NERC

NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

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

Version 1
October 2010

to ensure the reliability of the bulk power system

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Table of Contents

Revision History

Rev.	Date	Reviewers	Revision Description
	October 15 2010	David Hilt, Tom Galloway, David Nevius, Karen Spolar	Initial Draft by Earl Shockley, Director of Event Analysis and Investigations.

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*[1]. 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 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 factors, and equipment design or maintenance issues.

> ***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.***

[1] To be accompanied by an EA Process Field Trial (Oct 2010-Jan 2011).

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.

3.2 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 method flow charts:

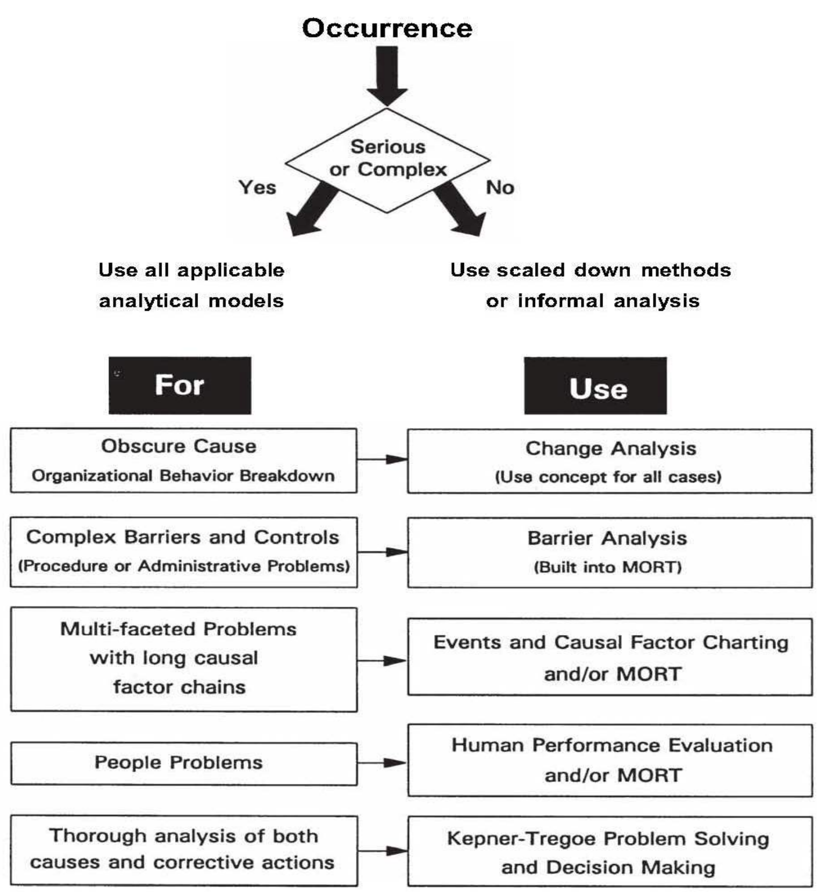


TABLE 1. SUMMARY OF ROOT CAUSE METHODS

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 the 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	Use 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	Use 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 spects 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.

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

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:

Single Incident Investigation/Analysis (Most common method)

1. Develop problem statement
2. Initiate event and causal factors chart (E&CF); update this chart throughout the process
3. Perform a task analysis (what should have happened) — inspect event scene and perform walk-through task analysis if possible
4. Perform a change analysis
5. Develop questions for interviews
6. Conduct interviews (one-on-ones with the individuals involved)
7. Identify any inappropriate actions on E&CF chart
8. Determine causes and barriers for any inappropriate action (there are 12 human barriers to choose from)

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

Validate and Verify Facts — No Opinions!

Multiple Incident Investigation/Analysis

Common cause method uses barrier analysis approach — most effective approach

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

Equipment Failure Investigation/Analysis

Use Kepner-Tregoe (K-T) problem analysis[2] or similar equipment failure method

- Steps:

1. State problem
2. Quantify what are (identity, location, timing, and magnitude)
3. Quantify what is not
4. Determine difference between what is and what is not
5. Determine if difference suggest a change
6. List all possible causes
7. Test possible causes using “if……then…..” questions.
8. Verify most probable cause(s)

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

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

- 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)

Equipment-People Investigation/Analysis

- Use both E&CF charting (for human performance) and
- K-T Problem Analysis (for equipment failures)

Multiple Incident Common Cause Investigation/Analysis Form

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

3.3 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: ACS is not industry standard for system disturbances or major events and is not referenced in the 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.

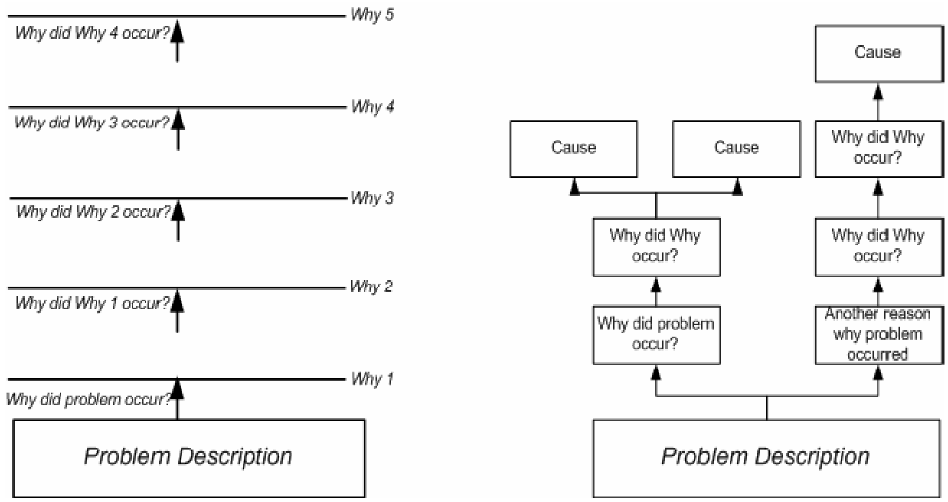
The "why staircase" is a method used to help determine the apparent cause(s) for events that do not require root-cause analysis. It begins with asking why a deficiency occurred followed by asking why each why occurred. For a simple single branch, the "why staircase" methodology is as follows:

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 10 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 can be seen below.



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 put in 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
Initiating Action

3.4 Root Cause Analysis

A root-cause analysis 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 a root-cause analysis.

Root-cause analysis 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 root-cause analyses are performed at the discretion of management to determine why less significant deficient conditions occurred. A root-cause analysis grading list template can be found in **Appendix B** of this document.

Typically, a root-cause analysis 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 root-cause analysis approach is dependent upon whether the deficient condition being investigated is the result of inappropriate personnel action(s), equipment failure, or both. (See section 3.6 of this process titled "Cause Analysis Tools" for specific information on the different root cause analysis tools.)

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 sub-standard, correct all root causes, and apply corrective actions to other affected areas (i.e., generic implications)

Typical Investigation Steps

The key steps for an investigation are:

1. Assemble a team
2. Develop a scope
3. Appoint a custodian to protect physical evidence
4. Collect available data pertinent to the problem including:
   - Initial system and plant conditions,
   - Statements of personnel involved with the event
   - pertinent computer printouts (e.g., post-trip log sequence of events) and charts
   - pertinent documentation such as operator logs, work permits, work plans, etc. as required to establish conditions prior to and during the event
   - voice recordings
   - photographs and videotapes taken to document equipment prior to repair
5. Reconstruct the problem using the collected information.
   - Validate the facts through a review of plant design, physical data, personnel statements, and interviews.
   - Verify whether consistency exists between:
     a) personnel statements
     b) interview data
     c) plant characteristics and documentation,
     d) historical and analytical data
   - previous problem data and documentation
   - 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 comparison of the proper response of plant systems to the actual and expected response during the problem.
   - An evaluation of the adequacy of procedures.
   - 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.

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, and
- 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. Subject matter experts are a very valuable asset especially to the individual investigator as well as the analysis itself.

3.5 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 (prevent recurrence). In developing and implementing corrective actions, consideration of the following questions can help ensure adequacy:

- Do the corrective actions address all the root causes?
- Will the corrective actions cause detrimental effects?
- What are the consequences of implementing the corrective actions?
- What are the consequences of not implementing the corrective actions?
- What is the cost of implementing the corrective actions?

  * Capital costs?
  * O & M Costs?
- Will training be required as part of the implementation?
- In what time frame can the corrective actions reasonably be implemented?
- What resources are required for successful development of the corrective actions?
- What resources are required for successful implementation and continued effectiveness of the corrective actions?
- Is the implementation of the corrective actions measurable?
- What Impact will the development and implementation of the corrective actions have on other work groups or Management?
- Is the implementation of the corrective actions measurable?

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 to 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, and when. For equipment condition, a good problem statement should simply state what occurred, and when.

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.

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.

Objectives

- On paper break down the task into different subtasks, actions, or steps that are expected to be performed during some activity.
- Identify information, controls and displays, materials, and other requirements for performance of task.
- Establish a knowledge baseline for the evaluator on how the task being evaluated is performed.
- Identify potential problems with the performance of such task such as inadequate procedures, inappropriate plant conditions, etc.

Method

1. Obtain preliminary information in order to know what the circumstances were when the inappropriate action occurred.
2. Select the task of interest.
3. Obtain necessary information
    - Relevant procedure(s)
    - System drawings, block diagrams, Pen and Ink (P&I) drawings
    - Interviews with individuals that have performed the task
4. Divide the task of interest into component actions or steps.
5. Write step name or action in order of occurrence on task analysis worksheet (following page)

Paper and Pencil Task Analysis Form

Step	Who	Required Action	Component	Tools	Remarks / Questions

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 walk-through rather than the control room.

OBJECTIVES

- Determine how a task was really performed.
- Identify problems in human factors design, discrepancies in procedural steps, training, etc.

PRECONDITIONS

- Participants must be the people who actually perform the task.

STEPS IN CAUSE-AND-EFFECT TASK ANALYSIS

1. Obtain preliminary information in order to become familiar with the circumstances when the problem or inappropriate action occurred.
2. Decide on task of interest.
3. 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

   •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:
     - the evaluator will know what to look for
     - the evaluator will be able to easily record actions

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.
     - 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.
     - 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.
     - 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.
     - 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).

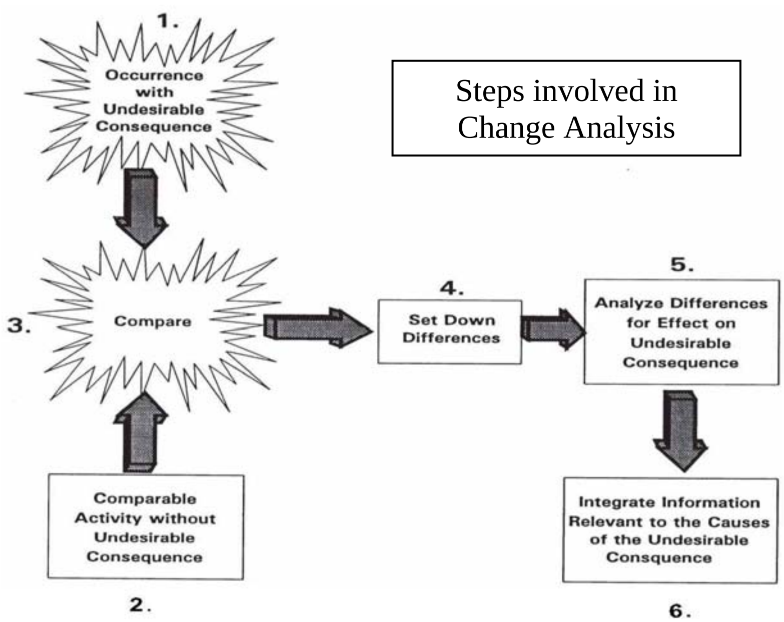
5. Integrate information into the investigation process relative to the causes of, or contributors to, the undesired consequences.

Change analysis is a good technique to use when the causes of the condition are obscure; it’s 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:

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

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.

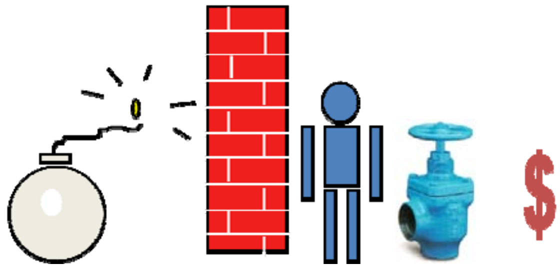
Flawed barriers and defenses allow the consequences of the occurrence to propagate from simple errors and latent conditions into full-blown events. Defects with the barriers and defense measures, under the right conditions and circumstances, may fail to protect the system or people against hazards. Some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

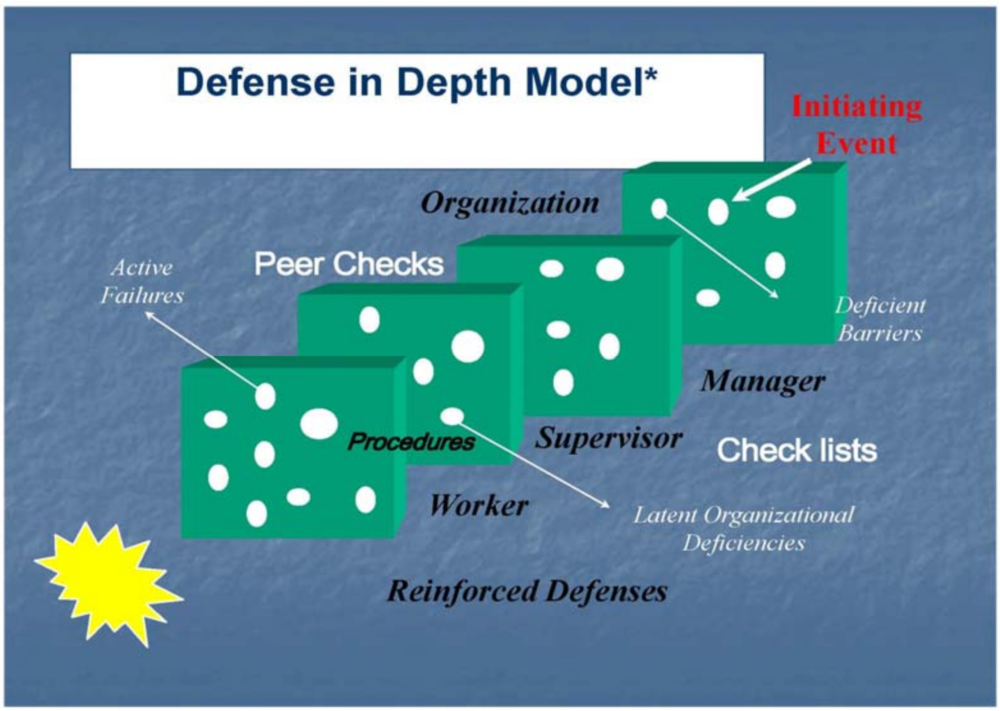
Barrier analysis is an effective tool for determining the root cause of human performance error events. It focuses on the barriers that should have prevented the error from occurring or mitigated its consequences.
Barrier analysis defines the three elements of an unwanted event as follows:

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

3 Note: The term "barrier" is used to mean any barrier, defense or control that is in place to increase the safety of a system.

Barriers prevent the threats from reaching the targets





Methodology

1. Identify and list the consequences.
2. Identify and list the failed barriers in place for each consequence.
3. Determine why (causes) the barriers failed (e.g., procedure not followed correctly)
4. Verify the results.
5. 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.

1. What barriers existed between the second, third, etc., condition or situation and the second, third, etc., failures?

2. If there were barriers, did they perform their functions? Why not?

3. Did the presence of any barriers mitigate or increase the event severity? How?
4. Were any barriers not functioning as designed? Why?
5. Was the barrier design adequate? Why not?
6. Were there any barriers on the condition or situation source(s)? Did they fail? Why?
7. Were there any barriers on the affected component(s)? Did they fail? Why?
8. Were the barriers adequately maintained?
9. Were the barriers inspected prior to expected use?
10. Why were any unwanted energies present?
11. Is the affected system or component designed to withstand the condition or situation without the barriers? Why not?
12. What design changes could have prevented the unwanted flow of energy? How?
13. What operating changes could have prevented the unwanted flow of energy? How?
14. What maintenance changes could have prevented the unwanted flow of energy? How?
15. Could the unwanted energy have been deflected or evaded? How?
16. What other controls are the barriers subject to?
17. Was this event foreseen by the designers, operators, maintainers, or anyone else?
18. Is it possible to have foreseen the event? How?
19. Is it practical to have taken further steps to have reduced the risk of the event occurring?
20. Can this reasoning be extended to other similar systems or components?
21. Were adequate human factors considered in the design of the equipment?
22. What additional human factors could be added? Should be added?
23. Is the system or component user-friendly?

24. Is the system or component adequately labeled for ease of operation?

25. Is there sufficient technical information for operating the component properly? How do you know?

26. Is there sufficient technical information for maintaining the component properly? How do you know?

27. Did the environment mitigate or increase the severity of the event? How?

28. What changes were made to the system or component immediately after the event?

29. What changes are going to be made? What changes might be made?

30. Have these changes been properly and adequately analyzed for effect?

31. What related changes to operations and maintenance should be made immediately?

32. Are these expected changes cost-effective? Why? How do you know?

33. What would you have done differently to have prevented the event, disregarding all economic concerns (in regards to operation, maintenance, and design)?

34. What would you have done differently to have prevented the event, considering all economic concerns (in regards to operation, maintenance, and design)?

Human (administrative) Barriers and Associated Causal Factors

The 12 administrative barriers and associated causes for inappropriate actions are as follows:

1. Verbal communication (inadequate information exchange whether face-to-face or via telephone)*
2. Written procedure and documents (inappropriate maintenance, operating, or special test procedures and instructions, inappropriate drawings, equipment manuals, technical specifications)
3. Man-machine interface (insufficient or incorrect label, gauge, annunciator, control device)
4. Environmental conditions (inadequate lighting, work space, clothing; noise; high radiation; ambient temperature)
5. Work schedule (excessive overtime, insufficient time to prepare for or accomplish the task)
6. Work practices (lack of self-checks, failure to follow procedure)
7. Work organization or planning (insufficient time to prepare or perform, maintenance not scheduled)

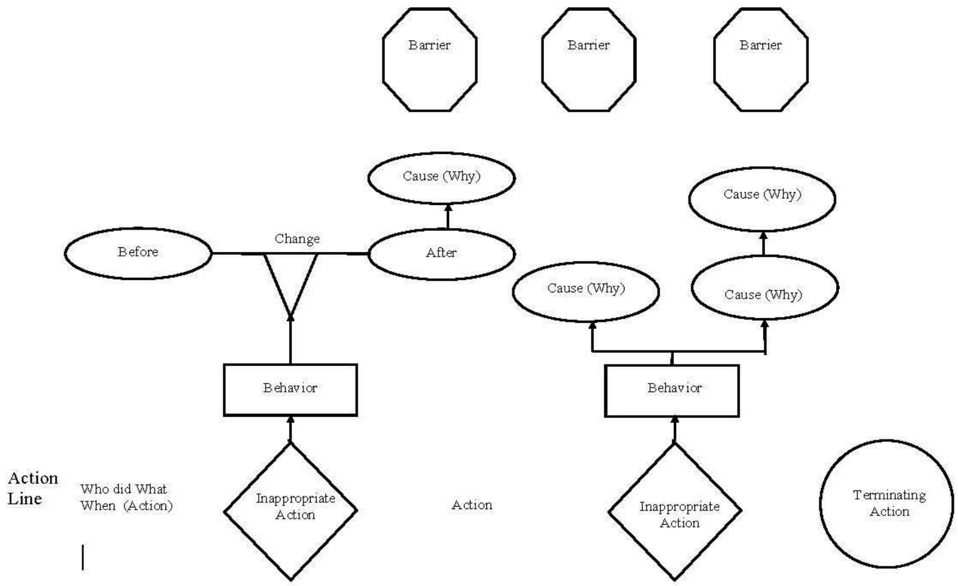
8. Supervisory methods (inadequate direction, supervisor interference, overemphasis on schedule)
9. Training and qualifications (insufficient technical knowledge, lack of training, inadequate training materials, improper use of tools, insufficient practice, ineffective on-the-job training)
10. Change management (inappropriate plant modification; lack of change related retraining, procedures, documents)
11. Resource management (unavailability of tools, information, personnel, supervision)
12. 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 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

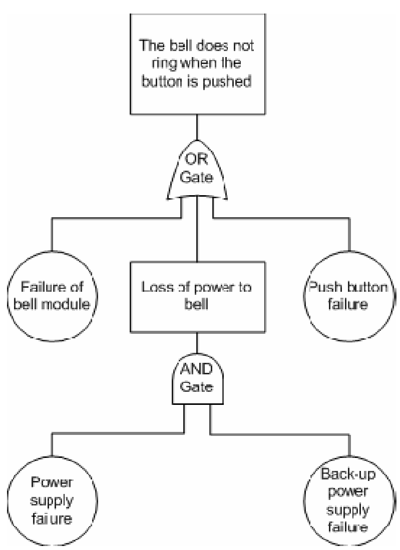
A fault tree analysis (FTA) is used when trying to select between multiple possible hardware failure modes; this tool requires system and component knowledge for hardware root causes. In this method all possible failure modes and mechanisms are assembled, and probable root causes for each are developed. 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.

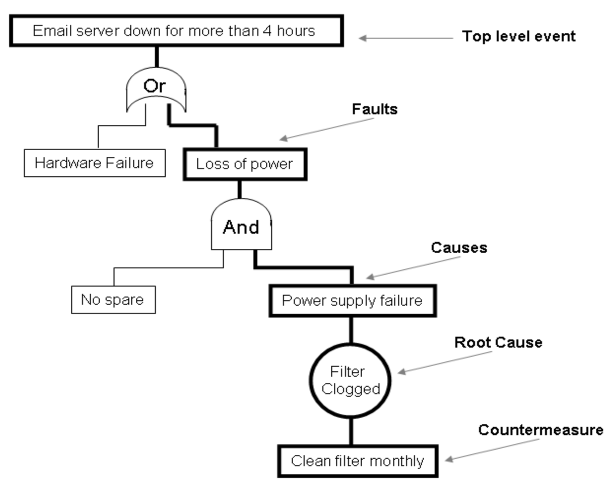
Often there will be only one failure mode indicated if applied correctly. Steps to construct an FTA are as follows:

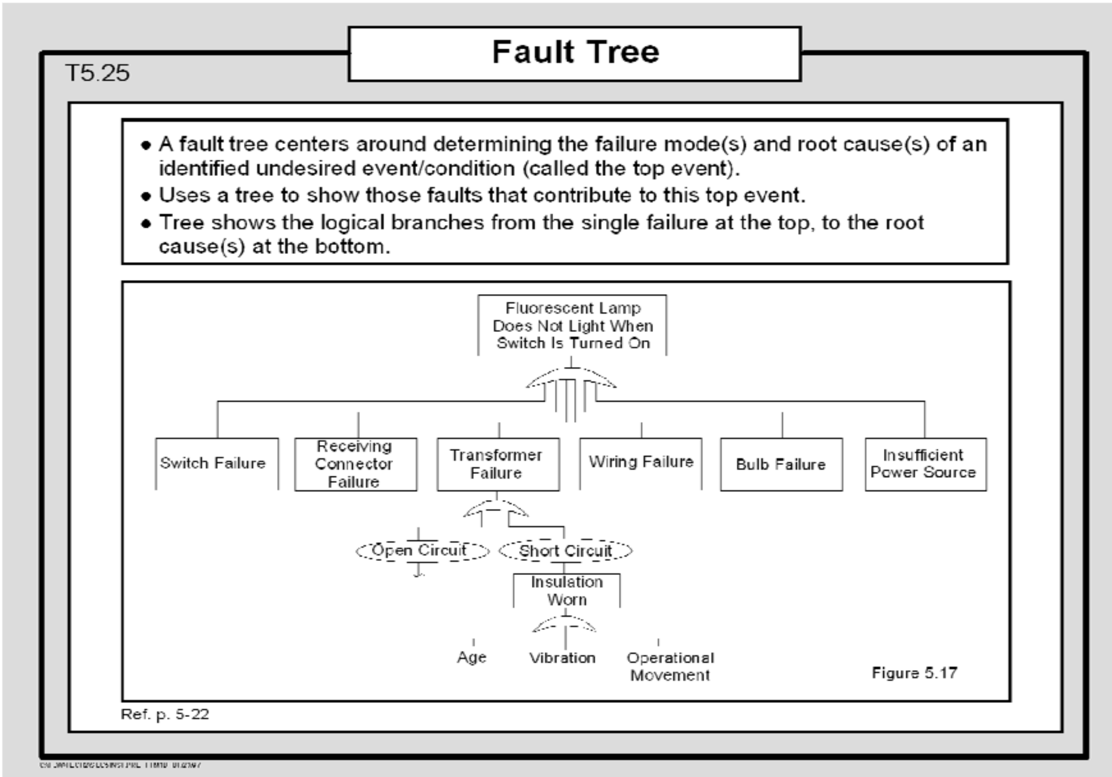
- Select an event or probable event to analyze
- Find all the lower level (component) failures that could cause the event
- Show these in a "tree" diagram and connect them with the appropriate logic gate.
- Search for lower level failures that could lead to the intermediate higher level failures
- Continue 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.

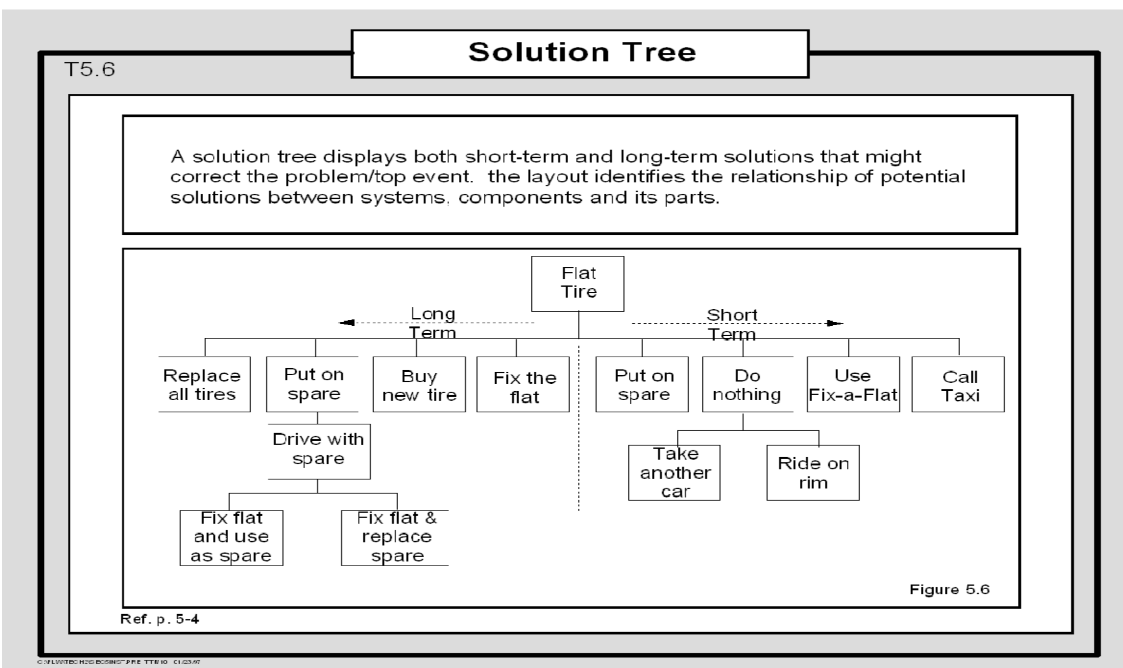
The following are example of fault trees







The following is an example of a short and long term solution tree



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.

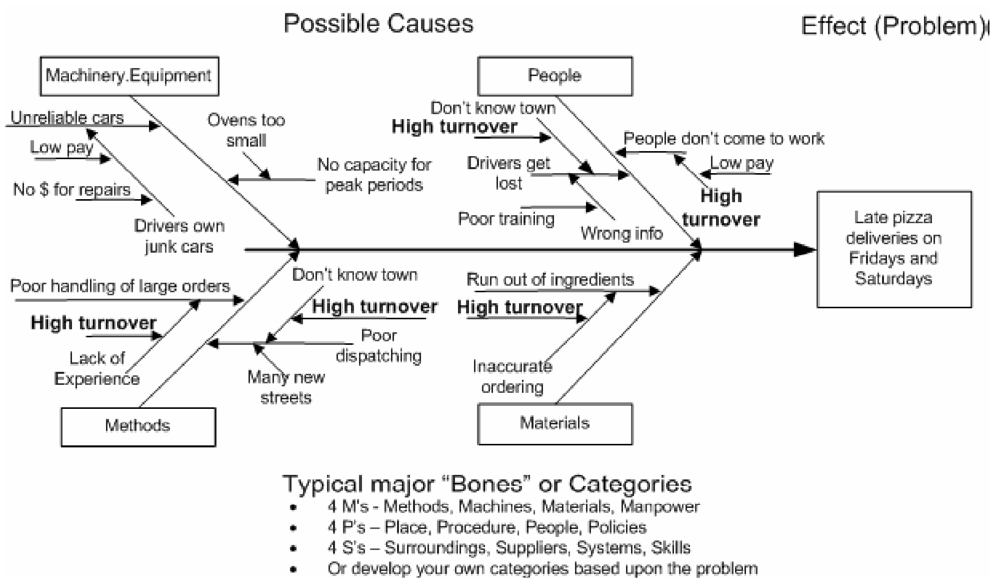
4.81 Management Oversight and Risk Tree (MORT) Analysis

MORT and Mini-MORT are used to identify inadequacies in barriers or controls, specific barrier and support functions, and management functions. It identifies specific factors relating to an occurrence and identifies the management factors that permit these factors to exist.

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.



4.83 K-T (Kepner-Tregoe) Problem Analysis

The K-T problem analysis technique is an advanced root-cause determination method. It is the most effective technique 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:

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

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

K-T (Kepner-Tregoe) Problem Analysis				
STATE DEVIATION:				
Specify the Problem	IS	IS NOT	**Distinctions** of IS compared with IS NOT	**Changes** in distinctions (list Dates)
What identity				
Where location				
When timing				
Extent magnitude				
Develop Possible Causes from experience, changes, distinctions			**Test for Probable Cause** against specifications (list assumptions from destructive test)	
1 2			does not explain:	explains only if:
Determine Most Probable Cause:			**Verify True Cause** (steps): 1 2 3 4	

4.84 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 man-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 man-machine interface 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 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.”

5.1 Why focus on Human Performance?

An analysis conducted in the 1990’s regarding causal factors of significant events (as classified by INPO[4]) 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

[4] Reference – INPO Human Performance handbook

of human systems and human factors is necessary to improve BPS resistance to human error and events.

HPE can be described in a simple formula (as seen to the right.)

Concept:
HP = B + R

Human Performance = Behavior + Results

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:

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

- **Active Errors**: Active errors are actions that change equipment, system, or plant state and trigger immediate, undesired consequences and unfavorable results.
- **Latent Errors**: Latent errors are created by errors or mistakes that are unnoticed at the time they are made. 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.

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.

When it is determined that human performance is 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.

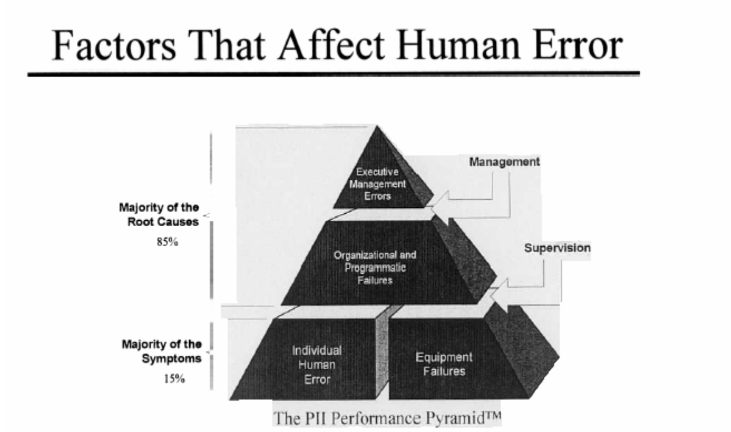
Therefore, it is essential to understand what drives human error by understanding and planning around human error drivers:

Top 10 Human Error Drivers Are:

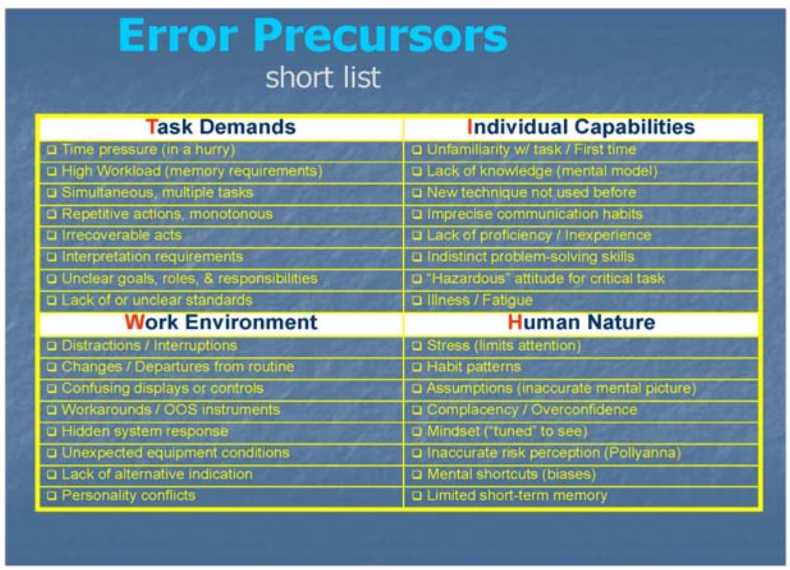
1. Time Pressure
2. Distractive Work Environment
3. High Workload
4. First Time Evolution
5. First Working Day After Days Off
6. One-Half Hour After Wake-Up or Meal
7. Vague or Incorrect Guidance
8. Over-Confidence
9. Imprecise Communication
10. Work Stress

59

Human Performance Pyramid

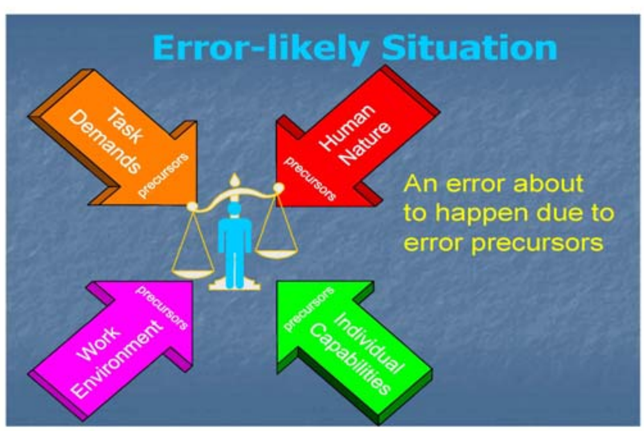


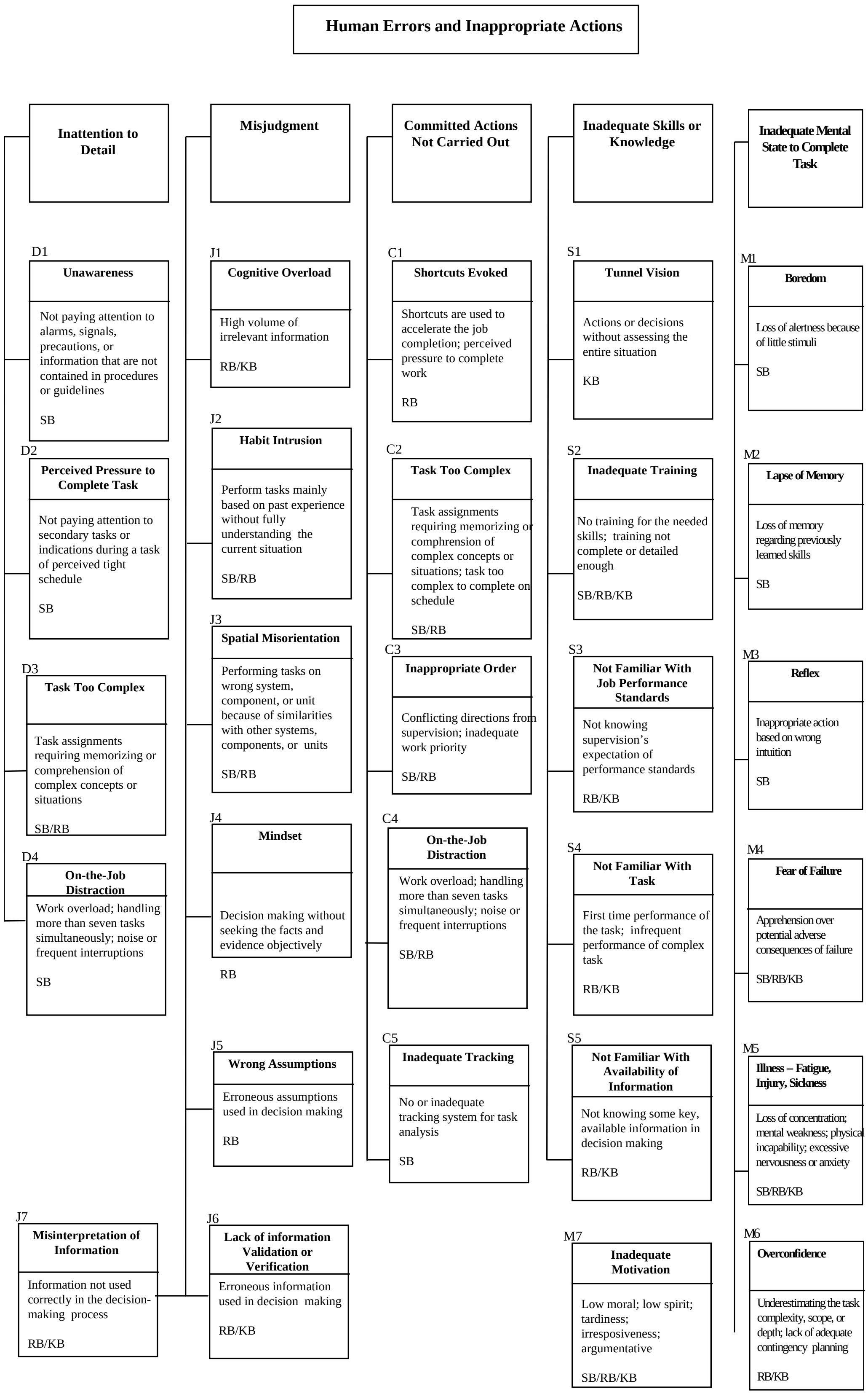
The following is the short list of error precursors that are predictable elements which can be planned for and reduced or prevented. The formula is also known as (TWIN) Task Demands, Individual Capabilities, Work Environment, and Human Nature.



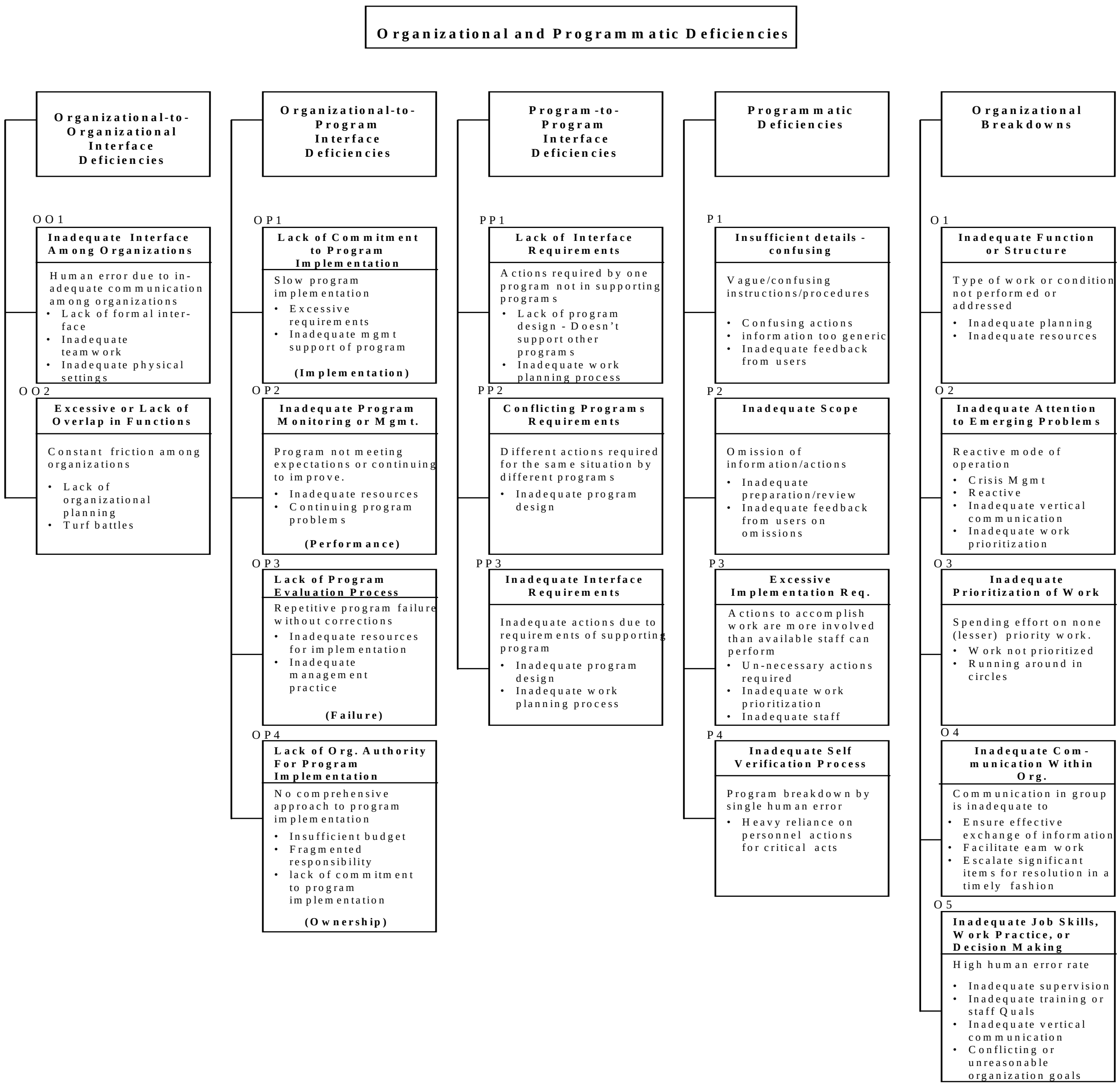
Task Demands	Individual Capabilities
Time pressure (in a hurry)	Unfamiliarity w/ task / First time
High Workload (memory requirements)	Lack of knowledge (mental model)
Simultaneous, multiple tasks	New technique not used before
Repetitive actions, monotonous	Imprecise communication habits
Irrecoverable 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 (limits attention)
Changes / Departures from routine	Habit patterns
Confusing displays or controls	Assumptions (inaccurate mental picture)
Workarounds / 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

The Model for an Error Likely Situation



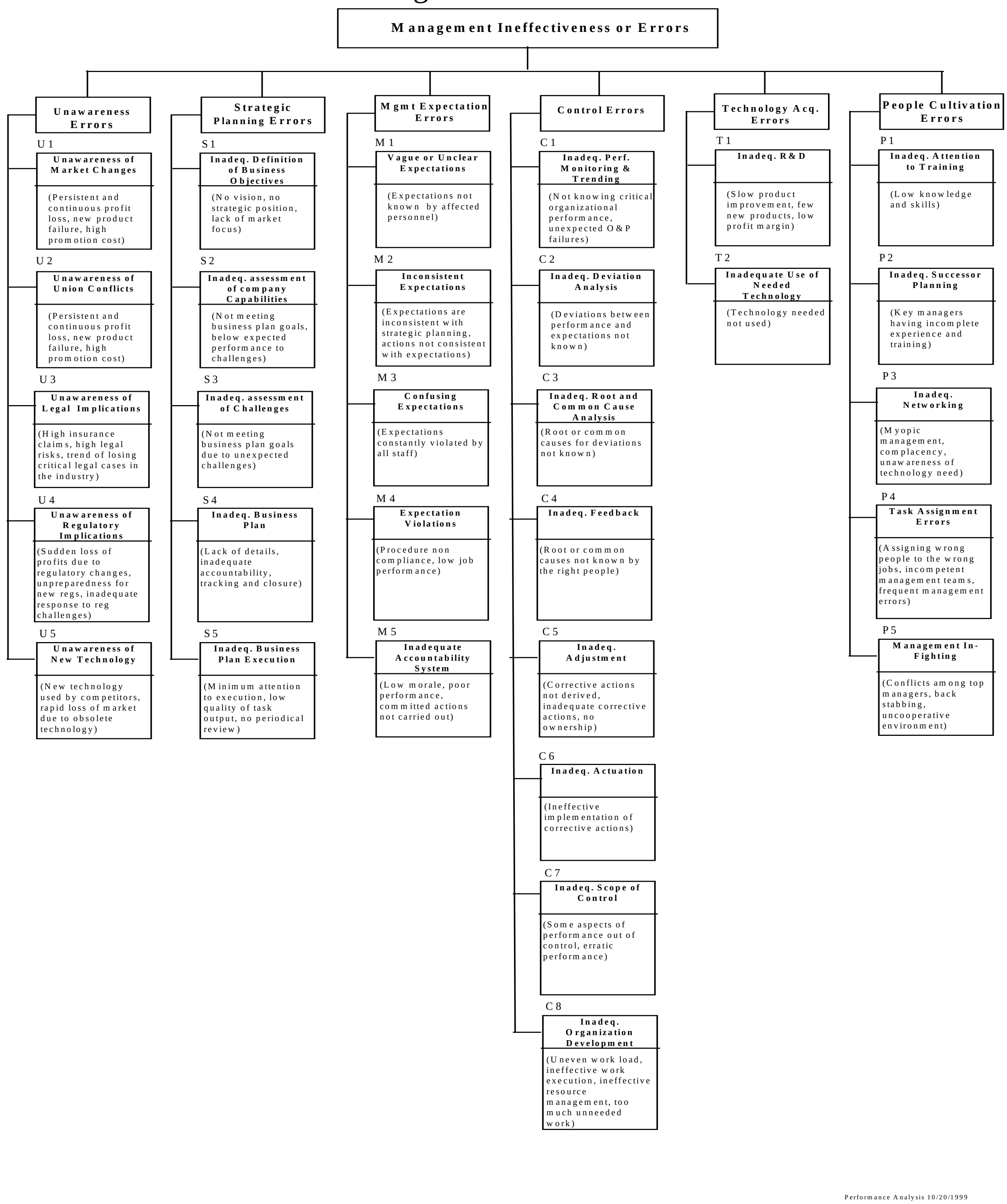

Human Errors and Inappropriate Actions
Inattention to Detail
Misjudgment
Committed Actions Not Carried Out
Inadequate Skills or Knowledge
Inadequate Mental State to Complete Task
D1
Unawareness
Not paying attention to alarms, signals, precautions, or information that are not contained in procedures or guidelines
SB
D2
Perceived Pressure to Complete Task
Not paying attention to secondary tasks or indications during a task of perceived tight schedule
SB
D3
Task Too Complex
Task assignments requiring memorizing or comprehension of complex concepts or situations
SB/RB
D4
On-the-Job Distraction
Work overload; handling more than seven tasks simultaneously; noise or frequent interruptions
SB
J1
Cognitive Overload
High volume of irrelevant information
RB/KB
J2
Habit Intrusion
Perform tasks mainly based on past experience without fully understanding the current situation
SB/RB
J3
Spatial Misorientation
Performing tasks on wrong system, component, or unit because of similarities with other systems, components, or units
SB/RB
J4
Mindset
Decision making without seeking the facts and evidence objectively
RB
J5
Wrong Assumptions
Erroneous assumptions used in decision making
RB
J6
Lack of information Validation or Verification
Erroneous information used in decision making
RB/KB
J7
Misinterpretation of Information
Information not used correctly in the decision-making process
RB/KB
C1
Shortcuts Evoked
Shortcuts are used to accelerate the job completion; perceived pressure to complete work
RB
C2
Task Too Complex
Task assignments requiring memorizing or comphrension of complex concepts or situations; task too complex to complete on schedule
SB/RB
C3
Inappropriate Order
Conflicting directions from supervision; inadequate work priority
SB/RB
C4
On-the-Job Distraction
Work overload; handling more than seven tasks simultaneously; noise or frequent interruptions
SB/RB
C5
Inadequate Tracking
No or inadequate tracking system for task analysis
SB
S1
Tunnel Vision
Actions or decisions without assessing the entire situation
KB
S2
Inadequate Training
No training for the needed skills; training not complete or detailed enough
SB/RB/KB
S3
Not Familiar With Job Performance Standards
Not knowing supervision's expectation of performance standards
RB/KB
S4
Not Familiar With Task
First time performance of the task; infrequent performance of complex task
RB/KB
S5
Not Familiar With Availability of Information
Not knowing some key, available information in decision making
RB/KB
M7
Inadequate Motivation
Low moral; low spirit; tardiness; irresposiveness; argumentative
SB/RB/KB
M1
Boredom
Loss of alertness because of little stimuli
SB
M2
Lapse of Memory
Loss of memory regarding previously learned skills
SB
M3
Reflex
Inappropriate action based on wrong intuition
SB
M4
Fear of Failure
Apprehension over potential adverse consequences of failure
SB/RB/KB
M5
Illness – Fatigue, Injury, Sickness
Loss of concentration; mental weakness; physical incapability; excessive nervousness or anxiety
SB/RB/KB
M6
Overconfidence
Underestimating the task complexity, scope, or depth; lack of adequate contingency planning
RB/KB

Organizational and Programmatic Chart



Performance Analysis 10/20/1999

Executive Management Failure Mode Chart



6.0 Common Cause Analysis Definitions:

1. **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.
1. **Cause Analysis** — the methodologies used to systematically perform an analysis of a given event to determine why the event occurred.
2. **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.
3. **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.
4. **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.
5. **Facts** — independent verification of data or information.
6. **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.)
7. **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).
1. **Failure Scenario** — a series of chronological events beginning with an initiating event and ending with the identified failure mode.
2. **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.
3. **Error** — an action (behavior) that unintentionally departs from an expected behavior according to a standard.

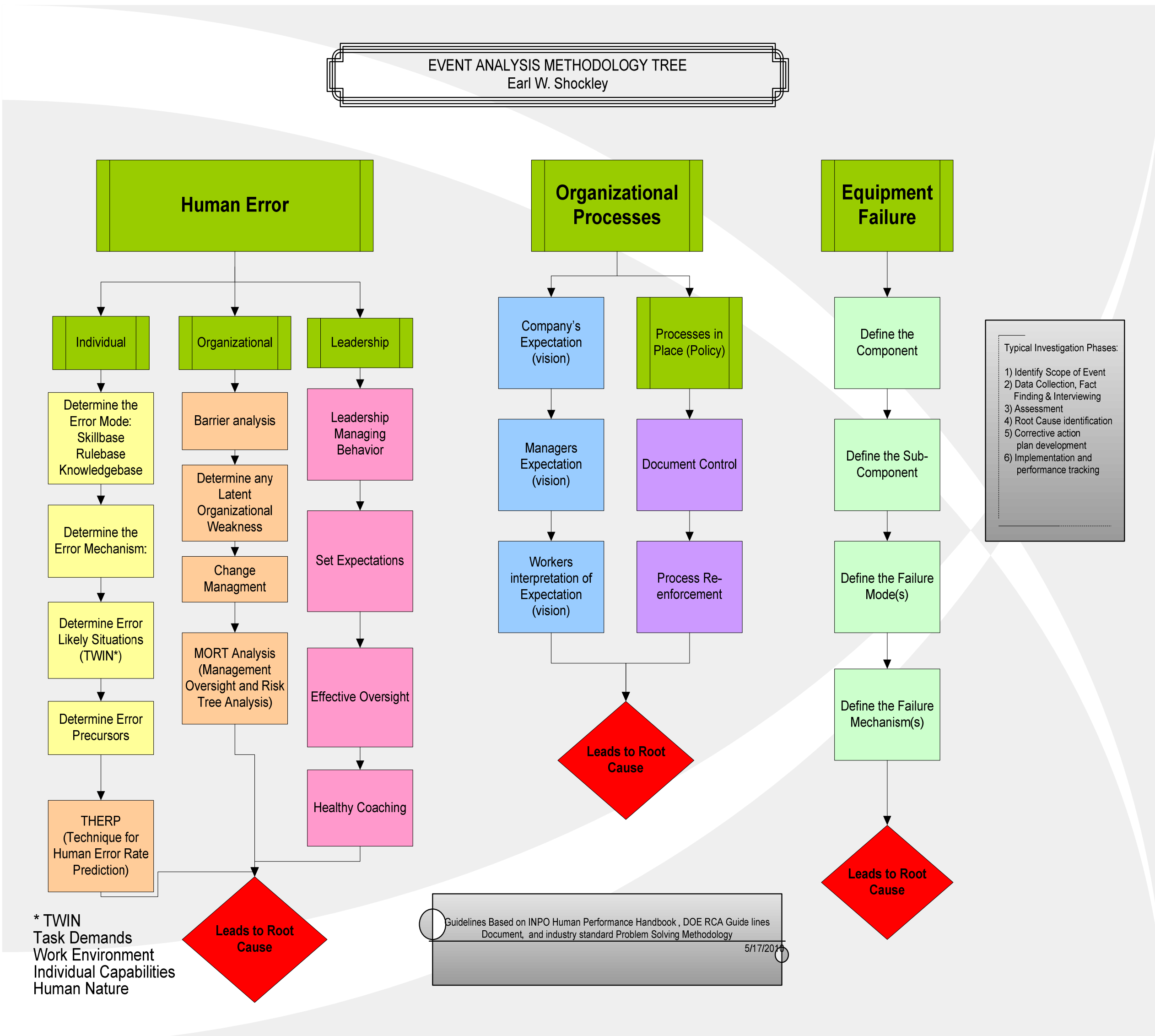
4. **Event** — an unwanted, undesirable consequence to the safe and reliable operation of the system.
5. **Event Analysis** — a review of activities causing or surrounding a disturbance of the BPS.
6. **Error Precursors** — unfavorable prior conditions that reduce the opportunity for successful behavior at the jobsite. *Precursors provoke error…..*
7. **Error-Likely-Situation** — A task-related predicament involving a potential error provoked by unfavorable jobsite conditions that reduce the chances for success
8. **Error Mode** — a description of how the process step or task was performed incorrectly.
9. **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.
10. **Active errors** — Errors that change equipment, system, or plant state triggering immediate undesired consequences.
11. **Latent errors** — (typically by management and staff) Errors resulting in undetected organization-related weaknesses or equipment flaws that lie dormant.

7.0 References

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

- Department of Energy (DOE) Root Cause Analysis Guidance Document DOE-NE-STD-1004-92
- INPO Human Performance Handbook, Desk Reference, 1997
- *Human Performance Fundamentals Course,* Institute of Nuclear Power Operations, 1997
- Johnson, W.G., *Management Oversight and Risk Tree*, U.S. Atomic Energy Commission, Division of Operational Safety, 1973
- *Root Cause Analysis*, Institute of Nuclear Power Operations, 1990
- Johnson, W.G., *Accident/Incident Investigation Manual*, U.S. Energy Research and Development Administration, Division of Safety, Standards, and Compliance, 1975
- *Human Performance Enhancement System Coordinators Manual,* Institute of Nuclear Power Operations, 1991
- Walton, M., *The Deming Management Method*, The Putnam Publishing Group, New York, NY, 1986
- Scholtes, P. R., *The Team Handbook*, Joiner Associates Inc., Madison, WI, 1988
- Porras, J. I., *Steam Analysis*, Addison-Wesley Publishing Company, Madison, WI, 1987
- Reason J., *Managing the Risks of Organizational Accidents*, Ashgate Publishing Limited, Aldershot, England, 1997
- Reason J., *Human Error,* Cambridge University Press, New York, NY, 1990

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