Guide 2

ACCIDENT INVESTIGATION

This Book was originally created in 1996-97 to provide basic accident and incident investigation knowledge, skills and practices for investigation programs, as a supplement to a training film on the topic. It is out of print, and no longer available from the publishers or Emergency Film Group. It is the second of four such guides created by and containing material copyrighted by Ludwig Benner Jr.

It is posted here for reference by accident investigators who are interested in improving their accident investigation knowledge and skills by exploring and applying alternative methods for investigations and investigation quality assurance processes

Guide 2

ACCIDENT INVESTIGATION

To complement the Emergency Film Group's
Accident Investigation video

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Published By
Fire Protection Publications
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FPP

ISBN 0-87939-141-3
Library of Congress 97-60614
First Edition
First Printing, April 1997

Printed in the United States of America

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PREFACE

Guide 2, **Accident Investigation**, is the second in a series of four investigation guides. It emphasizes the investigation of vehicle mishaps, equipment failures, and occupational injury, death, and illness. It complements the Emergency Film Group's **Accident Investigation** video, produced in cooperation with IFSTA. Guide 2 highlights and supplements the information found in the video.

Other guides and videos in the Emergency Film Group's series include:

Introduction to Investigation covers the basic investigation process and general investigation procedures.

Hazmat Investigation covers investigations of hazardous materials incidents, spills, leaks, and explosions.

Fire Investigation covers comprehensive investigations of fires.

These videos and guides are available from IFSTA.

INTRODUCTION TO ACCIDENT INVESTIGATION

Everyone "knows" intuitively how to "investigate" something. People "investigate" events every day to try to understand what happened by using whatever personal "investigation" techniques they happen to know. This is how they learn from their experiences. They do the best they can with what they have. Most of the time they are the only ones affected by the results of their investigations.

When someone has to conduct investigations that may affect others, more is required. For those investigations, investigators need to use methods and techniques that produce objective, valid, complete, and consistent investigation work products. They should base their investigations on *investigation* knowledge, skills, and tools designed from the ground up for *investigations*. Borrowed investigation tools are not as productive.

The series of Emergency Film Group's investigation films and this guide are designed to help you conduct efficient and effective investigations. The ideas and methods provided in this Guide reflect over 20 years of research into investigations and successful application of findings during accident investigations of all kinds — from smashed fingers to team investigations of nationally important accidents. This Guide complements the Emergency Film Group's **Accident Investigation** video, which is the first of four in their series on investigations.

Guide 2 gives investigators a basic understanding of the essential investigation knowledge, methods, and tools needed to produce good accident investigations — efficiently and quickly. Investigators can gain this understanding with modest effort. If you are an experienced investigator, the guidance should help you do your best possible investigations. Additional detailed guidance for all investigators can be found in the references.

You can use this guidance to do any level of investigations efficiently and consistently. During Level 1 investigations, the focus is on gathering data to fill in forms created by someone else. Level 2 investigations develop a description of what occurred. Level 3 investigations develop a description and explanation of what happened. Level 4 investigations develop descriptions and explanations and use them to identify, define, and assess problems and propose performance improvement recommendations.

WHO SHOULD USE THIS GUIDE?

- *Accident investigators and fire officers* can use this Guide to prepare for accident investigations, check off tasks to do during their investigations, and check the quality of their work.
- *Industry safety personnel* can use this Guide to help them prepare for and do accident investigations.
- *Supervisors of accident investigations* can use this Guide to help them complete specific investigations on budget and on schedule and to control testing expenses.
- *Managers* responsible for establishing accident investigation programs can use this Guide to design and establish an investigation program and to judge its quality and value over time.
- *Training* or *seminar leaders* can use this Guide to help trainees build their general accident investigation knowledge and skills.
- *Data analysts* can use this Guide to help them analyze episodic accident reports and other information from which they wish to identify problems disclosed by others' experience.
- *Expert accident investigators* can use this Guide to improve their efficiency and effectiveness and to evaluate their own performance.
- *Designers* can use the Guide to identify kinds of problems they need to address when designing their products.
- *Regulatory agency investigators* and *codes/standards technical representatives* can use this Guide to investigate the effectiveness of their regulations or codes or standards scheme.

CHAPTER 1
GENERAL PREPARATIONS FOR INVESTIGATIONS

The investigator's preparations for the required tasks determine what is done during an investigation. Those preparations include how they and others think about "accidents" and what they are asked to do, as well as what they know how to do and how well they do it. The following section describes the preparations required before good investigation thinking can produce good investigation results.

INVESTIGATOR PREPARATIONS

As an investigator, your basic preparations for investigations include a working knowledge of your organization's investigation mission, policies, and objectives. These provide the framework for all that you do during investigations. Then you need to gain an understanding of what exactly you will be investigating and how to do it. You then need to make sure that you have the tools to do the investigations and know how to use those tools as you follow preferred investigation procedures. In your preparations, ensure that you:

- Recognize what an accident or incident is.
- Know your investigation objectives.
- Know your limitations.
- Recognize others' interests.
- Know your investigation process and procedures.
- Prepare the equipment you will need.
- Know work product quality assurance procedures.
- Know sources for help during investigations.
- Know contents of this guide.
- Know what to do if crime is suspected.

Recognize What an Accident or Incident Is

An *accident* is a complex process of interacting events involving people and things that affect each other in unintended ways. The normal flow of events is disrupted, producing a loss instead of the intended outcome. If disruption of events is a deliberate act, a crime may have been committed. We describe what happened during an accident in terms of *who (or what) did what to produce the unintended outcome.* To develop a description of what happened:

- Determine who or what did something to initiate the process.
- Determine who or what did anything to propagate it.
- Determine who or what finally acted to terminate it.

To determine why events occurred, you need to apply additional logic tests to descriptions, and get more data.

Part of your preparations is to decide when an accident process starts and when it ends. Accidents or incidents occur during some activity. An accident or incident begins while the activity is progressing normally when something happens that disturbs it. Elements engaged in the activity are then diverted from their intended outcome to a harm or loss outcome. An accident or incident ends at the time the last loss to the accident process occurs.

Your view of the nature of these occurrences, called an *accident* or *incident*, influences what you look for as you investigate. If you look at them as processes, you will look for interactions among the process components and how they produced the outcome.

Know Your Objectives

Investigation objectives influence the level of investigation that you do. Investigation objectives vary with the intended use of the results. Investigation objectives can be very subjective. The fundamental reason for investigating an accident or incident is always to determine, describe, and explain irrefutably what happened. This description provides the basis for learning which you and others can use to do better in the future.

Investigation Project Objective

Finding out what happened is always more important than assigning blame or fault. A description should include intervention actions by people or objects to influence the process. A valid, complete description of what happened will satisfy many objectives. Therefore, this Guide focuses on helping you develop your descriptions and explanations of what happened. It also helps you develop performance improvement recommendations for Level 4 investigations.

Investigation Task Objective

You establish task objectives by working with information created before, during, and immediately after the occurrence. You must find the information in people and things after the occurrence. Your overall *investigation task objectives* are to observe, document, organize, and test that information *quickly, efficiently,* and *without bias.* If done well, the investigation process enables you to describe accurately what happened during the occurrence and why it happened — at reasonable cost and in minimal time.

Reporting Objective

Do you know who your "customers" are, what they expect, and how they will use what you deliver (your "deliverables")? Identify all your customers and their reporting *format, scope, content,* and *delivery demands* that you have to satisfy.

- What are the *formats* of your expected deliverables — verbal, completed form(s), written narrative, flowchart, or some other format?
- What is the *scope* of the findings that you are expected to deliver? Are any of your customers looking for your conclusions about causes, root causes, immediate causes, proximate causes, causal factors, probable cause or probable causes, all causes, causal relationships, fault, blame, or findings? If you are to report "cause," blame, or fault, what are the criteria for selecting one or more such opinions? How should you handle any unrelated deficiencies you observe? Should you report problems or needs and propose recommendations?
- Should the *content* include a summary only or a complete description of what happened or some combination of the two? How can you best serve the needs of anyone who must act on the information you provide? To what degree should you report the rationale and trade-offs supporting any recommendations? Should the content be only factual, or are you expected to offer your opinions and beliefs?

Also determine the degree of detail to which you are to report losses or harm. For example, do your reporting objectives include:

- A description of all injuries and why they occurred or just categories of injuries and why they occurred
- A full or partial injury or loss distribution map
- Discussion of regulatory prevention or loss-limiting shortcomings
- Emergency response analysis and critique

The time to settle these points is before rather than after you submit your report.

Investigation Scope

It is important that you establish the expected level of investigation and the scope of your investigation tasks before you start each investigation. The scope of investigations involves numerous choices. For example, should you:

- Develop only a description of what happened, or are you also expected to develop explanations and performance improvement recommendations?
- Investigate only what actually happened, or should you also investigate hazards that you find but that had no direct role in the occurrence?
- Investigate only the direct interactions of people and objects involved, or should you also investigate the influence of regulations, standards, or procedures on what happened?
- Look only at what people did during the accident, or should you investigate what they were "programmed" to do?
- Ignore or assess the effectiveness of actions by planned or spontaneous intervenors in the occurrence?

The larger the loss is, the more impact the answers to these questions have on your investigation workload.

Restarting Facility Operation

Quickly restarting or restoring operations may be a significant objective. Should you abbreviate or skip an investigation to permit a vital facility to reopen? Are you expected to determine how to safely restart or reopen the facility, or is that someone else's task? Based on the answer, the scope of your investigation might expand to determine, as quickly as possible, what actions to take to reopen the facility without introducing unreasonable risks and when that can be accomplished. Often these decisions depend on a sufficient understanding of what happened and defining quickly what actions are needed.

Know Your Limitations

You cannot always do everything you want during an investigation because of limitations imposed by others or limitations you impose on yourself. Before you begin a specific investigation, understand any imposed limitations:

- Know how many days or hours you have to do investigations.
- Know where and how you can access expert help.
- When you need help, know what you need to do to receive it.

- Should you skip any investigation tasks?
- Know whether you are expected to take investigation shortcuts, limit interviews, avoid testing, skip quality controls, or limit your descriptions.
- Know what your customers expect you to investigate — all or just parts of the accident process. If parts only, know which parts.
- What work products do you have to deliver when and to whom?
- Know any limitations in content, format, style, size, length, distribution, access, duplication, disclosure, or other limitations.
- Know your customers' basis for judging your work before you prepare it; twenty-twenty hindsight is very common after investigations.
- What personal safety risks do you face?
- Know your safety risk exposures for the types of accidents you investigate.
- What do you do if you suspect any criminal activity may be involved?
- Know whom, when, and where to contact someone to whom you can hand off a criminal case.

During an investigation, remember one very important self-imposed investigation constraint: **DO NO DAMAGE!!**

Manage your own actions to avoid damaging your potential data sources. Resist the temptation to disturb things before you document them, or to test things without a well-conceived test plan. Few problems frustrate investigators faster than learning what they are observing was changed since the incident ended.

Another limitation is your own knowledge of how systems work. Recognize your knowledge limitations and seek help so that you do not miss important data or make premature judgments or unsupported conclusions. To guard against false confidence and failure to work within your own limitations, use a systematic investigation process.

Recognize Others' Interests

It is important that you recognize and are prepared to deal with others' interests in your investigations. Always expect others to act in what they perceive to be their best interests, and you will never be disappointed.

The main point is that as an investigator you have to deal with people who have concerns about what you are doing.

Determination of cause, fault, or blame is at the root of much concern. Any opinions like that in your outputs have the potential to ignite a controversy as interested persons scramble to protect their interests. Be aware of such behavior.

Another group of interested persons to prepare for are witnesses. A willing witness during an investigation is obviously much more helpful than an antagonized, threatened, or intimidated witness. Recognize what people think is in their best interests so that you can use that information to your mutual advantage during interviews.

The media is another interested group for which you will need to prepare. Their interests rarely correspond with your interests

Know Your Investigation Procedures

Over time, you will probably be called on to conduct or participate in different levels of investigations of varying complexity and scope. This means that you will need to become acquainted with and skilled in applying pertinent investigation tools and techniques. Your procedural preparations should enable you to:

- Recognize the beginning and end of the process you want to understand.
- Identify and find data you need during your investigation.
- Transform your observations into documented events.
- Organize those events into their sequential and logical order.
- Identify and record causal relationships among interacting events.
- Create informed hypotheses to fill gaps in your understanding.
- Apply quality-assurance procedures to your work products during the investigation.
- Discover, define, assess, and document problems and needs from your description and explanation of what happened.
- Formulate effective recommendations to improve future performance.
- Produce a satisfactory report of your investigation results.

To maintain proficiency, you should occasionally use your investigation procedures. Practice applying your knowledge and skills — you do not have to wait for accidents to practice. Practice applying your investigation skills whenever you want to

understand something that has happened. Once you become used to using these procedures, you will find more and more opportunities to apply these skills.

Another excellent way to practice is to take reports of past incidents and apply your skills to "flowchart" those incidents. You will find the quality control tasks especially helpful, and you will probably learn more about the incident and the investigations.

Prepare the Equipment You Need

You will need certain equipment on short notice, and you should know how to lay your hands on it when called on to do an investigation. The equipment you need depends on the investigation levels you will do. Many investigators maintain a personal "go-kit" containing all the equipment they may need. In addition to tools customarily carried on your job, you should consider including the following in your "go-kit":

- A bound notepad to keep together any notes you make
- Pens
- Several 3 x 3-inch Post-It™ notepads to capture data in a *working* format
- Extra batteries and at least three extra rolls of 36-exposure fast (400) color film to document the scene and other points you want to illustrate
- A small handheld tape recorder (with extra tapes and batteries) to capture interviews and also to keep your oral notes and reminders
- This Guide as a reminder checklist and "how-to" resource

You may need personal protective safety equipment (PPE) if sources of data at the site are in risky locations or may be contaminated. PPE should be commensurate with the threats encountered at an incident site.

Know Work Product Quality-Assurance Procedures

This Guide assumes you want to find out what happened. The process depends on you to check your own investigation work against quality-assurance standards as your investigation proceeds. Build quality into your investigation tasks and work products *throughout* the investigation. This is a key to getting more done in less time than you may spend now. The ideas and procedures that follow help you to do this.

Know Sources for Help During Investigation

Another kind of help is needed to fill gaps in your knowledge of some topic you encounter during an investigation. This may involve systems knowledge or materials knowledge that technical specialists can provide.

During investigations, you may need help. Part of your preparations are to consider the kinds of help you might need and how to get access to that help. Plan for help with your workload or to supplement your knowledge. Workload help may involve manpower or knowledge capabilities.

Manpower Help

You may need help with the investigation workload in large investigations or complicated cases when the time available to complete the investigation is less time than you can devote to the case. How do you access additional investigators to help you, and how do you use them when you get them?

Lab Capabilities

At other times, you may find it necessary to have someone perform laboratory examinations, tests, or simulations to support your investigation. What capabilities do you have access to in your own organization? What capabilities are available in your community to help you?

System Knowledge

As a trained investigator, you are the expert with the best *investigation* knowledge and skills at the scene. You are best equipped to develop the description and explanation of what happened. At times during the investigation or during the recommendation development process, you will need advice from someone who knows the system that experienced the incident. It is not unusual to need to know in more detail about how a system was designed to operate or how it did operate. Where do you go for expert help? Where would you find references to look up the information you need in published sources?

Materials Knowledge

When you deal with objects, you sometimes need help identifying reasons for the behavior of the materials during incidents. At other times, you need to identify events that produced the physical changes in the material properties observed after the incident. In another case, you may need to know about chemical behaviors or changes in properties. When these situations arise, be prepared to access help from experts or references.

Know who is available or whom to ask about help and ways to access their advice on short notice during an investigation. You may need in-house expertise or contracted services. In any case, you should be able to get access to such help through prior arrangements that are completed before you reach the site.

Know Contents of This Guide

Know and be prepared to apply the contents of this Guide before you begin an investigation. By following its guidance, you are unlikely to have any serious problems you cannot resolve during an investigation. Therefore, read it at least twice, and know where to find specific help during your first few investigations.

Know What To Do if a Crime Is Suspected

The conduct of accident and incident investigations is, generally, guided by courtesy and respect rather than constrained by requirements of law. Conduct of crime investigations, on the other hand, must meet strict requirements established to protect individual and property rights under the Constitution. Those requirements affect much of what investigators do because the evidence must help identify perpetrators and support their prosecution and conviction.

The instant you begin to suspect that the incident involved an intent to do harm, call law enforcement investigators into the case. Be prepared to turn over all data and objects to that investigator.

Throughout this Guide, four levels of investigation are discussed.

- Level 1 investigations focus on gathering data to fill in forms created by someone else.
- Level 2 investigations develop a description of what occurred.
- Level 3 investigations develop a description and explanation of what happened.
- Level 4 investigations develop descriptions and explanations and use them to identify, define, and assess problems and propose performance improvement recommendations.

(**NOTE:** These levels of investigation were established by the author for his discussion in the Investigation Guides.)

CHAPTER 2
KNOWLEDGE FOR INVESTIGATIONS

This section presents the general knowledge an investigator needs to conduct acceptable investigations. Two categories of knowledge are discussed in this section. The first is knowledge of the nature of an accident or incident. The second is knowledge of the accident and incident investigation processes.

KNOWLEDGE OF ACCIDENTS

What is an accident? Before you start doing investigations, answer the question: *What is the nature of what we call an accident or incident, accidental injury or spill, or accident or near miss?*

Nature of an Accident

How we view an accident determines what we do during an investigation and what we try to produce. Individuals may consciously or unconsciously hold views of what an accident is. Different views lead them to investigate for different purposes. Those purposes vary widely. A view may lead to a search for the following:

- Cause or probable causes
- Factors
- Causal factors
- Violations
- Root causes
- Proximate causes
- Multiple causes
- Precursors
- Hazards
- Unsafe acts
- Unsafe conditions

- Causal relationships
- Events flows
- Failures
- Errors
- Fault or blame

If more than one individual is investigating an accident and each investigator holds a different view, you can predict what will happen — controversy.

Research[1] has shown that technically an accident is a complex multilinear continuum of interacting events involving people and things that affect each other in ways that are not intended. The normal flow of events transforms into an undesired and a usually unplanned loss outcome. How can we apply these insights?

A practical way to look at accidents is to think of them as processes. A *process* is a group of people and objects acting on each other to produce an outcome. Processes can produce desirable products or results, for example a "peace process," or in the case of accidents or incidents, undesired harm or a loss outcome. During an accident process, people and objects interact to produce unintended and unwanted changes in other people or objects. Thus, for purposes of investigation: *An accident is the process that produced the unintended, unwanted harm or loss.*

Describing What Happened

Listen carefully to someone describing an accident. You will hear them describe what happened during an accident by relating who (or what) did what, when, where, how, and why to produce the outcome. When we refer to developing a description of an accident by investigating it, that is the kind of description an investigation should produce — regardless of the investigation level

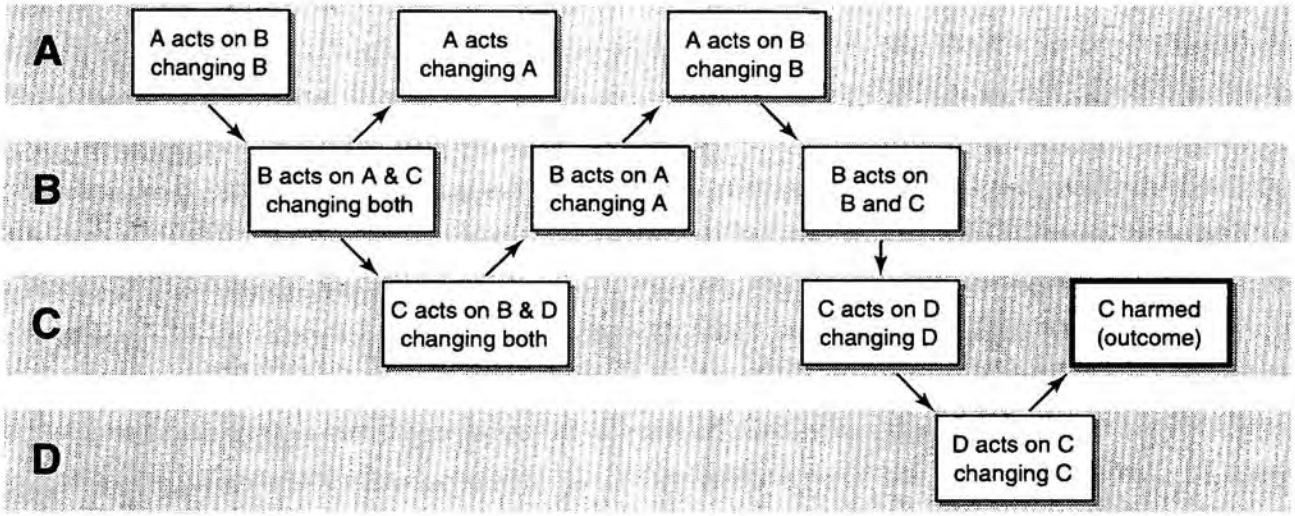
What occurs during an accident to produce the outcome is *event dependent*. This means the outcome depends on events that preceded it. Events are actions by the people and objects involved — the *who* did *what* for your description. To understand and describe an accident or incident process, you must identify the flow of the change-producing events (actors' actions) that produced the specific outcome. These change-producing actions occur both in sequence and at the same time (simultaneously).

Figure 2.1 shows how to think about process actors interacting to produce changes during an accident process that ends with a "harm" outcome. To help you understand the *event-dependent* nature of the accident process, this simple illustration shows you how one "change" event or action by an actor leads to other events. It also shows a way you can describe interactions when more than

[1]This work is reported in Hendrick (1986) and Benner (1985).

one event is occurring during the same time interval. It also offers a framework for organizing events to describe what happened in a way that can incorporate the timing of related events.

Figure 2.1 Accident Process Representation



In an actual investigation, you might want to expand your description of the interactions between the individual, the braking system, the car, and the street. For example, if the operator stepped on the brakes and they did not slow down the car, you would want to learn more about what happened. You do this by expanding the description to show the behavior of additional components of the brake system, car, or street during this incident. You would, for example, *break down* the actor "brakes" B to describe actions of individual braking system anti-skid system components (power supply, sensor, actuator, etc.) during the incident. You would also perform additional investigative tasks to develop the explanation of why these events occurred, using procedures described in the next section.

Accident and Incident Losses

Think of the terms "loss" and "harm" broadly as you investigate. Examples of losses to think about include:

- Injury
- Damage
- Destruction
- Illness
- Disruption

Assume that driver A needs to stop car C on snow-covered street D, and driver A steps on brakes B. Driver A jams on brakes B, changing the state of the braking system. The brakes B in turn act on car C wheels, trying to reduce its speed, and push driver A forward in the seat. This leads driver A to grasp the steering wheel harder to maintain control of the car (A acts on A). While this is happening, car C starts to skid, leaving skid tracks on street D and activating the brake B anti-skid devices. The brake B anti-skid device cycling sends strange sounds. So, out of old habits, driver A starts pumping brakes B. The brakes' B anti-skid operation disengages, and car C starts to skid sideways toward the curb of street D. The street D curb abruptly stops skidding car C and bends (harms) the wheels on C.

- Delay
- Reduced production
- Loss of confidence or credibility
- Tarnished reputations
- Environmental harm or degradation
- Diminished capacity
- Any other kinds of *undesired* outcomes

Try to define or at least list the kinds of losses you find. In automobile accidents on a busy urban freeway, for example, do not overlook the cost of delays because of traffic tie-ups. If an equipment breakdown results in lost confidence in the equipment and replacing all present equipment with better equipment, the incident cost should address these losses. Crude estimates are better than no estimates. Professional appraisals are better than crude estimates. The amount of money that changes hands is not necessarily a good measure of loss because it is often negotiated.

What Are Incidents

Thinking about "incidents" or "near misses" or "near accidents" as candidates for investigations is also very productive. Only a small or partial loss occurred in instances such as disruption, reduced output, delay, and diversion. The ultimate potential loss was prevented by some successful, amelioratory actions of people or objects as the process progressed. This means:

- Lower losses reduce the stakes for anyone involved in the incident, making them more likely to talk freely about what happened and why they might have done something.
- Witnesses survived and are more ready to work with you to find problems.
- Objects are damaged less during the incident, making more data available about what happened and why it happened.
- You are likely to find *verified* performance improvement actions because what was done worked to reduce losses.
- Think of incidents as successes, and investigate them with that attitude.

It is always better to prevent losses than to clean up after they occur.

Accident and Incident Models

Past investigations have produced "models" of incidents or parts of incidents. Such models are representations of what

happened. Models developed from investigations are available to help you. Appendix C, "General Human Decision Model," is an example of such a model, representing decision-making steps in a situation requiring intervention to prevent an accident. You can find other helpful information in other appendices and references.

INVESTIGATION PROCESS KNOWLEDGE

The primary reason for investigating accidents and incidents is to determine what happened and why it happened and to prevent similar accidents and incidents in the future. You must document what you find so that all of your "customers" can use your description as a basis for actions to satisfy their needs.

Laws or regulations or sometimes insurance or labor contracts may require investigations to be conducted by either the owner or a governmental agency. Other reasons for investigations include:

- Settling claims or distributing costs for the loss
- Determining causes or root causes
- Supporting litigation
- Checking effectiveness of prevention measures

The law and similar requirements describe what you must do (investigate) but they do not say much about how to do it. Observe the following guidelines:

- Know your organization's investigation policy if it has one, and do what you can to help implement the policy. Try to identify the investigation level if it is not stated.
- Be aware that your customers include everyone who needs and uses your outputs. They are the people who, generally, pay for you to do investigations. Any customer can, potentially, give you a hard time if your work is not done well. Develop tested descriptions of what happened and why it happened, and you can satisfy all your customers.

  Investigators are routinely asked "What caused this accident?" by uninformed media or others. This demands a judgment call, but you can handle the question with a good description of what happened and why it happened.
- Know how to identify parties interested in your investigation. This takes some skill and practice. They include all your customers and anyone else your work impacts. Other interested people may include system designers, resource managers, trade unions, or "outsiders" required to investigate by law. The latter might include local governmental response or law enforcement groups

or state or federal agencies (who may also send investigators). The media also need special care. This can become complicated when investigators from several organizations — both private and governmental — are involved in an investigation.

- Know how to establish who is the "boss" of an investigation. This requires some knowledge about jurisdictions and about investigation management authority, power, and responsibilities. Who is the boss of the investigation? For example, who settles conflicts, commits expenditures, or makes technical decisions? In any case, establish who has what authority to do what and when and to *protect* and share data found during investigations.

How Investigators Should Investigate

Investigators need to know how to conduct investigations so that they will produce high-quality results. Past investigation efforts have used a lot of technology and techniques borrowed from other fields. However, a systematic, integrated investigation process designed specifically for investigating accidents and incidents can help you produce the most efficient, effective, reliable, and useful work products. Such a systematized investigation process incorporates tasks common to all investigations and tasks or procedures specific to the type of occurrence or level of investigation.

Systematic Investigation Process Tasks

To perform your investigation tasks, it is important to understand what needs to be done during the investigation process, why it needs to be done, and how to do it. To satisfy your customers' needs, base the investigation process on an integrated body of investigation concepts, principles, and procedures. This process guides you through each investigation in an orderly, consistent, efficient and timely way.

- The starting point for an integrated systematic investigation process is knowledge of the nature of an accident or incident.
- For all investigations, the investigation process enables you to fill in forms and help you produce properly sequenced descriptions of what happened.
- For Level 2 investigations, this process enables you to produce tested descriptions of what happened and facilitate continual application of objective quality-assurance tests during investigations.
- For Level 3 investigations, it enables you to produce completed, validated descriptions of what happened and helps you determine and explain what happened.

- For Level 4 investigations, it helps you define problems and needs indicated by the occurrence; it helps you find viable options for successful performance improvement actions; and it enables you to develop monitoring actions to verify that the predicted results are achieved.

Investigation Observations

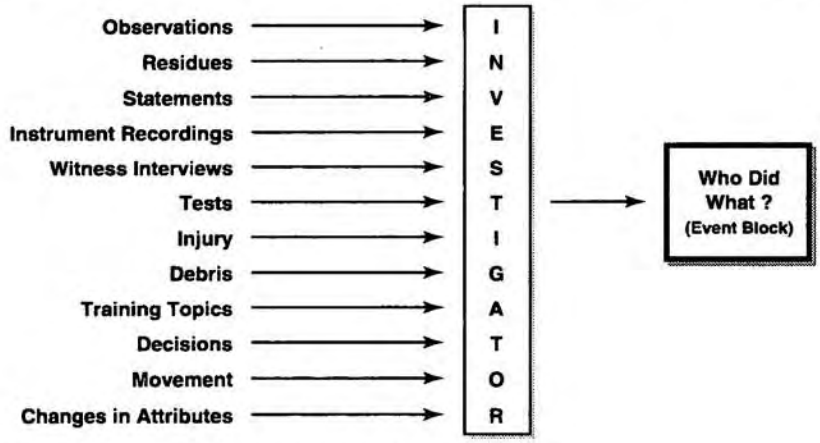
The next need is an understanding of investigation "observations." Outputs produced by investigations are based on investigators' observations and what they do with their observations. Your observations provide the basis for determining what happened during an incident and why it happened.

An *observation* is a noting and recording of an action, condition, or state by an observer. During an investigation you are an observer. Your observations range from looking over the scene of the incident and hearing (and seeing) witnesses tell what they remember to looking at objects to "read" the information they hold. You make observations to develop a description of what happened and why it happened.

How do you get from what you observe to a description of what happened? An essential investigation skill is to take your observations and turn them into a description of what happened.

You will make many kinds of observations of many kinds of people and things during an investigation. Your observations result in data that need further processing to produce the desired understanding. Your constant challenge is to take any observations of anything and transform them into a common format you can manipulate. You do this by transforming data into a description of who did what or an "event block" that you can process further. This challenge is described in Figure 2.2.

Figure 2.2 Investigators Data Transformation Challenge

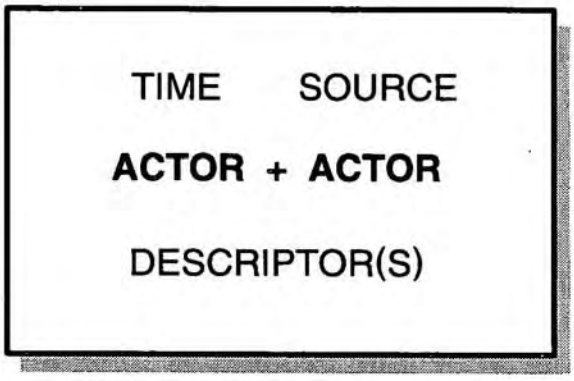


Said another way, you must look for events during the entire investigation process. This means that you must examine your data — all the actors and actions — to find out who or what did what to produce the outcome. When you encounter a "condition" — **think events** — who or what had to do what to produce the condition you see or want to describe. A *condition* is an ending state that actions by someone or something had to produce. How did what you see come to be? **Think events**. Who or what did what to produce the observed conditions or actions?

Formatting and Organizing Data

You need a consistent format for recording your observations to help create event building blocks that you can process for analysis tasks. A format that has worked best for many is the "who did what, when, and where" format, as shown in Figure 2.3.

Figure 2.3 Event Blocks



For convenience, let's call event blocks "events" (1 actor + 1 action) during the rest of the Guide. To transform and document your observations into events, use this simple procedure. That may seem tedious, but it really pays off throughout the entire investigation process. It also helps you recognize and define an event when you see one. If you think this way, you will start to use the term "event" consistently. If you are not sure who did it, or you do not know yet what someone did, use a question mark or a tentative name plus a question mark to indicate what you do not know. (Each question mark indicates what you still need to find out during your investigation.)

LOOK FOR EVENTS: *who or what did what?*
an event = one actor + one action

For each observation, identify what happened:

- Identify and record the name of each actor (a person or object that did something.

- Record what each actor did and any additional descriptive words needed to visualize the action. Describe each action so that you can visualize it from your description. (It is hard to visualize "failed" without a picture or sketch, so try to do so with words when you can.)
- Record the time if you know it (or a note about relative times such as after AA or at same time as BB, for example).
- Record the data source from which the event block was formed.

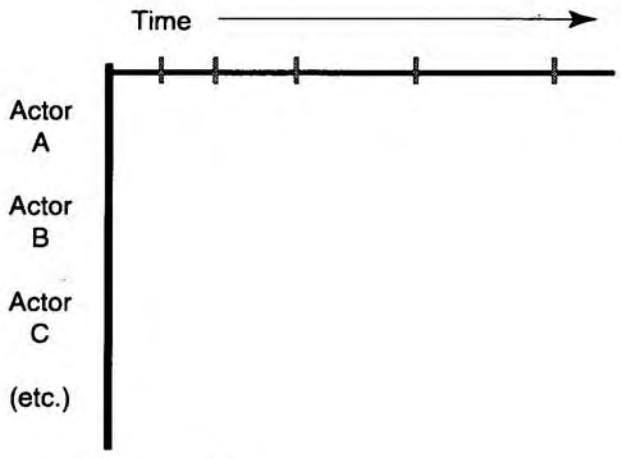
The source note allows you to go back to the source of the event when that becomes necessary. The source notes also tell you what records to retain at the end of your investigation. Finally, if the event is controversial, you can list all the sources available to support the event.

Organize the events you acquire by who did what when so that you can develop a description of what happened. To do this, you need some kind of layout or work sheet to assemble the events so that you can see what you have and what you do not have. You also need to apply logical reasoning tests to your work to help find out what happened.

As you identify new actions by people or objects (events), you *must* have some way to keep track of them and organize them so that they help you figure out what you know and what you still have to find out next. It is not a good idea to just go out with a big net and go fishing for all the information you can, hoping you have what you need when you start to analyze it. A better way is to analyze what you have when you get it.

The easiest and fastest way to organize information is to lay out your newly acquired events on a work sheet. As shown in Figure 2.4 use a matrix with time and actor as the coordinates.

Figure 2.4 Events Matrix Work Sheet



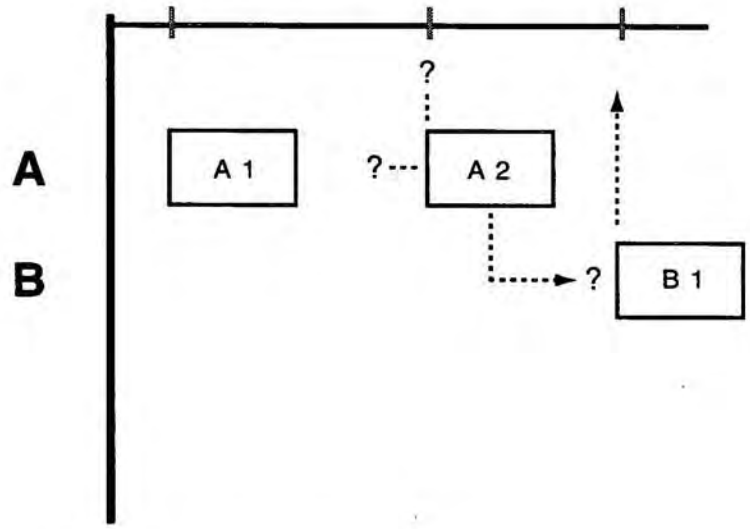
Source: Reference 1

By using this procedure, you can reduce your investigation workload and the total time required to produce your description of what happened.

> *Event work sheets enable you to organize your information as you get it into a* **direct description** *of what happened, by using the relative times or locations to put the events into their proper sequence.*

When you record your first observation as an event, you can start making your work sheet. Follow the example in Figure 2.5. You have learned about event A1 and placed it on your work sheet in the A row. You then learned about event B1, which happened after A1. You added a new row (for actor B) and placed event B1 on the work sheet along the B row. Next you found out about another action by A described by event A2. To place A2 in A row on the work sheet you need to determine *when* it happened relative to A1 and B1. The placement shown in Figure 2.5 indicates that you found it occurred after A1 and before B1. Each time you learn of an event, add it to your work sheet in the same manner until you have the complete description or as much as you can recover.

Figure 2.5 Placing Events On Work Sheet



Applying Logical Reasoning

During investigations, knowledge of logic principles and reasoning skills are used frequently. Four kinds of logical reasoning are involved: sequential logic, cause-effect logic, necessary and sufficient logic, and deductive logic.

Sequential Logic

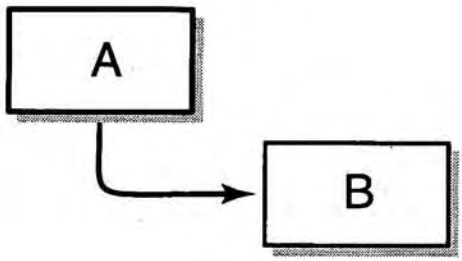
Sequential logic is the reasoning process applied to data in the time sequence in which it occurred or in the sequence in which movements of people or objects occurred. To understand *who* did *what* when, investigators have to put the information they acquire into sequential order. For example, "A had to happen before B."

Cause-Effect Logic

Cause-effect logic is the reasoning process used to determine whether one event led to another event. You do this to establish relevance and relationships among events you identify. For

example, when event A occurs during a process, it may cause B or more events. If so, you show this by drawing a "causal link" from A to B. If you think that there may be a causal relationship but need more data, add an arrow with a question mark on it. Cause-effect logic is applied to Level 3 and 4 investigations.

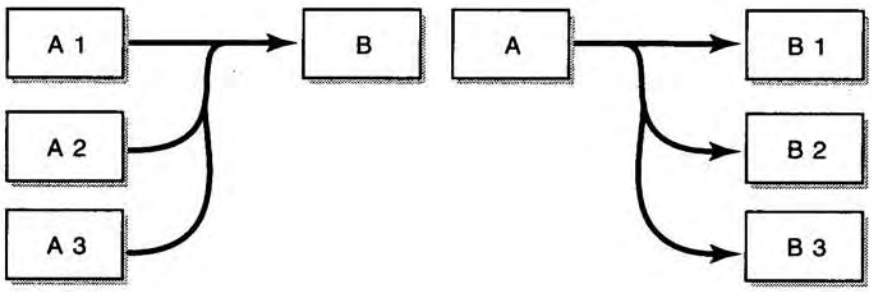
Figure 2.6



Necessary and Sufficient Logic

Necessary and sufficient logic is the reasoning process applied to pairs of events or event sets with identified cause-effect relationships to determine the validity and completeness of the description of the incident. For example, necessary and sufficient tests disclose that A1, A2, and A3 were all necessary for B to occur or that only A was necessary and sufficient for B1, B2, and B3 to occur. To do this you need to understand how a system works. Necessary and sufficient logic is used in Level 3 and 4 investigations.

Figure 2.7



Deductive Logic

Deductive logic is the reasoning process applied to the observations during investigations to define events and to develop scenarios to fill gaps in your understanding of what happened. For example, apply natural laws and scientific principles to infer the specific events that produced the observed damage to objects. It is also used to develop hypothesized events to fill gaps in your understanding of what happened. Deductive

logic is applied during all levels of investigations to read data from objects and in Level 3 and 4 investigations when looking for events to fill gaps or find missing events.

Mental Movies

Experienced investigators apply sequential logic intuitively by capturing what they see in their minds as "mental movies." As new data become available, they picture the actors and try to visualize what they did to sustain the accident process. The mental movie helps them to put all the observed data into sequential order — using time and spatial sequencing logic. Movies are most useful for Level 1 and 2 investigations but can be used for parts of Level 3 and 4 investigations.

Mental Movie Limits

Mental movies work well for uncomplicated accidents and if you are interested only in getting your facts in the right sequence. With more actors and activity or in activities with high loss potentials, the movie gets so complicated that the memory begins to mislay or forget data. Sequencing the data tells you what happened, but you cannot reliably analyze a mental movie with the additional logic tools that have to be used. Additionally, other people cannot see the mental movie in your head, so they cannot help you much with its development. It also is difficult to communicate orally what happened to other people so that they can draw conclusions solely from a movie in your head. That is why it is a good idea to record the actions as soon as you can, rather than trying to memorize and test everything in your head.

Analyzing Your Events

You probably noticed that when you position new events on your work sheet, you look at two events together before and after the sequential logic tests. This is called "event pairing." This "event pairing" is the basis for analyzing all your investigation information as fast as you acquire it. This is called a "progressive analytical process" because the analysis progresses as data become available, rather than waiting until you get all the data to draw and prove your conclusions. By recording and organizing your observations this way, you are able to analyze your information each time you add a new event to your work sheets.

Linking Causally-Related Events

As you place new events on a work sheet, you also look for cause-effect relationships between events. For example, after placing A2 onto the work sheet in the position shown in Figure 2.5, you can ask yourself whether A1 had to happen for A2 to occur. If it did, then you can link A1 to A2 with a linking arrow to show that cause-effect relationship. Similarly, looking at A2

and B1, ask the same question; if A2 had to happen for B1 to happen, link the events. By examining events in pairs (event pairs) on your work sheet, you can add links as your work sheet develops.

Finding Gaps in Events Flow

After a few links are added, you will see events that you recognize as part of the accident process, but they are not linked to any earlier "causal" events yet. Another way you see gaps is by visualizing the sequence of an actor's actions as shown by gaps in the events flow on that actor's work sheet row. The gaps between known events, or event pairs that you cannot link on a row, point to what you do not know and to specific information you must still get. They steer your investigation efforts and can help you avoid wild-goose chases.

Mental movies can work similarly for investigators because a "blank" frame between two other frames points to a gap in what you know. This is a lot more efficient than approaches where you "get all the facts" and then analyze them and draw your conclusions.

Filling Gaps

When you see gaps during your investigation, you do one of the following:

- Get more observations about the actor for which data is missing.
- Identify the other actor(s) that probably did something during the gap and get more observations about such actor(s) to show causal events or effect events.
- Apply deductive logic to develop potential scenarios describing what might reasonably have occurred during the gap. Then get more observations about such events to determine what happened or which scenario was more likely to have occurred if you discover several events pathways.

Any of these choices will focus your investigation efforts to increase your efficiency. Document and fit any events you develop into your data organization scheme.

Determining Completeness of Your Description

To understand *why* an accident occurred, you must apply *cause-effect* and also *necessary and sufficient* logic tests. To apply those tests in Level 3 and 4 investigations, you must use consistently formatted and properly organized events.

Each time you decide to link a pair of events, you define a *cause-effect* relationship between the two events. To determine

whether your description and explanation are complete, apply the necessary and sufficient logic test process on each linked event pair or event set (more than two linked events).

For this logic testing procedure, examine each linked event pair by asking yourself several questions. You know the causing event in a linked pair was *necessary* to produce the effect event. Then ask if the causing event was *sufficient* — will it *always* produce the effect event each time it occurs. If the answer is yes, this is all you have to do. If the answer is no, which is much more common, then you have to analyze how the system works. You also need to determine what else that people or objects have to do to make the effect event occur every time.

When you define all the sufficient events, look for observations to confirm that they happened. When you verify them, add them to your work sheet, and complete the links. If you cannot verify that they happened, you may show what you think happened if you indicate your events with a question mark or as unconfirmed.

When all the linked events have been subjected to necessary and sufficient tests, a clear explanation of why the incident happened becomes readily visible on work sheets. Beginning with the last event or outcome, trace backward the prior causally-related event(s). By the time you finish this part of the investigation process, you will recognize that questions like "What caused the accident?" or "What was the root cause?" can be answered by describing event-pair relationships. Remember, ALL linked events had to occur to produce the process outcome.

Use a Question Mark to Indicate Uncertainties

Use of the question mark to indicate uncertainties and incomplete data have been previously described. If you have to estimate times or any other dimension or relationship, you can show an "E" before the entry. The reason for showing the question marks and Es is to acknowledge "holes" in your investigation. This is so that someone else with a vested interest in your results does not undermine your credibility and the credibility of your description.

Another use is to decide whether the additional information is worth the cost of the additional investigation effort. If the workload to fill in gaps or to establish "sufficient" events requires a cost overrun, get approval of the extra expenditures.

Using Visualization Aids for Documentation

You will need to know about the preparation of graphic records; such graphics should capture the condition of the site to help you recall details about events. They are also used to help others visualize the scene when they try to create their mental movie of the accident from your work. These aids may take the form of photos, sketches, diagrams, maps, drawings, and similar graphics.

Photographs

Cameras record everything in a field of view, including the state of objects at the time of the pictures (Appendix A, "Photography Support for Accident Investigations"). Your objective is to record what you see in a way that lets you effectively use it later. Humans have a tendency to focus narrowly on whatever catches their attention, and our eyes go where the mind goes. Therefore, cover the entire scene with your camera, taking photos from the front, back, both sides, and above or below objects, if possible. Photograph the scene systematically starting at some point and going around the entire scene until you get back to the starting point. Be sure to keep notes as you take photographs.

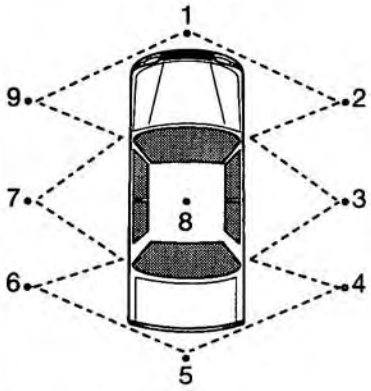
Sketches

Generally, *sketches* are moderately detailed, artistic renditions of objects or relationships intended to highlight certain features considered relevant to the understanding of what happened. Label all objects with names used elsewhere in work products. Make sketch items large enough so that if the sketch is reduced to 8½ x 11-inches for your report, it will still be legible. Include in title blocks:

- A name and location of the incident site
- The topic or main subject of the sketch or diagram
- A legend showing what any symbols represent
- Relative or actual dimensions of objects or components
- A "north" indicator to orient the user, if relevant
- Distances between objects or a scale that can be used to measure them
- A case identifier, including incident date(s)
- The preparer's name
- Page numbers if more than one page is used
- The revision number and the date it was last revised

Use previously prepared sketches or templates of vehicles or people to show damage or harm. For example, use a template of a car to show damaged areas conveniently and quickly during a Level 1 or 2 investigation (Figure 2.8). Templates using parallel lines to show roadway features are also useful. Use templates of body features to sketch bodily injury. Whenever sketches are repeatedly used, consider making templates. Sketches are preferable to photographs in your reports when you have to indicate the location and nature of injuries to people.

Figure 2.8



Diagrams

Diagrams are generally line drawings with symbols designed to demonstrate or explain something or to clarify relationships

among the parts of a whole or to show patterns observed. For investigations, diagrams should contain the same information previously listed for sketches.

Diagrams are used extensively for vehicle accidents to show the layout of the roadway, roadway features, vehicle movements, and similar data. Insurance and police report forms provide guidance for sketches.

Drawings

Generally, *drawings* are considered to be in the nature of a blueprint or plan formally prepared by a designer or professional staff member and properly referenced and described. For example, buildings, equipment, highway, and process drawings — to name a few — are frequently referenced during investigations. Drawings can be used to help users visualize what happened, but drawings are usually too complex to serve that purpose as well as sketches do. Drawings are more exact than sketches. Sketches can be edited and highlighted to make specific points.

Maps

Maps with topographic features as well as facility locations are helpful when the scope of an accident covers a relatively large area. Maps are useful for depicting where objects moved in large facilities, showing emergency response or evacuation routes, and similar purposes. For example, maps can be created for incidents such as a haz mat spill with a dispersing gas cloud, environmental effects maps, or aircraft wreckage distribution after an inflight breakup. Directional orientation is needed for maps. On a smaller scale, maps with dimensions can be used to show residues and deposits, although sketches are usually as informative. **(NOTE:** Watch that you or your mapmaker, sketcher, or diagrammer do not become carried away with clever detail at the expense of basic data.)

Off-Site Data Gathering

Not all data are available at the site; therefore, you may have to seek data about what happened off-site. The purpose of off-site data collection is to get events to complete your description of what happened. Sometimes such data are available at the site, but other times the data are elsewhere.

Object Data

Examples of data for vehicle accidents, equipment failures, and occupational injuries that you may need to seek away from the site include:

- Vehicle ownership registration, maintenance, service history, incident records, design or as-built drawings and records, risk assessments, and incident history

- Manufacturer manuals, as-built drawings, materials of construction, ownership, use or production records, service history, terms of sale, training specifications, design drawing, sales offerings or limitations, and hazard analyses
- Equipment data, industry codes and standards, and personnel data

People Data

You may need data about people, such as victims and participants, whose actions affected the incidents. Examples of off-site data include:

- Knowledge data from prior employment, training, and claims history to identify similar actions and incidents; decision-making experiences that may have affected events in this case
- Skill data from training course curricula and objectives, on-the-job training, or incidents to help determine diagnostic and intervention skill levels that may have affected actions in this case
- Decision-making capabilities and influences from prior involvement in incidents, pay-plan incentives, basis of awards or citations or bonuses, or performance evaluation criteria that may have affected decisions made in this case
- Physiological capabilities from prior medical history about any physical handicaps to assess physical capabilities that might have affected actions in this case

Programmer Data

Programmer data gathering establishes the pre-incident design and operating assumptions, plans, documented and undocumented operating expectations, and communications that did or should have influenced what happened. You are looking for data to describe expected actions before an incident and to help define differences between what was expected and what happened so that you can address expectations if needed. Often these programmers are off-site and may include:

- Training course developers; training materials designers; and actual curricula, handouts, or instructors' guides
- Additional witnesses who can describe supervisors' and coworkers' manners of giving directions, silence after incidents, encouragement of risk taking, etc.
- Analysts who defined needs and prepared regulations, standards, codes, and distribution system
- Equipment designers, buyers, procedures writers, signs creators, and related-operating histories or materials used to arrive at assumptions and decisions

- Managers who established working environmental policies, funding priorities, fund allocations, performance incentives, and discipline practices
- Customer demands or customer specifications that influenced actions
- Physicians, nurses, psychologists, or other medical advisors who influenced behavior
- Investigators of previous accidents who may have missed vital parts of an incident
- Magazines or other media that help influence attitudes toward tasks and risk taking

"Library" Data

Another useful off-site data source is the "libraries" of information about codes, standards, practices, and regulations that influenced actions involved in incidents. Examples of data you might get from libraries include:

- Codes, regulations, and standards
- Operating procedures to compare what happened and to identify expectations
- System operating models, drawings, and performance analyses
- Data about materials such as physical properties, chemical behavior, toxicity, flammability, and composition

Completing Investigations

For Level 3 and higher investigations, the additional events added to your work sheet as a result of your data searches complete your work sheet as much as the surviving data allow. Your completed work sheet should contain only relevant events such as linked events or events with a tentative link and question marks.

Remove events with no final or hypothesized causal links from your final description of what happened. If they do not lead to any other events, they played no direct role in the process. Appendix E, "Investigation Data Organization," indicates the elements that the completed work sheet should display. After you finish your description on your work sheets, check one last time the quality of your description and explanation (see Appendix G, "Recommendation Development Process"). When you make your last possible entry on your work sheet and remove unlinked events, you have produced the best possible flowchart describing what happened and explaining why it happened.

To gain maximum benefits from your work, it is important to recognize that investigations of any kind of accident or incident involve two distinct stages. For higher level investigations the

first stage is to determine what happened and why it happened and to document this information. The second stage is to use your description and explanation to identify needs indicated by the incident and to develop recommended actions to improve future performance. Both stages are required to "learn from our experience." Each stage requires different knowledge and skills. This section discusses the kinds of investigation knowledge and skills needed to develop a description and explanation of what happened.

NOTE: Many investigation programs do not require investigators to develop recommendations. Therefore, they are not addressed in this section. However, if you are tasked to prepare recommended actions based on what you learned, see Guide 1 *Introduction to Investigation* and Appendix G at the end of this guide. Both offer guidance for tasks required to produce recommendations such as discovering, defining, and assessing problems, developing recommended actions to improve future performance, and assuring quality work.

OBJECTS AS DATA SOURCES

Investigators rely on data from people and objects to determine what happened and why it happened. Only people and objects can be data sources. A good rule to remember is:

> *Data from objects are more reliable than data from people.*

In setting your data-gathering priorities, keep this rule in mind. Objects react in a predictable manner according to natural laws. Thus, you can draw inferences from your observations of objects with adequate confidence to serve your investigation needs.

People think about and may rationalize or otherwise change their recollection of what they did, so that you have to ask them for their data and then verify it in a different way. Thus, you will usually want to get data from objects before you talk to any people. However, the one possible exception is to talk to emergency response personnel during your initial walk-around if they are still on site.

Objects capture data through energy exchanges. Things serve as witness plates during many occurrences and capture data during an incident. As energy impinges on an object, it changes in some way. If you strike a piece of wood with a hammer, the indentation left by the hammer is an example of a how the wood becomes a witness to the hammer blow. Objects are trustworthy witnesses. Things do not "talk" to investigators; therefore, investigators have to be able to "read" every bit of information the things "recorded." The investigator's reading knowledge and

skills determine the data that they receive from objects. This is a task for which expert help is often needed. Learn what you can about the physics of changes to objects, but do not be embarrassed to acknowledge your need for help in actual cases until you build your own knowledge base.

Stressors and Stressees

To read data from things, you must know about "stressors" and "stressees." The hammer was the stressor — the energy source that introduced a change into the wood. The wood was the stressee or stressed object. When you see an object that shows indications of some change during an incident, you will want to find the stressor or "changemaker" that produced the observed change.

Sometimes a stressee becomes the stressor. When the struck car bumper (stressee) reaches its distortion limits, it may begin to rebound and become the stressor acting on the striking car (then the stressee) because it is now putting rebounding energy into the striking vehicle.

What this means for you is that interactions between objects are likely to be observable by changes to both striking and struck objects in most cases. The challenge is to time the changes so that the initial stressor can be distinguished from the initial stressee. This is where you call on your sequential logical reasoning knowledge and skills.

Sometimes, you have to try get "things" data to verify or supplement data obtained from people. Track the actions of people or objects on other objects from tracks left on objects during the accident. The way to get data from objects is to:

Track successive changes of state producing the outcome.

- Identify energy flows into and out of the "object." (See Appendix D, "Energy Source Checklist.")
- Identify the object or person that provided the energy to produce the observed change.

Extract data by working backwards from observed ending states or in either direction from intermediate states by:

- Observing the present state of objects changed during the incident
- Comparing the observed present state with known pre-incident state(s)
- Tracking known or likely energy flows by stressors that induced changes from beginning to ending states
- Transforming observed changes into inferred stressor actions or by stressor events

Stressors = the actors for your things events

Appendix D, "Energy Source Checklist," presents a comprehensive list of potential stressor energies that you can use as a checklist if the energies are not obvious from your observations.

The Six Ps

Sources of data about objects are the investigator's "Six Ps":

- Paper
- People
- Parts
- Positions
- Patterns
- Properties

Paper

Paper is used to track stressor actions or compare actual versus intended actions. Examples are tracings of recording instruments; standard procedures; operating logs; correspondence about systems design, startup, or operations; maintenance records; work orders; purchase orders; training records; incident records; production records; regulatory directives such as recalls and maintenance directives; design applications or approvals; engineering change orders, etc.

NOTE: If you are working with a system for which a safety analysis was performed before the incident, get a copy of that analysis to find out how an object or controls were expected to act.

People

People are used to learn what the objects did or how they reacted during the incident. Examples are what people saw objects do before or during the incident; how they operated objects; how they were trained or instructed to operate an object; how objects behaved in known circumstances; conditions they observed while an object was operating; any actions they took in response to what they saw object doing; and how it turned out.

Parts

Parts are used to define stressor actions that produced effects. Examples are deformation indicating stressor(s); changes to identify sequence of stressor impingement; discoloration or changes indicating exposure to high or low temperatures; variants in chemical composition; changed physical attributes; etc.

Positions

Positions are used to define effects of stressor actions. Examples look at positions in which objects, such as control

knobs, glass inside or outside windows, structural members, access openings, vehicles relative to each other, debris locations, etc., came to rest during or at the end of an incident to discover how positions changed from pre-incident positions.

Patterns

Patterns are used to infer or define stressor behaviors, intensities, exposure durations, and velocities, for example. Examples are patterns in metal or material fractures, wreckage distribution patterns, deposit patterns on objects, residues on objects, fragment distribution, chemical deposits, injuries to animals or damage to vegetation, charring patterns, thermal discoloration patterns, damages to interacting parts, computer memories, electrical discharge patterns, radiation effects, water stains, etc.

Properties

Properties are used to determine susceptibility to effects of stressors. Examples are changes in materials of construction or inherent properties of objects such as metallurgical properties, chemical composition, radioactivity level, buoyancy, resistance, melting point, boiling point, or other physical properties.

Testing Objects to Get Data

When you conduct Level 3-4 investigations, you may encounter a need to "test" objects to read the data. The general approach to accessing events data is to get all the information you can from the object before you do anything to change it. The sequence is to:

1. Look.
2. Dismantle.
3. Operate.
4. Destroy.

The objective is to get events to add to the description or explanation of the incident. As you learn about what things did and put them into your mental movie or onto your work sheet, you may find that you have trouble getting data you need. Before you can read what something has to tell you, you may need help to understand how something works or was supposed to work. To keep from doing unintentional damage to your data:

- Get help! Work with someone who knows the structure of the vehicle or equipment and how pieces are supposed to fit together and work before you do anything to it.
- Make a test plan, describing who will do what to what, when, where, and how. Specify that whatever experts give

you fits into your mental movie or your work sheet. Settle any test plan *before* you sample, change, dismantle, and try to operate or test anything! (See Appendix H for test planning guidance.)

One indispensable rule to remember is: No plan, no test!

- Stick to your plan. Experts from other fields or laboratories may not have the experience to satisfy your need, which is to get events to finish your description. If you pay for the tests you are clearly in charge, so get events you still need.

PEOPLE DATA SOURCES

To understand people as data sources, recognize how people acquire and store data, what different categories of witnesses can tell you, and how their memories can change before or while you access their data. Know how to plan for and get the data you need from people by asking the right questions.

How People Record Data

People record data by sensory inputs, conclusions or reasoned decisions, and personal feelings.

- *Sensory inputs.* People see, hear, smell, taste, or touch something and remember the sensory stimulus. Actions and observations are often stored as visualizations or mental movie clips.
- *Conclusions or reasoned decisions.* People select data and arrive at some conclusion based on the data or choose some action or course of action based on their conclusions. They may remember the inputs and steps that led them to their conclusions, or they may not.
- *Personal feelings and beliefs or cultural patterns.* Perceptions or truths, rather than logic, that people adopt from an authoritative source, experience, or faith may affect people data.

Witness Categories

During an investigation, you may find the following types of witnesses:

- Victims who were hurt by the accident or failure
- Participants who were not hurt but did something before or during the incident
- Observers who were not involved but saw what happened
- Programmers who influenced "how what you see came to be"

- Responders or physicians who can describe harm-producing actors and actions and what they changed during and after an accident

Why People Data Can Change

The data that people remember may change because people may:

- Simply forget observations or conclusions
- Rationalize their observations to fit previous experiences
- Deny or dismiss observations or conclusions
- Be influenced by what others tell them happened
- Distort data to hide or obscure their role

To minimize memory changes in witnesses, try to keep witnesses from talking to anyone about the incident until you have talked to them. Schedule the interview as quickly as possible after your walk-around.

Planning Interviews

Your general interview objective is to hear the witness's entire "mental movie" of events during the occurrence and to place the relevant events onto your work sheet or into your own mental movie. The plan does not need to be formal. An outline of points can help you remember to get needed data during interviews. Goals of an interview plan include the following:

- Gain and keep control of the interview.
- Gain and keep the witness's cooperation.
- Get all the events that the witness has.
- Satisfy any legal requirements.
- Leave the door open for follow-up questions.

Preparing for a Specific Interview

Before you start an interview, make sure that you:

- Can conduct the interview in a private, neutral interview setting. Schedule interview for locations where witness will be comfortable, and allow adequate time for the witness to talk to you.
- Clear your mind of your similar experiences, assumptions, preconceptions, expected answers, and what should have happened.
- Be able to state interview purpose so that you gain witness cooperation.

- Have established your interview procedures, and be ready to enforce them, especially if others will be present at your interview!
- Have identified what the witness might be able to tell you, and be ready to follow an orderly questioning sequence to ensure the witness's continued cooperation.
- Be ready to give the witness the opportunity to do most of the talking by the questions you ask.
- Be prepared to hear and document what the witness says and not what you are expecting to hear.
- Prepare equipment and props that you will need to conduct interview and to process interview data.

95% rule: Run interview so that witness talks 95% of time to maximize information acquired.

Documenting Your Interview

During or immediately after an interview, document the interview data.

- Document actions, decisions, conclusions, etc., as events.
- List names and then track the actions of new actors mentioned by the witness, if needed.
- After you have the witness's data, record the actions described to you in the event format, resolving differences in the names of all actors and citing the witness as the source on each event.
- Ask the witness for name, address, and phone number. If appropriate, because of investigation purpose, ask for the witness's employer, employment date, data of birth, license number, or social security number.
- Ask the witness to describe the incident setting, witness location, and when witness first became aware of something happening.
- As witness to describe what happened.

"CREATING" EVENTS TO FILL GAPS

Often you will find that you have a gap in your understanding — but that you have acquired all the data that you can think of — and you do not know where to look next. At that point, you can hypothesize or "create" events *on paper* to see whether you can fill the gap with one or more possible scenarios.

Hypothesizing Events to Fill Gaps

During Level 3-4 investigations, you will find that you have gaps in your understanding but you have wrung out all the data of what survived the incident. You do not know where to look or what to do next. At that point, a conscientious investigator can legitimately "create" events *on paper* to see what might fill the gap. An alternative is to end the investigation and live with the gaps. Some investigators do this without realizing it because they do not organize their data well.

"Creating" events during an objective investigation may sound like heresy, but it is not. If you use work sheets, they will help you to discipline your guesses. Any hypothesized scenarios must be bounded by the events on each side of a gap and tested logically before they can be used. (See the references at the end of the appendices [Hendrick 1986] for an example of a method.) As you develop your hypotheses, you also try to define the events data you might get from objects before you touch, move, tear down, operate, or test objects. Test those events with necessary and sufficient logic against events already on your work sheet. By doing this on paper, you often find that you do not have to do actual (and costly) data searches, teardowns, or tests.

SPECIAL INVESTIGATION CONSIDERATIONS

Everyone has biases or preconceptions; however, minimize biases by using the mental movie or work sheet process. **Think carefully about what you say to whom during investigations.** Listen a lot and talk little during investigations. Some investigators like to show off how smart they are by telling everything they know and think. Do not do this. It is okay to share information with someone whom you are asking for help, but otherwise, premature communication of speculation or judgments do more harm than good

Have a response ready when you are asked for information during a case by a reporter, witness, participant, owner, claimant, regulator, manager, victim, or other third party. A valid and truthful response is that you are still gathering information and trying to make sense out of it. Until you understand what happened, you do not want to run the risk of leaving something out that could change the entire focus of the investigation.

If you have to fill in forms, keep them handy and fill them in as much as you can during your investigation. Use the work sheet or mental movie events to fill in the blanks to the best of your ability. Forms do not always allow enough room for you to describe what happened in specific incidents, so you may have to generalize to fill in a block. Most forms provide room for a narrative description of what happened, so use that space to describe what happened in the sequence you found.

The investigation process may sound complicated. Unfortunately, it takes longer to describe it than to actually use it, regardless of the level of investigation you do. If you use work sheets or mental movies, their complexity reflects directly the complexity of the incident and how much of the incident process you investigate.

These procedures are actually quite simple, fast, and efficient as you gain experience. The hardest part is transforming information you get into events. Doing the logic checks as you add events to work sheets cuts down the time wasted on blind alleys. By documenting observed data this way on paper, you also can reduce other costs, too, such as extra paperwork, filing, testing, review, approvals, and potential litigation.

Don't be intimidated by the process. Your work sheet has all the capacity you can use, and if the incident was complicated, the work sheet helps you stay in command of your information. Armed with this knowledge, good observation and logic skills, and some practice, you are ready to do good investigations and to keep your experience from getting in your way.

CHAPTER 3
SPECIAL INVESTIGATION TASKS

This section, in a condensed format, highlights data acquisition, analysis, and reporting and recommendation development tasks.

PRE-INCIDENT INVESTIGATION TASKS

Before departing to an accident site, complete the following tasks:

- *Verify investigation objectives.* Know what level of investigation you are expected to conduct. Your principal objective in all investigations is to determine what happened and why.

  Strive for results that enable you to visualize from your description what happened and why it happened; include accompanying pictures, sketches, diagrams, or maps.

- *Verify deliverable specifications.* For quality assurance purposes, ensure that you know the criteria used to judge your deliverables, and work toward them as you investigate. If you are asked to find the cause or causal factors, this is an objective someone wants you to accomplish.

- *Verify authority and constraints.* Whoever tells you to investigate should also tell you what investigation authority you have. Find out the following:

  — How much time and money you have

  — When your deliverables are due

  — How to handle the situation if you need more hours or money

Do not overspend your allotted hours without getting more time. If you pinpoint the remaining uncertainties and do not get the time to resolve them, your supervisor will explain why the remaining uncertainties were not pursued.

Leave a little slack time for delays you cannot control such as witness access, parts removal and testing, and review for legal comments if applicable.

- *Verify who takes your directions or gives you direction.* Establish who directs whom at the incident site. You need authority to request and get access to the site, witnesses, debris, or records. Therefore, write a brief letter of introduction stating your task and authority. Clarify the chain of command if more than one investigator will be investigating. The authority of governmental investigators usually takes precedence over any private sector authority.
- *Verify who resolves disputes.* Before you leave your office for the site, clarify who resolves disagreements or disputes if they arise while you are investigating. It is important to know where to turn when someone is walking away with your property, and you do not like what they are going to do with it.
- *Start your data organization.* After you receive notification of an accident to investigate, start organizing newly acquired data. Usually you learn about an occurrence by telephone or in person. The information about what happened is sketchy, incomplete, and inconsistent. Transform what you learn into tentative events to add to your mental movie or your work sheet.

ON-SITE INVESTIGATION TASKS

First, **think events** from the beginning to the end of your investigation. Always keep in mind that your goal is to develop a description by defining events of who or what did what to produce the loss or harm outcome.

While en route to the site or upon arrival at the site, you or someone helping you should identify ownership data, site control needs, capabilities, and authorities for investigation purposes. The tasks in the following sections indicate what you need to do.

Interview Official in Charge

Ask the officials in charge at the scene about their understanding of what happened until you are able to picture the scenario in your mind. Ask questions such as:

- When did they first learn of the incident?
- What did they do next?
- What did they see next?

If you have any reason to suspect that actions of the response personnel influenced the outcome, identify and interview briefly those responders before they leave the scene.

Identify Owners

Identify the owner of the vehicle, equipment, or facility as soon as possible to determine whom to interview. The owner also has basic property rights that you are obligated to respect. The site owner may or may not be the owner of all the objects involved in the incident.

Many laws give governmental authorities the power to establish control of the investigation site, regardless of who owns it. Governmental authorities are given this control to prevent harm from being inflicted on what remains or covering up what happened. If there is something that looks willful, consult with law enforcement personnel immediately. On government property, follow the ownership too. For example, highways are typically government owned; however, the owner's representative is the local law enforcement agency, state police, the fire and rescue organization, or the highway department.

If you are the investigator in charge, make sure that the person selected for the site control task is able to maintain control until your needs are satisfied. Site ownership and debris ownership may differ. For example, when a private vehicle crashes on a government highway, the ownership is different.

Before any debris is changed or destroyed at the site or in a laboratory, the owner of the accident debris should have a voice in its removal for testing and analysis. The exception to this is when the urgency of reopening a vital facility overrides the investigation needs. In some incidents, government investigators have the authority under laws to commandeer debris for investigation purposes. In these cases determining ownership is not a priority.

Who is in charge of the site? Make sure changes in shifts or personnel do not leave you stranded when you need something. If an incident — for example, a haz mat spill — extends the duration of the incident, you need to find out the name(s) and access information for contact(s) to get something done at the site.

Site Control

Site control requires control of individual access to and egress from the site. Be a party to defining who is granted access to the site and for what specific investigation purpose they are admitted. Control egress to prevent unauthorized removal of incident-related debris, parts, or documents.

When is the site control task completed? This task is finished when the site managers have been contacted and site control materials and procedures have been negotiated, implemented, completed, and removed.

Site Safety Risks

Before entering a site, consider your own safety. Check with the site controller to identify any entry risks such as dangerously damaged structures, leaked chemicals, noxious gases, uninvited flammable gases, exposed animals, charged electrical wires, blood-borne pathogens, or other energy sources. (See Appendix D, "Energy Source Checklist," for a list of energy sources to consider.) Remember that **NO INVESTIGATION DATA IS WORTH AN INVESTIGATOR'S LIFE, LIMB, OR HEALTH.**

Work with the site controller to identify, eliminate, or control risks before entering a site to start investigating. Have an egress or escape plan and emergency equipment available if it is essential to enter a hazardous site.

Site Data Risks

You need to guard against two kinds of damage or harm to data at the site — to the people or objects containing data and to others gathering data at the site.

Protect People From Unintended Changes

The most serious change occurs when potential witnesses start to rationalize what they remember to fit what they think should have happened. You need to protect people from outside influences until they have given their data to you. Minimal protection is to instruct them not to discuss their experience until you have a chance to talk to them. If the stakes are high, as in a fatal injury, physical separation or isolation of witnesses is preferred. Fit the protection to the case.

Protect Objects From Unintended Changes

Do not go onto a site and start touching, moving, altering, or taking objects before you know what you need. Because you rely on observations of objects for data, you do not want them changed prematurely. You will need data from parts, positions, patterns, pieces, papers, and people — the "Six Ps" for investigators. Any of these may be present at the site, and you want a chance to examine them before they are changed.

Keep People Out

After you stabilize the site, keep people out until you have your first look around. (If the site is very small, you may want to give your walk-around priority and not bother setting up site controls.) Nature can change objects too. Thus, you want to consider how objects might change and work out something that would protect or preserve the information until you get your look. Rain, for example, can wash off residues, start oxidation in metals, or dissolve chemical deposits. Sunshine or rain can melt ice. Running a bulldozer over a small object can also ruin your data.

Security Boundaries

You may need to set up site security boundaries and secure the area within those boundaries if objects are scattered over an appreciable area. The actual physical barriers and boundaries depend on the nature of the incident, what was involved, and the resources available to establish the boundaries. Barriers such as highway roadblocks can be very disruptive, so the strategy is to put barriers around only what is needed for the investigation and then restore the activity as quickly as possible.

When setting up barriers, disrupt as little as you can for as short a time as possible. During this task, keep trying to figure out who and what were a part of the incident process. Therefore, the data they hold can be protected until the data can be observed, documented, analyzed, and tested.

Media Contact Procedures

Accidents, especially in urban or suburban areas, seem to attract media attention. If reporters are interested in your incident, someone will contact you. A good and truthful response during an investigation is to tell reporters that you are trying to find out what happened and that until you do, it would be unfair to discuss the case. Everything has to fit together before you can talk about it. Avoid offering the media subjective judgment calls or speculations. Stick to facts.

DATA GATHERING TASKS

After you make the site command connections and secure the site, keep looking for events. Proceed with the data search, acquisition, documentation, testing, and refinement stages of the investigation. When you get to a site, you have to make decisions about what information you want to find and the order in which you look for it. Your task priorities at the site are to:

- Set up events data handling materials.
- Start looking for events.
- Do site walk-around.
- Identify relevant people and objects involved.
- Document ending conditions at site.
- Acquire events to tell you what they did during the incident.

Reordering these priorities may be necessary in some cases or where some objects or changes are perishable. For example, when you arrive at a site while the incident is still in progress, you may have to delay the walk-around. If a site is unstable where traffic keeps moving, as during a fire or a highway accident, the ending state documentation may have to wait. However, each task has to be completed.

Set Up Events Data Handling Materials

If not already initiated, set up your materials for handling data so that you can process any events you identify. As an alternative, at least set up your mental movie. Have someplace to put any new observations quickly and efficiently. Format and organize your events data as you get them.

Start Looking For Events

Your data search and data gathering begin with the first verbal notification of the incident. Your first *direct* observations for data begin on arrival at the site of the incident. You will want to use direct observations to develop events for your description and explanation. Focus on observations that yield events (who or what did what).

Do Site Walk-Around

Become acquainted with the incident setting as soon as possible. Do a "walk-around" of the incident scene to get generally acquainted with the location, nature and scope of the incident, and the kinds of people and objects that might have played a role in producing the outcome. A walk-around is just that — you walk, observe, and start to document and organize your observations. You do not touch, nudge, move, kick, turn over, clean off, push aside, or do anything that alters what you see. This comes later.

Record names of any potential witnesses and contact information if feasible. Take lots of photos and notes during a walk-around; take photos of any crowd around an accident site to help identify potential witnesses later. Get help to cover the full perimeter around the site adequately. Keep notes describing what you document (see Appendix A, "Photography Support for Accident Investigations").

Identify Relevant People and Objects Involved

During the walk-around you will become familiar with the "stage" on which the action occurred. To make your mental movie, you will need to identify and name each of the "actors" and what they did on that "stage." Record the names on Post-It™ notes or cards, and organize them promptly. If early in your investigation you do not know their official names, use a question mark and your own temporary name until you receive this information. The data source for these notes is "my walk-around."

During your "walk" and initial development of your mental movie, you try to identify any people who may have "witnessed" what happened sometime before, during, or after the incident. Look for:

— Responders

— Observers who saw what the objects or other people did

— Victims who were injured

— People (participants) who did something before or during the incident

— "Programmers" who influenced what people or objects did during the incident

These are the people you probably want to interview when you know enough to ask them good questions.

As you do your "walks," you will see objects that were changed during the incident. These changed objects are also *candidate witnesses* — candidate changemakers or objects that you may want to examine or "read." Other kinds of objects to note are any things that influenced what happened such as safety systems, signs, procedures manuals or guides, etc. Look for objects that changed something during incident process. Separate the actors or changemakers from the "reactors" or stressed objects.

Document Ending Conditions at Site

During the walk-around, start to document the "relevant" objects at the scene. Try to see and record the ending state of objects affected by the incident process; you will have a faithful record of their condition to use for the rest of the investigation. During your initial walk-around, you probably will not have a clear understanding of what is truly relevant and what is not. Therefore, try to photograph or video everything at the scene that seems to have been changed. This may be impossible for accidents with large or widespread damages. In these cases, you may want to defer your picture taking until after your first walk-through. This enables you to narrow the scope of the photographic workload to items indicated to be relevant.

Record the ending state of objects affected by the incident:

- If people are involved, document the site where they were found after the incident and before they were rescued, treated, or removed from the site. Capture the scene and ending conditions with photographs, videos, sketches, diagrams, drawings, or maps. Do not try to remember everything you see. (**CAUTION**: Remember to add something you can use to determine.)
- If vehicles are involved, document the vehicle(s), vehicle movements, pathway(s), controls, spills, debris, and cargo.
- If equipment failure is involved, site documentation involves documentation of involved:
  - — Equipment
  - — Anything being processed in equipment

- — Anything processed recently by equipment
- — Anything awaiting processing
- — Energy sources
- — Energy flows in and out
- — Control system elements
- — Operator action (active)
- — Self-activating (passive)
- — Barriers
- — Setting
- — Behavior in setting
- — Effects of failure (patterns)

- When an occupational injury occurs, site documentation involves documentation of the injury, injuring agent(s), controls and barriers, and setting.
- For acute occupational illnesses resulting from exposure to some toxin or other harmful material, the site documentation should include all chemical or natural materials and their form and quantity over time. Medical examination is required to identify the harming material, but the inventory of what was possible helps medical personnel identify the suspected agent.
- Occupational illnesses developing over a long period of time are more difficult to relate to specific materials at a scene, unless the symptoms have been linked to specific materials. Conduct such investigations with medically trained physicians or investigators, focusing on exposure events.

Acquire Events

After a walk-around, the next task is to narrow your focus to get specific data to support additional events for your description and explanation.

Identify Stressor(s)

Energy flows produce observed harm or changes to objects. Try to identify the energy sources (stressors) and their related energy flows.

In passenger vehicle accidents, the most common sources of energies are linear kinetic energy (Appendix D, "Energy Source Checklist," Table D.4, Item 5). If fire is involved, energy sources also include thermal energy, Item 9. Any of the other sources listed in Tables D.1 and D.4 may be involved; therefore, do not overlook them as possibilities in an unusual accident. All the energies listed in Tables 1 and 4 were added to the list because they were noted in one or more incidents.

In equipment failure incidents, you really have to go where the harm to observed objects and components leads you. The source could be any of the energies listed. Keep Appendix D handy for reference. Be alert to the role of machinery and equipment "loads" handled at the time of the incident.

In occupational injury incidents, the same guidance applies. Acute injuries can result from any energies on the list. In longer-term hazardous exposures, initial emphasis on Appendix D, Table D.4, Items 8, 10, and 11 may be involved, but do not limit your search for the energies to those items.

After you determine the energy source(s) and flows, decide whether the flow was a natural or accidental occurrence or whether it was a result of deliberate actions and potentially a crime. If deliberate, shift to criminal investigation procedures until you can get a criminal investigator to take over the investigation. This means you start chain of custody procedures immediately and delay all interviews.

Apply General Human Decision Model to Guide Data Search

When people's actions are involved in incidents, you need to address if and how the energy sources and flows were detected and identified by the persons who would have to act to change the flow of events. This is often called the man-machine interface. Use Appendix C, "General Human Decision Model," and application notes to support investigation of these aspects of a vehicle accident, equipment failure, or occupational injury process.

Sometimes, damages to objects during the incident process prevent you from tracking all the energy flows you need to understand. This may require you to work backward from the ending state. This is a perfectly acceptable and orderly way to proceed as long as you organize the data to point to data still needed to identify earlier events.

Identify Energy Barriers

Be alert to the barriers involved in the incident. Watch for barriers that did and did not work. Describe their condition before and after the incident, if possible.

Barriers take many forms, depending on the inherent nature and energy content of the objects involved. Haddon's strategies illustrate the many kinds of barriers. Consider all kinds of barriers such as:

- Bumpers on vehicles
- Machine guards on equipment
- Crushable vehicle bodies or packaging

- Air bags or cushioned dashboards on vehicles
- Warning signs
- Hand rails
- Lock-out procedures
- Insulation
- Emergency controls
- Warning horns
- Showers
- Standards
- Periodic maintenance programs
- Vaccinations
- Personal protective equipment
- Training

Do not overlook regulations as barriers. If actual behavior of objects or people differed from what the regulations require, examine what happened if it played a role in the process! See also Appendix D, "Energy Source Checklist," Table D. 3 to help your thought processes and question formulation. Determine their role by displaying what happened on the work sheet and test their casual relationships to subsequent events or the outcome. Any time some object or procedure that was designed to control energy exchanges did not achieve its purpose, you need to examine and understand the reasons for the barrier performance.

NOTE: If barriers were designed to do something during the accident process and *did not*, the barriers will not show up in your description as an actor unless you say something like "(actor) did nothing" at the time it was expected to act. Their ineffectiveness will show up when you take your description and analyze it for problems during the recommendation development process. (See Appendix D.)

Document Beginning Condition of Changed Objects

Before you can recognize and interpret changes to objects and relate them to the accident, you have to identify their states before the incident started. The source of this information varies with the type of accident and objects involved. Use the unique identifier information as the name of the object where available or some unique *cross-referenced* nickname, as the actor in events describing what the object did. Identify the unique name of the vehicle, equipment, or injuring object.

Vehicle Data

Vehicles involved in highway accidents can be defined by their unique vehicle identification number (VIN) attached to the dashboard of each vehicle. Every car has a unique VIN so this

should be the first vehicle information your record. Use the VIN or some nickname (Veh 1, Veh 2, etc.) as the name of the vehicle in your events.

Other information about the vehicle is found on the owner's card issued by state licensing authorities. If the card is not available, try to identify other information defining the vehicle such as its license number and expiration date, make, model, body type, weight, fuel type, and safety features. From the cargo manifests or shipping documents of cargo vehicles, record information with special emphasis on cargo weights and load configuration. Many trucks have DOT identification numbers that should be recorded. If heavily loaded vehicles are involved, you may need to record rated cargo capacities, axle loadings, tire data, and cargo tie-downs. (If hazardous cargo is involved, see Guide 3, **Hazmat Investigation** for additional help.)

This information may not always be available at the site, so you will have to contact the owner or state licensing authorities for additional information about the vehicle. Document vehicle name, attributes, and ownership.

Pathway Data

Vehicles travel on pathways. Pathways can be divided highways, streets, alleys, dirt roads, trails, or event open fields. Highways and streets have formal and unique designations, such as names or numbers, within a jurisdiction. Each street or highway has mileposts or similar specific markers that can be used to pinpoint where something happened. Identify and document the designations and any mileposts or survey markers, or give them your unique name (Table 3.1).

Objects you document should be related to some event or action that helps you describe what happened.

Table 3.1
Other Information About Vehicle Pathways

- ☐ design standards
- ☐ potholes
- ☐ barriers
- ☐ berms
- ☐ culverts
- ☐ curbs
- ☐ curvatures
- ☐ dimensions
- ☐ dividers
- ☐ lateral slopes
- ☐ longitudinal slopes
- ☐ medians
- ☐ piers
- ☐ paving materials
- ☐ retainment walls
- ☐ shoulders
- ☐ surfacing materials
- ☐ temporary features
- ☐ squeezes, gores, or converging lanes
- ☐ drainage problems
- ☐ ice or snow
- ☐ undulations in surface
- ☐ speed bumps
- ☐ excavation plates
- ☐ crash cushions
- ☐ guardrail configuration
- ☐ emergency turnoffs
- ☐ construction barriers
- ☐ construction surface discontinuities
- ☐ construction traffic sites
- ☐ truck scales
- ☐ curbside phones
- ☐ tunnel features
- ☐ intersection guard rails
- ☐ grades/changes
- ☐ skid mark

Traffic Controls

Vehicle travel on pathways must be controlled to permit use by more than one vehicle or a mix of users. Vehicle operators rely on controls for safe use of pathways. Documentation of the controls is approached from the direction traveled before the collision or incident by the vehicle(s) involved. Depending on the nature of the incident, controls as much as two miles from the accident site may have influenced the operator. One way to capture the controls is by videotaping the approach route while actually driving the route. Another way is to drive or walk the route and take photos with a still camera (Table 3.2).

Table 3.2
Control Elements Along Vehicle Pathways

FLOW CONTROL SIGNS
- ☐ highway speed limits
- ☐ cautionary speeds
- ☐ city speed limits
- ☐ special speed zones
- ☐ stop signs
- ☐ yield signs

PAVEMENT MARKINGS
- ☐ lane markings
- ☐ edge markings
- ☐ crosswalks
- ☐ intersection limit
- ☐ speed markings
- ☐ lane restrictions
- ☐ utility markings
- ☐ lane reflectors
- ☐ other reflectors

ROUTE SIGNAGE
- ☐ street signs
- ☐ local route markers
- ☐ overhead route billboards
- ☐ lane arrows
- ☐ turn on red, green
- ☐ detour signs
- ☐ hazmat routes

ACTIVE SIGNALS
- ☐ traffic lights
- ☐ school zones
- ☐ RR gates
- ☐ crosswalk lights
- ☐ intersection flashing lights

PEDESTRIAN SIGNS
- ☐ school crossing
- ☐ signal buttons at intersections
- ☐ crosswalk marks

CONSTRUCTION INFO
- ☐ warning signs
- ☐ speed reduction
- ☐ worker hard hat
- ☐ end construction
- ☐ mowing ahead
- ☐ lane guide lights

LANDMARKS
- ☐ tourist facilities like parks, stadiums, etc.
- ☐ airports, other terminals
- ☐ historic sites

MISCELLANEOUS
- ☐ traffic radio info.
- ☐ police flares
- ☐ breakdown reflectors
- ☐ slides or falling rocks
- ☐ low-flying aircraft

As you understand more and more about what happened, any one of the pathway or control items may become an actor that was needed to produce the outcome.

Equipment Failure

When you investigate an equipment failure, the same principles apply: Get the unique identification data for the equipment. This will usually be the name, make, model, and serial number of the equipment found on plates or labels on the equipment or in purchase or operating documents. Document the equipment owner's name and the equipment name, manufacturer, make and model, serial number, date built, date(s) modified, any code stamps, or markings.

As your understanding of what happened grows, you may need to find additional data from object records stored away from the scene. For example, you many need to identify who repaired a certain part or object and what they did from recent maintenance records, service reports, repair descriptions from work orders, or logs or similar documents kept by the owner or maintainer. You may need to find out how equipment was expected to be operated from supplier's operating instructions or manuals.

NOTE: Pursue these records only after you find you have a need for them in order to identify missing or needed events.

Organize Event Information

If you use forms, fill them in as you find the data. Fill in narrative sections after you find out what happened. For other investigation levels, add any new event information to your work sheets, mental movies, note cards, or whatever system you are using. To do this efficiently, you must document, organize, and logic-test information as you get it. This is the only way you can keep up with what you have and what you still need as your investigation proceeds. If you do not do this, you will have no realistic basis to get at the unknowns that you do not even know about — the unknown unknowns sometimes called "unk-unks."

Documentation includes the following:

- Transforming your observations into events
- Fitting new data into previous events in the scenario
- Testing what you add for its sequential and cause-effect logic
- Adding causal links when found
- Identifying remaining gaps in your events flow.

Any gap or question mark constitutes an open investigation item on which to act. Either get more data, or make a reasoned decision not to go after the data and report the gap or uncertainty.

Get Remaining Data

After you finish the walk-around stage of your investigation, focus on what you still need to complete your description of what happened. When you get to this point in the investigation, you know much about what happened, but you still have uncertainties or gaps in your description. If you use work sheets, you will have estimates (marked with an E) and unknowns (marked with a question mark) that you may want to resolve. Each requires more data. This is when you can really concentrate on specific data to finish your investigation because you will recognize which people or objects can tell you what you still need to know.

You may have to contact the first responders again to get their observations and information about what they did to specific objects or what they saw objects do. Transform their data into events, and add them to your growing mental movie or work sheet. The source of the events should be the responder's name.

At this stage, events on both sides of your gaps can point to objects you need to read. For example, you observe that no skid marks are present on the pavement before a vehicle collided with another. This points to a need to determine whether this occurred because the vehicle's braking features malfunctioned or because the operator continued to operate the vehicle unaware of the consequences (the collision).

Reason Backwards From Harm Outcome

The outcome is a useful place to start because you want to show how the accident process produced the outcome. The outcome pinpoints the relevant actors harmed, and from that starting point you can work backward to identify what acted on those actors to produce the ending (harmed) condition. This is where causal logic and necessary and sufficient logic reasoning help you. Work with event pairs to find out what caused what.

As you look at a damaged vehicle or objects around it, you can reason backward from the damages to the people or objects and actions (stressors) that produced the damage. When you look at an injury, the same approach applies — look at the injury and ask yourself what object produced that effect.

Break Down Events

Another technique is called *breaking down events*. Take a known actor and try to break down what the actor did into more specific actions or break down an actor into smaller components. To understand more details, break down actors or actions in events you have.

To break down what an actor did, add actions by the actor during the time of the gap. You know the operator was there and did something during the gap in time you need to fill. Thus, you can pinpoint who to ask for more information about what the operator did or what objects to examine for possible changes brought about by the operator during that time period. Many cases have been clarified by breaking down exactly what an operator did before being injured by a machine. Often the role of events timing can only be identified by breaking down the actions this way.

To break down the actor, separate the actor into component parts. For example, you can break down the actions of a car into what the wheels, the brake system components, steering components, etc., did. You can say a car struck a tree, or you can say the car bumper struck the tree. By getting more specific, you

will usually be able to clarify how events rippled through a system and identify more precisely what might need fixing.

Test Events as They Are Documented

As you keep adding events, you still must do the basics. Look at events in pairs to check their relationships for valid sequence, cause-effect role, and necessary and sufficient logic:

- *Sequence.* Do the events on your work sheet represent the sequence in which events occurred? All investigation levels?
- *Cause-effect role.* Do the events displayed have cause-effect relationships to any subsequent events, and if so, are they linked to show that relationship? All levels greater than 2?
- *Necessary and sufficient logic.* Have all the linked events been checked for the necessity and sufficiency of the cause-effect links? All levels greater than 2?

Repeat the sufficient test until you have linked all and only the event blocks required to produce the "effect" event for the incident process to continue.

Fill Gaps in Your Work Sheet

As the investigation proceeds, each event you add to your work sheet or mental movie provides a more and more detailed understanding of what happened, why it happened, and what you still need to understand. The remaining gaps drive what you do next. To fill gaps, you may need to:

- Talk to more witnesses or go back to previous witnesses to get the additional data.
- Examine, reexamine, or test objects to find what you need.
- Guess what might have happened to bridge the gap, lay out on paper the scenario to see whether it is feasible, and if so, start looking for data to support such hypotheses.
- Simulate events during that part of the incident to understand what might have happened, and seek data to verify part or all of the simulated events.

"Read" Objects

Your challenge is to "read" data from objects to learn what they can tell you about events that happened or why they happened.

The following are useful strategies to find and read relevant objects:

- Use the Six Ps to locate and describe objects to read.
- Read the objects or remaining parts and components.

- Read effects of actions, interactions, or residues on objects.
- Talk to people about what objects did.
- Read objects for more events.

NOTE: If you have not photographed the objects during the walk-around, photograph them before disturbing them! Prepare notes describing what you photograph or videotape. On video, describe what you are looking at. Use close-up photos to capture details about ending conditions of objects likely to be causally related to the incident process.

To read data from things, start by trying to:

- Determine pre-incident states, locations, and configurations.
- Observe and document post-incident states, locations, and configurations.
- Visualize what people or objects had to do to produce the post-incident states, locations, positions, or configurations you see.

Examine specific objects to get data for events, such as:

- Change(s) that occurred and times involved
- Actor(s) that acted upon them (stressors)
- Action(s) they are exposed to
- Sequence(s) of changes that occurred
- Duration of events or interim changes
- Exposure concentrations, duration

Proposals to test objects or samples should address these needs!

Additional Observations

Keep recording additional observations and data as events on a work sheet or in a mental movie until you have everything you can get out of the objects you had available. Be alert to indicators of the following:

- Area(s) of stress origins
- Actions by reaction products
- Unexpected behaviors
- Hardware safeguard operation
- Objects that accelerated or impeded the incident growth
- Other events that changed the incident process growth

Add events to your mental movie or work sheet if they fit.

Test events as they are documented for correct time and spatial sequence, for investigations greater than Level 2, for cause-effect relationships among events, and for necessary and sufficient logic completeness or uncertainties.

Get Data From People

Objects are your most reliable data sources and behave predictably if you know how to read them. People are less reliable and predictable but should be used as data sources. Get the data you need from people after you have some idea about what to expect. Remember, they have what you need, and they do not have to give it to you. Establish realistic expectations of what your witnesses can give you:

- What could the witness have observed?
- What did the witness do?
- Why did the witness do it?
- What did the witness think was expected?
- If indicated, explore witness beliefs about operation.

Interview Preparations

Before starting your interviews, make sure that you have built your mental movie or work sheet as much as you can from your walk-around and events read from objects. Get any physical models or photos, sketches, drawings, or other documents showing the site, equipment, vehicle, or other object ready to use during your interviews. Sequence your interviews in the following order to maximize your effectiveness:

1. Responders
2. Observers
3. Available victims
4. Participants
5. Programmers

People Data Changes

Watch for changes in the data people offer. Cross-check what one witness tells you during interviews with what others said and against what your observations of objects tell you. The best way to do this is to lay out the events they all describe next to each other — preferably on an event work sheet or at least a mental movie.

Interview Procedures

Before you schedule an interview, read previous witness statements or other previous witness reports for needed data

and to prepare initial parts of your mental movie or points to address. When conducting your interviews, perform the following:

- Assure the witness that he or she will have adequate time to talk to you. Often, additional information comes to light after your interview formally ends.
- Open the interview with an explanation of what you are doing and why the witness should help you.
- Explain how the witness can help you by describing what he or she saw other *people* and *things* do and what he or she did during the time interval you describe.
- Work out with the witness a way to document (preferably by tape recorder) what he or she tells you.
- Ask for the following information: name, address, and phone number. If appropriate, also obtain employer, employment date, date of birth, license or social security number, or anything else you need to fill in a form.
- Ask the witness to describe the incident setting, location, and when the witness first became aware of something happening. Show this location on a sketch.
- Visualize the beginning of the witness's mental movie.
- Track the witness's observations and actions with questions such as:

  "What happened?"

  "Then what happened?"

  "What did you see?"

  "What did you see next?"

  "What did you do??"

  "What did you do next?"

- Visualize what the witness tells you in your mental movie. Do this so that you can follow the witness from the beginning to the end of the incident. Use the movie to raise questions to fill in remaining gaps in your mental movie. Account for all the time witness was at the scene if you need the data. Everyone and everything have to be someplace doing something during an incident.
- When you need to restart your mental movie, use questions such as:

  "I cannot picture what you said when you said..."

  "Forgive me, but I couldn't follow what you said when you said..."

- During the entire interview keep looking for information about changemakers that produced outcomes.
- Ask "easy" or "what happened" kinds of questions first to finish action scenario, so if the witness ends the interview, you have as much data as you can get. Then, get into the more personal questions.
- Identify the witness's understanding of expected actions during the incident; start to explore why events happened with questions about conclusions and opinions.
- Finish conclusions and expected actions before asking questions about responsibilities, duties, authority, contradictions, etc., which the victim, participant, or programmer witnesses can construe as potentially threatening.
- Do not hesitate to make event blocks with the witness during personal face-to-face interviews if a point in an incident is unclear to the witness and you.
- Close interview with a thank-you, and ask how you can make contact again if anything else is unclear. Leave your card or note so that the witness can contact you with more information.

Remember, focus on finding changemaker actions.

Some Interview Don'ts

- Do not use threatening terms such as:
  Fault
  Cause
  Failed to
  Failure
  Wrong
  Poorly
  Inadequate
  Mistake
  or similar words reflecting your judgment of what happened
- Do not talk about human error without comparing pre-incident expectations with what actually happened.
- Do not assume procedures, regulations, specifications, standards, and design are correct.
- Do not let the prior incident scenario bias your questioning during this investigation — start with a blank piece of paper and use data you get from this case.

Data Sources for Expected Behaviors

For Level 3 or 4 investigations, do not stop with something the person did if it affected the harm or loss. Find out who did what to program the person to do it the way it was done by interviewing the following:

- Trainer and training course developer — look at training materials, handouts, or instructors' guides
- Supervisors and coworkers
- Those in charge of regulations, standards, penalties, or codes
- Equipment designers and buyers
- Managers — regarding policy, funding, scheduling, and incentives
- Customer service — ask about customer demands and customer specifications
- Media
- Other programmers

Enter data from witnesses into your mental movie or work sheet as soon as possible after each interview and preferably before you start the next interview. It is worth the time. You have to keep current about what you still need to find out.

Cut Out Irrelevant Information and Words

As you build your work sheet and add links during Level 3-4 investigations, you will note some events that do not play a direct cause-effect role in the process. As it becomes clear they are irrelevant, remove these events from the work sheet. Do not discard them until you have completed the final report. Concentrate on the necessary event blocks needed to describe what happened and why it happened.

Quality-Check Your Description

You need an event work sheet for objective quality assurance. Checks for your description of what happened and why it happened should consist of reviewing every event you describe in a narrative or every entry on a work sheet for form, content, causal relationships, and completeness. Guide 1 has a more extensive discussion of quality-assurance procedures.

PREPARING DELIVERABLES

You are now ready to produce your deliverables. Exactly what you deliver, of course, depends on your customers and the investigation level. For Level 3-4 investigations, event work sheets provide the script for your reports. If permitted, use a neat

copy of the work sheet as a flowchart describing and explaining what happened. Use photos, sketches, diagrams, drawings, or maps to enable the users to visualize what happened. This is the most efficient way to report what happened.

If you have to fill in forms at any level of investigation, you can use the work sheet events for information to put into the blanks and to write the narrative description. To write the narrative, simply state who did what, when, and then what happened. Use the words or phrases "before" or "after" or "at the same time" to describe relative timing. (If recommendations are required, the problems identified on the work sheet and the options as well as the rationale for selecting the recommended actions can be described in the narrative.)

Narrative reports should not have to be works of art; they should be judged on their technical merit rather than their literary merit or political correctness. Judge the narrative reports by how well the reader can visualize what happened and understand why it happened.

Prepare Description and Explanation of What Happened

Your reports should satisfy your specifications but should include at least the following:

- The scene and what happened when and for higher level investigations, why it happened
- What started the incident
- The people and objects that played roles in the outcome
- The events that brought the stressor and stressees together
- Any actions by the safety systems that limited or contributed to the loss
- If not reported elsewhere or if response activities limited or contributed to the losses, descriptions of those actions
- The losses attributable to the incident or response activities
- The actual or estimated times of key loss or response events

Satisfy Visualization Rule

Any report or work product you produce should satisfy a general rule:

> *Make it easy for users of your work products to visualize the incident process, the points you want to make, and arguments that support your conclusions.*

To satisfy this rule, add illustrations to reports if appropriate. Your photographs, sketches, etc., help readers visualize settings for events constituting the haz mat incident and help you make your points.

NOTE: Do not include medical records without "owner's" permission.

Review Investigation Process

To learn from your investigations, try to document and report any investigation innovations or opportunities for improvements in procedures or tools that would help other investigators in future investigations. It is preferable to put such suggestions in a separate report for internal use.

SUMMARY

Vehicle Accidents

Vehicle accidents can involve one or more vehicles. In single vehicle accidents, the main focus is on the vehicle and operator involved and what each did. In multiple vehicle accidents, track the actions of more than one vehicle and operator. When pedestrians are involved, you have to determine interactions between the vehicle(s) and pedestrian(s).

In every vehicle accident, your list of actors to track includes the vehicle, the vehicle operator, the roadway, the traffic flow controls or signs, and any objects the vehicle may have impacted. Depending on the incident, additional actors may include:

- Other vehicles and operators
- Other vehicle occupants
- Vehicle cargo
- Barriers or structures along pathway
- Barriers in vehicle(s)
- The weather or environment
- Vehicle or pathway designers
- Law enforcement personnel
- Construction or maintenance personnel

Track operator decision-making information and the decision making process, if possible.

Call in experts when needed during examination of vehicle components. Before you initiate any destructive testing, make sure that the test plan is satisfactory.

Equipment Failures

Equipment failures typically involve the equipment that failed, an operator, the controls, and a "load" of some kind on the equipment. Equipment investigations may involve moving parts or components that perform some subfunction that did not work as intended. Some equipment may involve nonmechanical components where familiar motions of mechanical components are not involved. In all failures the challenge is to work backward from the ending state to the events that produced it.

Use failure analysis techniques to track changes in objects and identify the energies required to produce them. If operators were actively operating the equipment, track what they did before and during the failure. Track the loading to which the equipment was exposed if it was processing something to identify the resistance energy imposed on the equipment or components. Power sources and any energy transfer subsystems, such as heaters or coolers, may also be involved as may environmental influences. If any testing is needed, have a satisfactory test plan before changing or performing destructive testing on any objects.

Note the damage or loss that followed the failure. If the failure involves fire, try to identify the types of damage from each energy type.

Job-Related Injury or Fatality

Job-related injury may be accidental, self-inflicted, or inflicted by others. Each requires a different investigation. Accidental injury investigation involves tracking the injured person, the injuring object(s), and the setting in which the injury occurred and any actions to ameliorate the injury. Often medical expertise will be needed to document and define the injury events.

CHAPTER 4
SUMMARY OF ACCIDENT INVESTIGATOR'S TASKS

The tasks you perform during an accident investigation are listed below to help you place your investigation workload into perspective. This list describes, in the typical sequence you will do them, the tasks you have to complete during the conduct of an accident investigation. It is designed for you to use as a checklist. Your general strategy is to first get a feel for what happened and then develop a valid description and explanation of the accident process.

PREPARING FOR INVESTIGATION

- ☐ Understand investigation preparation tasks.
- ☐ Know what you are investigating.
- ☐ Understand investigation program mission, objectives, and policies.
- ☐ Practice investigation procedures.
- ☐ Have investigation supplies and kit ready.

VERIFYING PLANS UPON NOTIFICATION OF A SPECIFIC ACCIDENT

- ☐ Know your objective(s), deliverable specifications, schedule, hours, and authority.
- ☐ Start your data organization.

ARRIVING AT SITE

- ☐ Think events (who did what).
- ☐ Interview official in charge.
- ☐ Identify owners.

- ☐ Who is in charge of the site? How long is this person in charge?
- ☐ Ensure access and egress controls.
- ☐ Control site safety risks.
- ☐ Control site data risks.
- ☐ Obey "do no harm" rule.
- ☐ Set security boundaries.
- ☐ Establish media contacts.

SETTING DATA-GATHERING TASK PRIORITIES

- ☐ Set data search priorities.
- ☐ Set up documentation materials.
- ☐ Set up source collection file(s).
- ☐ Start looking for events.

WALK-AROUND AT SITE

Use investigator's models to guide search and interpretation tasks.

Document observed or estimated losses:

- ☐ Fatalities
- ☐ Injuries
- ☐ Property
- ☐ Contents
- ☐ System
- ☐ Other

Document responder losses, if any:

- ☐ Fatalities
- ☐ Injuries
- ☐ PPE
- ☐ Responder property
- ☐ Other

Identify or assign unique names to every person and object, and record names.

- ☐ Look for and identify contact data for potential witnesses.
- ☐ Photograph bystanders and others at site.
- ☐ Solicit witnesses.

Record all potential witness's names and contact information:

- ☐ Responder
- ☐ Observer
- ☐ Participant
- ☐ Victim
- ☐ Programmer
- ☐ Other
- ☐ Look for and document changed objects at site.
- ☐ Identify and document object "witness plates."

Document ending conditions of objects at site with:

- ☐ Photos
- ☐ Videos
- ☐ Sketches
- ☐ Map
- ☐ Drawings
- ☐ Other
- ☐ Record what each photo, video, etc., is intended to show.

GETTING SPECIFIC EVENTS DATA

Use investigator's models to guide search and interpretation tasks.

- ☐ Find stressor(s).

Identify changemaker energy source type.
If accidental:

- ☐ Identify and list source(s) involved (cars, barriers, cargo, people, animals, etc.) and what they did.
- ☐ Ensure documentation shows the points you need.

If natural:

- ☐ Identify and list source(s) involved (sun, rain, snow, and earthquake, etc.) and what they did.
- ☐ Ensure documentation shows the points you need.
- ☐ Identify energy flow detection and diagnosis events.
- ☐ Identify energy barriers.
- ☐ Identify and document pre-incident data.

If deliberate:

- ☐ Shift to criminal investigation procedures.
- ☐ Start chain-of-custody procedures.
- ☐ Manage energy sources and natural external sources.

Vehicle accident:

- ☐ Describe activity during which incident occurred.

For each vehicle:

- ☐ Record VIN number.
- ☐ Copy data if state registration card is available. If not available, identify and record owner, vehicle maker, model, year, license number, and special accessories.
- ☐ List people and objects carried in/on vehicle.
- ☐ Identify actions of energy barriers and controls.
- ☐ Add events to your mental movie or work sheet.

Failure:

- ☐ Describe activity during which incident occurred.
- ☐ Record equipment owner, name, manufacturer, make and model, serial number, date built, date(s) modified, and any code stamps or markings.
- ☐ Review recent maintenance records and date(s).
- ☐ Read the supplier's operating instructions.
- ☐ Learn what the equipment was doing at the time accident started.
- ☐ Identify actions of energy barriers and controls.
- ☐ Add events to your mental movie or work sheet.

Injury:

- ☐ Describe activity during which incident occurred.
- ☐ Identify and record name, maker, model, serial number, and other data about object(s) involved in injury.
- ☐ Read the supplier's operating instructions and any other operating procedures for each object.
- ☐ Identify actions of energy barriers and controls.
- ☐ Add events to your mental movie or work sheet.

DOCUMENTING REMAINING DATA AND EVENTS AT SITE

Use the work sheet, mental movie, or investigation models to guide search for events.

- ☐ Recheck question marks and Es with first responders.

Locate Objects to Read for Additional Events:

("If this condition exists, then (that) must have happened.")

- ☐ Work from the least damaged areas toward most damaged areas, if possible.
- ☐ Break down events.

- ☐ Find energy sources in the operation and what their "barriers" did.
- ☐ Document what you see — as you see it — with pictures.
- ☐ Record description of what each picture or video is supposed to show.
- ☐ Keep notes so that you can tell people later what you did during the investigation.
- ☐ Test events as you document them.
- ☐ Fill gaps in your work sheet.

General Object "Reading" Procedure:

- ☐ Determine and document pre-incident states, locations, and configurations.
- ☐ Observe and document post-incident states, locations, and configurations.
- ☐ Try to visualize what people or objects had to do to produce changes.
- ☐ Add events to mental movie or work sheet, and test them.

For Specific Objects, Examine Them to Establish:

- ☐ *Change(s)* that occurred between the pre-accident and post-accident conditions
- ☐ *Actor(s)* data to tell you who or what made change occur
  - — Thermal
  - — Mechanical
  - — Chemical
  - — Electrical
  - — People
  - — Other
- ☐ *Action(s)* data so that you can describe what stressors did to stressees
- ☐ *Sequence(s) of changes* data to determine which changes occurred before others
- ☐ *Duration of events* or *interim changes* data to show relative-event timing
- ☐ *Exposure concentrations, duration* data to define exposure differences
- ☐ Add events to your mental movie or work sheet and test them

Additional Observations of Objects:
In fires:

- ☐ Indicators pointing to area(s) of accident origin
- ☐ Actions by accelerants
- ☐ Unexpected fire loads
- ☐ Successful and unsuccessful intervenors and safeguards
  - — Active devices
  - — Passive devices
  - — Warnings
  - — Procedures
  - — Designs
- ☐ Objects that accelerated or impeded the accident spread
- ☐ Other events that changed the accident process growth or decline
- ☐ Add events to your mental movie or work sheet
- ☐ Test events as they are organized for correct time and spatial sequence

For Level 3 and 4 Investigations:

- ☐ Test event pairs for cause-effect relationships among events.
- ☐ Check completeness or uncertainties for necessary and sufficient logic.
- ☐ Fill gaps in work sheet with data, hypotheses, or question mark.

Identify Interviewees With Data:

- ☐ Establish expectations of witnesses.
- ☐ Determine what the witness observed.
- ☐ Establish what the witness did.
- ☐ Determine the witness's motive.
- ☐ Determine the witness's expectations.
- ☐ Establish what your witnesses can give you.

Develop Your Interview Plan:
Schedule your interviews in the following order:

- ☐ (1) Responders
- ☐ (2) Observers
- ☐ (3) Available victims
- ☐ (4) Participants

- ☐ (5) On-site programmers
- ☐ Read any statements or reports to identify needed data.
- ☐ Prepare initial mental movie to define what you want to know.
- ☐ Assure witness will have adequate time to talk to you.
- ☐ Ask "easy" questions first.
- ☐ Explore why events happened; ask questions about expectations and opinions.

Conduct Interviews:

Apply 95% rule during interviews.

- ☐ Open each interview with explanation of who you are, what you are doing, and why the witness should help you.
- ☐ Explain how the witness can help you by describing what he or she saw.
- ☐ Ask the witness for his or her name, address, phone number, and if appropriate for investigation purpose, employer, employment date, data of birth, license number, or social security number.
- ☐ Work out a way with the witness to document the interview.
- ☐ Ask witness to describe the incident setting, witness location, and when the witness first became aware of something happening. Show location on sketch.
- ☐ Try to visualize what witness tells you, and add it to your mental movie.

Track the witness's observations and actions with questions such as:

- ☐ Then what happened?
- ☐ What did you see?
- ☐ What did you see next?
- ☐ What did you do?
- ☐ What did you do next?

Track the witness's observations

- ☐ Identify witness's understanding of expected actions before or during accident, if applicable.
- ☐ Finish questions before potentially threatening any witnesses with responsibility questions.
- ☐ Don't hesitate to make event blocks with witness during personal face-to-face interviews if a point in an accident is unclear to witness and you.

- ☐ Close interview with a thank-you and a phone number exchange.
- ☐ Keep looking for data about changemakers that produced outcome.

When you need to get your mental movie restarted, use questions such as:

- ☐ "I can't picture what you said when you said..."
- ☐ "Forgive me, but I couldn't follow what you meant when you said..."

Programmer Data:

- ☐ Define performance expected by supervisor(s).
- ☐ Define expectations established by trainers.
- ☐ Define cultural considerations.
- ☐ Add events to your mental movie or work sheet as you get them.

> *Interrogations differ from interviews; trained criminal investigators should do interrogations.*

Off-Site Data Gathering Tasks:

- ☐ Object-related data
- ☐ People-related data
- ☐ Knowledge data from prior employment such as from past incident records, etc.
- ☐ Skill data such as operating courses or training, records, and tests
- ☐ Decision-making influences such as incidents, past awards, disciplinary records, and citations
- ☐ Medical capabilities data

Programmer Data:

Establish expected behavior programming by:

- ☐ Trainer, training course developer, training materials, handouts, or instructors' guides
- ☐ Supervisors and coworkers' direction, silence, or examples
- ☐ Regulations, standards, penalties, or codes
- ☐ Equipment designers, buyers, procedures, signs, and operating history
- ☐ Manager's policy, funding, scheduling, and incentives
- ☐ Customer demands and customer specifications

- ☐ Physicians, nurses, and psychologists (medical advice)
- ☐ Investigators of previous accidents
- ☐ Magazines or other media
- ☐ Other programmers (names, actions)

Acquire Library Data:

- ☐ Regulations, codes, and standard
- ☐ Comparative operating procedures
- ☐ System operating models
- ☐ Material attribute data

Prepare Description of What Happened:

- ☐ Level 1: Fill in form, including narrative if provided.
- ☐ Level 2: Prepare description of what happened from events you found.
- ☐ Level 3: Prepare description and explanation of what happened.
- ☐ Level 4: Prepare description, explanation, and performance improvement recommendations.
- ☐ Cut out irrelevant information and words.
- ☐ Quality-check your work.
- ☐ Prepare reports from work sheet or mental movie and sources.
- ☐ Support report with visualization aids.
- ☐ Review and comment on investigation process.

For Level 4 Investigations:

Prepare recommendations (see Appendix G, "Recommendation Development Process").

- ☐ Develop recommendations.
- ☐ Prepare in some ranked order a discussion of problems disclosed by investigation.
- ☐ Prepare potential remedial or preventive actions in some order of preference.
- ☐ Develop recommendations for remedial actions.
- ☐ Develop monitoring plan to verify expected effectiveness.
- ☐ Discuss uncertainties if needed.

APPENDIX A
PHOTOGRAPHY SUPPORT FOR ACCIDENT INVESTIGATIONS

WHY TAKE PICTURES DURING AN INVESTIGATION?

People tend to focus on what attracts their attention in a scene, and photos record everything within camera sight. Photos provide visual documentation that will not change. Photos quickly show the "stage" on which the actions of the incident occurred.

Preplan

- Arrange for a camera with auto exposure, zoom, flash, and date/time stamp features.
- Practice with the camera you will use so that you can use it properly.
- Arrange for local photographers who will know what is needed in advance.
- Give someone authority to hire and direct photographers.
- Make sure that everyone knows investigation policy — too many photos are always better than not enough photos.

Rules for Accident Investigation Photography

Rule 1. Photos should provide an accurate record of the scene: You are not seeking an artistic or sensational prize-winning creation. The scene, especially in fires, should include not only the accident but also the bystanders.

Rule 2. Make sure that the photos are not reversed, cropped, or off-color. If more detail is needed, changing contrast can help. Use color referent if accuracy is important.

Rule 3. Ensure correct perspectives. Use appropriate focal length and lens angle. Grids may work on flat surfaces. Have horizontal lines to aid perspectives.

Rule 4. Use camera settings needed for the situation. To cope with lighting differences, take photos with different light sources and angles. Check shutter speed versus film speed. Use meters, extra lighting, etc.

Rule 5. Provide accurate size reference. Use people, coins, ruler, etc. Sometimes it is okay to show your hand in the picture.

Rule 6. Use color for maximum information content. Record data in colors. If exact color is important (as it is with fires), use color bar and charts to help developers and investigators.

Rule 7. Always identify each photo (OSHA has a nice form). Documentation should include: date and time, film type, lighting and exposure, location, subject/purpose of view, photographer's name, and witness (if litigation is involved).

Rule 8. Show enough of the scene to provide good orientation. Go from long shots to close-ups of detail. Cover from different angles. Aerial is invaluable for outside accidents, fires, and explosions. Aerial may be available as baseline for before and after information (check U.S. Geological service photo sources).

Rule 9. Do not skimp on film — film is relatively cheap. You may not have to print everything by the time you understand what happened. On the other hand, look at shots to see what you might be missing.

Rule 10. Do not overlook other options, such as multispectral, stereo, thermal, motion picture, and videotape techniques, to capture data visually.

SUMMARY

1. Think of visual records as documentation of incident witness plates.
2. Get as much as you can before it changes.
3. Better too much than too little.
4. Watch tricks and distortions with photography.

(Adapted from DOE MORT training)

APPENDIX B
MEDICAL SUPPORT FOR INVESTIGATIONS

MEDICAL SUPPORT IN AN INCIDENT

- Treat victims.
- Identify victims.
- Establish cause(s) of death.

COMMUNICATIONS ABOUT INVESTIGATION

- Establish rapport with medical examiner and/or coroner to get cooperation.
- Communicate with victim's personal physicians.
- Get information about the postmortem from the examiner or coroner.

DATA ACQUISITION AND INTERPRETATION

- Advise or help regarding collection of specimens for subsequent analyses.
- Assist in medical examinations of witnesses to verify injuries (back injury, for example) for potential claims.
- Advise regarding photography or documentation of injuries.
- Help identify what events victim may have been subjected to from observable intermediate trauma and implied injury mechanism/exposures.
- Rule in or out human degradation, failure during accident process.
- Assess adequacy of medical care in the incident emergency response.

- Analyze witness claims against physiological observations.
- Assess potential survivability and how it might be enhanced.
- Verify effectiveness of protective equipment during operations.
- Arrange for medical literature search of similar accidents/problems.
- Determine fitness for tasks.

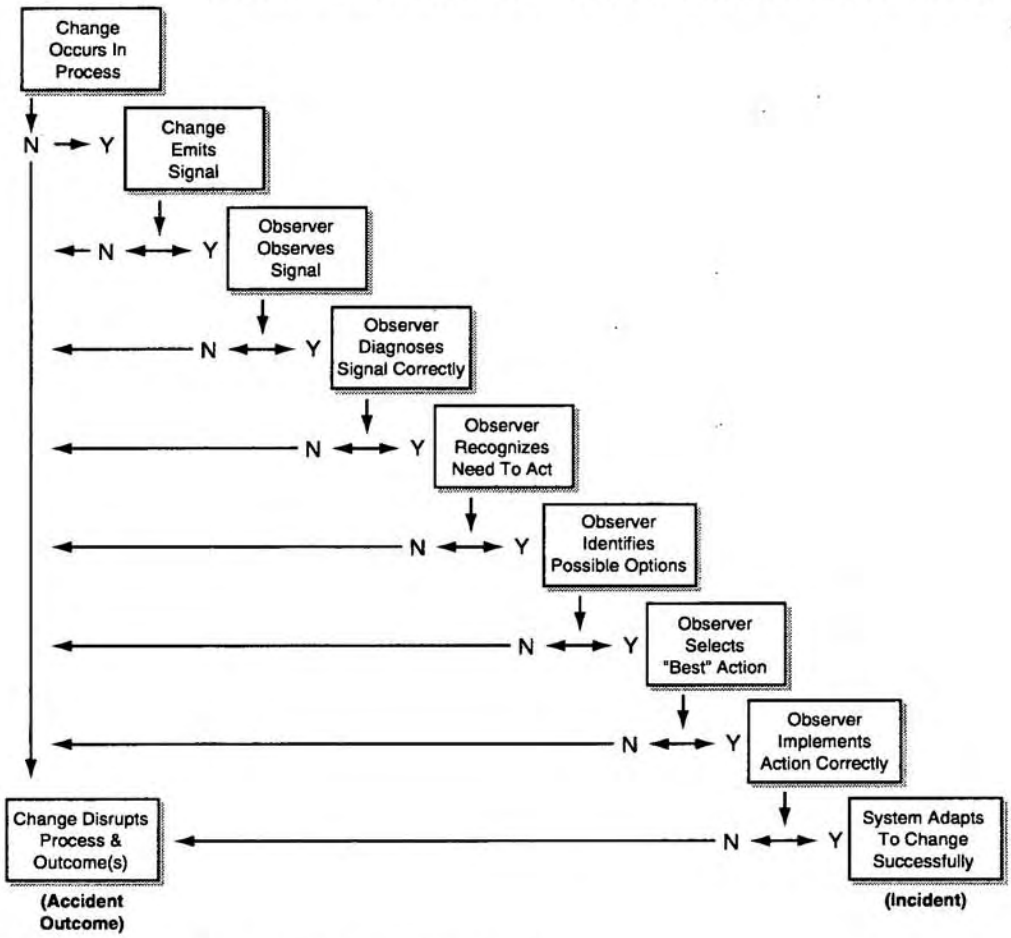
QUALIFICATION FOR MEDICAL INVESTIGATORS

- Job performance analysis limited by state-of-the-art in psychiatry and psychology.
- Cannot eliminate any one categorically; test must be ability to perform tasks, as in simulators.

NOTE: When reporting medical aspects, do not use medical pictures in your accident reports — respect the individual's privacy. (Make and use sketches to convey data, if necessary.

APPENDIX C
GENERAL HUMAN DECISION MODEL

Figure C.1 General Human Decision Model For Accident Investigators



APPLICATION OF THE GENERAL HUMAN DECISION MODEL FOR INVESTIGATORS

This Model deals with the man-machine interactions during systems operations. It helps you deal with communication; diagnostic, decision-making, and procedural issues; and training, design, and many other issues related to "human factors" in a way that enables you to define specific problems, needs, and actions.

To apply this Model during investigations or interviews, identify people who appear to have had a role in the incident process. Then begin to look for a change in the activity that would have created a need for action by that person to keep the activity progressing toward its intended outcome.

- When you identify that change, determine whether it emitted some kind of signal that the person *could* have noticed. If it did not, you explore why it did not and what effect that had on the outcome.
- If it did emit a signal, explore whether the person saw, heard, felt, or otherwise "observed" the signal. If the person did not, explore why and what effect that had on the outcome.
- If the person observed the signal, was the signal diagnosed correctly? Was the person able to predict the consequence of the change from the signal and his or her knowledge of the system and its operation? If not, explore why and its effects.
- If the predicted consequences of the change were correctly identified, did the person recognize a need to do something to counter those consequences? If not, explore why and its effects.
- If so, did the person identify the choices for action that were available for successful intervention? Was this a new situation where the action had to be invented? Was this something that prior training anticipated and provided the responses to implement? In other words, was the person confronted by an *adaptive* or *habituated* response? (Here, you start to get into the person's decision-making process and potential personal judgment issues; therefore, explore this area with empathy toward the witness, particularly for adaptive responses.)
- If any response actions were identified, did the person choose the "best" or effective response to implement? If a successful response was not chosen, explore why. To this point, you are asking for observations during an interview.

- If a successful response was chosen, did the person successfully implement the desired action? If not, explore why.
- If a suitable response was implemented, the system adapted to the change without an accidental loss or harm. If the response did not achieve a no-accident outcome, explore why. Often, this leads to discovery of invalid system design assumptions or other design problems.

After working with this model, you will be in a much better position to describe and explain what happened when a so-called "human error" or "failure" is alleged. You will also be in a better position to identify concrete actions to improve future performance of that system.

APPENDIX D
ENERGY SOURCE CHECKLIST

ENERGY TRACE ANALYSIS TABLES

Energy produces changes in objects. This appendix provides a list of energy types for investigators to use as they examine changes in objects during investigations.

Energy produces useful work and occasionally harm or loss. To do work, energy typically must be confined and directed by barriers to the point where the work is to be done. For example, such work takes various forms such as deformation, deposits, chemical reactions, motion, or heating. Work generally produces some change in the prior state of the target object on which the energy works. Investigators need to know that energy leaves tracks when it does unintended work in incidents. Those tracks may be in the barriers that were intended to control the energies or the tracks may be outside the barriers. When looking at changed objects, investigators can use these tables as checklists to look for energy sources that might have produced the changes.

Table D.1 describes natural energy sources. Table D.2 describes energy flow change questions to ask. Table D.3 describes strategies for controlling hazards associated with energies to help with development of performance improvement recommendations. Table D.4 describes managed energy sources.

The symbols ○ = input energy and □ = output energy.

Table D.1
Natural Energy Sources

[ ]Terrestrial	[ ]Atmospheric
❍ Earthquake	❍ Wind velocity, density, direction
❍ Floods/drowning	❍ Rain (warm/cold/freezing)
❍ Landslide/avalanche	❍ Snow/hail/sleet
❍ Subsidence	❍ Lightning/electrostatic
❍ Compaction	❍ Particulates/dust/aerosols/powders
❍ Cave-ins	❍ Sunshine/solar
❍ Underground water flows	❍ Acid rain, vapor/gas clouds
❍ Glacial	❍ Air (warm/cold/freezing, inversion)
❍Volcanic	

Table D.2
ETBA Change Analysis Checklist

Energy Flow Changes	Changes in Barriers
1. Flow too much/too little/none at all	7. Barrier too strong/too weak
2. Flow too soon/too late/not at all	8. Barrier designed wrong
3. Flow too fast/too slowly	9. Barrier too soon/too late
4. Flow blocked/built up/released	10. Barrier degraded/failed completely
5. Wrong form/wrong type input or flow	11. Barrier impeded flow/enhanced flow
6. Cascading effects of release	12. Wrong barrier type selected

Table D.3
Haddon's Ten Strategies For The Control Of Energy Hazards

1. Prevent creation in first place.
2. Reduce amount brought into being.
3. Prevent release of what exists.
4. Modify rate/distribution of release.
5. Separate hazard from exposure in time/space.
6. Separate hazard from exposure by a barrier.
7. Modify basic attributes of hazard released.
8. Make exposures more resistant to damage from hazard.
9. Counter damage already done by hazard.
10. Rehabilitate object harmed.

Table D.4
Managed Energy Sources Checklist

(1) [ ] **Electrical**
- ❍ ☐ AC or DC current flows
- ❍ ☐ stored electrical energy/discharges
- ❍ ☐ electromagnetic emissions/RF pulses
- ❍ ☐ induced voltages/currents
- ❍ ☐ control voltages/currents

(2) [ ] **Mass/Gravity/Height (MGH)**
- ❍ ☐ trips and falls
- ❍ ☐ falling/dropped objects
- ❍ ☐ suspended objects

(3) [ ] **Rotational Kinetic**
- ❍ ☐ rotating machinery/gears/wheels
- ❍ ☐ moving fan/propeller blades

(4) [ ] **Pressure/Volume/Kinetic Displacement (P/V/KD)**
- ❍ ☐ overpressure ruptures/explosions
- ❍ ☐ vacuum
- ❍ ☐ growth
- ❍ ☐ liquid spill/flood/buoyancy
- ❍ ☐ expanding fluids/fluid jets
- ❍ ☐ uncoiling object
- ❍ ☐ ventilating air movement
- ❍ ☐ trenching/digging/earth moving

(5) [ ] **Linear Kinetic**
- ❍ ☐ projectiles, missiles/aircraft in flight
- ❍ ☐ rams, belts, moving parts
- ❍ ☐ shears, presses
- ❍ ☐ vehicle/equipment/movement
- ❍ ☐ springs, stressed members

(6) [ ] **Noise/Vibration**
- ❍ ☐ noise
- ❍ ☐ vibration

(7) [ ] **Dust**
- ❍ ☐ mineral
- ❍ ☐ organic
- ❍ ☐ metallic

(8) [ ] **Chemical (acute & chronic sources)**
- ❍ ☐ anesthetic/asphyxiant
- ❍ ☐ corrosive
- ❍ ☐ dissolving/solvent/lubricating
- ❍ ☐ decomposable/degradable
- ❍ ☐ deposited materials/residues
- ❍ ☐ detonable
- ❍ ☐ oxidizing/combustible/pyrophoric
- ❍ ☐ monomer/polymerizable
- ❍ ☐ chemical toxin/embryotoxin
- ❍ ☐ waste/mixture
- ❍ ☐ water reactive

(9) [ ] **Thermal**
- ❍ ☐ radiant/burning/molten
- ❍ ☐ conductive
- ❍ ☐ convective/turbulent
- ❍ ☐ evaporative/expansive heating/cooling
- ❍ ☐ thermal cycling
- ❍ ☐ cryogenic

(10) [ ] **Etiologic Agents**
- ❍ ☐ viral
- ❍ ☐ bacterial
- ❍ ☐ fungal
- ❍ ☐ parasitic
- ❍ ☐ biological toxins

(11) [ ] **Radiation**
- ❍ ☐ ionizing
- ❍ ☐ nonionizing/laser

(12) ❍ ☐ **Magnetic Fields**

(13) [ ] **Living Creatures or Things**
- ❍ ☐ actions/interactions by people
- ❍ ☐ actions by animals, other species
- ❍ ☐ actions by trees, shrubs, etc.

(14) ❍ ☐ **Moisture/Humidity**

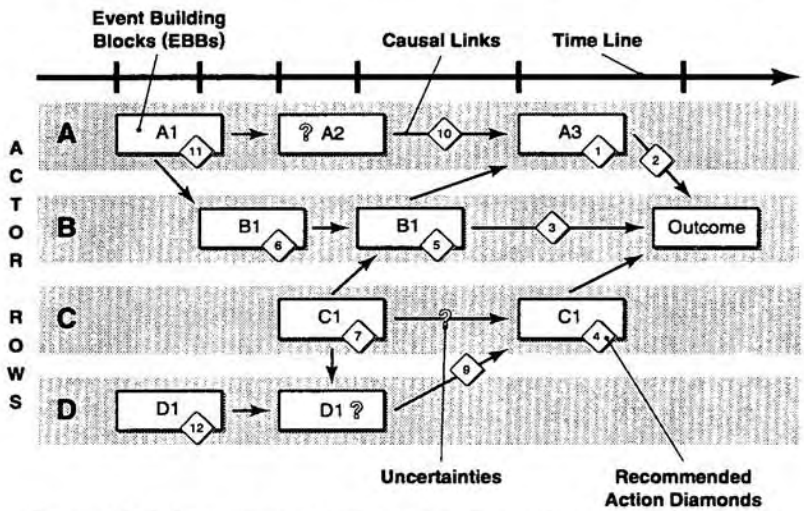
APPENDIX E
INVESTIGATION DATA ORGANIZATION

TIME/ACTOR MATRIX WORK SHEET ELEMENTS

This appendix provides a simple example of the general elements found in a completed time/actor matrix work sheet after it has been completed by an investigator. It includes both the description and explanation elements and the problem and recommendation elements of the investigation task.

Time scales are flexible. The number of actor rows may be increased as needed. The links represent relationships that have been tested with sequential, cause-effect, and necessary and sufficient logic. Uncertainty or unknowns are shown by question marks.

Appendix E Investigation Data Organization



Source: 10 MES Investigation Guides, Ludwig Benner & Associates, Oakton, VA

Note that all events are linked on the completed work sheet. Narrative reports can be written from the work sheet, using the sequenced events. The numbers in the diamonds represent candidate problems identified and addressed by the recommendation development process.

APPENDIX F
QUALITY ASSURANCE FOR INCIDENT DESCRIPTIONS

Your investigation will be remembered only by the report(s) you produce! The best investigation will be wasted by a poor report.

To ensure a quality check of your description of what happened, do the following:

- Eliminate words that can "poison" your work.
- Ensure that all events used have referenced sources and that all referenced source documents are available.
- Ensure that reader can make a mental movie to visualize your incident from the words in the narrative, append visual aids, and eliminate nonessential information.
- Check to see that your spelling, grammar, and syntax say what you intend.
- Make sure that opinions are in opinion sections and are not in descriptive sections of your report. Then make sure that ALL opinions you offer are supported with your rationale and basis for comparative conclusions. A good self-test is to ask yourself whether you could make your opinion stand up under cross-examination by the operator or public.
- Say that you do not know what happened at gaps, and explain why so that the reader will not discover gaps and lose confidence in the whole report.
- Include quotations if a deviation from some standard is noted. Do you use "their" words to show "their" problems? Will your "evidence" survive attacks?

- Include the pictures, sketches, and test reports needed to help you make your points.
- Double-check that your accident description seems believable to informed readers. Is your report complete, correct, consistent, logical, and valid?

To do a quality check of your work sheet, use the following checklist.

- ☐ Is the event block form and its content okay?
- ☐ Are the event block names consistent?
- ☐ Are the sources noted okay?
- ☐ Are the sources in your file?
- ☐ Is the work sheet scope adequate?
- ☐ Are the causal links valid?
- ☐ Are the uncertainties indicated?
- ☐ Is the mental movie supported?
- ☐ Are the question and answer checks completed?

Sign your name to the work sheet if all checklist items are checked.

APPENDIX G
RECOMMENDATION DEVELOPMENT PROCESS

If tasked to do so, develop recommendations to reduce future losses. Investigators may or may not be required to prepare performance improvement recommendations. When recommendations are required, you have to shift mental gears to think about and improve future performance. To do this, you need to know how to discover, define, and assess problems and needs; identify, define, and assess options for reducing future risks; and develop a plan to determine whether the changes implemented are producing the predicted effects.

NOTE: To develop recommendations, you must understand clearly what happened and why it happened, and you need to develop additional and different data to *predict* the effects of future actions you might propose.

To develop recommended actions, an investigator needs to:

- Define candidate problems in terms of who did what when and with what effects (causal links), and restate as a need.
- Determine which problems need to be fixed.
- Select the best technical strategy, and identify candidate controls to fix those problems in terms of who should do what and when.
- Predict "benefit" and "cost" trade-offs of each option, and balance them against each other's "best" candidate recommendations.
- Do a question and answer check of your selected recommendations.

The most efficient way to do these tasks is to use the time/actor events sets on the matrix work sheets showing the accident process. If you are required to define a "cause," make sure you have a recommendation that fixes each "cause."

DEFINE CANDIDATE PROBLEMS

Use the description and explanation of the accident to discover, define, and assess problems disclosed by your investigation.

Using Descriptions

The accident description on the time/actor matrix work sheet identifies all relevant events that need to be examined to discover, define, and assess problems. Thus, it facilitates innovative thinking regardless of your experiences.

Mental movies can provide detailed explanations of what happened, but you typically have more difficulty in finding and defining problems and tend to overlook many problems that are poorly defined. But mental movies are better than other methods. Simplistic determinations of cause, root cause, or causal factors, which are subjective judgments, may or may not accurately identify or define problems or needs.

When you use a work sheet, start by looking for candidate problems by examining one linked event pair or set at a time until all that were necessary to produce the accident outcomes have been studied. Start anywhere, but cover every pair or set on your work sheet. For *each event pair, set,* or *link,* ask yourself questions to determine whether the event or relationship should be considered a candidate problem.

- "Was this event or relationship expected to happen?"
  - — at all?
  - — the way it did?
  - — where it did?
  - — when it did?
  - — why it did?
  - — to whom it did?
- "Can this event or relationship indicate a need for action, and if so, why?"

The answer to each question may suggest a problem event or relationship and that leads to your problem definition in terms of its MOTEL (acronym for magnitude, origin, timing, effects, and location).

- *Magnitude*: how strong or weak or how long the relationship affects something
- *Origin*: whether the relationship should have occurred at all
- *Timing*: how fast, when it happens, or how long it lasts
- *Effects*: who or what it affects and how or when
- *Location*: where it starts or happens in relation to exposures at risk

When you identify a problem, restate it in terms of what needs to get done to eliminate or control it. The wording of the statement of need can establish the objective for any action to fix it.

Does Problem Need Fixing

After identifying all the candidate problems, you need to decide which problem or deficiency is worth fixing. The recommendation development process should separate those worth fixing from those you can afford to live with. Focus on the problems you select to fix. Also, look for recommendations that will fix more than one problem. Usually this decision is most heavily influenced by the extent of the likely future harm if the problem is not fixed.

Document Problems

Record your description of the problem. This description identifies who did what and why this is a problem. Next, describe the action needed in terms of what needs to get done.

Keep track of your efforts on the work sheet by marking each event or link defined as a problem with numbered diamonds or some similar marking system. This notation system helps you to systematically identify events or links considered candidate problems.

Fix Problems

> *Control strategies consist of changing people behaviors or object behaviors.*

As you look at the LINKS, consider introducing changes to achieve:

- *Addition* of other events or relationships between events
- *Elimination* of events or the relationship between events
- *Modification* of observed events, links, or energy exchanges

(See also Appendix C for additional control strategies.)

Any possible change that would favorably change the course of future events indicates a candidate for a possible recommendation. At this point in the search for options, do not rule out any possibilities based on past experiences. Experienced judgment usually recycles previous problems and imposes restrictive limits on the process.

Predict Effects and "Costs" of Each Candidate Option

This task requires knowledge of how things work and how any of the changes would affect future performance if implemented. You usually need help with this part of the investigation from "experts" who can help you predict whether it affects:

- Only one event or link
- Only this specific kind of occurrence
- Several kinds of occurrences in this operation
- Several kinds of occurrences in this organization
- Several kinds of occurrences throughout the area or industry

> *These effects give you a way to state your improvement goal for your recommendation later.*

Identify Trade-Offs to Rank Order Candidates[1]

If you find more than one fix, rank order them to reflect their relative desirability. You must weigh and balance other considerations to help you choose the "best" recommendation(s). These additional considerations might include:

- Who creates, who bears, and who accepts the risks of NOT acting?
- Trade-offs with overlapping priorities such as schedule, quality, cost, motivation, and public opinion
- Credibility of the problem and need
- Any external or internal pressures for change
- Acceptance of the need for and feasibility of implementing the preferred corrective actions
- The effectiveness of the proposed action as perceived by those at risk

Consult with people affected by the potential changes. Be aware that accident prevention or loss reduction or more effective response actions are not the sole basis for acting on your recommendations and that superiors in your hierarchy may veto your planned actions because they give different weights to the same considerations.

As you go through the various steps, you will recognize the differing trade-offs among the various options. The most effective prevention or suppression action may not be worth recommending when weighed against the severity of the accident and other concerns. The least costly may result in unacceptable performance improvements and production delays or may undermine the public's or operators' credibility.

Do Quality Assurance Check

You have to decide whether or not to make any recommendations from each accident. If you identified action(s) that would truly improve future performance and that seemed necessary, feasible, and credible, check their quality before forwarding them.

> *The Bottom Line: Will your recommendation achieve your performance improvement objectives, and will you get convincing proof over time that they did?*

[1] For additional discussion of this task, see Benner, L., *Ranking Safety Recommendation Effectiveness*, International Society of Air Safety Investigators, Proceedings of 1992 Conference, Dallas, TX.

APPENDIX H
BASIC OBJECT TESTING PLAN ELEMENTS

During investigations you may need to examine something to find out what happened. Examinations may address the following:

- Chemical residues from reactions on a wide range of objects
- Debris formed during reactions
- Damaged or impaired parts or components
- Subsystems such as haz mat container or process control systems or "safety" devices

To ensure that you get what you need from any testing work, insist on a test plan that describes what will be done and what that work is expected to produce. This appendix indicates elements of such a test plan. Tailor them to develop any test plans.

CAUTION: Get all the data from objects before you agree to their destruction by testing.

TEST PLAN ELEMENTS

1. *Test/examination objectives*
   Why do you want to do a test on something — to either verify that what you think happened actually did happen or to discover what did happen. Focus on gaps in the incident description that you want to address or the hypothesis for which validating data are sought. If more than one party is involved, you may have to document objectives desired by each of the parties. *Your* deliverables should be events to add to your incident description and documentation of the source data used to define them.

2. *Physical objects*
   Describe the object(s) being tested or examined, and document them with photos to ensure tests are performed on parts everyone expects to be examined. State any protective measures for the objects, and preserve them for more tests or chain-of-custody needs.

3. *General test approaches*
   Use this section to record any general principles for the testers to follow, to document any assumptions before the test begins, and to describe how the objects and tests will be documented. Identify and resolve any differences in the approach. For example, should a device be operated before it is dismantled, or should the dismantling be done before it is operated? Should chemical samples be combined or tested separately? What is the progression from nondestructive examination to destructive testing?

4. *Test/examination procedures*
   State the name of the test protocol and equipment and the citation if it has been formalized in the literature or elsewhere. Define and document the measurements to be produced. Specify chain-of-custody requirements, precautions and responsibilities, points of contact, and any security tasks.

   This section should state the specifications for the deliverables produced and the quality control criteria used to verify the results.

5. *Interpretation of results*
   Hypothesize potential test outcomes, and state how each potential outcome will be stated in event block format. If this task is done properly, the specific outcome may be uncertain, but there should be no surprises at the end of the test. The place to discover differences between you and the persons performing the work is in a backSTEP or logic tree procedure on paper and not after the test has been run, the money spent, and the results unsatisfactory.

6. *Schedule of testing*
   State what work will be accomplished, when it will start and where, the schedule for any drafts to be circulated if applicable, and when deliverables will be delivered.

7. *Distribution of deliverables*
   State who "owns" rights to the deliverables and has authority to distribute them and who can use or allocate them and for what purposes in the future. Specify in this section any confidentiality or security precautions.

8. *Disposition of tested objects*
   State who will specify disposition of the tested object(s) and the time limit for disposition. Anticipated litigation may influence this section.

9. *Funding of test work*
   Specify who pays what to whom. Who will pay for the test(s)? If more than one party is asking for work to be done, who will pay for what part of the test(s)? Who will spend, and who will get what monies? Be aware that this requirement can be used very effectively in negotiations to dissuade proponents of unsound hypotheses to pay for tests or forego them. It separates the "needed" from the "nice to know" work.

OPTIONAL TEST PLAN ELEMENTS

1. *Media inquiries*
   Accidents often generate media interest — especially large ones or one that involved a lot of people. Describe how individuals and organizations actually performing the test(s) should handle media inquiries.

2. *Safety precautions*
   Where risk of injury or property damage is associated with the test procedures, state any required risk control precautions and responsibilities.

3. *Concurrence*
   When more than one party is involved, get every interested party — including the testers — to affix a signature to the test plan signifying concurrence in the plan.

Some Guiding Principles for Test Plan Development

1. Whoever owns the ball calls the game.
2. A golden rule of investigation testing: **NO PLAN, NO TESTS!**
3. Keep test(s) relevant. (Get event blocks.)
4. Scale the plan to the value of the data it will produce.

Test Plan Quality Assurance

The quality-control process begins with checking the quality of the event blocks created during the test. If they are flawed, further use will create problems. Difficulty designing a test plan to produce the supporting data is usually an indicator that the event being sought may not be adequately defined or that the event may have to be broken down further into additional actors or actions to get supporting data. Sometimes you find you are looking at the wrong object to test for the data.

Flow-chart the planned procedures on a time/actor work sheet, especially if any controversy occurs during the planning process or is expected during the test or after the results are received.

The concurrence process will disclose points of difference that may reflect quality problems, as well as differences in opinions among investigators. Forcing funding decisions about who will pay often improves the efficiency and quality of the testing or may motivate alternative analyses plans.

Make sure that the testers are familiar with the work sheet and your event block needs for a work sheet before they begin their planning, testing, or examination.

Source: Benner, L., 10 Mes Investigation Guides, Ludwig Benner and Associates, Oakton, VA, 1994

APPENDIX I
EXAMPLES OF OBJECT TESTING METHODS

Do not confuse these *data extraction methods* with *data analysis methods*. Extraction methods only give data. Analysis methods use the extracted data to get to an understanding of the process being investigated. (Add your own if needed.)

NONDESTRUCTIVE TEST EXAMPLES

1. Visual inspection for residues, deviations from blueprints, deformations, etc.
2. Radiographic inspection techniques, including X-ray, fluoroscopy, and other radiographic scanning techniques
3. Reconstruction of surviving parts in mock-ups
4. Microphotography of parts, residues, etc.
5. Electron microscopic examination of parts, residues, surfaces, etc.
6. Char pattern inspections for burned parts
7. Scratch mark inspections for material displacement or removal
8. Weighing techniques for deposition or removal of material
9. X-ray diffraction examination of crystalline structures
10. Thermal gradient inspection techniques for examination of evidence of temperature gradients experienced by materials
11. Stress pattern inspection techniques for evidence of directions of stressors and deformation of stressees
12. Ultraviolet or infrared photographic examination for evidence of changes of state, blood, and tissue

13. Electrical conductivity/resistance tests (if arcing not involved)
14. Flow tests for viscosity, angle of repose, and air-entrainment data
15. Dimensional analysis documentation to identify changes from as-new condition
16. Dye-penetrant or magnetic inspection for cracks or defects
17. Lubricity tests to identify lubricant service performance data
18. Operating test of subsystem to identify operating parameter data and performance data
19. High-speed photography of operating subsystem to observe timing and nature of process

DESTRUCTIVE TEST EXAMPLES

1. Wet chemical, gas chromatographic, infrared spectrum, and other chemical test methods to identify chemical constituents
2. Chemical tests to identify properties of chemicals such as pH (acidity/alkalinity) tests, miscibility, and reactivity with other materials
3. Physical tests for melting points, boiling points, freezing points; gas, liquid, or solid densities; etc.
4. Metallurgical tests such as charpy, bend, and tensile test methods
5. Micrometallurgical, X-ray, and microphotographic inspections of specimens cut from parts
6. Thermal testing of materials for char pattern data, effluent gas data, rate-of-burn data, residue confirmation data, extinguishability data, BTU content, heat of combustion, and decomposition rates
7. Simulation or reenactment of collision, fire, explosion, etc., to reproduce debris and residues
8. Flash point and autoignition tests to determine ignition temperature data for liquids, gases, dusts, and powders, etc.
9. Toxicological tests for toxicity data; asphyxiation tests for concentration/effects data
10. Chemical liquid and gaseous exposure corrosion tests for material degradation data
11. Polymerization tests for material reaction data
12. Crystal growth tests to identify environment at time of crystal formation

13. Incubation tests for etiologic and infectious agents
14. Electrical flow, conductivity, resistance, arcing, and related tests for electrical behavior
15. Air buoyancy tests for mixing, fallout, and dispersion data
16. Proof-pressure testing of components to destruction to validate design assumptions

APPENDIX J
GLOSSARY OF INVESTIGATION TERMS

Actor
The person or object that does something to influence the progression of the accident process to its loss outcome.

Change
A transition from one steady or dynamic condition to another; may occur quickly or gradually.

Conclusion
A decision or judgment reached after a logical reasoning process.

Data source
Any person or object that has and can make available information about an accident or incident that will help an investigator understand what happened and why it happened.

Deviation
An action that differs from what was planned, intended, or expected and known before the accident began.

Event
The investigators' basic investigative and analytical building block; for investigation purposes, what someone or something did — technically, one actor plus one action.

Incident
An aborted accident process; an incipient accident process that was prevented from igniting or reaching a significant loss level by successful intervention actions by some person(s) or object(s).

Intervention
Actions by people or objects to change the course of events constituting the accident process.

Investigate
To observe and inquire into what happened and why it happened; examine systematically. (Informal: How did what you see come to be?)

Objective
The desired accomplishment for which a task is undertaken.

Observation
A noting and recording of an action, condition, or state by an observer.

Opinion
A belief held confidently, but reached without positive proof.

Process
A system of interacting components producing changes in people and things for the production or achievement of some output.

State
A condition of existence of a person or thing; what is.

Systematic
A set of orderly, structurally interrelated steps based on a coherent network of concepts, principles, and rules.

Witness Plate
Something on or in which is implanted a partial or complete record of events to which it was exposed.

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Additional information can be found in local or state public safety department investigation manuals.

Information about vehicle accident investigation formulas and equations is available in sources such as the TARR *Accident Investigation Handbook* available through the American Association of Safety Engineers, Chicago, IL. Information about recording injuries is available from the American Association of Automotive Medicine or from local medical examiners.

Information about investigations performed within a legal framework can be found in Chapter VIII of the *Field Operations Manual* (FOM) published by the US Department of Labor, Occupational Safety and Health Administration, Washington, DC (1993).

ISBN 0-87939-141-3