3.0 MAN FACTORS IN AEROSPACE MAINTENANCE: PERSPECTIVES FROM NASA RESEARCH AND OPERATIONS

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The contributing causes of human error in maintenance operations are not well understood. Because errors may remain latent over long periods of time and operational use, error event chains and their consequences are often difficult to trace and identify. In addition, human errors typically stem from multiple, interrelated sources; some are relatively easy to assess, such as workplace conditions or adequacy of resources; others are more indirect in their effect, such as organizational culture and communication barriers. Consequently, the process of managing error may involve multiple and diverse interventions with no single "magic pill" to cure the problems. Recognizing these challenges, National Aeronautics and Space Administration (NASA) is committed to improving the understanding of human error in maintenance through research as well as developing interventions for immediate use. In the following presentation, Ames Research Center (Ames) and Kennedy Space Center (KSC) jointly present NASA's approach to human factors in aerospace maintenance from both research and operational perspectives.

AMES RESEARCH CENTER: HUMAN FACTORS RESEARCH

Over the past 8 years, researchers at NASA Ames have investigated human factors issues in the maintenance domain. Although there has not been a formal program of research, NASA and the Federal Aviation Administration (FAA) have provided the support to maintain several initiatives. The work has been accomplished by teaming with aircraft manufacturers and airline operators, collaborating with human factors and industrial engineering groups at Kennedy Space Center, and learning from research colleagues.

This year, maintenance human factors has been recognized as an element in the new NASA Aviation Safety Program, and NASA Ames researchers will build upon the current research foundation in order to develop a focused program of research in four main areas:

- Improved procedures

- Human factors task and risk analysis tools
- Maintenance resource management skills, training and evaluation
- Advanced displays for maintenance aiding

Goals and Approach

NASA's Maintenance Operations Research Project supports the National Goal of Safety by fostering a better understanding of human factors in maintenance operations and by developing interventions and task aids that reduce human error and enhance safety and effectiveness.

Customer/partner participation

Central to the research approach, industry/government/research partnerships will be made that ensure: 1) research issues are relevant to industry needs, 2) research products are realistic and consistent with operational standards and requirements, and 3) researchers make effective use of existing human factors knowledge, techniques and databases. Among industry partners, airlines, unions, and manufacturers will be included. Government and research partners will come from the FAA, NASA, Department of Energy, other government laboratories, as well as the academic community.

Metrics and success criteria

It is important to both researchers and customers that research products be operationally validated. From the research standpoint, a proof of concept is often field-tested in order to make needed refinements and to make recommendations for larger scale implementation. From the customer standpoint, the costs and benefits of implementing new technologies and programs must be carefully evaluated against one's own needs and resources. Although it is desirable to collect as many assessment measurements as possible, often it is not feasible to burden the workforce with additional data collection. Therefore creative and unobtrusive methods of acquiring existing and new data must be devised. Existing databases may include company safety and audit data as well as training records and other routinely monitored performance indicators. In addition, qualitative methods, including surveys, interviews and observational methods may prove to be useful.

Four phases

For each of the research areas, four phases make up the research approach:

1. Identify high priority human error problems in maintenance
2. Define human factors requirements through task analyses
3. Develop human factors interventions to errors

4. Validate improvements in operational field sites

These phases are depicted along the bottom of the Roadmap in Figure 1. Consider the research area "Improved Procedures" shown near the top. The products for this research area are tools for evaluating, standardizing and documenting procedures. An example of a specific project may be "guidelines for incorporating human factors in the engine change procedure". In this project, the "guidelines" would constitute the Human Factors intervention developed in phase 3, and operationally validated in phase 4. The Roadmap also shows that there are pre-cursor phases 1 and 2 in which maintenance human errors (related to engine change procedures) are identified and in which human factors requirements are defined (through an analysis of the engine change task). By basing the development of interventions on phase 1 and 2, we ensure that the intervention addresses relevant high-priority human factors problems and that the intervention is based on an operationally realistic understanding of how the task is performed.

Similarly, the research area, Maintenance Resource Management (MRM), Skills and Training will generate products which need to be operationally validated, based upon an understanding of maintenance human error related to MRM. The intervention itself is based on human factors requirements related to the type of MRM skill involved (e.g., communication, team leadership). The research areas Human Factors Task Analysis Tools and Advanced Displays for Maintenance Aiding follow the same 4-phase approach.

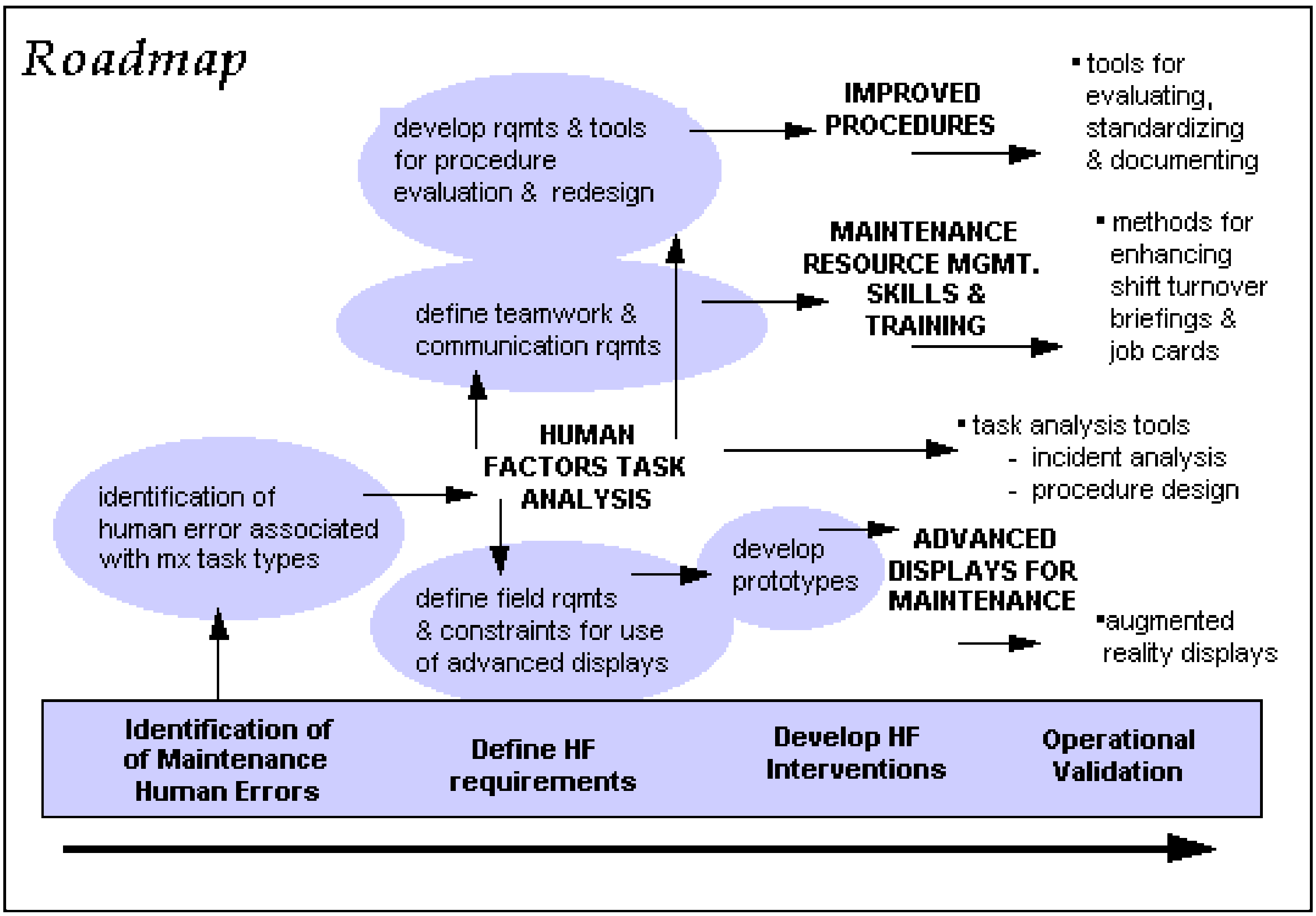

Figure 3.1: Roadmap to Maintenance Operations Research Program: 4-Phase Approach

It should be noted that specific research projects may emphasize the different phases to different degrees. For example, the goals of some basic research projects are to develop a proof of concept (phase 3) and little more. In such cases, phase 4 operational validation may not be immediately feasible. In contrast, however, all projects need a solid grounding in phases 1 and 2 so that interventions are relevant to industry needs.

Understanding the Nature of Human Error in Maintenance

Aviation Safety Reporting System (ASRS) maintenance error study

A study reported in 1995 by Veinott and Kanki[1] was the first to analyze maintenance incidents reported to the Aviation Safety Reporting System. Eighty-three reports from 1986-1992 were coded with respect to type of error, contributing factors and operational impact. Among the most interesting findings were the following:

- 60% of the errors were related to procedures
- 27% of the errors were related to practices
- At least 50% of the cases implicated more than a single individual
- 39% results in an air return

It is interesting to note that in spite of the fact that the forms submitted were "pilot" forms (i.e., forms that were not specifically adapted for the maintenance technician), more than two thirds were from ground personnel as opposed to flightcrew.

ASRS maintenance error study II

Since the ASRS maintenance form has been available since April 1997, a current research project is analyzing more recent submissions. We presume that a form tailored to the maintenance technician will yield more accurate and complete information. In addition to comparing results to the earlier study, this work focuses on procedural errors only and incorporates a much more detailed coding scheme. Specifically, procedural errors are broken down into 8 error subcategories as shown in Table 1. Incidents involving written documents are coded according to the aspect of the document in question, as well as 7 categories of contributing factors. In addition, incidents are coded for errors related to verbal information support. When verbal communications are involved, the aspect of the communication as well as contributing factors are also assessed. The codes have been developed to be consistent with categories incorporated in the Maintenance Error Decision Aid[2] and performance shaping factors incorporated in the Framework Assessing Notorious Contributing Influences for Error.[3]

Developing Interventions

Each research area has the potential for developing different types of interventions. Therefore the program relies on information from maintenance practitioners for specific guidance. Essentially, each project needs to identify the most critical problems and to develop the products which will be most useful. Collaborative help from operational partners are essential for determining an appropriate research focus.

Improved procedures

As we are seeing in the ASRS incident reports, procedural errors may be tied to a variety of human factors. Documents themselves may lack sufficient detail, may be poorly organized, may be inconsistent with company practices, and other documents. In addition, technicians may simply not use or complete them for some reason. Some procedures may be technically correct but may be improved through the incorporation of human factors principles. In other words, procedures may be re-designed to enhance team coordination, planning ahead and the management of time, people and resources.

In recent work with Boeing, we evaluated a procedure re-design process by identifying the structural and functional changes made to an engine change procedure.4 Since the new procedure improved productivity by 14%, our goal was to identify the types of changes responsible for this enhancement. Certainly existing procedures differ in their potential for improvement, but there are general guidelines that may be followed for systematic evaluation.

This project is in the stage of completion of the Guidelines intervention. We next will move into the operational validation phase by testing the guidelines against airline procedures. We may also consider the applicability of these guidelines to other types of procedures; for instance, in the KSC shuttle operations.

Table 3.1: Coding Process for ASRS Maintenance Error Study II	
Question 1: Does the incident involve procedural error? ⇒ ⇓	NO - do not analyze

YES - Code for Error Type	1. Procedural Omission 2. Error of Intent 3. Selection Error 4. Awareness and Task Execution Error 5. Fault Identification/Diagnosis Inadequate 6. Inspection/Verification Incomplete 7. Values/Units/Scales/Indicators Related Error 8. Maintenance Repair Inadequate
Question 2: Is Written Support Information Involved? ⇒ ⇓	NO - skip to question 3
YES Identify Document Type	(0-10)*
Code for Aspect of the Document	1. Correctness & Completeness (0-8) 2. Usability (0-6) 3. Supporting Data (0-7) 4. Verification & Inspection (0-3) 5. Warnings/Cautions/Notes (0-6)

Code for Contributing Factors ⇓	1. Airplane/Part Design (0-6)) 2. Tools/Equipment (0-5) 3. Personnel (0-3) 4. Environment (0-3) 5. Organizational (0-4) 6. Work Group (0-6) 7. Task Related (0-8)
Question 3: Is Verbal Support Information Involved? ⇒ ⇓	NO - skip to End
YES Identify Communication Type	(0-7)
Code for Aspect of Communication	1. Problem Solving & Decision Making (0-7) 2. Interpersonal Relationships (0-3) 3. Behavioral Patterns (0-2) 4. Attention to Task/Monitoring (0-2) 5. Communication as Mgmt Tool (0-4)

Code For Contributing Factors ⇓	1. Airplane/Part Design (0-6) 2. Tools/Equipment (0-5) 3. Personnel (0-3) 4. Environment (0-3) 5. Organizational (0-4) 6. Work Group (0-6) 7. Task Related (0-8)
End	

* Numbers in parentheses indicate coding selections within category

Human factors task and risk analysis tools

A three-year project recently completed by the Idaho National Engineering and Environmental Laboratories (INEEL) introduced human error analysis tools and concepts long used in the nuclear power industry to the aviation maintenance domain. Their research investigated the association between maintenance tasks and human error opportunities. In addition, it identified human factors (performance shaping factors) most likely to influence task performance. Although it may not be feasible to provide exact risk probabilities for specific tasks, the possibilities of unknown risk are narrowed as the relationship between human error and tasks is clarified.

The goal of this research area is to develop task analysis tools that enhance our understanding of causal and contributory factors of maintenance human error. Such a tool can be adapted for many purposes. The original INEEL study focused on developing tools that aid in the design of maintenance procedures. However, this analysis tool could also help safety specialists and investigators better understand the causes of incidents and accidents and to identify interventions most needed. Human factors task analysis tools can also be adapted for training uses, such as targeting error-prone areas for special training emphasis.

Maintenance Resource Management skills, training and evaluation

The third research area focuses on maintenance resource management (MRM) skills, training, and evaluation. Many airlines have successfully developed the concept of MRM as an intervention to a broad set of human factors problems, including communication, leadership, teamwork, interpersonal relations, problem solving, etc. The next step is to move from "awareness" training of concepts to practical skills training; from one-time stand-alone classes to a continuous recurrent program integrated with technical training. For example, it is essential that technicians become aware of how communication problems can lead to human error. However, such training cannot substitute for training performance-based communication skills such as verbal briefings and writing skills.

As mentioned earlier, it is important to both researchers and practitioners that interventions be operationally validated. In order to develop the most effective MRM training materials and media, and to leverage both short and long-term impact of the training, evaluation metrics should be conscientiously collected and analyzed. For example, the work of Taylor and Robertson5 has made great progress in this area and they have given us a model of how MRM training can influence attitudes, behaviors and performance in the workplace. We have also learned the importance of linking training departments with engineering and safety departments who may be providers of useful, existing performance measures.

Advanced displays for maintenance aiding

The fourth research area pertains to information displays. Because maintenance work often requires information to be read and used on-line during task performance, the development of display technologies which provide task-relevant information in a timely, convenient form is a promising maintenance error intervention. Information sources which create interruptions to the work flow are not only deterrents to efficiency, but foster opportunities for mistakes to be made.

Industry is developing a variety of technologies for displaying procedures, visual graphics, blueprints, OJT notes, and even virtual objects and many of these should be considered for application to the maintenance domain. For example, a head-mounted see-through display may provide direct access to 3-D aircraft wireharness assembly diagrams or a view of virtual assembly instructions. Another technology may provide video images of live "targets" with superimposed information such as fastener positions and "stay out" areas. In short, the technology is available. Yet we need to know how to make such technologies compatible and useful to technicians in the context of their everyday workplace. The implementation of new technologies, measurement strategies, and training are interrelated issues to be addressed.

ARC/KSC technology transfer workshops

Together, NASA Ames and NASA KSC initiated a series of technology transfer workshops on specific human factors topics for the purpose of identifying issues, problems, and "lessons-learned" in common interest areas across spacecraft processing and aircraft maintenance. Workshop I, held in September, 1996, focused on incident investigation and analysis. Researchers and practitioners from aircraft and shuttle operations participated in a hands-on type meeting, sharing information on the practical aspects of current approaches and solutions. In May, 1997, Workshop II focused on human factors training. Future plans for Workshop III indicates a focus on procedure improvements.

KENNEDY SPACE CENTER: HUMAN FACTORS PRACTITIONERS

The human factors practitioners in Shuttle processing at Kennedy Space Center face many of the same challenges and issues related to human errors found in aviation maintenance operations. Incidents are analyzed using a diagnostic tool to identify the systemic causes of errors and to design multiple interventions. KSC targets four main areas of error intervention. Primary human factors interventions are aimed at identifying and correcting work conditions and work processes that induce errors. These “upstream” interventions address 1) Workplace and Task Design/Ergonomics, and 2) Organizational/ Cultural Issues. Secondary human factor interventions address the last two error reduction targets: 3) the Individual, and 4) the Team. These “downstream” interventions focus on enhancing workers’ awareness of how individual/group behaviors affect safety, and how to develop personal “safety nets” to stop an error from occurring.

Human Factors Program at KSC: A Brief History

NASA’s initial human factors collaboration between the Kennedy Space Center and Ames Research Center began in 1991 under a formal Human Factors Engineering Memorandum of Understanding. The first research project, between NASA KSC and NASA Ames also involved the Center for Creative Leadership and the United States Air Force Academy. Research data was collected on the effectiveness of KSC’s teaming and leadership behaviors, during the summers of 1993 and 1994. See Table 2 for a summary of key accomplishments.

The following KSC observations resulted from that research:

- Hierarchical Culture
- Formed versus Intact Teams
- Task Execution versus Self Managed Teams
- Real Authority is “The Paper”
- Task Team Leader is an “Assembler” of Co-Acting Individuals

- Hesitancy to Give Feedback to Team Members

While the observations verified the KSC workers' technical competence, the data identified a need to enhance the skills required for optimum teaming and leadership behaviors.

Table 3.2: KEY ACCOMPLISHMENTS: Kennedy Space Center's Shuttle Ground Processing Human Factors Team

1991	Human Factors Engineering **Memorandum signed** between NASA's Ames Research Center (ARC) and NASA's Kennedy Space Center (KSC).
1992 to **1994**	**Research conducted at KSC**, in collaboration with NASA Ames, the Center for Creative Leadership and the United States Air Force. Data collected on the **effectiveness of workers' teaming and leadership behaviors.**
1993	**Formation of the KSC Shuttle Ground Processing Human Factors Team**, (July).
1994	Began a **Close-Call Reporting System:** The Positive Initiative Effort (PIE) Program, (July).
	Initial collaboration with NASA Ames and the KSC Human Factors Team, on human error investigation techniques and data analysis methods.
1995	Developed initial **diagnostic tool** for investigating shuttle ground processing errors.
	Developed and presented **"Human Factors Awareness Training"** to contractor ground operations management personnel. (8/95 - 9/97 = 1,261 personnel trained)

1996 Validated and refined the diagnostic tool and **began applying this "model" consistently**, when investigating shuttle ground processing human errors. Received recognition of a "best practice" by the Best Manufacturing Practices Center of Excellence. **Developed a database**, from the causal factors collected. Initial reports to Shuttle Processing management.

Published the inaugural **"Time-Out" Newsletter**, (July).

Developed **"Task Team Roles & Responsibilities"** course, for the hands-on workers, (1/96 - 6/96). Presented course to 2,800 workers, (7/96 - 6/97)

Initial "Technology Transfer" Human Factors Workshop, hosted by NASA Ames Research Center, focused on "Accident Investigation Data Analysis," (September).

1997 **Published the "User's Manual"** for the Human Factors Investigation Model. Refined data analysis and reporting techniques. Applied a modified version of the tool to close calls.

Second "Technology Transfer" Workshop hosted by NASA KSC, focused on "Human Factors Training" issues, (May).

Presented error analysis trend data to both NASA and Contractor Senior Management, (July). Addressed the need for a full time human factors team, instead of an Ad Hoc team.

NASA and Contractor management attended a 2 day workshop on "Creating a Safety Culture," which was conducted by an independent consultant, (last Qtr. 1997).

Concurrent with this research, NASA Headquarters (Washington, DC) directed KSC to "assess the human factor aspects of all incidents." This direction was based on an independent (non-KSC) review of shuttle ground processing errors. An analysis of 28 months of data (10/90 through 1/93) revealed that the primary causal category, for 72% of the incidents, was "human error." As a result, the KSC Shuttle Processing Human Factors Team was chartered in July 1993. This team continues to be an ad hoc team comprised of both NASA and Space Flight Operations Contractor (SFOC) personnel. Team membership is cross functional and includes participation from front-line employees who represent safety, quality, shop, systems engineering, industrial engineering, and human factors. Their common goal is to improve ground processing safety in a rapidly changing workplace. The current industry-wide challenge to perform "better, faster, and cheaper" makes the successful attainment of this safety goal all the more imperative.

Error Data Collection Tool: The KSC Human Factors Investigation Model

Since the KSC Human Factors team was chartered to investigate incidents, the members needed a diagnostic tool that would provide a consistent method of identifying the systemic causes of ground processing errors. Investigations typically stopped at the "tip of the iceberg" and did not delve into the deeper, underlying causes that resulted in well-intentioned workers making mistakes. As a result, work conditions and processes that induced these human errors continued to exist.

The KSC Human Factors Investigation Model is based on the "Team Effectiveness and Leadership Model" designed by Dr. Robert Ginnett, of the Center for Creative Leadership. The research data from observations of KSC work teams also supported the development of the KSC Human Factors Investigation Model. Dr. Ginnett's model was designed for use as a team formation guide and a diagnostic tool for evaluating team performance. The Human Factors Team expanded Dr. Ginnett's original model so it could be used to assess a Shuttle ground processing task team's performance from a safety perspective.

The KSC Model provides a more in-depth analysis of causal factors beyond the readily visible operator error. The Model guides an investigator to look at the "big picture" and to analyze the often invisible processes of teaming and leadership dynamics, group norms, organizational practices, and the corresponding unspoken cultural beliefs and values. The KSC Model also is used as a proactive tool to *prevent* errors from occurring. Just as the "Dirty Dozen" enhance a worker's awareness of potential error traps so they can be avoided, the KSC Model highlights the work process ingredients that are needed to ensure optimum, safe task performance.

The collection of causal data is valuable only to the extent that it helps *change the conditions* in which people must work. Human Factors interventions are prioritized according to an analysis of the causal data. The most prevalent recurring causal conditions are targeted for countermeasures. The next two sections will describe KSC's primary and secondary error interventions.

Primary Interventions

Workplace & Task Design Ergonomics

Although the team's original charter was to "assess human factor related incidents," members recognized the need to be proactive and prevent errors from occurring. As a result, the team took the initiative to expand its charter and focused its first project on identifying and correcting error-prone conditions in the workplace. The team developed a close call reporting system called the "Positive Initiative Effort" (PIE) Program. The PIE Program provides an easy method for the hands-on workers to report unsafe conditions and/or work processes.

A pilot effort was implemented in July 1994, at one of the three Orbiter Processing Facilities (OPF) high bays. The program's success at this initial site encouraged management to expand the close call reporting initiative. By January of 1996, all major Shuttle ground processing facilities implemented the PIE Program. The primary benefit of this close call reporting system has been the reduction of "tech traps." The PIE program emphasizes the importance of being aware of human/workplace mismatches and taking the initiative to report these situations. In several cases, the technicians have recommended simple, inexpensive hardware modifications that have eliminated or significantly reduced the impact of the original problem.

Organizational/Cultural Issues

As Walt Whitman once said, "We convince by our presence." The heritage at the Kennedy Space Center is exemplified in a "Can Do!" attitude. While this cultural belief has resulted in many amazing accomplishments, it also has been a causal factor in some incidents. The challenge is in knowing where to draw the line between, "I can do it safely" and "I can do it, *but* I'll have to take a risk." This line, however, isn't fixed and its position often shifts depending on the status of the processing schedule. Historically, NASA's culture has rewarded "problem solvers" which has reinforced a reactionary mind set.

The Human Factors Team recognized the need to unveil these cultural beliefs and openly discuss the invisible value structure of the KSC culture. The unspoken beliefs, values and practices, which had been carried over from the Apollo era, were not always appropriate or effective in the rapidly changing environment of the Shuttle program.

Technical controls

An example of how past practices have not kept pace with the current workplace conditions is found in the KSC work procedures. The causal trend data reveals "inadequate paper" as the top contributing cause. While improving the quality of the paper certainly is important, team members realized a more systemic problem was beneath the more obvious symptom of inadequate paper.

In most instances of less than adequate technical controls, the workers were unsure of what to do, so they "relied on the paper." Our human factors data indicates that KSC's cultural "rule based" approach to tasks (i.e., "Follow the Paper"), *in lieu of relying on specific task experience and system knowledge*, is a definite link in the error chain.

As our workforce resources diminish due to reduced budgets, our "critical skills" are being stretched thin. Along with improving the paper, management interventions need to address core work processes such as Integrated Resource Planning and Scheduling, as well as Training. Organizational structures must *design out opportunities for errors*, by ensuring the right workers are assigned to the right tasks, with the right tools. Procedures support - not substitute - the technicians' hardware knowledge.

KSC also recognizes the need to enhance the work instruction system. Through technology transfer and informal benchmarking with aircraft maintenance centers, the KSC Human Factors Team is striving to incorporate aviation maintenance "lessons learned" into Shuttle ground processing procedures.

Cultural change: Doing (goals) versus Being (values)

The current challenge at KSC involves a re-balancing of priorities. We have excelled at achieving "mission milestones" by focusing on near-term *technical* tasks. To maintain this level of excellence, however, in the new era of "faster, better, cheaper," KSC will also focus on *non-technical* long term values. A worker infers what management values by how they act. The only way to communicate a value, therefore, is to *act* in accordance with it. KSC realized the need for management to demonstrate that safety *is* first and schedule is second. Based on this need, all of Shuttle ground operations contractor management participated in an intensive two-day safety workshop taught by an outside consultant.

In an effort to "walk the talk," all levels of management have been tasked to "walk a mile in their workers' shoes." Through regular, periodic visits to the shuttle ground processing facilities, management will gain an understanding of the process-induced workload factors that create opportunities for errors. Some of the workplace conditions that management will focus on correcting include the following:

- lack of task specific experience/technical proficiency
- scheduling conflicts due to a less than adequate (LTA) integrated workload management system
- lack of appropriate material resources
- organizational barriers that impede communications and reduce situational awareness
- culture that often responds negatively to a "Time-Out" concern, thereby reinforcing the belief that schedule is more important than safety
- procedures that do not reflect the actual work situation/ergonomic mismatches
- role accumulation due to downsized workforce

Secondary Interventions

Education & Training

As Albert Einstein observed, "Problems cannot be solved at the same level of consciousness that created them." KSC needed to dispel myths about human errors, as well as provide proven methods for enhancing workers' safety. These new methods had to go beyond the traditional management refrain, which told workers to "Be more careful."

Human Factors awareness course

Realizing that awareness is the first step towards change, the team developed a “Human Factors Awareness” course. This class was presented to 1,261 *management* personnel during a two (2) year period (8/95 - 9/97).

This four hour course was designed to give a basic orientation to human factors and ergonomic principles, as well as explain how these factors influence human performance. The ultimate intent was to help change management’s traditional “blame and train” approach to errors, by presenting the KSC Human Factors Team’s philosophy on errors:

- Errors are not intentional.
- Errors result from a series of interrelated contributing causes.
- Most contributing causes are part of organizational processes and can be managed.
- Errors often occur due to a mismatch between the work design and the workers’ cognitive and physical capabilities.

Management also was encouraged to actively support their employees’ participation in the close call reporting PIE program, as well as provide positive feedback to workers who asked for a “Time-Out” due to a concern. Additionally, management was reminded of the old adages: “If you’re not part of the solution, then you’re part of the problem;” and “Change begins with me.” The extent to which management personnel gained an awareness of how their *own* beliefs and behaviors have contributed to the current culture, will determine the extent to which they begin to change, thereby helping to influence a culture shift.

Task team roles & responsibilities

Since no workplace is designed perfectly, the team’s secondary training focus was on alerting the *workers* to conditions that create opportunities for errors. The best detectives know what clues to look for, before they even begin trying to solve a mystery. Likewise, since workers often are the “last line of defense,” we wanted to enhance their awareness of certain workplace clues, (i.e., “Links in the Error Chain”), so they could call a “Time-Out” before an error happens. Teaming and Leadership skills were emphasized as “safety nets” to help prevent errors from occurring. The sharing of “Crew Resource Management” (CRM) and “Maintenance Resource Management” (MRM) information, by the various aviation communities greatly enhanced the development of this four hour class.

The design of the course content was a collaborative effort between the Human Factors Team and the hands-on workers. The teaching approach used was "Train the Trainer." Thirty-nine workers were trained initially and they, in turn, presented the class to their peers. Since part of the course involved challenging current perceptions of certain organizations, we wanted to ensure that the trainers represented a cross-section of the workers. For this reason, a team of three trainers presented the class. Each of the three trainers represented a different ground processing organization: Safety, Quality, Shop, Engineering, Facilities, or Scheduling. Furthermore, classes were organized so the trainers were presenting to the people they interfaced with on a daily basis. The workers who had been selected to be the trainers were regarded, by their peers, as being positive role models. KSC wanted to maximize the trainers' opportunity to be a "catalyst for change" by facilitating an open dialogue with their own co-workers on the importance of positive teaming and leadership behaviors. The Task Team Roles & Responsibility class was presented to 2,800 shuttle ground processing personnel within a one year period (7/96 - 6/97).

Team members understood that initial learning often is passive and that these skills wouldn't be acted upon with a one time "inoculation." A Phase Two "Teaming and Leadership" course is being developed based on workers' feedback from the initial class. They requested additional training on interpersonal skills: Decision Making, Conflict Resolution, Assertiveness in Calling a "Time-Out", and Effective Communications Across Organizations.

Generally, comments from the class participants were positive. Traditionally, KSC training focused on improving the workers' technical skills. This was the first course aimed at enhancing the workers' interpersonal, "soft" skills. The participants' comments also included a consensus of the need for management to "walk the talk." Workers wanted management expectations to be explicit - not through words - but through actions.

Just in Time training

The third component of KSC's educational intervention is providing workers with computer based and video refresher training. These "Just in Time" reminders are provided to the workers prior to the start of an infrequent or hazardous task. These computer aided training programs and videos were designed with input from both the technicians and the engineers. The intent of the "Just in Time" training is to heighten the worker's awareness of the job's hazards, necessary protective equipment, and "lessons learned" from past operations.

Time-Out newsletter

Concurrent with the beginning of the "Task Team Roles & Responsibilities" course, the Human Factors Team published the first "Time-Out!" newsletter in July 1996. The newsletter reinforced the training that the workers were receiving in the class, by encouraging them to be alert for error-likely situations. The newsletter also gave positive recognition to "Human Factor Heroes," who called a time-out when they noticed a link in the error chain. Subsequent newsletters have been distributed on a quarterly basis.

SUMMARY

Since most human errors result from interrelated causes, KSC believes that the most effective approach to controlling errors is through multiple, interrelated interventions. As with all organizational change initiatives, the linchpin of change rests with an acceptance of responsibility for how one's *own* beliefs and behaviors have contributed to the current condition. The successes of KSC's human factors program are a reflection of management's increased understanding - and acceptance - of how errors really occur.

Like most industries and government agencies, KSC has many future obstacles to overcome in the era of Shuttle ground processing contractor mergers and downsizing due to reduced budgets. As the KSC workforce is challenged to "do more with less" and accomplish tasks "better, faster and cheaper," the Human Factors Team's goal remains the same: to improve safety, through focused interventions aimed at the work environment, the task, the team, and the individuals.

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