Air Safety Investigation
The Journey

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Air Safety Investigation - The Journey

Michiel Schuurman

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Keywords: Air safety investigation, air safety, investigation, logic, critical thinking.

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Dedication

I am dedicating this book to the many students I have taught over the years, who inspired and encouraged me to write this book. With the best of intentions and a lot of hard work, including many sleepless nights, I have written this book in the hope that it will be a valuable resource for students and future generations. While not everyone may become an investigator, having a safety-oriented mindset can benefit in enhancing the overall industry safety standard. I hope that this book will inspire and educate those who read it, and contribute to the ongoing efforts to improve safety in the aviation industry.

Special acknowledgements go to my wife, who has been a great support throughout this process. I am grateful for her shared interest in safety investigations.

Thank you to all who helped me publish this book.

Michiel Schuurman

Introduction

As a former senior air safety investigator and current assistant professor, I have dedicated my career to understanding and improving air safety. In this book, "Air Safety Investigation: The Journey", I draw on my years of experience investigating airplane accidents and incidents in order to provide a comprehensive guide to the principles and practices of air safety investigation.
In six chapters, I will lead you on a journey through the different steps of an air accident investigation. We will start with the initial field investigation and end with the final reporting and recommendation phase. Along the way, I will share inspirational stories and examples to help you get familiar with the process of conducting an investigation. By highlighting possible pitfalls and challenges, I aim to provide the reader with a deeper understanding of the complex and demanding field of air safety investigation. Whether you are a professional investigator, an aviation student, or simply interested in the inner workings of air safety investigation, this book will provide valuable insights and practical knowledge that will deepen your understanding of this critical field. So strap in and join me on this journey into the world of air safety investigation.

In this book, we will look at the process of investigating a major aviation accident. However, in many cases, this process is no different than investigating smaller, less serious incidents. We will start with answering the question "What is a Safety Investigation?" in Chapter 1. This chapter gives background information on accident investigation procedures and process. Furthermore, some insight will be given on how to investigate an event and perform the investigation effectively. With this background information, the stage is set for the next chapters.

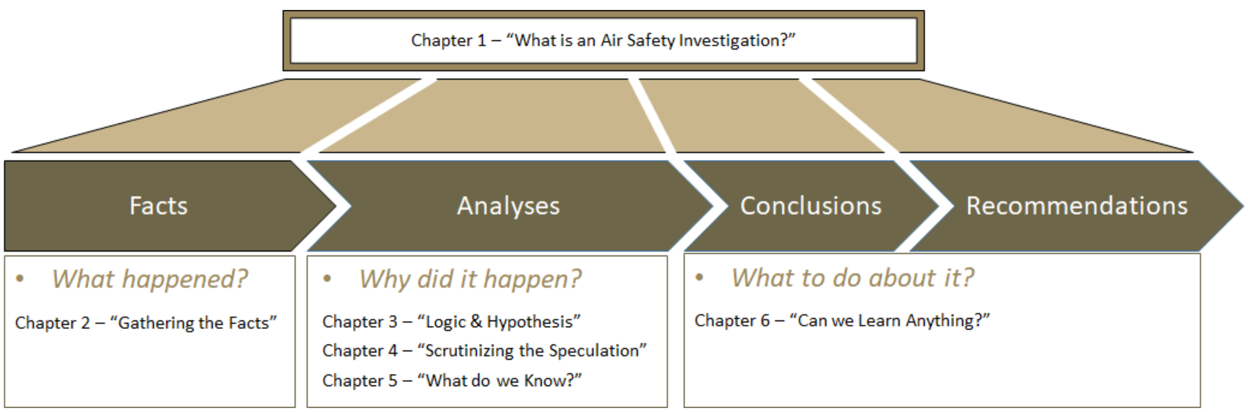


Figure introduction 1: Book structure with chapter overview and investigation steps.

The next step in our investigative journey is Chapter 2, "Gathering the Facts". The main aim in this chapter is to explain how we can find out what actually happened by gathering facts. Gathering the facts is a hands-on task performed at an accident site, and it is of the utmost importance to have a thorough understanding of the process and the steps that need to be taken during the investigation. This chapter will therefore focus on things to note and common pitfalls while performing the field investigation.
The description of the analyses phase starts with Chapter 3, "Logic & Hypothesis", where we will examine different types of logic and explain how to formulate a hypothesis. It seems trivial, but understanding logic and knowing how to use hypotheses is vital to the analysis phase of an investigation.

Chapter 4 "Scrutinizing the Speculation" and Chapter 5 "What do we Know", focus on how the available (mis)information can be examined and validated. As finishing up the investigation and writing the report takes priority, these two steps are often skipped in an investigation due to (time) constraints. However, these two steps serve a purpose; sometimes it is necessary to take a step back from the investigation and re-evaluate what the investigation is all about; thus, what do we (really) know? As mentioned before, Chapters 3 to 5 describe the analyses phase of the investigation. In this phase, the general question "Why did it happen?" is answered.

Finally, in Chapter 6, "Can we Learn Anything?", the aim is to explain how the question "What can we do about it?" can be answered. In other words, this chapter explains how recommendations based on the accident can help to prevent future occurrences. Although one would think that carrying out a thorough investigation and finding the cause will result in a perfect outcome, this is not always the case. Closing the loop, which means making appropriated and substantiated recommendations to enhance future safety, is difficult. The formulation of recommendations is a challenging but essential part of an investigation.

Let the journey begin.

How to read this book

The main text (in black) explains the essential knowledge for the various investigative steps. This is also the text of your investigative journey. Each chapter will be preceded by a Greek myth that exemplifies the core thought of the chapter. Feel free to jump to a chapter that grabs your attention. However, the book has been written as a journey, reading the chapters sequentially is therefore advised. Still, it should be noted that the investigative journey is long and at times difficult. When the top of the mountain is not yet reached, a final push is required before you can relax and enjoy the view. Some chapters of the book might be dense in information, so take your time and reflect on what the chapter means to you. Students have suggested not to read the book in one go; at most do a chapter a day.

In several chapters, Investigator Top Tips are given, which give a memory aid or describe best practices for performing an investigation. Just as an investigator is not afraid to ask questions, I have included some common questions I receive from students when teaching, as these questions are very relevant. The answers will provide you with a positive learning experience without having to read the full paragraph.

In the course of the book, one case study, "Finding the Truth in Falsehoods" will illustrate the content of the chapters. The aim of this case study is to let you think and reflect about each chapter. The stories and cases used are based on real-life situations, but changed for educational purposes, in order to show good investigation techniques and approaches. With the help of these stories and tips, I hope to help you overcome your first challenges as an investigator.

After each chapter, several questions are included to quiz your knowledge and understanding. The answers to the questions can be found at the back of the book. Please read and think carefully before answering the questions, as they are intended to help and verify you understanding of the chapter. When you are unsure, don't hesitate and re-read the chapter or ask for help from a fellow student or friend. Similar to a journey or investigation, doing something together is always better.

Before we start, I want to emphasize that this book does not cover general information about aviation. It assumes the reader has basic knowledge of aviation; this can be found in *Pilot's Handbook of Aeronautical Knowledge* (FAA-H-8083-25B)[FAA, 2016)].

Figure 0.1: Greek temple.

We will start our journey through ancient Greece by looking at a Greek temple. Temples are grand buildings of a simple design, starting on a solid foundation. On the outside, the foundation is surrounded by columns which support the roof. The temples were freestanding and designed to be seen from all sides. Although it is a simple design, temples serve a purpose. Greek temples were not meeting places for people, but instead served to store offerings and house the statues of gods. Around the temples, storytellers could be found. In each chapter, a storyteller who walks around the temple will introduce us to an ancient Greek myth.

Chapter 1 What is an Air Safety Investigation?

Introduction

Before beginning an air safety investigation, it is important to determine the purpose of the investigation. In case of a major accident with fatalities, with emotions running high, it is good to have a plan and establish ground rules beforehand. Having rules and a structure on how to approach an investigation will help in carrying out and reaching the investigative goal. This chapter will explain what an air safety investigation is and what it is not, what the general process is for an investigation, and how it is organized. This knowledge is required to be able to understand the air safety investigation process which will be discussed in the succeeding chapters. Now, let us begin and start the journey.

Why Air Safety, Not Air Crash Investigation?

Several well-known TV shows and documentaries exist that dive into the world of air crash investigations. These shows portray the investigation as a singular path, where evidence is found piece by piece and in the correct sequence. This bite-size presentation of evidence in sequential order helps to explain the event to the TV audience. The goal of the TV show is to show why the crash happened, as well as to entertain. This is all done in 30 minutes to 1 hour, not including commercial breaks. An air safety investigation is very different: there are no commercial breaks, and investigators are constantly challenged, as there is no script, and pieces of potential evidence are all around, or maybe not. The eventual outcome is unknown, and not only the investigators have questions.

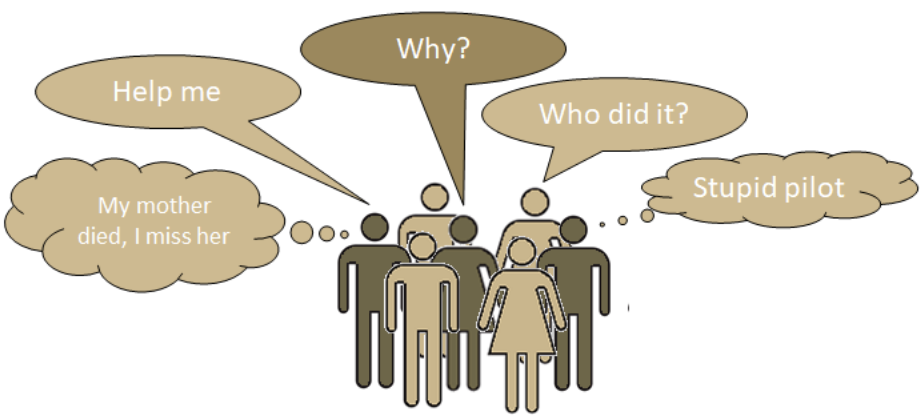


Figure 1.1: Public emotions and questions following a major aviation accident.

After an event, the public and the media have many questions and they demand information. The crisis management and aftercare following an accident take some time to set up. In the meantime, as time goes by, questions turn into frustration and sometimes anger. It is important to acknowledge the emotions following an accident. However, it is not the goal of an air safety investigation to address these emotions. There are rules and regulations in place that govern family assistance following an aircraft accident. It speaks for itself that this is separate from the investigation. It seems harsh in reading this but the goal of an air safety investigation is to improve aviation safety.

An investigator in an investigation should be calm and collected in order to the job. Being led by emotions does not help in carrying out an investigation. As an example, in the past an active air safety investigator was involved in an event himself. Therefore, for the investigation the safety board of another country was requested to carried out this investigation. Apart from the emotions involved, another reason for this is possible conflict of interest. In order to carry out a professional and independent investigation, one should make sure that emotions or other pressures are not part of the investigation.

Again, I want to be clear that it is important to acknowledge the emotions and the suffering that come with an accident. But for an investigator, emotions will not help in solving the event. You might miss valuable information or clues if you are distracted by emotion. Can you think of something recently that made you emotional?

> Student question: What happened to me that made me emotional? I just failed an exam last week. I hate the topic and the lecturer is bad!
> Answer: I'm sorry to hear you failed the exam. Can you take a step back and ask yourself why you think you failed? Be honest, was is because you didn't study? You just said you hate the topic. Or, did you start studying at the last minute? I know, a long time ago I was a student too. For a lecturer it is also interesting to know why you failed. It could be, but I'm not saying this is the case, that the teaching material is unclear. It could also be that the examples given may not be sufficient for you. You may have needed more exercise material to understand the topics. Failure is not bad; it is an opportunity to learn. Just like an accident where something went wrong, let us try to see what we can learn and prevent it from happening in the future.

Another aspect to remember is that, just like you investigate without emotion, you should also refrain from using emotional words in an air safety report. The word crash has an emotional ring to it, compare this to an air accident or incident which is more abstract description of the event and not emotional. The report title should not be similar to the TV show titles or words used in the trailers to promote these shows. Now that we have established why we will use the term 'air safety investigation', we will look at the procedures and rules to carry out an investigation.

The Vade Mecum for Accident Investigators

In order to conduct a successful investigation, given the wide variety of people and interests involved, internationally recognized guidance material is required. The vade mecum, a guide is that is kept constantly at hand for consultation, for investigators is Annex 13, "Accident and Incident Investigation," of the international regulations published by International Civil Aviation Organization (ICAO). ICAO is a United Nations organisation that coordinates the principles and techniques of international air navigation, and fosters the planning and development of international air transport to ensure safe and orderly growth of the aviation sector. It is not a regulator, but has laid down basic principles for accident investigation that aims to ensure aviation safety. Annex 13 lays down the basic rules governing air safety investigations worldwide. The first edition of Annex 13 was published in 1951 and it is regularly updated to reflect new policies or incorporate rules regarding new technologies. In Annex 13 paragraph 3.1 [ICAO, 2020], the objective of an investigation is defined as:

"The sole purpose of an accident or incident investigation shall be to prevent accidents and incidents. It is not the purpose of this activity to apportion blame or liability."

The definitions of the terms ‘accident’, ‘serious incident’ and ‘incident’ according to Annex 13 is shown below. Please note that this is a condensed version of definitions. A more detailed description can be found in Annex 13 – Aircraft Accident and Incident Investigation [ICAO, 2020]

Annex 13 definitions [ICAO, 2020]

Accident. An occurrence associated with the operation of an aircraft which takes place between the time any person boards the aircraft with the intention of flight until such time as all such persons have disembarked, in which:
a) a person is fatally or seriously injured as a result of:
— being in the aircraft, or
— direct contact with any part of the aircraft, including parts which have become detached from the aircraft, or
— direct exposure to jet blast,
b) the aircraft sustains damage or structural failure which:
— adversely affects the structural strength, performance or flight characteristics of the aircraft, and
— would normally require major repair or replacement of the affected component
c) the aircraft is missing or is completely inaccessible.

Serious incident. An incident involving circumstances indicating that an accident nearly occurred.

Incident. An occurrence, other than an accident, associated with the operation of an aircraft which affects or could affect the safety of operation.

Annex 13 also stipulates who and in which capacity can work on an air safety investigation. It may come as no surprise that people involved in an air accident themselves (pilots, passengers, etc) cannot conduct the investigation. In general, only governmental employees and designated specialists are allowed to participate in an investigation. More details on participation can be found in Annex 13.

Seeing Double: The Safety and Legal Investigation

Another matter that should be addressed are the two different investigations that are conducted after an air accident: a judicial investigation and safety investigation. Both investigations serve a different purpose and are conducted by different agencies or organizations. Judiciary investigations are typically conducted by law enforcement agencies or by the courts and are focused on determining the facts of a case and determining whether there is sufficient evidence to bring charges against an individual or group of individuals.

An air safety investigation, on the other hand, is carried out with the objective to make recommendations based on the facts in order to avoid future accidents or events of a similar nature. This means that the focus of an air safety investigation lies in discovering what happened leading up to the event and learning from it to prevent future events or mitigate their outcomes.

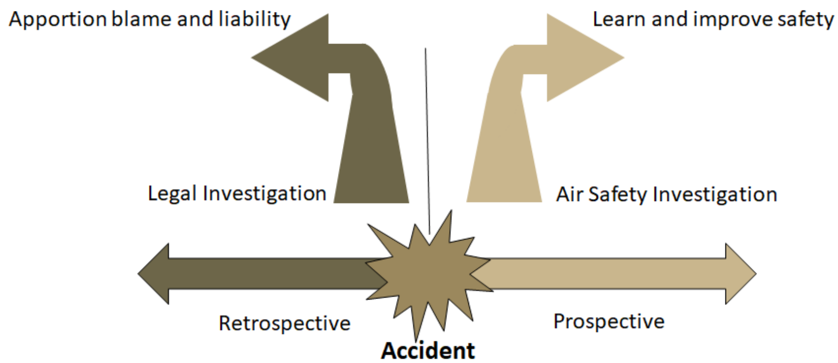


Figure 1.2: Difference between the legal investigation and air safety investigation.

As in most cases, there is one accident site, which means that both the legal investigation and air safety investigation need to coordinate access and primacy. Another aspect is the safety information gathered during an investigation and the final report in relation to the legal investigation. Annex 13 paragraph 5.12 [ICAO, 2020] gives a description of which information should be protected and, in some cases, withheld from public disclosure in order to reach the safety objective of an air safety investigation. For example, names are withheld from the public, as it does not matter for the safety investigation who were involved. If names and references to individuals would be published, the future cooperation of people involved in an event might be compromised.

This is also noted in Annex 13 [ICAO, 2020]: it is in the interest of safety to not disclose personal information to investigators as it will hamper future access to information. Lack of access of such information would impede the investigation process and seriously affect aviation safety. In other words, a constant balancing act is necessary between protection and openness. Although the information of an air safety investigation is often protected, this depends on the country. Rules and regulations differ and sometimes the public (legal) weight tips the balance.

> Student question: Which investigation is more important, the safety or the judiciary investigation?
>
> Answer: Both safety investigations and judiciary investigations serve important roles and are necessary for the functioning of society. Judiciary investigations are carried out to determine whether a crime has been committed and, if so, to identify and hold accountable those who may be responsible. Safety investigations are conducted in order to identify the cause of an accident or incident and identify any factors that may have contributed to it, with the goal of preventing similar accidents from occurring in the future. It is not possible to say that one type of investigation is more important than the other, as both serve different but equally important purposes.

Investigation process

Following Annex 13, the investigation process is a set of activities that are aimed to achieve the result of enhancing aviation safety through recommendations. The recommendations are written down in a final accident investigation report, which explains by analyses how the facts relate to the outcome. In order to understand the investigative process, it is necessary to study the accident scene and systematically work towards writing the final report.

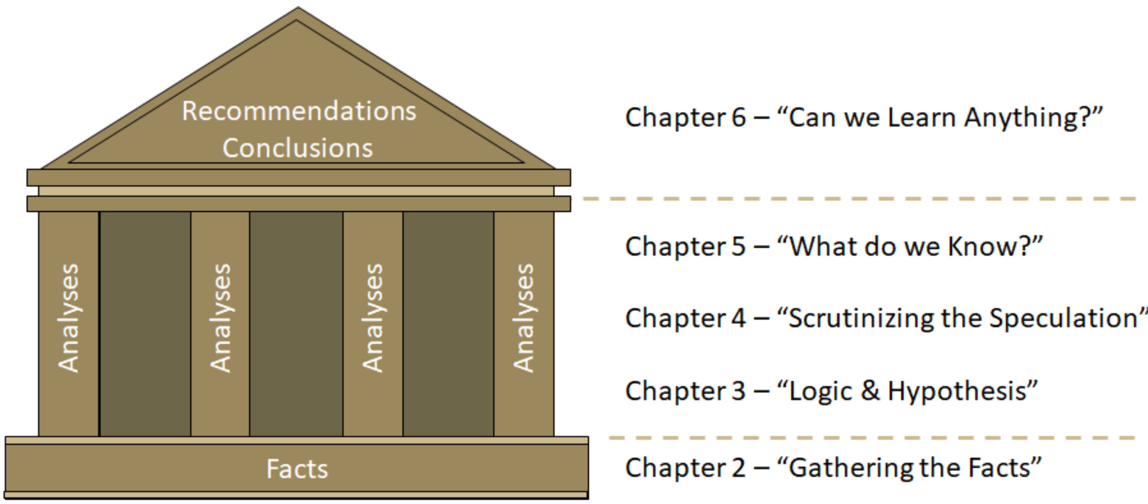


Figure 1.3: The investigative temple showing the facts as the foundation for the analyses, conclusion and the recommendation.

The first step in the investigative process is data collection, or finding the facts. In this phase, either a field investigation and/or desk research information related to the accident is collected. The field investigation entails the observation of the technical system in its (failed) state after the event. Samples of fluids (fuel, hydraulic etc.) may be collected for further testing, if required, and records (papers, manual, etc.) may be taken for examination. During the field investigation interviews with witnesses and other relevant parties are also conducted. A concurrent fact-finding process is desk research, by which I mean finding the facts that are "outside" the field. This may focus, for example, on aircraft documents, training records, manuals, weather reports, etc.

It depends on the event which desk research is required. However, it is standard procedure to study certain records to establish the airworthiness of the aircraft and the experience of the pilots involved. Looking for similar events may also give a hint of what to look for and to reflect on in the analyses. One aspect to keep in mind during the data collection process is the time (in)dependence of the facts. Some types of evidence may disappear, for example traces washing away in the rain, which will mean you will lose evidence. This means that most likely, the field investigation is very time-critical. On the other hand, manuals and certificates are safely stored and are therefore not as time-critical to study. This does not mean you should not retrieve them, but this has a lower priority at the start if the investigation. The balance between factual needs and time criticality must be kept in mind during the investigation.

The next investigation phase is to analyse the facts. This is done by evaluating the available evidence in order to establish the sequence of events, which may in turn determine the cause of the accident. Sequential ordering of the facts and creating a timeline can help in the analysis. In this phase it is important to apply logic and create hypotheses, so that potentially valuable lessons to be learned are not overlooked. The scientific process of objectively establishing facts through testing and experimentation can further help in narrowing down possibilities or to substantiate what is known. Examining the wreckage pieces in more detail and establishing the failure mode will possibly unlock more information that can help in analysing and solving the event. During this process, it is also important to scrutinize the evidence and address any possible speculation or bias that may have crept into the investigation. Once the case has been evaluated and re-evaluated, it is time to establish what you really know; not what you think happened, but what you know happened, as determined by verified and weighted facts. The final step is to draw conclusions and make recommendations based on the investigation process in order to improve safety and prevent similar occurrences in the future.

It is important to follow these steps in the correct order, so as to reach a successful outcome. A common mistake is thinking that a successful investigation is one that results in establishing only one cause of the event. But remember, this is not a pass or fail test, but an investigation. In fact, if multiple safety issues were identified during the investigation, which could prevent future events, this is a good result. Furthermore, identifying other safety issues or risks not directly related to the event is also a good result, as this will help to prevent future accidents which may not have occurred yet. And finally, just as in science, reaching no definitive outcome or cause does not mean the investigation was unsuccessful. Therefore, an investigation is never ineffective or in vain.

As you may have noticed, the phases in the investigative temple as described earlier are similar to the titles of Chapters 2 to 6 of this book. This explains the setup of the book and shows the journey you are taking. It should be no surprise that the final accident report format as prescribed by Annex 13 has a similar chapter order.

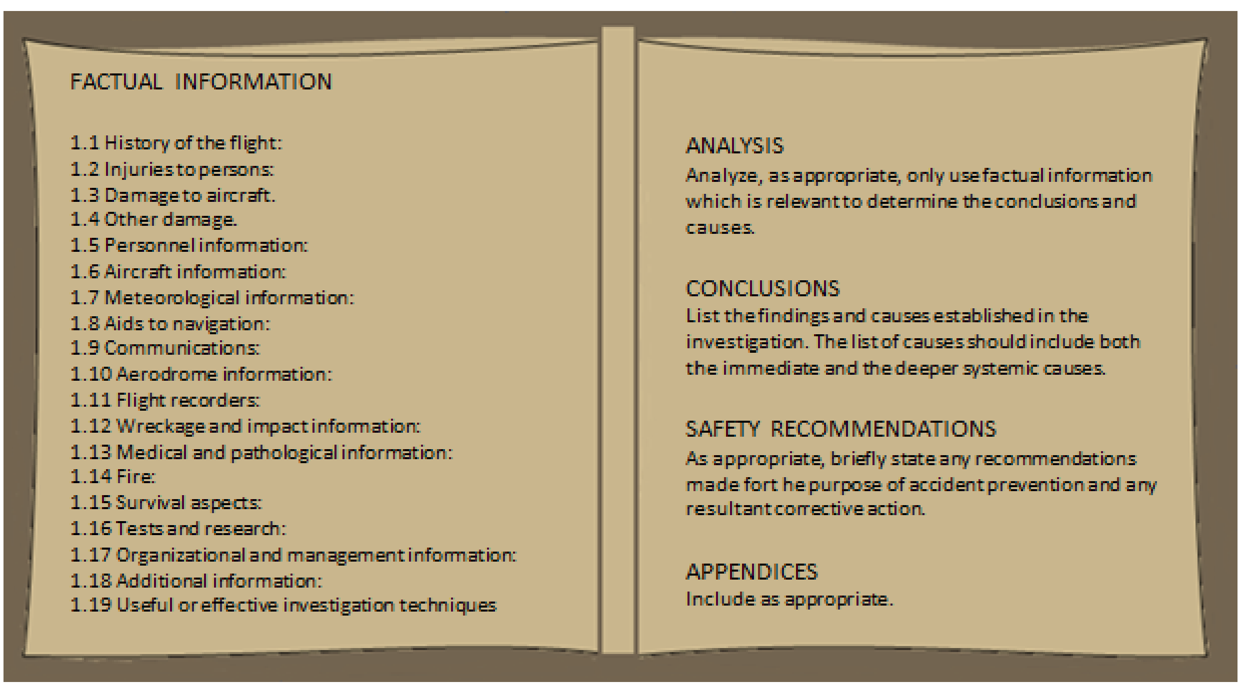


Figure 1.4: Format for the Air Safety Investigation Report according to Annex 13 [ICAO, 2020].

Report Audience

It is crucial to consider the audience when crafting a message or piece of written work. In writing this book on air safety investigation, I carefully tailored the content and style to ensure that it is relevant, understandable, and engaging for the reader. By including elements such as Greek myths and real-life case studies, I aim to provide a rich and immersive learning experience that will help you to better understand the subject matter. Additionally, by including questions from students in the text and exercises at the end of each chapter, I hope to stimulate your thinking, which in turn will enhance your understanding and hopefully enjoyment of the book. Overall, by considering the needs and preferences of the intended audience, I have strived to create a work that is both informative and enjoyable for the reader.

Similarly, the primary audience of an accident investigation report is a person, group, or organization that, with the knowledge of the report, can contribute to greater aviation safety. The audience can achieve this aim by gaining knowledge from the report or by taking action following a recommendation in the report. Thus, the potential report audience, who may bring about changes in air safety, is rather broad. This creates an inherent problem, as the technical knowledge varies per audience type; therefore, it is important to make sure the appropriate language is chosen to reach the greatest effect in bringing about change. Not only the relatively small group of aviation specialists should read the report; this could, in theory, hamper its effectiveness. On the other hand, writing a report for too broad an audience may make it too superficial and too simple, so that the true scope and depth will be lost.
It is clear that the industry, government, media and general public are all important audiences.

However, keep in mind that the objective of an investigation is to produce a well-written report with effective recommendations to enhance aviation safety. The target audience should not be used as a reason to adapt the report's language or complexity. Instead, the report should be tailored to an audience that can improve safety. Although it is understood that government agencies need to acknowledge the public (taxpayers), this particular audience may benefit more from another communication method. In some cases, a public-friendly report or summary can help deal with the diversity of the audience. However, care and time should be taken to at least partially explain the complexity of the accident and not oversimplify the cause. Journalists are looking for a headline; this does not mean the headline will improve safety. It can, however, help in spreading the message. The public has a right to know what has been investigated and what the results were.

Organizing an Investigation Team

In order to organize an effective investigation, it is important to understand different organization types. The control structure of an organization can be categorised as centralized or decentralized. Furthermore, an organization can have two different social structures: either formal or informal. According to Charles Handy, organizations can be categorized based on the level of control and social structure. He described each organization type as being associated with an ancient god: Dionysus (The Existential Culture), Zeus (The Club Culture), Apollo (The Roles Culture) and Athena (The Task Culture). According to Handy, Athena is the god who represents a ‘task culture’, where the organisation is focused on solving a series of problems. The task culture usually consists of a team, study group or committee that works on solving a problem. The problem to be solved goes beyond the scope of one individual and thus this organisation relies upon team interaction. By getting together the right experts and the appropriate resources, the task will be completed quickly. The organisation structure is flexible and can change depending on the task.

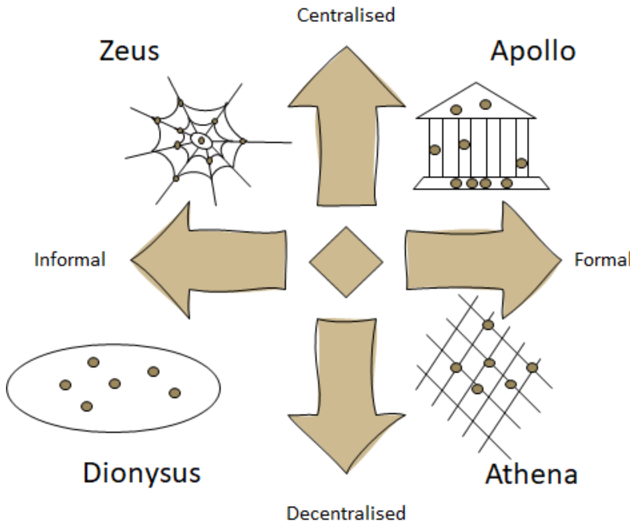


Figure 1.5: The Gods of management by Charles Handy [Handy, 1996] [no further use is allowed]

A safety investigation board, such as the National Transportation Safety Board (NTSB) in the United States of America, could be considered an "adhocracy organization", which is a type of organization that is characterized by a focus on innovation, flexibility and adaptability. These adhocracy organizations are well suited to tasks that require a high degree of creativity and problem solving, and they often rely on cross-functional teams and networking to get things done. However, adhocracy organizations can be unpredictable and chaotic, and they may struggle to maintain stability and control in times of crisis or uncertainty.

In order to maintain control and stability during a crisis, it is of the utmost importance to have the right people working on the right task. The “party system” is therefore usually adopted in a major accident investigation. This is similar to the task culture of Athena, where each group of experts investigate a subtopic (part) of the accident. At the top is the Investigator In Charge (IIC) who will make sure all the (sub)tasks are completed and the facts are found. An IIC has year of investigative experience and is qualified to be in charge of an air safety investigation.

After a major accident it is not uncommon to have a large number of people involved in the investigation, with various backgrounds and expertise, which is necessary for a successful investigation. As Annex 13 gives certain parties (government, air safety personnel, airline, air traffic control, etc.) specific rights and obligation to participate in an investigation, the structure needs to be flexible to accommodate these various experts. This explains the term “party system”.

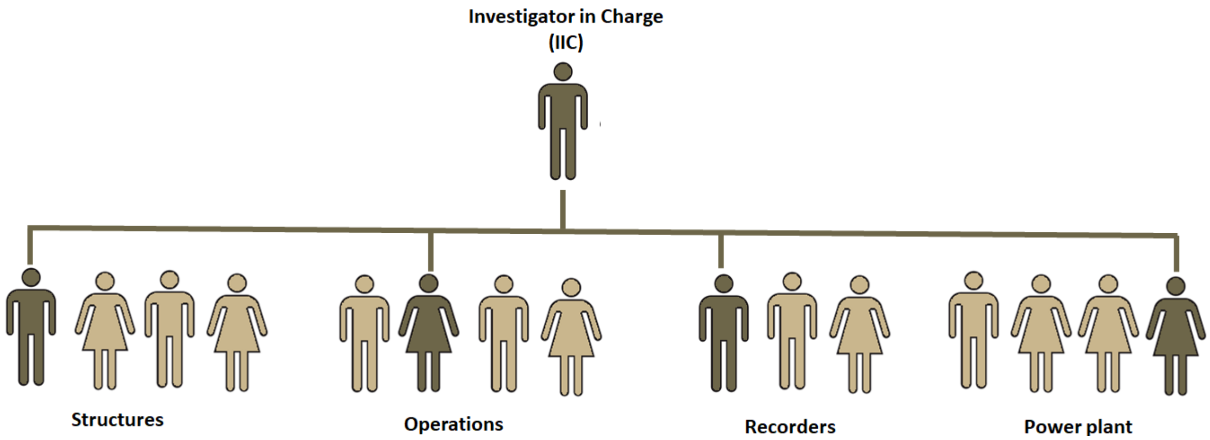


Figure 1.6: Overview of the "party system" with the Investigator in Charge (IIC) leading the investigation. The group chairpersons are each responsible for a specific investigative task. Each chairperson is assisted by a group of experts.

By implementing the "party system", relevant expertise from different parties involved can be used to assist in the investigation. This ensures that the investigation is done effectively and is evenly balanced, as different parties to the investigation all contribute. Each group of experts is headed by a group chairperson. The group chairperson reports to the IIC on the progress and facts found. The chain of command from the IIC to the group chairmen and group members further ensures the investigation is done effectively.

> Student question: Are other organisation structures not used in an investigation?
> Answer: No, in general an investigation is very task oriented with rules how to do it (formal) and many different people (decentralised). In order to get the fastest outcome this type of organisation has proven itself.

Summary

This chapter examined the question "What is an Air Safety Investigation?" The general investigation process was explained and elaborated using Annex 13. The goal of an Annex 13 is to prevent accidents and incidents in the future or to mitigate their consequences. It is not the purpose of an investigation to apportion blame or liability. As the investigation ends in writing a report, the structure and goals of an investigation report were discussed. The main aim of a report is to enhance aviation safety, and thus the report must be tailored to those who can make the necessary changes to achieve this. However, an extended summary or a separate public version of the report can be wise to bridge the gap between readability and complexity and make the results known to a wider audience.

Finally, the investigation team and its organisation were discussed. For an efficient investigation it is important to have the appropriate management structure. The investigative group structure, the "party system", is a useful group management structure to accomplish the investigate tasks. The Investigator in Charge (IIC) is the lead accident investigator, who will make sure all investigative tasks are performed.

The IIC is assisted by several group chairpersons, who are each tasked to perform a smaller part of the investigation. The group chairperson leads a group of experts who are qualified to perform that particular part of the investigation. For each investigation, irrespective of the event type and complexity, it is important that the IIC uses the available resources as effective and efficiently as possible.

Questions: What is an Air Safety Investigation?

Question 1: What is the goal for using the party system in an investigation?

A. The party system makes sure everybody can work on the accident and has a task to do.
B. The party system uses the skills and experience of investigators to accomplish a task.
C. The party system is aimed to provided work for all investigators depending on the task.
D. The party system uses the skills of investigators in order to work efficiently.

Question 2: What is the objective of an ICAO Annex 13 Accident and Incident Investigation?

A. To prevent accidents and incidents
B. To prevent accountability and conspiracy
C. To minimize the chance of an accident
D. To prevent risk and harm to persons

Question 3: What does the acronym IIC stand for?

A. Investigator and Incident Coordinator
B. Investigator in Charge
C. Inspector in Charge
D. Incident Inspector in Charge

Question 4: Who is not the intended audience for an Annex 13 air safety report?

A. Judge
B. Public
C. Aviation product manufacturer
D. Aviation community

Question 5: What is the chapter sequence in an Annex 13 report?

A. Facts, Evaluation, Conclusion, Recommendations
B. Evidences, Analyses, Conclusion, Recommendations
C. Evidences, Study, Decision, Sanctions
D. Facts, Analyses, Conclusion, Recommendations

Question 6: What differentiates an accident from a serious incident?

A. There is no difference, both are the same,
B. An accident differs from a serious incident as it relates to aircraft damage.
C. The difference is in the type of aircraft involved.
D. The difference lies only in the result.

Exercise 1 (Regulations)
Read part 831, Investigation procedures, of the NTSB carefully and answer the questions below [CFR (2017)].

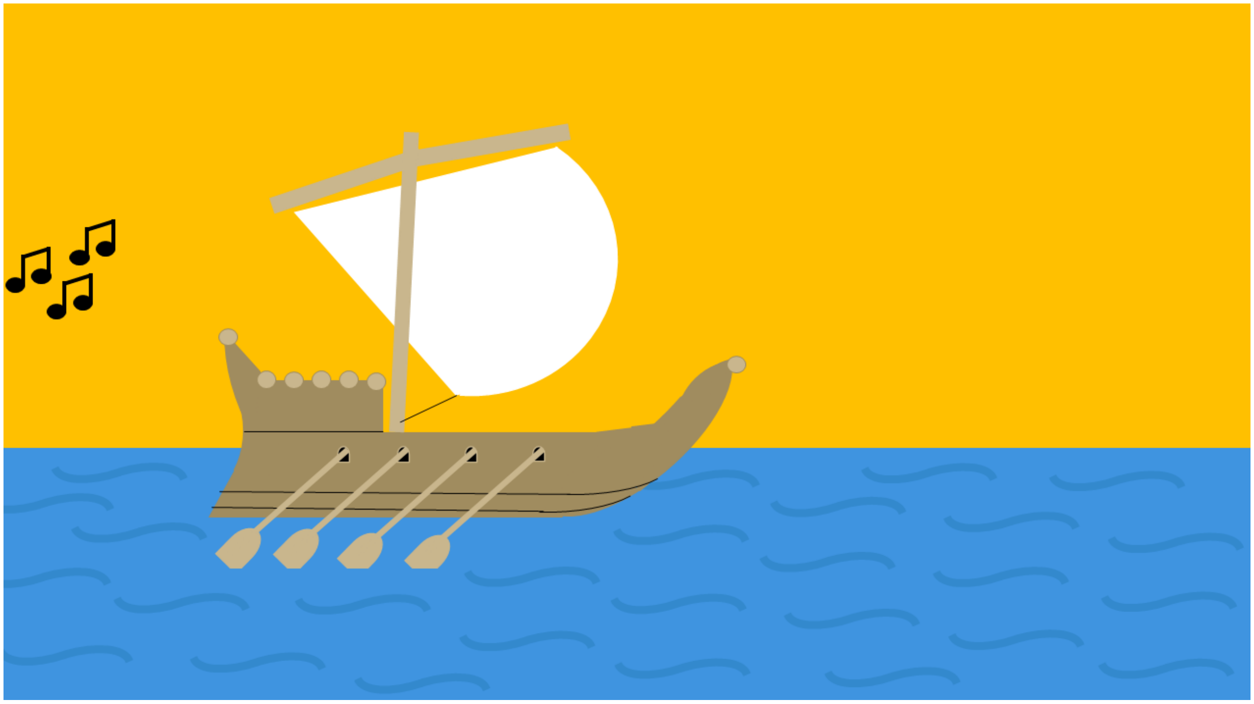
> *PART 831—INVESTIGATION PROCEDURES*
> *Subpart A—General*
> *831.4 Nature of investigation.*
>
> *(a) General. The NTSB conducts investigations, or has them conducted, to determine the facts, conditions, and circumstances relating to an accident. The NTSB uses these results to determine one or more probable causes of an accident, and to issue safety recommendations to prevent or mitigate the effects of a similar accident. The NTSB is required to report on the facts and circumstances of accidents it investigates. The NTSB begins an investigation by monitoring the situation and assessing available facts to determine the appropriate investigative response. Following an initial assessment, the NTSB notifies persons and organizations it anticipates will be affected as to the extent of its expected investigative response.*
> *(b) NTSB products. An investigation may result in a report or brief of the NTSB's conclusions or other products designed to improve transportation safety. Other products may include factual records, safety recommendations, and other safety information.*
> *(c) NTSB investigations are fact-finding proceedings with no adverse parties. The investigative proceedings are not subject to the Administrative Procedure Act (5 U.S.C. 551 et seq.), and are not conducted for the purpose of determining the rights, liabilities, or blame of any person or entity, as they are not adjudicatory proceedings.*

Exercise Question 1.1: According to article 813.4, does the NTSB conduct all investigations? (explain)
Exercise Question 1.2: According to article 813.4, can every party be involved in an NTSB investigation? (explain)

Exercise 2 (Example Event)
Examine the synopsis and provide answers to the questions with this limited information.

SYNOPSIS: A Cessna 172, AB-CDE, with a solo Student Pilot on board, was given clearance by the Air Movements Controller (AMC) to backtrack and line up on Runway (RWY) 25 at Foxtrot Airport. While AB-CDE was taxiing, a second Cessna 172, GH-JKL, with a Flight Instructor and Student on board, was given take-off clearance on RWY 35. As GH-JKL was climbing away, the AMC saw that AB-CDE had become airborne from RWY 25 without clearance.

Exercise Question 2.1: What is the occurrence (event) description of this event?
Exercise Question 2.2: What is the occurrence (event) rating for this event?



Odysseus

After Odysseus elected to go back to Ithaca he was warned of dangers on the way back. Odysseus would be traveling past the Sirens who, with their singing, be enchanting and will not let you leave once you will hear them sing. This danger was real and Odysseus made a plan which he could hear the sirens but not the crew. Therefore, he made his crew fill their ears with beeswax which made them not hear the sirens. Odysseus was tied to the mast so he could not escape.

When the ship sailed past the Sirens Odysseus wanted to break free but he couldn't. the crew did not react to the Sirens as they could not hear. Odysseus sailed passed the Sirens without a problem.

This myth shows that common sense and the plan to protect oneself and one's crew are vital. It also highlights the importance of having a plan and sticking to it, even if it may become uncomfortable.

Based on the Odyssey by Homerús

Chapter 2 Gathering the Facts

Introduction

To start an investigation, we need a solid foundation, the foundation of facts (Figure 2.1). Only when the facts are gathered, we can continue to analyse, draw conclusions and make recommendations. This chapter will examine the way in which facts are gathered, how to do a field investigation and what other sources can be looked at during an investigation.

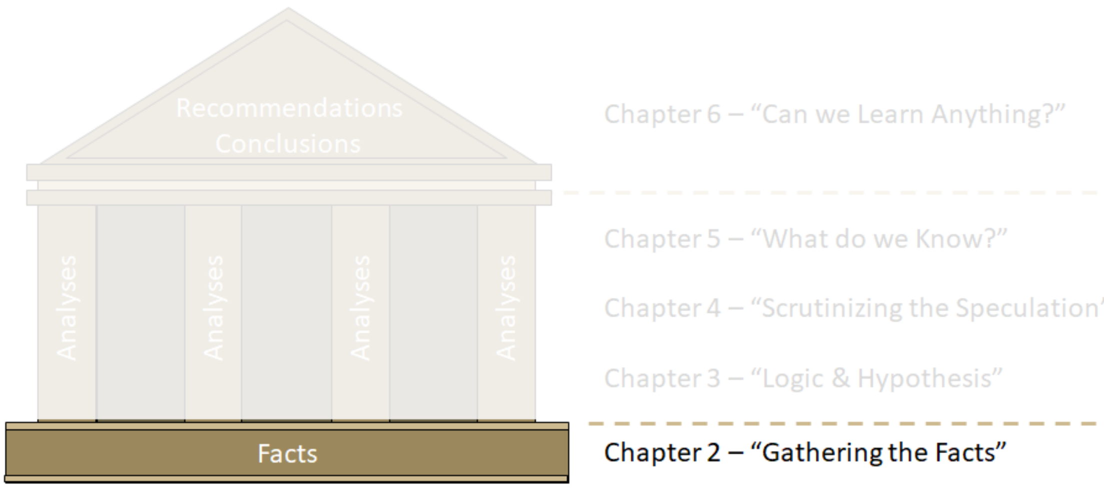


Figure 2.1: The investigative temple with the foundation of facts, as described in the chapter Gathering the Facts.

Field Investigation Tasks and Challenges

Going on scene as an investigator is a challenge every time. Apart from some preliminary information you receive on the way to the scene, you are heading into the unknown. Your heart is racing and your mind is asking a million questions. Once on scene it can be overwhelming with all the distractions and emotions in the hectic environment around you. Breathe in and relax: it is time for your investigative mind-set to go to work! Listen, observe and note down facts – that is the main task of the investigator carrying out the field investigation. Although it sounds simple, take your time and focus.

The investigator-in-charge is tasked to keep track of what is happening on scene. Keeping a helicopter view is hard and there is an inherent danger, as illustrated by the Odysseus myth. In the myth, Odysseus sailed through the sirens while being restrained by the crew. Although he heard their seductive voices, he could not act out his desire. This is similar to the field investigation: facts should be gathered, not stories. The beeswax shielded the sailors from hearing the enchanting calls of the sirens. As a result, they kept on sailing and Odysseus travelled safely past the sirens.

Just like a field investigator, the sailors were tasked to do a job. However, without the beeswax they would have been tempted to fall for the sirens' song and die. I am not saying that investigators should put beeswax in their ears, but they should be mindful of outside influences. Hearing a news story or witness explanation about what happened at the beginning of an investigation can be misleading. It may lead the investigator to start looking for evidence that only supports this one theory, without considering others. On the other hand, investigators should not exclude outside input, as it can help them in an investigation. An investigator-in-charge should be listening to these stories, but facts should always be leading in the investigation, not the stories.

One task of the investigator-in-charge is making administrative notes. These notes are related to the tasks being performed on-scene. Knowing which field investigator conducted which part of the investigation is worthwhile to keep track of. On a regular basis, the IIC should have a debrief with the field investigators to check for progress and make sure the field investigation is progressing in a safe, efficient and structured manner. In sports you have a huddle in which a team gathers in a circle to strategize and insulate opponents from sensitive information. Similar to a sport huddle, it is worthwhile for an IIC to regroup after a certain point in time to reflect and strategize future investigative efforts. This is also the time to make sure everybody is still up to the task of continuing the investigation.

For the IIC, another important task is to maintain a thorough and accurate Evidence Recovery Log. This log documents the evidence collected during the investigation. When collecting and securing wreckage or other physical evidence, it is important to clearly identify the evidence by tagging it with relevant information, such as the date, registration and case number (if available). Items that need to be tested should be sent to the appropriate laboratory for analysis.

As part of the Evidence Recovery Log, it is important to document every action taken with regard to the evidence, including any changes in custody. This is critical because the judicial investigation may also need access to certain pieces of evidence, and it is important to maintain a clear record of who has primary custody and who can be contacted when the evidence is released. This might happen, for example, at the end of the investigation, when the wreckage is returned to the owner or to an insurance company. By keeping a thorough and accurate Evidence Recovery Log, the IIC can ensure that the integrity of the evidence is maintained and that the investigation is conducted in a transparent and credible manner. The field investigators should focus on the field and collect the facts.

How to Start a Field Investigation?

The main goal of the field investigation is to gather facts that could help in determining the probable cause of the incident and identify safety-related issues. In order to complete a field investigation, several steps need to be taken. Firstly, the investigator should make sure that the site is safe. Although this sounds trivial, in my experience it is the most basic step, although commonly overlooked. Therefore, a preliminary survey should take place in order to establish site safety and get a feel for the scene. As there is not one standard approach to investigate the scene, getting a general idea of what the field looks like is a must in order to create an appropriate plan of action to investigate. As such, a preliminary survey (walkaround) has two goals: it establishes the search area, determines the level of personnel protection and equipment may be required for the investigation to make it safe to work. In other words, the area which will be cordoned off is established where investigators will do their work. The second but more importantly, given the state of the wreckage the personal protection against dangers (sharp pieces) or dangerous goods (cylinders, tires etc.) will be identified. This will allow the investigator in charge to make a plan of action how to proceed.

During the walk around other aspects which investigators need to deal with for conducting a thorough search will also be identified. If the search area includes a pond or a lake, you may need to bring in a boat. Depending on the scale of the scene, a 30-cm ruler or a 30-metre measuring tape may be needed to document the scene. If the debris field is even larger, GPS coordinates are more appropriate. It sounds trivial, but it is efficient and effective to identify these problems before you start an investigation.

While performing the preliminary survey, the general condition of the parts and pieces found at the scene are documented. For instance, you may note things such as witness marks or ground scars and big items missing which you would expect to find. A sketch with some key findings is advised to be made at this time. The survey with the sketch can help you develop a plan of action to investigate, keeping in mind the level of protection needed. It should be noteworthy that during the walkaround is also the time to determine to do a thorough search for the flight recorders if the aircraft is equipped with it.

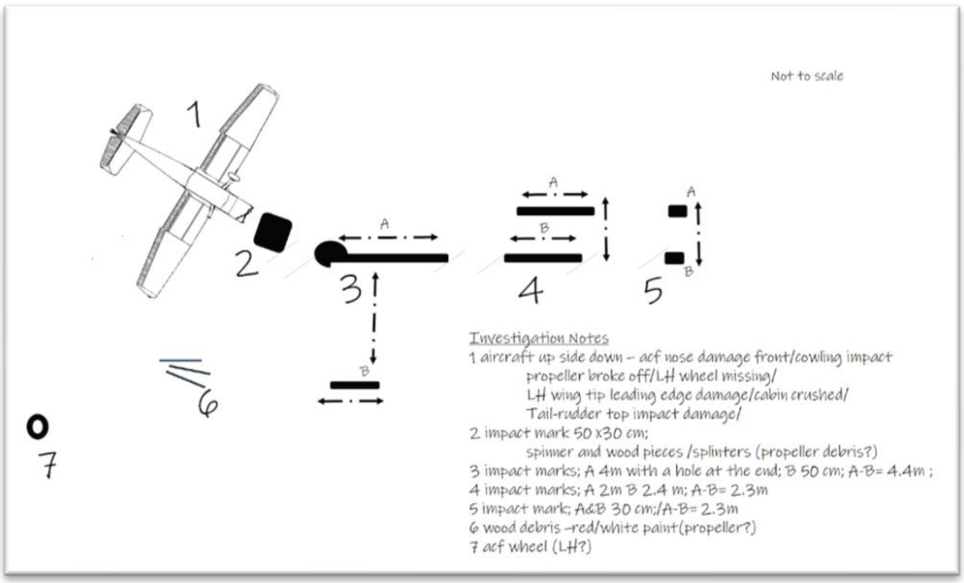


Figure 2.2: Making a sketch in the walkaround phase. Measurements, observational notes and possible explanations and interpretations will follow later in the field investigation.

It is important to control access to the scene, since any time someone moves in or out, you risk the possibility of contaminating the evidence. Do your best to prevent random physical activities happening at the scene, since it is not uncommon that over time perishable evidence is destroyed. Access to the scene should be limited, this helps in not only preserving the evidence but also helps on-scene investigators to focus on the job at hand.

> Student question: If you found the definitive cause, for example the wheel got hot and set the aircraft on fire, you can stop the investigation, right?
> Answer: No, even if the cause is that obvious, and in some cases it is, you still need to conduct an investigation. For example, after the fire started, was it possible for people to get out the aircraft on time? How long did it take for fire services to arrive? Was a fire extinguisher used? Remember: the aim of the investigation is to improve safety, so the evacuation of the plane should also be taken into account. I want to warn you, please refrain from making a pretty picture (Figure 2.3), you are conducting an air safety investigating. I have seen it several times where the cause of the event was different as was initially thought. Only by a thorough investigation it was possible to really determine what happened and reach the goal of enhancing safety.

Investigator Top Tip - Pretty Picture Syndrome

During the initial investigation phase of the accident, it is worthwhile to look at the sequence of events and see what is being investigated and what we know. This is similar to when you were a kid and made a drawing by connecting the dots. Sometimes you were able to mentally connect the dots in your imagination, and mentally finished the drawing before you had actually followed all the dots.

The "pretty picture syndrome" is a term used to describe a phenomenon where people are drawn to, or prefer, visually pleasing or attractive information, even if it is not accurate or relevant. It is a pitfall that an investigator should avoid. It is important to be aware that just because a single fact has been discovered or observed, it does not necessarily mean that it is true. It is important to consider multiple sources of evidence and to critically evaluate the validity and reliability of each piece of evidence before reaching a conclusion. In the next chapters, this will be discussed further.

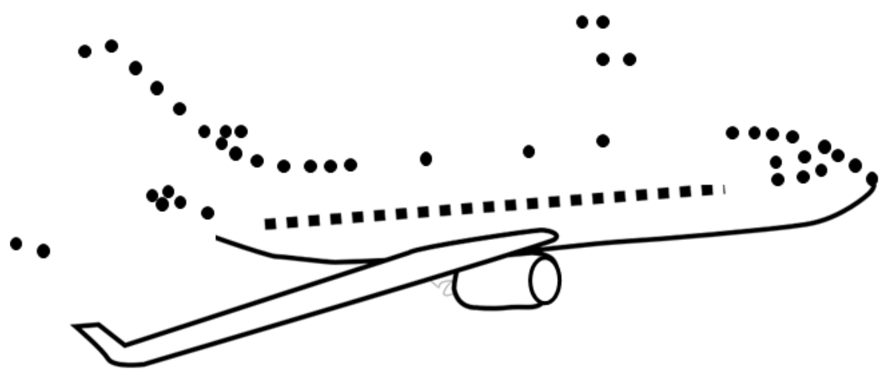


Figure 2.3: Connect the dots and the image will appear – or can you see it already?

Now that you have completed the preliminary survey and established which personal protection is required and where to look, it is time to make a plan. The plan should be to work systematically in order to make sure all the evidence is gathered that is available.

What to do During the Field Investigation?

The main purpose of a field investigation is to observe, determine particulars and in some cases collect physical evidence. Although it is hard, do not act like a headless chicken on the field. I have seen it multiple times: the stress, the sirens, the unfamiliar sights are all sensory inputs you have to deal with. Be calm, observe and register, and commence by making a narrative description of the wreckage pieces. The narrative description is the documentation that is produced by an on-scene investigator. These written notes and sketches, along with any photos or video recording, will be used later in the investigation. For now, it is important to document the scene as much as possible, and as accurately as possible.

As stated before, you would have done a preliminary survey establishing an overview of the field. Using the survey sketch, the potential size of the area to be investigated and an investigative path can be identified. Thus, you will bring structure in the field investigation. It ensures the team will not forget anything that needs to be looked at, hopefully.

Investigators Top Tip: Remember the 4 Ps
When conducting a field investigation, it can be helpful to remember the 4 Ps in order to ensure that all relevant information is gathered and considered. The 4 Ps are:

Parts and Position: This refers to the state and location of the wreckage pieces. During the field investigation, it is important to carefully observe and document the condition and position of the wreckage in order to provide a clear and accurate understanding of the events leading up to the accident.

People and Paper: People are witnesses who can provide valuable information about the accident. Paper refers to a variety of documents, such as logbooks, manuals and reports, that may contain important information related to the event. It is important to be open-minded and actively seek out both witness testimony and relevant documents in order to gather a comprehensive understanding of the accident.

By keeping the 4 Ps in mind, investigators can ensure that they have a thorough and complete understanding of the events leading up to and surrounding the accident.

One approach is to start from the outside and work towards the centre. Another approach is to systematically zigzag the field to avoid missing any clues (Figure 2.4). If multiple investigators are present, it's recommended to divide the field into areas and assign investigators with relevant expertise to each area. There is not one approach that can be applied to an investigation; the field and wreckage pattern dictates the approach. Think logically and assess the best pattern which covers the search area, and which allows you to find all the evidence that is present.

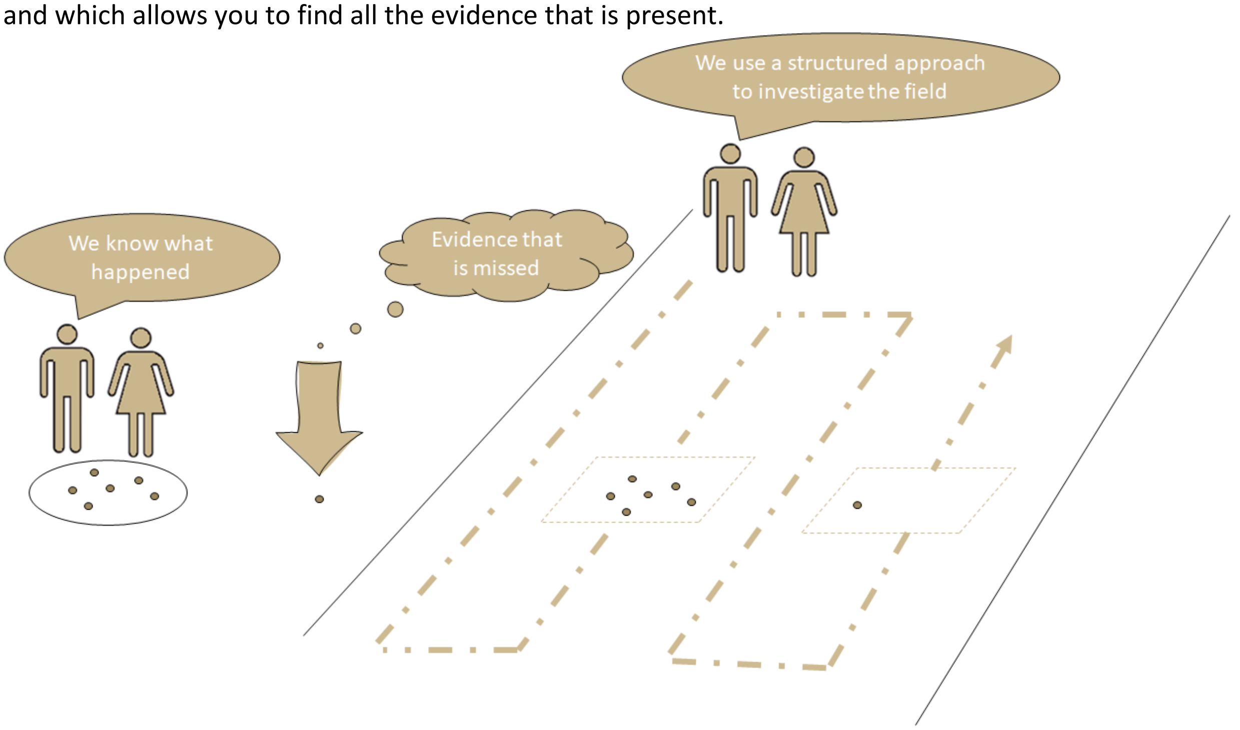


Figure 2.4: A structured approach will allow you discover all the pieces of evidence.

Now that you have started, it is time to actually look at the evidence. Noting down the state and describe the damage of each piece is a slow but necessary process. After a while - I cannot give a specific period - it is time to evaluate what has been found. Again, you have to start first and explore before you can enjoy the fruits of your labour. There are no guarantees that it will work, or you will be successful, but by exploring you at least work towards getting to grips with the event. Over time, depending on the efforts taken, you can retrieve more facts that help you. An investigation is a dynamic situation and you are in the middle of it. You will start with high uncertainty and you will hopefully finish with low uncertainty. It is a balancing act which with, common sense and some experience, will get easier. Focus and structure in the investigation will help in reaching the field investigation goal to get as much information as possible and as accurately as possible.

Don't forget to look around. Part of the investigation search area may consist of houses or forest. Apart from ground marks, attention should be given to trees which also might have been hit or damaged. This information could help in determining the direction of the aircraft before hitting the ground.

Photographs are a (digital) record of the scene and therefore need to depict the accident scene accurately. By taking an overall, medium and close-up photograph the wreckage can be recorded for later use. The photograph should be taken to record the location as well as details that relate to the state of wreckage or physical damage. Once the field investigation is over the photographs should be able to reflect the scene in a digital format.

Investigators Top Tip – Don't be a Tourist

One common mistake that is made during a field investigation is that photographs are take at close range without any context where it is in relation to other pieces of wreckage. Once a photograph is made it is sometimes hard to get an indication of scale. There is a reason why a special ruler is used for making crime scene photographs. Remember that in order to make a good photographs you need to tell the story why you took the photographs and what you see. Just making a photograph of an instrument in the cockpit (lamp in a room) will not help to set the stage what it is you trying to tell. The photograph should help you in the investigation and possibly show something and be useful in the report. It is of course not the goal to put all the photographs in the report, the primary purposed is to have a digital record of the scene. Have the right photograph can be useful in the analyses and drawing conclusions.

The same holds true for people who are walking around an accident scene and making photographs left and right of what they believe is something 'interesting' – these people are called tourists. Remember it is your job to observe and note down evidence. Take photographs in a structured manner that enables an investigator who was not present at the scene to form a mental image at a later stage in the investigation.

Apart from taking photographs it is also very important to makes notes and document your observations. Although it has been said a picture is worth a thousand words, writing down observations is good practice. The notes should be aimed at recording observations to items which are photographed. It will serve as a memory aid but also will focus you to observe. Another aspect of taking notes is to make a sketch (Figure 2.2). The sketch should be made of wreckage pieces and its relationship (distance) between each other pieces or objects. The sketch should be made on the fly and entail relevant information. At a later date you can redraw (to scale) the sketch and make it into a wreckage diagram. The wreckage diagram, in conjunction with the observational notes and photographs you take are all part in recording the accident scene.

Student question: How to do a Field Investigation? There is so much to do and think about.
Answer: I am always asked how to do a field investigation. There is no definitive answer to this question. It depends on the type of event and how many investigators are available. We assume that there is, for example, a field with a wreckage that could hold valuable evidence. Standing next to the field, you will not find any facts and the cause will not present itself. By gathering the facts, we can work towards less uncertainty and establish the cause with some degree of confidence. In other words, somehow you have to overcome the barrier and start somewhere. We can use the exploration-exploitation trade-off (Figure 2.5) to determine the best course of action for gathering more information and evidence. In this case, exploration refers to the process of searching for new and potentially valuable information, while exploitation refers to the process of utilizing known information to make decisions.

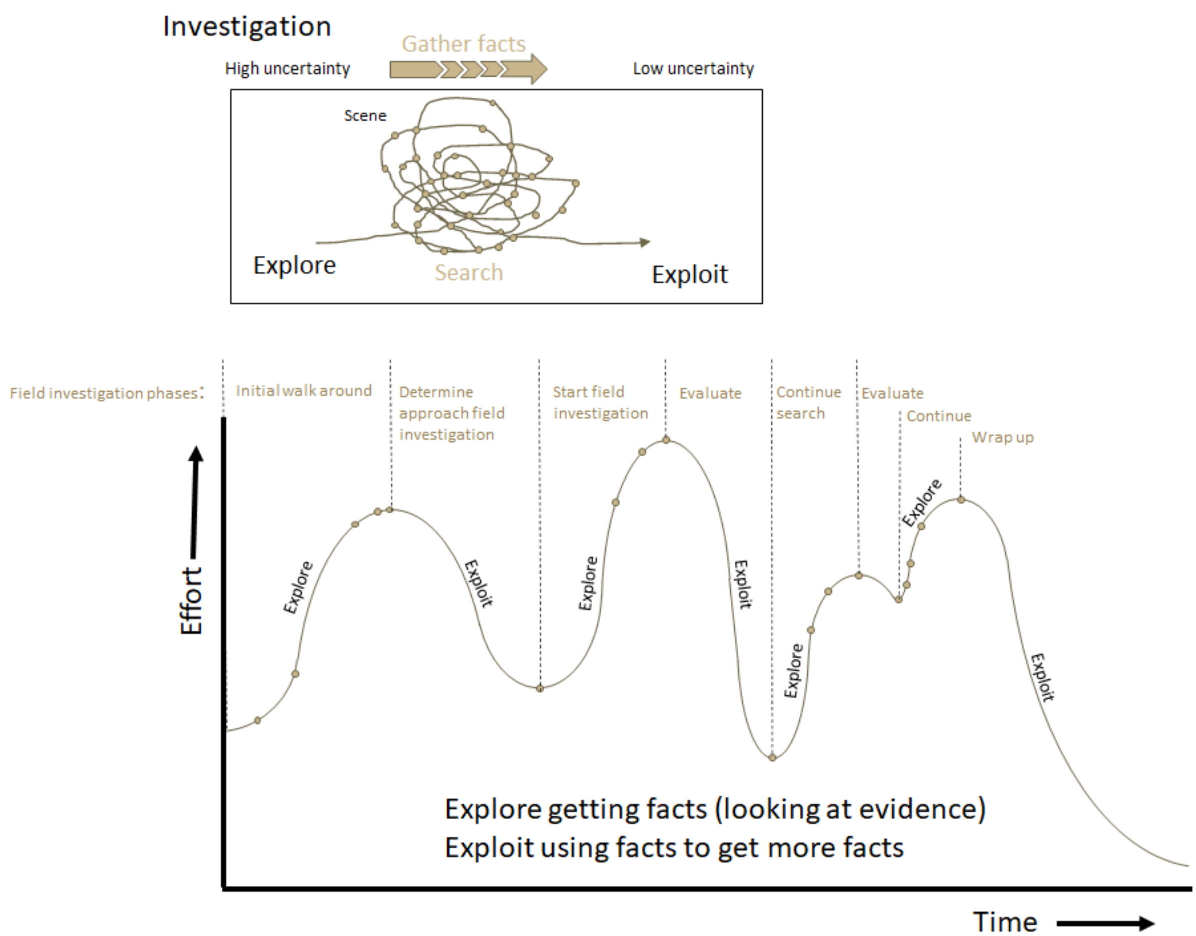


Figure 2.5: The exploration and exploitation trade-off with effort over time, as an example for an investigation.

Interview

An important aspect of Gathering the Facts is the interviewing of witnesses. Witnesses can be people who were directly involved in the event, such as pilots or on-scene witnesses. Other witnesses can be indirectly involved, such as mechanics or air traffic control personnel. The importance and relevance of a witness testimony may vary depending on the specific circumstances of the event and the proximity of the witness to the event.

At an early stage in an investigation, strategic decisions are required with regard to which investigators should interview which witnesses. This is especially critical because witness memory retention tends to decline over time, and valuable "perishable" information may be lost if witnesses are not interviewed as soon as possible. Assessing each witness' relevance is the responsibility of the IIC. The challenge the IIC faces is the availability of investigators and the scope of the field work. The IIC, having a good overview and plan, should ensure all witnesses are interviewed within the appropriate timeframe.

When interviewing witnesses as part of an investigation, it is important to consider the mental state of the witness, the proximity of the witness to the event, and the specific circumstances of the event. The goal of the interview is to gather as much accurate and relevant information as possible; therefore, it is important to approach the witness in a way that makes them comfortable and willing to talk.

Investigators Top Tip – Interview with Care

Performing an interview is hard and requires preparation. It helps to put yourself into the position of the interviewee. How would you like to be treated? Have two persons available for the interview: one to conduct the interview, while the other makes notes for the interview transcript.

Step 1. Make the interviewee comfortable, introduce yourself and explain what you expect from the interviewee. Carefully ease into the interview by explaining to the witness what the purpose of the interview is and how it will be conducted; in this way, you will get the most relevant information.

Step 2. Start with open questions to encourage the interviewee to speak freely in order to gain facts, knowledge, insights and opinions they may have about the event. Open questions usually begin with:

- What?
- Could you tell me?
- How?
- Why?

This type of question gives the interviewee a chance to explain their thoughts, feelings and opinions. Listen carefully and note down topics or items that you want to ask more details about.

Step 3. If you want to know more, use closed questions to gain more insights and details about the statements provided. Closed questions usually begin with:

- When?
- Where?
- Which?
- Who?
- How many?

• How much?

This type of question gives the interviewee a chance to elaborate and provide more details. It is important to keep listening carefully, as in this phase of the interview you may get more insight and explanation of what was observed or done during the incident.

Step 4. Now that you have all the information, it is time to check your notes and verify what you have gained from the witness. This checking and verifying is done by asking yes/no questions. Care should be taken when using yes/no questions, because they discourage further explanation or discussion. Therefore, these questions should be used only at the end of the interview.

Step 5. At the end of the interview, make sure the witness' state of mind is positive and they have a positive feeling about the interview. If in any doubt, ask if the witness needs anything. Close the interview by thanking them and get contact details for possible future questions. Give you own details so the interviewee can contact you if they remember something which might be useful.

In theory it makes no sense to conduct an interview when you are not ready. But in practice, unfortunately, you sometimes have to conduct an interview as an opportunity presents itself, having a witness on the spot next to you. Do the best you can and try to follow the steps outlined above. Again, there are multiple ways to conduct an interview; the steps above serve as general guidance and are not exhaustive.

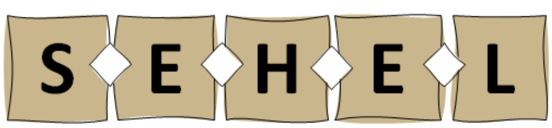
After gathering all the necessary information from the witness, it is important to properly close the interview and thank the witness for their cooperation. Depending on the internal procedures of the safety board, the witness may be asked to review and sign a transcript of their statement. In some cases, the information gathered may be limited and a full transcript may not be necessary. Instead, a general summary of the statement may be provided on the spot and confirmed by the witness, and this summary can be filed in the case docket. Regardless of the specific procedures followed, it is important to ensure that the witness testimony is accurately documented and properly recorded for inclusion in the case file. By following these steps, the safety board can ensure that it has a thorough and accurate understanding of the events under investigation.

Summary

In this chapter, gathering the facts was discussed, both by field investigation and through interviews. It is clear that before starting an investigation, it is important to establish a secure and controlled area around the accident scene. This will help preserve the integrity of the scene and prevent contamination or tampering with evidence. The wreckage, debris and other objects may provide clues about the cause of the accident. Use the explore and exploit tactic to start and proceed the field investigation. If you do not do anything, you will not gather anything, but use what you have gathered wisely. Therefore, it is important to document the accident scene systematically. This includes taking photographs or videos, making sketches and recording measurements and other observations. Identify and collect physical evidence from the accident scene that may later be examined in more detail. Interview witnesses and gather statements from people who were present at the time of the accident. To ensure the success of the investigation, it is important to carefully assess the witness proximity and to prioritize the interviewing of direct witnesses as early as possible.

Student question: Is there a checklist for an accident investigation?
Answer: No, there is not one checklist for all accident types. Keep in mind that there is a difference between a puzzle and an accident scene. A puzzle can be considered as a static event, where we can apply the same strategy for solving a different puzzle each time. An accident scene is dynamic, since the environment, the type of event (mid-air, landing accident etc.) and aircraft type and model change. Therefore, we can apply a generic (puzzle) approach, but we need to adapt this to make it an effective investigation. This is where common sense and experience comes into play. I know you would like to have a checklist, but maybe it is good to remember the SEHEL model. The SEHEL acronym stands for Scene, Environment, Human, Equipment, and Legal and regulatory. The model will allow you to check the various aspects which should be looked at in an investigation. Depending on the event one or more aspects can play a bigger or smaller role. I hope that this model helps you and provides some guidance of what you need to look at.

Investigator's Top Tip – SEHEL framework



The SEHEL model is a conceptual framework for conducting a safety investigation. It helps the investigator to addresses the various aspects which should be investigated.
Scene: This refers to the physical location where the incident or accident occurred.
Environment: This refers to the environmental conditions that may have contributed to the incident or accident, such as weather, terrain and lighting conditions.
Human: This refers to the people involved in the incident or accident, including the crew, passengers, ground personnel, ATC and any other individuals who may have been involved.
Equipment: This refers to the radar, fuel truck, vehicles and other equipment involved in the incident or accident.
Legal and regulatory: This refers to the legal and regulatory requirements that may have been relevant to the incident or accident, including any applicable laws, regulations and standards. Obtaining information about the applicable licences and the airworthiness status of the aircraft is also part of the legal and regulatory aspects to be investigated.

Questions Gathering the Facts

Question 1: What is the first priority before starting the field investigation?

A. Determine the area to be investigated and safeguard personal safety
B. Get an overview of the people involved
C. Review the wreckage piece
D. Establish the area to be investigated

Question 2: Below are four investigation actions. Which action(s) should be taken during the field investigation first?

1. Obtain aircraft registration documents
2. Obtain the aircraft certification regulation
3. Get the aircraft weight and balance
4. Perform an aircraft wreckage investigation
5. Obtain weather information

Question 3: For the following witnesses, prioritize the interview order:

1. Search and rescue crew - fire chief
2. Pilot involved in the event
3. Witness with dog who saw the crash
4. Journalist

Question 4: What should not be done at the start of a field investigation?

A. Sort wreckage pieces
B. Catalogue wreckage pieces
C. Describe wreckage pieces
D. Locate wreckage pieces

Question 5: Why are (wreckage) parts recorded in a log book when removed from the scene?

A. For documentation
B. For traceability and custody purposes
C. For recordkeeping
D. For insurance purposes

Exercise 1

What did the investigator forget to note down in the investigation notes in Figure 2.3? Examine the figure carefully.

Exercise 2:

Finding the Truth in Falsehoods: Both engines failed - Prologue

A commercial twin jet engine aircraft made an emergency landing with two engines inoperative. According to preliminary information, at about 16.500 feet, both engines flamed out. The APU was started and electric power was restored. The crew was unable to restart the engines and elected to make a straight in landing. No injuries were reported.

Looking at the SEHEL framework:

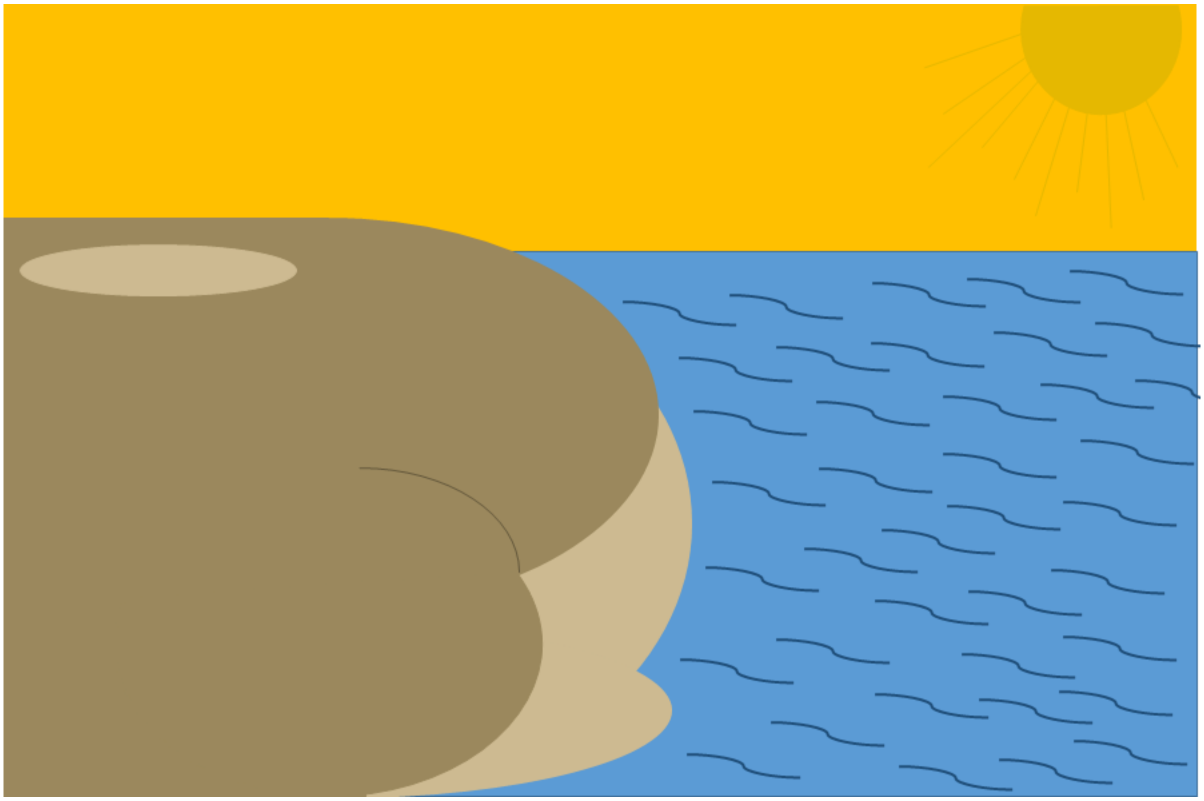
A. What on the Scene would you investigate and how?

B. What Environment would you investigate and how?

C. What Human interaction would you investigate and how?

D. Which Equipment would you investigate and how?

E. What Legal and Regulatory aspects would you investigate and how?



The Riddle of the Sphinx

The sphinx is a mythical animal with a lion's body, eagle's wings and a human face. According to Greek myth, the sphinx was stationed outside of the city of Thebes and would only allow travellers to pass if they answered a riddle. If they answered incorrectly, they would be killed. When Oedipus came to Thebes, the sphinx asked: "What walks on four legs in the morning, two legs at noon, and three legs at dusk?" As a baby crawls on all fours, an adult walks on two legs, and an old person uses a cane to walk on three legs, Oedipus was able to solve the riddle by responding: "man." Infuriated that the mystery had been solved, the sphinx jumped off a cliff and died. This myth is often told to symbolize clear and logical thinking.

Chapter 3 Logic and Hypothesis

Introduction

Now that we have gathered the facts, it is time to start the analyses phase of the investigation. In this phase it is important to evaluate the facts and start working towards drawing conclusions. The journey from facts to conclusions is long, however. Therefore, in the next three chapters we will look at the process of analysing the facts. In this chapter the focus will be on applying logic and creating hypotheses.

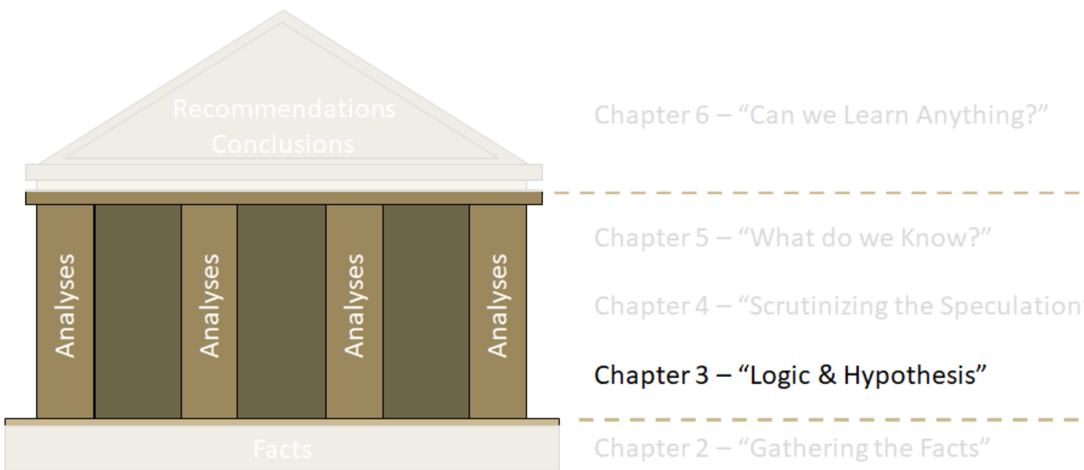


Figure 3.1: The investigative temple with, in the analyses phase, the chapter Logic and Hypothesis.

Hypothesis generation

Let us take a step back: the start of the investigation has been completed. You have some preliminary data and facts gathered at the scene and interviewed witnesses. It is time to start the next step in the investigation: hypothesis generation. This is the process of creating and proposing potential explanations for the cause of the accident. By analysing all available data and information about the accident, including witness statements, flight data recorder (FDR) and cockpit voice recorder (CVR) data, maintenance records and physical evidence from the wreckage, you may generate a number of hypotheses about the possible causes of the accident.

To aid in systematically taking all possible causes into consideration and avoid overlooking any plausible causes when generating hypotheses, it helps to look at the different life-cycle phases related to the event: Design, Manufacturing and Operation. For each of these phases, reflect on and evaluate the assumptions made and conditions experienced. In other words, under which regulations was the aircraft designed and certified? Was the aircraft used under these circumstances and conditions? Reflect on and evaluate the failure conditions, as well as the environmental human and system interactions that were present during the event (weather, organisation, training etc.). Do some logical thinking and use common sense to come up with possible theories on what could have happened and define hypotheses to reflect this.

During hypotheses generation, the investigator compiles a list of possible explanations for what may have caused the failure(s). What might have been technical or procedural causes? What was the chain of events leading to the failure? What ultimately triggered the failure onset (the root cause)? It should be noted that any observed failure could be the result of another failure or a cause of a subsequent failure.

Once the hypotheses have been generated, the investigation team can, by logical analysis, evaluate the hypotheses and determine which ones are the most likely to be true. In this phase, simulations, laboratory testing and expert analysis can be used to supplement the facts.

Finding the Truth in Falsehoods: Both engines failed - Part I

This example of hypothesis generation involves an event where a commercial twin jet engine aircraft made an emergency landing with two engines inoperative. Please note that this is for reference only and not an exhaustive example.

Hypothesis 1: The investigation team generates a hypothesis that the engine failure was caused by poor maintenance.
The investigation team reviewed the aircraft maintenance records and found that both engines were properly serviced according to the maintenance documents. No outstanding technical issues were found.

Hypothesis 2: Based on the available information the investigation team may generate another hypothesis that the engine failure was caused by the flight crew.
The data from the aircraft Flight Data Recorder (FDR) indicates the throttle system inputs were consistent with engine operation up until the left engine stopped operating. Review of the left engine data performance indicate fluctuation in both temperature and engine rotation speed before it stopped working. Similar to the left engine, the right engine also experienced fluctuations in the same time period, but continued operating.

Hypothesis 3: The investigation team looks at another possible factor, such as weather conditions.
The investigation team reviews the weather data and finds that the aircraft was flying through an area with severe thunderstorms at the time of the engine failure.

Primer on Logic

The message from the previous chapter, Gathering the Facts, was that it is important to work in a structured way. Although this is very important, there is another aspect that is just as important: thinking logically. Although several different types of logic exist, for determining the cause of an accident, three types of logic will be discussed. The first type is abductive logic. For this type of logic, you start with an incomplete set of observations and use them to identify the most likely explanation for the accident. One could say that this is a ‘best guess’. This type of logic is used in extraordinary circumstances where, for example, the aircraft is not accessible or missing. Assuming the wreckage is available and more evidence can be found, there are two types of logic that an investigator can apply: deductive and inductive logic.

Deductive reasoning is a method of logical thinking that involves starting with a general principle or statement and using that statement or principle to arrive at a specific conclusion. This is sometimes called the "top-down" approach. In the context of accident investigation, deductive reasoning can be used to draw conclusions about the cause of an aviation accident or incident based on observations. As an example: An aircraft engine failed mid-flight. According to the aircraft's maintenance records, reviewed in the investigation, a mechanic recently overhauled the failed engine. The mechanic was new at his job and had minimal experience with engine overhauling. Using deductive reasoning, it can be concluded that the engine failure was likely caused by improper engine overhauling. In this example, deductive reasoning is used to draw specific conclusions based on the general theory that failures are less likely to occur when qualified personnel perform aircraft maintenance.

Inductive reasoning works the other way, moving from specific fact to broader generalizations of patterns (theory) to form a tentative hypothesis that is tested against the available facts, after which a conclusion is drawn. We sometimes call this the "bottom-up" approach. In accident investigation, inductive reasoning can be used to infer the cause by examining the facts and circumstances of the event. For example, the investigation team finds that the crashed aircraft's wing was damaged and finds propeller slash marks and paint marks not belonging to the event aircraft. Another aircraft is located and it is observed that the propeller is damaged and the aircraft is painted with the same colour as the paint marks found on the wing of the event aircraft. Using inductive reasoning, the investigation team concludes that the crash was likely caused by a mid-air collision with the other aircraft, which is consistent with the paint and impact marks found on the other aircraft. In this example, inductive reasoning is used to draw general conclusions or principles based on facts, such as the relationship between mid-air collisions and the damage to the aircraft.

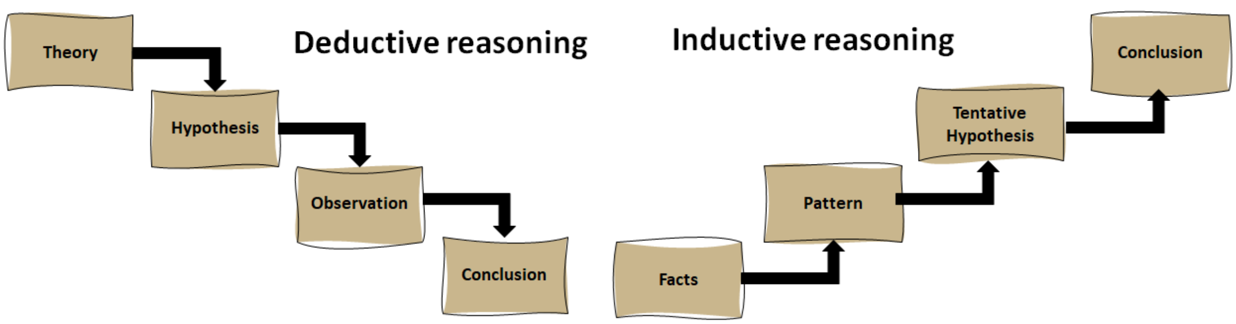


Figure 3.2: Top-down deductive reasoning and bottom-up inductive reasoning.

For deductive reasoning, an observation or statement is assumed to be true and used as the basis for reaching a conclusion. A fact is a piece of information or observation that can be independently verified as true. An observation might be factually true, but it could also be false. Both fact and observation will be discussed in the next chapter in more detail. Using inductive reasoning, we reach a conclusion based on the facts, an established pattern based on the facts and tentative hypothesis. In investigations we work with facts; it is therefore not surprising that inductive logic is the most appropriate approach to use. In the next chapter, "Scrutinizing the Speculation", this aspect of observations and facts will be discussed further.

Another aspect to be aware of when dealing with an accident and applying logic is that deductive reasoning involves starting with a general principle or theory and applying it to a specific case or situation. It is assumed that the general principle or theory is true. But in some cases the assumption may not be true, which means that the accident could not have happened based on the theory or general principle. Wait, the theory is not true? Yes, there is a possibility right. But the accident happened, so it must be true. No, this is the case when an investigation even more interesting to prove that something is else might be the cause of accident and not the common accepted theory or principle. In other words, the power of deductive reasoning is also its weakness; in Chapter 5, “What do we know?”, this aspect will be discussed in more detail. In summary, the type of logic to use in any given situation will depend on the nature of event, the information and time that is available. The preferred logic is inductive as it allows for the most consistent non-bias result. In either case, the validity of the conclusion will depend on the quality and reliability of the information and reasoning used.

Using logic to evaluate hypotheses

Now it is time to look at forming and evaluating hypotheses. This is a vital part in conducting an investigation. It is possible to "verify" an erroneous hypothesis by using the gathered factual information and interpreting it incorrectly. The verification of a false hypothesis is an unwanted outcome that we attempt to avoid by applying logic to the interpretation of factual evidence.
Below, you will find a flowchart that outlines the procedure for testing the plausibility of hypotheses. During hypotheses testing, the hypothesis is tested against the collected data. It is checked whether the collected data provides a logical explanation, which is consistent with the hypothesis. This check can be done by reasoning or by conducting validation calculations, simulations or real-life tests. Sometimes, it is necessary to look for additional hypotheses or data, if the generated list of hypotheses does not provide a satisfactory answer to the main investigation questions or if the available data are insufficient to answer all questions or test all hypotheses. Most likely not all the information and facts have been gathered, which means additional investigation or research needs to be performed in order to proceed. If you take a close look at this flowchart, you will notice that the procedure for evaluating hypotheses using logic, i.e. the scientific method, never results in a hypothesis being proven outright. All we are able to do for certain is narrow down to one or more plausible hypotheses. Using the gathered facts, analysis and hypothesis testing yield those hypotheses which cannot be ruled out. What does this mean?

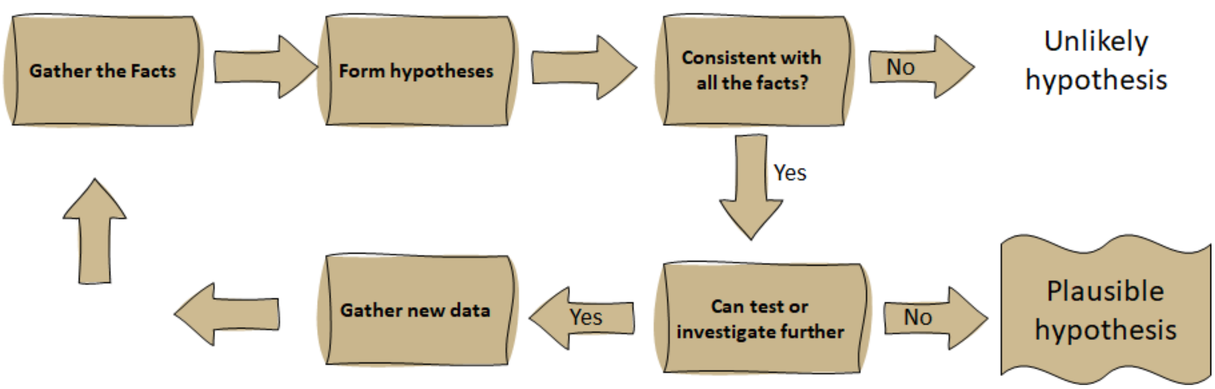


Figure 3.3: Scientific method: from gathering the facts to testing hypotheses.

In ongoing investigation, you may hear an investigator say: "we are unable to rule out [a specific cause or possibility] at this time." This does not necessarily mean that this cause or possibility is the leading (possible) cause for the accident, as it is so often interpreted. It simply means that insufficient evidence, analysis or follow-up testing has been performed to completely rule it out. This may be a result of resources being allocated to focus on other hypotheses that pose a larger safety risk. As it is a safety investigation risk as it relates to the event is always a point of inquiry.

The hypothesis in an investigation

A practical example of hypothesis generation for an event where a small aircraft made an emergency landing due to engine failure.

Based on the available information, the investigation team may generate a hypothesis that the engine failure was caused by the student pilot, who did not operate the aircraft engine properly.
According to instructor the student performed the appropriate procedure. The instructor took over control and also tried to restart the engine, but was unsuccessful.

The investigation team generates a hypothesis that the engine failure was caused by poor maintenance.

The investigation team reviewed the aircraft maintenance records and found that both engines were properly serviced and no outstanding technical issues were found.

The investigation team generates a hypothesis that the engine failure was caused by weather conditions.

The investigation team reviews the weather data and finds that the aircraft was flying in icy conditions.

The investigation generates a hypothesis that the engine failure was caused by carburettor icing.

According to the investigator field notes, carburettor de-icing was set to off in the cockpit. During interviews, both the instructor and the student pilot did not mention anything about the carburettor setting.

As you can see, using the facts the investigation team has evaluated several hypotheses. It is clear that the application of the scientific method is an iterative process. It should be noted that an investigation may end up with several plausible hypotheses for the accident cause. This may not be satisfactory for the general public, nor be of much consolation for the families of the victims, who want to get one definitive explanation as to why the accident occurred. However, as you will recall, the sole objective of the investigation of an accident or incident is the prevention of future accidents and incidents. This means that when an investigation is able to identify and support multiple plausible hypotheses and identify potential safety factors that can mitigate accidents in the future, the investigation is successful.

Assessing the plausible hypotheses

Another way of looking at an accident is that during for example the impact the evidence has been deconstructed and mixed into finite factual elements. Or take a dish and you are asked to find the ingredients from which the dish has been made. The investigator’s job is to find these facts and reconstruct the sequence of events. Thus, it is important to assess the different hypotheses. In general, a hypothesis (or scenario) can be assessed in four ways:

1. the scenario is likely and logically consist with the facts;
2. the scenario is likely and logically inconsistent with the facts;
3. the scenario is unlikely and logically consist with the facts;
4. the scenario is unlikely and logically inconsistent with the facts.

For scenario 2 and 4, which are logically inconsistent with the facts, we have already shown how to discard these hypotheses in the previous paragraphs. This leaves scenario 1 and 3, which are both consistent with the facts and need further examination. When solving a sequence of events, there is always a degree of uncertainty to contend with. Using analysis techniques and logic, the facts can be interpreted in different ways. It is not uncommon, especially at the start of the investigation, that several scenarios are equally likely to have occurred.

> Student question: What can we do at this stage to make sure we don't miss anything or interpret the facts in the wrong way?
> Answer: At this stage it is important not to be afraid of being wrong. What I mean is that you are free to interpret a fact and explain why you 'see' or put the fact into this 'context'. However, you could be wrong, you could have missed something. It is therefore important to abide by the four-eye principle where at least two or more investigators look at the evidence and logically evaluate the facts.

The principle of parsimony, also known as Occam's Razor, is a way to assess a hypothesis. This principle states that when faced with multiple scenarios, the scenario that makes the fewest number of assumptions is most likely to be true. The idea behind the parsimony principle is that the fewer assumptions are made in an explanation, the simpler it is and the more likely to be true. Although this simplicity approach can be useful, the inherent complexity of aircraft accidents diminishes its potential. As we strive to gather as many facts as possible, the applicability of the parsimony principle decreases.

Another approach is to look at the likelihood of an event occurring. In this approach 'likelihood' should not be confused with 'frequency', that is, a measure of how often an event occurs. After all, we are dealing with something that may not have happened before. When an accident scenario is explained by frequency, i.e., the same has happened before, it is very likely there is a systemic failure or safety issues. The investigation focus should in this case focus on the common theme and outcome to each event and address this particular point in a final report with a recommendation. Instead, likelihood is a subjective judgement based on the information available and heuristics. As subjective judgement and heuristics are involved, the hypothesis is not assessed objectively. However, this approach is not fool proof either. That is not to say the (expert) judgement was wrong and the assumed scenario was indeed correct.

There is a reason to gather all the facts, and go back to find more when necessary, in order to apply logic and objectively assess the accident scenarios. The systematic approach is to assess each hypothesis separately with the available evidence, that is, the facts. It is possible that one singular hypothesis or final sequence of events is not found. This, in principle, is not a problem, as it shows thoroughness and transparency in the investigation. If the parsimonious method is used to define a likely cause, it should be addressed in the report. In this case, assumptions were made which may not be valid, since more evidence was not gathered due to outside factors, for example the wreckage not being accessible. Some speculation may still exist, since even with a systematic approach and logic we are not fully able to perform an analysis to find a cause. We need to (re)examine the evidence in more detail and find the true value it has. In the next chapter, we will look at the facts in another way and assess their evidential value. In addition, the bias of an investigator and bias in an investigation generally will be discussed.

Investigator's Top Tip – SHELL model
The SHELL model is a conceptual human factors model that clarifies the scope of aviation-related human factors and assists in understanding the relationships between aviation system resources/environment (the flying subsystem) and the human component in the aviation system (the human subsystem) (ICAO, 2018).
Software includes rules, instructions, regulations, policies, norms, laws, orders, safety procedures, standard operating procedures, customs, practices, conventions, habits, symbology, supervisor commands and computer programs.
Hardware includes physical elements of the aviation system such as aircraft (including controls, surfaces, displays, functional systems and seating), operator equipment, tools, materials, buildings, vehicles, computers, conveyor belts etc.
Environment represents the physical environment outside the immediate work area, such as weather (visibility/turbulence), terrain, congested airspace, and physical facilities and infrastructure including airports, as well as broad organizational, economic, regulatory, political and social factors.
Lifeware is the human component or people in the aviation system.

The single lifeware component is considered to represent the human performance, capabilities and limitations of for example the pilot. The lifeware - lifeware (interaction) component represents, for example, the captain – first officer (pilot – pilot) interaction. It also can be related to the interaction between the pilot and the cabin crew, ground crew, or management or administration personnel. As stated previously, the model aims to show and facilitate the relationship analyses in an investigation.

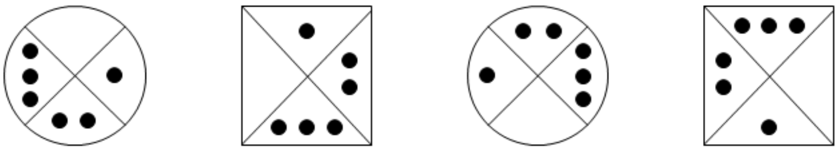
Summary

After the facts are gathered, the next step is to perform the analyses. In this phase of the accident investigation, it is useful to define hypotheses and asses them using the scientific method. This chapter has provided some general procedures on how to do this. using logic. In this chapter, three different types of logic have been discussed. The first logic type, abductive, may be used when no wreckage was available, but secondary evidence can be used to determine the cause (best guess). Assuming the aircraft, and therefore the evidence, is available, two types of logic remain which can be applied in accident investigation: inductive and deductive logic. For each there are merits, given the circumstances and the facts available.

Questions: Logic and Hypothesis

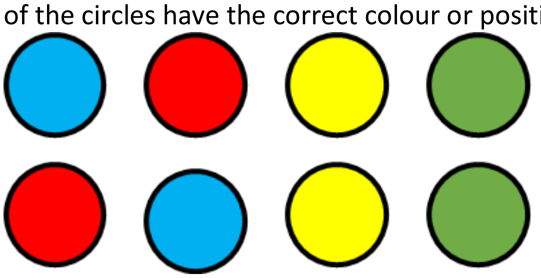
Question 1: Below find a sequence of figures. Answer the two questions.

1.1 Predict by logic the next figure in the sequence:



1.2 Which steps did you take to come to the logical conclusion?

Question 2: Below are two rows of four circles, each with a specific colour. According to the given data, in the first row, two out of the four circles have the correct colour and position. In the second row, none of the circles have the correct colour or position.



2 correct

0 correct

2.1 Predict by logic the correct sequence.

2.2 How did you arrive at this conclusion?

Question 3 Which logic type is applied in examples A and B? Pick from (1) deductive logic, (2) inductive logic, (3) abductive logic.

Example A. An airline is trying to determine the cause of a series of accidents involving aircraft icing up during flight. They review the weather conditions and flight data for the affected flights and find that all of the accidents occurred during flights through areas with freezing temperatures and high humidity. The airline concludes that the aircraft icing was likely caused by the combination of freezing temperatures and high humidity.

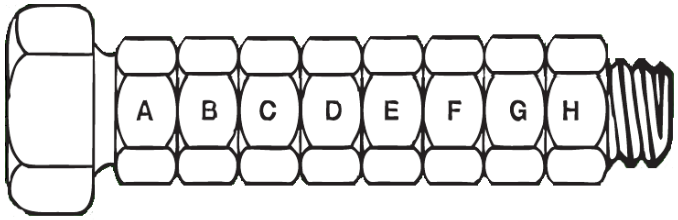
Example B. An airline is trying to determine the cause of a series of accidents involving aircraft landing gear failures. The affected aircraft maintenance records were not signed off and completed as required per procedure. As a result, the landing gear was not inspected and maintained in accordance with the manufacturer's guidelines. The airline concludes that the landing gear failures were likely due to a lack of proper maintenance.

3.1 Example A uses ….. Explain your reasoning.

3.2 Example B uses …. Explain your reasoning.

Question 4: Below is an image of a bolt with 8 nuts. Answer the two questions.

4.1 How many solutions are there to remove all the 8 nuts from the bolt?



4.2 If all the 8 nuts are removed from the bolt, how many solutions are there to screw 8 nuts on the bolt when the nut order can be random?

Exercise 1

Find the final report of a major accident on the internet. The reports can be found of your countries safety board. Read and review it and answer the following questions:

- Which type(s) of logic was applied during the investigation and how?
- Which hypotheses did investigators look at?
- How were these hypotheses confirmed or rejected?

The Thales myth

One day, Thales was walking along a river when he saw a group of geese flying overhead. He was so entranced by the sight that he fell into the river. The current of the river was quite strong; constantly being swept away, Thales had trouble getting back to the riverbank. As he was trying to swim to safety, he dropped his walking stick, which floated downstream rapidly. He realized that the stick was floating downstream at the same rate as the current, so he swam downstream and was able to catch up to the stick. He then used the stick to help him get to the shore and climb out of the river. The Thales myth is often used to illustrate the importance of logic and critical thinking in solving problems and making sound decisions. It shows that even when faced with unexpected challenges or difficult circumstances, it is possible to use rational thought and problem-solving skills to overcome obstacles and find a solution.

Chapter 4 Scrutinizing the Speculation

Introduction

Once a major event has occurred, a wave of information, first- and second-hand, is distributed to the world by social and other media. The media attempts to keep the public informed on current events and newsworthy developments. However, the media is also motivated by competing for viewership and engagement (clickbait). The news media will ask experts to put what is shown on the news in perspective and to provide opinions. The expert provides insight and opinion, which is subsequently used as a “quoted” statement. Example are: “Pilots are not trained for this” or “The manufacturer had design issues”, and many more. On social media, posts will circulate expressing the writers’ thoughts and opinions; some of these get more likes and are placed in more feeds to attract more engagement. Thus, speculation is born, and, in the absence of reliable information or statements by experts, in time the public comes to accept this information as definitive. This public news speculation is a challenge and puts pressure on a safety investigation. It is important to look at, as speculation has in the past led to distractions, with investigators having to spend time and effort to disprove speculation instead of having time and resources available to solve and promote aviation safety.

I think we can agree that, in the case of absence of information, assumptions will be made based on prior knowledge and experience. Although assumptions might be wrong, they seem right and appropriate at the time, and thus the stories and one-liners will stick to them. However, as a result the public may feel that the investigation was conducted poorly, as - after a year of investigation - a different outcome is presented compared to the previous headlines. It is therefore important to examine and understand the investigative threat that stems from speculation and bias.

This chapter will look at the bias that can arise as a result of speculation by the public, and to the ways in which we can identify potential investigation bias. Before diving deeper into bias, it is important to first examine and define facts and observations, which form the foundation of the investigation, in more detail.

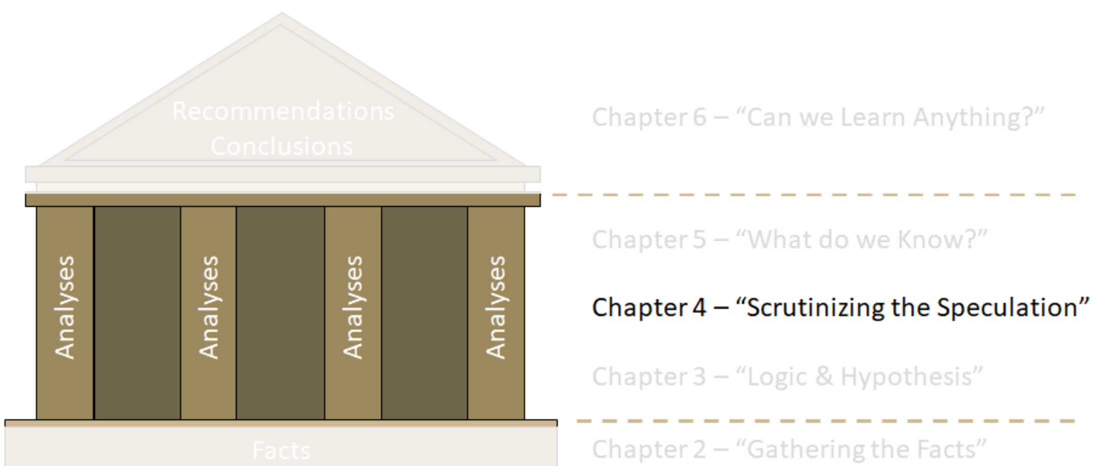


Figure 4.1: The investigative temple with, in the analyses phase, the chapter Scrutinizing the Speculation.

Defining Observation and Fact

An observation is a statement made by, for example, an investigator based on something that is perceived or detected. A conclusion based on an observation can be assumed to be true, but may also turn out to be false further along in the investigation. In case of multiple observations, for all practical purposes, the conclusion drawn is accepted as "true". A fact can be defined as something that can be independently verified; the conclusion drawn from it is therefore true.

Thus, all facts are observations, but an observation is not a fact (Figure 4.2). It is worthwhile to consider this. If something is not an observation or fact, it may be called an assumption. An assumption is not based on observation or fact, but a general statement based on previous experience or knowledge. An assumption is something that is taken for granted, and can be based on experiences or common sense. Assumptions can be used to make inferences or deductions when limited information is available, usually this inferences is based on probability. Using this method helps us to quickly reach a conclusion, but this is a best guess and not a hard conclusion. There is also presumption: an idea or belief that is based on the available evidence. It is a reasonable inference that is made about something, but is not necessarily proven true, unlike a fact. Care must be taken to when dealing with assumptions or presumptions.

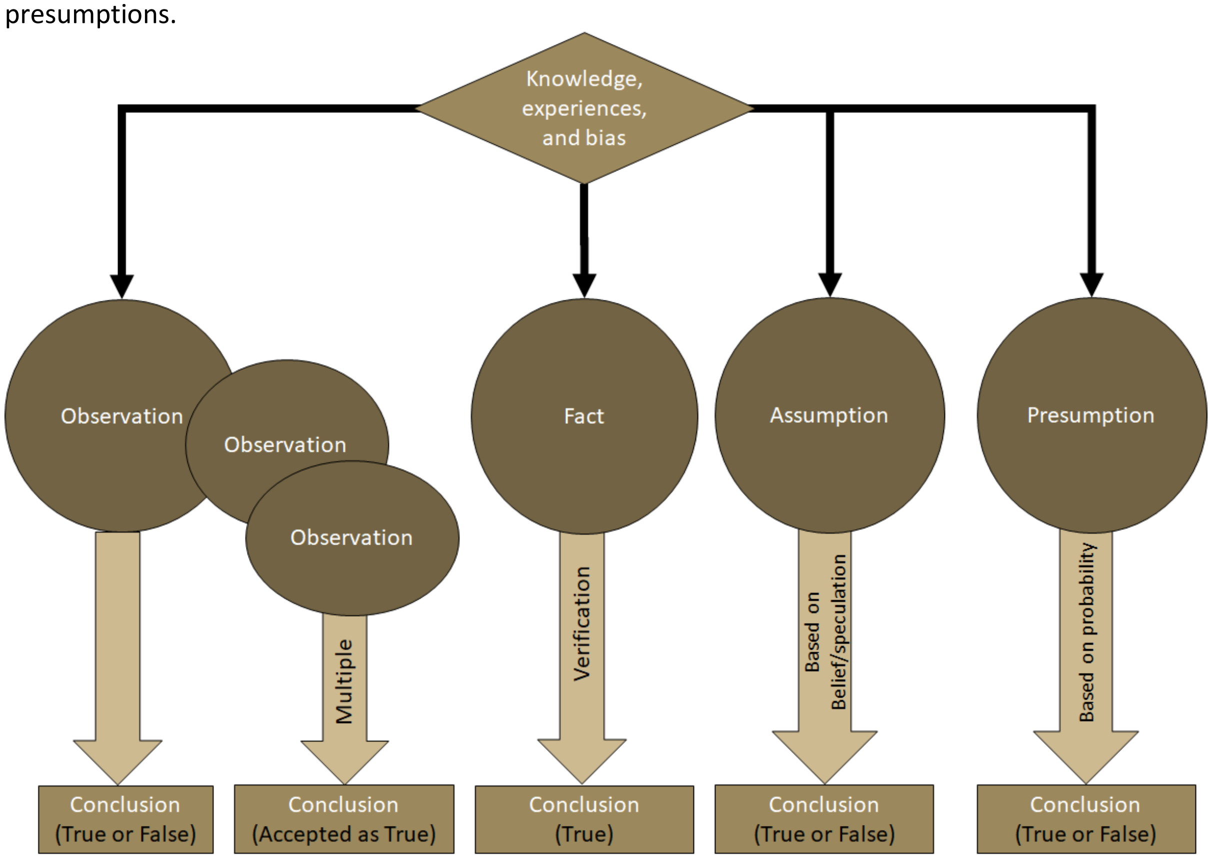


Figure 4.2: The world with observations, fact, assumption and presumption, presented with the resultant conclusion being false, accepted as true or true. Please note that 'accepted as true' does not necessarily mean the conclusion is (absolutely) true.

Going back to facts, you should be aware that just because a single fact has been discovered, it does not necessarily mean that it is true. It is still required to verify the fact before drawing a conclusion. Just as multiple observations result in a conclusion which is accepted to be true, it is important to gather

multiple facts in order to reach a conclusion. Again, the truthfulness of the conclusion depends on the information used and thus it can be both true and false. Even a fact which is accepted as true, meaning it is reasonable, should still be treated with care. A conclusion drawn from a single fact should be excluded when other information or facts are inconsistent.
A way to objectively analyse evidence is to compare it to other evidence or information in order to see if it is consistent and supported. It is important to consider multiple sources of information and to be open to the possibility that different sources may provide conflicting or contradictory evidence. The observation may be inaccurate due to errors or mistakes in the data collection. Each fact should be critically evaluated on its validity and reliability. When you don't know, ask an expert; there is no harm in asking for help or have a second person look at the evidence. The four-eye principle comes to mind: at least two independent individuals looking at the same information in order to reduce the risk of making a mistake. By considering the available evidence objectively, it is possible to reduce the influence of bias and make drawing more accurate conclusions possible.

Understanding Bias

We can be influenced by the opinions and (unfounded) remarks of people and news entities we trust as being reliable information sources. The media discussed at the beginning of the chapter are a good example. When opinions are expressed as reasonable or logical (without being tested), it becomes a serious challenge for an investigator to remain unmoved. In short, we can state that investigators always feel the presence of bias. In this time and age, with easy access to media and other information, we sometimes easily state or conclude something which is not based on what we heard or saw. It is very uncommon to take the time to seek more and more accurate information and verify it. This means that it's common to jump to a conclusion. But sometimes it is a bit more subtle, when the bias comes from the investigator who is influenced by the media narrative.

An example of such an investigator bias might be that the investigator has a preconceived notion that a certain piece of equipment was the cause of the accident. As a result, the investigation focus is on that piece of equipment only, ignoring other potential causes or failing to consider alternative explanations. This could result in an incomplete or inaccurate understanding of the accident cause.
This internal bias is a challenge, but there are ways to combat this. As mentioned before, the party system entails working together as a team on a specific investigative task. This means that, as a team, each member should be aware and speak up if a bias is present. At first glance, the wing could be labelled as the right wing. After review of the wing shape, the wing profile and the landing gear bay, the initial label is changed to left wing. It is not uncommon to adjust, over time, certain observations, so as to finally reach a factual (correct) statement.

In addition, it is important to be aware of the potential for bias or other factors that may influence the evidence accuracy. For instance, a person may be biased due to his/her perspective or may have a specific motivation to provide or hide information. Similarly, an organization not familiar with the investigation can present information in a certain way. Based on personal relationships or experience, an investigator is more likely to believe the testimony of certain witnesses over others, based on preconceived notions about their credibility.

Figure 4.3: Confirmation bias showing the facts and evidence we ignore and the (internal) beliefs which we feel to be true. The overlap indicates the facts that we believe are true - but are they?

We should also look at confirmation bias (Figure 4.3), which is the tendency to favour facts and evidence that confirms or strengthens our own beliefs or values. In other words, because we believe something is logical and therefore should have happened, we 'see' the facts and evidence that supports this premise. We (conveniently) ignored other facts and evidence which indicate something else.
As an example: an aircraft experienced engine failure and the first belief is that this was due to fuel starvation. When checking the fuel tank, it is evident that it is empty, which makes the investigator happy being spot-on in the fuel starvation conclusion. It doesn't matter that there is hole in the tank and a puddle of fuel on the ground. This fact is chosen to be ignored, since it is easier to accept the evidence that support our beliefs as true.

There is also hindsight bias, where we believe we predicted something, after an event has occurred. It is very easy to state what the flight crew should have done to prevent the accident, when you have all the evidence and understand the sequence of events. Yet, at the time of the event the flight crew didn't know or understand what was happening and was unaware what the outcome would be. In fact, they responded to the situation at hand with the training and knowledge they had. The office chair pilot behind his desk knows how the accident could have been prevented, but this type of bias, of course, does not help in enhancing aviation safety. It should be clear what was known and unknown at the time of the event. In the following chapter we will examine this in more detail.
The bias examples discussed here are not exhaustive and many others exist. At least we should be aware that we have to deal with some bias in any investigation. In general, it is important to approach evidence with a critical mind-set and to consider multiple sources of evidence before reaching a conclusion. Furthermore, working in a team and getting second opinions helps to combat bias and overcome tunnel vision.

A true story: Biases - Where can we find them?

Each year at our campus, an exam is held nicknamed "Crash Day". During Crash Day, somewhere on campus, a mock but real wreckage is laid out as part of an exam. Students are tasked to perform a field investigation in groups and write an accident report about it. In this case, a hot-air balloon was positioned in a field. Next to the field was a parking area for cars. As I got hold of a free caravan which needed to be destroyed, it was decided to incorporate this caravan into the exam. The scenario described to the students was that the balloon had hooked the caravan with a rope hanging out of the basket while crashlanding in the field. The balloon had dragged the caravan over the field and crashed. As part of the exam, students were informed that a witness was available. The students got the opportunity to interview the witness before going on scene. After the interview, the students could visit the accident scene.

An American student asked, while going to the accident scene: "What does the tent have to do with a caravan accident?"

I replied: "You are here to investigate an aviation accident, not go on holiday." Then we looked at each other in utter confusion. It took some time to figure this one out and it didn't register until the end of the day for me. So let's examine what just happened here in a bit more detail.

In UK English, a caravan is a wheeled vehicle for living or traveling in, especially for holidays, which can be pulled by a car. In US English a caravan is a group of people with vehicles or animals who travel together for safety through a dangerous area, especially across a desert on camels. This is an irrelevant meaning of the word 'caravan'. However, what the dictionary does not mention is that a Caravan is also a Cessna model 208. Given the fact that the American student had a private pilot license and was familiar with many aircraft types, it showed that the word 'caravan', in the context of the exam, may have a different meaning.

Now let's put everything in context - we have a caravan that the student interpreted as an aircraft and a tent that in fact was a balloon. Imagine now the shock and surprise this student felt when looking at the accident scene.

After the exam, the student wrote a reflection report that showed his learning experience. The reflection report stated: "I was even impressed that a first responder could identify an aircraft model. When we got to the scene, I realized my mistake pretty quickly. Had I not been thinking that a Cessna 208 Caravan was involved, it would have changed my line of questioning for the first responder. The witness was talking about a tent and sandbags and I didn't question her enough about the overall scene because I was not being objective enough. I should have asked more questions about the sandbag situation and what was around the injured people, if they said anything to her, etc. Instead, I made an assumption which was incorrect and consequently did not perform a thorough interview."

What did I learn myself? I learned that a caravan in the UK is something else than in the US and I'll never forget this for the rest of my life. What can we all learn? Be open-minded; for me and my colleagues this was a prime example of what can go wrong (and fast) when a different mind-set is present. Something was lost in translation but it furthermore shows the bias we all inherently have.
[Shared with permission from the student - Thank you]

Determining Evidential Value

Apart from bias, there is another investigative danger, relating to the evidential value. In the previous paragraph, it was stated that observations and facts should be critically evaluated. In other words, the evidential value should be examined. The question now is: what does evidential value entail? In this paragraph we will examine this in a bit more detail.

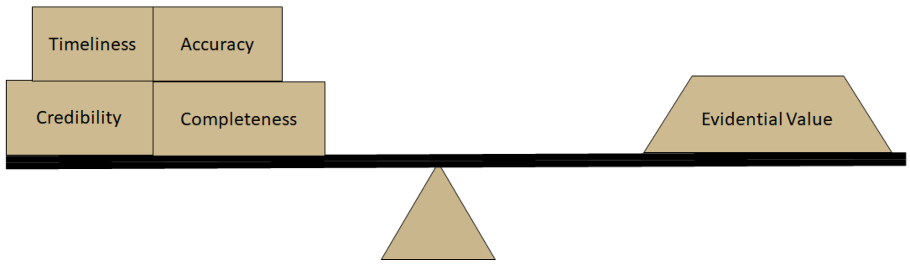


Figure 4.4: Parameters that influence the weight of the evidence, i.e. the evidential value.

The first parameter that influences the evidential value is timeliness. Facts or observations are more valuable if collected at the earliest possible time. This also holds true for witnesses, since in general the longer you wait, the more they forget. In case of wreckage pieces, the sooner you catalogue and describe them, the less likely they are to have been disturbed or moved. As stated in the Gathering the Facts chapter, when performing a preliminary survey it is important to find and identify possible ground impact marks that might be destroyed over time when people (including investigators) are not careful. The second parameter is credibility, by which we mean how accurately the evidence reflect the events or circumstances being investigated. Here the investigator bias comes into play; maybe an investigator is more likely to believe the testimony of certain witnesses over others, or they have preconceived notions about their credibility. It also relates to the difference between what is being said as opposed to what is actually observed. In other words, the description should be given without interpretation, but as just facts. With witnesses this is most likely a problem as they – "to help you" – want to tell a story. The story you want to hear, which in some cases is that was heard on the news

Another parameter related to evidential value is accuracy: evidence is more valuable when it is accurate. Whether a temperature reading is given with a 5-degree or 1-degree accuracy may matter, given the circumstances, even more so when the temperature is recorded every hour, minute or second. Another example is a witness who describing what he saw of a car accident. The witness provided every detail possible, but when asked where he was standing, it turned out that it was impossible for him to see the actual accident. In other words, the witness was too accurate in his statements, while he could not have accurately seen the accident. The evidential value of the information provided was therefore zero. Completeness is another aspect that influences evidential value, even it is sometimes not impossible to reach. Having one or both broken pieces may matter. Having all the wreckage means a full and accurate picture of the events or circumstances being investigated. This also relates to one or multiple observations.

It is worthwhile to have a look at the legal system related to evidential value in court. We can distinguish two different types of courts: the criminal court deals with criminal cases and the civil court which handles non-criminal disputes. Generally, the standard of proof in criminal cases is higher than the standard of proof in civil cases. In a criminal court, it is determined whether a person is guilty or not guilty of a crime. If found guilty, a punishment is imposed and therefore the crime should be proven

"beyond reasonable doubt". In a civil case, the dispute involves compensating the injured party. The burden of proof is based on the "balance of probabilities" or "preponderance of evidence". This means that the evidence presented in civil court by one party must be more likely true than not.
Now going back to investigating an aircraft accident, the goal is not put someone in jail or acquire monetary compensation, but to improve safety. An investigator looks at the evidence (facts) to determine the cause. This is differently from a legal (police) perspective, where the goal is to find the responsible person(s). This explains in part that a safety investigation can (and sometimes will) asses the evidence of facts differently and looks for different evidence, as the outcome of the investigation is different. This does not mean investigators do not assess facts on their merit; they do. Similar to the legal system, the facts are evaluated and logic is used to assess the evidential value. However, the way investigators look at the facts is different. In some cases, an investigator will use strong evidence to support a scenario. However, the strong evidence may not be as strong as one likes. There is no common yardstick to which the value of evidence is measured. In some cases, the evidential value needs to be assed in a probabilistic context.

An engineering approach to evidential value is to put a numerical value (likelihood) to the evidence. This can be described as more of a probabilistic framework, where evidential value is quantified numerically. It is possible to use probability calculus to assess the evidence. Using a fault tree with probabilities is an example. Another approach is to assess the argument strength and reasoning to determine a quantitative value. The Australian Transport Safety Bureau ATSB has published a graph that quantifies primary and secondary terms to a probability scale. Although the figure is clear and the work procedure of the ATSB is well documented, it is questioned regularly, especially because the words used in the scale are not always clear (enough) for the public and media to distinguish the differences. Again, the public and media are looking for who did it, for a soundbite without context, while the aim of investigation is to promote aviation safety.

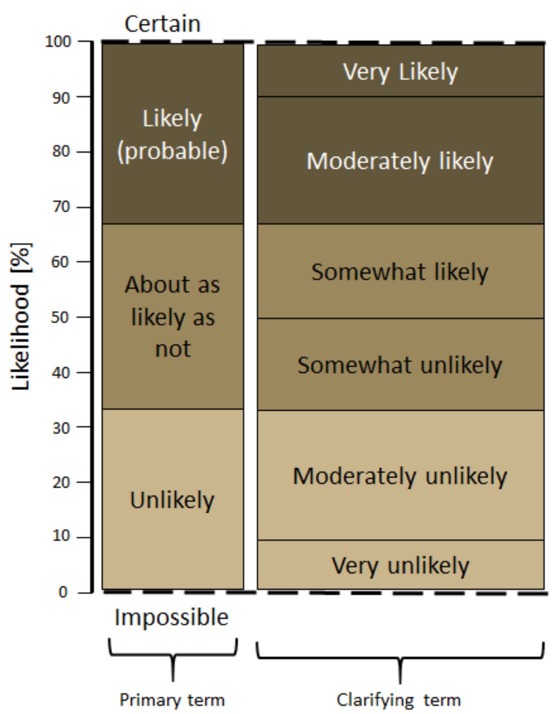


Figure 4.5: Numerical scaling for primary and secondary qualifying terms of likelihood, which can be used in the analyses and conclusion section of the report. [Walker (2008) [no further use is allowed].

The evidential value of the individual fact needs to be described in the report analyses section. Again, think critically and assess the evidential value using primary terms (direct and observable) and secondary (tainted or found at a later date) terms to describe the evidence found. If, at a later stage in the investigation, a new piece of evidence is found, it should be addressed (timeliness). This does not mean the evidence collected earlier is not valuable; it shows transparency and professional investigative conduct.

At the end of the report analyses section, all the facts, each with its own evidential value, are assessed and weighed together to draw a final conclusion(s). A strong conclusion is based on strong evidence. If the conclusion is weaker, quantify and address it in the appropriate terms. Do not cherry-pick facts in order to support a preferred outcome or conclusion. The analyses in the report should be clear and transparent with respect to the process by which the conclusion was reached.

Using the Evidential Value of Facts to Determine the Cause

What about defining the cause? This is what an investigator is looking for, right? Remember that during the accident the aircraft has been deconstructed and mixed into finite factual elements. The investigators' job is to find the facts and reconstruct the sequence of events which led to the aircraft accident. The final outcome of this reconstruction is the accident scenario or sequence of events. When solving a sequence of events, there is always a degree of uncertainty to contend with. The facts can be interpreted using analysis techniques and logic. It is not uncommon, especially in the early stage of the investigation, that multiple scenarios are (very) likely – we just do not know at this stage.
The principle of parsimony, also known as Occam's Razor, is a principle that states that when faced with multiple scenarios, the scenario that makes the fewest number of assumptions is most likely to be true. The idea behind the principle is that the fewer assumptions are made, the simpler and more likely it is to be true. In other words, the more facts you have, the fewer assumptions need to be made, which means the validity of the conclusion increases.

> Student question: This sounds like Sherlock Holmes.
> Answer: Correct, Arthur Conan Doyle wrote: "Once you eliminate the impossible, whatever remains, no matter how improbable, must be the truth." There is a reason why Sherlock Holmes was an excellent detective.

This approach can be effective in situations where there are multiple potential scenarios or sequences, as it helps to narrow down the focus and makes it easier to identify the most likely explanation or solution. However, it is important to be aware that this approach is not fool proof, as it is possible for an improbable explanation or solution to be true. It is therefore important to carefully evaluate the remaining possibilities in order to determine the most likely explanation or solution.
When facts are not available, another systematic approach is to eliminate the impossible explanations or solutions one by one, which will often lead to the simplest and most likely explanation or solution being left. This principle is often used in scientific research to guide the selection of the most parsimonious explanation for a given set of observations. However, for transparency, it should be stated in the report that this approach was used, as assumptions were made which may not be valid.
If it is not possible to completely substantiate the cause or conclusion, the report should, in a positive manner, state the likely cause. Included should be the reasoning behind this professional judgement and what it was based on.

Summary

In general, speculation refers to the formation of an opinion or theory without a sufficient basis of evidence. It is important to distinguish between observations and facts in order to draw informed and reliable conclusions. In order to ensure that a conclusion is not based on speculation, it is important to base it on evidence that has been carefully gathered and analysed. This may involve conducting research, collecting additional information or data, and critically evaluating the evidence before forming a conclusion.

It should be noted that external (witnesses, public, news media, etc.) and internal (investigator) bias is always present. Don't make it a problem, but be aware of this. Use proper techniques to address bias and do not work alone. Every accident is different and should be approached with an open mind.
An accident is an unwanted outcome which, under normal circumstances, leaves evidence behind that makes it possible to determine the accident scenario. In contrast to a legal investigation, an evidential value or probability assessment is not always required. In a legal context, a 'balance of probabilities' is applied, where more serious allegations require an adverse finding to be supported by strong evidence. In safety investigations there is no yardstick for evidential value. However, it is the investigators' job to find the evidence in the form of facts, in order to determine the accident scenario. There are a number of factors that can affect the evidential value.

Timeliness, reliability, credibility and completeness all influence the evidential value positively and, if absent, negatively. The analysis in the final report should clearly show the process by which the gathered facts have been weighted and assessed on their merit. As the outcome of a safety investigation is a recommendation, not sending someone to jail, the legal 'balance of probabilities' is not applied. Despite this difference, due diligence in the analysis and drawing of conclusion is still required.

Questions: Scrutinizing the Speculation

Question 1: Below are several statements. Assign the correct term to each statement.
[Assumption, Presumption, Observation, Fact]

A. The sun will rise tomorrow: …
B. The pilot was experienced and suitable to fly the aircraft: ….
C. The speed dial showed 121 knots: ….
D. The wind is blowing in that direction: ….

Question 2: Complete the following sentences with the most appropriate words [1-5] for [A-B-C].
1. assess
2. prove beyond reasonable doubt
3. (probable) cause
4. facts
5. evidential value
Police officers and investigator will look at the scene and gather facts. The goal of the police is to get evidence to use in criminal court to [A] what happened. However, the goal for the investigator is to establish [B]. Both investigate the same wreckage, but the [C] for each might be different.

Question 3: An aircraft wingtip was found in a forest approximately 1 km from the main wreckage impact point. Investigators investigated the main wreckage 3 months ago and at the time it was noted that the wingtip was missing. Fire crew extinguishing a forest fire found the wingtip. The wingtip was subjected to a microscopic investigation of the wing connection structure. The wingtip construction elements connecting it to the wing showed signs of an overstress failure in an upward direction.
3.1 What is the evidential value of the wingtip?
3.2 What is the evidential value of the failure?
3.3 What is the evidential value of fire damage?

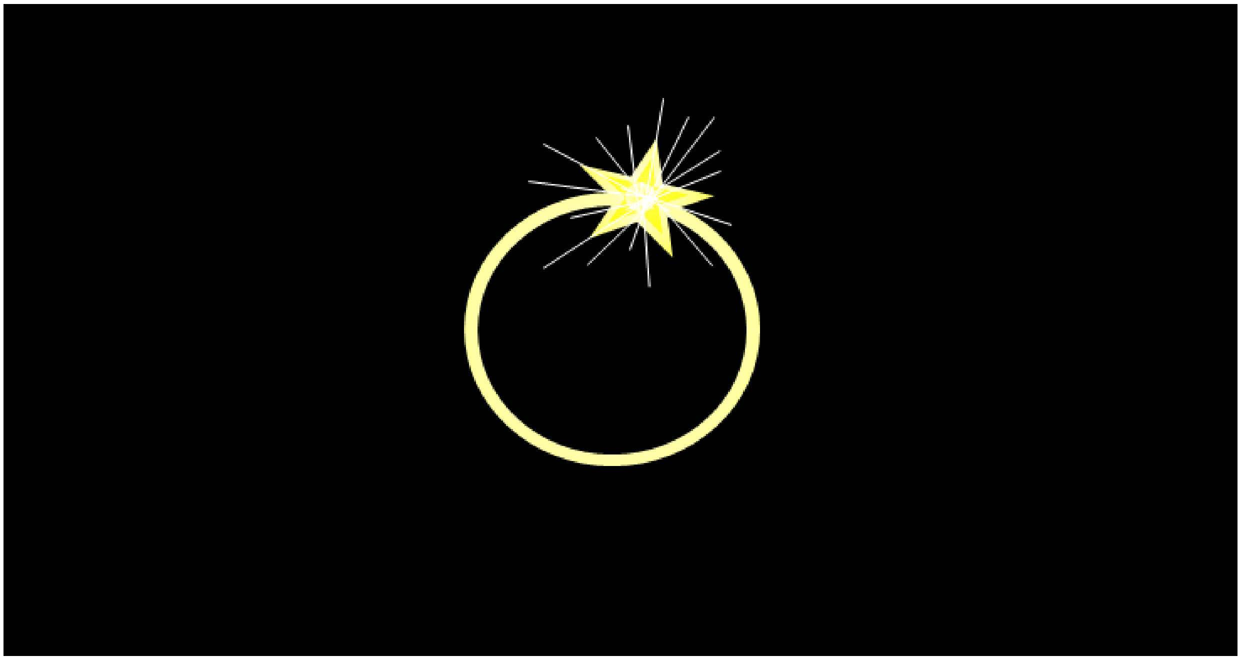
Question 4: Is speculation bad?

Question 5: Test you bias: Which witness is able to explain better what happened? Explain why.

1. Search and rescue crew - fire chief
2. Pilot involved in the event
3. Witness with dog who saw the crash
4. Journalist

Exercise 1:
Read and review a final report of a major accident with fatalities by searching on the internet and answer the following questions:

- Was speculation part of the investigation? (Tip: search and review news articles at the start of the investigation)
- Did the investigation look at and/or address speculation in the report?



The Eclipse Myth

According to myth, Thales of Miletus was able to accurately predict a solar eclipse in 585 BC. He used his understanding of the movements of the sun, moon and earth to calculate that an eclipse would occur on a specific date. He announced his prediction to the people of Miletus. On that day, the eclipse occurred as predicted and he was hailed as a genius and a prophet. The eclipse was a something the people did not (yet) know that would happen; it was unknown.

Chapter 5 What do we Know?

Introduction

"Cogito, ergo sum" ("I think, therefore I am"), is Descartes' famous statement in which he argues that the only thing we can be certain of is our own existence. He proposed the method of doubt, also known as Cartesian doubt, a systematic method of questioning and evaluating all beliefs and assumptions in order to determine which are certain and which are not. Descartes proposed this method as a means of finding a foundation for knowledge that is certain and unquestionable. This means that, in order to understand what we (do not) know, we should examine knowledge. In the next paragraphs, we will have a look at several models and provide you with some food for thought about your knowledge.

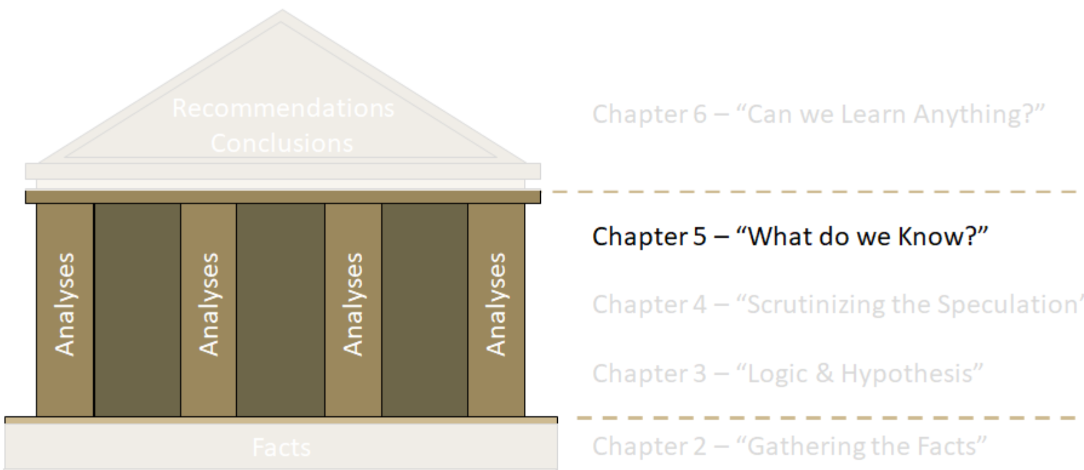


Figure 5.1: The investigative temple, with in the analyses phase the chapter Logic and Hypothesis.

Knowledge Framework

In order to examine knowledge, we will look at the Data, Information, Knowledge, Wisdom (DIKW) framework. This framework shows the relationship between the different types of knowledge and how they are interconnected. The DIKW model is generally applied in knowledge management and information system research. However, the framework has been adapted to be useful in other areas as well. In the DIKW framework, data is understood to mean raw facts and figures, such as numbers, dates and measurements. Data is often unorganized and requires some form of processing to be useful. When the data is transformed into something useful, it becomes information. This information is interpreted and put into context, which is subsequently used to make an informed decisions and solve problems, i.e. knowledge. The final and highest level of knowledge and understanding is wisdom. It involves the ability to use knowledge to make sound, broader decisions, even in difficult or uncertain situations. As shown, each transformation adds value to the next in order to reach wisdom.

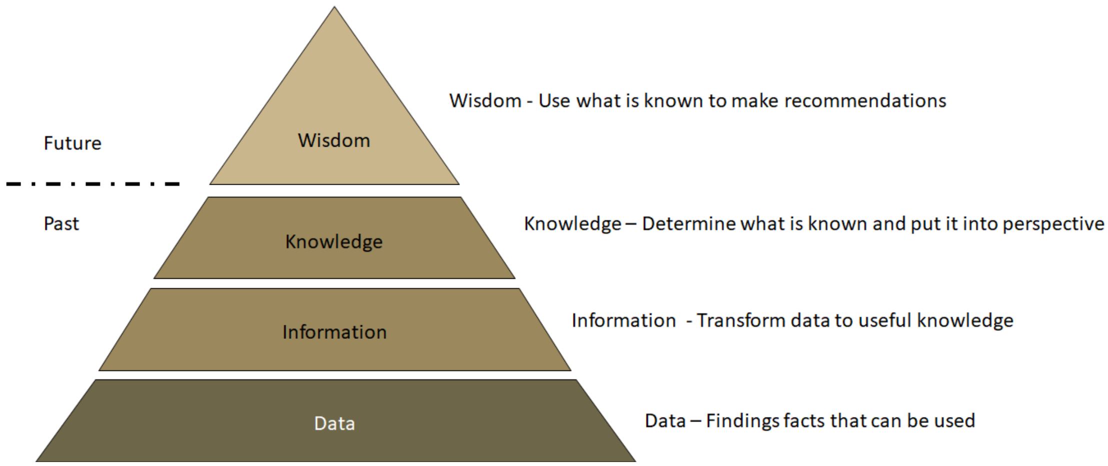


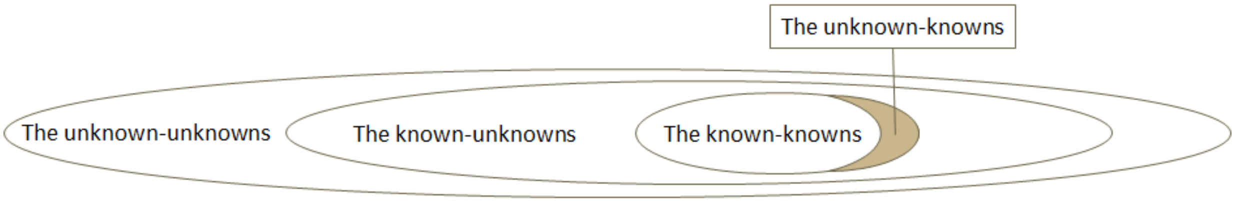
Figure 5.2: The DIKW framework pyramid. The pyramid shape does not mean there is no relationship between the different levels, nor is there a single path from top to bottom.

The DIKW framework can be applied in accident investigation to understand the data management process. In accident investigation, data is collected from a variety of sources, such as the wreckage, witness statements and on-board systems. This data can include things like measurements, timings and sensor readings. The data is processed and organized to create information that can be used to answer questions or create new ones. The information is subsequently used to create knowledge about the cause of the accident. This might involve identifying the sequence of events that led to the accident, and understanding the factors that contributed to it. This knowledge can then be used to create wisdom, i.e. make recommendations to prevent similar accidents from occurring in the future. The main point of the DIKW pyramid is to understand the data in order to reach wisdom. In this book we have not yet reached that stage. For this, we will in this chapter first have to understand what we actually know - remember Cartesian doubt?

What is Known?

In 2002, United States Secretary of Defence Donald Rumsfeld explained during a press briefing the difficulty of finding weapons of mass destruction in Iraq. He stated that: "As we know, there are known-knowns; there are things we know we know. We also know there are known-unknowns; that is to say, we know there are some things we do not know. But there are also unknown-unknowns, the ones we don't know we don't know." The concept put forth by Rumsfeld about what we know and what is unknown is interesting (Rumsfeld, 2013).

If we examine this concept in a bit more detail, there is something to be understood. The concept separates two notions. The first notion is that something is identified; in other words, we ‘observe’ or we are aware of it. The second notion is the fact that something is understood. Now, given the world we live in is infinite, we recognize that there are unknown-unknowns (Figure 5.3). We know that we do not know everything and we have not identified everything. Within the unknown-unknown (that is, everything), we sometimes know that something exists but we have not yet explained it: the known-unknown. Fortunately, we do know some things that we have identified and we can explain: the known-known. However, we sometimes forget things; we (still) understand them, but they do not exist anymore (they are unidentified): the unknown-known.



	Identification	Understanding	
Known-knowns	V	V	Things (i.e.: problems) we know that we know
Known-unknowns	V	X	Things we are aware that we don't know or think we know but miss in fact knowledge
Unknown-knowns	X	V	Generally caused by collective forgetfulness of past knowledge or ignorance
Unknown-unknowns	V	V	Something that has not or could not have been imagined or anticipated

Figure 5.3: A schematic representation of the Knowns and Unknowns.

So, what do we know? The short answer is: if it is a known-known, we know. Nevertheless, this is not helpful, as it does not mean anything, right? Well, because we know, it means we have identified and understood it. Here again, similar to the previous chapter, it is important to make sure we know what we know and the fact is indeed fact. So, what can we do to make sure we know that we know? We may need to change our perspective to be sure.

Change your Perspective

During an investigation we should consider multiple perspectives. As the saying goes: assumption is the mother of all screw-ups that could have been avoided by taking a more critical and analytical approach. The analytical approach we have discussed in Chapter 3 and 4, and consists of using logic and addressing speculation. In this chapter we will focus on the critical thinking attitude an investigator should have.

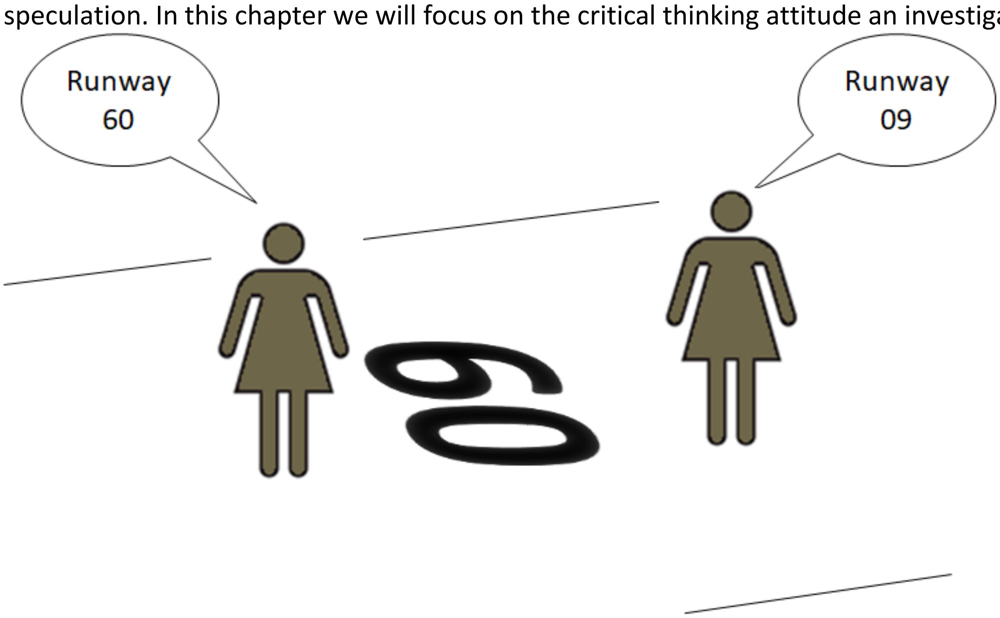


Figure 5.4: Example of the effect of changing your perspective.

This includes being open to different perspectives and considering alternative solutions or explanations. What do I mean by 'changing perspective'? In fact, it means looking at what you have in a different way. For example, when painting it is difficult to overcome the brain's preconceptions of what something should look like. Some artists on occasion turn a portrait upside down as a way of forcing their eye to see in terms of forms and shades. If you turn the painting upside down, you no longer see a nose, but a mass of colour and shadow that either does or does not have the same shape. Forcing to change your perspective will help in thinking differently (Figure 5.5).

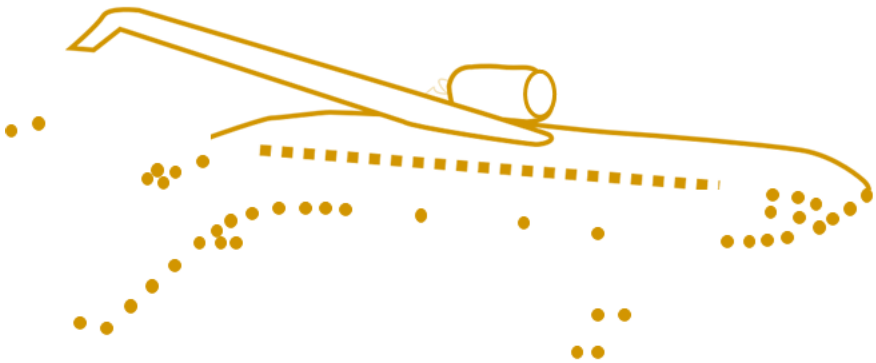


Figure 5.5: Connect the dots, turn the page upside down and the image will appear.

Thinking Differently

Another way of being critical is being willing to question one's own thinking and the thinking of others. This includes being open to changing one's mind in light of new information. What I often do is ask 'dumb questions'. This is usually a question nobody asks, or maybe dares to ask. By 'dumb question', I mean a fundamental question that queries the foundation what we know, the general principle or widely accepted premise; the question no one thought to ask.

For example: Why wouldn't foam insulation impacting a surface create damage? It has almost no weight, so it doesn't matter – or does it? For the observant reader, this question references the Space Shuttle Columbia accident. On 1 February 2003, the Space Shuttle Columbia broke apart during re-entry, killing all seven crew members. The accident was caused by a piece of foam insulation that had fallen off the external fuel tank during launch, damaging the heat shield on the wing. The knowledge of how insulation debris could cause such damage was not well understood at the time. Extensive modelling by NASA and others, when the conditions of the launch were simulated, showed that it was possible that insulation foam could damage the shuttle's protective shield. When this new knowledge was used, it explained the sequence of events. Again, at the time of the event this knowledge was not present and common belief was that it did not matter.

Finding the Truth in Falsehoods: Both engines failed - Part II

Remember in Chapter 3 Logic and Hypothesis the investigation team looked a commercial twin jet engine aircraft that made an emergency landing with two engines inoperative. A few hypotheses were looked at. The final hypothesis was that the weather conditions had caused the crash. The investigation team reviewed the weather data and finds that the aircraft was flying through an area with severe thunderstorms at the time of the engine failure. Closer examination of the weather data revealed that hail and rain were also present.

Now it is time to ask the difficult questions. Can we explain the event? What is it that we know? According to experts, water ingestion is not a problem for a jet engine. Most of the water never makes it through the actual engine core. Instead, it flows into the bypass duct near the first or second stage of the compressor. In essence, the engine design prevents water (and debris) from entering the core. Water that does make it past the ejector will be vaporized by the heat generated in the high-pressure compressor. That steam will simply energize the combustor and power turbine, adding a bit of power to the engine.

At this point you should have seen some red flags. Before you continue reading, ask yourself this: What did the experts really tell you? The expert said: the premise was that bypass engines are not susceptible to rain and hail, given the design. However, for older model turbojets hail and rain can be a problem. In this engine design, large amounts of water can enter the engine core. This can affect not only the performance of the compressor, but also impair the functioning of the combustion chamber. Now, if we look back at the event flight, the engine was indeed an older turbojet model. The hypothesis that rain or hail could have caused the engine failure went from impossible to very likely, given (new) certain information. However, this was not the case, since the engines on the aircraft were high-bypass turbofans.

So, are we back to square one? Maybe not; we may assume that the certification standard for water ingestion was sufficient. Following further investigation, it was determined that the certification standards at the time of the event did not reflect the rates that can be expected in moderate or higher-intensity thunderstorms. Therefore, in theory, the engine was "allowed to fail", given the certification standard. I am not saying that it's a good thing to lose both engines due to a thunderstorm with hail and rain, but it is the current state of affairs. I do think that we can agree that maybe it is wise to make a recommendation related to this. In the next chapter we will look at recommendations in more detail.

Test when in Doubt

As mentioned previously in Chapter 4, Scrutinizing the Speculation, we need to take a step back, assess what we (think we) know and identify the unknown. There is no harm in seeking new information through testing; in fact it is appropriate within an investigation to verify what you know. In the previous paragraph NASA engineers did it during the Columbia investigation, so why not you?
Verification in accident investigation is the process of confirming the accuracy and validity of the information gathered during the investigation. In events where structural failure is suspected, it is wise and required to do a material and fracture examination. In this case a laboratory test and engineering analysis of the fracture surface will provide insight and additional facts which can be used later in the analyses phase of the investigation. Another method that can be applied is computer testing or modelling, which uses verified aircraft models to simulate, for example, flight data. An interesting note: this type of testing is also used to validate recorded data. When the FDR data can look 'good' and it is consistent with aerodynamic models, it can be considered verified.

Another example is a functional test that can show whether a piece of equipment was operating as designed and/or expected. The different types of testing described can be considered a mini hypothesis that is tested. A mini hypothesis relates to a small part of the investigation, but can help to prove or disprove different hypotheses. In general, the laboratory test and engineering analyses aim to ensure that the facts are accurate and reliable. There are also laboratory tests, simulations or full-scale tests that are used to gather (more) facts, as some knowledge is missing.
In order to perform such tests, it is important to formulate a test objective. Going back to the reason why an investigation is done using the party system: the brainpower of different parties is available.

Using the input from several parties, a useful test can be designed to gather (more) information. Once the goal is established and the test can be executed, it can be determined what information this test will yield. In a perfect world, the test will show what was expected. Thus, the conclusion can be formulated that the test confirms what you wanted to know. Great, you have done it - or maybe not? It is still important to determine if the test is representative: are the boundary conditions of the test consistent with other facts surrounding the accident? Again, it does not mean the test is wrong; it just means your test had an observed outcome.

On the other hand, and it happens, the test may show something unexpected. Now, this is where it becomes interesting. As before, ask yourself whether the test is wrong or the boundary conditions are not representative for the event. In both cases, use critical thinking to make sure you are doing what is expected in an investigation. It might be a surprise if a block of foam impacted and actually penetrated the wing surface. The NASA engineers were just as surprised as you would be, but it was a very valuable test outcome.

Being mindful of using the facts you have and applying logic is crucial in the analysis phase. After putting in a significant amount of effort to gather the facts, it is imperative to pay the same level of attention to detail in the analysis phase. Failure to do so can lead to a lack of understanding and context, making it difficult to gain any meaningful insights from the facts. This is a topic that will be explored further in the next chapter, which will focus on the question of whether or not we can truly learn anything. It is important to remember that the analysis phase is just as important as the data collection phase, and that only by putting the facts into the appropriate perspective, we gain a deeper understanding of the event.

> Student question: Should you question everything in an investigation?
> Answer: Maybe; it is not a bad idea to question the assumptions on which the main hypothesis or scenario is based. That is to say, be mindful of the difference between being able to explain the scenario versus the scenario being substantiated by facts. I have seen it happen several times: one hour into an investigation, the initial conclusion about what happened was already formulated into a draft report. I am not sure what the drive was to finish the investigation so quickly; it might be nice from a job performance point of view, but it is not the goal of an investigation. Remember that Rome was not built in a day.

Line up What is Known

Now that we have discussed the analysis part, it is important to know what we know and what it will lead to. The analysis part is not only important to figure out a sequence of events, but also gives us the opportunity to investigate areas which may not have been identified as important before. There are many analysis methods; some are simple while others are complex. In general, it is recommended to start simple and, if required, extend the analysis method, depending on the complexity of the event. A common analysis method is the sequence analysis. The main purpose of a sequence analysis is to determine if it makes sense, i.e. whether it is likely and logically consistent with the facts. This method is useful in checking whether more investigation needs to be done.

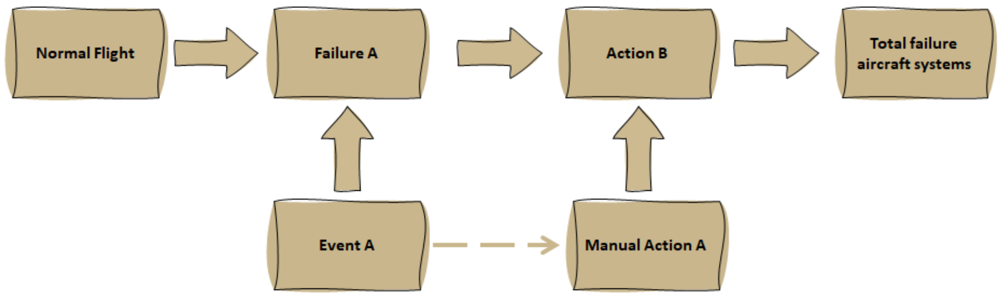


Figure 5.6: Sequence of events leading to a total failure of aircraft systems. The action required for failure A was not Action B. Scenario Failure A with Action B would explain the total failure of aircraft systems.

Another useful method is timeline analysis, whereby the event sequence is projected on a timeline. Because the dimension 'time' is added, other aspects like workload and the unexpectedness of the events can be investigated. The sequence, the actions of pilots and their interaction can be analysed over time.

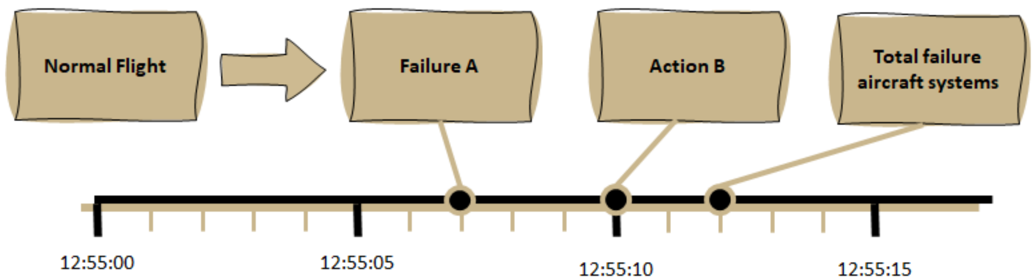


Figure 5.7: Timeline analysis for an event sequence.

Another method is to use a fault tree analysis, whereby the aim is to examine by logic whether, and maybe how, a failure can have a certain result. Keep in mind that the usefulness of a method depends on the event type. Keep an open mind and have your work reviewed by others according to the four-eye principle.

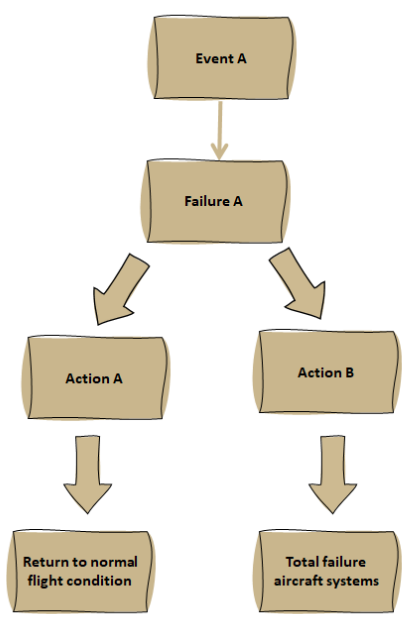


Figure 5.8: Fault tree analysis showing the resulting difference between Action A and Action B following Failure A.

Summary

The Data Information Knowledge Wisdom (DIKW) model was introduced to understand the different levels of knowledge and the way data is converted to wisdom. It is a high-level model that aimed to show the different steps required for knowledge. The first pitfall is to understand what we know and why. Once we know, it is time to challenge our knowledge and determine its validity. By changing perspective and thinking differently, the facts may make sense and the accident can be explained. In the past, accidents have occurred which exemplify the knowledge gap either being overlooked or not appreciated. This may cause problems in the future.

When thinking differently and changing your perspective creates any doubt, it is time to take the analysis to the next level. Test what you want to know. Similar to gathering the facts and applying the scientific method, sometimes more facts are required. Set a goal for testing: what is it that we want to test? Once a test has been completed, it is important to establish which additional data have been acquired. Given this data, which is put into context, certain new information will become known. As mentioned before, sometimes a definitive answer cannot be given or the test does not show what is expected. These are all valid outcomes and should be addressed in the report. The ultimate goal is to create a foundation and (deeper) understanding to explain the cause(s) of the event and what can be learned. This process takes time and should be done systematically. Establishing the sequence of events and creating a timeline helps us to order the event and analyse it in more detail. Depending on the event, other analytical methods may be more useful. Do not be shy and apply critical thinking, which means you actively and skilfully analyse, evaluate and synthesize information to reach a justified conclusion.

Questions: What do we Know

Question 1: When the DIKW model was discussed, different hierarchies were explained. Given the statements below, find the most appropriate answers to questions 1.1 and 1.2.

A. The temperature is 18 degrees
B. The thermometer indicates 18 degrees
C. The weather is hot
D. The temperature is warm

1.1 Which of the statements above can be defined as data?
1.2 Which of the statements above can be defined as information?

Question 2: In the late 1980s, accidents and incidents occurred due to wire chafing. Because of these events, changes were implemented in the rules and regulation to prevent re-occurrence. In the 2010s accidents and incidents have occurred which can be attributed to wire chafing.
How would you put the wire-chafing concept in the “Knowns and Unknowns” model as discussed?
Question 3: What, in general terms, does ‘changing your perspective’ mean as described in this chapter?

A. Stand upside-down to look at a picture differently
B. Be a critical thinker
C. Reasoning why you’re right and the other is wrong
D. Approach the problem to solve it

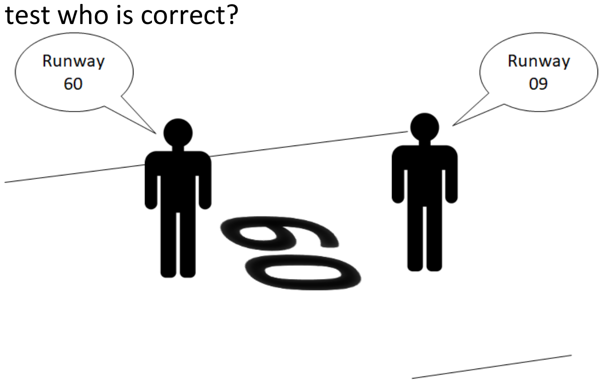
Question 4: What, in general terms, does ‘think differently’ mean as described in this chapter?

A. Use your brain differently
B. Be a critical thinker
C. Think why you’re right and the other is wrong
D. Think about the problem to solve it

Question 5: In what way does testing help in an investigation?

A. To establish what we know by testing material properties
B. To confirm or refute what we know about the operation of a system
C. To determine the possibility of a failure of a component
D. To simulate the FDR data and reconstruct the pilot’s actions to establish the sequence of events

Exercise 1: You have seen this example before in the paragraph Think Differently. What are options to test who is correct?



Exercise 2: Read and review the scenario called ‘Finding the Truth in Falsehoods: Both engines failed’ that were discussed previously. Based on the information provided, make an overview of what is known.

The rainbow and Iris

According to Greek myth, Iris was the daughter of Thaumas and Electra and was one of the many divine beings who lived on Mount Olympus. She was known for her beauty and her ability to travel through the air at great speeds. Iris was described as a general messenger, who served all the gods. She was vital in facilitating communication and understanding between the divine and mortal world. As Iris was able to move swiftly through the air from one world to another, she created a rainbow in her wake. A rainbow can be seen as a bridge between heaven and earth.

Chapter 6 Can we Learn Anything?

Introduction

This is the final chapter, marking the closure of your investigative journey. Throughout the investigation, you have no doubt encountered numerous challenges and obstacles, but with perseverance and hard work, you have gained the opportunity to create a "rainbow" - a tangible outcome in which valuable lessons are learned from the accident. In this chapter, we will conclude the investigation by discussing the process of drawing conclusions and making recommendations, the final steps in ensuring that something is learned from the accident. In order for recommendations to be effective, they must be based on a thorough understanding of the factors that led to the accident and must be targeted at addressing these issues in a meaningful way. By following a careful and systematic process for drawing conclusions and making recommendations, we can ensure that valuable lessons are learned from accidents and that steps are taken to prevent similar accidents from occurring in the future.

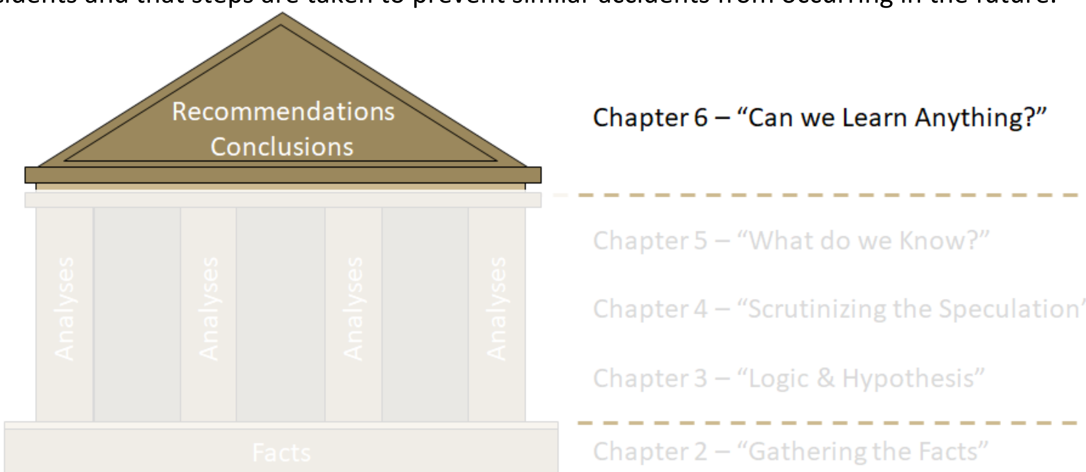


Figure 6.1: The investigative temple with in the roof showing the chapter Can we Learn Anything?

Drawing Conclusions

Following the investigation phases, in which facts were gathered and analyses performed, it is now time to draw conclusions. In order to draw conclusions, it is important to have carefully analysed all the available evidence and information gathered during the investigation. There needs to be a direct relationship between the conclusions drawn and the facts found. The conclusions should be based on the facts and not go beyond the investigated areas. When certain areas (human factors, airworthiness etc.) were not investigated, the investigator should refrain from making statements or drawing conclusions in that particular area. If at a later stage, from a safety standpoint, this area is deemed to be important, the necessary facts should be gathered and relevant analyses performed. It sometimes also happens that during the analysis a new investigative avenue is found which needs to be studied. In this case, you should go back to the 'gathering of facts'-phase of the investigation and address this area.

According to the report format in Annex 13, a conclusion should list the findings and causes established in the investigation. The list of causes should include both the immediate and the deeper systemic causes. In the next two paragraphs, we will look at findings and causes separately.

Formulating Findings

Findings are statements of all significant conditions, events or circumstances in the accident sequence [reference ICAO. (2003)]. Some findings point out the conditions that pre-existed the accident sequence, but they are usually essential to the understanding of the occurrence. The findings should be listed in a logical sequence, usually in a chronological order. Examples of findings are:

- The weather conditions at the time of the accident were cloudy with low visibility.
- The pilot had not received proper training on emergency procedures.
- The aircraft's maintenance records showed that the last inspection had not been completed properly.
- The aircraft's navigation system was not functioning properly during the event flight.

These findings are important because they provide information about the conditions and circumstances that preceded the accident. The aim of the 'findings' section of the report is to address the relevant steps in the accident sequence, but these are not always causally related to the accident or indicate deficiencies. The findings should be described objectively and avoid any bias or preconceived notions. It should not be a surprise that the findings should be based solely on the evidence gathered during the investigation. And finally, the 'findings' section should be clear, concise and to the point, avoiding unnecessary details or tangents. In order to achieve this, it is sometimes required to use technical jargon or complex terms in order to be specific and describe a finding unambiguously.

Some safety board's elect to separate findings related to causes from findings related to safety. Causal findings identify the factors that directly or indirectly contributed to the occurrence, whereas findings related to safety are those findings which did not (directly) contribute to the event, but could have a negative impact on safety. As an example, if the aircraft's maintenance records showed that the last inspection had not been completed properly, this is a safety finding, if it is not directly causal. However, if incomplete maintenance directly led to the accident, this finding should be addressed accordingly.

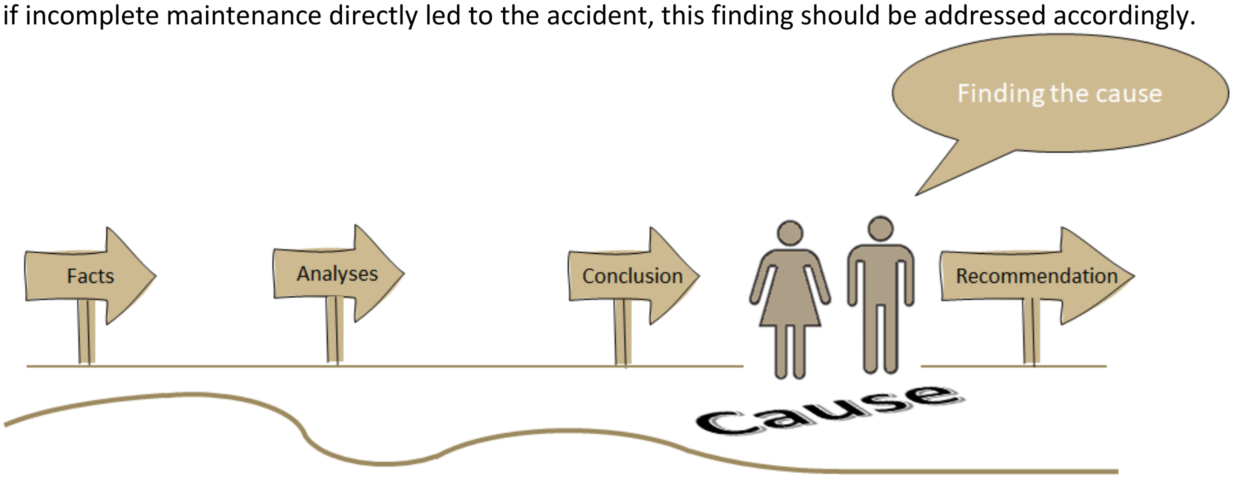


Figure 6.2: Finding the cause before reaching a conclusion.

Formulating Causes

Causes are defined as actions, omissions, events, conditions, or a combination thereof, which led to the accident or incident [Doc 9756]. A cause is an act, omission, condition or circumstance which, if eliminated or avoided, would have prevented the occurrence or would have mitigated the resulting injuries or damage.

A detailed analysis of an accident will normally reveal three cause levels: basic, indirect and direct causes. Basic causes can be defined as the root cause(s) of an accident. They are the underlying factors that contribute to an accident, and they are often the result of multiple failures or deficiencies. Examples of basic causes might include poor safety management, inadequate training, or flawed design. Indirect causes are the intermediate causes of an accident. They are the factors that contribute to the basic causes, and they often involve the failure of equipment or systems. Examples of indirect causes might include the failure of a component or the failure to maintain equipment. Direct causes are the immediate causes of an accident, i.e. the factors that directly led to the accident occurring. Examples of direct causes might include pilot error, weather conditions, or a failure to follow procedures.
The list of causes should include all the cause levels, for examples:

- The maintenance crew's inability to properly inspect and verify the performed maintenance actions before releasing the aircraft for flight.
- A navigation system malfunction, resulting in the aircraft flying off course.
- The pilot's failure to follow emergency procedures.

When drawing a conclusion on the causes of an accident, it is important to use a logical and systematic approach, such as the "Five Whys" method, which involves repeatedly asking "why" to delve deeper into the root cause(s) of the issue. It is also important to consider all possible contributing factors, rather than focusing on a single cause or jumping to premature conclusions. Consider potential causes from different perspectives, including technical, human, organizational, and regulatory. In addition, it is important to ensure that the conclusion is based on factual evidence and is objective, rather than influenced by personal biases or assumptions. It is also important to consider the implications of the conclusion and to communicate these clearly and concisely in the final report. The aim of the investigation report is to formulate recommendations for identified safety issues in order to prevent reoccurrence or to mitigate the consequences of the event if it happens again.

> Student question: I sometimes read in an accident investigation report that the probable cause of the accident was…. Why does it say ‘probable’? When I read the report, it is clear what happened and why.
> Answer: Good question. We should look at it from a legal perspective. Some safety boards, for example the National Transportation Safety Board in the US write in their statute that the purpose of an investigation is to determine the probable cause(s) of an accident [Independent Safety Board Act Public Law 93-633). In other words, they must formulate the cause as probable.

Making Recommendations

If an investigator wants to make recommendations, how should they be written? What should it say? And to what end? How do we make sure we get the safety message across to the appropriate audience? In this chapter, we will take a deeper look at a safety recommendation in the context of a safety investigation and try to answer the question posed before.

Similarly, to the formulation of conclusions, which should be clear, concise, and supported by evidence from the investigation, a recommendation should be formulated with the same rigor and attention. According to Annex 13 a safety recommendation is a proposal of an accident investigation authority based on information derived from an investigation, made with the intention of preventing accidents or incidents, and which in no case has the purpose of creating a presumption of blame or liability for an accident or incident.

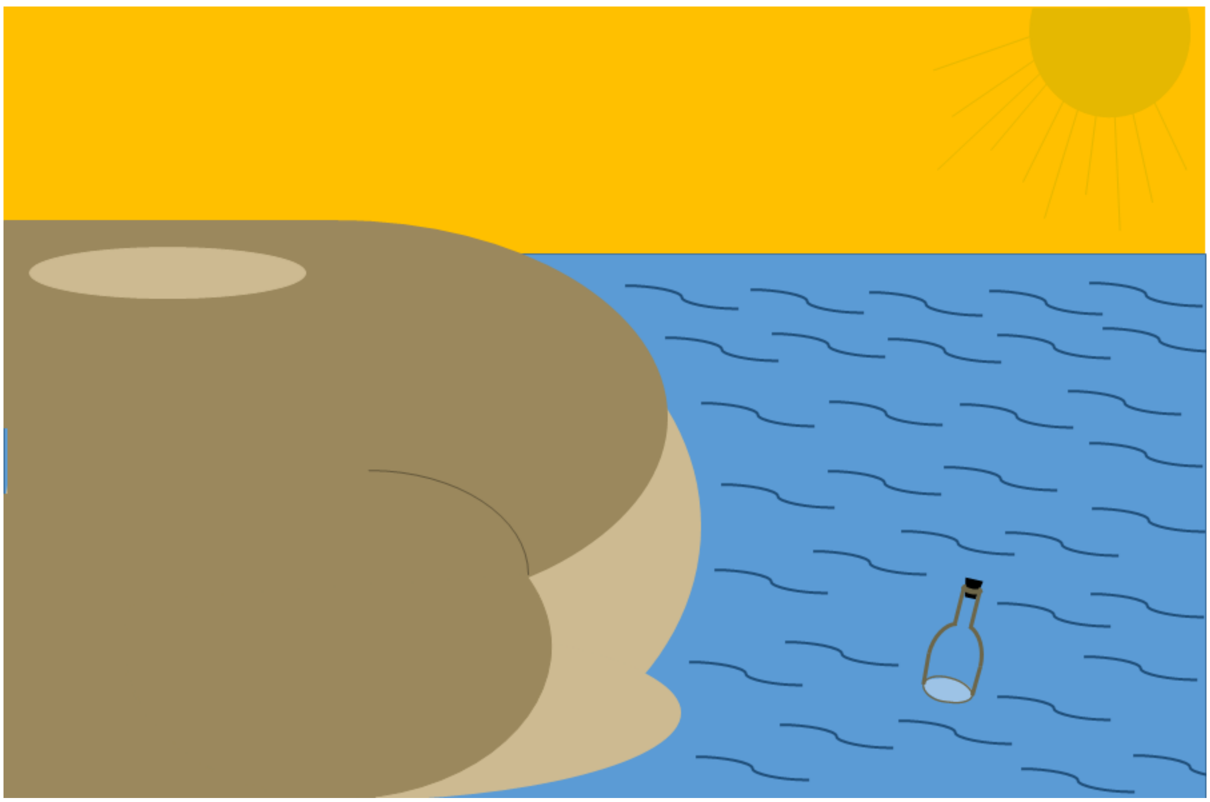


Figure 6.3: Message-in-a-bottle drifting in the sea.

A particular form of communication is a message that is written on a piece of paper which is then sealed in a bottle and released into a large body of water: a message-in-a-bottle. Messages-in-a-bottle have been used in romantic movies for love letters to that special someone. In other cases, people on deserted islands have used the message-in-a-bottle to ask for help. The message-in-the-bottle method has also been used in scientific studies on ocean currents. As you can see, something as simple as a message in a bottle can have many forms and outcomes. Depending on the current, the message can miss its intended recipient and drift further away, only to be found years later. Similarly, a recommendation (message) may or may not find its way to the right person or entity. Remember that we are talking about the safety issue uncovered in the investigation, which is addressed by the recommendation. Therefore, careful thought should go into drafting a recommendation to address the safety issue, in order for it to be successful.

> Student question: Should a recommendation be discussed with a recipient/stakeholder during the investigation?
>
> Answer: Normally the draft report does not contain safety recommendations, mostly due to internal safety board regulations. However, the same regulations provide parties the opportunity to submit their recommendations during the (technical) review of the draft report. Although it might seem odd, writing a recommendation to your own company it is strongly encouraged by safety boards. Remember that being critical when it comes to safety, even towards your own organisation, should be considered normal and be respected by company management. Knowledge that is not shared loses its worth. This is why investigators should strive for the golden wings of angels in order to be able to deliverer messages of change where required.

Identifying the Safety Issue

Now that we have drawn conclusions and formulated the (probable) causes of the accident, it is time to reflect and determine the safety issue. The identified causes are assessed to determine the chance that they contributed to the event. In other words, although a cause is determined to be contributory, the risk cause may be determined to be of lesser importance compared to other determined causes (Figure 6.4). For example, an oversight by a pilot, although causal to the event, could be deemed of lesser importance to the risk than a system or procedural mismatch that led to the failure. Addressing the riskier (systemic) cause will lead to an increase in safety. The improvement or evaluation recommendation addresses the safety issues that have been identified in more detail.

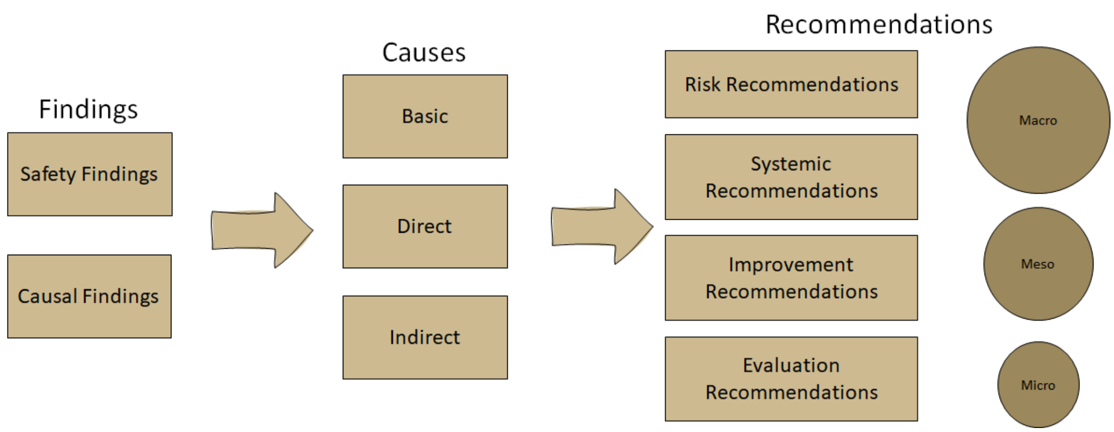


Figure 6.4: The relationship between findings and causes, with the resulting recommendation types and the related organisational level.

As such, the recommendations that come out of an investigation are sometimes disjointed from a cause, even though there was high evidential value. This explains, for example, why in the public eye recommendations do not fully reflect the event, resulting in understandable confusion or even frustration. The investigation and recommendations are written to enhance aviation safety, while the public interest and the judicial investigation have a different goal: they are looking for responsibility (blame).

For a recommendation to be effective, meaning it will be implemented, it is important to assess the organisational level of the safety issue. Safety issues that are local, i.e. operational or environmental (related to one type of aircraft), can be considered to be at the micro level. During the accident analyses phase of an investigation, it could be determined that certain risk controls were in place to mitigate the safety issue, but they may not be as effective due to organisational factors. This can be considered to be the meso level. When supporting evidence is found that the issue occurs at a broader scale, the recommendation should be formulated to address the meso level. If safety issues are found which can be considered to be broad or systemic within the total aviation framework (global), a macro level recommendation should be considered.

Given the required improvement, the next step is to determine who can make the improvement. Similar to assessing the safety issue, the recommendation recipient should also be selected carefully. Once the recipient level is determined, the investigator should consider which stakeholder is responsible to address the identified safety issue. Although a recommendation can be valid and addressing it to a specific stakeholder seems reasonable, if the stakeholder is not responsible or lacks the power to implement change, the recommendation has no merit. During the investigation, it is therefore important to assess and determine the appropriate stakeholders for each recommendation. Again, using the word 'responsible' does not mean liable; it means that the investigation identifies a certain stakeholder who is the most appropriate recipient to make changes and address the identified safety issue.

Now that the safety issue and recommendation recipient are identified, one should determine why the recipient should make an improvement. Tailoring the recommendation is very important, as it will, in part, determine its acceptance and implementation. The recommendation recipient should have some level of control and responsibility; if this is not addressed, the risk of future accidents will not decrease. An aircraft design is based on rules and regulations, engineering knowledge, and trade-offs in order to produce a safe and economical operational aircraft. The process of developing any aircraft design has taken a long time and includes rigorous flight tests and certification programs. In most cases, a safety investigator does not have a complete overview of the trade-offs made by a manufacturer. A recommendation that specifies a solution may in fact be an unsuitable way to address the safety issue, given the design and trade-offs made by the manufacturer. Furthermore, a safety board should not recommend a specific solution, since any solution, which may be implemented in the future, could become the cause of a new accident. Thus, the value of the accident investigation is lost.

Thus, a recommendation should address the safety problem, but not provide a solution to the identified problem. When it is not possible to eliminate the identified safety issue, the recommendation should aim to reduce its likelihood. Care should therefore be taken to make sure the formulated recommendation is both appropriate in scope and reflects the safety issue. Here, a recommendation can be made to evaluate the assumptions made during the design by the manufacturer. There are many ways to formulate a recommendation to address a safety issue, so think carefully.

Student question: A major accident report gets all the attention and recommendations are therefore probably more often implemented. So, why do incident and serious incident investigations for smaller events?

Answer: Major accidents are high-profile events which definitely get public attention. This attention helps in getting resources and finishing the investigation in a short timeframe. However, it does not mean that the resulting reports are worth more; the investigation procedure is the same for events of any scale and the recommendations are formulated using the same principle. From my personal experience, a serious incident and incident report with earnest recommendations are very beneficial and have resulted in major changes. Investigating a (serious) incident, which is often a precursor to a larger event, can be valuable in preventing an even worse outcome.

Investigator's Top Tip – Recommendation specification checklist

When drafting a recommendation, it is important to consider the following key points.

Identify the safety issue: Clearly define the problem or issue that needs to be addressed. This includes the evaluating the risk associated with the safety issue.

Identify the recipient: Determine who is responsible for addressing the issue and is capable of implementing the recommendation.

Recommendation goal: Clearly articulate the desired outcome or goal of the recommendation and explain why it is important.

By addressing these points, you ensure that your recommendation is focused, targeted, and effective. It is also important to base your recommendation on the facts and analyses presented in the report, as this will help to provide a solid foundation for your proposal. By following a structured approach to recommendation development, you can effectively communicate the steps that need to be taken to address safety issues and improve overall safety performance.

Summary

It is important to identify and analyse the causes of an accident or incident in order to prevent similar occurrences from happening in the future. A safety recommendation is not intended to assign blame or liability, but rather to identify and address any underlying issues that may have contributed to the accident. This requires a thorough understanding of the events leading up to the accident, as well as the conditions and circumstances that contributed to it. A first step towards making recommendations is formulating findings based on the investigation facts and analyses. After formulating the findings, causes are identified which contributed directly or indirectly to the event. The cause could be very basic, but there are underlying issues which in most cases have the potential to contribute to other events in a variety of ways. By identifying the root causes of an accident, investigators can make recommendations. It is important for a safety recommendation that the appropriate recipient is targeted, and the desired outcome is clearly articulated. This is done by identifying the safety issue clearly and determine who is the appropriate recipient to address it.

> Student question: I know when to start an investigation, but when does an investigation end?
> Answer: The end goal of an investigation is to determine the causal factors and identify safety issues. The safety issues should be addressed and improved by recommendations. This is not a singular path; as was shown in the previous chapters, an investigation is an iterative process. Do not be afraid to go back and (re)examine the evidence, re-establish the facts and draw conclusions by analyses. Because of the complexity of the aviation system, having input from various sources is vital; it is a team effort. Using a solid analysis method and having regular meetings with colleagues or the investigation team will help to overcome bias. A recommendation is not the end; it’s the beginning of change to improve aviation safety.

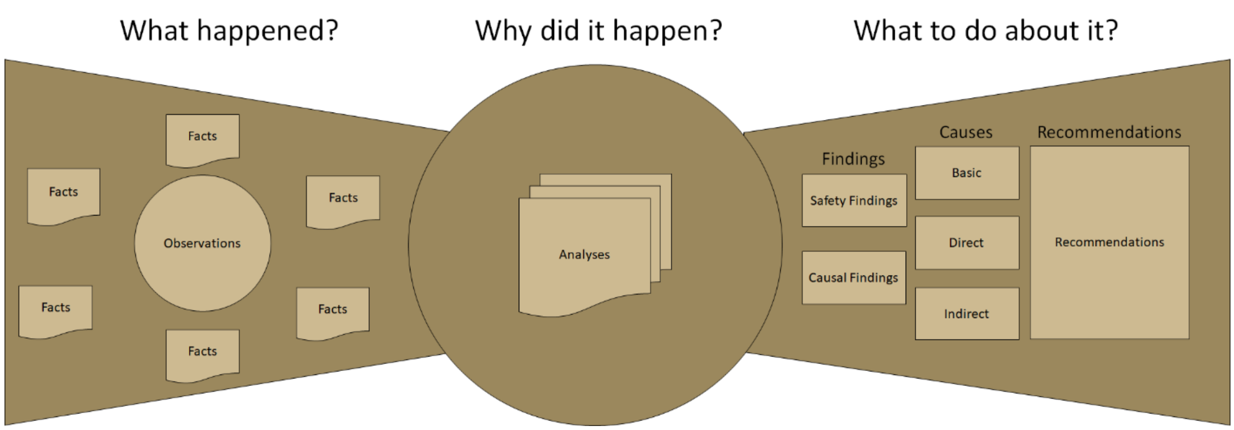


Figure 6.5: Overview of the investigation process with the information flow from facts to recommendations.

Questions: Can we Learn Anything?

Question 1: Please indicate which of the following constitute a finding:

A. The flight crew members were licensed and qualified for the flight in accordance with existing regulations.

B. The aircraft was airworthy.

C. The mass and centre of gravity of the aircraft were tested according to maintenance procedures.

D. Prior to the accident, there was no airframe damage.

Question 2: Please indicate which of the following constitute a cause:

A. The failure of Mr. John Doe to identify and correct poor runway drainage.

B. The failure of airport management to identify and correct poor runway drainage.

C. The airport director's failure to correct the airport drainage problem.

D. The known and uncorrected lack of runway drainage.

Question 3: Please indicate which of the following causes are: basic, indirect, and direct causes:

A. The maintenance crew's inability to properly inspect and verify the performed maintenance actions before releasing the aircraft for flight.
B. A navigation system malfunction, resulting in aircraft flying off course.
C. The pilot's failure to follow emergency procedures.

Question 4: What can help to formulate a recommendation?

A. Identify the goal, recipient and safety issue.
B. Identify the cause, target and objective.
C. Categorise the safety issue and establish who can be held responsible.
D. Categorise the accident cause and recipient.

Question 5: Who is not a recipient of a safety recommendation?

A. The manufacturer
B. The pilot
C. The certifying authority
D. Air Traffic Control facility

Exercise 1: Read the text below and formulate two recommendations.

> Finding the Truth in Falsehoods: Both engines failed - Part III
>
> The investigation showed that the rules and regulations are not representative for the circumstances the aircraft is flown in. It is therefore recommended that the engine design is modified to cope with heavy rain, in order to reduce the probability of flame out. Given the timeframe, current operators of aircraft with this type of engine are advised to follow manufacturer guidance related to engine operation during heavy rain.

Epilogue

Before you close the book, we need to tie up some loose ends. First let us go back to Chapter 1, Why air safety investigation, not air crash investigation? Here we examined the emotion that comes after an aviation accident. Now that you know a bit more about the investigation, let us see how that works in practice:

> Student: Remember me? I was the student who failed the exam. I was very upset about it. Thank you for addressing this emotion and let me reflect and learn from my failure. It turned out that I was not able to attend two lectures in which several important definitions and approaches to solving problems were discussed. I got notes from a fellow student and they helped me to understand the concepts I was missing. Thank you for teaching me to investigate my own failures. Studying past exams is not enough, I should study all the material.

In Chapter 2, Gathering the facts, we looked at how to perform a field investigation. In figure 2.3 a sketch was presented of an accident. A common question I get is: what happened? The event that is depicted was an engine failure case, where the pilot performed an emergency landing in a field. The sketch shows that the main landing gear touched down at (5), after which a second impact occurred at (4). A few meters further, a third impact with only the left gear is present (3A), with the LH wingtip (3B) also touching the ground. After this, the aircraft turned over on its engine (2) and ended up upside down (1). The LH gear separated (7) and the propeller was damaged and parts ended up in a wider area (6). I hope that this example of reading the field helps.

In Chapter 3, Logic and Hypothesis, we started Finding the Truth in Falsehoods. This case study was meant to exemplify the analysis phase of an investigation. In Chapter 6, we discussed how to finish the investigation with the formulation of recommendations. This is how this case study ends.

Finding the Truth in Falsehoods: Both Engines Failed - Epilogue
The report is finished and the Airworthiness Directive has been published the investigation journey has come to an end. It is time to enjoy the fruits of our labour, as the main purpose of a safety investigation has been fulfilled: to improve safety.

But wait, you get call. A similar aircraft as the one you investigated made an emergency landing with one engine inoperative. Preliminary information shows that it’s the same type of engine and the aircraft went through a thunderstorm with heavy rain. It all sounds too familiar. A few months later, you read the preliminary report from the investigative authority.

The aircraft was descending through heavy precipitation with throttles at flight idle. The investigation showed that this was not according to company procedure. A previous event had shown that this type of engine can experience flame out when subjected to heavy rain or hail. Per recommendation, the manufacturer is in the process of updating engine design to decrease the flame out probability in heavy rain.

Finally, to end the book on a positive high note and to make sure you live long, here's a healthy story to wrap up the journey.

In order to do a plum job, one needs be as cool as a cucumber in an investigation. At the accident scene you may not get a second bite of the cherry. Watch out for apples and oranges and do not cherry-pick the facts, otherwise your investigation will go pear-shaped. As sure as God made little green apples, you need to verify your facts and analyse the event. Don't giving a fig will make you become a bad apple.

Sometimes an accident sequence is a hard nut to crack, but using logic and a systematic approach, it will bear fruit in the end. Be careful, the forbidden fruit is always the sweetest and it will get you into a pickle if you are not careful.

At times it is required to upset the apple cart in an investigation, but make sure to be a real peach in order to conduct a solid investigation. As an investigator you may hear things through the grapevine, but don't go bananas: just get the facts and everything will be peaches and cream.

And at the end of an investigation, the fruit of one's labour comes. Not only address the low-hanging fruit, but also put the recommended cherry on the cake.

Congratulations: you have finished the book!

Michiel Schuurman

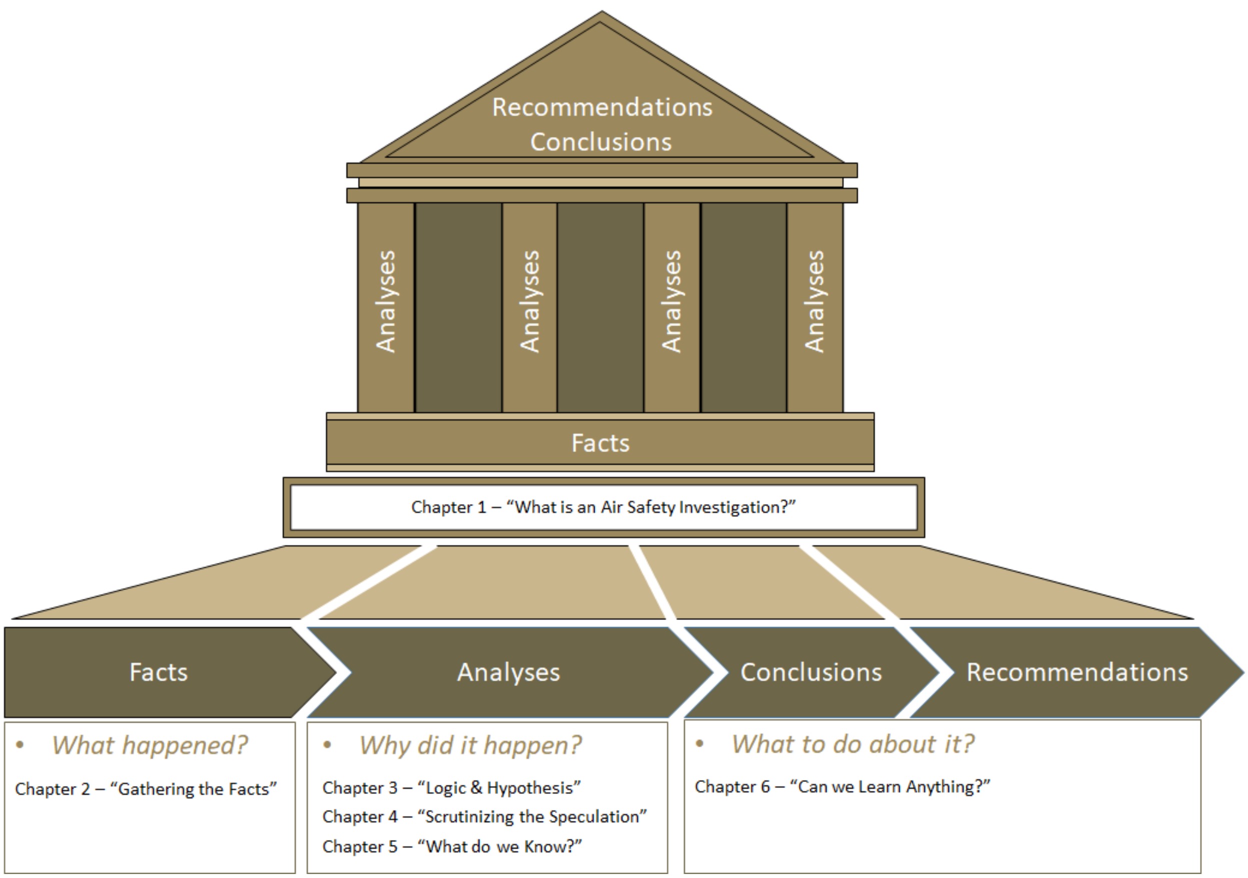


Figure E.1 Overview of the investigation temple and the book chapters as discussed.

Answers to questions

Chapter 1 What is an Air Safety Investigation

Question 1: B. The party system's main purpose is to use the skills and experience of investigators to accomplish a task.

Question 2: According to Annex 13, the sole purpose of an accident or incident investigation shall be to prevent accidents and incidents. One could think that minimizing the chance of an accident is also an aim of accident investigation, but this is more related to safety management. The same applies to preventing risk and harm to persons, which is more related to working conditions.

Question 3: B. Investigator in Charge.

Question 4: A. An Annex 13 report is focused on safety. A judge cannot contribute to this effort.

Question 5: D. Facts, Analyses, Conclusion, Recommendations

Question 6: D. The difference lies only in the result.

Exercise Question 1.1: No, an NTSB investigation can be conducted by the FAA (831.4 article a). In most cases, general aviation accidents are conducted by a FAA representative who reports to the NTSB.
Exercise Question 1.2: No, an NTSB investigation is a fact-finding, not an adjudicatory proceeding (831.4 article c). Therefore, parties whose objective is to appoint blame or liability are excluded from an investigation.

Exercise Question 2.1: A. Take-off from an engaged runway.

Exercise Question 2.2: A. Serious incident.

Chapter 2 Gathering the Facts

Question 1: A. Determine the area to be investigated and safeguard personal safety.

Question 2: 4 has first priority. The other actions should be performed in due course for the investigation to be complete.

Question 3: 2-1-3-4. It is important to prioritize the interview with the pilot who was involved in the event, as they will have first-hand knowledge of what happened and can provide valuable information about the circumstances leading up to the incident or accident. The search and rescue crew, particularly the fire chief, will also have important information about the scene and any actions taken in response to the incident or accident. This is not limited to whether a fire was present, but also changes to the wreckage due to the rescue effort. The witness with the dog and the journalist can provide additional details, but their accounts are likely to be less valuable. At least, the witness has first-hand knowledge, which is more helpful than the journalist.

Question 4: A. Sorting wreckage pieces during a field investigation is not appropriate. The field investigation should focus on locating, cataloguing and describing each wreckage piece.

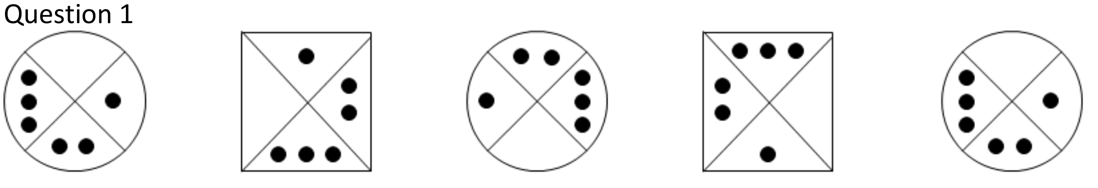
Question 5: B. For traceability and custody purposes

Exercise 1
The interrelation measurements of the pieces are provided. The distance measurements between the marks and wreckage are not provided.

Exercise 2
A. An example would be to investigate the engine and its damage – inspect and take notes.
B. An example would be the weather conditions during the event – get the weather report.
C. An example would be pilot error, procedures and actions crew. Both flight recorders can help in this respect.
D. An example would be the fuel truck – get sample of fuel and send to a laboratory.
E. An example would be the certification for the engine – request the information from certifying authority.

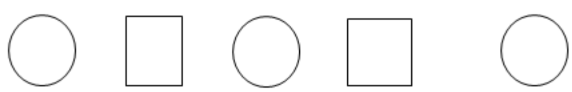
Chapter 3 Logic and Hypothesis

Question 1



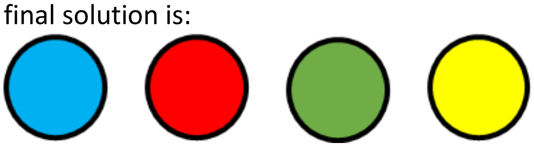
Pattern

- Figure shape



- Dots within the shape

Question 2
In the first row, two positions were correct, in the second row there were none. The change from the first to the second row was the switch of blue and red. As in the second row, none were correct, one can conclude that the blue position is 1 and the red position is 2. Given this fact, the yellow and green should be switched, as in both rows their positions were wrong and their position did not change. The final solution is:



4 correct

Question 3
3.1. Example A uses inductive reasoning (2): the airline can conclude that the aircraft icing was likely caused by the combination of freezing temperatures and high humidity. These factors are data and based on factual observations and analyses.

3.2 Example B uses deductive reasoning (1): the airline can conclude that the landing gear failures were likely due to a lack of proper maintenance. The evidence is based on general principles and the failure was not explained in relation to the causation of maintenance procedures not filled in.

Question 4

4.1. There is one way to remove all the nuts from the bolt.

4.2 There are 8! possibilities or 40320 total.

Exercise 1 – no answer available

Chapter 4 Scrutinizing the Speculation

Question 1: The sun will rise tomorrow is an assumption, because it is based on past experiences and the regularity of the solar system. Please note that a fact cannot be in the future, as facts are statements that describe something that has already happened or currently exists.
The pilot was experienced and suitable to fly the aircraft is a presumption, because experience does not equal competency or certification to fly the aircraft.
The speed dial showed 121 knots is a fact, because it is verifiable.
The wind is blowing in that direction is an observation, since the act of blowing and the direction are not quantifiable statements and thus cannot be verified.

Question 2: A policeman and investigator will look at the scene and gather facts. The goal of the police is to get evidence to use in the criminal court to prove beyond reasonable doubt what happened, whereas the goal for the investigator is to establish a (probable) cause. Both investigate the same wreckage but the evidential value for each might be different.

Question 3: The wingtip has potential high evidential value to establish the cause and sequence of events. The investigation of the fracture surface (given that it is not damaged) has a high evidential value. The observed fire damage to the wingtip has low evidential value, given that it was found after a forest fire. The damage should be noted in the report, with the time and circumstance. If, in conjunction, with other evidence fire of the wing is proven the evidential value increases.

Question 4 Answer: In general, speculation is harmful when it is used to make decisions or draw conclusions without using facts. Speculation can lead to inaccurate or unreliable results in situations where accuracy and objectivity are critical, such as an accident investigation. Furthermore, speculation can cause confusion, bias and mistrust, which is unproductive and takes up a huge amount of investigation time.

Question 5 Answer: There is bias when interviewing. A witness is someone who has (or thinks he has) pertinent information related to the investigation. Depending on the circumstances, the pilot can say more about what happened and what actions were taken. However, the witness who observed the event from a distance may have a better vantage point and relevant information. Both the journalist and the fire chief are not able to provide pertinent information related to the accident sequence. As mentioned, before the fire chief has relevant information related to the state of the wreckage before the rescue and for example the state of the pilot and/or passengers (injury).

Exercise 1 – no answer available.

Chapter 5 What do we Know?

Question 1:
1.1 Data; B. The thermometer indicates 18 degrees (measurement)
1.2 Information; A, C, D - the sentences are contextual (based on a measurement)

Question 2: According to the text, the aviation community understands wire chafing as a mechanical failure process. This process was identified in the 1980s, after which the rules, which are valid to date, were changed to implement lessons learned. Given that we (still) understand wire chafing, but not appreciate it, because events still happen, we can conclude that it is a Unknown – Known. On the other hand, one could argue that if we fully understand the process and performed the required steps to prevent and detect the wire chafing failure, it is a Known-Known.

Question 3: B. The purpose in changing your perspective is meant to question and force you think critically.

Question 4: B. The purpose to think differently is meant to question and force you think critically.

Question 5: All answers are correct; each describe a valid but different goal for testing in an investigation.

Exercise Question 1: The keep-it-simple solution: walk to the other end of the runway. The more elaborate options: if the sun is out, look at the sun and current time to get an idea. Get out your compass. Get a satellite image or airport runway map. However, the question can be solved by logic: runway designations are numbered according to closest magnetic heading of the runway. The runway heading is rounded to the nearest 10 degree, which means the runway designation goes from 1 up to 36. Thus, it is not possible to have a runway designation of 60, with would mean 600 degrees.

Exercise Question 2: In the review of the available information, you should have found an inconsistency between the title - Finding the Truth in Falsehoods: Both Engines Failed - and the review of the Flight Data Recorder, which showed the right engine continued normal operation.

Chapter 6 Can we Learn Anything?

Question 1: A finding; B and D statement with no reference/support; C is a statement for describing testing or action performed during the investigation.

Question 2: All examples are formulated as causes. Please note that a cause should be formulated in a way which, as much as practicable, minimizes the implication of blame or liability. Nevertheless, the accident investigation authority should not refrain from reporting a cause merely because blame or liability might be inferred from the statement of that cause. Statement D is formulated to accomplish all of the above.

Question 3: A – Basic cause, B – Indirect cause, C – Direct cause.

Question 4: According to the Investigators' Top Tip, it is helpful, in order to formulate a well-balanced recommendation, to identify the safety issue, recipient and goal.

Question 5: The pilot. An individual person/pilot cannot be a recommendation recipient. Such a recommendation will not help to promote aviation safety; it only assigns blame and liability.
Exercise answer:

- Complete the review of the current turbofan engine certification standards for rain and hail ingestion, and, if necessary, revise the standards in consideration of recent service experience and atmospheric data.
- Require that all turbofan engine and turbofan-powered aircraft manufacturers, working with operators of such aircraft, develop effective operational strategies and related guidance materials to minimize the chance of a dual-engine power loss. The Certification Authority should then verify that these strategies and guidance materials are incorporated into operating manuals and training programs in a timely fashion.

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Air Safety Investigation - The Journey

Michiel Schuurman

“Air Safety Investigation – The Journey” is an introductory book that explores the world of air safety investigation. Unlike a how-to manual for investigating aviation accidents, this book focuses on the essential knowledge and mindset required to conduct a safety investigation. It covers the various phases of an investigation, from gathering facts to formulating safety recommendations, with each chapter addressing a different relevant aspect. With the increasing complexity of investigations, critical thinking, logic, and speculation are essential skills for investigators to possess. This book delves into these topics, offering thought-provoking examples and questions to address the challenges of drawing conclusions and obtaining positive investigative outcomes. Its aim is to help students and readers interested in air safety develop the necessary mindset and knowledge to conduct an investigation. By the end of the book, readers will gain a deeper understanding of the complexities involved in an air safety investigation.

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