Improving Operator Performance

Research from the Center for Operator Performance

Antoon Tuerlings, Yokogawa
David Strobhar, Beville Engineering
Mark Nixon, Emerson
Tom Fiske, Yokogawa

Agenda

Time	Topic
1000	Welcome – Yokogawa
1015	COP Introduction
1030	Event Prediction & Mitigation – Mark Nixon (Emerson)
1115	Break
1130	Shadowbox
1215	Lunch
1230	Student Projects (through lunch)
1300	Procedure Modularization
1345	Break
1400	Overviews – Mark Nixon (Emerson)
1445	Alarm Rates
1530	New Projects – Tom Fiske (Yokogawa)
1545	Conclusion

Welcome

Center for
Operator Performance
An Industry/University
Center for Excellence

YOKOGAWA

CoP Speakers today

Dave Strobhar

Mark Nixon

Tom Fiske

Antoon Tuerlings

Who is the Center for Operator Performance?

Center for Operator Performance

An Industry-Academia Collaboration

www.operatorperformance.org

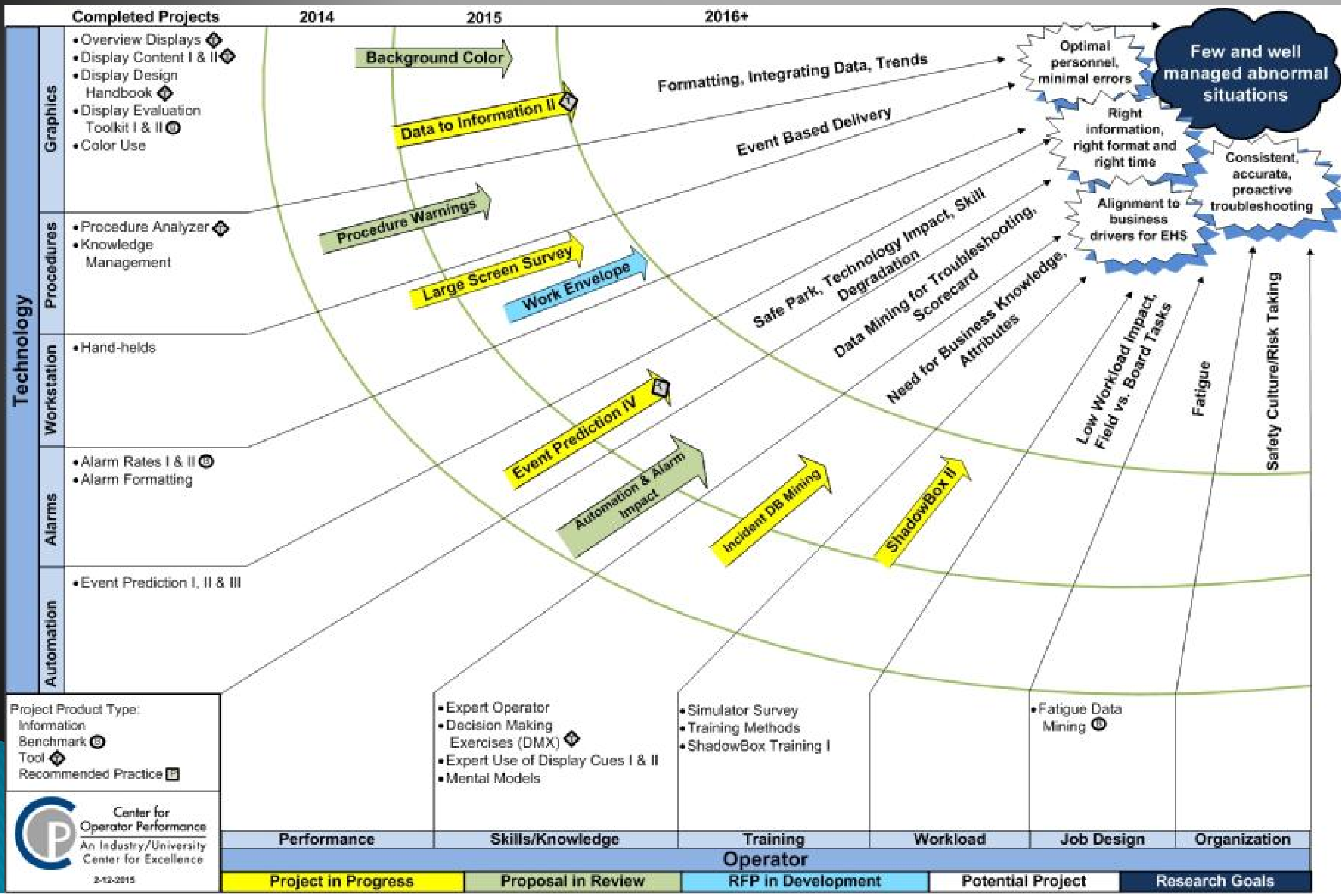
We had questions –

- How can I make expert operators faster?
- Are alarm targets valid?
- Is it worth changing exist displays to current practices?
- How can I get operators the support information they need, when they need it?
- How do I create a hierarchy?
- What does a good overview look like?
- Should I use a large monitor for the console operators?

So we banded together

- Operating company driven
- Shared risk
- Focus on enhancing the safety and environmental performance of plants
- Open
- Prevent “black-eye” that hurts entire industry

COP Vision


Completed Projects
2014
2015
2016+
Technology
Graphics
Procedures
Workstation
Alarms
Automation
•Overview Displays
•Display Content I & II
•Display Design Handbook
•Display Evaluation Toolkit I & II
•Color Use
•Procedure Analyzer
•Knowledge Management
•Hand-helds
•Alarm Rates I & II
•Alarm Formatting
•Event Prediction I, II & III
Background Color
Data to Information II
Procedure Warnings
Large Screen Survey
Work Envelope
Event Prediction IV
Automation & Alarm Impact
Incident DB Mining
ShadowBox II
Formatting, Integrating Data, Trends
Event Based Delivery
Safe Park, Technology Impact, Skill Degradation
Data Mining for Troubleshooting, Scorecard
Need for Business Knowledge, Attributes
Low Workload Impact, Field vs. Board Tasks
Fatigue
Safety Culture/Risk Taking
Optimal personnel, minimal errors
Few and well managed abnormal situations
Right information, right format and right time
Consistent, accurate, proactive troubleshooting
Alignment to business drivers for EHS
Project Product Type:
Information
Benchmark
Tool
Recommended Practice
Center for Operator Performance
An Industry/University Center for Excellence
2-12-2015
•Expert Operator
•Decision Making Exercises (DMX)
•Expert Use of Display Cues I & II
•Mental Models
•Simulator Survey
•Training Methods
•ShadowBox Training I
•Fatigue Data Mining
Performance
Skills/Knowledge
Training
Workload
Job Design
Organization
Operator
Project in Progress
Proposal in Review
RFP in Development
Potential Project
Research Goals

Research

Tools	Knowledge	Benchmarks
Decision Making Exercises	Expertise	Alarm I & II
Procedure Modules	Knowledge Management	Fatigue (Data Mining)
Display Content (Decision Mapping)	Color Use	Display Metrics
Event Prediction & Mitigation	Simulator Survey	Use of hand-held devices
Display Evaluation Toolkit	Training Methods	Large Screen
Overview Displays	Mental Models	Incident data mining
Student projects		
Decision Aids	Use of red for stop/closed and warning	Symbol Size
Large Monitor	Data Entry Devices	Emergent Features

Event Prediction IV Update

Michael Baldea/Mark Nixon

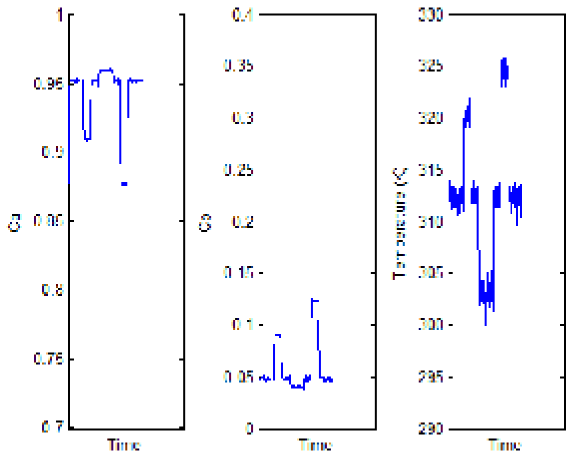
November 19, 2014

Austin, TX

Project Overview

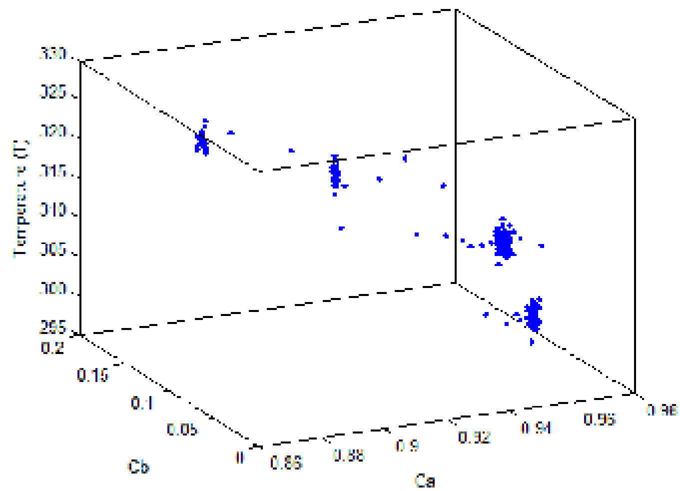
Goal: Develop visual data analysis and decision support tools

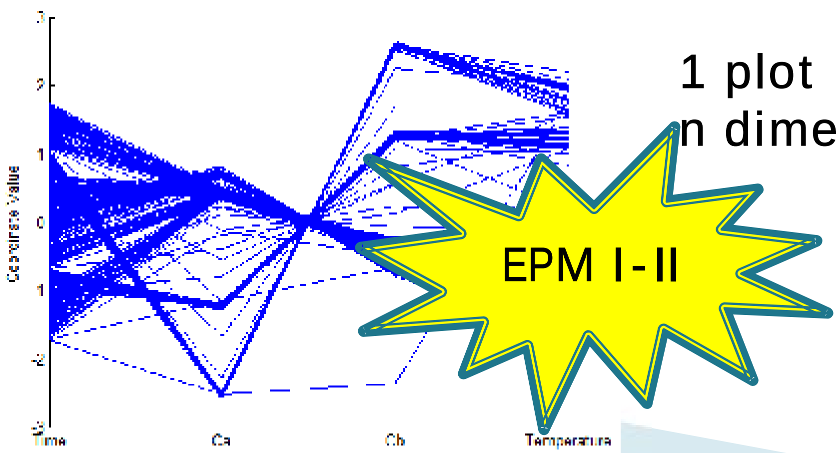
EXPLICIT time



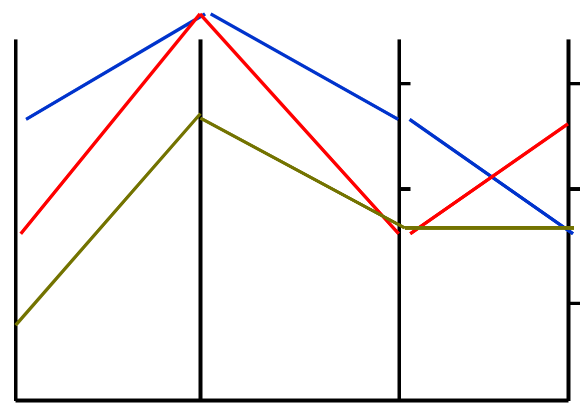
n plots
2 dimensions

IMPLICIT time





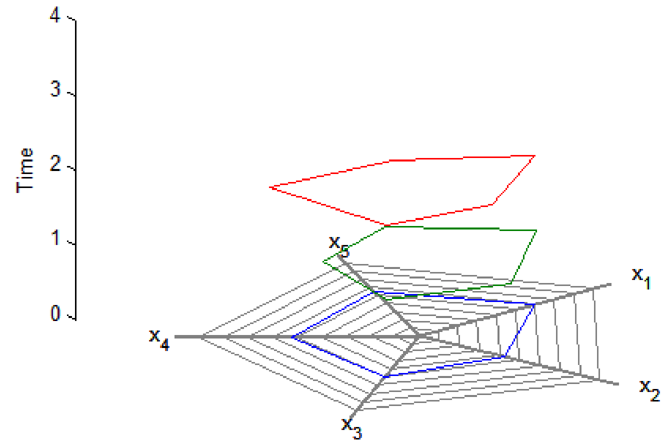
1 plot
n dimensions



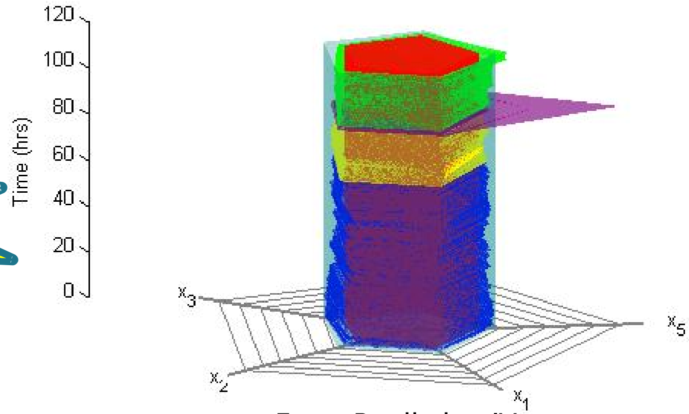
Inselberg, Comput. Stat., 1998

Task Progress to Date

- Concept: 3D Radial Plots

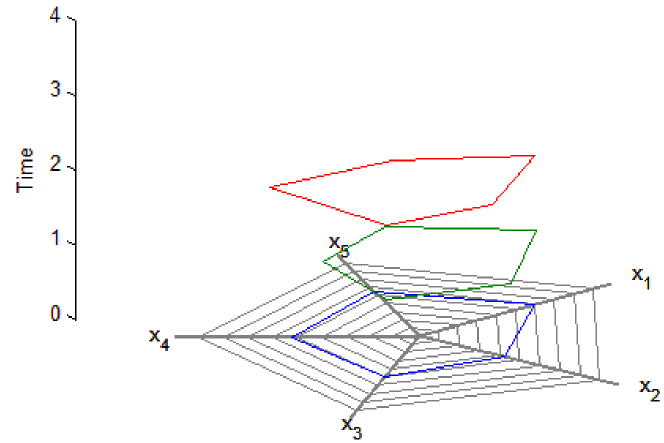


- Fault detection: use operating envelope

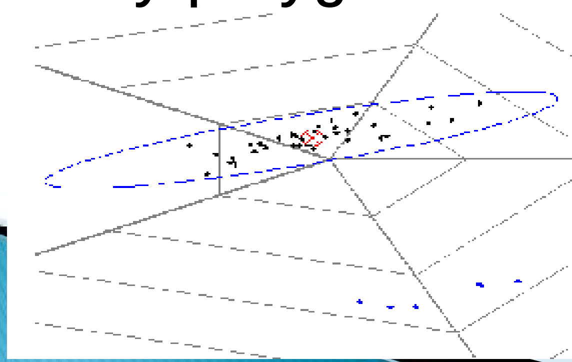


Task Progress to Date

- Concept: 3D Radial Plots



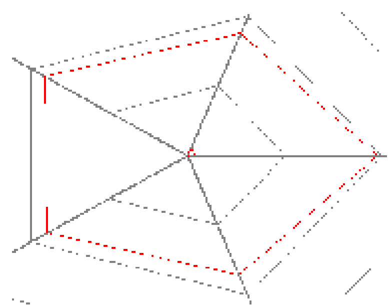
- Centroid representation
  - Every polygon can be represented by its centroid



Multiple polygons result in multiple centroids

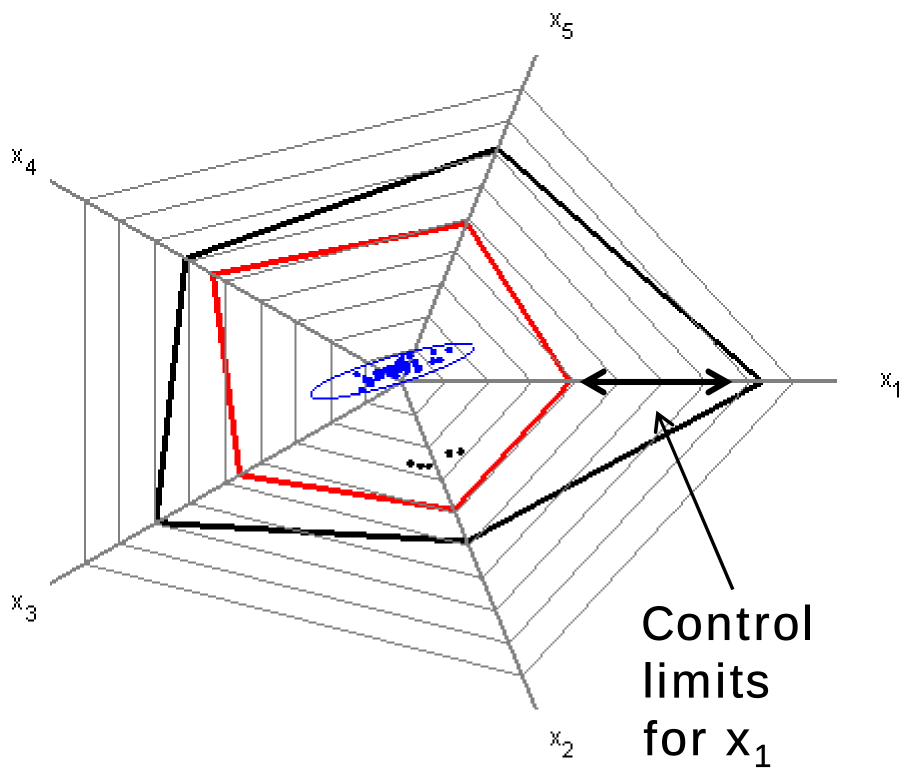
Centroid representation

- Empirical definition: “If a cardboard cutout of a planar figure is suspended from its centroid, it will remain horizontal”
- For any given polygon, the centroid is defined as the average of all vertices in the polygon



For a near regular polygon, the center of gravity is close to the intersection of the bisectors

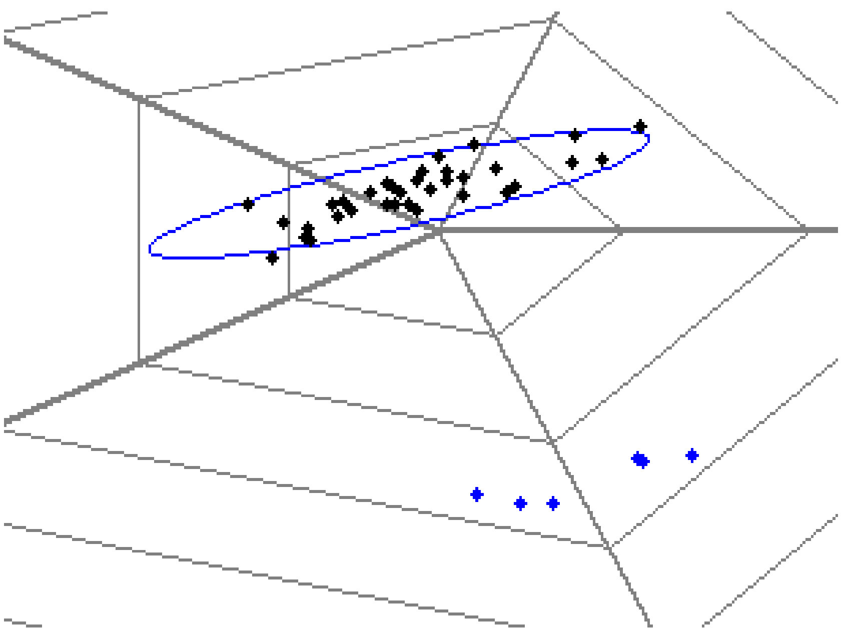
Multivariate Analysis

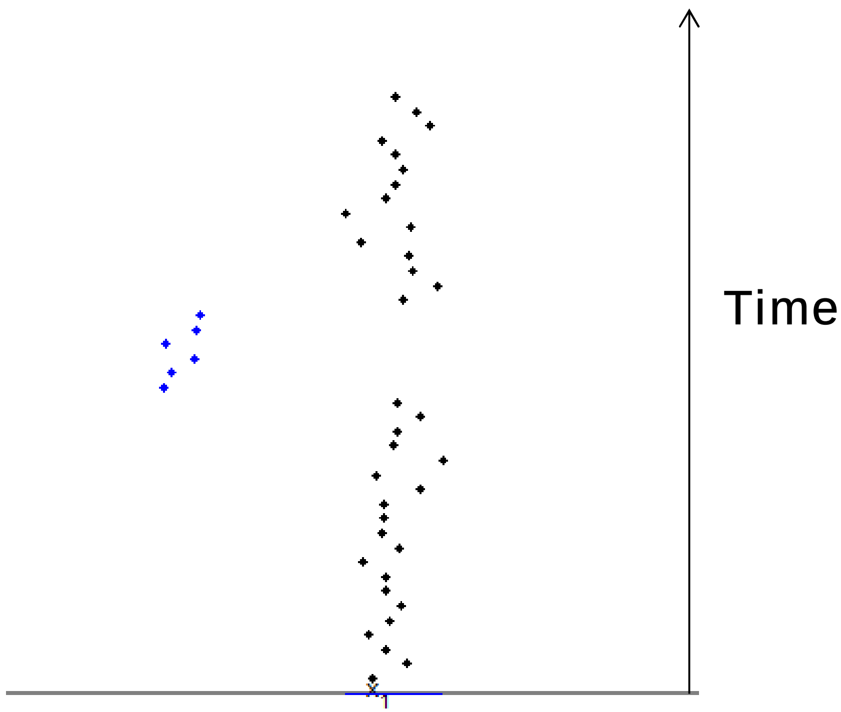


- A change in the process = distortion of polygon = movement of centroid
- Black and red lines represent the univariate operating envelope for each principal component / variable
- Ellipse represents the *multivariate* operating envelope for the steady-state data (blue)

Visualization of Large Dataset

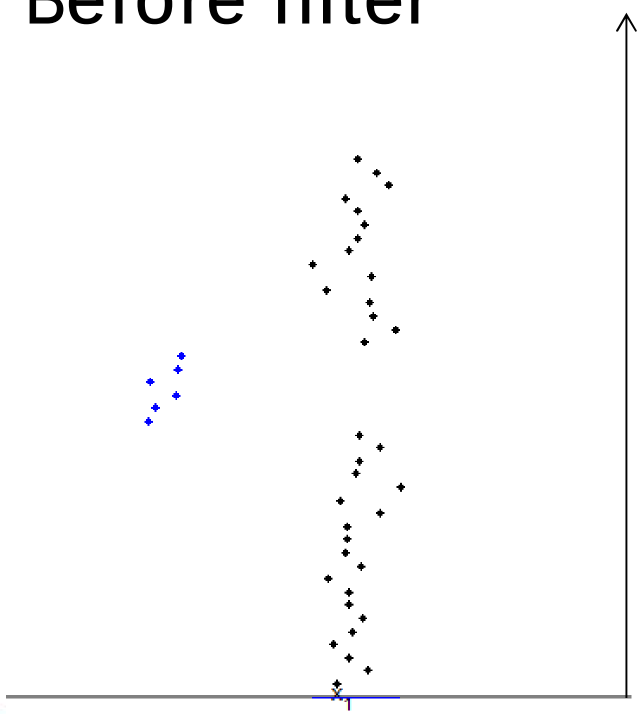
- Amenable to one scan – one point representation



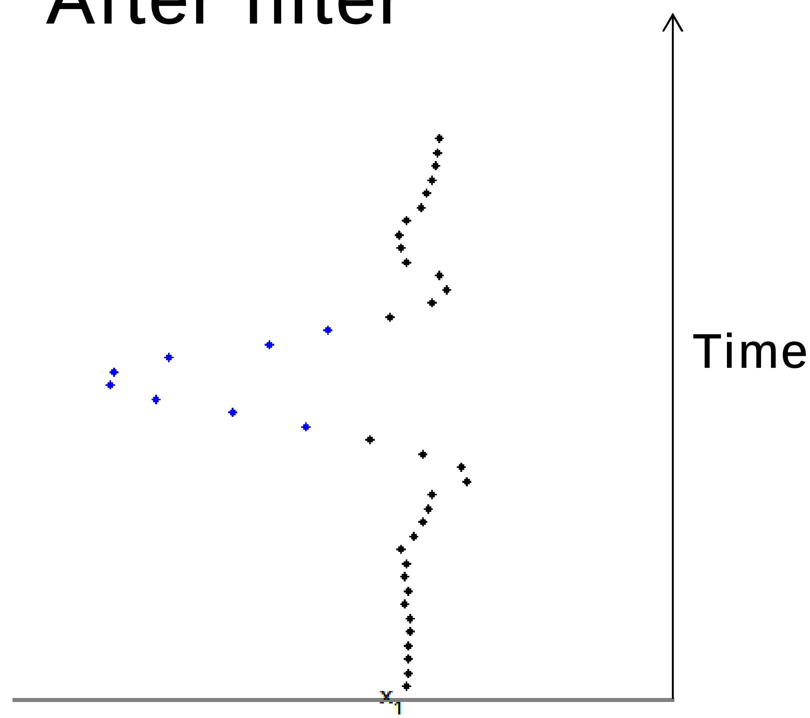


Filtering of the Centroids

- In a 3D perspective the data is smoothened out in time.
- Before filter



After filter



Looking at Transitions – Motivation

- Only looked at faults deviating from a single steady state thus far
  - What about data containing multiple steady states?
  - How to account for process startup/restart (see previous example)?
  - What about batch processes (blending, reaction…)?

- Dealing with process transitions can be difficult
  - Faults can be masked by transition dynamics and be difficult to detect

Looking at Transitions – Purpose of Transition Paths

- Desire to find the “normal” process transition
  - Avoid and/or correct “poor” transitions
  - Prevent operator error/disturbances/malfunction
- If a “good” transition path is known, then transitions that deviate from the path can be considered faulty
- Plant startup, shut down, and batch processes all contain transitions
  - Avoiding poor transitions is key to keeping plants online for longer

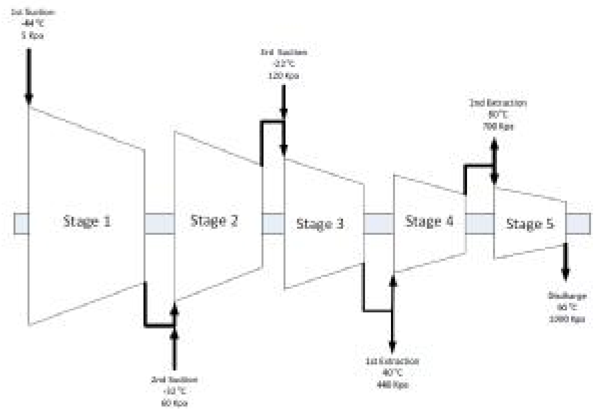
COP Projects

- Individual compressor surge
- Column flooding
- Long-term compressor surge
- Flaring event analysis

Long-term Comp. Surge

- Given large compressor system dataset over 16 years
  - 1998-2014 in 2 hour samples

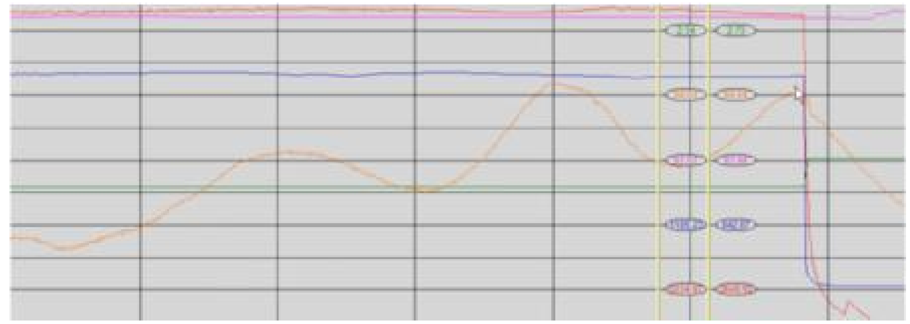
- Smaller datasets at a faster sample rate
  - Aug/14 and Sept/14 in 1 minute sample
  - Validate findings
    - August – detect fault
    - September – no fault TO detect (test for false positives)

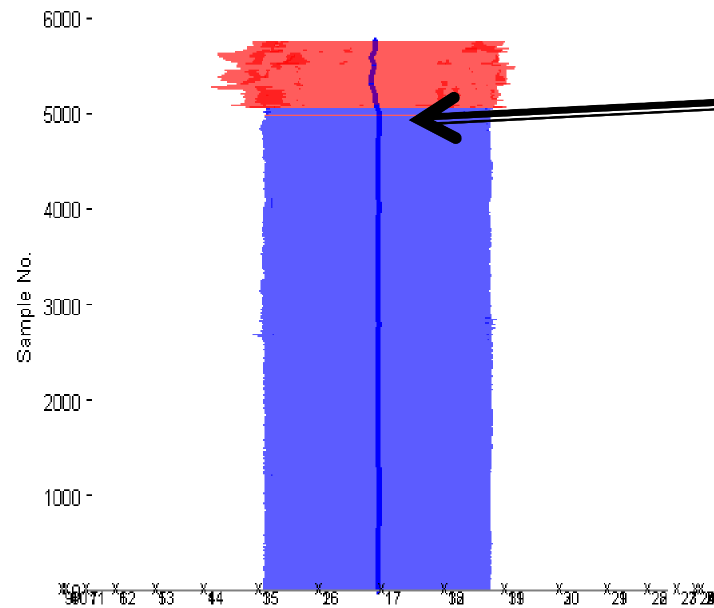


- Build model using large dataset and attempt to use model to detect validate findings in the smaller datasets

Long-term Comp. Surge

- Results:
  - August fault successfully detected
    - Predicted at 11:48 AM
    - Vs: actual at 1:17 PM
  - Top contributing tags
    - Second suction level
    - Second stage pressure
    - Third stage suction temperature
    - Third suction level
    - Discharge pressure
  - No false positives raised in the September dataset

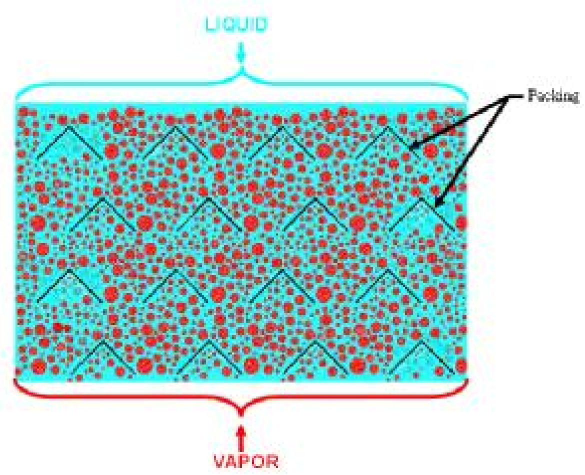




Early detection

Column Flooding

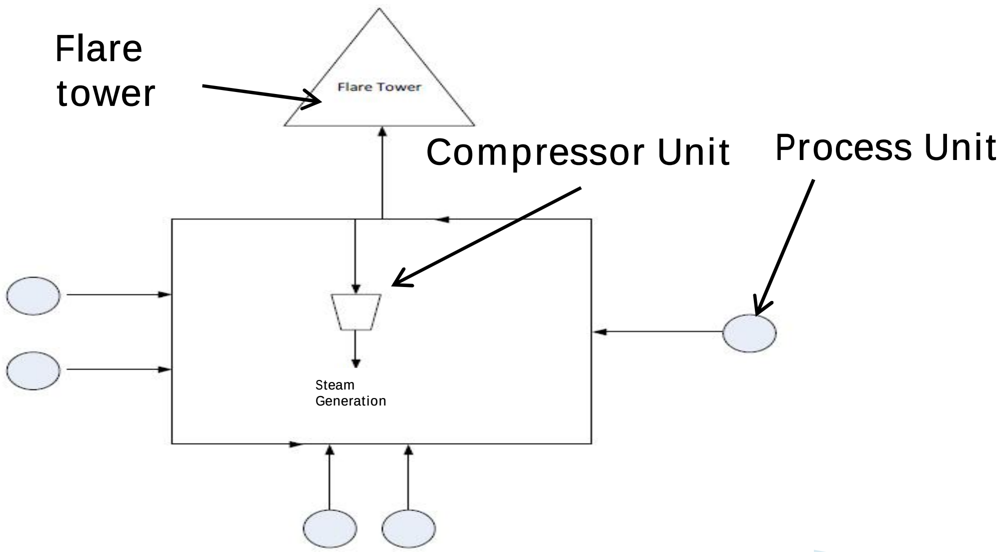
- Given monthly data of column operation
  - 4 months total (June-September)
  - 1 minute sample rate
  - 60+ variables
    - 75% variance captured on average using PCA



All 8 floods were predicted

Flaring Event Analysis

- Data on a system with flares present
- System properties
  - Multiple process units feeding into a main loop
  - Connected to a compressor that feeds into steam generator outside of the system
  - Flare tower burns off excess gas that the compressor cannot handle



Flaring Event Analysis

- A large dataset is provided for model building purposes
  - 1 year duration
  - 1 minute sample rate – 500 thousand samples
  - 100+ variables

- Try to predict and detect flare events in the year
  - Contains points 500 minutes before and after flare event occurrence

- Project is underway

Future/Impact

- Current Effort
  - Batch processing
  - Phase transition
  - Flaring
- Goal
  - Package software for individual company testing
  - Create tool to work beside DCS
  - Integrate tool into DCS

Training for Improved Decision Making

Gary Klein, Ph.D.

Efforts to Date

- Nature of Expertise
- Decision Making Exercises
- Shadowbox I & II

Characteristics of Expertise	**Crude Unit Operator**	**Fluid Catalytic Cracker**	**Pipeline Analyst**
1. Form expectancies	Ö	Ö	Ö
2. Monitor cues	Ö	Ö	
3. Anticipate team member needs and limitations	Ö	Ö	Ö
4. Know where equipment and human resources can mislead you	Ö	Ö	Ö
5. Seek information to spot opportunities	Ö		Ö
6. Adapt the way they perform	Ö	Ö	Ö
7. Describe how events came about and will play out	Ö		Ö
8. Utilize time horizons			Ö
9. Use recall processes to overcome memory limitations	Ö	Ö	Ö
10. Construct mental simulations	Ö		Ö
11. Decenter			
12. Engage in deliberate practice	Ö	Ö	
13. More recognitional decisions than option comparisons	Ö	Ö	Ö

Decision Making Exercises (DMX)

- Good decision making requires practice
- Adapt military training exercises
- Scenario based
- Time pressure
- Ambiguous
- Low cost
- Easy to apply (< 1 hour before shift)

Decision Making Exercises (DMX)

- Project

Adapted military training exercises to process control. Military use DMX to train platoon leaders to make faster and more accurate decisions during urban operations.

- Impact

Proved to be low-cost and easy to apply method to enhance decision making.

  - One-hour periodically at beginning of shift
  - Identified skill/knowledge gaps
  - Identified lost practices
  - Helps build mental model

Scenario phase 1

Background

It's late spring and the weather for the last few weeks from the South to the Mid-West has been volatile, with several major thunderstorms moving along the Mississippi River. One of these storms knocked out power to a pump station just last week.

Today one of the lines on your console you'll be working is the Beaumont to Creal Springs Line. The Beaumont-Creal Springs 24"- 26" Products Line is 644 miles long. There are six booster stations on this line: Beaumont (BEAU), Sugartown (SUGT), Kilbourne (KILB), Tutwiler (TUTW), Fisherville (FISH), and Obion (OBIN). It also has a Pump Matrix, giving you information on optimal unit combinations and start/stop sequences.

(The Hydraulic Gradient Screen 1 provided should give you a picture of this line's current status.)

Shift change reveals nothing unusual going on with this line.

You spend some time checking your other lines and making sure that everything's on schedule. You're having a busier morning than usual as you spend a couple of hours just "fighting fires" and trying to stay ahead of the problems.

At 1030, SUGT calls you and says they need to do some pump maintenance and need you to shut down the unit for about 20 minutes.

Requirement: You have two minutes. What is your plan for supporting the SUGT maintenance?

- **A. What do you think is going on here? / What are your biggest concerns right now? (elicit their situation assessment)**
- **B. What are the difficult decisions? (elicit decisions)**
- **C. What things are you paying attention to to figure out what's going on? (elicit cues/factors)**
- **D. What are the potential courses of action you could take right now? (elicit COAs and their COA analysis)**
- **E. Which one would you follow?**
  Why?

Shadowbox Technique

- Method
  - Present complex scenarios
  - Insert Decision Points with a small set of options
  - Trainees record their responses and their rationale under time limits/stress
  - Trainees compare responses and rationale to a panel of SMEs
  - Trainees identify what the SMEs were seeing and thinking that they (the trainees) were not

Portion of Scenario

Scenario Continues...

12:00 PM – *Screen Shot #3*
The heart of the cold front and thunderstorm has arrived, and you are getting considerable amounts of rain and lightning. Because of this, you decide to cease the ongoing tasks. You pull the outside operators from dumping caustic, and ask the operators withdrawing the catalysts to hold off until the rain and lightning pass.

You are also experiencing alarms in the Gas Con unit. The cold air and rain is affecting the amount of condensing within the units.

Additionally, you begin to receive multiple alarms on the FCC Feed page. For unknown reasons the Heater Outlet temperature seems to be dropping. The Burner Tip Pressure has begun to increase.

** Please use your ShadowBox to record important information.*

Now proceed to Decisions 2 and 3 on the following pages.

ShadowBox Illustration

Decision 2:

What cues are you monitoring most closely at this moment? Rank these options (1 = most important, 4 = least important). Please explain your rankings.

Rank	Options
	A) The heater – watching the fuel gas pressure.
	B) Temperatures in the Gas Con unit – avoiding low alarms and checking fans.
	C) Watching the propylene unit charger (splitter head level control valve).
	D) LPR condensing + Flare KO pot levels.

Explain rationale for your top three rankings:

Pilot Results – Refinery FCC

Scenario	Expert	Novice
#1	88%	80%
#2	88%	70%

Variations

- Variety of response
  - Prioritize information to remember
  - Prioritize goals
  - Prioritize actions
  - Anticipatory actions
  - Desired information
  - Cues via video clips
- Presentation
  - Paper & Pencil
  - Tablet
  - PC

Future/Impact

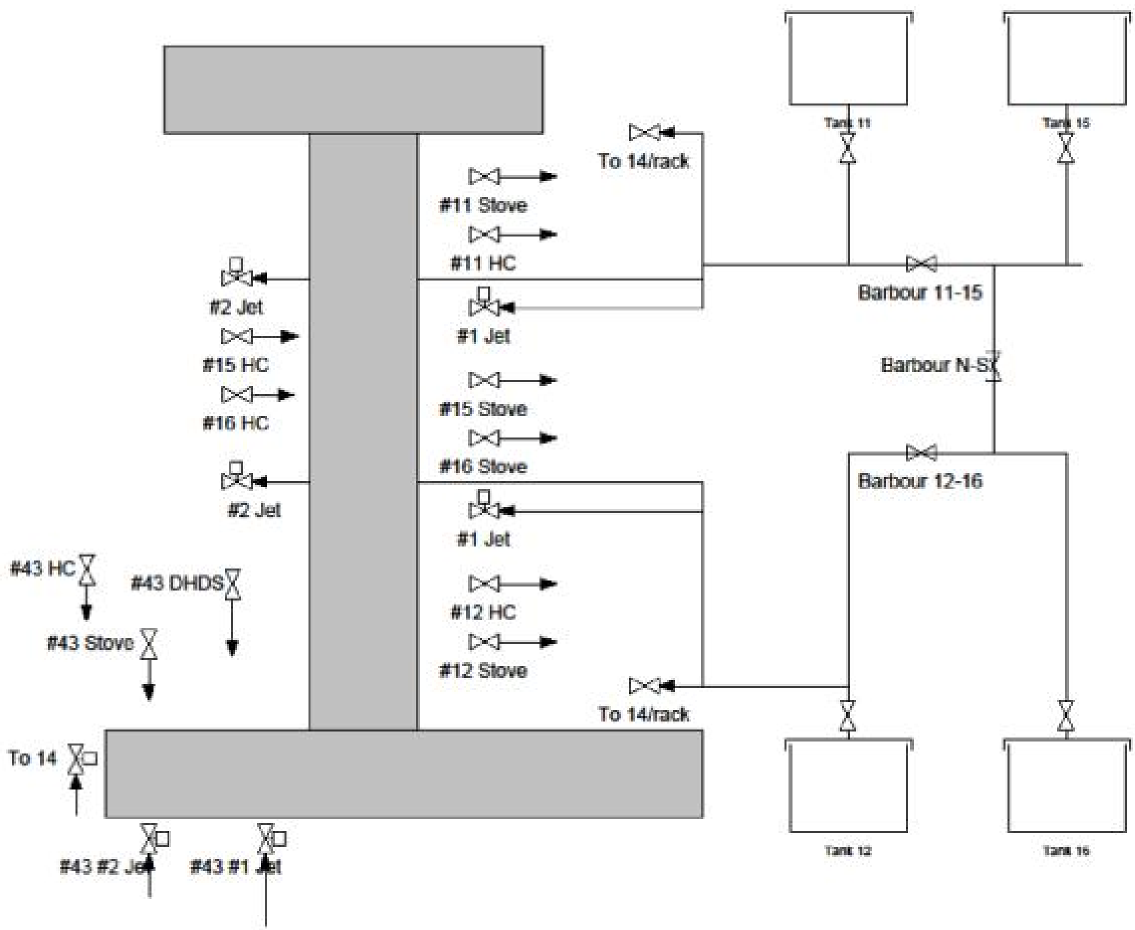
- DMX Impact
  - Enable detection of mental models to focus training
  - Aided in training of new engineers
  - Useful in sharing lessons of events
- Shadowbox
  - Test scalability, is it useful beyond unit for which it was created
  - If true, then create
    - library of exercises for COP members
    - training program to allow members to design their own

Student Projects

Decision Aids

Large Screen Impact

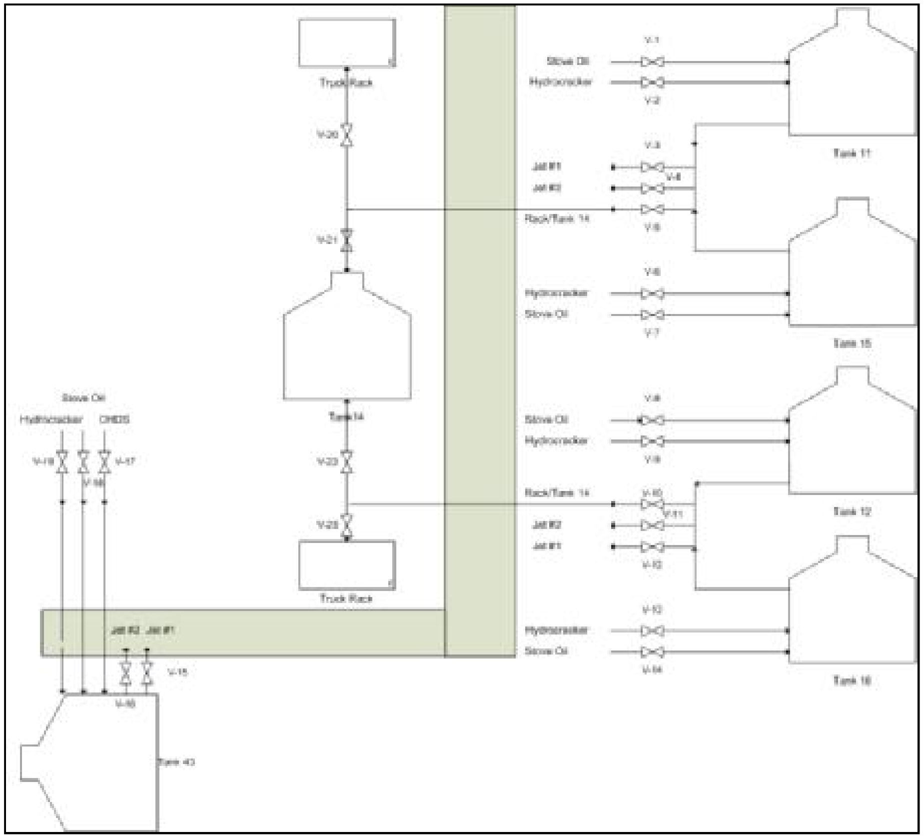
A Typical Manifold



Job Aids

- No job aid
- Manifold diagram
- Line demarcation
- Checklist
- Combinations of the individual job aids

Job Aids

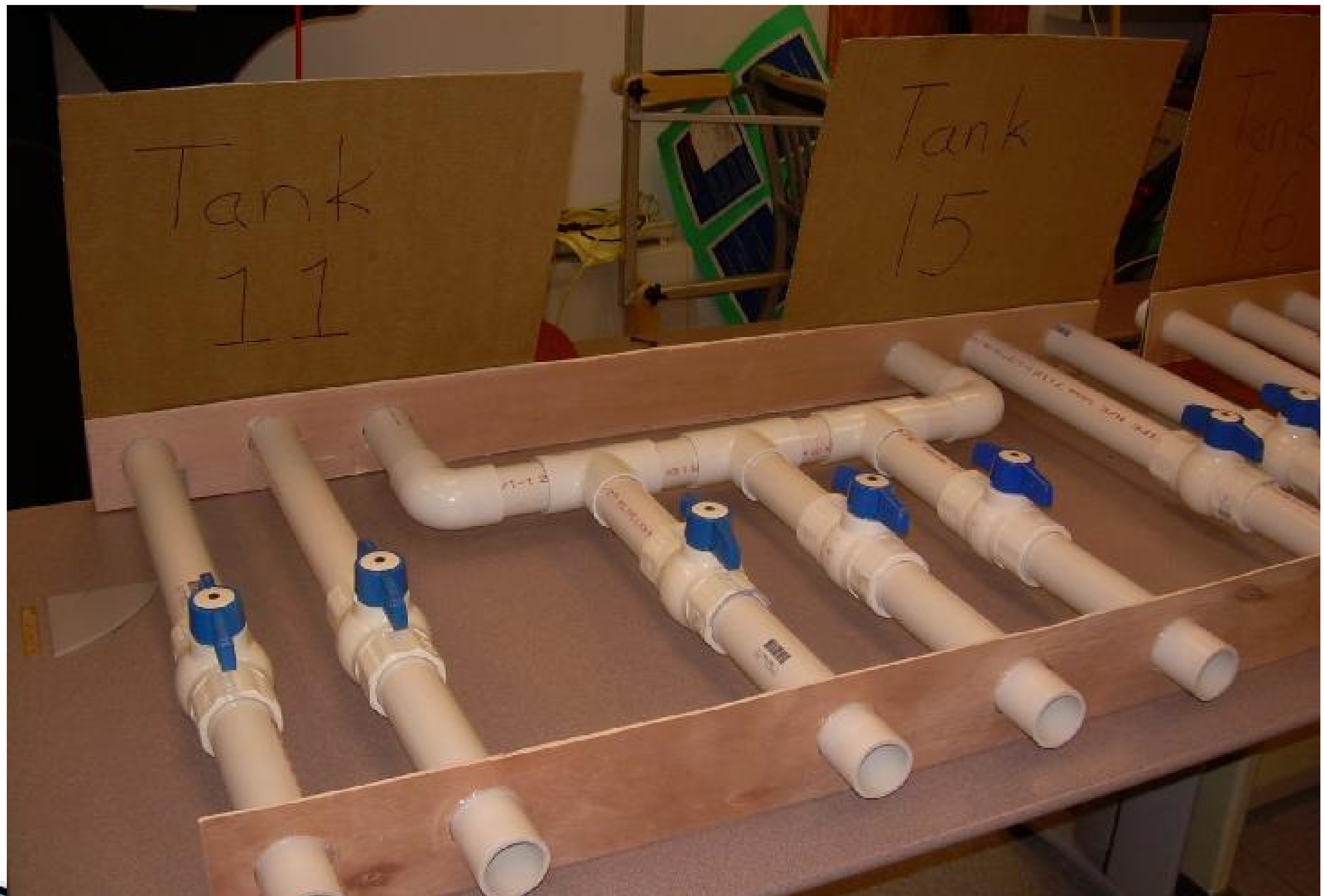


Training Checklist

Hydrocracker to Tank 43 and Tank 16 to Truck Rack

open	Valve 19
CLOSE	Valve 18
CLOSE	Valve 17
CLOSE	Valve 16
CLOSE	Valve 15
open	Valve 10
open	Valve 23
CLOSE	Valve 11
CLOSE	Valve 12
CLOSE	Valve 13
CLOSE	Valve 14
CLOSE	Valve 22

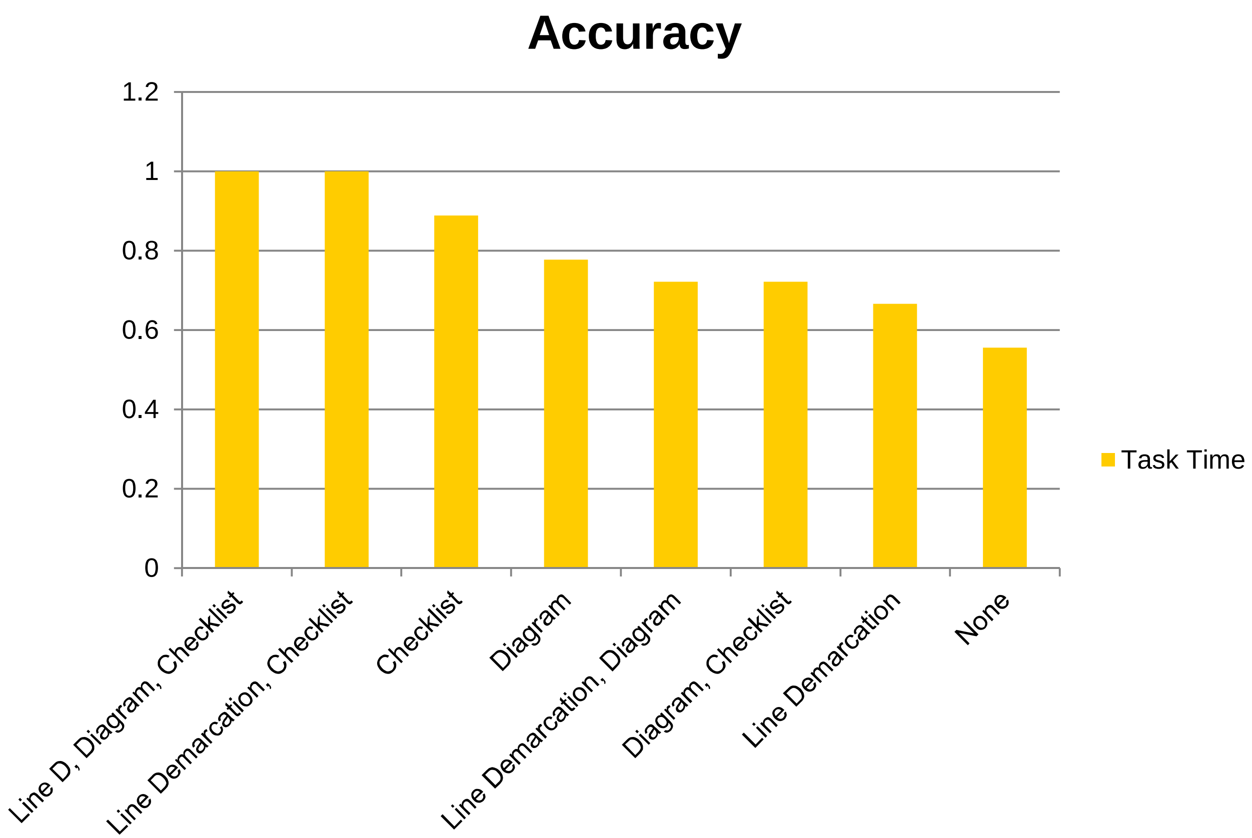
Tank 11 and Tank 15



Procedure

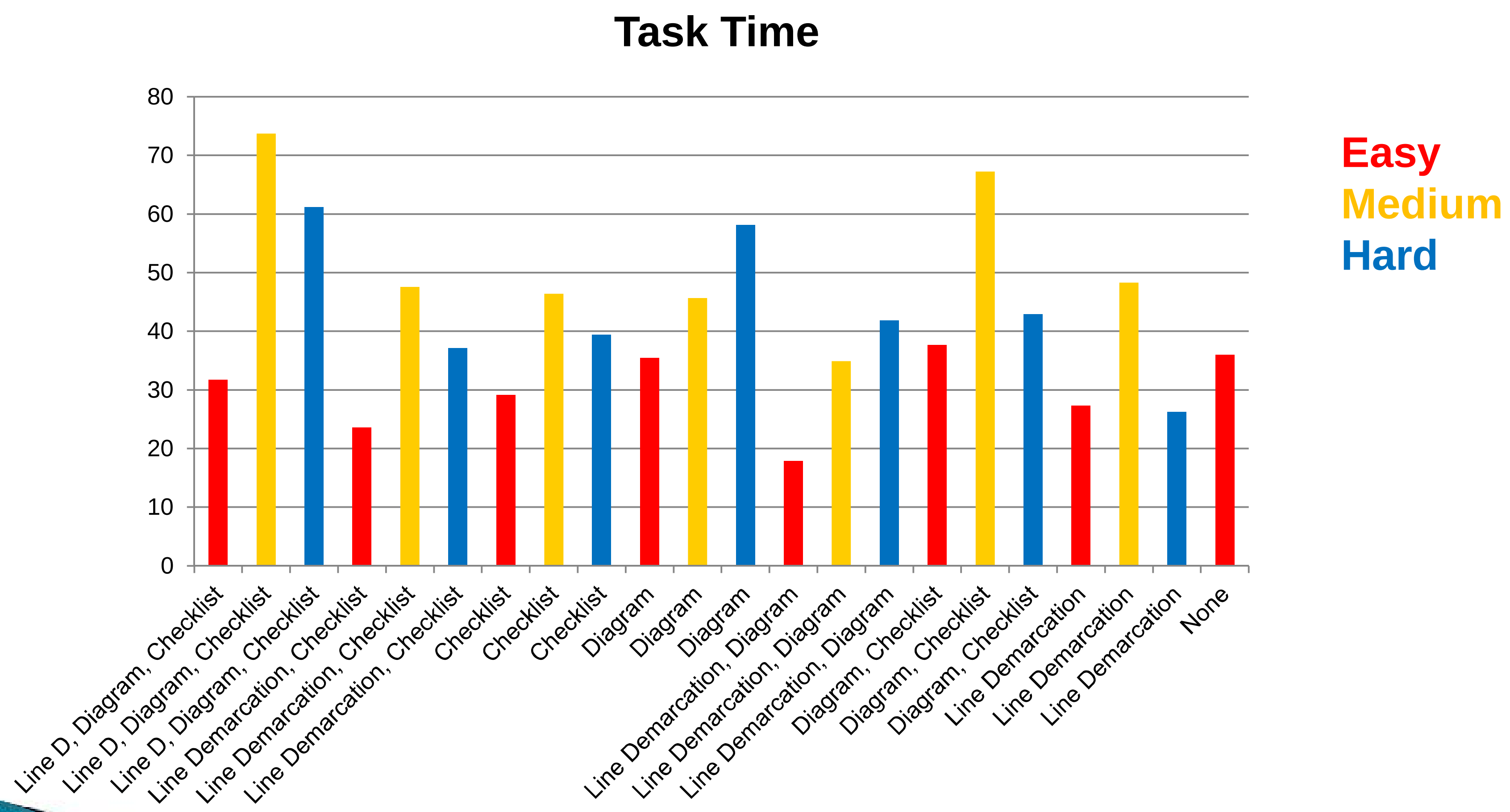
- 24 subjects
- 1st visit
  - Training
  - 3 different tasks
  - Questionnaire
- 2nd visit (1 week later)
  - 3 different tasks
  - Questionnaire
- Received IRB approval

Accuracy



Accuracy
1.2
1
0.8
0.6
0.4
0.2
0
Line D, Diagram, Checklist
Line Demarcation, Checklist
Checklist
Diagram
Line Demarcation, Diagram
Diagram, Checklist
Line Demarcation
None
Task Time

Time



Task Time
80
70
60
50
40
30
20
10
0
Line D, Diagram, Checklist
Line D, Diagram, Checklist
Line D, Diagram, Checklist
Line Demarcation, Checklist
Line Demarcation, Checklist
Line Demarcation, Checklist
Checklist
Checklist
Checklist
Diagram
Diagram
Diagram
Line Demarcation, Diagram
Line Demarcation, Diagram
Line Demarcation, Diagram
Diagram, Checklist
Diagram, Checklist
Diagram, Checklist
Line Demarcation
Line Demarcation
Line Demarcation
None
Easy
Medium
Hard

Extended Operator Workplace

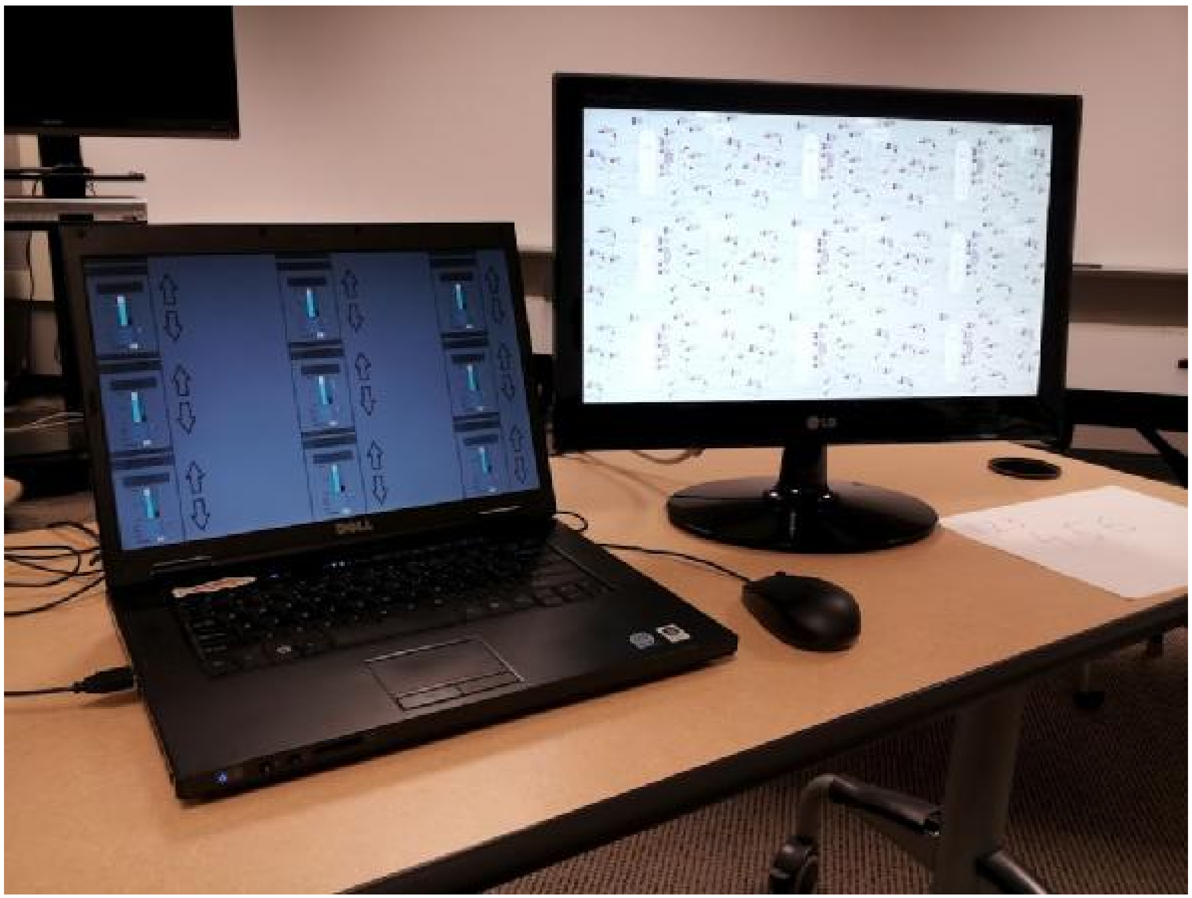
Scope

- Compare reaction times:
  - Information on large 52’’ monitor
    - 12 feet away
  - Information on small nearby monitor
    - 2 feet away

Design of the experiment

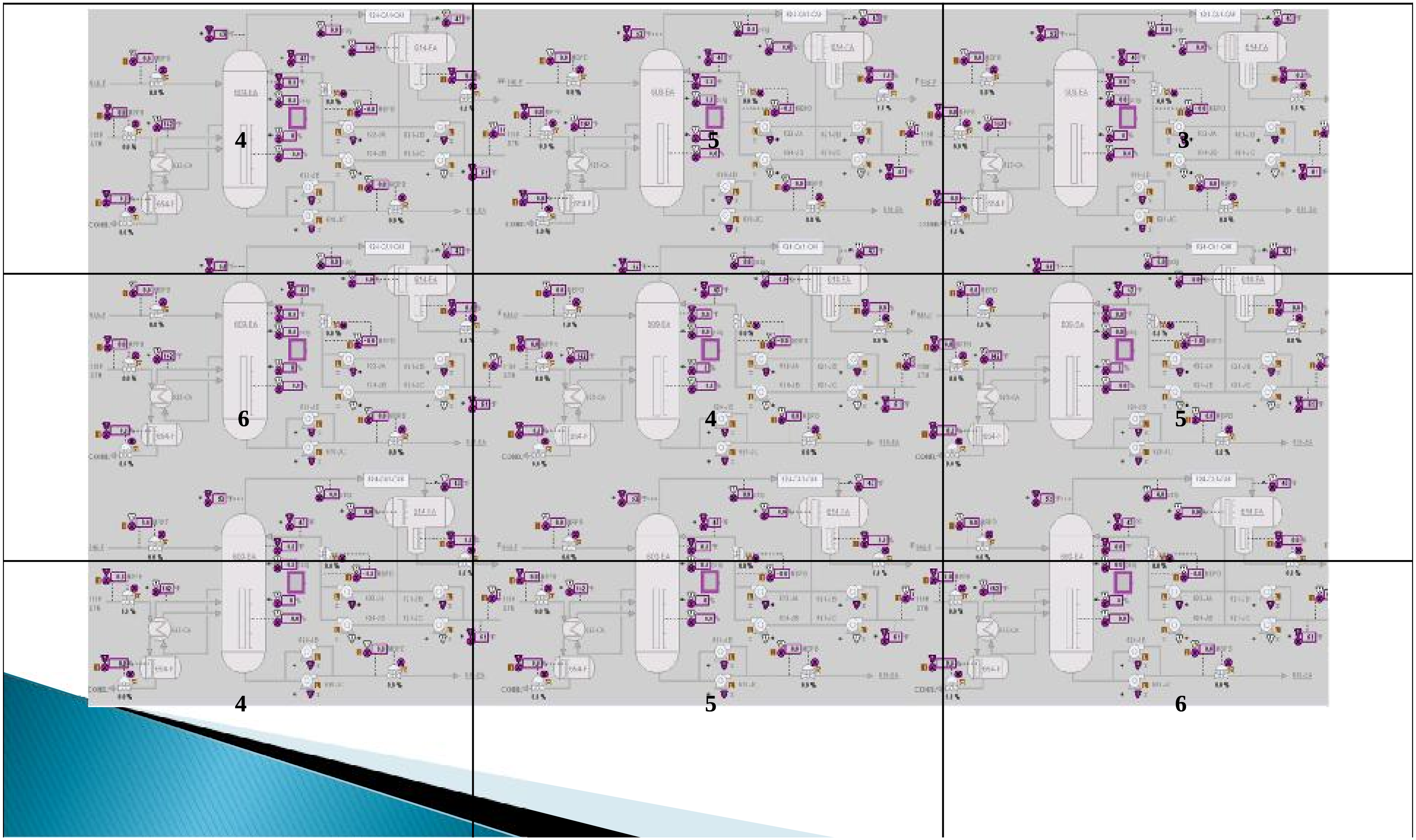
- “Information” and “Control” screens
- Changing numbers on *information screen*
- Control arrows on *control screen*
- Operator must make change on *control screen* to keep values within range

Nearby Information Screen

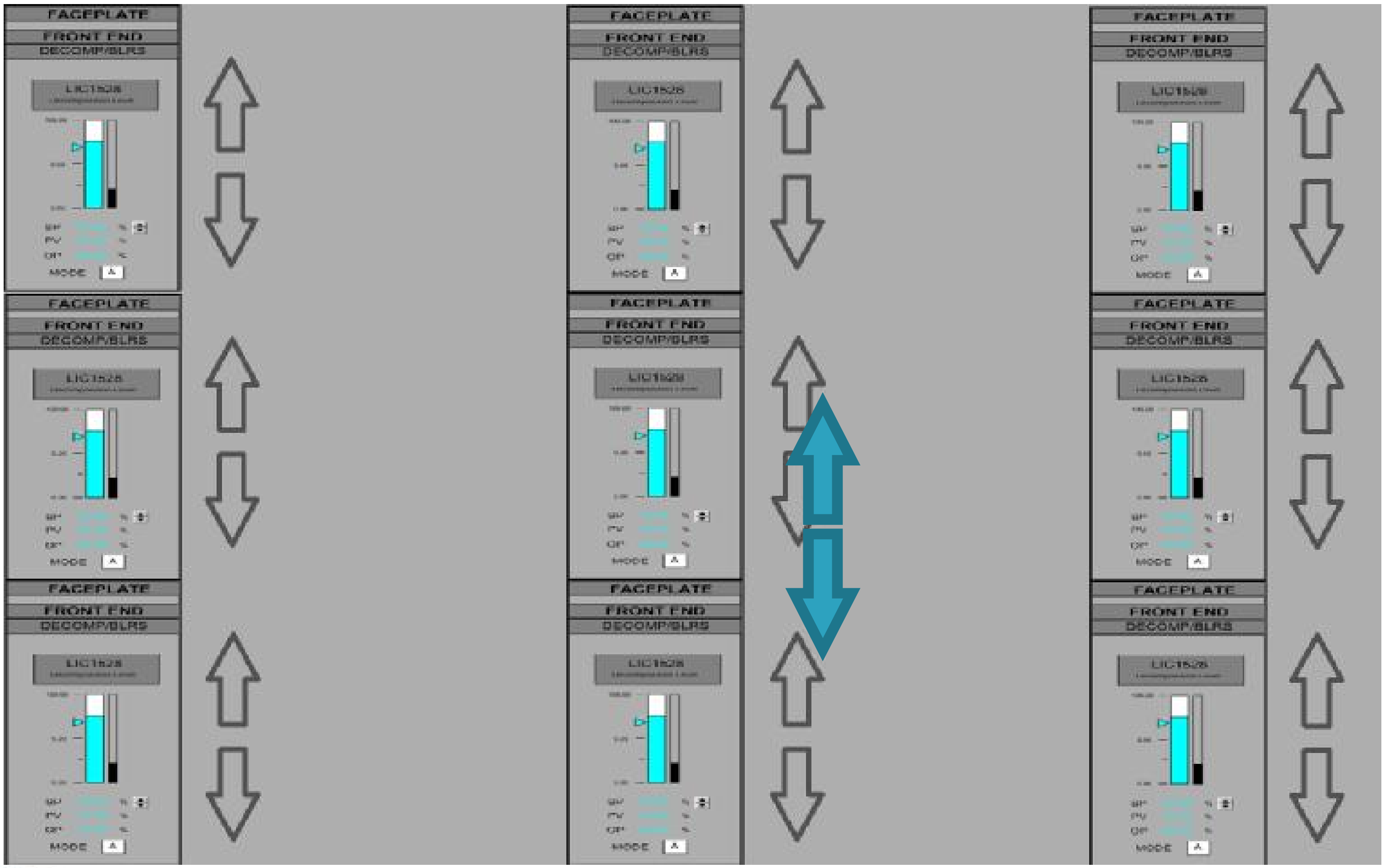


Distant Information Screen

Operator Information Screen

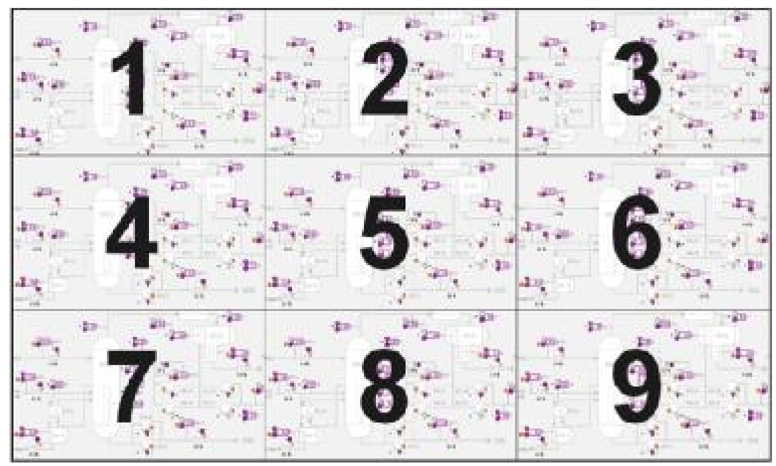


Operator Control Screen



JMP ANOVA Analysis

- Average response times
  - Nearby = 4.30 seconds
  - Distant = 4.64 seconds
- Distance of the target is marginally significant
  - p = 0.08



- Longest response time in sections 1 and 9

Situation Awareness (Overview) Displays

Overview Example Review

This is really a Unit Control Display

KEY DECISONS
The display appears to support key decisions

STRUCTURE
The display is reasonably well organized with grouped information

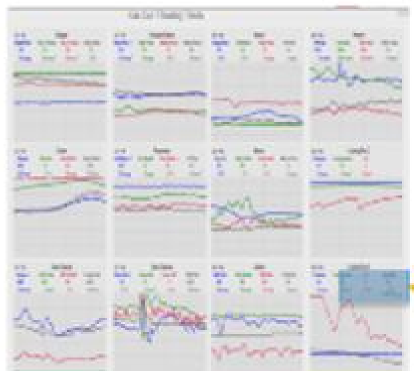
DISPLAY HIERACHY
Navigation is well structured. 1-clicks to any L2 display and 2-clicks to any L3 display

CONVENTIONS AND CODING
Consistent coding and color conventions

SITUATIONAL AWARENESS
Displays doesn't seem to provide much support for the operator in determining if the process is running on target. The display includes KPIs.

QUANTITATIVE VS QUALITATIVE
Most values appear to be quantitative

RECOMMENDATIONS:
-Indicate good versus bad
-Place trends to show patterns
-Place display elements to show patterns
-Convert some of value to qualitative
-Some equipment missing



This is a form of an Overview Display

KEY DECISONS
Not sure whether/how the display supports key decisions

STRUCTURE
The display is reasonably well organized with grouped information (4 trend lines per trend)

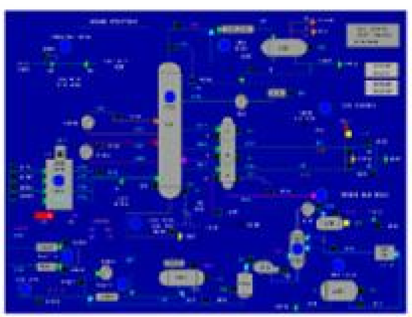
DISPLAY HIERACHY
Not clear what the hierarchy is? Navigation included at the top of the screens.

CONVENTIONS AND CODING
Displays follow consistent coding and color usages. Some concern about using red for trend traces

SITUATIONAL AWARENESS
Can't tell of the equipment is operating within range. What does the this mean? What are the process time constants? Are trend times correct?

QUANTITATIVE VS QUALITATIVE
Most values appear are qualitative

RECOMMENDATIONS:
-Indicate good versus bad
-Place display elements to show patterns
-Convert some of value to quantitative



This is really a Unit Control Display

KEY DECISONS
The display appears to support key decisions

STRUCTURE
The display is reasonably well organized with grouped information. Lacks closures.

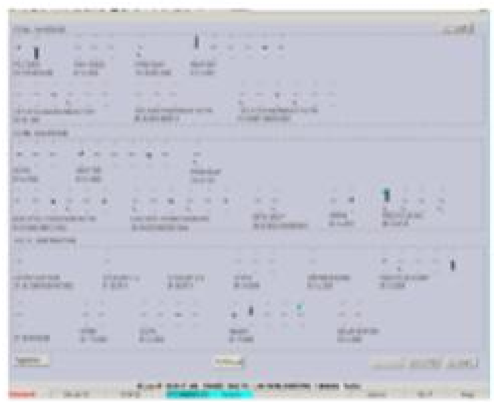
DISPLAY HIERACHY
Navigation is unclear

CONVENTIONS AND CODING
Excessive use of color and arrows

SITUATIONAL AWARENESS
Displays doesn't seem to provide much support for the operator in determining if the process in running on-target

QUANTITATIVE VS QUALITATIVE
Most values appear to be quantitative

RECOMMENDATIONS:
-Indicate good versus bad
-Place trends to show patterns
-Place display elements to show patterns
-Convert some of value to qualitative



STRUCTURE
The display is reasonably well organized with grouped information

DISPLAY HIERACHY
Navigation is unclear

CONVENTIONS AND CODING
Displays follow coding and color conventions

SITUATIONAL AWARENESS
Displays provides considerable support for the operator in determining if the process is running on-target

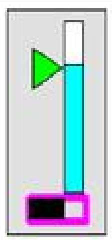
QUANTITATIVE VS QUALITATIVE
All values appear to be qualitative

RECOMMENDATIONS:
-Place trends to show patterns

4 Seconds

- Enable the operator to determine the health of the units under their span of responsibility
- If a problem exists, directs them to displays from which they can troubleshoot and correct the problem.
- Do this by:
  - Present the correct data, well formatted to answer the operator questions:
    - "Is my process ok?" and, "Is it running at the desired target?"
  - As the questions are qualitative in nature, the information should generally be presented in a qualitative manner.

Quantitative vs Qualitative

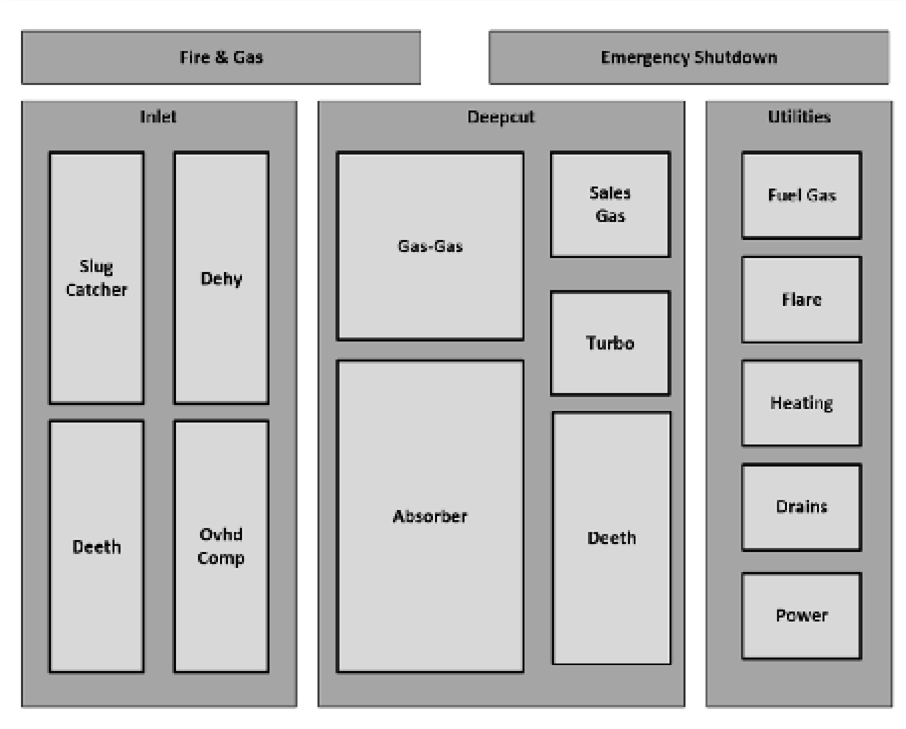
		Time to Assess Experiment (seconds)	
		Quantitative Question	Qualitative Question
PV 78.5 PCT SP 78.0 PCT OP 62 MANUAL	Quantitative Presentation (less abstract)	**102**	115
	Qualitative Presentation (more abstract)	118	**101**

How full is the tank?

Am I running at the setpoint and will it stay there?

How Should The Information Be Organized?

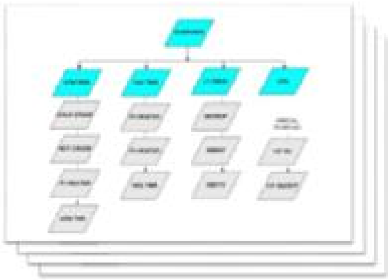
- Creates a carefully organized system of displays
  - Navigate directly to primary operating display, and to detail where needed.
  - Display organized by function
  - Typically less than 100 PV's on the display
- Just for this operator position
- No more than 10 sections on an overview display



An Overview

- Supports Operator’s key decisions
  - “Is my domain OK?”
  - “Is it operating at the desired target?”
  - 4-second situational awareness
  - Overview Display is always visible

- One Overview Display per operators span-of-responsibility
  - Display organized by function
  - Utilizes qualitative information
  - Typically less than 100 parameters on the overview



Steps to Design Overview Displays

Final

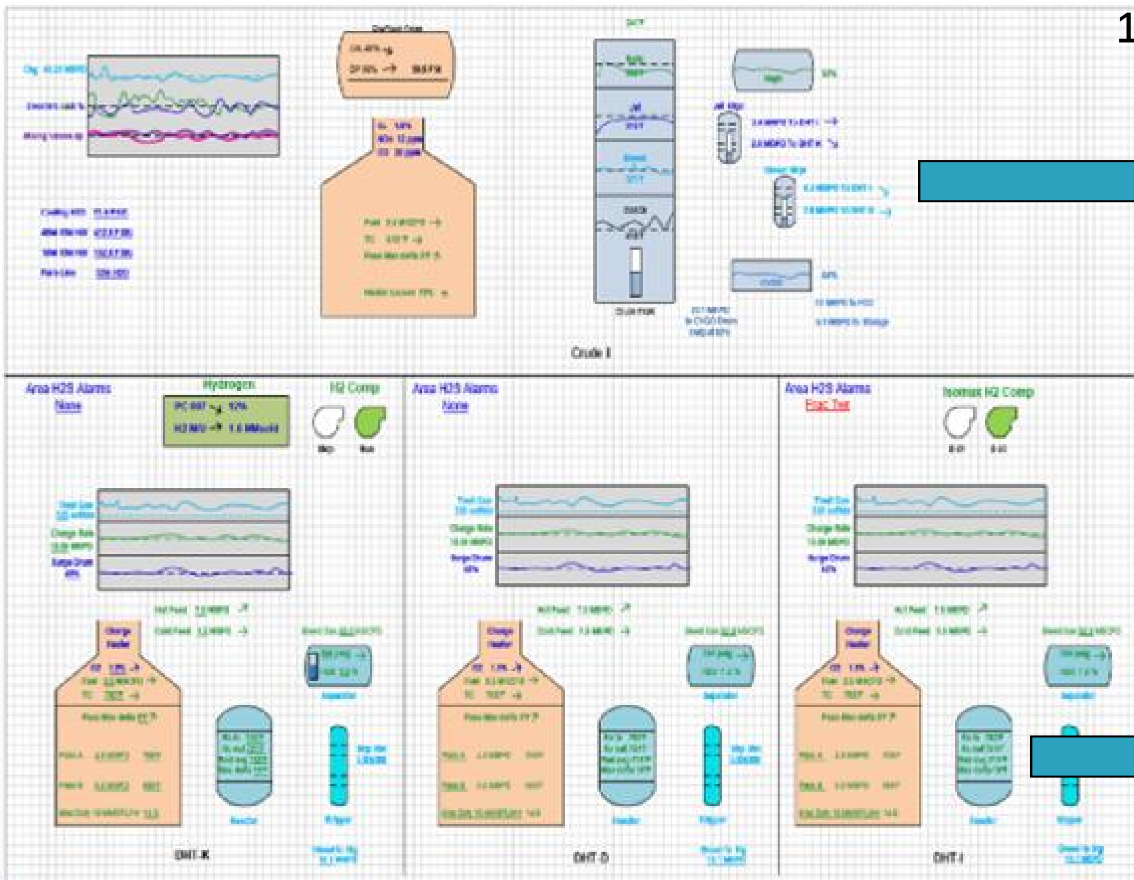
Content	Organization	Format
• Do I need every single data point? • What data points are important? • What data should be fused into information?	• What information is needed for high level situation awareness? • How do I choose the information for overviews down to details? • What information should be grouped together? • Which sets of information should be grouped across screens?	• What is the best frame of reference? • What is the best way to move across screens and into details? • What colors should be used? • What sizes of font, lines, etc...

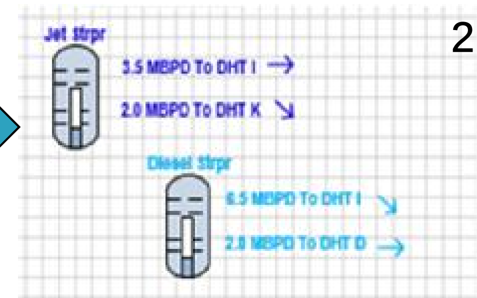
Content

What Data Should Be Included In A Display?

- Decision Mapping
- Interviewing
- Facilitation Process
- Key Leading Indicators of changes in the Process
- Story telling

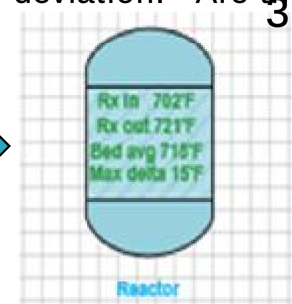
How Should The Information Be Formatted?





Has the process been steady, increasing or decreasing?

Average value, maximum deviation. Are they OK?




CHG
DSLTR A
DSLTR B
MIX VLV A
MIX VLV B
PREFLASH DRUM
CRUDE II
CRUDE TWR
NAPH
JET STRPR
DIESEL STRPR
TO DHT K
TO CVGO DRUM
CVGO
TO FCC
TO STORAGE
COOLING H2O
400# STM HDR
150# STM HDR
FLARE LINE
AREA H2S ALARMS
DHT-K
DHT-D
DHT-I
TREAT GAS
CHARGE RATE
SURGE DRUM
HOT FEED
COLD FEED
BLEED GAS
SEPARATOR
STRP STM
STRIPPER
REACTOR
PRODUCT TO STG
H2 COMP

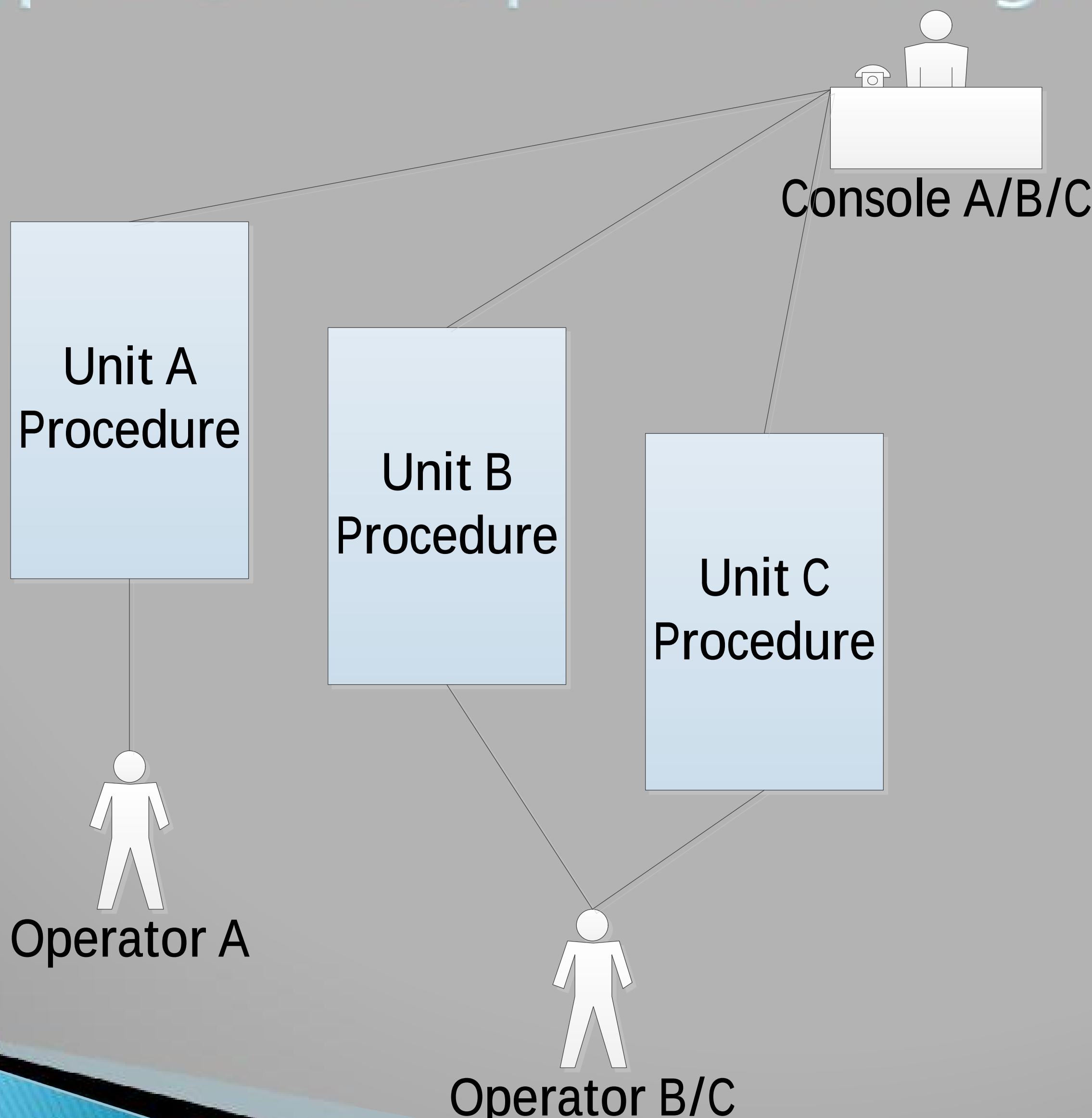
Future/Impact

- Impact
  - Overview created for project
  - Positive feedback has led to creation for 11 other consoles in control room
- Future
  - Team moved on to lower levels
  - Creating representation options for key equipment (reactors, heaters)
  - Developing rules for display system creation

Procedure Modularization

Sandeep Purao
Penn State University

Multiple Unit-Operator Alignments



Procedure Assessment

- Issues
  - Same steps in multiple procedures
  - Different levels/types of information (task versus training)
  - Different users
  - One size fits all
- Improvement option
  - Break procedures into chunks that can be recombined
- Problems
  - Volume
  - Style/format

Development procedure

STANDING INSTRUCTION NO. DGHE-8

LOSS OF HYDROGEN RECYCLE COMPRESSORS

Feed control valves will close, MA-14 and GH-376 will shut down. Check to see if this has happened.	Close feed control block valve. Also close liquid recycle valve if recycling product.	Fuel gas control valve will close, steam to heater will open.
Shut off makeup hydrogen. Shut down compressor GH-572 if in service.	Start venting plant to H.P. fuel via recycle drip vessel 1252. Notify Cracking.	Start N_2 to plant via suction bottle on compressor GH-504 (open bypass) when plant pressure is 160 psi, close vent to fuel on V-1252 open to flare via LPG Drip 1257. (Close Suction on Com-

Application of Heuristics

Conjunctions and Conditions

if (∀ k ∈ Si, ∃ conj ∈ ConjuntionList | k == conj,
and ∀ j ∈ Si | cond ∈ ConditionList | j == cond)
{conjunction(Si) = k; Condition(Si) = j;}

Conjunction

ConditionList

```
Close hot feed valve to Platformer. Pump striper bottoms to
Close off product separato with normal operating level
Continue circulating hydrogen until reactor temperature is below 500F,
Continue stripper bottoms circulation through heater 35 until radiant
Shut off hydrogen to compressors 503 and 504. Switch make hydrogen to
Stop the condensate injection and sour water pumps.
Close in lean and fat DEA circulation.
Shut down the vent gas compressors
```

Procedure	Action	Target	Step-Break	Conjunctio	Condition
Continue circulating hydrogen until reactor temperat	continue	hydrogen	TRUE	until	temperature
Shut down compressors 503 and 504.	shutdow	compressors 503	TRUE		
Vent system to flare if necessary.	vent	system			
…oms circulation through heate	continue	striper bottom		until	temperature

Procedure Chunking

Procedure Elements for Chunking

Procedures: DDHE 10-DS.txt

File: DDHE 10-DS.txt

Break-Eq...	Break-Op...	Break-Int...	#	Lines of ...	Subject	Subject ...	Predicate	Adverbial...	Object	Object M...	Purpose	Condition	Conjuncti...
			1	Cooling w...	field		Cooling		water fail...				
	*												
			2	Close anni...	field		Close		annin valve	in the fee...			and
			4	Shut dow...	field		Shut down		the field f...				
			5	Throw swi...	field		Throw		switch BS...	on DHT e...	to shut He...		
			6	Open Delu...	field		Open		Deluge sy...	to HDU an...			
			7	Shut dow...	field		Shut down		Compess...	at emerge...			
			8	Block off t...	field		Block off			to make H...		if operatin...	
		*											
			9	Manually ...	field		Manually		unload co...				
			10	Shut dow...	field		Shut down		Heater 30...				
			11	Start stea...	field		Start		steam	to Htr .29 ...			
			12	Open dam...	field		Open		dampers				
			13	Close mai...	field		Close		main block	on fuel an...			
			14	Vent unit t...	field					Ventunitto...			
			15	Close in w...	field		Close in		warm an...	with norm...			
			16	Close in le...	field		Close in		lean and ...				
			17	Notify the ...	field		Notify		the SRU				
			18	Stop cond...	field		Stop		condensa...				
			19	Pump only...	field		Pump			onlyenoug...		as to avoi...	
			20	Watch pu...	field		Watch		pump be...	temperature			
			21	Close strip...	field		Close		steam			if open	
		*											
			22	Vent strip...	field		Vent		stripper	to flaretoc...			
			23	As time p...	permits f...							As	
			24	Stop feed ...	field		Stop		feed and ...				
			25	Unload co...	field		Unload		compress...				
			26	Purge syst...	nitrogen		Purge		system	with hydro...		if availabl...	
		*											
			27	If unable t...	field		notify		Process ...			If unable t...	
		*											

Test – 40 pages of Emergency Procedures

LOSS OF POWER		
Procedure: D-900-07.05 Revision: 0 Effective Date: 11-Sep-2009	**07 - Emergency Operations** Laurel Refinery	Operations Zone D 900 - ULSD

PURPOSE

Loss of Power

SCOPE

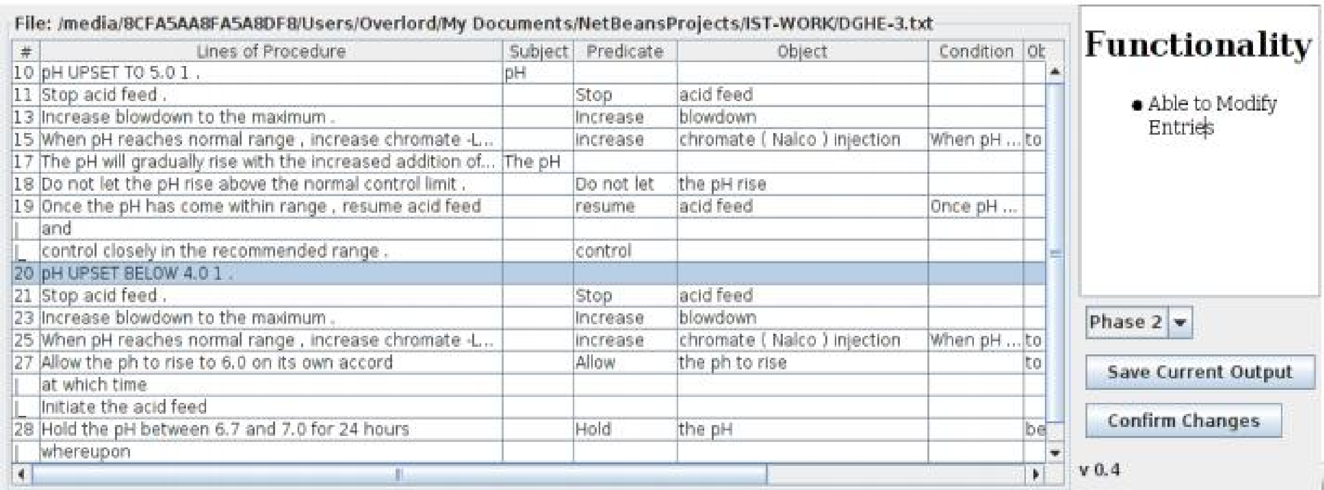
This procedure details the steps needed to safely respond in the event of a power loss

Role	Description of Task	Initials
	The following procedure details the steps needed to safely respond in the event of a total loss of power. It is a requirement of operation personnel to have in depth understanding of ESD procedures prior to operating the plant	
CO	1. Trip the Reactor Charge Heater Emergency Shutdown System, (I-904) HZ-9056 A. • Closes Reactor Charge Heater Fuel Gas Emergency Shut-off Valve, fuel gas control valves and shuts down Charge Pump P-901 A/B.	______
ZN	2. Block in the Reactor Charge Heater H-901 fuel gas control valve FV-9028 A/B and burner block valves..	______
CO	3. Trip the emergency fuel gas shut down system for the Fractionator Reboiler with (I-914) HZ-9441A. • Closes Fractionator Reboiler Fuel Gas Emergency Shut-off Valve XV-9508A and fuel gas control valve FV-9425	

Results – 4 Pages of Unique Actions

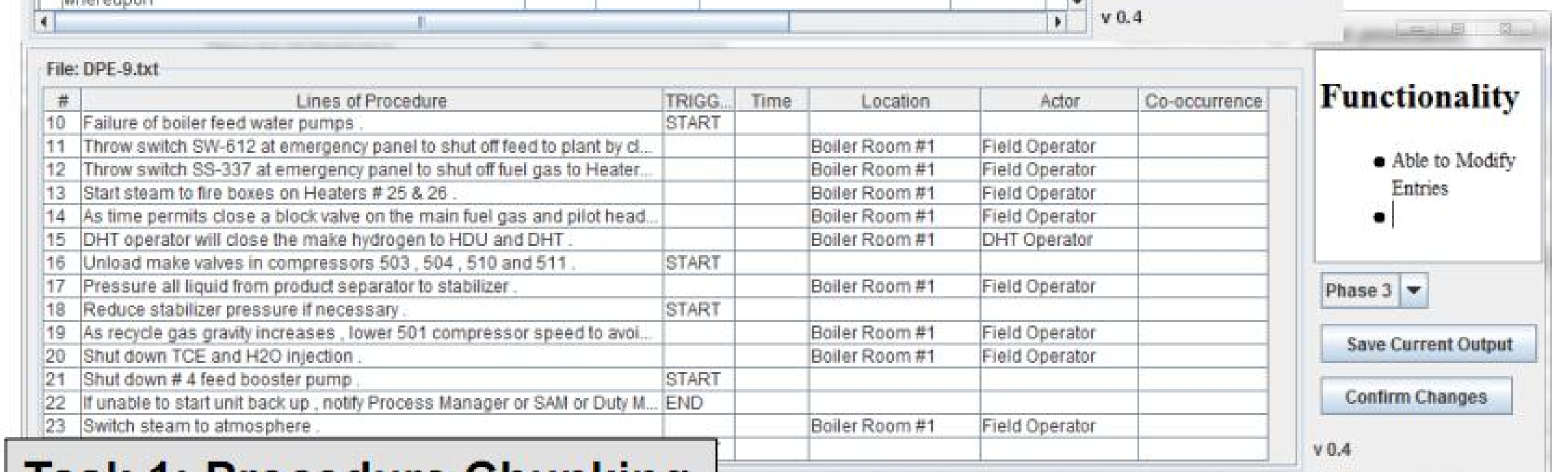
#	Chunk	Steps
1	Clear exchanger tubes	2
2	Shutdown Unit	2
3	Isolate frac	4
4	Make Notifications	4
5	Total Reflux	1
6	Secure Heaters	3
7	Trip Charge Heater	2
8	Total Recycle	3
9	Troubleshoot Cause	3
10	Line-up to offspec	4
11	Secure Amine and H2	4
12	Bottle in 900 unit	13
13	Charge Heater ESD	10
14	Conserve H2	32
15	Depressure unit	7
16	Event Follow-up	15
17	Frac Reboil Heater ESD	9
18	Isolate Feed Rundown	8
19	Low H2 operation	8
20	Prevent Runaway	14
21	Secure 900 Unit	18
22	Shutdown Charge	4
	Total	170

Procedure Splitter Ver. 0.7



#	Lines of Procedure	Subject	Predicate	Object	Condition	Ob
10	pH UPSET TO 5.0 1 .	pH				
11	Stop acid feed .		Stop	acid feed		
13	Increase blowdown to the maximum .		increase	blowdown		
15	When pH reaches normal range , increase chromate -L...		increase	chromate (Nalco) injection	When pH ...	to
17	The pH will gradually rise with the increased addition of...	The pH				
18	Do not let the pH rise above the normal control limit .		Do not let	the pH rise		
19	Once the pH has come within range , resume acid feed		resume	acid feed	Once pH ...	
	and					
	control closely in the recommended range .		control			
20	pH UPSET BELOW 4.0 1 .					
21	Stop acid feed .		Stop	acid feed		
23	Increase blowdown to the maximum .		increase	blowdown		
25	When pH reaches normal range , increase chromate -L...		increase	chromate (Nalco) injection	When pH ...	to
27	Allow the ph to rise to 6.0 on its own accord		Allow	the ph to rise		to
	at which time					
	initiate the acid feed					
28	Hold the pH between 6.7 and 7.0 for 24 hours		Hold	the pH		be
	whereupon					

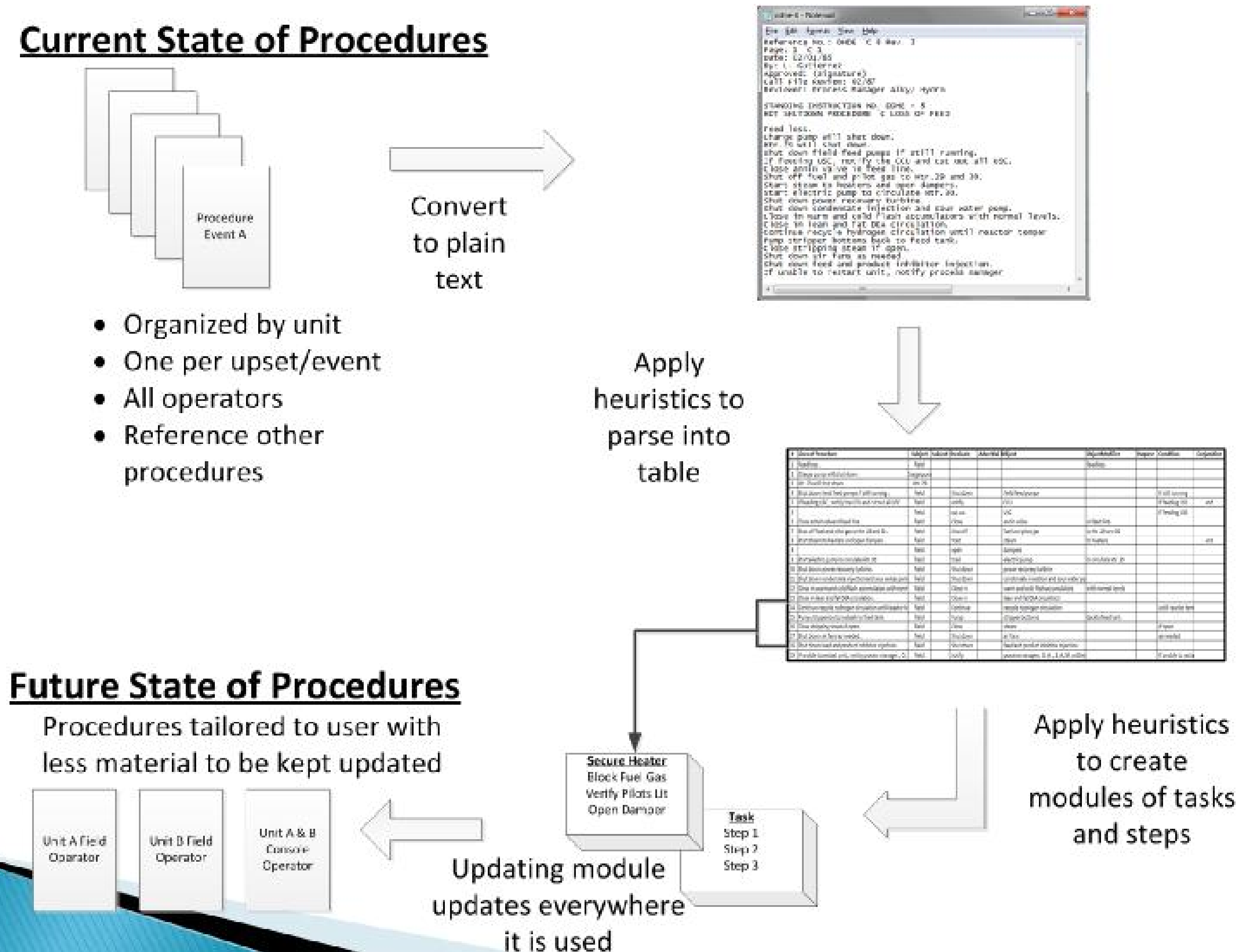
Proc-Splitter Version 0.4



#	Lines of Procedure	TRIGG...	Time	Location	Actor	Co-occurrence
10	Failure of boiler feed water pumps .	START				
11	Throw switch SW-612 at emergency panel to shut off feed to plant by cl...			Boiler Room #1	Field Operator	
12	Throw switch SS-337 at emergency panel to shut off fuel gas to Heater...			Boiler Room #1	Field Operator	
13	Start steam to fire boxes on Heaters # 25 & 26 .			Boiler Room #1	Field Operator	
14	As time permits close a block valve on the main fuel gas and pilot head...			Boiler Room #1	Field Operator	
15	DHT operator will close the make hydrogen to HDU and DHT .			Boiler Room #1	DHT Operator	
16	Unload make valves in compressors 503 , 504 , 510 and 511 .	START				
17	Pressure all liquid from product separator to stabilizer .			Boiler Room #1	Field Operator	
18	Reduce stabilizer pressure if necessary .	START				
19	As recycle gas gravity increases , lower 501 compressor speed to avoi...			Boiler Room #1	Field Operator	
20	Shut down TCE and H2O injection .			Boiler Room #1	Field Operator	
21	Shut down # 4 feed booster pump .	START				
22	If unable to start unit back up , notify Process Manager or SAM or Duty M...	END				
23	Switch steam to atmosphere .			Boiler Room #1	Field Operator	

Task 1: Procedure Chunking

Automated Procedure Chunking



Future/Impact

- Future
  - Creating integrated analysis & database software
  - Add ability to utilize/insert standard descriptors
  - Enable lookup tables to replace instrument numbers for redundant equipment (e.g., heaters)

Alarm Rate Analysis

Craig Harvey, Ph.D.
Louisiana State University

Alarm Rate Standards

EEMUA Alarm Rate Standard

Long Term Average Alarm Rate in Steady Operation	Acceptability
>1 alarm per minute	Very likely to be unacceptable
1 alarm per two minute	Likely to be excessively demanding
1 alarm per five minutes	Manageable
<1 one alarm per ten minutes	Very likely to be acceptable

ISA Alarm Rate Targets

Very Likely to be Acceptable

~150 Alarms per day

~6 Alarms per hour (average)

~1 Alarms per 10 minutes (average)

Maximum Manageable

~300 Alarms per day

~12 Alarms per hour (average)

~2 Alarms per 10 minutes (average)

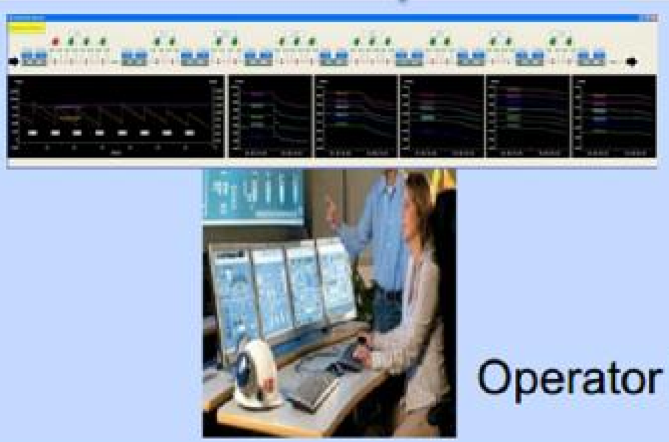
Alarm Displays

- Categorical
- Chronological

20 in First 10 Minutes	Chronological and Categorized Alarm display
10 in First 10 Minutes	Chronological and Categorized Alarm display
5 in First 10 Minutes	Chronological and Categorized Alarm display
2 in First 10 Minutes	Chronological and Categorized Alarm display
1 in First 10 Minutes	Chronological and Categorized Alarm display

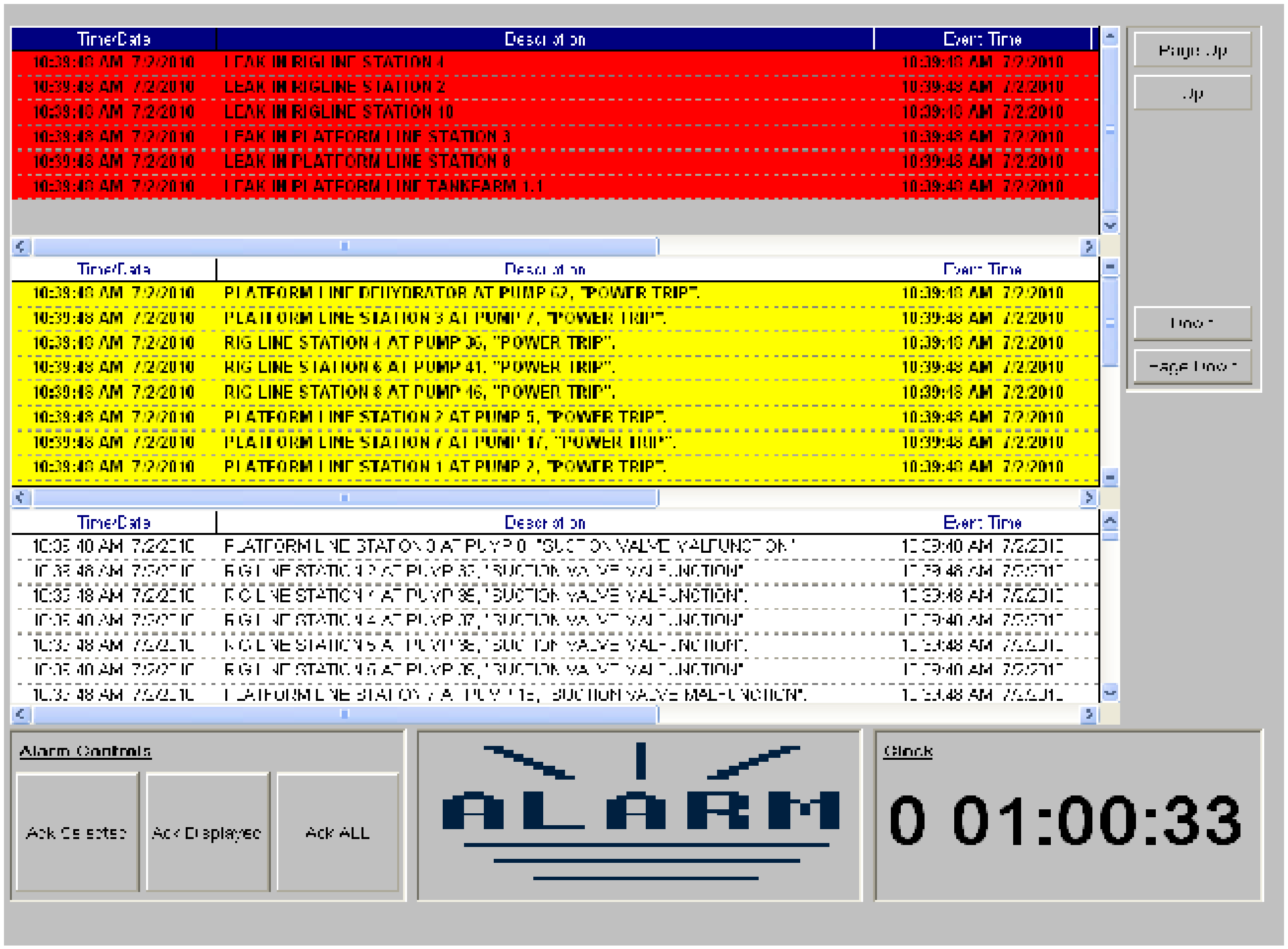
Alarm Rates

- 1 per 10 min
- 2 per 10 min
- 5 per 10 min
- 10 per 10 min
- 20 per 10 min

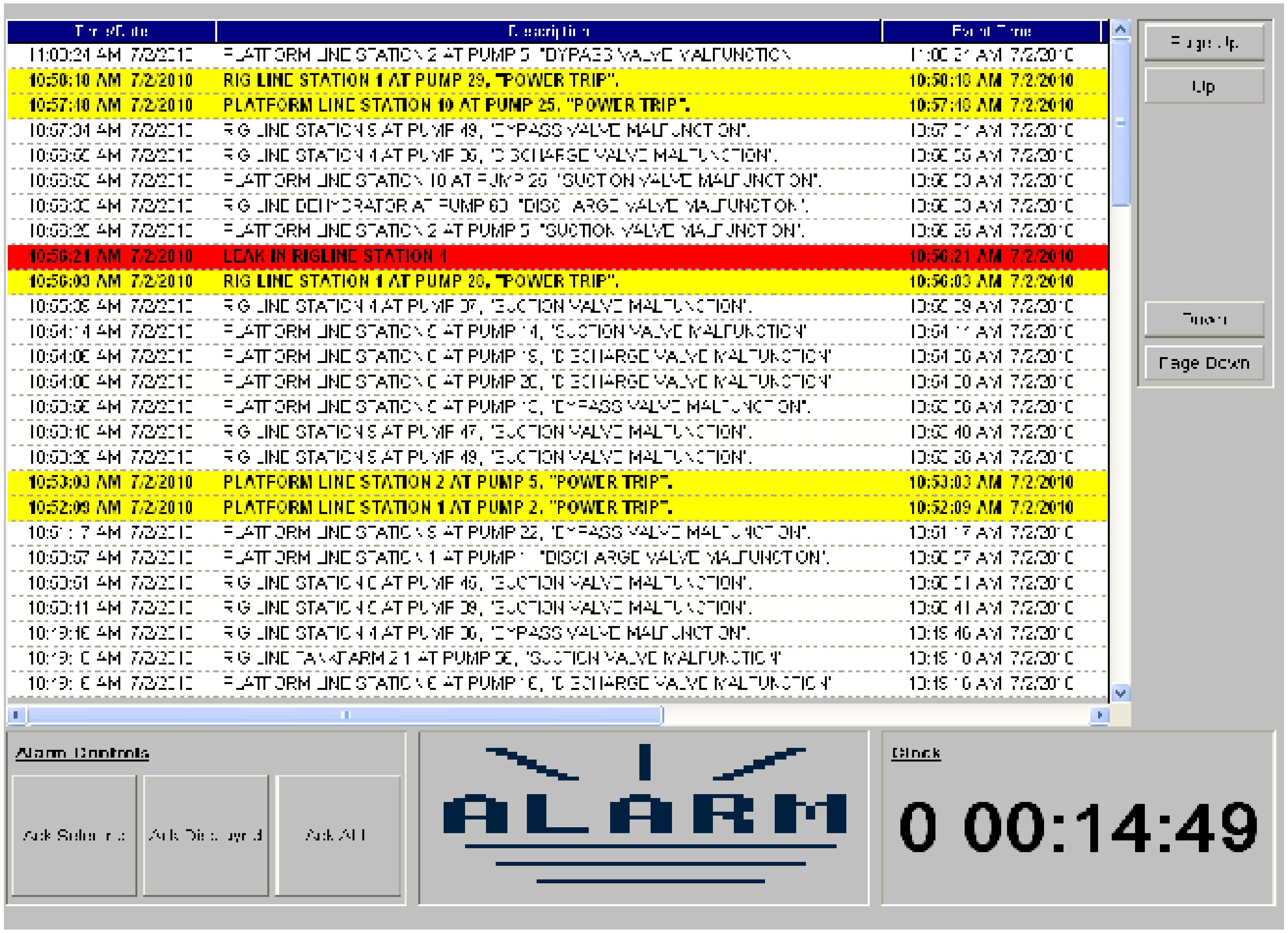


Operator Performance

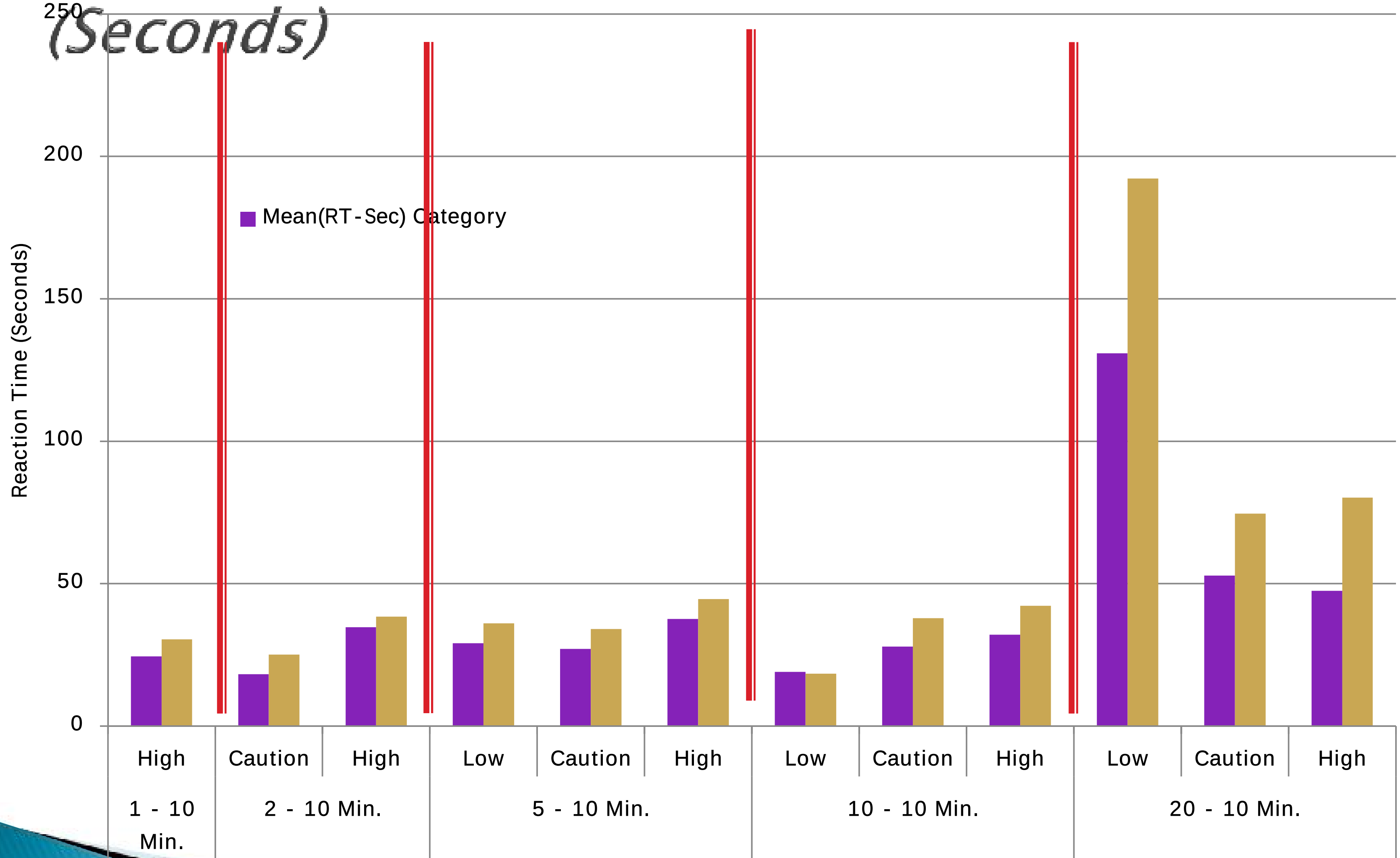
Categorical Alarm Display



Chronological Alarm Display



Descriptive Statistics – Mean Reaction Time (Seconds)

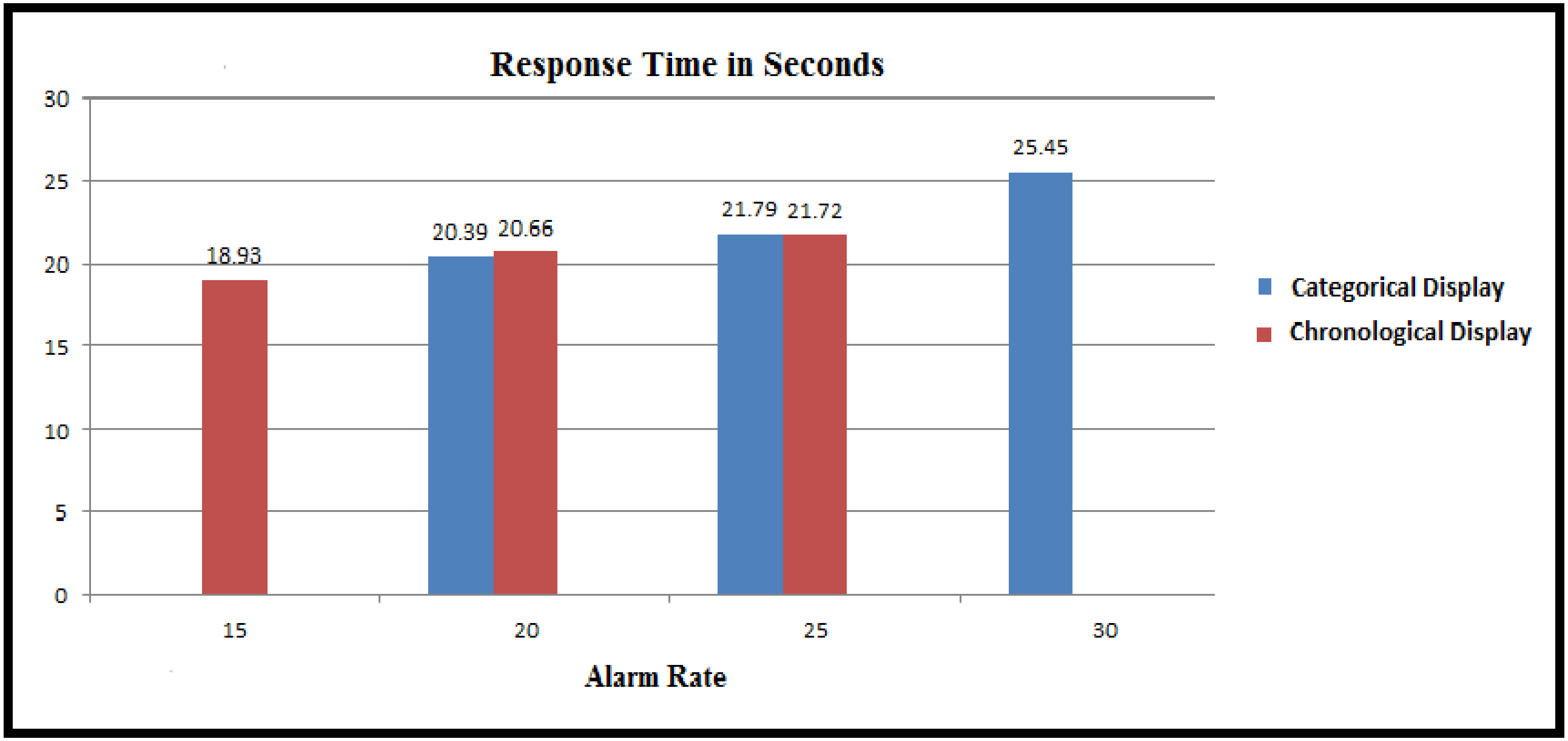


Overview

- Minimum of 30 operators will run the experiment.
- Two kinds of alarm display's will be used (Chronological and Categorical).
- All treatment simulations are 1 hour and the alarm rates used as below:

Alarms/10 minutes	Chronological	Categorical
15	X	
20	X	X
25	X	X
30		X

Response Time by Alarm Rate



RT – Alarm Rates v. Student/Operator

Level							Least Sq Mean (sec)
Student,20	A						93.016354
Operator,20		B					47.676607
Student,10		B					31.785469
Operator,10		B					24.217462

- Students and Operators reaction time for solving an alarm can not be distinguished from one another except at the alarm rate of 20 alarms per 10 minutes
  - Students performed significantly slower than operators at 20 alarms per 10 minutes

Future/Impact

- Impact
  - Published alarm targets are at best for novice operators
- Future
  - Examining smart alarming
    - How to develop and document
  - Quantify benefits of alarm management
    - Does alarm management improve performance?
    - Current adoption is article of faith
    - Look at in conjunction with procedure automation

New COP Projects

Background Color

Business case:
Background color and color contrast is a very effective technique for presenting information to operators. The use of appropriate color schemes allows operators to very rapidly recognize and interpret information on the display.

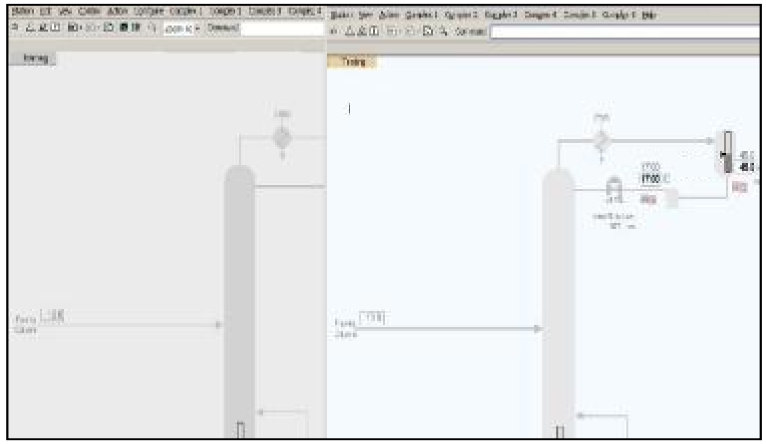
Purpose:
Determine which variables have the greatest affect in selecting the background / foreground color palette for a given ambient light source?

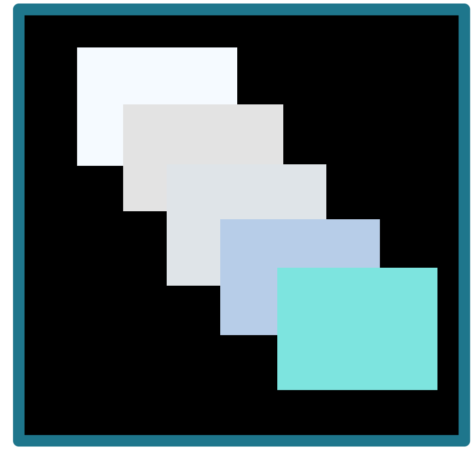
What characteristics, aspects or principles of ambient lighting conditions influence the usability of sets of color on an operator display?

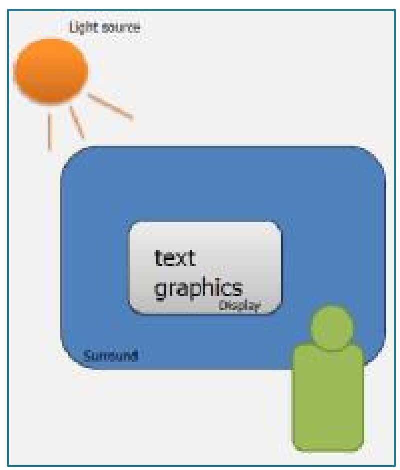
What characteristics, aspects or principles of the display device (screen, monitor, LCD panel) influence the usability of sets of color on an operator display? (examples include viewing angle, contrast ratio, brightness, glare, and treatments.)

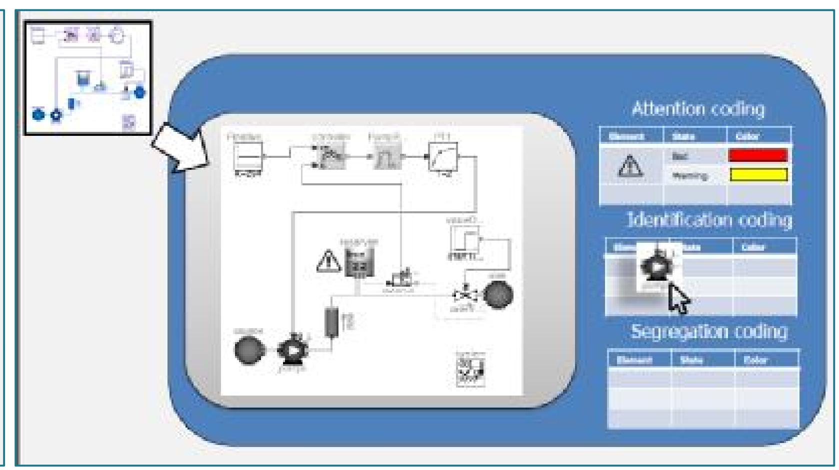
How can these findings provide a starting point when considering other situations like uncontrolled environments outside the central control room? Standard office, roving operator in sunlight and shadow, airport gate lounge, etc.

Deliverable:
Ideal color design tool









Large Screen Display Survey

Purpose:
A survey of both member and non-member companies is being conducted to determine how large screens are or are not being effectively used in the petrochemical industry and the reason why.

In addition to size and number of monitors, the survey elicits input on the intent of the monitors, the formatting of the data, and suggestions for use.

The survey has sections for supervisors, operators, engineers, and designers.

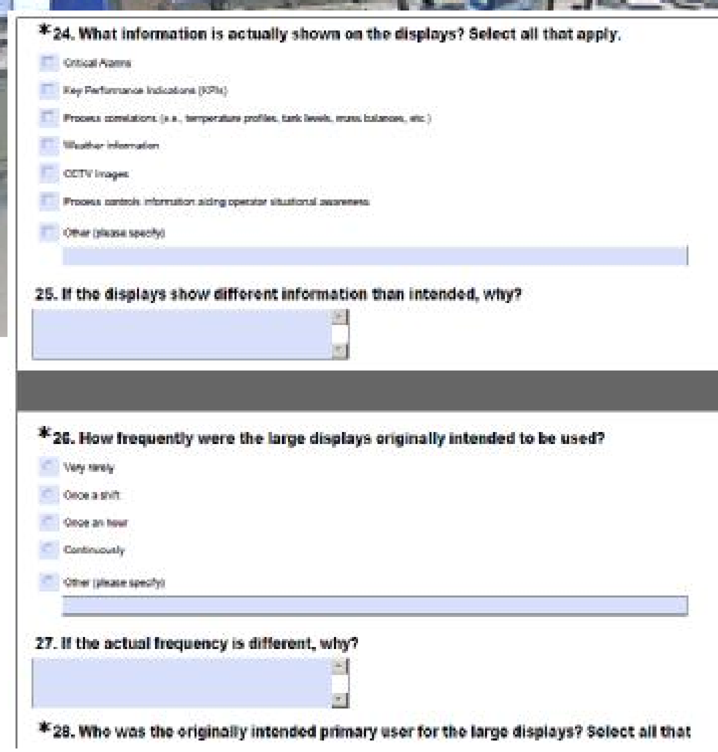
This survey is open to any operating company, with results provided to all who participate.

The survey is on the ABB and COP websites.

As of March 13, 2015 about 60 responses have been received.

Factors:
Location, role of user, utilization, effectiveness, display format, etc.

Deliverable:
The survey results will be analyzed to identify current best practices and lessons learned, and will set the groundwork for future research to develop large display standards.


*24. What information is actually shown on the displays? Select all that apply.

- Critical Alarms
- Key Performance Indications (KPIs)
- Process correlations (e.g., temperature profiles, tank levels, mass balances, etc.)
- Weather information
- CCTV Images
- Process controls information aiding operator situational awareness
- Other (please specify)

25. If the displays show different information than intended, why?

*26. How frequently were the large displays originally intended to be used?

- Very rarely
- Once a shift
- Once an hour
- Continuously
- Other (please specify)

27. If the actual frequency is different, why?

*28. Who was the originally intended primary user for the large displays? Select all that

Optimal Workstation

Purpose:
Control rooms are sized to accommodate the console operator's workstation. The console operator's workstation has evolved with more information being presented. Where once only three, 15" monitors were present per operator now six or more might be provided along with additional monitors for the business network.

The reduced cost of monitors has resulted in far more of them, with potentially negative consequences. Not only are the excess monitors not adding value, they occupy valuable real estate. This project seeks to answer:

- What is the optimal design for an operating console?
- What factors influence the design
- How does the console design interact with the structure of the display system?

Deliverable:
Part of the deliverable will be to define from an analytic perspective the optimal operator workspace. The results will include the optimal number, size, and layout of the console workstations, with the basis of the layout. The analysis will account for differences in display system structures (i.e., linear versus hierarchical) for similar systems.

Procedure Warnings

Purpose:
Health, Environment and Safety (HES) and informational statements in operating or maintenance procedures are used to draw the operator's attention to any consequences of hazard exposure as a potential result of performing a procedural step and provide instruction(s) to avoid the hazard.

Unfortunately, there is no clear consensus regarding HES and informational statement representation within procedures. Additionally, there are human performance concerns regarding distracting template formats.

How can warning information be displayed such that such that operators globally can quickly identify, process, and comply with this information and perform the procedure safely without incident?

Is symbol with text best? Which symbols?
What is the optimum placement of each?
What is the importance of signal words?
What the best color to use?

Deliverable:
Recommendations of symbols, choice of signal words, color formats for symbols, text placement, format of information presentation (levels) within HES and informational statements, color formats for other information and operator/technician training methods.

Handheld Usage

Background:
One of the fastest growing trends in the automation industry is the use of mobile devices. They are significantly changing the way users communicate, collaborate, obtain information, and interface with equipment. Mobile devices have opened up a wide range of applications possibilities, yet companies are struggling to take advantage of their full potential in operations.

Purpose:
The focus of the project is to determine guidelines on how to apply mobile technology based on operator tasks to save time, improve maintenance and prevent accidents. The project will identify important variables to increase the effectiveness of information presented and displayed to operators in situations where mobile devices can support and enhance human decision making.

It will also show how can text aware computing factors, sensor information, and input modalities be combined to provide an intuitive human computer interaction in the context of field operators in the process industry?

Deliverable:
Identification of important variant and invariant attributes that affect handheld displays information presentation. The development of display design policy and guidelines / recommendations for the graphic design targeted on small handheld devices

Why should I get involved

- Get to direct research – COP is member driven(driven by Champions members)
- No time requirement (limited as you desire)
- Share costs/risk (with active project managements direction)
- Research tailored to your site/problems (driven by operator taken at your site)

Who is the Center for Operator Performance?

Center for Operator Performance

An Industry-Academia Collaboration

www.operatorperformance.org