Paper TA006D

Supporting Key Console Operator Interactions through the Control System Interface

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Abstract

In today's world of rapidly developing control systems supporting the key interactions between the console operator and their control system is a difficult task that continues to grow as more process data from the field and more information from outside the control system becomes available. The control system interface forms a core part of a decision support system that can aid the operators in preventing or minimizing the impact of unplanned plant disturbances and improving plant performance.

This paper will discuss how plant data and external information have been combined in a single interface to meet the key console operator interaction requirements. The resulting interface includes integrated trending, yoked multi-windows, and simultaneous increasingly detailed views of process equipment.

A recent case study that compared the performance of console operators using this interface to operators who used a traditional control system interface is reviewed.

Introduction

In 1996, NOVA Chemicals Corp. (NOVA Chemicals) launched a major project in Alberta to expand its Joffre production facility. At the time, Joffre was the home of two ethylene plants, a polyethylene plant and a large utilities unit. In total, the site produced over three billion pounds of product each year. The expansion project was to add new ethylene, polyethylene and cogeneration plants as well as expand the utilities plant to support the expanded facilities. When completed in the summer of 2000, the new facilities would increase the site production to over 6 billion pounds per year making it one of the largest ethylene / polyethylene sites in the world.

At this time, NOVA Chemicals was a very active member of the Abnormal Situation Management Consortium® (ASM)[2]. The ASM Consortium was developing a novel approach to operator interface design for its Abnormal Event and Guidance Information System (AEGIS) prototype. The ASM Consortium member companies were funding the AEGIS prototype as a multi-year, multi-million dollar project with additional support from NIST (National Institute of Standards and Technology). The goal of the AEGIS project was to demonstrate that with current technologies, a significant improvement in petrochemical plant performance and reliability could be achieved.

The ASM interface approach used a structured multi-window format to improve the console operator's awareness to changing plant situations so that abnormal situations were identified early and averted or mitigated. The structured format included explicit use of colour, navigational strategies, windows management, and coordinated display associations.

With NOVA Chemicals' knowledge of the AEGIS work, NOVA Chemicals applied and further enhanced the approach that had been pioneered by the Consortium and move it from the lab to the field to work with a plant control system.

NOVA's ASM style of operator interface was in place for all of the new Joffre plant startups in mid-2000. Operator acceptance of the new interface design approach was wide ranging. Some operators welcomed the new approaches while others were more reluctant during the project. Extensive training on dynamic simulators in the major units prior to the plant startup significantly aided the adoption of the new approaches. Following the plant startups, operators reported that they found many of the elements of the new interface invaluable and would not go back to the older more traditional interface designs.

[2] Abnormal Situation Management and ASM are registered trademarks of the Abnormal Situation Management Consortium.

As a follow-up case study[3] in 2004, NOVA Chemicals and the ASM Consortium wanted to quantify the response performance difference of operators of similar experience levels due to the use of either the ASM or a Traditional style. A set of simulated plant malfunctions were developed that could be run on two of the ethylene plant simulators where one of the simulators used the new ASM style of interface while the other used a more Traditional style. Two of the key features of the ASM style of interface that differentiate it from the Traditional style are the number of simultaneous views available and the direct integration of process trends.

This paper will describe the design approach of the ASM style of interface and present a summary of the case study.

Interface Design Elements

The objective of NOVA Chemicals' ASM style of operator interface is to improve the operator's situational awareness of changing plant conditions so that abnormal events can be avoided or mitigated. To achieve this objective the operator interface must address how the operators interact with the control system and it must support their decision-making.

Through the ASM research, it was determined that a good operator interface design needed to integrate process alarms, process and trend information cohesively together. To create a new interface approach, learning's from the strengths and weaknesses of the earlier approaches (such as large panel boards, strip chart recorders, alarm annunciators, off-normal indicators and former DCS display formats) were used in conjunction with an understanding of human factors.

The earlier approaches showed that people worked best with a fixed structured format that emphasized key physical and process interrelationships. The ability to see strip charts or trends of key variables immediately alongside a controller was also very useful in making decisions on what should be changed. Pulling controllers out of the panel to indicate that they were in an "off-normal" mode helped people remember this during the shift and at shift-change when they needed to relay experiences to the next crew. The location of the alarm annunciators, showing the critical but very limited number of plant alarms, in association with the corresponding section of the plant gave people an immediate localization of the where a problem was occurring. These were all examples of approaches that were taken from the pre-control system interface formats.

The human factors' aspect of the interface design approach is best described by a definition of human factors: "Human factors discovers and applies information about human behavior, abilities, limitations, and other characteristics to the design of tools, machines, systems, tasks, jobs, and environments for productive, safe, comfortable and effective human use."[4] An interface design therefore should enhance people's attention and perception of the plant.

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[3] Errington, J. et al. *ASM Operator Interface Case Study, Understanding ASM: Business Case Justification,* (2004) ASM Consortium internal publication

[4] Sanders, M.S, and McCormick, E.J., "Human Factors in Engineering and Design", (1993) McGraw-Hill, New York

From the historical practices and the human factors appreciation, the major design principles of the NOVA ASM style of interface included:

- Support the operator's scope of work
    - Situational awareness
    - Routine operations
    - Mode changes
- Take advantage of human and computer strengths
- Present information through the use of data in context
- Maximize focus on task at hand
    - Minimize distractions such as desktop and windows management

Problems that can be experienced by operators using a poorly designed operator interface can be wide ranging. When trying to locate the source of a plant upset, operators can miss important information, be overloaded with too much information or be distracted by an aspect in the interface. When evaluating a problem to understand what is occurring, operators can often not get the information that they need immediately from the interface. For example access to trend information is often several awkward steps away in most interfaces. When the operator is ready to take action, the poor interface is often prone to entry errors, may provide limited feedback to the operator, or require additional actions to make the changes needed. After making a corrective action, an operator will need to assess if the correction is having the desired impact, and will need a "big picture" of the plant so that they can see the broad impacts of the changes and not get focused on a very small section.

The major design elements of the NOVA ASM style of interface included:

- Single, Integrated View
- Window Management and Layout
- Navigation Scheme
- Visual Coding Scheme – use of colour & shapes
- Interaction Objects
- Contextual Menus
- Task View Organization

The NOVA Chemicals' ASM style of interface is illustrated in Figure 1. The interface uses a set of eight - 21" screens. The screens are operated from four dual-headed workstations. The four screens across the top of the console show an area-wide overview summarizing the status of the console operator's scope of responsibility. It is made up of 4 different displays. In the top left corner a Type 1 graphic shows a Status View. Beside that is an Alarm Summary with two related trends. Further to the right are two screens showing key area variables in either a standard trend format or a newer specialized event detection application format.

The operator interactions are typically performed though one pair of lower screens in Figure 1 labeled as Operations View. Each pair is identical and allows for a second operator to support the console during upset or planned high workload periods.

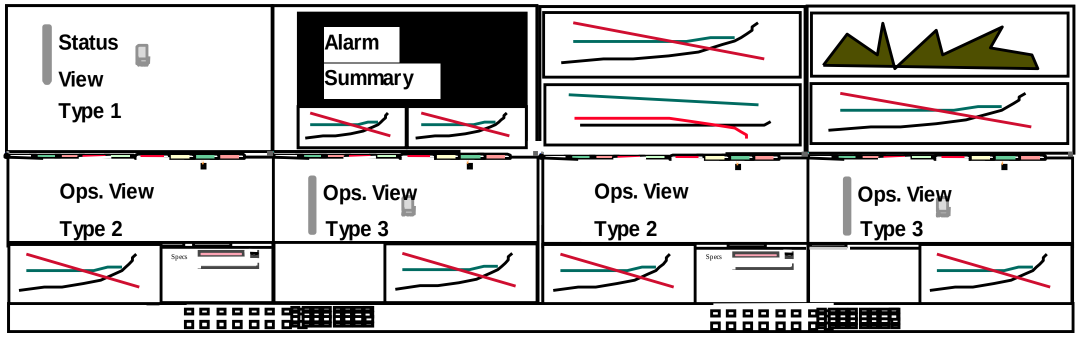

Figure 1: NOVA Chemicals' ASM Style Interface

The Operations View is comprised of four levels of displays with two fixed trends as shown in more detail in Figure 2. The Type 2 display (upper left) provides a high-level view of an individual process unit. The Type 3 display shows a portion of that unit in higher detail. Below the Type 3 display is a region used to provide detailed control loop information and a trend object. Below the Type 2 display there is another trend plus a detail view showing the selected point.

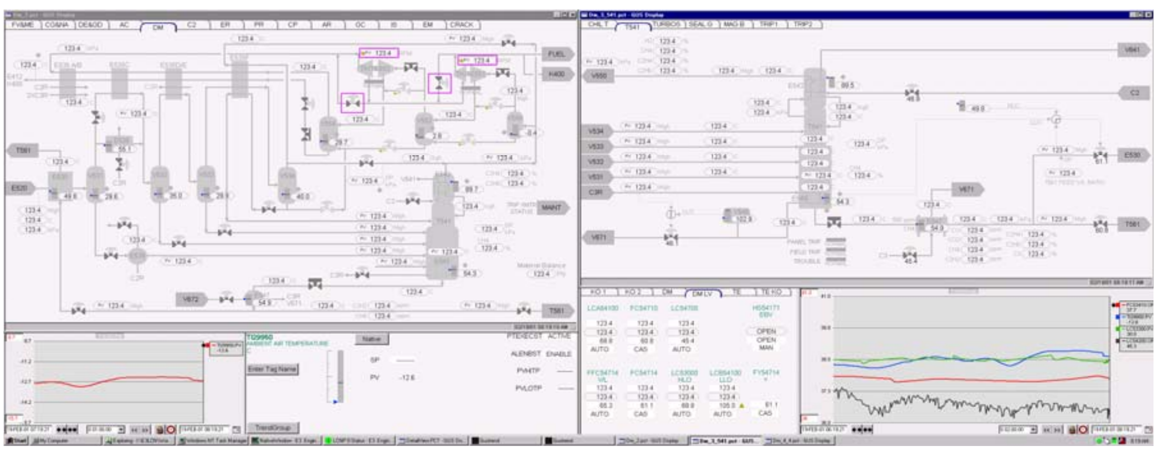

Figure 2: NOVA Chemicals' ASM Style Operator View

Key features of the Operations View include

- On-screen navigation via display tabs with integrated alarm information
- Restricted use of colour, reserving colour to highlight off normal conditions
- Windows management minimizing display overlays
- Automated display invocation through pre-configured display associations (i.e., assisted, task-relevant navigation)
- Access to online information
- Integration of trend information

The ASM style is intended to provide a continuous broad overview of process conditions while simultaneously giving access to the needed detail information to reduce the potential for “tunnel visioning” when operators are solving complex process problems.

Interaction Requirements

“The design of an operator interface that enables efficient and effective job performance requires the anticipation of the operators’ needs in understanding the plant’s process interactions, their interactions with computers and with other individuals in the workplace.”[5] Often an operator interface is described as merely presenting information to people however this description is about a one-way communication flow. The operator is an active and integral element to good plant performance and their working with the operator interface is a two-way process. A well designed operator interface will provide for not only an effective display of process information but will also meet the operator’s interaction needs that are critical to job performance.

Aspects of the NOVA ASM style interface explicitly addressed the interaction requirements of the console operator in working with the control system. The key element of this portion of the design was the integration of trend information, the use of context sensitive menus and the development of the detail display.

Figure 3 shows a picture of a detail view in the NOVA ASM style of interface for a regulatory controller. Its key features with respect to meeting operator interaction requirements are items such as:

- highlighted dialog boxes
- highlighted operator entry points (white background)
- control valve status message box (STSMSG)
- instrument maintenance status (REDTAG)
- alarm limits displayed with philosophy matching highlights
- access to the setpoint target value (SPTV) and ramp controls (RAMPTIME, TVPROC)
- access to an alarm acknowledge button and alarm summary controls
- access to group trend control menu (TrendControl)
- off-normal indicators (magenta)
- ramp boxes (displayed on selection of setpoint or output)

[5] Bullemer, P., Reising D.V., Hajdukiewicz, J., Errington, J, *Interaction Requirements Methods for Effective Operator Interfaces*, Abnormal Situation Management Consortium internal publication, (2004)

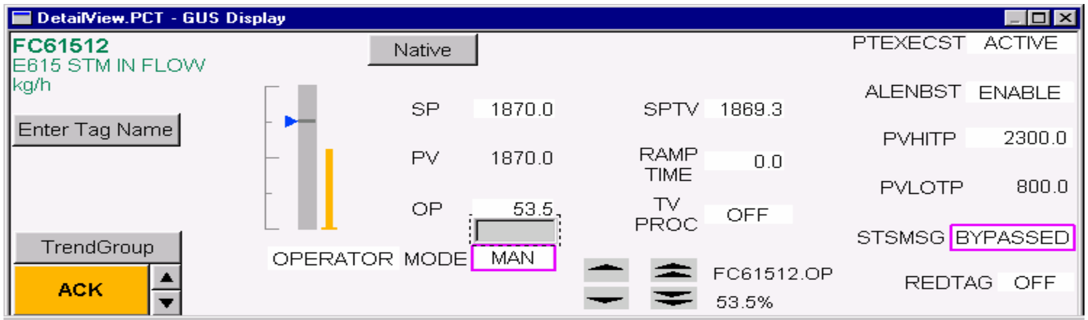

Figure 3: NOVA ASM Style Detail View

Anytime an operator selects an object on any of the displays, it is immediately placed in the Detail View (Figure 3). As part of this action, trend information about this tag is also immediately created in a detail trend (Figure 4) adjacent to the Detail View. The trend used in the interface integrated both historical and real-time data about each point to give the operator a strip-chart like component to see how the tag had changed and project the tags trajectory into the future.

Figure 4: NOVA ASM Style Detail Trend

The operator has a wide range of interactions that they can do with the trend in terms of changing time scales, scrolling back in time, tag ranges, changing from a trend to a tabular format, and adding scooter markers so that they can get the information that they need. For regulatory control tags, the process value, setpoint, output and controller mode were all simultaneously trended. For other tag types, the traces are configurable to any available parameters.

Online Support Information

To further support the operator's interactions, three additional types of information are provided and examples are listed in the following table. Point specific information is provided through context sensitive menus for the tag that the operator is focusing on.

Table 1: Online Support Information

Single DCS Point (Context Sensitive Search)	DCS System/Console Alarm Information	Desktop Tools Access
• Alarm Objective Analysis (AOA) Information • Alarm /Operator Change History • APC Cross Reference • Document/Procedure/Logic Search	• Disabled/Inhibited Alarm Summary • Alarm System Metrics (Bad Actors, KPI's)	• SAP Access for Maintenance Requests • Electronic Operator Logbook • Desktop – Internet, Intranet, MS Office Tools

Figure 5 shows an example of a context sensitive menu that has been used to recall alarm configuration information. The menu is displayed from a "right-mouse" click on any dynamic object in the displays. What the menu offers is both a direct access to additional information about the point in question for the operator or control of the group trend information. If a group trend change is requested by the operator, then that additional or deletion of a trend element is made immediately on the station's group trend.

If the operator requires additional information it is presented in a separate window either on an adjacent workstation display or on the screen that they are working from. The choice of display location is made so that on primary workstations, the additional information does not cover or obscure any critical process information that might be needed by the operator.

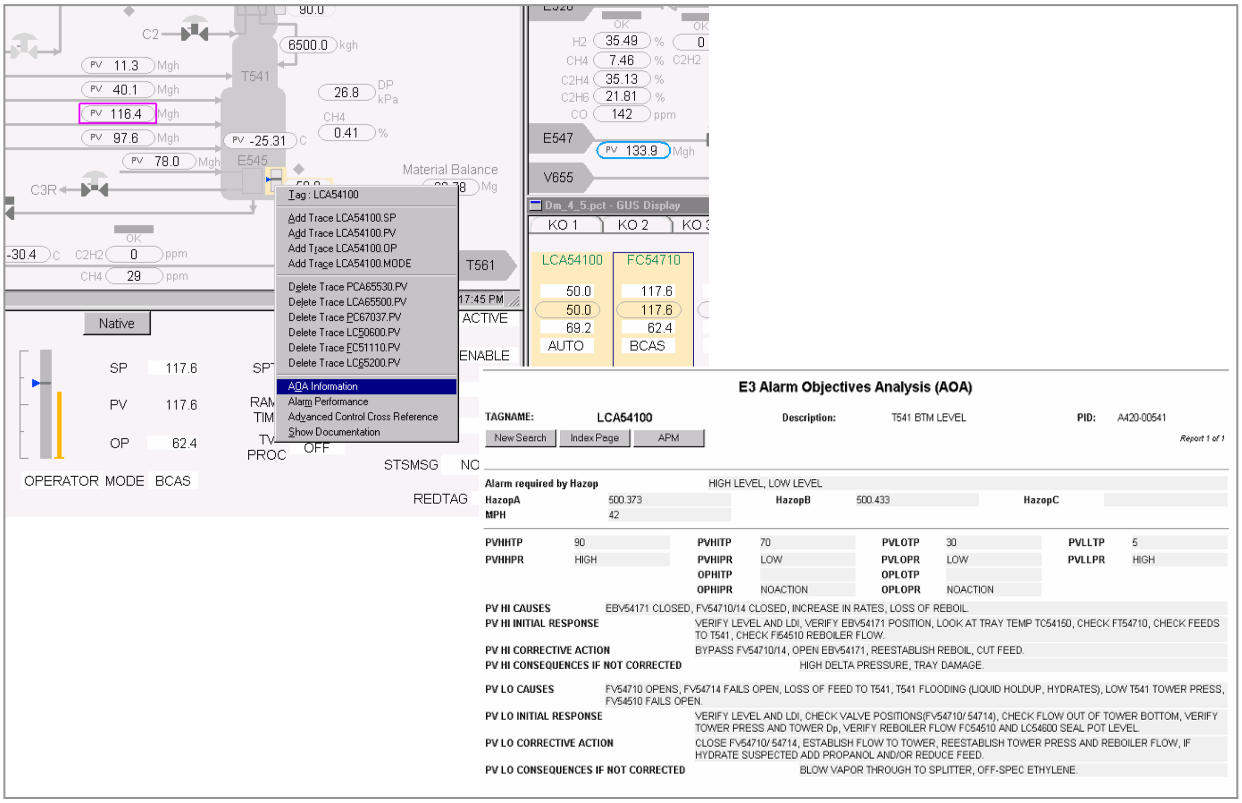

Figure 5: Context Sensitive Menus

Providing a user interface to support operations with the procedural step information enables a more consistent execution of routine procedures such as a furnace swing. Process control tuning and monitoring can best be setup when the procedure is executed the same way each time. Figure 6 details an example of a furnace swing application that utilizes the integrated displays and trending to allow operations to monitor this task while executing the swing application. In this case additional trending displays are invoked for monitoring purposes.

Figure 7 details an example of a semi-automated compressor trip application to expedite execution of immediate response items while flagging those steps still incomplete. Access to all emergency procedures is via a single click through this interface.

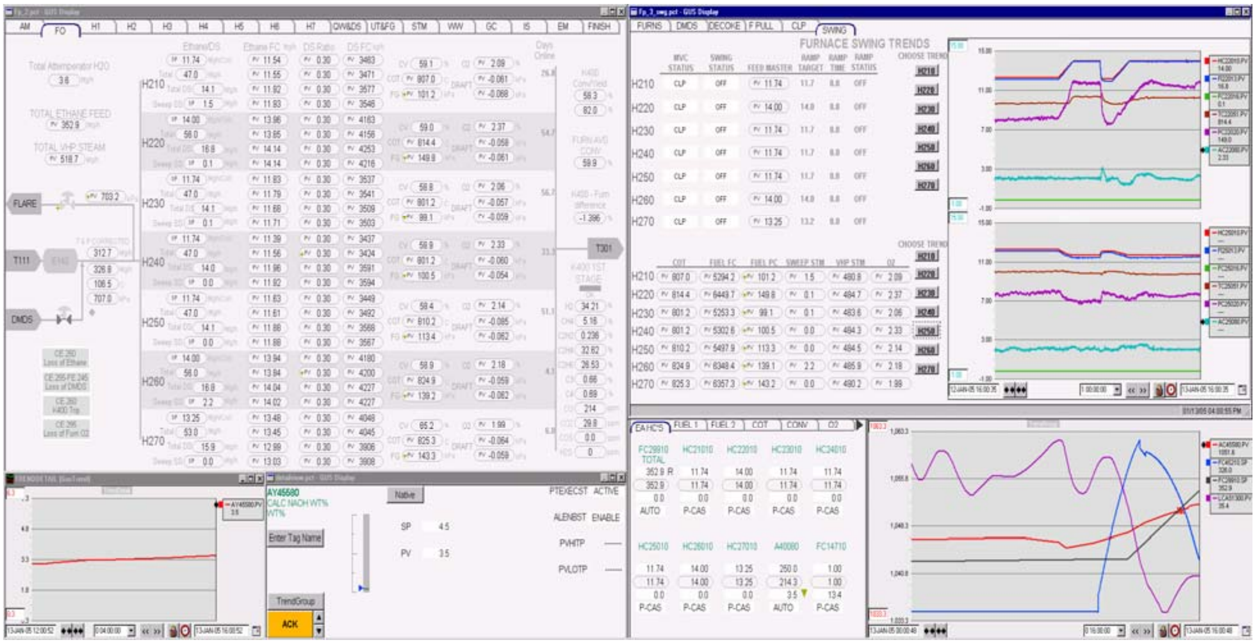

Figure 6: Furnace Swing Procedure Support

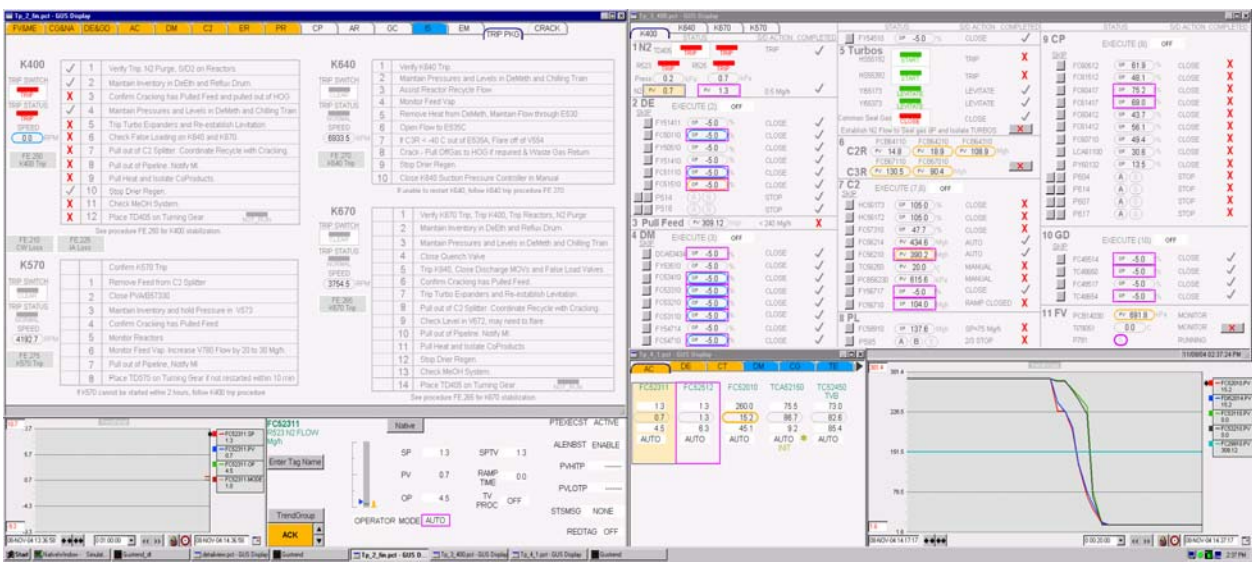

Figure 7: Semi-Automated Trip Procedure Support

Case Study Background

The objective of this case study was to evaluate an ASM style of operator interface used in one unit at the NOVA Chemicals Joffre site against a more traditional style of interface used in another unit at the same site. The key features of the ASM style of interface that differentiate it from the Traditional style are the number of simultaneous views available and the direct integration of process trends.

The project was part of a larger overall project to understand the business case values of designing for ASM. The ASM Consortium and NOVA Chemicals Corp. (NOVA Chemicals) funded this interface case study portion of the project.

The interface case study compared the response performance of two groups of operators using either the ASM style of interface described earlier in this paper, or a more Traditional style of control system interface. Each group of operators worked on matching problems using two of NOVA's high fidelity plant simulators. The two simulators were configured to match each group's respective plant and operator interface. The time for each operator to orient to the problem and the total time to solve the problems was recorded. A third element, identified as early event detection was also recorded during the trials and this captured the point that the operators first identified an upset.

Other components of the study included tests of plant knowledge, individual experience records and other information so that a comparison of the two groups could be examined to see if differences other than the interface design were impacting any observed upset performance differences.

The NOVA Joffre site has three ethylene plants operating on it. The first two ethylene plants were commissioned in 1979 and 1982 while the third plant went into production in 2000. The original two plants have gone through several control system changes over the years but both are currently using Honeywell Total Plant control systems. The operator interfaces in these plants are single window interfaces developed on the proprietary Honeywell workstations. An example of a typical traditional interface display is shown in Figure 8.

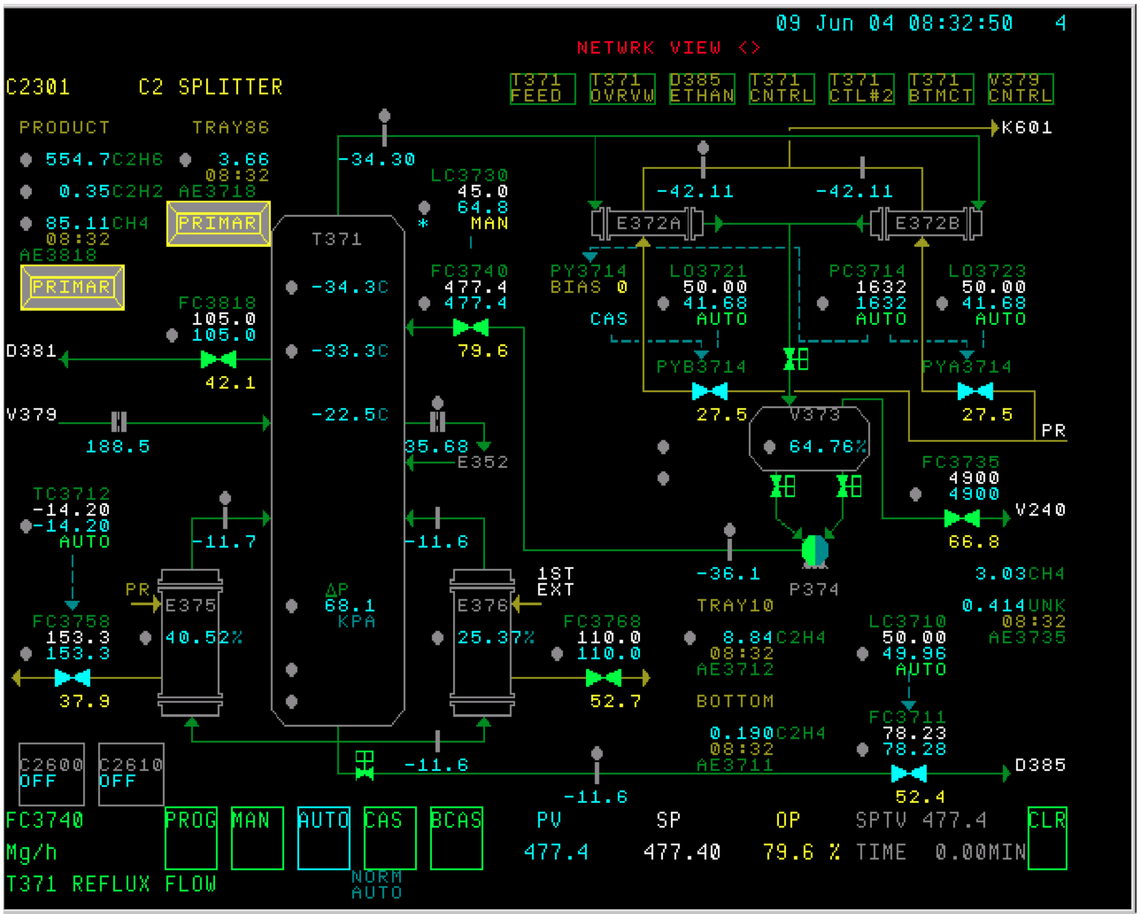

Figure 8: Example of Traditional Operator Interface Display

Navigational aids are in boxes across the top of the display and links to other areas of the plant are accessible from the text boxes at the ends of the process lines. Process variables are generally shown as a group of text where the tag name is in half-intensity green, setpoints are white, process values are cyan and valve outputs are yellow. Control valves are also colour coded to show the mode of the controller (yellow is manual, green is auto and blue is cascade). Motor-operated valves (MOVs) are displayed with the valve positioners on top of the controllers. Values in alarm are in red along with the sensor object that will flash until the alarm has been acknowledged by the operating technician. Process lines are colour-coded to distinguish between utility (half-intensity white) and hydrocarbon lines (half-intensity green). The pieces of equipment, such as the compressor and steam turbine in the centre of the display, are outlined in the display with half-intensity white lines. The half-intensity dashed lines represent the instrument connections from the controllers to the control valves.

When an operator selects a tag on the display to make changes or to get additional information (i.e. historical or trend), a horizontal change zone is displayed at the bottom of the display highlighting that tag with the required access points (setpoint, output or mode).

To test the hypothesis that the ASM style interface provided an advantage in diagnosing and responding to abnormal situations, a between-subjects experiment (ASM vs. Traditional) was designed that consisted of three phases: pre-test, scenario performance evaluation, and post-test.

High fidelity simulators are used extensively in the Joffre ethylene plants for operator training, refresher and qualification testing platform for all of the console operators. These platforms became the ideal testing ground for the scenario performance portion of the case study. The training coordinators in the two ethylene units developed a series of matching plant malfunctions. The operators participating in the study were asked to monitor the plant and respond to any upsets that occurred. Operator actions such as display changes, alarm responses, trend requests and setpoint changes were recorded during each scenario. In all, each participant was presented with 9 different plant scenarios.

Case Study Result Summary

One of the key study results was the total time to solve the simulated problems. Total time data was analyzed in a Repeated Measures Analysis of Variance with Interface type (ASM vs. Traditional) as the between-subjects factor, and Scenario as the within-subjects (repeated) measure. Using an 80% confidence level[6], the results of the Repeated Measures analysis of variance indicated a significant difference for Interface Type, $F(1,19) = 11.689$, $p < .001$ only, and no significant effect of Scenario or Scenario by Interface Type interaction. In general, operators using the ASM interface spent significantly less total time solving each scenario than did operators using the Traditional interface.

In addition, an examination of the results shown in Figure 9 shows not only did the operators require less time, but also that the variability for the operators using the ASM interface was much smaller than those of the operators using the Traditional interface. A difference between scenarios was expected, as no attempts were made to ensure overall equality between scenarios, and the fact that the interaction between Scenario and Interface Type was not significant indicates that any differences in Scenario had no effect on the time performance of either operator group.

[6] Wickens, C.D. (1998, Oct.), Commonsense Statistics. *Ergonomics in Design*, 6(4), pp.19-22

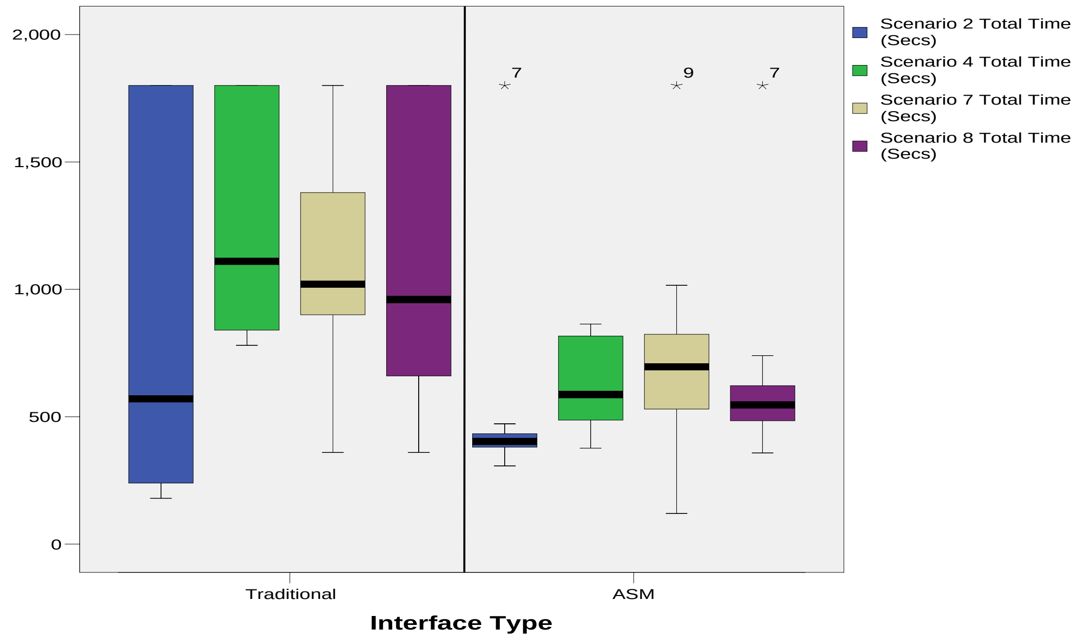

Figure 9: Total Time to Solve Scenarios (Traditional vs. ASM Interface) – Box Plot

In summary, the case study results (Table 2) showed that the operators using the ASM multi-level, multi-view interface rather than a Traditional style of interface:

- Recognized problems faster and more consistently
- Responded and solved problems faster and more consistently
  - 6.5 – 9.7 min improvement (35 – 48 %) on four scenarios of 15 – 20 minute durations
- Were more likely to successfully solve the problems
  - 25 % higher success rate for participants using the ASM interface versus Traditional interface

Table 2: Case Study Key Results Summary

	Traditional	ASM
Scenario Times to Complete - Mean (min)	18.1	10.6
Scenario Completion (%)	70.0	95.5
Early Event Detection (%)	10.0	47.7

Overall, the ASM style interface has demonstrated in this case study to be superior to the Traditional interface in terms of its impact on operator performance in handling abnormal situations.

Acknowledgements

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