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Best Practices – Human Error Management

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Abstract

Human error contributes to over 50 percent of all errors in aerospace manufacturing due to the complexity of tasks associated with producing and testing space hardware. Prevention is important, but due to the pervasiveness of human involvement in the manufacturing process, errors are unavoidable and need to be managed. This MAIW mini-topic product identifies 5 Best Practices of a successful Human Error Management (HEM) Program: Principles, Organizational Environment, Training, Communication Forums, and Closed-Loop Assessments. These Best Practices will help leaders and managers create the right environment for HEM to be implemented and sustained. The Best Practices also help move an organization (management, leaders, and team members) from a reactive culture to a proactive culture. Sustainment of these practices by leadership reinforcement and team member involvement is key to ensuring that complacency, which increases human errors, does not set in.

Although this product focuses on integration and testing, the same HEM practices can be applied across the Systems Engineering "Vee." This product provides a means of self-assessment for companies to identify where they could strengthen their strategies for managing and mitigating errors introduced by humans. It is up to each company to establish its own program; this product alone will not establish a HEM program. Culture determines the success of HEM programs. Proactive HEM programs that include preventative actions and processes to manage errors are stronger and more cost effective than HEM programs that are solely reactive in responding to mishaps.

Best Practices – Human Error Management

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Section 1 Introduction

1.0 Introduction: Why Human Error Management is Important

- Human contribution can be considered the most chaotic part of our processes
- Human error…"it" happens, and is accountable for over **50 percent**(1-1) of errors in the aerospace industry
  - *These errors cost money, impact schedule, destroy hardware, and cost lives*
  - *These errors happen regardless of the measures in place to design them out, write the perfect procedure, or train all employees on how to do their tasks*
- Goals of the Human Error Management (HEM) Best Practices product:
  - *Emphasize PROACTIVE rather than reactive approach to managing human errors*
  - *Emphasize a top-down-supported CULTURE based on more than just training*
  - *Define uniform Best Practices with the objective of REDUCED human errors across the industry*

1.0 Introduction: Why Human Error Management is Important (cont.)

- Think about the last time you sat at your desk and wrote an email…
  - *How many times did you hit backspace to correct a typo or rewrite your thought?*
  - *How many times were you interrupted by a phone call, co-worker walking in, or another email?*
  - *Were you distracted by something going on at home (Sick loved one? Squabble with the spouse? College bills?)*
  - *These are some of the mind traps that impact human errors. This product is geared around the management of these mind traps.*
- Think about the last time your company had an incident or failure due to human error…
  - *Did the time and resources to solve this issue suddenly become available?*
  - *Were some of the statements heard*
    - "Whose fault is it?"
    - "They should have known better?"
    - "Why did that happen again?"…
  - *Was a reaction to the incident to implement "Human Error" training AFTER the fact?*
  - *Did someone think or say, "If 'so and so' felt empowered to speak up, this wouldn't have happened?"*
  - *These are some examples of a organizational environment that does not have a Best Practices HEM Program.*

1.0 Introduction: Human Error…"It" Happens

1.0 Introduction: Future Guideline

- Recommend creation of Guideline Document for implementing and sustaining human error management
  - *Uniform expectations and understanding across industry will lead to better cultural acceptance of processes*

- AS9100 [1-2] Rev. D now includes section 8.5.1, which states, “The organization shall implement production and service provision under controlled conditions. Controlled conditions shall include, as applicable […] g. the implementation of actions to prevent human error”
  - *Use of this Best Practices Product is an example of an action to prevent human error*

1.0 Introduction: Human Error Examples

- Manufacturing
  - *Beryllium central cylinder filed by technician, causing evacuation of high bay*
- Assembly
  - *Placing identification (ID) on the backs of application-specific integrated circuit (ASIC) chips with a sharp metal scribe instead of using a marking pen. Hundreds of ASIC chips mounted on printed circuit boards (PCBs) with cracks due to scribe markings*
  - *Optical mirror coating scratched while mounted in interferometer due to attenuator falling against it from an inadequate mounting fixture*
  - *Bolts were torqued from memory, resulting in panel inserts being pulled from panel after design change occurred*
  - *Screws were used that were too long to mount traveling wave tube amplifiers (TWTAs), causing heat dissipation issues*
  - *Boxed communications panels were damaged when stacked on top of one another*
  - *Duct tape was left on reflector mechanism housing and found by security guard when spacecraft was on launch vehicle*

1.0 Introduction: Human Error Examples (cont.)

- Integration and Testing
  - *C-Band reflectors removed and reinstalled on wrong sides at launch base*
  - *Rework X-ACTO knives accidentally dumped into spacecraft interior during rotation*
  - *Tools left inside spacecraft were found during spacecraft rotation*
  - *Unit under vibration exploded because undocumented procedure step was not followed by replacement technician*
  - *Technician dropped tool on payload attach fitting (PAF) during spacecraft mate with PAF*
  - *Manager walked into antenna while inspecting spacecraft*
  - *Spacecraft stretched during move because it was still fastened to integration stand*

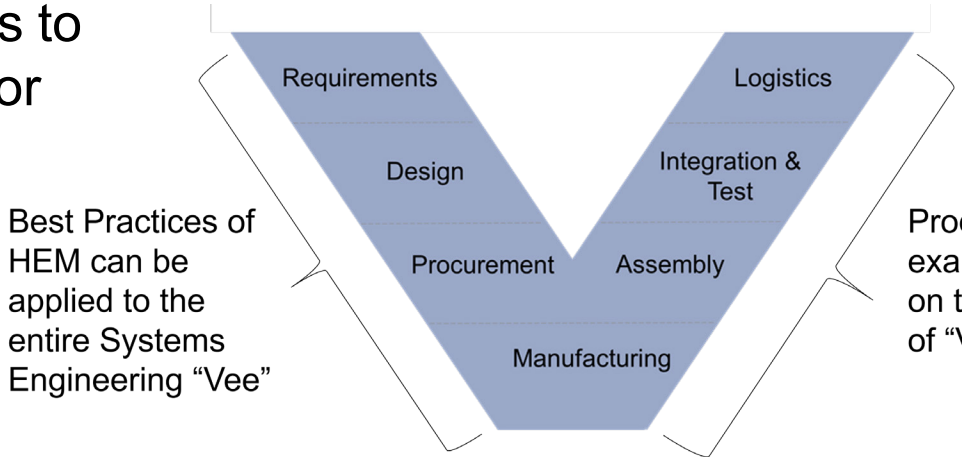
1.0 Introduction: Human Error Examples (cont.)

- Logistics
  - *Lifting sling installed 180 degrees out of phase, causing satellite to fall on floor*
  - *Hydraset reel pendulumed into optical solar reflector (OSR) panel*
  - *Scissor lift collided with reflector when lift was being elevated*
  - *Bolts not installed on handling dolly, so satellite fell onto floor*
  - *Critical venting pressure relief valve was not opened, causing shipping container to collapse on spacecraft during shipment on plane*
  - *Shipping container was gashed open by light pole during transport because everyone was focused on other side*
  - *Shipping container ran into overpass because maximum heights were not checked on shipping route*
  - *Security guard's chair collided with spacecraft in storage when he got up*

Section 2 Scope

2.0 Product Scope: What's In

- Outlines Best Practices of Human Error Management (HEM) for implementation at aerospace companies and subcontractors
  - *Product focuses on empowering the employees to MANAGE human error*
  - *Product provides tools, models, and ideas to manage human error opportunities*
- Provides examples of human error that focus on the right side of the Systems Engineering (SE) "Vee"
  - *Human errors and 5 Best Practices apply through entire lifecycle*
- Presents areas of 5 Best Practices for companies to develop, improve, and/or strengthen their human error management strategies



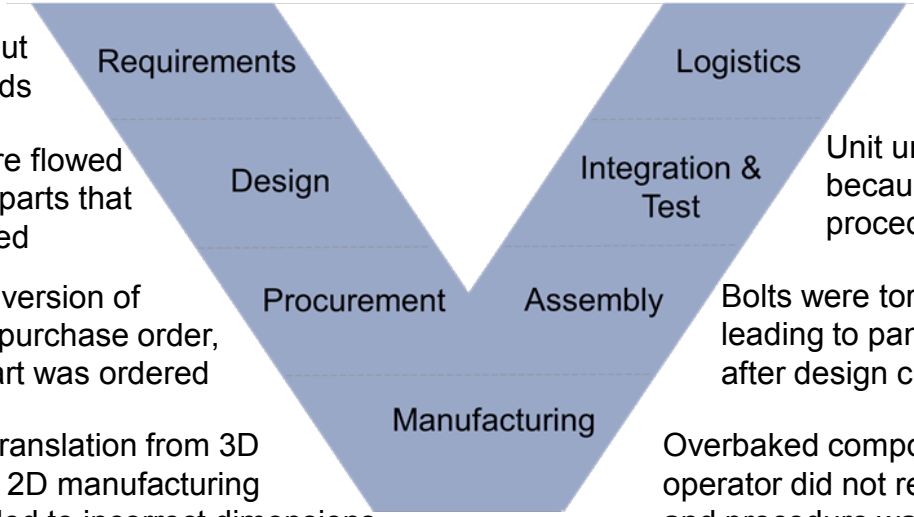
2.0 Product Scope:
Human Error Examples and SE "Vee"

Re-using heritage requirements blindly without verifying new mission needs

Mismatched units were flowed down to two different parts that were going to be mated

Sent incorrect version of drawings with purchase order, so incorrect part was ordered

Error in translation from 3D model to 2D manufacturing drawing led to incorrect dimensions



Shipping container ran into overpass because maximum heights not checked along shipping route

Unit under vibration exploded because undocumented procedure step was not followed

Bolts were torqued from memory, leading to panel inserts pulling off panel after design change occurred

Overbaked component because operator did not realize oven was in °C and procedure was in °F

2.0 Product Scope: What's Out

- Product does not address
  - *Specific HEM challenges of "Project Definition"(left side) portion of Systems Engineering "Vee"*
  - *Protocol associated with HEM and Human Resources (HR)*
    - Interaction with HR may be required for HEM, e.g., violations
  - *Protocol associated with HEM and personnel management challenges (e.g., distress/work-life balance)*
    - Interaction with management may be required to reprioritize tasks for individual to ensure successful HEM
  - *Personnel technical training*
    - Mismatches between human-machine and human-task
    - Screening required to match individuals to tasks
    - Training regarding task-specific activities and techniques such as soldering joints
  - *HEM challenges in software development, cyber security, and automation*

Section 3 Product Overview

3.0 Product Overview

- Human error management (HEM) is not simply about taking training classes or a card employees wear on badges to remember to apply HEM responsibilities, it IS also about culture:
  - *A culture that empowers, communicates with, and supports all employees around human error management*
  - *A culture where employees recognize their fallibility, and supervisors and managers do not point fingers*
  - *A culture that incorporates all best practices into the company processes and way of thinking*

- This product:
  - *Outlines 5 Best Practices of Human Error Management* ***(Section 7.0)***
  - *Provides abstracts on industry literature on HEM* ***(Section 5.0)***
  - *Facilitates learning of HEM 5 Best Practices through use of examples* ***(Section 6.0)***
  - *Provides general overview for HEM evaluation and implementation via 5 Best Practices* ***(Section 8.0)***

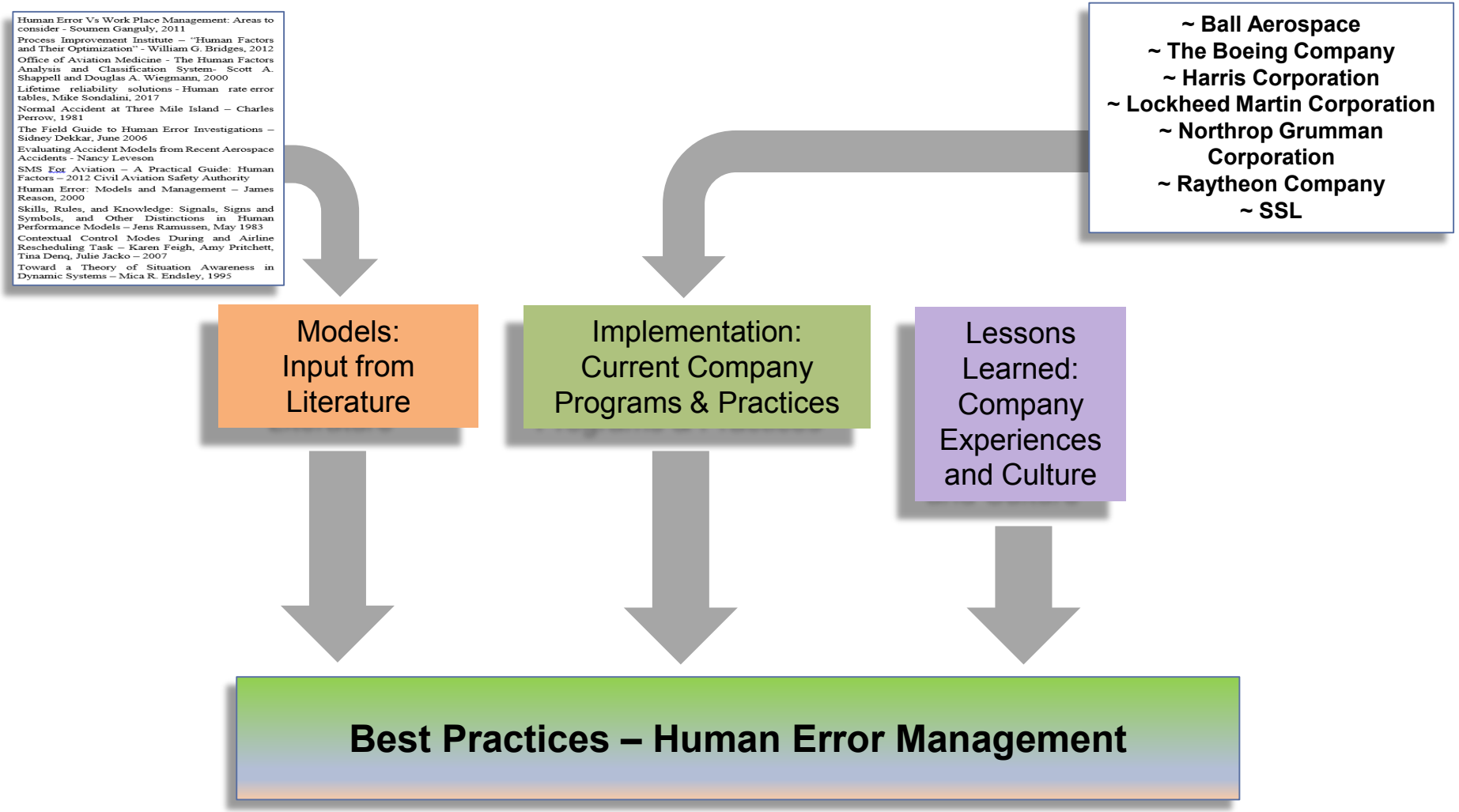
3.0 Product Overview (cont.)

- Who is the target audience?
  - *Aerospace and defense industries*
  - *Customers*
  - *Program management, operations management, functional management, mission assurance management, senior management/leadership*
  - *Individuals: engineers, technicians, inspectors*

- Product enables organizations to:
  - *Raise management and employee awareness of HEM programs*
  - *Identify potential arenas for failures in 5 Best Practices areas*
  - *Communicate concept of personal responsibility to empower individuals to flag human errors*

Section 4 Development Process for Best Practices

4.0 Development Process for Best Practices



4.0 Development Process for Best Practices (cont.)

- Collected data from team member institutions
  - *Discussed existing human error management (HEM) techniques, both formal and informal*
  - *Some institutions use commercial off-the-shelf (COTS) HEM tools, as described in Section 5.1*
  - *Gathered examples of issues and scenarios seen in the past*
  - *Note: None of the institutions used techniques that perfectly modeled the 5 Best Practices described in this product*
- Sourced human error management documents from other industries and academia
- Team reviewed input to produce high-level 5 Best Practices recommendations
- Product reviewed by independent subject matter experts (SMEs)
  - *SMEs from aerospace industry*
  - *Feedback incorporated into product*

Section 5 HEM Tools and Literature

5.0 HEM Tools and Literature

- To determine potential Human Error Management (HEM) Program 5 Best Practices, COTS tools and industry models were reviewed
  - *Section 5.1 describes commercial HEM tools*
  - *Section 5.2 lists literature resources on human error models and management techniques*
  - *Note: The tools and literature listed are not all inclusive of work done on this subject, but represent a good cross section of that work*

5.1 Commercial Off-the-Shelf (COTS) HEM Tools

5.1 COTS HEM Tools

- Center for Error Management (CEM) – TEBS® (Task, Equipment, Barriers, Skills) Model (5-1)
  - *TEBS® is a methodology and set of tools that can be applied to organizations and processes to manage human errors*
  - *Philosophy: "People make mistakes….For modern business these errors, be they in judgment, values, communications or otherwise are costly. They result in lost revenues and time, lost contracts, accidents, low morale, redundancy and many other factors that strike a direct hit to the bottom line"*
  - *CEM "has developed a series of broadly applicable and cost-effective tools that impact the bottom-line by reducing, managing and in some cases eliminating human errors from a variety of business processes"*

5.1 COTS HEM Tools (cont.)

- Error Prevention Institute, Inc. – AESOP™ Model (5-3)
  - *AESOP is a set of trademarked processes and tools developed by the Error Prevention Institute that is used by many aerospace companies and government agencies to enhance their human error management programs*
  - *Centered around the following elements: Assignment, Equipment, Situation, Obstacles, and Personnel (AESOP)*
  - *Error-prevention technique used to ensure that all personnel associated with an operation are familiar with and understand their roles and responsibilities, and that risks of failure are identified and mitigated*

Section 5.2 Human Error Management Literature

5.2 Human Error Management Literature

- **James Reason, "Human Error: Models and Management"** (5-4)
  - *Excerpt: "The human error problem can be viewed in two ways: the person approach and the system approach. Each has its model of error causation and each model gives rise to quite different philosophies of error management. Understanding these differences has important practical implications for coping with the ever present risk of mishaps."*
  - *Introduces the "Swiss Cheese Model of system accidents" in which "the holes in many layers momentarily line up to permit a trajectory of accident opportunity—bringing hazards into damaging contact* with victims."
- **Jens Rasmussen, "Skills, Rules, and Knowledge: Signals, Signs and Symbols, and Other Distinctions in Human Performance Models"** (5-5)
  - *From abstract: "The introduction of information technology based on digital computers for the design of man-machine interface system has led to a requirement for consistent models of human performance in routine task environments and during unfamiliar task conditions. A discussion is presented of the requirement for different types of models for representing performance at the skill, rule, and knowledge-based level, together with a review of the different way in which information is perceived at the different levels in terms of signals, signs and symbols."*

5.2 Human Error Management Literature (cont.)

- **William G. Bridges, "Human Factors and Their Optimization"** (5-6)
  - *From abstract: "This paper discusses each of the 10 primary human factors and describes what we know about their relative importance in accident causation. The data presented is from basic research by the authors on the root causes of more than 2000 accidents and near misses; and also based on the review on the review of hundreds of accidents analyzed by others and on summary data from many companies. This paper lists where focus should be placed (i.e., which human factors tend to be key) and provides proven ways to optimize these human factors so that the base human error rate at a site is as low as possible."*
- **Soumen Ganguly, "Human Error vs. Workplace Management in Modern Organizations"** (5-7)
  - *Brief overview of human error management that includes categories of human error, factors influencing human behavior, how to manage human error, and common pitfalls in managing human error*

5.2 Human Error Management Literature (cont.)

- **Scott A. Shappell and Douglas A. Wiegmann, "The Human Factors Analysis and Classification System"** (5-8)
  - *From abstract: "…the [Human Factors Analysis and Classification System (HFACS)] framework has been used within the military, commercial, and general aviation sectors to systematically examine underlying human causal factors and to improve aviation accident investigations. This paper describes the development and theoretical underpinnings of HFACS in the hope that it will help safety professionals reduce the aviation accident rate through systematic, data-driven investment strategies and objective evaluation of intervention programs."*
- **Sidney Dekkar, *The Field Guide to Understanding Human Error*** (5-9)
  - *Excerpt from preface: "People do not come to work to do a bad job. Safety in complex systems is not a result of getting rid of people, or reducing their degrees of freedom. Safety in complex systems is created by people through practice—at all levels of an organization. […] The New View embodies this realization and lays out a new strategy for understanding safety and risk on its basis. Only by understanding the New View can you and your organization really begin to make progress on safety. And the Field Guide is here to help you do just that."*
  - *Introduces terminology of "The Bad Apple Theory" for the "Old View" that specific people are to blame*

5.2 Human Error Management Literature (cont.)

- **Nancy Leveson, "Evaluating Accident Models from Recent Aerospace Accidents – Part I: Event-based Models"** (5-10)
  - *From executive summary: "Accident models are used to explain how accidents occur. […] The models impose patterns on an accident and this will influence both the data collected and the factors identified as causative. While accident models are a way to organize data and set priorities in accident investigations, at the same time they may either act as a filter in the collection of data that narrows the investigation or they may expand the investigation by forcing consideration of factors that are often omitted. […] Part I considers event-based accident models including domino and single event, chains of events, and hierarchical."*
- **Australian Government Civil Aviation Safety Authority, "SMS [Safety Management System] For Aviation – A Practical Guide: Human Factors"** (5-11)
  - *Excerpt: "Human factors is about understanding humans - our behavior and performance. Then, from an operational perspective, we apply that human factors knowledge to optimize the fit between people and the systems in which they work, to improve safety and performance. ICAO [International Civil Aviation Organisation] uses the SHEL [Software, Hardware, Environment, Liveware] model to represent the main components of human factors. SCHELL [Software, Culture, Hardware, Environment, Liveware, Liveware] is an expanded version of this model. The SCHELL model gives an idea of the scope of human factors."*

5.2 Human Error Management Literature (cont.)

- **Charles Perrow, "Normal Accident at Three Mile Island"** (5-12)
  - *Excerpt: "[Three Mile Island] was a 'normal accident'; these are bound to occur at some plant at some time, and bound to occur again, even in the best of plans. […] Normal accidents emerge from the characteristics of the systems themselves. They cannot be prevented. They are unanticipated. It is not feasible to train, design, or build in such a way as to anticipate all eventualities in complex systems where the parts are tightly coupled."*
- **Mike Sondalini, "Human Error Rate Table Insights"** (5-13)
  - *Extract: "The problems we have with our plant and equipment are not plant, equipment or machine problems. Our equipment and machines are fine. Their engineering, the materials-of-construction of their parts and their manufacturing methods are fine. The problems …are almost entirely due to human errors that happen throughout our companies—from the Boardroom to the Shop floor. Currently the only protection against human error is to design and manage our business processes so we protect our machines and businesses from ourselves. The focus to take is clear once you interpret the information contained in human error rate tables."*

5.2 Human Error Management Literature (cont.)

- **Larry Tew, "Managing Human Fallibility in Critical Aerospace Situations"** (1-1)
  - *From abstract: "We will discuss success stories, including those associated with electro-optical systems, where very significant reductions in human fallibility errors were achieved after receiving adapted and specialized training. In the eyes of company and customer leadership, the steps used to achieve these results lead to a major culture change in both the workforce and the supporting management organization."*
- **Barbara G. Kanki, Robert L. Helmreich, and Jose Anca, editors, *Crew Resource Management*** (5-14)
  - *HEM being implemented today in medicine, fire service, and the aerospace industry is an evolution from Crew Resource Management (CRM) created by the aviation industry in the 1970s. By examination of accidents, the aviation industry determined that the major causes of errors were not technical, but were the result of undesirable human performance in the cockpit. They determined that the major contributors to accidents were a lack of leadership and a lack of assertiveness by crew members.*
  - *CRM has evolved in a series of phases. Recent phases created specific activities and approaches to prevent errors, and, accepting that humans are liable to make errors, recognized the need to manage them. Most recent phase recognized that to successfully detect and avoid errors, it was necessary to determine risks associated with activities.*

Section 6 Aerospace Industry HEM Experience

6.1 Existing HEM Implementations in Aerospace Industry

- Participating MAIW aerospace companies provided information on their Human Error Management (HEM) program implementations
- HEM programs can be divided into two categories: formal and informal
  - *Formal HEM programs include documented policies, procedures, instructions, and training, often using a COTS HEM tool*
  - *Informal HEM programs rely on the inclusion of "best practices" into existing operations and processes without documentation. The "best practices" are successfully integrated into the culture.*

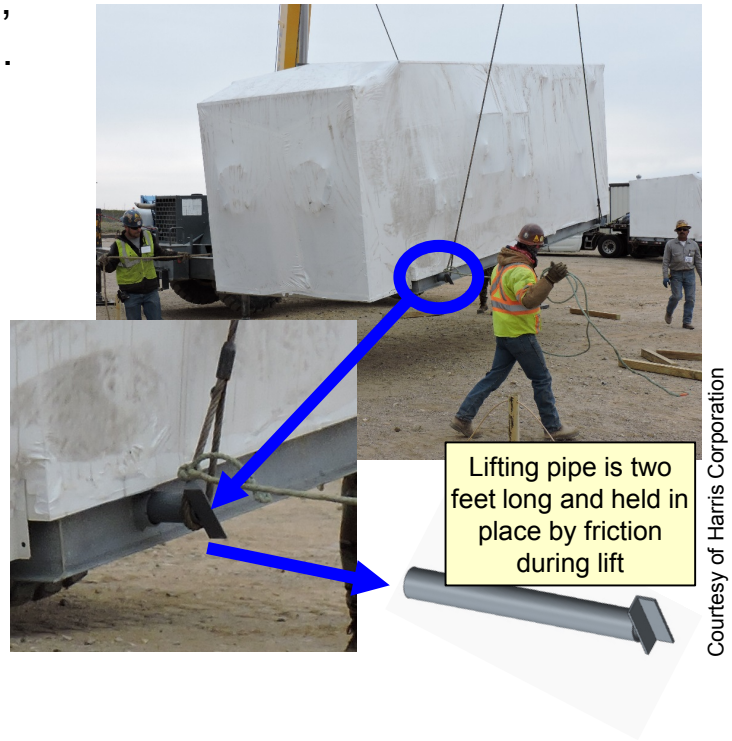
Section 6.2 Human Error Examples

6.2 Human Error Examples

- Human Error (HE) examples in this product were provided by participating MAIW aerospace companies for assessment against 5 Best Practices, demonstrating a variety of HE scenarios from the right side of the Systems Engineering "Vee." One HEM success story is also included.
  - *HE Example 1: Equipment Shelter Incident*
  - *HE Example 2: Dropped Hardware*
  - *HE Example 3: Material Traceability*
  - *HE Example 4: Inadequate Oven Cure Time*
  - *HE Example 5: Successful Best Practices Story*

6.2 HE Example 1: Equipment Shelter Incident

- **Situation:** While relocating an equipment shelter using a crane lift, one of four lift attachments for the shelter came loose, causing the other three attachments to loosen as well. The shelter dropped one to two feet to the ground causing minor visible shelter damage but no personnel injuries.



Courtesy of Harris Corporation

- **Background:**
  - *Lift was successfully accomplished 18 times previously*
  - *All safety precautions were observed*
  - *Lifting personnel were trained, qualified, experienced*
  - *Lift observed by Quality Assurance (QA) Rep, Safety Rep, Transport Point of Contact (POC), and Project Engineer, among others*
  - *Lifting crew followed manufacturer's lifting procedure*
  - *Manufacturer's lifting procedure was found to be inadequate; did not address side loads imparted by rigging equipment*
  - *A geographically separated crew had recognized the need to modify the procedure during a previous lift but did not communicate this knowledge across the program*

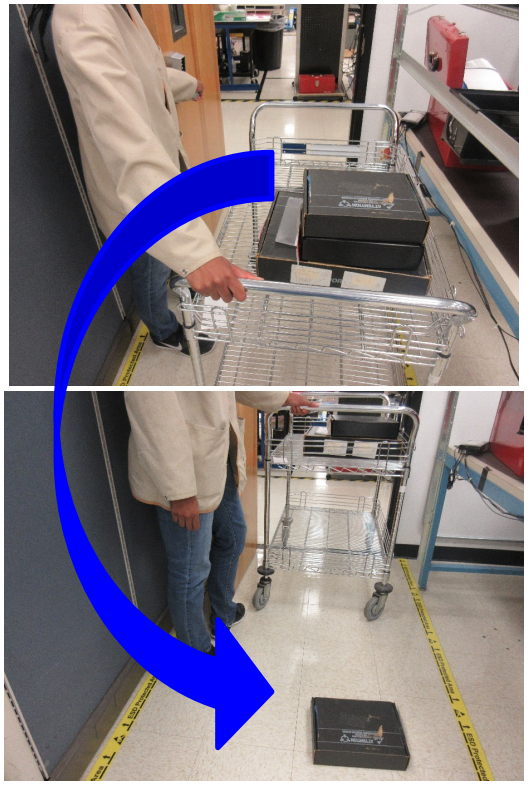
6.2 HE Example 1: Tied to Best Practices Principles*

- **What was the Human Error?**
  - *Complacency caused by 18 successful moves*
  - *Failure to modify a known procedure defect and communicate it to other teams*
- **What was the Source of the Human Error?**
  - *Environmental: organizational and process issue*
- **Were there any applicable Pitfall(s) or Mind Trap(s) that may have been in place?**
  - *Complacency, repetitive tasks, communication breakdown*
- **What Tool(s) may have helped?**
  - *Questioning attitude: asking what could go wrong*
  - *Assertive statement (informing teams of procedural changes at other sites)*
- **What Human Error Management area may this HE have fallen under?**
  - *Communication management*

*** See Section 7.1 for further details on Best Practices Principles.**

6.2 HE Example 2: Dropped Hardware

- **Situation:** While moving three circuit card assemblies from shelving storage to a work station, a technician bumped the transport cart against a door jamb. The jolt caused the top storage box on the stack of three boxes to fall from the cart three feet to the floor.
- **Background:**
  - *Technician was trained and experienced in hardware movement*
  - *Technician followed all handling and transport procedures for hardware class*
  - *Inadequate door clearance due to new door installation*
  - *New door did not have door stop which required door to be propped open with foot; technician pushed the cart through with one hand*
  - *Management previously denied purchase of new carts with higher side walls due to expense*
  - *Movement procedure to be modified to incorporate the use of cart nets and to revisit rule that permits stacking boxes up to three high*



Courtesy of Harris Corporation

6.2 HE Example 2: Tied to Best Practices Principles*

- **What was the Human Error?**
  - *Procedure: may not have included caution/warning regarding stack height of equipment and keeping door open with foot*
  - *Facility: did not do proper check (environmental source/facility design), no door stop, cart too low*
- **What was the Source of the Human Error?**
  - *Stress: perceived pressure to move all items concurrently*
  - *Environmental: new door with cart too low*
- **Were there any applicable Pitfall(s) or Mind Trap(s) that may have been in place?**
  - *Accommodation of risk: management accepted risk of lower cart walls*
  - *Repetitive tasks, distraction, perceived pressure to get the work done*
  - *New situation: new door*
  - *Communication breakdown: no alternative to management saying no to new cart*
- **What Tool(s) may have helped?**
  - *Situational awareness: new door without door stop, think how to move through it safely*
  - *Questioning attitude: asking what could go wrong*
  - *Training on new door*
- **What Human Error Management area may this HE have fallen under?**
  - *Situational awareness management, attitude management, and communication management*

*** See Section 7.1 for further details on Best Practices Principles.**

6.2 HE Example 3: Material Traceability

- **Situation:** Engineering and Quality Assurance were unable to verify the material traceability of a fabricated part for a satellite program. It was discovered that a machinist manufactured the deliverable part using raw stock that potentially did not meet design specifications. Subsequently, laboratory analysis of the part was conducted to confirm its compliance.
- **Background:**
  - *Machinist worked in fabrication shop that was commonly tasked with rapid-prototype, proof-of-design, troubleshooting, and other non-deliverable work*
  - *Engineering was under time pressure to complete project and had verbally directed machinist to start fabricating part before issuing proper documentation and failed to state that order was customer deliverable*
  - *Machinist assumed fabricated part was intended for breadboard and used uncontrolled stock material*
  - *Discrepancy was discovered when engineering formally issued work order and released the drawings*

6.2 HE Example 3: Tied to Best Practices Principles*

- **What was the Human Error?**
  - *Flight part made with stock material*
- **What was the Source of the Human Error?**
  - *Environmental/organization: communication breakdown*
  - *Stress/circumstantial: time pressure to complete project*
  - *Personnel/experience: past work order history led to incorrect assumption about what material to use*
- **Were there any applicable Pitfall(s) or Mind Trap(s) that may have been in place?**
  - *Repetitive task; communication breakdown, perceived pressure; new situation*
- **What Tool(s) may have helped?**
  - *Questioning attitude: ask clarifying questions*
  - *Slow Down to Speed Up*
  - *Use of HEM (COTS or home-grown)*
- **What Human Error Management area may this HE have fallen under?**
  - *Situational awareness management*
  - *Communication management*
  - *Workload management*

*** See Section 7.1 for further details on Best Practices Principles.**

6.2 HE Example 4: Inadequate Oven Cure Time

- **Situation:** A technician who was monitoring the oven cure times for two circuit card assemblies manually stopped the oven during its automated run profile before the allotted cure time had elapsed. It was later identified that the assemblies had been removed from the oven 10 minutes early.
- **Background:**
  - *Technician calculated elapsed cure time starting from when circuit boards were placed in oven; cure time actually begins after oven has ramped up to its targeted temperature and has stabilized*
  - *Oven controller automatically calculates correct ramp up/down times and dwell times to meet required cure time; oven controller prevents manual intervention (to reduce human error)*
  - *Technician overrode the programmed oven profile by manually shutting off oven*
  - *First time technician had used oven since receiving oven operation training*
  - *Technician was not supervised during first-time operation*
  - *Training did not adequately explain all conditions that must be met to successfully complete cure*

6.2 HE Example 4: Tied to Best Practices Principles*

- **What was the Human Error?**
  - *Override of oven controller program*
- **What was the Source of the Human Error?**
  - *Personnel/training: individual did not follow process, lack of experience, inadequate training procedure*
  - *Stress/circumstantial: desire to complete task quickly/time stress,*
- **Were there any applicable Pitfall(s) or Mind Trap(s) that may have been in place?**
  - *Risky attitude, new situation, perceived time pressure, communication breakdown*
- **What Tool(s) may have helped?**
  - *Tools: Checklists*
  - *Questioning attitude: asking what could go wrong*
- **What Human Error Management area may this HE have fallen under?**
  - *Attitude management, communication management, workload management (lack of supervision)*

*** See Section 7.1 for further details on Best Practices Principles.**

6.2 HE Example 5: Successful Best Practices Story

- **Situation:**
  - *Large, wide, and heavy piece of critical ground support equipment (GSE) was delivered on a truck bed that was too long to back into facility loading dock (vendor error)*
  - *Vendor insisted on attempting to maneuver truck to get into the building*
  - *After many two-point turn attempts to situate the truck perpendicular to the loading bay, not only did many trees need to be cut down, but the truck became stuck in the facility landscaping*
  - *Due to weight of GSE, the truck could not be moved until GSE was removed*
- **What Now?:**
  - *Vendor did not have equipment to remove GSE from truck bed*
  - *Prime contractor had crane inside building prepared to remove GSE once truck was inside.*
- **New and Unplanned Task:**
  - *Critical GSE needs to be safely removed from truck without damage to hardware or building or risking safety of personnel*
  - *Despite errors leading to this incident, contractor demonstrated proactive use of HEM Principles for safe arrival of hardware (see next page).*

Courtesy of Ball Aerospace and Technologies Corporation

6.2 HE Example 5: Tied to Best Practices Principles

Training
Employees on Program team had been proactively trained in the Principles of HEM

Culture
- Proactive Training
- Openly Discussed
- Successes & Activities openly communicated to customer

Principles

Workload Management
New Situation, Excessive/High Workload, Emotional Stress (frustrating situation); Physical Stress (long day, manual labor)

"Shout out to Bob and Sally for encouraging a Stop-and-Think approach when it came to next steps and human safety."

Group Dynamics
Group Think, Excessive Professional Courtesy, Strength of an idea, Hesitant to critique others
"TEBS® was used as a tool to manage life and safety," per RE who made a special effort to share how well the team did.

Risk Management
Continuous critical thinking about what can go wrong, Appreciation of outcome

"Lots of ideas, we were careful to not take risk despite everyone involved"
~ Safety Engineer

Attitude Management
Hero Syndrome, Perceived Pressure, Risky Attitudes, Pressure/ get-it done; anti-authority, hero/ show-off syndrome

"Even I got told to stop what I was doing."
~ Responsible Engineer (RE)

Situational Awareness
Distractions due to numerous observers, Sudden loss of judgment, Communication breakdown
Early on, RE requested barriers be put up and that only those needed remain

Communication
Communication barriers with vendor, Excessive Professional Courtesy
Pre-meeting for lift defining remove and replace (R&R) was held by System Safety Engineer

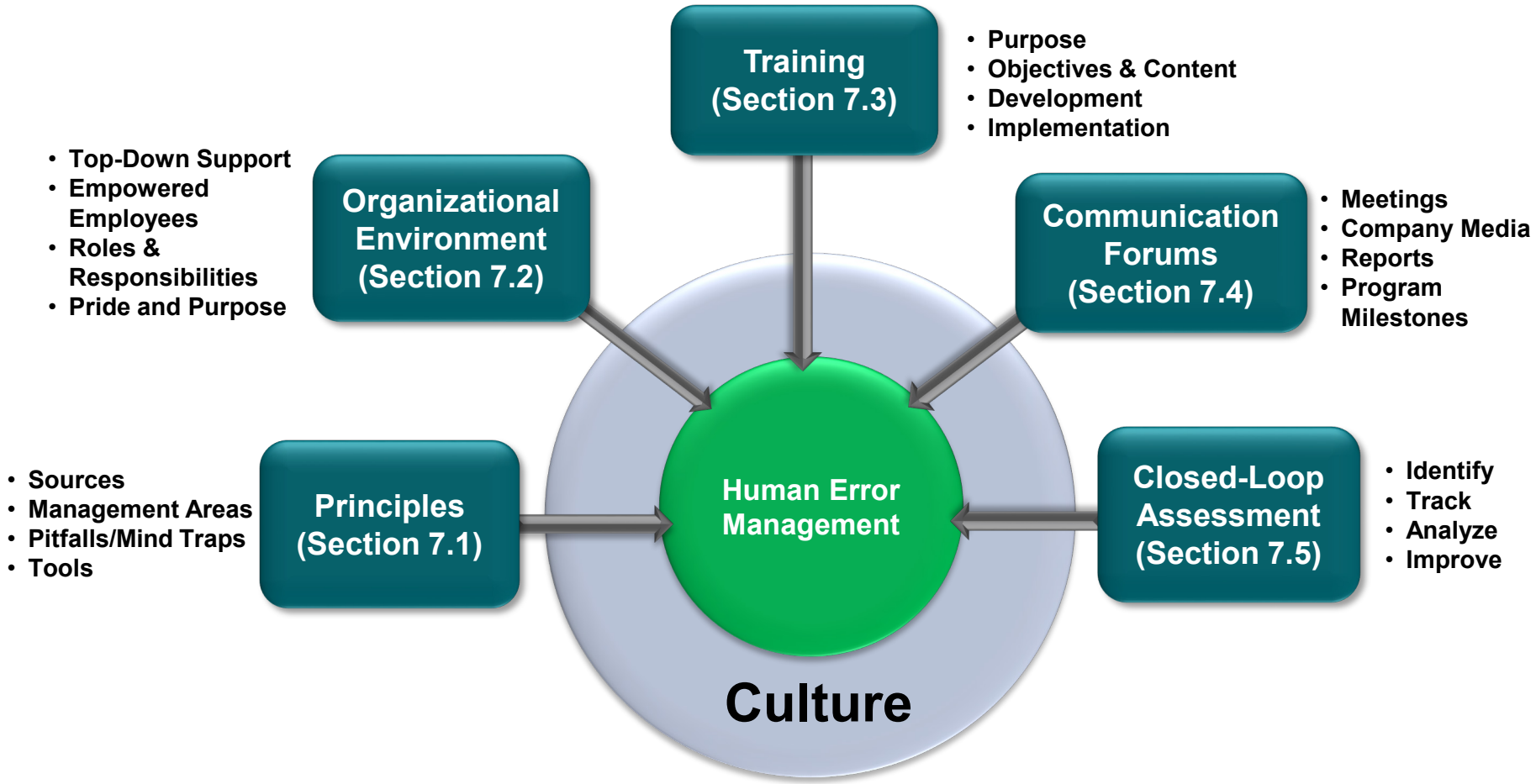
Best Practices | Management Areas (Principles) | Tools (Principles) | Pitfalls/Mind Traps (Principles)

Section 7 Best Practices Human Error Management

7.0 Best Practices Human Error Management

- This product focuses on providing aerospace companies insight into Human Error Management (HEM) 5 Best Practices in support of improving the industry's ability to control and reduce human errors.
- Best Practices for managing human error require more than training. 5 Best Practices are rooted in the following:
  - *Principles*
  - *Organizational Environment*
  - *Training*
  - *Communication Forums*
  - *Closed-Loop Assessment*
- Sections 7.1 through 7.5 describe the 5 Best Practices, including the relevance of culture on each

7.0 Best Practices Human Error Management (cont.)



7.0 Best Practices Human Error Management (cont.)

- 7.1 Best Practices – Core Principles
  - *Based on understanding of types of Human Errors (HEs), Sources and Pitfalls of HEs, and HE Management systems supported with tools, training, data and culture.*
- 7.2 Best Practices – Organizational Environment
  - *"An error avoidance culture can only develop by considering the existing leadership and workforce culture, adapting training appropriately, planning for strategic and tactical implementation, and developing a follow-up strategy to incorporate changes."* *(7-1)*
  - *"Ideally, an organization and its leadership create an environment where it is expected for individuals to feel free to speak up without the fear of retribution."* *(7-1)*
  - *"Individual awareness, leadership roles, and organizational culture must be considered in creating the right environment for avoiding human error."* *(7-1)*

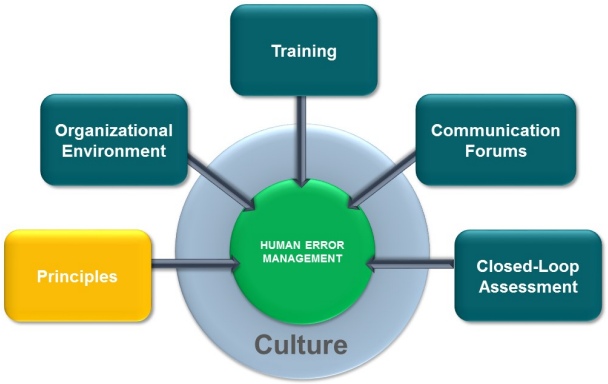
7.0 Best Practices Human Error Management (cont.)

- 7.3 Best Practices – Training
  - *Successful HEM program consists of training program rooted in core HEM principles, adapted to company's needs and culture.*
- 7.4 Best Practices – Communication Forums
  - *Well-rounded HEM program includes communication forums to support continual training, information on human errors, metrics, open discussion on incidents. Communication forums can fall into many categories such as media, human interactions, reports, and milestone reviews.*
- 7.5 Best Practices – Closed-Loop Assessment
  - *Highly effective HEM program must include closed-loop assessment process to identify, track, analyze, and manage human-induced errors.*

7.0 Best Practices Human Error Management (cont.)

- Best Practices – Culture
  - *Human error management is not simply about taking a training class or about the HEM tools card employees wear on badges, it IS also about culture:*
    - A culture that empowers, communicates with, and supports all employees around human error management
    - A culture where employees recognize their fallibility, and supervisors and managers do not point fingers
    - A culture that incorporates all 5 Best Practices into the company processes and way of thinking
    - An organization that cultivates a culture of error avoidance and strengthens the integrity of defenses to mitigate consequences of an error
    - A culture that creates an environment to share errors and corrective actions with others
      - *May consider a rewards-based reporting/sharing system*

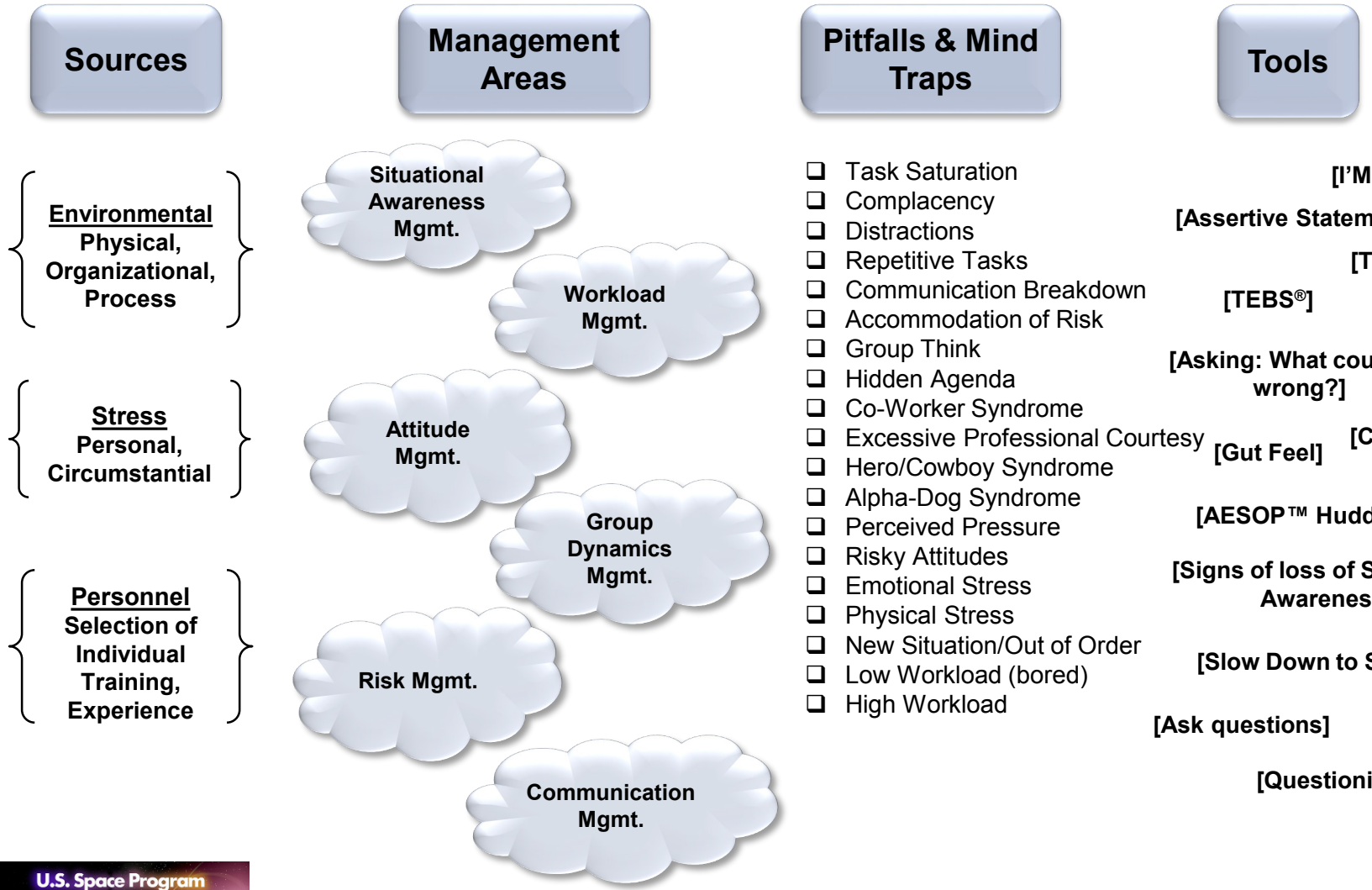
Section 7.1 Principles of Human Error Management



7.1 Principles of Human Error Management

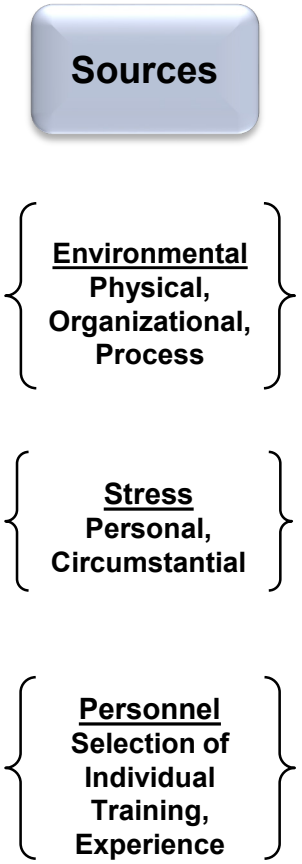
- Best Practices – Core Principles
  - *Based on understanding of types of HEs, Sources and Pitfalls of HEs, and HE Management programs supported with tools, training, data and culture.*
  - *Following pages show core HEM principles. A best practices program cannot start without a basic understanding of these underlying principles behind Human Error.*
- Culture and HEM Principles
  - *Including HEM Principles into the company processes, training, and way of thinking is the first step in creating a 5 Best Practices culture that is long lasting.*
  - *Continual renewal of HEM Principles within the company culture is important to keep HEM methods from becoming stale.*

Best Practices: Principles



7.1.1 Sources of Human Error

- Sources of Human Error
  - *Environmental*
    - *Physical*—Physical action performed incorrectly or omitted step
    - *Organizational*—Culture not conducive to promote HEM
    - *Process*—Latent error in existing process
  - *Stress*
    - *Personal*—Stressful situation at home, hard to concentrate on task
    - *Circumstantial*—More error prone late in the day
  - *Personnel*
    - *Selection of Individual Training*—may not have the level of skills for the intended task
    - *Experience*—long time since training, inadequate application of needed skills
    - Note: Human errors due to deficient personnel training and job experience are not covered in this product.



7.1.2 Human Error Management Areas

- Management Areas Associated with Human Error (7-1)
  - *Human Errors happen regardless of the measures in place to design them out, write the perfect procedure, or train all employees on how to do their tasks*
  - *Human Error scenarios, Mind Traps, and Tools can be categorized into the following management areas to better define and support overall human error management:*
    - Situational Awareness Management
      - *A continuous perception of self, human fallibility, and environment in relation to task accomplishment, and the ability to manage those actions based on that perception*
    - Workload Management
      - *Managing personal capabilities and integrating the capabilities of others in the workload environment to meet program objectives*
    - Attitude Management
      - *The awareness of how personality traits and risky attitudes can affect performance*

7.1.2 Human Error Management Areas (cont.)

- Management Areas Associated with Human Error (cont.)
  - Group Dynamics Management
    - *Group dynamics focuses on leadership, revolves around the authority of the leader, individual responsibility, respectful assertiveness, behavior styles, and team building*
  - Risk Management
    - *Identification of "What Could Go Wrong?" in an activity, the likelihood of occurrence, consequences, the impact of the consequences, and the approach to use to manage risk*
  - Communication Management
    - *Ensuring communicated messages are received completely and correctly*

7.1.3 Pitfalls and Mind Traps of Human Error

- Examples of Pitfalls and Mind Traps Associated with Human Error
  - *It is important to be reminded that regardless of all attempts to perfect a design, test procedure, or process, pitfalls and mind traps that influence the potential for Human Error will still exist.*

Group Dynamics

Group Think: Group takes action contrary what they individually would do

Co-worker Syndrome: Implicit confidence in team members resulting in lack of close attention and monitoring

Hidden Agenda: Consciously or unconsciously withholding information and/or making suggestions/decisions on desires not known by others

Situational Awareness

Task Saturation: Inability to handle multiple tasks
Distractions: Diverts attention from present task
Repetitive Tasks: The mind checks off things as being done by habit
Communication Breakdown: Tasks not clearly defined or understood

Risk Management

Accommodation of Risk: Become complacent to the risks of task environment
Task Saturation: Inability to handle multiple tasks

Pitfalls and Mind Traps

- ❑ Task Saturation
- ❑ Complacency
- ❑ Distractions
- ❑ Repetitive Tasks
- ❑ Communication Breakdown
- ❑ Accommodation of Risk
- ❑ Group Think
- ❑ Hidden Agenda
- ❑ Co-Worker Syndrome
- ❑ Excessive Professional Courtesy
- ❑ Hero/Cowboy Syndrome
- ❑ Alpha-Dog Syndrome
- ❑ Perceived Pressure
- ❑ Risky Attitudes
- ❑ Emotional Stress
- ❑ Physical Stress
- ❑ New Situation/ Out of Order
- ❑ Low Workload (bored)
- ❑ High Workload

7.1.3 Pitfalls and Mind Traps of Human Error (cont.)

Communications Management

Excessive Professional Courtesy: Hesitation to correct or even question another due to title, pay grade, or experience; yielding to peer pressure not to speak up
Communication Barriers: Ambiguous wording, jargon, technical wording, unfamiliar acronyms

Attitude

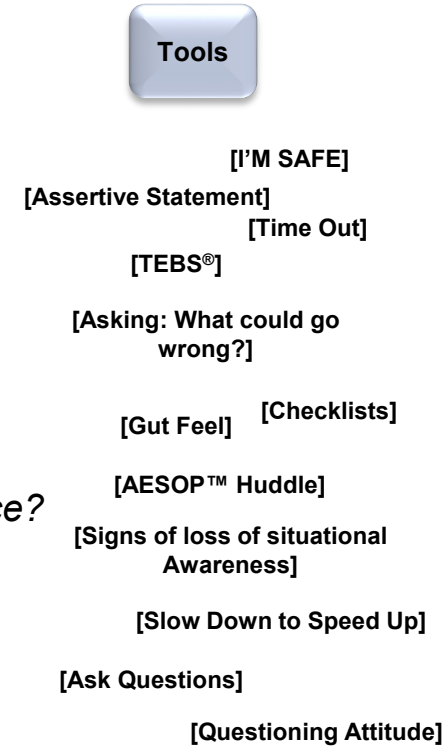
Hero/Cowboy Syndrome: Take actions not necessarily thought out or feel compelled to take action
Risky Attitudes: Anti-authority, impulsive, intimidating, resigned, get-it-done-ism
Perceived Pressure: Feeling your leader wants you to hurry or ignore process

Workload Management

Emotional Stress: Personal frustrations at home or at work that affects task performance, "can spill over at inappropriate times"
Physical Stress: Environmental factors that can affect an individual's body functions and performance
New Situation/Out of Order: Something new or out of the ordinary may increase chance for error
Low Workload: Little or no activity, can lead to loss of Situational Awareness
High Workload: Real or perceived pressure can lead to loss of Situational Awareness

7.1.4 Tools

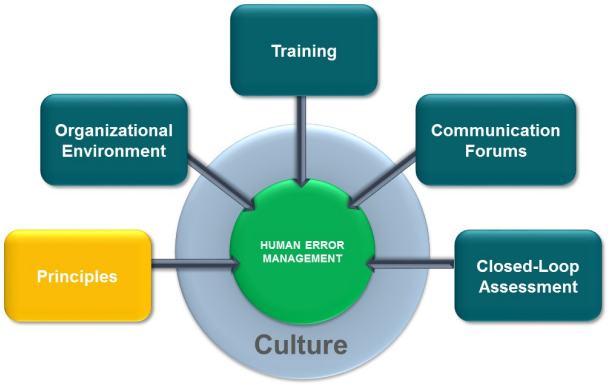
- HEM Program 5 Best Practices should include proactive Tools to accompany Mind Traps and Pitfalls. These Tools can be from COTS HEM Programs or tailored specifically for company's needs.
  - *COTS Tools (HEM Cards worn on badges, seen on posters, in command media)*
    - **TEBS®** (Task – Equipment – Barriers – Skills)
    - **AESOP™** (Assignment, Equipment, Situation, Obstacles, Personnel)
    - **I'M SAFE** (used with both TEBS® and AESOP™ as a personal self-check)
      - *Illness—Am I so ill that it could affect my performance or the performance of others?*
      - *Medication—Am I taking medication that could affect my performance?*
      - *Stress—What is my stress level – personal, physical?*
      - *Alcohol—Have I drunk alcohol that could affect my performance?*
      - *Food—Have I had enough food to perform effectively?*
      - *Eating—How long has it been since I ate?*



7.1.4 Tools (cont.)

- *Organic Tools*
  - **Gut Feel**—If something does not seem right, verbalize what you are feeling and let others know
  - **Regaining Situational Awareness**—Use TEBS® or AESOP™ to gain, maintain, or regain Situational Awareness
  - **Questioning Attitude**—Question ongoing attitudes to look for what could go wrong
- *Interactive Tools*
  - **Time Out, Yell or Say "Stop"** —Use immediately to get attention and initiate action
  - **Asking: What could go wrong?** —Continually apply critical thinking to the scenario
  - **Ask Questions**—If you do not understand, ask
  - **Ask Assertive Questions**—Ask questions to direct attention to an observation or a concern
  - **Slow Down to Speed Up**—Regain Situational Awareness by taking time to slow down
  - **Checklist**—Use TEBS®, AESOP™, or procedures as checklist

Section 7.2 HEM Organizational Environment



7.2 Organizational Environment

- Best Practices – Organizational Environment
  - *"An error avoidance culture can only develop by considering the existing leadership and workforce culture, adapting training appropriately, planning for strategic and tactical implementation, and developing a follow-up strategy to incorporate changes."* *(7-1)*
  - *"Ideally, an organization and its leadership create an environment where it is expected for individuals to feel free to speak up without the fear of retribution"* *(7-1)*
  - *"Individual awareness, leadership roles, and organizational culture must be considered in creating the right environment for avoiding human error."* *(7-1)*
- Culture and Organizational Environment
  - *Organizational leadership defines and supports company's HEM challenges and areas of emphasis*
  - *HEM roles and responsibilities of every employee are embedded in company culture*
  - *HEM requires continual review and assessment of all 5 Best Practices to ensure long-term sustainment*

7.2.1 Roles and Responsibilities(7-2)

- Every employee has a role and responsibility to HEM
  - ***Individual*** *(Person-in-Charge, Technician, Inspector, Engineer, Planner, QA, Safety, etc.)*
    - Understand specific task demands and personal unique capabilities and limitations
    - Demonstrate personal accountability and raise any concern
  - ***Team*** *(Program team, product line team, functional team, etc.)*
    - Watch for one another
    - Encourage team members to bring up concern and to stop unsafe operation(s)
  - ***Leadership and Management*** *(Program Managers, Functional Managers, Mission Assurance [MA] Managers, Team Leads, etc.)*
    - Encourage open communication, promote teamwork, and reinforce desired behaviors
    - Foster communication of bad news and acknowledge human fallibility
    - Lead by example and reinforce the desired jobsite behaviors
    - Allow employees to recognize their fallibility without supervisors and managers pointing fingers

7.2.1 Roles and Responsibilities (cont.)

- Every employee has a role and responsibility to HEM (cont.)
  - ***Corporation***
    - Empower, communicate with, and support all employees around human error management
    - Incorporate all best practices into company processes and way of thinking
    - Cultivate culture of error avoidance and strengthen integrity of defenses to mitigate consequences of an error
    - Create environment to share errors and corrective actions with others
    - Create culture of trust, not fear, in leadership

7.2.2 Critical HW Moves Example

- The following example demonstrates the HEM roles and responsibilities of each employee (from individual to management) involved with a critical hardware move, further demonstrating the importance of a corporate best practices program.
  - *It is important to note that without a best practices HEM program based on core principals that are reinforced by training, communication, and management support, this team would not be as effective in avoiding HEs.*

7.2.2 Critical HW Moves Example
Roles and Responsibilities – Integration and Test (I&T)

Personnel (HEM Role)	Critical Move Responsibility	HEM Responsibility
Person-in-charge ***(Individual, leadership)***	• Directing move	• Conduct pre-task review to ensure personnel clearly understand assigned tasks, roles, and responsibilities *(Use TEBS® or AESOP™)* • Encourage personnel to yell stop if needed • Request an impromptu use of *TEBS® or AESOP™* • Stop move if hardware/personnel is exposed to hazard • Be current on company HEM formal training program
Technicians ***(Individual)***	• Performing move	• Ask questions if assigned tasks are not well understood • Raise any concern or request an impromptu use of *TEBS® or AESOP™* • Yell "Stop" if hardware/personnel is exposed to hazard • Be current on company HEM formal training program
Inspector ***(Individual)***	• Observing move	• Ensure completion of pre-task review and that technicians understand their assigned task, roles and responsibilities • Ask questions if assigned tasks are not well understood • Raise any concern or request an impromptu use of *TEBS® or AESOP™* • Yell "Stop" if hardware/personnel is exposed to hazard • Be current on company HEM formal training program

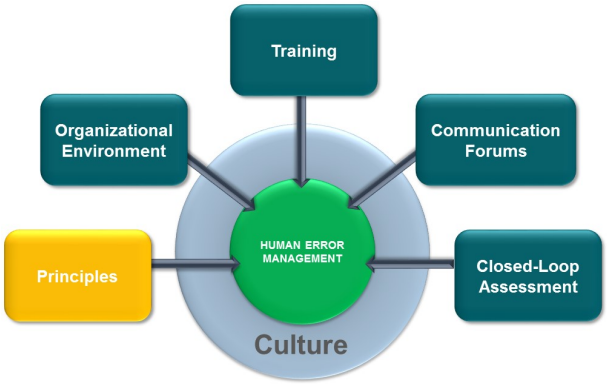
7.2.2 Critical HW Moves Example
Roles and Responsibilities – I&T (cont.)

Personnel (HEM Role)	Critical Move Responsibility	HEM Responsibility
Engineers ***(Individual)***	• Observing move	• Ensure potential hazards are clearly understood • Yell "Stop" if hardware/personnel is exposed to hazard • Raise any concern or request an impromptu use of *TEBS® or AESOP™* • Be current on company HEM formal training program
Safety ***(Leadership, Individual)***	• Observing move • Assessing hazard(s)	• Assess move (including operations) to eliminate or mitigate potential hazard • Yell "Stop" if hardware/personnel is exposed to hazard • Raise any concern or request an impromptu use of *TEBS® or AESOP™* • Be current on company HEM formal training program
Planner ***(Individual)***	• Generated planning • Observing move	• Obtain input from SMEs on potential hazards • Place warning on planning, if needed • Ensure planning is not ambiguous • Yell "Stop" if hardware/personnel is exposed to hazard • Be current on company HEM formal training program

7.2.2 Critical HW Moves Example
Roles and Responsibilities – I&T (cont.)

Personnel (HEM Role)	Critical Move Responsibility	HEM Responsibility
Management (I&T, MA, and Quality) ***(Leadership)***	• Supporting move • Provide key personnel • Approve procedures	• Yell "Stop" if hardware/personnel is exposed to hazard • Empower team • Be current on company HEM formal training and/or HEM awareness program
Senior Management ***(Leadership)***	• Observing move • Aware of move	• Promote a culture that values integrity, quality, and safety • Yell "Stop" if hardware/personnel is exposed to hazard • Promote empowerment culture around HEM principles • Be current on company HEM awareness program
Customer ***(Leadership)***	• Observing move • Insight/Oversight of move	• Yell "Stop" if hardware/personnel is exposed to hazard • Be current on company HEM awareness program

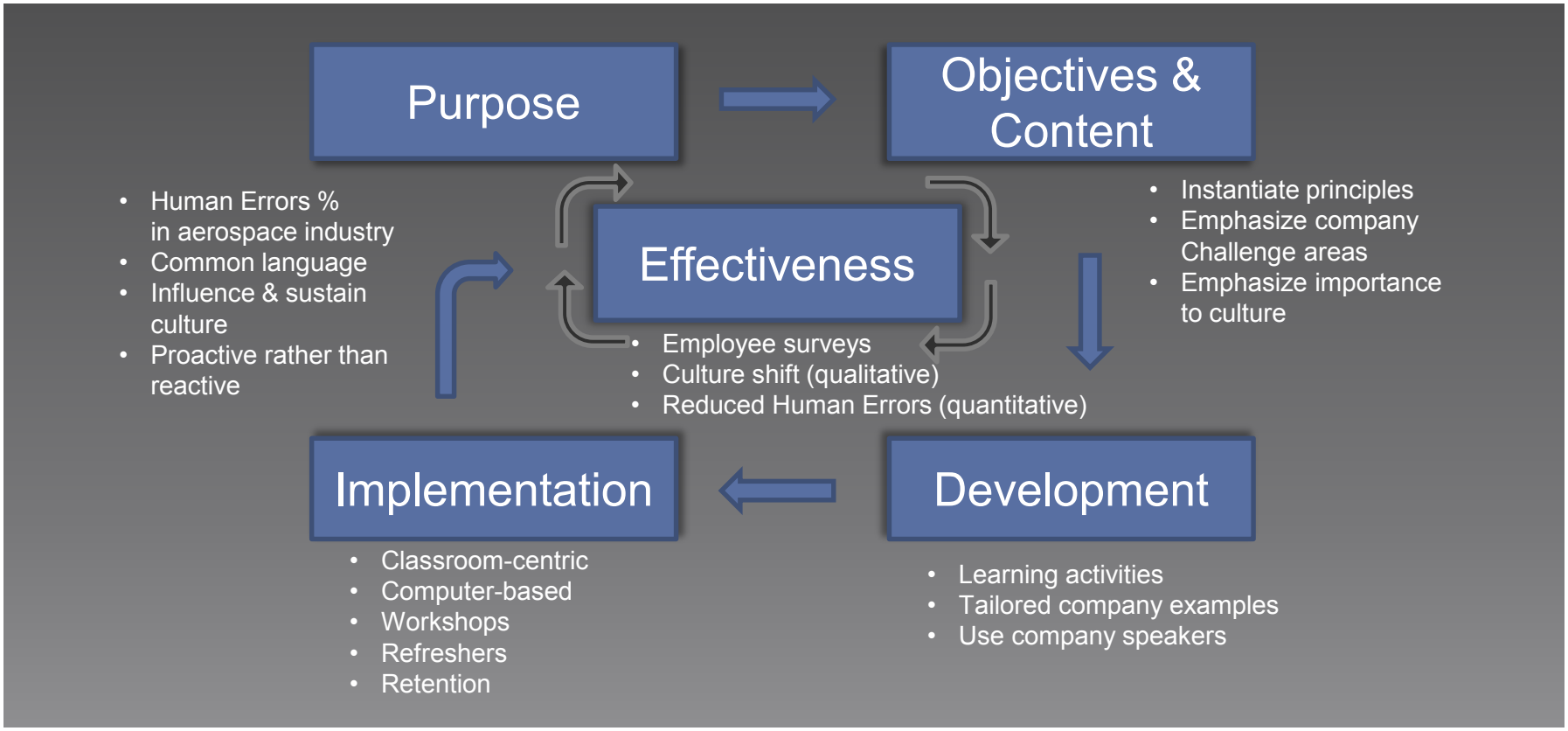
Section 7.3 HEM Training



7.3 HEM Training

- Best Practices – Training
  - *A successful HEM program consists of a training program rooted in the core HEM principles, while tailoring to the company needs, experiences and culture.*
  - *5 Best Practices training flow (next page) was created using Instructional System Design Model (ISDM)* [7-3] *and Analysis, Design, Development, Implementation, and Evaluation (ADDIE)* [7-4] *models that guide planning (1) to achieve specific goals and objectives and (2) to align objectives, instruction, and evaluation*
- Culture and HEM Training
  - *Training is a critical piece of sustaining a HEM program and the organizational environment culture.*

7.3 HEM Training (cont.)



7.3.1 Training Purpose

- Purpose (Why is HEM training needed?)
  - *Over 50% of errors in aerospace manufacturing are attributed to Human Error* *(1-1)*
  - *Provides consistency across company (language, methods, expectations, etc.)*
  - *Reduces Human Errors in the work place*
  - *Supports proactive mindset to prevent Human Errors*
  - *Is critical piece of HEM Program 5 Best Practices*
    - Without it, a HEM program cannot exist
    - Influences and sustains culture

7.3.2 Training Objectives and Content

- Objectives and Content
  - *What are learning objectives?*
    - Educate employees on HEM Principles and importance to organization
    - Use consistent training methodology tied to HEM Principles
    - Provide both the “what” and “how to” of HEM
  - *How is lesson content tailored?*
    - Understand audience and specific needs to create classroom and workshop training
    - Emphasize company challenge and areas to improve
      - *Defined by senior leadership (See Section 7.2, Organizational Environment)*

7.3.3 Training Development

- Development
  - *Define the specific learning activities for organization*
  - *Develop instruction*
    - Options: use COTS training, subcontract training, develop internal training
  - *Tailor training to organization*
    - Keep examples current (recently occurring)
    - Provide proactive (error avoidance) examples
    - Include company leaders or employees in examples (audio clips, video clips, quotes)
  - *Validate instruction (pilot training, surveys, etc.)*
    - See Section 7.3.5, Training Effectiveness

7.3.4 Training Implementation

- Implementation
  - *Training comes in many forms and is a continual process*
  - *Highest training retention comes from a combination of the methods listed in the table below*
    - See the next page for average retention rates of various methods

Method	Purpose	Frequency	Notes
Classroom	Provides the technical "what" content	One time	- Combine with "how to" workshop - If refresher training not kept current, repeat classroom training
Computer	Provides the technical "what" content via computer-based training (CBT) modules.	One time	- Combine with "how to" workshop - If refresher training not kept current, repeat classroom training
Workshop	Provides "how to" examples of HEM principles and applications	One time	Live interactive examples and role-playing of scenarios
Refresher	High-level summary of training content (live or CBT)	Annually	Provided to those who have completed full classroom/computer and workshop training
Awareness	Higher level background of HEM	Annually or as needed	For those who do not interact directly with hardware; may consider a CBT module (same as refresher) or 1-hour presentation
On-the-job	Daily use and application of HEM principles	Ongoing	Organizational environment that supports the HEM culture and enables daily practice of HEM principles to be easy and effective

7.3.4 Training Implementation – Retention Rates

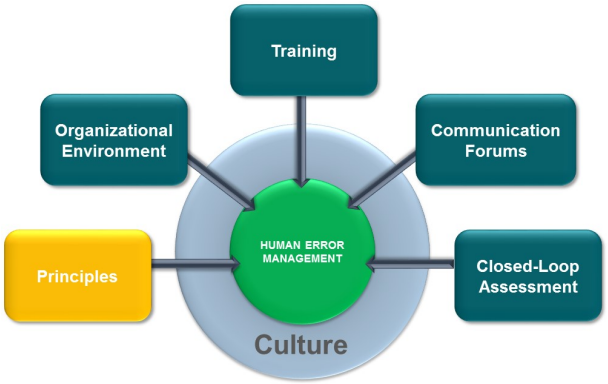
- A best practices HEM program requires high retention rates of HEM principles
  - *The table below shows the average retention rates for common activities associated with training [7-5]:*

Activity	Average Retention Rate
Lectures (classroom)	5%
Reading (computer, newsletters, reports)	10%
Audio/visual (computer, video examples)	20%
Demonstrations (workshop)	30%
Discussion groups (workshop, communication forums)	50%
Practice by doing (on the job)	75%
Teach others/use immediately (on the job, leadership, HEM champions)	90%

7.3.5 Training Effectiveness

- Ways to evaluate HEM training
  - *Employee surveys*
    - Conduct immediately after training to get impression and possible updates for training
    - Conduct periodically throughout year for assessments of implementation and application of training
  - *Qualitative evaluation (culture shift)*
    - Increased communications
    - Increased assertiveness in bringing up things that do not seem right
    - Individuals reporting near misses and discussing them in the workgroup
    - Perform follow-up surveys with employees to determine what is and is not working
  - *Quantitative evaluation (reductions in Human Errors, increase in reporting)*
    - Identifying near misses and lessons learned and reporting them to employees
    - Tracking of incidents and reductions
    - Trending metrics on nonconformance
    - Observing decrease in injury rate

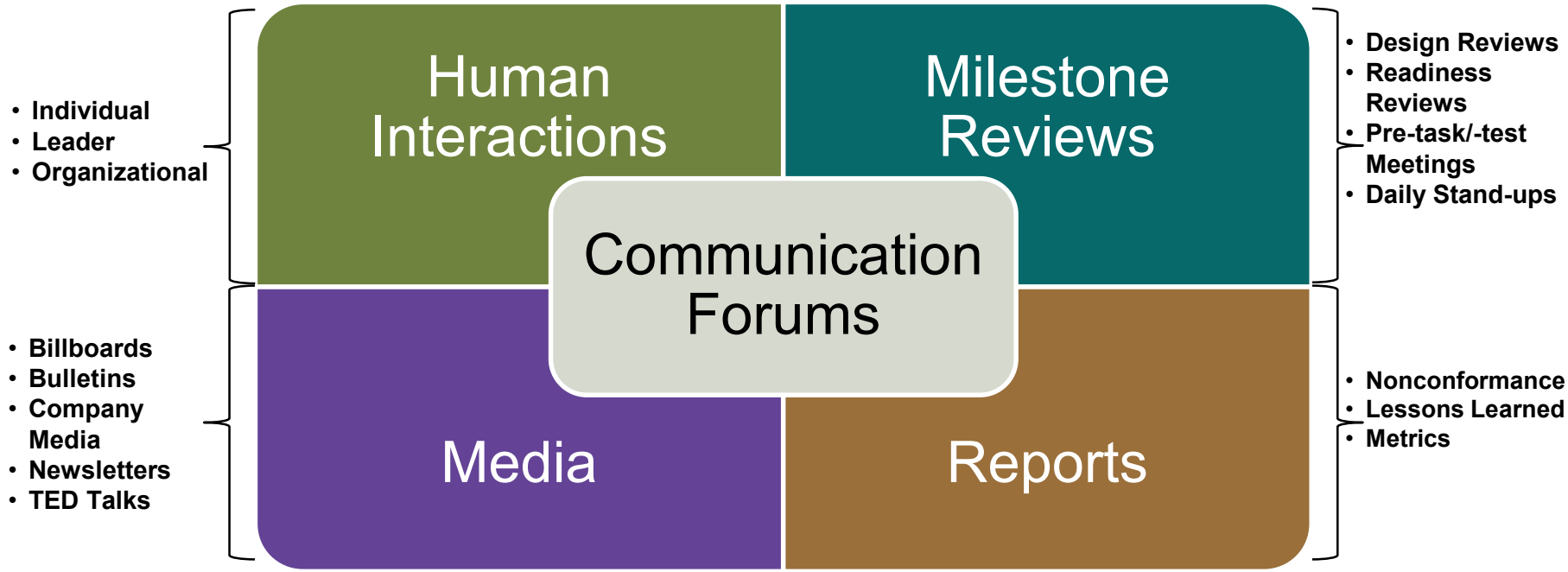
Section 7.4 HEM Communication Forums



7.4 Communication Forums

- A best practices HEM program includes many communication forums to support continual training, information on human errors, metrics, and open discussion on near misses and company incidents. Communication forums can fall into many categories such as reports, command media, reviews, open dialogue, and perhaps most importantly, leadership meetings.
  - *Communication forums should be adjusted to company and group culture to be meaningful*
- There are different types of communications forums that can be used depending on the situation
  - *There is not a right or wrong method*
  - *There are multiple ways to communicate; do not use just one*
- Culture and communication forums
  - *A culture that empowers, communicates with, and supports all employees around human error management*
  - *A culture where individuals feel free (and possibly are rewarded) to speak up if something does not seem right and know that there will be no retribution*

7.4 Communication Forums



7.4.1 Communication Forums: Human Interactions

- The different types of human interactions provide unique opportunities to openly discuss lessons learned, ideas, near misses, and any other HE-related topic.
  - *Individual*
    - Walking the Floor
    - Weekly Activity Report
    - Open-door policy

  - *Leader*
    - Management by Walking Around (MBWA)
    - Leadership forums
    - Staff meetings
    - Leader tag-ups
    - All-Hands
    - Supervisors/managers encouraging other forms of communication

  - *Organizational*
    - Brown Bags
    - Team tag-ups
    - Forums
    - Mission assurance meetings

7.4.2 Communications Forums: Milestone Reviews

- Milestone reviews such as design and readiness reviews provide a great opportunity to discuss and evaluate HEs
  - Design and requirements reviews
    - System requirements review (SRR)
    - Preliminary design review (PDR)
    - Critical design review (CDR)
  - Readiness reviews (reviews where TEBS® or AESOP™ can be effectively used as Tools to manage HE—see below)
    - Test readiness review (TRR)
    - Manufacturing readiness review (MRR)
    - Pre-task briefings/review
    - Pre-ship readiness review (PSRR)

Pre-Task Review Demonstrating TEBS®

- What is the task flow/sequence/duration? **(Task)**
- Who is in charge? **(Skills)**
- Do we have what we need? **(Barriers)**
  - People **(Skills)**
  - Planning/Procedure/Instructions **(Task)**
  - Parts/Kit/Data **(Equipment)**
  - Tool/Support **Equipment** (special test equipment [STE], GSE, Infrastructure)
  - Access **(Barriers)**
- What are the risks or safety concerns for this task? Are precautions in place? Does everyone understand their role for spotting and safety? **(Barriers)**
- Are we ready to execute flawlessly? **(Barriers)**
- Does everyone concur with the course of action? **(Assertive Statement, Ask questions)**

Pre-Task Review Demonstrating AESOP™

- What is the task flow/sequence/duration? **(Assignment)**
- Who is in charge? **(Personnel)**
- Do we have what we need? **(Obstacles)**
  - People **(Personnel)**
  - Planning/Procedure/Instructions **(Assignment)**
  - Parts/Kit/Data **(Equipment)**
  - Tool/Support **Equipment** (STE, GSE, Infrastructure)
  - Access **(Barriers)**
- What are the risks or safety concerns for this task? Are precautions in place? Does everyone understand their role for spotting and safety? **(Obstacles)**
- Are we ready to execute flawlessly? **(Obstacles)**
- Does everyone concur with the course of action? **(Assertive Statement, Ask questions)**

7.4.3 Communication Forums: Reports

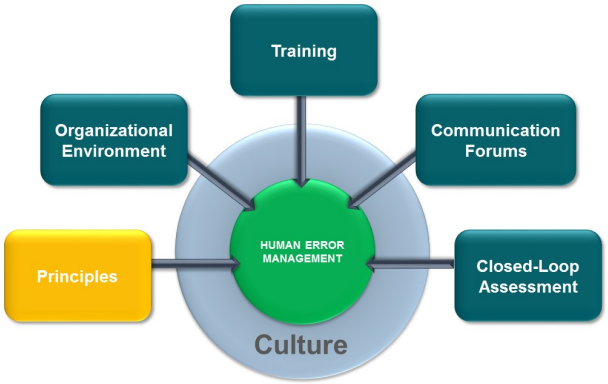
- Reports are a formalized method of communication that systemically keeps the organization informed on HE. This communication is an important part of sustaining the HEM culture at a company and includes:
  - *Procedure verification*
  - *Command media (instructions/checklists)*
  - *Nonconformance reports*
  - *Metric reports*
  - *Near-miss reports*
  - *Independent peer reviews*

7.4.4 Communication Forums: Media

- Media communication can be used to fit what is best for your organization. It provides an unofficial format to communicate stories and lessons learned, encouraging messages across the enterprise, and includes
  - *Posters (culture)*
  - *Billboards*
  - *Sound bites*
  - *Newsletters*
  - *Websites*

- Some specific examples are:
  - *HEM Bulletin—communication device to keep employees apprised of human traps both encountered and avoided. Items to be addressed are:*
    - What is happening in your area?
    - What are the Traps that affect you or your area most?
    - Have you experienced a Trap and were you able to utilize a HEM Tool to correct the situation?
  - *"There We Were" stories—stories used to share key mishaps and near misses. The objective is to learn from the mistakes.*
    - What is happening in your area?
    - What are the Traps that affect you or your area most?
    - Have you experienced a Trap and were you able to utilize a HEM Tool? Use the There We Were stories in weekly staff meetings, daily huddles, or pre-operation meetings to reinforce HEM with your team. Choose one or two topics that apply to your operation. The stories are a great way to correct the situation and stimulate HEM discussions.

Section 7.5 HEM Closed-Loop Assessment



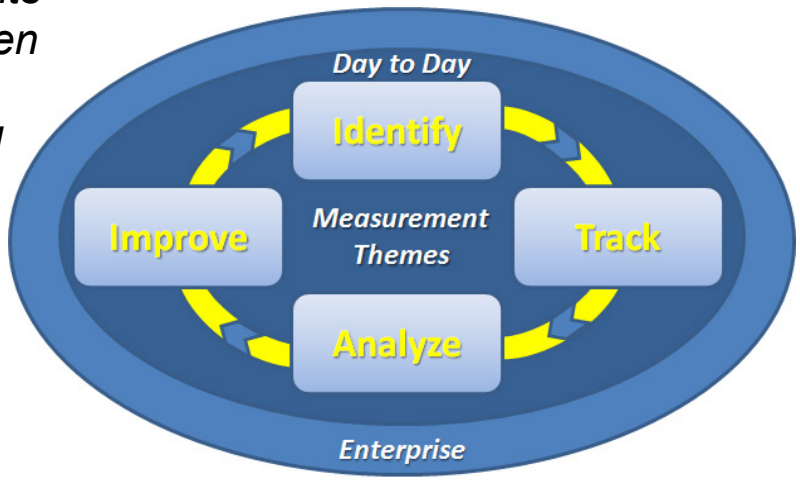
7.5 Closed-Loop Assessment

- Best Practices – Closed-Loop Assessment
  - *Highly effective HEM program must include a closed-loop assessment process to identify, track, analyze, and manage human-induced errors*
  - *Ultimate goal of a HEM program is to implement actions that will reduce potential for human errors*
  - *Successful HEM program is highly dependent on learning, company culture, and understanding data to identify opportunities to manage human errors*
  - *Well-selected metrics are invaluable to manage human errors*
- Culture and Closed-Loop Assessment
  - *Proactive, open culture enables employees to share errors and corrective actions*

7.5 Closed-Loop Assessment (cont.)

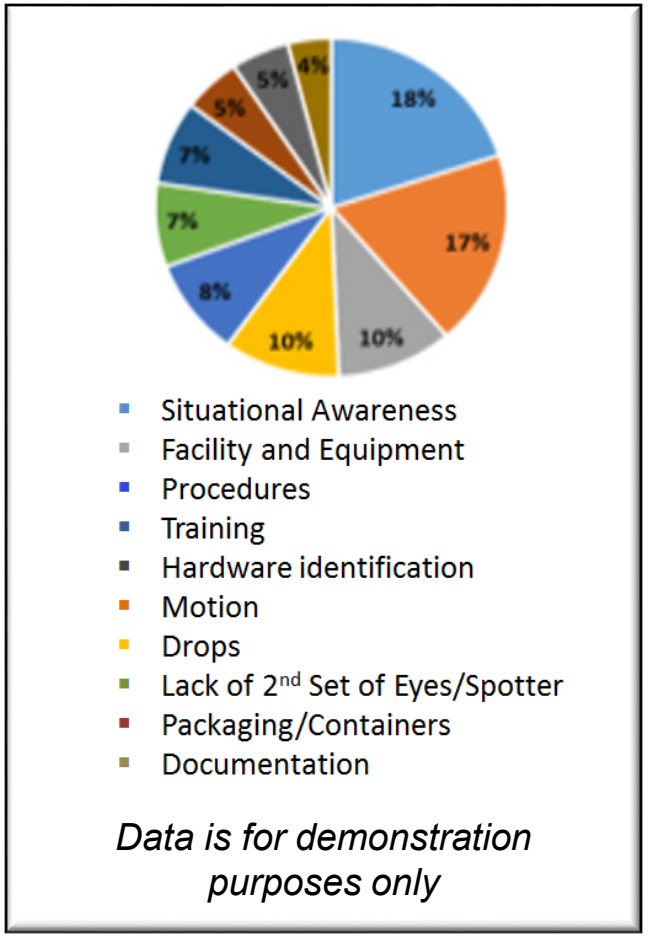
- Value of metrics
  - *Drive good and bad behaviors*
  - *Help people focus on what is important*
  - *Critical to understanding implications of change to organization*
  - *If developed well, metrics will enhance strengths of organization*
    - *Shows where it has been*
    - *Indicates where it is going*
    - *Identifies problems early*
    - *Defines success*
    - *Drives improvements*
  - *Refresh to new goal when achieved*
  - *Should be reviewed and changed as needed*

- Measurement themes
  - *To be effective, all measurements should be implemented at both day-to-day level and enterprise level*
  - *Day-to-day activities are tactical in nature, such as root cause and corrective action (RCCA)*
  - *Enterprise-level analysis would identify trends so that entire organization can benefit from actions implemented toward prevention*



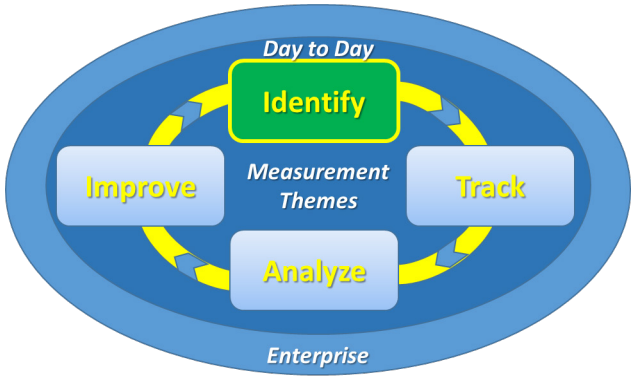
7.5 Closed-Loop Assessment (cont.)

- Develop categories of “incident causes” to use in trend analysis and identification of systemic issues
  - *Deep dives can be initiated in areas where trend analysis shows potential system issues*
  - *Results of trend analysis can be communicated to all employees (1) to emphasize problem areas and (2) to explain actions to correct issues*
  - *Trend analysis can be used to identify processes that need to be modified to manage Human Error*
  - *Trend analysis can identify training that needs to be modified or developed*



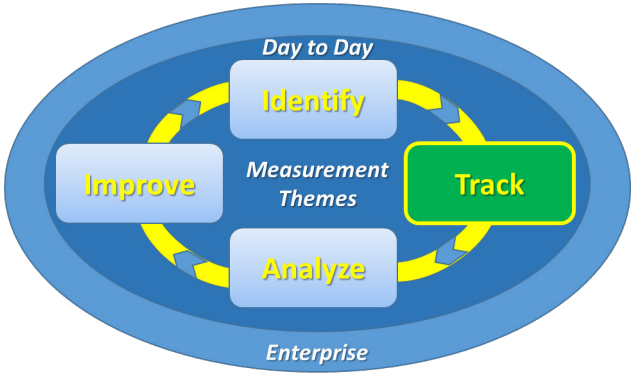
7.5.1 Closed-Loop Assessment – Identify

- **Identify** metrics for Human Error Management Program
  - *Human Errors (HEs) are symptoms and not the cause*
  - *Examine symptoms that clearly identify aspects of human errors such as:*
    - Problem reports coding (i.e., operator error, test error, workmanship, subcontractor, etc.)
    - Performance metrics with goals
    - Near-miss reporting
    - Self reporting
    - Failure Reporting, Analysis, and Corrective Action System (FRACAS) data
  - *If the current system does not capture aspects of human errors, determine ways to capture this symptom for baseline purposes*
  - *Once identified, use RCCA approach to find root cause*



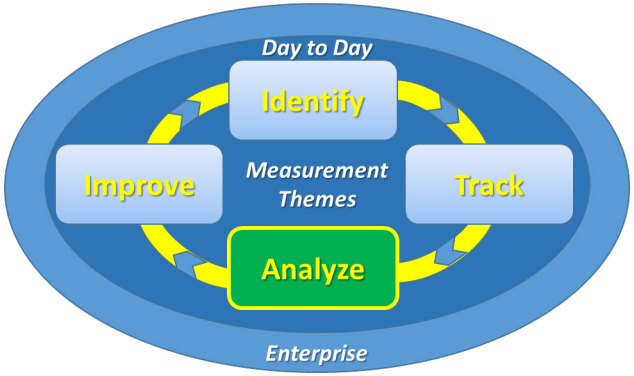
7.5.2 Closed-Loop Assessment – Track

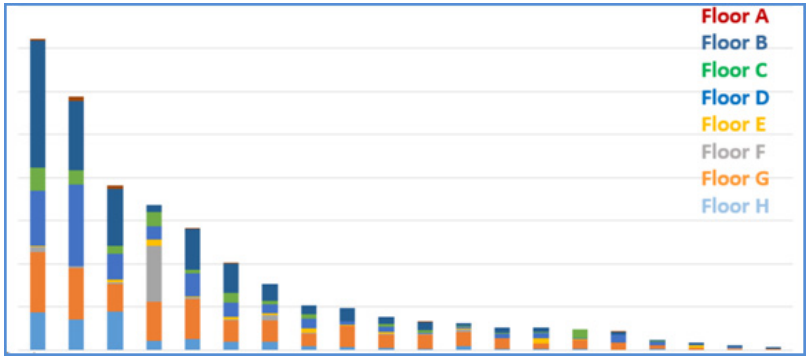
- **Track** symptoms identified as Human Errors
  - *Utilize data to determine impact to day-to-day hardware and establish baseline to examine enterprise effect*
  - *Dive deeper when problem is coded with HE type code*
    - Human Error is often used as cause code due to lack of understanding of what the true root cause is
      - *Ask 5-Whys* (7-6)
    - Perform additional work to identify true root cause
    - Develop reports based on metrics that track and provide information on both day-to-day and enterprise-level activities
  - *Enterprise tracking should produce reports that inform organization on path forward to improve human error management*



7.5.3 Closed-Loop Assessment – Analyze

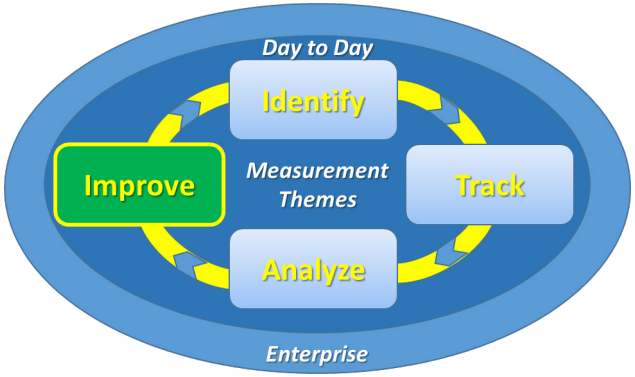
- Data **analysis** themes
  - *Day-to-day (tactical)*
    - Utilize existing Human Error-related data in FRACAS, RCCA, audits, etc., databases
    - Identity common themes (utilizing existing practices)
    - Use data to adjust processes and eliminate problems within common process areas
    - Analyze data to determine actions for improvement and HEM success
  - *Enterprise (strategic)*
    - Review data collectively to determine if common problems are occurring
    - Review trends in organizational process areas





7.5.4 Closed-Loop Assessment – Improve

- **Improve**
  - *Day-to-day*
    - Utilize existing RCCA systems to address root cause of HE symptoms
      - *Dive deeper than symptom*
      - *Determine real root cause*
      - *Evaluate hardware and processes root causes*



  - *Enterprise*
    - Consider or utilize continuous improvement team of process area representatives to improve HEM
    - Review data analysis and suggest actions that consider
      - *Schedule*
      - *Cost to implement and not to implement*
      - *Risk and opportunity*

Section 8 Suggested Implementation of Program

8.0 Suggested Implementation

- 8.1 Human Error Management (HEM) Program Inventory
  - *Identifies key HEM areas and provides ability to assess company's current maturity level of HEM techniques*
  - *Points to resources within this product to mature specific facets*
- 8.2 Subcontractor Flowdown
  - *Addresses ways to flow HEM awareness and development to subcontractors*
- 8.3 Program Development and Rollout Steps
  - *Outlines steps when rolling out new or improved HEM program*

8.1 HEM Program Inventory

- Perform a Needs Analysis that would reflect the class of mission
  - *Expectations of HEM program will change based on level of mission*
- Closed-loop guidance from “corporate” and “mission” expectations
  - *Expectations would be merged to determine the level of HEM program*
    - Corporate expectation determines Culture, Environment, Training, Principles
    - Corporate and mission expectations determine Communication
- Use HEM Diagram in Section 7.0 to perform initial assessment in 5 Best Practice areas:
  - *Principles, Organizational Environment, Training, Communication Forums, Closed-Loop Assessment*
- Determine if there is need to flow elements of HEM program to subcontractors

8.1 HEM Program Inventory: Maturity

- HEM program is highly mature if it meets the Needs Analysis
  - *Philosophy/approach of HEM has sufficient rigor*

- Style and rigor of HEM program can be determined by size of team. If team is small, may not need as much rigor since there is greater communication.

- Style of HEM is defined by culture of organization
  - *HEM actions should resonate/align with team to increase success*

8.2 Subcontractor Flowdown

- Prime provides training at subcontractor based on HEM program
- Share Prime HEM training resources but apply with less rigor or only some parts of HEM
- Perform Just-in-Time (JIT) training for critical moves/events at subcontractor
- Consider the following actions:
  - *Host meetings and/or workshops to promote HEM awareness and to engage all necessary personnel at subcontractor*
  - *Provide examples of how impacts of HEM can affect products and services from supply chain up to end user/customer*
  - *Incentivize and/or provide recognition to subcontractors that implement best practices*
  - *Leverage AS9100 [1-2] Rev. D standard to institutionalize HEM at subcontractor*
- The following MAIW products provide guidance on subcontractor interactions:
  - *"Supplier Risk Evaluation and Control," TOR-2011(8591)-18, The Aerospace Corporation, 2011.[8-1]*
  - *"Supply Chain Escapes Lessons Learned Handbook," TOR-2016-02189, The Aerospace Corporation, 2016.[8-2]*

8.3 Program Development and Rollout Steps

- Review diagram of 5 Best Practices Human Error Management in Section 7.0
- Read Section 7 to understand concepts presented in diagram
- Assess which components your company already covers and what gaps you have
- Prioritize how gaps will be addressed
  - *Consider using method that fits well with pre-existing processes for optimal program rollout*

Section 9 Future Topics

9.0 Future Topics

- HEM challenges in
  - *Software development*
  - *Cybersecurity*
  - *Automation*

- Generate HEM guideline document
  - *Develop process of uniform implementation*

Section 10 Reference Documents

10.0 Reference Documents

Section	ID	Reference
1	1-1	Larry Tew, “Managing Human Fallibility in Critical Aerospace Situations,” Proceedings of SPIE, vol. 9197, 91970A, 2014.
1	1-2	Aerospace Standard, SAE AS9100D, Quality Management Systems - Requirements for Aviation, Space and Defense Organizations. Warrendale, PA, SAE International, 2016
1	1-3	Place holder for "safety reference: "One accident for 10 incidents for 30 near misses for 600 unsafe acts " Behind Human Error Page 44
5	5-1	Center for Error Management – TEBS Model, Larry Tew, 2017, http://manageerror.com/
5	5-2	HRO (High Reliability Organizations) – 5 Key Principles, (1987 Karl Weick)
5	5-3	Error Prevention Institute, Inc. – AESOP Model, https://smartpeopledumbthings.com

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Section	ID	Reference
5	5-4	James Reason, "Human Error: Models and Management," British Medical Journal, vol. 320, 18 March 2000.
5	5-5	Jens Rasmussen, "Skills, Rules, and Knowledge: Signals, Signs and Symbols, and Other Distinctions in Human Performance Models," IEEE Transactions on Systems, Man, and Cybernetics, vol. SMC-13, no. 3, May-June 1983.
5	5-6	William G. Bridges, "Human Factors and Their Optimization," Process Improvement Institute, http://www.process-improvement-institute.com/_downloads/Human_Factors_and_their_Optimization_website.pdf, 2012.

10.0 Reference Documents (cont.)

Section	ID	Reference
5	5-7	Soumen Ganguly, "Human error Vs. Work place Management in modern organizations," International Journal of Research in Management and Technology, vol. 1, no.1, October 2011.
5	5-8	Scott A. Shappell and Douglas A. Wiegmann, "The Human Factors Analysis and Classification System," Office of Aviation Medicine, Report DOT/FAA/AM-00/7, 2000.
5	5-9	Sidney Dekkar, The Field Guide to Understanding Human Error, CRC Press, 2006.
5	5-10	Nancy Leveson, "Evaluating Accident Models from Recent Aerospace Accidents - Part I: Event-based Models," Massachusetts Institute of Technology Engineering Systems Division, Report ESD-WP-2002-06, 2001.

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5	5-11	Australian Government Civil Aviation Safety Authority, "SMS For Aviation – A Practical Guide: Human Factors", https://www.casa.gov.au, 2012.
5	5-12	Charles Perrow, "Normal Accident at Three Mile Island," Society, vol. 18. no. 5, Jul-Aug 1981.
5	5-13	Mike Sondalini, "Human Error Rate Table Insights," Lifetime Reliability Solutions, http://www.lifetime-reliability.com/cms/tutorials/reliability-engineering/human_error_rate_table_insights/, 2017.
5	5-14	Barbara G. Kanki, Robert L. Helmreich, and Jose Anca, editors, Crew Resource Management, Elsevier, San Diego, CA, 2010.

10.0 Reference Documents (cont.)

Section	ID	Reference
7	7-1	AT-M-06A, 1-Dec-1998, CREW RESOURCE MANAGEMENT (CRM) BASIC CONCEPTS, and adapted by CEM for classroom and computer based training
7	7-2	Larry Tew, Avoiding Human Error - Creating the Right Environment. Retrieved from http://manageerror.com/n_asq.htm
7	7-3	Robert Gagné and Karen Medsker, The Conditions of Learning: Training Applications, Wadsworth Publishing, 1995.

10.0 Reference Documents (cont.)

Section	ID	Reference
7	7-4	Branson, R. K., Rayner, G. T., Cox, J. L., Furman, J. P., King, F. J., and Hannum, W. H. (1975). Interservice procedures for instructional systems development (5 vols.) TRADOC (Pam 350-30). Ft. Monroe, VA: U.S. Army Training and Doctrine Command, August 1975.
7	7-5	Erica J. Keeps and Harold D. Stolovitch, Telling Ain't Training, 2002
7	7-6	Roland Duphily, "Root Cause Investigation Best Practices Guide," The Aerospace Corporation, TOR-2014-02202, 2014
8	8-1	Supplier Risk Evaluation and Control, TOR-2011(8591)-18, The Aerospace Corporation, 2011
8	8-2	Supply Chain Escapes Lessons Learned Handbook, TOR-2016-02189, The Aerospace Corporation, 2016.

Section 11 Acronyms and Definitions

11.0 Acronyms

ADDIE	Analysis, Design, Development, Implementation, Evaluation
AESOP	Assign, Equipment, Situation, Obstacles, Personnel
ASIC	Application-specific integrated circuit
CBT	Computer-based training
CDR	Critical design review
CEM	Center for Error Management
COTS	Commercial off-the-shelf
CRM	Crew Resource Management
DCMA	Defense Contract Management Agency
FRACAS	Failure Reporting, Analysis, and Corrective Action System
GSE	Ground support equipment
HE	Human Error

11.0 Acronyms (cont.)

HEM	Human Error Management
HFACS	Human Factors Analysis and Classification System
HR	Human resources
I&T	Integration and test
I'M SAFE	Illness, Medication, Stress, Alcohol, Food, Eating
ICAO	International Civil Aviation Organisation
ID	Identity, identification
ISDM	Instructional System Design Model
JIT	Just-in-Time
MA	Mission Assurance
MAIW	Mission Assurance Improvement Workshop
MBWA	Management by Walking Around

11.0 Acronyms (cont.)

MRR	Manufacturing readiness review
OSR	Optical solar reflector
PAF	Payload attach fitting
PCB	Printed circuit board
PDR	Preliminary design review
POC	Point of contact
PSRR	Pre-ship readiness review
QA	Quality assurance
R&R	Roles and responsibilities
RCCA	Root cause and corrective action
RE	Responsible engineer
SCHELL	Software, Culture, Hardware, Environment, Liveware, Liveware

11.0 Acronyms (cont.)

SE	Systems Engineering
SHEL	Software, Hardware, Environment, Liveware
SME	Subject matter expert
SMS	Safety Management System
SRR	System Requirements Review
STE	Special test equipment
TEBS	Task, Equipment, Barriers, Skills
TOR	Technical operating report
TRR	Test readiness review
TWTA	Traveling wave tube amplifier

11.0 Definition of Terms

Term	Definition
Accident	An undesired incident that happens unexpectedly and unintentionally, typically resulting in damage or injury
Accommodation to risk	Where one discounts the severity and probability of risk when the risk is clear and present every day, since the risk has yet to be realized
Attitude Management	The awareness of how personality traits and risky attitudes can affect performance
Best Practices	Procedures that are accepted or prescribed as being correct or most effective
Command media	Configuration-controlled written instructions used by an organization to facilitate a desired action or result
Communication Barriers	Ambiguous wording, jargon, technical wording, unfamiliar acronyms
Communication Breakdown	Tasks not clearly defined or understood
Communication Management	Ensuring communicated messages are received completely and correctly
Corrective action	Improvements to processes taken to eliminate causes of undesirable results

11.0 Definition of Terms (cont.)

Term	Definition
Co-worker Syndrome	Implicit confidence in team members resulting in lack of close attention and monitoring.
Culture	The underlying pattern of meaning articulated in both the formal and the informal aspects of an organization that expresses the appropriate way to cope (perceive, think, feel, behave) with problems
Deep Dive	An extensive analysis of a subject or problem
Defect	The variance between expected and actual result
Distractions	Anything that diverts attention from present task
Emotional Stress	Personal frustrations at home or at work that affects task performance, “can spill over at inappropriate times”
Error	A planned action that unintentionally deviates from objectives, rules, or standards
Error management	An approach directed at effectively handling errors and their consequences after they have occurred. Its goal is to reduce the consequences of an error, optimize error detection and reporting, recover quickly from an error, and promote organizational learning

11.0 Definition of Terms (cont.)

Term	Definition
Error prevention	An approach directed at eliminating errors before they have occurred
Error reduction	Measures designed to limit the frequency of errors
Excessive Professional Courtesy	Hesitation to correct or question another due to title, pay grade, or experience; yielding to peer pressure not to speak up.
Failure	A state or condition that occurs that indicates a human, component, or system has failed to function as required
Failure Reporting, Analysis, and Corrective Action System (FRACAS)	A disciplined closed-loop process for solving technical issues that arise during the testing of flight deliverable hardware. FRACAS can also be implemented at the design, development, production, and deployment stages.
Group Dynamics Management	Group dynamics focuses on leadership, revolves around the authority of the leader, individual responsibility, respectful assertiveness, behavior styles, and team building
Group Think	Group takes action contrary what they individually would do

11.0 Definition of Terms (cont.)

Term	Definition
Hero/Cowboy Syndrome	Take actions not necessarily thought out or feel compelled to take action
Hidden Agenda	Consciously or unconsciously withholding information and/or making suggestions/decisions on desires not known by others.
High Workload	Real or perceived pressure that can lead to loss of Situational Awareness
Human error	An error whose direct cause is initiated by a human actor
Human Factors Analysis and Classification System (HFACS)	A system developed by Dr. Scott Shappell and Dr. Doug Wiegmann. HFACS provides a framework that enables investigators to systematically identify the active and latent failures within an organization that culminated in an accident. The goal of HFACS is more to understand the underlying causal factors that lead to an accident than to establish blame.
Human factors engineering	An applied science that coordinates the design of devices, systems, and physical working conditions with the capacities and requirements of the worker

11.0 Definition of Terms (cont.)

Term	Definition
Incident	Failure of a planned action to achieve a desired outcome
Latent error	The less-apparent error of an organization or design that creates the local condition that promotes the commission of an active error; it is committed before the active error and lies dormant until its effects are realized when the event occurs. May also be known as contributing factor in RCA.
Low Workload	Little or no activity that can lead to loss of Situational Awareness
Metrics	A system of standard of measurement
Mistake	A kind of error in which the actions are executed as planned, but the plan itself is not adequate
Near miss	Leading indicator that you could be developing a problem

11.0 Definition of Terms (cont.)

Term	Definition
New Situation/Out of Order	Something new or out of ordinary, may increase chance for error
Perceived Pressure	One's perception/feeling that leader wants one to hurry or ignore process
Physical Stress	Environmental factors that can affect an individual's body functions and performance
Repetitive Tasks	The mind checks off things as being done by habit.
Risk Management	Identification of "What Could Go Wrong?" in an activity, the likelihood of occurrence, the impact of the consequences, and what approach to use to manage risk
Risky Attitude	Attitude that is anti-authority, impulsive, intimidating, and/or resigned; desire to get it done without recognizing risks (get-it-done-ism)
Root cause	The primary cause of an undesired event based on facts and data

11.0 Definition of Terms (cont.)

Term	Definition
Root cause and corrective action (RCCA)	A process used for determining the cause of undesired events based on facts and data and followed up by design, process, or institutional changes that prevent their recurrence
Situational Awareness Management	A continuous perception of self, human fallibility, and environment in relation to task accomplishment, and the ability to manage those actions based on that perception
Subject matter expert (SME)	A person who is a recognized authority in a specific area
Swiss Cheese Model	A model developed by Dante Orlandella and James T. Reason that likens human systems to multiple slices of Swiss cheese, stacked side by side, in which the risk of a threat becoming a reality is mitigated by the differing layers and types of defenses which are layered behind each other
Task Saturation	Inability to handle multiple tasks
Violation	A planned action that intentionally deviates from objectives, rules, or standards in order to achieve a certain purpose
Workload Management	Managing personal capabilities and integrating the capabilities of others in the workload environment to meet program objectives

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