyses
  - Can optimize the background color to get some offset
Common Color Examples

- **Normal**
- **Protanopia**
- **Deuteranopia**
- **Tritanopia**
### Other Options for Valves

#### Hollow/Gray

<table>
<thead>
<tr>
<th>Type</th>
<th>Color</th>
<th>Brightness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>450</td>
<td>135</td>
</tr>
<tr>
<td>Protanopia</td>
<td>401</td>
<td>134</td>
</tr>
<tr>
<td>Deuteranopia</td>
<td>403</td>
<td>135</td>
</tr>
<tr>
<td>Tritanopia</td>
<td>400</td>
<td>135</td>
</tr>
</tbody>
</table>

#### White/Green

<table>
<thead>
<tr>
<th>Type</th>
<th>Color</th>
<th>Brightness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>637</td>
<td>180</td>
</tr>
<tr>
<td>Protanopia</td>
<td>520</td>
<td>149</td>
</tr>
<tr>
<td>Deuteranopia</td>
<td>531</td>
<td>161</td>
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<tr>
<td>Tritanopia</td>
<td>458</td>
<td>157</td>
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</table>

#### Hollow/Green

<table>
<thead>
<tr>
<th>Type</th>
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<th>Brightness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>592</td>
<td>165</td>
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<tr>
<td>Protanopia</td>
<td>474</td>
<td>134</td>
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<tr>
<td>Deuteranopia</td>
<td>486</td>
<td>146</td>
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<tr>
<td>Tritanopia</td>
<td>413</td>
<td>142</td>
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</table>

#### Black/Green

<table>
<thead>
<tr>
<th>Type</th>
<th>Color</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>128</td>
<td>75</td>
</tr>
<tr>
<td>Protanopia</td>
<td>244</td>
<td>105</td>
</tr>
<tr>
<td>Deuteranopia</td>
<td>233</td>
<td>93</td>
</tr>
<tr>
<td>Tritanopia</td>
<td>306</td>
<td>97</td>
</tr>
</tbody>
</table>
Practical Advice

• The fancy LP that optimizes the color separation and optimizes the color shift off neutral for the background is all well and good, but...
  – The video card and monitor have a huge impact.
  – As does the ambient lighting in the control center.
  – \(\Rightarrow\) Check the theory in reality!
An Embarrassing Story

• There is new research to suggest that the chromatic aberration that comes with the aging of the eye (lens yellowing) happens earlier.
  – We used to think only the retired old geezers had an issue.
• I used to think that the older operators were whiny, when they said that could not really see some of the blue PVs on gray or the purple abnormal on gray.
  – But I am getting older and I can see their point.
  – Don’t get me started about my new bifocals either!
Alarm Colors on Gray

- **Normal**
  - CRITICAL
  - WARNING 1
  - WARNING 2
  - WARNING 3
  - ADVISORY
  - ABNORMAL

- **Protanopia**
  - CRITICAL
  - WARNING 1
  - WARNING 2
  - WARNING 3
  - ADVISORY
  - ABNORMAL

- **Deuteranopia**
  - CRITICAL
  - WARNING 1
  - WARNING 2
  - WARNING 3
  - ADVISORY
  - ABNORMAL

- **Tritanopia**
  - CRITICAL
  - WARNING 1
  - WARNING 2
  - WARNING 3
  - ADVISORY
  - ABNORMAL
Alarm Colors on Tan

Normal
- CRITICAL
- WARNING 1
- WARNING 2
- WARNING 3
- ADVISORY
- ABNORMAL

Protanopia
- CRITICAL
- WARNING 1
- WARNING 2
- WARNING 3
- ADVISORY
- ABNORMAL

Deuteranopia
- CRITICAL
- WARNING 1
- WARNING 2
- WARNING 3
- ADVISORY
- ABNORMAL

Tritanopia
- CRITICAL
- WARNING 1
- WARNING 2
- WARNING 3
- ADVISORY
- ABNORMAL
Doesn’t Have to be Gray
User Cognitive Limits

• A user’s performance and the underlying cognitive processes are affected by the workload level, situation awareness, and task compatibility.
• We likely know this, but it is important to remember that under stress, cognitive limits are impaired from normal.
Cognitive Limit Considerations

- Information displayed in directly usable format (no math!).
- Should not rely on recall memory for codes or complex commands.
- Use the simplest design that consistent with functional and task requirements.
- For items needed only intermittently, provide easy access, but do not clutter the main display.
- Use a design that fits the user’s mental model of the system.
Display Types & Styles

- Display types define how information is presented and organized to convey information in a consistent manner.
- Display styles refer to how the information on a single display is presented.
Selection of Type of Display

- Selection may be impacted by functional, technological and physical limitations of the HMI used.
- For example:
  - Position of the display,
  - Physical size of the screen,
  - Density of information that can be handled by the user.
Display Styles

- List Styles
- Process Styles
- Overview Styles
- Topology Styles
- Graph Styles
- Hierarchical Styles
- Dashboard Styles

- Location Styles
- Group Style
- Point Detail Display Style
- Logic Monitor Styles
- Sequence Styles
- Procedure Styles
- Health/Diagnostics Styles
Plan View Example
Plan View Drill Down
Fire & Gas Displays

- Clear visual distinction of confirmed event versus sensor issue.
- Broad overview always clear to show any escalation.
- “Chatty” sensors need to be clearly depicted.
- Do the engineering effort to make these effective tools in real time.
  - Consider an off-shore platform, where there is also a need to understand the levels of the platform.
Waste Water Operator’s Favorite

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Plan View Massive Fail

• Things that mattered:
  – Outfall permits, mix of instantaneous and daily totals
  – Disposal well permits
  – Disposal well steadiness of pressure and flow
  – Total volume left for waste and rainwater, mix of volume and time at current rates
  – Bugs dying or not, reactors and the outfall
• Eureka moment of plan view with roads and tanks
  – Fancy alarm groupings and easy drill down navigation
• Failed because that was not how the operators envisioned the plant
• Moved to “functional” grouping overview
Example Functional Grouping

- Boxes for areas
- Key controls and indication
- Best symbols
A Word on Display Hierarchy

• Commonly a four level display hierarchy is recommended to not diminish the operator’s performance on management activities.
• Each level is defined according to the type and location of display along with the information content of the display.
• Information content will convey increasing levels of detail and focus, with Level 1 having the broadest scope and Level 4 having the most focused scope.
• Although hierarchical in nature, display levels are not necessarily aligned with a navigation hierarchy which may have fewer or more levels.
A Few Thoughts on Navigation

• The “best” navigation depends on the nature of the process and the level of instrumentation.

• Older system may not have enough instrumentation to support multiple levels of drill down.
  – Particularly if the shutdown system is relay based and very limited troubleshooting brought into the system.

• Level 1-4 is not the only and may not be the best concept for your process
Navigation Network Designs

• Hierarchical – This is the most commonly used structure.
  – In a hierarchical structure, information is organized like an inverted tree in which the lower branches provide increasingly specific information related to the upper branches and backbone.
  – There is extensive research in hierarchical structures and the depth and breadth recommended.

• Relational – Relational display network structures have multiple links between nodes, which are based on a variety of relationships.

• Sequential – A sequential display network organizes display pages in a series. This can be effective in batch environments where the process flows sequential through a logical structure.
User Interaction

• **Software Methods**
  – Data entry methods,
  – Navigation methods,
  – Error avoidance methods,
  – User access security,
  – Off system messaging.

• **Hardware Interfaces**
  – HMI Devices,
  – Monitors and
  – User Input Devices.
User Interaction Design

• Key design principles to consider include:
  – consistency in execution across all modes of interaction,
  – timely feedback for data entry and control actions,
  – streamlined user interaction (minimized number of selections or amount of typing),
  – use of appropriate salience for error messages and limited use of complex modal methods.
Data Entry Methods

• Consistent presentation of data entry.
  – Common conventions include: inset entry fields, clear indication of current selection, grayed items that are not available for entry, and “hand” cursor presentation.
  – It is also effective to give the operator visual clues as to the format of the entry if this is not known.

• Information is presented in a consistent manner for all types of interactions.
  – Common operator interaction needs should be contained on the display or in a popup or faceplate-style display that only changes a portion of the screen.
  – The operator should only be required to change screens or navigate deeper into the HMI structure for non-routine and non-critical interactions.
Number Presentation and Entry

• The font selected should be discernable from the normal operator position.

• Numbers with decimal formatting should be justified with respect to the decimal point. Presentation should follow the appropriate decimal format resolution required by users.

<table>
<thead>
<tr>
<th>Range</th>
<th>Display Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 - 9999.9</td>
<td>XXXX</td>
</tr>
<tr>
<td>10 - 99.99</td>
<td>XX.X</td>
</tr>
<tr>
<td>1 - 9.999</td>
<td>X.XX</td>
</tr>
<tr>
<td>0 - 0.9999</td>
<td>X.XXX</td>
</tr>
</tbody>
</table>

• If automatic rescaling of the decimal format is used, care should be taken to suppress rapid changes in decimal formatting to avoid repetitive shifting of the decimal point.
Critical Operating Ranges

• Where appropriate, numbers should be referenced to normal and critical operating ranges.
• The reference to normal and critical can be accomplished in a variety of manners, including the use of an abnormal color or reference curves and lines.
• Critical values can be referenced in a similar manner, with clear indication of impending or actual critical range violations.
Text Presentation and Entry

- Text should be left-justified with a ragged right hand edge.

- MIXED CASE LETTERING HAS BEEN SHOWN TO BE EASIER TO READ THAN UPPERCASE AND SHOULD BE GENERALLY USED.

- If a paragraph is required, the text width should be at least 50 characters wide for rapid scanning.

- Avoid hyphenation if possible.
Text Presentation and Entry

- Abbreviations and acronyms should be avoided unless they are part of the normal operator language.
- Underlining for emphasis should not be used. It is recommended that underlined text be reserved for hyperlinks.
- Display of text should be oriented horizontally unless unavoidable or for clarity.
- The font selected should have clear characters definition (the most common issue related to the presentation of 1, l and L).
- Affirmative statements rather than negative statements should be used.
- Active voice should be employed.
- Instructions that must be executed in order should be presented in order.
Command Entry

• For simple commands, any format supported by the language and training of the user is likely to be appropriate.
• All inputs to and effects of a given command should be visible to the user where possible.
• Users should be in command of the entry process at all times, with a clear means for cancelling the operation or recovering quickly to prior configuration.
Complex Commands

- The HMI should support multiple selections by the user, followed by a confirmation of the intended composite action.
- If selection lists are long, artificial groupings should be constructed to allow for easier navigation, scanning and identification of desired selection.
- Command dialogs should be designed to support the expected work process of the user.
- Feedback and help should be provided for all complex steps.
- Feedback should be provided for all entries that are outside of an expected range.
  - If an input is critical, acceptable limits on entry should be enforced.
Buttons

• Buttons should be used only when suitable for the task. Labels should be clear to the users.
• Buttons should be sized large enough to allow users to select them rapidly and accurately with the pointing device in use on the console.
• Buttons that interact directly with the process should be distinct from buttons that provide navigation linkages or launch applications.
• Any buttons that are unavailable should indicate their temporary unavailability with consistent visual coding.
Navigation Methods

• The navigation design is one of the most important parts of the overall HMI design, since it directly impacts the speed and accuracy with which the operator can intervene and respond to process needs.

• Multiple navigation methods should be provided for robustness and to facilitate access to displays that is:
  – quick,
  – logical,
  – direct, and
  – consistent.
Navigation Method Examples

Navigation methods to consider include:

- Embedded Hyperlinks and Display Symbols with Hyperlinks,
- Menus and Tool Bars/Ribbons,
- Dashboard/Task panel,
- Buttons on the displays,
- Custom keyboard buttons (function and other custom buttons),
- Context Menu (e.g., mouse button right-clicks for a drop-down menu),
- Show/hide mechanisms for detailed information,
- Links to Directories of Displays, Files or Trends,
- Display Transfer Buttons,
- Voice commands,
- Yoking.
Navigation Guiding Principles

• Display access should be designed to minimize the operator keystroke-equivalent actions.
  – 1-2 keystrokes should be the maximum required to view any critical or high priority alarm in context with the associated process.
  – 2-3 keystrokes are acceptable for all other information.

• It should not be necessary for an operator to type in the display name or point identification, though support for that interaction should be provided.
Navigation Guiding Principles

- The HMI must support work flow for normal and abnormal conditions.
- Display symbols that are navigation targets have consistent and distinct visual coding.
- Display symbols that are selectable have consistent and distinct visual coding.
Navigation Guiding Principles

- Displays should be implemented in a standardized content structure that supports progressive exposure of detailed information.
- Where useful and appropriate, advanced HMI techniques can be employed to automatically display relevant information.
- This automatic display is commonly called "yoking" and can include such items as:
  - other displays in a multi-window HMI,
  - faceplate,
  - trending, and
  - related detailed displays.
Example Display Hierarchy

• Level 1
  – Overview of operator’s entire span of responsibility

• Level 2
  – Typically the operator’s main control interface
  – Visibility of relevant alarms; esp. high priority

• Level 3
  – Detailed displays, used for non-routine operations
  – May be more task based for line changes, startup, etc.
  – Visibility of all alarms

• Level 4
  – Rarely used for diagnostic and troubleshooting purposes
  – Interlock and permissive information (could be Level 3)
  – Procedure and help displays (could be Level 3)
Batch Navigation Example
More Complex Navigation Example

- Navigate horizontally and vertically.
Error Avoidance Methods

• Consideration should be given to error avoidance techniques and confirmation steps for important items.
• The items should be limited to avoid diluting the importance of the method.
• For safety critical items, the “error avoidance” should be executed in the control system application itself, rather than the HMI.
  – The Style Guide should clearly define error avoidance and the use of custom scripting in the HMI.
Error Avoidance Methods

• The error avoidance methods should not excessively hamper the operator’s ability to make changes rapidly, where appropriate.
• To avoid loss of effectiveness, these methods should be used sparingly and be carefully designed.
• Simple confirmation steps with a “yes” to confirm have been shown to be somewhat ineffective at improving accuracy.
  – Yes, yes, yes, yes….oops!
• It is also important to ensure that the confirmation employed is consistent in language and ensure that the reason for the confirmation, particularly when confirming entries outside of an expected range.
Off System Messaging

- Off-system messaging methods are used to help the operating team manage the process.
- These off-system messaging methods include:
  - Auto-dialer voice messages,
  - Remote alarms,
  - Pagers,
  - Digital message pagers,
  - Text messages,
  - Emails.
Off System Messaging

- Care should be taken in the design of these systems to ensure that adequate robustness is present to support the functional requirements.
- At a minimum, the systems should be automatically monitored for availability.
- In more critical systems, a backup system should be in place to provide the required functionality in the event of an outage.
User Access Security

- The HMI system generally has some level of HMI application specific security.
- The operator environment is designed to be resistant to users damaging the programs or data present on that workstation, or gaining access to unintended applications.
- The degree of restriction is often user configurable, so that the HMI is also suitable for use by trusted and higher skill level users.
- This scope does not include the overall user account management, which is covered by ANSI/ISA-99.
User Access Security

- HMI specific considerations include:
  - Temporary Log Over (ability to increase user rights without logging off completely) for specific tasks,
  - Concept of multiple roles and privileges within an application (role based restriction),
  - Location based content restriction,
  - Use of electronic signatures,
  - Authentication notes (requirement of a user to add a reason for a control action),
  - Use of other biometrics.
Hardware: HMI Devices

• Monitors can vary from hand-held devices to indoor and outdoor monitors of varying sizes to larger post or wall-mounted monitors.

• Selection should include consideration of viewing angles and resolution for color perception and readability, physical reach for input devices, and related environmental factors.

• When a fixed workstation is desired, some consideration of sitting and standing options should be made.

• With portable devices, the battery life and ruggedness are likely to be key considerations.
  – Wireless devices have special security and reliability considerations that are outside the scope of this standard (see ISA100).
Design Not By Furniture Sales Rep

- Key point, decide what you need, then pick the furniture!

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User Input Devices

• Consider sound design for use and selection of:
  – Keyboards (QWERTY or other industrial type),
  – Keyboards with programmable keys,
  – Pointing Devices (mouse, trackball, etc.),
  – Other custom keyboards,
  – Touch screens,
  – Video wall controls,
  – Handwriting input devices,
  – Voice input,
  – Bar-code scanners,
  – RFIDs,
  – Cameras,
  – Pushbuttons/toggle switches
  – Others (biometric readers for security, etc.).
Performance

- Performance by HMI Categories
- HMI Duty Factors
- HMI Performance Shaping Factors
HMI Categories

• Consideration in the standard for:
  – High Speed Machine Control
  – Small Systems
  – Process Systems
  – SCADA
  – Geographically Widespread RTU systems
HMI Duty Factors

### Maximum Times (all units in seconds unless otherwise stated)

<table>
<thead>
<tr>
<th>Metric</th>
<th>Display Type</th>
<th>Machine Control</th>
<th>Small System</th>
<th>Process System</th>
<th>SCADA System</th>
<th>RTU System</th>
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</thead>
<tbody>
<tr>
<td>Call-up Time (Note 1)</td>
<td>Level 1, 4</td>
<td>2</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
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<tr>
<td></td>
<td>Level 2, 3</td>
<td>1</td>
<td>5</td>
<td>5</td>
<td>5</td>
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<tr>
<td></td>
<td>Faceplate</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Yoke</td>
<td>6</td>
<td>6</td>
<td>6</td>
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</tr>
<tr>
<td></td>
<td>Trend</td>
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<tr>
<td></td>
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<td>Display Refresh Rate (Note 2)</td>
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<tr>
<td></td>
<td>Level 2, 3</td>
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<td>3</td>
<td>5</td>
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<td>5-15</td>
<td>5-15</td>
<td>5-15</td>
<td>5-15</td>
</tr>
</tbody>
</table>

- **Recommended max times for:**
  - Call-up Time,
  - Display Refresh Rate,
  - Write Time,
  - Write Refresh Time,
  - Access to Alarms.

- **Also considers:**
  - Navigation,
  - Switching users,
  - Changing language.

- Based on dial up schedule and bandwidth
- Based on network topology (i.e. may have to dial a modem)
- <5 minutes for very large systems

### Notes:

1. **Call-up Time**
   - Applies to all display types
   - Based on dial up schedule and bandwidth

2. **Display Refresh Rate**
   - Applies to all display types
   - Based on network topology (i.e. may have to dial a modem)
   - <5 minutes for very large systems

3. **Write Time**
   - Applies to all display types
   - Based on dial up schedule and bandwidth

4. **Navigation**
   - Critical displays: 1-2 clicks
   - Non-critical displays: 3 clicks
   - Alarm summary: 1 click
   - System diagnostics: 1-2 clicks

5. **System state changes**
   - Switching operators: 5
   - Language change: 5
The principles behind Performance Shaping Factors are:

- control system operator displays should be an effective tool for the safe and efficient control of the process, in both normal and abnormal situations,
- the HMI should assist in the early detection, diagnosis, and proper response to abnormal situations,
- the HMI should be structured to aid operator to prioritize response to major or multiple simultaneous system upsets,
- the HMI is designed for the use of the operator in running the process. Proper HMI design is therefore not compromised for any special-use purposes of maintenance, engineering, staff, or training,
- failure of a display or items on the display should be immediately apparent to the operator,
- a clear, but not overwhelming, indication that the graphic is not connected to or communicating with the system it is linked to.
Training

• User Training
  – Operations,
  – Maintenance,
  – Engineering,
  – Administrators,
  – Management.

• Documentation
HMI Training

- Adequate training is absolutely essential to safe and effective operation of the HMI
- Materials for training should be generated at the Design and Implementation Stages
- Training materials should be verified during the Testing and Commissioning steps
- Materials should be in a format that is consistent with existing procedures and is effective for the audience
  - Paper, on-line ‘help’ tools, full simulation & testing
Documentation

• Application specific details of HMI implementation, generated during Design Stage:
  – Display indexes,
  – Display functional descriptions,
  – Navigation diagrams, etc.

• The information needed to reconstruct the HMI application if necessary.
Concluding Thoughts

• There simply is no silver bullet.
  – Ask hard questions to anyone that suggests that there is...

• Well considered and well executed, the HMI may be the hardest engineering that you ever do.
References


Thank you

20 YEARS & KNOWING
OUR MEMBERS ARE THE MOST AGILE COMPANIES IN THE WORLD. THEY KNOW THEY HAVE A RESPONSIBILITY TO INDUSTRY AND TO ONE ANOTHER. THEY KNOW THE CONSEQUENCES OF AVOIDING A SINGLE IMPROVEMENT CAN MEAN MILLIONS OF DOLLARS AND A POSSIBLE GLOBAL IMPACT. THEY KNOW THE POWER OF KNOWING WHAT MESA KNOWS.

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DO YOU KNOW MESA?
MESA International Headquarters 107 S. Southgate Drive, Chandler, AZ 85226 USA
+1 480 893 6883 | hq@mesa.org | www.MESA.org