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DOE-HDBK-1028-2009
June 2009

DOE STANDARD

HUMAN PERFORMANCE IMPROVEMENT HANDBOOK

VOLUME 1: CONCEPTS AND PRINCIPLES

U.S. Department of Energy **AREA HFAC**
Washington, D.C. 20585

Available on the Department of Energy

Technical Standards Program

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http://www.hss.energy.gov/nuclearsafety/ns/techstds/

VOLUME 1: CONCEPTS AND PRINCIPLES

PREFACE

This *Human Performance Improvement Handbook* is a reference for anyone working in the Department of Energy (DOE) community who wants to learn more about human performance and how it can be improved. The handbook consists of five chapters entitled: "An Introduction to Human Performance," "Reducing Error," "Managing Controls," "Culture and Leadership", and "Organizations at Work." The handbook addresses the roles of individuals, leaders, and the organization in improving performance. Principles of human performance, outlined in Chapter 1, are the foundation blocks for the behaviors described and promoted in the handbook. The strategic approach for improving performance is to reduce human error and manage controls so as to reduce unwanted events and/or mitigate their impact should they occur. For the purposes of this handbook, an event is an undesirable change in the state of structures, systems, or components or human/organizational conditions (health, behavior, controls) that exceeds established significance criteria.

Human performance improvement (HPI) as addressed in this handbook is not a program per se, such as Six Sigma, Total Quality Management, and the like. Rather, it is a set of concepts and principles associated with a performance *model* that illustrates the organizational context of human performance. The model contends that human performance is a system that comprises a network of elements that work together to produce repeatable outcomes. The system encompasses organizational factors, job-site conditions, individual behavior, and results. The system approach puts new perspective on human error: it is not a cause of failure, alone, but rather the effect or symptom of deeper trouble in the system. Human error is not random; it is systematically connected to features of people's tools, the tasks they perform, and the operating environment in which they work. A separate volume, Human *Performance Improvement Handbook Volume II: Human Performance Tools for Individuals, Work Teams, and Management*, is a companion document to this handbook. That volume describes methods and techniques for catching and reducing errors and locating and eliminating latent organizational weaknesses

This volume is an introductory summary document that addresses a human performance improvement approach as was initially introduced within DOE in recent years. The content and the approach to the topic are based on concepts and practices found useful in the commercial nuclear power industry and similarly adopted by other industries. The Institute of Nuclear Power Operations (INPO) generously provided assistance in helping the Department roll out its human performance courses, which were patterned on the INPO model. This handbook reflects heavily on the human performance research and practical applications so expertly chronicled in INPO's *Human Performance Fundamentals Course Reference* (2002) and its later revision of the material in *Human Performance Reference Manual*, INPO 06-003 (2006). The Department is greatly appreciative of this outstanding assistance and support. It is just one more recent example of a long-standing collaborative relationship between these two organizations that spans more than two decades.

The concept of high reliability organizations (HRO) has captured the interest of many organizational leaders in recent years. HROs provide real examples of organizations that operate successfully while almost never experiencing an unwanted event. HROs by definition operate under very trying conditions all the time and yet manage to have very few accidents. (An accident is an unfortunate mishap, especially one causing damage or injury.) Examples of HROs include aircraft carriers, air traffic controllers, power grid dispatch centers, nuclear submarines, airline cockpit crews, nuclear power plants, and offshore platforms, among others. HPI is one approach toward achieving the attributes evident in HROs. (see Chapter 5)

This handbook is not a human factors manual. HPI is not a substitute for, nor is it intended to impinge upon in any way on, the workings of human factors professionals to improve organizational and individual effectiveness. Neither is it the intent of this handbook to modify any requirements of other health, safety, and security regulations and obligations. The principles of HPI can be used to enhance the value of these programs.

Reading The Handbook

Individuals will approach the reading of this handbook either from a personal interest in the subject matter or from a practical need to know the information contained in it. HPI trainers and practitioners are likely to read it cover to cover, highlight sections, dog-ear certain pages and make it one of their valued references. Managers, supervisors, and performance improvement leaders wanting to learn about HPI with the goal of implementing it in their workplace will approach reading in a somewhat different vein than persons who read it for their personal use. The following guidance is intended to help users focus their reading.

Recommended Reading by User Groups = X	Individual Contributors	Managers Supervisors HPI Leaders	HPI Trainers HPI Practioners
Chapter 1: Introduction to HPI	X	X	X
Chapter 2: Reducing Error	*X	X	X
Chapter 3: Managing Controls	pp.1-17	X	X
Chapter 4: Culture and Leadership		X	X
Chapter 5: HPI Evolution			X

* Selected sections in Chapter 2 only are designated as "essential reading."

Readers may come across unfamiliar terms while reading this handbook. If the term is not defined in the text the first time it is used, refer to the glossary at the end of handbook for the definition.

Both footnotes and endnotes are used in this document. The convention for footnotes is an asterisk (*) followed by a number. Footnotes appear at the bottom of the page. Endnotes are intended to reference source material. The convention for endnotes is a superscript number. Endnotes are listed at the end of each chapter.

CHAPTER 1 - INTRODUCTION TO HUMAN PERFORMANCE

OVERVIEW

In its simplest form, human performance is a series of behaviors carried out to accomplish specific task objectives (results). Behavior is what people do and say—it is *a means to an end*. Behaviors are observable acts that can be seen and heard. In the Department of Energy (DOE) the behaviors of operators, technicians, maintenance crafts, scientists and engineers, waste handlers, and a myriad of other professionals are aggregated into cumulative acts designed to achieve mission objectives. The primary objective of the operating facilities is the continuous safe, reliable, and efficient production of mission-specific products. At the national laboratories, the primary objectives are the ongoing discovery and testing of new materials, the invention of new products, and technological advancement. The storage, handling, reconfiguration, and final repository of the legacy nuclear waste materials, as well as decontamination, decommissioning, and dismantling of old facilities and support operations used to produce America's nuclear defense capabilities during the Cold War are other significant mission objectives. Improving human performance is a key in improving the performance of production facilities, performance of the national laboratories, and performance of cleanup and restoration.

It is not easy to anticipate exactly how trivial conditions can influence individual performance. Error-provoking aspects of facility*[1] design, procedures, processes, and human nature exist everywhere. No matter how efficiently equipment functions; how good the training, supervision, and procedures; and how well the best worker, engineer, or manager performs his or her duties, *people cannot perform better than the organization supporting them.*[1] Human error is caused not only by normal human fallibility, but also by incompatible management and leadership practices and organizational weaknesses in work processes and values. Therefore, defense-in-depth with respect to the human element is needed to improve the resilience of programmatic systems and to drive down human error and events.

The aviation industry, medical industry, commercial nuclear power industry, U.S. Navy, DOE and its contractors, and other high-risk, technologically complex organizations have adopted human performance principles, concepts, and practices to consciously reduce human error and bolster controls in order to reduce accidents and events. However, performance improvement is not limited to safety. Organizations that have adopted human performance improvement (HPI) methods and practices also report improved product quality, efficiency, and productivity.[2] HPI, as described in this handbook and practiced in the field, is not so much a program as it is a distinct way of thinking. This handbook seeks to improve understanding about human performance and to set forth recommendations on how to manage it and improve it to prevent events triggered by human error.

This handbook promotes a practical way of thinking about hazards and risks to human performance. It explores both the individual and leader behaviors needed to reduce error, as well

*[1] The word "facility" used in this handbook is a generic term. It is recognized that D&D work is accomplished by projects and that laboratory work is accomplished through experiments, etc. The reader should apply the term "facility" to their recognized unit of work

as improvements needed in organizational processes and values and job-site conditions to better support worker performance. Fundamental knowledge of human and organizational behavior is emphasized so that managers, supervisors, and workers alike can better identify and eliminate error-provoking conditions that can trigger human errors leading to events in processing facilities, laboratories, D & D structures, or anywhere else on DOE property. Ultimately, the attitudes and practices needed to control these situations include:

- the will to communicate problems and opportunities to improve;
- an uneasiness toward the ability to err;
- an intolerance for error traps that place people and the facility at risk;
- vigilant situational awareness;
- rigorous use of error-prevention techniques; and
- understanding the value of relationships.

INTEGRATED SAFETY MANAGEMENT AND HPI

DOE developed and began implementation of Integrated Safety Management (ISM) in 1996. Since that time, the Department has gained significant experience with its implementation. This experience has shown that the basic framework and substance of the Department's ISM program remains valid. The experience also shows that substantial variances exist across the complex regarding familiarity with ISM, commitment to implementation, and implementation effectiveness. The experience further shows that more clarity of DOE's role in effective ISM implementation is needed. Contractors and DOE alike have reported that clearer expectations and additional guidance on annual ISM maintenance and continuous improvement processes are needed.

Since 1996, external organizations that are also performing high-hazard work, such as commercial nuclear organizations, Navy nuclear organizations, National Aeronautics and Space Administration, and others, have also gained significant experience and insight relevant to safety management. The ISM core function of "feedback and improvement" calls for DOE to learn from available feedback and make changes to improve. This concept applies to the ISM program itself. Lessons learned from both internal and external operating experience are reflected in the ISM Manual to update the ISM program. The ISM Manual should be viewed as a natural evolution of the ISM program, using feedback for improvement of the ISM program itself. Two significant sources of external lessons learned have contributed to that Manual: (1) the research and conclusions related to high-reliability organizations (HRO) and (2) the research and conclusions related to the human performance improvement (HPI) initiatives in the commercial nuclear industry, the U.S. Navy, and other organizations. HRO and HPI tenets are very complementary with ISM and serve to extend and clarify the program's principles and methods.[3]

As part of the ISM revitalization effort, the Department wants to address known opportunities for improvement based on DOE experience and integrate the lessons learned from HRO organizations and HPI implementation into the Department's existing ISM infrastructure. The

Department wants to integrate the ISM core functions, ISM principles, HRO principles, HPI principles and methods, lessons learned, and internal and external best safety practices into a proactive safety culture where:

- facility operations are recognized for their excellence and high-reliability;
- everyone accepts responsibility for their own safety and the safety of others;
- organization systems and processes provide mechanisms to identify systematic weaknesses and assure adequate controls; and
- continuous learning and improvement are expected and consistently achieved.

The revitalized ISM system is expected to define and drive desired safety behaviors in order to help DOE and its contractors create world-class safety performance.

In using the tools, processes, and approaches described in this HPI handbook, it is important to implement them within an ISM framework, not as stand-alone programs outside of the ISM framework. These tools cannot compete with ISM, but must support ISM. To the extent that these tools help to clarify and improve implementation of the ISM system, the use of these tools is strongly encouraged. The relationship between these tools and the ISM principles and functions needs to be clearly understood and articulated in ISM system descriptions if these tools impact on ISM implementation. It is also critical that the vocabulary and terminology used to apply these tools be aligned with that of ISM. Learning organizations borrow best practices whenever possible, but they must be translated into terms that are consistent and in alignment with existing frameworks.

ISM Guiding Principles

The objective of ISM is to systematically integrate safety into management and work practices at all levels so that work is accomplished while protecting the public, the workers, and the environment. This objective is achieved through effective integration of safety management into all facets of work planning and execution. In other words, the overall management of safety functions and activities becomes an integral part of mission accomplishment. [4]

The seven guiding principles of ISMS are intended to guide Department and contractor actions from development of safety directives to the performance of work. As reflected in the ISM Manual (DOE M 450.4-1dated 11-16-06) these principles are:

- Line Management Responsibility For Safety. Line management is directly responsible for the protection of the public, the workers, and the environment.
- Clear Roles and Responsibilities. Clear and unambiguous lines of authority and responsibility for ensuring safety shall be established and maintained at all organizational levels within the Department and its contractors.
- Competence Commensurate with Responsibilities. Personnel shall possess the experience, knowledge, skills, and abilities that are necessary to discharge their responsibilities.

- Balanced Priorities. Resources shall be effectively allocated to address safety, programmatic, and operational considerations. Protecting the public, the workers, and the environment shall be a priority whenever activities are planned and performed.
- Identification of Safety Standards and Requirements. Before work is performed, the associated hazards shall be evaluated and an agreed-upon set of safety standards and requirements shall be established which, if properly implemented, will provide adequate assurance that the public, the workers, and the environment are protected from adverse consequences.
- Hazard Controls Tailored to Work Being Performed. Administrative and engineering controls to prevent and mitigate hazards shall be tailored to the work being performed and associated hazards.
- Operations Authorization. The conditions and requirements to be satisfied for operations to be initiated and conducted shall be clearly established and agreed upon.

ISM Core Functions

Five ISM core functions provide the necessary safety management structure to support any work activity that could potentially affect the public, workers, and the environment. These functions are applied as a continuous cycle with the degree of rigor appropriate to address the type of work activity and the hazards involved.

- *Define the Scope of Work*. Missions are translated into work; expectations are set; tasks are identified and prioritized; and resources are allocated.
- *Analyze the Hazards*. Hazards associated with the work are identified, analyzed, and categorized.
- *Develop and Implement Hazard Controls*. Applicable standards and requirements are identified and agreed-upon; controls to prevent or mitigate hazards are identified; the safety envelope is established; and controls are implemented.
- *Perform Work within Controls*. Readiness to do the work is confirmed and work is carried out safely.
- *Provide Feedback and Continuous Improvement*. Feedback information on the adequacy of controls is gathered; opportunities for improving how work is defined and planned are identified and implemented; line and independent oversight is conducted; and, if necessary, regulatory enforcement actions occur.

Human error can have a negative affect at each stage of the ISM work cycle; for example:.

1. *Define Work Scope:* Errors in defining work can lead to mistakes in analyzing hazards.
2. *Analyze Hazards:* Without the correct hazards identified, errors will be made in identifying adequate controls.

3. *Develop Controls:* Without an effective set of controls, minor work errors can lead to significant events.

4. *Perform Work:* If the response to the event only focuses on the minor work error, the other contributing errors will not be addressed.

Integration of ISM and HPI

Work planning and control processes derived from ISM*[2] are key opportunities for enhancement by application of HPI concepts and tools. In fact, an almost natural integration can occur when the HPI objectives—reducing error and strengthening controls - are used as integral to implementing the ISM core functions. Likewise the analytical work that goes into reducing human error and strengthening controls supports the ISM core functions.

For purposes of this Handbook, a few examples of this integration are illustrated in the following table. The ISM core functions are listed in the left column going down the table. The HPI objectives appear as headers in the second and third column on the table.

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*[2] For a detailed discussion of work planning considerations, readers should refer to a document published in January 2006 by the National Nuclear Security Administration (NNSA). That document is entitled "Activity Level Work Planning and Control Processes **:** Attributes, Best Practices, and Guidance for Effective Incorporation of Integrated Safety Management and Quality Assurance"**.**

Integration of ISM and HPI

<table>
<tr><th>Integrated Safety Management</th><th colspan="2">Human Performance Improvement Strategic Approach</th></tr>
<tr><td>ISM Core Functions</td><td>Reduce Human Error</td><td>Manage Controls</td></tr>
<tr><td>Define the Scope of Work

The Task Preview HPI tool supports this core function. It can be used to help eliminate error when reviewing the scope of work. During the task preview individuals who will perform the work:

• Identify the critical steps (see definition)
• Consider the possible errors associated with each critical step and the likely consequences.
• Ponder the "worst that could happen."
• Consider the appropriate human performance tool(s) to use.
• Discuss other controls, contingencies, and relevant operating experience.

This approach is intended to expand the work definition considerations and thus preclude omissions that could be overlooked during analyzing the hazards associated with the work to be accomplished.</td><td>When management expectations are set. the tasks are identified and prioritized, and resources are properly allocated (e.g., supervision, tools, equipment, work control, engineering support, training), human performance can flourish. These organizational factors create a unique array of job-site conditions – a good work environment – that sets people up for success. Human error increases when expectations are not set, tasks are not clearly identified, and resources are not available to carry out the job.</td><td>When work scope is defined and all the preparation to complete the task is at hand, the error precursors – conditions that provoke error – are reduced. This includes things such as:

• Unexpected equipment conditions
• Workarounds
• Departures from the routine
• Unclear standards
• Need to interpret requirements

Properly managing controls is dependent on the elimination of error precursors that challenge the integrity of controls and allow human error to become consequential.</td></tr>
</table>

Integrated Safety Management	**Human Performance Improvement Strategic Approach**	
ISM Core Functions	Reduce Human Error	Manage Controls
Analyze and Categorize the Hazards*[3] All types of hazards (e.g., nuclear, industrial, chemical) to workers, the public, and the environment. HPI tools that support this core function including job-site review, pre-job briefing, and questioning attitude. These tools can be used to identify hazards and unsafe conditions before starting a job.	When hazards are properly analyzed during the ISM cycle, the results can be used to analyze the work procedure for latent weaknesses and initiate procedure changes to eliminate those weaknesses. Similarly, robust hazards analysis should consider error precursors in the work place such as: Adverse environmental conditions Unclear roles/responsibilities Time pressures High workload Confusing displays or controls	Reducing latent weaknesses in the procedures strengthens the engineering and administrative controls that are an important cornerstone of the overall defense system. Strong administrative and cultural controls can withstand human error. Controls are weakened when conditions are present that provoke error. Eliminating error precursors at the job site (in the workplace) reduces the incidences of active errors.
Develop and Implement Hazard Controls HPI Principle 2, "Error-likely situations are predictable, manageable, and preventable," complements this ISM core function. Hazards are the markings for error-likely situations – a work situation in which there is greater opportunity for error when performing a specific action or task due to error traps. The recognition in HPI that error-likely situations can be managed and prevented supports the ISM core function that hazards are identifiable and controllable. HPI tools that support this core function are self-checking, peer check, procedure use and adherence.	The ISM core function, Implement Hazard Controls, improves conditions at the job-site. HPI describes the job site as the location where behavior occurs during task performance and is characterized by both environmental and individual factors. Environmental factors include conditions external to the individual and often beyond his or her direct control, such as procedure quality, component labeling, human-machine interface, heat, and humidity. Individual factors include conditions that are a function of the person assigned the task, such as knowledge, skills, experience, family problems, and color blindness.	Hazard controls initiated in the ISM framework are supplemental reinforcements to the engineered and administrative controls and barriers discussed in association with the HPI performance model (Chapter 3). Hazard controls not only help ensure worker and environmental safety, hazard controls also relieve workers from worry, stress, and anxiety when performing work in the face of known hazards. Such conditions provoke human error and mistakes. When hazard controls are in place, worker stress and anxiety drops, human performance improves, and human error decreases.

*[3] Hazards analysis in DOE is an iterative and multi-disciplined process that begins with gross analysis in the earlier stages of work planning and proceeds to ever more detail refinements that determine the controls to be used. Because the qualifications of work planners varies across DOE, hazards analysis for many work activities requires input of engineers, scientists, safety professional staff and work performers. This chart is merely illustrative of how HPI concepts and tools can add new dimensions to the execution of the ISM functions. For more information on Hazards Analysis, refer to 10CFR830 and DOE Order 414.1.

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<tr><td>Perform Work

The consistent and effective use of HPI error-reduction tools when performing work reduces the probability that an active error may cause an accident or serious event. Error-reduction tools include among others:
• Self-checking
• Questioning attitude
• Stop when unsure
• Effective communication
• Procedure use and adherence
• Peer-checking
• Second-person verifications
• Turnovers

Descriptions of these and other HPI tools are in Volume 2.</td><td>This ISM core function supports the third HPI Principle, “Individual behavior is influenced by organizational processes and values.” When operations authorization is performed correctly, it can be used as an independent verification of the work planning and control process for specific tasks. Management can use this verification process to ensure that the organizational processes and values are in place to adequately support performance at the job-site (i.e., the task and the individuals are properly aligned and supported to successfully complete the work).</td><td>The core value expectation that work can be performed safely is balanced by the first principle of HPI that states, “People are fallible, and even the best people make mistakes.” Because people err and make mistakes, it is all the more important that controls are implemented and properly maintained.</td></tr>
</table>

Integrated Safety Management	Human Performance Improvement Strategic Approach	
ISM Core Functions	Reduce Human Error	Manage Controls
Feedback and Improvement The post-job review supports this ISM core function. This HPI tool can help identify the adequacy of controls and point out opportunities for improving work planning and execution. Topics addressed during post-job reviews includes among others: • Surprises or unexpected outcomes. • Usability and quality of work documents • Knowledge and skill shortcomings • Minor errors during the activity • Unanticipated job-site conditions • Adequacy of tools and resources • Quality of work planning/scheduling • Adequacy of supervision Investigating Events Triggered by Human Error is an HPI tool used to find system problems. When a near miss or unwanted event occurs, focusing attention on problems beyond the individual – deeper within the system (e.g., engineering flaws, manufacturing flaws, weaknesses in work processes, ineffective tools, poor work conditions, training short-falls) helps identify latent or dormant organizational conditions, which, if left unresolved, can continue to provoke mishaps and occurrences.	The fifth principle of HPI is that *Events can be avoided through an understanding of the reasons mistakes occur and application of the lessons learned from past events (or errors)*. Even though errors during job performance are inevitable, they need not lead to events. Seeking to understand the reasons non-consequential errors occur can help strengthen controls and make future performance even better.	Line management and independent oversight are important controls that support “oversight control,” the fourth line of defense in the HPI defense hierarchy, as described in Chapter 3. Volume 2, section 3, of the HPI manual describes several management tools used to identify and eliminate organizational weaknesses that weaken controls.

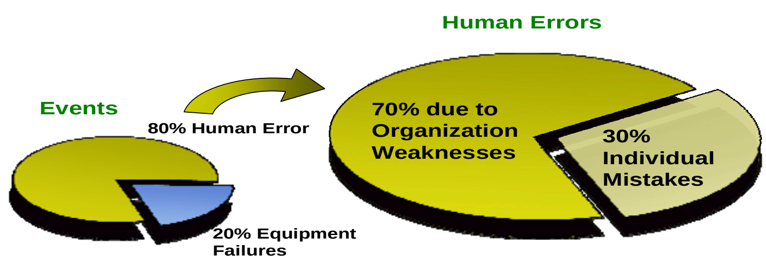
As illustrated in the table above, the integration of HPI methods and techniques to reduce error and manage controls supports the ISMS core functions.

The following leadership behaviors promoted in HPI (discussed in Chapter 4) support ISMS Guiding Principle 1—*line management responsibility for safety*.

- Facilitate open communication.
- Promote teamwork.
- Reinforce desired behaviors.
- Eliminate latent organizational weaknesses.
- Value prevention of errors.

Perspective on Human Performance and Events

The graphic below illustrates what is known about the role of human performance in causing events. About 80 percent of all events are attributed to human error. In some industries, this number is closer to 90 percent. Roughly 20 percent of events involve equipment failures. When the 80 percent human error is broken down further, it reveals that the majority of errors associated with events stem from latent organizational weaknesses (perpetrated by humans in the past that lie dormant in the system), whereas about 30 percent are caused by the individual worker touching the equipment and systems in the facility.[5] Clearly, focusing efforts on reducing human error will reduce the likelihood of events.



An analysis of significant events in the commercial nuclear power industry between 1995 and 1999 indicated that three of every four events were attributed to human error, as reported by INPO. Additionally, a Nuclear Regulatory Commission review of events in which fuel was damaged while in the reactor showed that human error was a common factor in 21 of 26 (81 percent) events. The report disclosed that *"the risk is in the people—the way they are trained, their level of professionalism and performance, and the way they are managed."*[6] Human error leading to adverse consequences can be very costly: it jeopardizes an organization's ability to protect its workforce, its physical facility, the public, and the environment from calamity. Human error also affects the economic bottom line. Very few organizations can sustain the costs associated with a major accident (such as, product, material and facility damage, tool and equipment damage, legal costs, emergency supplies, clearing the site, production delays, overtime work, investigation time, supervisors' time diverted, cost of panels of inquiry). It should be noted that costs to operations are also incurred from errors by those performing security, work control, cost and schedule, procurement, quality assurance, and other essential but non-safety-related tasks. Human performance remains a significant factor for management attention, not only from a safety perspective, but also from a financial one.[7]

A traditional belief is that human performance is a worker-focused phenomenon. This belief promotes the notion that failures are introduced to the system only through the inherent unreliability of people—*Once we can rid ourselves of a few bad performers, everything will be fine. There is nothing wrong with the system*. However, experience indicates that weaknesses in organizational processes and cultural values are involved in the majority of facility events. Accidents result from a combination of factors, many of which are beyond the control of the worker. Therefore, the organizational context of human performance is an important consideration. Event-free performance requires an integrated view of human performance from those who attempt to achieve it; that is, how well management, staff, supervision, and workers function as a team and the degree of alignment of processes and values in achieving the facility's economic and safety missions.

Human Performance for Engineers and Knowledge Workers

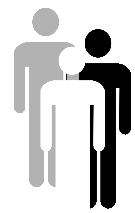
Engineers and other knowledge-based workers contribute differently than first-line workers to facility events. A recent study completed for the Nuclear Regulatory Commission (NRC) by the Idaho National Engineering and Environmental Laboratory (INEEL)[8] indicates that human error continues to be a causal factor in 79 percent of industry licensee events. Within those events, there were four latent failures (undetected conditions that did not achieve the desired end(s) for every active failure. More significantly, design and design change problems were a factor in 81 percent of the events involving human error. Recognizing that engineers and other knowledge-based workers make different errors, INPO developed a set of tools specific to their needs.[9] Many of these tools have been incorporated into DOE's *Human Performance Tools* manual.

With engineers, specifically, the errors made can become significant if not caught early. As noted in research conducted at one DOE site, because engineers as a group are highly educated, narrowly focused, and have personalities that tend to be introverted and task-oriented, they tend to be critical of others, but not self-critical.[10] If they are not self-critical, their errors may go undetected for long periods of time, sometimes years. This means that it is unlikely that the engineer who made the mistake would ever know that one had been made, and the opportunity for learning is diminished. Thus, human performance techniques aimed at this group of workers need to be more focused on the errors they make while in the knowledge-based performance mode as described in Chapter 2.

The Work Place

The work place or job site is any location where either the physical plant or the "paper" plant (the aggregate of all the documentation that helps control the configuration of the physical plant) can be changed. The systems, structures, and components used in the production processes make up the physical plant. Error can come from either the industrial plant or the paper plant. All human activity involves the risk of error. Flaws in the paper plant can lie dormant and can lead to undesirable outcomes in the physical plant or even personal injury. Front-line workers "touch" the physical plant as they perform their assigned tasks. Supervisors observe, direct, and coach workers. Engineers and other technical staff perform activities that alter the paper plant or modify processes and procedures that direct the activities of workers in the physical plant. Managers influence worker and staff behavior by their oral or written directives and personal example. The activities of all these individuals need to be controlled.

Individuals, Leaders, and Organizations



This handbook describes how individuals, leaders, and the organization as a whole influence human performance. The role of the individual in human performance is discussed in Chapter 2, “Reducing Error.” The role of the organization is discussed in Chapter 3, “Managing Controls.” The role of the leader, as well as the leader’s responsibilities for excellence in human performance, is discussed in Chapter 4, “Culture and Leadership”. The following provides a general description of each of theses entities:

- **Individual —** An employee in any position in the organization from yesterday’s new hire in the storeroom to the senior vice president in the corner office.

- **Leader —** Any individual who takes personal responsibility for his or her performance *and* the facility's performance *and* attempts to positively influence the processes and values of the organization. Managers and supervisors are in positions of responsibility and as such are organizational leaders. Some individuals in these positions, however, may not exhibit leadership behaviors that support this definition of a leader. Workers, although not in managerial positions of responsibility, can be and are very influential leaders. The designation as a leader is earned from subordinates, peers, and superiors.
- **Organization —** A group of people with a shared mission, resources, and plans to direct people's behavior toward safe and reliable operation. Organizations direct people's behavior in a predictable way, usually through processes and its value and belief systems. Workers, supervisors, support staff, managers, and executives all make up the organization.

HUMAN PERFORMANCE

What is human performance? Because most people cannot effectively manage what they do not understand, this question is a good place to start. Understanding the answer helps explain why improvement efforts focus not only on results, but also on behavior. Good results can be achieved with questionable behavior. In contrast, bad results can be produced despite compliant behavior, as in the case of following procedures written incorrectly. Very simply, human performance is behavior plus results (P = B + R). [11]

Behavior

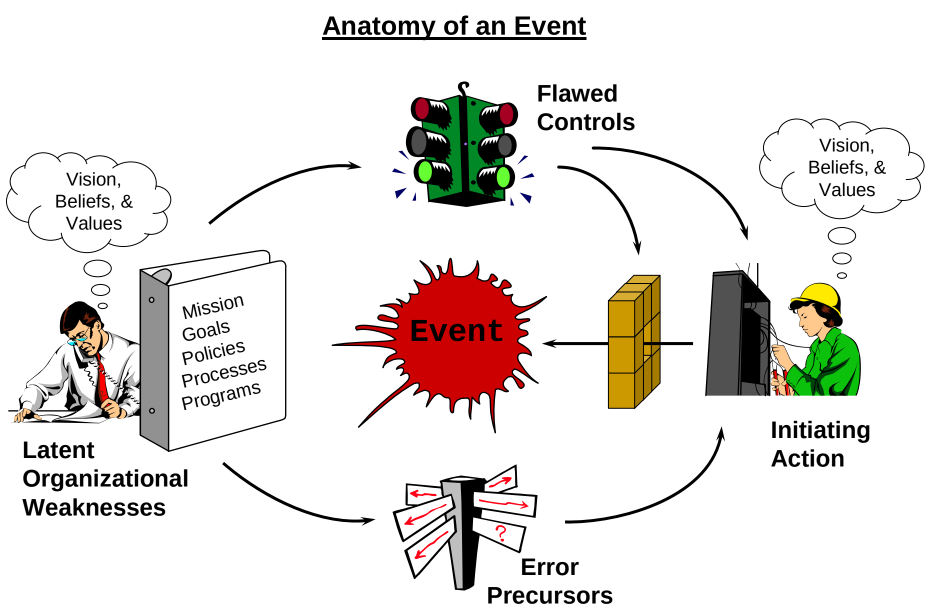
Behavior is what people do and say—a means to an end. Behavior is an observable act that can be seen and heard, and it can be measured. Consistent behavior is necessary for consistent results. For example, a youth baseball coach cannot just shout at a 10-year old pitcher from the dugout to "throw strikes." The child may not know how and will become frustrated. To be effective, the coach must teach specific techniques—behaviors—that will help the child throw strikes more consistently. This is followed up with effective coaching and positive reinforcement. Sometimes people will make errors despite their best efforts. Therefore, behavior and its causes are extremely valuable as the signal for improvement efforts to anticipate, prevent, catch, or recover from errors. For long-term, sustained good results, a close observation must be conducted of what influences behavior, what motivates it, what provokes it, what shapes it, what inhibits it, and what directs it, especially when handling facility equipment.

Results

Performance infers measurable results. Results, good or bad, are the outcomes of behavior encompassing the mental processes and physical efforts to perform a task.[12] Within DOE, the "end" is that set of outcomes manifested by people's health and well-being; the environment; the safe, reliable, and efficient production of defense products; the discovery of new scientific knowledge; the invention and testing of new products; and the disposition of legacy wastes and facilities. Events usually involve such things as challenges to reactor safety (where applicable), industrial/radiological safety, environmental safety, quality, reliability, and productivity. Event-free performance is the desired result, but is dependent on reducing error, both where people touch the facility and where they touch the paper (procedures, instructions, drawings, specifications, and the like). Event-free performance is also dependent on ensuring the integrity of controls, controls, barriers, and safeguards against the residual errors that still occur.

ANATOMY OF AN EVENT

Typically, events are triggered by human action. In most cases, the human action causing the event was in error. However, the action could have been directed by a procedure; or it could have resulted from a violation—a shortcut to get the job done. In any case, an act initiates the undesired consequences. The graphic below provides an illustration of the elements that exist before a typical event occurs. Breaking the linkages may prevent events.



Anatomy of an Event

Event

An event, as defined earlier, is an unwanted, undesirable change in the state of facility structures, systems, or components or human/organizational conditions (health, behavior, administrative controls, environment, etc.) that exceeds established significance criteria. Events involve serious degradation or termination of the equipment's ability to perform its required function. Other definitions include: an outcome that must be undone; any facility condition that does not achieve its goals; any undesirable consequence; and a difference between what is and what ought to be.

Initiating Action

The initiating action is an action by an individual, either correct, in error, or in violation, that results in a facility event.[13] An *error* is an action that unintentionally departs from an expected behavior. A *violation* is a deliberate, intentional act to evade a known policy or procedure requirement and that deviates from sanctioned organizational practices. Active errors are those errors that have immediate, observable, undesirable outcomes and can be either acts of commission or omission. The majority of initiating actions are active errors. Therefore, a strategic approach to preventing events should include the anticipation and prevention of active errors.

Flawed Controls

Flawed controls are defects that, under the right circumstances, may inhibit the ability of defensive measures to protect facility equipment or people against hazards or fail to prevent the occurrence of active errors. Controls or barriers are methods that:

- **protect** against various hazards (such as radiation, chemical, heat);
- mitigate the consequences of the hazard (for example, reduced operating safety margin, personal injury, equipment damage, environmental contamination, cost); and
- promote consistent behavior.

When an event occurs, there is either a flaw with existing controls or appropriate controls are not in place.

Error Precursors

Error precursors are unfavorable prior conditions at the job site that increase the probability for error during a specific action; that is, error-likely situations. An error-likely situation—an error about to happen—typically exists when the demands of the task exceed the capabilities of the individual or when work conditions aggravate the limitations of human nature.[14] Error-likely situations are also known as error traps.

Latent Organizational Weaknesses

Latent organizational weaknesses are hidden deficiencies in management control processes (for example, strategy, policies, work control, training, and resource allocation) or values (shared beliefs, attitudes, norms, and assumptions) that create work place conditions that can provoke errors (precursors) and degrade the integrity of controls (flawed controls).[15] Latent organizational weaknesses include system-level weaknesses that may exist in procedure development and review, engineering design and approval, procurement and product receipt inspection, training and qualification system(s), and so on. The decisions and activities of managers and supervisors determine what is done, how well it is done, and when it is done, either contributing to the health of the system(s) or further weakening its resistance to error and events. System-level weaknesses are aggregately referred to as latent organizational weaknesses. Consequently, managers and supervisors should perform their duties with the same uneasy respect for error-prone work environments as workers. A second strategic thrust to preventing events should be the identification and elimination of latent organizational weaknesses.

STRATEGIC APPROACH FOR HUMAN PERFORMANCE

The strategic approach to improving human performance within the DOE community embraces two primary challenges:

I. **Anticipate, prevent, catch, and recover from *active errors* at the job site.**

II. **Identify and eliminate *latent organizational weaknesses* that provoke human error and degrade controls against error and the consequences of error.**

If opportunities to err are not methodically identified, preventable errors will not be eliminated. Even if opportunities to err are systematically identified and prevented, people may still err in unanticipated and creative ways. Consequently, additional means are necessary to protect against errors that are not prevented or anticipated. Reducing the error rate minimizes the frequency, but not the severity of events. Only controls can be effective at reducing the severity of the outcome of error. Defense-in-depth—controls, or safeguards arranged in a layered fashion—provides assurance such that if one fails, remaining controls will function as needed to reduce the impact on the physical facility.

To improve human performance and facility performance, efforts should be made to (1) reduce the occurrence of errors at all levels of the organization and (2) enhance the integrity of controls, or safeguards discovered to be weak or missing. Reducing errors (Re) and managing controls (Mc) will lead to zero significant events (ØE). The formula for achieving this goal is **Re + Mc → ØE**. Eliminating significant facility events will result in performance improvement within the organization.

Reducing Error

An effective error-reduction strategy focuses on work execution because these occasions present workers with opportunities to harm key assets, reduce productivity, and adversely affect quality through human error. Work execution involves workers having direct contact with the facility, when they touch equipment and when knowledge workers touch the paper that influences the facility (procedures, instructions, drawings, specifications, etc.). During work execution, the human performance objective is to anticipate, prevent, or catch active errors, especially at critical steps, where error-free performance is absolutely necessary. While various work planning taxonomies may be used, opportunities for reducing error are particularly prevalent in what is herein expressed as preparation, performing and feedback.*[4]

- **Preparation** — *planning* – identifying the scope of work, associated hazards, and what is to be avoided, including critical steps; *job-site reviews* and *walkdowns* – identifying potential job-site challenges to error-free performance; *task assignment* – putting the right

*[4] For a detailed discussion of work planning considerations, readers should refer to a document published in January 2006 by the National Nuclear Security Administration (NNSA). That document is entitled "Activity Level Work Planning and Control Processes **:** Attributes, Best Practices, and Guidance for Effective Incorporation of Integrated Safety Management and Quality Assurance"**.**

people on the job in light of the job's task demands; and *task previews* and *pre-job briefings* – identifying the scope of work including critical steps, associated hazards, and what has to be avoided by anticipating possible active errors and their consequences.

- **Performance —** performing work with a sense of *uneasiness;* maintaining *situational awareness; rigorous use of human performance tools* for important human actions, avoiding unsafe or at-risk work practices; supported with quality *supervision* and *teamwork.*

- **Feedback —** *reporting* – conveying information on the quality of work preparation, related resources, and work place conditions to supervision and management; *behavior observations* – workers receiving coaching and reinforcement on their performance in the field through observations by managers and supervisors.

Chapter 2 focuses more on anticipating, preventing, and catching human error at the job-site.

Managing Controls

Events involve breaches in controls or safeguards. As mentioned earlier, errors still occur even when opportunities to err are systematically identified and eliminated. It is essential therefore that management take an aggressive approach to ensure controls function as intended. The top priority to ensure safety from human error is to identify, assess, and eliminate hazards in the workplace. These hazards are most often closely related to vulnerabilities with controls. They have to be found and corrected. The most important aspect of this strategy is an assertive and ongoing verification and validation of the health of controls. Ongoing self-assessments are employed to scrutinize controls, and then the vulnerabilities are mended using the corrective action program. A number of taxonomies of safety controls have been developed. For purposes of this discussion of the HPI strategic approach, four general types of controls are reviewed in brief.

- **Control of Hazards by elimination or substitution –** Organizations evaluate operations, procedures and facilities to identify workplace hazards. Management implements a hazard prevention and elimination process. When hazards are identified in the workplace they are prioritized and actions are taken based on risks to the workers. Management puts in place protective measures until such time as the hazard(s) can be eliminated. An assessment of the hazard control(s) is carried out to verify that the actions taken to eliminate the hazard are effective and enduring.*[5]

- **Engineered features—** These provide the facility with the physical ability to protect from errors. To optimize this set of controls , equipment is reliable and is kept in a configuration that is resistant to simple human error and allows systems and components

*[5] From the standpoint of worker safety, the following hierarchy of controls should govern: elimination or substitution of the hazards when feasible; engineering controls; work practices and administrative controls; and personnel protective equipment. Refer to 10 CFR Part 851 Federal Register, Worker Safety and Health Program**;** June 28, 2006

to perform their intended functions when required. Facilities with high equipment reliability, effective configuration control, and minimum human-machine vulnerabilities tend to experience fewer and less severe facility events than those that struggle with these issues. How carefully facility equipment is designed, operated, and maintained (using human-centered approaches) affects the level of integrity of this line of protection.

- **Administrative provisions—** Policies, procedures, training, work practices processes, administrative controls and expectations direct people's activities so that they are predictable and safe and limit their exposure to hazards, especially for work performed in and on the facility. All together such controls help people anticipate and prepare for problems. Written instructions specify what, when, where, and how work is to be done and what personal protective equipment workers are to use. The rigor with which people follow and perform work activities according to correctly written procedures, expectations, and standards directly affects the integrity of this line of protection.

- **Cultural norms —** These are the assumptions, values, beliefs, and attitudes and the related leadership practices that encourage either high standards of performance or mediocrity, open or closed communication, or high or low standards of performance. Personnel in highly reliable organizations practice error-prevention rigorously, regardless of their perception of a task's risk and simplicity, how routine it is, and how competent the performer. The integrity of this line of defense depends on people's appreciation of the human's role in safety, the respect they have for each other, and their pride in the organization and the facility.

- **Oversight —** Accountability for personnel and facility safety, for security, and for ethical behavior in all facets of facility operations, maintenance, and support activities is achieved by a kind of "social contract" entered into willingly by workers and management where a "just culture" prevails. In a just culture, people who make honest errors and mistakes are not blamed while those who willfully violate standards and expectations are censured. Workers willingly accept responsibility for the consequences of their actions, including the rewards or sanctions (see "accountability" in the glossary). They feel empowered to report errors and near misses. This accountability helps verify margins, the integrity of controls and processes, as well as the quality of performance. Performance improvement activities facilitate the accountability of line managers through structured and ongoing assessments of human performance, trending, field observations, and use of the corrective action program, among others. The integrity of this line of defense depends on management's commitment to high levels of human performance and consistent follow-through to correct problems and vulnerabilities.

Chapter 3 focuses on controls and their management. Chapter 4 emphasizes the role managers and informal leaders play in shaping safety culture.

PRINCIPLES OF HUMAN PERFORMANCE

Five simple statements, listed below, are referred to as the *principles* or underlying truths of human performance. Excellence in human performance can only be realized when individuals at all levels of the organization accept these principles and embrace concepts and practices that support them. These principles are the foundation blocks for the behaviors described and promoted in this handbook. Integrating these principles into management and leadership practices, worker practices, and the organization's processes and values will be instrumental in developing a working philosophy and implementing strategies for improving human performance within your organization.

1. **People are fallible, and even the best people make mistakes.**

   Error is universal. No one is immune regardless of age, experience, or educational level. The saying, "to err is human," is indeed a truism. It is human nature to be imprecise—to err. Consequently, error will happen. No amount of counseling, training, or motivation can alter a person's fallibility. Dr. James Reason, author of *Human Error* (1990) wrote: *It is crucial that personnel and particularly their managers become more aware of the human potential for errors, the task, workplace, and organizational factors that shape their likelihood and their consequences. Understanding how and why unsafe acts occur is the essential first step in effective error management.*

2. **Error-likely situations are predictable, manageable, and preventable.**

   Despite the inevitability of human error in general, specific errors are preventable.[16] Just as we can predict that a person writing a personal check at the beginning of a new year stands a good chance of writing the previous year on the check, a similar prediction can be made within the context of work at the job site. Recognizing error traps and actively communicating these hazards to others proactively manages situations and prevents the occurrence of error. By changing the work situation to prevent, remove, or minimize the presence of conditions that provoke error, task and individual factors at the job site can be managed to prevent, or at least minimize, the chance for error.

3. **Individual behavior is influenced by organizational processes and values.**

   Organizations are goal-directed and, as such, their processes and values are developed to direct the behavior of the individuals in the organization. The organization mirrors the sum of the ways work is divided into distinct jobs and then coordinated to conduct work and generate deliverables safely and reliably. Management is in the business of directing workers' behaviors. Historically, management of human performance has focused on the "individual error-prone or apathetic workers."[17] Work is achieved, however, within the context of the organizational processes, culture, and management planning and control systems. It is exactly these phenomena that contribute most of the causes of human performance problems and resulting facility events.[18]

4. **People achieve high levels of performance because of the encouragement and reinforcement received from leaders, peers, and subordinates.**

   The organization is perfectly tuned to get the performance it receives from the workforce. All human behavior, good and bad, is reinforced, whether by immediate consequences or by past experience. A behavior is reinforced by the consequences that an individual experiences when the behavior occurs.[19] The level of safety and reliability of a facility is directly dependent on the behavior of people. Further, human performance is a function of behavior. Because behavior is influenced by the consequences workers experience, what happens to workers when they exhibit certain behaviors is an important factor in improving human performance. Positive and immediate reinforcement for expected behaviors is ideal.

5. **Events can be avoided through an understanding of the reasons mistakes occur and application of the lessons learned from past events (or errors).**

   Traditionally, improvement in human performance has resulted from corrective actions derived from an analysis of facility events and problem reports—a method that reacts to what happened in the past. Learning from our mistakes and the mistakes of others is reactive—after the fact—but important for continuous improvement. Human performance improvement today requires a combination of both proactive and reactive approaches. Anticipating how an event or error can be prevented is proactive and is a more cost-effective means of preventing events and problems from developing.

REFERENCES

[1] Maurino, Reason, Johnston, and Lee. *Beyond Aviation Human Factors,* 1995, p. xi.

[2] Weick and Sutcliff. Managing the Unexpected: Assuring High Performance in an Age of Complexity, 2001, Chapter 1; Longman, "The Best Care Anywhere. Washington Monthly. Jan, 2005; Department of Veterans Affairs. Press Release, "VA Receives 2006 Innovations in Government Award" (July 10, 2006) Veterans Administration shown to reduce costs and errors while increasing safety and efficiency. National Energy Institute (NEI) www.nei.org/resources & statistics, reports the commercial nuclear power costs are down, while proficiency is improving and significant events are decreasing.

[3] Department of Energy 450.4-1, Integrated Safety Management Systems Manual, 2006, pp. 1-2

[4] Department of Energy. Policy DOE P 450.4 *Safety Management System Policy,*1996. pp. 1-2

[5] Perrow, Normal Accidents. Living with High-Risk Technologies, 1984, p. 183; Reason. Human Error. 1999, p.187.

[6] INPO 91-008. In-reactor Fuel Damaging Events.

[7] Four out of five petrochemical organizations that suffer a major disaster without recovery procedures never reopen for business. Reason. *Managing the Risks of Organizational Accidents,* 1998, p. 239.

[8] NUREG/CR-6753. Review of Findings for Human Error Contribution to Risk in Operating Events, 2001, p. xi.

[9] INPO 05-02 (Rev. 1). Human Performance Tools for Engineers and Knowledge Workers.

[10] Van Der Molen, Schmidt, and Kruisman. Personality Characteristics of Engineers. Journal of Engineering Education, October 2007, pp 495-50; William Rigot, WSRC. Engineering Mentoring Program at Savannah River site highlighted a statistically significant correlation between personality profiles and Engineering Human Performance. The DISC personality profile was administered to over 300 newly hired engineers and their mentors over a 6-year period to help them understand their own personalities and how they related with others. Approximately 70 percent of the sample population was in the 'introverted/compliant/analytical' quadrant. These people tend to see things as more black and white, and have poor communication skills. While they view the work of others very critically, they tend to be defensive of criticism of their own work.

[11] Gilbert. Human Competence, Engineering Worthy Performance, 1974, pp. 15-19.

[12] Reber. *Dictionary of Psychology,* 1995, 2nd ed., pp. 86-87.

[13] Senders and Moray. Human Error: Cause, Prediction, and Reduction, 1991, p. 20.

[14] Reason. Managing the Risks of Organizational Accidents, 1998, p. 142.

[15] Reason. Managing the Risks of Organizational Accidents, 1998, p. 10-18.

[16] Center for Chemical Process Safety. *Guidelines for Preventing Human Error in Process Safety,* American Institute of Chemical Engineers, 1994, pp.12-17, 103-107.

[17] Reason. Managing the Risks of Organizational Accidents, 1998, p.127.

[18] Demming. *Out of the Crisis,* 1986, p.315.

[19] Daniels. Bringing Out the Best in People, 1994, pp.8-9.

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CHAPTER 2 - REDUCING ERROR

INTRODUCTION

As capable and ingenious as humans are, we do err and make mistakes. It is precisely this part of human nature that we want to explore in the first part of this chapter. This inquiry includes discussions of human characteristics, unsafe attitudes, and at-risk behaviors that make people vulnerable to errors. A better understanding of what is behind the first principle of human performance, “people are fallible, even the best make mistakes,” will help us better compensate for human error through more rigorous use of error-reduction tools and by improving controls. Certain sections of this chapter are considered essential reading and will be flagged as such at the beginning of the section.

HUMAN FALLIBILITY (Essential Reading)

Human nature encompasses all the physical, biological, social, mental, and emotional characteristics that define human tendencies, abilities, and limitations. One of the innate characteristics of human nature is imprecision. Unlike a machine that is precise—each time, every time—people are imprecise, especially in certain situations. For instance, humans tend to perform poorly under high stress and time pressure. Because of “fallibility,” human beings are vulnerable to external conditions that cause them to exceed the limitations of human nature. Vulnerability to such conditions makes people susceptible to error. Susceptibility to error is augmented when people work within complex systems (hardware or administrative) that have concealed weaknesses—latent conditions that either provoke error or weaken controls against the consequences of error.

Common Traps of Human Nature

People tend to overestimate their ability to maintain control when they are doing work. Maintaining control means that everything happens that is supposed to happen during performance of a task and nothing else. There are two reasons for this overestimation of ability. First, consequential error is rare. Most of the time when errors occur, little or nothing happens. So, people reason that errors will be caught or won’t be consequential. Second, there is a general lack of appreciation of the limits of human capabilities. For instance, many people have learned to function on insufficient rest or to work in the presence of enormous distractions or wretched environmental conditions (extreme heat, cold, noise, vibration, and so on). These conditions become normalized and accepted by the individual. But, when the limits of human capabilities are exceeded (fatigue or loss of situational awareness, for example), the likelihood of error increases. The common characteristics of human nature addressed below are especially accentuated when work is performed in a complex work environment.

Stress. Stress in itself is not a bad thing. Some stress is normal and healthy. Stress may result in more focused attention, which in some situations could actually be beneficial to performance. The problem with stress is that it can accumulate and overpower a person, thus becoming detrimental to performance. Stress can be seen as the body’s mental and physical response to a perceived threat(s) in the environment. The important word is perceived; the perception one has about his or her ability to cope with the threat. Stress increases as familiarity with a situation decreases. It can result in panic, inhibiting the ability to effectively sense, perceive, recall, think, or act. Anxiety and fear usually follow when an individual feels unable to respond successfully. Along with anxiety and fear, memory lapses are among the first symptoms to appear. The inability to think critically or to perform physical acts with accuracy soon follows.

Avoidance of Mental Strain. Humans are reluctant to engage in lengthy concentrated thinking, as it requires high levels of attention for extended periods. Thinking is a slow, laborious process that requires great effort.[1] Consequently, people tend to look for familiar patterns and apply well-tried solutions to a problem. There is the temptation to settle for satisfactory solutions rather than continue seeking a better solution. The mental biases, or shortcuts, often used to reduce mental effort and expedite decision-making include:

- **Assumptions –** A condition taken for granted or accepted as true without verification of the facts.
- **Habit –** An unconscious pattern of behavior acquired through frequent repetition.
- **Confirmation bias –** The reluctance to abandon a current solution—to change one's mind—in light of conflicting information due to the investment of time and effort in the current solution. This bias orients the mind to "see" evidence that supports the original supposition and to ignore or rationalize away conflicting data.[2]
- **Similarity bias –** The tendency to recall solutions from situations that appear similar to those that have proved useful from past experience.
- **Frequency bias –** A gamble that a frequently used solution will work; giving greater weight to information that occurs more frequently or is more recent.
- **Availability bias –** The tendency to settle on solutions or courses of action that readily come to mind and appear satisfactory; more weight is placed on information that is available (even though it could be wrong).[3] [4] This is related to a tendency to assign a cause-effect relationship between two events because they occur almost at the same time.[5]

Limited Working Memory. The mind's short-term memory is the "workbench" for problem-solving and decision-making. This temporary, attention-demanding storeroom is used to remember new information and is actively involved during learning, storing, and recalling information.[6] Most people can reliably remember a limited number of items at a time often expressed as 7+1 or -2. The limitations of short-term memory are at the root of forgetfulness; forgetfulness leads to omissions when performing tasks. Applying place-keeping techniques while using complex procedures compensates for this human limitation.

Limited Attention Resources. The limited ability to concentrate on two or more activities challenges the ability to process information needed to solve problems. Studies have shown that the mind can concentrate on, at most, two or three things simultaneously.[7] Attention is a limited commodity—if it is strongly drawn to one particular thing it is necessarily withdrawn from other competing concerns. Humans can only attend to a very small proportion of the available sensory data. Also, preoccupation with some demanding sensory input or distraction by some current thoughts or worries can capture attention. Attention focus (concentration) is hard to sustain for extended periods of time. The ability to concentrate depends very much upon the intrinsic interest of the current object of attention.[8] Self-checking (Stop, Think, Act, Review) is an effective tool for helping individuals maintain attention.

Mind-Set. People tend to focus more on what they want to accomplish (a goal) and less on what needs to be avoided because human beings are primarily goal-oriented by nature. As such, people tend to "see" only what the mind expects, or wants, to see.[9] The human mind seeks order, and, once established, it ignores anything outside that mental model. Information that does not fit a mind-set may not be noticed; hence people tend to miss conditions and circumstances which are not expected. Likewise because they expect certain conditions and circumstances, they tend to see things that are not really present.[10] A focus on goal tends to conceal hazards, leading to inaccurate perception of risks. Errors, hazards, and consequences usually result from either incomplete information or assumptions. Pre-job briefings, if done mindfully, help people recognize what needs to be avoided as well as what needs to be accomplished.

Difficulty Seeing One's Own Error. Individuals, especially when working alone, are particularly susceptible to missing errors. People who are too close to a task, or are preoccupied with other things, may fail to detect abnormalities. People are encouraged to "focus on the task at hand." However, this is a two-edged sword. Because of our tendency for mind-set and our limited perspective, something may be missed. Peer-checking, as well as concurrent and independent verification techniques, help detect errors that an individual can miss. Engineers and some knowledge workers, by the nature of their focus on producing detailed information, can be especially susceptible to not being appropriately self-critical.

Limited Perspective. Humans cannot see all there is to see. The inability of the human mind to perceive all facts pertinent to a decision challenges problem-solving. This is similar to attempting to see all the objects in a locked room through the door's keyhole. It is technically known as "bounded rationality."[11] Only parts of a problem receive one's attention while other parts remain hidden to the individual. This limitation causes an inaccurate mental picture, or model, of a problem and leads to underestimating the risk.[12] A well-practiced problem-solving methodology is a key element to effective operating team performance during a facility abnormality and also for the management team during meetings to address the problems of operating and maintaining the facility.

Susceptibility To Emotional/Social Factors. Anger and embarrassment adversely influence team and individual performance. Problem-solving ability especially in a group may be weakened by these and other emotional obstacles. Pride, embarrassment, and the group may inhibit critical evaluation of proposed solutions, possibly resulting in team errors.

Fatigue. People get tired. In general, Americans are working longer hours now than a generation ago and are sleeping less. Physical, emotional, and mental fatigue can lead to error and poor judgment. Fatigue is affected by both on-the-job demands (production pressures, environment, and reduced staffing) and off-duty life style (diet and sleep habits).[13] Fatigue leads to impaired reasoning and decision-making, impaired vigilance and attention, slowed mental functioning and reaction time, loss of situational awareness, and adoption of shortcuts. Acquiring adequate rest is an important factor in reducing individual error rate.

Presenteeism. Some employees will be present in the need to belong to the workplace despite a diminished capacity to perform their jobs due to illness or injury. The tendency of people to continue working with minor health problems can be exacerbated by lack of sick leave, a backlog of work, or poor access to medical care, and can lead to employees working with significant impairments. Extreme cases can include individuals who fail to seek care for chronic and disabling physical and mental health problems in order to keep working.

Unsafe Attitudes and At-Risk Behaviors

An attitude is a state of mind, or feeling, toward an object or subject. Attitudes are influenced by many factors. They are formulated by one's experiences, by examples and guidance from others, through acquired beliefs and the like. Attitudes can develop as a result of educational experiences, and, in such cases, it can be said that attitudes may be chosen.[14] Attitudes can also be acculturated—formulated by one's experiences and influences from beliefs and behaviors within one's peer group. For example, the Mohawk Indians, often referred to as "skywalkers," are renowned for their extraordinary ability to walk high steel beams with balance and grace, seemingly without any fear. It is commonly thought that this absence of fear of height was inborn among the woodland Indians. It seems more likely that the trait was learned. [15]

Anyone can possess an unsafe attitude. Unsafe attitudes are derived from beliefs and assumptions about workplace hazards. Hazards are threats of harm. Harm includes physical damage to equipment, personal injury, and even simple human error. Unsafe attitudes blind people to the precursors to harm (exposure to danger). Notice that hazards are not confined to the industrial facility; they exist in the office facility as well. The unsafe attitudes that are described below are detrimental to excellent human performance and to the physical facility and are usually driven by one's perception of risk.

People in general are poor judges of risk and commonly underestimate it.

Examples of Risk Behaviors

- Before the Park Service made it unlawful to feed the bears at Yellowstone National Park, in the summer time a long line of automobiles would be stopped at the side the road where the bears foraged for food in garbage cans. Tourists eagerly fed the animals through open windows—a very risky business. Every day of the year in our larger cities, television news cameras chronicle tragedies that have resulted from someone taking undue risks: trying to beat the train at a railroad crossing; playing with a loaded firearm; swimming in dangerous waters; binge drinking following the "big game"; and the like.

Each individual "decides" what to be afraid of and how afraid he or she should be. People often think of risk in terms of probability, or likelihood, without adequately considering the possible consequences or severity of the outcome. For instance, a mountain climber presumes he will not slip or fall because most people don't slip and fall when they climb. The climber gives little thought to the consequences of a fall should one occur. (broken bones, immobility, unconsciousness, no quick emergency response) People take the following factors into consideration in varying degrees in assessing the risk of a situation.[16] People are less afraid of risks or situations:

- that they feel they have "control" over;

- that provide some benefit(s) they want;
- the more they know about and ”live” with the hazard
- that they choose to take rather than those imposed on them;
- that are “routine” in contrast to those that are new or novel;
- that come from people, places, or organizations they trust;
- when they are unaware of the hazard(s);
- that are natural versus those that are man-made; and
- that affect others.

It has been said that risk perception tends to be guided more by our heart than our head. What feels safe may, in fact, be dangerous. The following unsafe attitudes create danger in the work place. Awareness of these unsafe, detrimental attitudes among the workforce is a first step toward applying error-prevention methods.

- **Pride.** An excessively high opinion of one's ability; arrogance. Being self-focused, pride tends to blind us to the value of what others can provide, hindering teamwork. People with foolish pride think their competence is being called into question when they are corrected about not adhering to expectations. The issue is human fallibility, not their competence. This attitude is evident when someone responds, “Don't tell me what to do!” As commander of the U.N. forces in Korea in 1950, General Douglas MacArthur (contrary to the President’s strategy) sought to broaden the war against North Korea and China. President Truman and the Joint Chiefs were fearful that MacArthur’s strategy, in opposition to the administration’s “limited” war, could bring the Soviet Union into the war and lead to a possible third world war. In April 1951, Truman fired MacArthur for insubordination. At the Senate Foreign Relations and Armed Services committee hearing on MacArthur’s dismissal, the General would admit to no mistakes, no errors of judgment, and belittled the danger of a larger conflict.[17]

- **Heroic.** An exaggerated sense of courage and boldness, like that of General George Armstrong Custer. At Little Big Horn, he was so impetuous and eager for another victory that he ignored advice from his scouts and fellow officers and failed to wait for reinforcements that were forthcoming. He rode straight into battle against an overwhelming force—the Sioux and Cheyenne braves—and to his death with over 200 of his men.[18] Heroic reactions are usually impulsive. The thinking is that something has to be done fast or all is lost. This perspective is characterized by an extreme focus on the goal without consideration of the hazards to avoid.

- **Fatalistic**. A defeatist belief that all events are predetermined and inevitable and that nothing can be done to avert fate: “que será, será” (what will be will be) or “let the chips fall as they may.” The long drawn-out trench warfare that held millions of men on the battlefields of northern France in World War I caused excessive fatalistic responses among the ranks of soldiers on both sides of the fighting. "Week after week, month after month, year after year, the same failed offensive strategy prevailed. Attacking infantry forces always faced a protected enemy and devastating machine gun fire. Millions of men killed and wounded, yet the Generals persisted. The cycle continued—over the top, early success, then overwhelming losses and retreat."[19]

- **Invulnerability**. A sense of immunity to error, failure, or injury. Most people do not believe they will err in the next few moments: “That can’t happen to me.” Error is always a surprise when it happens. This is an outcome of the human limitation to accurately estimate risk. The failure to secure enough lifeboats for all passengers and to train the seamen how to launch them and load them ultimately resulted in the biggest maritime loss of civilian lives in history on the Titanic. Invulnerability was so ingrained in the minds of the ship owners about the ship being unsinkable that to supply the vessel with life boats for all passengers was foolhardy and would somehow leave the impression that the ship could sink. Hence, only half enough life boats were brought on board for the maiden voyage. When disaster struck, seaman struggled to launch the available craft. In the panic and confusion, numerous boats floated away from the mother ship only partially loaded.

- **Pollyanna – All is well.** People tend to presume that all is normal and perfect in their immediate surroundings[20] Humans seek order in their environment, not disorder. They tend to fill in gaps in perception and to see wholes instead of portions.[21] Consequently, people unconsciously believe that everything will go as planned. This is particularly true when people perform routine activities, unconsciously thinking nothing will go wrong. This belief is characterized with quotes such as “What can go wrong?” or “It's routine.” This attitude promotes an inaccurate perception of risk and can lead individuals to ignore unusual situations or hazards, potentially causing them to react either too late or not at all.[22]

- **Bald Tire**. A belief that past performance is justification for not changing (improving) existing practices or conditions: “I've got 60,000 miles on this set of tires and haven't had a flat yet.” A history of success can promote complacency and overconfidence. Evidence of this attitude is characterized with quotes such as, “We haven't had any problems in the past,” or “We've always done it this way.” Managers can be tempted to ignore recommendations for improvement if results have been good. What happened with the Columbia space shuttle is a good example. Over the course of 22 years, on every flight, some foam covering the outer skin of the external fuel tank fell away during launch and struck the shuttle. Foam strikes were normalized to the point where they were simply viewed as a “maintenance” issue—a concern that did not threaten a mission’s success. In 2003, even after it became clear from the launch videos that foam had struck the Orbiter in a manner never before seen, Space Shuttle Program managers were not unduly alarmed. They could not imagine why anyone would want a photo of something that could be fixed after landing. Learned attitudes about foam strikes diminished management’s wariness of their danger.[23]

At-risk behaviors are actions that involve shortcuts, violations of error-prevention expectations, or simple actions intended to improve efficient performance of a task, usually at some expense of safety. At-risk practices involve a move from safety toward danger. These acts have a higher probability, or potential, of a bad outcome. This does not mean such actions are “dangerous,” or that they should not ever be performed. However, the worker and management should be aware of at-risk practices that occur, under what circumstances, and on which systems. At-risk behavior usually involves taking the path of least effort and is rarely penalized with an event, a personal injury, or even correction from peers or a supervisor. Instead it is consistently reinforced with convenience, comfort, time savings, and, in rare cases, with fun.[24]

Examples of at-risk behaviors on the job

- hurrying through an activity;
- following procedures cookbook-style (blind or unthinking compliance);
- removing several danger tags quickly without annotating removal on the clearance sheet when removed;
- reading an unrelated document while controlling an unstable system in manual;
- having one person perform actions at critical steps without peer checking or performing concurrent verification;
- not following a procedure as required when a task is perceived to be “routine”;
- attempting to lift too much weight to reduce the number of trips;
- trying to listen to someone on the telephone and someone else standing nearby (multitasking);
- signing off several steps of a procedure before performing the actions; or
- working in an adverse physical environment without adequate protection (such as working on energized equipment near standing water—progress would be slowed to cleanup the water or to get a rubber floor mat).

Risky behaviors at DOE worksites have contributed to events, some causing injury and death, including:

- working on a hot electrical panel without wearing proper protective clothing;
- carrying heavy materials on an unstable surface while not using fall protection;
- failing to adhere to safety precautions when using a laser;
- operating a forklift in a reckless manner;
- opening a hazardous materials storage tank without knowing the contents; and
- failing to follow procedures for safeguarding sensitive technical information.

Persistent use of at-risk behaviors builds overconfidence and trust in personal skills and ability. This is a slippery slope, since people foolishly presume they will not err. Without correction, at-risk behaviors can become automatic (skill-based), such as rolling through stop signs at residential intersections. Over the long-term, people will begin to underestimate the risk of hazards and the possibility of error and will consider danger (or error) as more remote.[25] People will become so used to the practice that, under the right circumstances, an event occurs. Managers and supervisors must provide specific feedback when at-risk behavior is observed.

Workers are more likely to avoid at-risk behavior if they know it is unacceptable. Without correction, uneasiness toward equipment manipulations or intolerance of error traps will wane.

Slips, Lapses, Mistakes, Errors and Violations

Error. People do not err intentionally. Error is a human action that unintentionally departs from an expected behavior.[26] Error is behavior without malice or forethought; it is not a result. Human error is provoked by a mismatch between human limitations and environmental conditions at the job site, including inappropriate management and leadership practices and organizational weaknesses that set up the conditions for performance.

Slips occur when the physical action fails to achieve the immediate objective. Lapses involve a failure of one's memory or recall. Slips and lapses can be classified by type of behavior when it occurs with respect to physical manipulation of facility equipment.[27] The following categories describe how an incorrect or erroneous action can physically manifest itself or ways an action can go wrong:

- timing – too early, too late, omission;
- duration – too long, too short;
- sequence – reversal, repetition, intrusion;
- object – wrong action on correct object, correct action on wrong object;
- force – too little or too much force;
- direction – incorrect direction;
- speed – too fast or too slow; and
- distance – too far, too short.

Mistakes, by contrast, occur when a person uses an inadequate plan to achieve the intended outcome. Mistakes usually involve misinterpretations or lack of knowledge.[28]

Active Errors

Active errors are observable, physical actions that change equipment, system, or facility state, resulting in immediate undesired consequences.[29] The key characteristic that makes the error active is the immediate unfavorable result to facility equipment and/or personnel. Front-line workers commit most of the active errors because they touch equipment. Most errors are trivial in nature, resulting in little or no consequence, and may go unnoticed or are easily recovered from. However, grievous errors may result in loss of life, major personal injury, or severe consequences to the physical facility, such as equipment damage. Active errors spawn immediate, unwanted consequences.

Latent Errors

Latent errors result in hidden organization-related weaknesses or equipment flaws that lie dormant.[30] Such errors go unnoticed at the time they occur and have no immediate apparent outcome to the facility or to personnel. Latent conditions include actions, directives, and decisions that either create the preconditions for error or fail to prevent, catch, or mitigate the effects of error on the physical facility. Latent errors typically manifest themselves as degradations in defense mechanisms, such as weaknesses in processes, inefficiencies, and undesirable changes in values and practices. Latent conditions include design defects, manufacturing defects, maintenance failures, clumsy automation, defective tools, training shortcomings, and so on. Managers, supervisors, and technical staff, as well as front-line workers, are capable of creating latent conditions. Inaccuracies become embedded in paper-based directives, such as procedures, policies, drawings, and design bases documentation. Workers unknowingly alter the integrity of physical facility equipment, such as the installation of an incorrect gasket, mispositioning a valve, hanging a danger tag on the wrong component, or attaching an incorrect label.

Usually, there is no immediate feedback that an error has been made. Engineers have performed key calculations incorrectly that slipped past subsequent reviews, invalidating the design basis for safety-related equipment. Craft personnel have undermined equipment performance by installing a sealing mechanism incorrectly, which is not discovered until the equipment is called upon to perform its function. The table below summarizes the general characteristics of each kind of error.

	Active Errors	**Latent Errors**
Who?	Workers	Managers, engineers, workers, corporate and support staff
What?	Equipment	Paper, values, and beliefs
When?	Immediately	Later or delayed, dormant
Visible?	Yes	No

As one can see from the table, latent errors are more subtle and threatening than active errors, making the facility more vulnerable to events triggered by occasional active errors. A study, sponsored by the Nuclear Regulatory Commission (NRC), focused on the human contribution to 35 events that occurred over a 6-year period in the nuclear power industry.[31] Of the 270 errors identified in those events, 81 percent were latent, and 19 percent were active. The NRC study determined that design and design change errors and maintenance errors were the most significant contributors to latent conditions. The latent conditions or errors contributed most often to facility events and caused the greatest increases in risk.

Violations

Violations are characterized as the intentional (with forethought) circumvention of known rules or policy. A violation involves the *deliberate* deviation or departure from an expected behavior, policy, or procedure. Most violations are well intentioned, arising from a genuine desire to get a job done according to management's wishes.[32] Such actions may be either acts of omission (not doing something that should be done) or commission (doing something wrong). Usually adverse consequences are unintended—violations are rarely acts of sabotage. The deliberate decision to violate a rule is a motivational or cultural issue. The willingness to violate known rules is generally a function of the accepted practices and values of the immediate work group and its leadership, the individual's character, or both. In some cases, the individual achieved the desired results wanted by the manager while knowingly violating expectations. Workers, supervisors, managers, engineers, and even executives can be guilty of violations.

Violations are usually adopted for convenience, expedience, or comfort. Events become more likely when someone disregards a safety rule or expectation. A couple of strong situations that tempt a person to do something other than what is expected involve conflicts between goals or the outcome of a previous mistake. The individual typically underestimates the risk, unconsciously assuming he or she will not err, especially in the next few moments. People are generally overconfident about their ability to maintain control.

Examples: When People Commit Violations

Research has found that the following circumstances, in order of influence, prompt a person to violate expectations.[33]

- low potential for detection
- absence of authority in the immediate vicinity
- peer pressure by team or work group
- emulation of role models (according to the individual concerned)
- individual's perception that he or she possesses the authority to change the standard
- standard is unimportant to management
- unawareness of potential consequences; perceived low risk
- competition with other individuals or work groups
- interferences or obstacles to achieving the work goal
- conflicting demands or goals forcing the individual to make a choice
- precedent: “We've always done it this way” (tacitly acceptable to authority)

The discussion on violations intends to help clarify the differences between the willful, intentional decision to deviate associated with violations and the unintended deviation from expected behavior associated with error. This handbook focuses on managing human error.

Dependency and Team Errors

For controls to be reliable, they must be *independent*; that is, the failure of one does not lead to the failure of another. If the strength of one barrier can be unfavorably influenced by another barrier or condition, they are said to be *dependent*. Dependency increases the likelihood of human error due to the person's interaction or relationship with other seemingly independent defense mechanisms. For example, in the rail transportation industry, although a train engineer monitors railway signals during transit, automatic warning signals are built into the transportation system as a backup to the engineer. However, the engineer can become less vigilant by relying on an automatic warning signal to alert him/her to danger on the track ahead. What if the automatic signal fails as a result of improper maintenance intervals? Instead of one barrier left (an alert engineer), no barriers are left to detect a dangerous situation. There are three situations that can cause an unhealthy dependency, potentially defeating the integrity of overlapping controls:[34]

- **Equipment Dependencies –** Lack of vigilance due to the assumption that hardware controls or physical safety devices will always work.
- **Team Errors –** Lack of vigilance created by the social (interpersonal) interaction between two or more people working together.
- **Personal Dependencies –** Unsafe attitudes and traps of human nature leading to complacency and overconfidence.

Equipment Dependencies

When individuals believe that equipment is reliable, they may reduce their level of vigilance or even suspend monitoring of the equipment during operation. Automation, such as level and pressure controls, has the potential to produce such a dependency. Boring tasks and highly repetitive monitoring of equipment over long periods can degrade vigilance or even tempt a person to violate inspection requirements, possibly leading to the falsification of logs or related records. Monitoring tasks completed by a computer can also lead to complacency. In some cases, the worker becomes a "common mode failure" for otherwise independent facility systems, making the same error or assumption about all redundant trains of equipment or components.

Diminishing people's dependencies on equipment can be addressed by:

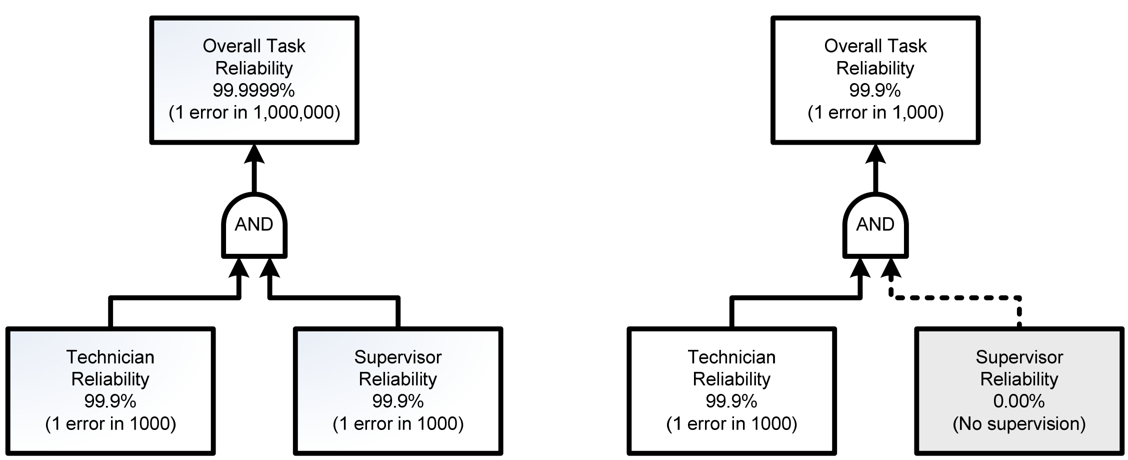
- applying forcing functions and interlocks;
- eliminating repetitive monitoring of equipment through design modifications;
- alerting personnel to the failure of warning systems;
- staggering work activities on redundant equipment at different times or assigning different persons to perform the same task;

- diversifying types of equipment or components, thereby forcing the use of different practices; for example, for turbine-driven and motor-driven pumps;
- training people on failure modes of automatic systems and how they are detected;
- informing people on equipment failure rates; and
- minimizing the complexity of procedures, tools, instrumentation, and controls.

Team Errors

Just because two or more people are performing a task does not ensure that it will be done correctly. Shortcomings in performance can be triggered by the social interaction between group members. In team situations, workers may not be fully attentive to the task or action because of the influence of coworkers. This condition may increase the likelihood of error in some situations. A *team error* is a breakdown of one or more members of a work group that allows other individual members of the same group to err—due to either a mistaken perception of another's abilities or a lack of accountability within the individual's group.

The logic diagram below illustrates the mathematical impact of such a dependency, using the example of a supervisor (or peer) checking the performance of a maintenance technician. Assuming complete independence between the technician and the supervisor, the overall likelihood for error is one in a million; the overall task reliability is 99.9999 percent. However, should the supervisor (or peer) assume the technician is competent for the task and does not closely check the technician's work, the overall likelihood for error increases to one in a thousand, the same likelihood as that for the technician alone. Overall task reliability is now 99.9 percent. [35] System reliability is only as good as the weakest link, especially when human beings become part of the system during work activities. The perception of another's capabilities influenced the supervisor's decision not to check the technician's performance—a team error.



Several socially related factors influence the interpersonal dynamics among individuals on a team. Because individuals are usually not held personally responsible for a group's performance, some individuals in a group may not actively participate. Some people refrain from becoming involved, believing that they can avoid answerability for their actions, or they "loaf" in group activities.[36] Team errors are stimulated by, but are not limited to, one or more of the following social situations.

- **Halo Effect –** Blind trust in the competence of specific individuals because of their experience or education. Consequently, other personnel drop their guard against error by the competent individual, and vigilance to check the respected person's actions weakens or ceases altogether. This dynamic is prevalent in hospital operating rooms, where members of the operating teams often fail to stay vigilant and check the procedures and actions in progress because a renowned surgeon is leading the team and there are several other sets of eyes on the task at hand. Each year it is estimated that there are between 44,000 and about 90,000 deaths attributable to medical errors in hospitals, alone.[37] Never mind the transfusions of mismatched blood plasma, amputations of the wrong limbs, administration of the wrong anesthesia, or issuance of the wrong prescriptions. It is the medical instruments, sponges, towels, and the like left in patients' bodies following surgery that are hard for laymen to understand.
- **Pilot/Co-Pilot –** Reluctance of a subordinate person (co-pilot) to challenge the opinions, decisions, or actions of a senior person (pilot) because of the person's position in a group or an organization. Subordinates may express "excessive professional courtesy" when interacting with senior managers, unwittingly accepting something the boss says without critically thinking about it or challenging the person's actions or conclusions.[38]

Example of Pilot/Co-Pilot Error

A classic example of this dynamic occurred between the pilot and co-pilot of Air Florida Flight 90 at Washington's National Airport in January 1982. The temperature was about 25 degrees. It had snowed hard for some time while the plane sat on the ground during airport closure because of weather. The aircraft had not properly been de-iced, and there was snow on the leading edges of the wings as the flight crew prepared for takeoff. During the after-start checklist procedure, the co-captain called out "engine anti-ice system." And the captain reported, "engine anti-ice system off," and then failed to turn it on. The system should have been on. Consequently, ice interfered with the engine pressure ratio (EPR) system, the primary indication of thrust being developed by the engines. The co-pilot called the captain's attention to the anomalous engine indications at least five times in the last moments before the plane rotated off the runway, but he did not oppose the captain's decision to continue takeoff. Given the engine indications, he should have insisted the takeoff be aborted. (All other engine parameters were later found to be well below limit values.) The pilot thought the EPR settings were at the indicated limits when he took off; in reality, the aircraft had only three-fourths of the necessary thrust in both engines. The plane failed to achieve adequate lift. It hit the 14th Street Bridge and plunged nose down into the freezing Potomac River, killing 74 of the 79 people on board.[39]

- **Free Riding –** The tendency to "tag along" without actively scrutinizing the intent and actions of the person(s) doing the work or taking the initiative. The other person takes initiative to perform the task, while the free-riding individual takes a passive role in the activity.

Example of Free Riding Error

The water flushing of compound salts inside the transfer piping at the fertilizer and pesticide plant in Bhopal, central India, was a routine task. The flushing operation was normally carried out under the direction of a shift maintenance supervisor. On December 2, 1984, the maintenance supervisor was called to another assignment, and the flush was carried out under the direction of the operations supervisor. A new compound, methyisocyanate (MIC), was used to produce the pesticide Sevin at the plant. MIC is unstable and highly reactive to water. The procedure to ensure isolation of water from a MIC tank during piping flushes was to close the valve to the tank, and then insert a slip blind (blank flange) into the piping to make sure that water did not leak through the valve and enter a MIC storage tank. During the investigation of the accident, an operator testified that he noticed the closed valve had not been sealed with a slip blind (metal disc), but he said, “It was not my job to do anything about it.”[40]

- **Groupthink** – Cohesiveness, loyalty, consensus, and commitment to the team are all worthy attributes of a team. However, at times, these characteristics can work against the quality of team decisions. There can be a reluctance to share contradictory information about a problem for the sake of maintaining the harmony of the work group. This is detrimental to critical problem-solving. This dynamic can be made worse by one or more dominant team members exerting considerable influence on the group's thinking (pilot/co-pilot or halo effect). Consequently, critical information known within the group may remain hidden from other team members. Groupthink can also result from subordinates passing on only “good news” or “sugar-coating” bad news so as to not displease their bosses or higher level managers. The symptoms of groupthink are as follows:

  - *Illusion of invulnerability – Creates excessive optimism and encourages extreme risk taking.*
  - *Collective rationalization* – Discounts warnings that might lead to reconsidering assumptions before recommitting to past decisions.
  - *Unquestioned morality* – Inclines members to ignore the ethical or moral consequences of decisions because of unquestioned belief in the group’s inherent morality.
  - *Stereotyped view* – Characterizes the opposition as too evil for genuine negotiation or too weak and stupid to effectively oppose the group’s purposes.
  - *Direct pressure* – Discourages dissent by any member who expresses strong arguments against any of the group’s stereotypes, illusions, or commitments that this type of dissent is contrary to what is expected of loyal members.
  - *Self-censorship* – Reduces deviations from the apparent group consensus reflecting each member’s inclination to minimize to himself the importance of his doubts and counter arguments.
  - *Illusion of unanimity* – Shared by members with respect to the majority view (partly resulting from self-censorship of deviations, augmented by a false assumption that silence means consent).
  - *Self appointed mind-guards* – Emerge from the members to protect the membership from adverse information that might shatter their shared complacency about the effectiveness and morality of their decisions.[41]

- **Diffusion of Responsibility** often causes a "risky shift" in decision-making and problem resolution. It involves the tendency to gamble with decisions more as a group than if each group member was making the decision individually[42]—responsibility is diffused in a group. As the saying goes, "there is safety in numbers." If two or more people agree together that they know a better way to do something, they will likely take the risk and disregard established procedure or policy. This has been referred to as a "herd mentality."

Example of Diffusion of Responsibility Error

At a DOE production facility in the late 1980s, a shift manager in the operating contractor organization, along with a small group of shift supervisors, planned and carried out the replacement of a faulty pump over a weekend. This undertaking was performed to support the startup of a system that had been shut down for an unusually long time. Operating within the work control system to get the job done had not been successful. Continued reliance on that system, the supervisory group reasoned, would not get a new pump in place, and the stream would continue to be unusable. Faced with pressures to meet a "startup" schedule, and frustrated with their inability to get work done through routine channels, the men took matters into their own hands and did the work themselves. In so doing, the team violated numerous procedures governing the work control system, in-process quality inspections, the worker certification program, and the union labor rules governing work assignments and responsibilities. No single salaried supervisor would have considered doing a union mechanic's job on his/her own. In a group situation, given the urgency, it seemed to make good sense. The outcome for these men included days off without pay and a demotion for the shift manager.[43]

The following strategies tend to reduce the occurrence of team errors.

- Maintain freedom of thought from other team members.
- Challenge actions and decisions of others to uncover underlying assumptions.
- Train people on team errors, their causes, and intervention methods.
- Participate in formal team-development training.
- Practice questioning attitude/situational awareness on the job and during training.
- Designate a devil's advocate for problem-solving situations.
- Call "timeouts" to help the team achieve a shared understanding of plant or product status.
- Perform a thorough and independent task preview before the pre-job briefing.

Personal Dependencies

An unsafe personal dependency exists when an individual relies on his or her personal experience, proficiency, or qualifications to maintain control. Because past practices have not led to a problem, the individual becomes indifferent toward the need for care and attention. Competence does not guarantee positive control. At the beginning of this chapter, "Traps of Human Nature" and "Unsafe Attitudes" were discussed regarding their impact on human fallibility. Such psychological and physiological factors can create unsafe personal dependencies and lead to error. Of particular concern is overconfidence in one's own ability at a critical step, inhibiting the rigorous use of human performance tools. Overcoming personal dependencies usually involves:

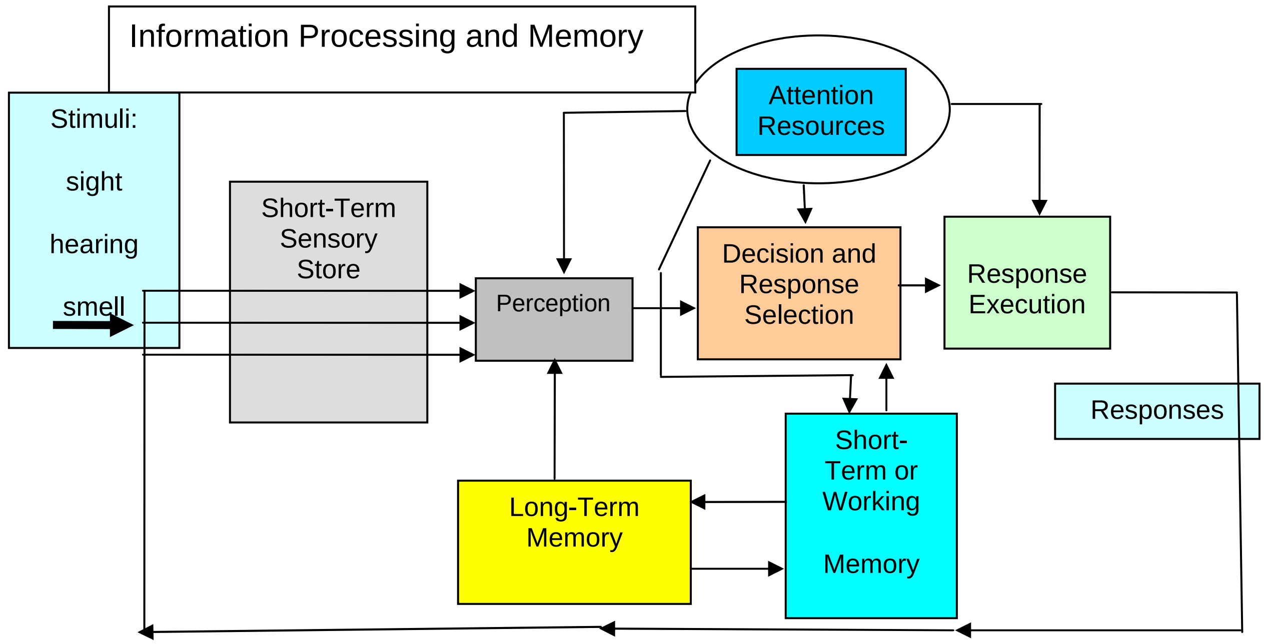
- training that addresses the limitations of human nature;
- promoting a culture that supports situational awareness and a questioning attitude;
- reinforcing and coaching the proper application of human performance tools during in-field observations; and
- improving the knowledge of risk-important equipment and critical steps.

PERFORMANCE MODES (Essential Reading)

Information Processing, Memory, and Attention

Cognition is the mental process of knowing. It is our mental activity encompassing perception, mental imagery, thinking, remembering, problem solving, decision-making, learning, language, and conscious direction of motor activities. Cognitive psychology is the study of how we process information from our environment; how we attend to, perceive, process, and store information; and how we retrieve and act on information from memory. To better anticipate and prevent error, we need to better understand how people process information. Psychologists have explained memory in terms of three basic components. Refer to the graphic below on information processing and memory:

- **Sensory Memory –** Each sensory system, (sight, touch, smell, taste, and hearing) has corresponding sensory memory, or sensory register, or store. Each sensory memory briefly stores and transforms the stimuli it receives into a form that can be processed by short-term memory. All incoming information is not processed. Information that is not "attended to" decays or is "overwritten" by new incoming stimuli.
- **Short-Term Memory –** Short-term memory (STM) receives, holds, and processes information from the sensory memory. Processing in STM is necessary before information can be transferred and retained in long-term memory. Short-term or "working" memory has limited storage capacity, as the name implies. Information entering short-term memory "decays" after about 12 to 30 seconds, unless it is "rehearsed" or otherwise consciously attended to and encoded for transfer into long-term memory. STM also retrieves information from long-term memory when needed.[44]



- **Long-Term Memory –** Long-term memory (LTM) receives information from short-term memory and stores it indefinitely. LTM capacity is considered unlimited for practical purposes. LTM holds all of the learning and memory of our life experience. Information that is stored in long-term memory is retrieved by short-term memory to support recall and recognition.

The shared **Attention Resources** depicted in the model by Wickens (see footnote 43), above, enables the mind to attend to information while performing one or more tasks (such as driving a car and talking with a passenger at the same time).[45] How much attention is required to perform satisfactorily defines the mental workload for an individual, as some tasks require more attention than others.[46] Knowledge, skill, and experience with a task decrease the demand for attention.

Humans control their actions through various combinations of two control modes—the conscious and the automatic. The conscious mode is restricted in capacity, slow, sequential, laborious, error-prone, but potentially very smart. This is the mode we use for 'paying attention' to something. It is needed for handling entirely novel problems, trained-for problems, or problems for which procedures have been written.

The automatic mode of control is the opposite in all respects. It is largely unconscious. The automatic mode is seemingly limitless in its capacity. It is very fast and operates in parallel; that is, it does many things at once rather than one thing after another. It is effortless and essential for handling the recurrences of everyday life—the highly familiar, everyday situations. But it is a highly specialized community of knowledge structures. It knows only what it knows; it is not a general problem-solver, like consciousness.[47]

We do not experience reality exactly as it exists, but as our experience and memories cause us to perceive it. Our sensory systems detect and take in stimuli from the environment in the form of physical energy. Each sensory receptor type is sensitive to only one form of energy. These receptors convert this energy into electrochemical energy that can be processed by the brain. However, our perception involves more than the receipt of sensory information. We must attend to, select, organize, and interpret this information to meaningfully recognize objects and events in our environment. Our interpretation of sensory information requires retrieval from long-term memory. Our prior experience and knowledge, emotional state, and value system (including prejudices) determine our perceptions.[48]

In summary, the information-processing model depicts sensory stimuli entering short-term sensory store, where they are transformed into a form that the perceptual processes within the brain can understand. Processed stimuli are transferred to working memory. Working memory draws upon and interacts with long-term memory to develop our perception of the world and to determine our response to these perceptions.[49] The retrieval and processing of long-term memories by STM enable us to function in the world.

Although the brain is designed for information transfer, sometimes it fails.[50] Error is a function of how the brain processes information related to the performance of an activity. When people err, there is typically a fault with one or more of the following stages of information processing.

- **Sensing –** Visual, audible, and other means to perceive information in one's immediate vicinity (displays, signals, spoken word, or cues from the immediate environment). Recognition of information is critical to error-free performance.
- **Thinking –** Mental activities involving decisions on what to do with information. This stage of information-processing involves interaction between one's working memory and long-term memory (capabilities, knowledge, experiences, opinions, attitudes).
- **Acting –** Physical human action (know-how) to change the state of a component using controls, tools, and computers; includes verbal statements to inform or direct others.[51]
- **Attention –** Determines what information is transmitted to the mind’s working (short-term) memory. The amount of stimuli that can be taken in by our sensory systems is considered to be unlimited. However, the amount of information that can be held in working memory is limited to 7 $\pm$ 2 items.[52] Working memory therefore, creates a “bottleneck” for incoming information. In a sense, it is a bottleneck with a purpose—otherwise we would be inundated with irrelevant stimuli.

Attention is also influenced by the following:

- **Expectancy –** We direct our sensory receptors—eyes, ears, nose, fingers to where we anticipate locating information within our environment. Surprise occurs when events differ from our expectations.
- **Relevance –** We seek information/stimuli relevant to our immediate tasks and our goals.[53]

Our attention constantly shifts as a result of voluntary direction (internal) or automatically as a result of attention attracting stimuli (external) in the environment. Our focus of attention results from whether a stimulus activates top-down (internal) or bottom-up (external) processes.

- **Top-Down –** Attention control is conscious direction, using information residing in memory stores. It is also termed concept-driven or effortful attention. Top-down attention is purposefully directed and is influenced by expectancy and relevance, as well as prior knowledge and experience. Examples are a search task, such as when looking for the face of a friend in the crowd, seeking a specific item on a control display, or conducting a parts inspection. Top-down attention is slower than bottom-up attention.

- **Bottom-Up –** Attention is captured by external stimuli, usually unexpected events or salience. This is also termed data-driven or automatic attention. Examples are a bright flash of light, a loud sound, loss of balance due to slippery conditions, or impact by an object. Bottom-up attention is very rapid, reaching its maximum 100-200 milliseconds after stimulus perception.[54]

Inattention to detail is an often-cited cause of human performance problems. Avoiding error is not as simple as telling someone to "pay attention." First of all, attention is a limited commodity; second, we can only attend to a very small proportion of the available sense data and; third, unrelated matters can capture our attention.[55] There are three attention modes. Attention can be focused, divided, or selective. If attention is focused, something has to be ignored. If attention is strongly drawn to one particular thing it is necessarily withdrawn from other competing concerns. *Divided attention* involves paying attention to two or more sources of information on a time-share basis, similar to using a flashlight in a dark room trying to see two different items, moving the flashlight back and forth. Divided attention can be dangerous; for example, a driver's attention is significantly distracted while using a cell phone.[56] *Selective attention* means an individual gives preference to distinct information, such as one's name in a noisy meeting room. It is impossible for humans to pay attention to everything all the time. This can lead to the occasional error.[57] The likelihood of error is enhanced when someone attempts to do more than one activity in one stage of information processing (sensing, thinking, acting), such as listening to the radio and a passenger simultaneously while driving an automobile. This is why it is so important to control the environment in which people work by minimizing interruptions and distractions or other stimuli that can negatively affect a performer's attention capabilities. Trained, experienced operators can consciously attend to a maximum of two or three channels of information (such as flow, temperature, pressure) and still be effective.[58] Beyond that, error is likely due to limited attention resources of human nature.

Jens Rasmussen developed a classification of the different types of information processing involved in industrial tasks. This influential classification system is known as the Skill, Rule, Knowledge based (SRK) approach (p. 22). Rasmussen's scheme suggests a useful framework for identifying the types of error likely to occur in different operational situations, or within different aspects of the same task where different types of information processing demands on the individual may occur. The terms *skill, rule,* and *knowledge* based information processing refer to the degree of conscious control exercised by the individual over his or her activities. Tasks individuals perform every day on the job vary from doing a lot and thinking a little to thinking a lot and doing a little. Depending on the situation, as perceived by the individual, he or she will conduct work according to the level of performance that seems adequate to control the situation. *The level of performance is a function of the familiarity an individual has with a specific task and the level of attention (information processing) a person applies to the activity.*

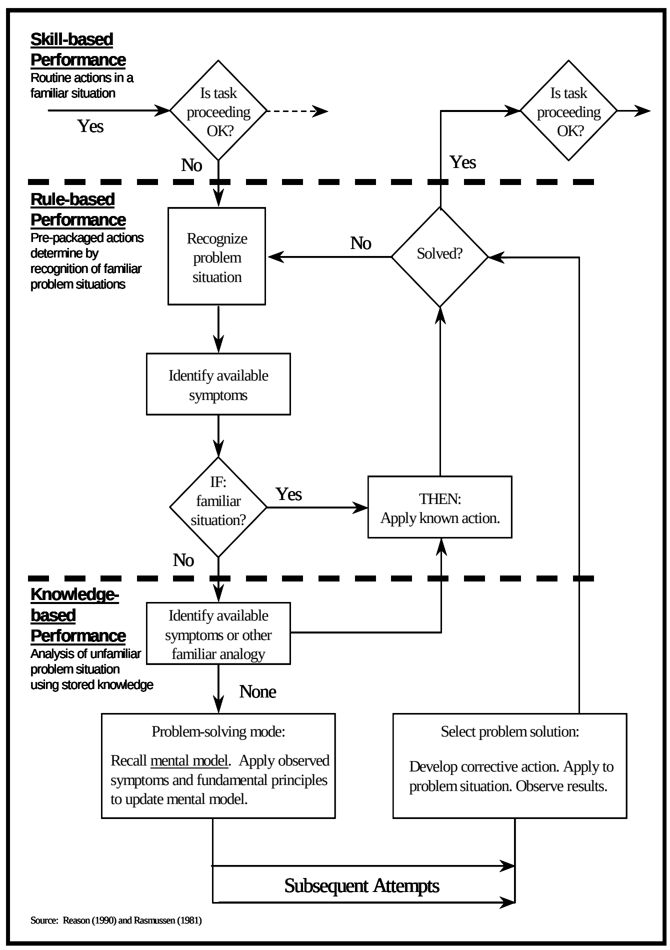
Example Uses of Performance Levels

The three performance levels can be readily applied to a familiar activity like driving an automobile. For an experienced driver, the control of speed and direction of the vehicle occur almost entirely at the skill-based level (an automatic mode of control). Things related to how the driver relates to other drivers on the road are covered by rules (speed limit, distance from other cars, right of way, etc.) of the kind if (situation X occurs) do—or don't do—(action Y). Here the driver is in a rule-based level of performance. While traveling at a good clip along a main highway, the driver hears on the radio that there is a traffic jam up ahead. To continue will result in long delays. So the driver has to use his/her knowledge of directions and road connections and accesses to find an alternative route. This problem-solving "mind-work"' occurs at the knowledge-based level (conscious mode) .[59]

Generic Error Model System (GEMS)

The GEMS model illustrates how humans make use of information processing for a particular task and how they move from one performance level to another as they complete a task. The flowchart illustrates the distinctions between the three levels of performance.[60] How GEMS is applied can be illustrated by an example.

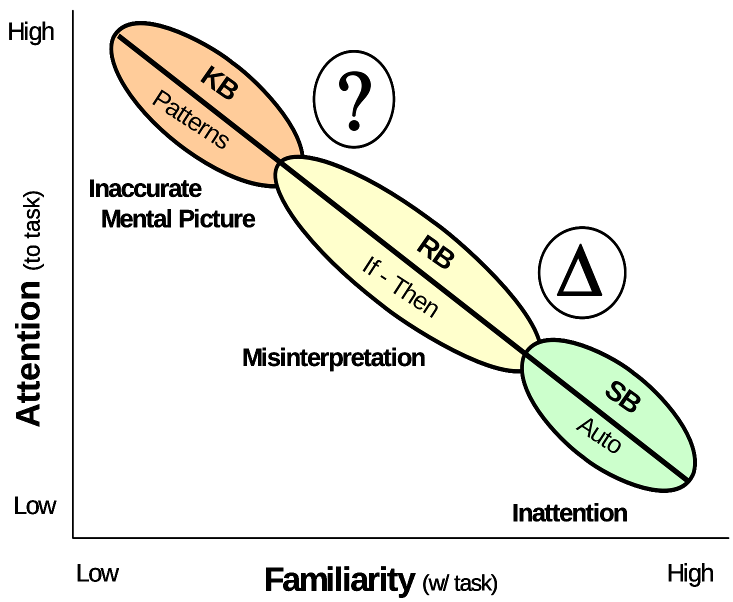
Example Application of GEMS



A process worker is monitoring a control panel in a batch processing plant. The worker executes a series of routine operations such as opening and closing valves and turning on agitators and heaters. Since the worker is highly practiced, he is carrying out the valve operations in an automatic skill-based manner, only occasionally monitoring the situation at the points indicated by the "OK?" boxes at the skill-based level. If one of these checks indicates that a problem has occurred, perhaps indicated by an alarm, the worker then enters the rule-based level to determine the nature of the problem. This may involve gathering information from various sources such as dials, chart recorders, and VDU screens, which is then used as input to a diagnostic rule of the following form: <IF> symptoms are X <THEN> cause of the problem is Y. Having established a plausible cause of the problem on the basis of the pattern of indications, an action rule may then be invoked of the following form: <IF> the cause of the problem is Y <THEN> do Z. If, as a result of applying the action rule, the problem is solved, the worker will then return to the original skill-based sequence. If the problem is not resolved, then further information may be gathered in order to try to identify a pattern of symptoms corresponding to a known cause. If the cause of the problem cannot be established by applying any available rule, the worker may then have to revert to the knowledge-based level. It may become necessary to utilize chemical or engineering knowledge to handle the situation.[61]

As shown in the above example, uncertainty declines as knowledge about a situation improves (learning and practice). Consequently, familiarity (knowledge, skill, and experience) with a task will establish the level of attention or mental functions the individual chooses to perform an activity. As uncertainty increases, people tend to focus their attention to better detect critical information needed for the situation. People want to boost their understanding of a situation in order to respond correctly.[62]

Skill-Based Performance



Skill-based performance involves highly practiced, largely physical actions in very familiar situations in which there is little conscious monitoring. Such actions are usually executed from memory without significant conscious thought or attention (see illustration). Behavior is governed by preprogrammed instructions developed by either training or experience and is less dependent upon external conditions.[63] Information that can be processed with little or no allocation of attention resources is called automatic processing. When skills are learned to the point of being automatic, the load on working memory typically is reduced by 90 percent.[64] This occurs after extensive practice of a task so that, literally, it can be performed "without thought." Many actions in a typical day are controlled unconsciously by human instinct, such as keyboarding, writing one's signature, taking a shower, driving a car. In the skill-based mode, the individual is able to function very effectively by using pre-programmed sequences of behavior that do not require much conscious control. It is only occasionally necessary to check on progress at particular points when operating in this mode.[65]

Examples of Skill-Based Activities

Examples of skill-based activities for well-trained and practiced individuals include:

- mowing the lawn;
- using a hammer or other hand tool;
- controlling various processes manually (such as pressure and level),
- hanging a tag;
- analyzing chemical composition of a routine sample;
- performing repetitive calculations;
- using measure and test equipment;
- opening a valve;
- taking logs; and
- replacing parts during maintenance.

Error Modes are the prevalent ways, not the only ways, people err for the particular performance mode. Error modes are generalities that aid in anticipating and managing error-likely situations aggravated by inattention, misinterpretation, and inaccurate mental models.

Skill-Based Error Mode – Inattention

The error mode for skill-based performance is *inattention.* Skill-based errors are primarily execution errors, involving action slips and lapses in attention or concentration. Errors involve inadvertent slips and unintentional omissions triggered by simple human variability or by not recognizing changes (note the Δ symbol on the above chart) in task requirements, system response, or facility conditions related to the task. Some examples of errors committed while in the skill-based performance level follow.

- When addressing an envelope, he put his old address in the return box instead of his new (correct) address.
- She forgot to drop off shoes at the shoe shop to be repaired, and instead drove right past the shoe shop and straight to her home.
- An electrician had been asked to change a light bulb that indicated whether a hydraulic on/off switch was selected. The hydraulic system was being worked on, and the electrician was aware that it would be unsafe to activate the system. Nevertheless, after changing the bulb, and before he had realized what he was doing, he had followed his usual routine and pushed the switch to the ”on” position to test whether the light was now working.
- Intending to shut down lines A and B, the operator also pressed the “shut-off’“ control buttons for lines C and D.

Under ideal conditions, the chance for error is less than 1 in 10,000, according to a study in the nuclear power industry.[66] People most often possess an accurate understanding of the task and have correct intentions. Roughly 90 percent of a person's daily activities are spent in the skill-based performance mode.[67] However, only 25 percent of all errors are attributable to skill-based errors in the nuclear power industry.[68] Potentially, a person can be so focused on a skill-based task that important information in the work place is not detected.[69] Another concern for skill-based tasks is that people *are* familiar with the task. The greater the familiarity, the less likely perceived risk will match actual risk. People become comfortable with risk and eventually grow insensitive to hazards.[70] Several tools in the HPI Handbook volume 2 are designed to help anticipate, prevent or catch skill-based errors (task preview, job-site review, questioning attitude, stop when unsure, self-checking, pre-job briefing, place-keeping, peer check and concurrent verification)*[6].

Rule-Based Performance

People switch to the rule-based performance level when they notice a need to modify their largely pre-programmed behavior because they have to take account of some change in the situation. The work situation has changed such that the previous activity (skill) no longer applies. This problem is likely to be one that they have encountered before, or have been trained to deal with, or which is covered by the procedures. It is called the rule-based level because people apply memorized or written rules. These rules may have been learned as a result of interaction with the facility, through formal training, or by working with experienced workers. The level of conscious control is between that of the knowledge- and skill-based modes. The rule-based level follows an *IF* (symptom X), *THEN* (situation Y) logic. In applying these rules, we operate by automatically matching the signs and symptoms of the problem to some stored knowledge structure. So, typically, when the appropriate rule is applied, the worker exhibits pre-packaged units of behavior. He/she may then use conscious thinking to verify whether or not this solution is appropriate.[71]

The goal in rule-based performance is to improve one's interpretation of the work situation so that the appropriate response is selected and used.[72] This is why procedures are prepared for situations that can be anticipated. Procedures are pre-determined solutions to possible work situations that require specific responses. Rules are necessary for those less familiar, less practiced work activities for which a particular person or group is not highly skilled. Not all activities guided by a procedure are necessarily rule-based performance. In normal work situations, such activities are commonly skill-based for the experienced user.

Examples of Rule-Based Activities

Examples of rule-based activities include:

- deciding whether to replace a ball bearing inspected during preventive maintenance;
- responding to a control board alarm;

*[6] The primary tool suggested for skill based work is self check.

- estimating the change in tank level based on a temperature change (thumb rules);
- feeling equipment for excessive vibration or temperature on operator rounds;
- performing radiological surveys;
- using emergency operating procedures; and
- developing work packages and procedures.

Rule-Based Error Mode

Since rule-based activities require interpretation using an if-then logic, the prevalent error mode is *misinterpretation.* People may not fully understand or detect the equipment or facility conditions calling for a particular response. Errors involve deviating from an approved procedure, applying the wrong response to a work situation, or applying the correct procedure to the wrong situation.[73] Examples of errors committed when working in the rule based performance level include the following.

- A driver was about to pull out into the traffic flow following a stop at the side of the road. He checked the side-view mirror and saw a small green car approaching. He briefly checked his rear-view mirror (which generally gives a more realistic impression of distance) and noted a small green car some distance away. He then pulled out from the shoulder of the road and was nearly hit by a small green car. There were two of them, one behind the other. The driver assumed they were one and the same car. The first car had been positioned so that it was only visible in the side-view mirror.
- The technician knew that normal tire pressures in automobile tires is 32-35 psi. So, when he was required for the first time to air up a smaller, temporary-use automobile tire, he filled the tire to the customary 35 lbs. In actuality, small-diameter, temporary-use tires are aired up to 55-60 psi.
- A northbound commuter train in London in 1988 ran into the back of a stationary train after having passed a green signal. Thirty-five people died and 500 were injured. The signal light had given the wrong signal because the old signal wires had come into contact with nearby equipment for the new signal system that caused a wrong-side signal failure. The light should have shown red, for stop. The electrician who had wired the signal on the new system just the day before the accident had never been properly trained. He failed to cut off or tie back, and then insulate, old wires as he wired in the new signal system. He merely bent old wires back out of the way. The untrained technician had learned bad habits on his own that became his "strong but wrong rules." His application of a bad rule went uncorrected. [74]

The chance for error increases when people make choices or decisions, especially in the field. Rule-based and knowledge-based performance modes involve making choices. With less familiarity for the activity, the chance for error increases to roughly 1 in 1,000.[75] In terms of reliability, this is still very good (99.9 percent). In the nuclear power industry, studies have shown that roughly 60 percent of all errors are rule-based.[76] HPI Handbook volume 2 includes tools to help anticipate, prevent or catch rule-based errors. They include for example: task preview, procedure adherence, pre-job briefing, questioning attitude, peer-checking and concurrent verification among others.*[7]

Knowledge-Based Performance

Warning; the terminology of knowledge-based performance can be confusing! It is tempting to think that much of the engineering design work and the scientific investigations and research at DOE laboratories falls in the knowledge based category – simply because such work is performed by highly knowledgeable people. We must however at all costs avoid the temptation to shrug off the essential nuances and simply argue that since we do research or one of a kind work, and our people are highly educated and skilled, then our work is knowledge based. The truth is quite the opposite. The situation described as "knowledge based mode" might better be called "lack of knowledge" mode.

Knowledge based work, as defined by Rasmussen, generally means that we don't really understand what we are doing. Clearly, that is not the case with most DOE work. Even in the most cutting edge science, the ability to develop and conduct controlled experiments depends on control; keeping the uncontrolled variables as few as possible so that we may observe the results of the experiment in order to hypothesize, test theories and ultimately develop new knowledge. It in fact might be argued that the accomplished researcher has highly refined abilities to work in skill and rule modes in order to be able to work in knowledge mode, since working in knowledge mode is so difficult.

Not all hazards, dangers, and possible scenarios can be anticipated in order to develop appropriate procedures. Even training is unable to anticipate all possible situations that can be encountered. There are some situations in which no procedure guidance exists and no skill applies. Dr. James Reason concludes that the knowledge-based level of performance is something we come to very reluctantly. Humans only resort to the slow and effortful business of thinking things through on the spot after they have repeatedly failed to find some pre-existing solution.

Hence, knowledge-based behavior is *a response to a totally unfamiliar situation* (no skill or rule is recognizable to the individual The person must rely on his or her prior understanding and knowledge, their perceptions of present circumstances, similarities of the present situation and similarities to circumstances encountered before , and the scientific principles and fundamental theory related to the perceived situation at hand.[77] People enter a knowledge-based situation when they realize they are uncertain (see the **?** symbol on previous chart) about what to do. If uncertainty is high, then the need for information becomes paramount.[78] To effectively gain information about what we are doing or about to do, our attention *must* become more focused.[79]

Knowledge-based situations are puzzling and unusual to the individual. Often our understanding of the problem is patchy, inaccurate, or both. In many cases, information sources contain conflicting data, too much data, or not enough data, amplifying the difficulty of problem-solving. Additionally, consciousness is very limited in its capacity to hold information, storing no more

*[7] The primary tools suggested for rule based work are procedure use and adherence.

than two or three distinct items at a time. Consciousness tends to behave like a leaky sieve, allowing things to be lost as we turn our attention from one aspect of the problem to another.[80] Because uncertainty is high, knowledge-based tasks are usually stressful situations.

Examples of Knowledge-Based Activities

Knowledge-based activities involve problem-solving. Such situations require the use of fundamental knowledge of processes, systems, and so on—"thinking on your feet." Examples of common problem-solving situations include the following:

- troubleshooting;
- performing an engineering evaluation of a new design;
- reviewing a procedure for 'intent of change;'
- resolving conflicting control board indications;
- holding meetings to address problems;
- conducting scientific experiments;
- resolving human performance problems;
- planning business strategies, goals, and objectives;
- performing root cause analysis of events;
- conducting trend analyses;
- designing equipment modifications;
- making budget allocation decisions
- allocating resources;
- changing policies and expectations; and
- performing an engineering calculation.

Knowledge-Based Error Mode

Knowledge-based activities require diagnosis and problem-solving. There are considerable demands on the information-processing capabilities of the individual that are necessary when a situation has to be evaluated from first principles. It is not surprising that humans do not perform very well in high stress, unfamiliar situations where they are required to 'think on their feet' in the absence of rules, routines, and procedures to handle the situation.[81] People tend to use only information that is readily available to evaluate the situation. Also, problem solvers often become over-confident in the correctness of their knowledge; an "I know I'm right" effect. They also become enmeshed in one aspect of the problem to the exclusion of all other considerations.[82] Decision-making is erroneous if problem-solving is based on inaccurate information. Often, decisions are made with limited information and faulty assumptions. Consequently, the prevalent error mode is an *inaccurate mental model* of the system, process, or facility status. Under such circumstances, the chance for error is particularly high, approximately one in two (50 percent) to one in ten.[83] In the nuclear power industry, studies indicate that roughly 15 percent of all errors are knowledge-based.[84] HPI Handbook volume 2 provides several tools to help anticipate, prevent, or catch knowledge-based errors. They include, for example, technical task pre-job briefing; project planning; problem-solving; decision-making; and peer review.

How Performance Modes Can be Used

A better contextual understanding of individuals' conscious and automatic behaviors as described in the skill, rule, and knowledge performance modes, and knowing the kinds of errors individuals tend to make while working in those various modes, can be extremely useful. Managers responsible for establishing and maintaining effective controls can make good use of this information. Workers need accurate, complete, and unambiguous procedures and guides for reference when doing rule-based work. They may also need access to a subject matter expert when making choices about the rules to select and for correct application of those rules. Workers performing skill-based work need adequate tools to minimize action slips, and they need to be free from interruptions and distractions that aggravate concentration, divide their attention, and contribute to lapses in memory that cause error. When working in skill-based performance mode, workers may benefit from simple job aids and reminders. On the other hand, for individuals working in the knowledge-based mode, where their understanding of the problem is often patchy, or inaccurate, or both, and where the slow and effortful business of thinking things through is needed, collaboration with a small team of thoughtful, committed, and experienced individuals is needed to help in problem-solving and decision-making. Individuals performing work in any of the performance modes can benefit from the use of the error-reduction tools addressed later in this chapter.

When errors and mistakes of consequence occur that indicate some corrective action is needed to minimize recurrence, knowing the work processing method or performance mode the individual was working in is instructive. All too often, workers involved in skill-based performance who err are scheduled for retraining as a logical solution. But, retraining workers to do work that is already basically memorized and automatic, performed with little conscious thought because of the nature of the work, is a waste of time and is an insult to the worker. *It is very hard to train a worker not to repeat something he or she did not intend to do in the first place.* Training is not the solution in these instances. Observations of work can be very beneficial. People don't always know why something went wrong.

Observations are used to gather data about the worker behaviors, the job-site conditions, and organizational support that may have been wanting. Inadequate tools, incomplete work packages, scheduling conflicts, poorly written procedures, excessive noise, extreme heat or cold, poor lighting, and so on, may be contributing factors to poor performance. Some one-on-one time with the individual may be in order. The purpose is to learn of the circumstances surrounding the slip, trip, or lapse and what, if anything, can be changed in the work environment or with the individual to eliminate a similar reoccurrence. The error may have been provoked by fatigue and stress; the worker may have lost sleep worrying about a teenager who left home. It may be that the worker has become complacent and was careless. Distractions and interruptions may have disrupted the worker's concentration and that led to the error. Those conditions can be controlled.

Errors that occur when working in rule-based performance may be corrected through retraining. Generally, the worker has misinterpreted a requirement or a "rule." He or she has applied a bad rule to a given application; or, conversely, has used a good rule in a wrong application. In these instances, understanding requirements and knowing where and under what circumstance those requirements apply is cognitive in nature and must be learned or acquired in some way. Rule-based errors can be caught or mitigated by individuals exhibiting a questioning attitude, by calling a time out, or by stopping work when they are unsure. Peer checks can also be used to stop someone from committing a consequential error.

Corrective action to reduce knowledge-based mistakes is more complicated. An analysis of what went wrong will need to be carried out to formulate a corrective action. It may be that the person's understanding and knowledge of the system and the scientific principles and fundamental theory related to the system were inadequate. Training or retraining could help. It may be that people's technical knowledge was adequate, but that the three individuals working on the problem lacked problem-solving skills, fell victim to team errors, or failed to effectively communicate with each other in order to solve the problem. Perhaps the team could not make good decisions in an emergency. Coaching is a pro-active solution to helping individuals eliminate error when working in any performance mode, but is particularly adept for knowledge-based performance modes. Peer-evaluations are also effective in this instance.

Mental Models

A person handles a complex situation by simplifying the real system into a mental image he/she can remember (such as a simple one-line drawing). A mental model is the structured understanding of knowledge (facts or assumptions) a person has in his or her mind about how something works or operates (for example, facility systems).[85,86] Mental models are used in all performance modes. In fact, mental models give humans the ability to detect skill-based slips and lapses. They aid in detecting deviations between desired and undesired system states, such as manually controlling tank water level.[87] A mental model organizes knowledge about the following.

- what a system contains
- why it works that way
- fundamental laws of nature
- how components work as a system
- current state of a system

An individual's mental model may reflect (1) the true state of the system, (2) a perceived state of the system, or (3) the expected state of the system that is developed through training and experience with the system and recent interactions with the system. Note that all mental models are inaccurate to some extent[88] because of the limitations of human nature.

It is important to remember that knowledge-based performance involves problem-solving, and mental models should be considered explicitly when a team works on a problem.[89] Team members should agree with the model they intend to use to diagnose and solve a problem. Otherwise, misunderstandings and assumptions may occur. Frequent time-outs can help teams keep mental models up to date.

Assumptions

Knowledge-based situations can be stressful, anxious situations. Assumptions reduce the strain on the mind, allowing a person to think without excessive effort. Assumptions are necessary at times to help constrain a problem. Consequently, assumptions tend to occur more often when people experience uncertainty, leading to trial-and-error and cause-and-effect problem-solving approaches. Assumptions also occur as an outgrowth of unsafe attitudes and inaccurate mental models. Statements such as “I think ...,” “We've always …,” or “I believe ...” are hints that an assumption has been or is being made. These phrases are known as “danger words.” Inaccurate mental models, in turn, can promote erroneous assumptions that may lead to errors.

Often, assumptions are treated as fact. Challenging assumptions is important in improving mental models, solving problems, and optimizing team performance. Assigning a devil’s advocate in a critical problem-solving situation may be worthwhile to achieve a better solution. Also, challenging assumptions helps detect unsafe attitudes and inaccurate mental models. A devil’s advocate can challenge assumptions using the following process.[90]

- Identify *conclusion*(s) being made by another person or yourself.
- Ask for or identify the *data* that leads to the conclusion(s). “How did you get that data?” “What is the source of your concern?”
- Ask for the *reasoning* (mental model) that connects the data with the conclusion. “Do you mean…?” “Why do you feel that way?”
- Infer possible beliefs or *assumptions*.
- Test the assumption with the other person. “What I hear you saying is…”

Mental Biases – Shortcuts

Humans tend to seek order in an ambiguous situation and to seek patterns they recognize. Mental biases, or mental shortcuts, offer the human mind several unconscious methods to create order and simplicity amid uncertainty, reducing mental effort.[91] Personnel should be aware of the potential for error that mental biases and mental shortcuts create during problem-solving and decision-making, such as troubleshooting and diagnostics during emergency operation. More will be said about underlying unconscious assumptions and taken-for-granted beliefs in the opening pages of Chapter 5 on organizational culture. In some form or another, all humans use mental biases. Biases were discussed earlier in this chapter with respect to the limitations of human nature and include the following, among others:

- confirmation bias;
- similarity bias;
- frequency bias;
- availability bias;
- representative bias; and
- framing bias.

Conservative Decisions

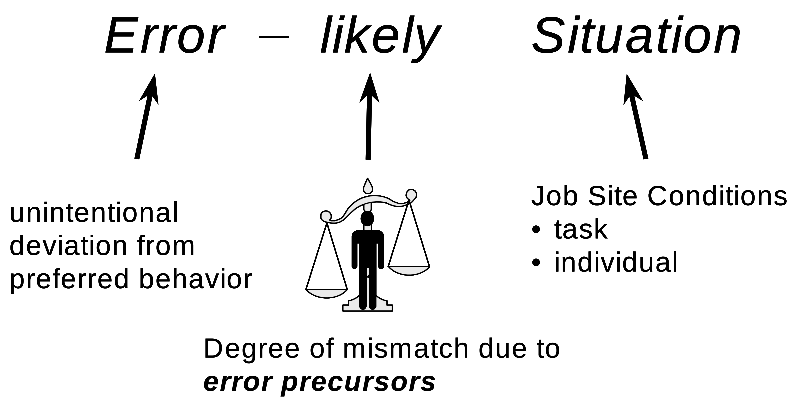
To be conservative means to be cautious and protective of what is truly important—safety, reliability, quality, security, and so on. It is an attitude that operational and personnel safety must be protected regardless of current schedule and production pressures. In light of the limitations of human nature, it makes sense to be conservative, especially when a decision potentially affects operational or personnel safety. Who knows what information is missing or what data was not considered? A systematic, team-based approach is called for so that safety considerations are not compromised. In several INPO documents related to conservative decision-making, the following factors are repeatedly mentioned as important to success in making conservative decisions.

- Recognize conditions that could challenge safety and reliability.
- Place structures, systems, and components in a known safe condition when uncertain.
- Seek prompt assistance from persons with relevant expertise.
- Avoid hasty decisions and hurried actions.
- Assign roles and responsibilities.
- Explore and evaluate alternatives rigorously, asking challenging questions to confirm technical assumptions.
- Understand the potential consequences to safety and reliability of various alternatives.
- Adopt a deliberate and carefully controlled approach.
- Make a deliberate decision, providing clear direction, roles and responsibilities, contingencies, and abort criteria.
- Do not proceed in the face of uncertainty.

ERROR-LIKELY SITUATIONS (Essential Reading)

> Error-likely situations are defined as: *A work situation in which there is greater chance for error when performing a specific action or task in the presence of error precursors*.[1]

The second principle of human performance states: "error-likely situations are predictable, manageable, and preventable." An *error-likely situation comes into play* when task-related factors exceed the capabilities of the individual, creating a mismatch at the point when the individual is "touching" either the physical or the paper plant.[92] The simple presence of adverse conditions cannot be error-likely unless a specific action is to occur within that set of adverse conditions. The elements of error likely situations appear in the graphic below.



Error Precursors

Error precursors are unfavorable conditions embedded in the job site that create mismatches between a task and the individual. Error precursors interfere with successful performance and increase the probability for error.[93] Simply stated, they are conditions that provoke error. They can be organized into one or more of the following four categories.[94]

- **Task Demands –** *Specific* mental, physical, and team requirements to perform an activity that may either exceed the capabilities or challenge the limitations of human nature of the individual assigned to the task. Task demands include physical demands, task difficulty, and complexity. Examples include excessive workload, hurrying, concurrent actions, unclear roles and responsibilities, and vague standards.

- **Individual Capabilities –** *Unique* mental, physical, and emotional characteristics of a particular person that fail to match the demands of the specific task. This involves cognitive and physical limitations. Examples are unfamiliarity with the task, unsafe attitudes, level of education, lack of knowledge, unpracticed skills, personality, inexperience, health and fitness, poor communication practices, fatigue, and low self-esteem.

- **Work Environment –** *General* influences of the workplace, organizational, and cultural conditions that affect individual behavior. These include distractions, awkward equipment layout, complex tagout procedures, at-risk norms and values, work group attitudes toward various hazards, work control processes, and temperature, lighting, and noise.

- **Human Nature –** *Generic* traits, dispositions, and limitations that may incline individuals to err under unfavorable conditions such as habit, short-term memory, stress, complacency, inaccurate risk perception, mind-set, and mental shortcuts.

Error precursors are, by definition, prerequisite conditions for error and, therefore, exist *before* an error occurs. If discovered and removed, job-site conditions can be changed to minimize the chance for error. This is more likely if people possess an intolerance for error precursors or error traps. Examples include reporting an improperly marked valve or a malfunctioning gauge in a safety system, taking a broken ladder out of service, immediately cleaning up an oil spill, stopping work until a change can be made to the procedure, calling in a replacement to relieve a worker who has become ill, seeking technical help when unsure, asking for a peer review on engineering calculations, routinely performing safety self-assessments, and so on.

Common Error Precursors

Error precursors are not mysterious or obscure. To the contrary, they are *noticeable*, even obvious, if people look for them. The error precursors listed below (in order of impact) were compiled from a study of INPO's event database and from human performance, ergonomics, and human factors sources. These are the more common conditions associated with events triggered by human error. Some organizations distribute a plastic-coated error precursor card to their front line workers to carry with them on the job. Workers refer to these cards during pre-job briefings to help identify precursors related to the upcoming task. A more extensive list of error precursors and error precursor descriptions is provided in Attachments A and B of this chapter.

Task Demands	**Individual Capabilities**
1. Time Pressure (in a hurry)	1. Unfamiliarity with task / First time
2. High workload (large memory)	2. Lack of knowledge (faulty mental model)
3. Simultaneous, multiple actions	3. New techniques not used before
4. Repetitive actions / Monotony	4. Imprecise communication habits
5. Irreversible actions[α]	5. Lack of proficiency / Inexperience
6. Interpretation requirements	6. Indistinct problem-solving skills
7. Unclear goals, roles, or responsibilities	7. Unsafe attitudes
8. Lack of or unclear standards	8. Illness or fatigue; general poor health or injury

Work Environment	**Human Nature**
1. Distractions / Interruptions	1. Stress
2. Changes / Departure from routine	2. Habit patterns
3. Confusing displays or controls	3. Assumptions
4. Work-arounds / OOS[β] instrumentation	4. Complacency / Overconfidence
5. Hidden system / equipment response	5. Mind-set (intentions)
6. Unexpected equipment conditions	6. Inaccurate risk perception
7. Lack of alternative indication	7. Mental shortcuts or biases
8. Personality conflict	8. Limited short-term memory

[α]Irreversible actions are not necessarily precursors to error, but are often overlooked, leading to preventable events. It is included in this list because of its importance.

[β]OOS - out of service

Remember, by themselves, error precursors do not define an error-likely situation. A human act or task must be either planned or occurring concurrent with error precursors to be considered error-likely. Several examples are provided below. For each example, notice the underlined action. Recall that an error is an unintended action.

1. *Writing* the wrong year on personal checks at the beginning of a new year.

Error Precursors:	• *Change* – new year • *Repetitive action* – write several checks • *Habit pattern* – written previous year numerous times during the previous year

2. *Turning* the charging pump switch instead of the dilution valve switch.

Error Precursors:	• *Confusing displays and controls – identical switches* – both pistol-grip style • Adjacent – within an inch apart – both pistol-grip controls very close together • *Interruption* – verifying the status of several annunciator alarms just at the moment to start dilution • *Repetitive action* – done several times during shift while performing system startup

3. *Pouring* engine oil (the wrong product) into a hydraulic fluid system.

Error Precursors:	• *Time pressure* – behind schedule getting equipment on line • *Departure from routin*e – poor lighting in store room where products were stored • *Complacency, mind-set* – location of fluids on unmarked shelves next to each other • *Assumptions* – containers appear nearly identical

Many different factors can affect performance. Considering the number and variety of factors involved with a specific job, many things can change, even with simple, repetitive tasks. Consequently, *no work should be considered routine*. When people believe a job is routine, they subconsciously think that "nothing can go wrong," and they expect only success. This mind-set leads to complacency and overconfidence. Then, when something does go wrong, people tend to rationalize the situation away, inhibiting proper response in time to avert the consequences.[95] Most events originate during routine activities. A sub-principle of human performance is *there are no routine tasks.*

ERROR-PREVENTION TOOLS

There are two ways to prevent human error from disturbing the facility or harming other important assets: either keep people from making errors (error prevention) or prevent the errors from harming the facility's (controls). The design of systems, structures, and components aids in performing the latter through engineered controls such as physical barriers, interlocks, keyed parts, shaped/color-coded controls, automation, and alarms. However, the prevention of or detection of errors also depends on people, either the performer or other people. For example, self-checking and procedures provide individuals with the means of avoiding or detecting mistakes, while peer-checking and three-way communication engage another person. Human performance tools are designed to help people anticipate, prevent, and catch active errors.

Methods of controlling latent errors are designed more to *catch* them than to prevent them because, by definition, people are usually unaware when latent errors occur.

Human Performance Improvement Handbook Volume 2: Human Performance Tools For Individuals, Work Teams, and Management, is a companion publication to this handbook. Volume 2 provides an explanation of numerous tools that individuals and work teams can employ to reduce errors. The fundamental purpose of human performance tools is to help the worker maintain *positive control* of a work situation; that is, *what is intended to happen is what happens, and that is **all** that happens*. Every person wants to do good work, to be 100 percent accurate, 100 percent complete, and meet 100 percent of the requirements. However, error is a normal characteristic of being human. Regardless of one's intention to do a job well, errors still occur because of the inherent fallibility and variability of all human beings. On occasion, people still err despite how rigorously they use human performance tools. For this reason, we take the dual approach to manage controls as well as reducing error ($R_e + M_c = ØE$).

System Changes

Although this handbook focuses on what people can do to reduce human error, it is recognized there is another whole dimension associated with error reduction. This involves improvements or changes in the engineered systems so the machines and working conditions better support the human needs, thus reducing human error. The location of instruments and controls on operating control panels, the accessibility and positioning of monitoring equipment, the lighting in passage ways, the sounds of warning alarms, the heights of working surfaces, the distance from communication sources, the number of work a-rounds present, and numerous other conditions can either enhance or hinder human performance. Human error is more likely when tools and equipment, procedures, work processes, or technical support are inadequate. Human factors professionals study and report on adverse engineered and management systems within an organization and recommend modifications or improvements to eliminate these and other conditions. Implementation of such recommendations improves worker perform and reduces human error.

Reporting errors and error precursors is an essential behavior needed to acquire feedback from the field about flawed engineered or management systems. Managers and supervisors should encourage workers to report adverse system-related conditions that promote error (error precursors) when ever they are encountered. With input from worker reporting, management can direct needed engineering and system changes. Reporting should be carried out in accordance with the organization's reporting policies, procedures and practices. More will be said about how to encourage a reporting culture in Chapter of this handbook.

ATTACHMENT A – ERROR PRECURSORS

The conditions listed below were derived from an in-depth study of INPO's event database and several highly regarded technical references on the topic of error. Many references refer to error precursors as *behavior-shaping factors* or *performance-shaping factors*. The **bolded error precursors** are more prevalent and are listed in order of impact.[96] Other error precursors are not listed in any particular order.

Task Demands	Individual Capabilities
• **Time pressure** (in a hurry)	• **Unfamiliarity with task / First time**
• **High workload** (memory requirements)	• **Lack of knowledge** (faulty mental model)
• **Simultaneous, multiple tasks**	• **New technique not used before**
• **Repetitive actions / Monotony**	• **Imprecise communication habits**
• **Irreversible acts**[α]	• **Lack of proficiency / Inexperience**
• **Interpretation of requirements**	• **Indistinct problem-solving skills**
• **Unclear goals, roles, or responsibilities**	• **'Unsafe' attitudes for critical task**
• **Lack of or unclear standards**	• **Illness / Fatigue / injury** (general health)
• Confusing procedure / Vague guidance	• Unawareness of critical parameters
• Excessive communication requirements	• Inappropriate values
• Delays; idle time	• Major life event: medical, financial, and emotional
• Complexity / High information flow	• Poor manual dexterity
• Long-term monitoring	• Low self-esteem; moody
• Excessive time on task	• Questionable ethics (bends the rules)
	• Sense of control / Learned helplessness
	• Personality type

Work Environment	Human Nature
• Distractions / Interruptions	• **Stress** (limits attention)
• **Changes / Departure from routine**	• **Habit patterns**
• **Confusing displays / Controls**	• **Assumptions** (inaccurate mental picture)
• **Work-arounds / OSS[β] instrumentation**	• **Complacency / Overconfidence**
• **Hidden system response**	• **Mind-set**
• **Unexpected equipment conditions**	• **Inaccurate risk perception** (Pollyanna)
• **Lack of alternative indication**	• **Mental shortcuts** (biases)
• **Personality conflicts**	• **Limited short-term memory**
• Back shift or recent shift change	• Pollyanna effect
• Excessive group cohesiveness / peer pressure	• Limited perspective (bounded rationality)
• Production overemphasis	• Avoidance of mental strain
• Adverse physical climate (habitability)	• First day back from vacation / days off
• No accounting of performance.	• Sugar cycle (after a meal)
• Conflicting conventions; stereotypes	• Fatigue (sleep deprivation and biorhythms)
• Poor equipment layout; poor access	• Tunnel vision (lack of big picture)
• Fear of consequences of error	• “Something is not right” (gut feeling)
• Mistrust among work groups	• Pattern-matching bias
• Meaningless rules	• Social deference (excessive professional courtesy
• Nuisance alarms	• Easily bored
• Unavailable parts or tools	• Close-in-time cause-effect correlation
• Acceptability of “cookbooking” practices	• Difficulty seeing own errors
• “Rule book” culture	• Frequency and similarity biases
• Equipment sensitivity (inadvertent actions)	• Availability bias
• Lack of clear strategic vision or goals	• Imprecise physical actions

Work Environment	Human Nature
• Identical and adjacent displays or controls	• Limited attention span
• Out-of-service warning systems	• Spatial disorientation
• Lack of procedure place-keeping	• Physical reflex
•	• Anxiety (involving uncertainty)

$^{\alpha}$ Irreversible actions are not necessarily precursors to error, but are often overlooked, leading to preventable events. It is included in this list because of its importance.

$^{\beta}$ OOS - out of service

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ATTACHMENT B – COMMON ERROR-PRECURSOR DESCRIPTIONS

The first eight error precursors from the table on the previous pages are described below. These tend to be the more commonly encountered conditions that provoke errors. The error precursors for each category are arranged in order of influence.

Task Demands	Description
Time pressure (in a hurry)	Urgency or excessive pace required to perform action or task Manifested by shortcuts, being in a hurry, and an unwillingness to accept additional work or to help others No spare time
High workload (high memory requirements)	Mental demands on individual to maintain high levels of concentration; for example, scanning, interpreting, deciding, while requiring recall of excessive amounts of information (either from training or earlier in the task)
Simultaneous, multiple tasks	Performance of two or more activities, either mentally or physically, that may result in divided attention, mental overload, or reduced vigilance on one or the other task
Repetitive actions / Monotony	Inadequate level of mental activity resulting from performance of repeated actions; boring Insufficient information exchange at the job site to help individual reach and maintain an acceptable level of alertness
Irrecoverable acts	Action that, once taken, cannot be recovered without some significant delay No obvious means of reversing an action
Interpretation requirements	Situations requiring “in-field” diagnosis, potentially leading to misunderstanding or application of wrong rule or procedure
Unclear goals, roles, and responsibilities	Unclear work objectives or expectations Uncertainty about the duties an individual is responsible for in a task that involves other individuals Duties that are incompatible with other individuals
Lack of or unclear standards	Ambiguity or misunderstanding about acceptable behaviors or results; if unspecified, standards default to those of the front-line worker (good or bad)

Work Environment	Description
Distractions / Interruptions	Conditions of either the task or work environment requiring the individual to stop and restart a task sequence, diverting attention to and from the task at hand
Changes / Departure from routine	Departure from a well-established routine Unfamiliar or unforeseen task or job site conditions that potentially disturb an individual's understanding of a task or equipment status
Confusing displays / controls	Characteristics of installed displays and controls that could possibly confuse or exceed working memory capability of an individual Examples: • missing or vague content (insufficient or irrelevant) • lack of indication of specific process parameter • illogical organization and/or layout • insufficient identification of displayed process information • controls placed close together without obvious ways to discriminate conflicts between indications
Work-arounds / Out-of-Service instrumentation	Uncorrected equipment deficiency or programmatic defect requiring compensatory or non-standard action to comply with a requirement; long-term materiel condition problems that place a burden on the individual
Hidden system response	System response invisible to individual after manipulation Lack of information conveyed to individual that previous action had any influence on the equipment or system
Unexpected equipment condition	System or equipment status not normally encountered creating an unfamiliar situation for the individual
Lack of alternative indication	Inability to compare or confirm information about system or equipment state because of the absence of instrumentation
Personality conflict	Incompatibility between two or more individuals working together on a task causing a distraction from the task because of preoccupation with personal differences

Individual Capabilities	Description
Unfamiliarity with task / First time	Unawareness of task expectations or performance standards First time to perform a task (not performed previously; a significant procedure change)
Lack of knowledge (mental model)	Unawareness of factual information necessary for successful completion of task; lack of practical knowledge about the performance of a task
New technique not used before	Lack of knowledge or skill with a specific work method required to perform a task
Imprecise communication habits	Communication habits or means that do not enhance accurate understanding by all members involved in an exchange of information
Lack of proficiency / Inexperience	Degradation of knowledge or skill with a task because of infrequent performance of the activity
Indistinct problem-solving skills	Unsystematic response to unfamiliar situations; inability to develop strategies to resolve problem scenarios without excessive use of trial-and-error or reliance on previously successful solutions Unable to cope with changing facility conditions
“Unsafe” attitude for critical tasks	Personal belief in prevailing importance of accomplishing the task (production) without consciously considering associated hazards Perception of invulnerability while performing a particular task Pride; heroic; fatalistic; summit fever; Pollyanna; bald tire
Illness / Fatigue	Degradation of a person's physical or mental abilities caused by a sickness, disease, or debilitating injury Lack of adequate physical rest to support acceptable mental alertness and function

Human Nature	Description
Stress	Mind's response to the perception of a threat to one's health, safety, self-esteem, or livelihood if task is not performed to standard Responses may involve anxiety, degradation in attention, reduction in working memory, poor decision-making, transition from accurate to fast Degree of stress reaction dependent on individual's experience with task
Habit patterns	Ingrained or automated pattern of actions attributable to repetitive nature of a well-practiced task Inclination formed for particular train/unit because of similarity to past situations or recent work experience
Assumptions	Suppositions made without verification of facts, usually based on perception of recent experience; provoked by inaccurate mental model Believed to be fact Stimulated by inability of human mind to perceive all facts pertinent to a decision
Complacency / Overconfidence	A “Pollyanna” effect leading to a presumption that all is well in the world and that everything is ordered as expected Self-satisfaction or overconfidence, with a situation unaware of actual hazards or dangers; particularly evident after 7-9 years on the job[97] Underestimating the difficulty or complexity of a task based upon past experiences
Mindset	Tendency to “see” only what the mind is *tuned* to see (intention); preconceived idea Information that does fit a mind-set may not be noticed and vice versa; may miss information that is not expected or may see something that is not really there; contributes to difficulty in detecting one's own error (s)
Inaccurate risk perception	Personal appraisal of hazards and uncertainty based on either incomplete information or assumptions Unrecognized or inaccurate understanding of a potential consequence or danger Degree of risk-taking behavior based on individual’s perception of possibility of error and understanding of consequences; more prevalent in males[98]

Human Nature	Description
Mental shortcuts (biases)	Tendency to look for or see patterns in unfamiliar situations; application of thumb rules or “habits of mind” (heuristics) to explain unfamiliar situations: • confirmation bias • frequency bias • similarity bias • availability bias
Limited short-term memory	Forgetfulness; inability to accurately attend to more than 2 or 3 channels of information (or 5 to 9 bits of data) simultaneously The mind’s “workbench” for problem-solving and decision-making; the temporary, attention-demanding storeroom we use to remember new information

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REFERENCES

[1] Dorner. *The Logic of Failure*, 1996, pp.185-186.

[2] Senders and Moray. Human Error Cause, Prediction, and Reduction, 1991, pp.44, 67.

[3] Reason. *Human Error*, 1990, pp.38-39.

[4] Wickens. Engineering Psychology and Human Performance, 1992, pp.277-281.

[5] Swain and Guttman. Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications (NUREG/CR-1278), 1983.

[6] Wickens. Engineering Psychology and Human Performance, 1992, pp.211-222.

[7] Spettell and Liebert. "Training for Safety in Automated Person-machine Systems," *American Psychologist*, May 1996.

[8] Reason and Hobbs. *Managing Maintenance Error*, 2003, p.22.

[9] Weick and Sutcliffe. *Managing the Unexpected,* 2002, pp.33-41.

[10] Russel. *The Brain Book*, 1979, pp.211-215.

[11] Simon. "A Behavioral Model of Rational Choice," Models of Man, Social and Rational: Mathematical Essays on Rational Human Behavior in a Social Setting, 1957.

[12] Turner and Pidgeon. *Man-Made Disasters*, 1997, pp.109-115.

[13] Hursh. "Fatigue and Alertness Management using *FAST*™." Presentation at nuclear industry annual workshop on *Human Performance/Root Cause/Trending* in Baltimore, Maryland, June 6, 2001. Dr. Steven Hursh is a professor at Johns Hopkins University School of Medicine. *FAST*™ (Fatigue Avoidance Scheduling Tool) is a software program aimed at minimizing personnel fatigue.

[14] Keller. *Attitude is Everything*, 1999, pp.14-16.

[15] Oswalt and Neely, This Land was Theirs, 1999. p.

[16] Ropeik and Gray. Risk: A Practical Guide for Deciding What's Really Safe and What's Really Dangerous in the World Around You, 2002, pp.15-18.

[17] David McCullough. *Truman*, Simon & Schuster, 1992, pp.835-855.

[18] Benjamin Capps. *The Indians*, Time-Life Books, Alexandria Virginia, 1973.

[19] Erich Maria Remarque. *All Quiet on the Western Front*, 1957. pp. 82-83; H. Stuart Hughes. *Contemporary Europe : A History* 1961, pp. 48-49.

[20] Yates. *Risk-Taking Behavior,* 1992, p.52.

[21] Dorner. *The Logic of Failure*, 1996, p.109.

[22] Turner and Pidgeon. *Man-Made Disasters*, 1997, p.34.

[23] Columbia Accident Investigation Board Report, 7.2 *Organizational Causes: Insights from Theory*, p.1-2.

[24] Geller. *The Psychology of Safety*, 1998, pp.41-43.

[25] Turner and Pidgeon. *Man-Made Disasters*,1997, p.34.

[26] Senders and Moray. Human Error: Cause, Prediction, and Reduction, 1991.

[27] Hollnagel. Cognitive Reliability and Error Analysis Method, 1998, p. 164.

[28] Reason. Managing the Risks of Organizational Accidents, 1998, p. 71.

[29] Center for Chemical Process Safety. *Guidelines for Preventing Human Error in Process Safety*, American Institute of Chemical Engineers, 1994.

[30] Rummler and Brache. *Improving Performance*, 1990, p. 73.

[31] NUREG/CR-6753. Review of Findings for Human Error Contribution to Risk in Operating Events, 2001.

[32] Health and Safety Executive. *Improving Compliance with Safety Procedures, Reducing Industrial Violations*, 1995. The Violations Sub-group of the Human Factors Reliability Group (HFRG) prepared this report for HSE. HSE is an arm of the government of the United Kingdom.

[33] Reason, Managing the Risks of Organizational Accidents, 1998, p. 146.

[34] Health and Safety Executive. "Preventing the propagation of error and misplaced reliance on faulty systems: A guide to human error dependency," Offshore Technology Report 2001/053. 2001, pp.12-16.

[35] Greenstreet and Berman, Ltd., for Health and Safety Executive. "Preventing the Propagation of Error and Misplaced Reliance on Faulty Systems: A Guide to Human Error Dependency," 2001, pp.7-11.

[36] Latane. "Many heads make light the work: The causes and consequences of social loafing," *Journal of Personality and Social Psychology*, 1979.

[37] Kohn, L.R., Corrigan, J.M., Donaldson, MS. (Eds). *To Error is Human: Building a Safer Health System*, Washington DC: National Academy Press, 1999.

[38] Hopkins. Preventing Human Error, A Practical Guide to Quality – Safety – Effectiveness. 2000, p. 44-45.

[39] Hop Howlett. The Industrial Operator's Handbook, 1995.

[40] Hop Howlett. The Industrial Operator's Handbook, 1995.

[41] Adapted from Irving Janis, *Victims of Groupthink*, Houghton Mifflin, (Boston) 1972.

[42] Yates. *Risk-Taking Behavior*, 1992, pp.168-173.

[43] This incident occurred at the PUREX facility in the 200 area of the Hanford Washington site. The writer was employed by Westinghouse-Hanford as the 200 area training manager at the time of this incident.

[44] Wickens, C.D. *Engineering Psychology and Human Performance*, Harper-Collins, New York, 1992. as produced in the Federal Aviation Administration Webtraining Module that appears on line at: www.hf.faa.gov/Webtraining/Cognition/CogFinal1008.htm.

[45] *Marrietta Daily Journal*. "Scientists: People cannot drive safely, talk at same time." July 30, 2001.

[46] Wickens. Engineering Psychology and Human Performance, 1992, p.69.

[47] Reason. Managing the Risks of Organizational Accident, 1997, pp. 68-69.

[48] Wickens. Engineering Psychology and Human Performance, 1992.

[49] The Model is Adapted from Wickens, *Engineering Psychology and Human Performance*, 1992.

[50] Restak. *Brainscapes*, 1995, p.60.

[51] Wickens. Engineering Psychology and Human Performance, 1992, pp.17-20.

[52] Miller, G. "The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity for Processing Information," *The Psychological Review, 1956, Vol. 63, pp. 81-97.*

[53] Wickens, C.D. "Attention to Safety and the Psychology of Surprise," Keynote address: Symposium on Aviation Psychology: Ohio State University.

[54] Taylor, J.G. "Recent Advances in Understanding Attention," *Science & Consciousness Review, 2003, online.*

[55] Reason and Hobbs. *Managing Maintenance Error*, 2003, p.22.

[56] Strayer, Drews, and Johnson. "Cell Phone Use Can Lead to Inattention Blindness Behind the Wheel," *Injury Insights*, National Safety Council, Feb/Mar 2003.

[57] Wickens. Engineering Psychology and Human Performance, 1992, pp.386-391.

[58] Spettell & Liebert. "Training for Safety in Automated Person-machine Systems," *American Psychologist*, May 1996.

[59] Reason and Hobbs. *Managing Maintenance Error*, 2003, pp. 27-28.

[60] Reason. Managing the Risks of Organizational Accidents. 1998, pp.68-70.

[61] Embrey. *Understanding Human Behaviour and Error*, Human Reliability Associates Ltd, p. 8

[62] Turner and Pidgeon. *Man-Made Disasters*, 1997, pp.124-126.

[63] Reason. *Human Error*, 1990, p.56.

[64] Schneider, W. "Automaticity in complex cognition," Center for Cognitive Brain Imaging at Carnegie Mellon University, 2003.

[65] David Embrey. *Understanding Human Behaviour and Error*, Human Reliability Associates Ltd. p. 6.

[66] Health and Safety Commission. Advisory Committee on the Safety of Nuclear Installations Study Group on Human Factors, Second Report: Human Reliability Assessment - A Critical Overview, Her Majesty's Stationery Office, 1991, p.9.

[67] Catoe, J. "Hypnotherapy," *Atlanta Journal and Constitution*, November 22, 1998.

[68] Performance Improvement International. An internal study of errors across the nuclear industry revealed that 25 percent of errors were skill-based, 60 percent were rule-based, and 15 percent were knowledge-based. 2000.

[69] Health and Safety Commission. Advisory Committee on the Safety of Nuclear Installations Study Group on Human Factors, Second Report: Human Reliability Assessment – A Critical Overview, Her Majesty's Stationery Office, 1991, p.7.

[70] Geller. *The Psychology of Safety*, 1998, p.61.

[71] Reason. Managing the Risks of Organizational Accidents, 1998, p.70.

[72] Reason. Managing the Risks of Organizational Accidents, 1998, p.70.

[73] Reason. *Human Error*, 1990, pp.74-86.

[74] Reason and Hobbs. *Managing Maintenance Error*, 2003, pp. 48-52.

[75] Swain & Guttman. Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications (NUREG/CR-1278), 1983.

[76] Performance Improvement International. An internal study of errors across the nuclear industry revealed that 25 percent of errors were skill-based, 60 percent were rule-based, and 15 percent were knowledge-based. 2000.

[77] Reason. *Human Error*, 1990, pp.53-55.

[78] Turner and Pidgeon. *Man-Made Disasters*, 1997, pp.124-126.

[79] Wickens. Engineering Psychology and Human Performance, 1992, p.20.

[80] Reason. Managing the Risks of Organizational Accident, 1997, p. 70.

[81] Embrey. *Understanding Human Behaviour and Error,* Human Reliability Associates Ltd., p. 8

[82] Embrey. *Understanding Human Behavior and Error,* Human Reliability Associates Ltd., p. 8.

[83] According to a conversation with Dr. James Reason, professor of psychology at the University of Manchester in the United Kingdom, the chances for error in a knowledge-based situation are roughly a toss-up, “If you're good.” Otherwise, the chances for success get worse. February 1997.

[84] Performance Improvement International. An internal study of errors across the nuclear industry revealed that 25 percent of errors were skill-based, 60 percent were rule-based, and 15 percent were knowledge-based. 2000.

[85] Dorner. *The Logic of Failure*, 1996, pp.71-79.

[86] Reason. *Human Error*, 1990, pp.61-66; 86-89.

[87] Howlett. The Industrial Operator's Handbook, 1995, p.45.

[88] Baxter and Bass. “Human Error Revisited: Some Lessons for Situational Awareness,” Fourth Symposium On Human Interaction with Complex Systems, March 22-24, 1998, pp.81-87.

[89] Dorner. *The Logic of Failure*, 1996, p.42.

[90] Senge. The Fifth Discipline Fieldbook 1994, pp.245-246.

[91] Senge. The Fifth Discipline Fieldbook, 1994, pp.86-95.

[92] Center for Chemical Process Safety. *Guidelines for Preventing Human Error in Process Safety*, American Institute of Chemical Engineers, 1994, pp.12-15.

[93] Health and Safety Commission. Advisory Committee on the Safety of Nuclear Installations Study Group on Human Factors, Second Report: Human Reliability Assessment - A Critical Overview, Her Majesty's Stationery Office, 1991, p.33.

[94] Gilbert. Human Competence, Engineering Worthy Performance, 1996, pp.82-89.

[95] Turner and Pidgeon. *Man-Made Disaste*rs, 1997, p.34.

[96] Institute for Nuclear Power Operations, *Human Performance Reference Manual;* INPO 06-003, p. 60-61.

[97] Institute for Nuclear Power Operations, *Human Performance Reference Manual;* INPO 06-003, p. 65.

[98] Pyszczynski. “Gender Differences in the Willingness to Engage in Risky Behavior: A Terror Management Perspective”. Death Studies, 26 (Feb 2002), pp. 117-142.

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CHAPTER 3 - MANAGING CONTROLS

Controls

In this chapter, the reader will become familiar with controls as they relate to DOE facilities. From that introduction, the reader will gain an appreciation of the importance of controls in preventing events. The various categories of controls used and their relative dependability will be addressed. Most importantly, the emphasis will be placed on how to identify and eliminate latent organizational conditions in the system that weaken controls by using a variety of available and familiar methods (tools) introduced herein.

For readers who have taken DOE sponsored Human Performance Improvement training or who are familiar with some of the key HPI literature such as the research of Dr. James Reason, the term “defenses” is often used. Depending on the linguistic traditions of various hazardous technological domains, the terms “defenses, barriers, controls”, or similar terms may be used. In general, they all connote technological or organizational features specifically designed to protect against hazards. To emphasize the role of HPI in supporting the DOE’s Integrated Safety Management systems, the term “controls” is used in this Handbook in preference to the word “defenses” or other similar terms.. The meaning of the terms is essentially the same. ISM uses the term “controls” so this is the term used throughout this Handbook to promote consistency of usage and consistency of understanding.

Controls are extremely important in DOE facilities; successful controls prevent or mitigate the severity of events. Proper understanding and use of controls are important to understanding and preventing accidents.

- An accident occurs only when one or more controls have failed; either they did not serve their purpose or they were missing.

- Once the origin of an accident has been determined and the causes identified, controls and barriers can be used as a means to prevent the same or a similar accident from taking place in the future.[1]

Controls comprise any human, technical, or organizational features that protect the facility and personnel against hazards.[2] In addition to human error, other hazards include radiation, industrial safety hazards, hazardous chemicals, and various forms of energy, such as electricity and rotating equipment. Controls can protect against a hazard, mitigate consequences, or warn. Controls take the form of containments; physical interlocks; redundant equipment, power sources, and annunciators; personal protective equipment; procedure use; caution tags; and self-checking, among others

Example of Failed Controls in Industry: Chernobyl

The Chernobyl Unit 4 nuclear reactor accident in the Ukraine on April 26, 1986, is a classic example of multiple failed or missing controls—some resulting from design flaws and some from the errors of operators. The schedule that day called for a safety demonstration test to determine how long the turbines could provide electrical power from residual momentum alone in the event of a power loss.[3]

Operators failed in their role as the most important line of protection because they did the following.

(1) **Violated safe operating parameters –** Operators decided to continue the testing of the voltage generator, even though an initial operating error had caused the power level to fall to 7 percent of full power. The station operating procedures strictly prohibited any operations below 20 percent of full power. Operations at these low power levels created a positive void coefficient in the reactor's core, which can lead to runaway reactivity. The operators should have aborted the test completely and returned the reactor to normal power to prevent this, but they did not.

(2) **Disabled engineered safety systems –** Operators subsequently disabled the emergency cooling and shutdown systems in order to complete the experiment by controlling the reactor themselves. That operators could physically disable these safety systems was indeed a flaw in the design of the system.

(3) **Retracted control rods beyond regulations –** When power dropped too low, operators forcibly raised power by retracting the control rods to an extreme level—much greater than that allowed by regulations. Here again a design flaw allowed such a manipulation. During the test, steam flow to the turbines was reduced. Thus, heat was not being carried away from the core as normal. When temperature in the core increased rapidly, giving rise to more boiling and increasing reactivity, an operator attempted a manual scram. The operator likely did not understand the consequences of his actions. Rather than slow down reactivity, insertion of the graphite-tipped control rods caused quite the opposite effect. The power surge triggered multiple steam explosions. The reactor vessel head was blown off, and, in a second chemical explosion, the roof of the building was blown off.

(4) **Design flaw: No containment –** The RBMK reactor design did not include a steel-reinforced concrete containment structure present in all other reactor designs. The presence of a containment structure would have precluded the release of aerosolized fuel and fission products into the environment. Instead, there was a total meltdown of the fuel and fire in the reactor housing burned for 10 days, dispensing radionuclides into the atmosphere.

The Chernobyl accident took dozens of lives, completely destroyed the plant, and forced relocation of tens of thousands of people. Adverse impacts to the environment continue to this day.

Examples of Controls in Every-day Life

Controls are built into our everyday lives. We will consider two examples—fire protection and driving a car. Take the controls against a fire in your home. There are fire-resistant building materials (*exterior:* brick, stucco, or cement-based siding, metal or tile roofs, steel doors, and so on.; *interior:* metal studs, sheetrock walls and ceilings, ceramic tile flooring, and so on).

Ground-fault interrupter (GFI) circuit breakers automatically cut off electricity when they sense shorts in the circuit. The above controls guard against a fire starting or they slow its spread in the event of a fire. Smoke detectors and alarms warn of danger should a fire start. Fire extinguishers, fire hydrants and hoses, and the local firemen are controls that contain and put out a fire if it should break out.

There are many controls associated with driving an automobile. Traffic lights signal drivers to proceed or stop at an intersection. Speedometers help drivers control vehicle speed. Drivers' licenses provide proof that people are qualified to operate an automobile. Seatbelts and air bags mitigate the effects of collisions. Ripples built into the edges of asphalt highways alert drivers with a rumbling noise when the vehicle is riding on the edge of the road. Likewise, controls in the facility take the form of procedures; physical interlocks; redundant equipment, power sources, and annunciators; as well as those that rely on people, such as self-checking, peer-checking, three-way communication, reviews and approvals, and supervisory oversight.

Severity of Events

The significance, or severity, of a particular event lies in the *consequences* suffered by the physical plant or personnel, not the error that initiated the event.[4] The error that causes a serious accident and the error that is one of hundreds with no consequence can be the same error that has historically been overlooked or uncorrected. For a significant event to occur, multiple breakdowns in controls or barriers must first occur. Whereas human error typically triggers an event, it is the number of controls and the weaknesses of those controls that dictate the severity of the event.

The existence of many flawed controls is directly attributable to weaknesses in the organization or management control systems. Individual error-prevention practices are important and need to be implemented and maintained. However, to focus only on error reduction to prevent events is a bad strategy for this reason. Error reduction can only reduce the time between events. The greater successes in minimizing the occurrence of severe events are realized by focusing on defense-in-depth. Improving controls will minimize severity. Therefore, one of management's top priorities must be verifying the integrity of controls.

The Organization's Role in Controls

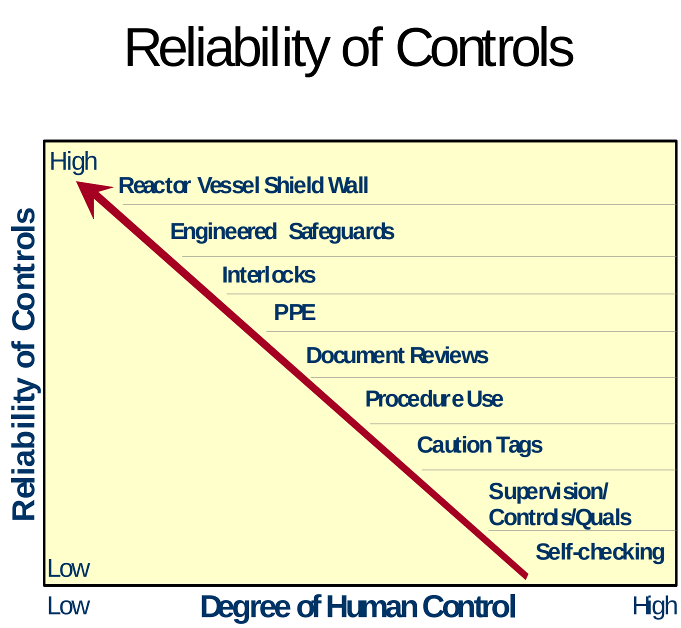
Human performance occurs within the context of the organization—its processes, physical structures and culture. It is the organization that acquires, organizes, and makes use of resources (people, money, and equipment) in support of facility operations. When facility operations fail to accomplish what is intended, events are the results. Significant events triggered by human error are rightfully characterized as *organizational failures.* Significant events, excessive DOE oversight, and extended facility shutdowns are reflective of severe organizational failures. At the other extreme, facilities that demonstrate sustained operational excellence are managed by strong organizations that execute processes effectively and whose workforce adheres to high standards.

Defense Functions

Controls serve various functions, including the following.[5]

- **Create Awareness** – understanding the risks and hazards and recognizing the presence of hazards. Examples include pre-job briefings, post-job reviews, risk assessments, procedures, component labeling, color-coding, self-checking, computer screen layout, logs, meetings, communication practices, danger tags, and radiological postings.
- **Detect and Warn –** alerted to the presence of off-normal conditions or imminent dangers. Examples include alarms and annunciators, equipment operator rounds, concurrent verification, peer-checking, supervision, confined-space entry requirements, self-checking, and problem-solving methodology.
- **Protect** – guarding people, equipment, and the environment from error or harm. Examples include personal protective equipment, supervision, equipment lockout, interlocks, shielding, and ventilation.
- **Recover** – restoration from off-normal conditions and restoring the system to a safe state. Examples include independent verification, emergency procedures, eye wash stations, pre-established response procedures, continuity of operations plans, re-entry teams, and decontamination.
- **Contain** – restricting or limiting the accidental release of harmful energy or substances. Examples include double-shell storage tanks, glove boxes, remote manipulations, tank berms, piping and valves, and containment.
- **Enable Escape** – providing the means to flee from uncontrolled hazard. Examples include emergency plans, crash bars on doors, emergency lighting, and network installation management (NIM) routes.

Reliability of Controls



As might be expected, some controls are more reliable than others. Controls, barriers, or safeguards tend to be more reliable when they are not dependent on people to carry out their protective functions. In general, physical controls tend to perform their intended functions despite human action or inaction. Engineered controls, such as physical interlocks and equipment design, are more reliable than administrative controls, such as procedures, human performance tools, and training programs, as shown in the graphic above. When the effectiveness of a defense mechanism relies on the performance of people—as do procedures, training, self-checking, and verifications—then it is less reliable. When plant safety and reliability are dependent on people during risk-important activities, the physical plant is more vulnerable to their errors. Reliability is related to the dependability of the defense or barrier to perform its intended function when needed. If it is imperative to prevent error, then physical, engineered controls are more appropriate.

DEFENSE-IN-DEPTH

Controls themselves are not necessarily perfect. Multiple, overlapping controls are needed to compensate for this reality. The Defense-in-depth concept is achieved by imbedding controls in an overlapping fashion into the organization, its culture, and the physical facility. Thus, if one controls fails or is ineffective, other systematically placed redundant controls will fulfill the same defensive function. Controls include various devices, methods, or practices that make an activity or process go safely and predictably to protect key assets from human error. Four types of lines of controls—engineered, administrative, cultural, and oversight controls—work together to anticipate, prevent, or catch active errors from causing a significant event. An explanation of each of these four types of control, as well as examples and common flaws associated with each follow.

Engineered Controls

Engineered design controls are all those hardware, software, and equipment items in the physical environment that affect people's behavior, choices, and attitudes, and are a result of engineering design. Engineered controls act either actively or passively. *Active controls include equipment such as pumps or valves that perform a specific safety-related function. Passive controls include pipes, vessels, and berms that provide containment and generally do not have moving parts.* The most reliable defense mechanisms are passive because they require no operational or maintenance support to remain effective, eliminating dependence on human involvement.

- **Elements of Effective Engineered Controls**

  The *human-machine* environment contains several opportunities to "control" human error. Human-centered designs consider human error and its potential consequences, eliminating or minimizing error traps with equipment.

  - The habitability and accessibility of the physical work environment.
  - The elimination of unnecessary human interactions with facility equipment or the automation of the equipment.
  - The use of interlocks and error-tolerant designs are used to mistake-proof human-machine interactions, especially those with risk-important systems and critical components.
  - Provision of interlocks and protection systems to prevent improper operator actions and to initiate automatic protective actions when necessary. Interlocks and protection systems will not prevent all possible operator errors, but they can substantially reduce the risks if they are properly maintained.

- Supervisors initiate modifications to eliminate or minimize errors associated with workarounds and human-machine interface deficiencies. These actions are especially important at critical steps.
- Reliance on configuration control, material condition, foreign material exclusion (FME), and housekeeping practices.
- Resolution of problems with environmental conditions, labeling, accessibility, lighting, and habitability, if possible, to minimize their impact on performance, especially on risk-important equipment. These are administrative controls in support of the engineered controls.

▪ **Common Flaws with Engineered Controls**

The following list highlights some of the more common equipment-related conditions that challenge worker performance and can contribute to facility events:

- out-of-service equipment, controls, alarms, and indicators;
- workarounds, temporary repairs, or long-term temporary modifications/alterations;
- nuisance alarms and disabled annunciators;
- excessive noise;
- missing labels or labels oriented such that they cannot be seen or read easily;
- poor lighting;
- high temperatures or high humidity (heat stress factors);
- unusual plant or equipment conditions; and
- poor accessibility, cramped conditions, or awkward layout of equipment.

Administrative Controls

Administrative controls, such as procedures, inform people about what to do, when to do it, where it is to be done, and how well to do it, and are usually documented in various written policies, programs, and plans. Administrative controls rely on human judgment, training, and personal initiative to follow the direction contained in documents. Consequently, administrative controls are not as reliable as engineered controls.

▪ **Example: Administrative Controls**

A wide range of management methods exists to ensure proper facility operations and to control various hazards. Administrative controls that significantly impact human performance include the following:

- strategic business planning (goals, budgeting, priorities, plans, resource acquisition, and so forth);
- formal organizational structure, lines of authority, roles, and responsibilities;
- policies, programs, and processes for the conduct of production work activities (preventive maintenance, procedure development, modifications, configuration control, operations, and so forth);
- communication methods (conversations, e-mail, logs, meetings, reports, newsletters, signs, postings, telephones, radios, alarms, and so on);
- technical and administrative procedures (clearances/tagging, foreign material exclusion, industrial safety, human performance, troubleshooting, records, parts and materials, self-assessment, corrective action, and so forth);
- training programs;
- qualification standards that establish the physical, psychological, educational, or proficiency requirements for the assigned duties of a position;
- work management processes (work initiation, prioritization, review and approval, planning, and scheduling);
- human resources policies and practices related to staffing levels, overtime, and discipline;
- human performance tools, expectations, and standards; and
- information technology and information handling.
- work authorization permits such as radiation work permits (RWPs) and confined space permits
- lock out - tag outs

▪ **Common Flaws with Administrative Controls**

The following administrative conditions, among others, can be causes or contributing factors in facility events:

- two or more actions embedded in one procedure step;
- vague expectations and standards;
- superficial document reviews or the lack of a “qualified reviewer” process for technical procedure development;
- critical steps not identified in procedures and work packages;
- excessive work package backlog that exceeds planner resources;

- work packages planned without inclusion of operating experience;
- unresponsive procedure revision process;
- excessive deferred preventive maintenance;
- insufficient staffing leading to excessive overtime, workload, and fatigue;
- routine authorization to exceed overtime limits (leading to chronic fatigue);
- inadequate time for direct supervision of work in the field;
- unclear qualification standards; and
- incomplete or missing electrical load lists to aid in ground isolation.

Cultural Controls – Values, Beliefs, Attitudes

An effective safety culture engenders the belief that when production and safety conflict, safety will prevail. Cultural controls include those leadership practices that teach (consciously or unconsciously) people how to perceive, think, feel, and behave toward challenges to safety.[6] Culture is defined by people's behavior, and safe behavior is value-driven.[7] What an organization says its values are may not be reflected in its behavior. The true values of an organization are reflected in the observed acts of its people, especially its managers.[8] For instance, when procedures are vague or incomplete, people tend to default to what they think is important for success as they define it.

Organizational culture comprises a set of *shared* assumptions, values, and beliefs that characterize the choices and behaviors of the members in an organization. Culture is to the group what character and personality are to the individual. Because of the special nature of hazards present at DOE facilities, organizations that work in these facilities need a *strong* safety culture. "Strong" implying the extent to which the organization's members adopt or internalize such values and behaviors. More will be said about culture in Chapter 5.

Values What managers place importance on and what is considered "high priority" becomes valued in the organization, whether this is publicly espoused or not. Key management values are usually visible at the site or at the facility in meeting rooms and conspicuous, high-traffic areas (both in the facility and outside the facility) where everyone sees them. When workforce behaviors become consistent with management's espoused values over the long term, then the organization has truly internalized those values.

Beliefs What people believe (or perceive) to be true tends to drive their attitudes and behavior. A belief is an acceptance of and conviction in the truth, existence, or validity of something, including assumptions about what will be successful. People erroneously believe they can always maintain control whenever and wherever. Typically, this is the case when people decide to take shortcuts or violate a safety policy. This belief changes as people understand the realities associated with human performance. The following beliefs have a significant positive impact on event-free performance.

- Absolutely safe environments do not exist.
- Human beings are fallible.
- People want to do a good job.
- Human error is normal.
- There is no such thing as a "routine" task or activity.
- Significant events are organizational failures.
- Error presents an opportunity to learn and improve organizational effectiveness.

Attitudes An attitude is a state of mind, or feeling, toward an object or subject. Importantly, attitudes affect people's choices and behaviors toward safety and error prevention. Positive feelings follow safe behaviors when people experience positive and consistent feedback from supervisors and peers and they understand why the feelings are important. If people experience negative feelings when they use safe behaviors (pain, fear, anxiety, frustration, humiliation, embarrassment, boredom, or discomfort) they will tend to avoid those behaviors and practices. The following attitudes promote safe work behaviors.

- **Uneasiness toward human fallibility** – individuals acknowledging their capacity to err, to make a mistake or slip at any time, and being wary of conditions conducive to error; tending to follow procedures carefully and applying human performance tools rigorously.
- **Questioning attitude** – maintaining vigilant situational awareness toward surrounding working conditions to detect error-likely situations, unsafe or hazardous working conditions, or otherwise unusual conditions; not proceeding in the face of uncertainty and basing decisions on facts
- **Conservative approach –** taking actions or making decisions that err in the direction of safety rather than production, especially when doubt exists; exhibited by placing systems, equipment, or the facility in a safe condition before stopping an activity
- **Avoiding "unsafe" attitudes –** being aware of and avoiding attitudes and practices detrimental to high levels of reliability, such as Pollyanna, summit fever, heroic, pride, fatalism, and invulnerability to error

Work Group Norms

A person's peer group is the largest, single determinant of an individual's behavior on the job. Norms tell people what they are supposed to do, wear, say, and believe; what is acceptable and what is unacceptable; what to look for; what to ignore; how to see things; and how to interpret what they see and hear. Norms are passed on by word of mouth and are enforced by how a person's peers respond when a norm is broken.[9] If work group members think one person is working too hard, they may make jokes and unkind remarks to the person until he/she adopts the group's norm for what is considered an appropriate level of effort. In extreme cases, the peer group may shun or attack the person until he or she complies with the group's "rules."

Leadership Practices

Management's style and response to various challenges or opportunities has a distinct impact on the work culture . Management, through the following leadership practices as described in Chapter 5, "Culture and Leadership," tends to shape the culture of the staff by the following:

- facilitating communication;
- promoting teamwork;
- coaching and reinforcing expectations;
- eliminating latent organizational weaknesses; and
- valuing the prevention of error.

Common Flaws with Cultural Controls

Sometimes it is easier to know when a culture is unhealthy by observing the practices, choices, interactions, and decisions of the organization's personnel. The following examples illustrate some flawed cultural controls:

- placing importance on personal judgment;
- being overly confident in one's own abilities to solve problems;
- being reluctant to challenge the decisions of others;
- relying only on one's own resources;
- applying human performance tools carelessly;
- lacking correction or coaching of at-risk practices, or using human performance tools improperly;
- having inconsistencies between what managers say they want and what they reward or pay attention to;
- making uncritical observation comments so as to not offend those observed;
- initiating disciplinary action for honest mistakes;
- providing bonuses based solely on productivity measures; and
- proceeding to the next action or step before signing off concurrent verification.

Oversight Controls

Vulnerabilities with controls can be found and corrected when management decides it is important enough to devote resources to the effort. The very nature of latent conditions is such that they will not self-reveal, they must be discovered. The fundamental aim of oversight is to improve facility resilience to significant events triggered by active errors in the workplace—that is, to minimize the severity of events. Oversight controls provide opportunities to see what is actually going on in the facility, to identify specific vulnerabilities or performance gaps, to take action to address those vulnerabilities and performance gaps, and to verify that they have been resolved.

Senior Management Team Focus on Human Performance

Since human error is one of the greater sources of risk to the facility, the senior management team must give it careful and regular consideration. Instituting a standing working group structure to monitor human performance has proven successful. This structure promotes management awareness of current challenges to human performance and their effects on performance. This group establishes the vision, strategy, and processes for managing human performance toward a vision of event-free operations. The members of the senior management team, as an example, may serve on a *Human Performance Steering Committee.*

The steering committee or equivalent promotes accountability for human performance at the department-manager level using various measures of human performance, self-assessments, the corrective action program, and other sources of feedback. Managers closely monitor human performance events and trends, evaluate their causes and contributors, and communicate the results to personnel to increase their understanding and awareness. This system of accountability helps verify that human performance processes and changes are implemented as intended, consistent with the organization's purposes, resources, and goals; that expectations are performed to stated standards; and that performance gaps are identified and closed.

Performance Improvement Processes

Systematic performance improvement processes promote continuous improvement. However, weaknesses with oversight and performance improvement have contributed to long-term poor performance. The following flawed oversight controls tend to degrade this line of defense.

- Senior management oversight of the human performance is inadequate.
- Meetings of the Human Performance Steering Committee are held irregularly.
- Self-assessments are not focused on important attributes, or are not formally performed or tracked.
- The measurement and trending of risk-important processes are insufficient or are not performed.
- Root cause analyses are shallow and focus on individual errors without addressing organizational contributors to events.
- There is a lack of rigorous observations of work in the field.
- Managers are unaware of current human performance challenges in their organizations.

- Performance indicators of human performance are ineffective or are not in place.
- Expectations for change management are inadequate.

Human Performance Improvement Plans

Human performance improvement plans (HPIP) provide management with a systematic approach for correcting identified problems. Without plans, improvement is unlikely and rework is probable. An ongoing HPIP addresses the latest challenges to safety related to human performance. The HPIP, a living plan that is updated as new issues emerge, is reviewed during every Human Performance Steering Committee meeting to verify improvement is actually occurring.

PERFORMANCE MODEL

Human Performance – A system is a network of elements that function together to produce an outcome. A facility contains numerous systems, among them, the electrical system, the water circulation system, the work process system, the telephone system, the fire suppression system, and the heating, ventilation, and air conditioning (HVAC) system. There are also numerous intangible systems that function in the facility environment. For instance, the social system, the organizational system, incentives and disincentives systems, and belief systems are examples that typically function behind the scenes. *Human performance can also be considered a system.*

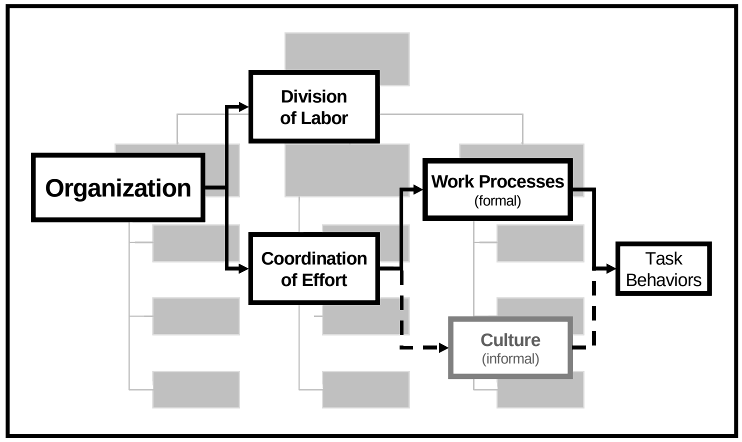
Understanding organizational systems and the impact of facility processes and values and leadership dynamics on performance is important to improving human performance. Systems-thinking involves pondering the multiple causes and effects, the variables that come to bear on the worker at the point of touching equipment in the facility.

An organization is defined as a group of individuals, including managers, supervisors, and workers, with a shared purpose or mission and means (processes) to efficiently apply resources toward the safe and reliable (values) design, construction, operation, and maintenance of the physical facility. Recall that the third principle of human performance states: *individual behavior is influenced by organizational processes and values.* Thus, human performance does not take place in a vacuum. Rather, performance occurs within the confines of the organization. No matter how well work is organized, how good procedures are, how well equipment is designed, or how well teamwork is achieved, people will never perform better than what the organization will support.[10]

Workers make decisions, perform tasks and carry out activities in the workforce according to prescribed protocols Procedures, policies, programs, training, and even culture influence worker behavior. The organization affects all of these. As illustrated in the *Anatomy of an Event* (Chapter 1), organization and the associated management control systems are the prevalent origins of events. Events are not so much the result of error-prone workers as they are the outcome of error-prone tasks and error-prone work environments, which are controlled by the organization.[11]

There is a direct cause-and-effect relationship between the organization and the individual performer. It is the organization that determines the division of labor and the coordination of effort—what people do, when they do it, under what conditions it is accomplished, and how well it is to be done.[12] Roles and responsibilities have to be clearly determined.

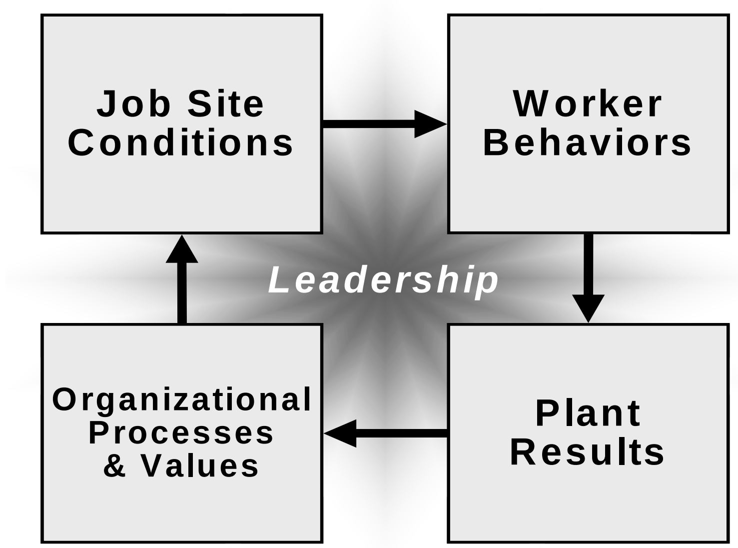
Organizational Effectiveness



Organizational effectiveness is demonstrated by the organization's ability to accomplish its goals. To achieve organizational effectiveness, the management team must organize it resources, especially its people. Organizing involves determining the *division of labor* and *coordinating the effort* as shown in the graphic on organization. Establishing functions, goals, roles and responsibilities, structure, and job assignments determines the division of labor. Managers pay attention to the tools of the organization—things typically written on paper (the administrative control system). They use formal policies, business plans, priorities, directives, goals and objectives, programs, processes, planning and scheduling, action plans, and expectations and standards to provide direction and controls to accomplish the facility's mission. The purpose of controls is to make processes (or tasks) go smoothly, properly, and according to high standards.[13]

Managers shoulder the *responsibility* for overall facility performance. To discharge their responsibilities, managers use work processes as the primary mechanism to coordinate work.[14] Functions carried out by managers to establish work processes include:

- deciding the administrative and functional structure needed to establish a standardized sequence of tasks to be accomplished;
- developing and approving procedures to direct workers' production and maintenance tasks;
- training people to do the work, specifying what, how, why, and when they are expected to accomplish their tasks;
- establishing processes that provide feedback and identify opportunities for improvement; and
- setting priorities of the organization.



The effectiveness of work processes is improved when managers communicate clear expectations to the workers, when they promote open communication, and when they strive for quality procedures and make use of an effective corrective action program.

The *Performance Model* shown in the boxes above is a simple, cause-and-effect model of these interdependencies that shows the organizational nature of human performance. The individual boxes in the model represent either conditions or action, and arrows indicate influence or causality.

Organizational Factors

Organizational factors have a strong influence on human performance. Organizational factors encompass all the ways management uses to direct and coordinate the work of the facility, which together shape the behavior of the people performing their jobs.[15] Collectively, they are the hub of all that goes on at the facility. Organizational factors reveal themselves in engineered controls, administrative controls, cultural controls, and oversight controls (corporate and independent). Some of the more important organizational factors known to impact performance are the following:[16]

- communication methods and practices
- management styles and degree of workforce participation
- tools and resources
- procedure development and review
- cleanliness of the work environment
- layout of facilities and structures
- staffing levels
- experience level of the workforce
- design and modification
- work processes
- management visibility
- human resources policies and practices
- training programs
- priorities (production and safety)
- expectations and standards
- emphasis on health and safety
- work planning and scheduling

For specific jobs or tasks, organizational factors create a unique array of job-site conditions (work environment)—good or bad—that set people up for either success or failure.

Job-Site Conditions

These factors define the unique set of conditions for a particular worker about to perform a specific task or action. The job site is that location or place where behavior occurs during task performance and can be characterized by either environmental or individual factors. Environmental factors (overarching both from the organization and the work environment) include conditions external to the individual and often beyond his or her direct control, such as procedure quality, component labeling, human-machine interface, heat, and humidity. Individual factors include conditions that are a function of the person assigned the task, some of which are also beyond his or her direct control, such as knowledge, skills, experience, family problems, and color blindness.

> *Workplaces and organizations are easier to manage than the minds of individuals workers. You cannot change the human condition, but you can change the conditions under which people work.*
>
> *Dr. James Reason, Human Error*

A special subset of job-site conditions that provoke human error are called error precursors (described in Chapter 2). When such conditions cause a significant mismatch between the task environment and the individual, an active error is likely to occur. The individual's capabilities and limitations (mental, physical, or emotional) may or may not match well with the environmental factors for the work as planned. In summary, job-site conditions shape worker behavior, for good or for bad. More detail is provided in the section on the Behavior Engineering Model.

Worker Behaviors

Worker behaviors include all the actions (or inactions) by an individual at the job site. Examples are component manipulations, use of human performance tools and other work practices, calculations, tool use, verbal exchanges, and procedure use. The effect of individual behavior is a change in the state of facility structures, systems, and/or components—plant results—for good or bad.

Plant Results

This element of the performance model represents the outcomes to the physical plant—good or bad. Examples of facility results include productivity, rejections, non-conformances, forced shutdowns, equipment reliability, safety-system availability, and outage effectiveness, as well as injuries, overexposures, spills, and damage. The quality of facility performance depends on the presence, integrity, and effectiveness of both processes and controls.

MANAGING CONTROLS – Performance Improvement Model

It is a commonly held belief that people are always able to distinguish right from wrong and that people lack proper motivation when they act carelessly or without clear judgment.[17] This is a faulty assumption. Error-prone tasks and work environments are usually created by latent organizational weaknesses. These are undetected deficiencies in organizational processes or values or equipment flaws that create workplace conditions that provoke error (error precursors) or degrade the integrity of controls (flawed controls). Undetected organizational deficiencies plague human performance.

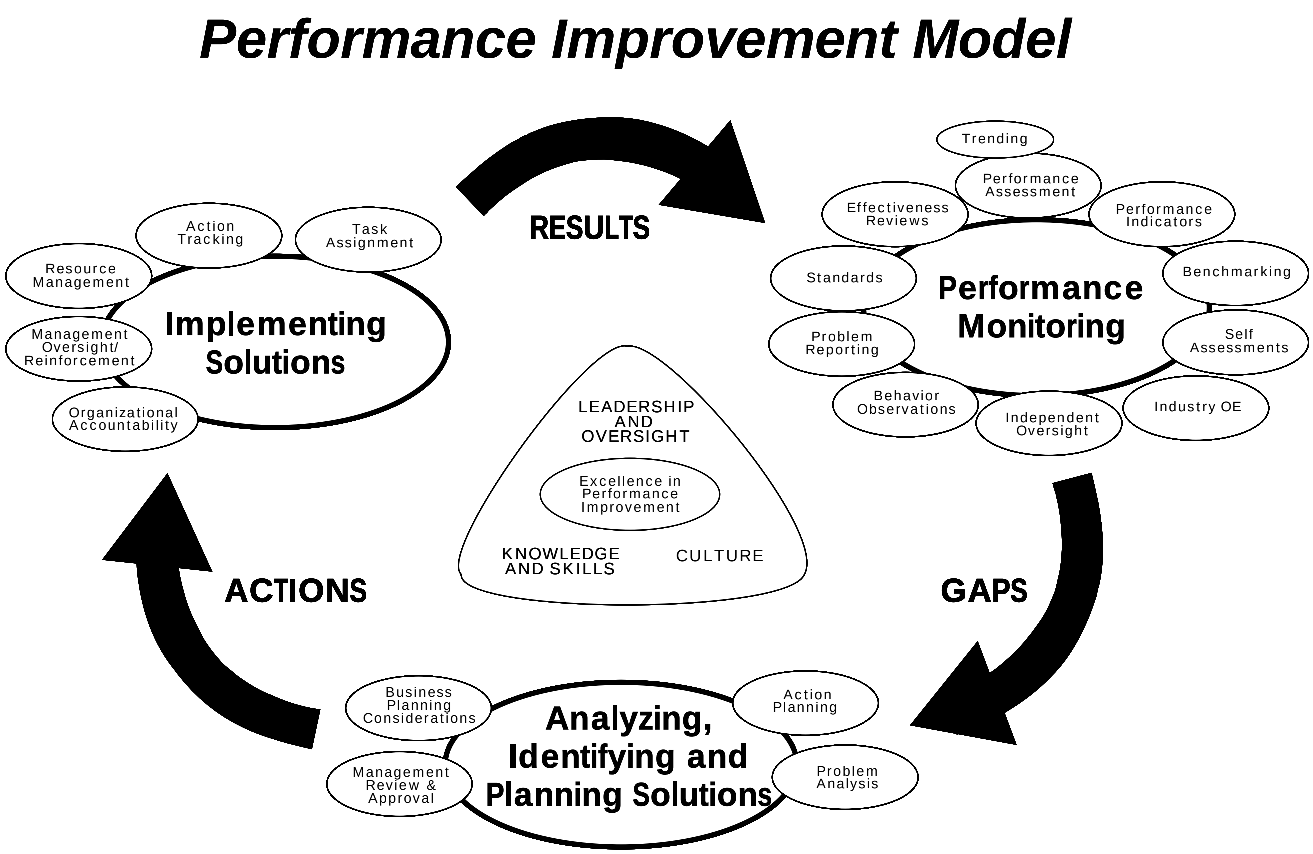
Latent errors or conditions are difficult to prevent. Once they are created they do not fade away, but rather they accumulate in the system. Because of their hidden characteristic, it is management's primary challenge to *limit the time these vulnerabilities exist.* Managers should aggressively identify and correct vulnerabilities with controls at the earliest opportunity. A more significant contribution to safety can be expected from efforts to decrease the duration of latent errors than from measures to decrease their basic frequency.[18]

"Managing" is the ongoing act of planning, directing, or controlling activities and resources toward accomplishing or achieving a purpose. Because significant events are few in number, less information is available about the presence of flawed controls and controls. This means that performance information has to be gathered from other sources. Luckily, these sources are pre-existing and are known to managers, supervisors, and staff. Typically, reliance is placed on field observations, self-assessments, benchmarking, apparent cause evaluations, and trending to provide management with information needed to improve performance and to eliminate vulnerabilities to facility events. See Appendix A for a list of factors known to defeat controls.

Performance improvement involves three primary activities.

- ***Performance monitoring*** – *activities that assess current performance, identifying gaps between current and desired levels of performance or results.*
- ***Analyzing, identifying, and planning solutions*** – *activities that determine actions needed to close the gaps.*
- ***Implementing solutions*** – *the collective activities that result in applying the chosen solutions and verifying their effectiveness to close the gaps.*

These three activities are depicted in the Performance Improvement Model below.



METHODS (Tools) FOR FINDING LATENT ORGANIZATIONAL CONDITIONS

- self-assessments
- trending
- operating experience
- behavior observations
- problem (causal) analysis
- surveys and questionnaires
- corrective action program
- performance indicators
- benchmarking
- independent oversight
- problem reporting
- management oversight, involvement, and reinforcement
- event investigation

Many of the methods for finding latent organizational conditions described below are addressed in more detail in HPI Handbook, Volume 2, section 3 "Management Tools." The information in this section and in section 3 of Volume 2 is targeted to managers and supervisors.

Self-Assessments

The organization can identify gaps in performance by comparing the present performance for a given work activity to the expected performance (based on standards). The difference between actual and expected performance is referred to as the "performance gap." An analysis of this gap in performance yields information about conditions and circumstances needed to determine corrective action. Improvements can then be targeted to reduce the performance gap. This same process can be used to compare actual processes and methods to expected, desired processes and methods. The self-assessment outcome may show shortfalls in worker knowledge, skill, attitudes and experience or in actions or behaviors caused by human fallibilities. It is more likely, however, to indicate deficiencies in job-site conditions related to task demands and the work environment or inadequate processes or weak organizational values that have influenced worker performance. The results of recurring self-assessments will yield patterns of weaknesses in controls.

Behavior Observations

Field monitoring of individual performance is an excellent technique for gathering information about how well the organization supports job-site performance. The purpose of an observation is not to criticize or to judge people, but to review the quality and effectiveness of work preparation, policies, and work practices, as well as their implementation.

An important purpose of observations is to identify opportunities to improve the organization of work, not just worker practices. The scope of behavior observations should include the whole job, not just worker behavior. Not only is it important to pay attention to worker practices but also to monitor the job-site context, potential hazards, and the controls relevant to the work activity. Results should be recorded for trending purposes to help identify strengths and weaknesses. Behavior observations can flush out organizational weaknesses that may not be obvious by other means, especially when this data is included with other information.

The quality of behavior observations is important to gathering accurate performance data. Managers and supervisors must be willing to be critical during an observation. Effective observations are planned, involve watching specific activities and critical steps, require feedback, and are recorded. Observers should be able to model expected behaviors. Their knowledge of human performance tools and at-risk practices must be sharp and exact. Behavioral checklists, such as scorecards or coaching cards, can be used to remind managers and supervisors what to watch for. For specific tasks, knowledge of critical steps, potential errors specific to the task, and targeted worker weaknesses are included within the scope of the observation.[19]

Error rates decrease when managers and supervisors are in the field with workers. Error rates tend to decrease when they monitor work in the field.[20] The following in-field supervisory practices contribute to fewer errors by the workforce:

- checking that workers accurately perceive the risks and priorities associated with the task;
- observing work practices at critical steps;
- reinforcing people appropriately when they exhibit proper and effective work practices;
- correcting people on the spot for at-risk and unsafe practices and coaching performance that otherwise does not meet expectations; and
- solving production problems and removing performance obstacles for the work team or individual.

Problem Reporting

Finding and eliminating latent weaknesses improve dramatically when worker feedback and communication are encouraged. Workers are in the best position to provide the feedback to help identify latent organizational weaknesses. Managers need to optimize related work processes that support work in the field to facilitate worker reporting issues. Workers are the beneficiaries of what the organization provides them, and they are keenly aware of its shortcomings.

Feedback via post-job reviews provides a credible and fresh source of information. The fundamental purpose of information gained from this review is to improve the organization of work as it supports worker performance at the job site—procedures, work packages, training, supervision, workarounds, and so forth. Such information will help improve productivity, identify opportunities to strengthen controls against error and events, and eliminate error precursors embedded in the task. To promote the use of post-job reviews on a routine basis, they should be easy and quick to do, and the worker must see appropriate changes in response to his or her feedback.

Benchmarking

Benchmarking is a powerful management tool that should be considered in strategic organizational improvement planning. Best practices are strategies and techniques employed by top performers. Since top performers are not generally “best in class” in every area, it is important to know exactly the areas being targeted in the top performing organization. Those areas should be matched to areas in the home organization where improvement has been shown to be necessary. From detailed gap analyses, organizations can implement action plans that include benchmarking to address performance shortfalls. Comparison of facility practices with the practices of other like operations that are considered “best in class” is an ongoing effort. The implementation of changes resulting from benchmarking should include an overall strategy to disseminate the need, urgency, methodology, and responsibilities for changing a facility process to match that of a benchmarked organization. Adopting a new process should be carried out with specific objectives in mind that are tied to eliminating identified weaknesses in the pre-existing process.

Performance Indicators and Trending

Performance indicators allow for the identification of undesirable trends. They are tools to help managers focus actions on pressing issues in order to drive continuous improvement. Managers must measure what is important not just what is easy to measure. The following are representative of indicators used at DOE facilities:

- event-free days (number of days between events);
- number of errors from all problem reports submitted during a period of time;
- changes in employee survey parameters from survey to survey;
- industrial safety accident rate;
- document revision requests;
- indices (weighted calculation of several other indicators related to human performance; for example, events, industrial safety, security, radiological);
- procedure compliance;
- observations (scoring of work performance and coaching feedback);
- re-work (amount of maintenance-related work that results in delays or additional costs over a given period);
- out-of-service errors (error rates associated with lockout/tagout activities);
- repeat events;
- workarounds; and
- backlogs.

The Pareto principle, or 80/20 rule, states that 80 percent of the consequences stem from 20 percent of the causes. This naturally occurring pattern helps identify the “big hitters,” so that limited resources can be concentrated on resolving or improving the issues that comprise 80 percent (more or less) of all the problems. Once the big-hitter categories have been identified, analysts can plot each category over time, and they can then be addressed. Corrective actions can be implemented to address apparent causes of those issues. Analysts can plot data over time for these categories to see how each category trends over time.

Operating Experience

There is a natural tendency for people to think “It can’t happen here” or “That won’t happen to me.” As was discussed in Chapter 2, humans underestimate risk and overestimate their ability to maintain control. This sense of invulnerability is an unsafe attitude. The use of operating experience (using feedback acquired from previously operating equipment or a system, both internal and external to the facility) has proven effective in improving performance and keeping facilities safer. Operating experience helps ground individuals to the risks and vulnerabilities associated with specific activities. This must be a relentless pursuit of leadership. Operating experience is most effective when the right information is communicated to the right people in time to make a difference. Lessons learned can be reinforced during various training forums and through day-to-day activities such as pre-job briefings, coaching and reinforcement by supervisors, as well as through engineering design reviews.

Managers must make effective use of operating experience tools (Operating Experience Summaries and the DOE Lessons Learned Program[21]). Managers routinely provide relevant operating experience information to workers at the time they have a need for it. The pre-job briefing is an excellent venue in which to share the operating experience. The challenge is to get workers to internalize the lessons learned and to apply them where appropriate to their upcoming job. Supervisors should ask individuals with key responsibilities in the work activity to explain how they will avoid specific errors committed in the events described. Supervision then considers appropriate controls to avoid or mitigate errors and the consequences suffered in the described event. Supervisors should elicit work history experiences from individuals experienced with the task and assigned to the present job. They will usually have pertinent information, notably about latent weaknesses that hampered previous job performance and what will prove very useful to the other assigned workers.

Independent Oversight

It is common for people to forget to be afraid of the risks and threats and to become complacent about latent weaknesses or flawed controls, especially when they are anxiously engaged day in and day out with their project or activities. Is this condition symptomatic of a lack of “situational awareness”—the accuracy of a person’s current knowledge and understanding of working conditions compared to actual conditions at a given time? Or, is it the absence of “mindfulness,” the presence of a certain “mindset,” or the existence of some unexplainable “blind spots”? How is it that an individual from another operation visiting in the facility can readily spot a process weakness, an unsafe practice, an error-likely situation, or a weakness in a defense that has gone unnoticed by resident workers and staff? It is because the outsider brings a fresh set of eyes, perceptions based on an ideal mental model of what should be and expectations that unencumbered by local culture, experience and constraints. It is exactly this disparity between insiders and independent observers in their ability to recognize degraded conditions that makes independent oversight such a powerful tool.

Reviews of facility activities by outside organizations provide an opportunity to reveal “blind spots” to facility management that otherwise would remain hidden or latent in the system. Quality Assurance departments, corporate oversight groups, DOE oversight and assistance groups, and independent assessment groups, such as the Defense Nuclear Facility Safety Board (DNFSB) oversight, provide opportunities to identify latent conditions. With an emphasis on nuclear safety, DOE evaluations and DNFSB reviews identify conditions, processes, and practices that fall short of expectations for safety and industry best practices that can possibly lead to degraded system performance if uncorrected.

Problem Analysis

Using tools or combinations of tools such as root or apparent cause analysis, and common cause analysis covers the underlying causes of problems or adverse trends, commensurate with their significance. It is not the intent of this handbook to describe these analysis tools in detail.

Analysts conducting root cause analysis of significant plant events should focus on what could have prevented the event rather than simply concentrating on who caused an event. It is also important to determine what controls worked to keep the event from being more severe. When causal analysis is fixated on individual culpability, finding effective corrective actions will be elusive at best, as it is unlikely the analyst will identify the real causes of the event.[22] An effective investigation focuses on discovering the latent weaknesses embedded in the organization, its culture, and the physical plant, rather than simply singling out one or two individuals for counseling or training.

"Inattention to detail" and "not following procedures" are not root causes even though these are still commonly cited as such in the DOE complex. A root cause is the cause that, if corrected, will prevent recurrence of the event. Human error cannot be eliminated completely—inattention will continue to occur despite our best efforts to eliminate it.

Investigations of events triggered by active error are usually distorted by hindsight—the analyst's knowledge of facts after the event that were not known, or knowable, by the principal individuals before the event. Hindsight predisposes the analyst to search for data that confirms the apparent shortcomings of the individual(s). Also, explaining what people could have or should have done explains nothing about why they did what they did. The challenge for the analyst is to determine why actions of the individuals made sense to them at the time. An analyst can build that context by identifying the following for each individual:[23]

- what they were trying to accomplish (goals);
- what they were paying attention to (focus); and
- what each person knew at critical points in the sequence of events (knowledge and situational awareness).

This information is obtainable from the individuals involved, through interviews and by a review of the job-site conditions for each individual (procedures, recorder traces, logs, computer printouts, review of the workplace, equipment, and so forth). The answers to the bulleted questions become the starting point for further investigation into the causes of the event.

The *Anatomy of an Event* model, introduced in Chapter 1, offers another structured approach to analyzing human performance issues. Working backward through the model from the event consequences to the organizational weaknesses that stimulated the event, helps explain the context of performance. Four major areas of fact need to be uncovered: (1) the specific consequences; (2) initiating actions (active errors) and error precursors that provoked the active errors; (3) flawed controls that either failed to prevent the active errors or failed to prevent or mitigate the event consequences; and (4) the organizational weaknesses that contributed to every factor previously mentioned.[24] In the end, the analysis should clearly show the causal links (line of sight) from the organizational weaknesses to the event consequences.

Management Oversight

Fundamentally, management must have assurance that the risk of human error is minimized and controlled, especially during risk-important activities. A system of accountability helps verify that challenges to human performance are aggressively identified and addressed. Management verifies that expectations are performed to standards, that performance gaps are identified and closed, that corrective actions are completed effectively, and so on. See *Human Performance Steering Committee* earlier in this chapter to review one way the senior management team can perform its oversight responsibilities.

Surveys and Questionnaires

Monitoring changes in employee attitudes via periodic surveys identifies trends in values and beliefs. Workforce responses to surveys and standard questionnaires enable comparison of attitudes, values, and beliefs across an organization and detection of changes over time.[25] Survey results help managers determine where their time and effort can be applied most effectively to address misunderstandings and inappropriate values that impact the organizational culture. Questionnaire and survey questions must be carefully designed, tested and tied to specific organizational realities to be effective. Be careful not to ask for input and then fail to do anything constructive with it. There is a tendency in management to ask for input from workers and then not to act on it. When people are uninformed of the results and changes derived from the information gathered, they will become doubtful of management's sincerity in wanting improvement, and will be uncooperative with future surveys.

Corrective Action Program

DOE's Corrective Action Management Program (CAMP) is a comprehensive tool to help management identify, document, evaluate, and trend performance issues to facilitate the development and implementation of appropriate actions to correct problems.[26] CAMP provides management with a tool to systematically adjust controls and performance.

Briefly, the four steps of the program include:

- identifying and reporting problem findings from operational events, internal or external assessments or investigations, observations during daily work performance and worker safety concerns;
- evaluating each problem finding and developing appropriate corrective actions and corrective action plans;
- closing and implementing corrective actions to resolve findings delineated in the corrective action plan; completion and implementation status is tracked and reported to ensure timely and adequate resolution of each finding; and

- completion of all corrective actions for the findings listed in the corrective action plan and an independent follow-up assessment to verify closure.

Change Management

Change management is a methodical process that enables managers to establish the direction of change, align people and resources, and implement the selected modifications throughout the organization. Regardless of the scope of the change, it should be managed. Typically, change management has been reserved for large-scale organizational change and is not considered for day-to-day activities. However, most daily management activity involves some degree of change, such as changes in crew composition, outage schedule, policies, procedures, and equipment. More specifically, schedule changes are a common contributor to facility events.

Experience has shown that change fails most often when it implemented without developing a plan that includes:[27]

- defining the problem;
- determining the current condition;
- determining the desired final condition—a vision of what is expected;
- sufficiently considering the new values, attitudes, and beliefs needed to accommodate the change;
- identifying who is responsible to ensure the change is successful;
- describing the process to achieve the desired change, including consulting with all the people affected by the change;
- establishing a schedule for implementation;
- providing positive reinforcement of new behaviors by supervision and management; and
- specifying the actions planned to verify that the change has been successful.

Effective change management reduces the potential of error by managers when they change things. Without a structured approach to planning and implementing change, the error potential of managers and the support staff is higher. Organizations that have been successful with change have used a systematic process driven by quality leadership as well as excellent management.[28]

APPENDIX A: Warning Flags—Factors that Defeat Controls

The Institute for Nuclear Power Operations (INPO), with the help of several utility executives, conducted a study of utilities that experienced extended plant shutdowns. The results of the study identified several common weaknesses with organization and management. INPO concluded that these latent conditions are conducive to the degradation and accumulation of flawed controls and human-performance-related events. If not responded to aggressively, these weaknesses could lead to permanent facility shutdown and possible closure. INPO refers to these common weaknesses as "warning flags." [29]

- **Overconfidence –** The "numbers" are good, and the staff is living off past successes. Consequently, the staff does not recognize low-level problems and remains unaware of hazards.
- **Isolationism –** There are few interactions with other utilities, INPO, and industry groups. Benchmarking is seldom done or is limited to "industrial tourism," without the implementation of good practices learned. As a result, the plant lags the industry in many areas of performance and may be unaware of it.
- **Defensive and Adversarial Relationships –** The mind-set toward the NRC or INPO is defensiveness or "do the minimum." Internal to the organization, employees are not involved and are not listened to, and raising problems is not valued. Adversarial relationships hinder open communication.
- **Informal Operations and Weak Engineering –** Operations standards, formality, and discipline are lacking. Other issues, initiatives, or special projects overshadow plant operational focus. Engineering is weak, usually through a loss of talent, or lacks alignment with operational priorities. Design basis is not a priority, and design margins erode over time.
- **Production Priorities –** Important equipment problems linger, and repairs are postponed while the plant stays on line. Nuclear safety is assumed and is not explicitly emphasized in staff interactions and site communications.
- **Inadequate Change Management –** Organizational changes, staff reductions, retirement programs, and relocations are initiated before their impacts are fully considered. Recruiting or training is not used to compensate for the changes. Processes and procedures do not support strong performance following management changes.
- **Plant Events –** Event significance is unrecognized or underplayed, and reactions to events and unsafe conditions are not aggressive. Organizational causes of events are not explored in depth.
- **Ineffective Leaders –** Managers are defensive, lack team skills, or are weak communicators. Managers lack integrated plant knowledge or operational experience. Senior managers are not involved in operations and do not exercise accountability or do not follow up.
- **Lack of Self-Criticism –** Oversight organizations lack an unbiased outside view or deliver only good news. Self-assessment processes, such as management observation programs, do not find problems or do not address them; or the results are not acted on in time to make a difference.

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REFERENCES

[1] Hollnagel. Accidents and Barriers, Linkoping, Sweden. p.1; eriho@ikp.liu.se.

[2] Maurino, Reason, Johnston, Lee. *Beyond Aviation Human Factors*, 1995, p.10.

[3] Reason. *Managing the risks of Organizational Accidents*, 1998, pp. 76-77; http://en.wikipedia.org/wiki/chernobyl_accident.

[4] INPO. Significant Event Evaluation and Information Network (SEE-IN) Program Description (INPO [94]-001), 1994, p.7.

[5] Maurino, Reason, Johnston, Lee. *Beyond Aviation Human Factors*, 1995, pp.11-13.

[6] Schein. *Organizational Culture and Leadership,* 3rd edition, 2004, p. 246.

[7] International Society for Performance Improvement. Handbook of Human Performance Technology: Improving Individual and Organizational Performance Worldwide, 1999, p.338.

[8] Porras. Stream Analysis, A Powerful Way to Diagnose and Manage Organizational Change, 1987, p.57.

[9] Porras. Stream Analysis, A Powerful Way to Diagnose and Manage Organizational Change, 1987, p.57.

[10] Maurino, Reason, Johnston, and Lee. *Beyond Aviation Human Factors*, 1995, p.xi.

[11] Reason. Managing the Risks of Organizational Accidents, 1998, pp.127-129.

[12] Schein. *Organizational Psychology*, 1994, pp. 12-15.

[13] Drucker. Management: Tasks, Responsibilities, Practices, 1974, p.218.

[14] Apostolakis. "A Structured Approach to the Assessment of The Quality Culture in Nuclear Installations." A paper presented at the American Nuclear society International Topical Meeting on Safety Culture in Nuclear Installations, Vienna, Austria, April, 1995, p.2.

[15] Porras. Stream Analysis, A Powerful Way to Diagnose and Manage Organizational Change, 1987, pp.35-40.

[16] United Kingdom Health and Safety Executive. Reducing Error and Influencing Behaviour, 1999, p.44.

[17] Wickens. Engineering Psychology and Human Performance, 1992.

[18] Reason. Human Error, 1990, pp. 179-80.

[19] Geller. The Psychology of Safety, 1998, pp. 194-212.

[20] After Entergy implemented its management observation program, which emphasized coaching time, it experienced a significant reduction in problem reports related to human error. 2000, as cited in INPO. Human Performance Reference Manual, 2006, endnote 21, p. 108. Entergy is a New Orleans based utility that provides electrical power to nearly three million customers in Arkansas, Louisiana, Mississippi and Texas.

[21] The DOE Corporate Operating Experience Program is at www.hss.energy.gov/csa/analysis/oesummary/index.html. The DOE Corporate Lessons Learned Program is at www.hss.energy.gov.csa.analysis/11/.

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[22] Maurino, Reason, Johnston, Lee. Beyond Aviation Human Factors, 1995, p. 34.

[23] Dekker. The Field Guide to Human Error Investigations, 2002, pp. 77-99.

[24] Maurino, Reason, Johnston, Lee. Beyond Aviation Human Factors, 1995, p.66.

[25] Rothwell, Sullivan, & McLean. Practicing Organization Development, 1995, pp. 149-152.

[26] The Corrective Action Management Program meets requirements of DOE Order 414.1C. Quality Assurance (6/05). Corrective Action Program Guidance is provided in DOE G-414.1-5. The Corrective Action Tracking System (CATS) is on the web at www.hss.energy.gov.CSA/CSP/CAMP.

[27] Interaction Associates. Facilitative Leadership (course notebook), 1990.

[28] Kotter. Leading Change, 1996, p. 20.

[29] INPO. Human Performance Reference Manual, 2006, pp. 95-96.

CHAPTER 4 - CULTURE AND LEADERSHIP

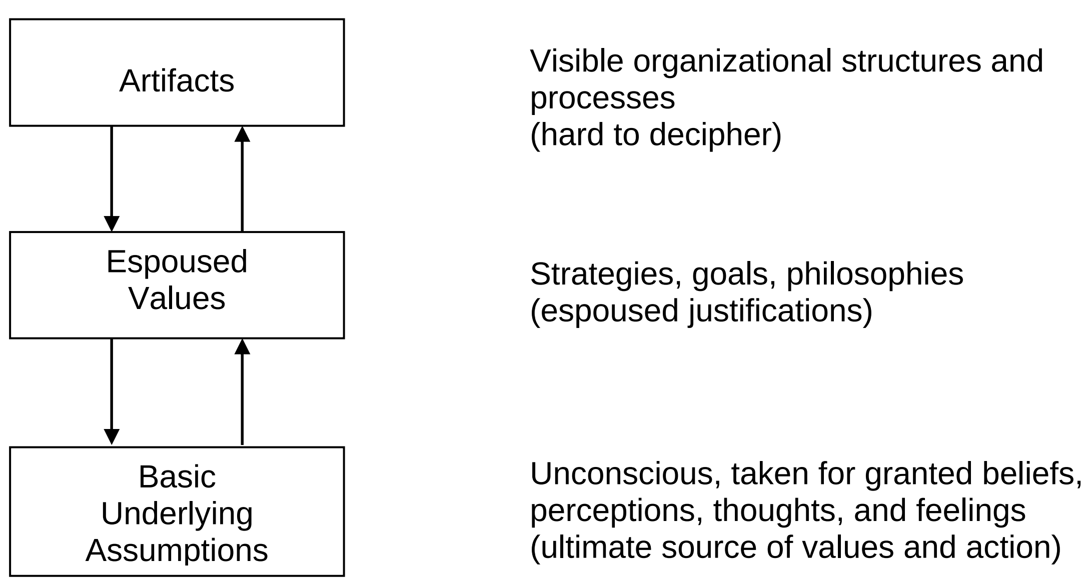
ORGANIZATIONAL CULTURE

Dr. Edgar Schein, professor emeritus at MIT's Sloan School of Management, has created a seminal body of work in the field of organizational development. Included among the 14 published books to his credit are those that deal heavily with organizational culture: *Organizational psychology*, *Organizational Culture and Leadership* and *The Corporate Culture Survival Guide."* Schein views culture as a pattern of shared basic assumptions that the group learned as it solved its problems of external adaptation and internal integration. Over time, this pattern of shared assumptions has worked well enough to be considered valid and, therefore, to be taught to new members as the correct way you perceive, think, and feel in relation to those problems.

Schein suggests that the simplest way of thinking about organizational culture is to liken it to personality and character in the individual. As we grow up we learn certain ways of behaving, certain beliefs and certain values that enable us to adapt to the external realities that face us and give us some sense of identity and integration. As organizations grow and succeed, they undergo the same kind of learning process. What are initially the beliefs and values of the group's founders and leaders gradually become shared and taken for granted if the organization is successful in fulfilling its mission and managing itself internally. It is the past history of success that makes cultural beliefs and values so strong. As organizations grow and age they also develop sub-units, and the learning process described here occurs in these sub-units as well since they have different tasks and different issues of internal integration.[1]

Schein suggests that organizational culture can be considered in three layers as shown in the following graphic.

Levels of Culture



Schein's organizational model illuminates culture from the standpoint of the observer, described by the three levels as shown above. At the first and most cursory level are artifacts (*organizational attributes)* that can be seen, felt, and heard by the uninitiated observer. Included here are facilities, offices, furnishings, visible awards and recognition, the way its members dress, and how each person visibly interacts with each other and with organizational outsiders.

The next level deals with the espoused values (*professed culture)* of an organization's members. Here, company slogans, mission statements, and other operational creeds are often expressed, and local and personal values are widely expressed within the organization. Organizational behavior at this level usually can be studied by interviewing the organization's membership and using questionnaires to gather attitudes about organizational membership.

At the third and deepest level, the organization's *basic underlying assumptions* are found. These are the elements of culture that are unseen and not cognitively identified in every day interactions between organizational members. Additionally, these are the elements of culture which are often taboo to discuss inside the organization. Many of these "unspoken rules" exist without the conscious knowledge of the membership. Those with sufficient experience to understand this deepest level of organizational culture usually become acclimatized to its attributes over time, thus reinforcing the invisibility of their existence. Because cultures are learned by members of the organization, changing culture requires much discussion, communication, and learning and takes a long time to bring to fruition. Changing behaviors is also difficult because people have very strong "patterns" that they follow from habit.[2]

In summary, organizational culture is best defined by the shared basic assumptions that have developed in an organization over time as it learns from and copes with problems. Culture is the sum total of the organization's learning. The culture of a group is defined as: *a pattern of shared basic assumptions that was learned by the group as it solved its problems of external adaptation and internal integration that has worked well enough to be considered valid and, therefore, to be taught to new members as the correct way to perceive, think, and feel in relation to those problems.*[3] In short, "it's the way we do things around here."

SAFETY CULTURE

It is vital that people's shared basic assumptions or beliefs are accurate and support safety. People can become very comfortable with the technology and the fact that "there hasn't been a major event here." Workers can come to believe (usually unconsciously) that their facility or system is robust—it has some safety margin. This mindset can be very dangerous. Assume for a moment that there is an operational hazard present in the system and there also exists this strong belief: the system is robust. This collective belief or assumption results in a lack of a sense of urgency about fixing defective equipment, so a physical barrier fails. Because the plant is robust, operators don't follow all the procedures, so the people barrier fails. Because the plant is robust, people fail to report minor problems or unusual observations, so the learning barrier fails. Finally, because the plant is robust, operators make non-conservative decisions in situations of uncertainty, and the "last chance" barrier fails—the outcome is an undesirable event.[4]

Because of the special characteristics and unique hazards associated with DOE research and defense operations, and the environmental restoration and D & D operations, associated organizations need to nurture a strong safety culture. It must be understood that safety is a collective responsibility in which everyone in the organization shoulders an obligation to ensure that it comes first.

There are several definitions of safety culture that apply to the DOE and its operations. Dr. Jonathan Wert[5] defines *Safety Culture* as "a work environment where a safety ethic permeates the organization and people's behavior focuses on accident prevention through critical self-assessment, pro-active identification of management and technical problems, and appropriate, timely, and effective resolution of the problems before they become crises." The British Health and Safety Commission defines *Safety Culture* as "the product of the individual and group values, attitudes, competencies, and patterns of behavior that determine the commitment to, and the style and proficiency of, an organization's health and safety programs."

Safety culture is about good safety management established by organizations with a holistic, whole of community, whole of life approach. Good safety culture implies a constant assessment of the safety significance of events and issues so that the appropriate level of attention can be given. A strong safety culture is dependent first and foremost on the organization's ability to properly manage safety in the facility over time. Dr. James Reason advocates that three ingredients are absolutely vital for driving the safety culture—and they are the province of top management. These driving forces are *commitment, competence, and cognizance*—the three C's.

Commitment consists of motivation and resources. High levels of commitment are comparatively rare and hard to sustain. This is why the organization's safety culture is so important. Will the organization seek to be the model for good safety practices or simply be content to stay just ahead of the regulators? A good safety culture has to endure changes in senior management. It must provide the necessary driving force regardless of who sits in the corner offices. The resources issue involves funding to achieve safety goals, but more pointedly it has to do with the caliber and status of the people assigned to direct the management of system safety.

Competence refers to the technical competence needed to achieve the safety goals. Paired comparison studies that examine pairs of companies matched in all respects except for safety performance have shown that the two characteristics most likely to distinguish safe organizations from less safe ones are (1) top-level commitment and (2) possession of an adequate safety information system. So, competence is closely related to the quality of the organization's safety information system. Does it collect the right information? Does it disseminate it? Does it act upon it?

Cognizance refers to the correct awareness of the dangers that threaten the facility's operations. Two features are common to organizations lacking the necessary level of cognizance. The first is where those at the top of the organization, possessing the largest degree of decisional autonomy, blame most of their safety problems on the personal shortcomings of those working at the sharp end. The second symptom is where managers treat safety measures like pieces of equipment. They put them in place, then tick them off as another job done. But safety measures have to be watched, worried about, tuned, and adjusted. Cognizant organizations understand the real nature of the "safety war." They see it for what it really is—a long guerilla struggle with no final conclusive victory.[6]

Reason's three C's needed to drive safety are supportive of the idea that a safety culture is a *leadership attitude that ensures a hazardous technology is managed ethically so individuals and the environment are not harmed.* Edgar Schein has said that ". . . one could argue that the only thing of real importance that leaders do is to create and manage culture. . . ." This section of the chapter addresses how leaders mold, influence, and sustain safety culture.

When people are tasked with a work assignment for which they lack specific guidance, they will defer to what they believe is the right thing to do. Often confronted with incorrect, incomplete, or inaccurate procedures or with equipment malfunctions, inadequate tools, and the like, workers regularly have to make tradeoffs between productivity and protection. It is a normal human behavior to want to "get the job done" rather than taking the time to do the job safely due to overconfidence, underestimating risks, and so on. This is especially true when supervisors expect and reward the results and are silent about behaviors needed to stay safe. The reality is that in many organizations safety tends to be assumed, and not much is said about it.

Core values are the underlying set of beliefs and assumptions an individual deems most important for him or herself, the work group, or the organization. Values are necessary to help people with day-to-day decision-making such as the dilemma noted above—an assignment with insufficient guidance. Values are embedded in the organizational culture. They are only helpful when they can be translated into concrete behaviors.[7] Managers must explicitly demonstrate to the workforce by their actions and behaviors that safety has to be preserved as a core value. Managing the culture requires conscious, careful consideration. Without the solidification and preservation of safety as a core value, managers will unconsciously reinforce getting the job done, with production becoming the default core value.[8]

Dr. Ron Westrum believes the flow of information is the most critical organizational safety issue associated with safety culture. Westrum's idea was to characterize general ways of coping with information, especially information that suggests anomaly. Failures in information flow figure prominently in many major accidents, but information flow is also a type marker for organizational culture. In some organizations, information flows well and elicits prompt and appropriate responses. In others, it is hoarded for political reasons or it languishes due to bureaucratic barriers.

Westrum identifies three typical patterns that define how information flows within an organization. The first is characterized by a preoccupation with personal power, needs, and glory. The second is a preoccupation with rules, positions, and departmental turf. The third is a concentration on the mission itself, as opposed to concentration on persons or positions. These patterns are called respectively pathological, bureaucratic, and generative. These preferences create recognizable climates that affect the processing of information and other cognitive activities. The climate not only shapes communication, but also cooperation, innovation, and problem-solving. The table below describes how organizations process information.

How Organizations Process Information

Pathological	Bureaucratic	Generative
Power-oriented Information is a personal resource to be used in a political power struggle. It will be withheld, doled out, or used as a weapon to advance particular parties within the organization. Messengers are shot, responsibilities are shirked. Cross-department bridging is discouraged. Faced with failure—scapegoating is standard.	Rule-oriented Information tends to be stuck in the control stage. This type generates only modest cooperation. Messengers are neglected, standard channels or procedures are used for getting information to the right recipient (often too late to be useful). New ideas often present problems. Cross-department bridging is only tolerated. Faced with failure—seek justice	Performance-oriented Encourage individuals to observe, to inquire, to make their conclusions known; and, where observations concern important aspects of the system, people are proactive in getting the information to the right people by any means necessary. Cross-department bridging is encouraged Faced with failure—inquiry into what is wrong

Patterns of information handling thus reflect the safety climate or culture. If leaders emphasize that information is to help accomplish the mission, then that use will predominate. If leaders emphasize that information must advance departmental goals, then that behavior will predominate. If leaders show through their behavior that information is only important as it advances or impedes their personal interests, then that use will predominate.[9]

Recognizing the varying definitions that have been proffered for safety culture, DOE in partnership with it's contractor community has adopted the following working definition:

An organization's values and behaviors modeled by its leaders and internalized by its members, which serve to make safe performance of work the overriding priority to protect the workers, public, and the environment.

The maturity and robustness of safety culture depends on the degree to which all employees internalize the attributes of safety. Even though the concept of safety culture is somewhat intangible, it is possible to reveal safety culture tendencies in our organizations by observing certain practices and behaviors.[10] The following attributes of a safety culture have been adopted from the DOE ISM Manual:

Leadership

Clear expectations and accountability

- Line managers provide ongoing reviews of performance of assigned roles and responsibilities to reinforce expectations and ensure that key safety responsibilities and expectations are being met.
- Personnel at all levels of the organization are held accountable for shortfalls in meeting standards and expectations related to fulfilling safety responsibilities. Accountability is demonstrated both by recognition of excellent safety performers as well as identification of less-than-adequate performers. In holding people accountable, in the context of a just culture, managers consider individual intentions and the organizational factors that may have contributed.
- Willful violations of requirements are rare, and personnel and organizations are held strictly accountable in the context of a just culture. Unintended failures to follow requirements are promptly reported, and personnel and organizations are given credit for self-identification and reporting of errors.

Management engagement and time in field

- Line managers are in close contact with the front-line; they pay attention to real-time operational information. Maintaining operational awareness is a priority. Line managers identify critical performance elements and monitor them closely.
- Line managers spend time on the floor. Line managers practice visible leadership in the field by placing “eyes on the problem,” coaching, mentoring, and reinforcing standards and positive behaviors. Deviations from expectations are corrected promptly and, when appropriate, analyzed to understand why the behaviors occurred.
- Managers set an example for safety through their personal commitment to continuous learning and by their direct involvement in high-quality training that consistently reinforces expected worker behaviors.

Conservative decision making

- Individuals are systematic and rigorous in making informed decisions that support safe, reliable operations. Workers are expected and authorized to take conservative actions when faced with unexpected or uncertain conditions. Line managers support and reinforce conservative decisions based on available information and risks.
- Individuals are intolerant of conditions or behaviors that have the potential to reduce operating or design margins. Anomalies are thoroughly investigated, promptly mitigated, and periodically analyzed in the aggregate. The bias is set on proving work activities are safe before proceeding, rather than proving them unsafe before halting. Personnel do not proceed and do not allow others to proceed when safety is uncertain.

Open communication/raising issues in an environment free from retribution

- Individuals promptly report errors and incidents. They feel safe from reprisal in reporting errors and incidents; they offer suggestions for improvements.
- A high level of trust is established in the organization. Reporting of individual errors is encouraged and valued. A variety of methods are available for personnel to raise safety issues, without fear of retribution.

Demonstrated safety leadership

- Line managers (from the Secretary to the DOE cognizant Secretarial Officer to the DOE Field Office Manager to the Contractor Senior Manager to the front-line worker) understand and accept their safety responsibilities inherent in mission accomplishment. Line managers do not depend on supporting organizations to build safety into line management work activities.
- Line managers have a clear understanding of their work activities and their performance objectives, and how they will conduct their work activities safely and accomplish their performance objectives.
- Line managers demonstrate their commitment to safety. Top-level line managers are the leading advocates of safety and demonstrate their commitment in both word and action. Line managers periodically take steps to reinforce safety, including personal visits and walkthroughs to verify that their expectations are being met.
- The organization demonstrates a strong sense of mission and operational goals, including a commitment to highly reliable operations, both in production and safety. Safety and productivity are both highly valued.
- Line managers are in close contact with the front-line; they pay attention to real-time operational information. Maintaining operational awareness is a priority. Line managers identify critical performance elements and monitor them closely.

Staff recruitment, selection, retention, & development

- The organization values and practices continuous learning, and requires employees to participate in recurrent and relevant training and encourages educational experiences to improve knowledge, skills, and abilities. Professional and technical growth is formally supported and tracked to build organizational capability.
- Training to broaden individual capabilities and to support organizational learning is available and encouraged – to appreciate the potential for unexpected conditions; to recognize and respond to a variety of problems and anomalies; to understand complex technologies and capabilities to respond to complex events; to develop flexibility at applying existing knowledge and skills in new situations; to improve communications; to learn from significant industry and DOE events.
- People and their professional capabilities, experiences, and values are regarded as the organization's most valuable assets. Organizational leaders place a high personal priority and time commitment on recruiting, selecting, and retaining an excellent technical staff.

- The organization maintains a highly knowledgeable workforce to support a broad spectrum of operational and technical decisions. Technical and safety expertise is embedded in the organization. Outside expertise is employed when necessary.
- The organization is able to build and sustain a flexible, robust technical staff and staffing capacity. Pockets of resilience are established through redundant resources so that adequate resources exist to address emergent issues. The organization develops sufficient resources to rapidly cope and respond to unexpected changes.

Employee/Worker Engagement

Personal commitment to everyone’s safety

- Responsibility and authority for safety are well defined and clearly understood as an integral part of performing work.
- The line of authority and responsibility for safety is defined from the Secretary to the individual contributor. Each of these positions has clearly defined roles, responsibilities, and authorities, designated in writing and understood by the incumbent.
- Individuals outside of the organization (including subcontractors, temporary employees, visiting researchers, vendor representatives, etc.) understand their safety responsibilities.
- Organizations know the expertise of their personnel. Line managers defer to qualified individuals with relevant expertise during operational upset conditions. Qualified and capable people closest to the operational upset are empowered to make important decisions, and are held accountable justly.

Teamwork and mutual respect

- Open communications and teamwork are the norm. People are comfortable raising and discussing questions or concerns. Good news and bad news are both valued and shared.

Participation in work planning and improvement

- Individuals understand and demonstrate responsibility for safety. Safety and its ownership are apparent in everyone's actions and deeds. Workers are actively involved in identification, planning, and improvement of work and work practices. Workers follow approved procedures. Workers at any level can stop unsafe work or work during unexpected conditions.

Mindful of hazards and controls

- Organizational safety responsibilities are sufficiently comprehensive to address the work activities and hazards involved.
- Work hazards are identified and controlled to prevent or mitigate accidents, with particular attention to high consequence events with unacceptable consequences. Workers understand hazards and controls before beginning work activities.
- Individuals are mindful of the potential impact of equipment and process failures; they are sensitive to the potential of faulty assumptions and errors, and demonstrate constructive skepticism. They appreciate that mindfulness requires effort.

Organizational Learning

Performance monitoring through multiple means

- Line managers maintain a strong focus on the safe conduct of work activities. Line managers maintain awareness of key performance indicators related to safe work accomplishment, watch carefully for adverse trends or indications, and take prompt action to understand adverse trends and anomalies.

- Performance assurance consists of robust, frequent, and independent oversight, conducted at all levels of the organization. Performance assurance includes independent evaluation of performance indicators and trend analysis.

- Line managers throughout the organization set an example for safety through their direct involvement in oversight activities and associated performance improvement.

- The organization actively and systematically monitors performance through multiple means, including leader walk-arounds, issue reporting, performance indicators, trend analysis, benchmarking, industry experience reviews, self-assessments, and performance assessments. Feedback from various sources is integrated to create a full understanding.

- Line managers are actively involved in all phases of performance monitoring, problem analysis, solution planning, and solution implementation to resolve safety issues.

Use of operational experience

- Operating experience is highly valued, and the capacity to learn from experience is well developed. The organization regularly examines and learns from operating experiences, both internal and in related industries.
- Organization members convene to swiftly uncover lessons and learn from mistakes.

Trust

- A high level of trust is established in the organization. Reporting of individual errors is encouraged and valued. A variety of methods are available for personnel to raise safety issues, without fear of retribution.
- Credibility and trust are present and continuously nurtured. Line managers reinforce perishable values of trust, credibility, and attentiveness. The organization is just – that is, the line managers demonstrate an understanding that humans are fallible and when mistakes are made, the organization seeks first to learn as opposed to blame. The system of rewards and sanctions is aligned with strong safety policies and reinforces the desired behaviors and outcomes.

Questioning attitude

- Line managers are skilled in responding to employee questions in an open, honest manner. They encourage and appreciate the reporting of safety issues and errors. They do not discipline employees for the reporting of errors. They encourage a vigorous questioning attitude toward safety, and constructive dialogues and discussions on safety matters.
- Individuals cultivate a constructive, questioning attitude and healthy skepticism when it comes to safety. Individuals question deviations, and avoid complacency or arrogance based on past successes. Team members support one another through both awareness of each other’s actions and constructive feedback when necessary.

Reporting errors and problems

- A high level of trust is established in the organization. Reporting of individual errors is encouraged and valued. A variety of methods are available for personnel to raise safety issues, without fear of retribution.

Effective resolution of reported problems

- Organizational systems and processes are designed to provide layers of defenses, recognizing that people are fallible. Prevention and mitigation measures are used to preclude errors from occurring or propagating. Error-likely situations are sought out and corrected, and recurrent errors are carefully examined as indicators of latent organizational weaknesses. Managers aggressively correct latent organizational weaknesses and measure the effectiveness of actions taken to close the gaps.
- Results from performance assurance activities are effectively integrated into the performance improvement processes, such that they receive adequate and timely attention. Linkages with other performance monitoring inputs are examined, high-quality causal analyses are conducted, as needed, and corrective actions are tracked to closure with effectiveness verified to prevent future occurrences.
- Processes are established to identify and resolve latent organizational weaknesses that can aggravate relatively minor events if not corrected. Linkages among problems and organizational issues are examined and communicated.
- Frequent incident reviews are conducted promptly after an incident to ensure data quality to identify improvement opportunities.
- Vigorous corrective and improvement action programs are in place and effective. Rapid response to problems and closeout of issues ensures that small issues do not become large ones. Managers are actively involved to balance priorities to achieve timely resolutions.
- Expertise in causal analysis is applied effectively to examine events and improve safe work performance. High-quality causal analysis is the norm. Causal analysis is performed on a graded approach for major and minor incidents, and near-misses, to identify causes and follow-up actions. Even small failures are viewed as windows into the system that can spur learning.
- Performance improvement processes encourage workers to offer innovative ideas to improve performance and to solve problems.

LEADERSHIP

Fostering the principles for a strong safety culture is one of the most challenging tasks facing the facility management team. Leadership that is successful in achieving a strong safety culture will most likely move a facility to the *next level* of human performance.[11]

> A leader is *any individual* who takes personal responsibility for his or her performance as well as the facility's performance *and* attempts to influence the improvement of the organization that supports that performance.

Human error and its consequences can occur anywhere and at anytime. Fortunately, most errors are trivial, having no consequence on the facility. But errors may challenge safety, and create dire consequences to the facility, its people, and the environment. Therefore, management must clearly understand how the organization influences people's behavior through shared values and the safety culture to get things done

Workers, supervisors, and managers must believe they can prevent human error and its consequences. The assumptions, values, and beliefs people cling to strongly influence the choices they make when they encounter unanticipated situations or when procedure direction is vague or absent. Influencing and managing these factors to encourage people to internalize the above principles is the central theme of leadership in human performance improvement. *Focusing on the people's shared assumptions, values, beliefs, and practices—the culture—is, perhaps, the most effective way to maximize the organization's resistance to events.*[12] A strong culture promotes long-term success of the facility. But culture is hard and slow to change. Focusing on performance, reducing errors and improving work processes is achievable in the short-run.

Leader's Role

The organization is the engine that drives the performance system (see the Performance Model in Chapter 3). This is achieved by directing and influencing human performance and insulating the job site and the performers with layers of controls, barriers, controls, and safeguards. In the past, human performance consisted primarily of workers simply paying attention and doing the job right the first time. However, it is clear from years of accident research that a significant event presents unmistakable evidence of an organizational failure, not simple individual failure. Multiple controls typically fail, contributing to the event's severity. Because it takes teamwork to suffer a significant event, it follows that managers, staff, supervisors, and workers have to work together to be free of events.

Balancing the competition for resources between production and prevention/safety presents a constant challenge to management. Therefore, the leader's role is to *align* organizational processes and values to optimize both production and safety at the job site.

Production and Prevention: Competing Purposes

Production and prevention (error and event) practices always compete in the minds of workers. Leaders have to work hard to keep the facility, environment, and personnel safe. Well-informed leadership at all levels of the organization will ensure that the vision, values, and beliefs (prevention-centered attributes) do not conflict with the mission, goals, and processes (production-centered attributes). Consistency and alignment promote both production and prevention behaviors—together generating the desired long-term results as illustrated in the graphic below.

Production behaviors are those actions or activities aimed toward meeting specific schedules to achieve mission objectives by producing a product within deadlines and budget considerations. The outcomes of production are self-evident—completing jobs on schedule, operating and maintaining equipment, generating products, minimizing expenses, and satisfying the customer.

Error-prevention behaviors, such as self-checking, peer-checking, reviews and approvals, and procedure use, *avoid* errors and events. Prevention behaviors require that people think, be "mindful," while executing prevention tactics. Production activities have to slow down long enough to allow people to think, while executing prevention tactics to prevent errors. In contrast to the noisy evidences of production behavior outcomes, the outcomes of prevention activities are the quiet non-events. There is no shouting, clapping of hands, exchanging "high fives," or staff parties. Following a near miss in the facility, people will express concern and will take part in discussions of the circumstances. Otherwise, workers do not generally comment or show emotion following a given period of safe operations. For this reason, it is relatively easy for workers to come to regard prevention activities as optional when they conflict with the accomplishment of production objectives.

Production behaviors naturally take precedence over prevention behaviors unless there is a strong safety culture—nurtured by strong leadership. Both production and prevention behaviors are necessary for long-term success. But sometimes managers err when they *assume* people will be or are safe. Safety and prevention behaviors do not just happen. They are value-driven, and people may not choose the conservative approach because of the stronger production focus of their immediate supervision or work group. Therefore, *leadership is a defense.* A robust safety culture requires aggressive leadership that emphasizes the principles and attributes of a strong safety culture.[13] *Leadership is not optional.*

KEY LEADERSHIP PRACTICES

Five leader behaviors that promote excellence in human performance have been identified. Leaders act to influence both individual and organizational performance in order to achieve high levels of facility safety and performance through the following practices:[14]

- facilitate open communication;
- promote teamwork;
- reinforce desired behaviors;
- eliminate latent organizational weaknesses; and
- value error prevention.

Facilitate Open Communication

In many major accidents there was someone who knew something that if it had been communicated in time to the right people could have prevented the accident from taking place. It is this knowledge that reinforces the dictum that communication is the most effective defense against significant events.[15] Effective leaders work hard to root out any obstacles to communication. The organizational atmosphere must promote open, candid conversations about safety. Leaders, no matter what positions they hold, actively encourage others to identify error-likely situations and latent organizational weaknesses.

A safe atmosphere is cultivated when people treat each other with honesty, fairness, and respect—when they establish healthy relationships. An atmosphere of camaraderie, teamwork and collaboration motivates individuals to improve the effectiveness of the organization. Eventually, people become more willing to be held accountable and they seek assistance by admitting to and learning from errors.

If an individual believes his or her errors will be punished, then information related to those errors will likely remain obscure. In a *just* environment, the likelihood that a problem will be reported increases. High-performing organizations do not punish employees who make errors while trying to do the right thing.[16] Healthy organizations view error as an opportunity to learn.

Promote Teamwork

People have difficulty seeing their own errors, especially when they are working alone. Teamwork may improve the ability of individual team members to collectively prevent human performance problems. Because people are fallible, teamwork should make individual thinking and reasoning *visible* to the other members of the team. Dialogue between members of a team gives each one the opportunity to challenge assumptions and to detect team errors.

Accident research conducted in the aviation industry in the late 1970s showed repeatedly that failures in the cockpit to work as a team had devastating consequences. Sixty-six percent of air carrier, 79 percent of commuter, and 88 percent of general aviation accidents involved flight crew failures in interpersonal communications, decision-making, and leadership. In fact, more accidents were caused by these failures than by lack of technical flying skills.[17] These findings led the airlines to create training programs to improve teamwork in the cockpit. Key goals of the "Crew Resource Management" (CRM) training included the following, among others:

- teaching team members how to pool their intellectual resources;
- acquiring collective situational awareness that admits challenges from junior team members;
- improving communication skills; and
- emphasizing the importance of teamwork.

The behavioral characteristics important to the success of pilot performance on the flight deck from the CRM training were adopted in the nuclear power industry in the early 1990s, with the development of the Control Room Teamwork Development Course. The following attributes for improving teamwork, proven essential to pilot performance and control room operator performance are applicable to teams working at DOE facilities.

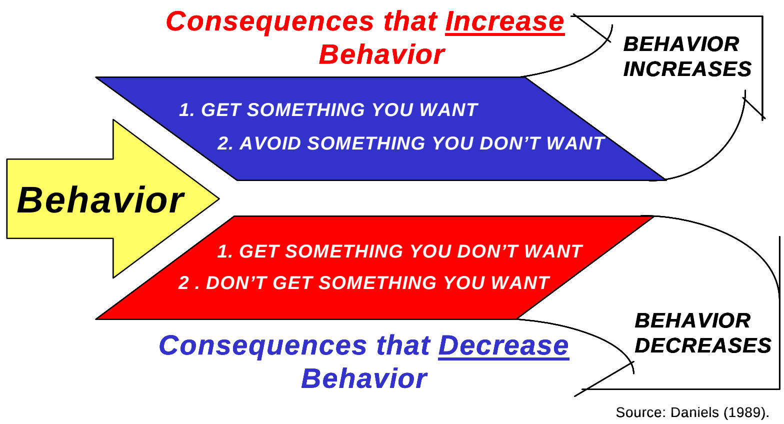
- **Ask Questions** – asking a series of questions to understand what is happening with the facility.
- **Advocate** – expressing a concern, position, or solution and making certain others understand what the individual knows.
- **Take Initiative** – taking the initiative to influence the behavior of others, especially when it comes to the condition of the physical plant (facility).
- **Manage Conflict** – resolving differences of opinion and getting all information on the table to reach the best solution; maintaining open communication channels among team members.
- **Critique Performance** – learning from experience, identifying what works well, and pinpointing what areas need improvement.

Reinforce Expectations

There is a direct cause-and-effect relationship between a manager's actions and an employee's behavior precisely because *behavior is motivated by its consequences*.[18] Consequences, far more than training, directives, or threats, reinforce behavior. People tend to seek and do things they like and avoid things they do not like.[19] This is a fundamental principle of human behavior. If people are to make a habit of applying human performance tools, then positive consequences must be associated with their behaviors.

Managers and leaders need to positively reinforce individuals who obtain value-added results through safe behaviors. Individuals who cut corners to get jobs done on schedule and under budget at the expense of quality and safety should be corrected, coached, or, perhaps, counseled. Consequences either keep the behavior going or stop it in the long term. Leaders should take time to understand and learn how to use reinforcement to promote targeted behaviors.

All behavior that is occurring in the facility now is the result of consequences that are also occurring now. Similarly, the organization is perfectly attuned to get the performance it is getting, right now. All behavior is reinforced. If at-risk behavior is common, it is because management has not made a difference with appropriate negative consequences. Behavior has four basic consequences.[20] The following model describes the effect consequences have on behavior.



The following consequences can be used to get the desired performance by targeting specific behaviors.

- **Positive Reinforcement – "**Get something you want" enhances the probability that the preferred behavior will recur and maximizes performance. This optimizes use of discretionary effort by the individual.
- **Negative Reinforcement –** "Avoid something you don't want" enhances the probability that the preferred behavior will recur, but only to meet the minimum standard.
- **Note**: Consequences that cause behavior to either increase or continue at a high standard are known as "reinforcers."
- **Punishment –** "Get something you don't want" reduces the probability that undesired behavior will recur if unwanted consequences are consistently coupled with the behavior. Punishment may also involve "losing something you don't want to lose"—a penalty. Sometimes this is necessary to get the new expectation started for an individual. However, it should not be used for the long term.
- **Extinction –** "Don't get something you want" reduces the probability that undesired behavior recurs, since nothing happens when that behavior occurs. Usually, the behavior eventually disappears after several repeated attempts.

Training, procedure direction, incentives, reminders from supervisors or peers, administrative policies, and expectations precede and set the stage for individual performance. These preexisting elements have more strength when they (a) specify the behavior, (b) specify whom, (c) occur at the right moment (just in time), and (d) imply the consequences.[21] The consequences in terms of reinforcers and incentives need to be determined for desired behavior. Expectations need positive reinforcers, while unacceptable behaviors need penalties—disincentives—or the elimination of positive reinforcers that motivate unsafe or at-risk practices. Any punishments or penalties existent in the system also need to be eliminated for expected practices. Positive reinforcers are more effective if they are *positive* for the individual, *immediate* with respect to when the behavior occurs, and *certain*. Penalties are stronger if the consequence is negative, immediate, and certain for the individual concerned.[22]

Eliminate Latent Organizational Weaknesses

Organizational weaknesses show up as vulnerabilities, flaws, and defects in controls and controls (engineered, administrative, cultural, and oversight controls). Methodically searching for and eliminating latent organizational weaknesses eliminates factors that contribute to significant events. Chapter 3 describes several methods of finding latent organizational weaknesses, which are listed here below for reference:

- self assessments
- performance indicators
- trending
- benchmarking
- operating experience
- independent oversight
- behavior observations
- problem reporting
- problem (causal) analysis
- management oversight, involvement and reinforcement
- surveys and questionnaires
- event investigation
- corrective action program

The use of a systematic diagnostic approach for discovering recurring individual or work group performance problems provides another means of identifying organizational weaknesses. Managers and supervisors need a tool that helps them develop a clear understanding of a performance discrepancy and why it is happening. With the aid of the Behavior Engineering Model (BEM) discussed below, performance analysis helps define the performance gap by contrasting current performance with desired performance and systematically identifying the factors that contribute to the performance gap. Once valid reasons for the performance gap are understood, the manager or supervisor can develop more effective and efficient corrective actions. A sample *Performance Gap Analysis* form is provided in Appendix A to help in the analysis and solution to human performance problems. Starting with a known performance problem, the user(s) searches for answers to a series of questions that help in determining the performance discrepancy and selecting potential corrective actions.

- what is the performance problem?
- Is the problem worth solving?
- Is there clear direction to perform as desired?
- Are there appropriate consequences for performance (behavior)?
- Do the workers already know how? (Could they do it if their lives depended on it?)
- Are there other obstacles to desired performance?

Value the Prevention of Error

People's beliefs and attitudes toward hazards and error traps affect their adherence to high standards. If error-free performance (avoiding active errors) is **not** held up as an important value or is not expected for daily work; then people may adopt unsafe practices to get their work done; possibly placing themselves, others, or the facility at risk of an event. Consistently maintaining high standards communicates the value of error prevention. By clinging to high standards regardless of the perceived risk, adherence to expectations will become the norm.

Positive attitudes about error prevention depend greatly on what is rewarded and which behaviors are reinforced. It is easier to change behavior when positive attitudes exist. Positive values and attitudes follow behaviors that consistently result in success for the individual. It is not necessary for values and attitudes to precede behavior, but it is preferable.

The most effective way to communicate values is to act in accordance with them while reinforcing people when they apply them.[23] The following leader behaviors convey the values of the organization, in order of influence:[24]

- what managers pay attention to, measure, and control;
- reactions to an accident, event, or crisis;
- allocation of resources;
- deliberate attempts to coach or role model;
- criteria for allocation of rewards and punishment; and
- criteria for selection, advancement, and termination.

If those in positions of responsibility and influence react appropriately, with integrity, and consistent with stated values, people will adopt safe behaviors.

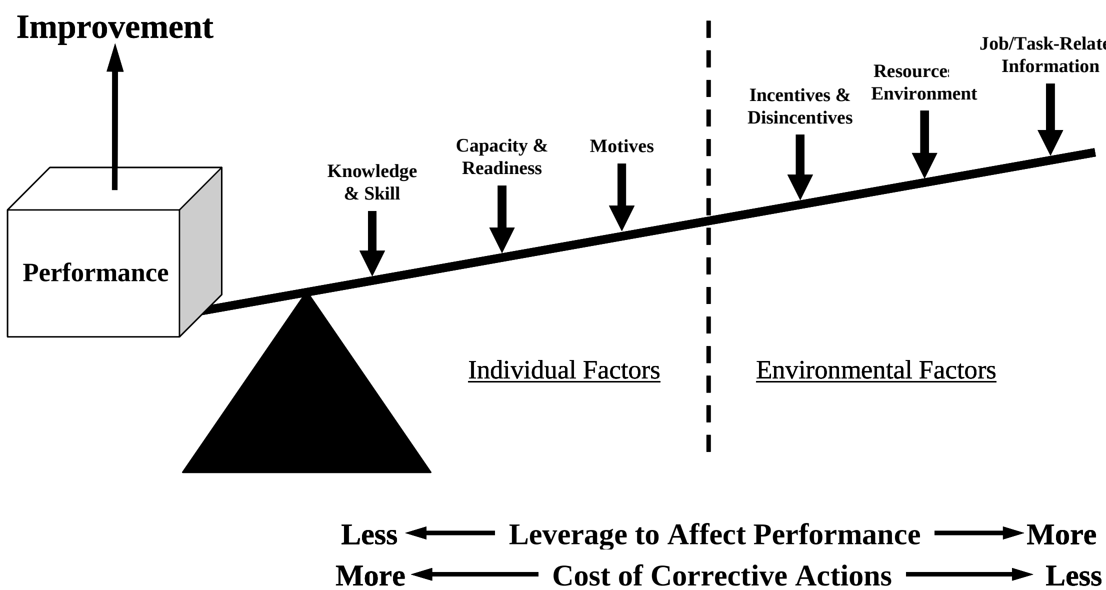
BEHAVIOR ENGINEERING MODEL (BEM)

The Behavior Engineering Model (BEM) is the original work of Tom Gilbert as described in his book *Human Competence, Engineering Worthy Performance* (1978). BEM is an organized structure for identifying potential factors that impact performance at the job site and for analyzing the organizational contributors to those factors. As previously stated, job-site conditions that affect behavior can be categorized into two types of variables: (1) the *environment* and (2) the *individual*. Environmental factors include conditions external to the individual; individual factors include internal conditions generally under the person's control. However, some aspects of human nature, such as stress, instinctive reflexes, and mental biases, are not always controllable.

The BEM specifies those factors relevant to the individual performer and the environment in which the person performs. The BEM illustrated in two tables on pages 4-15 through 4-18 is a derivation of Tom Gilbert's original work. In reference to headings on the BEM table, prior conditions that stimulate behavior—*direction to act*—include directives, knowledge, or cues that inform or prompt a person to act. Job-site conditions that set the occasion for behavior—

opportunity to act—include those factors that make action achievable or realizable. And conditions that tend to reinforce the act—*willingness to act*—are shaped by the match of the individual's motives with the incentives associated with the job or task. These categories attempt to describe the "stimulus-response" components of human behavior.[25]

Strategically, environmental factors provide the greatest leverage in terms of potential for improving human performance, shown below. Leverage and cost are important factors to consider when determining corrective actions. Think back to the *Anatomy of an Event*. It is estimated that 85 percent or more of the causes of facility events have their origins in the processes and culture of the organization. Changes in environmental factors offer greater impact at less expense on performance improvement than changes at the individual level.[26] For example, if the causes of a performance problem point to individual factors (motives, capacity/readiness, and knowledge and skills), implementation of corrective actions would have less immediate influence and the cost in generating the desired improvement will likely be greater.[27]



The BEM is illustrated in the following tables*[8]. The first describes those job-site conditions that are relevant to the performer's work environment, and the second describes conditions relevant to the individual. Deficiencies with the numbered items can create error-likely situations for the individual during the task at hand.

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*[8] INPO has since further defined the BEM concept to more specifically apply to nuclear power plants. The new model is referred to as BEM-N for BEM-nuclear. INPO also credits the International Society for Performance Improvement (ISPI) for their contributions to that work. DOE also credits ISPI and makes note of the many historical and ongoing contributions of ISPI members to advancing the scholarship and practice in performance management.

	Direction to Act	Opportunity to Act	Willingness to Act
	Job or Task-Related Information (requirements / guidance on what one is supposed to do and how well)	**Resources and Environment** (external conditions affecting performance of the job or task)	**Incentives and Disincentives** (an environment of rewards and sanctions explicitly or implicitly associated with the job or task)
Environmental Factors	1. Job or task goals, desired results, roles and responsibilities, and criteria for success are clearly identified. 2. The risk importance of the job or task and critical steps, if any, have been denoted and communicated as such. 3. Clear expectations and standards for the conduct of work exist and have been communicated. 4. The usability, accuracy, and availability of procedures support error-free performance. 5. Relevant feedback on previous job or task performance, including opportunities for development, has been given to the individual (if applicable).	1. Tools, material, clothing, furniture, facilities, systems, and equipment accommodate human limitations and are available and accessible. 2. Other individuals or organizations are available for support, if needed. 3. Adequate time is allotted, and other work conditions that could hinder performance are eliminated or minimized. 4. The values, attitudes, and beliefs of the person's immediate work group about hazards in the workplace support safe practices.	1. Financial and non-financial rewards and disincentives are contingent on performance. 2. Competing incentives for poor performance are eliminated. 3. The job or task provides opportunities for success and career advancement, meets employee needs, and results in identifiable pieces of work traceable to the individual. 4. People are treated with honesty, fairness, and respect regardless of position in the organization. 5. Work group standards are consistent with the above.

	Direction to Act	Opportunity to Act	Willingness to Act
Environmental Factors	**Relevant Error Precursors**: • simultaneous, multiple tasks • repetitive actions; monotonous • irreversible actions • interpretation demands • unclear goals, roles, and responsibilities • lack of or unclear standards • confusing procedure or vague guidance • unclear strategic vision • meaningless rules • excessive communication requirements • delays or idle time • long-term monitoring	**Relevant Error Precursors**: • time pressure • distractions / interruptions • changes / departures from routine • confusing displays or controls • identical and adjacent displays or controls • workarounds • OOS[ϕ] instrumentation or warning systems • hidden equipment response • unexpected equipment conditions • lack of alternative indication • complexity • unavailable tools, parts, etc. • high data flow • back shift / recent shift change • adverse physical climate / habitability • conflicting conventions; stereotypes • backshift; recent shift change • poor equipment layout / access • nuisance alarms • equipment sensitivity to vibration	**Relevant Error Precursors**: • high workload • fear of consequences of mistakes • production overemphasis • personality conflict • excessive time on task • repetitive actions / monotony • mistrust among coworkers / work groups • regular use of at-risk practices • excessive time on task • excessive group cohesiveness / peer pressure • no accounting of performance • acceptability of “cook-booking”

	Direction to Act	Opportunity to Act	Willingness to Act
	Knowledge and Skills (basic/specialized understanding of concepts, theories, system construction, fundamentals, and skills)	**Capacity and Readiness** (physical, mental, and emotional factors influencing individual's ability / capacity to perform a job or task)	**Personal Motives** (intrinsic & induced motivation related to an individual's needs for achievement, affiliation, security, and control)
Individual Factors	1. Individual is qualified for the job or task and possesses the knowledge, skills, experience, and proficiency necessary to perform the task successfully. 2. Individual understands the job or task objective(s), critical steps, and potential consequences if performed improperly. 3. Individual understands the roles and responsibilities of others.	1. Individual possesses the intelligence, sociability, aptitude, size, strength, and dexterity to perform the job or task successfully. 2. Individual is available for work, undistracted, and fit for duty.	1. Individual cares about performing the job or task well. 2. Individual possesses a healthy work ethic and is willing to do what is right regardless of what others would do. 3. Individual feels that the job or task is meaningful and attainable, progress is recognizable, and the task generates a personal sense of accomplishment.

	Direction to Act	Opportunity to Act	Willingness to Act
Individual Factors	**Relevant Error precursors**: • unfamiliarity with task • first time with task • new technique not used before • lack of proficiency • lack of experience • imprecise communication habits • indistinct problem-solving skills • unaware of critical parameters • tunnel vision (lack of big picture)	**Relevant Error precursors**: • stress • habit patterns • assumptions • complacency or overconfidence • mind set • Pollyanna risk perception • mental shortcuts (biases) • limited short-term memory; attention span • limited perspective (bounded rationality) • illness or fatigue • anxiety • poor teamwork skills • major life event • sugar cycle (after a meal) • poor manual dexterity • low self-esteem; moody • physical reflex or imprecise physical action • physical size too large or small for task • human variability • spatial disorientation	**Relevant Error precursors:** • production, "get-r-done" mindset • willingness to sidestep the rules for personal gain • "unsafe" attitude toward critical steps • questionable ethics • boredom • fear of failure / consequences • excessive professional courtesy • excessive group cohesiveness • social deference • no sense of control / learned helplessness • avoidance of mental strain

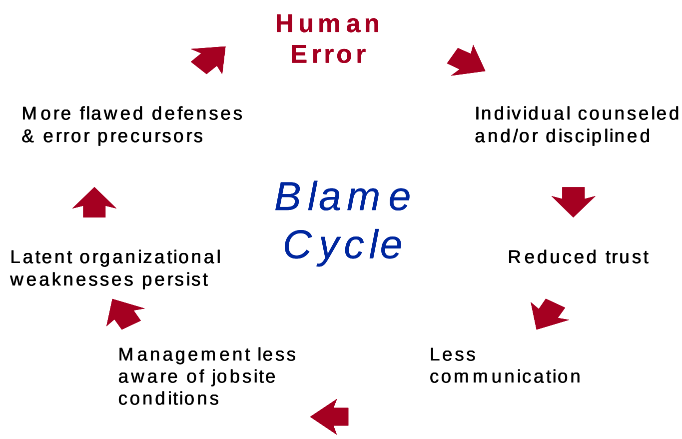
The BEM can serve as an analysis tool for evaluating human error and related performance problems, providing a framework for exposing the real root causes that originate within the organization.

The BEM contains many of the factors—good and bad—that influence human performance, including *error precursors*. The BEM is included here to show that error precursors, like other job-site conditions, are the result of organizational processes and values. In each case, one or more aspects of the organization that establish a job-site condition or error precursor can be identified. For instance, an individual's level of knowledge is likely an outcome of the organization's training program, or the human resources selection process may have overlooked required abilities necessary for the task at hand.[28]

CREATE A JUST CULTURE

The Blame Cycle

The "blame cycle" depicted below is urged on by the belief that human error occurs because people are not properly motivated.[29] In reality, no matter how motivated an individual is, active errors will continue to occur, occasionally. Events will continue as long as event investigations stop prematurely at the active human error. The true causes (typically organizational weaknesses) will not be discovered—will remain latent or hidden—and errors and events will persist.



Categories of Violations

It is important to recognize that there are at least two major categories of violations—*routine and thrill-seeking or optimizing*. Routine violations typically involve corner-cutting at the skill-based level of performance by taking the path of least effort between two task-related points. These shortcuts can become a habitual part of a person's behavior, particularly when the work environment is one that rarely sanctions violations or rewards compliance. Routine violations are also prompted by "clumsy" procedures that direct actions along what seems to be a longer-than-necessary pathway.[30] Routine violations are not necessarily reckless. Routine violations often look like latent weaknesses.

Thrill-seeking or optimizing violations are violations "for the thrill of it." Thrill-seeking violations reflect that human actions serve a variety of motivational goals and that some of these are quite unrelated to the functional aspects of the task. These violations are committed to appear macho, to avoid boredom, or simply for kicks. This category of violation is reckless.

In some organizations employees are named, blamed, shamed, and re-trained based on the consequence of their action, not the intent of the action. If either the violation or error they committed caused an accident or an event of some kind, they are disciplined, but the very same actions (both violations and errors) without a consequence, are ignored or allowed to slide. In some organizations people are allowed to commit violations right along until there is an event, then all hell breaks loose. What this means is that someone who inadvertently errs is held accountable for their actions in the same fashion that someone who intentionally performs work he or she knows is contrary to known standards.

A just environment is all about getting the balance right between how willful violations and unintentional errors are addressed in the organization. All too often organizations do not make clear the distinctions between errors and violations. A just organization clears the smoke in the air between erring and violating. To do so, management sets a zero tolerance policy for reckless conduct—bad acts that we call violations. Zero tolerance for violations is balanced by the belief and the widespread confidence among the leadership that the vast majority of unintended unsafe acts will go unpunished as honest errors—unintended departures from expected behavior—on the part of the performer. There are proven methods to help organizations determine culpability for serious incidences in which unsafe acts are involved.

The Foresight Test

The question to ask is: "Did the individual knowingly engage in behavior that the average individual in the work group would recognize as being likely to increase the probability of making a safety-critical error?" If the individual's peers respond that they would have recognized the action as promoting an error, then it is likely the individual in question should also have recognized the same thing. If the peers failed to see the connection between the action taken and increased risk, then it is reasonable to assume that the individual also did not see the connection. In any one of the following situations, however, the answer to this question is likely "yes" and as such is indicative of culpability:

- performing work under the influence of a drug or substance known to impair performance;
- clowning around while driving a towing vehicle or forklift truck or while handling other potentially damaging equipment;
- taking unwarranted shortcuts like signing off on jobs before they are completed; and
- using tools, equipment, or parts known to be sub=standard or inappropriate.[31]

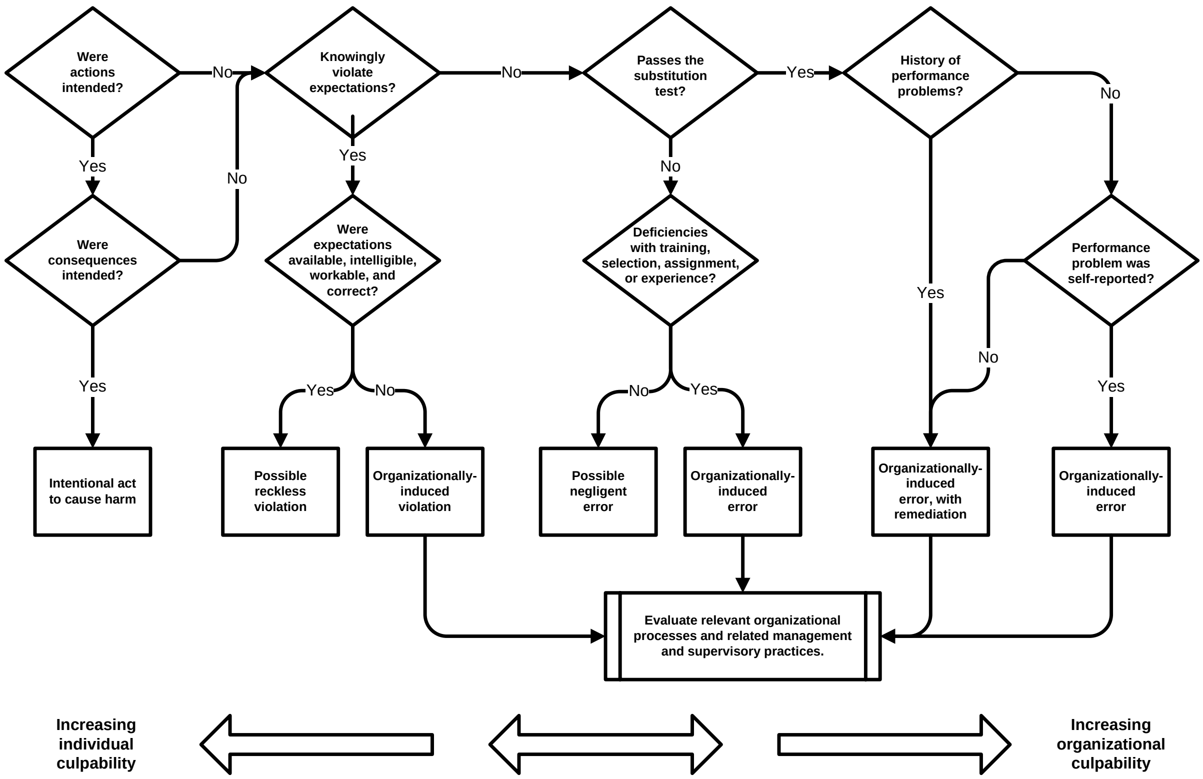
Keep in mind the Foresight Test is a "rule of thumb" measure. There will likely also be extenuating circumstances associated with any of these situations.

The Substitution Test

This test is in keeping with the principle that the best people can make the worst errors. This exercise involves substituting the individual concerned in the event with other individuals who do the same kind of work and who have comparable training and experience. Then the question is asked: "In light of how events unfolded and were perceived by those involved in real time, is it likely a different person with similar skills and training would have behaved any differently?" If the answer repeatedly comes back from the selected peers, "probably not," then apportioning blame has no place here and would likely obscure the underlying systemic deficiencies. Another way to use the substitution test is to ask the question in a different way of a small number of the erring individual's work mates: "Given the circumstances that prevailed at the time, could you be sure that you would not have committed the same or a similar type of unsafe act?" If the response is "probably not," then blame is very likely to be inappropriate. It is a "blameless" error."[32] The substitution test is often used in conjunction with the Culpability Decision Tree, which is discussed below.

The Culpability Decision Tree

The logic diagram below is a proven management tool intended to help determine the culpability level of an individual in response to events or near misses triggered by human error.[33] When used in conjunction with the organization's accountability policy, the tool supports the fair and consistent application of disciplinary outcomes across all departments and work groups. An explanation of how to make use of the Culpability Decision Tree is provided in Appendix B. The tool is an adaptation of Dr. James Reason's Culpability Decision Tree in his book, *Managing the Risks of Organizational Accidents*, which provides further in-depth description of the use of the diagram.



When an event is initiated by an *honest* error, as determined by one or more of the tools described above, the entire system that supports the performance in question should be evaluated (see "systems-thinking" in Chapter 3). Events triggered by human error are often symptomatic of a *system failure*. Instead of asking how the individual failed the organization, the question "how did the organization fail the individual?" would be more appropriate. In addition to the individual, what or who could have *prevented* the event? What flaws or oversights in work processes, policies, or procedures contributed, promoted, or allowed the error and event to occur? Because the majority of the causes of events originate in the system of controls, processes, and values established by the management team, management's first reaction to events should be to look within the organization.

A just culture is a prerequisite for a reporting culture. Useful tips for establishing a reporting culture appear in Appendix C.

ATTACHMENT A – PERFORMANCE GAP ANALYSIS♠

What is the performance problem?	a. What is currently happening?	
	b. What should be happening (desired performance)?	
Is the problem worth solving?	a. Does the problem affect plant performance or personnel safety?	Yes ☐ No ☐
	b. What is the potential cost or consequence of doing nothing?	Yes ☐ No ☐
1. Is there clear direction to perform as desired?	a. Are expectations, standards, priorities, roles, and responsibilities clear and understood by the performer(s)?	Yes ☐ No ☐
	b. Are resources, tools, equipment, and other assistance available and adequate?	Yes ☐ No ☐
	c. Are work documents accurate, do they contain sufficient detail, and are they usable for the performer(s)?	Yes ☐ No ☐
	d. Does the individual(s) get visible, objective feedback on the quality of work?	Yes ☐ No ☐
	e. Is the risk significance of the job/task clearly stated?	Yes ☐ No ☐
	f. Are there conflicts in direction and standards (between procedures, supervisors and managers, departments, and so forth)?	Yes ☐ No ☐
2. Are there appropriate consequences for performance (behavior)?	a. Is the desired performance punishing to the performer (more work, delays, anxiety, ridicule, fatigue, and so forth)?	Yes ☐ No ☐
	b. Is current performance rewarding to the performer?	Yes ☐ No ☐
	c. Does the performer experience positive consequences for good performance? (If yes, are they immediate and certain?)	Yes ☐ No ☐

3. Do they already know how? (Could they do it if their lives depended on it?)	a. Is the performer(s) qualified and has he/she done it properly before? (If yes, knowledge and skills are probably satisfactory.)	Yes ☐ No ☐
	b. Are the tasks performed often enough to maintain proficiency? (If yes, see 3.D. If no, then provide opportunities to practice.)	Yes ☐ No ☐
4. Are there other obstacles to desired performance?	a. Are there personal problems beyond the performer's control that hinder desired performance (such as FFD, medical, family issues, physical limitations)?	Yes ☐ No ☐
	b. Are ergonomic challenges present in the workplace for example, workarounds and problems with labeling, habitability, equipment accessibility, clothing, PPE, and human-machine interface)?	Yes ☐ No ☐
	d. Are there inappropriate distractions or interruptions in the workplace?	Yes ☐ No ☐
	e. Is the task or process too complex?	Yes ☐ No ☐
	f. Are there obstacles to communication between the performer(s) and supervision?	Yes ☐ No ☐
	g. Are job/task performance requirements beyond the performer's capabilities (such as fatigue, sleep decrement, strength, dexterity, and color blindness)?	Yes ☐ No ☐
	h. Does desired performance matter to the performer(s) (for example, unsafe attitudes, morale, work ethic, self-esteem, and peer pressure)?	Yes ☐ No ☐
5. Identify valid reasons for performance discrepancy.	Reasons:	
6. Select potential corrective actions.	Solutions:	

ATTACHMENT B – CULPABILITY DECISION TREE

Start with the assumption that the actions under scrutiny have contributed either to an accident or to a serious near-miss in which a bad outcome was only just averted. In an organizational accident, there are likely to be a number of different unsafe acts. The decision tree should be applied separately to each of them. The concern here is with individual unsafe acts committed by either a single person or by different people at various points in the accident sequence. Because of the subjectivity of the questions the Decision Tree should be used by a small team or committee vise a single manager or supervisor.

The questions of the inquiry relate primarily to intention. Unintended actions define slips and lapses, in general, the least blameworthy of errors. Unintended consequences cover mistakes and violations. The decision tree usually treats the various error types in the same way, except with regard to the violations question.

Start at the top left box on the logic diagram. The numbers below relate to the boxes left to right

Were the actions as intended? The key questions relate primarily to intention. If both the actions and the consequences were intended, then we are likely to be in the realm of criminal behavior, which is probably beyond the scope of the organization to deal with internally. Unintended actions define slips and lapses—in general, the least blameworthy of errors—while unintended consequences cover mistakes and violations.

1. **Knowingly violating expectations?** If the individual was knowingly engaged in violating expectations at that time, then the resulting error is more culpable since it should have been realized that violating increases both the likelihood of making an error and the chances of bad consequences resulting. Violations involve a conscious decision on the part of the perpetrator to break or bend the rules (except when noncompliance has become a largely automatic way of working). Although the actions may be deliberate, the possible bad consequences are not—in contrast to sabotage in which both the act and the consequences are intended. Most violations will be non-malevolent in terms of intent; therefore, the degree to which they are blameworthy will depend largely on the quality and availability of the relevant procedures.

   Procedures are not always appropriate for the particular situation. Where this is judged to be the case (perhaps by a "jury'" of the perpetrator's peers), the problem lies more with the system than with the individual. But, when good procedures are readily accessible but deliberately violated, the question then arises as to whether the behavior was reckless in the legal sense of the term. Such actions are clearly more culpable than "necessary" violations—the non-compliant actions necessary to get the job done when the relevant procedures are wrong or inappropriate or unworkable.[34]

2. **Passes the substitution test?** The "substitution test," or something similar, is used to help in judging the culpability of organizationally induced violations. Could some well-motivated, equally competent, and similarly qualified individual make the same kind of error under those or very similar circumstances? If the answer provided by a jury of peers is "yes," then the error is probably blameless. If the answer is "no," then we have to consider whether there were any system-induced deficiencies in the person's training,

selection, or experience. If such latent conditions are not identified, then the possibility of a negligent error has to be considered. If they are found, it is likely that the unsafe act was a largely blameless system-induced error.

3. **History of performance problems?** Keep in mind that people vary widely and consistently in their liability to everyday slips and lapses. Some individuals, for example, are considerably more absentminded than others. If the person in question has a previous history of unsafe acts, it does not necessarily bear upon the culpability of the error committed on this particular occasion, but it does indicate the necessity for corrective training or even career counseling along the lines of “Don’t you think you would be doing everyone a favor if you considered taking on some other job within the company?” Although absentmindedness has nothing at all to do with ability or intelligence, it is not a desirable trait in a pilot, a control room operator, a physician, or the like.

The line between acceptable and unacceptable behavior is more clear when the logic diagram is used. An intentional act to cause harm (lower left) is wholly unacceptable and should receive very severe sanctions, possibly administered by the courts rather than the organization. Knowingly violating expectations that were workable likely suggests reckless violation, a condition that warrants sanctions. The remaining categories should be thought of as blameless—unless they involve aggravating factors not considered here. Experience suggests that the majority of unsafe acts—perhaps 90 percent or more—fall into the blameless category.[35]

ATTACHMENT C – Establishing a Reporting Culture

It cannot be assumed that once a just environment is in place workers will naturally begin to report problems, errors and near misses. There are a number of organizational, as well as psychological, barriers that must be hurdled before a reporting culture can be put in place. The first barrier to overcome is a natural disinclination to confess one's blunders—no one wants to be held up to ridicule. The second barrier is the suspicion that such reports might go on the record and count against them in the future. The third is skepticism. People reason that if they go to the trouble of writing an event report that reveals system weaknesses, how will they be sure that management will act to improve matters? Fourth, actually writing the report takes time and effort, and many people conclude, "why bother?".

Following are some features of successful reporting programs. Each feature is designed to overcome one or more of the barriers noted above.

- *De-identification.* How this is achieved depends on the culture of the organization. In some organizations there is complete anonymity. Elsewhere organizations are content with confidentiality, wherein the person reporting is known only to a very few people.

- *Protection.* A very senior manager issues a statement guaranteeing that anyone who reports will receive at least partial indemnity against disciplinary procedures. Because some acts are culpable, it is not feasible to offer complete immunity from sanctions. Experience from successful programs indicates that circumscribed guarantees are sufficient to elicit large number of reports of honest errors.

- *Separation of functions.* Successful programs organizationally separate the functions of collecting and analyzing the reports from the authority to initiate disciplinary proceedings.

- *Feedback.* Rapid, useful, accessible, and intelligible feedback to the reporting community is essential to overcome any perception that reports were going into a black hole. This may be achieved by publishing summary reports of the issues raised and the measures that have been implemented.

- *Ease of making the report.* Experience shows that people prefer responding to a reporting style that allows them to tell a story and express their own perceptions and judgments, as opposed to having to force-fit responses into a highly structured pre-programmed format. [36]

The greatest value of a safety information system lies in its ability to identify recurrent event patterns, error traps, and gaps or weaknesses in the controls. Reporting systems are usually coupled with corrective action programs wherein identified problems in the field are researched and plans are devised and actions carried out to eliminate the problem and prevent recurrence. A primary objective of acquiring this safety information is to help the organization (workers, leaders, and management) learn from past near misses, mistakes, and inconsequential errors.

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REFERENCES

[1] Schein. "Taking Culture Seriously in Organization Development: A New Role for OD?" MIT Sloan working paper # 4287-03. 2003; pp. 2-3.

[2] Schein. *Organizational Culture and Leadership*, 2004, pp. 7-16. The model is from www.onepine.info/pschein.htm. Title "People Whose Ideas Influence Organizational Work--Edgar Schein."

[3] Schein. Organizational Culture and Leadership, 2004, pp. 17.

[4] Packer. "Safety Culture." Presentation at the Canadian Aviation Safety Seminar, April 2006. The author used the Chernobyl accident as a classic case of operators acting and behaving from the assumption their plant was robust. If not so, they would not have bypassed all the interlocks and ignored alarms as the reactor was moving towards disaster.

[5] Dr.Wert is President of Management Diagnostics Inc., a consultant to the Nuclear Industry, and an author.

[6] Reason. Managing the Risks of Organizational Accident, 1997, pp. 113-114.

[7] Senge. The Fifth Discipline, 1990, pp 223-225.

[8] Adapted from a quote by Dr. Erik Hollnagel, Professor of Psychology at CSELAB, Department of Computer and Information Science, University of Linköping, Sweden, during his presentation, "Understanding Accidents," at the 2002 IEEE Seventh Conference on Human Factors and Power Plants in Scottsdale, Arizona.

[9] Westrum. "A Typology of Organizational Cultures," *Quality and Safety in Health Care*, 2004:13, pp 22-27.

[10] INPO. Principles for a Strong Nuclear Safety Culture. November 2004, pp. iii-iv.

[11] Ramsey and Modarres. Commercial Nuclear Power, Assuring Safety for the Future. 1998, pp.220-221.

[12] Helmreich and Merritt. *Culture at Work in Aviation and Medicine*. 1998; p.133-139.

[13] Kotter. *Leading Change*. 1996, pp.25-30.

[14] INPO. Excellence in Human Performance. 199, pp. 13-19.

[15] INPO. Excellence in Human Performance. 1997, p. 3.

[16] Pool. "When Failure is Not an Option," *Technology Review Magazine*, July 1997. p. 45.

[17] Helmreich, Merritt, and Wilhelm. "The Evolution of Crew Resource Management Training in Commercial Aviation," *International Journal of Aviation Psychology*, 1999:1, pp 19-32.

[18] Fournies. Why Employees Don't Do What They're Supposed to Do, and What to Do About It, 1999, p. xv.

[19] Daniels. Bringing Out the Best in People, 1994, p. 25.

[20] Daniels. *Performance Management*, 1989, p. 29.

[21] Geller. *The Psychology of Safety*, 1998, p. 133.

[22] Daniels. Bringing Out the Best in People, 1994, pp. 65-66.

[23] Larkin and Larkin. "Reaching and Changing Frontline Employees," *Harvard Business Review on Effective Communication*, 1999, p. 147.

[24] Schein. Organizational Culture and Leadership, 1992, p .231.

[25] Gilbert. *Human Competence, Engineering Worthy Performance*, 1996, pp. 82-85. Reprinted with permission of the International Society for Performance Improvement, www.ispi.org.

[26] Rummler and Brache. *Improving Performance*, 1995.

[27] INPO 06-003. Human Performance Reference Manual, 2006, p. 92.

[28] INPO 06-003. *Human Performance Reference Manual*, 2006, pp. 91-94.

[29] Reason. Managing the Risks of Organizational Accidents, 1998, pp. 127-129.

[30] Reason. Managing the Risks of Organizational Accidents, 1998, pp. 72-73.

[31] Reason and Hobbs. *Managing Maintenance Error*, 2003, p. 150.

[32] Substitution Test is the work of Neil Johnston, "Do Blame and Punishment have a Role in Organizational Risk Management?," *Flight Deck*, spring 1995, pp. 33-36, referenced in Reason, *Managing the Risks of Organizational Accidents*, 1998, p. 208, 222.

[33] Reason. Managing the Risks of Organizational Accidents, 1998, pp.208-212.

♠ Adapted with permission from *Analyzing Performance Problems*, by Dr. Robert F. Mager and Peter Pipe © 1997, p. 5. The Center for Effective Performance, Inc., 1100 Johnson Ferry Road, Suite 150, Atlanta, GA 30342. www.cepworldwide.com;800-558-4237.

[34] Reason. Managing the Risks of Organizational Accidents, 1998, p. 210

[35] Reason. Managing the Risks of Organizational Accidents, 1998, pp. 207-211.

[36] Reason. *Managing Maintenance Error*, 2003, pp. 151-152.

CHAPTER 5 - HUMAN PERFORMANCE EVOLUTION

INTRODUCTION

The contents of this chapter provides background information on the examples of key research and concepts that have influenced the HPI approach discussed in this handbook. As one would expect, it is within the organization that performance improvement has evolved over time. The reader is introduced here to several significant influences and forces that have helped shape organizations' thinking about human performance and how organizations adjusted their approach to doing business in order to improve the way people work. Improving performance has been a linchpin not only for increasing efficiency, augmenting quality and meeting productivity expectations, but also for reducing human error and eliminating unwanted events. The lessons learned from failures in safety at Bhopal, Chernobyl, Challenger, Exxon Valdez, Three-Mile Island and elsewhere have given rise to new ways of thinking about the organization and its role in creating and sustaining a safety climate. The objective of this chapter is to illustrate how the organizational forces that evolved over time contributed to the development of human performance improvement as described in this handbook and promoted within DOE through training interventions in recent years. HPI builds upon these historical approaches to improve performance. The DOE/INPO HPI approach is one example of how improvement may be achieved.

A Perspective on Organizations

Organizations are ubiquitous across the landscape today in America. There are international, national, regional, state, and local organizations. There are business and industry organizations; social, political, economic, and professional organizations; as well as religious, health, academic, athletic, and scientific organizations, among many others. People in all walks of life assess their personal sense of worth, and that of their friends and acquaintances, in part based on the organizations they belong to or have been a member of in the past. People are greatly influenced by their association within an organization over time. This influence extends far beyond the stereotypical mental models we have of professional military people, retired policemen, or college professors. People everywhere are shaped and molded by their experiences within organizations—especially by the organizations in which they work day in and day out.

Organizations are so pervasive in American society that the paradigm shift for the reader from independent human agent to organizational human agent happens at nearly light speed.[1] Yet, this transformation of society [into organizations] has occurred slowly over time as a "*. . . revolution for which no flags were raised. It transformed our lives during those very decades in which, unmindful of what was happening, Americans . . . debated instead such issues as socialism, populism, free silver, clericalism, and colonialism.*"[2] As large employing organizations began to dominate society in the early 20th century, additional organizations arose to minimize the "frictions" of huge organizations working and colliding with one another. Government bureaucracies developed to regulate industries and labor organizations and to rein in profit-focused capitalist bureaucracies, and communities organized to provide social services once provided by industrial organizations.

During the so-called Progressive era (1900-1920), labor activists tied worker safety to larger social issues of safe housing, child labor, and minimum living wages. Concerned that reform activities might radically impact their profits, corporations reacted by adopting safety campaigns that emphasized the responsibility of the workers themselves, rather than that of industry, to prevent accidents. This effort to blame workers for their accidents was based perhaps on societal reactions to the large number of immigrants in that era. While progressives blamed industrial organizations for the large number of injuries and deaths, industrial organizations shifted the blame to the workers themselves.

Those who manage organizations, who make the decisions and set the standards for safety, are often removed in time and distance from the consequences of their actions. The workers within the organization suffer the consequences of decisions made and may be blamed for causing events. In many organizations individuals are held responsible for the outcome of organizational decisions. Morton Thiokol engineers accurately predicted that the Challenger space shuttle's solid rocket boosters were not designed for cold weather launches and voiced their concerns to management. As one of the engineers explained in an article after the 1986 Challenger accident: "*It is no longer the individual that is the locus of power and responsibility, but public and private institution. Thus, it would seem, it is no longer the character and virtues of individuals that determine the standards of moral conduct, it is the policies and structures of the institutional settings within which they live and work".*[3]

FACTORS THAT IMPACT ORGANIZATIONS

Production

Organizations flourish or fail primarily for two reasons—quality and safety—that is, their ability or inability to compete in the marketplace or their ability or inability to avoid major events. U.S. corporations demonstrated excellent capacity to produce gargantuan quantities of tanks, artillery, planes, landing craft, surface ships, and submarines, as well as rifles, machine guns, clothing, and so on, in support of the nation's challenge to wage war both in Europe and in the Pacific during World War II. Wartime production schedules in defense facilities everywhere called for all out capacity to support the millions of men and women in uniform on the battlefields, in the air and on the seas, and in support capacities. Factories operated around the clock. Millions of women took jobs in the defense industry. Car manufacturers halted auto production and began building jeeps, trucks, tanks and landing craft, and even airplanes. Henry J. Kaiser, a road and dam builder, who had never built a ship, contracted with the government to build ships in California. The Kaiser shipyards constructed over 1,400 ships, one a day, during the war. America's ability to out-produce its enemies in war machinery, weaponry, and munitions is one of the lasting legacies of the global conflagration of the 1940s.

The war had brought the United States out of the depression. The victories in Europe and Japan brought millions of military people back home into civilian life. Marriages surged, igniting the post-war "baby boom." The enormous demand for housing and household appliances and convenience items spurred production. The automobile industry that had been non-existent during the war, soon became the manufacturing giant in the country. Consumers' infatuation with, and demand for, automobiles further stoked post-war industry. Demand for increased electrical power and for better highways led to massive hydro-electric projects and the building of the interstate freeways. The seemingly endless capacity to produce characterized American corporations for the next two generations. Management's general view of itself and the workers during the production heyday was that they (managers) provided the head (thinking) and the workers provided the back, the hands, and the feet (brawn).

Quality Management

In the post-war world, Japan and Germany as well as other nations retooled for peacetime production with financial aid from the United States. In parallel, the world population expanded and the demand for goods and services exploded. Within a generation, the United States found itself competing with overseas rivals who could produce automobiles, machinery, radios and televisions, and hundreds of household convenience items cheaper, faster, and of equal or better quality. The Japanese had learned and applied quality control methods from American industrial engineers and statisticians, Joseph Juran, and William Edwards Deming.[4]

Defect Prevention The quality control techniques, actually formulated before the war by Juran and Deming, targeted manufacturing organizations. Central to their work was improving the control of production processes in order to reduce the number of defective parts, improve productivity and lower costs. This change in emphasis, from inspection to prevention, was quite revolutionary. It was achieved by using sampling methods to monitor processes and keep them under control. From this beginning, techniques and methodologies for process control were developed, including the philosophy that quality should be the responsibility of everyone in the organization. The process improvement ideas applied first to manufacturing were expanded to administrative functions and service industries so that the quality concept affected the whole organization. Japanese industry succeeded in taking over many markets. Corporations were able to drive down their costs while at the same time improve the quality of their products.

Quality is Everyone's Business The quality improvement movement in the private sector in this country in the late 1970s and 1980s emerged as a self-preservation initiative to reduce waste, cut costs, and improve product quality in order to compete.[5] Organizations had caught on to the idea that quality had to be built into the product, and not inspected, to be successful. Management's view of the workers as doers changed during this time. It became increasingly obvious that workers had to be included in plans to improve production processes. Numerous corporations adopted *Quality Circles* or similar programs rooted in employee participation. Small employee groups identified weaknesses in work processes, measured impacts, formulated root causes for the problems and weaknesses, and recommended to management ways and means of strengthening existing processes. Increased employee involvement in process improvement initiatives softened the earlier rancor and discord between management and workers. As the changes in processes resulted in improved products and a stronger competitive edge in the market, management's appreciation for the contribution of workers improved. Workers' seemed more willing to put more of themselves into the organization.

Customer Focus Quality is characterized as meeting or exceeding the needs and expectations of the customer. Thus, the goal of a business should be to find out what the customer wants and then fine-tune the process to ensure that they get it. The term "customer" is used to include internal customers as well as external customers. Thus, every work group has a customer—the person who receives their output.

Continuous Process Improvement Most people tend to think of their own work in terms of a task carried out in relative isolation from other work in the organization. The first step in quality improvement is for people to reorder their thinking about the work they do, to look at their work in terms of being part of a continuous process. A process is simply a sequence of tasks, which together produce a product or service. When all the steps in the process are flow-charted, it is easier to visualize one's own work in terms of being a step in a process. Every work group has a supplier and a customer. People take the output from another work group, do work that adds value, and then pass it on to another work group. The capability to achieve quality work is only as good as the weakest link in the process.

Continuous improvement processes are driven from the top, but implemented from the bottom. The selection of improvement projects needs a sharp focus. The problem areas must be prioritized; critical processes must be selected for improvement; and improvement goals must be set for the project team. This is a top-down process. The problem-solving and implementation is done by teams that include staff at the working level. This is a bottom-up process that requires the involvement and commitment of the staff. The slogan that "quality is everyone's business" drives home the idea that all employees—everyone from the mail room to the board room—play a role in improving quality. Employees are encouraged to report conditions adverse to quality, and they are encouraged to take part in quality improvement teams.

The blend of quality management techniques and philosophies noted above is generally referred to as Total Quality Management. Total Quality Management transformed into today's Six Sigma programs. Implementing quality improvement programs in the United States revitalized the automobile industry, telecommunications, and numerous other industrial and commercial enterprises. The quality improvement movement caught on in government agencies and among their primary contractors, including managing and operating contractors within DOE.[6] Quality management has had a notable and lasting imprint on organizations. Improving processes reduces waste and rework time; it raises product quality while reducing costs and stimulating productivity. The bottom line is that organizations become more cost effective. Workers' participation in problem solving and decision-making, while working in quality improvement teams, strongly influences how people think of themselves in the organization and how management views them. Workers have learned that the organization needs their brainpower as well as their brawn. Management learned that the people closest to the process know best how to improve the process when given a chance to participate in how work is accomplished. This teaming together of management and workers to improve organizational processes spilled over into the safety arena as we shall see.

Human Factors and Ergonomics

Human factors is the name of an engineering profession that focuses on how people interact with tasks, machines or computers, and the environment, with the consideration that humans have limitations and capabilities. Often, human factors will study the human within the system to ensure that we understand the limitations of the human within the current structure, product, or process. Human factors engineers will evaluate human-to-human, human-to-group, or human-to-organization interactions to better understand the phenomena associated with these interactions and to develop a framework for evaluation. Simply put, human factors involves working to make the environment function in a way that seems natural to people and attempts to optimize tasks, the machine design, and the environment. Under the banner of safety, the purpose of human factors research and practice is to maximize the safety and "healthiness" of work environments and work practices and to ensure the usability of tools, devices, and artifacts in general. A priority in human factors is consideration of users' physical, behavioral, and information-processing characteristics and requirements. Experience has shown that failure to deal with such characteristics can lead to wasted functionality, user frustration, inefficient practices, discomfort, and error-prone activity.

In the end, human factors are concerned with providing a good "fit" between people and their work or leisure environments. "Fit" might be the literal word, as with the design of ejector seats for aircraft (ejector seats designed for average size), or might be more metaphorical (designing to complement task activities, such as a specifically designed kitchen). Notably, the fit can be made in either direction. We can fit the environment to the person (by providing adjustable ejector seats to accommodate a range of heights, weights) or we can fit the person to the environment (providing extensive training or using people of a certain build)

Although the terms "human factors" and "ergonomics"—the science of making design account for human characteristics—have only been widely known in recent times, the fields' origins are in the design and use of aircraft during World War II to improve aviation safety. The war marked the development of new and complex machines and weaponry, and these made new demands on operators' cognition. The decision-making, attention, situational awareness, and hand-eye coordination of the machine's operator became key in the success or failure of a task. It was observed that fully functional aircraft, flown by the best-trained pilots, still crashed. In 1943, Alphonse Chapanis, a lieutenant in the U.S. Army, showed that this so-called "pilot error" could be greatly reduced when more logical and differentiable controls replaced confusing designs in airplane cockpits. Chapanis, a founding father of ergonomics, also pioneered the design of the standard telephone touchpad, teleconferencing, safety labels, night vision, digitized speech, and human-computer interaction.

Paul Fitts was an American Air Force Colonel who also examined the man-machine interface in aviation. He studied pilot accident records, digging through 460 cases of what were labeled as "pilot errors" in 1947. He found that a large part of the cases consisted of pilots confusing the flap and gear handles. Typically, a pilot would land and then raise the gear instead of the flaps, causing the airplane to collapse onto the ground and leaving it with considerable damage. Fitts' examined the hardware in the average cockpit to find that the controls for gear and flaps were often placed next to one another. They looked the same, felt the same, and, which one was on which side was not standardized across cockpits. This was an error trap waiting to happen. In other words, confusing the two handles was not incomprehensible or random, it was systematic; connected clearly to features of the cockpit layout.[7]

Areas of interest for human factors practitioners may include: training, learnability, staffing evaluation, communication, task analyses, functional requirements analyses and allocation, procedures and procedure use, organizational culture, human-machine interaction, workload on the human, fatigue, stress, shift work, safety, user interface, attention, vigilance, decision-making, human performance, human reliability, human differences, human-computer interaction, control and display design, visualization of data, and work in extreme environments, among others.

In the decades since the war, ergonomics has continued to flourish and diversify. The Space Age created new human factors issues such as weightlessness and extreme g-forces. How far could environments in space be tolerated, and what effects would they have on the mind and the body? The Information Age has resulted in the new ergonomics field of human-computer interaction. Further, the growing demand for and competition among consumer goods and electronics has resulted in more companies including human factors in product design

The contributions made by human factors and ergonomic engineers are numerous and have benefited organizations in many ways. The listing here is a small representative sample.

- Improving the design of control panel boards, instrument boards etc. by clearly and uniquely distinguishing buttons, switches, warning alarms, instrument indicators and so on, by the use of color, shape, size, position, labeling, and proximity to reduce the probability of operator error.
- Improving the design of equipment and components taking into consideration the tasks that will be required to maintain the equipment. This includes easy access to components, grouping together components that are functionally related, clear labeling, minimal use of special tools, reduction (if not elimination) of delicate adjustments in the field, and equipment design that facilitates fault isolation
- Providing research on human behavior and performance in which workers are exposed to prolonged overtime that causes excessive fatigue; adverse working conditions, such as interruptions, distractions caused by abnormal noise, adverse environmental conditions and numerous other circumstances that negatively impact worker attention; and the ability to focus, concentrate, and perform error-free work. Thoughtful organizations have used the results of these research findings to revise hiring and training practices in order to reduce excessive overtime, to better organize work, and to better control the work environment.
- Ergonomics research related to positioning of office equipment and computers, the design of furniture, seating, the design of industrial power tools, conveyer systems transport vehicles, and a myriad of other items that have emerged in the workplace in recent decades that better complement people's physical limitations and capabilities.

Organizational Development

A new, older definition of organizational development (OD) emerged at a time (1969) when an organization was considered to be much like a stable machine consisting of interlocking parts. It stated: *Organizational Development is an effort planned organization-wide, and managed from the top, to increase organizational effectiveness and health through planned interventions in the organization's processes using behavioral-science knowledge.*[8]

Definitions of organizational development penned in more recent times when organizations recognized the need to adapt to changing economic and social dynamics include the following:

- *Organizational development is a system-wide application of behavioral science knowledge to the planned development and reinforcement of organizational strategies, structures, and processes for improving an organization's effectiveness.*[9]

- *Organizational development is a body of knowledge and practice that enhances organizational performance and individual development, viewing the organization as a complex system of systems that exist within a larger system, each of which has its own attributes and degrees of alignment. OD interventions in these systems are inclusive methodologies and approaches to strategic planning, organization design, leadership development, change management, performance management, coaching, diversity and work/life balance.*[10]

Kurt Lewin is widely recognized as the founding father of OD, although he died in 1947 before the concept became current in the mid-1950s. From Lewin came the ideas of group dynamics and action research that underpin the basic OD process as well as provide its collaborative consultant/client ethos. Lewin founded the Research Center for Group Dynamics at MIT. Other leaders in the field include Richard Beckhard, who defined OD as cited above, taught at the Sloan School of Management at MIT, and started the Organizational Development Network. Chris Argyris is Professor Emeritus at Harvard Business School. He is known for his work in organizational learning, theories of action, and double-loop learning. Frederick Edmund Emery was an important figure in the field of OD, particularly in the development of theory around participative work design structures such as self-managing teams. Peter Senge's work on organizational learning and Edgar Schein's work on organizational culture will be discussed in some detail in this chapter. Numerous other researchers, writers, and teachers are prominent in the OD field.

Books on organizational development and its subsets (management development, leadership development, development of teams, etc.) abound. Seminars and workshops designed to help organizations improve their effectiveness are ubiquitous. Nowadays the *Journal of Applied Behavioral Sciences* is viewed as the leading OD journal. There are hundreds, if not thousands, of OD consulting firms providing services to America's corporations facing one or more of the following organizational development issues.

Leadership Development

- Management development
- Organizational communication
- Organizational diagnostics
- Organizational performance
- Succession planning
- Organizational engineering

Managing Change

- Diversity management
- Knowledge management
- Performance Improvement
- Strategic planning
- Systems-thinking
- Coaching and facilitation

Team Building

- Workforce planning
- Collaboration
- Organizational culture
- Organizational learning
- Process improvement
- Employee research

The practical applications of OD research appear as the case studies and lessons learned in numerous books, professional journal articles, and seminar and workshop publications. Over the years, a wide variety of organizational plans, schemes, and methodologies have been adopted and described. The following are just a sprinkling of the larger mix.

- *Flattening organizational structures by reducing levels of management and supervision*. This is often done to reduce overhead costs—to save money—but it has also been shown to be effective in improving vertical communication within larger organizations, which leads to improved overall proficiency and effectiveness.
- *Reorganizing work so it can be performed by self-directed work teams*. For some operations, self-directed work teams perform outstandingly. Because the workers are given more responsibility, greater decision-making power, and trust, a greater synergism develops, and individual team members demonstrate an increased personal ownership for their work.
- *Succession-planning*. In highly technical operations, especially, replacement of workers who retire or resign has become a major management consideration to ensuring that the organization can continue to function safely and efficiently. Recruiting, qualifying, hiring, and training large numbers of people with the proper skill mixes within the required time frames demands special human resource skills.
- *Developing the leadership qualities needed to support the desired safety culture is an essential ingredient in improving an organization's reliability to withstand potential safety threats*. Training, mentoring, and coaching leaders and future leaders has become commonplace in American industry.
- *Strategic planning is essential to the organization's ability to compete in the market, to keep up with changing technology, to anticipate changing customer and marketplace demands and to weather economic shortfalls*. Organizations that fail to do strategic planning loose their competitive edge, fall behind the competition, face operational obsolescence, and organizational irrelevance.

Learning Organizations

The concept of "learning organizations" is the groundbreaking work of Dr. Peter Senge. His research, described in the book, *The Fifth Discipline* (1990), is a seminal work that described successful organizations from a whole new perspective. Dr. Senge's premise was that business had become so complex, so dynamic, and so globally competitive that organizations had to change in order to survive. Excelling in a dynamic business environment, he advocated, requires more understanding, knowledge, preparation, and agreement than one person's expertise and experience can provide. Continuous improvement requires a commitment to learning. The learning organization is one in which people continually expand their capacity to create the results they truly desire, where new and expansive patterns of thinking are nurtured, where collective aspiration is set free, and where people are continually learning how to learn together. The five disciplines needed to build learning organizations are as follows:

- systems-thinking (the integrating discipline that ties and holds the other disciplines);
- personal mastery;

- mental models;
- shared vision; and
- team learning.

The first three disciplines have particular application for individuals; the last two disciplines are applicable to groups. Those in the organization who excel in these areas will be the natural leaders of the learning organizations. Senge's book provided numerous case studies to show how the five disciplines worked in particular organizations.

Systems-Thinking is the discipline of a shift of mind to seeing interrelationships, rather than linear cause-effect chains, and seeing processes of change rather than a snapshot. Systems-thinking starts with understanding "feedback" that shows how actions can reinforce or counteract (balance) each other. It builds to learning to recognize types of "structures" that recur again and again. Systems-thinking forms a language for describing interrelationships and patterns of change. It simplifies life by helping us to see the deeper patterns lying behind the events and the details.

Personal Mastery is the discipline of continually clarifying and deepening our personal vision, of focusing our energies, of developing patience, and of seeing reality objectively. If we have a personal vision, and we also see current reality objectively, then the difference between the two causes "creative tension." That tension can be used to draw us from where we are—in current reality—to the vision. Creative tension is a motivator to help people create the results in life that they truly seek.

Mental Models are deeply ingrained assumptions, generalizations, or even pictures or images that influence how we understand the world and how we take action. The discipline of working with mental models starts with turning the mirror inward; learning to unearth our internal pictures of the world, to bring them to the surface and hold them to rigorous scrutiny. Mental models also include the ability to carry on "learningful" conversations that balance inquiry and advocacy, where people expose their own thinking effectively and make that thinking open to the influence of others.

Shared Vision is a practice that involves unearthing shared "pictures of the future," which help foster genuine commitment and enrollment rather than compliance.

Team Learning is the discipline that involves mastering the practices of *dialogue* and *discussion,* the two distinct ways that teams converse. With dialogue, there is the free and creative exploration of complex and subtle issues, a deep "listening" to one another and suspending of one's own views. By contrast, in discussion, different views are presented and defended, and there is a search for the best view to support decisions that must be made at the present time. Dialogue and discussion are potentially complementary, but most teams lack ability to distinguish between the two and to move consciously between them.

The ideas and concepts associated with a "learning organization" resonated heavily with knowledge workers and with their employers. Traditional operating behaviors within organizations began to change. Unit Leaders and individual contributors became interested in and wanted to learn more about what other groups did and how they performed. Managers and supervisors aggressively started to use work teams to solve problems and make decisions. Organizations started benchmarking their programs against the programs of so called “first in class” organizations to learn how they did things and how they managed a process or function. The sale of books on corporations that thrived in business and industry skyrocketed. The corporate leaders of companies like General Electric, Fed-Ex, Motorola, and others became superstars of the speaking circuit. Books on organizational development that aligned with the disciplines of the learning organization sold like hotcakes. Workers in both the public and the private sectors went back to college by the hundreds of thousands, if not to complete their degrees or “do a masters,” to improve skills and strengthen their capabilities overall. Existing MBA programs overfilled with students, new ones sprang up almost overnight. (about 90,000 individuals in the United States receive MBA diplomas each year) Corporations and government agencies alike gave workers time off or allowed flex-time work so they could attend classes and reimbursed employees tuition costs. Everyone it seemed was spending more time “learning” and was in the pursuit of meaningful inquiry.

Human Performance Technology

The International Society for Performance Improvement (ISPI) is dedicated to improving productivity and performance in the workplace. Founded in 1962 as the National Society for Programmed Instruction, ISPI now represents more than 10,000 international and chapter members through the United States, Canada, and 40 other countries. ISPI develops and promotes Human Performance Technology (HPT)—the systematic approach to improving productivity and competence that ISPI believes is the key to global competitiveness. Whereas training and education are critical to increasing competitiveness, meeting the educational challenge is only part of the answer. ISPI advocates further that an effective human resource system needs an outstanding learning system that focuses on performance. To improve human performance, it follows that organizations must manage the performance improvement system. That system must be the core of an organization’s human resource efforts if it is to maintain its competitiveness in the long run.

ISPI has two missions; one is to advocate the use of HPT. HPT uses a set of methods and procedures and a strategy for solving problems for realizing opportunities related to the performance of people. HPT specifically is a process of selection, analysis, design, development, implementation, and evaluation of programs to cost-effectively influence human behavior and accomplishment. HPT is a systematic combination of three fundamental processes—performance analysis, cause analysis, and intervention selection—that can be applied to individuals, small groups, and large organizations.

ISPI’s second mission is to develop and recognize the proficiency of its members. The society’s vision is that members have the proficiency and insight to customize HPT to meet the needs and goals of their organizations and clients, such that its members are recognized as valued assets. In its efforts to meet this vision, the society sponsors a large annual conference, conducts workshops, facilitates the HPT institutes, publishes two periodicals, maintains a bookstore, administers a certification program for performance technologists, and maintains a placement service.

Error Management

The growth of large, complex, technology systems in recent decades, such as nuclear power plants, commercial aviation, the petrochemical industry, chemical process plants, marine and rail transport, and the like have spawned rare, but often catastrophic, events referred to as organizational or system accidents. The Three Mile Island nuclear accident, the Exxon Valdez oil spill, the Bhopal India gas leak, the Challenger disaster, and numerous airline accidents, among others, caused growing public concern over the terrible costs, loss of life, risk to the public, and threat to the environment. In most instances, human error was cited as the cause of these incidences.

Dr. James Reason, studied human error for years (as did several others) and published his first book by that title in 1990. A central thesis of his work is that the relatively limited number of error types, ways in which errors actually manifest themselves, are conceptually tied to underlying (non-error producing) normal cognitive processes. He advocates that errors result from normal cognitive processes, the same origin as comes success.[11] Another thesis is that disasters are rarely the product of a single monumental error. Usually, they involve the collaboration of several, often quite minor, errors committed either by one person or, more often, by a number of people.

In 1997, Reason published *Managing the Risks of Organizational Accidents.* Reason maintained that to understand how organizational accidents occur requires that we look deeper into the system. Unsafe acts by individuals may trigger an event. However, latent conditions within the organization, aligned with local workplace and task factors, contribute to accidents in the form of process errors or as error-likely situations. Thus it is the combination of these latent conditions in conjunction with an active error that more correctly accounts for events. From this perspective, errors are the consequences, not the causes, of disturbances in the organization. Accidents are the result of failed controls and barriers. People are fallible, even the best make mistakes. It is human nature to err. However, events can be eliminated or controlled by *changing the conditions in which people work*. Managing the risks of organizational accidents requires that managers, supervisors, and staff work to eliminate latent organizational weaknesses. Reason proposes three compelling reasons why latent conditions have to be eliminated.

- They combine with local factors to breach controls. In many cases, they are weakened or absent controls.
- They are like “resident pathogens” within the workplace that can be identified and removed before the event.
- Local triggers and unsafe acts are hard to anticipate, and some proximal factors are almost impossible to defend against (for example, forgetfulness, inattention, and the like).[12]

The challenge is great for organizations trying to change the condition in which people work, to improve the operating system and lower the risk of accidents. However, the risks associated with not accepting the challenge are enormous. Accidents cost lives and they are also economically disastrous. Very few organizations can sustain levels of financial loss associated with product and materials damage, plant damage, building damage, tool and equipment damage, legal costs, and similar losses plus the loss of business, recruitment difficulties, and loss of morale.[13] Dr. Reason’s work is the foundation for the human performance improvement model adopted by DOE and detailed in this standard. Chapter 2 of this document outlines worker tools used to reduce errors. Chapter 4 discusses tools for locating and eliminating latent organizational weaknesses and strengthening controls. The HPI Handbook, Volume 2 describes each of the tools, when they should be used, recommended practices when using a specific tool, and at-risk practices to avoid.

Mindfulness and Performance

Understanding "mindfulness" and its application to performance is informed by the work of Dr. Ellen Langer.[14] Mindfulness can be best understood as the process of drawing novel distinctions. It does not matter whether what is noticed is important or trivial, as long as it is new to the viewer. Langer suggests that actively drawing these distinctions keeps people situated in the present, the here and now. It also makes people more aware of the context and perspective of their actions than if they rely upon distinctions and categories drawn in the past. Under this latter situation, rules and routines are more likely to govern behavior, irrespective of the current circumstances, and this can be construed as "mindless" behavior. The process of drawing novel distinctions can lead to a number of diverse consequences important to performance, including:

- greater sensitivity to one's environment;
- more openness to new information;
- creation of new categories for structuring perception; and
- enhanced awareness of multiple perspectives in problem-solving.

The subjective "feel" of mindfulness is that of a heightened state of involvement and wakefulness of being in the present. Langer shares this example to make her point: When many of us learned to drive, we were told to pump the brakes slowly while trying to stop on a slippery surface. With the advent of antilock brakes, however, the more appropriate response is to firmly press the brakes down and hold them there. Thus, accidents that could be prevented in the past by our learned behavior can now be caused by the same behavior. This is an example of mindlessness that can easily occur in everyday life, as well as the workplace.

Langer contends that mindlessness can show up as the direct cause of human error in complex situations. Boredom and malaise, particularly, can be thought of as conditions brought on by mindlessness. Without noticing differences brought on by the passage of time within ourselves and the outside world, each day looks like every other. Employees in many occupations mechanically carry out the tasks that have been designed for them. The day when surgeons and airline pilots may check out psychologically because of standardization and routinization of their work is perhaps not very far off, with potentially disastrous consequences.[15]

High Reliability Organizations

In the early 1980s, Yale sociologist, Charles Perrow, investigated and wrote *Normal Accidents: Living with High Risk Technologies* (1984). Perrow concluded that while all organizations would eventually have accidents, because of their complexity and interdependence, some organizations were remarkably adapt at avoiding them. The question that high reliability organization (HRO) pioneering researchers sought to answer in their research is, "Why do some organizations not have as many failures as others?"

From this question grew the definition and characteristics of HROs. The research has identified some key characteristics of HROs. These include organizational factors (i.e., rewards and systems that recognize costs of failures and benefits of reliability), managerial factors (i.e., communicate the big picture), and adaptive factors (i.e. become a learning organization). More specifically, HROs actively seek to know what they don't know, design systems to make available all knowledge that relates to a problem to everyone in the organization, learn in a quick and efficient manner, aggressively avoid organizational hubris, train organizational staff to recognize and respond to system abnormalities, empower staff to act, and design redundant systems to catch problems early. In other words, an HRO expects its organization and its sub-systems will fail and works very hard to avoid failure while preparing for the inevitable so that they can minimize the impact of failure.[16]

In the mid 1980s, a research group at the University of California at Berkeley (Dr. Karlene Roberts, Todd La Porte, and Gene Rochlin) began to study organizations in which errors can have catastrophic consequences. They focused on organizations that seemed to behave very reliably, which they called high reliability organizations (HROs).[17] Another group at the University of Michigan (Dr. Karl Weick and associates) began addressing similar issues. These researchers represented different disciplines (psychology, political science, and physics); they came together with an organizational perspective. They were initially concerned with understanding success in organizations in which error can result in serious consequences.

The Berkeley group's initial work was done in the Federal Aviation Administration's Air Traffic Control Center, in a commercial nuclear power plant, and aboard the U.S. Navy's aircraft carriers. This group produced a number of findings that distinguish HROs.[18]

- Organizations that must be successful all of the time *continually reinvent themselves.* For example, when community emergency incident command systems realize what they thought was a garage fire is actually a hazardous material incident, they completely restructure the response organization. An aircraft carrier uses its functional units slightly differently depending on whether they are on a humanitarian mission, a search and rescue mission, or are engaged in night flight operations training.

- In HROs, decision-making migrates down to the lowest level consistent with decision implementation. The lowest level people aboard U.S. Navy ships make decisions and contribute to decisions.

- Systems of organizations operate together to produce risk-enhancing or risk-mitigating outcomes.[19] For a U.S. Naval battle group to behave reliably requires that all system members act in concert, openly sharing communication, reducing status differentials at sea, and letting people with the salient information and training make decisions. The carrier and its aircraft squadrons have to operate in concert with the battle group's submarine frigate, destroyer, and cruiser complement.

- The organizations are committed to learning from everything they do.

- They do not punish people for making honest mistakes.

Langer's concept of *mindfulness* was adopted and adapted by Dr. Karl Weick et. al to help describe attributes of HROs. Weick's innovation was to transfer the *mindfulness* concept described by Langer in the individual model to the group level and thus to the organizational context.[20] These researchers argue that what characterizes organizations as HROs is their collective mindfulness of danger. Dealing with the unexpected is likely the greatest challenge any organization faces. The unexpected usually does not take the form of a major crisis; instead, it is generally triggered by a deceptively simple sequence in organizational life. Problems become more pressing when the expected strategy and performance outcomes fail to materialize or when unexpected impediments to strategy and performance emerge. People often take too long to recognize that their expectations are being violated and that a problem is growing more severe. Once they finally do recognize that the unexpected is unfolding, their efforts at containment are often misplaced or are too little too late. People can either manage unexpected events poorly, in which case the events spiral, get worse, and disrupt ongoing activity, or they can manage them well, in which case the events shrink and ongoing activity continues.[21]

Karl Weick and associates concluded that managing the unexpected event well means *mindful* management of the unexpected. The term "mindful management" comes from careful study of HRO organizations that operate under very trying conditions all the time and yet manage to have very few accidents. Indeed, the better of these organizations rarely fails, even though they encounter numerous unexpected events. These organizations face an "excess" of unexpected events because their technologies are complex and the people who run these systems have an incomplete understanding of their own systems and what they face.

HROs success in managing the unexpected is attributed to their determined efforts to act mindfully. This means they organize themselves in such a way that they are better able to notice the unexpected in the making and halt its development. If they have difficulty halting the development of the unexpected, they focus on containing it. And, if some of the unexpected breaks through the containment, they focus on resilience and swift restoration of system functioning.

Various people in an HRO correctly perceive events before them and can artfully tie them together to produce a "big picture" that includes processes through which error is avoided. The mindful approach by HROs is a striving to maintain an underlying style of mental functioning that is distinguished by continuous updating and deepening of increasingly plausible interpretations of what the context is, what problems define it, and what remedies it contains. The key difference between HROs and other organizations in managing the unexpected often occurs in the earliest stages, when the unexpected may give off only weak signals of trouble. The overwhelming human tendency is to respond to weak signals with a weak response. Mindfulness preserves the capability to see the significant meaning of weak signals and to give strong responses to those weak signals. This counterintuitive act holds the key to managing the unexpected. Weick and associates identified five characteristics of HROs that together make up what they term "mindfulness". (Note the similarities with the Berkeley group findings.)

Preoccupation with Failure – HROs assess all anomalies, large and small; they treat any lapse as a symptom that something is wrong with the system, something that could have severe consequences if separate small errors happened to coincide at one unfortunate minute. HROs encourage reporting of errors and near misses, they elaborate experiences of a near miss for what can be learned. They are wary of the potential liabilities of success, including complacency and the temptation to reduce the margins of safety and drift into automatic processing. HROs are committed to learning.

Reluctance to Simplify – HROs take deliberate steps to create more complete and nuanced pictures. They simplify less and see more. They accept the world they face as complex, unstable, unknowable, and unpredictable. They encourage boundary spanners who have diverse experience, skepticism toward receiving wisdom, and negotiating tactics that reconcile differences of opinion without destroying the nuances that diverse people detect.

Sensitivity to Operations – This points to the HROs' concern with the unexpected. Unexpected events usually originate in "latent failures"—loopholes in the system's controls, barriers, and safeguards—whose potential existed for some time prior to the onset of the accident sequence, although usually without any obvious bad effect. These loopholes are imperfections in supervision, reporting of defects, engineered safety procedures, safety training, hazard identification, and the like. Normal operations may reveal deficiencies that are "free lessons" that signal the development of unexpected events. HROs do frequent assessments of the safety health of the organization.

Commitment to Resilience – HROs work to reduce errors and keep them small. The hallmark of an HRO is not that it is error-free, but that errors don't disable it. They improvise workarounds that keep the system functioning. HROs put a premium on experts, people with deep experience, special skills and training. They use flexible, informal ad hoc groups that come together quickly to solve problems and then disband (general uncommitted resources are crucial to resiliency), and HROs mentally simulate worst-case conditions and practice their own equivalent of fire drills.

Deference to Expertise – During normal operations, decisions come from the top. During high tempo, abnormal situations, decisions are pushed down and around. So decisions are made on the front line, and authority migrates to the people with the most expertise, regardless of their rank. The pattern of decisions "migrating" to expertise is found in flight operations on aircraft carriers, where uniqueness coupled with the need for accurate decisions leads to decisions that "search" for the expert and migrate around the organization. During times of danger, the predefined emergency structure makes decisions. The key is that members of the organization recognize clear signals for when to switch from one management mode to the other.[22]

The HROs maintain reliable performance despite constant exposure to the unexpected, in part by developing and maintaining their capability for mindfulness. A well-developed capability for mindfulness catches the unexpected earlier, when it is smaller; comprehends its potential importance despite the small size of the disruption; and removes, contains, or rebounds from the effects of the unexpected. HROs accumulate unnoticed events that are at odds with what they expected, but they tend to notice these accumulated events sooner, when they are smaller in size. They also concentrate more fully on the discrepancy, its meaning, and its most decisive resolution.

Organizations can learn to manage the unexpected better by acting more like a high-reliability organization. All organizations accumulate unnoticed events that are at odds with accepted beliefs about hazards and norms for avoiding these hazards. It is these similarities that encourage the transfer of the lessons of HROs to other organizations.

Researchers cite the following organizations as those that habitually exhibit the attributes of an HRO:

- power grid dispatching centers;
- naval aircraft carriers;
- hospital emergency departments;
- air traffic control systems;
- nuclear submarines;
- airline cockpit crews;
- offshore platforms;
- hostage negotiators[23]; and
- commercial nuclear power plants.

Resilience Engineering

Assessments of case studies and strategic analyses have identified the need to monitor and manage risk continuously throughout the life cycle of a system; and, in particular, to find ways of maintaining a balance between safety and the high pressure to meet production and efficiency goals. Resilience engineering is the work of Eric Hollnagel, David Woods, and associates (*Resilience Engineering,: Concepts and Precepts*, 2006). Resilience engineering is a field of study that uses the insights from research on failures in complex systems, organizational contributors to risk, and human performance to develop engineering practices. These engineering practices include measures of sources of resilience, decision support for balancing production and safety tradeoffs, and feedback loops that enhance the organization's ability to monitor and revise risk models and to target safety investments. Resilience engineering has emerged as a natural evolution from the principles of organizational reliability and a new understanding of the factors behind human error and performance.

Researchers who studied failures in different industries found that when failures occurred against a background of usual success there were multiple contributors referred to as latent conditions. These conditions arise in part because of the following.

- **Finite Resources –** there is never time or resources for all "adequate" reviews; there are never enough "well-qualified" systems engineers; and so on.
- **Uncertainty –** uncertainties in system performance, uncertainties in the environment, and uncertainties in the design process.
- **Change is Omnipresent –** as leaders exploit new capabilities, the result is change.

Recognizing these factors, researchers have identified the process that "a drift toward failure" precedes major events as planned controls erode in the face of production pressures and change. This failure arises from systematic and predictable organizational factors at work, not simply erratic behaviors by individuals. As described above, HRO's create safety by anticipating and planning for unexpected events and future surprises. HROs do not take past success as a reason for confidence. Instead, they continue to invest in anticipating the changing potential for failure because of the deeply held understanding that their knowledge base is fragile in the face of the hazards inherent in their work and in the changes always present in their environment. SAFETY then becomes a value that requires continuing reinforcement and investment.[24]

Resilience engineering looks for ways to enhance the ability of organizations to create processes that are robust, yet flexible, to monitor and revise risk models and to use resources proactively in the face of disruptions or ongoing production and economic pressures. The initial steps in developing resilience engineering have focused on three critical components:

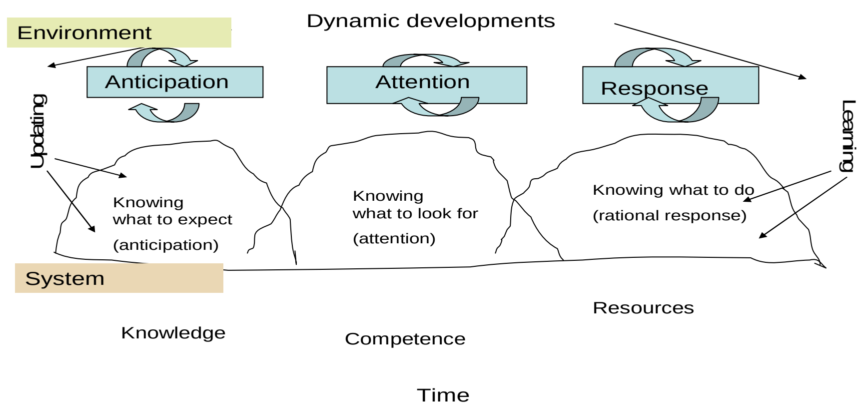
1. ways to measure the resilience of organizations;
2. tools for organizations to signal how to make tradeoffs in the face of pressure to achieve through-put and efficiency goals; and
3. techniques to visualize and anticipate the side effects of change and decisions on risk.[25]

Organizational Resilience

Organizational resilience refers to how well an organization can handle disruptions and variations that fall outside of a system's design or safety envelope. Resilience is concerned with the ability to recognize and adapt to and handle unanticipated disorders and disturbances that call into question the model of competence and demand a shift of processes, strategies, and coordination. Resilience is the successful adaptation to change necessary to cope with the real-world complexity. Success has been ascribed to the ability of groups, individuals, and organizations to anticipate the changing shape of risk before failures and harm take place; failure, on the other hand, is simply the temporary or permanent absence of that ability. From this viewpoint, failures do not stand for a breakdown or malfunctioning of normal system functions, but rather represent the inability to make necessary adaptations to cope with the complexities.[26]

Safety is often expressed in terms of reliability, measured as the probability that a given function or component would fail under specific circumstances. It is not enough, however, that systems are reliable and that the probability of failure that could cause harm is below a certain value. They must also be resilient and have the ability to recover from irregular variations, disruptions and degradations of expected work conditions. Resilience requires a continuous monitoring of system performance. The fundamental characteristic of a resilient organization is that it does not lose control of what it does, but is able to continue and rebound. In order to be in control, organizations must know what has happened (the past), what happens (the present) and what may happen (the future), as well as knowing what to do and having the required resources to do it. Common conditions that characterize how well organizations perform and when and how they lose control are lack of time, lack of knowledge, lack of competence, and lack of resources.[27]

There are three qualities that a system must have to be able to remain in control in the face of an anomaly; and, therefore, to be resilient—**anticipation, attention, and response.** The whole point about resilience is that these qualities have to be exercised continuously. The organization must constantly be watchful and prepared to respond. Also, it must constantly update its knowledge, competence, and resources by learning from successes and failures—both its own and those of others. A model of a resilient organization is shown below.[28]



Required qualities of a resilient organization

In addition to the qualities of anticipation, attention, and response, organizations must have the time to respond to disturbances and variations in its systems. Without time to respond before the incident, the response must come after the fact, and then is a reaction only to what happened.

Resilience requires a constant sense of unease that prevents complacency. It requires a realistic sense of abilities, or "where we are." It requires knowledge of what has happened, what happens, and what will happen, as well as of what to do. A resilient organization must be proactive; flexible, adaptive; and prepared. It must be aware of the impact of actions, as well as the failure to take action.[29]

Performance Improvement In the Work Place

Numerous industries in this country have embraced performance improvement. In the late 1970s following numerous airplane accidents involving human failures, the airlines developed crew resource management (CRM) training. CRM is designed to improve flight crew communication, team work, and delegation of responsibilities during abnormal conditions, among other things. The medical industry, the airline industry, and nuclear power industry adopted the use of full-scope simulators that authentically replicated operational situations. Simulators provided safe environments in which doctors, pilots, and control room operators alike could practice problem solving, decision-making, and 'performance of skills where they received feedback. For decades, simulator training has been a prerequisite for pilot and control room operator qualification and re-qualification. The U.S. Navy and the U.S. Coast Guard have also adopted HPI principles and practices.

In the mid-90's, the Institute for Nuclear Power Operations (INPO), representing about 100 nuclear power plants in this country, first introduced *Human Performance Fundamentals* training to educate nuclear power plant personnel. The training was an outgrowth of significant prior study conducted by the Institute to learn about human error, organizational accidents, and human performance. Striving for excellence in human performance at nuclear power stations is an ongoing industry effort to significantly reduce plant events caused by human error. Human error is caused by a variety of conditions related to individual behaviors, management and leadership practices, and organizational processes and values. Behaviors at all levels need alignment to improve individual performance, reduce errors, and prevent events. Alignment involves facilitating organizational processes and values to support desired behavior. The *Excellence in Human Performance* document describes a set of behaviors that fosters this alignment.[30]

Earlier attempts by the nuclear power industry to improve human performance focused on results and the individual behavior at the worker level, a characteristic response to human error that prevailed in many organizations. However, organization and management influences on human behavior are equally important but are often overlooked or underestimated. Experience had revealed that most causes of human performance problems exist in the work environment, indicating weaknesses in organization and management. This does not relieve individuals of their responsibility to work safety and reliably. The human performance strategy in general encompasses the following:

- reducing the frequency of events by anticipating, preventing, and catching active errors at the job site;
- minimizing the severity of events by identifying and eliminating latent weaknesses that hinder the effectiveness of controls against active errors and their consequences; and
- cultivating an environment where honest errors can be openly reported and learned from.

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REFERENCES

[1] Perrow C. "A Society of Organizations," *Theory and Society*, 12/1991, pp. 725-762.

[2] Scott, W.R. Organizations: Rational, Natural, and Open System,. 2003, p. 95.

[3] Boisjoly, Curtis, and Mellican. In Ermann and Lundman, Corporate and Governmental Deviance: Problems of Organizational Behavior in Contemporary Society (5th ed), (1986), pp. 207-231.

[4] A good overview of quality management is available on the web at www.eagle.ca/~mikehick/quality.html.

[5] Both William Edwards Deming and Joseph Juran were enormously influential in helping American businesses improve their product quality and improve the way organizations managed their people. Deming's major works are *Quality, Productivity and Competitive Position*, 1982 (reprinted as *Out of Crisis)* and *The New Economics for Industry, Government and Education*,1993. Juran wrote *Management of Inspection and Quality Control,* 1945; *Quality Control Handbook,* 1951; and *Managerial Breakthrough,* 1964.

[6] INEL contractor personnel attended extensive training on total quality management in 1990-91 using Philip Crosby quality principles and concepts from his book *Quality is Free, 1980.*

[7] Dekker, S. The Field Guide to Human Error Investigations, 2002, p. 61.

[8] Beckhard, R. Organization Development: Strategies and Models, 1969, p.9.

[9] Cummings, Worley. Organizational Development and Change, 1997, p.2.

[10] Minahan, M. MM & Associates, Silver Spring, Maryland.

[11] Reason. *Human Error*, 1990, Chapter 3.

[12] Reason. Managing the Risks of Organizational Accidents. 1997; pp. 236-237.

[13] Reason. Managing the Risks of Organizational Accidents, 1997, pp. 238.

[14] Ellen J. Langer is the author of several books and numerous articles on the subject of mindfulness including *Mindfulness,* 1989, and *The Power of Mindful Learning*, 1997.

[15] Langer and Moldoveanu. "The Construct of Mindfulness," *Journal of Social Issues*, Spring 2000.

[16] http://www.highreliability.org/

[17] Rochlin, La Porte, and Roberts. "The Self-Designing High-Reliability Organization: Aircraft Carrier Flight Operations at Sea," *Naval War College Review*, Autumn 1987.

[18] Schuman. "The Analysis of High Reliability Organizations," in Robert K. H., ed. *New Challenges to Understanding Organizations*, 1993; pp.33-54. Bigley and Roberts. "Structuring Temporary Systems for High Reliability," *Academy of Management Journal, 2001*; 44: 1281-1300.

[19] Grabowski and Roberts. " Risk Mitigation in Virtual Organizations," *Organizational Science*, 1999;10: 704-721.

[20] Weick, Sutcliff, and Obstfeld. "Organizing for High Reliability: Processes of Collective Mindfulness," *Research in Organizational Behavior*, 21, p. 90

[21] Weick and Sutcliff. Managing the Unexpected: Assuring High Performance in an Age of Complexity, 2001, Chapter 1.

[22] Weick and Sutcliff. Managing the Unexpected: Assuring High Performance in an Age of Complexity, 2001, Chapter 1.

[23] Wetherbee J. D. "NASA Safety: Cultural Improvements," PowerPoint presentation

[24] Woods D.D and Wreathall J. Managing Risk Proactively: The Emergence of Resilience Engineering, 2003; pp. 1-2.

[25] Woods D.D. and Wreathall J. Managing Risk Proactively: The Emergence of Resilience Engineering, 2003, pp. 3.

[26] Hollnagel, Woods, and Leveson. *Resilience Engineering: Concepts and Precepts,* 2006. pp. 21-23.

[27] Hollnagel and Woods. Joint Cognitive Systems: Foundations of Cognitive Systems Engineering, 2005, pp. 75-78.

[28] Hollnagel, Woods, and Leveson. *Resilience Engineering: Concepts and Precepts,* 2006, p. 350.

[29] Hollnagel, Woods, and Leveson. *Resilience Engineering: Concepts and Precepts,* 2006, p. 356.

[30] INPO. Excellence in Human Performance (Handbook), pp. 1-5.

GLOSSARY

Descriptions of Common Human Performance Terms and Phrases

Term or Phrase	Description
Accident	An unfortunate mishap especially one causing damage or injury.
Accountability	The expectation that an individual or an organization is answerable for results; to explain its actions, or be subject to the consequences judged appropriate by others; the degree to which individuals accept responsibility for the consequences of their actions, including the rewards or sanctions.
Action	Externally observable, physical behavior (bodily movements or speech). (See also *behavior.*)
Active Error	Action (behavior) that changes equipment, system, or plant state triggering immediate undesired consequences.
Administrative Control	Direction that informs people about what to do, when to do it, where to do it, and how well to do it, and which is usually documented in various written policies, programs, and plans.
Alignment	The extent to which the values, processes, management, and existing factors within an organization influence human performance in a complementary and non-contradictory way; facilitating organizational processes and values to support desired safe behavior.
Anatomy of an Event	A cause-and-effect illustration of the active and latent origins (linkages) of plant events initiated by human action.
Assumption	A condition taken for granted or accepted as true without verification of the facts. (See also *belief*, *mental model* and *unsafe attitudes.*)
At-Risk Practice	A behavior or habit that increases the chance for error during an action, usually adopted for expedience, comfort, or convenience.
Attitude	An unobservable state of mind, or feeling, toward an object or subject.
Barrier	Anything that keeps operations or processes within safe limits or protects a system or person from a hazard. (See also *controls* and *defense.*)
Behavior	The mental and physical efforts to perform a task; observable (movement, speech) and non-observable (thought, decisions, emotional response, and so forth) activity by an individual. Generally, we treat observable behavior as measurable and controllable.
Behavior Engineering Model	An organized structure for identifying potential environmental and individual factors that impact performance at the job site, and for analyzing the organizational contributors to those factors.
Belief	Acceptance of and conviction in the truth, existence, or validity of something, including assumptions about what will be successful.

Term or Phrase	Description
Benchmarking	A process of comparing products, processes, and practices against the best in class, the toughest competitors or those companies recognized as industry leaders; discovering innovative thinking or approaches.
Change Management	A methodical planning process to establish the direction of change, align people and resources, and implement the selected modifications throughout an organization, large or small.
Coaching	The process of facilitating changes in behavior of another person through direct interaction, feedback, collaboration, and positive relationships. (See also *feedback.*)
Cognitive (cognition)	Descriptive of mental activity related to sensing and thinking phases of information processing; perception, awareness, problem-solving, decision-making, and judgment.
Complacency	Self-satisfaction accompanied by unawareness of actual dangers, hazards, or deficiencies; being unconcerned in a hazardous environment.
Conservative Decision-Making	Reaching conclusions by placing greater value on safety than the production goals of the organization—decisions demonstrate recognition and avoidance of activities that unnecessarily reduce safety margins.
Controls	Administrative and engineering mechanisms that can affect the chemical, physical, metallurgical or nuclear process of a nuclear facility in such a manner as to effect the protection of the health and safety of the public and workers, or the protection of the environment. Also, error-prevention techniques adopted to prevent error and to recover from or mitigate the effects of error; to make an activity or process go smoothly, properly, and according to high standards. Multiple layers of controls provide defense in depth.
Critical Step	A procedure step, series of steps, or action that, if performed improperly, will cause irreversible harm to equipment, people, or the environment.
Culture	An organization's system of commonly held values and beliefs that influence the attitudes, choices and behaviors of the individuals of the organization. (See also *safety culture.*)
Cultural Control	Leadership practices that teach (consciously and unconsciously) their organizations how to perceive, think, feel, and behave.
Defense	Means or measures taken to prevent or catch human error, to protect people, plant, or property against the results of human error, and to mitigate the consequences of an error. Defense os a term used in much of the human performance literature. However in DOE the term "controls) is preferred as it is synomonous with the term "defenses" and "controls" is the term defined and used with the DOE ISMS. (See also *barrier* and *controls.*).

Term or Phrase	Description
Defense-in-Depth	The set of redundant and diverse controls, barriers, controls, and safeguards to protect personnel and equipment from human error, such that a failure with one defense would be compensated for by another defensive mechanism to prevent or mitigate undesirable consequences.
Dependency	The increased likelihood of human error due to the person's unsafe reliance on or relationship with other seemingly independent defense mechanisms. (See also *team error.*)
Engineered Controls	Those physical items (hardware, software, and equipment) in the working environment designed to modify behavior and choices, or limit the consequences of undesired actions or situations. These controls may be active (requires action/change of state) or passive (defense requires no action).
Error	An action that unintentionally departs from an expected behavior.
Error of Commission	An error that involves performance of an action other than the expected action.
Error of Omission	Failure to take an expected action.
Error Precursors	Unfavorable factors that increase the chances of error during the performance of a specific task by a particular individual. (See also *human nature*, *individual capabilities*, *task demands*, and *work environment.*)
Error-likely Situation	A work situation in which there is greater opportunity for error when performing a specific action or task due to error precursors (also known as "error trap").
Event	An undesirable change in the state of structures, systems, or components or human/organizational conditions (health, behavior, controls) that exceed established significance criteria.
Expectations	Established, explicit descriptions of acceptable organizational outcomes, business goals, process performance, safety performance, or individual behavior (specific, objective, and doable).
Facility	A building or structure in which operations are, or have been, conducted by or on behalf of, the Department of Energy. Included here are processing, laboratory (R&D), Decommissioned and Decontaminated buildings, storage buildings and the like, both nuclear and non-nuclear.
Factor	An existing condition that positively or adversely influences behavior. (See also *organizational factors.*)
Failure	The condition or fact of not achieving the desired end(s).
Fallibility	A fundamental, internal characteristic of human nature to be imprecise or inconsistent.

Term or Phrase	Description
Feedback	Information about past or present behavior, and results that is intended to improve individual and organization performance.
Flawed Controls	Defects with engineered, administrative, cultural, or oversight controls that, under the right circumstances, fail to: • Protect plant equipment or people against hazards; • Prevent the occurrence of active errors; and • Mitigate the consequences of error. (See also *anatomy of an event* and *defense-in-depth.*)
Function Allocation	The distribution of actions (functions) among human or machine elements of a system to achieve a particular outcome.
Gap Analysis	The process of comparison of actual results or behavior with desired results or behavior, followed by an exploration of why the gap exists.
Human Error	A phrase that generally means the slips, lapses, and mistakes of humankind.
Human Factors	The study of how human beings function within various work environments as they interact with equipment in the performance of various roles and tasks (at the human-machine interface): ergonomics, human engineering , training, and human resources.
Human-Machine Interface	The point of contact or interaction between the human and the machine.
Human Nature	The innate characteristics of being human; generic human limitations or capabilities that may incline individuals to err or succeed under certain conditions as they interact with their physical and social environments.
Human Performance	A series of behaviors executed to accomplish specific results (HP = B + R).
Human Reliability	The probability of successful performance of human activities, whether for a specific act or in general.
Individual	An employee in any position in the organization; that is, worker, supervisor, staff, manager, and executive.
Individual Capabilities	Unique mental, physical, and emotional abilities of a particular person that fail to match the demands of the specific task.
Infrequently Performed Task	Activity rarely performed although covered by existing normal or abnormal procedures.
Initiating Action	A human action, either correct, in error, or a violation; that results in an event. (See also *Anatomy of an Event.*)
Job	A combination of tasks and duties that define a particular position within the organization usually related to the functions required to achieve the organization's mission, such as Facility Manager or Maintenance Technician.
Job Site	The physical location where people touch and alter the facility.

Term or Phrase	Description
Job-Site Conditions	The unique factors associated with a specific task and a particular individual; factors embedded in the immediate work environment that influences the behavior of the individual during work. (See also *error precursors* and *organizational factors.*)
Knowledge & Skill	The understanding, recall of facts, and abilities a person possesses with respect to a particular job position or for a specific task.
Knowledge-based Performance	Behavior in response to a totally unfamiliar situation (no skill, rule or pattern recognizable to the individual); a classic problem-solving situation that relies on personal understanding and knowledge of the system, the system's present state, and the scientific principles and fundamental theory related to the system.
Knowledge Worker	An individual who primarily develops and uses knowledge or information (e.g. scientist, engineer, manager, procedure writer).
Lapse	An error due to a failure of memory or recall. (See also *slip* and *mistake.*)
Latent Condition	An undetected situation or circumstance created by past latent errors that are embedded in the organization or production system lying dormant for periods of time doing no apparent harm. (See also *latent organizational condition.*)
Latent Error	An error, act, or decision disguised to the individual that results in a latent condition until revealed later, either in an event, active error, testing, or self-assessment. (See also *latent condition*)
Latent Organizational Condition or Weakness	Undetected deficiencies in organizational processes, equipment, or values that create job-site conditions that either provoke error or degrade the integrity of controls.
Leader	An individual who takes personal responsibility for his or her performance and the facility's performance, and attempts to influence the organization's processes and/or the values of others.
Leadership	The behavior (actions) of individuals to influence the behaviors, values, and beliefs of others.
Leadership Practices	Techniques, methods, or behaviors used by leaders to guide, align, motivate, and inspire individuals relative to the organization's vision.
Management (manager)	That group of people given the positional responsibility and accountability for the performance of the organization.
Management Practices	Techniques, methods, or behaviors used by managers to set goals, plan, organize, monitor, assess, and control relative to the organization's mission. (See also *practices.*)

Term or Phrase	Description
Mental Model	Structured organization of knowledge a person has about how something works (usually in terms of generalizations, assumptions, pictures, or key words); a mental picture of the underlying way in which a system functions, helping to describe causes, effects, and interdependencies of key inputs, factors, activities, and outcomes.
Mistake	Errors committed because the intent of the act was incorrect for the work situation, typically defined by the condition of the physical plant; incorrect decision or interpretation. (See also *error* and compare with *slip.*)
Motives	The personal (internal) goals, needs, interests, or purposes that tend to stimulate an individual to action.
Near Miss	Any situation that could have resulted in undesirable consequences but did not; ranging from minor breaches in controls to incidents in which all the available safeguards were defeated, but no actual losses were sustained.
Norm	A behavior or trait observed as typical for a group of people.
Organization	A group of individuals with a shared mission, set of processes, and values to apply resources and to direct people's behavior toward safe and reliable operation.
Organizational Factors	1) Task-specific sense: an existing job-site condition that influences behavior and is the result of an organizational process, culture, and other environmental factors. 2) General sense: the aggregate of all management and leadership practices, processes, values, culture, corporate structures, technology, resources, and controls that affect behavior of individuals at the *job site.*
Oversight Control	Methods to monitor, identify, and close gaps in performance.
Performance	Any activity that has some effect on the environment; the accomplishment of work. (See also *human performance.*)
Performance Gap	The difference between desired performance and actual performance, whether in terms of results or behavior.
Performance Improvement	A systematic process of identifying and analyzing gaps in human performance, followed by developing and implementing interventions or corrective actions to close the gaps.
Performance Indicators	Parameters measured to reflect the critical success factors of an organization. A lagging Indicator is a measure of results or outcomes. A leading indicator is a measure of system conditions or behaviors which provide a forecast of future performance (also known as “metrics”).
Performance Mode	One of three modes a person uses to process information related to one's level of familiarity and attention given to a specific activity. People will likely use multiple modes to complete a task. (See also *Skill-based*, *Rule-based*, and K*nowledge-based performance.*)

Term or Phrase	Description
Performance Model	A systems perspective of the context of individual human performance, showing how plant results and individual behavior are interrelated with organizational processes and values through job-site conditions.
Performance Monitoring	Review and comparison of performance against expectations and standards using problem reporting, feedback, reinforcement, coaching, observation data, event data, trend data, and so on. (See also *performance indicator*, *performance gap*, and *gap analysis.*)
Performance Problem	A discrepancy in performance with respect to expectations or operating experience, or an opportunity to improve performance created by changes in technology, procedures, or expectations. (See also *performance gap.*)
Physical Plant	Systems, structures, and components of the facility.
Plant Results	The outcomes of the organization in terms of production, events, personnel safety, external assessments, configuration, and so on.
Population Stereotype	The way members of a group of people expect things to behave; for example, in the U.S., up, right (direction), or red implies on or energized.
Positive Control	Active measure(s) to ensure that what is intended to happen is what happens, and that is all that happens.
Practices	Behaviors usually associated with a role that can be applied to a variety of goals in a variety of settings. (See also *work practices.*)
Prevention Behaviors	Behaviors or practices oriented toward the prevention of errors or events. (See also *production behaviors.*)
Principles	A set of underlying truths that can be used to guide both individual performance and the management of human performance
Proactive	Preemptive measures to prevent events or avoid error by identifying and eliminating organizational and job-site contributors to performance problems before they occur; preventing the next event.
Process	A series of actions organized to produce a product or service; tangible structures established to direct the behavior of individuals in a predictable, repeatable fashion as they perform various tasks.
Production Behaviors	Behaviors oriented toward creating the organization's product from the resources provided (corollary to *prevention behaviors*).
Reactive	Taking corrective action in response to an *event* or *error*.
Readiness	An individual's mental, physical, and emotional preparedness to perform a job as planned.
Reinforcement	The positive consequences one receives when a specific behavior occurs that increases the probability the behavior will occur again.

Term or Phrase	Description
Rigor	Completeness and accuracy in a behavior or process; cautiously accurate, meticulous, exhibiting strict precision during the performance of an action.
Root Cause	A cause that, if corrected, will prevent recurrence of an event.
Rule-Based Performance	Behavior based on selection of a defined path forward derived from one's recognition of the situation; follows an IF (symptom X), THEN (action Y) logic.
Safety Culture	An organization's values and behaviors—modeled by its leaders and internalized by its members—that serve to make safety the overriding priority. (See also *values* and *culture.*)
Self-Assessment	Formal or informal processes of identifying one's own opportunities for improvement by comparing present practices and results with desired goals, policies, expectations, and standards. (See also *benchmarking* and *performance monitoring.*)
Shortcut	An action, perceived as more efficient by an individual, that is intended to accomplish the intent of actions rather than the specific actions directed by procedure, policy, expectation, or training. (See also *violation.*)
Situation Awareness	The accuracy of a person's current knowledge and understanding of actual conditions compared to expected conditions at a given time.
Skill-Based Performance	Behavior associated with highly practiced actions in a familiar situation executed from memory without significant conscious thought.
Skill of the Craft	The knowledge, skills, and abilities possessed by individuals as a result of training or experience. Activities related to certain aspects of a task or job that an individual knows without needing written instructions.
Slip	A physical action different than intended. (See also *error*, *lapse*, and compare with *mistake.*)
Standdown	A period of time devoted by an organization toward the education, training, and sensitization of personnel on issues associated with performance improvement.
Supervisor	That member of first-line management who directs and monitors the performance of individual contributors (front-line workers) in the conduct of assigned work activities.
System	A network of elements that function together to produce repeatable outcomes; the managed transformation of inputs (resources) into outputs (results) supported with monitoring and feedback.
Systems Thinking	Consideration of the multiple, diverse, and interrelated variables and their patterns that come to bear on a worker at the job site; knowledge of the interdependencies of processes and leadership dynamics on performance—the organizational nature of human performance. (See also *Performance Model.*)

Term or Phrase	Description
Task	An activity with a distinct start and stop made up of a series of actions of one or more people; sometimes a discrete action.
Task Demands	Specific mental, physical, and team requirements that may either exceed the capabilities or challenge the limitations of human nature of the individual assigned to perform the task. (See also *error precursor.*)
Team Error	A breakdown of one or more members of a work group that allows other members of the same group to err due to either a mistaken perception of another's abilities or a lack of accountability within the individual's group.
Uneasiness	An attitude of apprehension and wariness regarding the capacity to err when performing specific human actions on plant components.
Unsafe Attitudes	Unhealthy beliefs and assumptions about workplace hazards that blind people to the precursors to human error, personal injury, or physical damage to equipment.
Values	The central principles held in high esteem by the members of the organization around which decisions are made and actions occur, such as reactor safety. (See also *culture* and *safety culture.*)
Violation	A deliberate, intentional act to evade a known policy or procedure requirement and that deviates from sanctioned organizational practices. (See also *Shortcut.*)
Vision	A picture of the key aspects of an organization's future that is both desirable and feasible—to be the kind of organization people would aspire to—that guide employees' choices without explicit direction, but understandable enough to encourage initiative.
Vulnerability	Susceptibility to external conditions that either aggravate or exceed the limitations of human nature, enhancing the potential to err; also the weakness, incapacity, or difficulty to avoid or resist error in the presence of error precursors. (See also *error precursor.*)
Work Environment	General influences of the work place, organizational, and cultural conditions that affect individual behavior at the job site. (See also *error precursors.*)
Work Execution	Those activities related to the preparation for, performance of, and feedback on planned work activities.
Worker	An individual who performs physical work on equipment, having direct contact (touching) with equipment, and is capable of altering its condition. (Compare with *knowledge worker.*)
Work Practices	Methods an individual uses to perform a task correctly, safely, and efficiently including equipment/material use, procedure use, and error detection and prevention. (See also *practices.*)

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CONCLUDING MATERIAL

Review Activity:	**Field and Operations Offices**	**Preparing Activity:**
DOE	AL	HSS
DP-NNSA	CH	**Project Number:**
EM	ID	HFAC-0017
NE	NV	
NN-NNSA	OH	
SC	OR	
RW	RL	
	SF	
	SR	
	Carlsbad Field Office (CBFO)	
	Office of River Protection (ORP)	

Area Offices:

Amarillo Area Office

Argonne Area Office

Brookhaven Area Office

Fermi Area Office

Kirtland Area Office

Los Alamos Area Office

Princeton Area Office

Y-12 Area Office

Berkeley Site Office