TEMPORARY CHANGE REQUEST

TCR NO. **TCR-QA-019, R5-001**
(e.g., TCR-ENG-021,R0-001)

The Temporary Change Request (TCR) Form is to be used to process urgent or minor changes for PPPL Policies, Organization/Mission Statements and Procedures. The TCR should be used when changes are:
1) urgent, and can not wait the 2-4 week period for Department Head review/comment, or
2) minor, and do not warrant Department Head review.

Person Requesting Change: Judith Malsbury **Phone Ext: 2415**

Department Name: Best Practices and Outreach

Document Number: QA-019 **Revision No.: 5**

Document Title: Root Cause Analysis/Extent of Condition Analysis

Reason for change:
Added information from associated training document concerning interviews.
Added Records Section

Change description: (Summarize and attach changed pages, with changes clearly indicated)
See Attachment 1, page 2 and Records Section D.

1. Does this TCR significantly alter the intent or scope of the document? **YES:**_____ **NO:X**

2. Does this TCR significantly impact **ES&H**? **YES:**_____ **NO: X**

If 1 or 2 is **YES**, Explain why the changes should not be routed for Department Head review:

Judy Malsbury 8/11/15
Department/Division Head Approval **Date**

John DeLooper 8/11/15
Head, Best Practices and Outreach/designee **Date**

Release/Effective date of this TCR: **8/11/15**

Incorporate this TCR into next revision of this document? **YES: X** **NO:**_____

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PPPL	PRINCETON PLASMA PHYSICS LABORATORY	PROCEDURE	No. QA-019 Rev 5 page 1 of 8
Subject: Root Cause Analysis/Extent of Condition Analysis		**Effective Date:** 10/22/2012	**Initiated by:** Head, Quality Assurance
		Supersedes: QA-019, Rev. 4 8/4/08	**Approved:** Director

Management System (Primary): 12.00 Assurance and Improvement
Management System Owner: Head, Best Practices and Outreach Department
Management Process: 12.07 Lessons Learned/Operating Experience
Process Owner: Head, Best Practices and Outreach Department
Subject Matter Expert (SME): Head, Quality Assurance

Applicability

This procedure is applicable to all organizational units within the Laboratory.

Introduction

This procedure establishes the process and provides instructions by which the Laboratory conducts formal root cause analyses (RCA) and extent of condition (EofC).

Formal root cause analyses may be invoked per procedure GEN-006 to investigate and determine the causes of accidents, incidents, near-misses, and adverse conditions, by QA-002 for high priority audit findings, or at the request of management. Informal root causes analysis can be performed at any time and for any reason and should use this procedure for guidance.

Root cause analysis refers to the process of identifying those specific or systematic factors that caused or fostered adverse consequences. Care must be taken to clearly distinguish symptoms that indicate the existence or occurrence of a problem from the root causes. In addition, care must be taken to distinguish between what may appear to be causes and the true root causes. Properly performed, root cause analysis reduces the amount of subjectivity.

The advantages of root cause analysis include:

- Focuses on preventing recurrence as well as providing immediate corrective action.
- Provides objectivity in problem solving.
- Aids in identification of contributory circumstances.
- May predict other problems or systemic deficiencies.
- Provides comprehensive set of potential solutions.
- Suggests solutions that may be applied to other areas and problems.
- Identifies opportunities for improvement.
- Provides enhanced utilization of limited resources.

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Note that if during the execution of this procedure, potential personnel concerns arise, the leader performing the RCA should immediately discuss the concerns with Human Resources.

Formal Extent of Condition analyses may be performed to determine whether the causes of an accident, incident, near-miss, adverse condition, or significant audit finding may be affecting performance elsewhere. Doing so would allow PPPL to correct these extended conditions prior to their causing an additional problem or event.

Referenced Procedures

DOE-HDBK-1208-2012 Accident Investigation and Prevention

GEN-006, Investigation and Followup of Adverse Events and Conditions (including Occurrence Reporting and Price Anderson Amendment Act Reviews)

QA-002, PPPL Audit Program

QA-017, PPPL Tracking and Trending System

Resource Documents

Fictional examples for RCAs detailing the analysis process using the diagramming techniques described in attachment 2 may be found at http://www-local.pppl.gov/qa/MiscPub/PUBS.shtml.

The reports for actual PPPL Root Cause and Extent of Condition Analyses related to accidents and incidents may be found at http://www-local.pppl.gov/esh/SpecialReports/.

Definitions

Appropriate Manager	The manager requesting the root cause analysis. The level of the manager is dependent upon the significance of the RCA, but typically is a member of the PPPL Council.
Contributory Cause(s) -	An event or condition that collectively with other causes increases the likelihood of an accident but that individually did not cause the accident. [DOE-HDBK-1208-2012]
Direct Cause -	The immediate events or conditions that caused the accident. [DOE-HDBK-1208-2012]
Extent of Condition Analysis (EofC)	An analysis that reviews conditions and causes of a failure, malfunction, deficiency, defective item, weakness, or problem (typically identified by a root cause analysis) to determine if similar conditions or causes exist for other activities, projects, programs, facilities, or organizations.

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Judgment of Need (JON) — Managerial controls and safety measures determined by the Investigation Team to be necessary to prevent or minimize the probability or severity of a recurrence.

Root Cause - The most basic cause (or causes) that can reasonably be identified and management has control to fix and, when fixed, will prevent or significantly reduce the likelihood of the problem recurring. (TapRoot)

Root Cause Analysis (RCA) — A process of identifying the root and contributory causes of an event or nonconformity

Root Cause Analysis Report — A comprehensive report of a problem/event addressing all aspects of the event, conditions leading up to the reported event, conclusions, recommendations, and, optionally, planned corrective action. The content of the report is contained in Attachment 7, Format and Content for Formal Root Cause Analyses Reports.

Procedure

A. Performing a Root Cause Analysis

The steps below are applicable to all Root Cause Analyses (RCAs) performed as a result of GEN-006 or due to a high priority audit finding. Managers at all levels can request an RCA to address a concern within their area of responsibility. In this case, this section provides guidance for performing such an RCA. Quality Assurance is available to participate in or support RCA efforts.

Responsibility	Action
Appropriate Manager	1. Issues a charge for the RCA which assigns the Investigator(s) to perform the root cause analysis and communicates the expectations for report preparation and review and target dates. Typically, individuals assigned to an RCA team include a technical expert, an individual trained in methods of conducting root cause analysis, and an ES&H expert when appropriate. One member should be identified as the Team Leader. Consideration should be given to including a member of the DOE. Team members are responsible for the entire RCA and should not limit their participation in the analysis to their areas of expertise. Determines if the formal report should be issued before or after the corrective actions are specified. A list of personnel trained in root cause analysis is available from Human Resources. Just-in-time training for newly created teams is available from Quality Assurance.

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Investigator(s)

2. Begins the information and data collection phase immediately, per guidance of Attachment 1, to ensure that data are not lost. It is extremely important that, in the case of an accident or incident, after safe conditions are restored, the area be preserved as required by GEN-006.

3. Performs assessment using Attachment 2 as guidance for selecting and performing a specific technique(s) of analysis. Attachment 3 is a simple table format that is useful in documenting the time line for an accident or event and the associated analysis results.

4. Identifies the direct, contributory, and root causes and validates the proposed causes (Attachment 4).

   During this process, the team might also identify auxiliary issues, issues that did not impact the event for which the root cause analysis is being performed. If not identified, these auxiliary issues could impact other work being performed at PPPL. It is helpful to formally identify these auxiliary issues also to assure that they are addressed. These auxiliary issues may be identified in a separate report.

5. Identifies the levels of the organization having the responsibility and authority for correcting each cause using the tier diagramming technique described in Attachment 5.

6. Reviews the level of culpability for the causal factors using the Culpability Decision Tree contained in Attachment 6.

7. Identifies ”Judgments of Need” (JONs) for issues to correct. JONs should be stated in a clear, concise, and direct manner, be based on the facts/evidence, and stated so that they can be the basis for corrective action plans. These JONs may relate to an individual or to multiple causes.

8. Identifies recommended corrective actions for each auxiliary issue.

9. Documents the results of the root cause analysis, the causes, the JONs, and the recommended corrective actions using Attachment 7.

10. Distributes the draft report for review for factual accuracy and appropriateness of analysis as indicated in the charge. Reviews from additional individuals may also be requested, such as those responsible for work aspects included in the report or for any corrective actions or subject matter experts.

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Investigator(s)	11. Reviews comments and incorporates them, as appropriate, into the Root Cause Analysis report. Provides response to reviewers. Signs report.
Appropriate Manager(s)	12. Determines the actual corrective action(s) to be taken, assigns individual(s) to implement the action, and defines a completion date. Documents this determination and distributes to the investigation team. If an extent of condition (EofC) is to be performed, it should be recognized that some of the corrective actions, responsible individuals or due dates may change or expand based on the EofC.
Investigation Team Leader	13. Issues the report as indicated in the Charge, provides copies to the relevant Deputy Director and Department Head, and to the Head, Best Practices and Outreach. QA also receives a copy of the report for tracking per QA-017.

B. Performing an Extent of Condition Analysis

Responsibility **Action**

Appropriate Manager

1. Determines if an extent of condition (EofC) analysis should be performed. This determination may be based on:
    a. The potential of causal factors identified in the RCA to exist in other areas, hardware, or processes at the Laboratory;
    b. The potential of similar conditions or problems to exist in other areas of the Laboratory, hardware, or processes at the Laboratory;
    c. The similarity to other issues that have been identified previously at the Laboratory. In this case, the EofC should include a review of previous assessments, analyses, critique results, and cause determination to identify repetitive problems for which further investigation and inclusion in the EofC might be appropriate.

2. If a determination is made that an EofC would be appropriate, formally assigns the Investigator(s) to perform the EofC, including a team leader, if appropriate, and communicates the objectives of the EofC and target dates. One member of the assigned EofC team should be trained in the methods of conducting extent of conditions. Just-in-time training is available from QA (see section C). Team members should include an appropriate technical expert.

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Investigation Team	3. Reviews the objectives and uses Attachment 8 to determine the approach to be taken by the EofC team.
	4. Collects and analyzes the obtained data to identify causal factors. If a root cause analysis had already been performed, the new data may provide further clarification of the causal factors already identified or may identify new causal factors not previously identified.
	5. Identifies "Judgments of Need" (JONs) for issues to correct. JONs should be stated in a clear, concise, and direct manner, be based on the facts/evidence, and stated so that they can be the basis for corrective action plans. These JONs may relate to an individual or to multiple causes.
	6. Documents the results of the EofC, the causes, the JONs, and the recommended corrective actions using Attachment 9.
	7. Distributes the draft report to all those indicated by the Charge.
Investigation Team	8. Reviews comments and incorporates them, as appropriate, into the Extent of Condition report. Provides responses to reviewers. Signs report.
Appropriate Manager(s)	9. Determines the actual corrective action(s) to be taken, assigns individual(s) to implement the action, and defines a completion date.
Investigation Team	10. Issues the report as indicated in the Charge, provides copies to the relevant Deputy Director and Department Head, and to the Head, Best Practices and Outreach. QA also receives a copy of the report for tracking per QA-017.

C. Training

Two different training approaches are defined: comprehensive training for overall process knowledge and just in time training for newly created analysis teams.

1. Training for Overall Process Knowledge:

   Target audience: anyone wishing or needing to know more about performing a causal analysis.

   Instructor: RCA Process Owner or designee

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Training Method: Classroom

Frequency: Once unless major changes are made in the program.
When major changes are made in the system, individuals completing this course will either be required to read the revised QA-019 or retake the two-day class. QA, working with HR/Training, will determine the appropriate approach.

This is a two-day class.

2. Training for newly created analysis teams:

Target audience: Members of newly created analysis teams

Training method: three- part classroom training
Part 1: collecting data, interviewing, developing a timeline, analyzing the event
Part 2: determining the causal factors and writing the report
Part 3: performing an extent of condition

Instructor: RCA Process Owner or designee

Frequency: For all newly created analysis teams unless RCA Process Owner deems not necessary

Each part of the training is 1 – 2 hours long.

D. Records Requirements Specific To This Procedure

TCR-QA-019, R5-001

Records Custodians must assure records are maintained as follows:

Record Title	Record Custodian	Location	Retention Time
Root Cause Analysis Report	1. QA maintains RCAs for PPPL accidents or significant events 2. Manager who issued the charge for the RCA maintains RCAs for investigations limited to the department, division, or group	1. QA 2. Files of the manager who issued the charge for the RCA	Files that do not attract national media attention: Cut off annually. Destroy when 10 yrs old. Pending - DO NOT DESTROY *Reference Admin 22 (1.a.2.a)* Files that attract national media attention: Cut off annually. Transfer to NARA in 5-yr blocks when 10 yrs old *Reference Admin 22 (1.a.1.a)*

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Root Cause Analysis data	Same as above	Same as above	Files that do not attract national media attention: Cut off annually. Destroy when 10 yrs old. Pending - DO NOT DESTROY *Reference Admin 22 (1.a.2.a)* Files that attract national media attention: Cut off annually. Transfer to NARA in 5-yr blocks when 10 yrs old *Reference Admin 22 (1.a.1.a)*
Extent of Condition Report	1. QA maintains EofC for PPPL lab-wide analyses. 2. Manager who issued the charge maintains EofCs for analyses limited to the department, division, or group.	1. QA 2. Files of the manager who issued the charge for the RCA	Files that do not attract national media attention: Cut off annually. Destroy when 10 yrs old. Pending - DO NOT DESTROY *Reference Admin 22 (1.a.2.a)* Files that attract national media attention: Cut off annually. Transfer to NARA in 5-yr blocks when 10 yrs old *Reference Admin 22 (1.a.1.a)*
Extent of Condition data	Same as above	Same as above	Files that do not attract national media attention: Cut off annually. Destroy when 10 yrs old. Pending - DO NOT DESTROY *Reference Admin 22 (1.a.2.a)* Files that attract national media attention: Cut off annually. Transfer to NARA in 5-yr blocks when 10 yrs old *Reference Admin 22 (1.a.1.a)*

Attachments

1. Guidance for Data Collection
2. Root Cause Analysis Techniques
3. Documenting the timeline
4. Identifying and Validating Root, Contributory, and Direct Causes
5. Tier Diagramming
6. Culpability Decision Tree
7. Format and Content for Formal Root Cause Analyses Reports
8. Guidance for an Extent of Condition
9. Format and Content for Formal Extent of Condition Report

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Data associated with the event or condition that triggered the root cause analysis must be collected and preserved. Data in this sense refers to any information related to the items listed below in this Attachment. This attachment provides guidance regarding hardware, documentation, and information that should be accumulated and preserved. It is important that hardware evidence be preserved in its "as found" condition; photographing the evidence is highly recommended. Section 6 of the DOE Accident Investigation Workbook provides more information in this area. If any evidence indicates that a deliberate act may have caused the event, PPPL Site Protection should be immediately notified (x2899).

ENVIRONMENTAL CONDITIONS

- Work place design
- Location and placement of equipment, tools, and other materials
- Noise
- Heat
- Light
- Time of day
- Ice or water

HARDWARE

- Equipment
- Tools

DOCUMENTATION

- Procedures
- Work instructions including Job Hazards Analyses
- Sketches and Drawings
- Photographs
- Logs (Operator and Equipment)
- Process Strip Charts
- Work Orders
- Permits
- Equipment Maintenance & other History Records
- Quality Records
- Work schedules
- Computer printouts
- Inspection records
- Supplier manuals
- Design basis information

PEOPLE

- Involved people and their statements, including those involved in the event, supervisors or managers, other individuals who do similar work, and emergency response personnel
- Witnesses and their statements
- Work history

Interview Considerations

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Plan the interview in advance

Determine what information is required from each interview and what basis questions should be asked

Identify the role of each RCA participant in the interview, including who will control the interview and who will be responsible to take notes

Maintain confidentiality

Ask question such as what, why, when, how, where, or who

Ask open-ended questions, e.g., how did you prepare for this work or what did you do next?

Be unbiased and nonjudgmental. Watch your body language.

Be careful about discussing solutions. The team's role is to just understand what happened.

Do not make promises that cannot be met, e.g., there will not be any disciplinary action if you work with us. TCR-QA-019, R5-001

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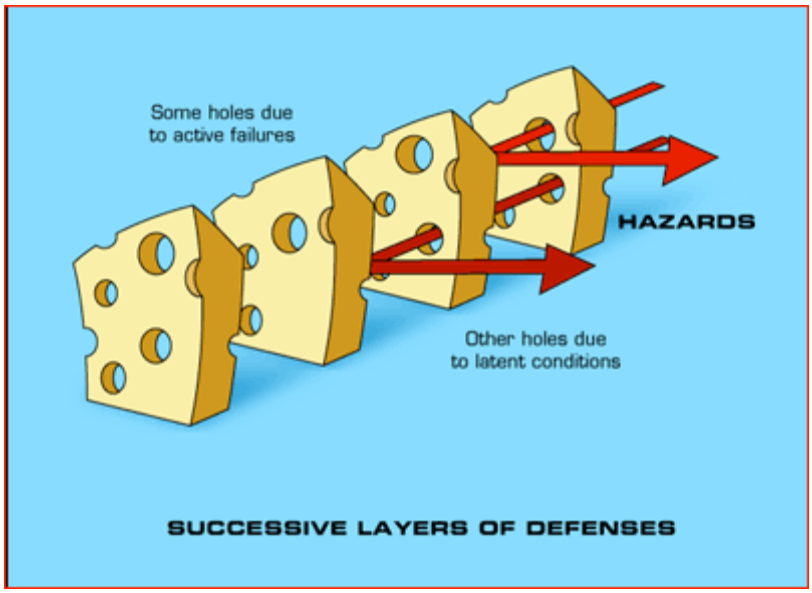
The primary aim of RCA is to identify the factors that resulted in the accident, incident, near-misses, or adverse conditions in order to identify what behaviors, actions, inactions, or conditions need to change to prevent recurrence of similar harmful outcomes.

Imagine many slices of Swiss cheese back to back, each from a different chunk of cheese, each slice representing a different process. Even the best designed process has inherent flaws or error situations, represented by the holes in each slice. The flaws or errors may be physical, human, or organizational flaws. Because these slices are from different chunks of cheese and therefore with holes that vary in size and position, they are unlikely to align and an event, incident, or accident less likely to occur. This is illustrated below[1]:



However, for the majority of accidents, these flaws or error situations line up, allowing the accident to occur, as indicated in the drawing below. The purpose of a root cause analysis is to identify the flaws or error situations that result in an event and either eliminate them or reduce the likelihood of their occurring again the future. If any hole in the arrow illustrated below can be closed or made much smaller in size, then the accident either cannot recur or is far less likely to recur due to the same conditions and the likelihood of other similar accidents or events are reduced.

[1] Figures from http://patientsafetyed.duhs.duke.edu/module_e/swiss_cheese.html . Concept originated by James Reason.

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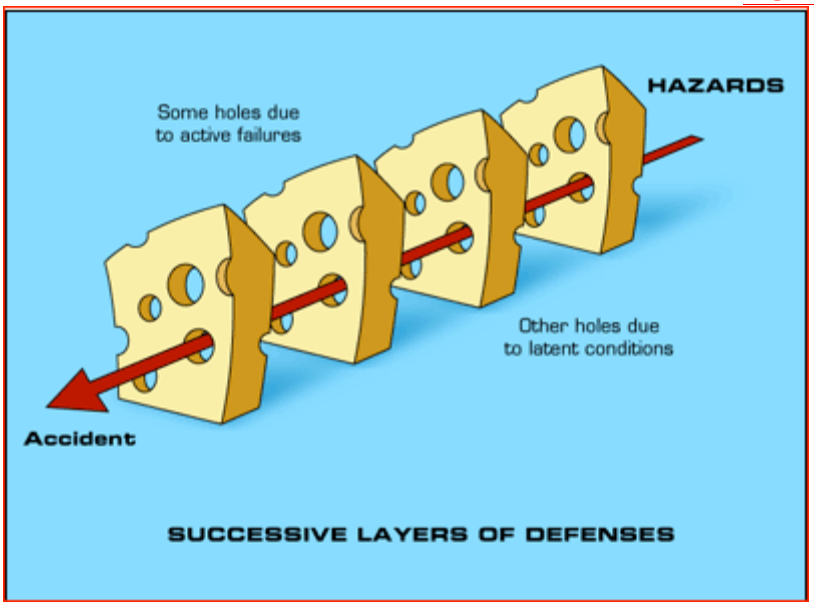

Root cause analysis is the process of identifying these errors or flaws.

There are three basic types of errors or flaws – physical, human, and organizational.

1. **Physical** – Tangible, material items failed in some way (for example, a car's brakes stopped working).
2. **Human** – People did something wrong, or did not do something that was needed. Human causes typically lead to physical causes (for example, no one filled the brake fluid, which led to the brakes failing).
3. **Organizational** – A system, process, or policy that people use to make decisions or do their work is faulty (for example, no one person was responsible for vehicle maintenance, and everyone assumed someone else had filled the brake fluid).

A good Root Cause Analysis should identify all three types of errors or flaws.

Different techniques exist for identifying these flaws or errors. The most frequently used techniques are summarized in the table below, beginning with the simplest. More detail on these techniques and descriptions of other techniques are provided in Section 2.6 of the DOE Accident Investigation Workbook or in the Human Performance Fundamentals Course Reference generated by the National Academy for Nuclear Training, December 2002. It is probable that two or more of the techniques will be required to thoroughly understand the event or condition being analyzed.

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Method	When to Use	Advantages	Disadvantages
Why Staircase	Use for simple situation	Easy to understand and use.	Not well structured, making it easy to miss significant root causes
Change Analysis	Use when a comparative non-event exists. Especially useful in evaluating equipment failures.	Simple process.	Danger of accepting "obvious" answers that may be incorrect.
Barrier Analysis	Use to identify barrier or equipment failures and procedural or administrative problems	Provides a systematic approach.	Requires familiarity with process to be effective.
Human Performance Improvement	Use whenever people have been identified as being involved in the problem cause.	Identifies the human factors associated with the problem	This methodology focuses on behavior issues, which is typically only one aspect of the event.
Events and Causal Factors Analysis	Use for multi-faceted complex problems with long or complex causal factor chains.	Provides a visual display of the analysis process. Identifies the probable contributors.	Time-consuming and requires more training than other techniques.
DOE Integrated Safety Mgmt Questioning Process	To determine the effectiveness of management systems, the adequacy of policy and policy implementation, and the effectiveness of management oversight.	Easy to understand and use	Requires facts before being used. Typically these facts are identified via one of the other RCA techniques.

The Why Staircase This is a simple technique for occurrences and findings where the causes are somewhat evident. It is illustrated below. This technique is not recommended for complex situations.

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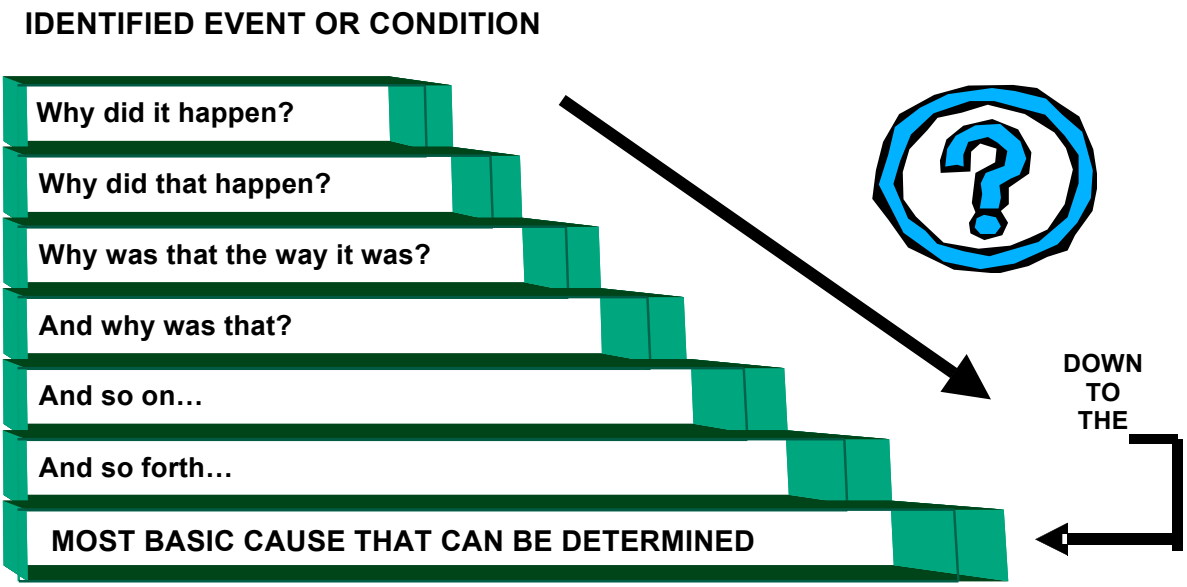

Here's a real example from PPPL. On November 17, 2009 a subcontractor fell while descending a short set of outsides stairs due to the failure of the step. This example is from the actual RCA performed for this event. Note that the analyst used seven whys to identify the causes.

1. Why did the worker fall?
   The accident occurred when the outer tread broke free from the second step from the bottom.

2. Why did the tread break free?
   The tread broke free because the stringer split all the way through between the notches for the treads. [Note: the stringer is the structural member that supports the treads and risers.]

3. Why did the stringer split all the way through?
   The stringer split due to natural checking (cracks) which propagated through and along the stringer

4. Why did the cracks propagate?
   The cracks propagated because the wood wasn't sealed to keep moisture out. Also, the stairs were set on uneven gravel and were moved several times to accommodate work in the area – possible causing the cracks to propagate.

5. Why wasn't the stringer sealed to keep moisture out?
   The stringer wasn't sealed because no standard or procedure at PPPL required sealing.

6. Why weren't the cracks detected prior to failure?

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There was no inspection performed on the steps. Therefore, the cracks were not detected.

7. Why weren't the steps inspected at a regular frequency?
   The steps were not inspected because inspections are not required at a regular frequency at PPPL.

Change Analysis – If a task had been performed successfully or if the equipment or process had been operating successfully before an event, accident, or incident, this technique will help to identify the changes that resulted in the event, accident, or incident or to identify the potential impact of a change.

Change analysis is an analytical technique that can be applied reactively or proactively. Change analysis may be performed in a reactive mode, typically for problems, by comparing previous trouble-free activity with the occurrence to identify differences. It may also be used in a proactive mode to ascertain potential effects of changes prior to their actual implementation.

For reactive change analysis, the steps are:

1. Describe the event situation including who was involved, what was involved, where the event took place, when the event took place, and how or what enabled the event to take place.
2. Describe an event-free situation also addressing who, what, where, when, and how questions.
3. Compare the two processes to detect any differences. Write down all the detected differences whether they appear to be relevant or not.
4. Analyze the differences to identify underlying changes and how they affect the event.
5. Integrate the information and specify the root cause.

An appropriate form to document this is given below:

	Event	Nonevent	Differences	Effect of differences on the event
What (events, conditions, activities, equipment present at time of event and not at time of nonevent)				
How (event or condition occurred)				
When (event or condition occurred)				

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	Event	Nonevent	Differences	Effect of differences on the event
Who (was involved in planning, reviewing, authorizing, performing, and supervising work)				
Where				

Why

The differences identified via the change analysis methodology may then be incorporated as causal factors for further analysis using other RCA techniques.

For proactive change analysis, the steps are:

1. Describe the present situation in terms of who will be affected by the change, what will change, where the change will take place, when the change will take place, and how the change will be implemented.
2. Describe the planned changes in the same terms of who, what, where, when, and how. Note that terms of people, locations, materials, processes, and barriers and controls could be used for steps 1 and 2 instead of who, what, where, when, and how.
3. List all known or potential effects of the proposed changes.
4. Analyze the potential effects and summarize the results.

A simple example of change analysis is given below. The example is to analyze failures in tensile strengths in a new lot of bolts.

	Event	Nonevent	Differences	Effect
What	Lot 109 received from Amazing Bolts fails tensile strength tests	All bolts received from Amazing Bolts pass the tensile strength test.	Tensile strength capability	High strength bolts could fail in service
How	Raw material for manufacturing bolts was not verified by Amazing Bolts upon receipt	Raw material for manufacturing bolts was verified by Amazing Bolts upon receipt.	Verification of raw material would have identified faulty material and prevented it from being used in the manufacturing process.	Amazing Bolts shipped bolts that did not meet the requirements.

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	Event	Nonevent	Differences	Effect
When	Lot dated Jan. 1999	Lots dated Dec. 1998 and earlier	Different manufacturing dates required different lots of raw material from supplier.	Reduced tensile strength
Who	Amazing Bolts manufactured the bolts	Amazing Bolts manufactured the bolts	--	--
Where	Same manufacturing line using same process at same facility	Same manufacturing line using same process at same facility	--	--

Why? The root cause of the failures was faulty raw material received by Amazing Bolts from their supplier. A contributory cause was lack of material verification by Amazing Bolts before use.

Barrier Analysis – This technique is based on the premise that barriers are developed to prevent events. For most events, multiple barriers typically failed; if one had worked, the event could have been prevented. This technique identifies physical or administrative barriers or controls that should have prevented an event or failure and determine why they failed and what is needed to prevent recurrence.

Barriers exist to eliminate harm to people, places, equipment, and the environment. The barriers may be administrative or physical. Examples of barriers include:

- Personal protective equipment (physical barrier).
- Safety training (administrative barrier)
- Hand rails (physical barrier)
- Flow and pressure regulators (physical barrier)
- Procedural steps or requirements (administrative barrier)

For barrier analysis, the steps are:

1. Identify the sequence of events leading to the failure or event
2. Identify established barriers that should have assured that no problems occurred.
3. Analyze the adequacy of these barriers, identifying those that were less than adequate.

A simple example of barrier analysis is given below. The scenario is a fall taken by an employee from a roof, where LTA is shorthand for less-than-adequate.

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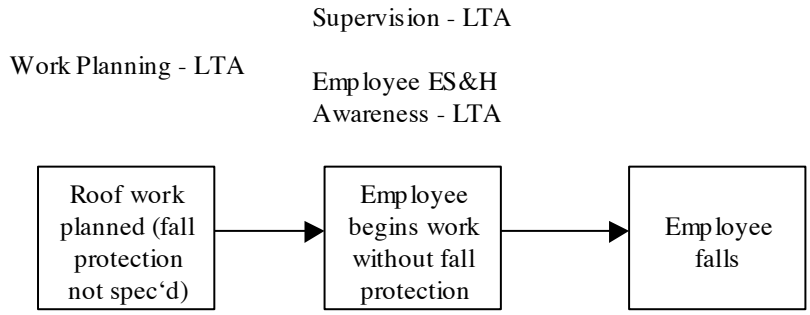

In the above example, three instances of failing barriers were identified:

- The hazards associated with the work were not properly identified during the work planning stage.
- Supervision for the work did not identify the hazard at the time that the work was being performed.
- The employee was not aware of the fall hazard or chose to ignore the hazard.

The information above may also be presented in a table format, which is easier to generate for more complex situations.

Human Performance Improvement Analysis Some of this information is from the *Human Performance Fundamentals Course Reference,* National Academy for Nuclear Training, December 2002, Revision 6. (Not available on line. See QA to borrow a copy.)

HPI is a technique for identifying the human factors that impacted the issue being investigated and exploring why people behaved the way they did.

HPI can be used in a preventive mode to avoid unintended situations or accidents. However, in this procedure, the use of HPI is limited to the investigation after an event has occurred.

Approximately 80% of all occurrences are due to human error. Of these errors, approximately 70% are due to latent organizational weaknesses. The intent of HPI is to identify and eliminate these organizational weaknesses, where possible, and, where not possible, set up defenses to reduce their impact. The process for performing HPI includes:

1. Identifying the errors, both active errors and latent errors. These errors may be identified via one of the other root cause analysis techniques described in this document. An active error concerns "changes to equipment, system, or plant state triggering *immediate* undesired consequences." A latent error is "an error, act, or decision that results in organization-related weaknesses or equipment flaws that lie dormant until revealed either by human error, testing, or self-assessment."

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2. Identifying the error precursors which are "Unfavorable factors embedded in the job site that increase the chances of an error during the performance of a specific task by a particular individual."
3. Identifying the human performance tools that might be appropriate for the work being done and indicating if they were used and, if used, effective.
4. Identifying the failed defenses, which might include weaknesses in the management control systems or organization weaknesses
5. And identifying whether the work being performed at the time of the failure was skill based, rule based, or knowledge based.

The list of error precursors and the definitions of the most common ones are on the following pages.

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Error Precursors (Bold are most frequent)

Driver Code	1 – TASK DEMANDS	Driver Code	3 – INDIVIDUAL CAPABILITIES
1A -Time Pressure (in a hurry)		**3A -Unfamiliarity with task/ First time**	
1B -High workload (memory requirements)		**3B -Lack of knowledge (faulty mental model)**	
1C -Simultaneous, multiple tasks		**3C -New technique not used before**	
1D -Repetitive actions/Monotony		**3D -Imprecise communication habits**	
1E -Irreversible actions		**3E -Lack of proficiency; Inexperience**	
1F -Interpretation requirements		**3F -Indistinct problem-solving skills**	
1G -Unclear goals, roles, or responsibilities		**3G -"Can do" attitude for safety-critical task**	
1H -Lack of or unclear standards		**3H -Illness or fatigue; general health**	
1I -Confusing procedure/Vague guidance		3I -Unawareness of critical parameters	
1J -Excessive communication requirements		3J -Inappropriate values	
1K -Delays: idle time		3K -Major life event; medical, financial, emotional	
1L -Complexity/High information flow		3L -Poor manual dexterity	
1M -Excessive time on task		3M -Low self-esteem; moody	
1N -Long-term monitoring		3N -Questionable ethics (bends the rules)	
		3O -Sense of Control. Learned helplessness	
		3P -Personality type	
Driver Code	2 – WORK ENVIRONMENT	Driver Code	4 – NATURAL TENDENCIES/HUMAN NATURE
2A – Distractions/Interruptions		**4A –Stress**	
2B -Changes/Departure from routine		**4B -Habit patterns**	
2C -Confusing displays/controls		**4C –Assumptions**	
2D -Work-arounds/OOS instrumentation		**4D -Complacency/Overconfidence**	
2E -Hidden system responses		**4E -Mind set (intentions)**	
2F -Unexpected equipment conditions		**4F –Inaccurate risk perception**	
2G -Lack of alternative indication		**4G -Mental shortcuts or biases**	
2H -Personality conflicts		**4H -Limited short-term memory**	
2I -Back shift or recent shift change		4I -Pollyanna effect	
2J -Excessive degree of group cohesiveness		4J -Limited perspective (bounded rationality)	
2K -Production overemphasis		4K -Avoidance of mental strain	
2L -Adverse physical climate (habitability)		4L -Tunnel vision (lack of big picture)	
2M -No accounting of performance		4M -"Something is not right"	
2N -Conflicting conventions; stereotypes		4N -Pattern matching bias	
2O -Poor equipment layout; poor access		4O -Social preference	
2P -Fear of consequences of error		4P -Easily bored	
2Q -Mistrust among work groups		4Q -Close-in-time cause-effect correlation	
2R -Meaningless rules		4R -Difficult to see own errors	
2S -Unavailable parts or tools		4S -Frequency & similarity bias	
2T -Acceptability of "cook-booking"		4T -Overload bias	
2U -"Rule book" culture		4U -Imprecise physical actions	
2V -Equipment sensitivity (inadvertent actions)		4V -Limited attention span	
2W -Lack of clear strategic vision or goals		4W -Spatial disorientation	
2X -Identical & adjacent displays or controls		4X -Physical reflex	
2Y -Out of service warning systems		4Y -Anxiety (involving uncertainty)	
2Z -Nuisance alarms			

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Common Error Precursor Descriptions

Task Demands	Description
1A–Time Pressure (in a hurry)	Urgency or excessive pace required to perform action or task. Manifested by shortcuts, being in a hurry, and an unwillingness to accept additional work or help others No spare time.
1B–High workload (high memory requirements)	Mental demands on individual to main high levels of concentration; for example, scanning, interpreting, deciding, while requiring recall of excessive amounts of information (either from training or earlier in the task)
1C–Simultaneous, multiple tasks	Performance of two or more activities, either mentally or physically, that may result in divided attention, mental overload, or reduced vigilance on one or the task.
1D–Repetitive actions/Monotony	Inadequate level of mental activity resulting from performance of repeated actions; boring Insufficient information exchange at the job site to help individual reach and maintain an acceptable level of alertness
1E–Irreversible actions	Action that, once taken, cannot be recovered without some significant delay No obvious means of reversing an action
1F–Interpretative requirements	Situations requiring "in-field" diagnosis, potentially leading to misunderstanding or application of wrong rule or procedure
1G–Unclear goals, roles, or responsibilities	Unclear work objectives or expectations Uncertainty about the duties an individual is responsible for in a task that involve other individuals Duties that are incompatible with other individuals
1H–Lack of or unclear standards	Ambiguity or misunderstanding about acceptable behaviors or results; if unspecified, standards default to those of the front-line worker (good or bad)
Work Environment	**Description**
2A – Distractions/Interruptions	Conditions of either the task or work environment requiring the individual to stop and restart a task sequence, diverting attention to and from the task at hand
2B – Changes/Departure from routine	Departure from a well-established routine Unfamiliar or unforeseen task or job site conditions that potentially disturb an individual's understanding of a task or equipment status
2C – Confusing displays/controls	Characteristics of installed displays and controls that could possibly confuse or exceed working memory capability of an individual Examples: • missing or vague content(insufficient or irrelevant) • lack of indication of specific process parameter • illogical organization and/or layout • insufficient identification of displayed process information • controls placed close together without obvious ways to discriminate conflicts between indications
2D- Work-arounds/OOS instrumentation	Uncorrected equipment deficiency or programmable defect requiring compensatory or non-standard action to comply with a requirement; long-term materiel condition problems that place a burden on the individual
2E-Hidden system responses	System response invisible to individual after manipulation Lack of information conveyed to individual that previous action had any influence on the equipment system
2F-Unexpected equipment conditions	System or equipment status not normally encountered creating an unfamiliar situation for the individual

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2G – Lack of alternative indication	Inability to compare or confirm information about system or equipment state because of the absence of instrumentation.
2H-Personality conflict	Incompatibility between two or more individuals working together on a task causing a distraction from the task because of preoccupation with personal differences
Individual Capabilities	**Description**
3A–Unfamiliarity with tasks/First time	Unawareness of task expectations or performance standards First time to perform a task (not performed previously: a significant procedure change)
3B–Lack of knowledge(mental model)	Unawareness of factual information necessary for successful completion of task; lack of practical knowledge about the performance of a task
3C-New technique not used before	Lack of knowledge or skill with a specific work method required to perform a task
3D-Imprecise communications habits	Communication habits or means that do not enhance accurate understanding by all members involved in an exchange of information
3E-Lack of proficiency/inexperience	Degradation of knowledge or skill with a task because of infrequent performance of the activity
3F-Indistinct problem-solving skills	Unsystematic response to unfamiliar situations; inability to develop situations; inability to develop strategies to resolve problem scenarios without excessive use of trial-and-error or reliance on previously successful solutions Unable to cope with changing plant conditions
3G–"Unsafe" attitude for critical tasks	Personal belief in prevailing importance of accomplishing the task(production) without consciously considering associated hazards Perception of invulnerability while performing a particular task Pride; heroic; fatalistic; summit fever; Pollyanna; bald tire
3H-Illness/Fatigue	Degradation of a person's physical or mental abilities caused by a sickness, disease, or debilitating injury Lack of adequate physical rest to support acceptable mental alertness and function
Natural Tendencies/Human Nature	**Description**
4A–Stress	Mind's response to the perception of a threat to one's health, safety, self-esteem, or livelihood if task is not performed to standard. Responses may involve anxiety, degradation in attention, reduction in working memory, poor decision-making, transition from accurate to fast Degree of stress reaction dependent on individual's experience with task
4B–Habit patterns	Ingrained or automated pattern of actions attributable to repetitive nature of a well practiced task Inclinations formed for particular train/unit because of similarity to past situations or recent work experience
4C-Assumptions	Suppositions made without verification of facts, usually based on perception of recent experience; provoked by inaccurate mental model Believed to be fact Stimulated by inability of human mind to perceive all facts pertinent to a decision

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4D-Complacency/ Overconfidence	A "Pollyanna" effect leading to a presumption that all is well in the world and that everything is ordered as expected. Self-satisfaction or overconfidence, with a situation unaware of actual hazards or dangers; particularly evident after 7-9 years on the job Underestimating the difficulty or complexity of a task based upon past experiences
4E-Mind-set	Tendency to "see" only what the mind is tuned to see (intention): preconceived idea Information that does fit a mind-set may not be noticed and vice versa; may miss information that is not expected or may see something that is not really there; contributes to difficulty in detecting one's own error(s)
4F-Inaccurate risk perception	Personal appraisal of hazards and uncertainty based on either incomplete information or assumptions Unrecognized or inaccurate understanding of a potential consequence or danger Degree of risk taking behavior based on individual's perception of possibility of error and understanding of consequences; more prevalent in males
4GMental shortcuts (biases)	Tendency to look for or to see patterns in unfamiliar situations; application of thumb rules or "habits of mind" (heuristics) to explain unfamiliar situations • confirmation bias • frequency bias • similarity bias • availability bias
4H-Limited short-term memory	Forgetfulness; inability to accurately attend to more than 2 or 3 channels of information (or 5 to 9 bits of data) simultaneously The mind's "workbench" for problem-solving and decision-making; the temporary, attention-demanding storeroom we use to remember new information

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Organizational Weaknesses If error precursors exist, the cause likely involves latent organizational weaknesses. These weaknesses are undetected deficiencies in organizational processes or values that create workplace conditions that provoke error or degrade the integrity of defenses. Often, the cause of human error is incorrectly attributed to individual work practices rather than the underlying latent organizational weakness. For example, failure to self-check may be cited as the cause of a procedure violation while the actual cause was failure to train the individual in its use. Look for and consider these weaknesses in your cause determination. They are usually associated with the following categories:

Category	
1. Training	• Lack of effective training • No task qualification requirement when the task is skill-based • Focus on lower level of cognitive knowledge • Failure to have management involved in training • Training not consistent with plant equipment, procedures or process
2. Communications	• Failure to reinforce use of the phonetic alphabet • Failure to reinforce use of 3-way communications • Failure to use specific unit ID numbers in procedures • Unclear priorities or expectations • Unclear roles and responsibilities
3. Planning and Scheduling	• Not anticipating failures and providing contingencies • Not considering multiple components out of service • Not providing required materials or procedures • Over scheduling resources • Tunnel vision/failure to consider misoperation or damage to adjacent equipment
4. Design or Process Change	• Inadequate involvement of users in design change Implementation • Inadequate training • Inadequate contingencies
5. Values, Priorities, Policies	• Management polices discourage line input • Too high priority placed on schedules • Willingness to accept degraded conditions or performance
6. Procedure Development or Use	• Human factors not considered in procedure development and implementation • Failure to perform procedure verification or validation • Failure to reference procedure during task performance • Assumptions made in lieu of procedure guidance
7. Supervisory Involvement	• Failure to perform management observations and coaching • Not correcting poor performance or reinforcing good performance
8. Organizational Interfaces	• Unclear interfaces for defining work priorities • Lack of clear lines of communications between organizations • Conflicting goals
9. Work Practices	• Failure to reinforce use of established error prevention tools and techniques (human performance tools)

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Human Performance Tools – The table below describes tools that can be used to prevent human errors.

Effective Communication	Acknowledging communication between individuals or groups of individuals
Independent Verification	Checking performed by individuals not directly involved in the work and at a separate time from the work being performed. An example is a QC inspection
Job Hazards Analyses	Intentionally reviewing the hazards associated with a job and the mitigation techniques used to either eliminate the hazards or, when not possible, reduce the consequences associated with the hazards.
Knowledge/Training	Assuring individuals have the appropriate knowledge to prevent errors
Peer Checking	A co-worker checking the work performed by a peer, such as checking that a step was performed correctly
Place-Keeping	Marking procedures or work instructions to indicate that a step was performed successfully
Pre-job Briefing	Reviewing, prior to its performance, the work to be done with a special focus on difficult or error prone steps and the hazards and their mitigation
Procedure Use	Using procedures that provide the adequate level of detail to assure that the work is performed without errors
Questioning Attitude	Individuals stopping and reconsidering the work when something doesn't look right
Self Checking	Checking a person's own work, e.g., measure twice, cut once
Stop Work	Stopping the work when concerns are identified and inviting the experts in to resolve the concerns.
Supervisor involvement and coaching	Observing work in progress and resolving any concerns in a timely manner
Turnovers	Establishing mechanisms to transfer work responsibilities from team to team, frequently as a result of shift changes

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Finally, it is helpful to determine the performance modes associated with the identified HPI errors in order to fully understand the event. The performance modes are:

Skill based - Behavior associated with highly practiced actions in a familiar situation, usually executed from memory without significant conscious thought.

Rule based - Performance behavior based on selection of stored rules derived from one's recognition of the situation; follows IF (symptom X), THEN (situation Y) logic

Knowledge-based - Performance behavior in response to a totally unfamiliar situation (no skill, rule or pattern recognizable to the individuals); a classic problem-solving situation that relies on personal understanding and knowledge of the system, a system' present state, and the scientific principles and fundamental theory related to the system.

Attachment 7 contains the Culpability Decision Tree, a tool to determine the level of culpability for the individuals most responsible for triggering the event.

Events and Causal Factors Analysis – For analysis of events, typically accidents or incidents

Events and Causal Factor Analysis, also known as Cause and Effects Task Analysis, is a technique that analyzes events, conditions, how conditions influence events, and the chronology or sequence of events and conditions. It is based on the fact that accidents are the result of a set of successive events and associated conditions that result in the accident or incident.

The objectives of this technique include determining how a task was really performed (the steps actually followed) and identifying problems in human-factors, design, discrepancies in procedural steps, training, etc. so that they can be resolved.

This technique typically may involve a step-by-step reenactment of the actions leading to the event. This reenactment should include people who actually do the task. An alternative approach is to determine the steps that lead to the event by reviewing documents and interviewing the people who perform the task, line managers, and witnesses, as appropriate.

Usually, a cause and effect chart is generated. A sample is given below. The chart is a time line of events culminating in the last event that is the accident or incident. Each event should describe an occurrence or happening. Events are symbolized by rectangles, usually with solid lines indicating factual accuracy; presumed events have dashed lines. Each event should be precisely described, describe a single occurrence, be quantified to the extent possible, and, if available, include time and date. It is frequently helpful to start at the incident triggering the need for a root cause analysis and move backwards in time to identify the events leading to the incident. Suggested criteria for event descriptions are (from SCIE-DOE-01-TRAC-14-95):

1. Each event should describe an occurrence or happening, e.g., the pipe wall ruptured.
2. Each event should be described in a short sentence with one subject and one active verb.
3. Each event should be precisely described, e.g., “operator pulled headlight switch to ‘on’ position” not “operator turned lights on.”

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4. Each event should describe a single, discrete occurrence, e.g., "pipe wall ruptured" not "internal pressure rose and pipe wall ruptured."
5. Each event should be quantified when possible, e.g., "plane descended 350 feet" not "plane lost altitude."
6. Each event should be derived directly and logically from the event preceding it indicating steps in a sequence. When this is not the case, it usually indicates that one or more steps in the sequence have been left out.

Associated with events are conditions that describe circumstances that were in existence at the time of an event. These conditions differ from events in that they describe states of circumstances rather than happenings or occurrences and are passive rather than active. They are typically denoted as ovals with solid borders representing factual accuracy and dashed borders representing presumed conditions. The conditions should be precisely described, quantified when possible, posted with date and time if possible, and related directly to the event.

All conditions and sequences of events should then be examined to determine those that in themselves may not cause adverse conditions, but together could cause an unwanted accident or incident.

Note that in actual practice it is a good idea to write all events and conditions on Post-it™ sheets that may then be rearranged until the true sequence is identified.

Some individuals also include another time line of events below the failed one indicating the events that would have happened if the proper actions occurred and proper conditions existed.

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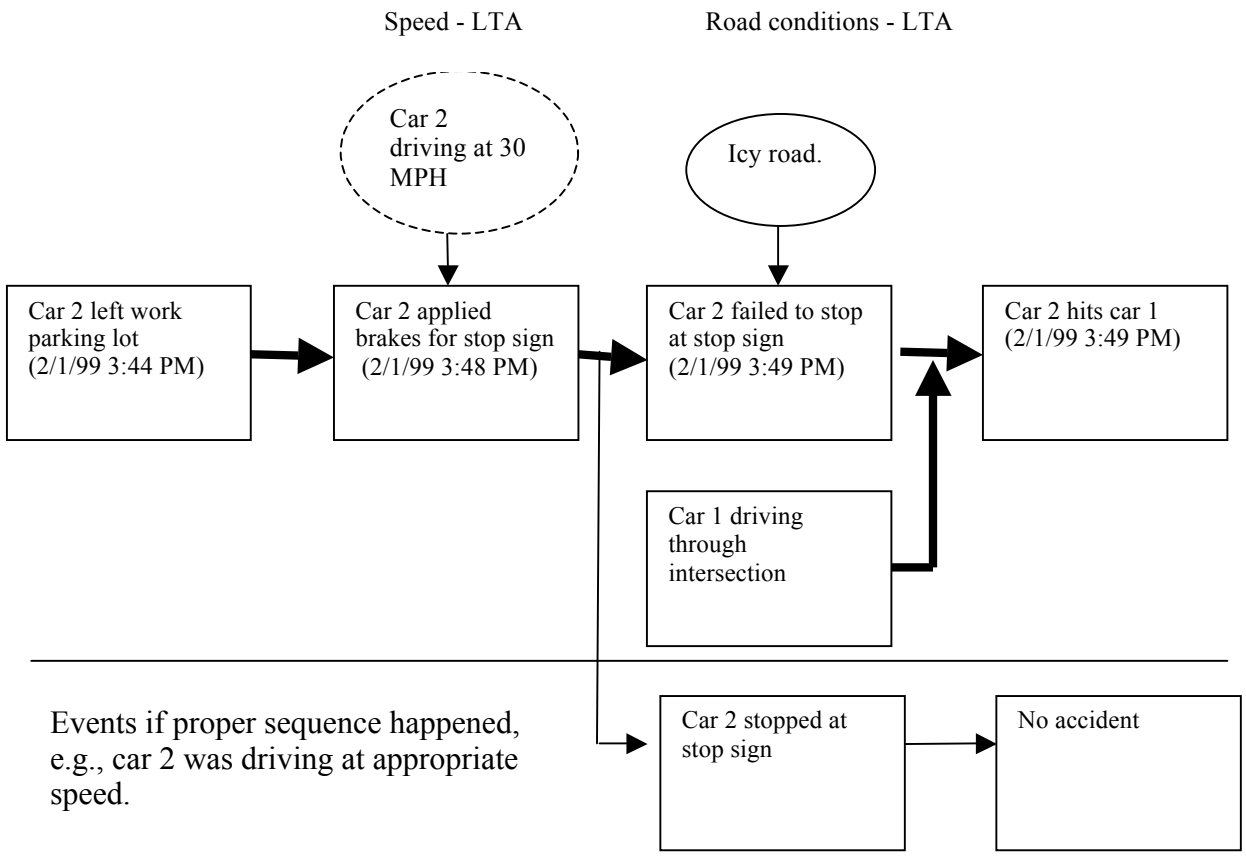

Root cause: Car 2 was driving too fast for the road conditions.

Most Events and Causal Analyses use the generated diagram to identify all the causes associated with an event. When appropriate, related causes are combined into one root cause.

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Using the ISM Functions and Principles to Review an Event[1]

This is another tool to help the analyst better understand an event.

Function #1: Define the scope of work.

- Were the purpose and scope of the work to be performed clearly defined so that workers could identify any unanticipated conditions and actions that would be outside the authorized work scope?
- Were expectations regarding the removal or control of hazards clearly defined and communicated to the workers?
- Were the required safety support activities identified?
- Were roles, responsibilities, and authorities for the work activity defined and executed appropriately?
- Were the worker qualifications required to safely perform the work identified?
- Were the design, operation, and configuration of equipment known and considered in work planning?
- Were the characteristics of the work environment known and considered in work planning?

Function #2: Identify and analyze the hazards.

- Were the type and magnitude of all possible hazards clearly understood?
- Was the accident potential analyzed?
- Were the consequences of potential accidents described and understood by line management, supervisors, and workers?
- Did the workers provide input to the hazard analysis?
- Did the workers receive any feedback regarding their input?
- Were the standards and requirements associated with the hazards identified?

Function #3: Develop and implement hazard controls.

- Were required physical and engineering hazard controls evaluated for likely effectiveness under the expected work conditions?

[1] From the DOE Conducting Accident Investigations, Rev. 2, available via search at http://www.hss.doe.gov/

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- Were the required administrative controls, such as technical procedures and safety support personnel, in place?
- Were the workers qualified and given hazard- or activity-specific training?
- Was a proper review, approval, and configuration control process in place?

Function #4: Perform work within controls.

- Was the readiness to perform the work checked and confirmed prior to starting work?
- Was appropriate authorization received to start work?
- Was the work performed as planned (i.e., by the intended workers using the pre-approved procedures with the required level of supervision and safety support present with effective hazard controls in place)?
- Were the workers empowered to stop work if unanticipated or unsafe conditions arose?

Function #5: Provide feedback and continuous improvement.

- Was there a system to collect and use feedback from workers on workplace hazards?
- Were workers aware of any hazards affecting the work activity that were not addressed in planning for it?
- Was management made aware of the hazard(s) identified by the workers?
- Were there any lessons learned locally, from audit or evaluation results, or from external operating experience, that applied to the work activity but were not addressed in planning for it?

Guiding principle #1: Line management responsibility for safety.

- Did contractor line management establish documented safety policies and goals?
- Was ISM fully implemented down to the activity level at the time of the accident?
- Was line management proactive in assuring timely implementation of ISM by line organizations, contractors, subcontractors, and workers?
- Were ES&H performance expectations for contractor organizations clearly communicated and understood?
- Did line managers elicit and empower active participation by workers in safety management?

Guiding principle #2: Clear roles and responsibilities.

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- Did line management define and maintain clearly delineated roles and responsibilities for ES&H to effectively integrate safety into site-wide operations?
- Was a process established to ensure that safety responsibilities were assigned to each person (employees, subcontractors, temporary employees, visiting researchers, vendor representatives, lessees, etc.) performing work?
- Did line management establish communication systems to inform the organization, other facilities, and the public of potential ES&H impacts of specific work processes?
- Were managers and workers at all levels aware of their specific responsibilities and accountability for ensuring safe facility operations and work practices?
- Were individuals held accountable for safety performance through performance objectives, appraisal systems, and visible and meaningful consequences?
- Did line management and oversight hold contractors and subcontractors accountable for ES&H through appropriate contractual and appraisal mechanisms?

Guiding principle #3: Competence commensurate with responsibilities.

- Did line managers demonstrate a high degree of technical competence and a good understanding of programs and facilities?
- Did line management have a documented process for assuring that DOE personnel, contractors, and subcontractors are adequately trained and qualified on job tasks, hazards, risks, and Departmental and contractor policies and requirements?
- Were mechanisms in place to assure that only qualified and competent personnel were assigned to specific work activities, commensurate with the associated hazards?
- Were mechanisms in place to assure understanding, awareness, and competence in response to significant changes in procedures, hazards, system design, facility mission, or life cycle status?
- Did line management establish and implement processes to ensure that ES&H training programs effectively measure and improve performance and identify training needs?
- Was a process established to ensure that (1) training program elements are kept current and relevant to program needs, and (2) job proficiency is maintained?

Guiding principle #4: Balanced priorities

- Did line management demonstrate a commitment to ensuring that ES&H programs had sufficient resources and priority within the line organization?
- Did line management clearly establish that integrated safety management will be applied to all types of work and address all types of hazards?

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- Did line management institute a safety management system that provided for integration of ES&H management processes, procedures, and/or programs into site, facility, and work activities in accordance with the Department of Energy Acquisition Regulation (DEAR) ES&H clause (48 CFR 970.5204-2)?
- Were prioritization processes effective in balancing and reasonably limiting the negative impact of resource reductions and unanticipated events on ES&H funding?

Guiding principle #5: Identification of safety standards and requirements

- Was there a process for managing requirements, including the translation of standards and requirements into policies, programs, and procedures, and the development of processes to tailor requirements to specific work activities?
- Were requirements established commensurate with the hazards, vulnerabilities, and risks encountered in the current life cycle stage of the site and/or facility?
- Were policies and procedures, consistent with current DOE policy, formally established and approved by appropriate authorities?
- Did communication systems assure that managers and staff were cognizant of all standards and requirements applicable to their positions, work, and associated hazards?

Guiding principle #6: Hazard controls tailored to work performed.

- Were the hazards associated with the work activity identified, analyzed, and categorized so that appropriate administrative and engineering controls could be put in place to prevent or mitigate the hazards?
- Were hazard controls established for all stages of work to be performed (e.g., normal operations, surveillance, maintenance, facility modifications, decontamination, and decommissioning)?
- Were hazard controls established that were adequately protective and tailored to the type and magnitude of the work and hazards and related factors that impact the work environment?
- Were processes established for ensuring that DOE contractors and subcontractors test, implement, manage, maintain, and revise controls as circumstances change?
- Were personnel qualified and knowledgeable of their responsibilities as they relate to work controls and work performance for each activity?

Guiding principle #7: Operations authorization

- Were processes in place to assure the availability of safety systems and equipment necessary to respond to hazards, vulnerabilities, and risks present in the work environment?

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- Did DOE and contractor line management establish and agree upon conditions and requirements that must be satisfied for operations to be initiated?
- Was a management process established to confirm that the scope and authorization documentation is adequately defined and directly corresponds to the scope and complexity of the operations being authorized?
- Was a change control process established to assess, approve, and reauthorize any changes to operations scope ongoing at the time of the accident?

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Most of the analyses performed are based on a timeline of events. If the analysis is triggered by an event, such as an accident, the analysis should cover the entire time frame from planning for the work to be done, performing the work, the event, and post-event activities, such as rescue work or clean-up. This timeline can be presented in a visual format, such as that presented in Attachment 2 for the events and causal factors analysis, using software such as Visio or Concept Draw for the PC or Concept Draw, OmniGraffle, or EazyDraw for the Macintosh. However, such diagrams can be difficult and time consuming to generate or modify. A simple timeline table, generated in Word as a table or Excel, might be more effective. An example of such a table is given below, where the purpose of each column is:

is a sequential number assigned to each row of the table (serves as a reference identifier and simplifies communication).

Date and time that the event listed in the row occurred

What happened on that day and at that time

What should have happened

Significance of the event versus what should have happened relative to the actual incident for which the root cause analysis is being performed

One or more columns used to document the results of the root cause analysis as applicable to the items of the timeline. These columns might list failed barriers that resulted in that step of the timeline or HPI codes associated with that line. An additional use of this tool is to add a full line where a status statement is beneficial as illustrated below.

#	Date/ Time	What happened	What should have happened	Significance	Result of analysis technique 1	Result of analysis technique 2
5	6/8/ 08 noon	Operator turned switch "water systems on"	The operator should have turned switch "backup water systems on"	The wrong system was enabled.	The barrier "labeling of controls" was LTA.	Confusing displays / controls (HPI code)
Sample status statement: As a result of switching on the water systems instead of the backup water systems, water did not flow into the system.						

It is helpful at this point to count the number of times a specific value was listed in the results table. For the sample above, there would be counts for the barrier "labeling of controls was LTA" and "HPI - Confusing displays/controls". These counts could provide some indication of the significance of a causal factor. However, one occurrence of a causal factor could still be very significant and not discarded casually.

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The direct cause is the immediate events or conditions that caused the accident or event.

The root cause is the most basic reason(s) for a problem/event, which, if corrected, will minimize the chance of recurrence of that and other similar problems or events. Note that there may be more than one root cause, though, in most cases, one will be most significant.

A contributory cause is an event or condition that, collectively with other causes, increases the likelihood of an accident but which did not individually cause the accident.

The appropriate criteria used to validate a root cause are:

- The event/problem would not have occurred had the root cause not been present.
- Correction or elimination of the cause(s) will ensure that the problem will not recur due to the same causal factors.
- Correction or elimination of the cause(s) will preclude repetition of the specific problem or of similar problems.

The root cause should provide an explanation (the why) of a direct cause, not a repeat of the direct cause. Root causes are generally attributable to an action or lack of action by a particular group or individual, typically at a management level.

Note that the root cause of an accident can be found at the worker level if and only if the following conditions are found to exist:

- Management systems were in place and functioning and provided management with feedback on system implementation and performance.
- Management took appropriate actions based on the feedback.
- Management, including supervision, could not reasonably have been expected to take additional actions based on their responsibilities and authorities.

Contributory causes are the remaining causal factors that are not root or direct.

it is helpful to determine if there are linkages between some causal factors that might result in these factors being either incorporated into one causal factor or result in an additional causal factor. As an example, causal factors associated with the maintenance and operation of equipment might result in an additional causal factor associated with inadequate management systems and oversight. This new causal factor might not eliminate the existing causal factors, but be an additional and more significant one.

In the process of doing the formal root cause analysis, the team might identify additional issues that are not direct, contributory, or root causes but are important and should be resolved. These are typically concerns that by themselves would not have impacted the specific problem or event, but, nevertheless, should be resolved. These auxiliary concerns should be included in the report or a separate, related report and identified as such in order to assure that they are properly addressed and future problems prevented.

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Tier diagramming is used once causes are identified via one of the techniques described in attachment 2. Tier diagramming is used to determine the levels of line management that have the responsibility and authority to correct the causal factors. It can also be used as a validation tool for the causal factors identified. Finally, it can also be used to identify linkages among causal factors to help further develop and refine appropriate root causes.

Tier diagramming is helpful in identifying and analyzing root causes because it:

- Helps organize and categorize the identified causal factors
- Provides a structured method for linking causal factors into higher-level, fundamental organizational deficiencies (root causes)
- Provides a structured and repeatable approach for assigning management or oversight responsibility for each causal factor
- Requires the assignment of responsibility for causal factors, from which appropriate judgments of need can later be developed
- Assists in visually and physically organizing significant causal factor data.

The tier diagram consists of multiple tiers, ranging from the worker at the bottom to senior management at the top. Each cause is then assigned to one or more tiers via a process that is described later. The highest level tier chosen for a given causal factor is the primary management level responsible for resolving the causal factor. If an appropriate level cannot be determined, then the analysis may be flawed and should be reviewed.

The table below is used for this analysis.

Tier	Typical Management Responsibilities	Sample Questions to Assist in Assigning Causal Factors to Management Levels
Tier 5: Senior Management, e.g. Department Head or higher	• Develop policies. • Communicate policies and expectations. • Prioritize activities and allocate resources. • Oversee compliance with contract terms and conditions. • Monitor performance.	• Did senior management establish policies and goals? • Did senior management define and maintain clearly delineated roles, responsibilities, authorities, and accountabilities? • Were these clearly communicated and understood? • Was senior management involved in the site-wide prioritization of work? • Did senior management hold line managers accountable for performance? • Did senior management monitor performance of its systems?

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Tier	Typical Management Responsibilities	Sample Questions to Assist in Assigning Causal Factors to Management Levels
Tier 4: Middle Management, e.g. Division Head	• Same as Senior Management with smaller span of control. • Develop plans and programs to implement policy. • Oversee problem identification and corrective action processes for items within span of control. • Solicit and respond to feedback and lessons learned.	• Did management implement the policy through plans and programs development? • Was management aware of the status of plans and program implementation? • When problems occurred, did management request feedback on the nature of problems? • Did management have a system for monitoring and measuring organizational performance? • Was management involved in the development and implementation of corrective actions for problems that were identified?
Tier 3: Lower Management, e.g. Section or Branch Heads	• Develop procedures to implement plans and program. • Ensure hazard awareness and communication. • Oversee work planning and execution. • Solicit and use worker input. • Implement corrective actions.	• Were required procedures developed and kept current to ensure a safe worker environment? • Did management implement the required program for worker safety? • Was management aware of problems regarding procedure implementation and compliance? • Was management involved in work planning, control, and execution process? • Did management have a system for eliciting feedback on the work being done? • Did management take timely corrective actions when problems occurred or were identified? • Did management have a system for identifying and disseminating work process lessons learned? • Was stop work authority defined for first line supervisors and their staff?

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Tier	Typical Management Responsibilities	Sample Questions to Assist in Assigning Causal Factors to Management Levels
Tier 2: Supervision	• Control the work scope. • Identify hazards. Implement appropriate hazard controls. • Monitor progress of jobs/tasks in progress. • Provide feedback and identify lessons learned. • Identify opportunities for improvement and reduced risks. • Ensure workers are aware of current work controls/procedures	• Were the work instructions adequate for the work to be done? • Was the environment for the work appropriate? • Were required procedures provided or communicated to the work by supervision? • Did the supervisor provide feedback to management on incidents or concerns? • Did the supervisor discuss job hazards and work activities with the worker prior to the start of work? • Did the supervisor implement timely corrective actions based on previous incidents or concerns? • Did the supervisor confirm the readiness to perform the work prior to its execution? • Did the supervisor provide the worker with the proper tools and equipment? • Did the supervisor clarify stop-work authority for workers?

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Tier	Typical Management Responsibilities	Sample Questions to Assist in Assigning Causal Factors to Management Levels
Tier 1: Worker Actions	• Maintain competence for position. • Maintain awareness of the work controls/procedures • Perform work within controls. • Identify hazards or problems and report. • Stop work, if necessary.	• Were the worker's knowledge, skills, and abilities adequate to perform the job? • Did the worker understand the work to be performed? • Were communications adequate to inform the worker of any hazards or complications associated with the work? • Was the worker knowledgeable of the type and magnitude of the hazards associated with the work? • Was the work covered by procedures? • Was the worker trained on the procedures? • Did the worker have the right tools and equipment for the work? • Did the worker have and understand stop-work authority?
Tier 0: Direct Cause		

The steps involved in this process include:

1. Identify the direct, contributory, and root causal factors using the root cause analysis techniques identified earlier in this attachment. Note that, when appropriate, multiple causal factors may be linked together into one.
2. Assign letter designators to each direct, contributory or root causal factor, e.g., A, B, C, etc.
3. Create a simple table with one row for each tier appropriately labeled. A model is presented below.

Tier	Associated Causal Factors
Tier 5: Senior Management, e.g. Department Head or higher	
Tier 4: Middle	

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Management, e.g. Division Head	
Tier 3: Lower Management, e.g. Section or Branch Heads	
Tier 2: Supervision	
Tier 1: Worker	
Tier 0: Direct Cause	

4. For each direct cause, indicate the associated letter in tier 0.
5. For each causal factor, in turn, using the sample questions as guidance:
    a. Evaluate whether the worker actions are responsible, at least in part, for this factor. If so, enter the letter associated with the causal factor in tier 1.
    b. Evaluate whether the supervisor had any responsibility associated with this causal factor. If so, write the causal factor letter (A, B, …) in tier 2 .
    c. Evaluate whether lower management had any responsibility associated with the causal factor. If so, write the causal factor letter in tier 3 .
    d. Continue the process up to the top tier – senior management. The goal is to identify the highest level of responsibility or authority for a causal factor.
6. Examine the causal factors as indicated on the tier diagram to identify any linkages. For example, are a group of causal factors related to poor conduct of operations or training? If so, consider combining these causal factors into one and assigning it to the highest tier with responsibility for the conduct of operations or training or responsible to resolve the causal factor Such groupings can be indicated by circling the related causal factors. Write a new causal factor to replace or supplement the individual causal factors.
7. Review the causal factors again for validity and completeness.

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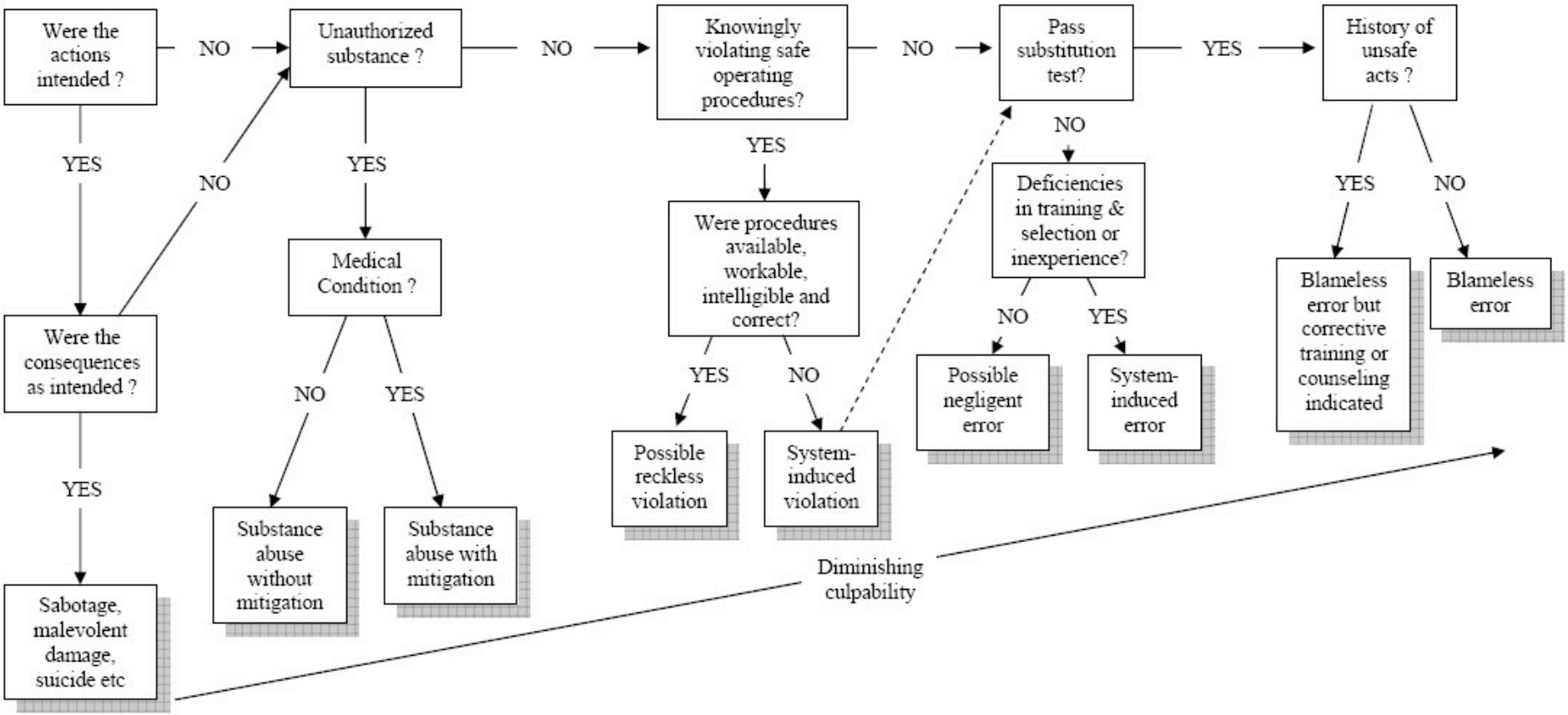

From James Reason - A decision tree for determining the culpability of unsafe acts.

Substitution Test – Would another individual coming from the same professional group, possessing comparable qualifications and experience, behave in the same way in similar circumstances?

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The suggested format is presented below, where "*" indicates required content:

1. Table of Contents
2. Acronyms used within the report
3. Executive Summary*
4. Introduction*
   a. Background – a very brief description of the event or conditions that triggered the analysis and the initiation of the root cause analysis
   b. Facility Description – for accidents, a description of the facility at which the accident occurred
   c. Scope, Conduct, and Methodology – a few words on how the RCA was performed
5. Causal Factor Analysis *
   a. Specifics on the techniques used
   b. Root Causes – as identified by the RCA
   c. Contributory causes – as identified by the RCA
   d. Direct cause –as identified by the RCA
   e. Auxiliary Issues – as identified by the RCA
   f. Tier Diagram, if performed
6. Conclusions and Judgments of Need/Recommendations*
7. Signatures of the committee members*
8. Appendices – possible appendices are:
   a. Memo appointing the investigate committee
   b. List of individuals interviewed
   c. List of documents reviewed
   d. Exhibits, Figures, Photos, and Tables
   e. Timeline

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The information in this attachment is partially based on information documented in the EFCOG - Price-Anderson Amendments Act Work Group White Paper on Extent of Condition Evaluations (http://www.efcog.org/guides/EXTENT%20OF%20CONDITION.pdf)

Imagine an iceberg. Typically, the visible part is much smaller than the actual size, with most of the iceberg under water. Likewise, the causal factors identified by a root cause analysis that resulted in an event might have a much broader potential impact. An Extent of Condition analysis searches for the larger potential impact.

Criteria for determining if an Extent of Condition is appropriate might be:

- Uniqueness – What makes an issue unique versus potential for occurrence elsewhere?
- Recurrence – Repetitive and similar issues suggest ineffective corrective/preventive actions and the need for an EOFC. Review the circumstances that led to the identification of the causal factor to determine what issues require follow-up for the extent of conditions review.
- Seriousness – Some lower threshold issues are more serious than others and should be considered for evaluation

An Extent of Condition is performed to determine if causal factors identified in a root cause analysis exist in other laboratory organizations, hardware, processes, programs, projects, etc. These issues may be technical, quality, or safety related.

Not every causal factor may be included in the EOFC. Each of the causal factors should be evaluated as a separate item unless there a correlation exists between two or more of them. The level of effort needed for the evaluation will vary depending upon the conditions of the causal factor. The following considerations are useful in determining what factors to include in the EOFC:

- Determine activities or facilities to which the causal factor applies.
- Review the results of investigations, critique results, or cause determinations, if applicable.
- Develop a line of inquiry or checklist based on the results of the review and the conditions described in the causal factor.
- Using responses to the line of inquiry or checklist, identify the extent of applicability to other activities, processes, equipment, programs, facilities, operations, and organizations.

The approach for conducting an EOFC typically includes collecting data, interviewing people, observing work in progress, etc.

It is usually helpful to organize a table for each causal factor identified during an RCA that is to be investigated further for the extent of condition. Each row represents other activities, hardware, facilities, etc. for which the causal factor may apply. Each column represents one of the aspects to be reviewed.

Examples are:

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A cause identified by an RCA concerns maintenance of hardware. The table might have a row for each piece of relevant hardware. The columns might list the name of the hardware, the type of equipment, the manufacturer, the property tag number, who is responsible to perform the maintenance, what type of maintenance is required, the periodicity of preventive maintenance, the adequacy of maintenance - whatever information is needed to determine if the condition identified by the root cause analysis might also exist in this hardware.

A cause identified by an RCA concerns the adequacy of training to perform certain tasks. The table might have a row for each task that is of concern. The columns might list the training that should be provided for the task with content topics, the training that is actually provided for the task with content topics, the adequacy of the content of the training, the types of individuals that should receive the training, the actual individuals who did receive the training, feedback from individuals who took the training, and any other information that might be relevant.

Once completed, the results documented in the table can be used to identify other instances to which the same or similar causal factors apply. From this information, new or modifications to existing causal factors and judgments of needs can be identified.

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If the extent of condition is to be documented separately from the root cause analysis report, the suggested format is presented below, where "*" indicates required content:

1. Table of Contents
2. Acronyms used within the report
3. Executive Summary*
4. Methodology*
5. Observations* - consider formatting the observations by charge statements
6. Judgments of Need, if any
7. Signatures of the committee members*
8. Appendices – possible appendices are:
    a. Memo appointing the Extent of Condition Investigation Team
    b. List of individuals interviewed
    c. List of documents reviewed
    d. Exhibits, Figures, Photos, and Tables

If the extent of condition is to be documented as part of the root cause analysis report, then an additional section should be added to the report for the extent of condition and include the information above.

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