Root Cause Analysis Overview

July 2003

**Office of Safety & Mission Assurance
Chief Engineers Office**

Agenda

- **Background**

- **Definitions: Proximate Cause, Root Cause, Root Cause Analysis (RCA)**

- **Steps in RCA**

- **RCA for Accident Investigation**

- **RCA Tools**

- **For More Information**

- **Definitions for Related Terms**

Background

We are "One NASA, one team on one journey"

Yet we are…

"Common people separated by a different language"

Winston Churchill

Currently multiple definitions exist for root cause and related terms in NASA Procedures and Guidelines (NPGs) and training courses.

This has led to many different interpretations of "root cause."

Background

Purpose of this Root Cause Analysis overview:

- **Establish common terminology in the NASA community to facilitate improved communication and understanding.**

- **Ensure that when teams say that they have performed "root cause analysis," they are describing the results of detailed evaluations which reach the same level of causation.**

Background

When performing root cause analysis, it is necessary to look at more than just the immediately visible cause, which is often the proximate cause.

There are underlying organizational causes that are more difficult to see, however, they may contribute significantly to the undesired outcome and, if not corrected, they will continue to create similar types of problems.

These are root causes.

Definitions

Revised definitions were made with input from Centers and Headquarters safety and engineering professionals.

<u>Proximate Cause(s)</u>
- The event(s) that occurred, including any condition(s) that existed immediately before the undesired outcome, directly resulted in its occurrence and, if eliminated or modified, would have prevented the undesired outcome.

- Also known as the <u>direct cause</u>.

- Examples of undesired outcomes: failure, anomaly, schedule delay, broken equipment, product defect, problem, close call, mishap, etc.

Definitions

Root Cause(s)

- One of multiple factors (events, conditions or organizational factors) that contributed to or created the proximate cause and subsequent undesired outcome and, if eliminated, or modified would have prevented the undesired outcome. Typically multiple root causes contribute to an undesired outcome.

Organizational factors

- Any operational or management structural entity that exerts control over the system at any stage in its life cycle, including but not limited to the system's concept development, design, fabrication, test, maintenance, operation, and disposal.

- Examples: resource management (budget, staff, training); policy (content, implementation, verification); and management decisions.

Definitions

Root Cause Analysis (RCA)

- A structured evaluation method that identifies the root causes for an undesired outcome and the actions adequate to prevent recurrence. Root cause analysis should continue until organizational factors have been identified, or until data are exhausted.

- RCA is a method that helps professionals determine:
    - What happened.
    - How it happened.
    - Why it happened.

- Allows learning from past problems, failures, and accidents.

Purpose of Root Cause Analysis

- The objective of RCA is to identify "root cause(s)" so that these latent failures may eliminated or modified and future occurrences of similar problems or mishaps may be prevented.

- <u>Analysis Pitfall:</u> If root cause analysis is <u>not</u> performed, and the analyst only identifies and fixes the proximate causes, then the underlying causes may continue to produce similar problems or mishaps in the same or related areas.

- For example: A fuse blows out and cause(s) the lights to go off. You can identify the proximate cause, "fuse blew", and replace the fuse. You can also identify the intermediate cause "a short" and repair the wire that shorted. However, if you do not identify and correct the organizational factor that led to the fuse going out (e.g., wiring not maintained because there was insufficient maintenance budget), other systems may have similar failures due to lack of maintenance. Root cause analysis seeks to identify the systemic problems, such as lack of maintenance budget, and correct these so that related problems or mishaps do not occur.

Overview of Steps in Root Cause Analysis

- **Clearly define the undesired outcome.**

- **Gather data, including a list of all potential causes.**

- **Create an event and causal factor tree.**

- **Continue asking "why" to identify root causes.**

- **Check your logic and eliminate items that are not causes.**

- **Generate solutions that address both proximate causes and root causes.**

Root Cause Analysis - Steps

Clearly define the undesirable outcome.

- **Describe the undesired outcome.**

- **For example: "relief valve failed," "employee broke his arm," "XYZ project schedule significantly slipped."**
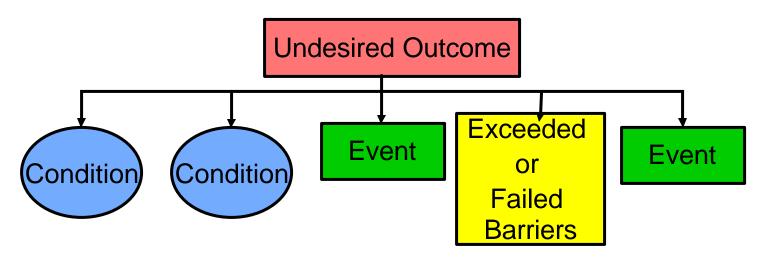
Gather data.

- **Identify facts surrounding the undesired outcome.**

  - **When did the undesired outcome occur?**

  - **Where did it occur?**

  - **What conditions were present prior to its occurrence?**

  - **What controls or barriers could have prevented its occurrence but did not?**

  - **What are all the potential causes?**

  - **What actions can prevent recurrence?**

Root Cause Analysis - Steps

Create an event and causal factor tree.

- **Place the undesired outcome at the top of the tree.**

- **Add all events, conditions, and exceeded/failed barriers that occurred immediately before the undesired outcome and might have caused it.**

- **Brainstorm to ensure that all possible causes are included, *NOT* just those that you are sure are involved.**

- **Be sure to consider people, hardware, software, policy, procedures, and the environment.**

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                    ┌─────────────────────┐
                    │  Undesired Outcome  │
                    └─────────────────────┘
       ┌──────────┬──────────┬──────────┬──────────┐
  (Condition)(Condition)  [Event]  [Exceeded  [Event]
                                     or
                                   Failed
                                   Barriers]
```

Definitions

Event

- **A real-time occurrence describing one discrete action, typically an error, failure, or malfunction.**
- **Examples: pipe broke, power lost, lightning struck, person opened valve, etc…**

Condition

- **Any as-found state, whether or not resulting from an event, that may have safety, health, quality, security, operational, or environmental implications.**
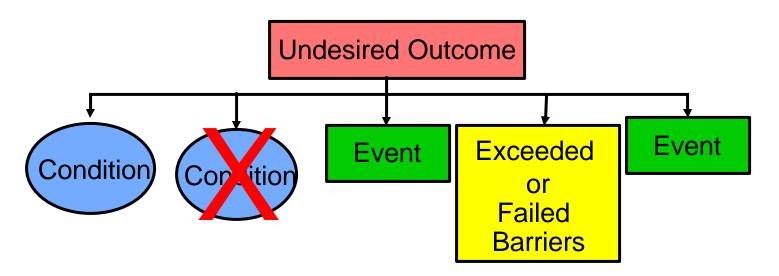
Barrier

- **A physical device or an administrative control used to reduce risk of the undesired outcome to an acceptable level.**
- **Barriers can provide physical intervention (e.g., a guardrail) or procedural separation in time and space (e.g., lock-out-tag-out procedure).**

Root Cause Analysis - Steps

Create an event and causal factor tree continued...

- **If you have <u>solid data</u> indicating that one of the possible causes is not applicable, it can be eliminated from the tree.**

- **<u>Caution</u>: Do not be too eager to eliminate early on. If there is a possibility that it is a causal factor, leave it and eliminate it later when more information is available.**
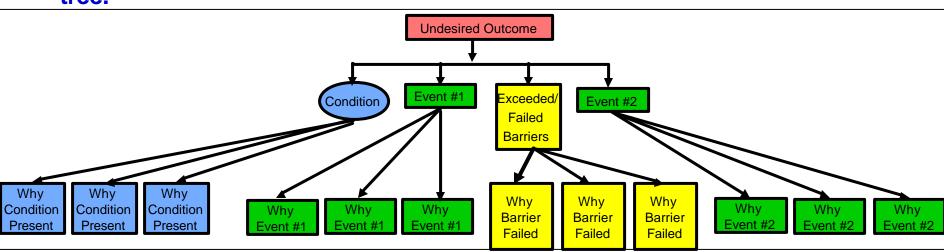
Create an event and causal factor tree continued…

- After you have identified all the possible causes, ask yourself "*WHY*" each may have occurred.

- Be sure to keep your questions focused on the original issue. For example "Why was the condition present?"; "Why did the event occur?"; "Why was the barrier exceeded?" or "Why did the barrier fail?"

- A fault tree, used to determine system failure causes down to the "basic event" (e.g., system component level), is often used as part of the event tree.
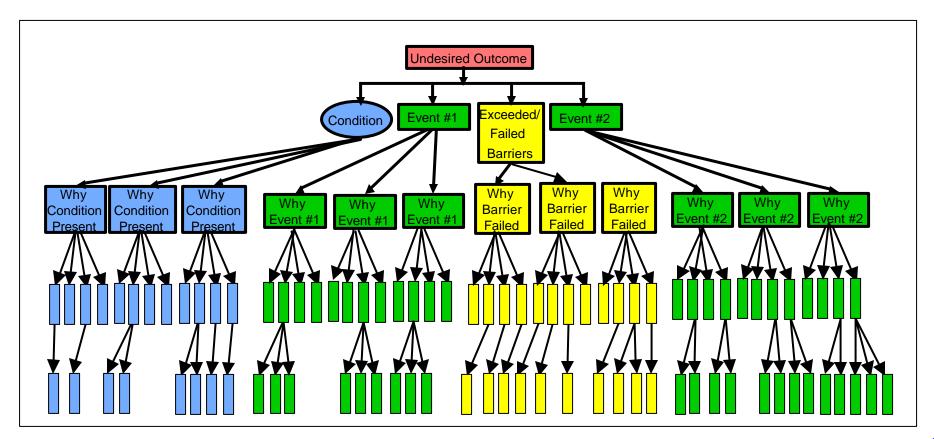
Root Cause Analysis – Steps

Continue to ask "why" until you have reached:

1. **Root cause(s) - including all organizational factors that exert control over the design, fabrication, development, maintenance, operation, and disposal of the system.**

2. **A problem that is not correctable by NASA or NASA contractor.**

3. **Insufficient data to continue.**

Root Cause Analysis - Steps

The resultant tree of questions and answers should lead to a comprehensive picture of _POTENTIAL_ causes for the undesired outcome.
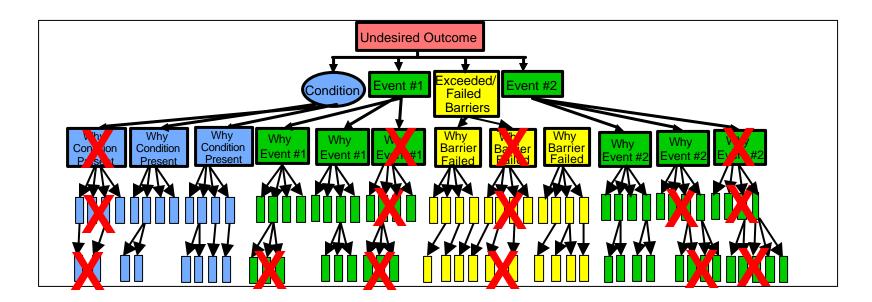
Root Cause Analysis- Steps

Check your logic with a detailed review of each potential cause.

- **Compare a cause with facts to verify it is a contributor.**
- **If the action, deficiency, or decision in question were corrected, eliminated or avoided, would the undesired outcome be prevented or avoided?**
  - > **If yes, then it is a cause. Keep it on the tree.**
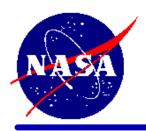 - > **If no, then eliminate it from the tree.**

Root Cause Analysis- Steps

Check your logic with a detailed review of each potential cause.

In some cases, it may be difficult to be 100% certain that an event or condition is a cause because the data necessary to provide certainty is not available (e.g. perhaps evidence was destroyed in the accident).

In these cases, the analyst can use the term "probable" to describe the proximate, intermediate, or root cause and indicate that it is a reasonable cause; having more evidence for it than against it.
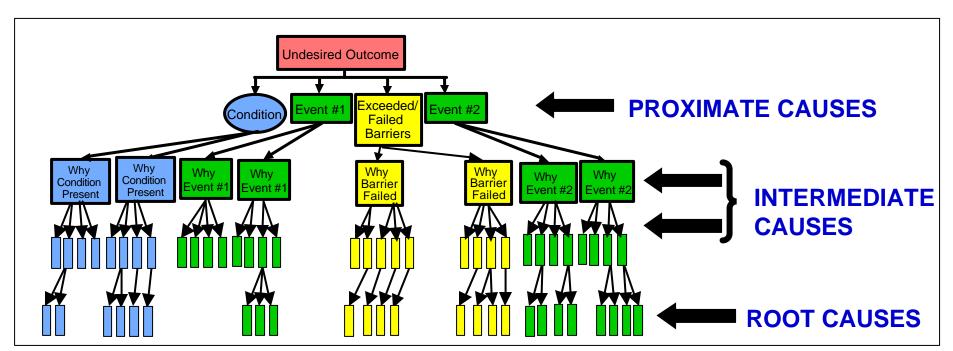
These causes should remain on the fault tree until disproved.

Root Cause Analysis - Steps

Create an event and causal factor tree continued…

- **The remaining items on the tree are the causes (or probable causes). necessary to produce the undesired outcome.**

- **Proximate causes are those immediately before the undesired outcome.**

- **Intermediate causes are those between the proximate and root causes.**

- **Root causes are organizational factors or systemic problems located at the bottom of the tree.**
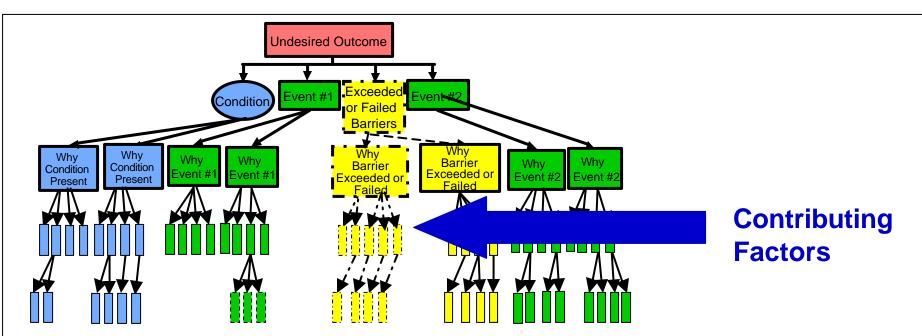
Root Cause Analysis- Steps

Some people choose to leave contributing factors on the tree to show all factors that influenced the event.

> **Contributing factor: An event or condition that may have contributed to the occurrence of an undesired outcome but, if eliminated or modified, would not by itself have prevented the occurrence.**

If this is done, illustrate them differently (e.g., dotted line boxes and arrows) so that it is clear that they are not causes.

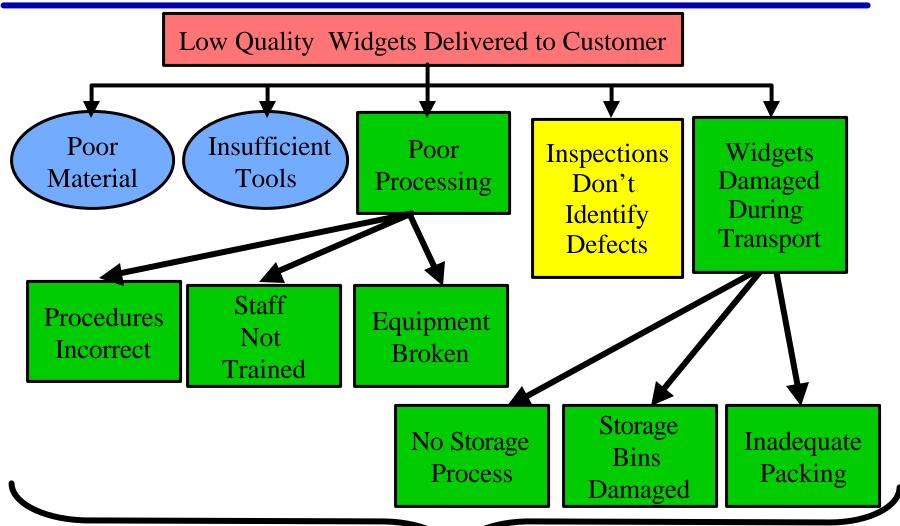# Root Cause Analysis- Steps

Generating Recommendations:

At a minimum corrective actions should be generated to eliminate proximate causes and eliminate or mitigate the negative effects of root causes.

When multiple causes exist, there is limited budget, or it is difficult to determine what should be corrected:

- **Quantitative analysis can be used to determine the total contribution of each cause to the undesirable outcome (see NASA Fault Tree Handbook, Version 1.1, for more information).**

- **Fishbone diagrams (or other methods) can be used to arrange causes in order of their importance.**

- **Those causes which contribute most to the undesirable outcome should be eliminated or the negative effects should be mitigated to minimize risk.**

Root Cause Analysis - Example

Low Quality Widgets Delivered to Customer

- Poor Material
- Insufficient Tools
- Poor Processing
  - Procedures Incorrect
  - Staff Not Trained
  - Equipment Broken
- Inspections Don't Identify Defects
- Widgets Damaged During Transport
  - No Storage Process
  - Storage Bins Damaged
  - Inadequate Packing

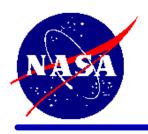**CONTINUE ANALYSIS FOR ALL PROXIMATE CAUSES**

RCA in Accident Investigation

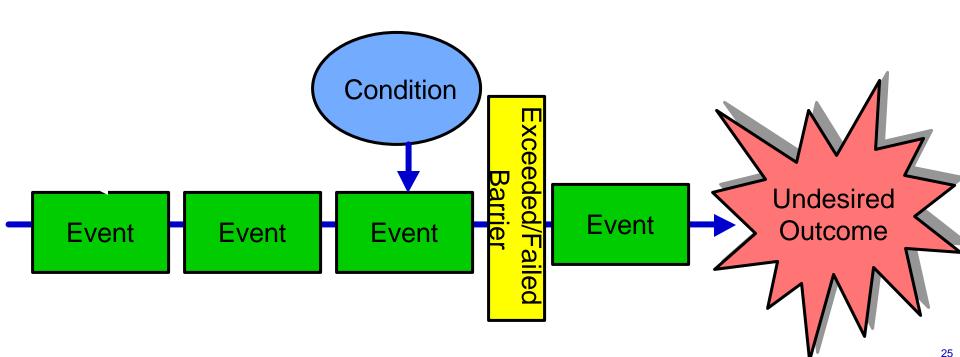RCA used in accident investigation has many similarities and a few notable differences:

Some Additional Steps for Accident Investigation

1) Create a timeline: Describe and illustrate the sequence of events and conditions that led to an accident. (RCA used to analyze some problems may also require a timeline.)

2) Create an event and causal factor tree that includes the following as *POTENTIAL* proximate causes:

- *harmful energy sources, energy flow, conditions*

- *events*

- *exceeded/failed barriers*

- *presence of target (person or object) affected by the harmful energy*

RCA in Accident Investigation

Create a timeline (sequence diagram)

- **Illustrate the sequence of events in chronological order horizontally across the page.**

- **Depict relationships between conditions, events, and exceeded/failed barriers.**

```
           Condition
              |
              v
Event -- Event -- Event -- [Exceeded/Failed Barrier] -- Event --> Undesired Outcome
```

RCA in Accident Investigation

Example: simple timeline.

Road wet

Dog ran into road → Driver swerved car → Car slid into guardrail → Guard rail broke → Car hit tree → Car destroyed

RCA in Accident Investigation

Create an event and causal factor tree.

- **Add all harmful energy, events, exceeded/failed barriers, and people/objects affected by the harmful energy that produced the undesired outcome.**

```
                    ┌──────────────────────┐
                    │  Undesired Outcome   │
                    └──────────────────────┘
```

- Harmful Energy, Condition, or Hazard
- Event
- Event
- Exceeded or Failed Barriers and Controls
- Person or Object Affected by Harmful Energy

RCA for Accident - Example

Damage to the equipment

Proximate Causes

LN2 in tank

valve opened

pipe leaked

quality did not detect leak

equipment under the pipe

tank is normal storage device

technician performing test

seal failed

quality looking at different location

insufficient time to put equipment away

no maintenance performed

defective seal

quality doing multiple tasks at same time

too many tasks scheduled

no routine maintenance procedure

quality inspection not performed

budget not allocated to create procedure

not enough quality personnel

Root Causes

RCA Tools

- **There are a variety of tools that can assist in root cause analysis. Below are just a few:**

  - **Flow Chart – Illustrates major processes in a business system.**

  - **Multi-linear Events Sequencing (MES) – Identifies main actor(s) and their actions and maps the relations between these along a timeline.**

  - **Fault Tree Analysis – Identifies possible causes and different levels of causation.**

  - **Barrier Analysis – Evaluates energy flows, events, exceed/failed barriers, and targets (victims or objects) to determine what barriers can prevent or mitigate the undesired outcome.**

  - **Change Analysis – Compares the normal situation and the accident situation and looks for changes that occurred. Evaluates changes to determine if they are causes of the accident.**

For More Information

- **NASA Safety Training Center Course**
  - **NSTC 049: Root Cause Analysis   (2-3 days)**

- **NASA PBMA Mishap Investigation Website (http://ai-pbma-kms.intranets.com/login.asp?link=)**
  - **Includes:**
    - **Links (e.g, to Root Cause Analysis Software, a RCA Library).**
    - **Documents (e.g., Methods, Techniques, Tools, Publications and Presentations).**
    - **Threaded Discussions and Polls.**

- **HQ Office of Safety & Mission Assurance**
  - **Faith.T.Chandler@nasa.gov**

Definitions of RCA & Related Terms

Cause (Causal Factor)	An event or condition that results in an effect. Anything that shapes or influences the outcome.
Proximate Cause(s)	The event(s) that occurred, including any condition(s) that existed immediately before the undesired outcome, directly resulted in its occurrence and, if eliminated or modified, would have prevented the undesired outcome. Also known as the direct cause(s).
Root Cause(s)	One of multiple factors (events, conditions or organizational factors) that contributed to or created the proximate cause and subsequent undesired outcome and, if eliminated, or modified would have prevented the undesired outcome. Typically multiple root causes contribute to an undesired outcome.
Root Cause Analysis (RCA)	A structured evaluation method that identifies the root causes for an undesired outcome and the actions adequate to prevent recurrence. Root cause analysis should continue until organizational factors have been identified, or until data are exhausted.
Event	A real-time occurrence describing one discrete action, typically an error, failure, or malfunction. Examples: pipe broke, power lost, lightning struck, person opened valve, etc…
Condition	Any as-found state, whether or not resulting from an event, that may have safety, health, quality, security, operational, or environmental implications.
Organizational Factors	Any operational or management structural entity that exerts control over the system at any stage in its life cycle, including but not limited to the system's concept development, design, fabrication, test, maintenance, operation, and disposal. Examples: resource management (budget, staff, training); policy (content, implementation, verification); and management decisions.
Contributing Factor	An event or condition that may have contributed to the occurrence of an undesired outcome but, if eliminated or modified, would not by itself have prevented the occurrence.
Barrier	A physical device or an administrative control used to reduce risk of the undesired outcome to an acceptable level. Barriers can provide physical intervention (e.g., a guardrail) or procedural separation in time and space (e.g., lock-out-tag-out procedure).