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Human Factoring the Procedures Element In a Complex Manufacturing System

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As a result of Human Factors evaluations of procedures associated with incidents at Rocky Flats Plant (RFP) it was determined that the existing procedure format created significant opportunities for confusion in their attempt to convey information about a work process. For instance, there was no mechanism to clearly identify the participants and their roles during the Instructions portion of the procedure. In addition, procedure authors frequently used complex logic to convey a series of contingent actions within steps. It was also difficult to discern the actual procedure steps from other types of information in the procedure. These and other inadequacies prompted the Human Factors Engineering (HFE) department to propose solutions to these problems that followed well-researched principles of cognitive psychology, dealing with how humans process information. Format and style contribute to procedure usability, and therefore to safety and efficiency in operations governed by the procedures. Since it was difficult to tie specific performance failures to specific format and style characteristics and thereby clearly define costs and benefits, it was difficult on that basis to sell the idea that changes in procedure format and style were really necessary to improve safety and efficiency. In addition, we found that the socio-political systems governing this process, particularly at the subprocess interface level, were not functioning efficiently. Both the technological aspects of the process and the socio-political aspects were contributing to waste and considerable re-work. Fixing the customer feedback loop to the process owners not only minimized re-work and waste, but also provided the data to persuade subprocess owners to make the necessary changes that heretofore were being met with great resistance.

Introduction

In 1989 the Secretary of Energy implemented a new way of doing business in the Nuclear Weapons Manufacturing Industry. It is called "Conduct of Operations" and among its tenets is the notion that we will no longer rely on "skill of the craft" to guide our operations. Instead, work will be governed by procedures, thereby ensuring greater standardization in processes which in turn, should result in greater safety and efficiency. The Rocky Flats Plant (RFP) came

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under this edict and began developing procedures for thousands of processes which involved a workforce of 7,000-10,000 employees and subcontractors. Many of the newly hired procedure writers did not have a security clearance (a process that takes approximately 18-24 months), so they could not actually observe the work they were writing about and had to rely on subject matter experts to describe their processes. Two years later, amid rumblings of dissatisfaction from procedure users, outside audits pointing to procedure deficiencies, a tabletop review of a sampling of the procedures being produced, and additionally buttressed by new DOE orders that procedures must be "human factored", our newly formed human factors group got involved.

Thesis

The procedure process at this plant, for all its effort, was deficient. Two maxims cited by Carr (1991), apply:

1. No task-based system is capable of defining on its own what its output should be or whether its output is satisfactory.
2. No matter how efficient and under control its processes, a system may produce an output that is unusable for its intended purpose or one that, in the customer's eyes, has no purpose at all. In other words, it can function completely properly by its own internal standards and still produce waste.

We were dealing with a process that was not only technologically broken, but also suffered from interface breakdowns. Our mission was not only to identify these problems and their solutions, but also to present the necessary changes in a manner acceptable all the players. We determined that the most successful approach was to alter the feedback loop from product output to the process owners so that feedback information was more directly tied to customer needs and satisfaction. Initial results indicate that this approach not only helped ensure a better product in the classic sense of systems (less waste and re-work), but it also provided the most persuasive data to enlist support among subprocess owners for the necessary changes.

Discussion

Procedures, along with human competencies and technology, make up the process aspect of a task-based system. The procedures effort at RFP can be viewed as a subsystem in the larger system that produces the manufactured output of the plant. For the past 40 years the output was triggers for nuclear weapons. More recently, the plant mission is transitioning to outputs associated with decontamination and decommissioning the facility, but many of the same processes used in the old mission still apply.

The Human Factors group participated as "external" consultants (we worked for the same company but not for the group responsible to "get it right"),

we identified problems in the procedure part of the task-based system AND in the socio-political system as it relates to subsystem interfaces at RFP.

From the perspective of the procedures themselves, the plant procedure describing how to write procedures was written with the writer in mind, not the procedure user. In this case, the process owner (procedure writers) failed to craft their output for the correct subsystem that would receive it as input. In addition, the standards put forth in this draft of the procedure writer's procedure did not adequately take into account human competencies; there was an absence of adherence to cognitive theory, which provides concrete guidance for crafting procedures to enhance user comprehension.

Our analysis of procedures associated with incidents at RFP indicated that the existing procedure format created significant opportunities for confusion. For instance, there was no effective mechanism to clearly identify which steps were to be performed by which participants, procedure authors frequently used overly complex conditional logic, and action steps could not be easily distinguished from other types of information in the procedure. The section label scheme used a decimal number system (i.e.: 1.1.1.1.1.1) that allowed the writer to "free-associate" ideas onto the page. Types of information were only loosely organized; typically no other organization to the information could be discerned. To a well trained, very experienced operator this may not seem to be a problem. However, we know from Root Cause Analyses and Probabilistic Risk Assessment and Human Reliability Analyses that even well skilled workers are significantly more likely to make errors if they don't have a clear, concise procedure to follow, even if it only serves as an aid to memory.

The solutions to these problems followed well researched guidelines about human competencies in information processing. They included the following:

1. A new format was introduced that required the procedure writer to understand and organize the procedure content so that the superordinate and subordinate concepts were clearly distinguishable. Action steps, lists, warnings and cautions, and explanatory information all were readily recognizable because of the numbering/letter scheme.
2. A specific mechanism was also provided to clearly call out the performer for each action step.
3. Specific guidance described when to use conditional logic as well as a standardized method for IF, THEN, AND, OR statements that minimized the conditions per statement and provided a visually recognizable format for the logic arguments.
4. A section was incorporated to aid procedure writers in gathering and organizing the necessary information to be included in the procedure.

5. A mechanism was included in the procedure format (previously not possible) where the procedure writer could provide a brief overview for the procedure and descriptive paragraphs that help the procedure user conceptualize what they are about to do before they begin the piecemeal step by step process.

Figures 1 and 2 depict an excerpt from a simple procedure about glove changes (from gloveboxes where workers process radioactive material in a protected environment). The BEFORE version is in the old procedure format; the AFTER version is in the new format.

BEFORE

5.6 Maintenance Management System (MMS)

- 5.6.1 The MMS is an online, database accessed through the unclassified IBM system.
 - 5.6.2 The MMS Database is maintained by EM/PM Administration plant wide.
 - 5.6.3 A monthly Glove Change Schedule is generated and includes information on overdue changes (delinquencies), as well as changes required within that month.
 - 5.6.4 A monthly delinquency report is generated and includes all overdue glove changes.
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Figure 1. *Procdure excerpt in old format*

AFTER**5.6 Glove Change Database**

The Glove Change Database, a component of the Maintenance Management System (MMS), is an online database. This system is currently accessed through the unclassified IBM system.

EM/PM Administrator

- [1] Update and maintain the Glove Change Database, as part of the MMS Database.

Glove Change Administrator

- [1] Generate a monthly Glove Change Schedule.
 - [A] List all required changes and any overdue changes (delinquencies) for that month.
- [2] Generate and deliver a monthly delinquency report to the Operations Manager.

Figure 2. *Procedure excerpt in new format*

While the changes to the procedure guidance document were fundamental, changes to the socio-political system were essential and less tractable. Socio-politically there was confusion as to who should control procedures. With limited resources should we create a centralized procedure group that will write all procedures and adhere to standards that will be validated, or should we decentralize procedure writing so that it is controlled by each of the manufacturing subprocesses. With limited resources it was clearly impossible to assume that a centralized procedure group could handle all the procedure requirements on plantsite. However, allowing each manufacturing group to write its own without oversight severely hampers efforts of standardization and quality control.

The socio-political problems ran even deeper than this. In addition to considering the interface with the procedure users (manufacturing elements)

there were a myriad of support groups that felt ownership in this process, including quality control, standards and evaluation, and a host of other related groups. All of these groups have a hand in review and oversight. It was consistently found that review cycles were extremely lengthy, often taking months. Reviewers commenting on draft procedures were at times at odds because of differences of opinions, but reviewers who felt strongly enough could persuade their management to withhold the concurrence signature on the document.

From a systems point of view, the feedback loop to determine quality of output involved reviewers from the procedure group, the numerous quality control groups, the engineering safety groups, health and safety, but little or no input from the real customers, those that will use the procedure. Acceptance from procedure user groups was usually acquired with a signature from members of the highest levels of management, several levels above the workers. It was no surprise to find considerable re-work in the procedure development process, and again in the numerous requests for changes once a procedure was released to the workplace.

Findings/Conclusions

The effort to proceduralize operations at RFP has been a long, arduous process. Viewing the process from a systems approach enabled us to more readily identify the root cause to some of their recurring problems. The Human Factors recommendations and inputs into this situation included the following:

1. We impacted the actual procedure writing process by taking over the re-write of the "meta-procedure" that described to procedure writers how to write procedures. We made several changes in format that significantly impacted content, its organization, and readability.

In conjunction with this effort, we provided input to a Department of Energy (DOE) Standard (DOE-STD-1029-92) that was being developed during this same time interval, based on the latest principles of cognitive science. In turn, we used this standard, along with our research, to develop our plant specific documents. This approach supplied us with the argument, for those who were resistant to change of any kind, that our new procedures agreed with the same standards by which our ultimate customer, DOE, would audit our success or failure in creating good, usable procedures.

2. We felt that to really minimize waste and rework in the procedure process, the socio-political system needed to be assessed and revised. In the tradition of participatory ergonomics, we encouraged the plant procedures management to maximize their limited resources by expending their time setting standards, teaching and **certifying** procedure writers from individual manufacturing groups, and providing support/advice to these trained writers.

3. We recommended that individuals directly involved in the work governed by the procedure, who are below the Associate General Manager level, be empowered to signoff on a procedure.

On a general level, the Human Factors group at RFP has joined forces with the Process Improvement Group to develop a training program available to all groups on plantsite that trains personnel on the fundamentals of:

- o How systems function, where their subsystem fits in the larger, much more complex network of subsystems at RFP.
- o Process Improvement Techniques, including Process Improvement Teams, and the corollary Team -building activities.

The challenges faced by the Plant Procedures group in improving their process were endemic at RFP. It was felt that the best way to provide a sustained solution to system breakdowns was to develop this Process Improvement program and implement it throughout the plant to affect the necessary changes in the socio-political systems within this organization.

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