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SYSTEM SAFETY HANDBOOK

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PREFACE

This handbook supports the requirements specified in NPD 8700.1 and describes the basic elements and techniques for managing a system safety program. It also provides guidelines to assist project managers and system safety engineers in tailoring a project system safety plan to meet NASA safety goals within the constraints of available resources.

The handbook defines the authority, responsibility, and accountability for performance of system safety tasks. The guidelines provided in the handbook apply to hardware, software, and operations associated with space flight systems, aeronautical flight systems, and groundbased test and research facilities during all phases of project development.

A description of current system safety analysis techniques used for the identification, evaluation, and assessment of hazards is provided. Examples of each technique with appropriate guidelines for their selection and implementation are also included

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CHAPTER 1: SYSTEM SAFETY PROGRAM

1.1 INTRODUCTION

System safety is the application of scientific and engineering principles, techniques, and analyses to reduce risks and hazards to the lowest level permitted by the nature of a given project. It is applied throughout all phases of a project life cycle, starting in the concept/design phase with a systematic approach to hazard identification and establishment of safety criteria, and then implementing a continual methodology for hazard elimination or reduction, assuring compliance with design criteria and insuring management awareness of potential risk.

This publication is a guideline supporting the implementation of the requirements of NPD 8700.1. System safety can -be applied to any project or level of effort. Historically, NASA has applied system safety to critical programs such as manned space flight or to high energy systems. Today, NASA's intent is to extend its application to research and development, facilities construction, and aviation where judiciously tailored system safety efforts can be likewise beneficial.

1.2 APPROACH

This manual provides guidelines for understanding established safety responsibilities and determining the required system management and safety engineering tasks for a particular system. The safety management guidelines herein begin with project management requirements, continue through contracting, contractor. selection and monitoring, hazard analysis, risk assessment, and finish with safety verification. The system safety 'engineer's responsibilities are discussed, and the Appendices provide an in-depth discussion of contract requirements, contractor evaluation and monitoring, and the various hazard analysis techniques, methodology, and format along with sample worksheets.

1.3 PURPOSE

The purpose of the system safety program within NASA is to ensure that the optimum degree of safety is achieved through management and engineering practices that minimize the number and magnitude of hazards in NASA systems. This is coupled with the application of system safety engineering analyses to detect and assess the nature and magnitude of risks so that they may be eliminated, reduced, or accepted depending on project requirements, schedule, and cost. This purpose is attained through the application of management, scientific, and engineering principles during all phases of a system life cycle.' The ultimate goal is to avoid loss of life or injury to personnel., damage to or loss of equipment or facilities, project or test failures, and undue exposure to risk and adverse environmental effects.

1. 4 POLICY

It is NASA policy to establish tailored system safety programs for space flight systems, aeronautical systems, facilities, and associated support equipment to achieve the optimum degree of safety in system development, off -the-shelf procurement, and operation consistent with project requirements . This policy is initiated to ensure that appropriate safety requirements are included in directives, project management plans, and contracts and procurements . In compliance with this policy, each NASA project manager must ensure that hazards are identified and that adequate measures are taken for the elimination, control, or acceptance of these hazards. In developing a system safety program, tailoring may take the form of addition, revision to, or deletion of specific safety program elements described herein.

1.5 RESPONSIBILITIES

1. PROJECT MANAGEMENT

Project managers must recognize the need for system safety in the overall program. They must incorporate the system safety milestones into the project schedule; assure that appropriate personnel are assigned to implement the safety effort; and accept- the risks which may result from balancing project requirements, schedule, and cost with safety considerations.

2. SYSTEM SAFETY MANAGEMENT

To carry out the system safety function effectively, an individual will be designated the system safety engineer to plan, organize, implement, and supervise the system safety effort. It is this system safety engineer's responsibility to keep project management informed of the status of the system safety effort and the hazards and risks identified. The system safety engineer's responsibilities typically include the following:

a. Performance, review, or provision of task requirements for safety studies including a hazard analysis during the conceptual phase and the generation or review of other hazard analyses required.

b. Preparation or review of safety portions of the project management plan or other project management documents including a separate detailed system safety program plan.

c. Development of safety requirements for system specifications and preparation of safety requirements for the contract statement of work (SOW).

d. Evaluation of contractor safety programs if applicable.

e. Monitoring of project in-house and contractor safety tasks and activities.

f. Coordination of project safety program activities with interfacing organizations of
contractors, other participating NASA Centers, and appropriate management personnel.

g. Establishment and management of risk management and hazard reporting/resolution/tracking system.

h. Providing safety consultation and guidance to the project manager.

1.6 SYSTEM SAFETY PROGRAM TASKS

Task areas of a typical project system safety program include planning, organizing, coordinating, analyzing, documenting, and evaluating.

1. PLANNING

Planning begins as soon as the project is identified and continues throughout the life cycle of the system. (See figure 1-1.) Initial system safety planning includes preparation of the system safety program plan, identification and evaluation of gross hazards, and documentation of technical requirements.

2. ORGANIZING

Organization is essential for the timely and effective implementation of the 'system safety program plan. Responsibility for system safety accountability should be clearly established. Lines of communication should be established for formal reporting. A close relationship should be maintained with all the project elements to accomplish integrated assessments and to assure that system safety continues through the life cycle. Reporting should be to the management level appropriate for risk decision-making.

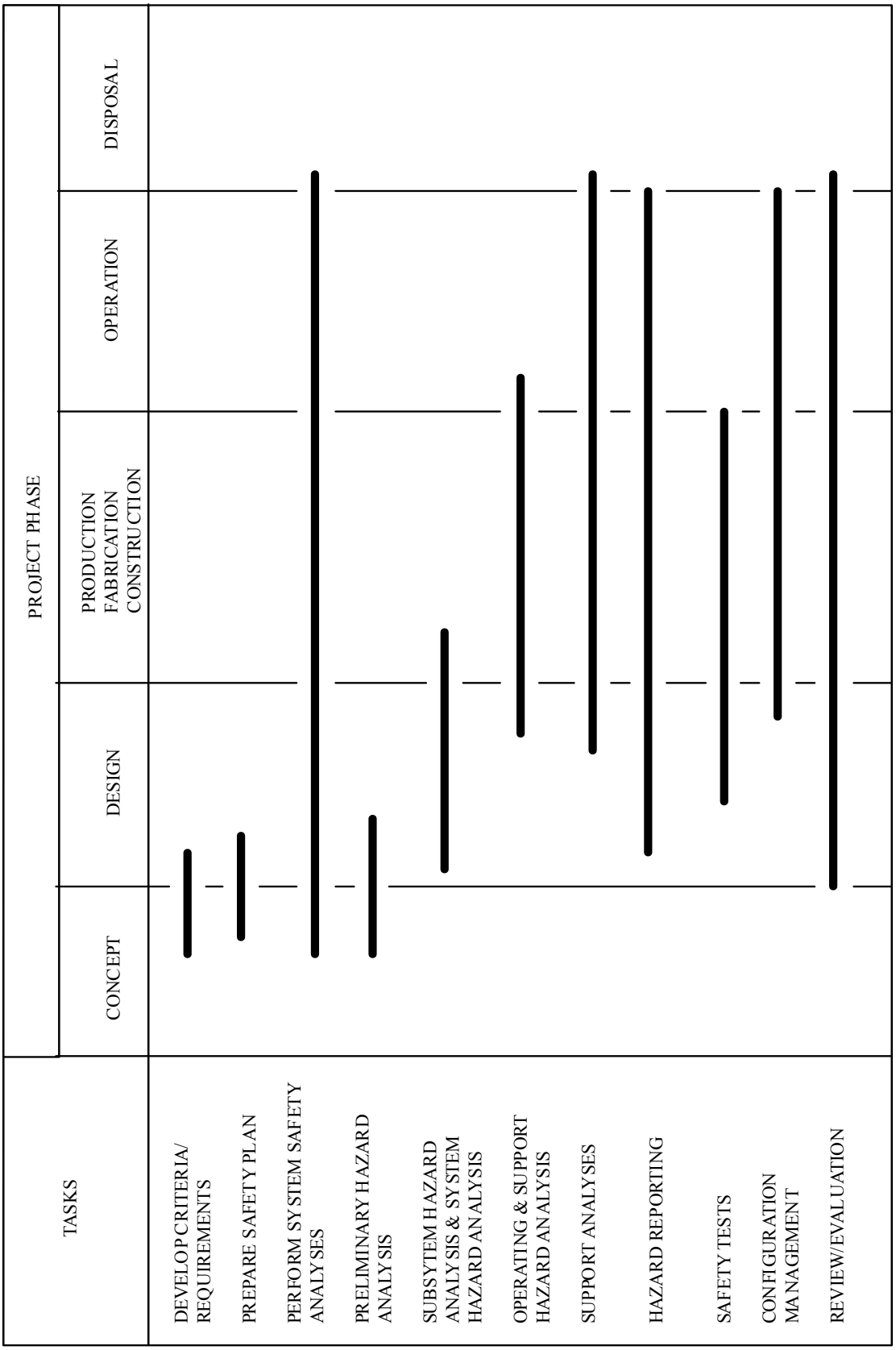


Figure 1-1 Relative Performance Periods for Major System Safety Activities

3. COORDINATING

The effectiveness of the system safety effort for the project will be greatly dependent upon the interfaces established with other project elements. Coordination with interfacing organizations should be established at the earliest possible time in project development. As the interfaces are established, the system safety engineer should strive to reach an understanding with all counterparts as to the type and availability of data required for system safety from other organizations and what data and reports will be provided by the system safety engineer. Typical data and information flow is illustrated in figure 1-2.

4. ANALYZING

System safety analyses are performed for the purpose of identifying hazards and providing recommendations for hazard 'elimination or reduction of risk to acceptable levels. These analyses provide the foundation for the development of safety requirements, the mechanism for determining if safety requirements have been fulfilled, and the assurance that recommendations have been implemented.

5. DOCUMENTING

The requirement for reporting of progress, hazards, and activities should be defined in the safety' plan. Reporting covers progress of the effort, milestones attained, and significant accomplishments, such as hazards identified and resolved. Documentation include safety inputs to program reviews relative to the risks being assumed and the status of hazard resolution. Significant data should be identified, filed, and readily retrievable. These data may include requirements, safety study reports, safety analyses, hazard reports, accident/ incident reports, safety audit reports, and safety waiver dispositions.

6. EVALUATING

Periodic evaluation of system safety programs is performed in conjunction with other project tasks and reviews to audit and assess the adequacy of the system safety plan. The review includes surveillance of all system safety aspects, both technical and administrative. The purpose is to ensure:

a. Objectives are being met and the planned tasks are being accomplished on schedule.

b. Adequate data are being provided by safety.

c. Effective use is being made of safety output.

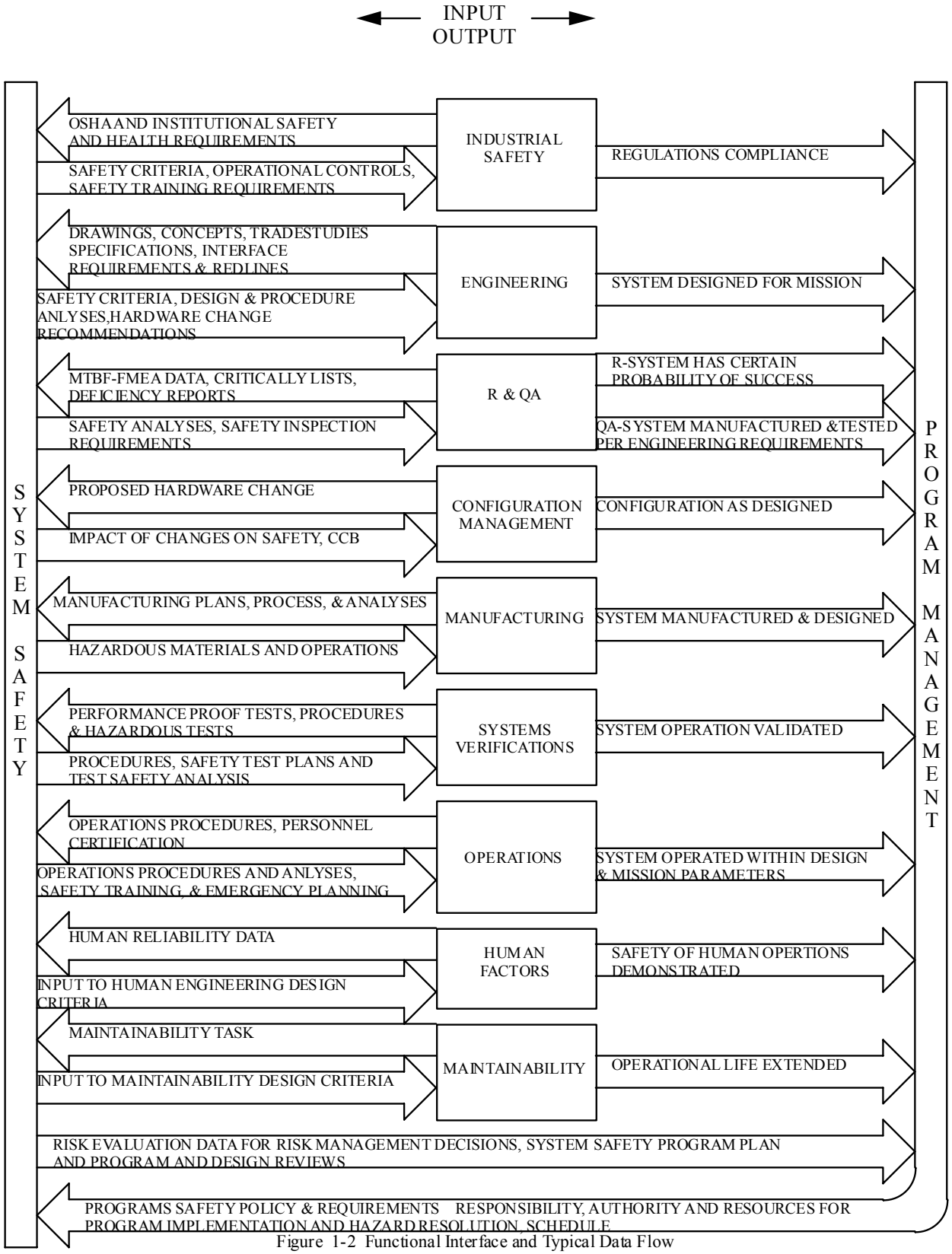


Figure 1-2 Functional Interface and Typical Data Flow

d. Provisions of the system safety plan are adequate.

e. Proper documentation of residual risk acceptance decisions.

f. Lessons learned are developed and used early to produce effective system safety input for requirements development.

g. An effective hazard tracking system has been implemented by the managing organization.

h. Effective system safety interface with other project management support function (i.e., human factors, quality assurance, maintenance, logistics, design engineering).

1.7 CONTRACT REQUIREMENTS

Recognizing that portions of the system safety activity may be contracted, it is essential that the SOW describes to the contractor the level of effort and safety tasks required for a particular -program. Although the safety requirements must not be over-specified, each SOW requirement should include the appropriate task objective,. description, and the preferred schedules as they relate to the major project milestones. The method of accomplishing the task will be determined by the contractor. The SOW requirements must be adapted and tailored to the unique needs of the particular project. .(Reference Appendix B.)

CHAPTER 2: SYSTEM SAFETY PROGRAM CRITERIA

2.1 SYSTEM SAFETY PROGRAM

The purpose of the system safety program is to assure that a systematic safety management and hazard identification and resolution method is implemented. The project plan will contain a system safety section which will ensure that emphasis is placed on safety during all program phases from concept to disposal.

2.2 SYSTEM SAFETY PLAN

1. The System Safety Plan is considered to be a major element of the Project Plan. It may be issued under separate cover but must be integrated into the Project Plan and must undergo the same approval process as the Project Plan.

2. The purpose of the system safety plan is to provide assurance that program requirements are understood by each participating organization and to define the tasks, schedule, products, and methods of implementation of the safety program. The preparation of the system safety plan. should be initiated during the concept phase. After completion of the preliminary hazard analysis, the SSPP should be updated to include the specific analyses required and their schedules. This plan should be available at the beginning of the design phase of the project and appropriately updated as the project matures. The content and formality of the system safety plan should be tailored on the basis of project safety criticality, size, and number of organizational interfacing centers involved.

3. The system safety plan will document the project's safety elements and the interfaces with other project disciplines. The plan will establish the safety tasks to be performed; the data to be delivered; and the completion schedule during the concept development, requirements definition, design, manufacture, test, operations, handling, transportation, and disposal phases of the project. Assignment of responsibilities, reporting procedures, and data to be 'exchanged will be delineated. See figure 2-1 for typical contents of a system safety plan.

Typical System Safety Plan

a. Scope
   (1) Overall purpose/objectives.
   (2) Applicable documents.

b. Organizational Responsibilities and Authority
   (1) Responsibility for safety.
   (2) System safety interface activities with other engineering disciplines.
   (3) Risk management requirements/responsibilities.

c. System safety milestones and Schedules.

d. System Safety Criteria and Requirements
   (1) Definition of safety criteria/requirements.
   (2) Hazard level categorization.
   (3) System safety procedures.
   (4) Risk.
   (5) Risk Reduction/closure.
      (a) Qualitative/quantitative.
      (b) Test and ground safety.

e. System Safety Analyses. Specify specific hazard analyses to be performed based on preliminary hazard analysis (PHA) and safety criteria.

f. Hazard Reporting and Resolution. Include procedure responsibilities and format for hazard reporting, corrective action, and verification for final sign-off.

g. Safety Test and Verification. Include requirements for safety tests, review of test requirements, procedures, and test equipment.

h. Safety Data. Include requirements for researching pertinent lessons learned and other historical data on similar systems.

i. Configuration Management. Include requirements for analyzing engineering change proposals to identify hazards associated with the change and predict the safety impact on the existing systems.

j. Reviews and Audits. Describe the procedures and types of reviews and audits to be utilized to ensure the objectives of the safety programs are being accomplished.

Figure 2-1 typical System Safety Plan

4. Further details of the System Safety plan development are given in the following paragraphs:

Purpose

The project System Safety Plan sets forth the areas of concern and risk that the project must concentrate its attention upon in order to obtain its objectives in the most efficient manner consistent with safe operating practices. The plan will detail what safety analyses will be performed and which milestones they will support. It will also detail which and what level of resources will be required to perform these analyses, i.e. in-house personnel, on-site contractors, project off-site contractors, etc.

The approved System Safety Plan should be viewed as a signed contract between upper management and project management.

Responsibilities

The responsibility for the writing and implementation of the System Safety Plan are clearly assigned to the Project Manager. However, because of the matrix management system at Ames-Dryden, each functional element at this Facility has a responsibility to assist the Project Manager in the determination of analysis requirements, analysis adequacy, and required risk assessment and resolution in areas that fall under their normal functional responsibility . Therefore, each functional element with a project responsibility will take part in the system safety process, with the Project Manager actually coordinating and ensuring the continuing process for his/her project.

Minimum Analysis

While it is recognized and highlighted that the NASA System Safety Handbook is written in guideline language and that no project is expected to perform all, available analyses, some are usually considered essential to the proper conduct of a project. These include:

A. Preliminary Hazard Analysis (PHA) - Conducted -in the very earliest stages of a project, this analysis is used to support initial project approval and the Preliminary Design Review.

B. Subsystem Hazard Analysis (SSHA) - Any newly designed, or highly modified, vehicle control system or major experiment that changes the functional configuration, would call for an SSHA to be performed. If this analysis is performed, an analysis of the interface between the subsystem or experiment and the vehicle must be included. These analyses must be available to support the Critical Design Review and updated to support the Flight Readiness Review.

C. Operational Hazard Analysis (OHA) - This is normally required to support the AFFTC Safety Review and our own Flight Readiness Review.

2.3 SYSTEM SAFETY REQUIREMENTS

1. Requirements should be established on the basis of (1) the identification of gross hazards during the conceptual phase, (2) requirements from experience gained on similar projects, and (3) pertinent standards, specifications, regulations, and design handbooks. See Appendix C for list of applicable documents. As an example, design criteria for pressure systems are contained in:

   a. NSS/HP-1740.1 - NASA Aerospace Pressure Vessel Safety Standard.

   b. MIL-STD-1522 - Standard General Requirement for Safe Design and Operation of Pressurized Missile and Space Systems.

   c. ASME Boiler and Pressure Vessel Code, Section VIII, Divisions I and II.

   Similarly, other consensus standards or Agency design criteria documents stipulate basic requirements and should be used to develop criteria for other systems or system elements.

   The system safety engineer must evaluate project requirements and system complexity to define safety requirements. Based on engineering experience gained on other similar projects, the system safety engineer can deduce safety requirements by consideration of the general personnel/ equipment interfaces, subsystem/ system interfaces, environmental constraints, and the type of equipment (electrical, mechanical, high energy) involved. Consideration should also be given to materials selection, fabrication, operations, maintenance, testing, storage, handling, transportation, and disposal.

3. Safety requirements should be integrated into the system design requirements documentation and coordinated with the design function. In addition, a special safety requirements document may be required on more complex systems to provide a controlled methodical means of tracking to ensure all safety requirements are addressed. The requirements document may also be used to develop specification and contract requirements. Requests for exemption from safety requirements should be a formal process with full documentation of the circumstances of its issuance and management concurrence.

2.4 SYSTEM SAFETY ANALYSES

The purpose of system safety analyses is to identify hazards and provide the mechanism for their disposal. It is an iterative process that begins in the concept phase and extends through the operational phase. The initial assessment, the preliminary hazard analysis (PHA), documents the gross hazards generally associated with assessment of the design and operational concept, and provides the framework for a master catalog of hazards and associated risks. As the design and operations are defined during subsequent life-cycle phases, the hazard catalog is updated to reflect results of more detailed hazard analyses. Analyses, such as subsystem/ system hazard analysis (S/SHA) and-operating and support hazard analysis (O&SHA), will be employed to the. extent and depth necessary to assure minimization of threat to personnel or damage to equipment and property. Analyses and techniques available to the system safety engineer are discussed in detail in Chapter 3.0 and Appendix D.

2.5 RISK MANAGEMENT

The purpose of risk management is to assure that (1) hazards are identified and evaluated in a timely manner, (2) the risks are assessed, acceptable, and consistent with the complexity of the system, and (3) the aggregate risk is recognized and accepted by project management.

1. RISK IDENTIFICATION

Hazards associated with each project will be identified, documented, and reviewed periodically to assure risk visibility.

2. RISK ASSESSMENT,

Risk assessment is a continuing process throughout the life cycle of a project, but formal risk acceptance must be performed prior to initial system operation and all significant project activities. Decisions regarding resolution of identified hazards will be based on assessment of the risk involved. To aid in the achievement of the objectives of
system safety, hazards will be characterized as to severity and probability. Since the priority for system safety is to eliminate hazards by design, a risk assessment procedure considering only severity will generally suffice during the early design phase. When hazards are not eliminated during the early design phase, a risk assessment procedure
based upon the probability, as well as severity, will be used to establish priorities for corrective action and resolution. Quantitative analysis will be performed only where the risks of parts/components failures and human errors for the operational environment are known with, reasonable confidence and the criticality. of alternative designs is sufficiently important to safety. The

risk, assessment criteria approach discussed in Appendix E may be used as a guide. After all risk avoidance measures have been identified and studied, and after technical rationale for risk acceptance has been documented, the risks will be presented to the appropriate level of management for approval.

3. RISK REDUCTION

The purpose of risk reduction criteria is to provide a consistent and systematic method for assuring that the risks associated with identified hazards are minimized. Risk closure criteria are established to assure risks are evaluated and closed uniformly. Hazardous conditions, causes, effects, control (or acceptance rationale), verification, results, and status are identified and documented as a product of the hazard analyses. It is the system safety engineer's responsibility to prepare and evaluate these analyses to assure that the requirements are being met and that risks associated with the hazards are reduced to the maximum practical extent. As the design progresses, actions for reducing. the risks will be undertaken in the following order of precedence:

a. Design to eliminate the hazard or hazardous operation.

b. Reduce risks to an acceptable level through the use of fixed, automatic, or other protective design features or devices.

c. Provide detection and warning/caution devices.

d. Develop procedures and training including protective equipment for personnel.

A lesser degree of safety desirability exists for each succeeding control method. If a risk reduction method other than elimination of the hazard source or hazardous operation is selected, a certain level of risk must be assumed by the project manager. The acceptability of hazard controls should be based on the nature of the risks and the options available to achieve the maximum benefit.

4. APPROVAL OF RISKS

Each risk will be evaluated, documented, and accepted by project management. Accepted risks will be reviewed periodically to take advantage of new technology, concepts, and conditions which may permit hazard elimination or control. The review process and documentation requirements may vary from project to project; however, all accepted risks must be documented and approved by the appropriate NASA management level as defined in the project plan. The flow of safety data from identification of

hazard,. through generation of controls, and hence to review and approval by project management, is illustrated in figure 2-2.

2.6 SAFETY VERIFICATION

The purpose of safety verification is to establish the validity of the hazard analyses and verify the system meets safety and-operational requirements. System safety management procedures for accomplishing this are effected by various reviews and system tests which provide independent technical assessment.

1. ANALYSES VERIFICATION

The technical assessment involves an independent review and evaluation of the hazard analyses results.. Verification should be performed on. a continuing basis by evaluating hazard analyses results performed for informal and formal design reviews. Further technical assessment of contractor hazard analyses should be performed by project system safety engineering with formal approval of the deliverable data. In verifying an analysis involving a serious (catastrophic or critical) hazardous condition, risk assessment techniques should be used.

2. TEST VERIFICATION

Test plans, specifications,. procedures, and results are reviewed by the project system safety engineer to confirm that the system will meet safety design and operational requirements. Monitoring and evaluation of the test program facilitate a cost-effective approach to the safety verification method. In turn, the project system safety engineer assists the test activity in identifying unique hazards and safety requirements required to minimize the risks.

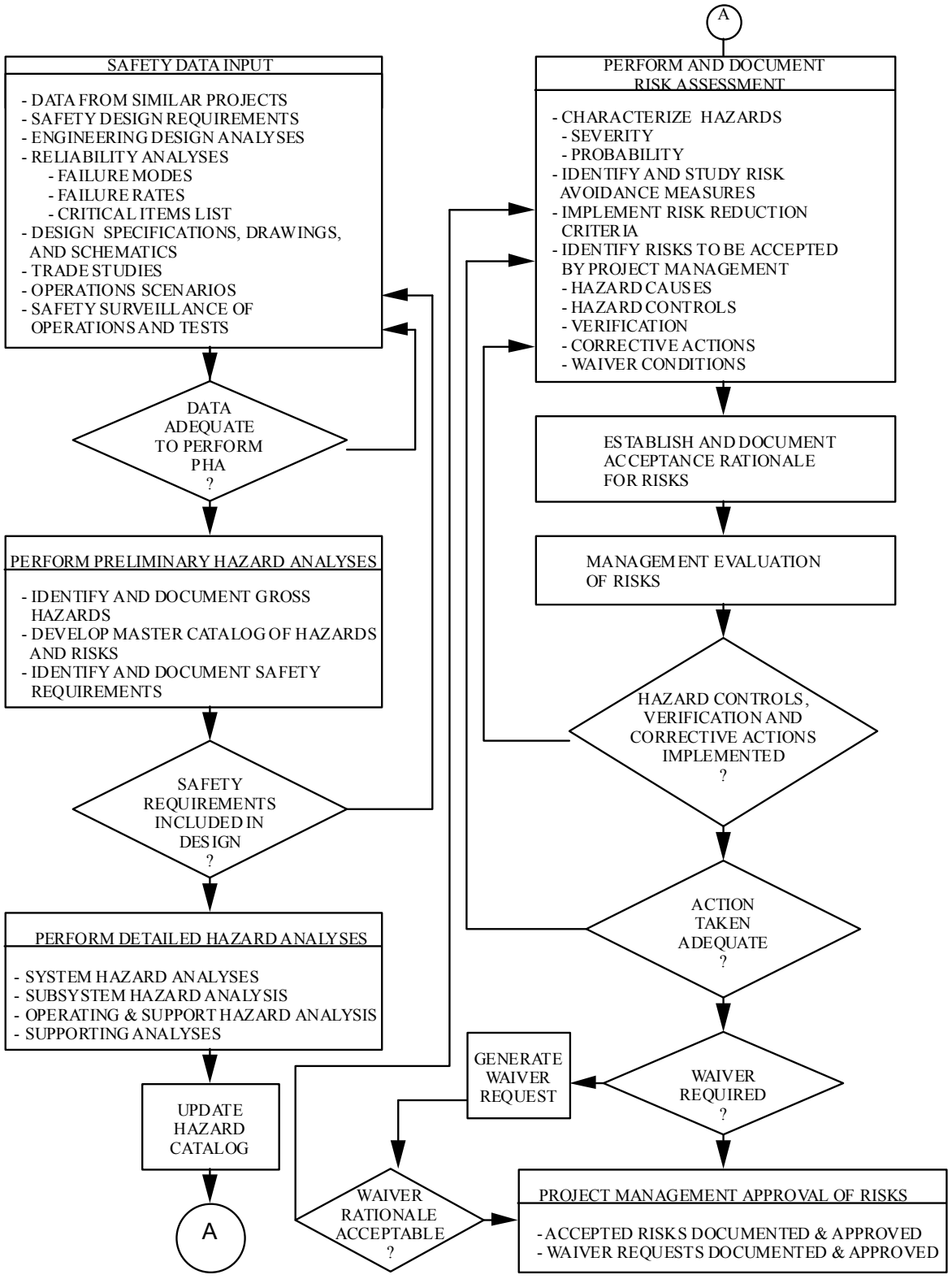


Figure 2-2 Safety Process Flow

a. Performance Proof Tests

Overall performance testing is monitored to verify that the system meets safety and operational requirements as demonstrated by the performance proof test program.

b. Special Safety Tests

Special safety tests may be required of critical components to demonstrate that safety margins and workmanship are adequate.

c. Safety Systems Tests

Functional testing of safety systems may be required to assure that hazardous conditions can be adequately controlled by the prescribed design, safety devices, and warning/caution devices.

3. HAZARD CLOSURE VERIFICATION

The system safety engineer will implement a procedure to ensure that the corrective actions defined for hazard closure have been successfully implemented, such as in design documentation, test plans, test reports, and operations and maintenance procedures. The acceptance of closure methodology and rationale will be formally documented and presented at the appropriate project reviews.

2.7 PROJECT REVIEW REQUIREMENTS

1. SYSTEM SAFETY PROGRAM MILESTONES

System safety program milestones will be integrated with the overall project milestones and reviews to assure that management has the safety information required to assist them in their decision-making. See figure 2-3. The purpose of safety participation in project reviews is to assure safety requirements have been imposed and implemented, and adequate verification methods have been established. Typical project reviews include, but are not limited to:

a. Conceptual Design Review.

b. Preliminary Design Review.

c. Critical Design Review.
d. Integrated Systems Review.

e. System Acceptance or Operational Readiness Review.

Reference Paragraph	Title	Project Phase				
		CoDR	PDR	CDR	ISR	OPT
2.2	System Safety Plan	S	G	M	M	M
2.3	System Safety Requirements	S	G	M	M	G
2.4	System Safety Analyses	S	G*	G	G	S
2.5	Risk Management	G	G	M	M	M
2.6	Safety Verification	-	G	M	M	S
2.7	Project Review Requirements	-	M	M	M	S
2.8	Safety Reviews	G	G	G	G	G
2.9	Configuraton Management	-	G	M	M	M
2.10	Mishap And Accident Investigation	-	G	G	G	M

Legend			
Applicability Codes		Project Phases	
S	Selectively Applicable	CoDR	Conceptual Design Review
G	Generally Applicable	PDR	Preliminary Design Review
M	Mandatory	CDR	Critical Design Review
*	PHA Mandatory Review	ISR	Integrated Systems
		OPT	Operations

Figure 2-3 Applications Matrix For Project Consideration

2. SAFETY ASSESSMENT

A safety assessment should be presented at each project review. This safety assessment will include the results of safety analysis activities including hazardous conditions, non-compliance's with established codes/

regulations/requirements, causes, effects, controls, safety verification methods, and risk acceptance rationale. All open safety work and action items should be documented and submitted with the final assessment. for management action.

a. Conceptual Design Review

A hazard analysis should be performed prior to the conceptual design review to assure that appropriate safety requirements will be identified.

b. Preliminary Design Review

A preliminary hazard analysis will be prepared to determine areas requiring special safety studies. Subsystem and system level hazard analyses may be performed to identify hazards and to assure that the safety requirements have been addressed in the design. A hazard tracking system will be implemented.

c. Critical Design Review

The review should include the hazard analyses results necessary to assure that the design can meet the safety requirements.

d. Integrated Systems Review

This review is normally held prior to systems level tests and integrates all the elements of a program. A safety assessment utilizing the results of all previously performed safety analyses should be provided. Each hazard control will be identified at this review.

e. Systems Acceptance Review/Operational Readiness Review

The systems acceptance review, or operational readiness review will include an overall safety assessment considering all aspects of equipment, facilities, personnel, and operations. Assurance should be provided that all safety analyses have been completed and that hazards have been identified, evaluated, and accepted by the appropriate level of management.

2.8 SAFETY REVIEWS

In the life cycle of a project, it is advisable to conduct periodic safety reviews to assess progress and implementation of safety program requirements, provide for interchange of information, and to evaluate the results of the safety effort. The necessity for such reviews is a function of project complexity and safety criticality.

Such reviews are a mechanism to assure Timely identification and tracking of hazards.

Specific objectives of the reviews should include evaluation of the adequacy of, safety program guidelines, constraints, and project requirements. These reviews should be conducted by an independent panel of senior engineers and operations management personnel exclusive of project . management. Review panel membership should be structured to assure that appropriate technical specialists knowledgeable of the systems under review are represented; but membership should also be tailored to ensure a continuity of project direction and implementation. Results of such special reviews should be documented with open items tracked to closure, and such results should be reported at the major project reviews for final management approval .

2.9 CONFIGURATION MANAGEMENT

The purpose of system safety involvement in configuration management is to maintain an understanding of the baseline configuration and any subsequent changes. This will allow hazard identification activities to be performed on the latest configuration. All requirements,

hardware, software, and procedural changes from the established baseline should be evaluated for safety impact. Change proposals and requests should be reviewed by the system safety engineer, and recommendations for change acceptance, rejection, or modification provided to the appropriate configuration control board. Hazard analyses and hazard lists should be updated, as required, to reflect hazards that have been introduced, eliminated, or modified as the result of a configuration change. The degree of formality of change controls and participation in configuration control boards may be tailored consistent with the project criticality, size, and number of organizations involved.

2.10 MISHAP AND ACCIDENT INVESTIGATION

Mishap and accident investigation and reporting are accomplished and tailored in accordance With NPD 8700.1. System safety participation normally includes:

1. Safety analyses preparation in support of the investigation board.

2. "Lessons Learned" generation and documentation for inclusion in the NASA mishap report files in the NASA Recon System.

CHAPTER 3: SYSTEM SAFETY ANALYSES

3.1 INTRODUCTION

This section presents a description of the three common system safety analyses used to satisfy project requirements. These analyses are the, preliminary hazard analysis', the subsystem hazard analysis and system hazard analysis, and the operating and support hazard analysis. Each analysis section includes the purpose, description, and project phase which is suggested for application of the particular analysis (Reference Appendix D).

3.2 PRELIMINARY HAZARD ANALYSIS (PHA)

1. PURPOSE

The purpose of the PHA is to identify safety-critical areas, evaluate hazards, and identify the safety design criteria to be used in the project . It also provides management with knowledge of potential risks during feasibility studies and project definition activities.

2. DESCRIPTION

The PHA is performed to document an initial risk assessment of a concept or system. Based on the best available data, including pertinent safety experience from similar systems and other lessons learned, hazards associated with the. proposed design or function will be evaluated for potential severity, probability, and operational constraints. Design control and alternatives needed to eliminate hazards or reduce their associated risk 'to an acceptable level should be considered. The PHA provides consideration of the following for identification and evaluation of hazards.

a. Hazardous components (e.g., fuels, propellants, lasers, explosives, toxic substances, hazardous construction materials, pressure systems, radiation sources, and other energy sources).

b . Safety-related interface considerations among various elements of the system (e.g., material compatibilities, electromagnetic interference, inadvertent activation, fire/explosion initiation and propagation, electrostatic susceptibility, and hardware and software controls).

c. Environmental constraints including the operating. environment; (e.g., drop shock, vibration, extreme temperatures asphyxiates noise, exposure to toxic substances, fire, electrostatic discharge, oxygen deficiency and/or hazardous atmosphere, lightning, electromagnetic environmental effects, and ionizing and non-ionizing radiation).

d. Operating, test, maintenance, emergency, and contingency procedures (e.g., human error analysis of operator functions, tasks, and requirements; effects of factors such as equipment layout and lighting requirements; effects of noise or radiation on human performance; life support requirements and their safety implications in manned systems, crash safety, egress, rescue, survival, and salvage).

e. Facilities, support equipment (e.g., provisions for storage, assembly, checkout, proof-testing of hazardous systems/ assemblies which may include toxic, flammable, explosive, corrosive or cryogenic fluids; radiation or noise emitters; electrical power sources) and training, (e.g., training and certification pertaining to safety operations and maintenance).

f. Safety related equipment, safeguards, and possible alternative approaches (e.g., interlocks, system redundancy, hardware or software fail-safe design considerations, subsystem. protection, fire suppression systems, personal protective equipment, ventilation, and noise or radiation barriers).

g. Identification of and compliance with pertinent regulations and standards.

3. PROJECT PHASE

The PHA effort should be initiated during the concept phase of a project so that safety Considerations are included in trade-studies and design alternatives .

4. PHA TECHNIQUE

A recommended format discussion is contained in Appendix D.

3.3 SUBSYSTEM HAZARD ANALYSIS (SSHA) AND SYSTEM HAZARD ANALYSIS (SHA)

1. PURPOSE

The purpose of an SSHA is to identify hazards associated with design of subsystems including component failure modes, critical human error inputs, and hazards resulting from functional relationships between components and

equipment comprising each subsystem. The purpose of an SHA is to determine the safety problem areas of the total system design, including interfaces, and potential safety-critical human error.

2. DESCRIPTION

The SSHA identifies and documents all components and equipment, including software, whose performance, performance degradation, functional failure, or inadvertent functioning could result in a hazard. The analysis includes a determination of the modes of failure including credible human errors as well as single failure points and the effects on safety when failures occur in subsystem components. The SHA identifies and documents hazards, and assesses the he risk of the total system design including the subsystem interfaces This analysis includes a review of subsystem interrelationships for:

a. Compliance with specified safety requirements.

b . Possible independent, dependent, and simultaneous credible. hazardous events, including failures of safety devices and common causes that could create a hazard.

c. Degradation in the safety of a subsystem or the total system from normal operation of another system.

d. Design changes.

e. Effects of credible human errors.

3. PROJECT PHASE

The SSHA effort should begin as the preliminary design and concept definition are established and progress through the detailed design of components, equipment, and software. The SSHA will be updated when needed as a result of any subsystem design changes. The SHA effort will begin as system and subsystem design and interfaces, including software, are defined. The SHA will be upgraded when needed as a result of system design and interface changes.

4. TECHNIQUE

The fault hazard analysis (FHA) is the inductive system analysis most commonly used for subsystem and system hazard analysis. See Appendix D.

3.4 OPERATING AND SUPPORT HAZARD ANALYSIS (O&SHA)

1. PURPOSE

The O&SHA is performed to identify and evaluate hazards associated with personnel, procedures, environment, and the equipment involved throughout the operation and maintenance of the system during all phases of intended use.

2. DESCRIPTION

The O&SHA is performed to examine procedurally controlled activities. It identifies and evaluates hazards resulting from the implementation of operations or tasks performed by persons and should consider the planned system configuration at each phase of activity; the facility interfaces; the planned environments, the supporting tools, or other equipment specified for use; operation or task sequence, concurrent task effects, and limitations; biotechnological factors;. regulatory or contractually specified personnel safety and health requirements; and the potential for unplanned events including hazards introduced by human error. The O&SHA identifies the safety requirements (or alternatives) needed to eliminate identified hazards, or to reduce the associated risk to a level which is acceptable. The analysis should identify:

a. Activities which occur under hazardous conditions, their time periods, and the actions required to minimize risk during the activities and time periods.

b. Changes needed in hardware and software, facilities, tooling, or support/test equipment to eliminate hazards or reduce associated risks .

c. Requirements for safety devices and equipment, including personnel safety and life-support equipment.

d. Requirements for warnings, cautions, and special emergency procedures (e.g., egress, rescue, escape, render-safe, backout, etc.).

e. Requirements for handling, storage, transportation, maintenance, and disposal of hazardous materials.

f. Requirements for safety training and personnel certification.

The O&SHA documents the system safety assessment of procedures involved in production, assembly, test, operation, maintenance, servicing, transportation, storage, modification, and disposal.

3. PROJECT PHASE

The O&SHA effort should begin when operational concepts are developed. The O&SHA development process is a continuing effort that parallels the manufacturing process and the 6 subsequent development of operational and maintenance procedures. The analysis is usually completed after all procedures have been written and validated.

The O&SHA will be updated, when needed, as a result of any system, design, procedures, or operational change.

4. O&SHA TECHNIQUE

An O&SHA columnar lumnar format discussion is contained in Appendix D. This format is designed with the intent of establishing a systematic method whereby operations are broken down into incremental parts and consistently analyzed for hazards. The O&SHA form should not necessarily be held rigid, but modified to the specific needs of the user.

O&SHA hazards can be recognized through checklists by comparing the configuration of the operations under analysis (hardware, tasks sequence, tools, environment, etc.) against the hazardous elements and hazardous conditions on the checklists. Operational elements which correlate with items on the checklist indicate a possible hazard or a possible safety critical area.

APPENDIX A: DEFINITIONS

Loss Hazard — General hazard that is identified during the preliminary hazard analysis process.

Hazard — The presence of a potential risk situation caused by on unsafe act or condition.

Hazard Analysis — The determination of potential sources of danger and recommended resolutions in a timely manner for those conditions found in either the hardware software systems, the person-machine relationship, or both, which cause loss of personnel capability, loss of system, or loss of life or injury to the public.

Risk — The chance (qualitative) of loss of personnel capability, loss of system, or damage to or loss of equipment or property.

Safety — Freedom from chance of injury or loss of personnel, equipment, or property.

Safety Critical — Facility, support, test, and flight systems containing:

a. Pressurized vessels, lines, and components.
b. Propellants, including cryogenics.
c. Hydraulic and pneumatics.
d. High voltages.
e. Radiation sources.
f. Ordnance and explosive devices or devices used for ordnance and explosive checkout.
g. Flammable, toxic cryogenic, or reactive elements or compounds.
h. High temperatures.
i. Electrical equipment that operates in the area where flammable fluids or solids are located.
j. Equipment used for handling program hardware.
k. Equipment used for personnel walking and work platforms..
l. Electrostatic susceptible devices.

System Safety	The optimum degree of risk management within the constraints of operational effectiveness, time, and cost attained through the application of management and engineering principles throughout all phases of a program.
Waiver	Granted use or acceptance of an article which does not meet the specified requirements, criteria, or standards.

APPENDIX B: SYSTEM SAFETY PROCUREMENT GUIDELINES

1.1 POLICY

1. System safety is a factor which must be considered in each step of program development, project planning., and the procurement process. The appropriate technical application of NASA safety publications and the inclusion of realistic requirements in procurement are essential to accomplish NASA mission objectives. Those ultimately responsible for the content and quality of requests for proposals will ensure that system safety requirements are treated prudently in the proposal preparation and negotiation process.

2. System safety requirements will be established as early as possible in the procurement cycle and will be made a part of the procurement request. The safety criteria and requirements for flight and flight related hardware, including ground support equipment and special facilities, will be directly related to the project, hardware, the stage of development, and procurement situation. The system safety requirements normally will be referenced is a subdivision of work or a task in the SOW and detailed in an Appendix to the SOW. When structuring such document, care should be taken to ensure that there is no duplication of requirements and a minimum of overlap between the areas of quality assurance, reliability assurance, and system safety.

3. System safety documentation will be phased into the proposal preparation and negotiation process in such a manner that the degree of detail required in the proposal is commensurate with the intended use of the system safety program as a factor or criterion in evaluating the overall proposal. In general, the greater the emphasis on the use of the contractor's program and procedures, the greater will be the degree of detail appropriate in the proposal. However, regardless of the degree of detail. required for the initial system safety plan, it is also necessary for evaluation purposes in major negotiated procurements, including those conducted on a noncompetitive basis, and that initial cost proposals include an estimate of man-hours and other costs associated with each major safety task area defined in' the request for proposal. Such estimates should be sufficiently detailed and time phased so as to commit the offer or to a level of performance for all tasks. In those competitive procurements where the proposal is not required to contain complete detailed system safety plans, offers should be required to provide a summary of their ultimate plan and to indicate in their original proposal that they understand that a detailed plan will be required if they are selected for negotiation and that it will be subject to evaluation, negotiation, and incorporation in the contract at the time of award.
4. Evaluation of system safety aspects of proposals should include consideration of current pre-award survey findings and historical information concerning

system safety experience with the proposed contractor(s) In applying the guidelines of NPD 8700.1. to existing and follow-on contracts, preparation of system safety requirements shall consider contract performance, project completion, status, and overall procurement phasing.

5. In procurements involving a continuation of effort on established projects, approved system safety implementation plans under previous contracts may be used. In such cases, technical negotiation of safety requirements should be limited only to required changes in the existing safety requirements. The contractor's revised system safety implementation plan will be incorporated in the continuation (or follow-on) contract at the time of award.

6. In noncompetitive procurements other than those identified in 5. above, the prospective contractor will be required to submit his detailed system safety implementation plan with his proposal. Estimated man-hours and other costs associated with each major system task area defined in the request for proposal will be submitted to support the proposal.

7. In all procurements involving system safety requirements developed from guidelines set forth in NPD 8700.1, the contractor's system safety implementation plan will be obtained and approved prior to award and will be incorporated in the contract at the time of award. Inclusion of the general requirements for safety and health will be as- stipulated in the NASA/FAR Supplement 18-23-70-Safety and Health. Both the system safety requirements and the approved contractor's system safety implementation plan should be incorporated in the contract. In those cases where strong low cost or other emphasis is placed on maximum use of contractor systems and procedures, all proposers should be required to submit complete detailed plans and the appropriate implementing procedures with their proposals to permit evaluation of these systems. Where such emphasis on costs is not a strong factor, final plans need not be required except from those proposers selected for final negotiations, and the final plans must be submitted sufficiently in advance of negotiation to permit necessary review. The request for proposal should so notify offerors, and, upon selection the selected. offeror(s) will be notified immediately of the date for submission of the full system safety implementation plan. The extent of detail required from the offeror(s) as a part of their initial proposals should be fully coordinated with program assurance, project, and procurement personnel.

8. Safety documentation which is to be submitted during contract performance will be defined in the request for proposal and the resulting contract.

1.2 RESPONSIBILITIES OF NASA PERSONNEL

1. ORIGINATORS OF PROCUREMENT REQUESTS

At the earliest possible time, originators of procurement requests Will ensure that personnel responsible for system safety develop detailed system safety requirements and that such requirements are made part of the procurement request.

2. PERSONNEL RESPONSIBLE FOR SYSTEM SAFETY

Personnel responsible for system safety will support, as appropriate, originators of procurement requests and the contracting officer by:

a. Participating in each phase of project planning and each step of the procurement process; determining and documenting the necessary system safety requirements;

b. Preparing funding estimates required to support the system safety requirements of the procurement requests;

c. Participating in pre-award and post-award surveys; presenting system safety requirements at pre-proposal or bidder's conferences or other oral briefings;

d. Participating in Proposal evaluations;

e. Reviewing system safety implementation plans for adequacy and cost effectiveness; coordinating reviews with originators of procurement requests;

f. Providing technical support in negotiation of system safety requirements with contractors;

g. Reviewing contracts prior to issuance to ensure inclusion of appropriate system safety requirements;

h. Preparing any system safety special instructions for inclusion in the letters of delegation for performance of contract administration services related to system safety requirements by other Government agencies; and

i. Evaluating contractor performance and monitoring the contractor's utilization of system safety resources after award.

3. CONTRACTING OFFICERS

The contracting officer, with or through personnel responsible for system safety, will:

a. Review each applicable procurement document to ensure that system safety requirements are selectively included;

b. Determine system safety requirements have been omitted or appear to be adequate and, where necessary, discuss the applicable system safety requirements by consultation and verification with personnel responsible for system safety and the originator of the procurement request;

c. Advise all prospective contractors of the system safety requirements for the particular procurement and clarify, as necessary;

d. Arrange for participation of personnel responsible for system safety in proposal evaluations and negotiations, as necessary.

e. Ensure that the provisions of the contract are specific as to the contractor's responsibility for meeting system safety requirements, and ensure that responsibility is assigned or delegated to perform the Government system safety functions. Letters defining the delegated assignments should be specific as to the system safety effort required. Those duties to be performed by Government personnel at plant sites should be set forth describing the assigned responsibilities and authority of installation personnel.

1.3 STATEMENT OF WORK AND DATA REQUIREMENTS DESCRIPTIONS

1. Data requirements descriptions to be considered typically include:

   a. SA-01, System Safety Implementation Plan.

   b. SA-02, Hazard Analysis Report.

   c. SA-03, Safety Assessment Report.

   d. SA-04, Safety Compliance Data Package.

   e. SA-05, Mishap Reporting.

2. The SOW shall contain a section on system safety project requirements as follows:

The contractor shall establish and conduct a system safety program that complies with NPD 8700.1. The system safety program shall ensure that safety characteristics consistent with project requirements are designed into the system.

The contractor. shall perform the tasks necessary to prepare the following data items:

a. System safety Implementation Plan (SSIP). The contractor shall prepare and submit an SSIP complying with data requirements description SA-01 (Attachment 1). The SSIP shall describe the tasks and activities of system safety management and system safety engineering required to control hazards throughout the project life cycle. It shall provide a basic understanding of how the system safety effort will be implemented by the contractor.

b. Hazard Analysis Report. The contractor shall prepare and submit a hazard analysis report complying with data requirements description SA-02 (Attachment 2). The hazard analysis report shall evaluate the hazards associated with the system's design, operations, support equipment, software, and their interface. It hall identify and evaluate hazard's associated with personnel, procedures, and equipment involved throughout the operation of the system. Emphasis shall be given to activities such as: testing, installation, modifications, maintenance, transportation, ground servicing, operations, and training. The hazard analysis report shall be updated accordingly as a result of any system design or operational change.

c. Safety Assessment Report (SAR). The contractor shall prepare and submit an SAR complying with data requirements description SA-03 (Attachment 3). The SAR shall evaluate the safety risk being assumed prior to test or operation of the system, shall provide specific controls or precautions to be followed -in the use of the system, and shall provide verification of compliance to standards and codes used to ensure the safe design of the system. All design changes and modifications shall be evaluated to determine the effect on system safety and provided in an updated report.

d. Safety Compliance Data Package. The contractor shall prepare and submit a safety compliance data package complying with data requirements description SA-04 (Attachment 4). The safety compliance data package shall document the identification, causes, controls, and verification methods for each hazard.

e. Mishap Reporting. The Contractor shall report mishaps as described in data requirements description SA-05 (Attachment 5) to alert the Government of accidents/ incidents that occur during the life of the contract. The contractor shall provide technical assistance to NASA boards investigating mishaps which occur within the NASA jurisdiction.

ATTACHMENT 1

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
DATA REQUIREMENT DESCRIPTION

1. TITLE SYSTEM SAFETY IMPLEMENTATION PLAN	**2. NUMBER** SA-01
3. USE The system safety implementation plan (SSIP) is a. detailed description of the tasks and activities of system safety management and system safety engineering required to identify, evaluate and eliminate or control hazards throughout the system life cycle. The purpose of the SSIP is to provide a basis of understanding between the contractor and the managing activity as to how the system safety effort will be accomplished to implement the applicable system safety requirements.	**4. DATE** **5. ORGANIZATION APPROVED BY:**
7. INTERRELATIONSHIP Other applicable data requirement-descriptions are SA-02, Hazard Analysis Report; SA-03, Safety Assessment Report;. SA-04, Safety Compliance Data Package; and SA-:05, Mishap Reporting.	**6. REFERENCE** NPD 8700.1

General Program Requirements. The SSIP shall:

a. Describe the scope of the overall program and the-related system safety program.

b. Describe, the tasks and activities and system safety management and engineering and the interrelationship between system safety and other functional elements of the program. System safety program requirements and tasks included in other contractual documents shall be cross-referenced in the SSIP to avoid duplication of effort.

c. List the contractor and Government documents which will be applied either as directives or guidance in the conduct of the system safety program. Contractor documents referenced in the SSIP shall be submitted with the plan.

System Safety Organization. The SSIP shall describe:

a. The responsibility and authority of system safety personnel, other contractor organizational elements involved in the system safety effort, subcontractors, and system safety groups. Identify the organizational unit responsible for executing each task. Identify the authority in regard to resolution of all identified hazards.

b. The staffing of the system safety organization for the duration of the contract to include manpower loading and the qualifications of key personnel.

c. The procedures by which the contractor will integrate and coordinate the system safety efforts including dissemination of the system safety requirements to action organizations and subcontractors, coordination of subcontractor's system safety programs, integration of hazard analyses, program and design reviews, program status reporting.' and system safety groups.

d. The process through which contractor management decisions will be made to include notification of critical and catastrophic hazards, corrective action taken, mishaps or malfunctions, waivers to safety requirements, and program deviations.

Hazard Analyses. The SSIP shall describe:

a. The analysis technique and format that will be used in qualitative analysis to identify hazards, their causes and effects, and recommended corrective action.

b. The depth within the system to which each technique will be used including hazard identification associated with the system, subsystem, components, personnel ground support equipment, Government-furnished equipment, facilities, and their interrelationship in the logistic support, training, maintenance, and operational environments.

c. The integration of subcontractor hazard analyses and techniques with overall system hazard analyses.

System Safety Data. The SSIP shall:

a. Describe the approach for searching, disseminating, and analyzing pertinent historical hazard or mishap data.

b. Identify deliverable data.

c. Identify non-deliverable data and describe the procedures for accessibility by the managing activity and retention of data of historical value.

Safety Verification. The SSIP shall describe:

a. The verification requirements for ensuring that safety compliance is adequately demonstrated.

b. Procedures for ensuring feedback of verification information for review and analysis for use in design modifications

c. The review procedures established by contractor's system safety organization to ensure safe conduct of all tests.

Training and Certification. The SSIP shall describe the safety training for engineering, technician, operating, and maintenance personnel; and describe the technique/procedure for certifying compliance with the training requirements.

Audit Program. The SSIP shall describe the techniques and procedures to be employed by the contractor to ensure that the objectives and requirements of the system safety program are being accomplished.

Mishap Reporting-and Investigation. The SSIP shall describe the mishap reporting and investigation procedures established by the contractor to alert the Government and mishaps that occur during the life of the contract.

System Safety Interfaces. The SSIP shall identify, in detail, the interface between system safety and all other applicable safety disciplines such as: Nuclear Safety, Range Safety, Explosive and Ordnance Safety, Chemical and Biological Safety, Laser Safety, etc. These interfaces may be attached as addendums to the basic SSIP.

ATTACHMENT 2

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
DATA REQUIREMENT DESCRIPTION

1. TITLE HAZARD ANALYSIS REPORT	**2. NUMBER** SA-02
3. USE Identify and evaluate all hazards associated with the system's design and operations to effect their elimination or control.	**4. DATE** **5. ORGANIZATION APPROVED BY:**
7. INTERRELATIONSHIP Data requirement description relating to this DRD is SA-01, System Safety Implementation Plan.	**6. REFERENCES** NPD 8700.1

Hazard Analysis report requirements must be tailored to the specific project; therefore, preparation instructions may be modified by the data requirements List (DRL) to require only certain paragraphs of this DRD.

The general format for all hazard analysis report DRDs, with the exception of the details required by the individual hazard analyses, is:

Introduction

a. State purpose of hazard analysis.

b. State the baseline documentation (drawings/specifications) used in performing the analysis.

c. Define any special terms, acronyms, and/or abbreviations used or reference same in an appendix.

Summary

Provide an abstract summarizing the major findings of the analysis and the proposed corrective or follow-up actions.

Technical Discussion

a. System description. State purpose and intended use of item and provide a description of the system hardware and configuration. List components of subsystems and provide flowcharts.. flow diagrams, and procedures, to describe the intended operation of the system to provide a system model for conducting the analysis.

b. Analysis assumptions and ground rules. State the basic ground rules and assumptions used in performance (including risk assessment criteria) of the analysis to ensure a baseline for understanding by reviewer.

c. Detailed discussion. Provide a detailed discussion of the analysis, the safety critical areas identified, and a summary table of all hazards identified.

Conclusions and Recommendations

State in brief terms the major references that can be drawn from the discussion based entirely on-the information stated in the detailed discussion. Provide recommendations and design methodology used for the correction of hazards.

References and Appendices

Provide a list of references in the order they appear in the report and include appendices necessary to an immediate understanding of the discussion.

Worksheet Data Requirements

Include under this heading the minimum requirements for the hazard analysis required for systematically documenting the analysis.

Preliminary Hazard Analysis

Provide the following information for each hazard identified:

a. Description of hazard, including cause and effect.

b. The hazard severity level.

c. Recommended corrective actions

   1. Hardware modifications/safety design features

   2. Text and location of proposed labels

d. Remarks (references, explanations, descriptions etc.)

System/Subsystem Hazard Analysis (S/SSHA)

Specific analysis techniques which may be used in the course of performing the S/SSHA's are listed below. Reports for these techniques will follow format and content requirements as contractually defined.

- Fault-hazard analysis (FHA)
- Fault-tree analysis
- Sneak circuit analysis

When the FHA technique is used, the information indicated below shall be provided for each hazard identified.

a. Component. Identify he major functional activity or hardware components within the subsystem being analyzed. The major component should be identified by part. number and descriptive title.

b. Failure mode. Identify all credible failure modes which are possible for the identified major component. The FMEA (failure modes and effects analysis) should supply this information., whenever applicable.

c. Failure rate. When performing quantitative analyses, enter a probability. of failure estimate of the component in the indicated failure mode. This is the component's primary failure rate.. The source of data must be indicated but is normally the FMEA.

d. System Operational mode. Identify the system mode of operation in which the major-component is -operating during the indicated failure mode.'

e. Effect of failure on subsystem. Identify the direct effect, on the subsystem and components with in -the subsystem, of the indicated component failure for the indicated system operational mode.

f. Secondary factors-that may cause failure. Identify the abnormal and out-of-tolerance conditions (generally environmental) which can cause the indicated failure mode under investigation. The specific tolerance limits must be given.

g. Upstream events that may "command" the failure mode. Identify those functions, events, or failures which directly place the component in the indicated failure mode.

h. Hazard classification. Provide a qualitative measure of significance for the indicated potential effect of each identified component failure mode.

i. Effect of failure on system. Identify the direct effect on the system of the component failure on the indicated system operational mode.

j. Remarks. Provide any additional information which may be pertinent to the analysis and is normally used to identify the recommended and actual means of hazard control.

Operating and Support Hazard Analysis

a. Specific task or general operation (subsystem or system). Identify and describe each operation, task, or procedure to the lowest level of detail possible to analyze the associated hazards. In the event operations have not been definitized, assumptions should be made to facilitate the analysis; however, the assumptions should be noted as such

b. Phase, mode, function. Identify the phase, mode, or function of the operation under analysis. This generally provides useful information necessary in identifying hazards.

c. Criteria, constraints, energy sources. Identify pertinent criteria and constraints of the operation under analysis which may affect safety (for example, the particular magnitude of voltage, current, pressure, radar frequency, etc.). It is also used to identify the presence and magnitude of any energy sources, such as propellants, explosives, velocity, etc. Generally speaking, this column is used to identify hazardous elements.

d. Hazardous conditions and their impact. Identify hazardous conditions involved in the operation under analysis and the potential impact or effect. of the hazardous conditions.

e. Hazard classification. Provide a qualitative measure of the risk assessment of each identified hazardous condition.

f. Safety guidelines and requirements. Provide recommended preventive measures for eliminating or controlling the identified hazardous conditions. These recommendations may take the form of guidelines, requirements, further analysis, etc.

g. Comments, correlation to data sources. Record pertinent information to the analysis which may facilitate someone else tracking the analysis at a later date. Included would be such things as design drawing and data used, source or derivation of requirements, calculations, concepts, etc. Also, key comments or ideas of the analyst should be recorded.

ATTACHMENT 3

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
DATA REQUIREMENT DESCRIPTION

1. TITLE SAFETY ASSESSMENT REPORT	**2. NUMBER** SA-03
3. USE The safety assessment report shall provide a formal, comprehensive safety report on the final design of a system. This report shall identify all system. safety features, inherent design and procedural hazards, and shall establish special procedures and/or precautions to circumvent the hazards.	**4. DATE** **5. ORGANIZATION APPROVED BY:**
7. **INTERRELATIONSHIP** Data requirements description relating to this. DRD is SA-01, System Safety Implementation Plan. 00	**6. REFERENCES** NPD 8700.1

Introduction

a. State purpose of this safety assessment report. Discuss any testing for which this report may be used.

b. Reference previously approved safety assessment report.

c. Provide an abstract, summarizing the major findings of the assessment and the proposed corrective or follow-up actions.

System Description

a. State purpose and intended use of system.

b. Provide historical summary *of* system development.

c. Provide a detailed system description and operating procedure, to include man/machine interfaces, name, type, and model number.

d. Provide photographs *of* each subassembly.

e. Provide system layout diagram (flow diagram)

f. Provide power flow schematics, to include grounding points.
g. Provide a definition of the equipment interfaces.

h. Describe the maintenance concept (which functions are accomplished at which maintenance levels).

i. As applicable, describe any other system(s) which will. be tested or operated in combination with this system.

System Operations

a. Briefly describe or reference the procedures for operating the system. Discuss the safety design features and controls incorporated into the system as they relate to the operating procedures.

b. Describe any special safety operational procedures needed to assure safe operations including emergency procedures.

c. Describe anticipated operating environments and any specific skills required for safe operations, maintenance, or disposal.

d. Describe any special facility requirements or personnel equipment to support the system.

System Safety Engineering

a. Include a short abstract of the results of-the System Safety Program.

b. Provide any software safety features and software safety analysis of software controlling hardware where the effects of failures are safety critical. List all software safety-critical hazards identified and corrective measures/procedures that are recommended and implemented. if no software safety issues can be identified or are applicable to the system under analysis, then a statement to that effect shall be included.

c. Furnish a copy of all system safety data, hazard analysis, and reports generated during design, development, production, and testing to identify hazardous conditions inherent in the system. A summary of all engineering change proposals (ECP's) and waivers that have safety implications shall be enclosed.

(1) Describe or reference the safety criteria and methodology used to classify and rank hazardous conditions.

(2) Summarize the results of hazard analysis and tests conducted and the impact, if any, on system operations/mission accomplishments due to hazards that have not been eliminated. include a list of all significant hazards along with specific. safety recommendations or precautions required to

ensure the safety of personnel and property. Categorize the list of hazards as to whether or not they may be expected under normal or abnormal operating conditions. Provide current status of any .outstanding corrective actions.

d. If system safety hazard analysis is not required by DRL, then include the following:

(1) List all hazards, including software induced safety critical hazards that have been identified and considered from the inception of the program in an appendix to the Safety Assessment Report. The list should be broken down to the subsystem or major component level and should be presented in a tabular format.

(2) For each hazard listed, provide a risk assessment.

e. If the system does not contain or generate-hazardous materials (i.e. explosives, toxic, radioactive, carcinogenic, etc.) a statement to that effect shall be included. For all hazardous materials generated by or used in the system, a Material Safety Data Sheet, shall be prepared to include the following information:

(1) Material identification as to type, quantity, and potential hazards.

(2) Safety precautions and procedures necessary during use, storage transportation., and disposal.

f. Provide a comparison of actual hardware parameters with established safety requirements in the equipment specification. This comparison shall be in a tabular format listing "Safety Critical" in another column. The analysis should show compliance/noncompliance of the listed safety criteria and provide justification for any noncompliance.

Conclusions and Recommendations:

a. State whether all identified hazards have been eliminated or controlled and that the system is completely safe and suitable for testing and operation or whether it is safe for testing with exceptions.

b. List exceptions for all known and potential hazards that may be encountered and-the specific safety recommendations to insure the safety of personnel and preservation of material and property. Related hazards should be classified as to whether they are expected to occur under normal or abnormal operating conditions.

c. High-light any known safety or health problems that will require further investigation during testing.

References. List all pertinent references such as test reports, Government safety inspection reports, preliminary operating manuals, technical manuals, and maintenance manuals.

Appendix. The appendix shall contain-charts, graphs, photos, or data which are too cumbersome for inclusion in the previous sections, or are applicable to more than one section, It may also contain detailed formulation or analysis which is more conveniently placed in an Appendix.

Safety Assessment Report (Update): If you have developed and submitted a Safety Assessment Report during a previous contract, it shall be updated to conform to the requirements stipulated in this DRD. in addition, the following shall be-addressed:

1. Discuss any new safety design features and controls added into the system as they relate to operating procedures.

2. List all safety deficiencies/shortcomings identified in test reports, Equipment Performance Reports, Government safety inspection reports, hazards introduced due to equipment design
changes, and those hazards identified as not being eliminated since last submission of Safety Assessment Report List shall be provided as an appendix to the Safety Assessment Report.

3. Summarize all new system safety data generated during production and testing. when it is found that the item presents no old or new hazards, the basis for such a determination and the supporting evidence shall be included.

ATTACHMENT 4

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION DATA REQUIREMENT DESCRIPTION	
1. TITLE SAFETY COMPLIANCE DATA PACKAGE	**2. NUMBER** SA-04
3. USE To provide information and data on identified hazards and to assess compliance with safety requirements.	**4. DATE**
	5. ORGANIZATION APPROVED BY:
7. INTERRELATIONSHIP Data Requirement descriptions relating to this DRD are SA-01, System Safety Implementation Plan; SA-02, Hazard Analysis Report; and SA-03, Safety-Assessment Report	**6. REFERENCES** NPD 8700.1

The Safety compliance data package shall contain:

a. A statement signed by the organization certifying the compliance of the system with the safety requirements in the technical requirements section of the contract.

b. A Safety Assessment Report which documents the results of the hazard analysis, including description controls, and safety verification methods.

c. Approved waivers to safety requirements.

d. A-listing of radioactive materials.

e. A list which identifies and characterizes all RF transmitters and all electromagnetic radiation which exceeds 10 milliwatts per square centimeter for ground safety purposes.

f. A log book maintained on each pressure vessel/system showing pressurization history, fluid exposures, and other pertinent data.

g. A summary of all safety-related failures or accidents related to fabrication, test and checkout, including an assessment of their potential impact to the systems operations.

h. A summary of the test, analyses, and/or inspection performed to show verification of the related safety requirements.

i. Detailed technical operating procedures (including contingency procedures) for operations which are hazardous in nature.

ATTACHMENT 5

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
DATA REQUIREMENT DESCRIPTION

1. TITLE MISHAP REPORTING	**2. NUMBER** SA-05
3. USE To provide adequate reporting, investigating, and documenting-for the occurrences, causes, and corrective actions associated with mishaps which may occur during NASA operations when contract personnel are involved or during contractor operations when NASA property is involved.	**4. DATE** **5. ORGANIZATION APPROVED BY:**
7. INTERRELATIONSHIP Data requirements description relating to this DRD is SA-01 System Safety Implementation Plan.	**6. REFERENCES** NPD 8700.1 NPD 8700.1

Immediately after notifying fire/medical /security and taking necessary action to preserve life and property, notify the cognizant installation safety office.

a. Type A and B mishap.

b. Any mishap of significant NASA interest.

Content and format for the report shall meet the requirements and guidelines set forth in NMI 8621.1, "Mishap Reporting and Investigating," NPD 8700.1, Vol-2, "Guidelines for Mishap investigation," NMI 1382.3, " Public Release of Accident Information Reports," and NMI 1382.4, "Release to News Media of Information Concerning Accidents and Casualties."

APPENDIX C: APPLICABLE DOCUMENTS

I. Agency Requirements

A. KHB 1700.7	Space Transportation System Payload Ground Safety Handbook
B. NPD 8700.1	Basic Safety Manual
C. NPD 8700.1	Guidelines for Mishap Investigations
D. NPD 8700.1	Safety Policy and Requirements For Payloads Using the Space Transportation System (STS)
E. NHB 5300.4 (1D-2)	Safety, Reliability, Maintainability, and Quality Provisions for the Space Shuttle Program
F. NHB 6000.1	Packaging, Handling, and Transportation for Aeronautical and Space Systems, Equipment, and Associated Components
G. NHB 8820.2	Facility Project Implementation Handbook
H. NMI 1800.3	NASA Environmental Health Program
I. NMI 8621.1	Mishap Reporting and Investigating
J. NMI 8710.2	NASA Safety and Health Programs

II. Design Requirements, Handbooks, and Guidelines

A. JSC-02681	Nonmetallic Materials Design Guidelines and Test Data Handbook
B. JSC-07700	Space Shuttle System Payload Accommodation Handbook
C. JSC-09604	JSC Government -Furnished Equipment Materials Selection List and Materials Documentation Procedures.
D. JSC-10615	Shuttle EVA Description and Design Criteria
E. JSC-11123	Space Transportation System Payload Safety Guidelines Handbook

F. JSC-13830	Implementation Procedure. For STS Payload System Safety Requirements
G. MSFC Design STD-512A	Standard Man/System Requirements for Weightless Environments
H. MSFC Handbook-505	Structural Strength Program Requirements
I. MSFC-SPEC-522	Design Criteria For Controlling Stress Corrosion Cracking
J. NHB 7320.1	NASA Facilities Engineering Handbook
K. NHB 8060.1	Flammability, Odor, and Off-gassing Requirements and Test Procedures for Materials in Environments That Support Combustion
L. NSS/HP-1740	NASA Aerospace Pressure Vessel Safety Standard
M. SE-R-0006	General Specification, NASA JSC Requirements for Materials and Processes

III. Reference Documents

A. DH 1-6	Air Force Systems Command Design Handbook AFSC DH 1-6 System Safety
B. DOE 76/45-4	MORT Users Manual
C. MIL-STD-882	System Safety Program Requirements

APPENDIX D: SYSTEM SAFETY ANALYSIS TECHNIQUES

1.1 INTRODUCTION

The selection of the most suitable analytical tool for a particular system safety task may be difficult. A reference chart which could provide correlation between the appropriate technique and the specific set of objectives, equipment, and constraints may be useful. Because of the extreme diversities in hardware factors and program considerations involved in the various situations where system safety analyses may be required, a universal system safety analysis technique selection chart is not possible. Instead, a method using certain basic guidelines-is provided for use in applying a systematic objective process to select the most appropriate system safety analytical technique. These guidelines are presented in a series of interrelated matrix charts, which must be cross-referenced for an understanding of the symbols and terms employed (figures D-1. D-2, D-3).

2.1 BASIC CONSIDERATIONS

In performing an objective evaluation of the appropriateness of system safety analytical tools for a given situation, and how to implement those selected, the following basic questions should be resolved:

1. Who will have a need for the results or information to be generated?

2. When will this information be needed?

3. In what detail and format will the data be most useful to the recipient?

4. What input information, data, and drawings will be needed before the analysis or study can be performed?

5. In what time frame should the analysis be initiated, reviewed, completed, submitted, and updated?

6. How will inputs required from subcontractors be provided to the responsible associated contractors; and inputs required by the integrating contractor be provided from the associated contractor in a timely and effective manner?

7. What must be added to contractual agreements, (e.g. work statements and contract data requirement list), to assure the desired task management and data flow control.

3.1 GUIDELINE DESCRIPTION

The following reference guidelines (Figures D-1 through D-3) are cross-referenced with each other for brevity, and therefore must be treated as a complete unit, rather than individual charts. These have been prepared to assist the non-system safety specialist in selecting the particular analytical techniques for a given need or set of objectives. The approach taken was as follows:

1. A list of generalized typical reasons/objectives for performing system safety analyses (note, special purpose safety studies, range safety data, nuclear safety data, etc. - are not covered) was developed. The listed reasons are documented in Figure D-1, and given a reference code number (Ref. Code), used to cross-reference that particular objective in the related matrix charts.

2. A matrix chart (Figure D-2) was prepared, relating each system safety analytical technique to the applicable reasons listed in Figure D-1. In this effort the following rationale was adopted:

   a. Each reason was. considered in turn for each technique, and assigned to one of three classes of relative applicability, i.e., primary, secondary, or contributory, or non-applicable.

   b. A primary classification means that the technique was developed to accomplish the Objective indicated.

   c. A secondary classification means that the technique will accomplish at least most of the objective indicated, but not as well as sane other technique with a "primary" classification.

   d. A contributory classification means that the-technique will provide output data usable for satisfying the objective when combined with other analyses and for studies.

   e. The matrix was then completed, assigning the reference code number from Figure D-1 to the appropriate column in Figure D-2.

   f. For each system safety analytical technique listed, a subsystem and system line was provided. For the purpose of this discussion, system (S) refers to the effort planned which is to consider the total system or program under evaluation, or at least does not have any significant part or subdivision intentionally omitted; subsystem (Sub) refers to the effort accomplished on any subdivision, subsystem, part-or element of a defined system or project.

3. Since most techniques were assigned two or three "primary" objectives and many objectives assigned to several techniques, a need to better indicate the

relative effectiveness (on a general basis) of the various techniques for the listed objectives was needed for guideline purposes. This was accomplished by means of a slightly modified matrix (Figure D-3), which provides for a single point technique/ reason evaluation rating for each possible combination. The explanation of the rating symbols used on this matrix was indicated in Figure D-3.

4. Figure D-3 shows the sequence of technique initiation based on a typical major. system life-cycle phase, and the manner by which input and output data should be transmitted. The interrelationships continually occurring between the analytical process and the system design, schedule, and ,testing are also illustrated as a reminder that system safety analysis cannot be effectively performed in any manner isolated from the other ongoing aspects of the program.

REF. CODE	REASON /OBJECTIVE
(1)	Obtain initial assessment of safety significant aspects of a contemplated (or actual) product, activity, system,. or project .
(2)	Establish objective basis for defining safety tasks, analyses, testing', and training on a given project .
(3)	Identify potentially hazardous equipment failure modes and Improper usage.
(4)	Provide guidance for the proper selection of specific safety related criteria, requirements or specifications.
(5)	Assist In the evaluation of safety considerations during design /procedural trade-studies.
(6)	Evaluate hazardous design considerations and establish relative corrective action priorities.
(7)	Organize baseline data. for quantitative deductive analyses
(8)	Document -subsystem level data for use in performing system level analysis.
(9)	Identify safety significant problems /requirements across subsystem /environment Interfaces.
(10)	Determine causative factors and Interactions leading to specified unwanted/hazardous events.
(11)	Evaluate probability (Quantitatively or Qualitatively) of specified unwanted /hazardous events occurrence, and Identify critical path of causative factors.
(12)	Identify, describe and establish relative importance of potential hazardous conditions associated with contemplated (or actual) activities involving the use, test, storage, handling, transportation handling, maintenance or disposal of an item of equipment, subsystem system.
(13)	Establish objective-basis for specifying precautions, personal protection, safety devices, emergency equipment /procedures/ training, or other safety requirements for facilities, support equipment and environment.
(14)	Provide documented evidence of compliance with specified safety tasks, objectives and design requirements.

FIGURE D-1 BASIC REASONS FOR CONDUCTING SAFETY SYSTEM ANALYSES

PHASE	SYSTEM SAFETY TECHNIQUE	SUB-SYSTEM	SYSTEM	REF. PARA. IN TEXT	REASON FOR LEAVING		
					PRIMARY	SECONDARY	CONTRIBUTORY
CONCEPTUAL	PRELIMINARY HAZARD ANALYSIS	X		APPENDIX ATTACHMENT 1	(1) (2) (8)	(4) (9)	(3) (5) (6) (12) (13) (14)
			X		(1) (2) (4)	(9)	(3) (5) (6) (12) (13) (14)
DESIGN	FAULT HAZARD ANALYSES	X		APPENDIX ATTACHMENT 2	(3) (7) (8)	(4)	(5) (10) (11) (12) (14)
			X		(3)	(4)	(5) (10) (11) (12) (14)
	FAULT TREE ANALYSIS	X		APPENDIX ATTACHMENT 4	(8) (10) (11)	(3) (4) (5) (6)	(9) (12) (14)
			X		(9) (10) (11)	(3) (4) (5) (6)	(12) (14)
	COMMON CAUSE	X		APPENDIX ATTACHMENT 5	(8) (9) (10)	(3)	(11) (12)
			X		(9) (10)	(3)	(11) (12)
	SNEAK CIRCUIT	X		APPENDIX ATTACHMENT 6	(3) (8) (10)	(5) (14)	(6) (12) (13)
			X		(3) (8) (10)	(5) (14)	(6) (12) (13)
	SOFTWARE HAZARD ANALYSIS	X		APPENDIX ATTACHMENT 7	(3) (8) (10)	(5) (14)	(6) (12) (13)
			X		(3) (10)	(5) (14)	(6) (12) (13)
OPERATIONAL	OPERATING AND SUPPORT HAZARD ANALYSIS	X		APPENDIX ATTACHMENT 3	(8) (12) (13)	(2) (4) (5)	(3) (10) (14)
			X		(9) (12) (13)	(2) (4) (5) (9)	(3) (10) (14)
	MANAGEMENT OVERSIGHT RISK TREE	X		APPENDIX ATTACHMENT 8	(9) (12)	(10)	(14)
			X		(9) (12)	(10)	(14)

FIGURE D-2 SAFETY ANALYSIS TECHNIQUES VS. REASONS FOR PERFORMING ANALYSIS

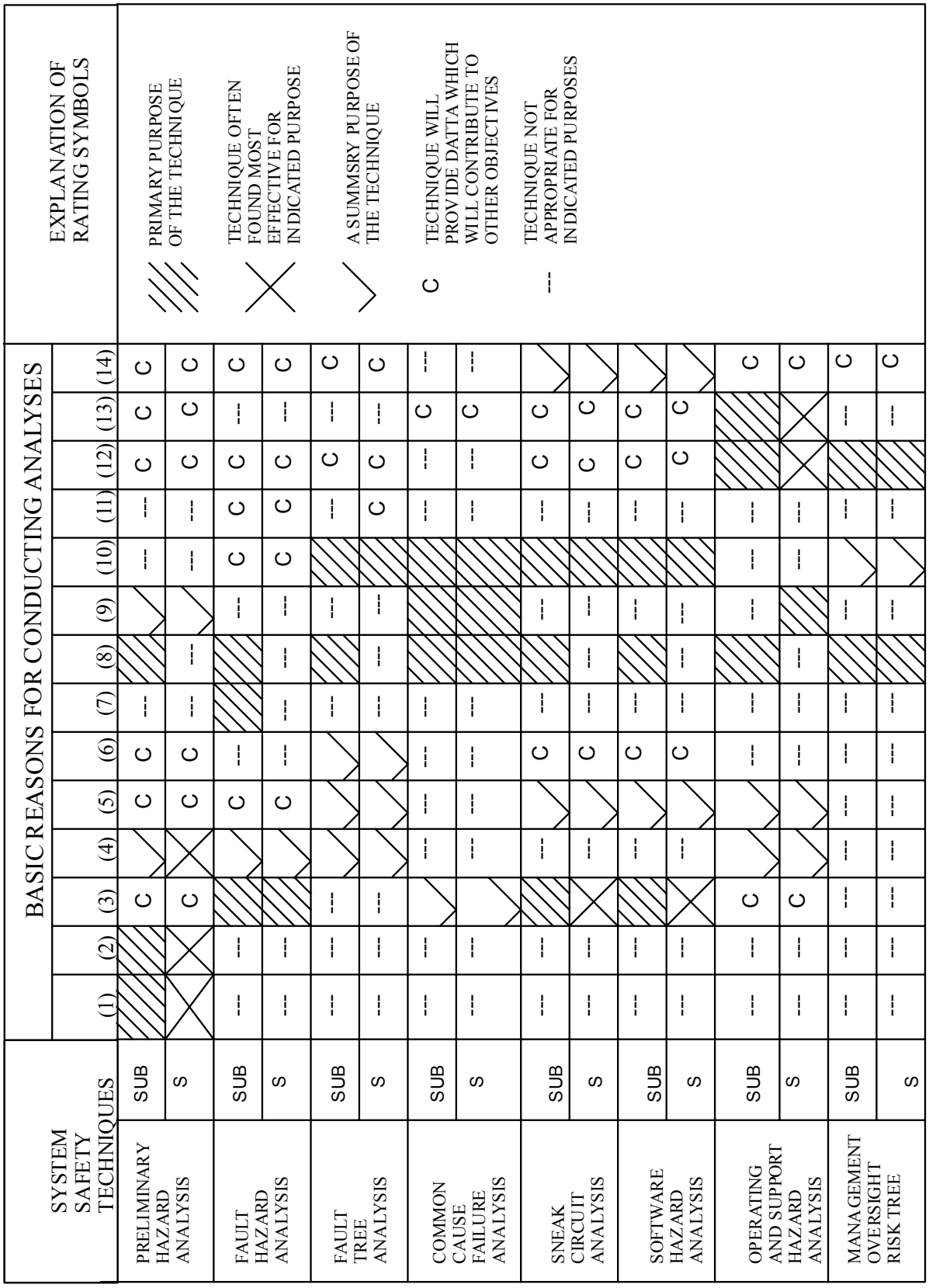


FIGURE D-3 TECHNIQUE/OBJECTIVE MATRIX

4.I GUIDELINE USAGE INSTRUCTIONS

In attempting to use the guidelines and references provided in this appendix, the following is suggested:

1. First consider the basic objectives (Figure D-1) which apply to your particular situation, and prepare a listing.

2. Compare the list of selected objectives with the information provided in Figures D-2 and D-3 to select those candidate techniques which appear to .best satisfy your primary requirements.

3. Considering the results of the questions addressed in paragraph 2.1, organize the implementation plan of the technique candidates, and make the final trade-off decisions through the preparation of a detailed system safety analysis plan, which may be used as part of the overall system safety program plan.

ATTACHMENT 1: PRELIMINARY HAZARD ANALYSIS (PHA)

1.1 PURPOSE

1. The PHA is usually the initial safety analysis performed for a project and the purposes of this analysis technique are to:
   a. Identify hazardous elements, hazardous conditions, and their causes.

   b. Determine the effects of these hazardous elements and conditions on the subsystem, system, and overall project.

   c. Categorize the severity level of each hazardous element or condition.

   d. Identify proposed corrective actions for eliminating the hazardous element or condition, or minimizing the hazard effects.

2. The data derived from the PHA will provide an input to other initial system safety activities such as the identification of:

   a. Potential problem areas associated with hardware, software, or procedural interfaces and interactions..

   b. Safety design or procedural requirements.

   c. Priorities for scheduling the safety effort.

   d. Areas requiring testing, further analyses, or trade studies.

2.1 DESCRIPTION

The PHA is a systematic safety analysis used to identify critical safety areas, to evaluate major hazards, and to identify the safety design requirements for the project. The format for documenting the PHA is usually a columnar form A top-level fault tree analysis may be developed to systematically guide the analysis effort and place emphasis on critical areas in the early stages of project development. See Appendix D, Attachment 4, for a discussion of the Fault Tree Analysis. The following data are required to perform a PHA:

1. The proposed or actual systems configuration or operation from drawings, scenarios, specifications, and analyses.

2. Hazard analyses, mishap data, and lessons learned from similar systems . and projects.
3. Trade studies.

3.1 PROJECT PHASES

The PHA is applicable to all types of projects including spaceflight, aviation, facilities. and ground support equipment. It is applicable to the hardware, software, and operations associated with all systems at any phase of project development. The PHA can be started at any phase of project development, but is most useful if started during the concept phase so that safety considerations can be included in project planning, trade studies, and the selection of design safety requirements. The PHA should be continually updated throughout the life cycle of the project.

4.1 ADVANTAGES/DISADVANTAGES

If the PHA is started early in the project, it will provide the basis for the establishment of design safety requirements, thus reducing the possibility of costly design changes later in the development of the project. The PHA provides a baseline of safety data from which further safety analyses can be conducted. The effectiveness of the PHA is dependent on the skill, knowledge, and experience of the analyst and the availability of safety data from similar systems.

5.1 TECHNIQUE

1. A typical columnar format for a PHA is shown in Figure D-4. Instructions for completing the form are contained in each column on the figure. The identification of hazardous elements or conditions is the first and most important step in performing the PHA. A hazardous element is any item or function that creates a hazard. The item or function may be inherently hazardous (such as radioactive materials or toxic materials) or it may create a hazard when combined with other elements (such as flammable materials and a heat source). Failures within the system, changes in the supporting environment, or operating errors may be required to create the hazard. Hazardous elements can be identified by using checklists or by using experience, engineering judgment, and intuition.

2. Checklists are the most commonly used method for the identification of hazardous elements and conditions. The analyst should develop or obtain a source of checklists for hazardous elements. These checklists are intended to stimulate ideas for the identification of hazardous conditions within the system or project being analyzed. The lists should include general sources that have been found to produce hazardous conditions, energy sources that are inherently hazardous, and operations that are hazardous. The following are examples of safety checklists.
   a. Energy sources should be isolated from each other and from personnel. The following is a list of typical energy sources:

      (1) Electric power generators.

(2) Fuel for heaters, generators, refueling operations.

(3) Explosives, propellants.

(4) Flammable liquids, gases.

(5) Heat producing equipment light bulbs, heaters, chemical reactions, heat sinks.

(6) Electromagnetic radiation including. RF generation and microwave

(7) Ionizing radiation.

(8) Stored energy in flywheels, other kinetic energy.

(9) Potential energy - equipment falling, guide wires breaking, springs.

(10) Implosion potential devices - CRT's, other evacuated items.

(11) Spark producing equipment.

(12) Batteries H2 reactive/corrosive/toxic chemicals.

(13) Pressure compressed gas cylinders, other pressure vessels.

(14) Static collecting equipment.

(15) Optical sources such as ultraviolet; infrared, and high intensity visible light sources.

b. Fuels and Propellants.

(1) Characteristics.

(2) Hazard levels.

(3) Quantity distance constraints.

MISSION _____
SUBSYSTEM _____

REF. NO.	HAZARDOUS CONDITION	HAZARD CAUSE	HAZARD EFFECT	HAZARD LEVEL	CORRECTIVE ACTION	REMARKS
Assign a reference number as required to provide traceability.	Use the checklist below to identify potentially hazardous conditions. 1. Can the system/subsystem fail to operate as intended? 2. Can the system/subsystem operate Inadvertantly? (untimely)? 3. Are there Inherent hazards such as the use or presence of: a. Shatterable Materials b. Corrosive Materials c. Pressure vessels d. Radiation sources e. Toxic materials f. Energy sources g. Propellants (list the materials such as glass or acid) h. Extremes of heat or cold j. Biological Record the identified hazards in the matrix. If no hazardous condition is Identified, enter "none identified."	Enter brief description of how each hazardous condition is created. ie., rupture of the O2 tank; wiring insulation overheating and ignitings; etc.	Record the potential effect of each hazardous condition on critical equipment, personnel, or the general public, i.e., loss of vehicles emergency landing in uninhabited area; etc.	Identify the hazard level as one of the following for each hazardous condition: CA-Catastrophic - No time or means are available for corrective action. CR-Critical - May be counteracted by emergency action performed in a timely manner. CN-Controlled - Has been counteracted by appropriate design, safety devices, alearm/ caution and warning devices, or special automatic/ manual procedures.	Identify proposed hazard reduction methods for open hazards and implemented reduction methods for controlled hazards.	Enter any statement required for further clarification.

Figure D-4. Preliminary Hazard Analysis Format

(4) Handling, storage, transportation safety features.

(5) Compatibility factors.

c. Environmental Constraints.

(1) Temperature, altitude (extremes) high temperature equipment.

(2) Humidity.

(3) Dust, fungus, salt spray, contamination, explosive atmospheres.

(4) Rain, etc.

(5) Noise.

(6) Vibration.

d. Use of Explosive Devices.

(1) Sensitivity.

(2) Quantity distance constraints.

(3) Compatibility factors.

(4) Handling, storage, transportation.

(5) Fragment site and velocity.

e. Compatibility of Materials.

(1) Enhanced corrosion possibilities.

(2) Catalytic reactions.

f. Effects of following (upon system or by system).

(1) Transient current.

(2) Electrostatic discharges

(3) Electromagnetic radiation
(4) Ionizing radiation

(5) Transient voltages - maximum safe transient voltages which may be applied to the parts of the equipment.

(6) Control design - inadvertent activation, wiring controls, etc., electrical interlocks, etc.

g. Pressure Vessels

(1) Fittings.

(2) Mountings.

(3) Hold down devices.

(4) Pressure relief valves.

(5) Gauges.

(6) Hoses.

(7) Expansion joints.

(8) Other safety devices.

h. Crash Safety.

(1) Survivability/crashworthiness

(2) Timely evacuation.

i. Safe Operation and Maintenance.

(1) Electrical safety provisions.

(2) Mechanical safety provisions.

j. Egress, Rescue, Survival and Salvage.

(1) Unobstructed exits.

(2) Sufficient exists.
(3) Opening in panic.

(4) Able to open from outside.

(5) Fire fighting equipment.

(6) Salvage and disposal provisions.

k. Life Support Requirements.

(1) Auxiliary breathing apparatus.

(2) Environmental control units.

(3) Fail safety operation

(4) Venting requirements.

(5) Parameter monitoring.

(6) Alarms.

(7) Toxic materials, elimination of.

l. Fire Ignition and Propagation Sources and Protection.

(1) Heat sources.

(2) Catalyst.

(3) Arcs.

(4) Spontaneous combustion.

(5) Friction.

(6) Chemical reaction.

(7) Lenses and mirrors.

(8) Flammable gases.

(9) Heat conductors.
(10) Flammable liquids.

(11) Readily combustible metals.

(12) Combustible fibers.

(13) Plastics - toxic gases evolved during combustion.

(14) Automatic fire extinguishing equipment.

m. Resistance to Shock Damage.

n. Human Factors and Ergonometric Factors.

(1) Work space - dimensions.

(2) Posture of maintenance personnel.

(3) Lifting provision.

(4) Visual acquity requirements.

(5) Glare Control

(6) Control illumination.

o. Fail Safe Design Considerations.

(1) Fusing.

(2) Automatic shutdown.

(3) Interlocks.

(4) Power sequencing.

p. Vulnerability and Survivability.

(1) Personnel armor.

(2) Equipment armor.

(3) Redundancy.
(4) Dependence on the system.

q. Protective Clothing, Equipment or Devices.

(1) Respirator.

(2) Flame-proof clothing.

(3) Gloves

(4) Goggles/safety glasses.

(5) Thermal clothing.

r. Lightning and Electrostatic Protection.

(1) Grounding rods and networks.

(2) Electrostatic collection electrodes.

(3) High current ground conductors for lightning towers, antennas, shelters.

(4) Electrostatic voltage controls for input/output leads, and power lines.

s. Human Error Analysis of Operator Functions, Tasks, Software, and Requirements.

(1) Error reducing design.

(2) Task assignment.

(3) Results of operator error

(4) Improper sequencing.

(5) Use of automatic sequencing and control.

(6) Use of software controlling hardware.

ATTACHMENT 2: FAULT HAZARD ANALYSIS (FHA)

1.1 PURPOSE

The FHA is a systems analysis most commonly used for performing subsystem hazard analyses (SSHA) and system hazard analyses (SHA). The FHA identifies hardware failures that can create a hazard.

2.1 DESCRIPTION

The FHA is a systematic, detailed investigation of subsystem or system failure modes and their primary and secondary effects on the subsystem or system. -The FHA format is similar to that used for the failure mode and effects analysis (FMEA); however, the FHA format contains an identification of upstream components that could command or initiate the failure mode. Also, the FHA identifies secondary factors, such as operational and environmental parameters that could cause the failure mode. The PHA is used to develop priorities for performing an FHA. The FMEA is also used as a source information for failure modes and failure rates (when quantitative analyses are performed). The FHA can identify areas requiring analysis using the fault tree or sneak circuit techniques.

3.1 PROJECT PHASE

The FHA can be performed during any project phase where detailed design information is available. The analysis is updated as the design, manufacturing, and testing phases continue.

4.1 ADVANTAGES/DISADVANTAGES

The FHA is a very versatile technique that is similar to the FMEA. In a project where a number of contractors or organizations are performing individual analyses, integration of these analyses can be easily performed. A disadvantage is that the analyst must have a detailed knowledge of subsystem and system operations to perform a comprehensive FHA.

5.1 TECHNIQUE

The FHA is usually performed using a columnar matrix such as shown in Figure D-5. The following is a description of the information required for each column of the matrix.

CONTROL PANEL - SUBSYSTEM A

1. COMPONENT	2. FAILURE MODE	3. FAILURE RATE	4. SYSTEM OPERATIONAL MODE	5. EFFECT OF FAILURE ON SUBSYSTEM	6. SECONDARY FACTORS THAT MAY CAUSE FAILURE	7. UPSTREAM EVENTS THAT MAY "COMM-AND" THE FAILURE MODE	8. HAZARD CLASS.	9. EFFECT OF FAILURE ON SYSTEM	10. REMARKS

REV LTR _____

FIGURE D-5 MATRIX - FAULT HAZARD ANALYSIS

1. COMPONENT

   This column identifies the major functional activity or hardware components within the subsystem being analyzed. The major component should be identified by part number and descriptive title.

2. FAILURE MODE

   This column identifies all credible failure modes for the identified major component. The FMEA should supply this information, whenever applicable.

3. FAILURE RATE

   When performing quantitative analyses, this column is used to enter a probability of failure estimate of the component in the indicated failure mode. This is the component's primary failure rate. The source of data must be indicated but is normally the FMEA.

4. SYSTEM OPERATIONAL MODE

   This column identifies the system mode of operation in which the major component is operating during the indicated failure mode.

5. EFFECT OF FAILURE ON SUBSYSTEM

   This column identifies the direct effect, on the subsystem and components within the subsystem, of the indicated component failure for the indicated system operational mode.

6. SECONDARY FACTORS THAT MAY CAUSE FAILURE

   This column identifies the abnormal and out-of-tolerance conditions (generally environmental) which can cause the indicated failure mode under investigation. The specific tolerance limits must be given.

7. UPSTREAM EVENTS THAT MAY "COMMAND" THE FAILURE MODE

   This column identifies those functions, events, or failures which directly place the component in the indicated failure mode.

8. HAZARD CLASSIFICATION

   This column provides a qualitative measure of significance for the indicated potential effect (column 5) of each identified component failure mode.

9. EFFECT OF FAILURE, ON SYSTEM

   This column identifies the direct effect of the component failure on the system when in the indicated system operational mode. Note that this column is used only when full system knowledge is available.

10. REMARKS

    This column provides for any additional information which may be pertinent to the analysis and is normally used to identify the recommended and actual means of hazard control.

ATTACHMENT 3: OPERATING AND SUPPORT HAZARD ANALYSIS (O&SHA)

1.1 PURPOSE

The purpose of the O&SHA is to ensure the evaluation of all man-machine elements and automatic unmanned operations. associated with the project. This includes the evaluation of procedures and tasks associated with production, installation, maintenance, testing , modification, transportation, operation, storage, training, and disposal.

2.1 DESCRIPTION

The O&SHA is used to examine procedurally controlled activities to identify and evaluate hazards resulting from the implementation of operations or tasks performed by persons. It must consider the planned system configuration at each phase of activity; the facility interfaces; the planned environments; the supporting tools or other equipment specified for use; operational/task sequence, concurrent task effects and limitations; biotechnological factors, regulatory or contractually specified personnel safety and health requirements; and the potential for unplanned events including hazards introduced by human efforts. Using the results of the PHA, SSHA, and SHA, the O&SHA identifies hazardous operations and tasks, the hazardous .conditions associated with the tasks, the causes of the hazardous conditions, the risks associated with the hazardous conditions, and recommendations to eliminate or reduce the effects of the hazardous conditions.. Data required to perform the O&SHA are drawings, specifications, timelines, procedures, schematics, and other hazard analyses such as the PHA, SSHA, and SHA. Operational scenarios should be developed to aid in the performance of the O&SHA.

3.1 PROJECT PHASE

The O&SHA is initiated as soon as practicable in the development phase of the project. If a general timeline for operations can be developed, the O&SHA can be started. This could be as early as the conceptual phase of the project. The-analysis must be updated and performed in more detail as
specific procedures are developed.

4.1 ADVANTAGES/DISADVANTAGES

The O&SHA technique is easily learned and provides safety data on procedures that are not directly derived from other analysis techniques. If the analysis is not performed early in the project development, it cannot easily affect the. design. Historically, the 0&SHA has been performed only after procedures are developed.

The only viable recommendations at this time are minor procedural changes and the insertion of caution and warning notes in the procedure.

5.1 TECHNIQUE

The O&SHA is usually performed using a columnar matrix format such as shown in Figure D-6. The following is a description of each column of the matrix:

1. SPECIFIC TASK OR GENERAL OPERATION

   This column is used to identify and describe each operation, task, or procedure to the lowest level of detail possible to analyze the associated hazards. The cases where operations have not been defined, assumptions should be made to facilitate the analysis; however, the assumptions should be-noted as such.

2. PHASE, MODE, FUNCTION

   This column is used to identify the phase, mode, or function of the operation under analysis. This generally provides useful information necessary in identifying hazards.

3. CRITERIA, CONSTRAINTS, ENERGY SOURCES

   This column is used to identify pertinent criteria and constraints of the operation under analysis which may affect safety (for example, the particular magnitude of voltage, current, pressure, radar frequency, etc.). It is also used to identify the presence and magnitude of any energy sources, such as propellants, explosives, velocity, etc. Generally speaking, this column is used to identify hazardous elements.

4. HAZARDOUS CONDITIONS AND THEIR IMPACT

   This column is used to identify hazardous conditions involved in the operation under analysis and the potential impact or effect of the hazardous conditions.

5. HAZARD CLASSIFICATION

   This column provides a qualitative measure of the risk assessment of each identified hazardous condition.

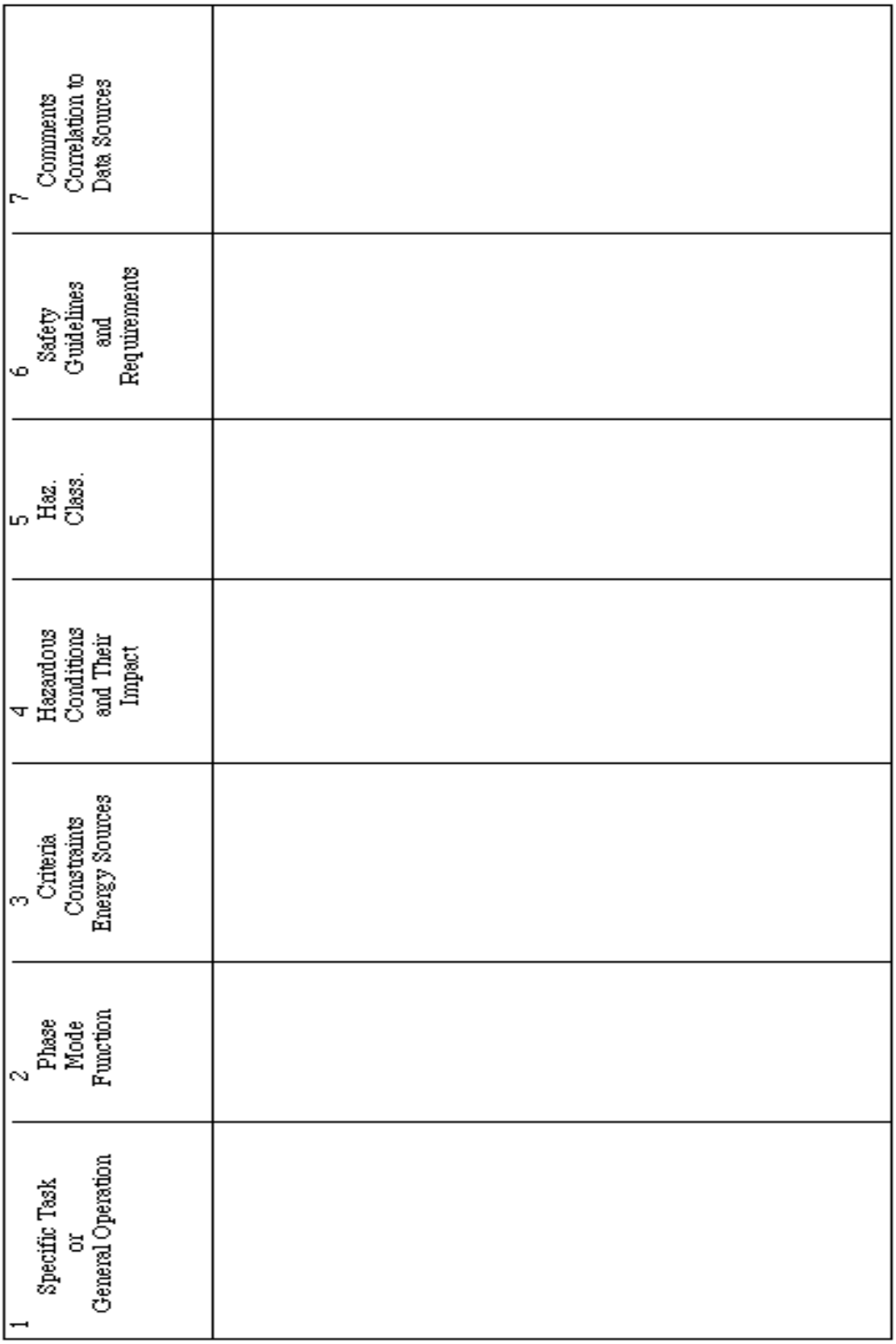


Figure D-6 Operating and Support Hazard Analysis

6. SAFETY GUIDELINES AND REQUIREMENTS

This column is used to establish recommended preventive measures for eliminating or controlling the identified hazardous conditions. These recommendations may take the form of guidelines, requirements, further analysis, etc.

7. COMMENTS, CORRELATION TO DATA SOURCES

This column is used to record information pertinent to the analysis which may facilitate tracking the analysis at a later date. Design drawing and. data used, source or derivation of requirements, calculations, and concepts should be included. Also, key comments or ideas of the analyst should be recorded.

ATTACHMENT 4: FAULT TREE ANALYSIS (FTA)

1.1 PURPOSE

1. The FTA is a deductive analytical technique which lends itself to detailed systems analysis, decision making, and communication. When used as a system safety analysis tool, the fault tree results in a graphic and logical representation of the various combinations of possible events, both fault and normal, occurring within a system, which can cause a pre-defined undesired event. An Undesired event is any event which is identified as Objectionable and unwanted, such as a potential accident or hazardous condition. This graphic presentation exposes the interrelationships of system events and their dependence upon each other, which may result in the occurrence of the undesired event.

2. When the fault tree structure is completed, an evaluation of the fault tree is performed to determine the results or significance of the analysis. Two types of evaluations' are possible, qualitative and quantitative. The qualitative evaluation is an engineering judgment assessment of the fault tree. The quantitative evaluation is a numerical evaluation. Failure rates of the system elements are Inserted into the fault tree structure and mathematically combined to yield probabilities. The validity of action taken to eliminate or control fault events can be enhanced in certain circumstances by. quantifying the fault tree and performing such a numerical evaluation. The quantification and numerical evaluation may provide three basic measurements for decision making relative to risk acceptability and required preventive measures. They are:

   a. The probability of occurrence of the undesired event;

   b. The significance or importance of the undesired event or the various paths leading to the undesired event;

   c. A baseline measure of the level of safety, which can be used to determine the effect of design changes.

3. As recommended preventive measures are incorporated into the design, their adequacy involving the safety problem may be verified. This is done by making the appropriate changes in the fault tree structure and then reevaluating the fault tree. The effects of the change, or the relative measure of improvement., should be apparent from the re-evaluation.

2.1 Description

1. Fault Tree Analysis is a technique by which the system safety engineer can rigorously evaluate specific hazardous events. It is a type of logic tree which is developed by deductive logic from a top undesired event to all sub-events which must occur to cause it. It is primarily used as a qualitative technique for studying hazardous events in systems, subsystems, components, or operations involving command paths. It can also be used for quantitatively evaluating the probability of the hazard and all sub-event occurrences when sufficient and accurate data are available. Quantitative analysis should be performed only when it is reasonably certain that the data for part/component failures and human errors for the operational environment exist.

2. A fault tree consists of the segments shown in Figure D-7. The tree should only be developed to the lowest segment required to identify and resolve the hazard. The top structure may be developed to aid the conduct of the PHA and to identify the project safety requirements and obvious hazards. The tree can be quantified with actual data, developed data, or simulation. There are computer programs available for plotting the tree and performing a qualitative or quantitative analysis.

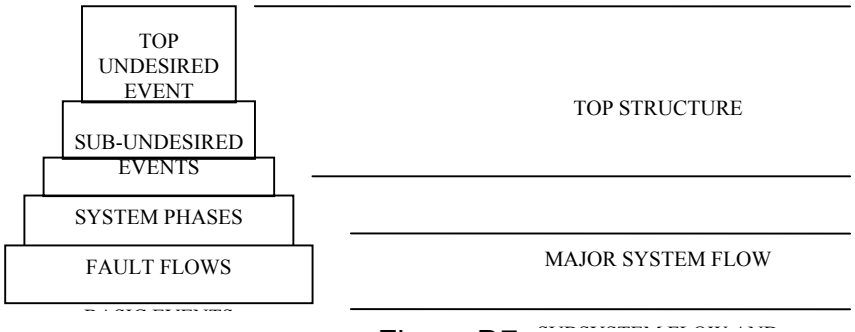


Figure D7

3.1 Project Phase

The FTA can be performed at any time in the life of a system as long as the required level of detail is available. The top structure can be used to support the PHA during project planning. The lower levels can then be developed in parallel and consistent with system development. FTA's can be very effective tools for accident or mishap investigation.

4.1 Advantages/Disadvantages

The FTA can be used in the most complex situations and need only be developed to the lowest level required. The structure must be developed by hand, but computer programs are available for all other efforts. Quantitative applications are

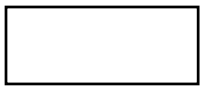
difficult to perform due to the lack of appropriated failure rate data. Sources of FTA computer programs are described in the “Fault Tree Handbook, “ NUREG-0492, Nuclear Regulatory Commission, January 1981, Government Printing Office (GPO) Sales Program Division of Technical Information and Document Control, U.S. Nuclear Regulatory Commission Washington, D.C. 20555. Failure rate data may be obtained from Department of Defense DOD-HDBK-217, “Reliability Prediction For Electronic Parts,“ or through the Government-Industry Data Exchange Program.

5.1 Technique

1. In fault tree construction, specific symbols are used to represent events and logic gates. The use of symbology primarily assures consistency throughout the fault tree, aids in the identification and reference of events and logic gates, and simplifies the logic projected by the fault tree. Only the basic FTA symbols and tree development techniques are described here. The basic or primary symbols are as follows:,

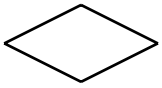
The “AND” gate describes the logical operation whereby the coexistence of all input events is required to produce the output event.

The "OR" gate defines a situation whereby the output event will exist if one or more of the input events exist.



The rectangle identifies an event that results from the combination of fault or failure events through an input logic gate.

The circle describes a primary failure event that requires no further development.



The diamond describes an event which is not further developed because of insufficient information or it is not of sufficient consequence.

An elementary example is illustrated in Figure D-8.

2. Suitable mathematical expressions representing the fault tree entries may be developed using Boolean algebra. When more than one event on a chart can contribute to the same effect, the chart and the Boolean expression indicate whether the input events must all act in combination (AND relationship) to produce the effect, or whether they may act singly (OR relationship). The probability of failure of each component or of the occurrence of each condition or listed event is then determined. These probabilities may be from actual

failure rates; vendors test data; comparison with similar equipment, events, or conditions; or experimental data obtained specifically for the system. The probabilities are then entered into the simplified Boolean expressions. The probability of occurrence of the undesirable event being investigated may then be determined by calculation. When an FTA is used for qualitative analysis, care is required in the description of each event to be sure it can be fitted with a suitable probability.

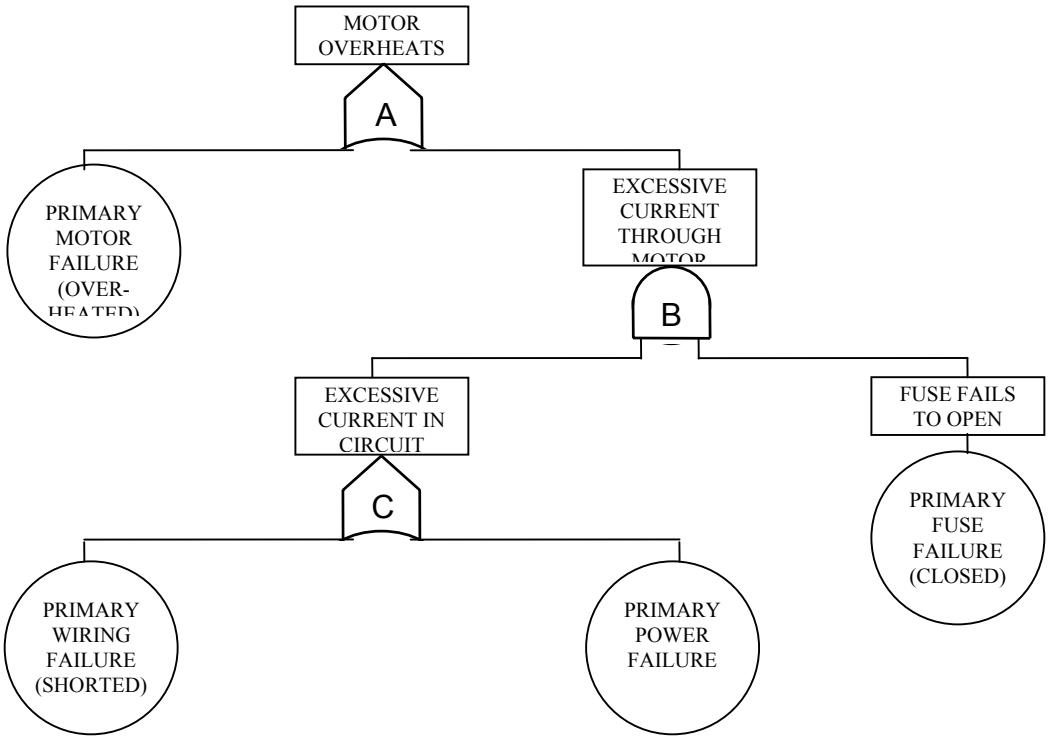


Figure D-8 Sample System Fault Tree

ATTACHMENT 5: COMMON CAUSE FAILURE ANALYSIS (CCFA)

1.1 PURPOSE

1. A CCFA is utilized to determine if there are combined multiple failures of. components and operator errors which result in degradation or disablement of a system and are set up by a common event or causative mechanism.

2. Common cause failures can affect redundant and interlocked design features in the system. when redundancy is provided by identical components, locations, or -channels, susceptibility to common cause failures may be, increased. For example, susceptibility of redundant systems due to identical locations is seen when fire can burn away insulation of collocated wire bundles such that the wires short together and render inoperative a primary system and its backup.

3. Common cause failures need not occur simultaneously. Generally, they should be considered to coexist prior to maintenance checks or other procedures which might reasonably be expected to discover any part of the failure.

2.1 DESCRIPTION

The CFA, in general, is an extension of the Fault Tree Analysis. Its emphasis is directed toward the identification of multiple failures that may result from a single cause or event. These single secondary cause/events may result from a ..common process, manufacturing defect, a common human operator error, or. some common external event. The analysis will identify the possible interaction of failures in independent redundant systems. Experience has shown that there is a finite list of common causes or events which should be checked. These typically deal with physical location and manufacturing characteristics such as common subjected environments, wire routing through a common connector or tray, common design processes which introduce a generic defect during manufacture, or susceptibility to common calibration errors- because a defective instrument (or procedure) was used !during installation or maintenance.

3.1 PROJECT PHASE

Functional level CCFA's should be performed early in the project phase to identify critical items for design consideration. Detailed or component level CCFA's can be performed only after the detailed design is completed.

4.1 ADVANTAGE/DISADVANTAGES

CCFA's offer advantages over other analyses in situations where a single causative factor results in failure of interactive systems or components, which may or may not be redundant. The procedure offers a highly organized approach for assessing potential common cause failures in complex electrical/electronic systems. A computer aided system is required for complex systems.

5.1 TECHNIQUE

1 . The overall task flow begins with the development or collection of topological network trees for the electrical portions of 'a control system. The trees are segregated for various. analytical tasks according to concerns evidenced in a top-level qualitative fault tree. Those trees which are- found to have significant system interdependency or redundancy are subjected to Common Cause Hazard Analysis (CCHA) at the Lowest Replaceable Unit (LRU) or piece-part level.

2. The CCFA is prepared with checklists, much like a Preliminary Hazard Analysis. The first check made on a group of interdependent/ redundant trees is to identify commonalties. The checklist for commonality identification can be tailored according to project, application boundaries, or experience. Generally, it appears as follows:

   a. Commonality checklist.

      (1) Location and environment.

         (a) Chassis.

         (b) Packaging/containment.

         (c) Elevation.

      (2) Manufacture.

         (a) Part numbers.

         (b) Equipment name/item.

         (c) Process.

         (d) Calibration/test.

      (3) Maintenance

(a) Period.

(b) Calibration equipment.

(c) Personnel.

(d) Materials.

(4) Operations.

(a) Status displays.

(b) Inputs.

Other entries such as TRANSPORTATION and INSTALLATION can be made. Sub-entries can be expanded, such as by adding THERMAL (COLD/HEAT),

EXPOSURE, HUMIDITY and VIBRATION to the ENVIRONMENT checks. Likewise, the sub-entries can be expanded where necessary. For example, the ELEVATION item can involve checks for ATMOSPHERIC PRESSURE/ CORONA or FLOODING.

b. For each commonality found, a second checklist is used to correlate possible, critical conditions of the tree. group within the area of commonality. The critical condition checklist is of the following form:

(1) Electrical.

(a) Short.

(b) Open.

(c) Clocking.

(2) Mechanical.

(a) Separation/shock.

(b) Welding.

(c) Obstruction.

(3) Chemical, corrosives.

(4) Biological.

c. The next step in the process is to apply a third checklist to suggest credible accident-initiating events, mechanisms, or causes. At this point, it should be realized that not every possible cause of a critical accident need be predetermined. There is no need to identify all contributing scenarios if a single credible cause of a critical accident can be foreseen. Corrective action should be instituted to prohibit design susceptibility for the whole class of conditions due to. any trigger event. Therefore, the third checklist represents a search for a credible trigger event scenario:

(1) Conductive contaminant.

(2) Mechanical shearing.

(3) Fire/explosion.

(4) Flood.

(5) Loss of cooling.

(6) Dust/grit.

d. Again, each entry can be broken down. For example, CONDUCTIVE CONTAMINANT can represent FLUIDS (salt water and acid) and METALTRIMMINGS. Sources for each trigger event can also be postulated with a fourth checklist, if desired, but this is usually unnecessary.

3. As with any analytical effort, no useful result is produced unless each significant activity is documented. Results must be recorded and tracked through appropriate resolution, otherwise, something may be overlooked or the corrective action may introduce a worse situation. Any kind of tracking form can be used to document the coverage of the effort, but significant hazards with their associated accident scenarios generally should be separately reported, illustrated, numbered, and tracked as high-risk items.

4. The approach to Common Cause Failure Analysis is shown in Figure D-9. The effort is performed in four steps. First, all common elements within the trees of each group are identified and listed. These commonalties may be shared connectors; common locations in terms of modules, cabinets, or wire bundles; or more generic features, such as common manufacturer or other

characteristics. The second step is to determine the credible failure modes of piece parts identified from the first step. Examples of failure modes might be electrical shorts, electrical opens, maintenance errors and calibration errors. The third step requires documentation of at least one credible cause of each failure mode identified in the second step. It is not 'productive to try to' list all possible causes of such failure modes, but listing at least one credible initiating event should suffice to show the need for design improvement. Comprehensive risk assessment may vary widely with each particular trigger mechanism that is suggested. Any resulting design modification should obviate the functional susceptibility to similar causes. Examples of the causes to be listed in the third step would be conductive contaminants, overheat, fire, floods, or other mechanisms which could cause. the electrical shorts, opens, maintenance errors and calibration errors. The last 'step of this procedure is to describe the failure effects and recovery methods for the items listed in step 1. This is documented on a form for subsequent tracking, risk assessment, and resolution as illustrated in Figure D-10.

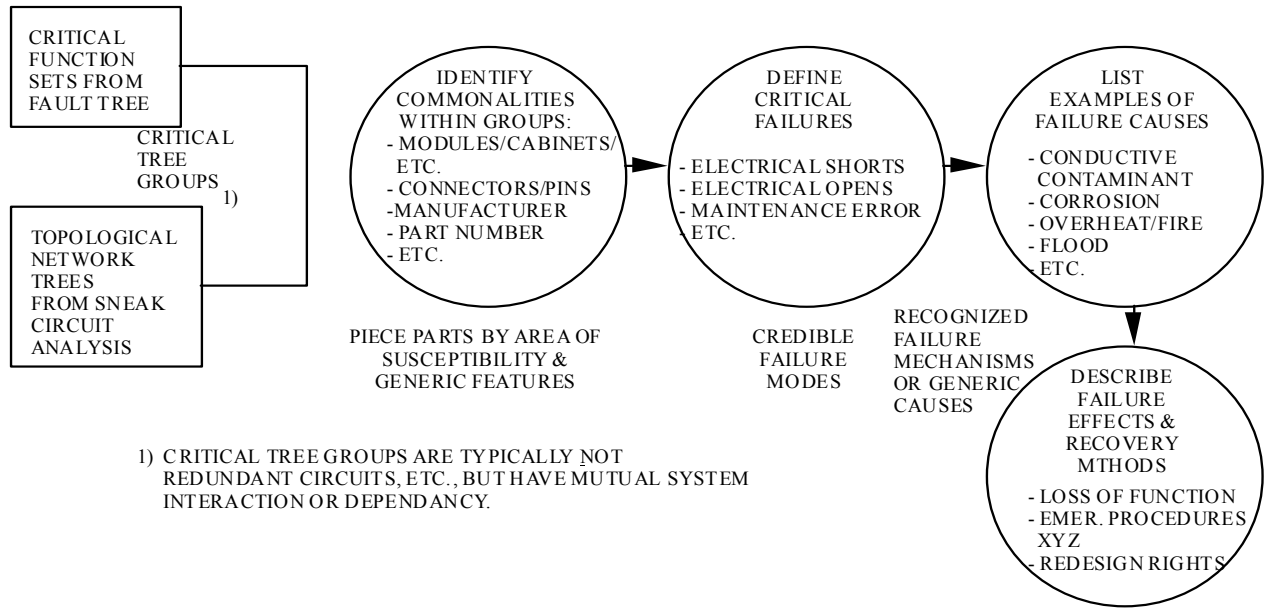


Figure D-9 Common Cause Failure Analysis Flow

(PROJECT) COMMON CAUSE FAILURE ANALYSIS

CRITICAL FUNCTION SET	COMMONALITY	CRITICAL EVENT	POTENTIAL CAUSE	EFFECT	REMARKS
DOOR & SPEED CONTROL 2-A) T_{38} - LEFT SIDE DOOR 2-B) T182 EMER. BRAKES	CONNECTOR DJ2	ELECTRICAL SHORTS: PINS H-J-K PINS C-J-Y	1) CONDUCTIVE CONTAMINANT 2) METALLIC SHEARING OF	LEFT SIDE DOORS DRIVEN OPEN AND EMER. BRAKES INHIBITED. DOORS 1 & 3 DRIVEN OPEN DOORS 5 & 7 DRIVEN OPEN	VIOLATION OFDESGIN CRITERIA - REDESIGN RECOMMENDED. ADJACENT PINS - CREDIBLE PINS NOT ADJACENT

Figure D-10 CCFA Tracking and Resolution Format

ATTACHMENT 6: SNEAK CIRCUIT ANALYSIS (SCA)

1.1 PURPOSE

An SCA is performed to identify areas where undesired functions could occur or desired functions could be inhibited during normal or off normal operations.

2.1 DESCRIPTION

A sneak is defined as an unexpected path or logic flow within a system which, under certain circumstances, can initiate an undesired function or inhibit a desired function. The path may be influenced by operator actions, and it may consist of hardware, software, fluid flows, or combinations of these elements. A computer-aided analysis approach is necessary for large-scale, complex systems. The computer-aided methods provide for automated development of network trees developed from circuit diagrams. Network trees can be easily analyzed for sneak conditions by using a checklist of clues applied at each junction or decision point.

3.1 PROJECT PHASES

Sneak Circuit Analysis should be initiated when component level data are made available. The preferred start time is prior to the critical design review in the full-scale engineering development phase. Sneak analysis of subsequent data releases and changes should be maintained.

4.1 ADVANTAGES/DISADVANTAGES

The Sneak Circuit Analysis technique is a formalized, rigorous, and orderly process of analytically. assuring that unintended conditions have been excluded from the system. It complements, but does not replace or supersede testing and the common design analysis techniques such as the FMECA (Failure Mode Effects and Criticality Analysis) and FHA. The performance of the SCA can require a significant percentage of the total assurance budget. Therefore, SCA should only be performed on safety critical systems as identified by FMECA or FHA.

5.1 TECHNIQUE

1. SCA is a unique approach to discovery of latent conditions which cause unwanted functions to occur or which inhibit wanted functions, independent of component failure. The technique involves accumulation of detail circuit diagrams and wire lists, arrangement of circuit elements into topological network. trees, and examination of these network trees for suspected sneak circuits.
2. The data used for SCA must represent the system circuitry as it actually is or will be constructed, contingent upon quality control checks, tests, and inspections.

All reports are written against these drawings. An analysis based on the detailed circuit drawings identifies more system conditions than an analysis performed using system or functional level schematics. The higher level drawings frequently represent design intent or a perception of intended system design. The process of translating this design into detailed schematics and wire lists typically results in latent sneak conditions. For this reason, analysis only at the higher level involves a risk that not all of the problems will be found.

3. In early program development phases, detailed drawings are not available and the system level drawings must be used for the analysis. Problems will be identified at this higher level, but the analysis should be extended to later design phases so that the system configuration can be analyzed in detail.

4. Direct analysis of manufacturing and installation drawing is difficult as these documents are laid out to facilitate hookup by technicians without regard to circuit function. Many details and un-apparent continuities exist in these drawings; an analyst could become entangled and lost in the maze. The first task of the SCA is to convert this detailed, accurate information into a form usable for analytical work. In many cases, the magnitude of data manipulation required for this conversion necessitates the use of computer automation. In projects having a small data base, manual data manipulation can be employed. In either case, the detailed' schematics are converted into topological network trees, drawn so that electrical current (power) is considered to flow down the page and signal flow from left to right across the page.

5. Once the trees have been produced, the next task of the analyst is to identify the basic topological patterns that appear in each tree. Five basic patterns exist: the Single Line (No-Node) Topograph, the Ground Dane, the Power Dane, the Combination Dome, and the "H" Pattern (as shown in Figure D-11 below, "PWR" represents electrical power, "S" indicates a switching element, and "L" indicates an electrical load). The "H" pattern.. typically has the highest incidence of problems due primarily to the higher number of power. sources, returns, loads, and switches. The main problem occurs with the "H" crossbar, which includes L3, S3, and S4. This can result in power reversals, ground reversals, and current reversals.

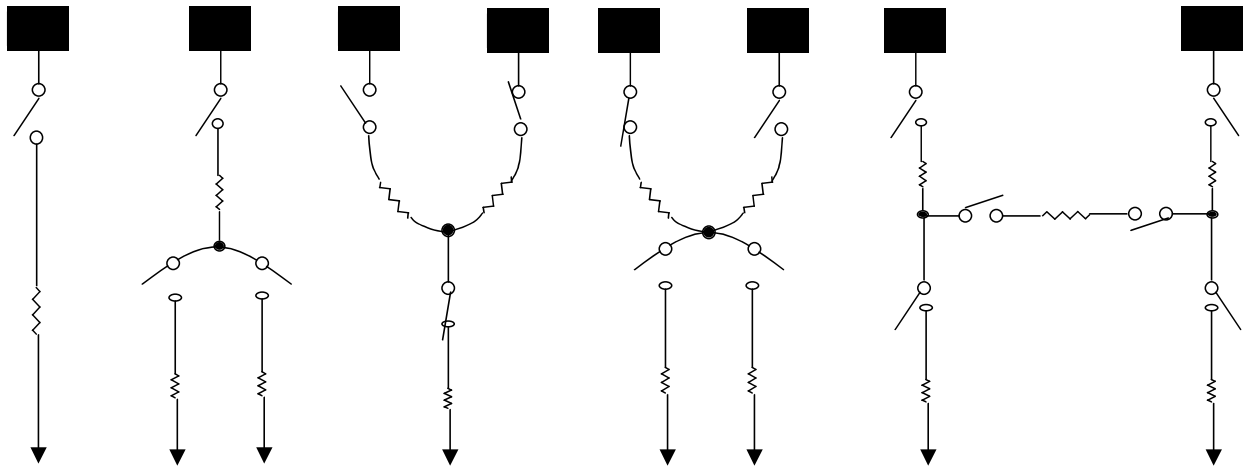


Figure D-11 Basic Topographs

6. Although at first glance, a given circuit may appear more complex than these basic patterns, closer inspection reveals that the circuit is actually composed of these basic patterns in combination. As the sneak circuit analyst examines each node in the network tree, he must identify which pattern or patterns best describe the node. The analyst then applies the basic clues that have been found to typify sneak circuits involving that particular pattern. These clues represent questions that the analyst must answer about the interrelationships of circuit elements involved in the pattern. The questions will lead to the identification of any capability of the circuit to experience a surprise or sneak condition at the node being analyzed. Off-nominal modes are considered equally with normal operations, and no assessment of probabilities is attempted in a standard SCA. The developed clues are typically proprietary to the performing contractor. A very basic clue in the Power Dome, Combination Dome, and "H" Pattern Dome is the reversal of the two power sources. In sane systems, the two power sources of the "H" pattern are to be mutually exclusive, and the lower circuitry must provide proper isolation. If isolation is not maintained, a bus to bus sneak is generated. Two equal power sources can still generate sneaks, whenever one bus develops an increased or decreased voltage level relative to the second bus. The resultant voltage and current shifts can inadvertently activate components in the "H" pattern. A short on one bus could short the second bus, resulting in inducing undesired equipment functions and no, convenient means or capability to reset the system.

7. The sneak circuits are classified into four basic types:

   a. Sneak paths which cause current or energy to flow along an unexpected route.

b. Sneak timing which may cause or prevent the flow of current or energy to activate or inhibit a function at an unexpected time.

c. Sneak indications which may cause an ambiguous or false display of system operating conditions.

d. Sneak labels which may cause incorrect stimuli to be initiated through operator error.

8. When a potential sneak condition is identified, the analyst must verify that it is valid. The circuit is checked against the latest applicable drawings or revisions, and operational information may be reviewed concerning the system in question. If the sneak condition is verified, a Sneak Circuit Report is written which includes applicable drawings, an explanation of the condition(s), system-level impact, and a recommendation for elimination of the sneak. A typical Sneak Circuit Report is provided in Figure D-12.

9. During the course of analysis, unnecessary or undesirable circuit conditions are sometimes. encountered. Such conditions as certain single failure points, un-supervised inductive loads, unnecessary components, and inadequate redundancy provisions are reported in the Design Concern Reports.

Project F-99 WCM Page___ OF___

SNEAK CIRCUIT REPORT -1

TITLE SNEAK CURRENT PATH RESULTS IN UNINTENTIONAL MASTER ARMING OF WPN RELEASE SQUIB FIRING CIRCUITS

REFERENCES

MODULE/EQUIPMENT

WEAPON CONTROLLER (9431A2)

EXPLANATION

As shown in Figure 1, when the Master Arm switch is off, Emergency Jettison has not been selected, and the Weapon Select switch is left in the Center Station position, a sneak path exists from the +28VDC Weapon Control power through the Weapon Select Switch (9417A3S3) through 9431A2A1R1 to charge capacitor 9431A2A1C1 and then through transistor 9431A2A1Q1 to the firing circuit. This bypasses the Master Arm 'A' function. Similar paths exist for Master Arm 'B' and the Left and Right Wing Stations.

POTENTIAL IMPACT

1. Unexpected Master Arm power may contribute to inadvertent weapon release.

2. The function of the Weapon Release 'A' and 'B' circuit breakers (2456A1CB1 and 2456A1CB2) may be bypassed.

RECOMMENDATION

Add a blocking diode as shown in figure 2.

REPORTED BY J. L. Vogas DATE October 16, 1980

CUSTOMER ACTION

Figure D-12 Sample Sneak Circuit Report

ATTACHMENT 7: SOFTWARE HAZARD ANALYSIS (SWHA)

1.1 PURPOSE

The SWHA is an analysis technique which is a blend of the Failure Mode and Effects Analysis and the Fault Tree Analysis. The SWHA process does not become intensive until the Software Requirements Review, when sufficient detail is available. At this time, the SWHA is directed by the contractually identified hazardous events and the hardware PHA and FTA identified hazardous events. The SWHA will identify the. ability or inability of software to take the necessary corrective action when potentially hazardous hardware systems function or malfunction. It will determine the software response to the system functioning or malfunction and will determine as a result of the software response what, if any, additional software constraints are required to preclude the occurrence of these identified hazardous events.

2.1 DESCRIPTION

The SWHA identifies potential hazardous effects on the system, both external to the software (such as erroneous or improperly timed commands) and internally controlled (such as computer skips causing illegal entry into critical routines). The analysis takes into consideration the adequacy, inadequacy, or omission in software requirements for routines which take corrective action to eliminate or control the hazardous events identified for analysis. It also takes into consideration software and hardware interaction in all phases of the system's life cycle: Test, deployment, operation, maintenance, and disposal.

3.1 PROJECT PHASE

The SWHA is begun early in the concept phase so that its findings can be readily incorporated in the design. An early start helps avoid schedule delays and redesign costs.

4.1 ADVANTAGES/DISADVANTAGES

The SWHA allows the analyst to review all software, and to focus only on software segments which are safety critical. Care must be taken by the analyst to not -be overly concerned with every code error, sign error, or unused logic, as it would result in undue expenditure of resources relating to items which may have no safety impact.

5.1 TECHNIQUE

The five phases of software development are concept, requirements, preliminary design, detailed design, and checkout and integration testing. The system safety analyst should participate in each of these five phases.

1. CONCEPT DEVELOPMENT

Based on a review of top level requirements, safety checklists are developed to define the system safety approach that must be developed. A typical checklist is illustrated in Figure D-13.

SAFETY CHECKLIST		
	Required	**Implemented**
1. Shutdown provisions for unsafe condition		
2. Monitoring of safety devices		
3. Secure launch codes		
4. Unique arming codes for critical safety devices		
5. Preclude a change of state If sync. lost		

Figure D-13 Safety Checklist

2. REQUIREMENTS

The initial approach is to establish an explicit set of safety requirements, based initially on safety checklists similar to that shown in Figure D-13, and to implement them within the design. The analysis concentrates on potential errors at the specification level in design requirements for operation, maintenance, and tests, and considers all overlapping conditions to ensure that an unplanned event does not occur due to multiple routines simultaneously changing state. The cause of errors in specifications is due to the requirements being improperly stated, improperly interpreted, incorrect, insufficient, or missing.

3. PRELIMINARY DESIGN

a. Through review and analysis of the appropriate software documentation, the analysis can reflect, in the SWHA, considerations of the effects of anomalies or deficiencies such as:

(1) Inadvertent character outputs.

(2) Coexistence of command, control or test routines.

(3) Improper sequencing.

(4) Improper timing.

(5) Failure to exit from routines.

The top-down software development approach that is generally utilized during the software development process is reflected by column headings in Figure D-14.

(a) Software function (change)	(b) Function description Summary	(c) System Hazard	(d) Hazard Category	(e) Safety Impact Discussion/ Conclusion	(f) Recommended Requirements to Control Hazard	(g) (h) Remarks/ Means of Implementation	Status

Figure D-14 Software Hazard Analysis Format

b. The following paragraphs provide instructions in the use of this format by reference to column heading.

(1) Software Function (Change). The particular software routine (or change if the original program is undergoing modification) is identified.

(2) Function Description Summary. Provide a brief summary of the purpose of the function, including identification of any critical command/monitor which impacts safety.

(3) System Hazard. Provide a brief identification of a system hazard that could occur from improper operation or-failure to operate.

(4) Hazard Category. If the overall hazard category can be identified, include here. If the effect of the hazard is across a system interface and therefore unidentifiable, a marginal flag (1>) should be entered.

(5) Safety Impact (Discussion/Conclusion). The potential hazard or non-normal interface configuration caused by the improper operation should be discussed and any conclusions and supporting rationale for specific safety requirements should be provided.

(6) Recommended Requirements to Control Hazards. Provide recommended safety requirements to eliminate or control the hazard within the software system. If the control cannot be implemented within the software, suggested external controls or requirement shall be listed.

(7) Remarks/Means of Implementation. Provide additional explanatory comments as required.

(8) Status. Include the status (open or closed), date of closure, and where the implementation is documented.

4. DETAILED DESIGN

a. An FTA (see Appendix D, Attachment 4) may be conducted at this point in the development of the software system. The FTA begins by identifying a hardware level hazard and works into the software design identifying contributory events or faults affecting its occurrence. For quantification, it is possible to obtain a worst case estimate by assuming that an error exists. For critical segments it may be necessary to use conventional system safety analysis techniques to determine if the system meets the safety requirements. The worst case unconditional. probabilities may be sufficient to conclude the analysis; however, if concerns remain, it may be necessary to extend the analysis through the application of more realistic failure rates.

b. As the system design evolves, the FTA is continually updated and eventually reflects the areas in which system hardware and software interaction (i.e., command, control and monitor) exists. To determine the significance of these software contributions to these potentially hazardous events, a detailed software hazard analysis will be accomplished. The software hazard analysis addresses the human interface and the hardware and software interfaces across all system elements at the system level and evaluates-both the effects of the software on all system elements and the effects of the system elements on the software. The safety analysis should reflect the ability or inability of the software to detect the status of safety critical devices, computer skip, entry into an improper routine, improper

sequencing or timing, and the resultant corrective action that will. be taken to control or eliminate the hazardous condition (i.e., going to a standby mode or existing routine and safely terminating computer operations). The analysis assures that safety critical functions are adequately protected by inhibits, interlocks, or hardware. The. FTA will include the results of the software hazard analysis.

ATTACHMENT 8: MANAGEMENT OVERSIGHT AND RISK TREE (MORT)

1.1 PURPOSE

MORT is an analytical procedure that provides a disciplined method for determining the causes and contributing factors of major accidents. It also is a tool to evaluate the quality of an existing safety system.

2.1 DESCRIPTION

1. The MORT is a special zed management system which focuses upon programmatic control of hazards. MORT utilizes a universal logic diagram or master "worksheet" to evaluate existing safety programs for accident/incident potential or to analyze a specific accident, and it makes extensive use of questions from the MORT User's Manual (ERDA-76/45-4, SSDC-4).

2. The MORT logic diagram is an idealized safety system model based upon the fault tree method of system safety analysis. Basically, MORT is a fault tree which asks "what" oversights and missions could have contributed to accidents or incidents and "why" in terms of what failed in the management system. It also addresses those risks which have been completely analyzed and accepted by management as having adequate control.

3.1 PROJECT PHASE

The MORT technique can be implemented at any time to serve as the primary system safety program, as a method for investigating real or potential accidents, or for investigating changes in the system safety program, the project's management system, or in the hardware itself.

4.1 ADVANTAGES/DISADVANTAGES

The MORT provides relatively simple decision points in an accident analysis or safety system evaluation and enables an analyst or evaluator to detect omissions, oversights, or defects in the system or project. The technique is of particular value in accident/incident investigation as a means of discovering system or project weaknesses or errors which provide an environment conducive to mishaps. The task of organizing and structuring safety into functionally defined relationships and measurements creates a large amount of complex detail. Repeated practice and experience with the MORT diagram are necessary before good dexterity and skill in its application are acquired.

5.1 TECHNIQUE

1. A MORT users manual has been prepared by the Department of Energy for use with the MORT analytical logic diagram. Both the manual and the diagram are essential to the understanding and full use of the MORT technique.

2. MORT is a special or specific application of an FTA. General features of the MORT event tree are indicated in Figure D-15.

3. Construction layout depicts three main "branches" ordered with S/M (Specific and Management), Oversights and Omissions on the left and R (Assumed Risks) on the right. The MORT technique requires events in the Assumed Risk Branch to be events transferred there from the Oversights and Omissions Branch. R factors are defined as only those risks that have been analyzed and accepted by the proper level of management; unanalyzed or unknown risks are not considered to be Assumed Risks.

4. Development of the two main branches comprising Oversights and Omissions is ordered with S (Specific Control Factors) on the left and more general M (Management Systems Factors) on the right.

5. M factors are shown separate from the process that produced the specific adverse event for two reasons:

   a. Depiction of the existing management systems will suggest related background aspects of the specific system or accident that should be closely examined, and

   b. The specific event may, in turn, suggest certain aspects of the management systems which may truly be LTA less than adequate).

6. In general, the further development of the S Branch is keyed to time as well as process. Left to right represents earlier to later, and bottom to top of the tree shows the sequence of causes from basic detailed causes to generic causes.

7. The key to understanding "programmatic" MORT is a close element-by element examination of the MORT diagram. The diagram branches, in large part, are self-explanatory. Each element of the diagram branch presents a relatively simple question. One starts at the top of the diagram with the actual losses resulting from an accident or the potential loss if the diagram is being used to evaluate an existing safety program. Each of the three main factors (branches) is considered in turn. Detailed consideration of the S Branch is accomplished by reasoning backward in time through several 'sequences of

contributing factors. The analysis ends when the question posed by the circled statement is answered with a "yes" or "no."

8. The MORT analytic diagram should be considered a working paper from which pertinent facts about an accident or problem are derived and from which a safety report is developed.

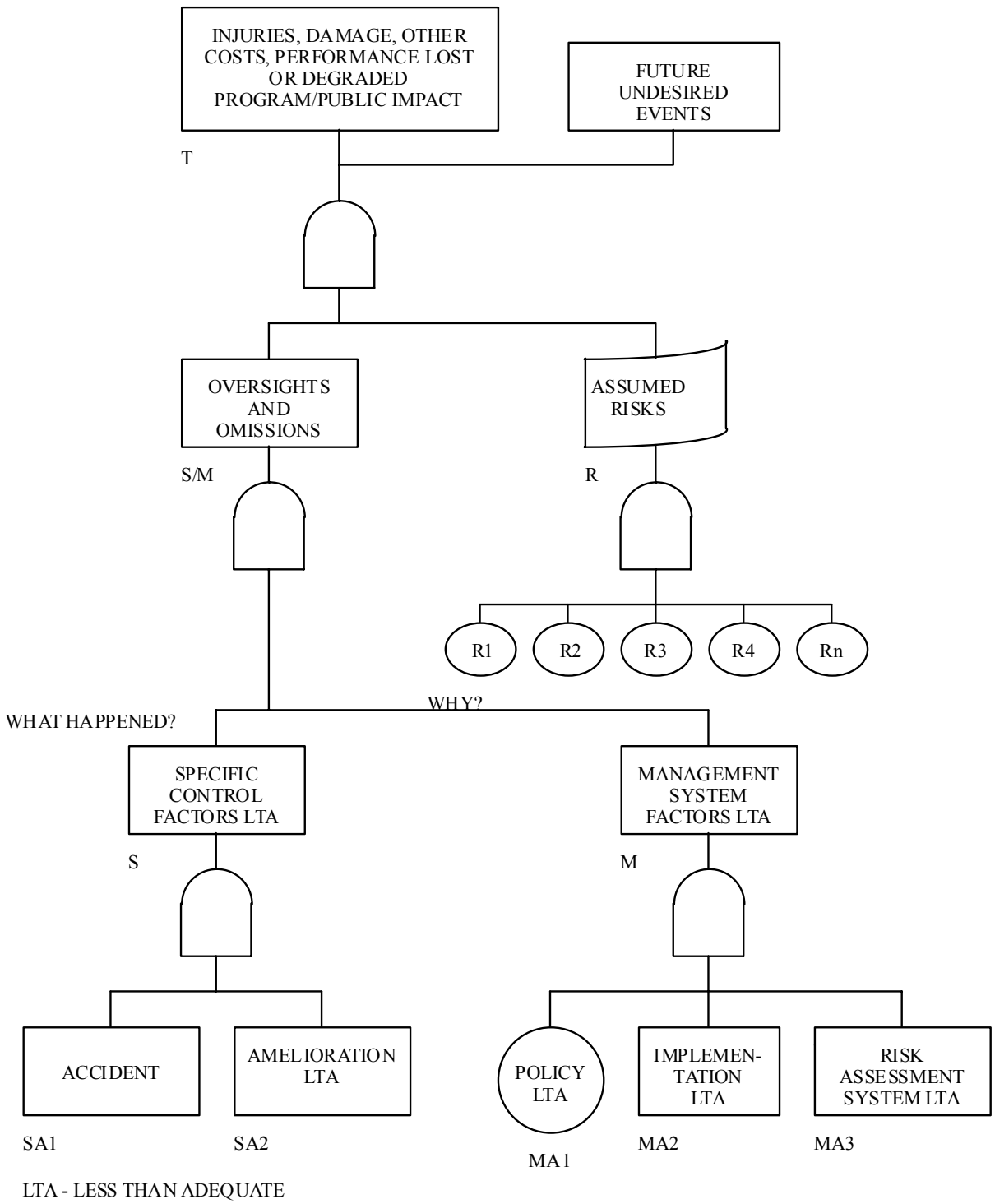


Figure D-15. MORT Top Events

ATTACHMENT 9: SUPPORT ANALYSES

1.1 INTRODUCTION

Support analyses may be required to validate selected safety features of a system, to determine hazard 'severity, or to establish the margin of safety of the design when such data are not otherwise available. The requirements for imposing these analyses for certain components in space flight systems, aeronautical systems, Government furnished equipment, and facilities should be included in the design specifications. Support analyses include:

1. Stress analysis.

2. Stress corrosion analysis.

3. Fracture control analysis.

4. Materials analysis - flammability, toxicity, and off-gassing.

5. Chemical hazard analysis.

6. Radiation (ionizing and non-ionizing) hazard analysis.

7. Mockups and simulations.

8. RF/EMI (radio frequency/electromagnetic interference) analysis.

9. Fluid compatibility analysis.

2.1 GUIDELINES

The following sections provide guidelines for imposing these analyses in applications not subject to the requirements of paragraph 2.2.

1. STRESS ANALYSIS

Stress analysis should be performed when the system safety engineer believes a single point of failure in a structural member may. cause injury or major facility damage. These are usually restricted to mandated structures but may be required elsewhere to, determine the need for additional safety requirements such as barriers, remote controls, or environmental protection.

2. STRESS CORROSION ANALYSIS

Stress corrosion should be considered most probable at the point at which a metallic structural member is most highly strained. The effects of corrosion are much more severe under stress then under ordinary conditions, and such members- will fail with fewer stress applications. Another factor to be considered is the corrosive environment in question. MSFC-SPEC-522, "Design Criteria for Controlling Stress Corrosion Cracking," provides guidance in selecting materials to be used in the design of equipment structures, support brackets and mounting hardware where stress corrosion is a factor.

3. FRACTURE CONTROL ANALYSIS

When adequate warning or redundancy measures are not feasible and the failure of a structure can result in a catastrophic event, a fracture control analysis should be considered. It can identify structural members subject to failure because of the propagation of flaws or crack-like defects introduced during fabrication, testing, and service life. A history of stress cycling should be maintained and allowances made for replacement, if necessary, at a later date.

4. MATERIALS ANALYSIS - FLAMMABILITY, TOXICITY, AND OFF-GASSING

Materials which are flammable, toxic, or produce toxic off-gassing should be avoided in habitable areas. NHB 8060.1, Flammability, Odor, and Off-gassing Requirements and Test Procedures for Materials in Environments that Support Combustion," provides guidance in selecting, testing, and certifying materials which may be used in contact with fuels, oxidizers, or combustible gases. SE-R-0006, "General Specifications, NASA JSC Requirements for Materials and Processes," provides guidance for selection of materials to be used in an atmosphere that supports combustion.

5. CHEMICAL HAZARD ANALYSIS

The need for chemical hazard analyses can be determined early by evaluating data such as drawings, procedures, and specifications to identify uses of chemicals. At an operating location, the purchase requests, project plans, and new proposals can identify potential chemicals and their use.

6. RADIATION (IONIZING AND NON-IONIZING) HAZARD ANALYSIS

All sources of radiation should be identified and analyzed for types of radiation, intended uses, locations, population and equipment exposures, and inspection requirements. Guidelines for these analyses and requirements include NHB 1700.7, KHB 1700.7, JSC 07700, JSC 13830, and DH 1-6. Radiation sources

can be identified by analyzing the drawings, procedures, specifications, work orders, purchase orders, project plans and proposals, and by monitoring with radiation detecting devices.

7. MOCKUPS AND SIMULATIONS

When adequate data are not otherwise available, the use of mockups and simulations can serve as primary sources of data and-are an excellent basis for safety judgments and design decisions for new systems. A reasonable approximation of the use environment can be obtained by]testing portions of the system which are considered essentially independent or whose interaction with the rest of the system can be simulated. In a simulation or isolation of a subsystem, the critical system interaction must be considered. Some cause-effect characteristics may be developed mathematically. This can be done with reasonable accuracy for electrical networks and structural components because of the accurate specifications of manufacturing tolerances and the ability to express theoretical relationships. In other cases, approximate models may be used and the engineer must be aware of the possibility of neglecting critical factors. When the approximation is based upon semi-quantitative data, liberal limits of error must be included.

8. RADIO FREQUENCY (RF)/ELECTROMAGNETIC INTERFERENCE(EMI) ANALYSIS

RF/EMI analyses should be considered for pulse or clock interface circuits with a pulse repetition rate of greater than 50K pps, signals with fundamental frequencies greater than 50 KHz, or circuits. processing pulse rise/fall times equal to or less than 10 microseconds. Guidelines for these analyses and tests include JSC specification SL-E-0001 and MIL-E-60511.

9. FLUID COMPATIBILITY ANALYSIS

Particular attention should be given to the analysis of materials used in systems containing hazardous fluids. These include gaseous oxygen, liquid oxygen, propellants, oxidizers, fine grained solids suspended in gas, and others that could theoretically cause exothermic or adiabatic reactions. Materials in a system which could be exposed to hazardous fluids directly or by a single failure should be included in these analyses. NHB 8060.1 provides requirements for materials exposed to hazardous fluids.

APPENDIX E: RISK ASSESSMENT APPROACH

1.1 INTRODUCTION

The decision to assume a risk is a management responsibility. The major factors to be considered should be the severity of the risk and the potential of the risk occurring. Paragraph 2.5 sets forth the criteria that risk assessments must be performed as a part of the risk management process. The intent of this appendix is to provide a technique for performing the risk assessment.

2.1 RISK ASSESSMENT TECHNIQUE

Decisions regarding resolution of identified hazards should be based on an assessment of the risk involved. To aid in the achievement of the objectives of system safety, hazards may be characterized by severity categories and probability levels. Since the priority for system safety is eliminating hazards by design, a risk assessment procedure considering only hazard severity will generally suffice during the early design phase. When hazards are not eliminated during the early design phase, a risk assessment procedure based upon the hazard probability, as well as hazard severity, should be used to establish priorities for corrective action and resolution of identified hazards.

1. HAZARD SEVERITY

Hazard severity categories (Figure E-1) are defined to provide a qualitative measure of the worst credible mishap resulting from personnel error; environmental conditions; design inadequacies; procedural deficiencies; or system, subsystem, or component failure or malfunction. These hazard severity categories may provide guidance for a wide variety of projects. Adaptation to a particular project is generally required to provide a mutual understanding between the NASA Center and the contractors as to the meaning of the terms used in the category definitions. The adaptation must define what constitutes system loss, major and minor system damage, and severe and minor injury, and severe and minor occupational illness.

DESCRIPTION	CATEGORY	MISHAP DEFINITION
CATASTROPHIC	I	Death or system loss.
CRITICAL	II	Severe injury, severe occupational illness, or major system damage.
MARGINAL	III	Minor injury, minor occupational illness, or minor system damage.
NEGLIGIBLE	IV	Less than minor injury, occupational illness, or system damage.

Figure E-1 - Hazard Severity Categories

2. HAZARD PROBABILITY

The Probability that a hazard will Occur during the Planned life expectancy Of the system can be described in Potential occurrences per unit of time, events, population items, or activity. Assigning a quantitative hazard probability to a potential design or procedural hazard is usually not possible early in the design process. A qualitative hazard probability may be derived from research, analysis, and evaluation of historical safety data from similar systems. Supporting rationale for assigning a hazard probability will be documented in hazard analysis reports. An example of a qualitative hazard probability ranking is shown in Figure E-2.

DESCRIPTION*	LEVEL	SPECIFIC INDIVIDUAL ITEM	FLEET OR INVENTORY**
FREQUENT	A	Likely to occur frequently	Continuously experienced
PROBABLE	B	Will occur several times in in life of an item	Will occur frequently
OCCASIONAL	C	Likely to occur sometime in life of an item	Will occur several times
REMOTE	D	Unlikely but possible to occur in life of an item	Unlikely but can reasonably be expected to occur
IMPROBABLE	E	So unlikely, it can be assumed occurrence may not be experienced	Unlikely to occur, but but possible

* Definitions of descriptive words may have to be modified based on quantity involved.
** The size of the fleet or inventory should be defined.

Figure E-2 Hazard Probability Ranking

3. ANALYSIS TECHNIQUE

Hazards should be prioritized for corrective action. Figures E-3 and E-4 show sample matrices for hazard risk assessment which can be applied to assign qualitative priority factors for obtaining corrective action. An identified hazard (Figure E-3) assigned a hazard risk of 1A, 1B, 1C, 1D, 2A, 2B, or 3A might require immediate corrective action. A hazard risk index of 2C, 2D, or 3B and 3C would receive a lower priority for consideration. A hazard risk index of 1E, 2E, 3D, or 3E might have lower priority for corrective action and may not warrant any tracking actions. In the second example, (Figure E-4), risk indices of 1 through 20 (1 being the highest risk) are assigned. This matrix design assigns a different index to each frequency-category pair, thus avoiding the situation caused by creating indices as products of numbers assigned to frequency and category which common results such as 2 X 6 = 3 X 4 = 4 X 3. This situation hides information pertinent to prioritization. These are only examples of a risk assessment method and may not fit all programs.

	HAZARD CATEGORIES			
FREQUENCY OF OCCURRENCE	I CATASTROPHIC	II CRITICAL	III MARGINAL	IV NEGLIGIBLE
(A) FREQUENT	1A	2A	3A	4A
(B) PROBABLE	1B	2B	3B	4B
(C) OCCASIONAL	1C	2C	3C	4C
(D) REMOTE	1D	2D	3D	4D
(E) IMPROBABLE	1E	2E	3E	4E

Figure E-3 - Example No. 1 Hazard Risk Assessment Matrix

Hazard Risk Index	Suggested Criteria
1A, 1B, 1C, 2A, 2B, 3A	Unacceptable
1D, 2C, 2D, 3B, 3C	Undesirable (project management decision required)
1E, 2E, 3D, 3E, 4A, 4B	Acceptable with review by project management
4C, 4D, 4E	Acceptable without review

HAZARD CATEGORIES				
FREQUENCY OF OCCURRENCE	I CATASTROPHIC	II CRITICAL	III MARGINAL	IV NEGLIGIBLE
(A) FREQUENT	1	3	7	13
(B) PROBABLE	2	5	9	16
(C) OCCASIONAL	4	6	11	18
(D) REMOTE	8	10	14	19
(E) IMPROBABLE	12	15	17	20

Figure E-4 - Example No. 2 Hazard Risk Assessment Matrix

Hazard Risk Index	Suggested Criteria
1 - 5	Unacceptable
6 - 9	Undesirable (project management decision required)
10 - 17	Acceptable with review by project management
18 - 20	Acceptable without review