

SAFETY CONSIDERATIONS IN EVALUATION OF MAINTENANCE PROGRAMS



EG&G Idaho, Inc.

P.O. Box 1625
Idaho Falls, Idaho 83401

MARCH 1978

UNITED STATES
DEPARTMENT OF ENERGY
DIVISION OF OPERATIONAL AND ENVIRONMENTAL SAFETY

DOE 76-45/12

SSDC-12

UC-41

SAFETY CONSIDERATIONS IN
EVALUATION OF MAINTENANCE PROGRAMS

Prepared By

R. J. Nertney

Work Performed At

EG&G IDAHO, INC.

IDAHO OPERATIONS OFFICE

Under Contract No. EY-76-C-07-1570

March 1978

DISCLAIMER

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Department of Energy nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, expressed or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

Available from:

System Safety Development Center
EG&G Idaho, Inc.
P. O. Box 1625
Idaho Falls, Idaho 83401

ACKNOWLEDGMENTS

The author wishes to express appreciation for the helpful comments received from the many individuals, inside and outside of the Department of Energy, who reviewed this document. Their comments made a very significant contribution to the completeness of the guide.

The administrative and editorial assistance of Della Kellogg and the drafting of the logic tree by Joann Walker are also gratefully acknowledged.

ABSTRACT

This guide is designed for the purpose of analyzing maintenance programs from the safety point of view. The necessary analytical trees are developed and converted to a series of analytical questions to be asked in safety evaluation of maintenance programs.

The guide provides a further and more detailed development of maintenance considerations included in the basic Management Oversight and Risk Tree (MORT)[¹]. It also uses the same topic headings and is designed to interface with the Maintenance Managers Guide[²] prepared by the Energy Research and Development Administration's (now the Department of Energy) Division of Construction Planning and Support.

GLOSSARY

ERDA Manual: The basic manual providing command and guidance information for work performed within or for the Energy Research and Development Administration (ERDA).

Misuse (Of Equipment): Use of equipment outside of specified or implied limits in such a way as to compromise the equipment's capability to meet its original specification.

MORT: The Management Oversight and Risk Tree. May refer to: (1) the basic MORT diagram, (2) the entire MORT system safety program, or (3) be used as an adjective, e.g., a "MORT (type) analytical tree".

Reactor: Nuclear reactor.

Sensitive Equipment or Materials: Within the context of this report, sensitive equipment or materials are those pieces of equipment or materials which: (1) are of safety concern because of property loss or damage considerations and (2) have capability for producing safety-related consequences through impaired function of the equipment or by virtue of the nature of the material (toxic, pathogenic, carcinogenic, pyrophoric, etc.).

CONTENTS

ACKNOWLEDGMENTS	ii
ABSTRACT	iii
GLOSSARY	iv
I. INTRODUCTION	1
II. THE ANALYTICAL TREE	8
1.0 Is the Program Coverage Adequate from the Safety Point of View?	8
2.0 Are Maintenance Policies Adequate from the Safety Point of View?	8
3.0 Does An Adequate Work Order System Exist?	9
4.0 Are Adequate Material Controls Included in the System?	10
5.0 Are Adequate Equipment Records Maintained?	10
6.0 Are Adequate Preventive Maintenance (PM) Activities Conducted?	11
7.0 Is the As-Needed, Breakdown Maintenance Program Adequate?	11
8.0 Is the Job Planning Program Adequate?	11
9.0 Do Adequate Maintenance Work Sampling Systems Exist?	12
10.0 Does An Adequate Work Scheduling System Exist?	12
11.0 Do Adequate Backlog Controls Exist and Are They Properly Related to Safety Considerations?	13
12.0 Do Adequate Maintenance Performance Measurement and Improvement Plans Exist?	13

CONTENTS (cont.)

13.0	Are "Control" (Management-Supervision-Staff) and "Doing" (Actual Field Performance) Maintenance Functions Properly Established and Related?	13
14.0	Do Adequate Work Prioritization Systems Exist?	14
15.0	Are Adequate Engineered Time Standards in Use?	14
16.0	Do Adequate Cost Identification and Cost Controls Exist to Lead to Proper Resource Allocations?	14
17.0	Do Adequate Methods and Systems Exist to Make Proper Maintain vs. Upgrade vs. Replace Decisions?	14
III.	REFERENCES	15

FIGURES

1.	The maintenance branch of the MORT diagram	2
2.	The maintenance analytical tree	3

I. INTRODUCTION

The basic Management Oversight and Risk Tree (MORT) diagram^[1] includes evaluation of maintenance programs as one of its subelements. As indicated in Figure 1, evaluation of the maintenance program is broken down into two basic considerations: the adequacy of the maintenance plan and the adequacy of the execution. This breakdown, in turn, leads to evaluation of the seven terminal considerations indicated in the circles as well as evaluation of general task error considerations. Since the operational adequacy of a system, regardless of initial design quality, is no better than the system maintenance program, it is often important that system analysis go far beyond the degree of analysis indicated in the basic MORT diagram.

The purpose of this monograph is to extend the analytical process which is begun in the basic MORT diagram to include additional detail. Since a basic guideline manual for maintenance management already exists in the Energy Research and Development Administration (ERDA) [now the Department of Energy (DOE)] literature, the Maintenance Managers Guide, prepared by the ERDA-DOE Division of Construction Planning and Support^[2], has been used as a basis for preparation of this guideline manual. The Maintenance Managers Guide, in turn, is designed to provide compliance with the policies and objectives of ERDA Manual Chapter 5401, "Maintenance of Property". In addition to the specific criteria included in the Maintenance Managers Guide and in this monograph, general attention should, of course, be paid to such factors as general work quality, housekeeping, etc. Overt maintenance task performance error is, of course, covered by Sd3b3 of the parent MORT diagram (Figure 1).

In Figure 2, much of the material included in the Maintenance Managers Guide has been rearranged in analytical tree format with minor modifications. This tree provides the basis for specific discussion of safety considerations in evaluation of maintenance programs. The Maintenance Managers Guide should be used in its original form for general functional evaluation of maintenance programs. While it might have been desirable, from the purely "safety" or "MORT" point of view, to rearrange the material in a different, logical format, we have chosen to closely parallel the Maintenance Managers Guide. This permits easier correlation of maintenance program evaluation from the safety point of view with similar evaluations relating to functional considerations.

Paralleling the structure of the Maintenance Managers Guide, safety considerations in evaluating maintenance programs fall into seventeen areas:

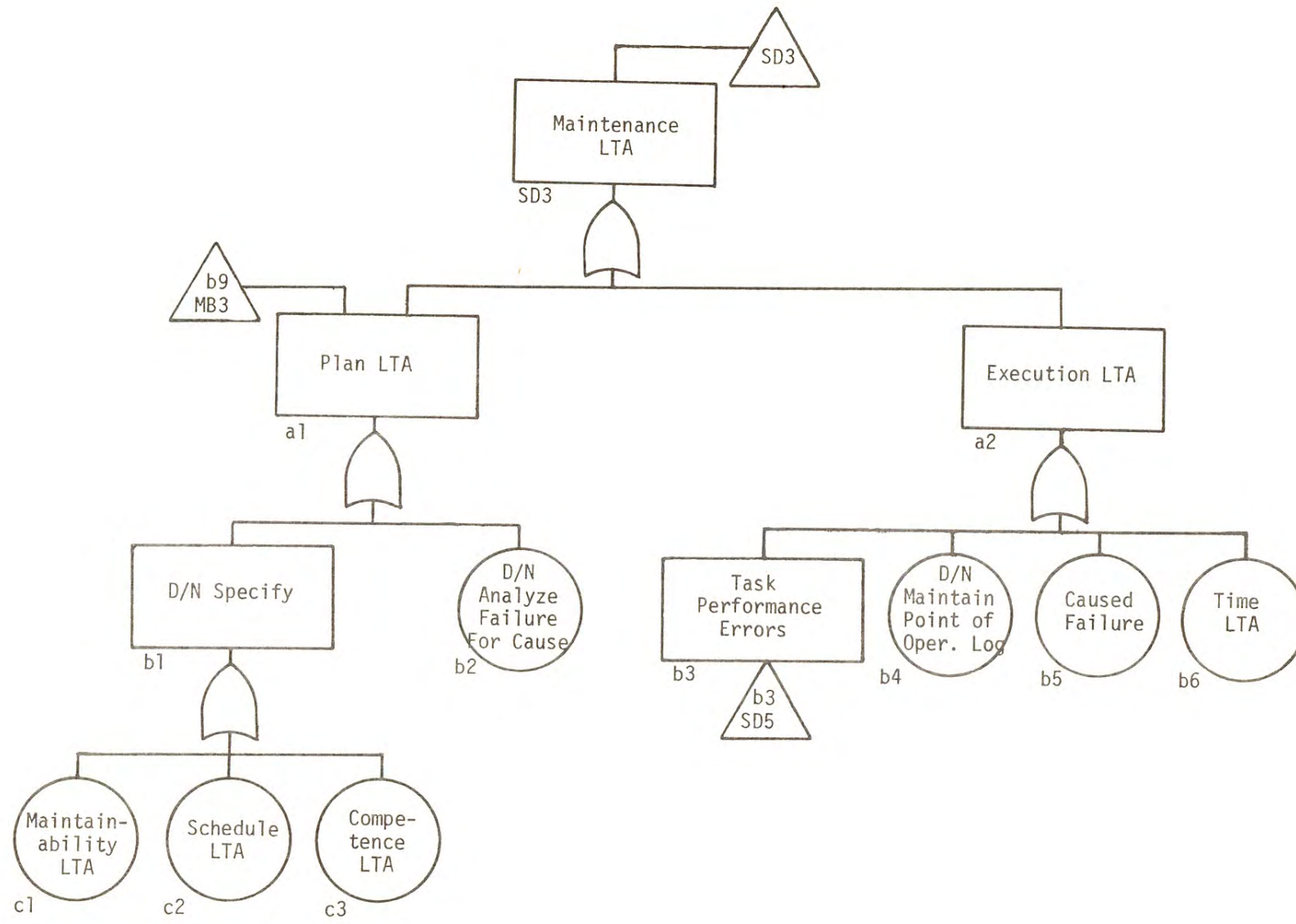


Fig. 1 The maintenance branch of the MORT diagram.

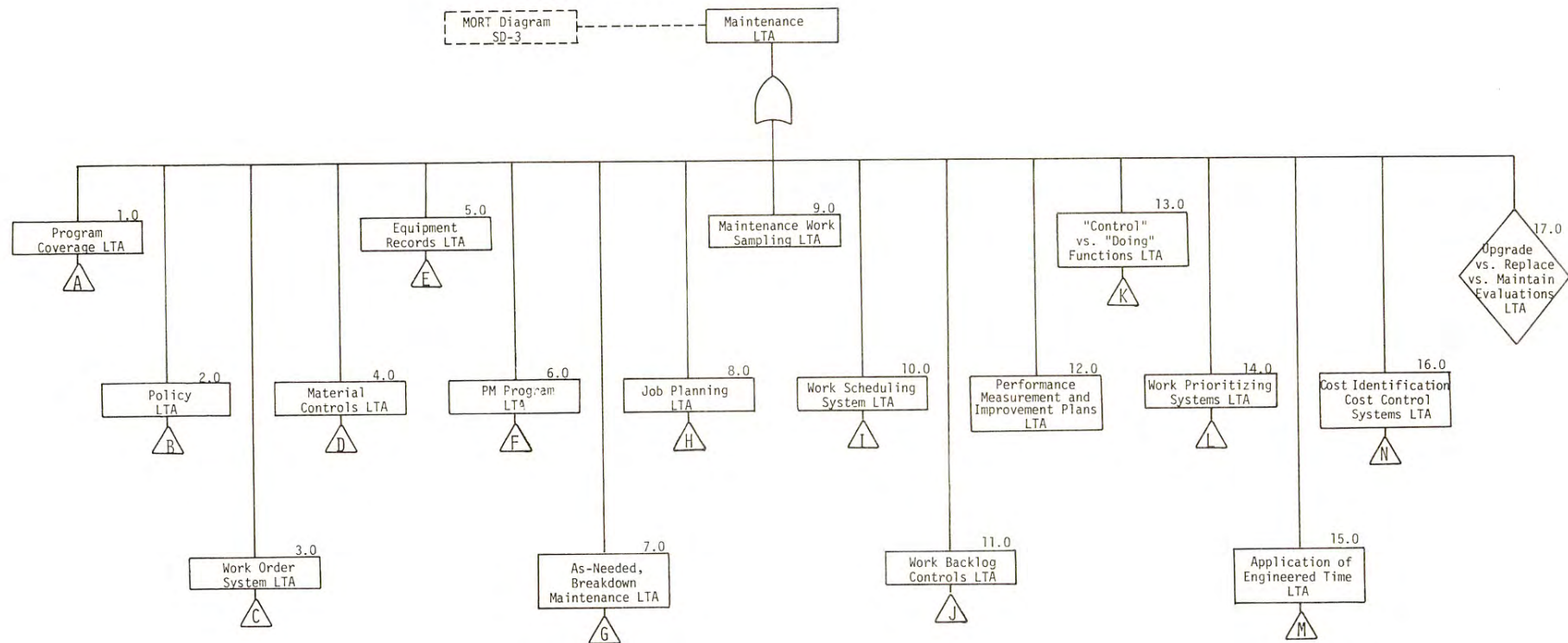


Fig. 2 The maintenance analytical tree.

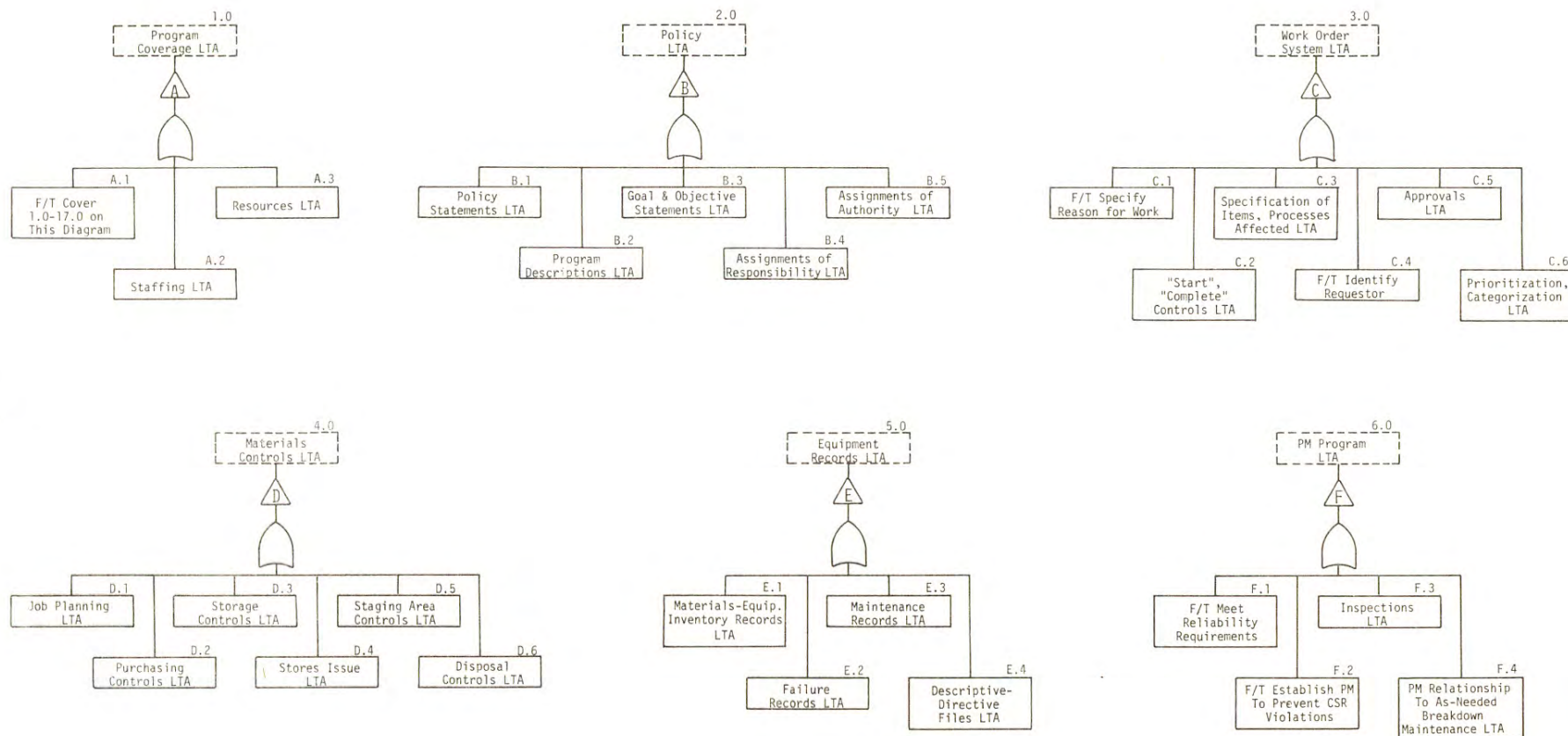
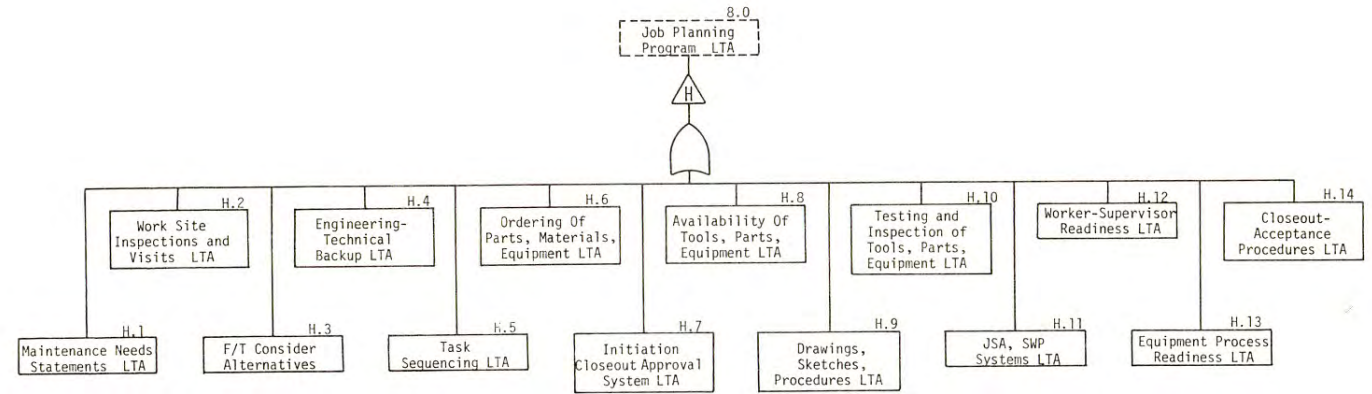
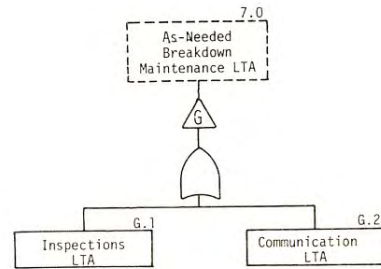


Fig. 2 (cont.)



67

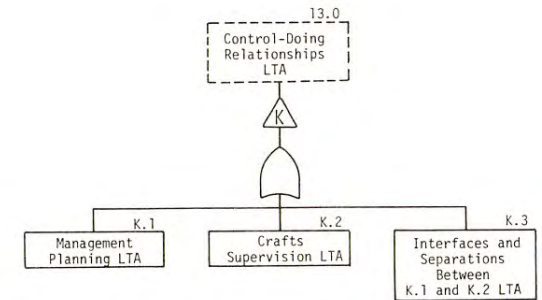
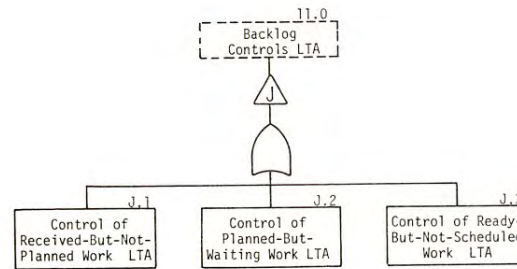
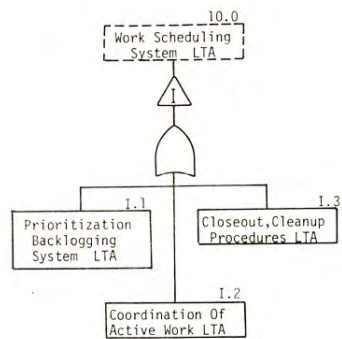


Fig. 2 (cont.)

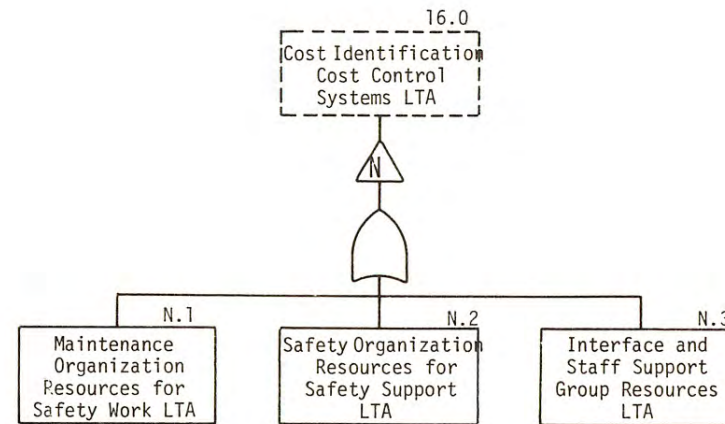
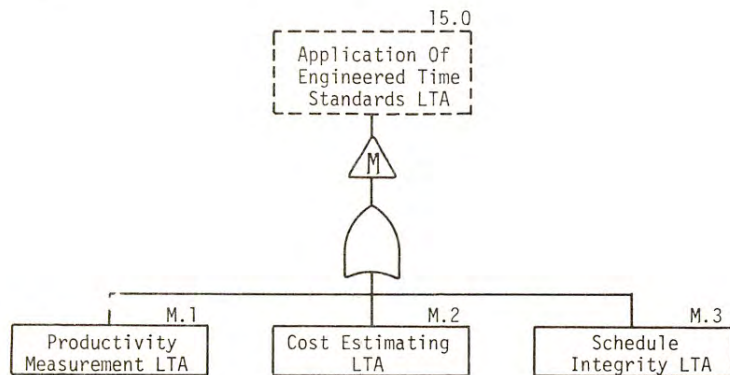
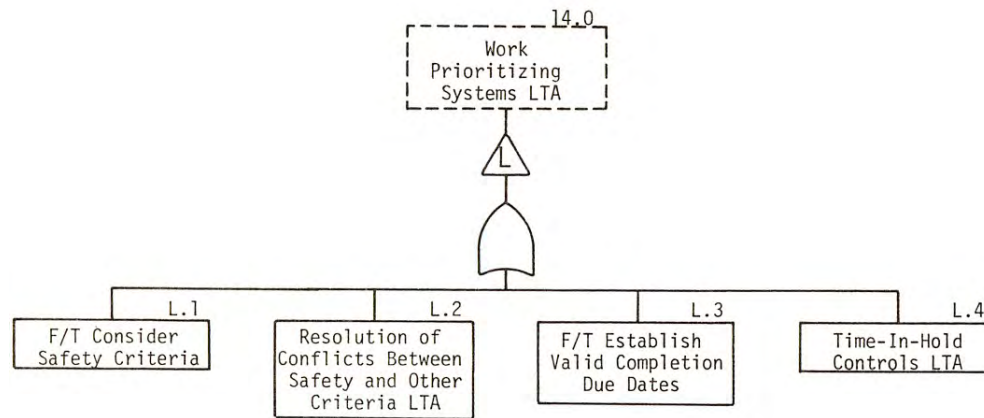


Fig. 2 (cont.)

- (1) Maintenance Program Coverage
- (2) Maintenance Program Policies
- (3) The Work Order System
- (4) The Materials Control System
- (5) The Equipment Records System
- (6) The Preventive Maintenance Program
- (7) The As-Needed and Breakdown Maintenance Program
- (8) Job Planning Methods and Procedures
- (9) The Maintenance Work Sampling Program
- (10) The Maintenance Scheduling System
- (11) The Backlog Control System
- (12) The Maintenance Performance Measurement and Improvement Program
- (13) The Relationships Between Maintenance "Control" and "Do" Functions
- (14) The Maintenance Prioritization System
- (15) Use of Engineered Time Standards in the Maintenance Program
- (16) Cost Identification and Controls
- (17) Criteria Relating to Maintenance vs. Upgrade vs. Replacement

In relating these seventeen maintenance program considerations to safety, we are often interested in job safety for the maintenance activity itself and in operational safety of the system being maintained and in safety for the system being maintained (property protection). Detailed evaluation of the maintenance program (safety considerations) beyond the breakdown included in the basic MORT chart may be performed through use of the analytical tree described in Figure 2. This tree is used in exactly the same manner as the parent MORT diagram, i.e., consider the questions raised in connection with each element of the tree and color code the element green (adequate), red [less than adequate (LTA)], or blue (don't know). As in the case of the MORT diagram, further investigation is required to change the blue coded elements to red or green.

This guide is intended for use in analysis of a wide variety of maintenance programs. There may be a few cases in which a question relates to a function which is covered adequately by some other means. In this case, rather than using the red color code for a "No" answer, the appropriate box on the analytical tree should be X'ed out with a black pen as "not applicable" for that particular maintenance program.

The material developed in this more detailed analysis of the maintenance program may then be transferred to the "PLAN LTA" or "EXECUTION LTA" portions of the basic MORT diagram and be used to augment the remainder of the MORT analysis of the system under study. As in the case of any analytical tree, one may develop any of the bottom tier items of this tree further if desired.

II. THE ANALYTICAL TREE

The Top Event - The top event on this tree is maintenance inadequacy leading to (or potentially leading to) the top events on the parent MORT diagram, i.e., injuries, damage, other costs, performance lost or degraded, program or public impact.

In the analysis that follows, the distinction between inadequacies in PLAN and EXECUTION must be considered in almost every case. This must be kept in mind even though the "cue" questions provided may appear to be directed to the planning function or the execution of the plan. Furthermore, attention should be given to documentation and distribution of documentation relating to maintenance activities. This attention should apply both to maintenance personnel and to maintenance users.

1.0 Is the Program Coverage Adequate from the Safety Point of View?

1.1 (A.1) Are all considerations on this tree (1.0 through 17.0) included in the program description and functions?

1.2 (A.2) Is staffing adequate to cover all of the functions? Numbers of people? Kinds of people? Organization of functions?

1.3 (A.3) Are financial and material resources adequate to cover all of the functions?

2.0 Are Maintenance Policies Adequate from the Safety Point of View?

2.1 (B.1) Do the maintenance policy statements include such safety-related criteria as:

- (1) Adequate "tag-out", "don't use" policies?
- (2) Adequate "working alone" or "buddy system" policy?
- (3) Requiring adequate maintainability criteria in the design and modification processes? Process running? Process shut down?

(4) Requiring adequate maintenance criteria and instructions for new or modified equipment?

(5) Do adequate policies regarding upgrading vs. maintenance vs. replacement exist?

2.2 (B.2) Are there adequate program descriptions describing the maintenance program and relating it to the safety and other staff support and operating programs? Safety? Quality assurance? Reliability? Operations?

2.3 (B.3) Are there adequate safety goal and objective statements relating to the maintenance program? Job safety? Process safety?

2.4 (B.4) Are there proper assignments of safety responsibility within the maintenance organization and in interface organizations? Job safety? Process safety?

2.5 (B.5) Are there proper statements of authority relating to safety? In the maintenance organization? For interface safety personnel? For other interface personnel (e.g., operations personnel)?

3.0 Does An Adequate Work Order System Exist?

3.1 (C.1) Does the system require that the reasons for performing the work be described for each work order (if this is relevant to safety)?

3.2 (C.2) Does the work order system contain adequate "start" and "complete" information and controls? Times? Authorities? Coordination with other work and functional requirements? Workers properly instructed and briefed? Identification of special safety techniques, procedures, and equipment?

3.3 (C.3) Does the work order system require adequate specification of items and processes directly or indirectly affected by the work? Is work being performed in temporary staging, testing, and assembly areas adequately covered?

3.4 (C.4) Does the system require identification of the requestor?

3.5 (C.5) Does the system require adequate approvals? Area (landlord) supervision? Job supervision? Safety? Process supervision? Quality assurance?

3.6 (C.6) Does the system require proper work prioritization and categorization, e.g., preventive maintenance, repair, installation, "must complete before startup", etc.? Are testing and other preoperational activities adequately covered?

4.0 Are Adequate Material Controls Included in the System?

4.1 (D.1) Do job planning controls include adequate safety participation? Selection of materials? Determination of need for special safety equipment? Use of alternate materials?

4.2 (D.2) Do purchasing controls include adequate safety participation, e.g., safety cognizance and/or approvals for purchase requisitions?

4.3 (D.3) Are safety considerations properly included in stores coordination, e.g., storage of flammable, explosive, toxic, pathogenic materials? Protection of sensitive equipment?

4.4 (D.4) Are safety considerations properly included in parts and materials issue, e.g., restriction of issuance of hazardous materials to authorized personnel, control on return and reissue of sensitive materials?

4.5 (D.5) Do appropriate controls exist for sensitive and hazardous materials in temporary staging areas? Is adequate attention given to the job safety of testing operations which are conducted in staging and operating areas? Does this include such activities as use of toxic, flammable, explosive materials in testing procedures, use of inert atmospheres, etc.? Are materials used in preoperational and extraoperational testing activities adequately controlled, e.g., use of mercury manometers in the neighborhood of aluminum hardware?

4.6 (D.6) Do appropriate safety controls exist on disposition of unused hazardous materials, e.g., surplus materials, spills, opened and unsealed containers, repackaged materials, waste, materials which have been mixed or combined for use?

5.0 Are Adequate Equipment Records Maintained?

5.1 (E.1) Are materials-equipment inventory records adequate to provide guidance for establishing safety program coverage?

5.2 (E.2) Are failure records properly maintained? Equipment failures? Failures caused by maintenance? Misuse records? Is this information properly fed back to design, engineering, and accident prevention programs?

5.3 (E.3) Are adequate maintenance records maintained? Central records? Point of use records (logs, calibration stickers and labels, etc.)?

5.4 (E.4) Are adequate descriptive-directive files maintained? Owner-operator-service manuals? Drawings? Parts lists? Specifications? Warantees? Quality assurance requirements?

6.0 Are Adequate Preventive Maintenance (PM) Activities Conducted?

6.1 (F.1) Are equipment reliability requirements and specifications relating to safety defined and met?

6.2 (F.2) Is PM sufficient to minimize temporary or permanent violations of Codes-Standards-Regulations during failure periods?

6.3 (F.3) Is inspection sufficient to reveal maintenance needs in areas not under PM and to determine new areas in which (improved) PM is required?

6.4 (F.4) Is the PM adequate to provide a total maintenance program which is adequate? Adequate PM in and of itself? Adequate distribution between PM and as-needed, breakdown maintenance? Maintenance of Reliability and Quality Assurance (R&QA) requirements? Are "old" systems related properly to "new" requirements?

7.0 Is the As-Needed, Breakdown Maintenance Program Adequate?

7.1 (G.1) Is inspection adequate to support the as-needed and breakdown maintenance program?

7.2 (G.2) Is communication from inspection-detection to the "do" portion of the as-needed and breakdown maintenance program adequate? (See also 8.0, 10.0, and 11.0.)

8.0 Is the Job Planning Program Adequate?

8.1 (H.1) Are the maintenance needs clearly established (safetywise)? Is there adequate communication between equipment users and the maintenance groups?

8.2 (H.2) Are adequate worksite inspections and visits conducted? By maintenance supervisors? By work requestors and users of the equipment? By technical-engineering personnel? By safety organization professionals? Are both work environment and work activities covered?

8.3 (H.3) Are alternative (safer) ways of performing maintenance jobs considered? From the job safety point of view? From the overall system safety point of view?

8.4 (H.4) Is adequate engineering and technical backup provided on a job-by-job basis? Prejob? During job? Follow-up? In-house technical personnel? Vendor representatives? Consultants? Is a safety literature search required prior to performing work with new hardware and materials?

8.5 (H.5) Is adequate attention given to sequencing tasks properly?

8.6 (H.6) Are adequate parts, materials, equipment ordered prior to the job?

8.7 (H.7) Does an adequate work initiation and closeout approval system exist? Is it used? Are inspection and testing activities properly included in the safety control system? Are adequate cautions, warnings, and barriers provided?

8.8 (H.8) Are proper tools, materials, parts, and equipment made available?

8.9 (H.9) Are proper drawings (up-to-date and as-built), sketches, procedures, instructions made available?

8.10 (H.10) Are tools, materials, parts, equipment properly tested and inspected? Those used to do the job? Those that are a part of the job?

8.11 (H.11) Do proper Job Safety Analysis (JSA), Safe Work Permit (SWP) supporting systems exist? Are they used? Are human stress factors properly considered?

8.12 (H.12) Are workers and first line supervisors "operationally ready" prior to initiation of work? Work orders in hand, prejob briefings, materials available, etc.? Is adequate prejob instruction provided each time a supervisor assigns a work order task? Are relationships between maintenance supervision and user supervision properly defined? Are workers properly selected for the job?

8.13 (H.13) Are there adequate procedures to assure that facilities and equipment are ready to work on when job starts? Pressure down? Power off? Interface organizations and workers informed?

8.14 (H.14) Do adequate procedures exist for work closeout and acceptance? Acceptance for "as-specified" work? Acceptance for work with variances? Rejection of inadequate work? Independent (R&Q/A, Safety) inspections? As-building drawings? Updating other software?

9.0 Do Adequate Maintenance Work Sampling Systems Exist? By Maintenance Supervision? By Maintenance Staff? By Safety? By Quality Assurance? By Operations-Project Groups? By Technical-Engineering Functions?

10.0 Does An Adequate Work Scheduling System Exist?

10.1 (I.1) Is there adequate handling of prioritization and backlogging?

10.2 (I.2) Is there adequate coordination of active work? Job-to-job? Job to process? Intergroup? Workers to supervisor?

10.3 (I.3) Is there adequate job closeout, cleanup, recordkeeping?

11.0 Do Adequate Backlog Controls Exist and Are They Properly Related to Safety Considerations?

11.1 (J.1) For "received-but-not-planned" work?

11.2 (J.2) For "planned" but waiting for personnel, equipment, materials, etc.?

11.3 (J.3) For ready-to-go but not scheduled work?

12.0 Do Adequate Maintenance Performance Measurement and Improvement Plans Exist?

- (1) For the work order system?
- (2) For materials control?
- (3) For equipment records?
- (4) For preventive maintenance?
- (5) For job planning?
- (6) For work sampling?
- (7) For scheduling?
- (8) For backlog control?
- (9) For productivity control?
- (10) For interrelations between "control" and "doing" functions?
- (11) For prioritization?
- (12) For application of engineering standards?
- (13) Analysis of failures for cause?

13.0 Are "Control" (Management-Supervision-Staff) and "Doing" (Actual Field Performance) Maintenance Functions Properly Established and Related?

13.1 (K.1) Are management and planning functions adequate? Are independent safety and quality reviews adequate? Is the system adequately protected from unnecessary use of "emergency" shortcut procedures?

13.2 (K.2) Are the skills and performance of crafts and first line supervision adequate? Are selection processes adequate? Training? Procedures? Do workers receive adequate supervisory attention?

13.3 (K.3) Are interfaces and separations between 13.1 and 13.2 adequately defined and maintained? Are field craft and work supervisors overloaded with staff-administrative work? Are managers too involved in staff work or detailed job supervision?

14.0 Do Adequate Work Prioritization Systems Exist?

14.1 (L.1) Is the safety importance of items and systems properly evaluated and considered in setting priorities? Do adequate classification criteria and schemes exist? Are they properly used? Are safety considerations properly related to R&Q/A levels of rigor?

14.2 (L.2) Do priority criteria include "type of maintenance" considerations in a proper manner, e.g., breakdown vs. routine, types of craft involved, system status? Specifically, does priority allocation actually depend, to too high a degree, upon factors other than the importance of the item or system involved?

14.3 (L.3) Are required completion due dates established? Are these due dates properly related to safety considerations and requirements?

14.4 (L.4) Do adequate "time-in-hold" controls exist for middle and low priority items?

15.0 Are Adequate Engineered Time Standards in Use?

15.1 (M.1) For productivity measurement?

15.2 (M.2) For cost estimates?

15.3 (M.3) Are time standards sufficient to insure adequate maintenance of schedule integrity?

Note: Study of DOE accident history shows that the factors 15.1, 15.2, and 15.3 can have important indirect impact on the total effectiveness of the safety program in terms of changes, "corner cutting", job phasing and coordination, work deferment, etc.

16.0 Do Adequate Cost Identification and Cost Controls Exist to Lead to Proper Resource Allocations?

16.1 (N.1) Is resource allocation adequate for safety-related work by maintenance organizations?

16.2 (N.2) Is resource allocation adequate for safety organization support?

16.3 (N.3) Is resource allocation adequate for safety-related work by other interface line and staff groups?

17.0 Do Adequate Methods and Systems Exist to Make Proper Maintain vs. Upgrade vs. Replace Decisions?

III. REFERENCES

- [1] N. W. Knox and R. W. Eicher, MORT User's Manual, ERDA-76/45-4, SSDC-4 (Rev. 1) (March 1976).
- [2] Maintenance Managers Guide, ERHQ-0004, Energy Research and Development Administration, Division of Construction Planning and Support (December 1976).

OTHER SSDC PUBLICATIONS IN THIS SERIES

SSDC-1	Occupancy-Use Readiness Manual
SSDC-2	Human Factors in Design
SSDC-3	A Contractor Guide to Advance Preparation for Accident Investigation
SSDC-4	MORT User's Manual
SSDC-5	Reported Significant Observation (RSO) Studies
SSDC-6	Training as Related to Behavioral Change
SSDC-7	ERDA Guide to the Classification of Occupational Injuries and Illnesses
SSDC-8	Standardization Guide for Construction and Use of MORT-Type Analytic Trees
SSDC-9	Safety Information System Guide
SSDC-10	Safety Information System Cataloging
SSDC-11	Risk Management Guide

