NERC

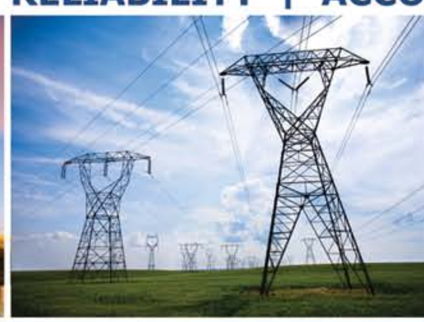
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Cause Analysis Methods for NERC, Regional Entities, and Registered Entities

September 2011

RELIABILITY | ACCOUNTABILITY






3353 Peachtree Road NE
Suite 600, North Tower
Atlanta, GA 30326
404-446-2560 | www.nerc.com

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Revision History

Rev.	Date	Reviewers	Revision Description
0	October 15, 2010	David Hilt, Tom Galloway, David Nevius, Karen Spolar	Initial Draft by Earl Shockley, Director of Event Analysis and Investigations
1	August 23, 2011	Earl Shockley, Tom Galloway	Drafted by Ben McMillan and James Merlo. • Reorganized document • Section 3.2 clarified what is needed for Problem statement, added discussion about Extent of Condition (EOC), and added Overview of Occurrence Analysis • Section 4.84 added Cause and Effect Charting as a technique • Section 5.6 added Cognitive Biases and Heuristics, Organizational Limitations • added Appendix C – Cause Codes • added Appendix D – Acronyms
2	September 20, 2011	Sandy Shiflett	• Placed on new NERC report template and updated formatting

1.0 Introduction

This document is designed to provide a ready reference of the methods and tools routinely used in the investigation, analysis, and determination of causal factors which lead to identification of root caused and causal factors that drive events on the bulk power system (BPS). It also provides guidance for analyzing problems with processes, human performance, and equipment failure, and recommends the sequence for documenting and collecting data to identify causal and contributing factors when a failure occurs.

This process applies to all levels of the Electric Reliability Organization (ERO) enterprise. This includes NERC, the Regional Entities, and industry participants that conduct event analysis and are involved in corrective action programs when a cause analysis is required. This process is designed to be a companion process to the *Electric Reliability Organization Event Analysis Process Manual*. It is designed to assist those responsible for determining the causal factors and latent deficiencies leading to BPS events or failures. The process will also aid in developing corresponding corrective action plans to address the causes of an event or failure and prevent reoccurrence of events.

2.0 Purpose

This document is designed to provide a ready reference of the methods and tools used for a systematic approach to conduct cause analysis. It will also assist all involved arrive at solutions (corrective actions) that eliminate causal and contributing factors and prevent event or failures from recurring. Use of these methods will result in effective determination of causes and the implementation of appropriate corrective actions. Formal training and routine use of root-cause methods are required for their efficient use, and training is offered by a number of organizations.

3.0 Cause Analysis Methodology

3.1 Anatomy of an Event

An event is defined as "an unwanted, undesirable change in the state of plants, systems or components that leads to undesirable consequences to the safe and reliable operation of the plant or system." The anatomy of an event is often driven by deficiencies in barriers and defenses, latent organizational weaknesses and conditions, errors in human performance and contextual factors, and equipment design or maintenance issues.

Events can be avoided proactively (through an understanding of the reasons mistakes occur) or reactively (through the application of lessons learned from past events or errors and actions derived from event analysis of disturbances and system events). The combination of proactive and reactive methods is the best strategic approach for the identification and elimination of hidden organizational weaknesses and error likely situations that can provoke human error and degrade barriers and defenses.

Events are not typically the outcome of one person's actions. More commonly, it is the result of a combination of faults in management and organizational activities.

Turner & Pidgeon, "Man-Made Disasters"

3.2 Overview of Occurrence Analysis

The basic reason for analyzing and reporting the causes of occurrences is to enable the identification of corrective actions adequate to prevent recurrence and thereby protect the health and safety of the public, the workers, and the environment.

Every root cause analyses and reporting process should include five phases. While there may be some overlap between phases, every effort should be made to keep them separate and distinct.

1. **Phase I. Data Collection.** It is important to begin the data collection phase of root cause analysis immediately following the occurrence identification to ensure that data are not lost. (Without compromising safety or recovery, data should be collected even during an occurrence.) The information that should be collected consists of conditions before, during, and after the occurrence; personnel involvement (including actions taken); environmental factors; and other information having relevance to the occurrence.
2. **Phase II. Assessment.** Any root cause analysis method may be used that includes the following steps:

   a. Identify the problem

      - *What* is the problem? This is the effect (sometimes referred to as the "primary effect") we do not want to recur.
      - *When* did it happen? This is the relative time of this primary effect. It may be the time of day, or it may be a point in a sequence of causes.
      - *Where* did it happen? This is a relative location of this primary effect. It may be a specific location (e.g., #2 Emergency Generator), it may be a relative geographic position (e.g., covering the states of New Jersey, New York, and parts of Connecticut), it may be a geographic region (e.g., the southern portion of WECC).
      - What is the *Significance* of the problem? This is the relative value this problem has on the organization, the grid, or the region. Knowing this upfront helps us to know the relative importance of the problem, and can involve many factors – cost, safety, and frequency are the most common ones, but other factors must also be considered.

   b. Identify the causes (conditions or actions) immediately preceding and surrounding the problem.

c. Identify the reasons why the causes in the preceding step existed, working back to the root cause (the fundamental reason which, if corrected, will prevent recurrence of these and similar occurrences throughout the facility). This root cause is the stopping point in the assessment phase.

3. **Phase III. Corrective Actions.**

   a. Implementing effective corrective actions for each cause reduces the probability that a problem will recur and improves reliability and safety.

   b. Evaluate the need for an "Extent of Condition (EOC) Evaluations" during the corrective action phase of an event analysis. Appropriate use of EOC evaluations will enhance BPS reliability, reduce risk of recurrence, reduce operating costs and foster a safer working environment. EOC is the actual or potential applicability for an event or condition to exist in other activities, projects, programs, facilities or organizations. It is generally defined as a generic implication of a failure, malfunction, deficiency, defective item, weakness or problem and does the issue exist elsewhere. A fully defined and well-established EOC evaluation process will assist in the identification of matters transcending a particular event or organizational boundary. Identifying and correcting these cross-cutting issues, deficiencies, weaknesses, or problems will reduce risk and operating costs and result in a safer working environment through the detection and correction of both latent and obvious adverse conditions. A graded approach is encouraged, with matters of greater potential consequence receiving more attention than matters of lesser consequence.

4. **Phase IV. Inform.** Entering the report in whatever problem-tracking system is in use is part of the inform process. Also included is discussing and explaining the results of the analysis, including corrective actions, with management and personnel involved in the occurrence. The proper entering of the results into the tracking system, including using Cause Codes (see Appendix C) as established for that tracking system, is critical to the eventual trend analysis efforts used to improve the performance of the BPS reliability. In addition, consideration should be given to providing information of interest to other facilities (Lessons Learned).

5. **Phase V. Follow-up.** Follow-up includes determining if corrective action has been effective in resolving problems. An effectiveness review is essential to ensure that corrective actions have been implemented and are preventing recurrence. Management involvement and adequate allocation of resources are essential to successful execution of the five root cause investigation and reporting phases.

3.3 Selection of Applicable Methodology

The selection of cause analysis methodology is based upon the potential for recurrence, the significance of the issue, and the resources available to solve the problem. The following sections outline the methodology for apparent cause and root-cause analysis and the tools used with each methodology. Understanding how each methodology functions and the tools used can help in the selection process.

The following are two examples of selection methods:

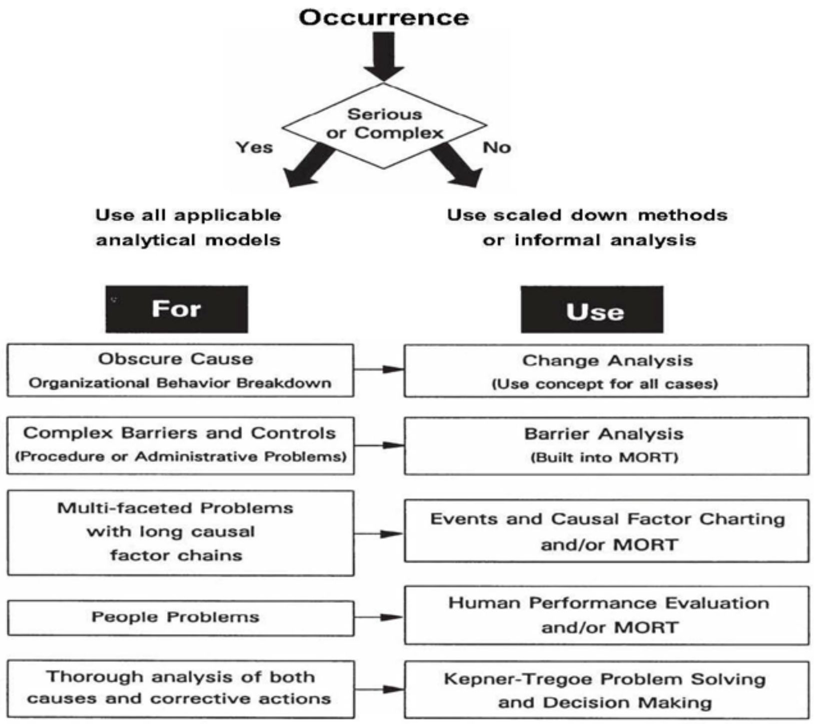


Table 3.3.1 — SUMMARY OF ROOT CAUSE METHODS

METHOD	WHEN TO USE	ADVANTAGES	DISADVANTAGES	REMARKS
Events and Causal Factor Analysis	Use for multi-faceted problems with long or complex causal factor chain	Provides visual display of analysis process. Identifies probable contributors to condition.	Time-consuming and requires familiarity with process to be effective.	Requires a broad perspective of the event to identify unrelated problems. Helps to identify where deviations occurred from acceptable methods.
Change Analysis	Use when cause is obscure. Especially useful in evaluating equipment failures	Simple 6-step process	Limited value because of the danger of accepting wrong "obvious" answer.	A singular problem technique that can be used in support of a larger investigation. All root causes may not be identified.
Barrier Analysis	Used to identify barrier and equipment failures, and procedural or administrative problems.	Provides systematic approach.	Requires familiarity with process to be effective.	This process is based on the MORT Hazard/Target concept
MORT/Mini-MORT	Used when there is a shortage of experts to ask the right questions and whenever the problem is a recurring one. Helpful in solving programmatic problems.	Can be used with limited prior training. Provides a list of questions for specific control and management factors.	May only identify area of cause, not specific causes.	If this process fails to identify problem areas, seek additional help or use cause-and-effect analysis.
Human Performance Evaluations (HPE)	Use whenever people have been identified as being involved in the problem cause.	Thorough analysis	None if process is closely followed.	Requires HPE training.

Kepner-Tregoe	Use for major concerns where all aspects need thorough analysis	Highly structured approach focuses on all aspects of the occurrence and problem resolution.	More comprehensive than may be needed	Requires Kepner-Tregoe training.
Cause and Effect Charting (e.g., Reality Charting™)	Useful for any type of problem.	Provides a direct approach to reach causes of primary effect(s). May be used with barrier/change analysis. Focus is on best solution generation.	May not provide entire background to understand a complex problem. Requires experience/knowledge to ask all the right questions.	Requires knowledge of the Apollo Root Cause Analysis techniques. Apollo RealityCharting™ software may be used as a tool to aid problem resolution.”

To aid investigators, the following guidelines in selecting the root-cause analysis approach are provided.

1. **Human Performance.** For human performance process-related deficient conditions, the approaches that can be applied are dependent on whether the analysis is for single or multiple events. For a single event the most effective approach is as follows:

   a. Single Incident Investigation/Analysis (most common method)

   - Develop problem statement
     - *What* is the problem? This is the effect (sometimes referred to as the “primary effect”) we do not want to recur.
     - *When* did it happen? This is the relative time of this primary effect. It may be the time of day, or it may be a point in a sequence of causes.
     - *Where* did it happen? This is a relative location of this primary effect. It may be a specific location (e.g., #2 Emergency Generator), it may be a relative geographic position (e.g., covering the states of New Jersey, New York, and parts of Connecticut), it may be a geographic region (e.g., the southern portion of WECC).
     - What is the *Significance* of the problem? This is the relative value this problem has on the organization, the grid, or the region. Knowing this upfront helps us to know the relative importance of the problem, and can involve many factors – cost, safety, and frequency are the most common ones, but other factors must also be considered.
   - Initiate event and causal factors chart (E&CF); update this chart throughout the process.
   - Perform a task analysis (what should have happened) — inspect event scene and perform walk-through task analysis if possible.
   - Perform a change analysis.
   - Develop questions for interviews.
   - Conduct interviews (one-on-ones with the individuals involved).
   - Identify any inappropriate actions on E&CF chart.

- Determine causes and barriers for any inappropriate action (there are 12 human barriers to choose from).
- Determine an error type for any inappropriate action.
- Make sure human error drivers are considered when determining the causes of any inappropriate actions.
- Determine behavior(s) for any inappropriate action.
- Evaluate E&CF chart to determine any organizational and programmatic deficiencies and management errors.
- Finalize E&CF chart — review chart for action sequence, logic, and for areas requiring additional fact gathering, validation, and verification.
- Develop corrective actions.
- Complete root cause documentation ensuring all root cause analysis elements are addressed.

Validate and Verify Facts --- No Opinions!

b. Multiple Incident Investigation/Analysis. Common cause method uses barrier analysis approach — most effective approach.

- Identify incidents to be analyzed.
- Group incidents by consequence.
- For each consequence, identify barriers that should have prevented occurrence (there are 12 barriers to consider for each consequence).
- Identify why (cause) each barrier failed.
- Interview individuals that perform the type of activities being analyzed to determine any human error drivers, organizational and programmatic deficiencies, or management errors.
- Determine corrective actions.
- Complete root cause documentation ensuring that all the root cause analysis elements are addressed.

2. **Equipment Failure Investigation/Analysis.** Use Kepner-Tregoe® (K-T) problem analysis[1] or similar equipment failure method

a. Steps:

- State problem.

[1] http://www.kepner-tregoe.com/TheKTWay/OurProcesses-PA.cfm

- *What* is the problem? This is the effect (sometimes referred to as the "primary effect") we do not want to recur.
- *When* did it happen? This is the relative time of this primary effect. It may be the time of day, or it may be a point in a sequence of causes.
- *Where* did it happen? This is a relative location of this primary effect. It may be a specific location (e.g., #2 Emergency Generator), it may be a relative geographic position (e.g., covering the states of New Jersey, New York, and parts of Connecticut), it may be a geographic region (e.g., the southern portion of WECC).
- What is the *Significance* of the problem? This is the relative value this problem has on the organization, the grid, or the region. Knowing this upfront helps us to know the relative importance of the problem, and can involve many factors – cost, safety, and frequency are the most common ones, but other factors must also be considered.

- Quantify what are (identity, location, timing, and magnitude).
- Quantify what is not.
- Determine difference between what is and what is not.
- Determine if difference suggest a change.
- List all possible causes.
- Test possible causes using "if/then" questions.
- Verify most probable cause(s).

b. Some of the common conditions that result in equipment failures are:

- Design configuration and analysis (inappropriate layout of system or subsystem; inappropriate component orientation; component omission; errors in assumptions, methods, or calculations during design or establishing operational limits; improper selection of materials or components; operating environment not considered in original design).
- Equipment specification, manufacture, and construction (improper heat treatment, machining, casting, on-site fabrication, installation).
- Maintenance/testing (inadequate maintenance, insufficient post- maintenance testing, inadequate preventive maintenance, inadequate quality control function).
- Plant/system operation (operating parameters, changes in parameters, performance).
- External (storm, flood, grid perturbation).

3. **Equipment-People Investigation/Analysis**

a. Use both E&CF charting (for human performance).

b. K-T Problem Analysis (for equipment failures)

Multiple Incident Common Cause Investigation/Analysis Form

Consequence(s) (List one at a time) Need not be in sequential order.	**Barrier(s) that should have precluded event** (Identify all applicable physical and administrative barriers for each consequence).	**Barrier assessment (Why the barrier(s) failed)** (Identify if barrier was missing, weak, or ineffective and why).	**Organizational and programmatic, management error, and human performance error drivers that enabled the whys** (List all applicable)	**Corrective Actions** (Identify a corrective action for each: why, organizational and programmatic, management error, and human performance error)

3.4 Apparent Cause Analysis (ACA)

An apparent cause is defined as a determination based on the evaluator's judgment and experience, and where reasonable effort is made to determine WHY the problem occurred. ACA seeks to determine why the problem occurred based on reasonable effort and the investigator's judgment and experience (the investigator is often a subject matter expert.) The emphasis of an ACA is primarily to correct a particular event or problem without a special effort to identify the underlying system or process problems that may have contributed to the problem. Performing an ACA should not prevent the identification and correction of these underlying contributors if they can be discovered and addressed easily. Several tools can be used to accomplish an ACA. One of the simplest and most effective tools is the "why staircase."

NOTE: ACA is not industry standard for system disturbances or major events and is not referenced in the Department of Energy (DOE) Guidelines for Root Cause Analysis. A proper corrective action plan cannot be determined based on apparent causes. To establish proper corrective action plans to prevent reoccurrence, the root causes of the event must be determined. By only looking at apparent causes, the underlying root cause may be overlooked allowing a reoccurrence of the deficiency leading to the event.

The "why staircase" is a method used to help determine the apparent cause(s) for events that do not require root-cause analysis. It begins with asking why a deficiency occurred followed by asking why each why occurred. For a simple single branch, the "why staircase" methodology is as follows:

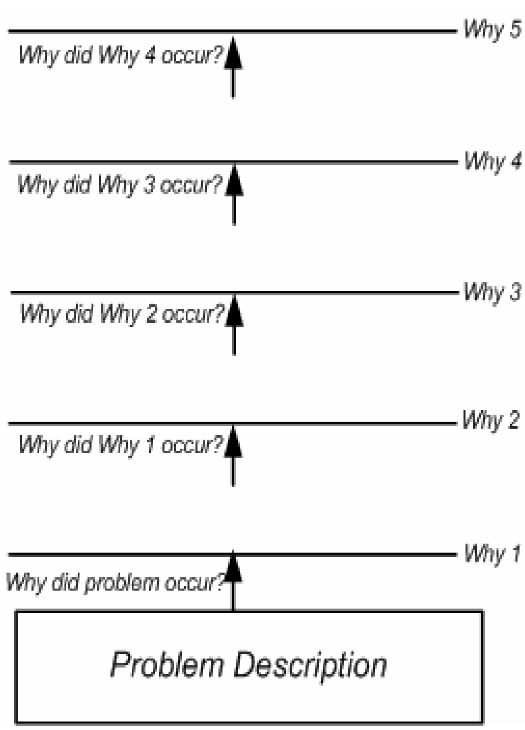
1. Write a clear problem statement.
2. Why did the condition (problem statement) occur?
3. Why did the previous "why" occur?
4. Why did the previous "why" occur?

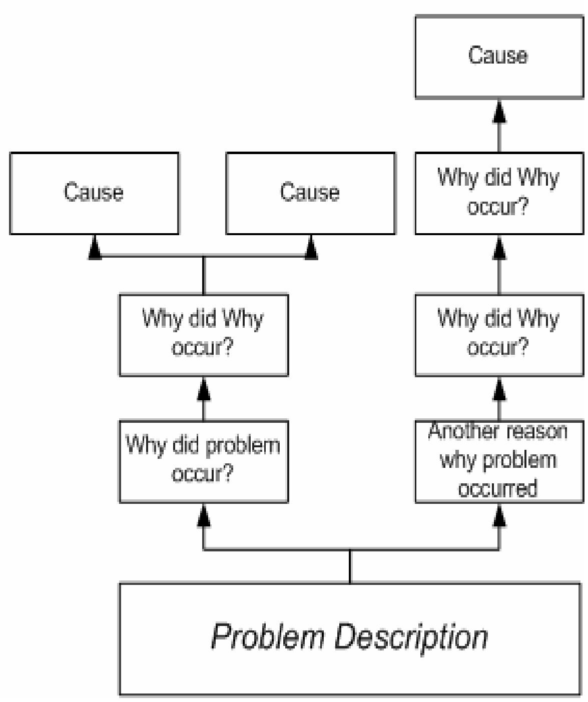
5. Why did the previous "why" occur?
6. Continue asking why until the corrective action(s) that should be taken will not change, regardless of how many "whys" have been asked. This could stop at only two iterations or could be as many as ten or more.

For more complex problems, multi-branch or multiple "why staircases" may be required. The essential element of this method is the continued asking of "why" until no additional causes (whys) can be stated. It is important to keep in mind that the causes (whys) should be verifiable, in some cases the most probable, to ensure corrective actions are developed and implemented to fix and prevent the condition from recurring. Root-cause techniques can be used to determine, validate, and verify "why" statements.

The "why" statements (apparent causes), should be written in the investigators own words. "Why" statements should be based on personal knowledge, judgment, and experience coupled with information gathered through interviews, review of documentation, and other fact-finding activities. Subject matter experts should be used to the extent reasonable to validate and verify that the "why" statements are factual.

Some examples of "Why Staircase" outlines





Example of a "Why Stair Case" for a Seized Pump

Document Control Back Log	Why 8
Mechanic did not have a drawing in work order	Why 7
Mechanic installed sight glass during over haul	Why 6
Sight glass installed upside down	Why 5
Operator did not replenish oil to correct level	Why 4
Not enough oil in Reservoir	Why 3
Inadequate lubrication	Why 2
Bearing wiped	Why 1

RAW WATER PUMP SEIZES

3.5 Root Cause Analysis (RCA)

An RCA seeks to discover the cause or causes (fundamental conditions) that, if corrected, would prevent recurrence of an inappropriate action or equipment failure that results in deficient or adverse condition(s). The root cause does not apply to this occurrence only, but has generic implications to a broad group of possible occurrences, and it is the most fundamental aspect of the cause that can logically be identified and corrected. There may be a series of causes that can be identified, one leading to another. This series should be pursued until the fundamental, correctable cause has been identified.

The number one deficiency in engineering analysis of events and occurrences is stopping the analysis at the failure or error "mode" (fingerprint) and not driving to obtain the failure or error mechanism (causal factor) which leads to the root cause. This is a typical deficiency with the apparent-cause analysis and can easily be prevented by understanding and conducting an RCA.

RCA should be performed for all events that have, or could have had, an impact to the BPS. There is a need to identify casual factors and contributing factors which need to be eliminated to prevent reoccurrence. Other RCAs are performed at the discretion of management to determine why less significant deficient conditions occurred. An RCA grading list template can be found in **Appendix B** of this document.

Typically, an RCA is led, conducted, or (at a minimum) overviewed by individuals that have been formally trained in various root-cause analysis methods. A quality analysis is more than just assigning well-intentioned individuals to make a determination of what happened, it is prescribing to industry standard methodology that delivers consistent causal factors and quality corrective actions. Selection of the RCA approach is dependent upon whether the deficient condition being investigated is the result of inappropriate personnel action(s), equipment failure, or both. (See section 4.0 of this process titled “Cause Analysis Tools” for specific information on the different root cause analysis tools.)

3.5.1 Root Cause Analysis Elements

The following elements need to be addressed in the root-cause documentation. Failure to address each of the following elements may result in not achieving the full value of the effort.

1. Analysis covers all relevant information (description, facts, data)
2. Critical information used in the analysis should be validated through a Quality, Validate & Verify (QV&V) process so that it is fact-based.
3. Analysis considers previous events of similar cause or consequence for diagnosis of common causes.
4. Analysis determines the extent of condition (i.e., was the event caused by isolated human error, isolated equipment failure, a local Organizational and Programmatic (O&P) issue, or a management issue?)
5. Analysis considers all possible causes in determining the root cause(s) (support the selected cause and refute other likely causes)
6. O&P issues and management issues confirmed and extent of conditions objectively assessed.
7. O&P issues and management issues are demonstrated substandard through objective review.
8. Root causes are fundamental enough that, if corrected, will prevent recurrence of this and similar events (i.e., satisfy the tests for root cause).
9. Analysis considers the effectiveness of corrective actions from previous similar events and from operating experience.

Corrective actions fix all conditions, correct contributing factors that are high risk or substandard, correct all root causes, and apply corrective actions to other affected areas (i.e., generic implications)

3.5.2 Typical Analysis Steps

The key steps for an analysis are:

1. Assemble a team
2. Develop a scope (problem statement)

a. *What* is the problem? This is the effect (sometimes referred to as the "primary effect") we do not want to recur.

b. *When* did it happen? This is the relative time of this primary effect. It may be the time of day, or it may be a point in a sequence of causes.

c. *Where* did it happen? This is a relative location of this primary effect. It may be a specific location (e.g., #2 Emergency Generator), it may be a relative geographic position (e.g., covering the states of New Jersey, New York, and parts of Connecticut), it may be a geographic region (e.g., the southern portion of WECC).

d. What is the *Significance* of the problem? This is the relative value this problem has on the organization, the grid, or the region. Knowing this upfront helps us to know the relative importance of the problem, and can involve many factors – cost, safety, and frequency are the most common ones, but other factors must also be considered.

3. Appoint a custodian to protect physical evidence.

4. Collect available data pertinent to the problem including:

   a. Initial system and plant conditions.

   b. Statements of personnel involved with the event.

   c. Pertinent computer printouts (e.g., post-trip log sequence of events) and charts.

   d. Pertinent documentation such as operator logs, work permits, work plans, etc. as required to establish conditions prior to and during the event.

   e. Voice recordings.

   f. Photographs and videotapes taken to document equipment prior to repair.

5. Reconstruct the problem using the collected information.

   a. Validate the facts through a review of plant design, physical data, personnel statements, and interviews.

   b. Verify whether consistency exists between:

      1. Personnel statements.

      2. Interview data.

      3. Plant characteristics and documentation.

      4. Historical and analytical data.

   c. Previous problem data and documentation.

   d. Resolve, to the extent practical, contradiction of facts.

6. Prior to release of quarantine or initiation of troubleshooting activities, the investigation team should review the plans for recovery with on-duty management. The recovery

plan should include: 1) a list of the concerns to be investigated or resolved, and 2) an action plan for the investigation and troubleshooting activities.

7. Analyze the event to determine the actions of personnel and the response of equipment. This should include:
    a. A comparison of the proper response of plant systems to the actual and expected response during the problem.
    b. An evaluation of the adequacy of procedures.
    c. If personnel error contributed to the problem, an E&CF chart should be performed.
8. Determine if the problem had detrimental effects on plant equipment or if other plant equipment may be subject to a similar problem.
9. Perform a root-cause analysis by a qualified individual using the appropriate methods.
10. Develop corrective actions and recurrence controls.
11. Provide update briefings to key personnel as required.

3.5.3 Team Composition

The majority of human performance errors and equipment failures are investigated by one or two subject matter experts. Typically, a team consisting of three or more individuals is used for significant deficiencies. If a team is formed, a team leader or event manager is normally designated by the authorizing manager.

Team assembly — if it is determined a team needs to be formed, the event manager should assemble the members. The team may include personnel who were directly involved or immediately responsible for the problem but not completely comprised of these individuals in order to provide for an objective and independent review of the event. In addition, consideration should be given to the following personnel as team members:

- Personnel from regulatory oversight groups.
- Engineering personnel familiar with the design aspects associated with the problem.
- Site industrial safety personnel for problems involving personnel injury.
- Corporate personnel with applicable expertise.
- An individual qualified in root-cause analysis methods.
- Subject matter experts in the areas of analysis.

Frequently obtaining the desired individuals as team members can be difficult however, in most cases support from the desired individuals can be obtained as subject matter experts (SME). Subject matter experts are a very valuable asset especially to the individual investigator as well as to the analysis itself.

3.6 Corrective Action Development

Developing quality corrective actions for each causal factor will not only address the issues, it will also address the systematic problems that allowed the issue to occur in the first place (preventing recurrence). In developing and implementing corrective actions, consideration of the following questions can help ensure adequacy:

1. Do the corrective actions address all the root causes?
2. Will the corrective actions cause detrimental effects?
3. What are the consequences of implementing the corrective actions?
4. What are the consequences of not implementing the corrective actions?
5. What is the cost of implementing the corrective actions?
    a. Capital costs?
    b. Operating & Maintenance (O & M) Costs?
6. Will training be required as part of the implementation?
7. In what time frame can the corrective actions reasonably be implemented?
8. What resources are required for successful development of the corrective actions?
9. What resources are required for successful implementation and continued effectiveness of the corrective actions?
10. Is the implementation of the corrective actions measurable?
11. What Impact will the development and implementation of the corrective actions have on other work groups or Management?

4.0 Cause Analysis Tools

The following are typical cause analysis elements and tools:

4.1 Problem Statements

The problem statement should be a complete sentence that clearly states what the issue is. This is extremely important for the investigator (event manager) in that it defines the task. If the problem statement is too general, the investigation can be drawn out and any results taken to the authorizing individuals could be incorrect. It is extremely beneficial to spend the time necessary to clarify the problem statement and obtain concurrence from the authorizing party that the correct issue is being addressed. It is not uncommon to revise the problem statement once the investigation is underway.

A good problem statement for personnel inappropriate actions should simply state who did what, where, when, and significance. For equipment condition, a good problem statement should simply state what occurred, where, when, and the significance.

4.2 Task Analysis

A task analysis is a tool that can be used in virtually every investigation and is performed to determine what should have happened. Instructions, procedures, and other documentation are reviewed and broken down into sub tasks leading up to the event. This analysis is followed with a comparison of what should have happened, with what actually happened to cause the event. Determination of the actual course of events often requires personnel statements and interviews.

4.2.1 Paper and Pencil Task Analysis

A paper and pencil task analysis is a method where a specific task is broken down, on paper, into subtasks which identify the sequence of actions, instructions, conditions, tools, and materials associated with the performance of that task.

1. **Objectives**
    a. On paper break down the task into different subtasks, actions, or steps that are expected to be performed during some activity.
    b. Identify information, controls and displays, materials, and other requirements for performance of task.
    c. Establish a knowledge baseline for the evaluator on how the task being evaluated is performed.
    d. Identify potential problems with the performance of such task such as inadequate procedures, inappropriate plant conditions, etc.
2. **Method**
    a. Obtain preliminary information in order to know what the circumstances were when the inappropriate action occurred.
    b. Select the task of interest.
    c. Obtain necessary information.
        - Relevant procedure(s).
        - System drawings, block diagrams, Pen and Ink (P&I) drawings.
        - Interviews with individuals that have performed the task.
    d. Divide the task of interest into component actions or steps.
    e. Write step name or action in order of occurrence on task analysis worksheet.

Paper and Pencil Task Analysis Form

Step	Who	Required Action	Component	Tools	Remarks / Questions

4.2.2 Walk-Through Task Analysis

Cause-and-effect (walk-through) task analysis is a method in which personnel conduct a step-by-step reenactment of their actions for the observer without carrying out the actual function. If appropriate, it may be possible to use the simulator for performing the walkthrough rather than the control room.

1. **Objectives**
   a. Determine how a task was really performed.
   b. Identify problems in human factors design, discrepancies in procedural steps, training, etc.
2. **Preconditions**
   a. Participants must be the people who actually perform the task.
3. **Steps in Cause-and-Effect Task Analysis**
   a. Obtain preliminary information in order to become familiar with the circumstances when the problem or inappropriate action occurred.
   b. Decide on task of interest.
   c. Obtain necessary background information.
      - Relevant procedure(s).
      - System drawings block diagram, etc.
      - Interview personnel who perform the task (but not those who will be observed) to obtain understanding of how the task should be performed.
4. Produce a guide outlining how the task will be carried out. The guide should indicate the steps in performing the task and key controls and displays so:
   a. The evaluator will know what to look for.
   b. The evaluator will be able to easily record actions.

   Note: A procedure with key items underlined is the easiest way of doing this.

5. The evaluator should be completely familiar with the guide and decide exactly what information will be recorded and how it will be recorded.
   a. The evaluator should check off each step and note the controls or displays used as they occur. Discrepancies and problems should be noted in the margin or in a space provided for comments, adjacent to the step.
6. Select personnel who normally perform the task. If task is performed by a crew, crew members should play the same role they fulfill when carrying out the task.
7. Observe personnel walking through task and record their actions and use of displays and controls. Note discrepancies and problem areas.
   a. The evaluator should observe the task as it is normally carried out; however, if necessary, the task should be paused to gain full understanding of all steps.
   b. Conduct the task under the conditions, as near as possible, which existed when the event occurred, this will provide the best understanding of the event causal factors.
   c. Summarize and consolidate any problem areas noted. Identify probable contributors to the event.

4.3 Change Analysis

A change analysis is used when the problem is obscure, is generally used for a single occurrence, and focuses on the elements that have changed. A change analysis studies the deviation between what is expected to occur and what actually does occur. The evaluator will attempt to determine mitigating factors that cause the outcome of this task or activity to result in an event. A good example is a switching order that is missing a step that causes an incident, you could compare and identify the deviation and seek to find out why there was a deviation.

This technique consists of asking the questions: What? When? Where? Who? How? Answering these questions will provide additional direction in order to answer the root-cause determination question, how did it occur?

Primary and secondary questions included within each category will assist in obtaining all the needed information. Some of the questions will not be applicable to any or all given conditions, and an amount of redundancy will exist in the questions in order to ensure all items are addressed.

Several key elements include the following:

1. Review the event or occurrence containing the undesired consequences.
2. Review a comparable activity that did not have an undesired consequence(s).
3. Compare the condition containing the undesirable consequences with the reference activity.

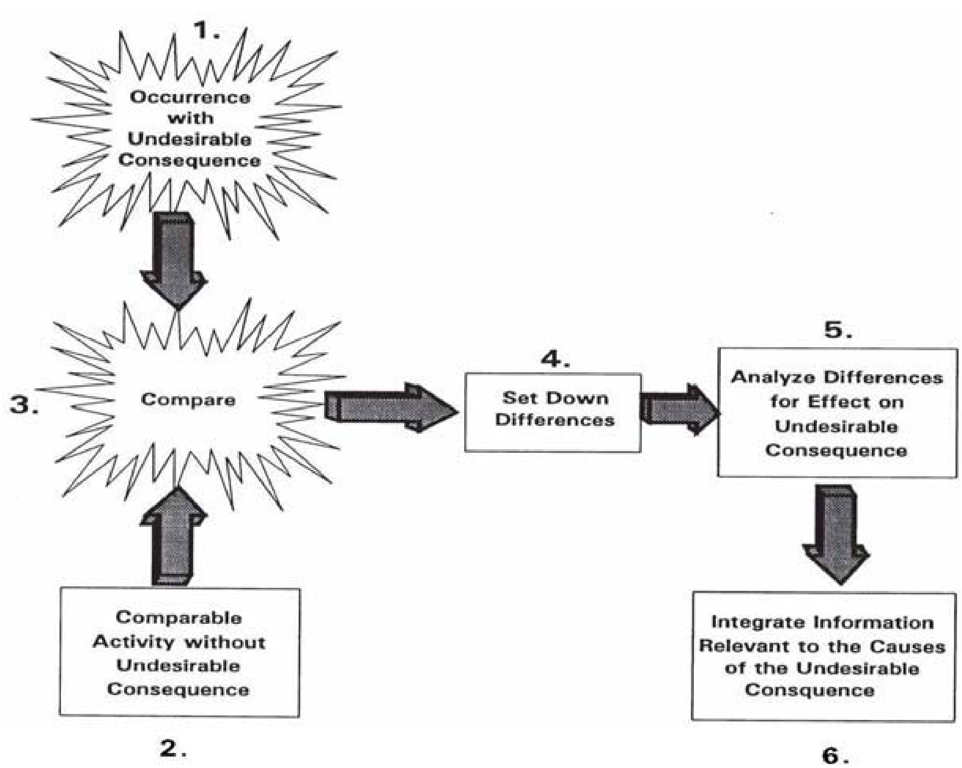
4. Identify all known differences whether or not they appear to be relevant at the time. Analyze any differences for their effects in producing the undesired consequences. This must be done with careful attention to detail, ensuring obscure and indirect relationships are identified (e.g., a change in color or finish may change the heat transfer parameters and consequently affect system temperature).
5. Integrate information into the investigation process relative to the causes of, or contributors to, the undesired consequences.

Change analysis is a good technique to use when the causes of the condition are obscure; it is difficult to determine a start point, or the evaluator suspects a change may have contributed to the condition.

There can be shortcomings with change analysis if the following are not recognized:

1. The compounding nature of change(s) (e.g., one made five years previously combined with a more recent change.
2. The introduction of gradual change(s).
3. Abrupt change(s).

This technique may be adequate to determine the root causes of a relatively simple event. However, in general it is not thorough enough to determine multiple root causes of more complex situations or conditions.



Change Analysis Form

Factors	Present Situation?	Prior, Comparable?	Differences?	Adverse Effects
What Object(s) Energy Defects Protective Devices				
Where On the Object In the Process Place				
When In time In the Process				
Who Operator Fellow Worker Supervisor Others				
Task Goal Procedure Quality				
Working Conditions Environment Overtime Schedule Delays				
Trigger Event				
Managerial Controls Control Chain Hazard Analysis Monitoring Risk Review				

4.4 Barrier Analysis

A barrier[2] is a control measure defined as something that separates an affected human or component from an undesirable condition or situation. Barriers are devices employed to protect people and enhance the safety and desired performance of the man-machine interface. They can be physical, such as engineered safety features, design allowances, locked doors or valves, alarms, fire barriers, or redundant equipment. The barriers can also be administrative, such as policies, plans, processes, and procedures or human action, such as devices that automatically eliminate the need for human control or intervention to remove the human fallibility factor.

[2] The term “barrier” is used to mean any barrier, defense or control that is in place to increase the safety of a system

The nuclear industry's defense in depth concept results in a number of barriers and defenses, such that single failures do not result in a significant event. Therefore, when an event happens, the barriers are analyzed to determine why they failed.

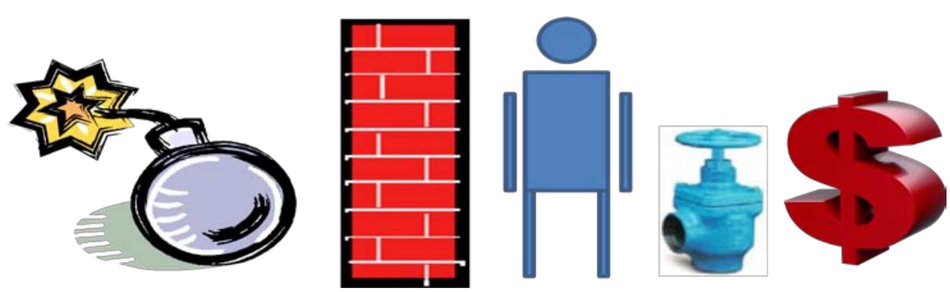
Flawed barriers and defenses allow the consequences of the occurrence to propagate from simple errors and latent conditions into full-blown events. Defects with the barriers and defense measures, under the right conditions and circumstances, may fail to protect the system or people against hazards. Some degree of human fallibility are predictable, therefore barriers and defenses can be put into place to prevent these shortcomings from becoming an event.

Barrier analysis is an effective tool for determining the root cause of human performance error events. It focuses on the barriers that should have prevented the error from occurring or mitigated its consequences.

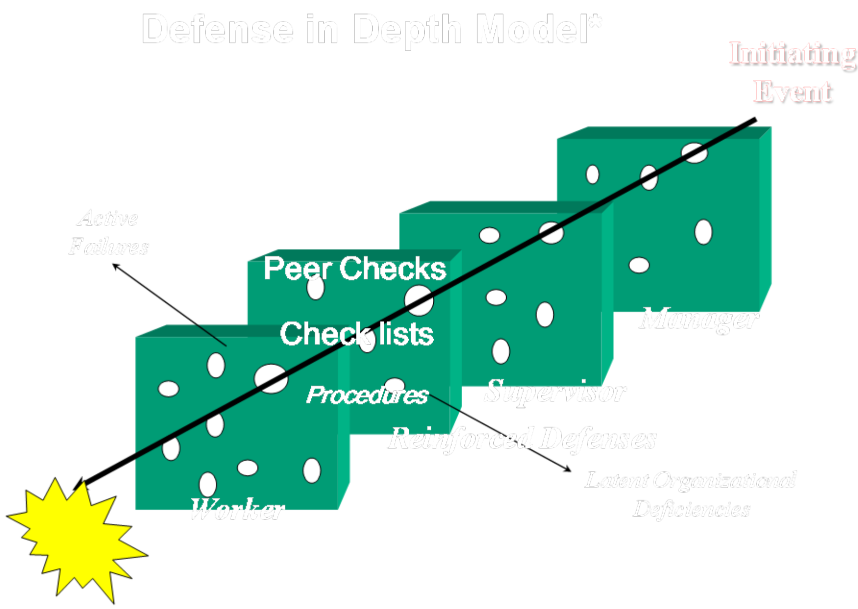
Barrier analysis defines the three elements of an unwanted event as follows:

1. The targets - The desired situation (e.g., flawless execution without errors, normally operating equipment, human safety).
2. Threats or hazards of forces that could adversely impact the "target" (e.g., errors).
3. Barriers or defenses that are designed to keep the threats from coming in contact with the targets.

Barriers prevent the threats from reaching the targets



* From INPO *Human Performance Fundamentals Course* notes



1. **Methodology**
   a. Identify and list the consequences.
   b. Identify and list the failed barriers in place for each consequence.
   c. Determine why (causes) the barriers failed (e.g., procedure not followed correctly)
   d. Verify the results.
   e. Develop corrective actions for each of the causes.

The questions listed below are designed as an aid in determining which barrier failed, resulting in the event.

- What barriers existed between the second, third, etc., condition or situation and the second, third, etc., failures?
- If there were barriers, did they perform their functions? Why not?
- Did the presence of any barriers mitigate or increase the event severity? How?
- Were any barriers not functioning as designed? Why?
- Was the barrier design adequate? Why not?
- Were there any barriers on the condition or situation source(s)? Did they fail? Why?
- Were there any barriers on the affected component(s)? Did they fail? Why?
- Were the barriers adequately maintained?
- Were the barriers inspected prior to expected use?

- Why were any unwanted energies present?
- Is the affected system or component designed to withstand the condition or situation without the barriers? Why not?
- What design changes could have prevented the unwanted flow of energy? How?
- What operating changes could have prevented the unwanted flow of energy? How?
- What maintenance changes could have prevented the unwanted flow of energy? How?
- Could the unwanted energy have been deflected or evaded? How?
- What other controls are the barriers subject to?
- Was this event foreseen by the designers, operators, maintainers, or anyone else?
- Is it possible to have foreseen the event? How?
- Is it practical to have taken further steps to have reduced the risk of the event occurring?
- Can this reasoning be extended to other similar systems or components?
- Were adequate human factors considered in the design of the equipment?
- What additional human factors could be added? Should be added?
- Is the system or component user-friendly?
- Is the system or component adequately labeled for ease of operation?
- Is there sufficient technical information for operating the component properly? How do you know?
- Is there sufficient technical information for maintaining the component properly? How do you know?
- Did the environment mitigate or increase the severity of the event? How?
- What changes were made to the system or component immediately after the event?
- What changes are going to be made? What changes might be made?
- Have these changes been properly and adequately analyzed for effect?
- What related changes to operations and maintenance should be made immediately?
- Are these expected changes cost-effective? Why? How do you know?
- What would you have done differently to have prevented the event, disregarding all economic concerns (in regards to operation, maintenance, and design)?
- What would you have done differently to have prevented the event, considering all economic concerns (in regards to operation, maintenance, and design)?

2. **Human (administrative) Barriers and Associated Causal Factors**

The administrative barriers and associated causes for inappropriate actions are as follows:

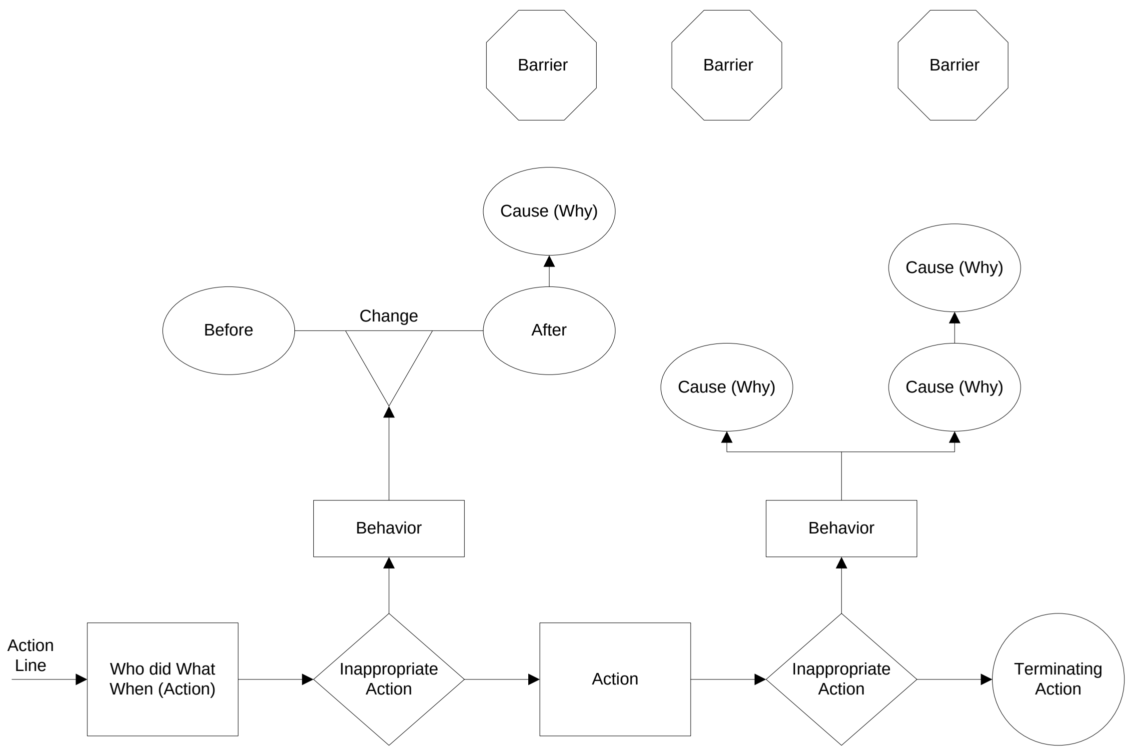
- Verbal communication (inadequate information exchange whether face-to-face or via telephone).
- Written procedure and documents (inappropriate maintenance, operating, or special test procedures and instructions, inappropriate drawings, equipment manuals, technical specifications).
- Human-machine interface (insufficient or incorrect label, gauge, annunciator, control device).
- Environmental conditions (inadequate lighting, work space, clothing; noise; high radiation; ambient temperature).
- Work schedule (excessive overtime, insufficient time to prepare for or accomplish the task).
- Work practices (lack of self-checks, failure to follow procedure).
- Work organization or planning (insufficient time to prepare or perform, maintenance not scheduled).
- Supervisory methods (inadequate direction, supervisor interference, overemphasis on schedule).
- Training and qualifications (insufficient technical knowledge, lack of training, inadequate training materials, improper use of tools, insufficient practice, ineffective on-the-job training).
- Change management (inappropriate plant modification; lack of change related retraining, procedures, documents).
- Resource management (unavailability of tools, information, personnel, supervision).
- Managerial methods (insufficient or lack of accountability, policy, goals, schedule; failure to ensure any previous issues are resolved; insufficient use of operating experience; lack of proper assignment of responsibility; not communicating or enforcing high standards; lack of safety awareness).

Items in parentheses are provided only as examples of the causal factors in each category. There may be many causal factors similar to these in each category.

4.5 Event and Causal Factors (E&CF) Charting

Event and causal factors analysis can be used to provide a visual display of events leading up to the problem and the identified causes. This is excellent for multi-faceted human performance and process-related issues, and can help identify holes in the analysis information. An event and causal factor chart provides a graphic display of the event on a time line. This technique is very effective because many of the causal factors become evident while plotting the time line for the event.

Event and causal factor charting is very useful for complex and complicated situations and is often used for multi-faceted problems or long, complex causal factor chains and is better than long narrative descriptions. It shows the exact sequence of events from start to finish, while allowing for the addition of barriers, other conditions, secondary events, presumptions, and causal factors that influenced the event. The simple example below shows a completed chart.



Some of the valuable benefits of this method are:

- A simple, straightforward approach for breaking down the entire sequence into a logical flow of events from the beginning to the end.
- It focuses the investigation, enabling resources to be spent appropriately.
- It provides a ready mechanism for briefing management, subject matter experts, and regulatory agencies on the status of an investigation.
- It ties actions, behaviors, causal factors, and barriers into a ready–to-use document.
- It captures pertinent information regarding the event without rereading the related information.
- It provides a ready method to integrate pertinent information as identified — thus providing a current logic diagram of the event.

Main elements of an E&CF:

- **Action Line —** provides a time sequence of the actions during the event.
- **Inappropriate Actions** — actions that are inappropriate due to time, procedural requirements, plant status or condition, etc.
- **Behaviors** — related to the individual's ability to sense, interpret, or act on a situation.
- **Causes** — conditions (whys) that either caused the situation or increased the chance of occurrence.
- **Change** — denotes a change in the process that resulted in the inappropriate action.
- **Barriers** — indicate devices (administrative) employed to protect people and enhance the safety and desired performance of the man-machine interface.

4.6 Fault Tree Analysis (FTA)

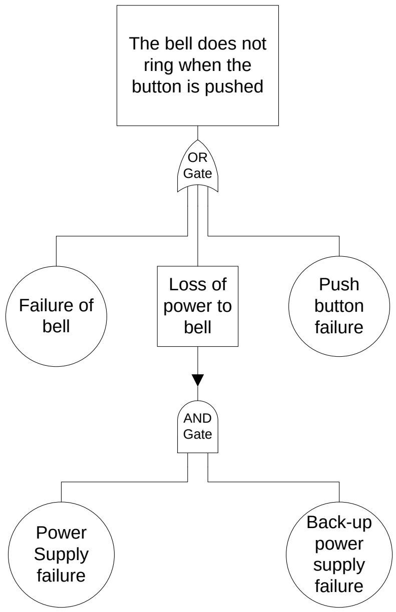
A fault tree analysis is used when trying to select between multiple possible hardware failure modes; this tool requires system and component knowledge for hardware root causes. In this method all possible failure modes and mechanisms are assembled, and probable root causes for each are developed. Each root cause is tested or verified until the cause is determined. Fault trees can also include the use of Boolean algebra (and/or gates etc.) to help analyze the probability of a failure or potential failure.

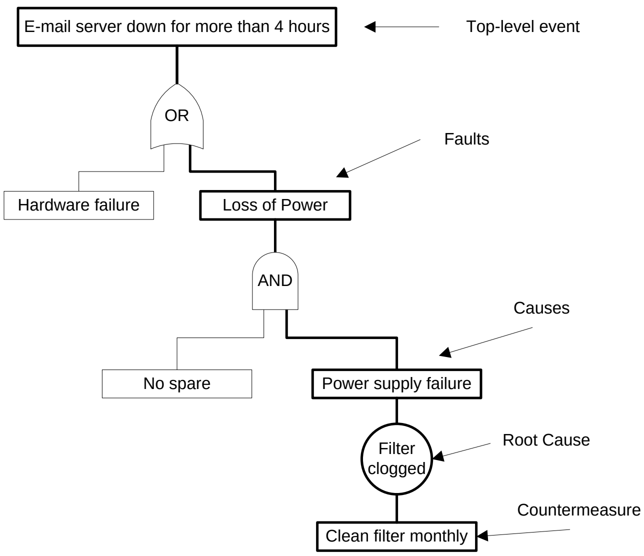
Often there will be only one failure mode indicated if applied correctly. Steps to construct an FTA are as follows:

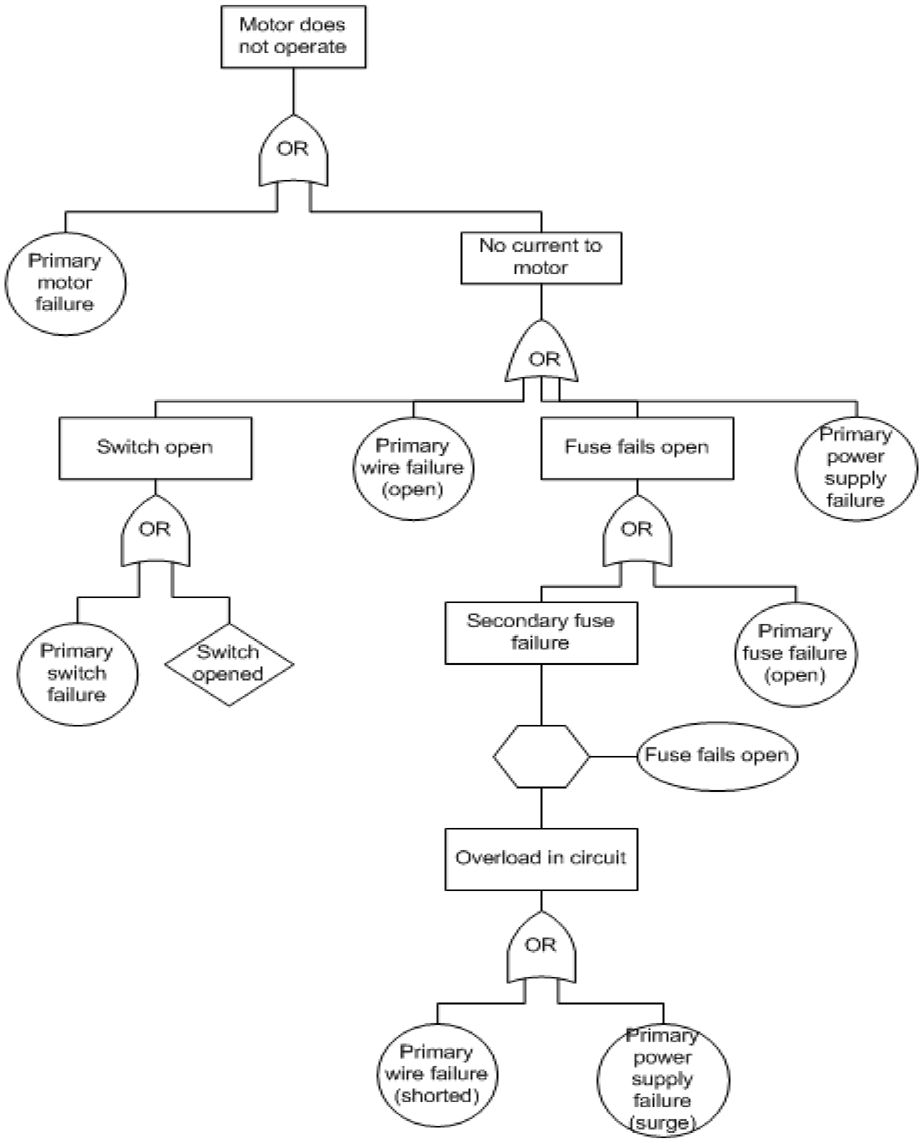
- Select an event or probable event to analyze.
- Find all the lower level (component) failures that could cause the event.
- Show these in a "tree" diagram and connect them with the appropriate logic gate.
- Search for lower level failures that could lead to the intermediate higher level failures.
- Continue until the limits of resolution are reached.
- Perform analysis.
- Identify and prioritize improvement opportunities.

There are many types of logic gates. Two of the simplest gates are shown below. The OR gate indicates that any of the three items (1 OR 2 OR 3) can cause the bell not to ring. The AND gate indicates that both the power supply AND the backup power supply have to fail to lose power to the bell.

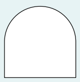
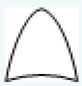
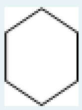
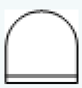
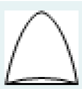
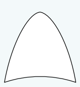
The following are examples of fault trees

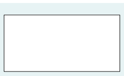
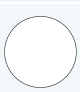
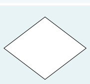


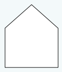
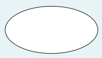
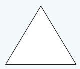



Motor does not operate
OR
Primary motor failure
No current to motor
OR
Switch open
Primary wire failure (open)
Fuse fails open
Primary power supply failure
OR
OR
Primary switch failure
Switch opened
Secondary fuse failure
Primary fuse failure (open)
Fuse fails open
Overload in circuit
OR
Primary wire failure (shorted)
Primary power supply failure (surge)

Symbols used for Fault Trees

Gate Symbol	Gate Name	Causal Relations
	AND gate	Output event occurs if all of the inputs occur simultaneously
	OR gate	Output event occurs if any one of the input event occurs
	Inhibit gate	Input produces output when conditional event occurs
	Priority AND gate	Output event occurs if all input events occur in the order from left to right
	Exclusive OR gate	Output event occurs if one, but not both, of the input events occur
 m:0:0	*m*-out-of-*n* gate (voting or sample gate)	Output event occurs if *m*-out-of-*n* input events occur

Event Symbol	Meaning
	Event represented by a gate
	Basic event with sufficient data
	Undeveloped event

	Either occurring or not occurring
	Conditional event used with inhibit gate
	Transfer symbol

4.7 Interviews

Interviews, especially involving personnel related events, are essential for determination of the cause(s) of the event. Key factors to remember for interviews are:

- The four steps to interviewing are preparation, opening, questioning, and closing.
- Be prepared — take the time to draft questions.
- Interviews should be conducted as soon as possible after the event.
- One individual should be interviewed at a time. Group interviews are not conducive.
- Interviews should be conducted prior to involved individuals getting together for a group discussion, whenever possible.
- Interviews should be conducted in a neutral environment.
- Interviews should be focused on obtaining facts to prevent recurrence of the event — not to fix blame.
- Face-to-face interviews are the most productive and are recommended.
- Telephone interviews should only be used in unusual cases and only when face-to-face interviews cannot be conducted.
- Panel interviews (inquisitions) should be avoided at all cost. Two interviewers should be used at most; having two interviewers enables one individual to focus on interviewing while the other acts as a scribe.
- Open-ended questions that allow the interviewee to talk are the most productive at obtaining pertinent facts.
- Good interview notes are essential — document what the interviewee says — seemingly unimportant information may become significant as the investigation evolves. This enables collection of facts before they get contaminated or changed as a result of the human rationalization process.
- Maintain good eye contact with the person being interviewed.
- Open the interview by introducing yourself(s), including relevant personnel information, why the person is being interviewed, how long the interview will take, that you will be

taking notes, and that you are very interested in their help in determining why the event occurred and how it can be prevented.

- Close the interview with a paraphrased summary of what the interviewee said, how you can be reached if additional information is remembered, that a follow-up interview may be required as the investigation progresses, and thank the individual for their time and help.
- Immediately after the interview, review notes and capture pertinent facts — update the E&CF chart prior to the next interview.
- Throughout the interview use paraphrased information received to ensure you understood what the interviewee meant and said.
- Use follow-up questions to clarify information being provided by the interviewee.
- Listen, Listen, Listen.
- IF the interviewee is aggressive or non-cooperative immediately terminate the interview.
- Minimize disruptions.
- Don't badger the interviewee.
- Schedule interviews through the department manager or supervisor — remember the individuals work for them.
- Be available and on time.

Interview involved personnel; do not rely on personal statements. Personal statements can be vague and document what the interviewee feels is important; not necessarily what is important and does not provide the face-to-face contact that is necessary for a good interview.

4.8 Advanced Methods

This section deals with other advanced methods and tools which are available; however, the use of such techniques usually requires specific training and skills.

4.81 Management Oversight and Risk Tree (MORT) Analysis

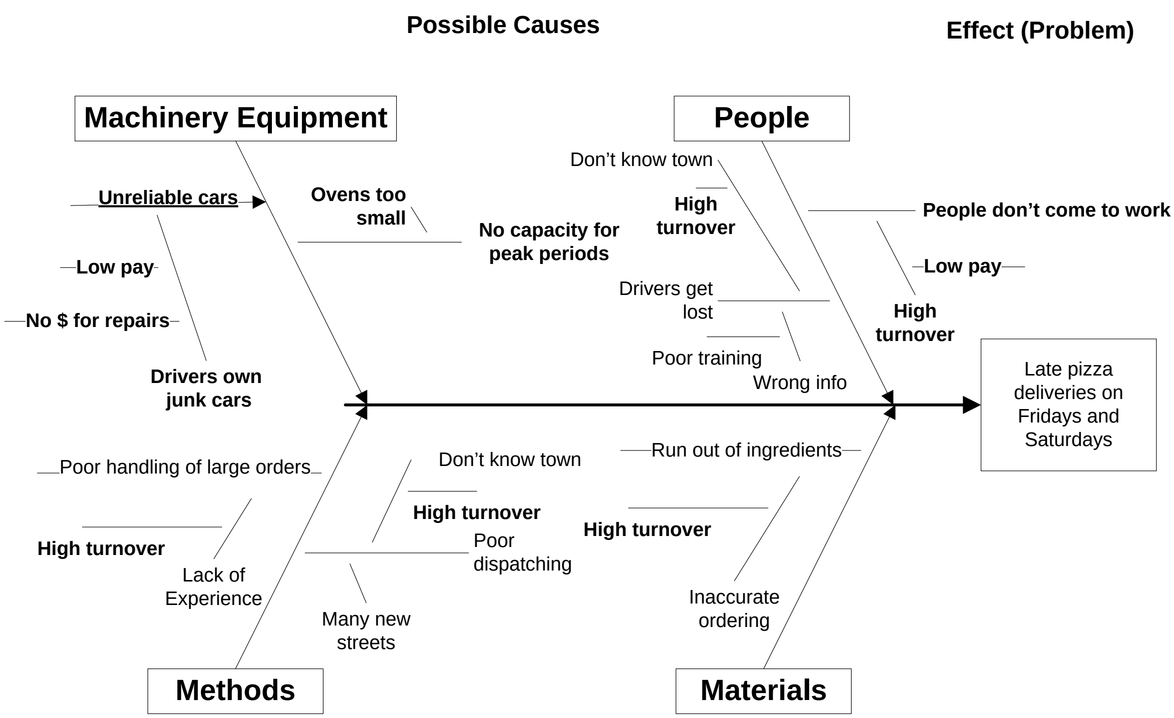
MORT and Mini-MORT (which uses only a portion of the full MORT method) are analytical procedures for investigating causes and contributing factors of accidents and incidents. These methods use logic tree diagrams (a MORT Chart) which lists topics to be investigated, with each topic having defined questions, in order to ensure a systematic method of clarifying the facts surrounding the incident.

Essential to the use of a MORT (or mini-Mort) investigation is the Barrier Analysis (see 4.4), for which MORT investigation seeks to determine which barriers exist, which are inadequate, and what additional barriers may be needed.

4.82 Cause and Effect Analysis.

The cause and effect diagram is also referred to as a "fishbone" diagram or Ishikawa diagram. It systematically organizes information into categories to determine potential causes of problems. The methodology is outlined as follows:

- Draw the cause and effect (fishbone) diagram.
- List the problem description in the head of the fish.
- Label each major bone of the fish to help organize your analysis. Typical categories are shown below, or you can use your own based upon the problem being analyzed.
- Use an idea-generating technique (e.g., brainstorming) to identify the possible causes in each category.
- For each possible cause, keep asking "why is this happening?" add an arrow into the appropriate bone until you get no more useful information.
- When completed effectively, this diagram shows possible causes. Select causes that show up on more than one category, or that seem probable; then test the causes to verify if they are, in fact, causes.



Typical major "Bones" or Categories

- 4M's – Methods, Machines, Materials, Manpower
- 4 P's – Place, Procedure, People, Policies
- 4 S's – Surroundings, Suppliers, Systems, Skills
- Or develop your owncategories based upon the problem

4.83 K-T (Kepner-Tregoe) Problem Analysis

The K-T problem analysis technique is an advanced root-cause determination method. It is one of the most effective techniques for the determination of the root cause of equipment-related problems.

This method is used by trained individuals. The effectiveness of the technique requires deliberate methodology and should be performed with direct involvement of subject matter experts or an expert panel.

It is essential to perform the technique in the following order:

1. State the deviation.
2. Specify the problem (i.e., what is, where is, when is, and extent (how and what)).
3. Then, what is not, where is not, when is not, and extent (how and what).
4. Distinctions (compare what is with what is not).
5. Changes in distinctions (list dates).
6. Develop possible causes.
7. Test for probable cause against specifications.
8. Determine most probable cause.
9. Identify steps to verify true cause.

A typical K-T problem analysis form is shown below.

<table>
<tr><td colspan="5"><u>K-T (Kepner-Tregoe) Problem Analysis</u>
STATE DEVIATION:</td></tr>
<tr><td>Specify the Problem</td><td>IS</td><td>IS NOT</td><td>Distinctions
of IS compared with IS NOT</td><td>Changes
in distinctions (list Dates)</td></tr>
<tr><td>What
identity</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Where
location</td><td></td><td></td><td></td><td></td></tr>
<tr><td>When
timing</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Extent
magnitude</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="3">Develop Possible Causes from experience, changes, distinctions</td><td>Test for Probable Cause
Against specifications (list assumptions from destructive test)</td><td></td></tr>
<tr><td colspan="3">1
2</td><td>Does not explain:</td><td>Explains only if:</td></tr>
<tr><td colspan="3">Determine Most Probable Cause:</td><td>Verify True Cause (steps):
1
2
3
4</td><td></td></tr>
</table>

4.84 Cause and Effect Charting (APOLLO Cause Analysis Process)

1. Define the problem by identifying what, when, where and significance.
    a. Collect physical evidence.
    b. Conduct interviews.
    c. Substantiate data.
    d. Determine the primary effect.
2. Create a Cause and Effect Chart
    a. For each primary effect ask why, continuing to the point of ignorance.
    b. Look for causes in Actions and Conditions. There should be at least one of each at

each level and, working backwards, the actions and conditions at each level should always have the same result.

c. Connect causes with “Caused By”.

d. Support causes with evidence or use “?”

3. Develop a solution

a. Create solutions for each cause.

b. Identify the best solution or solutions that will:

- Prevent recurrence.
- Be in the control of the assigned organization.
- Meet your goals and objectives.

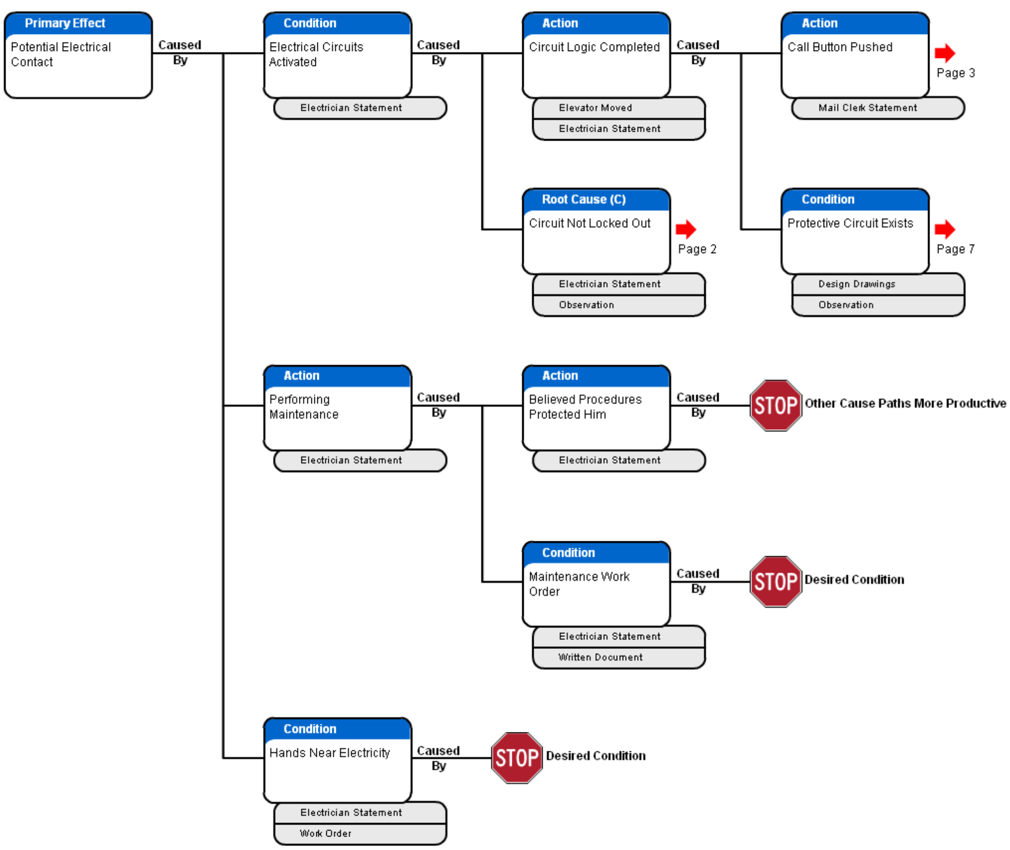
4. Implement the best solution

a. Actions should be taken as soon as practicable

b. For actions that cannot be implemented immediately develop interim actions.

NOTE: Apollo RealityCharting™ software may be used as a tool to aid problem resolution.

<u>Cause and Effect Charting </u>(example):



4.85 Technique for Human Error Rate Prediction (THERP)

The basic assumption of THERP is that the operator's actions can be regarded in the same way as the success or failure of a piece of equipment. The theory is the reliability of the operator can be assessed in essentially the same way as an equipment item. The operator's activities are broken down into task elements and estimates of the probability of an error for each task element are made, based on data or expert judgment.

THERP involves five steps:

1. Define the system or process. This involves describing the system goals and functions and the consequences of not achieving them. It also requires identifying mission, personnel, and hardware and software characteristics.
2. Identify and list all the human operations performed and their relationships to the system or process tasks and functions. This requires an analysis of all operator and maintainer tasks.
3. Predict error rates for each human operation or group of operations. Errors likely to be made in each task or subtask must be identified. Errors that are not significant in terms of system operation are ignored. This step includes estimating the likelihood of each error occurring and the likelihood of an error not being detected.
4. Determine the effect of human errors on the system or process, including the consequences of the error not being detected. This requires the development of event trees. The left limbs of the event trees are success paths; the right limbs are failure paths. Probabilities are assigned to each path. The tree reflects the effects of task dependence. The relative effects of performance-shaping factors, e.g., stress and experience, are estimated.
5. Develop and recommend changes that will reduce the system or process failure rate. The recommended changes can be developed using sensitivity analyses, in which factors and values are varied and effects monitored. THERP makes no assumptions about the dependence or independence of personnel behaviors. Data are taken from available sources.

5.0 Human Performance Evaluation

Human Performance Evaluation (HPE) is used to identify factors that influence task performance. It is most frequently used for human-machine interface studies. Its focus is on operability and work environment, rather than training operators to compensate for bad conditions. Also, HPE may be used for most occurrences since many conditions and situations leading to an occurrence ultimately result from a task performance problem such as planning, scheduling, task assignment analysis, maintenance, and inspections.

Training in ergonomics and human factors is needed to perform adequate HPEs, especially in human-machine interface (HMI) situations. This section is a brief primer in the methodology and philosophy of HPE. An excellent resource, in addition to this section, is found in the Institute of Nuclear Power Operations (INPO) Human Performance Handbook.

Erroneous Belief

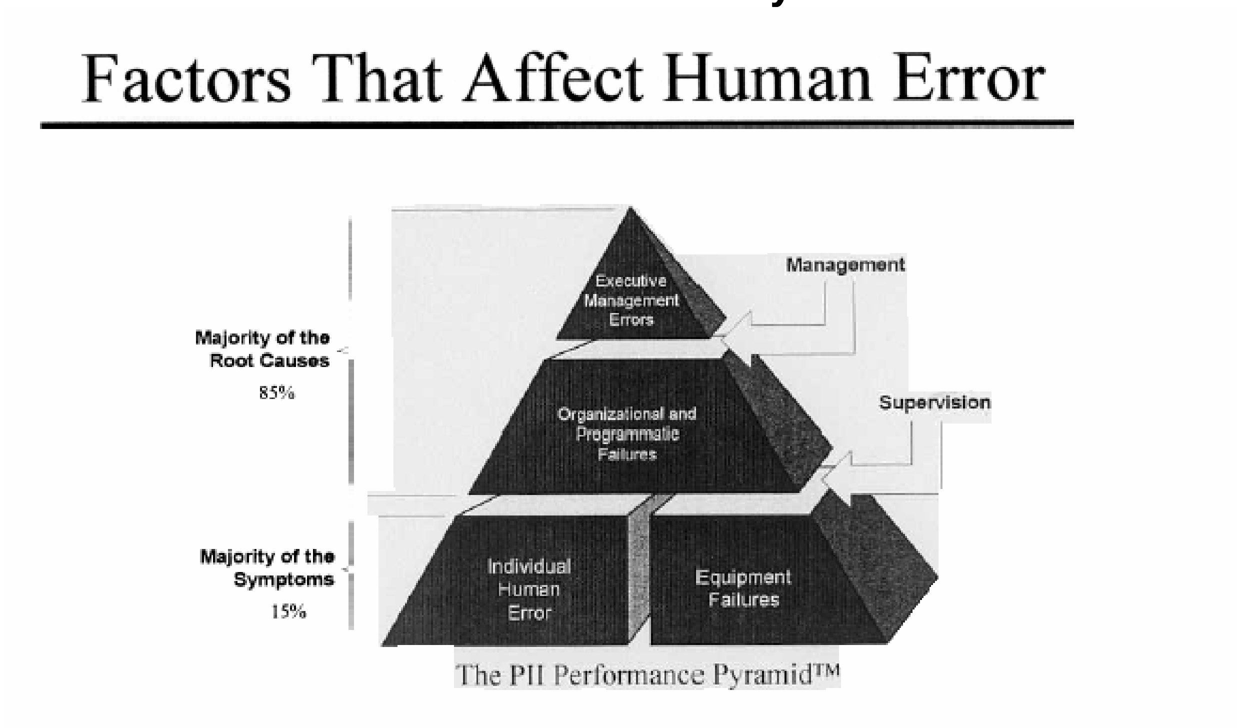
A popular illusion persists throughout many industries that people must possess a lack of proper motivation when they act carelessly or without clear judgment. A review of the industry event data base reveals that events occur more often due to error-prone tasks and error-prone work environments than from error-prone individuals. "You cannot change the human condition, but you can change the conditions under which humans work."

INPO Human Performance Handbook, 1997 (several locations, combined)

5.1 Why focus on Human Performance?

An analysis conducted in the 1990's regarding causal factors of significant events (as classified by INPO) revealed that three out of four significant events were triggered by human error. No matter how efficiently BPS elements function, how good the training, supervision, and procedures are, and how well the best worker, engineer, or manager performs his or her duties, people cannot perform better that the organization supporting them. Human error is caused not only by individual human fallibility, but also by incompatible management and leadership practices and organizational weaknesses in work processes and cultural values. Therefore, defense in depth with respect to all levels of human systems and human factors is necessary to improve BPS resistance to human error and events.

Human Performance Pyramid



HPE can be described in a simple formula:

The goal of this section is to proactively prevent events triggered by human error by promoting a practical way of thinking and a fundamental approach to predict and eliminate error precursors which can lead to events on the BPS.

There are important practical methods to approach HPE, therefore building upon excellence in human performance:

1. The recognition and uneasiness towards individual fallibility and a corresponding intolerance for error traps that place individuals and the BPS at risk.
2. A rigorous use of error prevention techniques and tools.
3. The will to communicate problems and the opportunities to improve upon those issues.
4. A proactive mental framework to guide thinking about error traps and barriers and defenses in the work place.
5. Increasing awareness that human error is both an organizational and individual problem.
6. Supplying a functional set of error-prevention tools.

As managers strengthen barriers and defenses, reinforce error-prevention techniques, and as people become uneasy about error traps during the preparation and conduct of activities, the principles of human performance will take root.

Human fallibility is like gravity, weather and terrain, just another foreseeable hazard. Error is pervasive… What is not pervasive are well developed skills to detect and contain these errors at their early stages.

Weick & Sutcliffe

Managing the unexpected

5.2 Principles of Human Performance

1. **People are fallible, and even the best people make mistakes.** Neither manager nor worker is immune. It is human nature to be imprecise — to err. Consequently, error will happen. No amount of counseling, training, or motivation can alter the person's fallibility. Fallibility is a permanent feature of the human condition. Therefore, use

considerable forethought before deciding to depend on humans as compensatory action or as the only defense against a plant upset or personal injury. Human activity should be backed up with more reliable defenses for critical activities.

2. **Error-likely situations are predictable, manageable, and preventable.** Despite the inevitability of human error, specific errors are preventable. Just as we can predict a person writing a personal check at the beginning of a new year stands a good chance of writing the previous year on the check; the same can be done in the context of work at the job site. Rigorous structure of one's thinking can help people identify error traps more consistently before doing work. Recognizing error traps and actively communicating these hazards to others permits us to manage the situation proactively and prevent its occurrence. By changing the work situation to prevent, remove, or minimize the presence of conditions that provoke error, job-site conditions (task and individual factors) can be managed to prevent, or at least minimize, the chance for error.
3. **Individual behavior is influenced by organizational processes and values.** Organizations are characterized by goal-directed behavior. Producing electricity and providing reliability of service is the central focus of the electric industry. Consequently, processes and values are developed to direct the behavior of the individuals in the organization. The organization is simply the sum of the ways work is divided into distinct jobs and then coordinated to produce electricity safely and reliably. Therefore, management is in the business of directing people's behavior. Traditionally, management of human performance has focused on the "individual error-prone or apathetic worker." However, all work is done within the context of the organizational processes, culture, and management planning and control system, which contributes to the majority of human performance issues and the resulting events.
4. **People achieve high levels of performance largely because of the encouragement and reinforcement received from leaders, peers, and subordinates.** The organization is perfectly tuned to get the performance it receives from the workforce. All behavior that occurs, good or bad, is reinforced, whether by immediate consequences or by past experience. A behavior is reinforced by the consequences that individual experiences when the behavior occurs. The level of safety and reliability of the BPS is directly dependent on the behavior of people; human performance is a function of behavior. Because behavior is influenced by the consequences, what happens to workers when they exhibit certain behaviors is an important factor in improving human performance.
5. **Events can be avoided through an understanding of the reasons mistakes occur and application of the lessons learned from past events (or errors).** In the past, improvement in human performance has been the outcome of corrective actions derived from an analysis of events and problem reports (reactive methods.) Today, human performance improvement demands a combination of proactive and reactive approaches. Events can be avoided reactively and proactively. Learning from our mistakes and the mistakes of others is reactive (after the fact) but is important for continuous improvement. Anticipating how an event or error can be prevented is

proactive. Proactive methods provide a more cost-effective means by preventing events and problems from developing.

5.3 Errors

Errors are predictable and for the most part “unintentional”. It is difficult to control unintentional actions.
There two kinds of errors:

1. **Active Errors**: Active errors are actions that change equipment, system, or plant state and trigger immediate, undesired consequences and unfavorable results.
2. **Latent Errors**: Latent errors are created by errors or mistakes that are unnoticed at the time they are made, often deeply hidden or embedded within a system. Latent errors have no immediate outcome except to alter procedures, policies, design-based documentation, or unknowingly change the integrity of BPS or plant equipment (e.g., incorrect labeling, equipment left in an abnormal state, or equipment tagged wrong).

The strategic approach to error prevention is to anticipate and prevent active errors at the job site, and proactively identify and eliminate latent organizational weaknesses that drive latent errors. This includes identifying, understanding, and managing error precursors that drive unfavorable prior conditions that reduce the opportunity for successful behavior at the job site.

The nature of an error must also be considered. This work focuses on the unintentional error, those actions or behaviors that were conducted without a conscious, malicious intent. Errors are commonly classified as slips, lapses and mistakes[3].

- **Slips**: Slips are actions that are not carried out as intended or planned, (e.g. a mistake with a tool sliding off its mark or telling someone to go right when you meant to say left).
- **Lapses:** Lapses are omissions or missed actions i.e. when one has failed to do something due to lapses of attention or memory or because they have forgotten something, (e.g. forgetting to replace or reset open or closed circuits).
- **Mistakes:** Mistakes (again unintentional) are a specific type of error that is a result of a faulty intention or plan, i.e. one does something believing it to be correct when it was, in fact, wrong, (e.g. over torque a bolt or under filling a transformer with oil).

The reason that the nature or classification of the error is important is that the remedy, management or prevention of each type of error is different. For example, slips typically occur at the task execution stage, lapses at the storage (or memory) stage and mistakes at the planning stage.

[3] Reason (1990)

5.4 Error Types — Generic Error Modeling

It is important to understand generic error modeling and understanding the performance modes in which humans make errors; this is essential to develop the necessary corrective actions need to address the error. This model was originally developed by Rasmussen & Jensen (1974) to diagnose electronic troubleshooting errors.

- **Skill Base** — highly practiced actions (routine activity) usually executed from memory without significant conscious thought in a familiar situation. Behavior governed by preprogrammed instructions developed by either training or experience. Actions guided by subconscious mind possess 10 times the capacity of conscious thought. Driving causes of skill base errors is a lapse or inattention. **(1 in 10,000 chance of making an error).**

- **Rule Base** — behavior based upon selection of stored rules derived from one's recognition of the situation result when a "rule" (from training, procedure, etc.) is misapplied or a shortcut is taken. Driving causes of rule-based errors is misinterpretation. **(1 in 1000 chance of making an error).**

- **Knowledge Base** — performing totally unfamiliar tasks based upon your understanding or knowledge of a situation. Driving causes of knowledge-based errors are inaccurate mental model or flaws in problem solving and decision making. **(1 in 2 chance of making an error).**

Over the years, many well-intentioned highly experienced individuals in the electric industry were given time off without pay or fired due to common human fallibility lapses. These mistakes could have been predicted by management and prevented by organizational barriers and defenses.

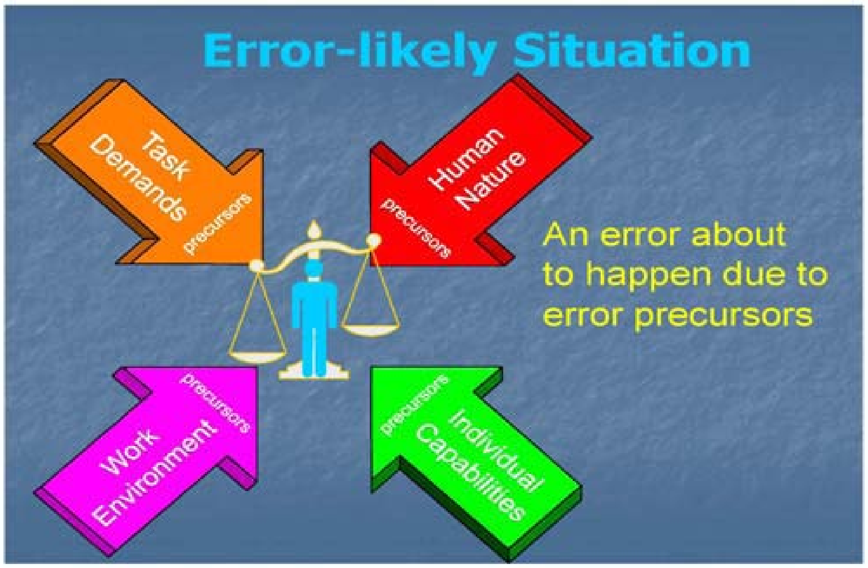
For example, based on the model above and an understanding that humans are imperfect, an error made while performing in a skill-based mode it is usually due to inattention or a lapse. Therefore, corrective actions should be based upon assurances that sufficient barriers are in place to prevent lapses from becoming events, rather than retraining as if they were rule- or knowledge-based errors.

Although it is preferred all critical tasks are conducted by individuals performing in a skill-base mode of performance, it is essential training is conducted to bring individuals into a minimum level of competence to complete the tasks at hand. That minimum level of performance is the rule-base performance mode.

5.5 Error-Likely Situation[4]

An **error-likely situation**, an error about to happen, typically exists when the demands of the task exceed the capabilities of the individual, or when work conditions exist that aggravate limitations of human nature.

The Model for an Error Likely Situation



5.5.1 Task Characteristics

Tasks can be described using attributes common to any work activity. Both positive and negative conditions which are associated with these attributes can be used to describe any specific task situation. These task-specific conditions can be grouped into one or more of the following attributes:

- **Task Demands** - specific mental, physical, and team requirements necessary to accomplish a particular task successfully, e.g., workload, time pressure, roles and responsibilities, and standards.
- **Individual Capabilities** - unique mental, physical, and emotional abilities of a particular person assigned a specific task, e.g., familiarity with task, values, education, knowledge, skills, attitudes, personality, experience, health and fitness, age, communication practices, and self-esteem.
- **Work Environment** - general influences of the workplace, organizational, and cultural conditions that affect individual behavior, e.g., distractions, equipment layout, tagout procedures, shared norms and values, attitude toward various hazards, and work control processes.

[4] Human Performance Fundamentals Course, Institute of Nuclear Power Operations, 1997

- **Human Nature** - generic traits or dispositions of being human that may incline individuals to err under certain unfavorable conditions, e.g., habit, short-term memory, fatigue, stress, complacency, and mental shortcuts.

5.5.2 Error Precursors

Unfavorable conditions that create mismatches are known as **error precursors**. As outcomes of latent organizational weaknesses, error precursors produce mismatches at the jobsite that reduce the chances for success, or increase the probability for error. Error precursors are, by definition**, prior conditions** for error; therefore, they exist before the error occurs. If discovered before the error, then the conditions can be changed to minimize the chance for error.

Error precursors are classified using the task characteristics mentioned above. Areas needing improvement before proceeding with the task can be communicated using the task characteristic terminology (acronym of TWIN).

Error Precursors
Short List

Task Demands	Individual Capabilities
Time pressure (in a hurry)	Unfamiliarity w/ task (first time doing it)
High workload (memory Requirements)	Lack of knowledge (mental model)
Simultaneous, multiple tasks	New technique not used before
Repetitive actions, monotonous	Imprecise communication habits
Irrecoverable acts	Lack of proficiency / inexperience
Interpretation requirements	Indistinct problem-solving skills
Unclear goals, roles, & responsibilities	"Hazardous" attitude for critical task
Lack of, or unclear, standards	Illness / fatigue
Work Environment	**Human Nature**
Distractions / Interruptions	Stress (limited attention)
Changes / Departures from routine	Habits
Confusing displays or controls	Assumptions (inaccurate mental picture)
Work-arounds / OOS instruments	Complacency / Overconfidence
Hidden system response	Mindset ("tuned" to see)
Unexpected equipment conditions	Inaccurate risk perception (Pollyanna)
Lack of alternative indication	Mental shortcuts (biases)
Personality conflicts	Limited short-term memory

When human performance has been identified as a causal factor or a contributing factor, it is important to determine if it is an organizational, leadership, or individual human performance deficiency (see **Appendix A** of this document). If it is determined it is an individual human performance issue, the performance mode of the individual who made the error should be analyzed to determine proper corrective actions.

Therefore, it is essential to understand what drives human error by understanding and planning around human error drivers:

Top 10 Human Error Drivers Are:

1. Time Pressure
2. Distractive Work Environment
3. High Workload
4. First Time Evolution
5. First Working Day After Days Off
6. One-Half Hour After Wake-Up or Meal
7. Vague or Incorrect Guidance
8. Over-Confidence
9. Imprecise Communication

5.6 Cognitive Biases and Heuristics, Organizational Limitations

5.6.1 Cognitive Biases and Heuristics

Cognitive biases are essentially mental errors caused by simplified information-processing strategies. It is important to distinguish cognitive bias from other forms of bias, such as cultural bias, organizational bias, or bias that results from one's own self-interest. In other words, a cognitive bias is not necessarily the result of an emotional or intellectual predisposition toward a certain judgment, but rather of subconscious mental procedures for processing information[5]. Another common term used when discussing the mental shortcuts is heuristics, commonly referred to as "rules of thumb". One of the ways to avoid the pitfalls and shortcomings associated with cognitive heuristics and biases is to be aware of them and to deliberately bring them to conscious to overcome or avoid them.

Instructing workers, managers, and supervisors on the dangers and benefits of cognitive shortcuts or strategies that are used consciously and unconsciously will potentially make them better decision makers, or at least more informed ones, especially under extreme conditions when physical and cognitive resources are potentially at their limits. The benefits of shortcuts for decision making are self-evident, for example, deciding which exit of a plane one would choose in an emergency or formulating an escape route when searching an apartment which is on fire. The pitfalls of certain heuristics and biases are, however, well known, from the sometimes unconscious framing of decisions, to the readiness to use what is available to the memory, or the availability heuristic.

Table 5.6.1 lists some common decision-making and behavioral biases of which all decision makers should be aware.

[5] Kahneman & Klein, 2009

[6]Table 5.6.1 — Common Decision-making and Behavioral Biases

Automation bias	The tendency to trust information provided via electronic information systems over intuition or humans; accepting information derived from the use of automation as a "best guess" instead of vigilant information seeking and processing
Bandwagon effect	The tendency to do (or believe) things because other people do, with the goal of gaining in popularity or being on the winning side
Confirmation bias	The tendency to search for or interpret information in a way that confirms one's preconceptions or course of action.
Professional deformation	The tendency to look at things according to the conventions of one's profession, ignoring broader points of view
Denial	The tendency to disbelieve or discount an unpleasant fact or situation
Expectation bias	The tendency to believe, certify results or analysis that agree with one's expectations of an outcome and to disbelieve, discard, or downgrade corresponding weightings for information that appears to conflict with those expectations
Extreme aversion	The tendency to avoid extremes, being more likely to choose an option if it is the intermediate choice
Framing effect	The drawing of different conclusions based on how data are presented
Illusion of control	The tendency to believe that one can control or at least influence outcomes that one clearly cannot
Information bias	The tendency to seek information even when it cannot affect action
Loss aversion	The disutility of giving up an object is greater than the utility associated with acquiring it
Normalcy bias	The tendency to discount novelty and to respond to such events with only routine procedures
Neglect of probability	The tendency to completely disregard probability when making a decision under uncertainty
Not invented here	The tendency to ignore that a product or solution already exists because its source is seen as an adversary
Reactance	The urge to do the opposite of what someone wants one to do out of a need to resist a perceived attempt to constrain one's freedom of choice
Selective perception	The tendency for expectations to affect perception

[6] Sweeney, P.2011

Unit bias	The tendency to want to finish a given unit of a task or an item often resulting in sequential behavior limiting simultaneous tasks
Wishful thinking	The formation of beliefs and making decisions according to what might be pleasing to imagine instead of by appealing to evidence or rationality
Zero-risk bias	Preference for reducing a small risk to zero instead of seeking a greater reduction in a larger risk

5.6.2 Organizational Limitations

While cognitive bias may blind individuals to emerging threats, organizational factors may prevent the integration of information until it is too late[7]. As events move from routine to complex, hurried decision makers tend to "segregate" functional tasks. What was once a convenient division of labor mutates into specialized fiefdoms, with little contact or communication between people performing one task and those performing another. This separation creates organizational blind spots in decision making[8]. There is a natural tendency for people with similar backgrounds to form homogeneous groups and provide more information to members of their own group and less to members outside the group. The organizational behavior of separating and providing information only within a certain group is known as organizational bias[9]. In some businesses, such behavior is necessary for maintaining a competitive advantage over the competition. In dangerous or confusing/fast-paced contexts, however, such behavior potentially limits situational awareness, creating barriers for decision making and directing.

The tendency of similar individuals to migrate to each other is called homophily[10]. Evidence has been found that as the stress and complexity of a crisis increase, people tend to narrow their focus on aspects they judge to be most important to them[11]. Under extreme pressure, they often feel little obligation to share valuable information with those outside their group, since responsibility for acting is diffused across the in-group. In most cases, people think that someone else in their organization will share the information. In social psychology this concept is referred to as a diffusion of responsibility and is what often leads to the well-known "bystander effect".

Most professionals who regularly operate in confusing or fast-paced contexts have the authority and often the experience to deal with these situations--until perhaps they are faced with novel and complex events. These events by their very nature are characterized as having a need to share information between various agencies or entities, thus requiring decisive

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7 Bazerman and Watkins, 2004

8 Senge, 2006

9 Pfeifer, 2007

10 McPherson, Smith-Lovin and Cook, 2001

11 Weick, 1995

leadership to overcome any existing cognitive and organizational biases. Failure to understand and address these biases will result in a diminished situational awareness and potentially poor decision making. In this situation, leaders and managers are at a distinct disadvantage in handling crises. During complex and novel events, incident management does not always rest with a single person; and managers should increase the rate of information exchange and foster collaboration to help generate new ideas and ways to approach the problem. Often the key issue for decision makers is not how to gain more personal-knowledge, but the ability to harness the knowledge of others.

6.0 Definitions:

1. **Active errors** — Errors that change equipment, system, or plant state triggering immediate undesired consequences.
2. **Adverse Trend** -A series of occurrences in which the frequency combined with the significance of the occurrences warrants further evaluation and/or corrective action.
3. **Apparent Cause** — problem- or condition-cause determination based on the evaluator's judgment and experience where reasonable effort is made to determine WHY the problem occurred. This might include fact finding, analysis, interviewing, benchmarking, reviewing data or maintenance history, or other methods as appropriate.
4. **Barrier Analysis** — An analysis of the adequacy of physical and administrative barriers in place to prevent the occurrence of an event. A barrier is any structure, rule, or work practice that separates or safeguards equipment or personnel from a potential event. Barriers may be physical (doors, lockout devices, guards) or administrative (procedures, forms, meetings).
5. **Cause** (**Causal Factor**) —. A condition or an event that results in an effect (anything that shapes or influences the outcome). This may be anything from noise in an instrument channel, a pipe break, an operator error, or a weakness or deficiency in management or administration. In the context of DOE Order 5000.3A there are seven major cause (causal factor) categories. These major categories are subdivided into a total of 32 subcategories (see Appendix C).
6. **Cause Analysis** — the methodologies used to systematically perform an analysis of a given event to determine why the event occurred.
7. **Change Analysis** — An analysis of the difference between what actually happened and what was expected to happen. Also, change analysis can be used to compare the conditions at the time of the event with conditions prior to the event.
8. **Common Cause** — A single cause that is common to several events.
9. **Common Mode Failure**— Multiple structures, systems or components (SSC's) failing or having the potential for failure in the same way or due to the same event.
10. **Contributing Factors** — those conditions or an event which, in combination with the cause, increases the consequences of an event or adverse trend or otherwise changes the outcome.
11. **Corrective Action** — actions taken to correct and prevent the recurrence of a problem or failure which may include both long- and short-term corrective actions.
12. **Direct Cause** — The active factor that triggered an undesirable event. If it had not occurred, there would have been no event or condition. There is usually a single direct cause: an initiating action or a failure mechanism.
13. **Error** — an action (behavior) that unintentionally departs from an expected behavior according to a standard.

14. **Error-Likely-Situation (ELS)** — A task-related predicament involving a potential error provoked by unfavorable jobsite conditions that reduce the chances for success; an error about to happen

15. **Error Mechanism** — a descriptor of casual factors which produced or made the error detectable (the error mode). Communication, work practices, work organization and planning, supervisory methods, managerial methods, etc.

16. **Error Mode** — a description of how the process step or task was performed incorrectly.

17. **Error Precursors** — unfavorable prior conditions that reduce the opportunity for successful behavior at the jobsite. *Precursors provoke error.*

18. **Event** — an unwanted, undesirable consequence to the safe and reliable operation of the system.

19. **Event Analysis** — a review of activities causing or surrounding a disturbance of the BPS.

20. **Facts** — independent verification of data or information.

21. **Failure Analysis** — Physical analysis performed on components, sub-components, and material to determine the failure mode and failure mechanism. Failure analysis does not determine root cause, but provides data for performing a cause and effect analysis.

22. **Failure Mechanism** — the descriptor of the medium or vehicle the agent used to produce the failure mode. (e.g., failure mode — burnt coil; failure mechanism — heat).

23. **Failure Mode** — a description, which should contain at least a noun and a verb that describes how the failure took place. The failure mode should be defined in enough detail at the component level to make it possible to select a suitable failure management policy. (e.g., bearing seizes, impeller jammed by foreign objects, blocked suction line, etc.).

24. **Failure Scenario** — a series of chronological events beginning with an initiating event and ending with the identified failure mode.

25. **Heuristics** — encouraging a person to learn, discover, understand, or solve problems on his or her own, as by experimenting, evaluating possible answers or solutions, or by trial and error: *a heuristic teaching method.*

26. **Homophily** — the propensity or tendency of similar individuals to migrate to each other.

27. **Human Performance Evaluation System (HPES)** — HPES is a system of charting and comparing causal factors specific to human error. HPES was developed by the Institute of Nuclear Power Operations (INPO) to identify causes of personnel performance errors and inappropriate actions.

28. **Immediate Action** — An action taken immediately after the discovery of a condition, or any time prior to Evaluation, that is intended to prevent the recurrence or further exacerbation of the condition or consequences. Immediate actions may include compensatory actions of a temporary change implemented to mitigate immediate risk, restore operability or to otherwise enhance the capability of degraded or

nonconforming structures, systems or components until appropriate cause determination and final corrective actions are complete.

29. **Inappropriate Action** — Human action or omission, either observed or unobserved, that:
    a. Resulted in an undesirable or unwanted condition/result.
    b. Led the task or system outside its acceptable limits.
    c. Was not desired by a set of rules or an external observer.
    d. Was not necessarily the fault of the individual committing it.
30. **Ineffective Corrective Action** — An action that did not prevent recurrence of an event for similar causes or reduce the likelihood of recurrence due to the following inadequacies:
    a. The action did not address the cause(s) for the event.
    b. The action did not address the extent of cause for Root Cause evaluations.
    c. The action did not address the extent of condition.
    d. The action did not correct the original condition as stated in the CR Evaluation.
    e. The action did not introduce undesired effects.
    f. The Evaluation did not include sufficient interim actions until full implementation could be completed.
    g. The action was not properly implemented or enforced after implementation, thus increasing the likelihood for recurrence.
    h. The action was not embedded in a process to ensure sustainability (e.g., expectations conveyed via email vs. implementing a procedural change).
31. **Initiating Event** — An action or condition that begins an event sequence that caused or allowed the error to occur.
32. **Interim Action** — Similar to compensatory actions in nature, interim actions are usually based upon a documented cause determination at the Apparent or Root Cause level. They are replaced by final corrective actions.
33. **Latent errors** — (typically by management and staff) Errors resulting in undetected organization-related weaknesses or equipment flaws that lie dormant.
34. **Latent Organizational Weaknesses** — hidden deficiencies in management control processes (for example, strategy, policies, work control, training, and resource allocation) or values (shared beliefs, attitudes, norms, and assumptions) creating workplace conditions that can provoke error (precursors) and degrade the integrity of defenses (flawed defenses). The decisions and activities of the station's managers and supervisors determine what is done, how well it is done, and when it is done, either contributing to the health of the organization or further weakening its resistance to

error and events. Therefore, managers and supervisors should perform their duties with the same uneasy respect for error prone work environments as workers are expected to at a job site. Understanding the major role organization plays in the performance of a station — a second strategic thrust to preventing events — should be the identification and elimination of latent organizational weaknesses.

35. **Primary Effect** — The action or condition to be prevented. Typically the event or adverse consequence that initiated the investigation. Usually the subject of the problem statement.

36. **Root Cause** — the most basic reason(s) for an undesirable condition or problem which, if eliminated or corrected, would have prevented it from existing or occurring.

37. **Safety Significance** — The actual or potential affect to human, environmental or equipment safety.

38. **Significance** — The actual or potential affect to Nuclear/Equipment Safety including Design Basis, Industrial (Human) Safety, Radiation Safety, Cost and Budget, Regulatory Confidence, Environmental Stewardship, and External Perception.

39. **Task Analysis** — A cause analysis method where tasks are broken down into sub-tasks to compare expected actions with actual actions performed during the event.

7.0 References

This process was built using the fundamentals and methodology as covered in the following publications:

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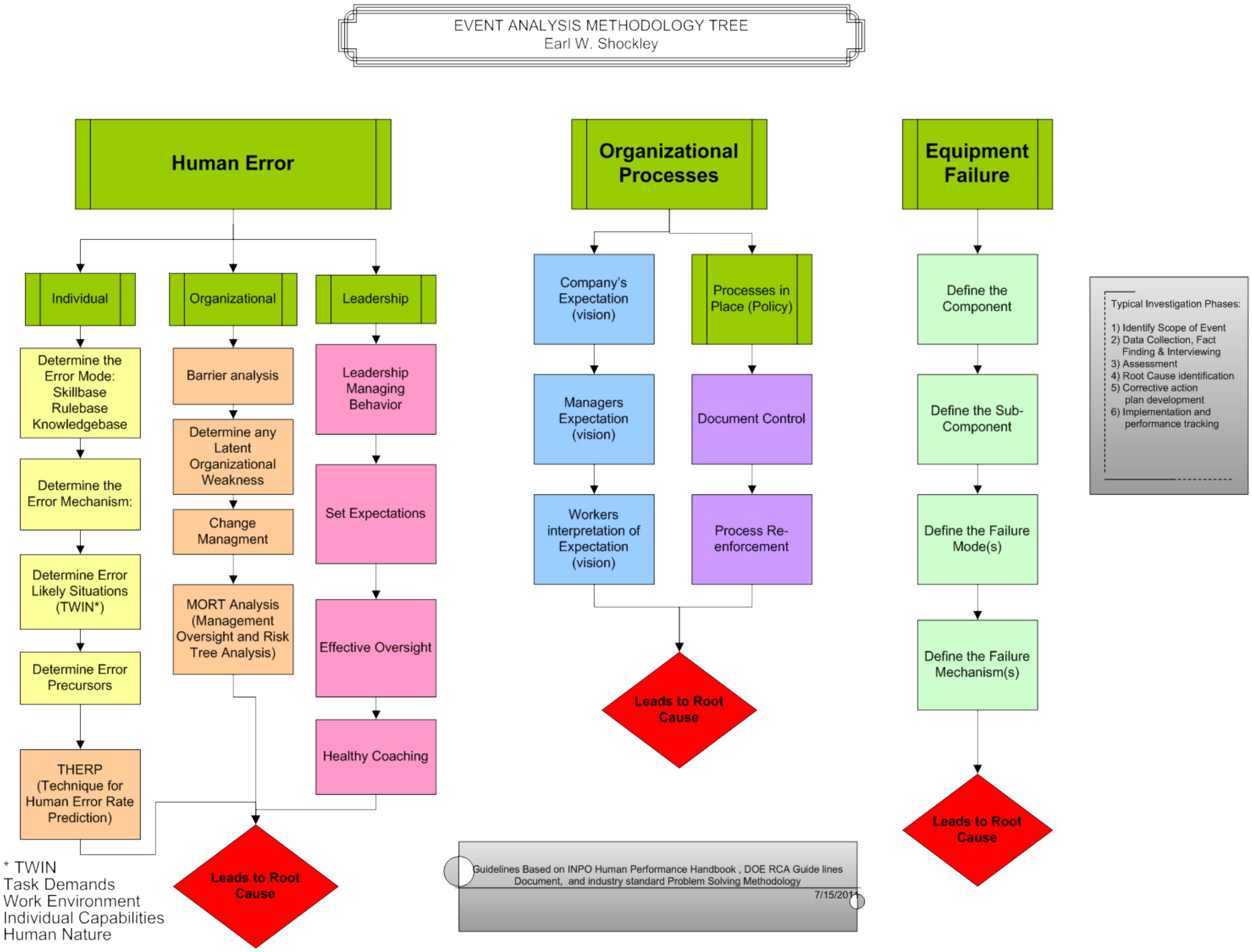
APPENDIX A — Flow Chart of how RCA methodologies lead to root cause



APPENDIX B — Root Cause Analysis Grading Checklist

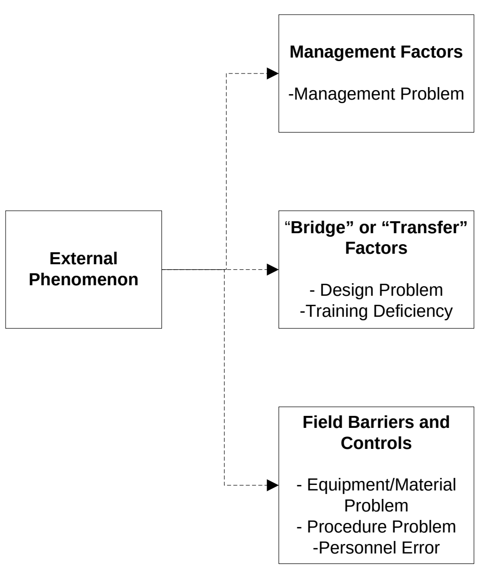
ROOT CAUSE ANALYSIS GRADING CHECKLIST	
DATE REVIEWED: _____________ **REVIEWER(s):** ___________________ **Grade:** _________	
Rating — Rate each area from zero to the maximum point value as indicated. Points are awarded based on a subjective review with consideration given to the following items. (There is no direct relationship between the number of yes or no answers and the rating given.)	
1. Problem Identification: (a) Is the investigation scope clear and concise? ____	____ 5 pts
2. Data Collection: (a) Is the sequence of events listed/event narrative stated? (b) Are the root cause methods used described? (c) Are the critical facts and data supported by independent sources?	____ 5 pts
3. Anatomy of an Event: (a) Are all errors identified and listed? (b) Are all error precursors identified and explained? (c) Are all flawed defenses linked to an error? (d) Have the latent organizational weaknesses been identified?	____ 10 pts
4. Cause Determination: (a) Are root causes clearly stated? (b) Do the root causes meet the definition of a root cause? (c) Are the root causes directly correctable? (d) Is the analysis sufficiently documented that the conclusions reached are supported? (e) Does the equipment root cause analysis consider organizational or process issues? _____	____ 30 pts
5. Previous Similar Events: (a) Were other site databases (EMPAC, INPO Nuclear Network, industry working groups, and vendors) utilized to determine similar events? (b) Were the results listed and used in determining root cause and subsequent corrective actions? (c) Did the analysis consider previous events and determine if this event was recurring? (d) Did the analysis assess the effectiveness of corrective actions for the previous event? (e) Was extent of cause considered?	____ 10 pts
6. Operability, Extent of Condition/Cause: (a) Did the root cause, as determined, raise additional questions related to operability? (b) Was the applicability of the problem determined to affect other trains, systems, or units? (c) Was it determined if other types of equipment or processes need to be reviewed? (d) Was extent of cause addressed?	____ 10 pts
7. Corrective Actions: (a) Are corrective actions created to fix what is broken and address the root cause (prevent recurrence)? (b) Are the corrective actions for the root cause cost effective and capable of being implemented in a timely manner? (Timely means no repeat events). (c) Was consideration given to interim corrective actions if the corrective actions to prevent recurrence cannot be implemented in a timely manner?	____ 30 pts
Total Score (sum of items 1 - 7) Below 80 will result in an inadequate Root Cause Analysis	

APPENDIX C — Cause Codes

The purpose of developing and using Cause Codes is to allow similar effects to be grouped for analysis – is this a common problem, how frequently is this problem occurring, is this problem occurring in a wide-spread manner or is it localized, are the steps being taken to eliminate this problem being effective, etc.? The Department of Energy, building on many studies, has developed seven major cause categories, and further identified these categories can be subdivided into 32 distinct cause codes (DOE-NE-STD-1004-92, Appendix A). The major cause categories are:

1. Equipment/Material Problem
2. Procedure Problem
3. Personnel Error
4. Design Problem
5. Training Deficiency
6. Management Problem
7. External Phenomena.

These categories have been carefully selected with the intent to address all problems that could arise in conducting operations. Those elements necessary to perform any task are equipment/material, procedures (instructions), and personnel. Design and training determine the quality and effectiveness of equipment and personnel. These five elements must be managed; therefore, management is also a necessary element. Whenever there is an occurrence, one of these six program elements was inadequate to prevent the occurrence. (External phenomena beyond operational control serves as a seventh cause category.) These causal factors can be associated in a logical causal factor chain as shown:



Note that a direct, contributing, or root cause can occur any place in the causal factor chain; that is, a root cause can be an operator error while a management problem can be a direct cause, depending on the nature of the occurrence.

These seven cause categories are subdivided into a total of 32 subcategories. The direct cause, contributing causes, and root cause are all selected from these subcategories.

1. Equipment/Material Problem

   1A = Defective or failed part

   1B = Defective or failed material

   1C = Defective weld, braze, or soldered joint

   1D = Error by manufacturer in shipping or marking

   1E = Electrical or instrument noise

   1F = Contamination

2. Procedure Problem

   2A = Defective or inadequate procedure

   2B = Lack of procedure

3. Personnel Error

   3A = Inadequate work environment

   3B = Inattention to detail

   3C = Violation of requirement or procedure

   3D = Verbal communication problem

   3E = Other human error

4. Design Problem

   4A = Inadequate man-machine interface

   4B = Inadequate or defective design

   4C = Error in equipment or material selection

   4D = Drawing, specification, or data errors

5. Training Deficiency

   5A = No training provided

   5B = Insufficient practice or hands-on experience

   5C = Inadequate content

   5D = Insufficient refresher training

   5E = Inadequate presentation or materials

6. Management Problem

6A = Inadequate administrative control

6B = Work organization/planning deficiency

6C = Inadequate supervision

6D = Improper resource allocation

6E = Policy not adequately defined, disseminated, or enforced

6F = Other management problem

7. External Phenomenon

7A = Weather or ambient condition

7B = Power failure or transient

7C = External fire or explosion

7D = Theft, tampering, sabotage, or vandalism

There are times when an organization may identify the need for further categories of cause codes, subsets of the above basic categories, in order to “dig deeper” into the analyses. In doing so, every effort should be made to ensure any such codes are suitably and adequately defined so everyone using them has the same understanding of what is meant by each. Examples of these types of cause codes (not intended to be an exhaustive nor all-inclusive effort) are provided in the following diagrams:

SB = Skill-Based error type
RB = Rule-Based error type
KB = Knowledge-Based error type

APPENDIX D — Acronyms

Acronym	Meaning
ACA	Apparent Cause Analysis
BPS	Bulk Power System
DOE	U.S. Department of Energy
E&CF	Event & Causal Factors
EOC	Extent of Condition
ELS	Error-likely situation
ERO	Electric Reliability Organization
FTA	Fault Tree Analysis
HMI	Human-machine Interface
HPE	Human Performance Evaluations
HPES	Human Performance Evaluation System
INPO	Institute of Nuclear Power Operations
K-T	Kepner-Tregoe
MORT	Management Oversight & Risk Tree analysis
O&M	Operating & maintenance
O&P	Organizational & Programmatic
QV&V	question, verify, & validate
RCA	Root Cause Analysis
SME	Subject Matter Expert
THERP	Technique for Human Error Rate Prediction
TWIN	Task demand, Work environment, Individual capabilities, human Nature