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CRDEC-SP-053

ROOT CAUSE ANALYSIS METHODOLOGY

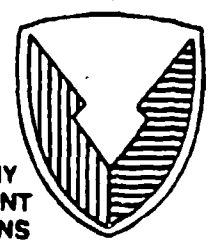
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RESEARCH DIRECTORATE

September 1992

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13. ABSTRACT (Maximum 200 words) A Root Cause Analysis is performed to identify the real source (i.e., root cause) of a problem. The process includes a sequential series of steps that will both determine the root causes as well as document the basis for this determination. There are many different techniques in use to achieve this same end and are referred to as Failure Analyses, Problem Investigations, etc. A particular Root Cause Analysis Methodology that is employed throughout AMCCOM will be presented. The purpose of this report is to present a description of the specific steps involved in this methodology including various procedures that aid in achieving thoroughness and objectivity.				
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ROOT CAUSE ANALYSIS METHODOLOGY

I. INTRODUCTION

The primary purpose of a Root Cause Analysis is to identify the real source (i.e., root causes) of a problem.^{1,2,3,4} It is someone else's job to solve the problem. A formal, systematic process is followed which identifies the root causes as well as documenting the basis for these results. There are many different techniques in use to achieve this end sometimes referred to as Failure Analyses, Problem Investigations, etc.. A particular Root Cause Analysis Methodology which is employed throughout AMCCOM will be presented in this report.

The Root Cause Analysis includes a sequential series of steps which will both determine the root causes as well as document the basis for this determination. Some flexibility is possible, where the technique can be adapted to fit various technical situations, time, funding, etc. The steps in the Root Cause Analysis are as follows:

- Establish Problem Statement
- Prepare Memorandum of Agreement
- Briefing by Blue Team
- Perform Independent Design Review
- Construct Critical Areas Diagram
- Complete Failure Mode Charts
- Categorize Failure Mode Charts
- Formulate Focus Chart and Focus Diagram
- Determine Probable Root Causes
- Plan Root Cause Confirmation Tests
- Propose Corrective Measures*
- Present Final In-Process Review
- Write Final Report

*NOTE: A Root Cause Analysis is usually limited to defining the root causes to a problem. However, an additional requirement is frequently included to recommend corrective actions or "solutions" for the problem.

The following is a detailed description of these steps along with various procedures which aid in achieving thoroughness and objectivity. Charts summarizing the main points of the various items discussed are included in the appendix and are referred to in the text in parenthesis as (A-).

II. ROOT CAUSE ANALYSIS OBJECTIVE/PROCESS

A Root Cause Analysis is usually initiated in response to a chronic problem on a project. If a problem has persisted for a long time and the proposed fixes are not working, it may be that the real problem is not being addressed. Accordingly, a Root Cause Analysis would establish the actual source of the problem. In many cases, it will confirm that the project people are truly aware of the real problem, but the Root Cause Analysis will document this and provide confidence that other factors are not being over-looked. (A-1) As noted previously, the objective of the Root Cause Analysis is to identify the source of the problem. It is someone else's job to solve the problem. It might also be noted that a Root Cause Analysis is not limited to technical problems; it can also be used for managerial, administrative, economic, and other non-technical situations. (A-2)

Essentially the job of the assigned "study team" (referred to as a Red Team, Tiger Team, Problem Analysis Team, etc.) is to perform the Root Cause Analysis. In this endeavor, they do not work alone, but act in an adjunct capacity to the people already working on the project who are termed the "Blue Team". The Red Team provides objectivity, acts as a guide in following the Root Cause Analysis process, and serves as a catalyst for the Blue Team.

Root Cause Analysis can involve various degrees of involvement from an extremely intensive, Red Team to a less intensive, Problem Analysis. Both extremes involve the same Root Cause Analysis procedure. The complete Red Team approach starts from the most general viewpoint and initially considers every aspect of the system or item being investigated. On the other hand, a Problem Analysis bypasses the initial broad evaluation and focuses immediately on the areas felt to be the most crucial. This latter approach, while shorter, introduces the risk of missing the real root cause.

In addition to the procedure itself, there are certain techniques which will help produce objectivity and thoroughness. The following is a step-by-step review of the methodology with a brief description of the purpose and activities associated with each step.

III. FORMING THE TEAM

The first step is to form the team which will perform the analysis. The individuals selected for the team depend on the type of "Team" being formed which, in turn, depends on the type of analysis deemed necessary for the particular problem.

At the one extreme is the so called "Red Team". This is the most thorough of analyses and usually lasts 6-8 weeks. A Red Team is composed of 6-8 individuals. These are chosen to have technical skills related to the problem being considered, but they have not been and are not involved with the project. It has been found valuable to have a statistician as one of the team members. For a Red Team, a full time secretary is also a good idea. Because of the importance of such efforts, it is often desirable to have some of the team members from other commands, services, etc.; in order to ensure objectivity and expertise. This obviously represents an expensive and extreme undertaking because several highly skilled personnel are being taken away from their regular jobs for a considerable time and on very short notice. The Red Team approach is not very efficient, but is very (98%) effective (if performed as prescribed)!

Not every problem will warrant (or could afford) a full-blown Red Team. Accordingly, there are variations of the Red Team approach that take less time and money. These range from a 2 week to a 4 week effort. For example, a so-called Problem Analysis includes a team of 4-6 people who either have been or are currently working on the project being studied. (A-3) Cutting corners on the Root Cause Analysis procedure, however, increases the risk that the true root cause could be overlooked.

Essentially the job of the assigned "analysis team" (Red Team, Tiger Team, etc.) is to perform the Root Cause Analysis. In this endeavor, they do not work alone, but act in an adjunct capacity to the people already working on the project and referred to as the Blue Team. It is important to convey to the Blue Team that the Root Cause Analysis is going to help them and that they are an integral part of the effort. A non-adversarial and mutually supportive relationship is not only critical but essential to the success of this effort. The project people probably think that if they were given the time to reflect on the problem, like the Red Team, that they could solve it too. In fact, now they are being given just that opportunity. The Red Team is merely acting as a coordinator, guide and coach. (A-4)

In this regard, the terms Red Team, Tiger Team, etc. may be counter-productive because they convey an adversarial connotation. It might be better to use the term "Project Assistance Team, Technical Support Team, etc. because it sounds less threatening. However, many of these terms now possess a historical basis and are difficult to change.

IV. FACILITIES

A special room should be made available exclusively for the Root Cause Analysis effort. It should be large enough to hold the combined Red and Blue Teams plus any other presenters or visitors. Notes should be written onto briefing sheets and these taped up on the walls to remind people of the thought conveyed. This is an extremely effective means of absorbing and retaining information during the large and rapid accumulation of material experienced during these analyses. For a long term, formal Red Team effort, the room should be equipped with its own phones, FAX and computers (word processors). (A-5)

V. TRAINING

While some knowledge of the Root Cause Analysis is advisable, especially for the chairman of a study, many of the team members will have no previous experience in this area. It is often useful to have someone with this training and experience to assist getting a team started. This so-called "facilitator" can then check back periodically to provide guidance and direction as needed. Sometimes a limited amount of training can be integrated into the team as it begins working on an actual analysis.

VI. PROBLEM STATEMENT

The Problem Statement is a concise, complete and accurate sentence citing what the problem is. It may or may not be the same as that indicated initially by the sponsoring agency or contained in the Memorandum of Agreement. A chronology of the problem should be established to help determine the what, when and where aspects which can aid in forming the Problem Statement. Figure 1 includes an example of such a chronology. It is desired to be as general as possible so that the attention of the analysis is not unnecessarily narrowed and the actual root cause missed. The specific wording can, and often does, change early in the study as more information is acquired. Sometimes, more than one Problem Statement will be required. Figure 2 includes representative Problem Statements from past analyses.

This statement is critical because it provides continual guidance as to the object of the study. It should be established, understood and agreed on by all team members. The Problem Statement is constantly referred to and can be changed and upgraded throughout the study as more information becomes available. It often acts as a "North Star" to keep the analysis on course. The large amount of information and intense nature of the effort sometimes results in the group "going off on a tangent" and getting into areas which do not relate to the problem being studied. Constantly referring to the Problem Statement will prevent this from happening. (A-6)

Dec 1982	M825 Type Classified
1982-1985	M825 completes Initial Production Tests. All test objectives met. (DPG). 685 rounds fired. 99% success rate.
Jul 1985	825E1 PIP(Domed Steel Base) tests. 586 rounds fired (including 157 with Standard Base). (DPG). 99% success rate.
May 1986 - Jun 1988	516 production rounds tested. Two lots of the 22 lots tested, had 1 failure each. One lot had 2 failures and was rejected. (DPG). 99% success rate.
1987-1988	Engineering study proposed to reduce canister functioning failures. Not considered cost effective because of high current success rate.
Mar 1988 - Sep 1988	M825E1 PIP (Short Domed Steel Base). 372 rounds tested. (DPG). 99% success rate.
Mar 1989	M825A1 Type Classified.
Mar 1989 - Dec 1990	120 production rounds tested. Four of the five lots had one failure each. One of the lots had two failures and was rejected. (JPG). 95% success rate.
Jan 1990 - Feb 1990	48 production rounds tested. Of the five lots had one had two failures and the other had three failures. Both lots were rejected (JPG). 90% success rate; 88% on the last lot alone.
Mar 1990	14 rounds tested with 4 failures from a single lot. (DPG). 71% success rate.
Mar 1990	48 rounds tested. No failures out of two lots tested. (JPG).
Mar 1990	Production of M825A1 canisters at Pine Bluff Arsenal stopped until problem resolved.
Mar 1990	MG Brailsford requests Red Team Study to determine cause and recommend corrective measure.

Figure 1. Example of Problem Chronology

EXAMPLES OF PROBLEM STATEMENTS

- * XM761 - "Projectile falls short range."
- * XM736 - "Payload canister expelled prematurely."
- * XM264 - "Failure to expell payload."
- * XM264 - "Failure to ignite payload."
- * M825 - "Failure of canister burster charge to detonate."
- * XM21 - "Failure to sustain alarm."
- * M40/M42 - "Nosecup discomfort."

Figure 2. Examples of Problem Statements

VII. MEMORANDUM OF AGREEMENT

Before any significant effort is started on the analysis, a Memorandum of Agreement (MOA) should be prepared and signed by the "Team" Chairman and the head of the sponsoring organization. It should include the objective, scope, time frame and funding source. This MOA has several objectives. First, it provides the authority necessary to perform the analysis. It is important to have this signed by the highest authority possible. This will allow the team to receive the necessary response from within and without its organization when others perceive the level of authority sponsoring the study. Secondly, it allows both parties to agree to what the objective of the study is and prevents any time being lost because of a misunderstanding. A clearly stated and understood scope should indicate when the job is completed. Any time constraints should also be revealed at this time because it will justify the form of the analysis selected. The estimation of the cost involved will allow the sponsor to recognize the commitment being requested. Finally, identification of funding will enable acquiring outside individuals, travel and, in short, indicate that the sponsor is serious about the study. Figure 3 contains an illustrative example of an MOA. (A-7)

4 March 1992

MEMORANDUM OF UNDERSTANDING
BETWEEN
THE CHAIRMAN, M40/M42 MASK NOSE
CUP DISCOMFORT PROBLEM ANALYSIS
AND
THE TECHNICAL DIRECTOR, CRDEC

SUBJECT: M40/M42 Protective Mask Problem Analysis Charter

1. Background: The M40 and M42 are individual gas masks for protection against chemical warfare agents for use by the general army personnel and vehicle crew members, respectively. The masks are essentially identical except that the M40 contains a filter canister attached directly to the side of the face plate whereas the M42 includes a hose connection between the face plate and the filter canister which is located on the wearer's belt. Both masks were Type Classified in 1987. The masks are currently being produced by two different companies: Mine Safety Appliances (MSA), Inc. and ILC-Dover, Inc. Both producers are adhering to the same Technical Data Package, but utilize different materials and manufacturing processes. The ILC-Dover manufactured units appear to be fully acceptable in every respect. However, the MSA manufactured units have been found to create considerable wearer discomfort where the nose cup contacts the top of the nose.

At the direction of the CRDEC Technical Director, the Associate Technical Director for Engineering and Test has formed a Problem Analysis Team to assess the source of the M40/M42 Mask Nose Cup Discomfort Problem. Because of the production status of the M40/M42 program, a rapid resolution to this situation is desired. Accordingly, the use of personnel on the team who have some technical background in gas masks is deemed prudent. A formal, Root Cause Analysis methodology will be followed to obtain the desired results while providing the rationale and documentation involved.

2. Specific Charge:

- a. Consider all possible failure modes and identify the probable root causes responsible for creating the "Nose Cup Discomfort Problem".
- b. Evolve a test plan to confirm the probable root causes determined by the analysis.
- c. Recommend corrective measures (both interim and long term) including proposed test plans to validate the proposed fixes.
- d. Present periodic status reports during the analysis.
- e. Prepare a final report documenting the rationale and results of the analysis.

3. Problem Analysis Team Members:

Figure 3. Example of Memorandum of Agreement

Team members were selected on the basis of their technical expertise and familiarization with mask technology and development.

The team members are:

Mr. John A. Scavnicky; Physical Protection Directorate, CRDEC. (Chairman)
Ms. Gayleen Fitzgerald; Product Assurance Directorate, CRDEC.
Mr. Charles R. Stone; Producibility Engineering Support Directorate,
Rock Island.
Mr. John S. Richardson; Producibility Engineering Support Directorate,
CRDEC.
Mr. Frank E. Johnstone; Research Development and Engineering Support
Directorate, CRDEC.
Miles C. Miller; Research Directorate, CRDEC. (Facilitator)

4. Proposed Schedule:

2 March	Training
3 March	M40/M42 project review/problem chronology Establish Problem Statement Plan schedule Prepare Memorandum of Agreement (MOA)
4 March	Perform Independent Design Review Select Critical Areas
5 March	Formulate Failure Mode Charts (Speculation)
6 March	Formulate Failure Mode Charts (Evaluation) Categorize Failure Mode Charts
9 March	Complete Failure Mode Charts
10 March	Prepare Focus Charts and Tables Identify Probable Root Causes
11 March	Present In-Process Review (IPR)
12 March	Finalize Failure Mode Charts
13 March	Plan Root Cause Confirmation Tests
16 March	Evolve corrective actions (interum)
17 March	Evolve corrective actions (long term)
18 - 19 March	Prepare Draft Final Report Final Memorandum For Record (MFR)
20 March	Final IPR
23 - 27 March	Complete Final Report

5. Funding: Labor (\$62,500.00) and travel (\$2,500.00) expenses for Red team members are necessary.

Total funding required is \$65,000.00.

John A. Scavnicky
Chairman, M40/M42 Problem
Analysis Team

CONCUR:

Donna C. Shandle,
Associate Technical Director
For Engineering and Test, CRDEC

Michael A. Parker,
Technical Director, CRDEC

VIII. BRIEFING BY PROJECT PERSONNEL

This is, of course, required in the case of a Red Team because they have absolutely no knowledge of the project. However, it is also important to go through this for a Problem Analysis because it may reveal here-to-fore unknown facts. Anyone already working on the project is considered to be a Blue Team member. It is a good idea to designate certain key Blue Team individuals including a Blue Team Chairman, who will work directly on the Root Cause Analysis. The Blue Team Chairman should prepare a "Read-Ahead" package describing the main features of the item being considered and pertinent data on the problem. This should also include a list of Points of Contact for each technical area associated with the item or project. (A-8) During the course of the study, the Blue Team is responsible for providing any data or information as well as performing any analytical work required for the Root Cause Analysis.

This initial briefing represents the first time that all of the Red and Blue Team members are gathered together. It is a good idea to have representatives from both the sponsor and from the Blue Team upper management present to express their support for the endeavor. This will help to establish a spirit of a joint objective and cooperation between the Red and Blue Teams.

It is prudent to periodically reconsider the Problem Statement to see if it is still accurate or should be altered in light of the recent information. Also, individual assignments should be made by the chairman for the various team members. Each individual should be given responsibility for particular areas: technical topics, test results, parts description, etc. In particular, someone (i.e., the secretary) should establish and maintain a repository and reference system for the information and data being gathered by the team.

IX. INDEPENDENT DESIGN REVIEW

At this point, the joint teams perform an Independent Design Review. The purpose is not only to define and understand the item being considered, but to document all parts and processes involved for future reference. In the case of a Red Team, an all-inclusive Parts Diagram is prepared as illustrated in Figure 4. Each part is designated by some form of numbering code. Figure 5 contains an example of a Parts Chart.

In addition, various flow diagrams can be developed to illustrate functional sequences or manufacturing processes. It is often helpful to prepare a Parts List which includes a detailed description of the physical attributes, intended function, manufacturing aspects, etc. of every part on the Parts Chart as shown in Figure 6. Each part should include the official drawing designation for reference. Figure 7 includes an example Parts List. The objective is to consolidate the information into charts, tables, graphs, etc. which allow a total and clear understanding of the various versions, functions, processes, etc. associated with the item being analyzed. This is important to defining and describing exactly what parts are involved. Bar charts, matrices, histograms, etc. as well as new and innovative forms of data presentation, statistical analysis and other techniques can be utilized.

(A-9)

PARTS CHART

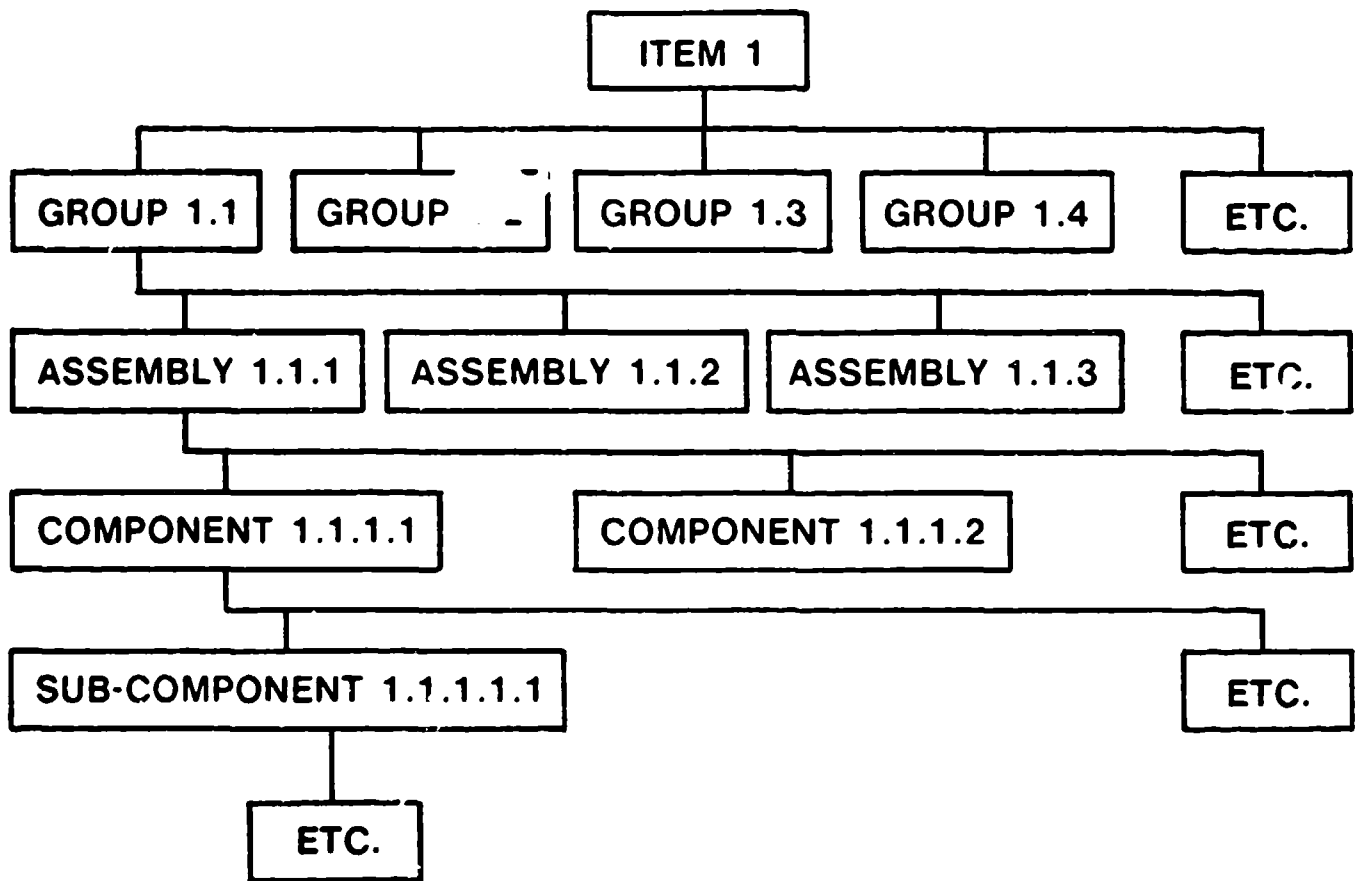


Figure 4. Parts Chart Format

PARTS DESCRIPTION

PART NO.

DESCRIPTION

Per Parts Chart

Name (include Part No. from project drawing). Describe shape, size, material, intended function, connecting items, manufacturing process, etc.

Figure 6. Parts Description Format

SINGLE FAULT LOGIC CHART DESCRIPTIONS

NOTE: The numbers in parenthesis refer to either drawings or MIL Specs.

- 1.1 Nose Cone Assembly (90-1-361)
The nose cone assembly consist of an ogive nose, umbilical cable, electrical clips, and umbilical cord strain relief devices.
- 1.1.1 Umbilical Cable (863328-079)
The umbilical cable provides an electrical connection between the rocket and the fire control computer in the launch system. The umbilical cable enters the rocket through the side of the nose cone assembly.
- 1.1.1.1 Environmental Protector (9349897)
A black neoprene rubber cap that fits over the electrical connector at the end of the umbilical cable, to protect the connector from damage due to rough handling and corrosion during warhead storage.
- 1.1.1.2 Eyelet (9334124)
Brass eyelet which centers the umbilical cable in the nose cone hole as the cable enters the nose cone assembly. Also protects the cable from being accidentally cut due to the cable rubbing on the sharp edge left when the hole is drilled into the nose cone.
- 1.1.1.3 Bushing (9334125)
Rubber bushing which protects the umbilical cable as it enters through the nose cone. The bushing also acts as a seal between the environment and the interior of the nose cone.
- 1.1.1.4 Silicone (MIL-A-46146)
Insulation to protect the electrical connections between the umbilical cord and the post on the Base Nose Cone (1.2.1.2)
- 1.1.2 Contact Locking Clips (2 each) (9334116)
The contact locking clips connect the umbilical cable to the contacts on the base nose cone, which then connects to the flexible flat cable.
- 1.1.3 Nose Cone (9334120-3)
The aluminum ogive nose cone provides a streamline aerodynamic shape for the air to smoothly flow around the missile.
- 1.1.3.1 Shear Pins (6 each) (9334102-1)
The aluminum alloy shear pins hold the Nose Cone (1.1.3) and the Base Nose Cone (1.2.1.1) to the warhead body (1.2). The pins are sheared by a pressure build-up due to the expulsion charge which pushes the red phosphorus pellet stack against the Base Nose Cone. The shear pins also provide a time delay between the time

Figure 7. Example of Parts Description

X. CRITICAL AREAS DIAGRAM

At this point, the teams have accumulated a considerable (seemingly overwhelming) amount of information, data, etc. and now want to begin to focus in on the problem. All team members together select the areas of the item where they feel the Root Cause lies and prepare a Critical Areas Diagram. One way to do this is to eliminate areas where they are sure that "it doesn't lie". For example, if the problem involves a rifle that isn't chambering properly, it probably isn't due to anything in the stock assembly. In this manner, we break the overall situation down into manageable pieces we can handle: Chunks, Bites, Morsels, etc.

A separate Critical Areas Diagram is prepared for each Problem Statement and the Problem Statement is the top-most item. All the information below must eventually flow into the Problem Statement. As illustrated in Figure 8, the item is gradually dissected into more detailed elements such as Groups, Assemblies, Sub-Assemblies, Components, Sub-Components, and Features. Each element is designated per the previous Parts Diagram. At the bottom, are additional Influence Factors which may influence the functioning of the item and initiate a Root Cause. These Influence Factors include:

Design Effects - The part is functioning as intended, but there may be a problem with the basic design.

Manufacturing Effects - Out of specification tolerances, materials, etc.

Dynamic Effects - Vibration, acceleration, spin, etc.

Materials Compatibility Effects - Corrosion, fit, wear, etc.

Environmental Effects - Moisture, temperature, etc.

Operational Effects - Human error, operational use, doctrine, etc.

Other Effects - Associated with a particular problem.

The elements are designated by a multi-digit number indicating the sequence of the failure from the Influence Factor to the Problem Statement such as:

X. - Refers to a particular Problem Statement

X.X. - Refers to a particular System Group

X.X.X. - Refers to a particular Assembly

X.X.X.X. - Refers to a particular Component

X.X.X.X.F. - Refers to a particular Influence Factor

CRITICAL AREAS DIAGRAM

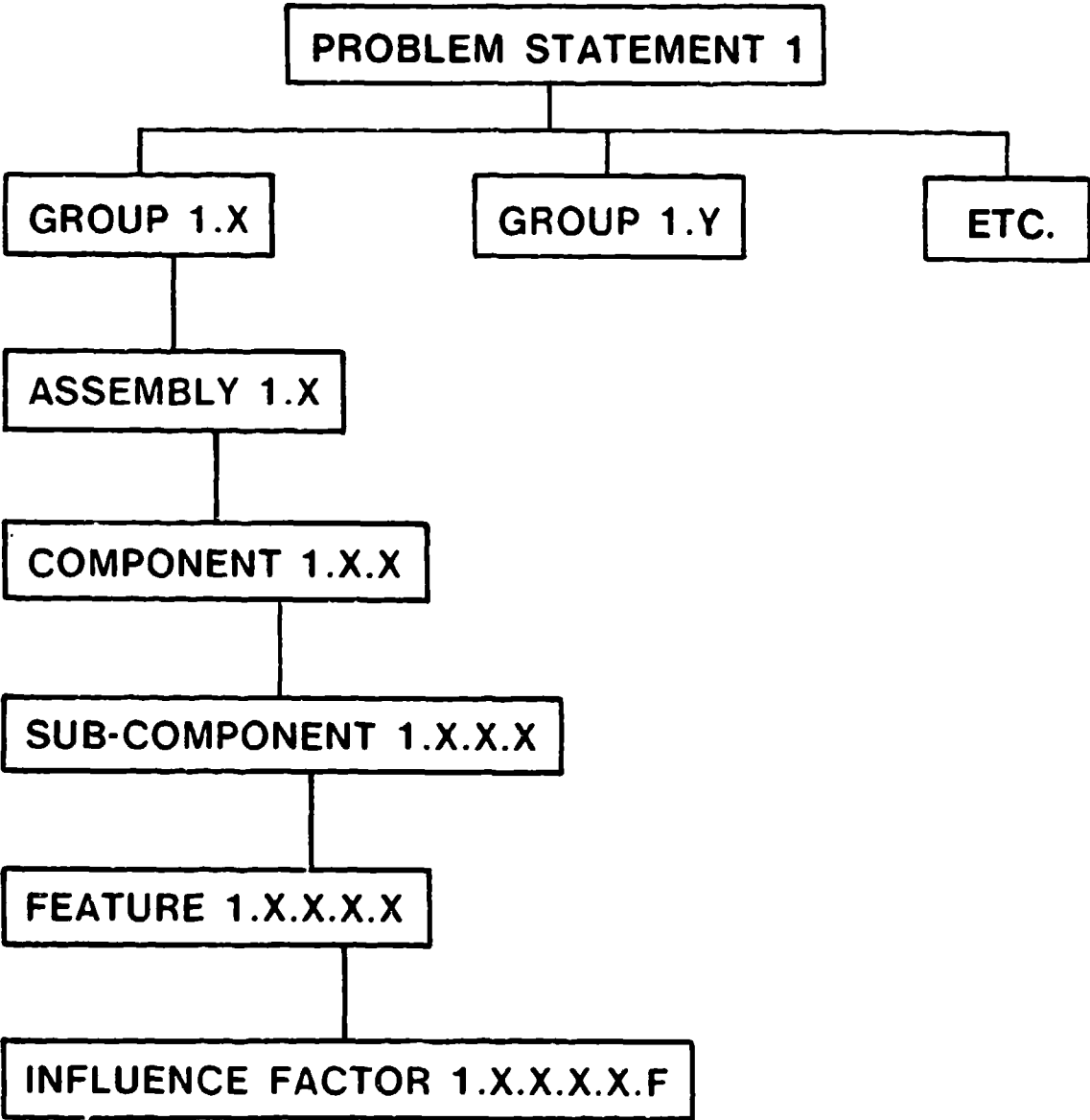


Figure 8. Critical Areas Diagram Format

In this way, a failure mode can be traced from an Influence Factor up to the Problem Statement. The Critical Areas Diagram provides a "road map" for identifying and describing potential failure modes. An example of this diagram is contained in Figure 9. (A-10)

For a very short analysis, it may be prudent to assemble a "panel of experts" to assist in this step. Again, these could be individuals already on the project or individuals with specific expertise. The panel of experts can be brought in briefly just for this aspect of the analysis.

CRITICAL AREAS DIAGRAM

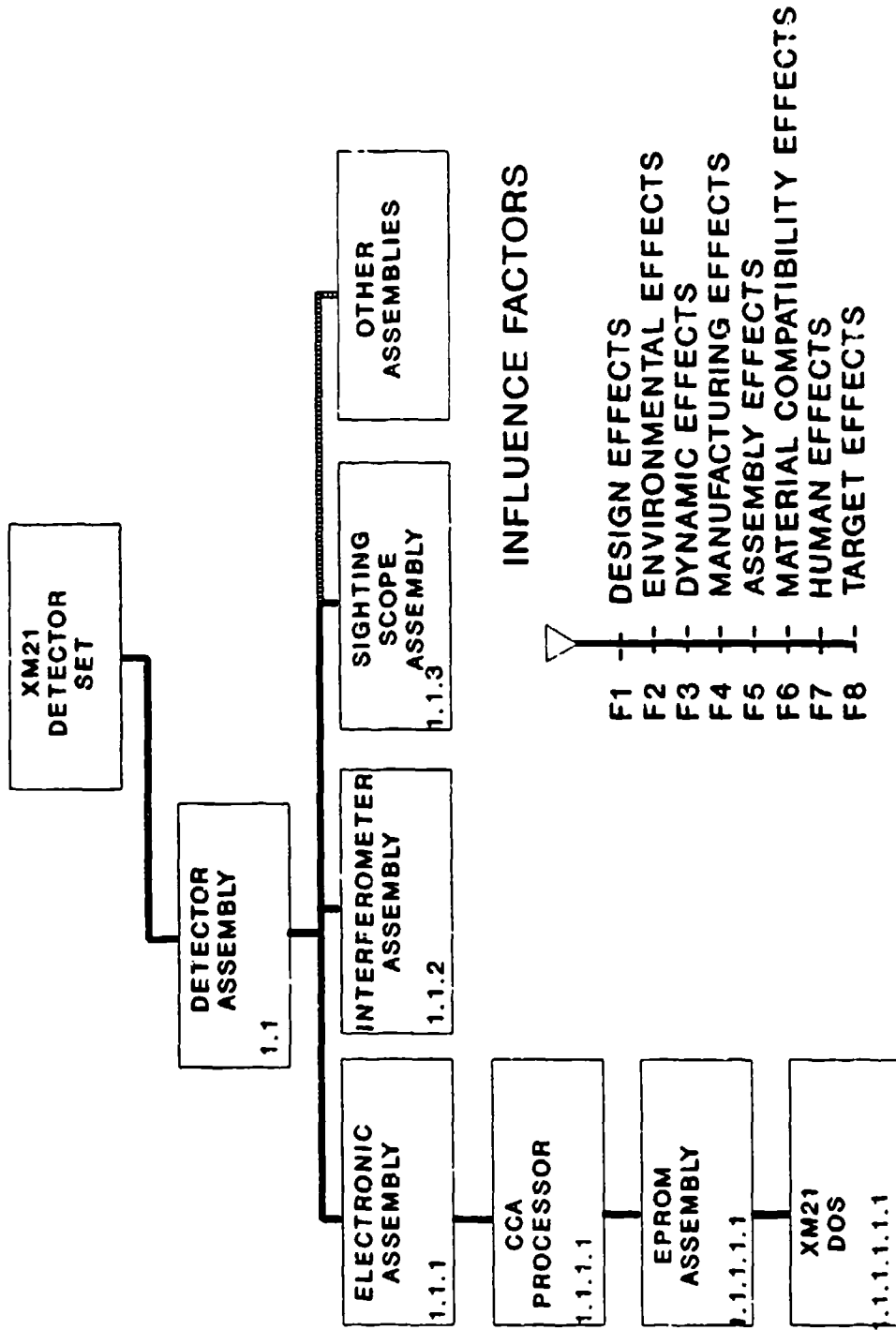


Figure 9. Example of Critical Areas Diagram

XI. FAILURE MODE CHARTS

The Failure Mode Chart is the single most important facet of the Root Cause Analysis. Each Failure Mode Chart describes a single failure Mode for a specific Problem Statement. As illustrated in Figure 10, it is essentially a T-chart with the left hand side labeled "Speculation" and the right hand side labeled "Evaluation".

A. Speculation:

The upper left hand portion of the chart contains a brief statement to identify the particular Failure Mode being considered. Included in this is the numerical designation of the Failure Sequence obtained from the Critical Problem Area Logic Chart. This defines the Failure Mode for future reference. Under this is the Failure Sequence which is a short narrative describing the sequence of events which occur during the Failure Mode. This should contain all of the steps and items involved. Each chart should be given an arbitrary number which can be used to identify the particular chart.

The assembled "teams" should formulate the speculation side of these charts together as a single group to benefit from the synergistic action of the group. Also, they should be prepared without stopping to argue their individual merits or shortcomings in order to benefit from "Deferred Judgement". "Deferred Judgement" can greatly increase effectiveness of the group effort producing 3 times the output of simultaneously performing speculation and evaluation together. A large number of charts should be generated at this stage and should include "obvious" as well as "far out" conjectures. Several dozen charts would not be uncommon. (A-11)

In the case of a "Red Team", this is a very lengthy and extensive exercise. Accordingly, the chances are very high that all possible Root Causes will be considered. In a shorter "Problem Analysis" the group immediately focuses in on the "apparent" Root Cause which incurs a risk that the "actual" Root Cause" could be missed!

B. Evaluation:

After the "Speculation" ideas have been exhausted, the group should turn to the "Evaluation" portion of the charts. Any supporting and refuting data are added to the appropriate columns. Specialists in selected technologies can be called in for discussions related to the problem at hand. If possible, entries should be referenced and obtained for the repository.

FAILURE MODE CHART

Date: Rev. No.

Cause Probability Estimate: Rating of Not Likely (NL), Likely (L) OR Highly Likely (HL)

Failure Indication: Problem Statement

EVALUATION			
SPECULATION	SUPPORTING DATA	REFUTING DATA	ADDITIONAL DATA TESTS REQUIRED
<p>FAILURE MODE: A brief title defining the failure mode.</p> <p>Numerical designation from the critical areas diagram indicates the items involved.</p> <p>FAILURE SEQUENCE: A concise and complete narrative description of the failure sequence from Effect Factor to Problem Statement.</p>	<p>List of data or information supporting the Failure Mode; reference sources.</p>	<p>List of data or information refuting the Failure Mode; reference sources.</p>	<p>List of data, testing, etc. which would provide additional supporting or refuting data for Failure Mode.</p>

NO: Identification Number of Chart

Figure 10. Failure Mode Chart Format

In citing and evaluating information for the Evaluation portion of the chart, it is often necessary to identify a reference or "baseline" configuration or situation with which to compare. In some respects, this might be included in the Problem Statement which could include what level of acceptable performance is being sought by elimination of the problem.

C. Additional Data/Tests:

Any additional data or testing which would provide additional supporting or refuting data are placed under the Additional Data/Tests portion of the charts. This is removed once the information is obtained.

D. Categorizing Failure Mode Charts:

While the team and the panel of experts is still present, all of the Failure Mode Charts are reviewed and categorized as to their likelihood of being the Root Cause. The categories are : Not Likely (NL), Likely (L) and Highly Likely (HL). If there is only Refuting data and no Supporting data, the mode should be considered as Not Likely. This will include most of the charts and they can be set off to the side. They will be included in the final report, but will not be considered further in the analysis. Conversely, charts which have a large amount of Supporting Data should be designated as Highly Likely. Some charts will have both Supporting and Refuting Data and can be considered as Likely.

Additional data in the form of existing test results, reference information, etc. can now be added to the HL and L charts. The bulk of the team's efforts during the analysis will be in accumulating supporting and refuting data for these HL and L Failure Modes. It may be possible to perform some limited tests and experiments during the analysis which could provide additional supporting or refuting data. However, because of time limitations, it may not be possible to conduct tests during the study. This information/test data requirement may be acquired during the Root Cause Confirmation Test proposed later in the study.

This phase of the analysis may require sending one or more of the team members to visit other experts, facilities, etc. to obtain, first hand, information related to a particular Failure Mode Chart. Figures 11, 12 and 13 show examples of NL, HL and L Failure Mode Charts, respectively. (A-12)

FAILURE MODE CHART

Date: 22 Mar 90 Rev. No. 2 Cause Probability Estimate: NL

Failure Indication: Failure of Canister Burster Charge to Detonate

SPECULATION		EVALUATION	
FAILURE MODE:	SUPPORTING DATA	REFUTING DATA	ADDITIONAL DATA TESTS REQUIRED
Felt disk left out during manufacturing. 1.3.2.2.F5	Two JPG recovered failed canisters show S&A functioned, but burster Comp A5 not detonated. (Appendix 7)	Felt disks present in recovered failed canisters at JPG and DPG.	
FAILURE SEQUENCE: Felt disk left out of burster assembly during manufacturing allowing burster tube to seat deeper into burster well increasing gap between S&A lead assembly and burster Comp A5. Large gap reduces energy transfer resulting in A5 not detonating (partially deflagration).	Two DPG recovered failed canisters show S&A functioned, but burster Comp A5 not detonated. (Appendix 7)		

NO: 40

Figure 11. Example of Failure Mode Chart - Not Likely (NL)

FAILURE MODE CHART

Date: 27 Mar 90 Rev. No. 2

Cause Probability Estimate: HL

Failure Indication: Failure of Canister Burster Charge to Detonate

EVALUATION			
SPECULATION	SUPPORTING DATA	REFUTING DATA	ADDITIONAL DATA TESTS REQUIRED
<p>Comp A5 in S&A lead assembly manufacturing process changed reducing density. 1.2.2.1.F2</p> <p>FAILURE SEQUENCE:</p> <p>Comp A5 in S&A lead assembly manufactured specification changed to lower density reduces ability to transfer energy to Comp A5 in burster.</p>	<p>1) Evidence that Comp A5 in PA508 lead assembly was reduced in density. Milan AAP AKT884001-001; reducing output performance.</p> <p>2) Problem may be exacerbated by gap presence in M825A1 application (M739 may not see problem).</p>	<p>1) No problem noted by M739 Fuze.</p> <p>2) Successfully used in other M825 lots.</p> <p>3) See Appendix 11.</p>	<p>1) Perform chemical analysis of Comp A5 in PA508 lead assemblies from S&A lead assemblies.</p> <p>2) Perform functioning tests of S&A lead assemblies.</p> <p>3) See Appendix 15.</p>

NO: 55

Figure 12. Example of Failure Mode Chart - Highly Likely (HL)

FAILURE MODE CHART

Date: 27 Mar 90 Rev. No. 1 Cause Probability Estimate: L

Failure Indication: Failure of Canister Burster Charge to Detonate

EVALUATION			
SPECULATION	SUPPORTING DATA	REFUTING DATA	ADDITIONAL DATA TESTS REQUIRED
<p>FAILURE MODE:</p> <p>Lacquer adhesive applied too thick on burster tube assembly. 1.3.2.4.F2</p> <p>FAILURE SEQUENCE:</p> <p>Lacquer adhesive applied too thick representing foreign material between S&A Lead Assembly and Burster Comp A5 reducing transfer of energy to Comp A5 resulting in A5 not detonating (partially deflagrating).</p>	<p>1) Two JPG recovered failed canisters show S&A functioned, but burster Comp A5 not detonated. (Appendix 7)</p> <p>2) Two DPG recovered failed canisters show S&A functioned, but burster Comp A5 not detonated. (Appendix 7)</p> <p>3) Proof rounds are heated to 145 deg F. Increased sensitivity of Comp A5 may counteract foreign materiel degradation effect.</p>	<p>1) Same burster lots were successful in other projectile lots.</p>	<p>1) Inspect lacquer/adhesive from accepted and rejected lots. (See Appendix 14.)</p>

NO: 53

Figure 13. Example of Failure Mode Chart - Likely (L)

XII. FOCUS CHART AND FOCUS DIAGRAM

A. Focus Chart:

A Focus Chart is now formed which summarizes information from the Highly Likely (HL) and Likely (L) Failure Mode Charts. This chart, shown in Figure 14, is used to distill out and identify the common Root Causes. All of the HL and L Failure Modes and their respective Failure Mode Sequences are presented in a single Focus Chart which allows redundant and similar Failure Modes to be identified. An example of a Focus Chart is found in Figure 15.

A Root Cause is defined as something that, if eliminated, will in turn eliminate the problem in the Problem Statement. The Root Causes determined from the previous tables and charts are termed Probable Root Causes at this point because they have not been confirmed. The Probable Root Causes can have the same titles as on the Failure Mode Charts or more concise and accurate terms can be used. (A-13)

B. Focus Diagram:

From this chart, a Focus Diagram can be established as shown in Figure 16. The Focus Diagram is similar to the Critical Areas Diagram, but only includes the elements associated with the Probable Root Causes which are located at the bottom of the diagram. The Probable Root Causes are indicated in boxes which include their HL or L Category designation and the Number of their particular Failure Mode Chart. This diagram is used to facilitate an understanding of the overall Probable Root Cause situation and to determine whether they are single, multiple, combined or sequential in nature. Figure 17 contains an example of this diagram. (A-14)

FOCUS CHART

CAUSE PROBABLE ESTIMATE	FAILURE MODE CHART NO.	FAILURE SEQUENCE	PROBABLE ROOT CAUSE
<hr/>	<hr/>	<hr/>	<hr/>
NL, L or HL from Failure Mode Chart	Failure Mode Chart No.	Failure Mode Sequence from Failure Mode Chart	Failure Mode from Failure Mode Chart or revised title

Figure 14. Focus Chart Format

ROOT CAUSE FOCUS CHART

<u>CAUSE PROBABLE ESTIMATE</u>	<u>FAILURE MODE CHART</u>	<u>FAILURE SEQUENCE</u>	<u>PROBABLI. ROOT CAUSE</u>
HL	55	<p>1.2.2.1.F2 Process change in manufacture of Comp A5 for S&A Lead Detonator results in reduced consolidation density, lowering energy output to Comp A5 in Burster Tube so that Comp A5 does not detonate.</p>	Manufactur- ing process of Comp A5 in S&A Lead Assembly
HL	52	<p>1.3.2.2.F2 Felt Disk manufactured from out-of-spec material allowing Burster Tube to seat deeper in Burster Well, increasing gap between S&A Lead Assembly and Comp A5 in Burster Tube. Large gap reduces energy transfer to that the Comp A5 does not detonate.</p>	Out-of-spec material in felt disk
L	51	<p>1.2.1.2.F2 Use of out-of-spec parts in the S&A Rotor Assembly results in the M55 Detonator being Mis-aligned with the S&A Lead Assembly reducing the energy transferred to the Comp A5 the Burster Tube so that the Comp A5 does not detonate.</p>	Out-of-spec parts in the S&A Rotor Assembly
L	27	<p>1.3.1.2.F2 Weak attachment from manufacturing process (i.e., out-of-spec material, poor weld, etc.) results in Burster Well separating from Front Plate during launch producing large gap and preventing sufficient energy transfer to detonate Comp A5 detonate Comp A5 in Burster Tube.</p>	Weak attach- ment between Burster Well and Front Plate

Figure 15. Example of Focus Chart

ROOT CAUSE FOCUS CHART

CAUSE PROBABLE ESTIMATE	FAILURE MODE CHART	FAILURE SEQUENCE	PROBABLE ROOT CAUSE
L	32	1.3.1.2.1.F2 Burster Tube wall made too thin during manufacturing reducing confinement effect on Comp A5 in Burster Tube so that Comp A5 does not detonate.	Out-of-spec Burster Tube Wall
L	36	1.3.2.1.F2 Burster Well wall made too thin during manufacturing reducing confinement effect on Comp A5 in Burster Tube so that Comp A5 does not detonate.	Out-of-spec Burster
L	21	1.3.2.1.F2 Use of out-of-spec chemical composition of Comp A5 (i.e., excessive cyclohexanone, incorrect amount of stearic acid, etc.) prevents Comp A5 from detonating.	Out-of-spec chemical composition of Comp A5
L	26	1.3.2.3.F5 Comp A5 pellet or pellets left out of Burster Tube during manufacturing resulting in a large gap between S&A Lead Assembly and Comp A5 in Burster Tube. Large gap reduces energy transfer so that Comp A5 does not detonate.	Comp A5 Pellet or Pellets left out of Burster Tube
L	53	1.3.2.4.F2 Lacquer/Adhesive applied too thick on surface of Comp A5 preventing transfer of energy from S&A Lead Assembly to Comp A5 in Burster Tube so that Comp A5 does not detonate.	Excessive Lacquer Adhesive on Burster Tube

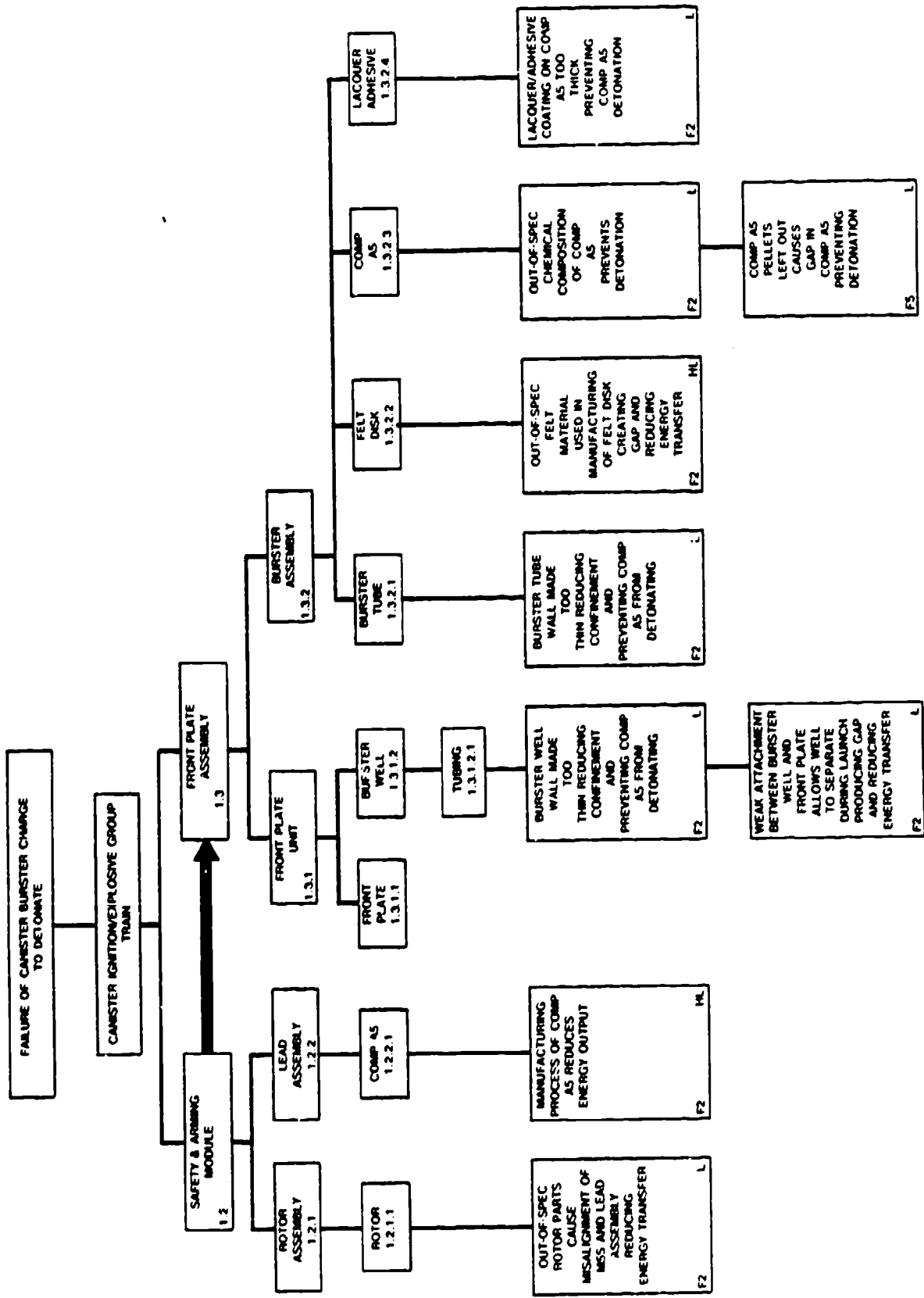


Figure 17. Example of Focus Diagram

XIII. PROBABLE ROOT CAUSES

It is helpful to prepare a detailed, narrative description of each Probable Root Cause based on their respective Failure Mode Charts. This would contain more details than the charts, including any qualifications, assumptions, caveats, etc.. This will make sure that the Probable Root Causes are thoroughly understood and there are no "loose ends" present. (A-15)

Another important factor in this process is termed "Incubation Time". This refers to providing some time to think and rethink about the various failure modes. This is one of the main drawbacks of rushing through a Root Cause Analysis because there is no opportunity to revisit and reassess the results. It is surprising, how highly relevant ideas don't occur until several weeks into these studies. These results would be included in a Red Team, but might be too late for a Problem Analysis. (A-16)

XIV. ROOT CAUSE CONFIRMATION TESTS

With the Probable Root Causes identified, the next step is to plan tests specifically to confirm or validate, beyond a shadow of a doubt, that they are Root Causes for the problem. In essence, it is desired to recreate and eliminate the problem at will. Some of these tests may seem trivial, but are necessary to prove the point. A series of experiments are planned which involve recreating the problem and then eliminating the problem by altering the Probable Root Cause. Figure 18 shows an example of a Confirmation Test. (A-17)

PROPOSED TEST PROGRAM TO VALIDATE ROOT CAUSES

<u>TEST SERIES</u>	<u>PROBABLE ROOT CAUSE</u>	<u>NO. OF WARHEADS</u>	<u>EXPULSION CHARGE PACKING</u>	<u>CENTER HOLE SIZE</u>	<u>TEMPERATURE (DEGREES F)</u>
1	EXPULSION CHARGE PACKING.	15	LOOSE	NOMINAL	-50
		15	TIGHT	NOMINAL	-50
		15	NOMINAL	NOMINAL	-50
2	CENTER HOLE	15	TIGHT	SMALL (NONE)	-50
		15	TIGHT	LARGE	-50
		15	TIGHT	NOMINAL	-50
3	AMBIENT TEMPERATURE.	15	NOMINAL	NOMINAL	+150
		15	NOMINAL	NOMINAL	+70
		15	NOMINAL	NOMINAL	-50

- NOTES:**
- 1) NOMINAL = XM264 BASELINE DESIGN.
 - 2) ALL TESTS CONDUCTED WITH WARHEAD SPINNING.

Figure 18. Example of Root Cause Confirmation Test

XV. IN-PROCESS REVIEWS (IPR)

Periodic In Process Reviews (IPR) are held at scheduled intervals. Regardless of the extent of the analysis, an initial IPR should be held within a week of the beginning of the analysis. This provides a means of receiving feedback from the sponsor as to whether the analysis is doing what they want. A final IPR is presented at the conclusion of the study.
(A-18)

A weekly written summary of the analysis status should be prepared each Friday. This will allow a team assessment of their progress as well as providing the sponsor with an up-to-date report.

XVI. FINAL MEMORANDUM FOR RECORD

A Final Memorandum For Record is prepared which contains a summary of the results of the analysis. This should be signed by the Analysis chairman and the sponsor. The text of this MFR can be the Summary section of the Final Report. An example of a Final MFR is contained in Figure 19. (A-19)

MEMORANDUM FOR SMCCR-TD

SUBJECT: XM264 RED TEAM STUDY

1. The XM264 Red Team Study was conducted from 30 October through 8 December 1989. The study had the following objectives:

- A. Conduct Independent Design Review of the XM264 System.
- B. Determine Root Cause for failure to reliably expel and ignite RP payload.
- C. Establish at least three alternate designs which will eliminate failures while meeting the "Out-of-Line" fuze functioning requirements.

2. Based on the findings of this study, the following are the Probable Root Causes for the associated Problem Statements:

<u>Problem Statement</u>	<u>Probable Failure Root Cause</u>
I. Failure to expel RP pellets.	<p>A. The hole in the center of pusher plate allows fuze detonation gases to pass through expulsion charge too quickly for expulsion charge to ignite.</p> <p>B. Loose expulsion charge constituents are separated due to dynamic motion of warhead (vibration and spin), producing void in center of expulsion charge such that flame from detonator does not impact expulsion charge sufficiently to ignite.</p> <p>C. Situations I-A and I-B. exacerbated by cold conditioning temperature which further reduces ignition sensitivity of expulsion charge constituents.</p>
II. Failure to Ignite RP pellets.	<p>A. Hole in center of pusher plate not adequate to produce long and wide flame to ignite entire stack of RP pellets.</p>

Figure 19. Example of Final Memorandum for Record

III. Failure to Pass "Out-of-Line" Fuze Functioning

A. Plastic fuze support fails structurally when impacted by "Out-of-Line" fuze detonation blast allowing expulsion charge constituents to spill from sealed cavity.

3. Four alternative designs are proposed in the priority shown, to eliminate these failures:

<u>Alternative Design Priority</u>	<u>Design Features</u>	<u>Problem Statement Addressed</u>	<u>Root Cause Corrected</u>
1	Replace plastic fuze support with aluminum unit.	III	A
	Reduce thickness of pusher plate (Consequence of increase in height of expulsion charge).	I	A
	Eliminate center hole in pusher plate.	I	A
	Replace with four holes located off-center.	I, II	A
	Use separate, sealed plastic expulsion charge holder.	III	A
	Tightly pack expulsion charge constituents.	I	B
	Eliminate M10 propellant and increase amount of black powder in expulsion charge.	I	C
	Increase amount of magnesium in expulsion charge.	II	*
	Increase shear pins from 4 to 6.	II	*

2	Eliminate center hole from pusher plate.	I	A
	Use a special RP ignition composition located in RP stack hole and initiated by hot match device.	II	A
	Include an abrasive surface at front of warhead to ignite RP pellets during expulsion.	II	A
3	Completely redesign warhead.	All	All

*NOTE: Not a specific Root Cause but considered to be a contributing factor.

Alternative Design 1 represents a design based on that evolved by the project personnel prior to the Red Team Study. This design is considered as the first priority because it appears to address every Root Cause determined from the Red Team Study and has been successful in testing to date. Thus, from both a technical and a developmental (i.e., time and cost) standpoint, this would be a the design of choice. In addition to indicating that this design should eliminate the failure modes ascribed to the XM264, the Red Team Study also proposes that a series of tests be completed, using a revised static test arrangement, which are statistically valid in demonstrating the reliability of the design, particularly the size, location and shape of the critical multiple holes in the pusher plate, in meeting the the XM264 performance requirements.

Alternative Design 2 corrects one of the general problems associated with the Baseline Design in that it eliminates the multifunctional hole in the pusher plate. Thus, the pusher plate does not contain any holes at all and the RP expulsion and ignition are each separate actions, not dependent on each other.

Alternative Design 3 was evolved to show to what extent the design would be changed if minimal constraints were imposed. While this design is intended to eliminate the problems experienced by the XM264, it would require a considerable development effort and the associated high cost and lengthened schedule may not be warranted in light of the other more mature designs. Thus, it is given the lowest priority.

4. The methodology and results of the XM264 Red Team Study are

documented in the attached draft final report.

Chairman: _____
Mr. Miles C. Miller, SMCCR-RSP-A

Members: _____
Mr. Gerald P. Young, SMCCR-MUP-S

Mr. Craig M. Sherwood, AMSMC-QAV-R(A)

Dr. John A. Vanderhoff, ARBRL-IB

Mr. Daniel J. Weber, SMCCR-RSP-A

Mrs. Carol S. Hansen, SMCCR-RSP-A

Facilitator: _____
Mr. A. E. Magistro, SMCAR-AST

XVII. FINAL REPORT

A final report should be prepared to document the study. It should be an all-inclusive report and should include all of the reference materials in appendices. It should be a "stand-alone" document that can be handed over to someone in the future and would contain everything associated with the analysis. Finally, it should be published as soon as possible so that it is accessible for use in follow-on efforts. Also, because of the short life of the team, if the report is not completed before the the team is disbanded, it probably never will be. (A-20)

XVIII. LESSONS LEARNED

In every Root Cause Analysis, certain items are revealed which, although not root causes, represent factors which contributed in some aspect to the problem. Identification of these items may allow their being recognized and prevented from occurring in future project. Accordingly, list of these "Lessons Learned" can an additional benefit of the Root Cause Analysis.

XIX. CORRECTIVE MEASURES

As stated earlier, the purpose of a Root Cause Analysis is to determine the problem and not the solution. There has been a trend recently to have the Root Cause Analysis also propose solutions to the problem. The thinking is that the analysis teams have acquired considerable knowledge of the system and situation and should be in a good position to come up with solutions to the problem. It's also tempting for the sponsor to attempt to get his entire problem solved (which is his real concern). However, this extra task may dilute the Root Cause Analysis from its main purpose. This should be left to the project people who have the greatest capability to solve the problem. Having the Red Team involved in this aspect tends to create extra friction between the Red and Blue Teams even though the proposed solutions (like the Probable Root Causes) would be a joint effort between them. (A-21)

One approach to this is to use the Failure Mode Charts as Success Mode Charts. This provides a similar formal method to show how a proposed solution will eliminate a Problem Statement. In this instance, the chart topics are reworded as shown in the example of Figure Figure 20. A single chart would be used to correct each Root Cause.

SUCCESS MODE CHART

Cause Probability Estimate: HL

Date: 16 Nov 89 Rev. No.

Success Indication: RP Pellets Ignite

EVALUATION			
SPECULATION	SUPPORTING DATA	REFUTING DATA	ADDITIONAL DATA TESTS REQUIRED
<p>Use striking surface or teeth at mouth of warhead case to ignite RP by friction at ejection.</p> <p>SUCCESS SEQUENCE: As the RP pellets translate past an inner sleeve (with sharp teeth or knurling) placed in the mouth of the warhead case the pellets will ignite on their outer diameter as they are scratched and expelled.</p>	<p>The RP mixture with NaNO₃ is extremely friction sensitive. Friction or scratching will ignite the RP/Mg/NaNO₃/Epoxy. Shear pins could be made stronger so that the nose cone breaks off, leaving sharp pins protruding inside the case. The pins would then become the striking surface.</p>	<p>Added parts, more rivets. Will collar remain in place as RP pellets are ejected? Will add additional resistance to pellet expulsion? Will expulsion charge have enough energy to overcome added resistance?</p>	<p>Test sharp inner collar to determine if it can be secured and not be ejected with the pellets. Determine affects of air stream on pellets ignited in this fashion.</p>

NO:

Figure 20. Example of Success Mode Chart

XX. FINAL COMMENTS

The Root Causes Analysis methodology results in a dramatic increase in the number of possibilities for the Root Causes during the initial phases of the study. This is termed a "Divergence" of ideas. However, at some point, the thoughts must "Converge" to the final answer as illustrated in Figure 21. This general Divergence/Convergence is depicted in terms of the Root Cause Analysis process in Figure 22. (A-22)

As noted previously, this is only one of many Root Cause Analysis Methods in use and can be amended for the specific study. New and innovative forms of data presentation, statistical analysis and other techniques can be included. A summary of the Root Cause Analysis steps depicting the differences between a Red Team and Problem Analysis is shown in Figure 23. While some flexibility must be present in the use of this methodology, there are certain major requirements for a successful Root Cause Analysis as shown in (A-23). Don't forget to have the sponsor's provide some form of "Thank You" letters for the Red and Blue Team members as well as anyone else who contributed to the effort.

Finally, for most of us, serving on a Root Cause Analysis is an imposition. It takes us away from our main job, sometimes for a considerable period of time, to solve someone else's problem. However, a Root Cause Analysis is usually only reserved for problems which are of significant importance to the organization and our participation is of great value for this purpose alone. However, there are several other benefits to be derived from serving on a Root Cause Analysis team as noted in (A-24).

GENERAL APPROACH

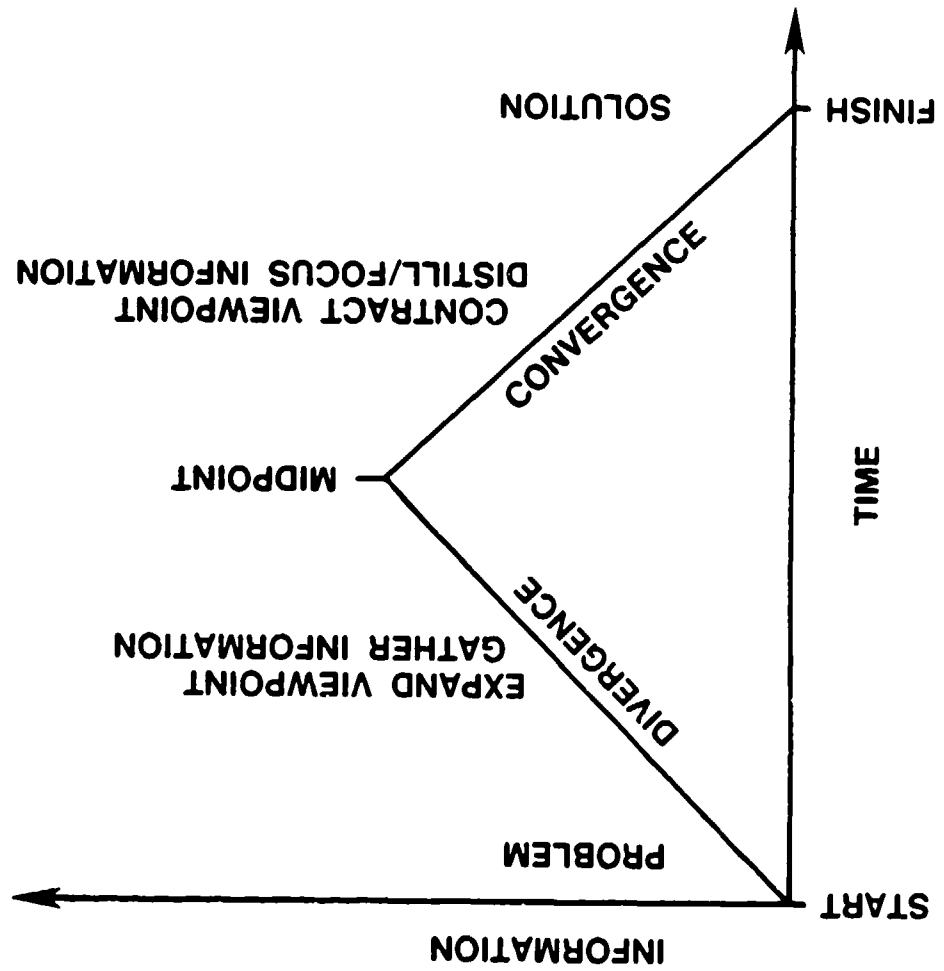


Figure 21. Diverging and Converging Process

ROOT CAUSE ANALYSIS

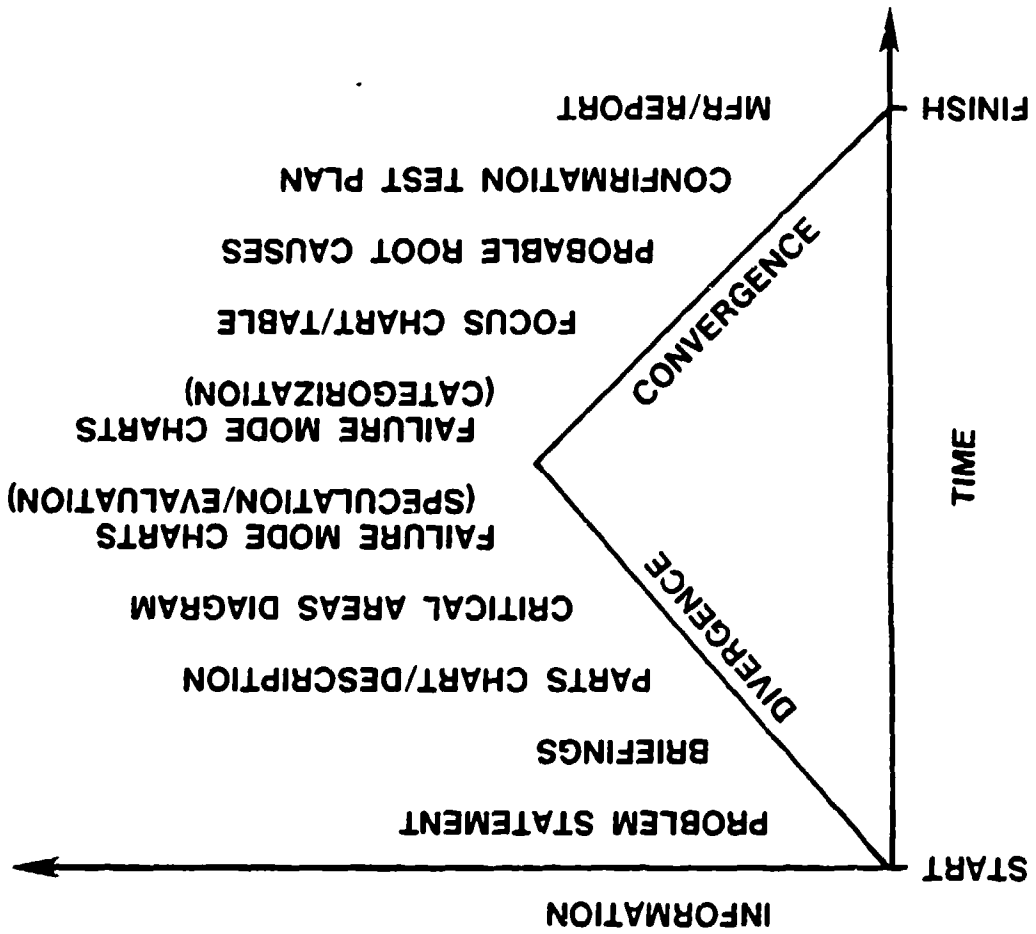


Figure 22. Diverging and Converging Process - Root Cause Analysis

ROOT CAUSE ANALYSIS PROCESS

ITEM

RED TEAM

(6-8 WEEKS)

PROBLEM ANALYSIS

(2-4 WEEKS)

* FORM TEAM *

Related Technical Skills
No Connection With Project
Some Outside People

Related Technical Skills
Current Connection With Project
No Outside People

* RECEIVE TRAINING *

3 days - Include Current Problem

2 hours - Overview

* ESTABLISH PROBLEM STATEMENT *

Concise Wording
Broad Meaning
All Understand/Agree
Can Change During Analysis

* MEMORANDUM OF AGREEMENT *

Authority (Who's the Customer)
Objective
Scope (When to Stop)
Funding

* BRIEFING BY PROJECT PEOPLE *

Read-Ahead Material
Blue Team Briefing

Read-Ahead Material
Project People

* REASSESS PROBLEM STATEMENT *

* INDEPENDENT DESIGN REVIEW *

Obtain Assembly/Parts Drawings
Prepare Parts Diagram
Prepare Functional Diagrams
Specify and Understand Processes

Figure 23. Summary of Root Cause Analysis Methodology

* SELECT CRITICAL AREAS *

COMBINED RED AND BLUE TEAMS

PROBLEM ANALYSIS TEAM
PANEL OF EXPERTS

* FAILURE MODE CHARTS *

CONJECTURE FAILURE MODES (DEFERRED JUDGEMENT)
SUPPORTING AND REFUTING DATA
ADDITIONAL DATA/TESTING REQUIRED

* CATEGORIZE FAILURE MODE CHARTS *

NOT LIKELY (NL)
LIKELY (L)
HIGHLY LIKELY (HL)

* FOCUS CHART AND FOCUS DIAGRAM *

FOCUS ON HL AND L
DISTILL TO COMMON CAUSES

* DETERMINE PROBABLE ROOT CAUSES *

SINGLE
MULTIPLE
COMBINED
SEQUENTIAL
PARALLEL

* PROPOSE TESTS TO CONFIRM PROBABLE ROOT CAUSE(S) *

CREATE/ELIMINATE PROBLEM AT WILL

* PRESENT IPR *

EVERY 2 WEEKS

PERIODICALLY

* PREPARE MEMORANDUM FOR RECORD *

* WRITE REPORT *

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APPENDIX
SUMMARIZED HIGHLIGHTS

ROOT CAUSE ANALYSIS

PURPOSE: To identify the real cause of a problem.
(It is someone else's job to solve the problem.)

APPROACH: Follow a formal, systematic, objective process which:

Considers all potential failure modes.
Identifies the Probable Root Causes.
Establishes experiments to confirm the Probable Root Causes.
Documents process.

Figure A-1. Root Cause Analysis Definition

ROOT CAUSE ANALYSIS METHODOLOGY

- * FORMING THE TEAM**
- * FACILITIES**
- * TRAINING**
- * PROBLEM STATEMENT**
- * MEMORANDUM OF AGREEMENT (MOA)**
- * BRIEFING BY PROJECT PEOPLE**
- * INDEPENDENT DESIGN REVIEW (IDR)**
- * CRITICAL AREAS CHART**
- * FAILURE MODE CHARTS**
- * CATEGORIZE FAILURE MODE CHARTS**
- * LOGIC FOCUS CHART AND DIAGRAM**
- * PROBABLE ROOT CAUSES**
- * ROOT CAUSE CONFIRMATION TESTS**
- * IN-PROCESS REVIEWS (IPR)**
- * FINAL MEMORANDUM FOR RECORD (MFR)**
- * FINAL REPORT**
- * SOLUTIONS TO PROBLEM**

Figure A-2. Root Cause Analysis Procedure

ROOT CAUSE ANALYSIS TEAM MEMBERS

RED TEAM (6-8 WEEKS)

Related Technical Skills.

No Association With Project.

Some Outside People.

Statistician

Secretary

PROBLEM ANALYSIS (2-4 WEEKS)

Related Technical Skills.

Associated With Project.

No Outside People.

Figure A-3. Team Members

FUNCTIONS OF RED AND BLUE TEAMS

RED TEAM

Direct, guide, coordinate and assist in Root Cause Analysis Process.

Act as catalyst and coach for Blue Team.

Present status briefings and prepare final report.

BLUE TEAM

Provide background information and data on item being analyzed.

Participate in Root Cause Analysis Process.

Gather supporting/refuting data details as required.

Non-Adversarial Relationship

Results are Truly a Combined Red/Blue Team Effort

Figure A-4. Functions of Red and Blue Teams

FACILITIES

- * EXCLUSIVE USE ROOM**
- * LARGE ENOUGH FOR BOTH TEAM MEMBERS PLUS VISITORS**
- * REPOSITORY FOR ALL DATA, INFORMATION, ETC.**
- * SHOULD HAVE MULTIPLE PHONES AND FAX**

Figure A-5. Facilities

PROBLEM STATEMENT

- * **BRIEF STATEMENT OF PROBLEM.**
 - **ACCURATE**
 - **COMPLETE**
 - **CONCISE**
- * **INITIALLY BROAD.**
- * **FOCAL POINT OF ANALYSIS.**
- * **CAN CHANGE THROUGHOUT ANALYSIS.**

Figure A-6. Problem Statement

MEMORANDUM OF AGREEMENT

- * OBJECTIVE**
- * SCOPE**
- * TIME FRAME**
- * COST ESTIMATE AND FUNDING SOURCE**
- * CUSTOMER/TEAM CHAIRMAN SIGNATURES**

Figure A-7. Memorandum of Agreement

BRIEFING BY BLUE TEAM

- * **PROVIDE "READ-AHEAD" INFORMATION PACKAGE.**
- * **LIST OF PROJECT PEOPLE, RESPONSIBILITIES, ORGANIZATIONS, PHONE NUMBERS, USERIDS, ETC.**
- * **PHYSICAL AND FUNCTIONAL DESCRIPTIONS OF ITEM BEING ANALYZED.**
- * **CHRONOLOGY OF PROBLEM.**
- * **SEPARATE PRESENTATIONS ON SELECTED DETAILS OF COMPONENTS, MATERIALS, MANUFACTURING, ETC.**
- * **SAVE NOTES ON BRIEFING SHEETS AND DISPLAY AROUND ROOM.**

Figure A-8. Briefing by Blue Team

INDEPENDENT DESIGN REVIEW

- * ASSEMBLY AND INDIVIDUAL PARTS DRAWINGS.**
- * PARTS BREAKDOWN CHART.**
 - NUMERICALLY DESIGNATE EACH PART.**
- * COMPONENT LIST AND DETAILED DESCRIPTION.**
- * FLOW DIAGRAMS OF FUNCTIONAL SEQUENCES.**
- * MANUFACTURING, ASSEMBLY AND OPERATIONAL ASPECTS.**

Figure A-9. Independent Design Review

CRITICAL AREAS DIAGRAM

- * CRITICAL AREAS (WHAT ARE NOT, WHAT ARE)**
- * FLOW CHART ELEMENTS (X)**
 - PROBLEM STATEMENT**
 - FUNCTIONAL GROUP**
 - ASSEMBLIES**
 - SUB-ASSEMBLIES**
 - COMPONENTS**
 - SUB-COMPONENTS**
- * INFLUENCE FACTORS (F)**
 - DESIGN EFFECTS - Functions as Intended**
 - MANUFACTURING EFFECTS - Out of Specifications**
 - MATERIALS COMPATIBILITY - Corrosion, Fit, Wear, Etc.**
 - DYNAMIC EFFECTS - Acceleration, Spin, Etc.**
 - ENVIRONMENTAL EFFECTS - Temperature, Moisture, Etc.**
 - OPERATIONAL EFFECTS - Human Error, Operational Use**
 - OTHER EFFECTS - Unique to Item**
- * SEQUENCE IDENTIFICATION (X.X.X.X.X.F.)**

Figure A-10. Critical Areas Diagram

DEFERRED JUDGEMENT

- * CONJECTURE AND SPECULATE WITHOUT EVALUATION OR CRITICISM.**
- * HIGHLY EFFICIENT AND EFFECTIVE (3X OUTPUT OF NORMAL PRACTICE).**
- * MAXIMIZES POSSIBILITY OF GETTING THE ROOT CAUSE.**
- * MINIMIZES POSSIBILITY OF MISSING THE ROOT CAUSE.**

Figure A-11. Deferred Judgement

FAILURE MODE CHARTS

- * SOMETIMES REFERRED TO AS "ROOT CAUSE ANALYSIS CHARTS"**
- * MOST IMPORTANT ELEMENT OF PROCESS**
- * CONSIDERS ONLY ONE PROBLEM STATEMENT**
- * SPECULATION**
 - Failure Mode**
 - Failure Mode Sequence**
- * DEFERRED JUDGEMENT**

Figure A-12. Failure Mode Charts - Speculation

FAILURE MODE CHARTS

*** EVALUATION**

- **Supporting Data**
- **Refuting Data**
- **Additional Data/Tests Required**

Figure A-13. Failure Mode Charts - Evaluation

FOCUS CHART AND FOCUS DIAGRAM

- * COMBINE FAILURE MODES IN FLOW CHART**
- * DISTILL DOWN TO COMMON CAUSES**
- * IDENTIFY PROBABLE ROOT CAUSE**

Figure A-14. Focus Chart and Focus Diagram

PROBABLE ROOT CAUSES

PROBABLE ROOT CAUSE: The most basic factor which causes the problem to occur, which, if eliminated, will eliminate the problem. Considered a "Probable Root Cause" until confirmed by testing.

Figure A-15. Probable Root Causes

INCUBATION TIME

- * **DELAY TIME TO REFLECT, REASSESS, AND RECONSIDER PAST RESULTS.**
- * **LACK OF "INCUBATION TIME" IS BIGGEST DRAWBACK TO SHORT ANALYSIS.**

Figure A-16. Incubation Time

ROOT CAUSE CONFIRMATION TESTS

- * DUPLICATE FAILURE MODE.**
- * ELIMINATE FAILURE MODE BY ELIMINATING PROBABLE ROOT CAUSE.**
- * CREATE AND ELIMINATE PROBLEM AT WILL.**
- * MAY REQUIRE STATISTICAL ANALYSIS.**

Figure A-17. Root Cause Confirmation Tests

IN-PROCESS REVIEWS (IPR)

- * HOLD MORE FREQUENTLY AT BEGINNING OF ANALYSIS.**
- * PROVIDES "FEEDBACK" FROM CUSTOMER.**
- * ESTABLISHES SCHEDULE TO WORK TOWARD.**
- * WEEKLY WRITTEN STATUS REPORT.**

Figure A-18. In-Process Reviews

FINAL MEMORANDUM FOR RECORD (MFR)

- * SUMMARIZES OBJECTIVE, PROCESS AND FINDINGS.**
- * SIGNED BY ANALYSIS CHAIRMAN AND CUSTOMER.**

Figure A-19. Final Memorandum For Record

FINAL REPORT

- * ALL INCLUSIVE, STAND-ALONE DOCUMENT.**
- * MFR IS SUMMARY SECTION OF FINAL REPORT.**
- * PUBLISH IMMEDIATELY.**

Figure A-20. Final Report

SOLUTIONS TO PROBLEM

- * NOT USUALLY PART OF A FORMAL ROOT CAUSE ANALYSIS.**
- * TAKES ADVANTAGE OF EXISTENCE OF GROUP OF KNOWLEDGEABLE PEOPLE.**
- * TENDS TO DETRACT TIME AND EFFORT FROM AN ALREADY DEMANDING TASK.**
- * SOLUTION MAY REQUIRE YEARS TO ACHIEVE.**
- * UTILIZE "SUCCESS MODE CHARTS".**

Figure A-21. Solutions to Problem

FINAL COMMENTS

- * DIVERGE THEN CONVERGE.
- * ONLY ONE OF MANY FORM OF ROOT CAUSE ANALYSIS.
- * CAN BE AMENDED MODIFIED, ETC.
- * INNOVATIVE CHARTS, LISTS, ETC. TO PRESENT/ANALYZE INFORMATION.
- * THANK YOU LETTERS TO TEAM MEMBERS AND OTHERS WHO HELPED.

Figure A-22. Final Comments

REQUIREMENTS FOR SUCCESSFUL RESULTS

- * HIGHEST POSSIBLE AUTHORITY.**
- * FUNDING AVAILABLE FROM START.**
- * NON-ADVERSARIAL RELATIONSHIP - RED/BLUE TEAM ON SAME TEAM.**
- * ESTABLISH BROAD PROBLEM STATEMENT.**
- * IDENTIFY ALL POTENTIAL FAILURE MODE COMBINATIONS.**
 - DEFERRED JUDGEMENT**
 - INCUBATION TIME**
- * PREVENT "TUNNEL VISION".**
- * DOCUMENT RESULTS AS YOU GO.**

Figure A-23. Requirements for Successful Results

BENEFITS OF SERVING ON ROOT CAUSE ANALYSIS TEAMS

- * ASSIST IN SOLVING CRITICAL CRDEC PROBLEM.**
- * BROADEN AWARENESS OF OTHER CRDEC TECHNICAL AREAS.**
- * INCREASES YOUR TECHNICAL KNOWLEDGE IN SEVERAL FIELDS.**
- * ROOT CAUSE METHODOLOGY CAN BE APPLIED TO YOUR OWN PROBLEMS.**
- * PRODUCES A CADRE OF TRAINED PERSONNEL FOR FUTURE STUDIES.**
- * MEET AND INTERACT WITH OTHER GROUPS/ ORGANIZATIONS FROM INSIDE AND OUTSIDE CRDEC.**
- * ESTABLISHES PERSONAL WORKING RELATIONSHIPS AND FRIENDSHIPS.**
- * PROVIDES VISIBILITY OF TEAM MEMBERS TO UPPER MANAGEMENT.**

Figure A-24. Benefits of Serving On Root Cause Analysis Teams