Chapter 5 – Human Performance Evolution

INTRODUCTION

Human error was long thought to be the genesis of events. In fact, human error is not the cause of failure. Human error is the effect, a symptom of trouble deeper in the system.[1] Accidents that occur in complex highly technological systems are often referred to as "system" accidents or organizational accidents. This designation recognizes that human performance does not take place in a vacuum, but occurs within the confines of the organization. James Reason reminds us that 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.[2] Recall the third principle of human performance: *Individual behavior is influenced by organizational processes and values.* 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.[3] The *Anatomy of an Event*, scenario described and shown graphically in Chapter 1, makes clear that organizational factors are a main contributor to events. It is fitting then that we briefly review major historical developments in efforts to understand and improve organizations that in turn lead to the development of the human performance improvement approach. Human performance is described in terms of a system. The model includes four elements (organization, job site, individual, and facility), illustrating the organizational nature of human performance through condition, action, influence and causality.

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.[4] 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*."[5] 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 on 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 institutions, 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".*[6]

INFLUENCES ON 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.[7]

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.[8] 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 them selves 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 at 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.[9] 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, situation 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.[10]

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 now, 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.*[11]

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.*[12]
- *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.*[13]

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 (in this chapter) and Edgar Schein's work on organizational culture (Chapter 5) will be discussed in some detail. 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	Managing Change	Team Building
• Management development • Organizational communication • Organizational diagnostics • Organizational performance • Succession planning • Organizational engineering	• Diversity management • Knowledge management • Performance Improvement • Strategic planning • Systems-thinking • Coaching and facilitation	• 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 the practice of shared vision 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 started aggressively 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.[14] 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 defenses 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 defenses. In many cases, they are weakened or absent defenses.
- 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). [15]

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.[16] 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 defenses. The *Human Performance Tools* manual 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 the work of Dr. Ellen Langer[17] 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:

- a greater sensitivity to one's environment;
- more openness to new information;
- the 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.[18]

High Reliability Organizations

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).[19] 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 took a different perspective than most of the researchers who preceded them. 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.[20]

- 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.[21] 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.

The following organizations are considered HROs:

- power grid dispatching centers;
- naval aircraft carriers;
- hospital emergency departments;
- air traffic control systems;
- nuclear submarines;
- airline cockpit crews;
- offshore platforms;
- hostage negotiators[22]; and
- commercial nuclear power plants.

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.[23] 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.[24]

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 defenses, 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.[25]

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.

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 have 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 defenses 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.[26]

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[27]

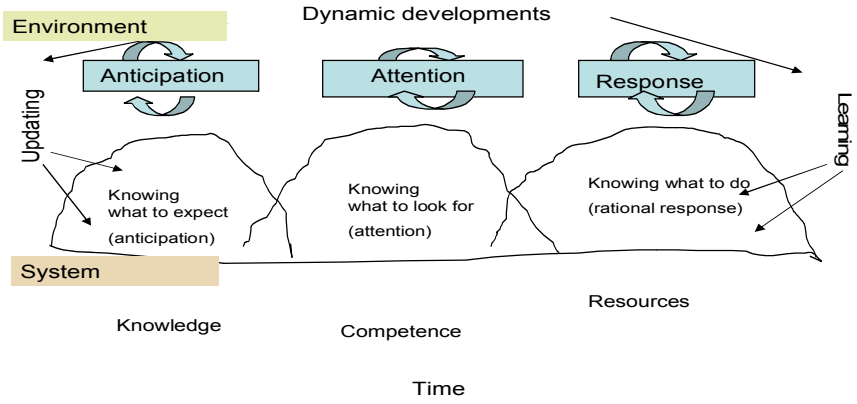
Organizational Resilience

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.[28]

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.[29]

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.[30]



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.[31]

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. [32]

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 defenses against active errors and their consequences; and
- cultivating an environment where honest errors can be openly reported and learned from.

The Secretary of Energy announced the formation of the DOE Human Performance Center in early 2007 to be operated by Health, Safety and Security (HSS). The Center's mission is to help organizations integrate HPI concepts into existing DOE and contractor systems and culture. The Center develops and provides consistent guidance and HP tools in the form of training, handbooks, and the like. The Center serves as a clearing house for HP information and resources. It also provides implementation assistance to the field and to Program Offices and assists in the analysis and evaluation of events and incidents

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