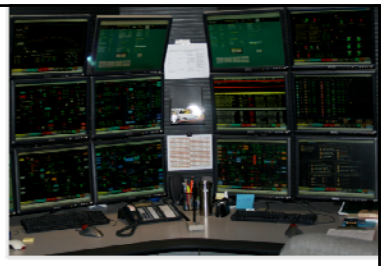

Use of Simulation for SCADA Alarm Study

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Louisiana State University

Glen Uhack II
MSIE Graduate Student

April 22, 2010

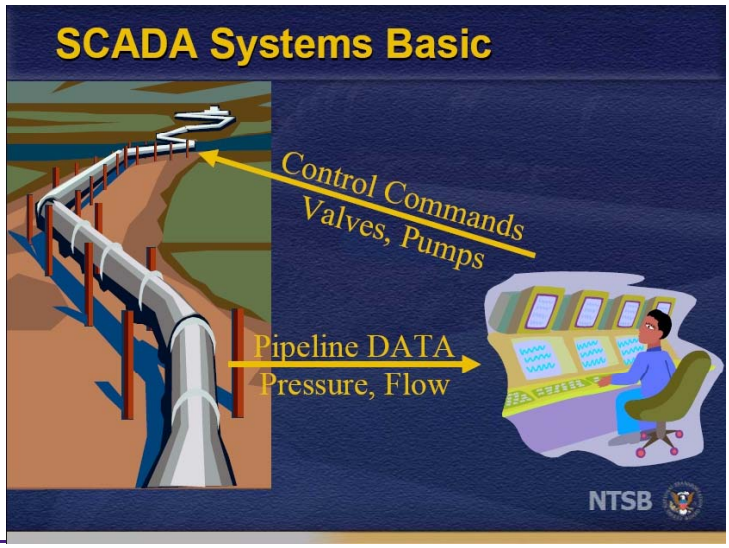
Overview

- Background
- How do we affect future SCADA systems?
- Current Standards
- Initial Simulation Study Experiment
  - Project Objectives
  - Experimental Method
  - Some Results
- Conclusions
- Limitations
- Further Research Questions

Introduction

- **Alarm**
  - An audible or visual means of alerting an operator of an equipment or process malfunction or abnormal situation that requires action.
- **Alarm Management**
  - The processes and practices for developing, documenting, designing, operating, monitoring, and maintaining alarm systems.
- **Alarm System**
  - The collection of hardware and software that detects an alarm situation, transmits the signal of that process state to the operator, and records changes in the alarm state.

What does an Operator do?



Project Background

- Human factors and alarm management in pipeline control rooms has recently become of increasing interest by many government entities.
- NTSB completed a study of approximately 79 control centers and later recommended improvements in **graphics design**, **alarm management**, **human factors** (e.g. fatigue), **training**, and **leak detection**.

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NTSB Enhancement Areas

- Roles and responsibilities of controllers.
- Shift change information and procedures.
- Fatigue mitigation and education.
- Clarity and content of SCADA displays.
- Alarm rationalization and management.
- Management of Change procedures and operating practices.
- Controller qualification and performance metrics.
- Analysis of operating experience and contributing factors.

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The future of Control Room systems?

- 54:15-54:50

Project Background

- Sept. 2006---Congress passed Senate Bill 3961. Bill specifies that DOT shall issue standards that implement the NTSB recommendations.
  - Dec. 2006---Amended version of S.3961 was signed into law by President Bush.

Project Background

- DOT has issued a ruling to implement NTSB recommendations.
  - 49 CFR Parts 192 and 195
    - Operators must prudently manage the factors affecting the controller. This includes relevant **human factors, such as factors that can affect controller fatigue, and operator processes and procedures for managing the pipeline from the control room**. PHMSA refers to the combination of all these factors as **control room management**.

Part 195 Specifics

- **195.446 Control room management.**
- (a) *General. This section applies to* each operator of a pipeline facility with a controller working in a control room who monitors and controls all or part of a pipeline facility through a SCADA system. Each operator must have and follow **written control room management procedures** that implement the requirements of this section.

Part 195 Specifics

- *Roles and responsibilities. Each* operator must define the **roles and responsibilities of a controller during normal, abnormal, and emergency operating conditions**. To provide for a controller's prompt and appropriate response to operating conditions, an operator must define each of the following:
- (1) A **controller's authority and responsibility** to make decisions and take actions during **normal operations;**
- (2) A **controller's role** when an **abnormal operating condition** is detected, even if the controller is not the first to detect the condition, including the controller's responsibility to take specific actions and to communicate with others;
- (3) A **controller's role** during an **emergency**, even if the controller is not the first to detect the emergency, including the controller's **responsibility** to **take specific actions and to communicate with others**; and
- (4) A method of recording **controller shift-changes** and any hand-over of responsibility between controllers.

Part 195 Specifics

- (c) *Provide adequate information.* Each operator must provide its controllers with the **information, tools, processes and procedures necessary for the controllers to carry out the roles and responsibilities** the operator has defined by performing each of the following:
- (1) Implement **API RP 1165** (incorporated by reference, *see § 195.3)* whenever a SCADA system is added, expanded or replaced, unless the operator demonstrates that certain provisions of API RP 1165 are not practical for the SCADA system used;
- (2) Conduct a **point-to-point verification** between SCADA displays and related field equipment when field **equipment is added or moved** and when other changes that affect pipeline safety are made to field equipment or SCADA displays;
- (3) Test and verify an **internal communication plan** to provide adequate means for manual operation of the pipeline safely, at least once each calendar year, but at intervals not to exceed 15 months;

Part 195 Specifics

- (4) **Test any backup SCADA systems** at least once each calendar year, but at intervals not to exceed 15 months; and
- (5) Implement section 5 of **API RP 1168** (incorporated by reference, *see* § 195.3) to establish **procedures** for when **a different controller assumes responsibility**, including the content of **information to be exchanged**.
- (d) *Fatigue mitigation.*
  - *Ok I think you get the idea…..*

So How do We Assess Methods

Applied Research to Address Industry Needs

WHO WE ARE

We are a diverse group of **industry**, **vendor**, and **academia** representatives addressing human capabilities and limitations with research, collaboration, and human factors engineering. Our mission to raise the performance level of our operators and improve Health, Safety, and Environmental effectiveness is accomplished through –

- Openly sharing knowledge and ideas
- Putting collaboration ahead of competition
- Including vendors in research decisions
- Teaming with leading human factors researchers and universities

http://www.operatorperformance.org/

Project Objectives

- Project attempted to empirically evaluate the following:
  - Alarm rate.
  - Alarm priority categories (e.g., critical, informational).
  - Alarm presentation method.

Alarm Rate Standards

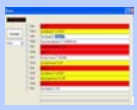
EEMUA Alarm Rate Standard

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	Maximum Manageable
~150 Alarms per day	~300 Alarms per day
~6 Alarms per hour (average)	~12 Alarms per hour (average)
~1 Alarms per 10 minutes (average)	~2 Alarms per 10 minutes (average)

Experiment Overview




Alarm Displays
- Categorical
- Chronological

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


Operator Performance

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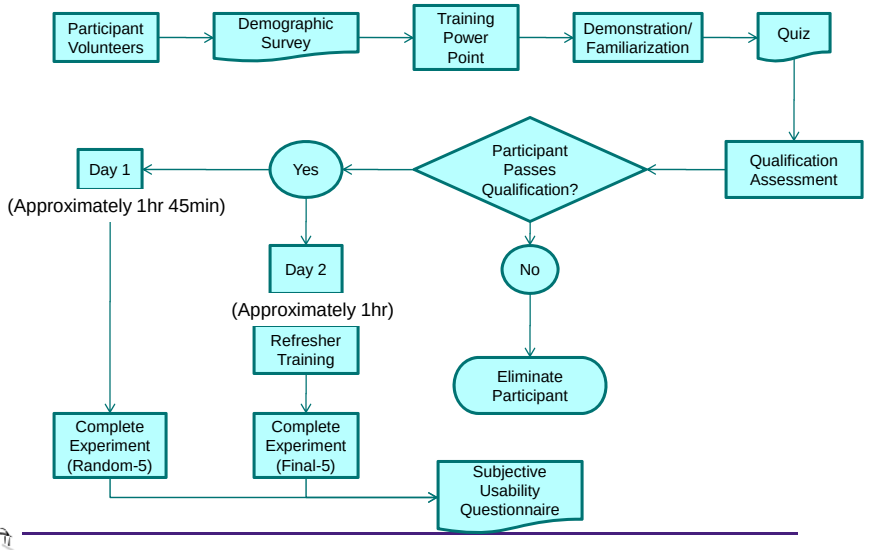
Experimental Flow Chart



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Simulation Apparatus

- Advantica
  - Stoner Pipeline Simulator and Operator Qualification software.
  - Scenarios with predefined scenarios and expected actions to correct abnormal operating conditions.
- Visual Basic
  - Alarm Screens.
  - Developed Visual Basic windows due to limitations and cost of Advantica application developer.
- Morae
  - Captures screens and user interaction.

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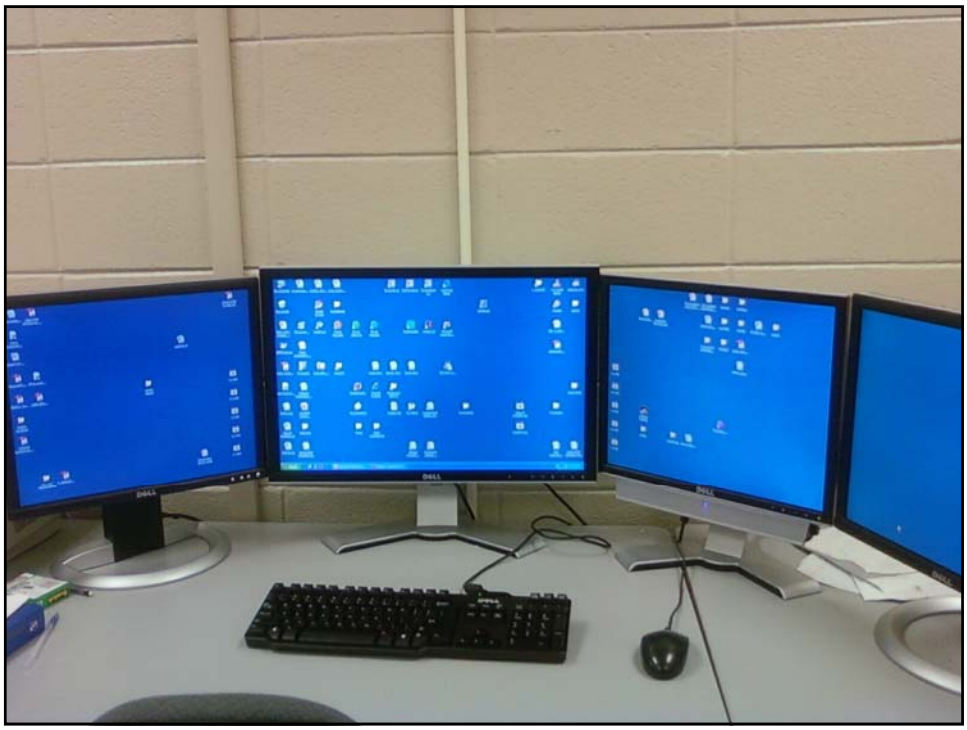
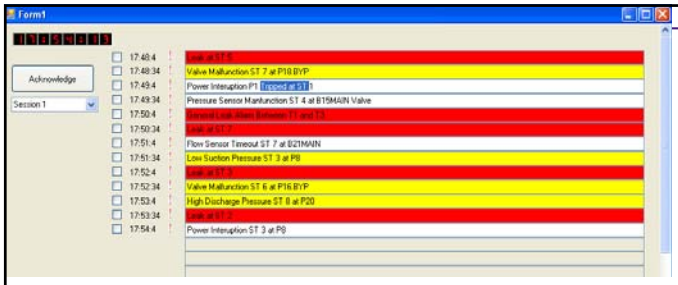
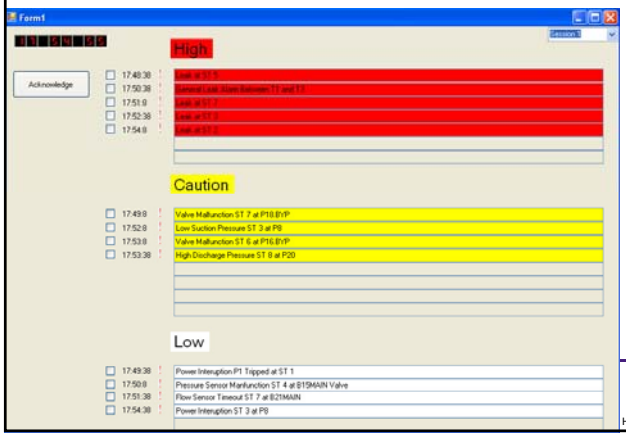




Alarm Window by Time (Chronological)



Alarms Window by Time within Priority Groupings (Categorical)

Alarm Priority Levels

Red – High priority alarms.

Yellow – Caution.

White – Low priority alarms.

Experimental Alarm Rates

Experimental Alarm Rates

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

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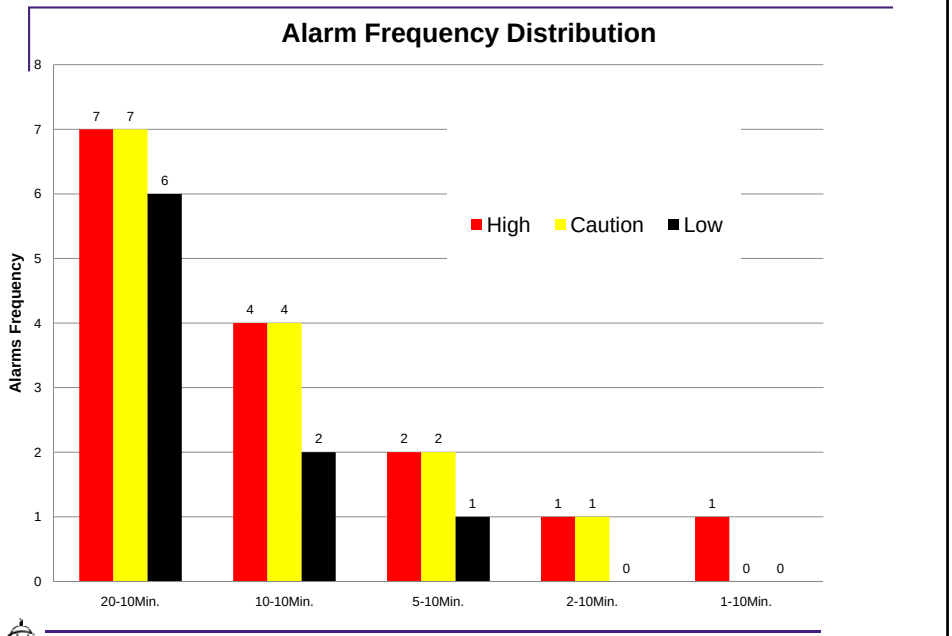

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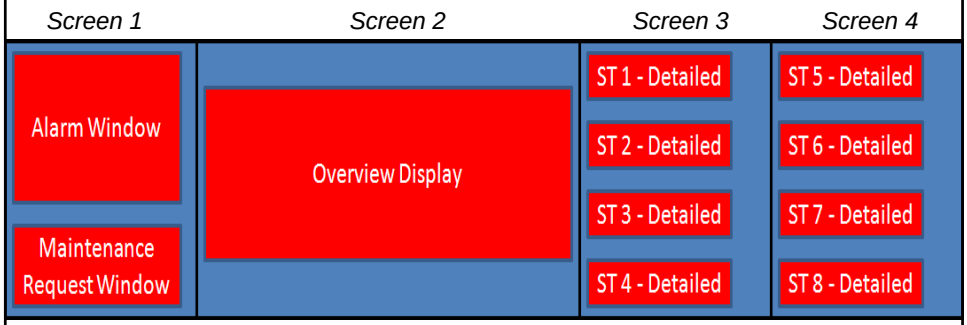
Human Machine Interface (HMI) Layout



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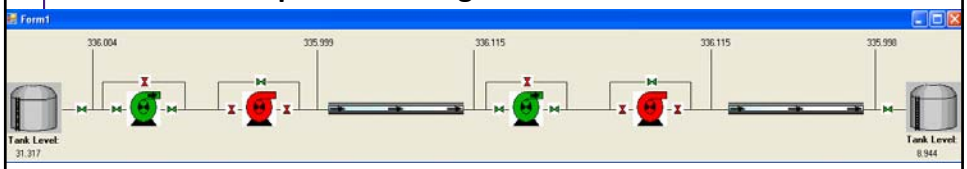
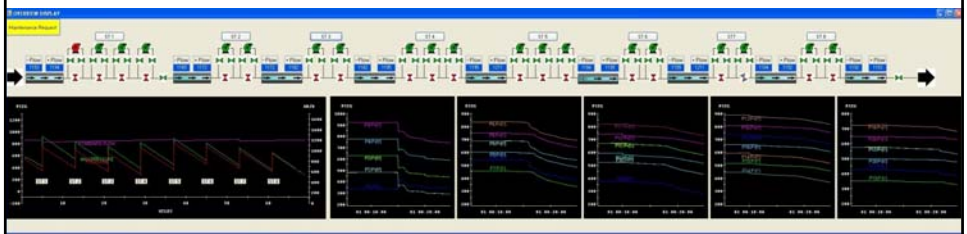
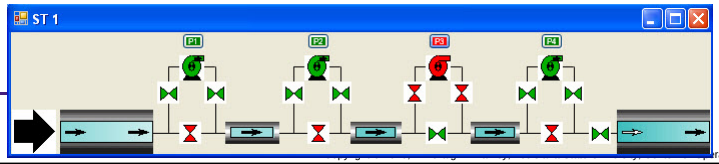
Simulation of Pipeline Training Qualification Overview Window



Overview Display – System Profiles (Flow Rates, Pressure)



Sub-System Detail Window



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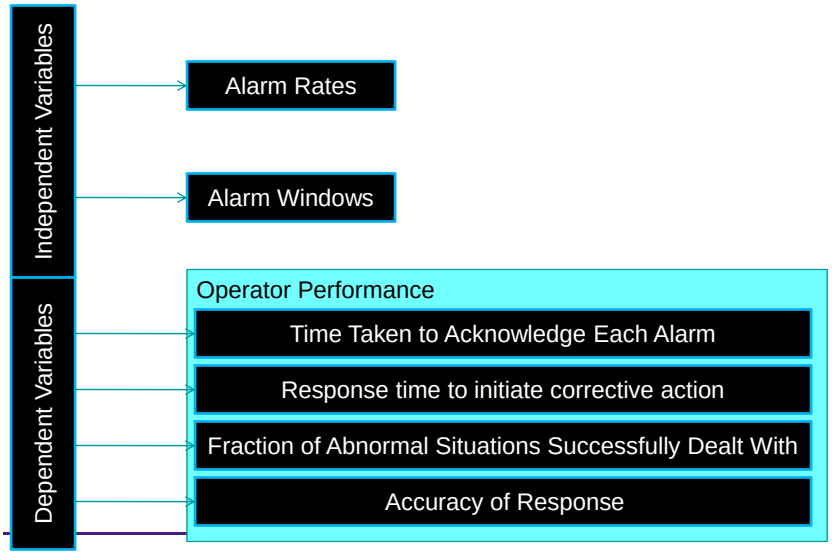
Experimental Design

- Repeated Measures Design
  - Every participant was exposed to same treatment (simulation scenarios)
  - Simulations completely randomized between participants
  - Subjects become one of your experimental variables
    - Generally they are eliminated and their error is combined into the overall error of the statistical model
      - This was the case in the experiment

Experimental Measures



Time Alarm Window Example – User Interaction

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Category Alarm Window Example – User Interaction

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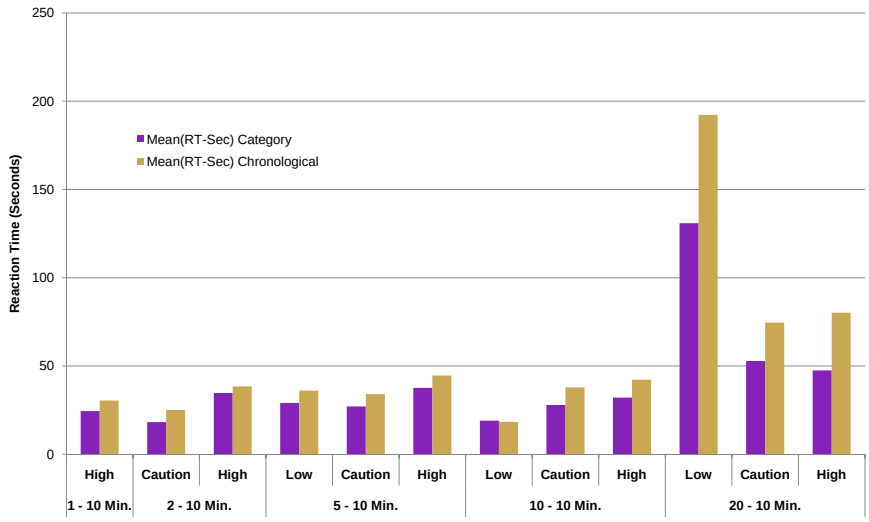
Descriptive Statistics - Mean Reaction Time *(Seconds)*



Reaction Time *(All Alarms)*

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	9	2590480	287831	25.8014
Error	2311	25780633	11156	**Prob > F**
C. Total	2320	28371113		**<.0001**

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Alarm Rate	4	4	2137765.9	47.9078	**<.0001**
Cat.(2)/Chron(1)	1	1	34194.5	3.0652	0.0801
Alarm Rate*Cat.(2)/Chron(1)	4	4	137439.4	3.0800	**0.0153**

Reaction Time *(All Alarms)*

Level		Least Sq Mean
2010	**A**	**92.846672**
510	B	35.192151
1010	B	31.749911
210	B	29.120968
110	B	27.451613

***Levels not connected by same letter are significantly different

Reaction Time *(All Alarms)*

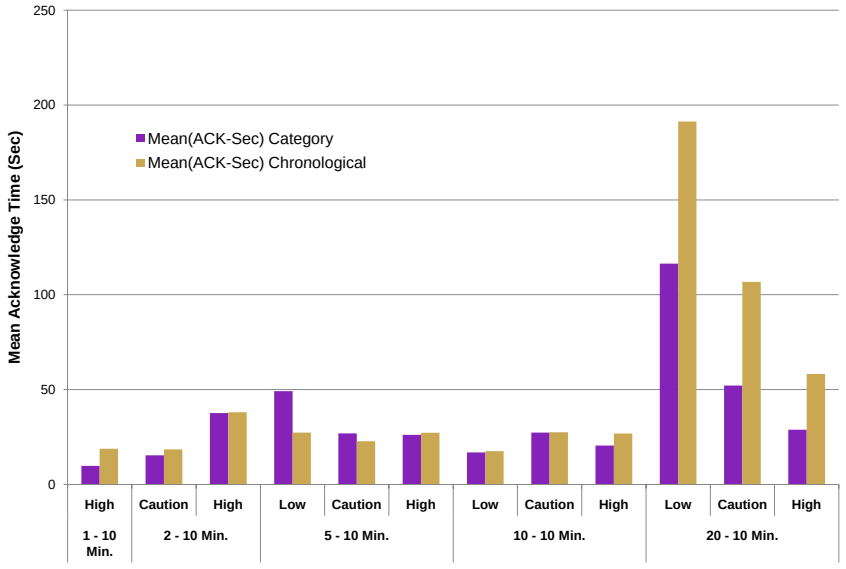
Level		Least Sq Mean
2010,1	**A**	**111.83361**
2010,2	**B**	**73.85974**
510,1	C	38.67097
1010,1	C	35.64821
210,1	C	31.77419
510,2	C	31.71333
110,1	C	30.41935
1010,2	C	27.85161
210,2	C	26.46774
110,2	C	24.48387

- 20 alarms in 10 minutes using a chronological display is statistically different than 20 alarms in 10 minutes using a categorical display.
- 20 alarms in 10 minutes for either display is statistically different than any other alarm rate using either display.
- 20 alarms in 10 minutes doubles or triples their response time.

***Levels not connected by same letter are significantly different

Note
1-Chronological
2-Categorical

Descriptive Statistics - Mean Acknowledge Time *(Seconds)*



Response Accuracy *(All Alarms)*

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	9	7.33149	0.814610	6.0500
Error	2346	315.87903	0.134646	**Prob > F**
C. Total	2355	323.21053		**<.0001**

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Alarm Rate	4	4	6.4710102	12.0149	**<.0001**
Cat.(2)/Chron(1)	1	1	0.0403008	0.2993	0.5844
Alarm Rate*Cat.(2)/Chron(1)	4	4	0.3103990	0.5763	0.6798

Response Accuracy *(All Alarms)*

Level		Least Sq Mean
210	A	1.9677419
110	A	1.9516129
1010	A	1.9145161
510	A	1.9129032
2010	**B**	**1.8201613**

***Levels not connected by same letter are significantly different

- 20 alarms in 10 minutes had the least response accuracy of all alarm rates.

Alarm Rates and 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
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ISA Alarm Rate Targets

Very Likely to be Acceptable	Maximum Manageable
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~6 Alarms per hour (average)	~12 Alarms per hour (average)
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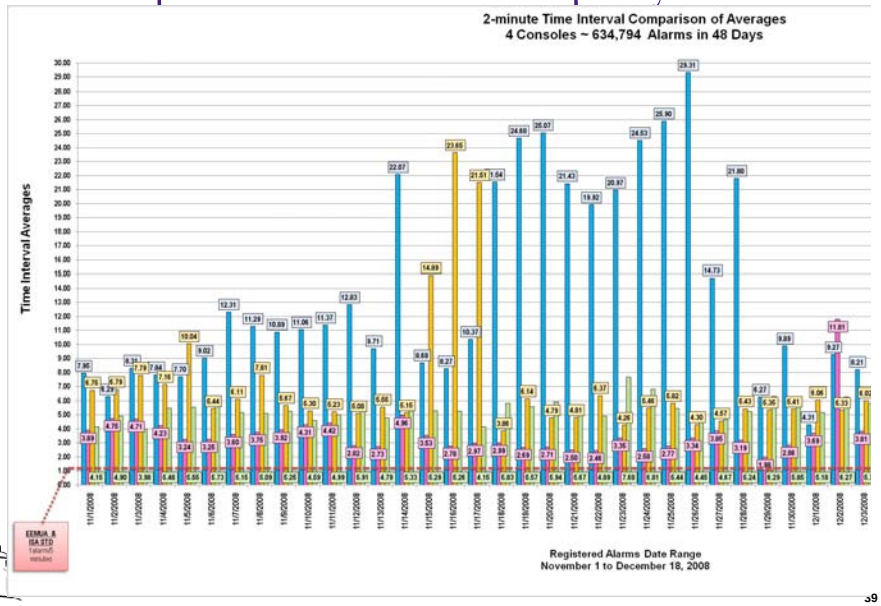
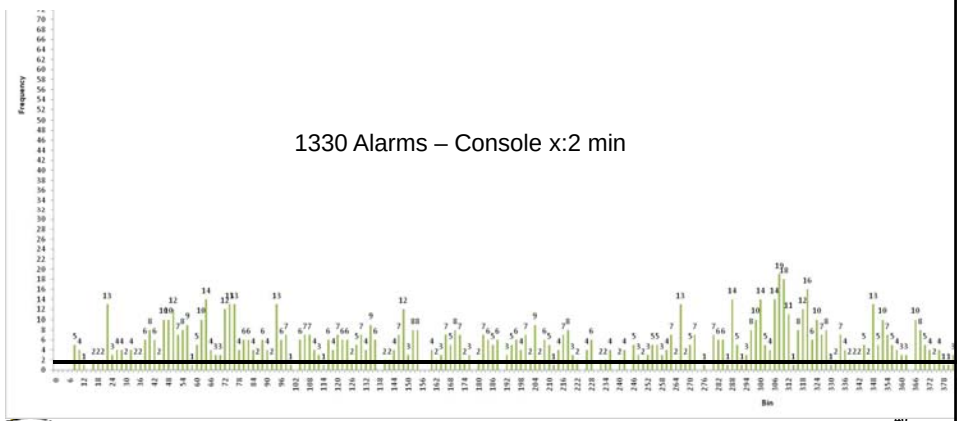
Example Data-Real Company



Example Data – Real Company

1330 Alarms – Console x:2 min



Conclusions

- Categorical alarm displays would be recommended over chronological.
- 20 alarms in 10 minutes seems to drastically impact user performance in **response time**, **acknowledge time**, and **accuracy**.

Level	Translation	Standards
2010	**2 alarms per minute**	
1010	1 alarm per minute	EEMUA- Very Likely Unacceptable
510	5 alarm per 10 minutes	
	2 alarm per 10 minutes	ISA- Maximum Manageable
110	1 alarm per 10 minutes	

Study Limitations

- 10 minute period
- No interruptions as controllers face in normal operations
- Student participants

Unanswered Questions

- *What happens to operator performance in real environment with all the "normal" realities of a control room (e.g., phone calls, noise)?*
- *What happens when alarm rates increase further?*
- *What would happen in a longer control period (e.g., 1 hour simulation, 8 hour simulation)?*
- *How do student controllers compare to real controllers?*

If you want to participate:

- Contact:
  - Dr. Craig Harvey
    - 3218 Patrick F. Taylor Hall
    - Dept of CMIE
    - Baton Rouge, LA 70803
    - harvey@lsu.edu
    - 225-578-8761

Before we end

- A brief advertisement for our sponsors…….

Glen Uhack II

- **EDUCATION:**
  - Graduate Program: Master of Science in Industrial Engineering *(Cumulative GPA: 3.7).*
  - Bachelors in Business Administration w/Management minor *(Cumulative GPA: 3.5).*
- **EXPERIENCE:**
  - Research Assistant LSU Dept. of Industrial Engineering *(Current)*.
  - Harrah's New Orleans Casino & Hotel
    - Title – Employee Relations Coordinator *(December 2007 – April 2008).*
    - Title – Human resources Intern *(June 2007 – December 2007).*
- **ACTIVITIES:**
  - Student member of Instrumentation, Systems, and Automation Society (ISA).
  - 1st Degree Black Belt American Taekwondo Foundation.

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