THE SYSTEM SAFETY HANDBOOK

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As a simple guide to System Safety, one should not expect to have a complete knowledge or understanding of such a complex topic. It is the guide's duty to only enlighten the reader's knowledge and make them aware of some very important topics related to system safety. It is impossible to fully encompass the total amount of information needed to become a safety professional just with in a simple system safety guide. Therefore, please note that in reading the following guide, your horizons will become enhanced and broadened, but you will not become an expert over night.

"As we approach the twenty-first century, many challenges face the safety, engineering, and management communities. Risks and the potential for catastrophic loss are dramatically increasing as technology advances at an ever-increasing rate. The public demands a high level of safety in products and services, yet, in the face of world competition, the safety effort must be timely and cost-effective" (System Safety, 1999 pg.xiii)

TABLE OF CONTENTS

THE HISTORY OF SYSTEM SAFETY

Prior to the 1940s, safety consisted of basically trial-and-error. The term fly-fix-fly was associated with generally having an aircraft make a circuit and if it broke they would fix it and fly it again. This process was repeated until the final solution and correction was made. This method worked in the aviation world of low and slow aircraft. However it had little success in the fields of nuclear weapons and space travel. Here the consequences of having trial-and-error were much too costly. There needed to by a way to implement safety into the design and production. Hence, making a flight a success the very first time.

This is where system safety was born. As we had discussed the first method was fly-fix-fly or trial-and-error this was not an adequate answer for aviation or space programs.

1. 1960s—MIL-STD-882 (DOD, NASA)
2. 1970s—MORT (Department of Energy)
3. 1980s—Other agencies

The actual roots of system safety are not clearly defined. It is presumed that they started back in the 1940s era. However pinpointing the exact date is not possible. It is evident that once both aircraft and weapon systems became more technologically advanced and more money was put into them, their accidents became less acceptable.

As defined by MIL-STD-882, system safety is the application of engineering and management principles, criteria, and techniques to achieve acceptable mishap risk, within the constraints of operation, effectiveness and suitability, time and cost, throughout all phases of the system life cycles. Today, system safety is pushing at the constrains of its MIL-STD definitions. To accurately define system safety, one must first determine the scope of the system in question. Is it composed of only one element (e.g., hardware or software), or will the system include the human factor as it applies to the design, operation, handling or maintenance of the system or its parts? It many be simple device, or it could be a complicated series of devices and/or sysbsystems all functioning together in a specific environment. Defining what comprises the system is an essential first step in determining its system safety.

THE 1960s—MIL-STD-882, DOD, AND NASA

In the 1960s system safety began to take on its own role. It became an issue that needed to be addressed.

1. USAF publishes "System Safety Engineering for the Development of Air Force Ballistic Missiles" (1962)

2. USAF publishes MIL-S-38130, "General Requirements for Safety Engineering of Systems and Associated Subsystems and Equipment" (1963)

3. System Safety Society founded (1963)

4. DOD adopts MIL-S-38130 as MIL-S-381308A (1966)

5. MIL-S-381308A revised and designated MIL-STD-882B, "System Safety Program Requirements" (1969) (Stephenson, 2000, p. 4).

Most people would agree that one of the first major formal system safety efforts involved the Minuteman Intercontinental Ballistic Missile (ICBM) program. This is a series of pre-Minuteman design-related silo accidents, which probably provided at least part of the incentive (U.S. Air Force 1987).

The U.S. Air Force Ballistic System Divisions were the ones who generated the early system safety requirements. Early air force documents provided the basis for MIL-STD-882 (July 1969), “System Safety Program for Systems and Associated Subsystems and Equipment: Requirements for.” This particular document (and revisions MIL-STD-882 and MIL-STD-882B) became, and still remain, the bible for the Department of Defense (DOD) system safety effort (Moriarty and Roland 1983).

Other early system safety efforts were associated with the aerospace industry, including civil and military aviation and the space program. Here the weapon systems were also a part in this.

The National Aeronautical and Space Administration (NASA) developed its own system safety program requirements. The development of this program closely paralleled the MIL-STD-882 approach given by the DOD. Reasons for these two agencies to use a similar process is because the two tend to share contractors, personnel, and, missions.

In the early to mid-1960s, Roger Lockwood in Los Angeles founded the System Safety Society. The society later became known as the Aerospace System Safety Society in California in 1964. The name was changed to System

Safety Society in 1967 (Medford 1973). In 1973, the System Safety Society was incorporated as “an international, non-profit, organization dedicated to the safety of systems, products, and services (System Safety Society 1989).

THE 1970s – THE MANAGEMENT OVERSIGHT AND RISK TREE

In the later part of 1960, the Atomic Energy Commission (AEC) made the decision to hire William G. Johnson, a retired manager of the National Safety Council, to develop a system safety program for the AEC. This decision was made due to the awareness of the system safety efforts in the DOD and NASA communities.

The AEC programs and AEC contractors had good (some better than others) safety programs in place, the programs and approaches varied widely. This lack of standardization or commonality made effective evaluation, monitoring, and control of safety efforts throughout the organization difficult, if not impossible.

Here the goals became to improve the overall safety effort by:

1. Develop a new approach to system safety that incorporated the best features of existing system safety efforts.
2. Provide a common approach to system safety and safety management to be used throughout the AEC and by their contractors

A risk tree (MORT) manual and revised management oversight was published by the AEC in 1973. William G. Johnson mired his MORT program heavily off of the existing DOD and NASA programs. However it bored little resemblance to the MIL-STD-882.

In the 1970s Bill Johnson expanded and supplemented the System Safety Development Center. (SSDC) in Idaho Falls, Idaho. The MORT program provides the direction for this second major branch of the system safety effort.

Progress in the 1970s included:

1. *NASA publishes NHB 1700.1 (V3), "System Safety" (1970)*
2. *AEC publishes "MORT – The Management Oversight and Risk Tree" (1973)*
3. *System Safety Development Center founded (1974)*
4. *MORT training initiated for AEC, ERDA, and DOE (1975)*
5. *MIL-STD-882A replaces MIL-STD-882 (1977)* (Stephenson, 2000, p. 6).

THE 1980'S – FACILITY SYSTEM SAFETY

Three factors throughout the 1980s have driven system safety tools and techniques in other than the traditional aerospace, weapons, and nuclear fields.

First, a more sophisticated upstream safety approach was the product of highly complex and costly non-flight, and non-nuclear projects. Second, added incentives to produce safe products had introduced product liability litigation. Third, the upstream safety efforts lead to better design because of system safety experiences that have demonstrated positive progress.

Significant programs initiated or developed in the 1980's include the facility system safety efforts of the Naval Facilities Command and the U.S. Army Corps of Engineers and initiatives in the petrochemical industry.

1. *MIL-STD-882B replaces MIL-STD 882A (1984)*
2. *NAVFAC sponsors system safety courses (1984)*
3. *AIChE publishes "Guidelines for Hazard Evaluations Procedures" (HazOps) (1985)*
4. *MIL-STD-882B updated by Notice 1(1987)*
5. *USACE-sponsored facility system safety workshops initiated (1988)* (Stephenson, 2000, p. 6).

The constant need for a system safety effort for major military construction projects resulted in the development of draft guidelines and facility systems safety workshops for the military safety and engineering communities. "By the end of the decade, facility system safety training programs for government employees were established, and similar courses for contractors were available. Regulations outlining facility system safety efforts were pending and facility system safety efforts were being required on selected military contraction projects. In additions, NASA was initiating facility systems safety efforts, especially for new space station support facilities (Stephenson, 2000, p. 6).

In 1985, the American Institute of Chemical Engineers (AIChE) initiated a project to produce the "Guidelines for Hazard Evaluation Procedures." This document, prepared by Battelle, includes many system safety analysis tools. Even though frequently identified as hazard and operability (HazOp) programs, the methods being developed by the petrochemical industry to use preliminary hazard analyses, fault trees, failure modes, effects, and criticality analyses, as well as similar techniques to identify, analyze, and control risks systematically, look very much like system safety efforts tailored for the petrochemical industry (Goldwaite 1985) (Stephenson, 2000, p. 6-7).

FUNDAMENTALS OF SYSTEM SAFETY

Lack of standardization or commonality was one of the major problems confronting the systems safety community. Having “universally accepted” definitions to even basic terms would be a good place to start, however these basic terms do not exist as of yet. Some of the terms that are provided are defined in non-technical language to ensure the reader understands each term as used in this article.

> <u>Safety</u>: *Freedom from harm. Safety is achieved by doing things right the first time, every time*
>
> <u>System</u>: *A composite of people, procedures, and plant and hardware working within a given environment to perform a given task*
>
> <u>System Safety</u>: *The discipline that uses systematic engineering and management techniques to aid in making systems safe throughout their life cycles*
>
> <u>Hazard</u>: *Something that can cause significant harm*
>
> <u>Risk</u>: *The chance of harm, in terms of severity and probability*

Safety Community: That group of individuals who provide staff support to the line organization in support of the safety effort. It includes occupational and industrial safety, system safety, industrial hygiene, health, occupational medicine, environmental safety, fire protection, reliability, maintainability, and quality assurance personnel. (Stephenson, 2000, p. 8-

FUNDAMENTAL SAFETY CONCEPTS

Five fundamental safety concepts apply to any safety effort.

1. *Safety is a line responsibility*
2. *Safety is productive*
3. *Safety requires upstream effort*
4. *Safety depends on the safety precedence sequence*
5. *Systematic tools and techniques help* (Stephenson, 2000, p. 9).

SAFETY IS A LINE RESPONSIBILITY

There is an old principle within safety. It is line managers and supervisors are responsible for the safety of their organizational units and operations. This fundamental must be understood and accepted company wide. The safety professional's job is to provide the staff support necessary to ensure that the line organization is able to do its job well and effectively.

SAFETY IS PRODUCTIVE

Safety is achieved by doing things right the first time, and from there on out every time. Not only is this the goal that everyone should strive for, you will want to have a safe, extremely efficient, productive, and cost-effective operation.

SAFETY RERQUIRES UPSTREAM EFFORT

The selection, initial training, development of the procedures, and the design of the facilities and equipment are the types of tasks that ultimately determine the safety of the workplace. However in order to ensure that these listed items are carried out effectively the “good safety practices” must begin at the top or as far upstream as possible. The good news about fostering a healthy and safe workplace is that if improvements are needed they can often be made for a minimal amount of money if they are caught far enough upstream.

Safety depends on the safety precedence sequence. This is a prioritized list of controls that should be considered and applied, in sequence, to eliminate or control identified hazards:

1. *Design for minimum hazard (the first and most effective way to control identified hazards is to eliminate them through design or engineering changes)*
2. *Provide safety devices (use physical guards or barriers to separate potential unwanted energy flows or other hazards from potential targets)*

3. *Provide warning devices (These should be applied to any remaining hazards)*
4. *Control with procedures and training (this should be a last resort to accepting the remaining residual hazards)*
5. *Accept remaining residual hazards (even after all of the above changes have been implemented there will be some left over hazards)* (Stephenson, 2000, p. 11).

Note: For most applications a combination of controls must be used.

<u>Upstream Process Diagram</u>

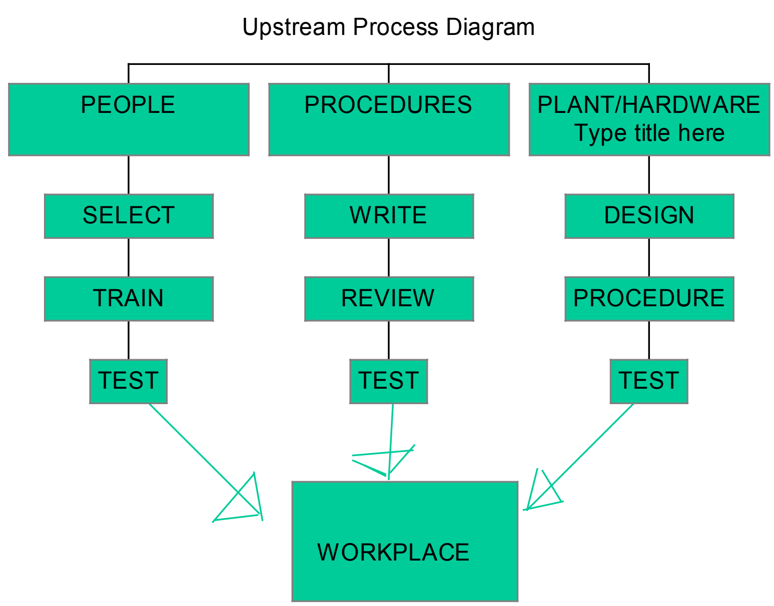


Figure 1. Upstream Process Diagram

<u>WHAT IS SYSTEM SAFETY?</u>

System safety is the name given to the effort to make things as safe as possible by systematically using engineering and management tools to identify, analyze, and control hazards. The system safety "effort" is sometimes called an approach, a discipline, a concept, a doctrine, and/or a philosophy.

WHY DO WE DO SYSTEM SAFETY?

The main reason that we practice and try to implement system safety is to achieve better safety. So you may ask how do we achieve better safety? This is done by complying with the appropriate codes, standards, and regulations that are, by at large, political documents.

Unfortunately safety is a reactive program usually. When in reality it should be a pro-active operation. It is said that safety is "written in blood" this is referring to the fact that for the most part the only time those operations or procedures will be changed is if some one sheds blood.

Here are a few analysis that have been created to help figure out why we do system safety.

THE MAIN ANALYTICAL TEQUINIUES OF SYSTEM SAFETY

PHL

The PHL (preliminary hazard list) it is an initial look at the entire system. If a PHL is available we are able to expand it by adding new hazards that may be identified as more project information is developed or available. If a PHL has not already been prepared, we can use what is called a PHA. This serves as the primary hazard identification tool as well as the starting point for the PHL. The PHA simple expands the PHL by identifying additional hazards, analyzing identified hazards, recommending hazard controls, and determining the level of risk after the controls are applied. This can be used in aiding of information for the PHL at a later date.

Preliminary Hazard List					
Project____________________				Date______________	
Prepared by________________				Page_____of_______	
Method(s) used:	Informal Conferencing	Checklist Review	ETBA	Other_______________	
Hazardous Event	**Causal Factors**	**System Effects**	**RAC**	**Comments**	

Risk Categorization		
Category	**Facility Type**	**Safety Data Required**
Low (low user involvement)	Housing, warehouses, administrative buildings	User-prepared PHL only; checklists may be used
Medium (moderate user involvement)	Maintenance facilities, heating plants, photo labs	User-prepared PHL, usually designer prepared PHA; other analyses may be required
High (heavy user involvement)	Explosive plants, chemical agent facilities, high energy facilities	User-prepared PHL, usually designer prepared PHA; other analyses prepared by designer may be required

Figure 2 and 3. PHL and Risk Categorization Charts

FMEA

FMEA, also known as Failure Modes and Effect Analysis is most commonly used for system and subsystem hazard analyses. FMEA was originally a tool created by SAE reliability engineers. This process analyzes potential effects caused by system elements ceasing to behave as intended. FMEA can not be done until the design process has proceeded to the point that the system elements have been selected at the level that the analysis is to explore.

Typically, FMEA is done in conjunction with or soon after the PHA. However it can be done anytime during the systems lifetime. Some principle limitations associated with FMEA are that there is a tendency to have human errors, and hostile environments are frequently overlooked. Sometimes faults of the system and effects of coexisting failures are not considered. If the system is complex enough the process can be tedious and time consuming as well.

Many times FMEA is done simply to satisfy the urge to need to “Do Safety”. However there are some benefits of using FMEA. The benefits include being able to discover potential single-point failures, and assesses risk for potential single-element failures.

Definitions associated with FMEA are:

> Fault: The inability to function in a desired manner, or operates in an undesired manner, regardless of cause.
>
> Failure: A fault due to breakage, wear out, compromise structural integrity, etc.

Failure Mode: The mode in which a fault occurs

So you may ask what is the use in knowing all this stuff about FMEA?

This will help you:

1. Optimize reliability
2. Guide design evaluation and improvement
3. Guide design of system to "fail safe" or crash softly
4. Guide design of system to operate satisfactorily using equipment of "low" reliability
5. Guide component/manufacturer selection

	Failure Mode and Effects Analysis					
System____________				Page____ of _____ Pages		
Subsystem_________				Date______________		
				Analyst____________		
Component Description	**Failure Mode**	**Effects on Other Components**	**Effects on System**	**RAC or Hazard Category**	**Failure Frequency Effects Probability**	**Remarks**

Figure 4. Failure Mode and Effects Analysis Chart

FTA

The Fault Tree Analysis (FTA) was developed by Bell Telephone Laboratories for the U.S. Air Force in 1962 and has been used as one of the primary system safety techniques since the system safety effort began. The FTA is a detailed way of determining where a failure will take place.

There are two different ways to look at the FTA. The first approach is the qualitative approach. The seconded way is by the quantitative approach. The FTA is considered one of the most reliable and meaningful system safety techniques used and available when we are looking at reducing an undesired event. The negative aspect of this technique is that it is a bit more pricey because it requires a skilled annalist and a large amount of time. The benefits of using this system however is that it provides quality data and can make the system being tested more reliable once the analysis is complete.

The purpose of FTA is to find where the failure will occur and fix it before if happens. You could say that using the FTA analysis is a preventative measure. Major input requirements for the FTA is the main event. In order to chose this “main event’ you must have data and history to back up your decision to test the problem at hand. A helpful tool in choosing what you want to do the FTA on is by looking at past hazard analysis if there are available. Lets look at the general approach to get started.

1. Determine the nature of the failure to be analyzed
2. Have a full understanding of the problem that you have selected for number one
3. Look at the three particular types of component failures
4. The three component failures are: primary failures, secondary failures, command failures
5. After the three failures have been selected you are ready to put the information into the FTA

6. Next prepare the FTA

7. Construct the tree by using the following construction steps

    a. Define the top event

    b. Know the system

    c. Construct the tree

    d. Use the below described symbols to build the tree

    e. Validate the tree

    f. Evaluate the tree

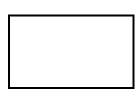
    g. Study tradeoffs

    h. Consider alternatives and recommend action

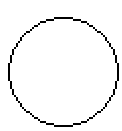
8. Once you have set up the tree evaluate it and make your conclusions based on the data being presented.

Event Symbols

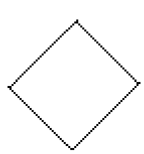
General Event – The primary building block for the FTA. (Stephenson, 2000, p. 168)



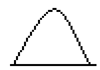
Basic Event – The symbol used for the bottom tier of the tree to indicate development is complete. (Stephenson, 2000, p. 168)



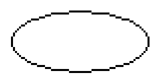
Undeveloped Terminal Event – The symbol used for events that could be further developed but are not because of lack of information, time, or interest. (Stephenson, 2000, p. 168)



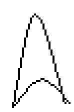
And-Gate – All inputs are required to generate output event. (Stephenson, 2000, p. 168)



Or-Gate – Only one or any combination of inputs is required to generate output event. (Stephenson, 2000, p. 168)



Constraint - Symbol used as a footnote or caveat or used to modify the meaning of a gate or event. (Stephenson, 2000, p. 168)



ETBA

Energy Trace and Barrier Analysis is a relatively new technique. It is based on some of the same principles as MORT. Some important questions to ask yourself before performing an ETBA is, what is the purpose of the analyzation?

1. Used to aiding in preparing preliminary hazard lists. (PHL)
2. Used to conduct preliminary hazard analyses. (PHA)
3. Used to conduct subsystem hazard analyses. (SSHA)
4. Finally it can be used to conduct system hazard analyses (SHA)

ETBA’s are helpful in performing operating hazard analysis (OHA’s) and accident analyses. They are also helpful in many other situations.

So how do you set up an ETBA? Here is the general approach.

1. Identify the types of energy associated with the project
2. For each energy type, locate the point(s) at which the energy enters or originates
3. Trace the energy flow or energy path throughout the project
4. Determine the risk associated with each potential unwanted energy flow
5. Express the risk in terms of a risk assessment code (RAC)
6. Recommend controls for unacceptable risks and for improving the overall safety of the project
7. Lastly if needed recommend systems or subsystems for further analysis

After collecting this information the you need to do the following:

1. Input the documents and reference resources
2. Include applicable codes
3. Standards and regulations
4. List of consultants
5. Lessons learned information
6. Examples of ETBA’s on similar projects
7. Other analyses and/or a PHL on this project

8. Other materials that may aid in the ETBA effort.

After all of this information is collected you will need to put it into ETBA Chart.

	Energy Trace And Barrier Analysis						
Project_____________________				Date______________			
Prepared by_________________				Page_____of_______			
Energy type_________________							
Drawing number (s)___________							
Energy Quantity & Location	**Barriers**	**Targets**	**RAC**	**Comments /Barrier Evaluation**	**Recommended Actions**	**Controlled RAC**	**Standards**

Figure 5. Energy Trace and Barrier Analysis Chart

What information goes where into the chart?

1. *Column 1. Describes the nature of the energy*
2. *Column 2. Describes all physical and procedural (if known) barriers in place at the indicated location to control or restrict any unwanted energy flow.*
3. *Column 3. List the persons or objects at the particular location that could be in the path of an unwanted energy flow.*
4. *Column 4. Enter the risk assessment code associated with this particular unwanted energy flow.*
5. *Column 5. Provide comments on the adequacy of the existing barriers to control potential unwanted energy flows at that particular location.*
6. *Column 6. Recommend steps to be taken to improve the safety of the project at this particular location.*

7. *Column 7. Enter the risk assessment code after the actions recommended in column 6 have been taken.*
8. *Column 8. Use this column to list any applicable codes, standards, or regulations.* (Stephenson, 2000, p. 150-151)

<u>MORT</u>

The MORT system is used by the TAC's ground safety community and the U.S. Air Force mainly. This is a very useful tool in accident investigations as well. However it is very complex with over 1,500 different events and multiple transfers to chose from. It tends to be overkill for some uses. Because MORT is so complex it is was essential that a new approach be devised. That is how PET (Project Evaluation Tree) was developed.

<u>PET</u>

Project Evaluation Tree otherwise known as PET was introduced in 1989. It was first introduced to NASA's general occupational safety community at the National Safety Congress in Chicago. It was also introduced to: Safety engineering students and the University of Houston as well as the U.S. Army Corps of Engineers at a conference in Bethesda.

PET can be described as an analytical tree to be used primarily as a graphic check in basically the same manner as a management oversight and risk tree. PET is very simple compared to MORT's 1,500 symbols and transfers. It consists of less than 200 symbols and no transfers. This makes it much more user friendly. The purpose of PET is to provide a relatively simple, straightforward, and efficient method of performing an in-depth evaluation or analysis of a project or operation.

The PET system is divided into three basic branches.

1. Procedures
2. Personnel
3. Plant and Hardware

There are some impute requirements needed for PET to work properly. They are, detailed information on the procedures, personnel, and facilities and hardware to be evaluated. The next needed information is, upstream documents requiring the procedures and outlining the protocol for the generation, review, distribution, and updating are also required. So you may ask what things are needed to evaluate facilities and hardware? (This is just a few, do not assume that this is a complete list)

1. Drawings
2. Procurement documents
3. Specifications
4. Test plans and records
5. System safety plans and records
6. Hazard analyses
7. Budget data

Note 1: The scope and depth of the analysis dictate the need for input data.

Note 2: The quality of the input data greatly influences the quality of the analysis.

In order to approach your newly collected data you must identify each procedure, individual and/or organization, facility, an dpiece of equipment or hardware to be analyzed and then systematically use the appropriate branch of the PET tree.

PET Analysis Worksheet							
Prepared by:_______ Office Symbol:______ Date:_____________			Purpose:__________ Operational Readiness________ Mission Failure______________			Change Analysis_____________ Accident Investigation_________ Inspection/Evaluation__________	
Item no.	**Item Evaluated**	**PET Event**	**Color**	**Problem /Comments**	**Responsible Person/Agency**	**Status**	**Final Completion Date**

Figure 6. PET Analysis Worksheet

What you should be able to evaluate after you have completed the chart.

1. Maintenance
2. Inspection
3. Operation for the facility
4. Hardware being designed

Where you should begin?

1. Define the scope of the analysis and the ground rules
2. Collect the appropriate input data

3. Organize the data into procedures, personnel, and facilities/hardware
4. Systematically evaluate they system or project using the PET users

Here are some questions that you should ask.

Note1. This is not a comprehinse set of questions; therefor you must tailor your questions to your specific project.

1. Procedures	10. Mission Ready
2. Contents	11. Assignment
3. Criteria	12. Facilities/Hardware
4. Validated	13. Design
5. Current	14. Construction
6. Used	15. Testing
7. Updated Provisions	16. Inspection
8. Personnel	17. Maintenance
9. Authorized	18. Change Control

CHANGE ANALYSIS

Change can be a positive factor that improves, effectiveness, efficiency, and/or safety of an organization. It is critical to have change and can sometimes be a wonderful addition to a system that is already good. There is one problem with change, typically change is almost always an causal factor in accidents, many times a very significant causal factor!

Change Analysis is associated with the Department of Energy's management oversight and risk tree (MORT) approach to system safety. The best part of change analysis is that it is very simple, straightforward, and extremely easy to learn and apply. It is also a great analysis because it is very quick and efficient. The most important value of using change analysis is that it is helpful in identifying obscure and direct causes. So where can we use change analysis? We can use this process anywhere a technique for evaluating changes and determining the need for counterchanges to keep the system in balance are needed. In using the change analysis it is easy to determine the significance or impact of the changes made.

This is also a very effective prevention tool. It provides an excellent method for conducting reviews. It should be performed as part of the review process at each review point in the system safety effort.

In order to use the change analysis it requires a detailed understanding of the system before and after the changes are made. You will also need to have a good understanding of the project and its description documents. You will need to know what is in the description documents so we have provided a non-collective list for the reader to view.

1. Analytical Trees
2. Narrative Descriptions
3. Block Diagram
4. Blueprints
5. Organization Structures
6. Job Descriptions
7. Personnel Qualifications

So you as the reader may ask what is the general approach and what are the steps. For the general approach you can follow these guidelines. All changes (that is, the differences between the present situation and the comparable situation) are systematically listed. Next comes the instructions.

1. Determine the two situations to be compared
2. A comparable situation is to compare the accident situation with a similar accident-free operation
3. Compare the accident situation with an idealized situation

Note1: The selection of an appropriate comparable situation is probably the most difficult step in performing a change analysis, but this step is quite simple if the change analysis is part of the review of the proposed changes.

Once you have completed selecting the comparable situation you should:

1. Collect sufficient information about the situation
2. Carefully list all the differences between the proposed and appropriate comparable situation
3. After all the changes have been listed evaluate and analyze each of them
4. Note each change
5. It is recommended to put into place, controls and countercontrols
6. Provide a summary of significant changes

COMMON CAUSE ANALYSIS FAILURE

The common cause analysis or otherwise known as common cause failure is usually used to evaluate many failures that may have been caused by one singe event, or it can be used to determine weather there was more than one component that lead to the event.

“Common cause failures can be a shred environment or locations” (Stephenson, 2000, p. 264). If redundant systems are relied on you must have reliable elements. These elements must not be subjected to having a single event or common causal factor.

When approaching commons cause failure analysis it is imperative to identify the critical systems or components. Once you have completed this step you can place the information into the energy trace barrier analysis (ETBA) to evaluate the system’s weak spots, unwanted energy flows, and barrier failures. As a back up to this analization we can also use the project evaluation tree (PET). This lets us evaluate an analyze common operating and maintenance procedures.

CONCLUSION

In conclusion our safety efforts are never complete. We must always have proactive mind set and continue the amazing advances in our safety world. We must never allow blood priority to take precedence over our prior knowledge and always be positive and open to new ideas.

DEFINITIONS:

All definitions were taken from this source, (Stephenson, 2000, p. 191-301)

AASE: American Society of Safety Engineers Dictionary of Terms Used in the Safety Profession

SSDC: System Safety Development Center Glossary of SSDC Terms and Acronyms

AFR 800-16: U.S. Air Force Regulation 800-16, USAF System Safety Programs (USAF)

MIL-STD-882: Military Standard 882B, System Safety Program Requirements (DOD)

NSTS 22245: National Space Transportation System, Methodology for Conduct of NSTS Hazard Analyses (NASA)

Acceptable Risk: The residual risk remaining after controls have been applied to associated hazards that have been identified, quantified to the maximum extent practicable, analyzed, communicated to the proper level of management and accepted after proper evaluation (SSDC).

Accident: An unwanted transfer of energy or an environmental condition which, due to the absence or failure of barriers and/or controls, produces injury to persons, property, or process (SSDC); as defined in NHB 5300.41 (1D-2), "An unplanned event which results in an unsafe situation or operational mode" (NSTS 22254); an unplanned and sometimes injurious or damaging even which interrupts the normal progress of an activity and is invariably preceded by an unsafe act or unsafe condition or some combination thereof. An accident may be seen as resulting from a failure to identify a hazard or from some inadequacy in an existing system of hazard controls (ASSE).

Assumed Risk: A specific, analyzed residual risk accepted at an appropriate level of management. Ideally, the risk has had analysis of alternatives for increasing control and evaluation of significance of consequences (SSDC).

Barrier: Anything used to control, prevent, or impede energy flows. Types of barriers include physical, equipment design, warning devices, procedures and work processes, knowledge and skills, and supervision. Barriers may be used to control or safety barriers or act as both (SSDC).

Component: As defined in NHB 5300.41 (ID-2), “A combination of parts, devices, and structures, usually self-contained, which performs a distinctive function in the operation of the overall equipment. A ‘black box’ (NSTS)

Contractor: A private sector enterprise or the organizational element of DoD or any other Government agency engaged to provide services or products within agreed limits specified by the MA (MIL-STD 882B)
Corrective Action: As defined in NHB 5300.41 (1D-2), “Action taken to preclude occurrence of an identified hazard or to prevent recurrence of a problem” (NSTS 22254).

Critical Item: A single failure point and/or a redundant element in a life-or mission-essential application where:

1. Redundant elements cannot be checked out during the normal ground turnaround sequence
2. Loss of a redundant element is not readily detectable in flight
3. All redundant elements can be lost by a single credible cause or event such as contamination or explosion

Critical Items List (CIL): A listing comprised of all critical items identified as a result of performing the FMEA (NSTS 22254).

Criticality: The categorization of a hardware item by the worst case potential direct effect of failure of that item. In assigning hardware criticality, the availability of redundancy modes of operation is considered. Assignment of functional criticality, however, assumes the loss of all redundant hardware elements (NSTS 22254).

Damage: The partial or total loss of hardware caused by component failure: exposure of hardware to heat, fire, or other environments; human errors; or other inadvertent events or conditions (MIL-STD-882B).

Failure: As defined in NHB 5300.41 (1D-2), “The inability of a system, subsystem, component, or part to perform its required function within specified limits, under specified conditions for a specified duration” (NSTS 22254).

Failure Modes and Effect Analysis (FMEA): A systematic, methodical analysis performed to identify and document all identifiable failure modes at a prescribed level and to specify the resultant effect of the failure mode at various levels of assembly (NSTS 22254); the failure of malfunction of each system component is identified, along with the mode of failure (e.g., switch jammed in the “on” position). The effects of the failure are traced through the system and the ultimate effect on task performance is evaluated. Also called failure mode and effect critically analysis (ASSE); a basic system safety technique wherein the kinds of failures that might occur and their effect on a system by the failure of a single component, such as a register or a hydraulic valve (SSDC).

Fault Tree: An analytical tree used to determine fault. These may be used in accident/incident investigation or to determine accident potential before one has occurred. (SSDC)

Hazard: A condition that is prerequisite to a mishap (MIL-STD-882B); a condition or changing set of circumstances that presents a potential for injury, illness, or property damage. The potential or inherent characteristics of an activity, condition, or circumstance which can produce adverse or harmful consequences (ASSE); a condition that is prerequisite to a mishap (DODI 50000.36) (AFR 800-16); the presence of a potential risk situation caused by an unsafe act or condition (NSTS 22254); the potential for energy flow(s) to result in an accident or otherwise adverse consequence (SSDC).

Hazard Analysis: The functions, steps, and criteria for design and plan of work, which identify hazards, provide measures to reduce the probability and severity potentials, identify residual risks, and provide alternative methods of further control (SSDC); a process of examining a system, design, or operation to discover inherent hazards, characterizing them as to level of risk and identifying risk-reduction alternatives (AFR 800-16); 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 (NSTS 22254).

Hazard Analysis Techniques: Methods used to identify and evaluate hazards. These techniques cover the complete spectrum from qualitative preliminary hazard studies to system logic diagrams containing quantitative probabilities of mishap (AFR 800-16)

Hazard Levels: The hazard level assigned to the identified hazard prior to applying the hazard reduction precedence sequence (HRPS) corrective action. Include hazard carried over for tracing from previous phases:

1. Catastrophic – No time or means are available for corrective action
2. Critical – May be counteracted by emergency action performed in a timely manner
3. Controlled – Has been countered by appropriate design, safety devices, alarm/caution and warning devices, or special automatic/manual procedures.

Hazardous Event: An occurrence that creates a hazard (MIL-STD-882B)

Hazardous Event Probability: The likelihood, expressed in quantitative or qualitative terms, that a hazardous event will occur (MIL-STD-882B)

Hazard Probability: The aggregate probability of occurrence of the individual hazardous events that create a specific hazard (MIL-STD-882B)

Hazard Report Closure Classification:

1. Eliminated Hazard – A hazard that has been eliminated by removing the hazard source or by deleting the hazardous operations
2. Controlled Hazard – The likelihood of occurrence has been reduced to an acceptable level by implementing the appropriate hazard reduction precedence sequence to comply with program requirements
3. Accepted Risk – Hazard which has not been counteracted by redundancy, purge provisions, appropriate safety factors, containment/isolation provision, backup system/operation, safety devices, alarm/caution and warning devices, or special automatic/manual procedures. Catastrophic hazards, critical hazards, hazards resulting from failure to meet program requirements, and Single Failure Points (SFPs) in emergency systems will be documented. A hazard will be classified as an "accepted risk" only after
    a. all reasonable risk avoidance measures have been identified, studied and documented
    b. project/program management has made a decision to accept the risk on the basis of documented risk acceptance rationale
    c. safety management has concurred in the accepted risk rational (NSTS 22254)

Hazard Report Status

1. Closed – Corrective action to eliminate or control the hazard is completed, evaluated, and verified and management actions to accept the safety risks are completed. Actions taken, organizations which performed actions and completion dates are to be documented in this data element
2. Open – Corrective action evaluation and verification is in progress. The status shall remain open until management has reviewed the actions taken and accepted the safety risk. Actions required, organization documented in this data element (NSTS 22254).

Hazard Severity: An assessment of the worst credible mishap that could be caused by a specific hazard (MIL-STD-882B).

Human Factors; Human Factors Engineering: The application of the human biological and psychological sciences in conjunction with the engineering sciences to achieve the optimum mutual adjustment of man and his work, the benefits being measured in terms of human efficiency and well being. The principle disciplines involved are anthropometry, physiology, and engineering (SSDC).

Implementing Command: The command or agency designated by HQ USAF to manage an acquisition program (AFR 800-2); AFR 800-4 includes modification programs (AFR 800-16)

Loss Of Personal Capability: As defined in NHB 5300.41(1D-2); "Loss of personnel function resulting in inability to perform normal or emergency operations. Also includes loss or injury to the public" (NSTS 22254).
Loss Of Vehicle System: As defined in NHB 5300.41(1D-2), "Loss of the capability to provide the level of system performance required for normal or emergency operations" (NSTS 22254).

Management Oversight and Risk Tree (MORT): A formal, disciplined logic or decision tree to relate and integrate a wide variety of safety concepts systematically. As an accident analysis technique, it focuses on three main concerns: specific oversights and omissions, assumed risks, and general management system weakness (SSDC).

Managing Activity: The organizational element of DoD assigned acquisition management responsibility for the system, or prime or associate contractors or subcontractors who wish to impose system safety tasks on the suppliers (MIL-STD 882B).

Mishap: An unplanned event or series of events that results in death, injury, occupational illness, or damage to or loss of equipment or property (MIL-STD-882B); an unplanned event or series of events that result in death, injury, occupational illness, or damage to or loss of equipment or property, or damage to the environment. (DODI 5000.36) (AFR 800-16); a synonym for accident. Used by some government organizations, including NASA and DOD (SSDC).

Mission Events: Time-oriented flight operations defined in flight checklists (NSTS 22254).

Near Miss: An incident or an accident resulting in minor consequences although the potential for serious consequences was high (SSDC).

Off The Shelf Item: An item determined by a material acquisition decision process review (DoD, Military Component, or subordinate organization as appropriate) to be available for acquisition to satisfy an approved material requirement with no expenditure of funds for development, modification, or improvement (e.g., commercial products, material developed by other Government agencies, or materiel developed by other countries). This item may be produced by the contractor or furnished to the contractor as Government-furnished equipment (GFE) or Government-furnished property (GFP) (MIL-STD-882B).

Operating And Support Hazard Analysis (O&SHA): As described in NHB 1700.1 (V1-A) and this document. The PHA is to identify safety-critical areas, to identify and evaluate hazards, and to identify the safety design and operation requirements need in the program concept phase (NSTS 22254).

Preliminary Hazard Analysis (PHA): As described in NHB 1700.1 (V1-A) and this document. The PHA is to identify safety-critical areas, to identify and evaluate hazards, and to identify the safety design and operation requirements needed in the program concept phase (NSTS 22254).

Program Manager: The single Air Force manager (system program director, program or project manager, or system, system program, or item manager) during any specific phase of acquisition life cycle (AFR 800-2) (AFR 800-16).

Quantified Safety Requirements: A desired, predictable, and demonstrable level of safety, usually expressed as a mishap rate or probability of mishap (AFR 800-16).

Residual Risk: Risk remaining after the application of resources for prevention or mitigation (SSDC).

Risk: Mathematically, expected loss; the probability of an accident multiplied by the quantified consequence of the accident (SSDC); an expression of the possibility of a mishap in terms of hazard severity and hazard probability (MIL-STD 882B); note: Hazard exposure is sometimes included (AFR 800-16) as defined in NHB 5300.4 (1D-2), "The chance (qualitative) of loss of personnel capability, loss of system, or damage to or loss of equipment or property" (NSTS 22254); a measure of both the probability and the consequence of all hazards of an activity or condition. A subjective evaluation of relative failure potential. In insurance, a person or thing insured (ASSE).

Risk Acceptance: The acceptance by an individual or organization of a level or degree of risk which has been identified as the potential consequence of a given course of action (ASSE).

Risk Analysis: The quantification of the degree of risk (SSDC).

Risk Assessment: The combined functions of risk analysis and evaluation (SSDC).

Risk Assessment: The amount or degree of potential danger perceived by a given individual when determining a course of action to accomplish a given task (ASSE).

Risk Evaluation: The appraisal of the significance or consequences of a given quantitative measure of risk (SSDC).

Risk Management: The process, derived though system safety principles, whereby management decisions are made concerning control and minimization of hazards of residual risks (SSDC); the professional assessment of all loss potentials in an organizations' structure and operations, leading to the establishment and the administration of a comprehensive loss control program. Related to and dependent upon an ongoing program of accident prevention, risk management encompasses the selection of purchased insurance, self-insurance, and assumed risk. Its goal is to reduce losses to an acceptable minimum at the lowest possible cost (ASSE).

Risk Visibility: The documentation of a risk related to hardware, operations, procedures, software, and environment that provides Safety, project offices, and program management with the ability to evaluate accepted risks associated with planned operations (NSTS 22254).

Safe: A condition wherein risks are as low as practicable and present no significant residual risk (SSDC).

Safety: The control of accidental loss and injury (SSDC); freedom from those conditions that can cause death, injury, occupational illness, or damage to or loss of equipment or property (MIL-STD-882B); a general term denoting an acceptable level of risk of, relative freedom from, and low probability of harm (ASSE); as defined in NHB 5300.4 (1D-2), "Freedom from chance of injury or loss of personnel, equipment or property" (NSTS 22254).

Safety Analysis: A systematic and orderly process for the acquisition and evaluation of specific information pertaining to the safety of an system (NSTS 22254).

Safety Analysis (Hazard Analysis): The entire complex of safety (hazard) analysis methods and techniques ranging from relatively informal job and task safety analyses to large complex safety analysis studies and reports (SSDC).

Safety Analysis Report (SAR): A document prepared to document the results of hazard analysis performed on a system, subsystem or operation. The specific minimum data elements for an SAE will be defined by data deliverable requirements for the program or project (NSTS 22254).

Safety Critical: As defined in NHB 5300.4(1D-2), "Facility, support, test, and flight systems containing:

1. Pressurized vessels, lines, and components
2. Propellants, including cryogenics
3. Hydraulics and pneumatics

4. High voltages
5. Radiation sources
6. Ordnance and explosive devices or devices used for ordnance and explosive checkout
7. Flammable, toxic, cryogenic, or reactive elements or compounds
8. High temperatures
9. Electrical equipment that operates in the area where flammable fluids or solids are located
10. Equipment used for handling program hardware
11. Equipment used for personnel walking and work platforms" (NSTS 22254).

Safety-Critical Computer Software Components: Those computer software components (processes, functions, values or computer program state) whose errors (inadvertent or unauthorized occurrence, failure to occur when required, occurrence out of sequence, occurrence in combination with other functions, or erroneous value) can result in a potential hazard, or loss of predictability or control of a system (MIL-STD 882B).

Single Failure Point: As defined in NHB 5300.4 (1D-2), "A single item of hardware, the failure of which would lead directly to loss of life, vehicle or mission. Where safety consideration dictates that an abort be initiated when a redundant item fails, that element is also considered a single failure point" (NSTS 22254).

Space Transportation System: An integrated system consisting of the Space Shuttle (Orbiter, External Tank (ET), Solid Rocket Booster (SRB), and flight kits)), upper stages, Spacelab, and any associated flight hardware and software (NSTS 22254).

Subsystem: An element of a system that, in itself, may constitute a system (MIL-STD-882B).
Subsystem Hazard Analysis (SSHA): As described in NHB 1700.1(V1-A) and this document. The SSHA is to identify hazards to personnel, vehicle and other systems caused by loss of function, energy source, hardware failures, personnel action or inaction, software deficiencies, interactions of components within the subsystem, inherent design characteristics such as sharp edges, and incompatible materials, and environmental conditions such as radiation and sand (NSTS 22254).

Supporting Command: The command assigned responsibility for providing logistics support; it assumes program management responsibility for the implementing command (AFR 880-2) (AFR 800-16).

System: A composite, at any level of complexity, of personnel, procedures, materials, tools, equipment, facilities, and software, The elements of this composite entity are used together in the intended operational or support environment to perform a given task or achieve a specific production, support, or mission requirement (MIL-STD-882B); a set of arrangement of components so related or connected as to form a unity or organic whole. A set of facts, principles, rules, etc., classified or arranged in a regular, orderly form so as to show a logical plan linking the various parts. A method, plan, or classification. An orderly arrangement of interdependent activities and related procedures which implements and facilitates the performance of a major activity or organization. A set of components, humans or machines or both, which has certain functions and acts and interacts, one in relation to another, to perform some task or tasks in a particular environment or environments. Any configuration of elements in which the behavior properties of the whole are functions of both the nature of the elements and the manner in which they are combined (ASSE).

System Analysis (Safety Analysis): The formal analysis of a system and the interrelationships among its various parts (including plant and hardware, policies and procedures, and personnel) to determine the real and potential hazards within the systems, and suggest ways to reduce and control those hazards (SSDC).

System Hazard Analysis (SHA): As described in NHB 1700.1 (V1-A) and this document. The SHA is identical to the SSHA but at the system level. Once the subsystem levels have been established, a combination of subsystems comprise a system. In turn, a group of systems may comprise another system until the top system is identified (NSTS 22254).

System Safety: The application of engineering and management principles, criteria, and techniques to optimize safety within the constraints of operation effectiveness, time, and cost throughout all phases of the system life cycle (DODI 5000.36) (AFR 800-16); an approach to accident prevention which involves the detection of deficiencies in system components which have an accident potential (ASSE); as defined in NHB 5300.4 (1D-2), “The optimum degree of risk management within the constrains of operation effectiveness, time and cost attained thought the application of management and engineering principled throughout all phases of a program (NSTS 22254); safety analysis (usually specialized and sophisticated) applied as an adjunct to design of an engineered system. While many associate system safety primarily with the hardware portion of the system, it includes all aspects of configuration control (SSDC).

System Safety Analysis: The safety analysis of a complex process or system by means of a diagram or model that provides a comprehensive view of the process, including its principal elements and the ways in which they interrelate (ASSE).

System Safety Engineer: An engineer who is qualified by training and/or experience to perform system safety engineering tasks (MIL-STD-882B).

System Safety Engineering: An engineering discipline requiring specialized professional knowledge and skills in applying scientific and engineering principles, criteria, and techniques to identify and eliminate hazards, or reduce the risk associated with hazards (MIL-STD-882B).

System Safety Group/Working Group: A formally chartered group of persons, representing organizations associated with the system acquisition program, organized to assist the MA system program manager in achieving the system safety objectives. Regulations of the Military Components define requirements, responsibilities, and memberships (MIL-STD-882B).

System Safety Management: An element of management that defines the system safety program requirements and ensures the planning, implementation and accomplishments of system safety tasks and activities consistent with the overall program requirements (MIL-STD-882B).

System Safety Manager: A person responsible to program management for setting up and managing the system safety program (MIL-STD-882B).

System Safety Program: The combined tasks and activities of system safety management and system safety engineering that enhance operational effectiveness by satisfying the system safety requirements in a timely, cost-effective manner throughout all phases of the system life cycle (MIL-STD-882B).

System Safety Program Plan: A description of the planned methods to be used by the contractor to implement the tailored requirements of this standard, including organizational responsibilities, resources, methods of accomplishment, milestones, depth of effort, and integration with other program engineering and management activities and related systems (MIL-STD-882B).

User: Identified and authorized NASA, element contractor, or integration contractor personnel; flight crew equipment annalist; Orbiter experiments analyst; payload accommodations analyst; detailed secondary objective annalist; or RMS analyst (not inclusive) that have necessary access to the intercenter hazard data base system (NSTS 2254)

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FIGURE REFERANCES

Figure 1:	Stephenson, 2000, p. 11
Figure 2:	Stephenson, 2000, p. 70
Figure 3:	Stephenson, 2000, p. 70
Figure 4:	Stephenson, 2000, p. 156
Figure 5:	Stephenson, 2000, p. 150
Figure 6	Stephenson, 2000, p. 196