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Hazards Awareness for Aircraft Accident Investigators

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PhD

Cranfield University

School of Engineering

PhD Thesis

2010

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Hazards Awareness for Aircraft Accident Investigators

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Academic Year 2006 to 2010

Abstract

Hazards on accident sites are such that investigators must balance personal safety against the risks involved in collecting evidence intended to prevent future loss of life. Better knowledge of hazards and their mitigation could reconcile these conflicting objectives to a point at which risk might be no greater than in other workplaces. Nevertheless, the magnitude and nature of the hazards at any accident site cannot be determined in advance.

The perceptions of novice accident investigators of potential hazards are not greatly different from the realities encountered by experienced investigators, although the former tend to focus on general health and safety issues, while experienced investigators are more aware of hazards arising from aircraft systems and materials. Experienced investigators reported most of the hazards they encountered over six years as arising within a narrow range of hazard categories - yet they must be prepared to carry out thorough investigations while protecting themselves against all hazards, including those encountered very infrequently.

Both generic and dynamic risk assessments are important in protecting investigators and the integrity of evidence. The ongoing management of an investigation in the field involves a continuous and iterative cycle: identification of hazards, determination of exposure, assessment of risk, introduction of controls, review and assessment of remaining risk, and identification and management of residual hazard. Lives and evidence depend upon the quality of this process.

At present, great reliance is placed on personal protection equipment as a control on hazards. Observation of participants in training programmes has identified instances of poor selection and ineffective use of such equipment to the extent that it has provided no protection.

The thesis points to required further directions in the training of investigators - an investment which will yield its dividend in the prevention of future accidents and loss of life.

Acknowledgements

There are a number of people who provided advice and support throughout the PhD process. Without their help, I would not have reached this point.

To my supervisor, Professor Graham Braithwaite:
Thank you for your time, support, patience, creativity and advice. There have been many ups and downs over the last four years, and you knew the right answers to solve them all!

To Bryan Stott, Matt Greaves and Yani Asmayawati:
If the Safety and Accident Investigation Centre didn't exist, then neither would my PhD! Thank you all for helping me along the research process. The courses, the site simulations, the shed (in its various re-incarnations) - I have had fantastic fun along the way - even if at 5am in the rain I didn't look like it.

To Sid Hawkins, Engineering Support and HSE Manager, AAIB:
Thank you for the original idea for research, for the industry advice, and for the constant support and assistance along the way.

To all the other investigators, experts, and delegates on accident investigator courses:
Thank you for your interest in the topic, anecdotal stories, and advice for the future. Keeping this research industry relevant was important, and without this support, it would not have achieved the goal.

To my friends, and other PhD students:
Having some light relief in the world outside of accident site hazards has kept me sane. But at the same time, it was nice knowing there were other people going through the same pain.

To my parents, and to Matt:
You know how much your love and support means, and how much it has helped along the way. Couldn't have done it without you. Thank you.

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Abbreviations

AAIB	Air Accident Investigation Branch (UK)
AAIU	Air Accident Investigation Unit (Ireland)
AUV	Autonomous Underwater Vehicle
ABI	Association of British Insurers
ACARS	Aircraft Communications Addressing and Reporting System
ACCID	Accident (ICAO initial notification)
ACPM	Aircraft Post Crash Management
ACPO	Association of Chief Police Officers
AFS	Airport Fire Service (also known as ARFF)
AIBs	Accident Investigation Branches
AIG	Accident Investigation and Prevention (ICAO)
AIMSG	The Accident Investigation Methodology Study Group (ICAO)
ALARP	As Low As Reasonably Practicable
AMSL	Above Mean Sea Level
AOPA	Association of Police Officers
APCM	Aircraft Post Crash Management
ARFF	Airport Rescue and Fire Fighting Service
ATC	Air Traffic Control
ATPL	Air Transport Pilots Licence
ATSB	Australian Transport Safety Bureau
BASICS	British Association of Immediate Care
BEA	Le Bureau d'Enquetes et d'Analyses (France)
BFU	Bundesstelle fur Flugunfalluntersuchung (Germany)
BGA	British Gliding Association
BHPA	British Hang Gliding and Paragliding Association
CAA	Civil Aviation Authority (UK)
CAIB	Columbia Accident Investigation Board
CASA	Civil Aviation Safety (AUS)
CAST	Commercial Aviation Safety Team
CBRN	Chemical, biological, radiological, nuclear
CCTV	Closed Circuit Television
CFIT	Controlled Flight into Terrain
CFRP	Carbon Fibre Reinforced Plastic
CICTT	CAST/ICAO Common Taxonomy Team
COSHH	Control of Substances Hazardous to Health
CPS	Crown Prosecution Service
CVR	Cockpit Voice Recorder

DARS	Directorate of Aviation Regulation and Safety
DMAT	Disaster Medical Assistance Team
DVI	Disaster Victim Identification
EASA	European Aviation Safety Agency
EGPWS	Enhanced Ground Proximity Warning Systems
EICAS	Engine Indication and Crew Alerting System
ELT	Emergency
EPIC	Emergency Procedures Information Centre (Heathrow)
ERS	The Emergency Response Services
EST	Eastern Standard Time
ETSC	European Transport Safety Council
EU	European Union
FAA	Federal Aviation Administration
FANY	First Aid Nursing Yeomanry
FDNY	Fire Department of New York
FDR	Flight Data Recorder
FOHE	Fuel / Oil Heat Exchanger
FTA	Fault Tree Analysis
GA	General Aviation
GAMA	General Aviation Manufacturer’s Association
GFRP	Glass Fiber Reinforced Plastic
GLARE	Glass Reinforced Aluminum Laminate
GPS	Global Positioning System
GTAA	Greater Toronto Airport Authority
HAI	High Altitude Illness
HASSG	Hazards at Accident Site Study Group
HRQoL	Health Related Quality of Life
HSE	Health and Safety Executive
HS&E	Health, Safety and Engineering support
HSW	Health and Safety at Work Act 1974
ICAO	International Civil Aviation Organisation
IHUMS	Integrated Health and Usage Monitoring System
IIC	Investigator-in-Charge
ILS	Instrument Landing System
INCID	Incident (ICAO initial notification)
ISIM	Integrated Safety Investigation Methodology
KIAS	Knots Indicated Air Speed

LESLP	London Emergency Services Liaison Panel
MACC	Military Aid to the Civil Community
MAIB	Marine Accident Investigation Branch
MIT	Mishap Investigation Team (NASA)
MLS	Microwave Landing System
MMMF	Man-Made Mineral Fibres
MOD	Ministry of Defence
MOD DCDC	Ministry of Defence Development Concepts Doctrine Centre
MORT	Management Oversight Risk Tree
MOU	Memorandum of Understanding
MSDS	Material Safety Data Sheet
MTOW	Maximum Take Off Weight
MZFW	Maximum Zero Fuel Weight
NDB	Non Directional Beacon
NDPB	Non-Departmental Public Body
NJ OEM	New Jersey Office of Emergency Management
NOTAMS	Notice to Airmen
NPIA	National Policing Improvement Agency
NTSB	National Transport Safety Board (USA)
NVM	Non Volatile Memory
NY OEM	New York Office of Emergency Management
NYPD	New York Police Department
NY WW	New York Waterway
OHS	Occupational Health and Safety
OSHA	Occupational Safety and Health Administration
PAR	Precision Approach Radar
PPE	Personal Protective Equipment
PTSD	Post Traumatic Stress Disorder
QAR	Quick Access Recorder
QFRP	Quartz Fiber Reinforced Plastic
RAF	Royal Air Force
RAN	Royal Australian Navy
RAIB	Rail Accident Investigation Branch
RFDS	Royal Flying Doctor Service
RFFS	Rescue and Fire Fighting Service
RIDDOR	Reporting of Injuries, Diseases and Dangerous Occurrences Regulation
ROV	Remotely Operated Vehicle
RPT	Regular Public Transport

RSPA	Research and Special Programs Administration
SAR	Search and Rescue
SARPs	Standards and Recommended Practices
SARWATCH	Search and Rescue Organisation
SFAIRP	So Far As Is Reasonably Practicable
SCAT	Systematic Cause Analysis Technique
SCG	Strategic Co-ordinating Group
SCSI	Southern California Safety Institute
SME’s	Subject Matter Experts
SMS	Safety Management System
SOP’s	Standard Operating Procedures
SSSI	Sites of Special Scientific Interest
STEP	Sequential Timed Events Plotting
TSB	Transportation Safety Board (Canada)
USC	University of Southern California
USCG	US Coast Guard
US&R	Urban Search and Rescue
UTC	Universal Co-ordinated Time
VHF	Very High Frequency
VOR	VHF Omnidirectional and Range
WAAS	World Aircraft Accident Summary
WEL	Workplace Exposure Limits
WRVS	Women’s Royal Voluntary Service
WTC	World Trade Centre

Chapter One

Introduction

1.1 Background

On the night of 12th February 2009, a Colgan Air Bombardier Dash 8 Q400 aircraft crashed while on an instrument approach into Buffalo International Airport. The accident killed all 49 passengers and crew on board, and caused one fatality on the ground. The aircraft crashed into a house, and both the house and the aircraft were destroyed by the impact and resulting post-crash fire. Within 15 minutes of the accident, emergency responders from four fire departments and three police departments had arrived on the site (NTSB, 2009a). The post-impact fire was not extinguished until 1045 hrs on the following day. It was later discovered that the accident impact had severed a gas pipe, which was fuelling the fire (NTSB, 2009b).

By the following morning, a team of twelve National Transportation Safety Board (NTSB) investigators had been deployed to attend the site. Investigators and advisors from the Federal Aviation Administration (FAA), the Transportation Safety Board of Canada (TSB), Bombardier Aerospace and Pratt & Whitney Canada arrived on site from the 13th February to support the investigation (NTSB, 2009c). The wreckage trail was largely confined to a single property. The systems group of the investigation team remained on site until 18th February 2009 (NTSB, 2009d). Once the on site investigation had been completed, the wreckage of the aircraft was moved to secure storage, for further analysis (NTSB, 2009e).

When an aircraft accident such as this occurs, the country in which it has happened (the 'State of Occurrence') has an obligation to investigate. This is documented by the International Civil Aviation Organisation (ICAO) in *Annex 13* (ICAO, 2001a), which defines an investigation as "a process conducted for the purpose of accident prevention, which includes the gathering and analysis of information, the drawing of conclusions, including the determination of causes, and, when appropriate, the making of safety recommendations" . The same document recommends that "when possible, the scene of the accident shall be visited, the wreckage examined and statements taken from witnesses". At any accident site, the aim of the investigation team is to collect as much evidence as is necessary to identify causal factors objectively and accurately.

Although different types and sizes of accidents require different approaches to evidence collection, they all have two factors in common. First, there is immense pressure on investigators to proceed rapidly with their work. Time is of the essence: the evidence is perishable, and those affected by the accident - and the public as a whole - want to know what went wrong and how such an accident could be prevented in the future. The pressure to deliver results is clearly apparent in the intense interest in the loss of an Air France A330 on 1st June 2009 in the South Atlantic Ocean: one of the world's major airlines lost a current-model aircraft built by one of the world's largest aircraft manufacturers, in circumstances yet to be explained.

Second, investigators themselves are at risk on accident sites. Considerations of investigator safety are becoming increasingly important in the literature and among practitioners and accident investigation authorities. The need for investigators to consider their own safety is an important emerging factor in air accident investigation. Several large accidents have demonstrated the myriad hazards that can face investigators on site, and even relatively small scale general aviation accidents may pose significant personal risk. This thesis considers the role of aircraft accident investigators, to examine how they might continue to solve complex problems without unacceptable risks to their health and welfare.

1.2 Motivation for the study

Within the United Kingdom, the *Health and Safety at Work Act 1974* (HSW), specifies that "it shall be the duty of every employer to ensure, so far as is reasonably practicable, the health, safety and welfare at work of all his employees". Other countries have similar legislation. The application of the legislation to aircraft accident investigation is an area of uncertainty.

Aircraft accidents and serious incidents, and all injuries to people sustained through such events, are investigated by the national investigation agencies: in the UK, this is the Air Accidents Investigation Branch (AAIB) of the Department for Transport, under *The Civil Aviation (Investigation of Air Accidents and Incidents) Regulations, 1996*. However, the health and safety of the AAIB investigators themselves is regulated formally by the Health and Safety Executive (HSE).

Although air accident investigators are not first responders to an accident in the same sense as the emergency services (fire, police and ambulance services), their objective is to arrive at an accident site as quickly as possible in order to collect and preserve perishable evidence. The risks they face might not be as high as those whose job it is to save lives, but the environment they enter is likely to contain many of the same hazards. This is no ordinary workplace. Managing the hazards without destroying evidence is a difficult task, and one for which much of the necessary guidance is inadequate or based largely on the personal experience of the investigator. Much of the available guidance material is based on the experiences of the authors, and not on measured research.

The overall aim of this study is to assist in improving investigator safety, while at the same time maintaining the quality of the investigation process. Air accident investigation makes an immense contribution to aviation safety, and the overzealous application of health and safety requirements must not be allowed to compromise the quality of the work of the accident investigator. To date, the HSE has not had reason to investigate the working practices of AAIB employees while on aircraft accident sites (HSE, 2010a), but it could potentially happen in the future.

1.3 Context of the research

1.3.1 An overview of aircraft accident investigation

ICAO is very clear about the purpose of air accident investigation: "the sole objective of the investigation of an accident or incident shall be the prevention of accidents and incidents. It is not the purpose of this activity to apportion blame or liability" (ICAO, 2001a).

Each country which is a signatory to ICAO is required to have an independent national aircraft accident investigation agency to investigate air accidents and incidents within its jurisdiction (ICAO, 2001a). The agency can be an aviation specific investigation authority, such as the AAIB (UK), the Air Accident Investigation Unit (AAIU, Ireland), Le Bureau d'Enquêtes et d'Analyses (BEA, France), and the Bundesstelle für Flugunfalluntersuchung (BFU, Germany). Alternatively, it can be part of an independent multi-modal investigation agency, such as the Australian Transport Safety Bureau (ATSB), the NTSB (USA), and the Transportation Safety Board of Canada (TSB). Countries within the European Union (EU) also have responsibilities for conducting independent no-blame investigations, as specified in *EU Council Directive 94/56/EC*.

In those parts of the world where accident investigation is not yet the responsibility of dedicated accident investigation agencies, investigation is carried out as an ancillary task by the air safety regulator, or conducted on a case-by-case basis by a specially convened inquiry.

1.3.2 Aircraft accident investigation in the United Kingdom

The AAIB has its roots back in the Royal Flying Corps in 1915, when Captain Cockburn was appointed to the position of Inspector of Accidents (AAIB, 2010a).

The investigative force of the AAIB currently consists of sixteen engineering inspectors, twelve operations inspectors, and five flight data recorder inspectors. The organisation receives 700-800 notifications of aircraft accidents and incidents each year. This results in 300-400 investigations annually, of which 120-150 require field investigation (AAIB, 2009a).

For a field investigation, the AAIB will deploy at least one engineering inspector and one operations inspector. Further engineering or operations inspectors, or a flight data recorder inspector, will be deployed as required. Investigation of the British Airways 777 accident at London Heathrow Airport (17th January 2008), required ten AAIB investigators on the site (AAIB, 2010b). When British Midland flight 92 crashed near Kegworth on 8th January 1989, eighteen days after Pan Am flight 103 crashed near Lockerbie, all AAIB investigators were either deployed on or between the two sites.

Non-fatal accidents involving sport aviation aircraft are normally investigated by the relevant sports associations (AAIB, 2008a), such as the British Gliding Association (BGA) or the British Hang Gliding and Paragliding Association (BHPA). Minor incidents not requiring AAIB investigation might nevertheless be followed up by company investigators from the airline, the manufacturer, the airport or the insurer.

1.3.3 On site investigations

For most accidents, the investigation starts at the accident site. Aircraft have crashed in a range of environments from Antarctica to the Sahara Desert, and from heavily populated areas to the depths of the oceans. Assuming that investigators can reach the site, they will be faced with a unique situation, and with a unique range of potential evidence to try to retrieve. As noted by former NTSB investigator, Greg Feith (in Faith, 1996), "... no rehearsal, no amount of experience or careful preparation ... can ever prepare an investigator for what he finds on the site ... The actual arrival at an accident site is probably the most traumatic thing anyone could ever experience".

The reaction of former AAIB Principal Inspector, Eddie Trimble is similarly stark: "Confronted with a scene of absolute disaster, whether it be Lockerbie or Kegworth, the average reaction is ... where do you start?" (Faith, 1996). Prioritising actions on an accident site where evidence may disappear or change is but one of the challenges. Given the urgency of collecting and recording evidence, the avoidance of injury might not be given the priority it requires.

Hazards abound at accident sites. They are defined in ICAO *Circular 315: Hazards at Aircraft Accident Sites*, in terms of five categories (ICAO, 2008a, p. v).

1. "Environment - location (both geographic and topographic), fatigue (effects of travel and transportation), insects/wildlife, climate, security, and political situation;
2. Physical - fire, stored energy, explosives, structures;
3. Biological - pathogens associated with human remains or cargo consignments and state of local hygiene;
4. Materials - exposure to and contact with materials and substances at the site; and

5. Psychological - stress and traumatic pressures imposed by exposure to the aircraft accident, and interaction with those associated with the air carrier and related aviation activities".

Concern about the effects that hazards on aircraft accident sites may have on site responders is not new. Site hazards have been referred to historically in a number of guidance documents, texts, and industry discussions (for example Culling, 1992; FAA, 2010a-e; Ferry, 1988; ICAO, 1970; ICAO, 2000; NTSB, 2002; Wood and Sweginnis, 2006). National aircraft accident investigation agencies have also published guidance on potential site hazards (for example AAIB, 2008a; AAIU, 2005; ATSB, 2006a). These documents have been prepared by subject matter experts (SMEs) who are all experienced aircraft accident investigators. However, they generally do no more than list potential dangers on accident sites: they offer only limited guidance on when the hazards might be expected, on how they might affect an investigator, and on how to protect against them. Additionally, they do not adequately consider new and emerging hazards arising from changes in aircraft technology and aviation operations.

Circular 315: Hazards at Aircraft Accident Sites (ICAO, 2008a) is significant in that it was the first document to focus solely on hazards-related guidance for aircraft accident investigators. It was the product of a decade's work by the Hazards at Accident Site Study Group (HASSG), a forum of subject matter experts from aircraft accident investigation agencies. Specifically, the document seeks to "... assist individuals to consider and apply effective occupational safety management practices both to their own activities, and to the activities of the teams that they work with, or for which they are responsible. The circular discusses the nature and variety of occupational hazards, and the management of risk associated with exposure to these hazards" (ICAO, 2008a).

The publication of *Circular 315* (ICAO, 2008a) represents a milestone in shifting attitudes towards the threats present at accident sites. It was long overdue, and the fact that it has been published only recently might suggest that the accident investigation community has been slow to acknowledge a potential problem.

1.4 Objectives of the Research

1.4.1 Research questions

Although the the body of literature on air accident investigation is extensive, there are gaps in our present knowledge about the potential hazards on aircraft accident sites. This thesis presents four studies which are designed to fill some of those gaps. The objective of the research is to increase the general awareness of accident site hazards among investigators, by answering the following questions:

1. What hazards may arise for investigators collecting evidence on aircraft accident sites?
2. What site hazards do novice aircraft accident investigators perceive to be a risk?
3. What hazards are experienced accident investigators identifying on sites?
4. How do accident investigators identify and manage the hazards?

The results of each of these studies will assist in shaping recommendations to improve hazards-specific training for aircraft accident investigators.

1.4.2 Context

Each of the four questions is answered using an applied research methodology, the purpose of which is to produce “knowledge that is practical and has immediate application to pressing problems of concern” (‘*Applied Research*’, Sage Encyclopaedia of Qualitative Research, 2008). The outcomes of the research need to be practical if they are to be of benefit to aircraft accident investigators.

In the broad scheme of accident investigation, the identification and management of hazards might seem incidental and of relatively minor importance, but if mismanaged it has the potential not only to cause injury and illness to the workforce, but also to destroy evidence. That in turn can affect the outcome of the investigation, and hence future aviation safety. The pressing nature of the accident investigator’s work does not allow for the same time to be spent on the preparation of detailed written risk assessments as in other workplaces, nor do accident investigators have the option of removing certain hazards from the site without affecting the evidence.

A variety of fieldwork measures have been applied in collecting data for the four studies, including surveys and observations. Fieldwork introduces variables into the analysis which cannot always be pre-determined, but can generally be accounted for through proper understanding. The fieldwork was complemented by analysis of literature and historical data.

The data are, in the main part, qualitative data, intended to provide “well grounded, rich descriptions and explanations of processes in identifiable local contexts” (Miles and Huberman, 1994). There is relatively limited capacity for accident investigators to define numerically the risk of a particular substance being on a particular site. What is most beneficial for them is to develop a generic knowledge base regarding potential hazards, and to understand the processes and tools available to mitigate the risks of those hazards that have been identified. It is for this reason that qualitative research data collection and analysis methodologies have been applied.

1.4.3 Structure of the thesis

Four studies have been used to answer the four research questions. Each study is a separate piece of research and is presented separately within the thesis, but each builds on the findings of the previous study. Figure 1.1 shows the structure of the thesis.

Study One (Chapter Three) reviews the hazards that investigators potentially might encounter when collecting evidence on an aircraft accident site. As discussed in Section 1.2 and Section 2.6.5, ICAO *Circular 315* (2008a) is the most up-to-date explanatory guidance on hazards at aircraft accident sites. However, it is only an overview, and by no means an exhaustive reference manual. The purpose of Study One is to complement the abbreviated guidance provided by the *Circular,* to develop an enriched understanding of how hazards may affect those on aircraft accident sites. It does this by analysis of accident reports and other empirical data.

Study Two (Chapter Four) identifies the hazards that novice investigators perceive as posing most risk on aircraft accident sites. By examining the awareness of particular hazards among novice accident investigators and their perception of the consequent risk, we can assess the level of general hazards identification skills possessed by investigators. From that basis, improvements can be made in the content and design of training courses.

Study Three (Chapter Five) reviews the hazards that experienced aircraft accident investigators have encountered while collecting evidence, and the personal protective equipment they used on the site. This study complements Study Two, by allowing for comparison to be made between hazards perceived and hazards actually identified. The purpose of this pair of studies is to understand whether the intrinsic knowledge of hazards will prepare an investigator for the actual hazards met on the job.

Study Four (Chapter Six) observed accident investigators on both simulated and real accident sites, to identify the processes used to identify, assess and manage hazards. The purpose of this was to assess the impact of training on the hazard assessment and management process.

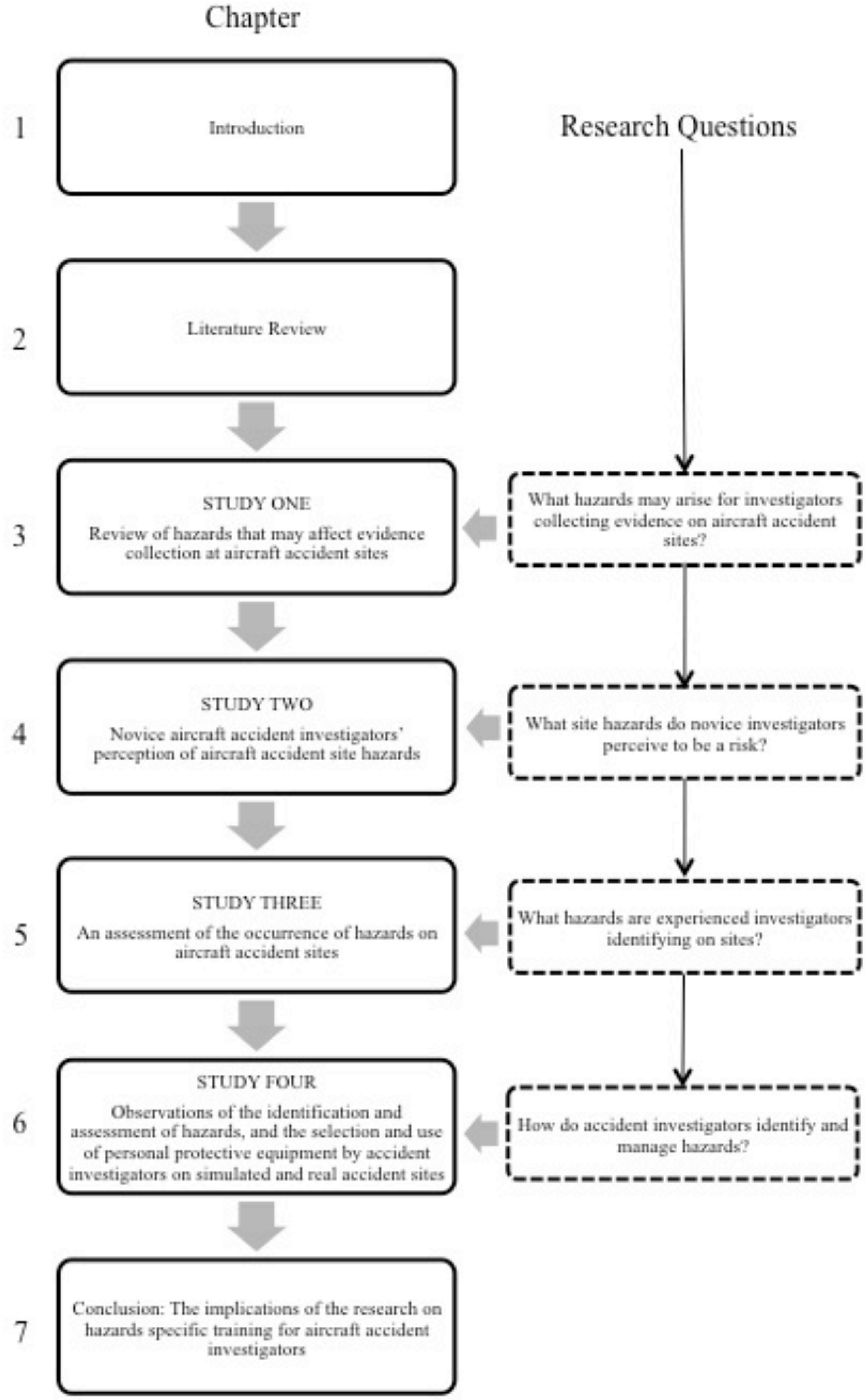


Figure 1.1: Structure of the thesis

1.4.4 Scope of the research

The number of potential hazards on aircraft accident sites is almost limitless. For that reason, some restrictions have been placed on the boundaries of the research problem.

First, as noted in Section 2.3.2.6, the research focus is on hazards of aircraft accident sites, and not on hazards posed by wreckage analysis off site. Second, it focuses only on hazards and processes which affect aircraft accident investigators and technical advisors during the evidence collection process, and not on other participants at other stages of the response to an accident. Emergency responders and wreckage recovery organisations perform different functions, and may face different risks from those encountered in the accident investigation phase.

Finally, the research is limited to hazards potentially occurring on accident sites investigated by civilian accident investigation agencies. Accidents involving military aircraft may create additional hazards: their investigation requires specialist military knowledge of systems and operations. However, the research does draw on some examples of hazards identified when civilian accident investigators have been involved with the investigation of military aircraft accidents.

1.4.5 Contribution to knowledge

Previous work on hazards at aircraft accident sites has been based on the site experience of investigators. These experiences have been the foundation on which guidance material has been developed for training purposes. This research is the first research to systematically review the effects of hazards on evidence collection, to compare the perceptions of hazards by trainees investigators with the realities encountered by experienced investigators, and to compare the different approaches of trainee investigators and experienced investigators to the identification and assessment of hazards in the field.

The findings of this research, on the design of hazards specific training for aircraft accident site attendees, were presented at the 2010 International Society of Air Safety Investigators (ISASI) annual conference and are published in the associated proceedings (Boston, Braithwaite and Hawkins, 2010).

Chapter Two

Literature Review

2.1 Aircraft accident investigation

2.1.1 The purpose of investigating aircraft accidents

ICAO is very clear about the function of aircraft accident investigation: "the sole objective of the investigation shall be the the prevention of other accidents and incidents. It is not the purpose of this activity to apportion blame or liability" (ICAO, 2001a). All countries contracting to ICAO must provide a means of investigating accidents and serious incidents involving transport aircraft which occur "between the time any person boards the aircraft with the intention of flight until such time as all such persons have disembarked" (ICAO, 2001a).

The 190 States which have contracted to ICAO (ICAO, 2009a) must under the *Convention of International Civil Aviation* (ICAO, 2006a) maintain a high degree of uniformity in terms of the regulations developed for all aspects of aviation. This uniformity has been achieved by the agreement of contracting States to eighteen annexes to the *Convention*, each of which provides standards and recommended practices (SARPs) for different areas of aircraft operation. *Annex 13* (ICAO, 2001a) is the relevant document for aircraft accident and incident investigation. The annexes, and the included SARPs, are directive only, not legislative. It is the duty of each contracting State to mandate the SARPs through national legislation, or to formally notify ICAO of any aspects of the SARPs which they do not propose to make mandatory (ICAO, 2006a).

An investigation is "a process conducted for the purpose of accident prevention, which includes the gathering and analysis of information, the drawing of conclusions, including the determination of causes, and when appropriate, the making of safety recommendations" (ICAO, 2001a).

Although the investigation of an aircraft accident "is a task that can be almost unlimited in scope" (ICAO, 2003a), there are elements common to all investigations: as noted by Wood and Sweginnis (2006), "All aircraft accidents are different, but the accident investigation process doesn't change very much". With rare exceptions, investigations into aircraft accidents and serious incidents follow similar stages: notification and deployment, on site investigation, off site investigation, analysis, safety recommendations, and report writing. One representation of this sequence is shown in Figure 2.1.

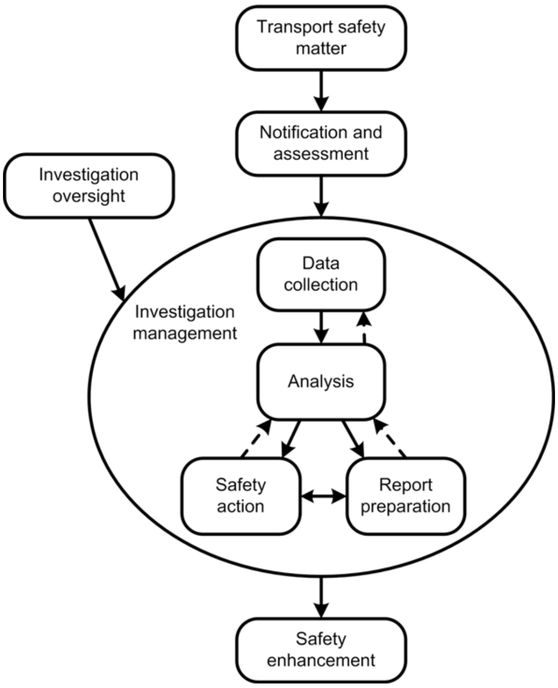


Figure 2.1: Overview of the investigation process for accidents and serious incidents
Source: Walker, 2008

Aircraft accident investigation agencies are usually notified of an accident by air traffic services or the aircraft operator (ICAO, 2000). This initial step in the investigation process is highly regulated by ICAO. Once an accident investigation agency in the State of Occurrence receives notification of an aircraft accident within their jurisdiction, it becomes responsible for notifying the State of Registry of the aircraft, the State of the Operator, the State of Design, the State of Maintenance, and ICAO (if the aircraft involved has a maximum take off weight [MTOW] greater than 2250kg). These various notifications might necessarily be very basic: the type of aircraft, the number of passengers and crew, and the location of the accident (ICAO, 2001a). An aircraft accident investigator deployed to an accident site initially might have no more than this very sketchy information, and lack any details of injuries, cargo or the physical characteristics of the site.

With the exception of accidents involving missing aircraft or wreckage that is inaccessible, “the accident site is the primary area of investigation” (ICAO, 2003a). The investigation is inevitably time-critical: any delay in the arrival of investigators might well result in “the deterioration or disappearance of essential evidence due to theft, displacement, or improper handling of the wreckage, adverse weather, corrosion of the wreckage, obliteration of ground scars or contamination of witness accounts through discussion among themselves” (ICAO, 2000). Additionally, investigators will seek evidence off site: such as witness interviews, air traffic control tapes and radar plots, maintenance records, training records and organisational information.

Once the site investigation is complete, the site is cleared and the accident investigators return to base to analyse the evidence. They may recover the wreckage in whole or in part for further analysis. Some aircraft accident investigation agencies, such as the AAIB, recover wreckage on an almost routine basis whereas others, such as the ATSB, recover parts only when necessary for further specific analysis, or when relating to a large scale accident. These differences are in part due to geography: being smaller, it is more feasible to transport wreckage by road in the UK than in Australia.

ICAO defines the analysis of evidence as "evaluation of evidence" (ICAO, 2003b). In evaluating evidence, investigators might select from one of many formal analytical tools: these include fault tree analysis (FTA), Management Oversight Risk Tree (MORT), Reason's Model, root cause analysis, Systematic Cause Analysis Technique (SCAT), Sequential Timed Events Plotting (STEP), Tripod-BETA and so on. Two aircraft accident investigation organisations, the ATSB and the TSB, have developed their own tools of analysis: the "ATSB investigation analysis model" (Walker and Bills, 2008) and the "Integrated Safety Investigation Methodology" (ISIM) (Ayeko, 2002). Alternatively, or as well, accident investigators might rely on their own tried and tested skills and judgements as subject matter experts and experienced investigators.

Accident reports are required to be published in a format compliant with guidelines in *Annex 13* (ICAO 2001a; further detail in ICAO, 2003b). This can be either a comprehensive final report in formal standard format, or - in the case of smaller aircraft accidents - a published accident report form (ICAO, 2003b). In 2009, the AAIB published only six formal reports, but 290 shorter accident report forms. Where necessary, accident investigation agencies might also issue interim reports to provide information about the progress of an investigation.

Safety recommendations are "actions which should prevent other accidents from similar causes or reduce the consequences of such accidents" (ICAO, 2003b). They can be issued at any time during an investigation, ahead of the final report (ICAO, 2001a): for instance, the AAIB issued nine safety recommendations during the investigation of the B777 accident at London Heathrow Airport on 17th January 2008 (AAIB, 2008b, 2008c, 2009b). The final report contained nine more safety recommendations (AAIB, 2010b).

Safety recommendations are advice rather than mandatory requirements, and do not require obligatory implementation (Baxter, 1995). It is however the duty of the recipient to consider the recommendation, and formally to decide whether or not to implement it. This maintains the necessary separation between the role of the investigation authority and the role of the regulator: only the latter can make mandatory requirements.

2.1.2 Regulation of aircraft accident investigation

ICAO *Annex 13* (2001a) sets out the process for developing policies and procedures on aircraft accident investigation, and is the standard document to which each member State of ICAO is required to adhere.

Within the European Union (EU), implementation of ICAO *Annex 13* is a legislative requirement under *Council Directive 94/56*, which established fundamental principles governing the investigation of civil aviation accidents and incidents. Compliance with this directive is mandatory for EU member states: under Article 288 of the *Treaty on the Functioning of the European Union,* the national legislation of each State must directly reflect the the *Directive*. Under UK legislation, the applicable instrument is *The Civil Aviation (Investigation of Air Accidents and Incidents) Regulations 1996*.

There is currently a proposal to revise *Council Directive 94/56* and upgrade it from a directive to a regulation (European Commission, Mobility and Transport, 2009). Proposed changes include the renaming of accident investigation authorities as “Civil Aviation Safety Investigation Authorities”, and the establishment of a “European Network of Civil Aviation Safety Investigation” comprised of the heads of the accident investigation agency in each EU member State (Department for Transport, 2010). This would not affect the responsibility of the AAIB, under UK regulations, to investigate all accidents or serious incidents within or above the UK, or involving UK registered aircraft in countries with no investigative agency.

AAIB inspectors also work under *The Civil Aviation (Investigation of Military Air Accidents at Civil Aerodromes) Regulations 2005*. These regulations require the AAIB to investigate military aircraft accidents occurring during take-off or landing at civil aerodromes in the UK, or when the investigation of an accident involving a military aircraft is likely also to be of benefit to civil aviation.

2.1.3 Aircraft accident investigation organisations

EU *Council Directive 94/56* requires each Member State to ensure that investigations are conducted or supervised by a permanent civil aviation body or entity, which is to be “functionally independent in particular of the national aviation authorities responsible for airworthiness, certification, flight operation, maintenance, licensing, air traffic control or airport operation and, in general, of any other party whose interests could conflict with the task entrusted to the investigating body or entity”.

Although it receives its budgetary appropriation through the UK Department for Transport, the AAIB is statutorily a non-departmental public body (NDPB) with responsibilities defined in legislation. The Chief Inspector of Air Accidents reports directly at Cabinet level to the Secretary of State for Transport, rather than to the

Permanent Secretary for the Department for Transport (AAIB, 2010c). The AAIB has no operational links with the UK Civil Aviation Authority (CAA), and - as required by ICAO as well as the EU - is not compromised in its independence.

In Australia, the ATSB has a similar governance structure, in that is the part of the Australian Department of Infrastructure, Transport, Regional Development and Local Government, but separate from the Australian CAA. In the United States, the NTSB is its own independent federal agency, separate from the US Department of Transport and the Federal Aviation Administration (FAA). Similarly in Canada, the TSB is independent from Transport Canada.

In each of these national jurisdictions, the objective is for aircraft accident investigators to be scrupulously independent from other aviation agencies. They must be able to make safety recommendations directed at other relevant agencies, without fear or bias, and therefore fulfil their intended purpose of preventing future aircraft accidents and incidents.

2.1.4 Training and skills of aircraft accident investigators

There is no specific qualification or training pathway necessary to become an aircraft accident investigator. Braithwaite (2002) notes that "... there are few roles as specialised or as skilled as accident investigation that do not carry a specific professional qualification or accreditation". Accident investigators come from a variety of backgrounds, but generally possess a high level of qualification and experience in their particular specialist fields, and normally complete some form of training.

The AAIB requires operations inspectors to hold an Air Transport Pilots Licence (ATPL), and to have command experience in either fixed-wing aircraft or helicopters. Engineering inspectors must have an engineering degree or be a chartered engineer, and ideally have experience as an aviation engineer. Additionally, the AAIB also looks for engineering inspectors to have some flying experience. Flight recorder inspectors must hold a degree in electronics, electrical engineering, or aeronautical engineering, or be a member of a chartered professional organisation with at least eight years of experience (AAIB, 2010c).

The ICAO training guidelines (2003a) recognise four stages of training for an aircraft accident investigator: initial training; on-the-job-training; a basic accident investigation course; and an advanced accident investigation course. It is also recommended that this be supplemented by specialist courses where required.

Initial training is intended to provide novice investigators with an understanding of local procedures. On-the-job training involves work-shadowing an experienced investigator, either within their own organisation or in another accident investigation organisation (ICAO, 2003a).

The topic areas recommended for the basic accident investigation course are (ICAO, 2003a):

- "the responsibilities of the States involved, as defined in Annex 13 - Aircraft Accident and Incident Investigation;
- the accident site considerations, such as security, hazards, safety precautions, wreckage diagramming, collection of evidence and control of access;
- the investigators' personal equipment and protective clothing;
- the examination and recording of the wreckage and witness marks;
- the range of apparatus available for recording evidence;
- witness interview techniques;
- the full range of in-flight recorders and ground-based recorders;
- the determination of the time and origin of any aircraft fires;
- crashworthiness and survival aspects;
- the properties and the modes of failure materials used in the aircraft structure;
- the design of aircraft systems and likely modes of failure;
- aerodynamics and aircraft performance;
- the examination of power plants;
- human performance;
- aviation medicine and pathology; and
- the methodology of report writing".

The syllabus for the advanced course is designed to develop these topics further, and additionally covers a range of new topics (ICAO, 2003a):

- "techniques used to investigate accident damaged systems that involve specialised technologies such as glass cockpit; fly-by-wire systems, GPS, and enhanced ground proximity warning systems (EGPWS);
- reconstruction of evidence recorded in damaged solid state recorders;
- the use of virtual video presentations in large structural reconstructions of wreckage; and
- the use of computer simulations and programmes for flight simulators to recreate aspects of the aircraft's flight path which are of interest to the investigation".

The advanced course also prepares the investigator to become an investigator-in-charge, and thus take responsibility for major investigations. Thus it includes:

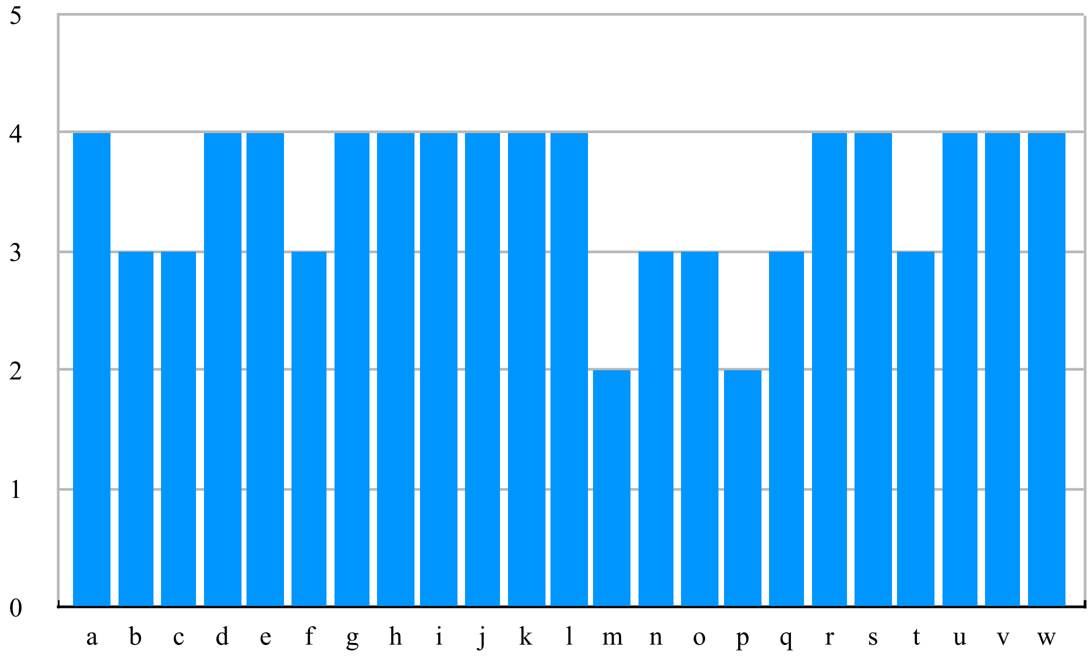
- the provision of family assistance to those involved in an accident;
- relations with the media;
- an introduction to methods for cataloguing a large number of fragments of wreckage;
- management of a large accident site for security, safety and protection of the personnel;
- preparation of briefings and answers to formal questions for members of government;
- the methods of undertaking investigations that involve both civil and military aircraft; and
- liaison with law enforcement authorities in accidents involving unlawful interference".

It is of course important that aircraft accident investigators should attend a range of courses regularly throughout their careers. The ICAO training manual (ICAO, 2003a) suggests that these programmes should include courses on aircraft types that they are likely to encounter in investigations, courses on the investigation of helicopter accidents, and courses on the investigation of human factors in the occurrence of accidents. The ICAO *Circular 315: Hazards at Aircraft Accident Sites* (ICAO, 2008a) additionally recognises the need for health and safety training of accident investigators.

Basic and advanced training courses are offered by training providers which are subsidiaries of accident investigation bodies, such as the NTSB Training Academy and ATSB training. They are also offered by independent training providers such as Cranfield University, Southern California Safety Institute (SCSI), and the University of Southern California (USC).

Flaherty (2008) studied the requisite skills needed by accident investigators employed by the UK Accident Investigation Branches (AIBs). Inspectors were asked to grade their self-perceived level of expertise in a variety of investigation skills, on a scale from 0 (little or no knowledge) to 5 (expertise). A score of 4 indicates "extensive knowledge where currency is maintained and the knowledge is regularly applied" (Flaherty, 2008). The median scores given by AAIB Inspectors for their general investigative skills are given in Figure 2.2. The median scores for aircraft specific investigation skills are shown in Figure 2.3.

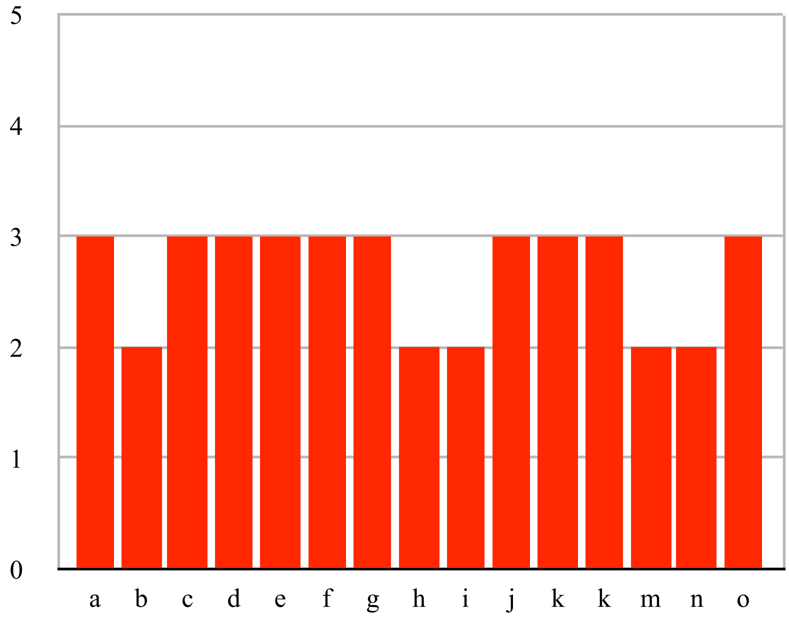
AAIB inspectors rated their skills highly in such key investigation areas as investigation management, evidence collection, data analysis, report writing, safety recommendation writing, and - of particular interest to this thesis - accident site health and safety. Areas where they do not rate their skills as highly - such as crash simulation, structures/ airframe, cabin equipment and air traffic control procedures - are areas in which specialist consultants are contracted in for assistance as technical advisors (see Section 2.3.2.1.3). The results of this study could reflect the particular specialisations in engineering and operations in the AAIB and might not be replicated in other investigation agencies such as the NTSB, where investigators have different specialisations, such as structures investigators and air traffic control investigators (NTSB, 2004a).



Key:

a: Investigation management
b: Resource management
c: Legislation
d: Accident site health and safety
e: Wreckage plotting
f: Photography
g: Evidence collection
h: Documenting evidence
i: Interviewing
j: Data gathering
k: Data recovery/analysis
l: Accident reconstruction
m: Crash simulation
n: Human performance
o: Ergonomics
p: Media relations
q: Family liaison
r: Expert witness/of face
s: Industry co-ordination
t: Analysis methods
u: Report/technical writing
v: Recommendation writing
w: Technical presentation

Figure 2.2: AAIB Inspectors' scoring of general investigative skills
Source: Adapted from Flaherty, 2008.



Key:
a: Aerodynamic/stability/control
b: Structure/airframe
c: Propulsion
d: Flight control systems
e: Aircraft operating systems
f: Flight deck engineering
g: Avionics
h: Flight dynamics modelling/simulation
i: Cabin equipment
j: Group operations
k: Airline flight operations
l: Crew procedures
m: Training/simulation
n: Air traffic control procedures
o: Atmospheric effects

Figure 2.3: AAIB Inspectors' scoring of aircraft design and operation knowledge
Source: Adapted from Flaherty, 2008.

As noted by Clitsome (2007) in his discussion of the management of major investigations, "No investigation agency is staffed to the level where it has all the required in-house expertise and resources to respond to a major occurrence". He recommends that investigation agencies develop "safety partnerships" with organisations which might assist in potential future aircraft accident investigations, informally or through formal memoranda of understanding.

The basic and advanced ICAO training guidelines (ICAO, 2003a) both refer to accident hazards and safety precautions. AAIB inspectors rate their skills in accident site health and safety at a score of 4, indicating that they believe they have extensive and current knowledge in this area and apply it regularly. In part, the present research tests this belief. Section 2.6.6 takes up the issue of hazards specific training for aircraft accident investigators and other accident site responders.

2.2 Aircraft operations and manufacture

2.2.1 Categories of aircraft operations

ICAO (2001b, pp. 1-3) defines three categories of aircraft operations, each of which can be conducted by fixed wing or rotary wing aircraft:

1. Commercial air transport: "An aircraft operation involving the transport of passengers, cargo or mail for remuneration or hire";
2. Aerial work: "An aircraft operation in which an aircraft is used for specialised services such as agriculture, construction, photography, surveying, observation and patrol, search and rescue, aerial advertisement, etc."; and
3. General aviation: "An aircraft operation other than a commercial air transport operation or an aerial work operation".

Each operation type may be conducted with either a fixed wing or rotary wing aircraft (traditional aeroplanes or helicopters).

Other organisations define aircraft operations slightly differently. For example, the ATSB (2009a) categorise operations into commercial air transport (including high capacity regular public transport [RPT], low capacity RPT and charter flights); other commercial (including aerial work, flight training and business); and private/sports aviation. Within the USA, operations may be divided into categories such as on-demand air taxi, person, business, instruction, corporate, aerial application, aerial observation, other work, public use, ferry, or positioning flights (AOPA, 2009).

In their guidance to accident responders, the AAIB (2010d, 2010e) divide operations into two categories: public transport aircraft and general aviation (GA) aircraft. This reflects the general level of response needed to an aircraft accident: in almost all cases, public transport aircraft accidents will require a much larger response than a general aviation aircraft accident.

2.2.2 The occurrence of aircraft accidents

2.2.2.1 Overview

The national accident investigation agencies and national aviation regulators all publish information on aircraft accidents within their jurisdiction. There are also a number of international databases in which aircraft accidents can be reviewed. These include the FAA cabin safety research technical group database (maintained by RGW Cherry and Associates, current to 2009), the Warwick Air Accident database (current to 1997), the World Aircraft Accident Summary (WAAS, maintained by ASCEND, current to 2009), the AOPA Air Safety Foundation Accident database (current to 2009), and the aviation safety network database (Flight Safety Foundation, current to 2009). These databases provide a wealth of searchable information about aircraft accidents, using information gathered from published accident reports. However, they focus solely on the outcomes of the investigations, and contain little information about the processes of investigation. Further, it is noted that a significant factor in variation in the number of aircraft accidents reported by different accident investigation bodies is their use of different definitions of accidents.

2.2.2.2 Commercial aircraft operations

In 2008, the most recent year for which complete data are available ICAO recorded twelve fatal aircraft accidents involving scheduled passenger flights on aircraft with an MTOW greater than 2,250kg (ICAO, 2009a). These twelve accidents killed 455 passengers. Aircraft that have an MTOW greater than 2,250kg and may operate commercially include Airbus and Boeing commercial airliners, regional jets and turbo-props such as the Embraer 145/170/190 variants, the Shorts 360, the BAe ATP, and helicopters such as the Sikorsky S-76.

Amongst European registered aircraft of the same MTOW, there were 35 commercial aircraft accidents in 2008, including three fatal aircraft accidents that killed 160 passengers and crew (EASA, 2009). For the same year, EASA recognised 54 fatal accidents world wide to aircraft in this weight category, including 28 passenger flights, fifteen cargo flights, five ferry/position flights, three air taxi flights, one emergency medical flight, one training flight, and one flight of unknown purpose (EASA, 2009). In the same aircraft category, commercial air transport in Australia in 2008 recorded 3,955 incidents, 53 serious incidents, and 30 accidents leading to six fatalities (ATSB, 2009a).

There are various ways in which statistical trends in aircraft accidents may be expressed. Within the Boeing *Statistical Summary of Commercial Jet Airplane Accidents 1959 - 2009* (Boeing, 2010), the historical accident rates for western-built commercially operated aircraft are presented in several ways, including by phase of flight (Figure 2.4), and by CAST/ICAO Common Taxonomy Team (CICTT) Aviation Occurrence Categories (Figure 2.5).

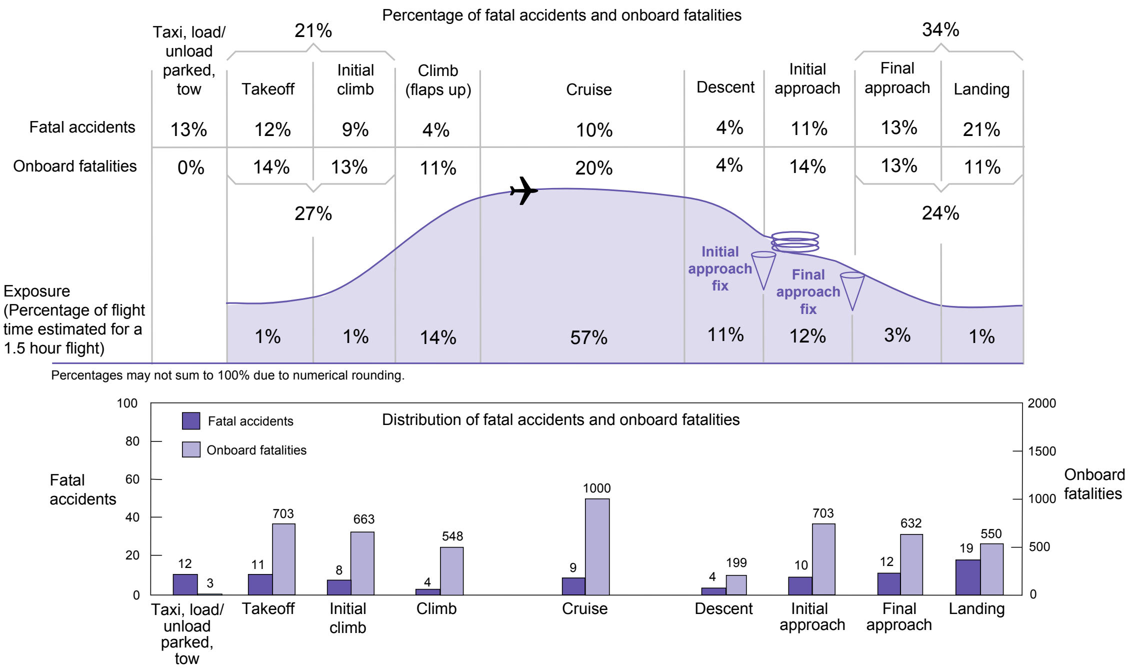
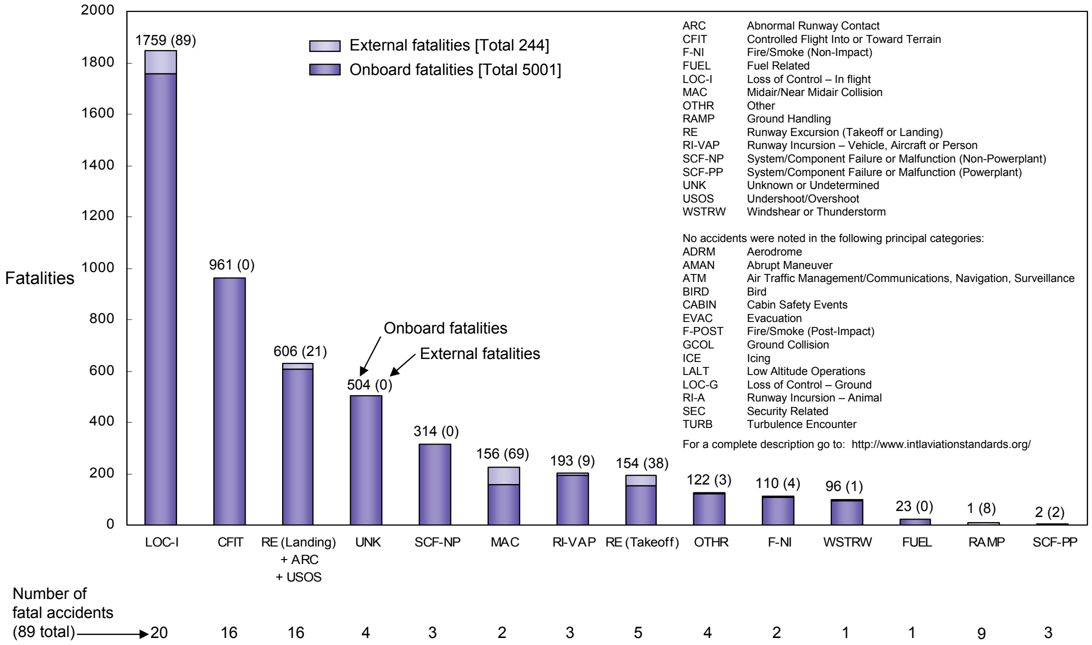


Figure 2.4: Fatal accidents by phase of flight, 2000 - 2009
Source: Boeing, 2010



Note: Principal categories as assigned by CAST.

Figure 2.5: Fatalities by CICTT aviation occurrence categories, 2000 - 2009
Source: Boeing, 2010

The importance of such different analyses for the present research is that the phase of flight, or the assigned aviation occurrence category, might be useful in identifying the hazards likely to be present at an aircraft accident site. This is discussed in Chapter Three.

Commercial aircraft have traditionally been manufactured with an aluminium skin. However, as noted by Rakow and Pettinger (2007), composites which were “historically reserved for control surfaces and secondary structures ... are now being employed for primary structures in major aircraft programs”. Figure 2.6 shows the location of components built from composites on a Boeing 737; Figure 2.7 shows location and types of composites on an A380; and Figure 2.8 is a similar representation of composites on a Boeing 787 .

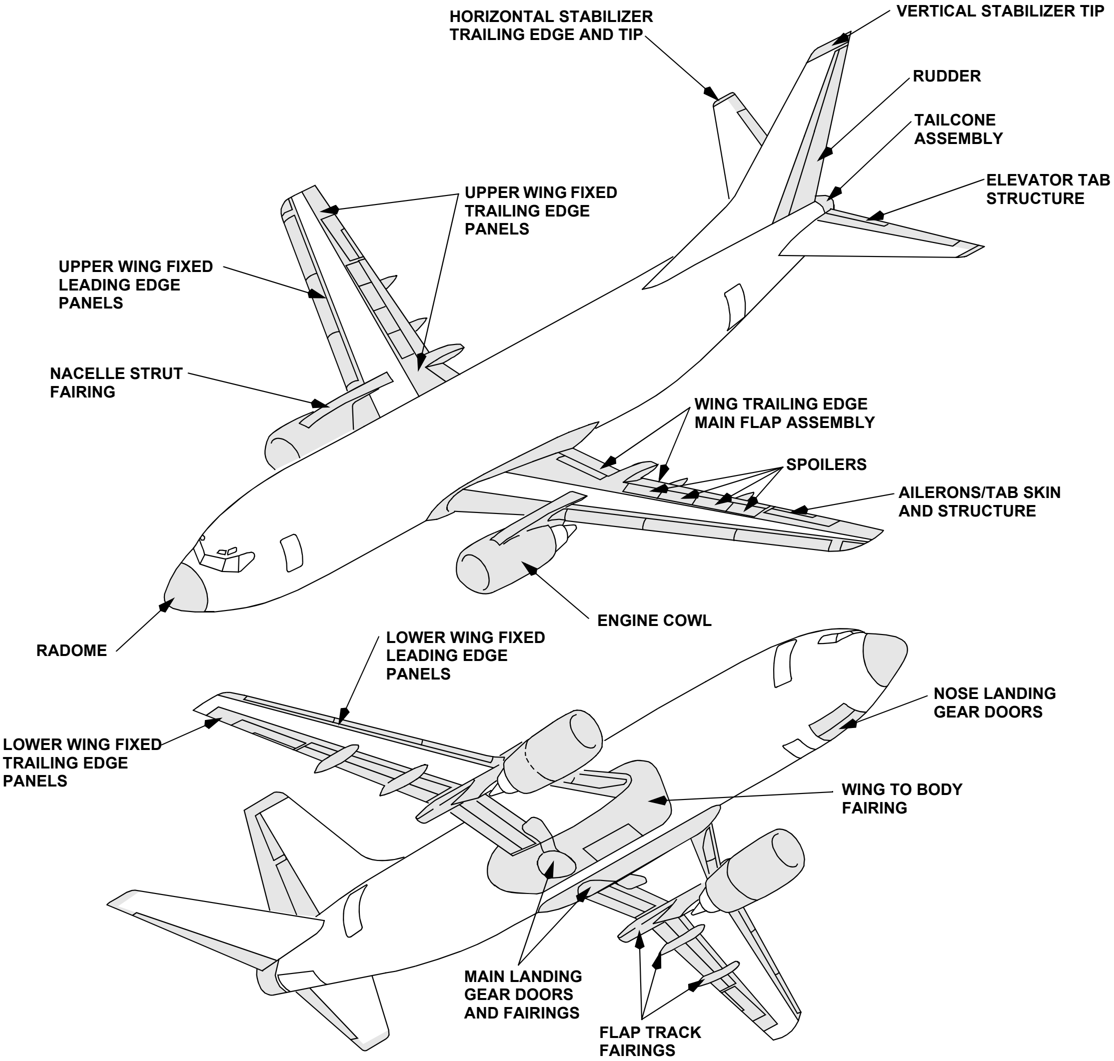


Figure 2.6: Location of composites on Boeing 737-100 to -500 series aircraft
Source: Boeing, 2009b

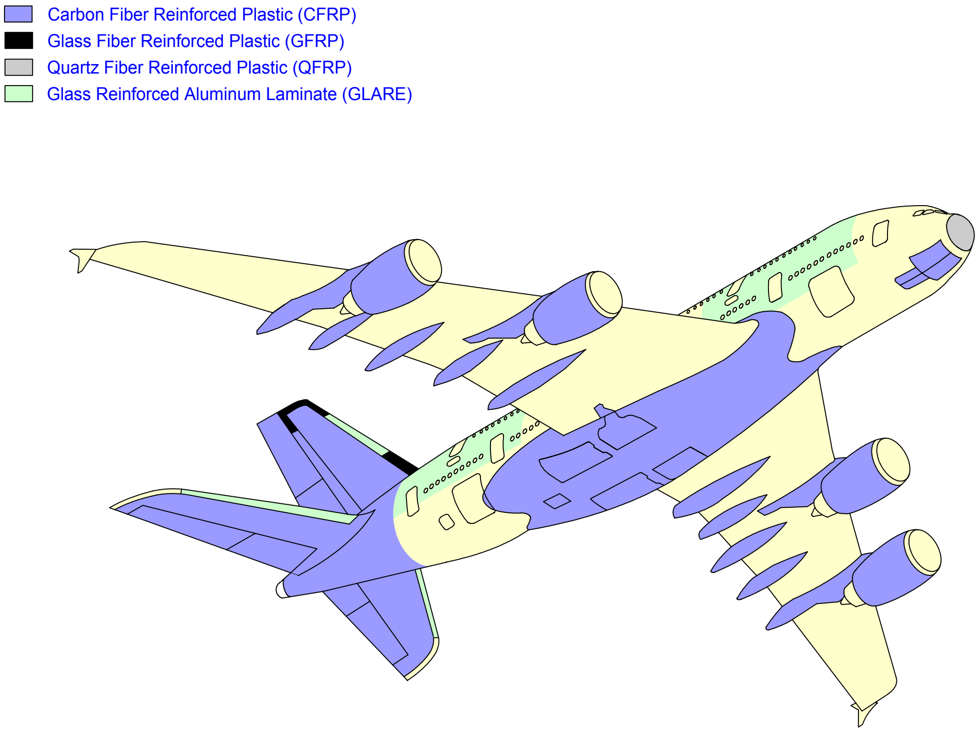


Figure 2.7: Location of composites on an Airbus 380
Source: Airbus, 2008

The composite materials CFRP, GFRP, and QFRP (Figure 2.7), comprise 22 per cent of the operating empty weight of an A380-800, with an additional 3 per cent GLARE (Janes's 2010a). GLARE is a recent composite development made from alternating layers of aluminium and glass fibres. The A380-800 has a slightly higher proportion of composites: its basic operating empty weight is 270,015kg (A380-841), of which 27 per cent by weight (72,905kg) is of composite material (Janes's, 2010a). The aircraft has a Maximum Zero Fuel Weight (MZFW) of 361,000kg, and an MTOW of 560,000kg (Jane's, 2010a).

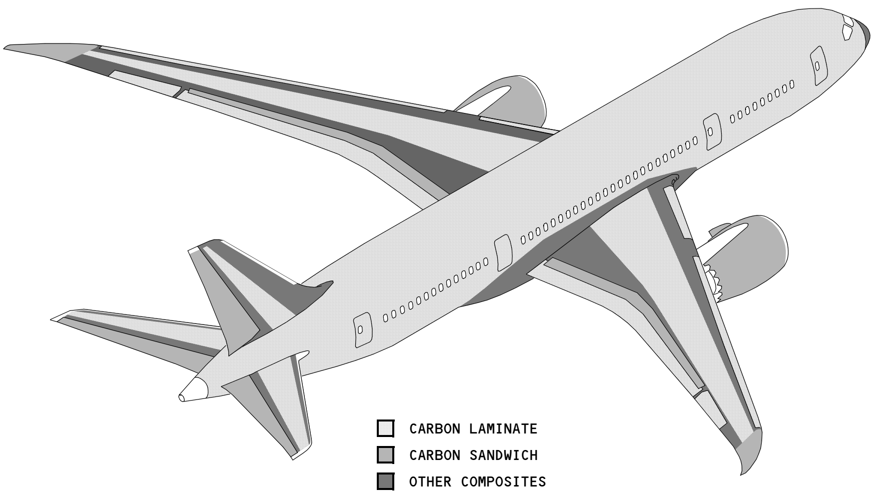
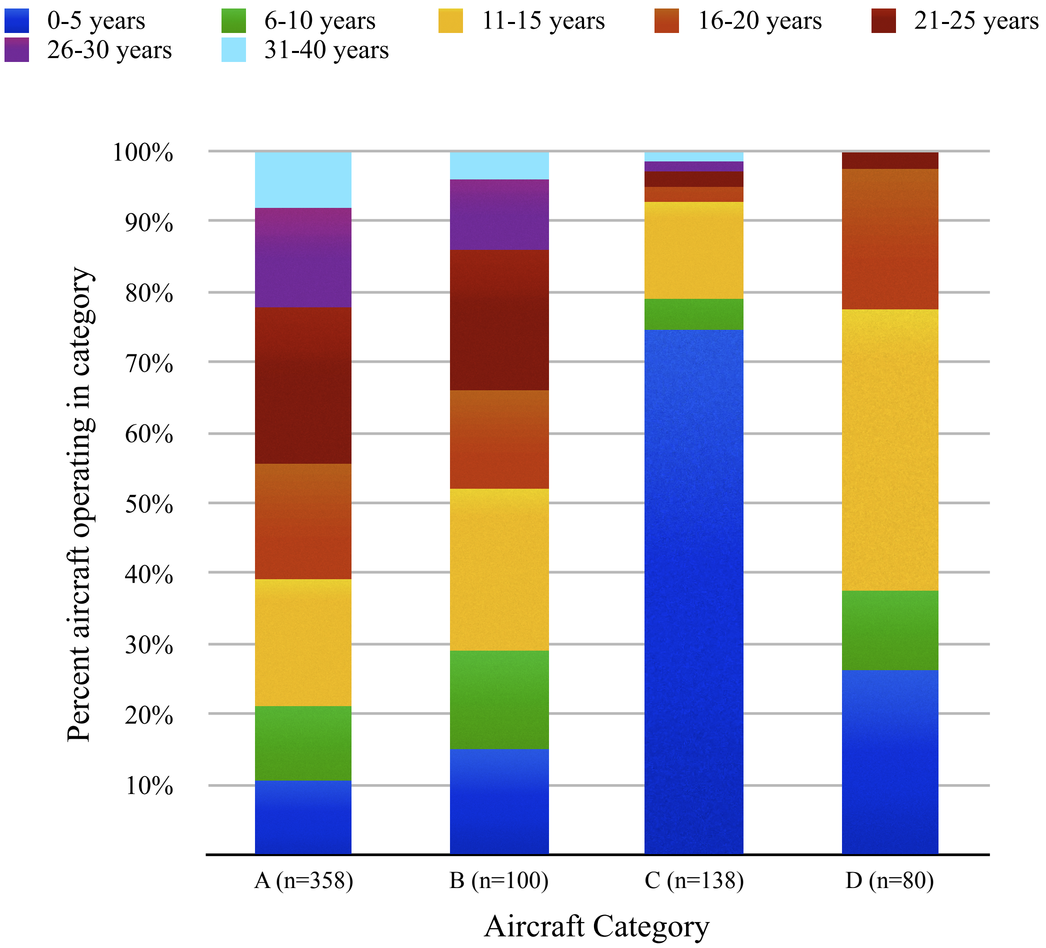


Figure 2.8: Location of composites on a Boeing 787 series aircraft
Source: Boeing, 2009b

By weight, the B787 (Figure 2.8) airframe is 50 per cent composite, 20 per cent aluminium, 15 per cent titanium and 10 per cent steel. The operating empty weight of the 787-8 (the standard commercial 787 model) is 108,860kg, with a MZFW of 156,500kg, and a MTOW of 219,550kg (Jane's, 2010b).

In 2007, the ATSB published data on the age of aircraft operating in different weight categories in Australia, based on 2005 statistics. Figure 2.9 presents the data by categories of size, and gives the percentages by age in each category. The average age of the largest category (Category A) - multi-engine turboprop aircraft, such as the Bombardier Dash 8 and Fairchild Metroliner - was eighteen years. The average age of small multi-engine turbofan aircraft (Category B), which includes the Cessna Citation and Embraer ERJ was sixteen years. The average age of medium multi-engine turbofan aircraft (Category C), such as the A320, B717 and B737 was six years: more than 70 per cent of these aircraft were no more than five years old. The average age of large multi-engine turbofan aircraft (Category D), which includes the A330 and B767, was eight years.



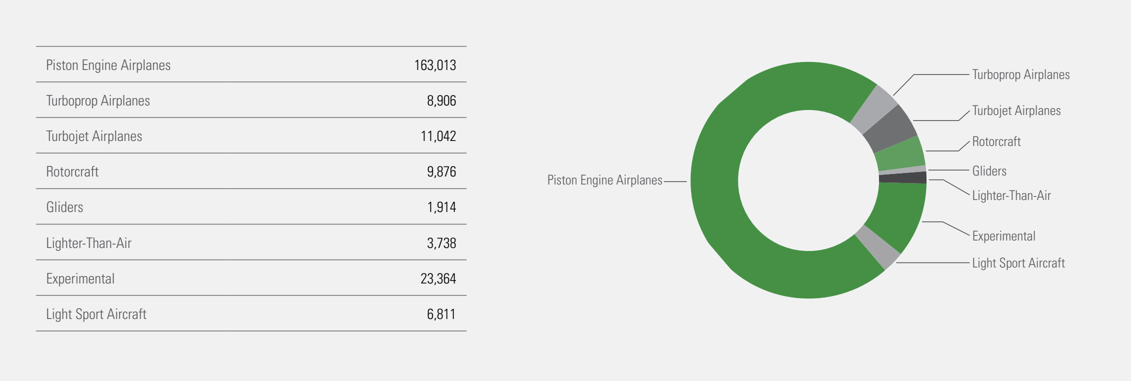
Category A: Multi-engine turboprop aircraft
Category B: Small multi-engine turbofan aircraft (MTOW < 50,000kg)
Category C: Medium multi-engine turbofan aircraft (50,001kg < MTOW < 100,000kg)
Category D: Large multi-engine turbofan aircraft (MTOW > 100,000kg)

Figure 2.9: Age bracket (years) of aircraft registered in Australia in 2005
Source: Adapted from ATSB, 2007

Air accident investigators can therefore be called upon to investigate accidents involving quite different generations of aircraft. More than 40 per cent of aircraft in Category A are 20-40 years old, but almost 80 per cent of Category C aircraft were built in the last ten years. Such information about the age distribution of aircraft, combined with knowledge of the materials from which they are constructed, is important in assisting investigators to anticipate hazards likely to be encountered on particular accident sites. Thus investigators are more likely to encounter hazards arising from composite materials at the site of an accident involving a medium multi-engine turbofan aircraft, than at a site involving a multi-engine turboprop aircraft, given the average greater age of the latter.

2.2.2.3 Aerial work and general aviation operations

Figure 2.10 shows the different categories of aircraft operating as GA in the USA. By far the most common aircraft type operating GA is the piston engine, fixed wing aeroplane.



Piston Engine Airplanes	163,013
Turboprop Airplanes	8,906
Turbojet Airplanes	11,042
Rotorcraft	9,876
Gliders	1,914
Lighter-Than-Air	3,738
Experimental	23,364
Light Sport Aircraft	6,811

Figure 2.10: Active General Aviation aircraft in the USA, 2008
Source: GAMA, 2010

The situation is similar in the UK: the UK civil aircraft register (CAA, 2010) lists 20,429 aircraft with an MTOW < 5,700kg registered on 1st January 2010, with fixed wing aircraft being the dominant category (Figure 2.11). The UK statistics do not differentiate between piston-engined, turboprop and turbojet aircraft.

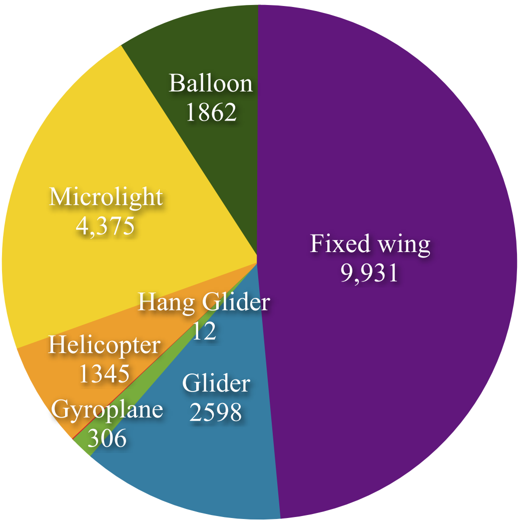


Figure 2.11: Aircraft with an MTOW < 5,700kg on the UK Civil Register
Source: CAA, 2010.

Within the European Union, EASA maintains an accident data base under two categories: aircraft for general aviation and aerial work (MTOW > 2,250kg), and light aircraft (MTOW < 2,250kg) (EASA, 2009). Table 2.1 gives the number of accidents involving the first category of aircraft in 2008. Such aircraft include the Cessna 414, the Piper Chieftain, the Beech Baron and Eurocopter EC135.

Table 2.1: Accidents to EU-registered aerial work and general aviation aircraft with MTOW > 2,500kg

Aircraft type	Operation type	Total Number of Accidents	Number of Fatal Accidents
Aeroplane	Aerial work	7	2
Aeroplane	General Aviation	17	7
Helicopter	Aerial work	5	1
Helicopter	General Aviation	3	1

Source: Adapted from EASA, 2009

In the same year, the number of accidents in the second category - light aircraft with an MTOW < 2,250kg - was higher (Table 2.2).

Table 2.2: Accidents to EU-Registered aerial work and general aviation aircraft with MTOW < 2,500kg

Aircraft Category	Total Number of Accidents	Fatal Accidents	Fatalities on board
Aeroplanes	517	53	98
Balloon	25	1	1
Glider	178	16	16
Gyroplane	12	3	3
Helicopter	64	7	12
Microlight	261	45	70
Motorglider	41	10	11
Other	46	5	5
Unknown	1	0	0
Total	**1145**	**140**	**216**

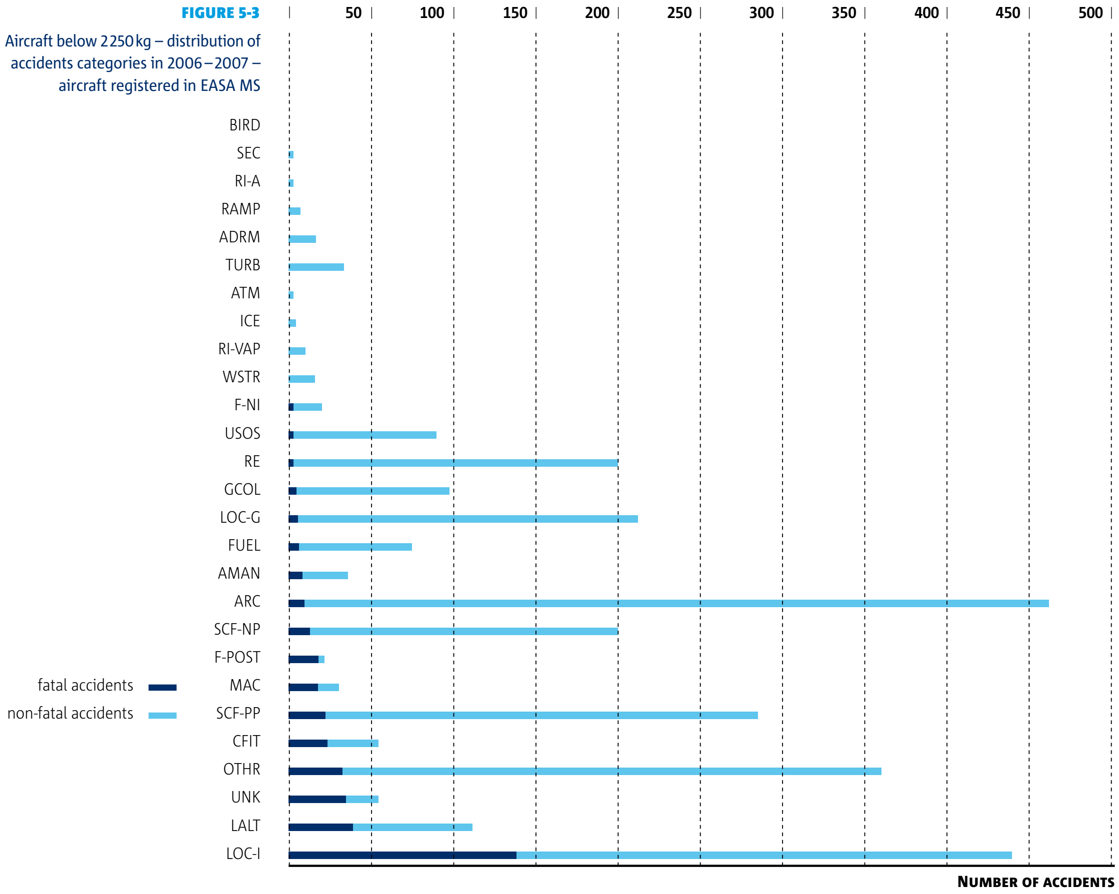
Source: Adapted from EASA, 2009

Typical aircraft in this weight category include the Schleicher ASK21 (glider); the Pegasus Quantum Trike Ultralight (microlight); Cessna 152, Piper PA-28 Warrior and Piper Seminole (aeroplanes); and the Robinson 22, Bell 206 Jetranger and Eurocopter

AS350 Squirrel (helicopters). Some particular variants of aircraft such as the Piper Chieftain and the Beech Baron (listed above as having an MTOW > 2,250kg) may have an MTOW < 2,250kg, and therefore could be in either category.

Australian and overseas registered aircraft engaged in aerial work operations in Australia in 2008 were involved in 36 accidents including five fatal accidents, two serious incidents and 284 incidents. Flying training operations over the same period resulted in 21 accidents including three fatal accidents, three serious incidents and 264 incidents. There was one accident and fourteen incidents in business aviation: and 62 accidents (including thirteen fatal accidents), four serious incidents and 237 incidents in private/sports aviation operations (ATSB, 2009a).

EASA (2009) publishes information on aircraft accidents by accident category for aircraft with an MTOW < 2,500kg, which is shown in Figure 2.12. This analysis for general aviation is similar to that for fatalities by CICTT aviation occurrence categories (see Figure 2.5 above).



Key:

BIRD	Bird strike
SEC	Security related
RI-A	Runway incursion - animal
RAMP	Ground handling
ADRM	Aerodrome
TURB	Turbulence encounter
ATM	Air traffic management / Communications, Navigation, Surveillance
ICE	Icing
RI-VAP	Runway incursion - vehicle, aircraft or person
WSTR	Windshear or thunderstorm
F-NI	Fire / smoke (non-impact)
USOS	Undershoot / overshoot
RE	Runway excursion
GCOL	Ground collision
LOC-G	Loss of control - ground
FUEL	Fuel related
AMAN	Abrupt manoeuvre
ARC	Abnormal runway contact
SCF-NP	System / component failure or malfunction (non-powerplant)
F-POST	Fire / smoke (post-impact)
MAC	Airprox / TCAS alert / loss of separation / near midair collisions / midair collisions
SCF-PP	System / component failure or malfunction (powerplant)
CFIT	Controlled flight into or toward terrain
OTHR	Other
UNK	Unknown or undetermined
LALT	Low altitude operations
LOC-I	Loss of control - inflight

Figure 2.12: EU Accidents by causal category, 2006-2007
Source: EASA, 2009

A further method of analysis is used in the NALL Report (AOPA, 2009), which categorises GA accidents in the USA by primary occurrence in terms of type and phase (Figure 2.13). This gives a more generalised overview than that provided by Boeing (2010) for commercial aircraft operations (see Figure 2.4 above), but is similarly informative for investigators.

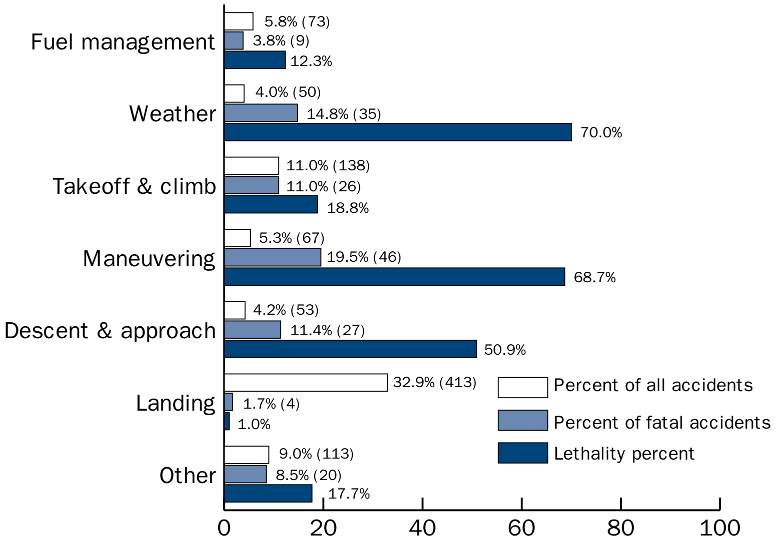


Figure 2.13: Categorisation of US GA accidents by primary occurrence type, 2008
Source: AOPA, 2009

In 2009 there were 1,474 GA accidents in the USA, of which 272 were fatal. There were 20,456,000 flying hours recorded for GA in that year: the accident rate was thus 7.20 accidents per 100,000 flying hours, or 1.33 fatal accidents per 100,000 flying hours (NTSB, 2010a).

Analyses of accidents by elements such as phase of flight and accident occurrence categories provide investigators with a frame of reference by which to assess the probability of encountering particular hazards on an accident site, such as hazards arising from the likely condition of the wreckage. For example, an aircraft that crashes on take-off and initial climb, or as a result of controlled flight into terrain (CFIT), is almost certain to crash with a higher impact force - due to the high power settings - than an aircraft which crashes on landing.

In general aviation, as in commercial aircraft operations, knowledge of the age of aircraft is important in assisting the investigator to assess the probability and nature of risks at the accident site. The ATSB ageing aircraft study (ATSB, 2007) found that the average age of single-engine fixed-wing GA aircraft in Australia in 2005 was 30 years. Over the period 1995-2005, the average age of this group of aircraft increased by seven years. Figure 2.14 shows the age range of this group of aircraft in 1995, 2000 and 2005: despite growth of almost 1000 in the number of GA aircraft over the decade, the fleet continues to age.

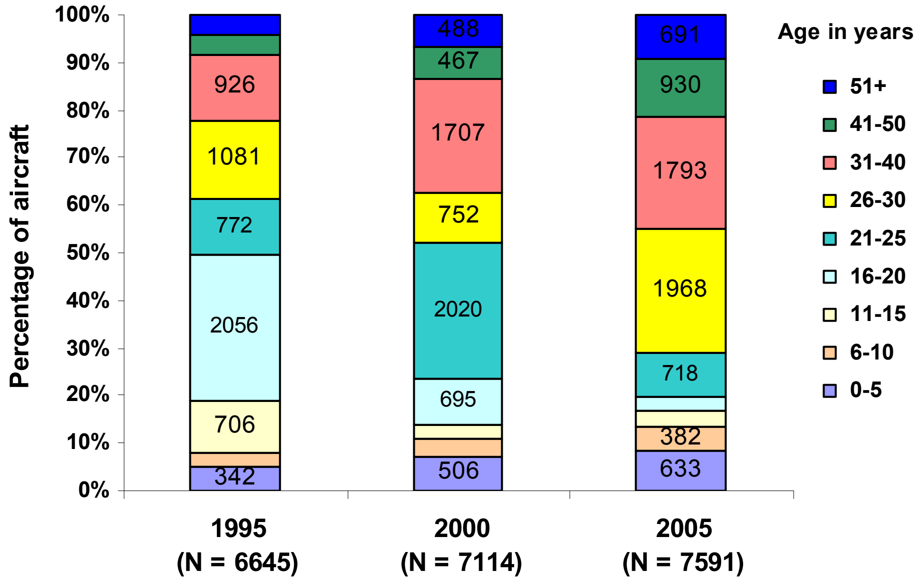


Figure 2.14: Age of single-engine, fixed-wing aircraft with an MTOW < 5,700kg in Australia
Source: ATSB, 2007

The study found the average age of single-engine piston helicopters in 2005 in Australia to be sixteen years, the average age of single-engine turboshaft helicopters was 23 years, and the average age of multi-engine turboshaft helicopters was fifteen years (ATSB, 2007).

Similar statistics for the USA (GAMA, 2010) show that in 2009 the average age of single-engine piston aircraft was 42 years, single-engine turboprop aircraft sixteen years, and single-engine jet aircraft 44 years (most single-engine jet aircraft are ex-military registered aircraft, which introduce some unique hazards for aircraft accident investigators). For multi-engine piston aircraft, the average age was 41 years, for multi-engine turboprop aircraft 28 years, and for multi-engine jet aircraft seventeen years. The average age of all GA aircraft operating in the USA in 2009 was 39 years.

As with commercial aircraft (Section 2.2.2.2), composite materials have become more frequently incorporated into GA aircraft, such as the Diamond range and the Cirrus range of aircraft. An ATSB review of amateur-built and experimental aircraft (Stanton and Taylor, 2009) showed that 30.9 per cent of these aircraft registered in Australia in 2008 had primary structures made from composites (Figure 2.15). This is a higher proportion of composites than for other general aviation aircraft types.

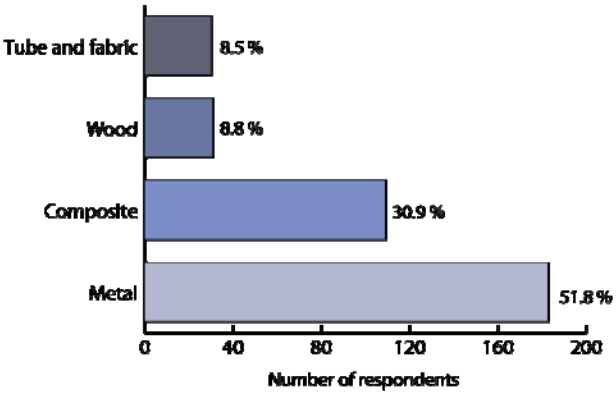


Figure 2.15: Materials used in primary aircraft structure, amateur-built and experimental aircraft in Australia, 2008
Source: Stanton and Taylor, 2009

The average age of operating aircraft can provide some form of guidance to investigators on hazards from the composition of aircraft at accident sites they may be likely to attend. If a particular aircraft type or operating category has a high average age, accident investigators are more likely to be encountering traditional metal airframes than composite structures.

2.3 The response to an aircraft accident

A major aircraft incident or accident triggers a number of events in response. The nature of this response is described by the London Emergency Services Liaison Panel (LESLP, 2007) in terms of four stages: the initial emergency response; the consolidation phase; the recovery phase; and the restoration of normality (Figure 2.16).

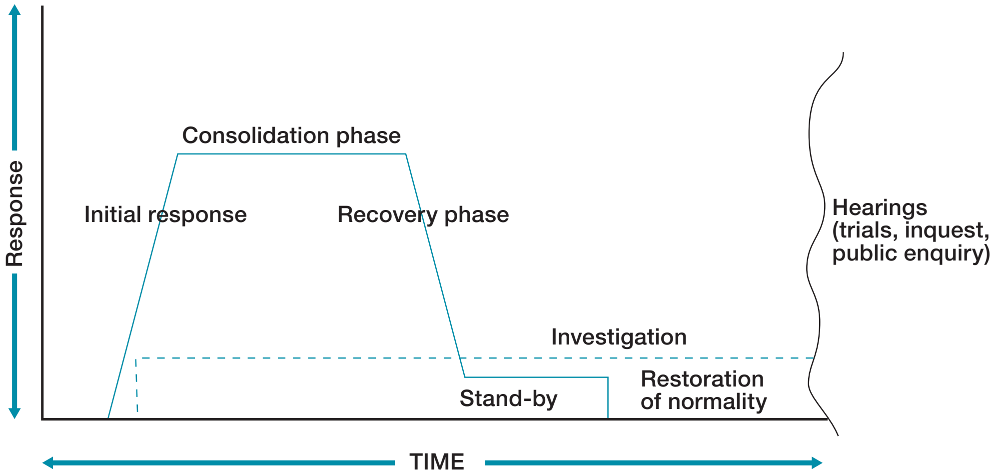


Figure 2.16: Stages of a major incident
Source: LESLP, 2007

Investigation into causes of an accident or incident will start as soon as possible after the event occurs, and continue well after the site is cleared away and any disrupted systems returned to normal. The stages in the response are not necessarily sequential: the emergency response, investigation, and site recovery might all be occurring at the same time.

2.3.1 The emergency response

The initial response to an aircraft accident is the emergency response. The nature of this response will depend on many factors, including the size of the aircraft involved, the level of injuries sustained, and the location of the accident.

2.3.1.1 Emergency responders

The fundamental objective of the emergency response is clear: as noted by the Association of Chief Police Officers in the UK, "The primary aim of all emergency services is to save life" (ACPO, 2009).

The *Civil Contingencies Act 2004* (UK) identifies two categories of responders to emergencies: Category 1 responders (core responders) and Category 2 responders (co-operating responders) (Table 2.3). Category 1 responders are notified immediately of the emergency, and are required to respond to it. Category 2 responders are on call to to provide support and assistance throughout the emergency response and recovery stages of the event, as requested by core responders. This might include immediate attendance at the accident site.

Although not listed in the table, aircraft accident investigators are in the same position as Category 2 responders. Although they are notified of an aircraft accident at almost the same time as the emergency services, they are not immediately needed on site for the emergency response, but for the subsequent period of the investigation (Section 2.3.2).

Table 2.3: Category 1 and Category 2 responders to a UK Civil Contingency

Category 1 Responders	**Category 2 Responders**
Emergency services • Police forces • British Transport Police • Fire authorities • Ambulance services • Maritime and Coastguard Agency	Utilities • Electricity distributors and transmitters • Gas distributors • Water and sewerage undertakers • Telephone service providers (fixed and mobile)
Local authorities • All principal local authorities (ie. metropolitan districts, shire counties, shire districts, shire unitaries) • Port Health Authorities	Transport • Network Rail • Train Operating Companies (passenger and freight) • London Underground • Transport for London • Airport operators • Harbour authorities • Highways Agency
Health Bodies • Primary Care Trusts • Acute Trusts • Foundation Trusts • Local Health Boards (in Wales) • Any Welsh NHS Trust which provides public health services • Health Protection Agency	Health Bodies • Strategic Health Authorities Government agencies • Health and Safety Executive
Government agencies • Environment Agency • Scottish Environment Agency	

Source: Cabinet Office, 2010

The police are the key core responders. It is their responsibility to "... co-ordinate all the activities of those responding at or around the scene of a land-based emergency" (Cabinet Office, 2003). The police are also responsible for cordoning off the site, to facilitate the work of the other emergency services and protect the evidence on the accident scene (ACPO, 2009).

The primary role of the fire service in a major emergency is "the rescue of people trapped by fire, wreckage or debris" (Cabinet Office, 2003). Depending on the location of the aircraft accident, it might be attended by the Airport Rescue and Fire Fighting Service (ARFF), which is also known as the Airport Fire Service (AFS), or Rescue and Fire Fighting Service (RFFS). This organisation is specialised in dealing with fire in disabled aircraft. Alternatively, if the accident is not at or near an airport, it is likely to be attended by local fire authorities without such specialist expertise.

As noted by the FAA (2009):

> “Saving of aircraft occupants’ lives is the primary objective. All other considerations, such as preservation of wreckage, must be secondary to rescue operations. Therefore, fire fighters in the performance of their primary mission of rescue through fire control or extinguishment should not be hampered or restrained by restrictions governing the preservation of evidence. However, during the final stages of salvage and overhaul, care should be taken to avoid unduly disturbing any evidence that may aid in determining the cause of the aircraft accident. Careful preservation of cockpit instruments, controls, areas of primary structural failure or damage, etc., in their original position is important. Any changes made in after-action documentation should be noted”.

Cherry and Associates (2009) analysed data on responses to on-airport aircraft accidents over the period of 1967 to 2000. It was found that the time taken for ARFF units to respond to accidents was between zero and ~1200 seconds (20 minutes). The lower limit - immediate response - was achieved when given advanced warning of an imminent crash: two examples are the pre-impact notification of fires on board an L1011 at Qatar in 1980 and a DC-9 in Cincinnati in 1983. The upper limit of greater than 20 minutes was the time taken to respond to the accident involving a Boeing 757 at Girona, Spain in 1999. On 50 per cent of occasions ARFF were in place to fight fires within four minutes, and on 90 per cent of occasions were there within twelve minutes. Once on site, ARFF established control of the fire within ten minutes for 50 per cent of accidents, and within 42 minutes for 90 per cent of the accidents.

The required levels of ARFF support on an aerodrome differ between countries, and within countries, according to the category and size of aircraft operating into the airport. Airport categories within the UK are shown in Table 2.4. These categories are in line with ICAO guidelines (ICAO, 1990).

Table 2.4: Aerodrome category for ARFF in the UK

Aerodrome Category	Aeroplane Overall Length	Maximum Fuselage Width	Minimum number of foam producing vehicles
1	up to but not including 9m	-	
2	9m up to but not including 12m	-	
3	12m up to but not including 18m	3m	1
4	18m up to but not including 24m	4m	1
5	24m up to but not including 28m	4m	2
6	28m up to but not including 39m	5m	2
7	39m up to but not including 49m	5m	2
8	49m up to but not including 61m	7m	3
9	61m up to but not including 76m	7m	3
10	76m up to but not including 90m	8m	4

Source: Adapted from CAA, 2008

Categories 3-10 are the standard categories for airports taking commercial aircraft. For each of these, there are required volumes of water, foam and other extinguishing agents which must be carried on each fire fighting appliance (CAA, 2008). To maximise the chance of saving lives, it is stipulated that ARFF response times should be within two minutes (120 seconds) to any point on the operational runway, and within three minutes (180 seconds) to any other part of the airport (CAA, 2008).

No specific fire fighting appliance is required at Category 1 and 2 airports, except that there must be a vehicle ‘fit for purpose’ (which can include trailers). Two fire fighters must be available for emergencies at Category 1 airports and three firefighters must be on station at Category 2 airports (CAA, 2008). The CAA (2008) also specifies requirements for ARFF at heliports, with guidelines similar to those for Category 1 and 2 airports.

The ambulance services are also vital emergency responders. Their role on an accident site is “... to sustain life through effective emergency treatment at the scene, to determine the priority for release of trapped casualties and decontamination in conjunction with the fire service, and to transport the injured in order of priority to receiving hospitals” (Cabinet Office, 2003).

If necessary, the Ministry of Defence (MOD) can be drawn into an emergency situation to assist in the search and rescue, or the guarding of cordons (Cabinet Office, 2003; ACPO, 2009). Further, in the event of a large commercial aircraft accident the British

Airways Emergency Procedures Information Centre (EPIC) can be brought into operation, to assist the emergency response. This centre is located at London Heathrow airport, and functions as the central airline co-ordination centre (Cabinet Office, 2003).

2.3.1.2 Management of an emergency response

Emergency response procedures are well defined, and have some common features whether they be for a natural disaster, technology disaster or transport accident, such as an aircraft accident. There is a considerable body of research and guidance on pre-disaster planning (for example HSE, 1999; HM Government 2005; ACPO, 2009) and on the management of major disasters (see Section 2.5.3).

Organisations which respond to accidents must maintain a constant state of readiness. In the UK there is a requirement that they have an established emergency response plan (Cabinet Office, 2003), compliant with the *Civil Contingencies Act* 2004. The exact manner of response will depend on the nature of the event, but the emergency response plan should cater for as many different scenarios as possible.

To manage the response to an accident, a three-level ‘Gold, Silver, Bronze’ command chain is now in general use within responding organisations in the UK. This structure - strategic, tactical and operational - is shown in Figure 2.17. The structure was adopted initially by the Metropolitan Police in the 1980s; soon after, it was taken up by the fire and ambulance services (Arbuthnot, 2008); and it is now common within the emergency response plans of other responding organisations. In the case of a large aircraft accident, this command structure will remain in place during the initial response and consolidation stages of the event.

The strategic, tactical and operational levels are referred to as gold, silver and bronze levels respectively. “Gold, Silver, Bronze is a three-tier structure of command, each level of which performs mutually exclusive roles at separate locations” (Pearce and Fortune, 1995).

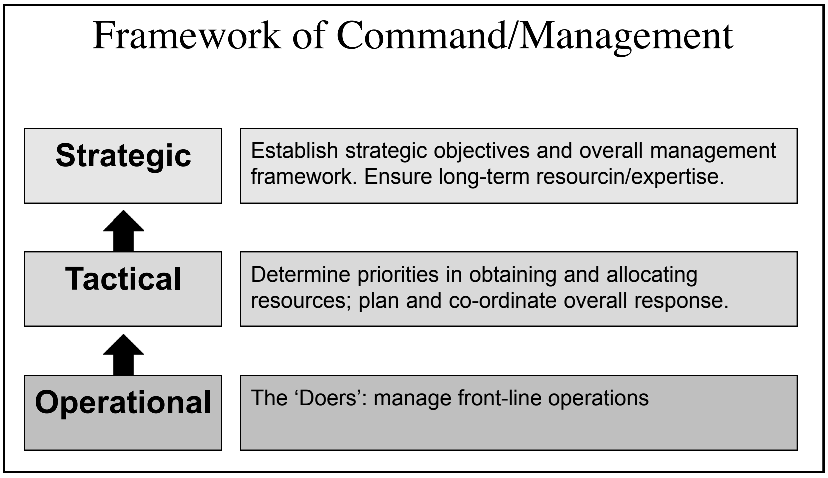


Figure 2.17: Civil Emergency Response command structure
Source: Cabinet Office, 2003

The strategic level, or gold command, is "invoked where an event or a situation could have a significant impact on resources, the wider community or the organisation's reputation" (Arbuthnot, 2008). It provides support to the silver and bronze team members in the form of logistics, intelligence and administration (Pearce and Fortune, 1995). In response to large events where designated gold commanders from multiple agencies work together, the group may be referred to as a Strategic Co-ordinating Group (SCG).

The silver (tactical) team manages the response. Silver command's role is to "determine priorities, allocate resources, plan and co-ordinate tasks to be undertaken, liaise with other agencies wherever necessary to co-ordinate efforts to achieve this, and also to give early consideration to the 'consequence management' and recovery phases of the incident" (Arbuthnot, 2008). The silver response team usually works close to the site, but not necessarily on it.

The bronze (operational) workers are directly present on the site, performing duties tasked to them by their individual organisations. This group provides information to silver command, and in turn is given directions for the response. The CAA (2008) describes the role of bronze command level in the following terms:

> "Bronze is the level at which the management of immediate 'hands-on' work is undertaken at the site(s) of the emergency. Personnel first on the scene will take immediate steps to assess the nature and extent of the problem. Bronze commanders will concentrate their effort on the specific tasks within their areas of responsibility - for example, the police will concentrate on establishing cordons, maintaining security and managing traffic. In most instances the police will co-ordinate the operational response at the scene to ensure a coherent and integrated multi-agency response."

Minor aircraft accidents or incidents might have no strategic or even tactical implications, and therefore not require all three levels of response. "Smaller incidents requiring the participation of a number of agencies would not be individually labelled 'bronze' unless the silver level was in place" (Arbuthnot, 2008).

2.3.1.3 Examples of emergency responses to aircraft accidents

It is important for aircraft accident investigators to be aware of the nature of the interaction that emergency responders have had with the wreckage, so that they can assess the impact the responders work might have had on the evidence.

On 19th July 1989, United Flight 232, a DC-10 crashed on landing at Sioux City Airport, after an engine failure and complete hydraulic power loss. Almost 45 minutes passed between the aircraft having reported the power loss, and the aircraft crash. Emergency response agencies received 20-30 minutes advance notice of the aircraft landing. In that space of time, two designated casualty receiving hospitals were alerted and prepared, and 29 ambulances were dispatched. Fire departments moved numerous units into pre-planned positions around the airport, and the police cleared the adjacent interstate road to provide a clear access route for emergency responders. All 88 injured victims rescued from the aircraft were transported to hospital within 39 minutes of the accident (Charles and Settle, 1991). In this aircraft accident, emergency responders had time to implement a pre-prepared response plan before the aircraft had crashed.

In comparison, at around 1530 hrs EST on 15th January 2009, a US Airways A320 ditched in the Hudson River following multiple bird strikes resulting in loss of thrust. There were only three minutes between the bird strikes and the aircraft ditching (NTSB, 2009f), during which time it was uncertain where the aircraft was planning to land. Numerous organisations responded to the emergency: the New York Waterway (NY WW) Ferry Boats; the US Coast Guard (USCG); the New York Police Department (NYPD); the Fire Department of New York (FDNY); the New York and New Jersey Port Authority; the New York Office of Emergency Management (NY OEM); and the New Jersey Office of Emergency Management (NJ OEM) (NTSB, 2009g). There is no complete record of the number of emergency units that actually responded to the accident, but they are known to have included seven passenger ferry boats (NTSB, 2009h), five NYPD boats (NTSB, 2009g) and 47 FDNY units (NTSB, 2009i). The aircraft was towed and secured to a Battery Point wharf by 1714 hrs; NYPD divers searched the Hudson River for six days to locate the left engine, and recovered it two days later (NTSB, 2009h). In this accident there was absolutely no time to implement a response plan in advance.

Figures 2.18 and 2.19 show responders on the site of a Turkish Airlines Boeing 737-800 crash on approach to Amsterdam Airport Schiphol on 25th February 2009.

Figures 2.18, 2.19: Responders to the 25th February 2009 Turkish Airlines B737-800 accident at Schiphol Airport
Source: BBC, 2009

The photographs show the devastation characteristic of major aircraft accidents. They are however not necessarily pictures of chaos. In circumstances such as this, it is important that the site is under the direction of the police, that only authorised responders are present, and that all personnel are monitored. Even so, the photographs suggest that it might be difficult for investigators attending this accident to distinguish between damage caused by impact and damage resulting from the emergency response. It also appears to be a site at which it would be difficult to monitor and manage responders and participants. It is of paramount importance that a proper command structure is in place during and after the emergency response, and that the health and safety of responders is directly managed.

2.3.1.4 Completion of site activities

Once rescue activities are completed, the responsibility of the police is to secure the site and to conduct any criminal investigation (Cabinet Office, 2003). In the case of transport accidents, the latter responsibility is qualified by a Memorandum of Understanding (MOU) between by the Crown Prosecution Service (CPS), the AAIB, the Marine Accident Investigation Branch (MAIB), and the Rail Accident Investigation Branch (RAIB) (CPS, 2008). The MOU asserts the potential primacy of considerations of public safety over criminal prosecution: "... the public interest requires that safety considerations are of paramount importance, the consequence of which may mean that the interests of an AIB investigation have to take precedence over the criminal investigation" (CPS, 2008). When the police are confident that an aircraft accident has not occurred as a result of terrorism or criminal activity, control of the site is handed to the AAIB. The police play no further role in the field investigation except on request.

The situation is the same in the USA, unless there are exceptional circumstances - an example of which was the site of the crash of a Piper PA-28 aircraft into a building in Austin, Texas on 18th February 2010. The secured site was released by the police to the NTSB for accident investigation, during the course of which the NTSB decided that there were grounds for transferring control of the site to the Federal Bureau of Investigation (NTSB, 2010b).

2.3.2 The accident investigation

Whilst the purpose of the emergency response is to save lives, the purpose of the aircraft accident investigation is to determine the cause of the accident and to assist in preventing similar accidents in the future.

From the point of assumption of control of the accident site, the accident investigation authority is in strategic and tactical (gold and silver) command of the investigation, and its Investigator-in-Charge (IIC) is its operational (bronze) commander. The IIC is responsible for managing the site, for authorising and managing access, for conducting the on site investigation, for securing the health and safety not only of the investigators but also that of other personnel, and for continuing the investigation off site until the report and recommendations are finalised.

2.3.2.1 Participants in the accident investigation

2.3.2.1.1 Overview

Many different agencies and bodies have a role at the accident site. It is the responsibility of the IIC to regulate their attendance, taking into account their various duties, entitlements and skills.

The Australian *Transport Safety Investigation Act 2003* gives the Chief Commissioner of the ATSB the power to prevent anyone from entering an accident site unless:

> "... the person entered the accident site, or remained on the accident site:
> a. to ensure the safety of persons, animals or property; or
> b. to remove deceased persons or animals from the accident site; or
> c. to move a transport vehicle, or the wreckage of a transport vehicle, to a safe place; or
> d. to protect the environment from significant damage or pollution."

Thus emergency responders, representatives of the coroner, recovery agents, and environmental protection agencies are entitled to access to the accident site even after the accident investigation authority has assumed control.

In the UK, *The Civil Aviation (Investigation of Air Accidents and Incidents) Regulations 1996* have a related provision which in practice also permits access to personnel other than investigators:

> a. The aircraft may be removed or interfered with so far as may be necessary for the purpose of -
>   i. extricating persons or animals;
>   ii. removing any mail, valuables or dangerous goods carried by the aircraft;
>   iii. preventing destruction by fire or other cause;
>   iv. preventing any danger or obstruction to the public, air navigation or other transport;
>   v. removing any other property from the aircraft under the supervision of an Inspector or with the agreement of an Inspector or of a constable;
>
> b. if an aircraft is wrecked on water, the aircraft or any of its contents may be removed to such extent as may be necessary for bringing it or them to a place of safety".

Specialist technical advisers from outside the investigation agency commonly attend accident sites at the request of the investigators, and the military might well be called in when additional manpower assistance is required. The range of potential participants in activities at accident sites creates a diversity of demands on the investigation agency.

2.3.2.1.2 ICAO recognised investigators

The aircraft accident investigation is conducted by the investigation agency for the State of Occurrence. The notified organisations in other countries - the State of Registry, the State of the Operator, the State of Design, and the State of Maintenance - are each entitled to send an accredited representative to participate in the investigation. The representative may be accompanied by a team of advisors to provide technical assistance (ICAO, 2001a).

Under ICAO *Annex 13* agreements, each authorised participant (investigators, accredited representatives, technical advisors), has the right to :

a. "visit the scene of the accident;
b. examine the wreckage;
c. obtain witness information and suggest areas of questioning;
d. have full access to all relevant evidence as soon as possible;
e. receive copies of all pertinent documents;
f. participate in read-outs of recorded media;
g. participate in off-scene investigative activities such as component examinations, technical briefings, tests and simulations;
h. participate in investigation progress meetings including deliberations related to analysis, findings, causes and safety recommendations, and
i. make submissions in respect of the various elements of the investigations". (ICAO, 2001a)

In addition countries whose citizens have been killed or injured may request to send one expert to participate in the accident investigation, with the right to:

a. "visit the scene of the accidents;
b. have access to the relevant factual information;
c. participate in the identification of the victims
d. assist in questioning surviving passengers who are citizens of the expert's State; and
e. receive a copy of the Final Report". (ICAO, 2001a)

Although the national accident investigation authority is in control of the investigation, the attendance of specialist nationals from other countries brings management complexity, potentially mitigated by benefit.

The AAIB has three categories of investigator, each with different specialities: operations, engineering, and flight recorders (AAIB, 2010d). The number of investigators deployed will depend on the size of the accident. One Operations Inspector and one Engineering Inspector would normally be deployed to the site of a small general aviation accident, their work being overseen by a Principal Inspector as IIC, who would generally remain at base. For a larger aircraft accident, the IIC would be deployed on site with at least one Operations Inspector and an Engineering Inspector, supported by a Flight Recorder Inspector if required to recover the aircraft recorders. Additional operations or engineering inspectors would be added as necessary.

For investigation of major aircraft accidents, the NTSB adopts a group structure. Investigators, accredited representatives and technical advisers are divided into working groups: operations; structures; power-plants; systems; air traffic control; weather; human performance; survival factors; and data recorders (NTSB, 2004a). These teams are each headed by an NTSB investigator, who reports directly to the IIC. The AAIB does not employ a group structure routinely, but may divide investigators, accredited representatives and technical advisors into specialist groups as required (AAIB, 2008a):

for example, a group structure was adopted by the AAIB during the investigation of the Boeing 777 crash at Heathrow in 2008 (AAIB, 2010b).

In addition to personnel covered by *Annex 13* agreements (ICAO, 2001a), the lead investigation agency may invite specialists to assist with individual investigations. These may include airline employees, manufacturers of engines and other components and representatives from other government agencies, such as pathologists (AAIB, 2008a). The number and mix of investigators and other specialists will depend upon the circumstances of the accident.

For example, the investigation into the 1988 B747-100 crash at Lockerbie involved twenty AAIB investigators: an IIC, supported by a Principal Inspector (Engineering), an Assistant Principal Inspector (Engineering), thirteen Engineering Inspectors, and four Operations Inspectors. The wreckage of the aircraft created a 47m long crater and two major wreckage trails. The northern trail was concentrated over a 16km distance east of the crater, with some items extending up to 25km distance. The southern wreckage trail reached across Scotland and northern England to the North Sea, although the majority of the wreckage was concentrated in a 30km band east of the crater. In all, over 1200 pieces of wreckage were collected (AAIB, 1990). Military personnel were drafted in to collect these pieces.

The loss of an Air France A330 on 1st June 2009 in the South Atlantic Ocean confronted aircraft accident investigators with the problem of remoteness. The French air accident investigation authority, the Bureau d'Enquétes et d'Analyses (BEA) organised a team of investigators the same day (BEA, 2009a), but the actual location of the aircraft wreckage was unknown: the initial search had a radius of 40nm and covered over 17000 km^2 (BEA, 2009b). Investigators had to travel to the search zone by ship from either Praia (Cape Verde), Natal (Brazil) or Dakar (Senegal), which took between two and four days (BEA, 2009c). It was not until 6th June that wreckage from the aircraft was identified (BEA, 2009b). So far there have been three sea searches at the mid-ocean site: the team has included investigators, accredited representatives, technical advisors, and observers from France, Brazil, the United States of America, the United Kingdom, Germany, China, Croatia, Hungary, Ireland, Italy, Lebanon, Morocco, Norway, the Republic of Korea, the Russian Federation, South Africa and Switzerland (BEA, 2009d).

2.3.2.1.3 Technical advisors

Flaherty (2008) identified the key skills needed by aircraft accident investigators (Section 2.1.4). When an investigation requires additional specialist knowledge or skills, the accident investigation agency will contract in subject matter experts (SMEs) as technical advisors. The accredited representatives of organisations notified under the provisions of *Annex 13* are also permitted to appoint technical advisors (ICAO, 2001a).

These advisors may participate only in areas of the investigation in which they are specialised.

Technical advisors may be representatives of the operator, the aircraft manufacturer, the engine manufacturer, or other aircraft component manufacturers (Wood and Sweginnis, 2006). Material specialists may also be required to carry out analysis on failed parts of the aircraft (NTSB, 2002): while their work will be predominantly in a laboratory, they may need to attend the site to collect evidence or to examine the evidence *in situ*. The transfer of parts of the wreckage for further examination, without loss of evidence, requires considerable skill.

Technical advisors generally have some level of training or experience in accident investigation, and some manufacturers, such as Rolls Royce, have an accident investigation department. However some technical advisors may not have extensive site experience, and therefore may not be fully aware of the hazards they are likely to encounter on the accident site. They therefore must be supervised, as set out in *Annex 13* guidelines (ICAO, 2001a).

The number of investigators, accredited representatives and technical advisors can be quite large. Following the Lockerbie accident in December 1989, the AAIB investigation team were supported by representatives from:

- “Air Line Pilots Association International
- Boeing Commercial Airplane Company
- British Airways
- British Army
- British Geological Survey
- Bureau d’Enquetes et d’Analyses
- Canadian Aviation Safety Bureau
- Civil Aviation Authority
- Cranfield Institute of Technology
- Federal Aviation Administration
- Independent Union of Flight Attendants
- National Transportation Safety Board
- Pan American World Airways
- Police Service
- Royal Aerospace Establishment
- Royal Air Force
- Royal Armaments Research and Development Establishment
- Royal Navy
- Royal Ordinance
- Royal Signals and Radar Establishment
- United Technologies International Operations (Pratt and Whitney)”

(AAIB, 1990, Appendix A)

2.3.2.1.4 The military

If a UK military aircraft crashes away from a civil aerodrome, the emergency response and investigation (or board of inquiry) is launched by the arm of the military involved (army, air force or navy). This is laid down in military Aircraft Post Crash Management

(APCM) procedures (Directorate of Aviation Regulation and Safety [DARS], 2008). Should a military aircraft crash at a civil aerodrome, or there are particular circumstances which make the accident of interest to civilian operations, then the AAIB will conduct the investigation, under *The Civil Aviation (Investigation of Military Air Accidents at Civil Aerodromes) Regulations 2005*.

Military assistance may also be provided following civil aircraft accidents. Under Military Aid to the Civil Community (MACC) provisions, the military may provide manpower for specialised on site tasks during natural disasters and major incidents (Cabinet Office, 2003). Their assistance may be requested by the AAIB (MOD DCDC, 2007).

Military personnel from the Royal Army, Royal Air Force (RAF) and Royal Navy provided assistance with wreckage collection following the Lockerbie accident (AAIB, 1990). The initial sea search for the wreckage of the Air France A330 in the South Atlantic in June 2009 involved naval vessels from Brazil, France, USA and Spain (BEA, 2009e). Following the break-up of TWA 800 on 17th June 1996 off the coast of Long Island, New York, the US Navy assisted with the debris search and mapping, and with the recovery of victims and wreckage (US Navy, 1998).

2.3.2.1.5 The coroner

In the UK, a coroner (or in Scotland a procurator fiscal) is required to inquire into all the circumstances of a sudden, violent or unnatural death (AAIB, 2008a). Similar provisions apply in other national jurisdictions. A coroner will normally inspect the site of an air accident.

Aircraft accident investigators are not required to participate in the identification and removal of accident victims. Police officers trained in disaster victim identification (DVI), and acting under instructions from the coroner, will remove the deceased from the site (Cabinet Office, 2009), before or soon after the aircraft accident investigators arrive. Where possible, any evidence around the deceased is collected by the police or accident investigators before it is disrupted. The DVI team have formalised management procedures covering removal techniques and methods of recording evidence, and any recorded evidence trail is shared with the AAIB (CPS, 2008).

ICAO *Annex 13* (2001a) requires the state conducting the investigation into a fatal accident to “arrange for complete autopsy examination of fatally injured flight crew and, subject to the particular circumstances, of fatally injured passengers and cabin attendants, by a pathologist preferably experienced in accident investigation”. For this purpose, the AAIB generally uses an aviation pathologist seconded from the RAF (AAIB, 2008a). Such examination is undertaken in conjunction with the coroner.

2.3.2.1.6 The insurer

There is no legal requirement for access to the site to be provided to the aircraft insurer. In the UK, site visits by insurance representatives are facilitated so long as they do not hamper evidence collection or conflict with other conditions of access, under a protocol signed by the Association of British Insurers (ABI), The Chartered Institute of Loss Adjusters, aviation insurers' representatives, AAIB, the Local Government Association, the Chief Fire Officers' Association and the Association of Chief Police Officers (ABI, 2007).

In the USA, Sarsfield, Stanley, Lebow, Ettedgui, and Henning (2000) have observed that "Insurance representatives arrive on the scene almost as soon as NTSB investigators, offering their assistance and co-operation, and at the same time obtaining almost immediate access to the crash site ... NTSB investigators readily admit that, despite NTSB regulations, they are 'happy to have the insurers show up'. The insurers offset costs and provide necessary support to the investigation, including heavy machinery, communications equipment, computers and accommodations" (Sarsfield *et al.*, 2000*,* p.102).

2.3.2.1.7 The media

An aircraft accident attracts media interest: a major accident will attract the attention of multiple national and international press agencies, which will often want access to the site. Guidance for the emergency services published by the investigation agencies includes information about dealing with the media (for example AAIB, 2008a; AAIU, 2005; ATSB, 2006a). The press may be provided with information by the accident investigators, and given access to a safe and suitable filming location. In the UK, a press officer is normally deployed by the Department for Transport to manage the press interest in major aircraft accidents (AAIB, 2008a).

2.3.2.1.8 Families and survivors

Families of those involved in an aircraft accident may wish to attend the accident site. This is recognised by ICAO in its family assistance plan (ICAO, 2001c), which gives the following guidance:

> "Where access is practicable, a visit to the accident site by the families and the survivors, as part of the grieving process, is important and has become common practice. ... Experience has show that the family members of those killed in an accident prefer not to share the visit to the accident site with survivors. Also, it is advisable to arrange the visit for family members of passengers separately from that of the visit for family members of the crew."

Similarly, the UK Home Office publication on *The Needs of Faith Communities in Major Emergencies: Some Guidelines* (2005), states that:

> "There will usually be a requirement for some form of simple observance at the scene of the major incident, particularly if there is loss of life. This will usually take place some days after the date the incident occurred and once the identify of the deceased has been established. Where possible, and subject to both police advice and safety considerations, such a service may be held either close to the scene - within the inner cordon - or actually at the point where the death occurred or is believed to have occurred"

While care of the families and survivors is not the direct responsibility of the accident investigators, they may have to facilitate at least three site visits (families of deceased passengers, families of deceased crew, and survivors), and ensure their safety on site.

2.3.2.1.9 Witnesses

Wood and Sweginnis (2006) identify three types of witness to aircraft accidents: participants involved in the accident; eyewitnesses who saw the event happen; and background witnesses who were not directly involved, but know something about the circumstances of the accident.

Accident investigators may bring witnesses back to an accident site to interview them *in situ*, or interview them off site. This will depend on the nature of their evidence. If on site, their safety and supervision is the responsibility of the investigation team.

2.3.2.1.10 Volunteer organisations

Many volunteer organisations can be called to assist the emergency services. Table 2.5 is an example of available volunteer organisations in London.

Following a large aircraft accident, volunteer organisations might remain on at the site to support the investigation. Volunteer organisations provide food, drink and rest facilities for investigators, from outside the accident site cordon. The US Navy thanked the American Red Cross for support during the TWA 800 investigation (US Navy, 1998). Following the September 2005 crash of a Boeing 737 in Medan, Indonesia, the Salvation Army remained on site for the benefit of rescuers and families (Salvation Army, 2005). Numerous volunteer organisations supported the 3,000 strong team searching for wreckage from the Columbia Space Shuttle daily (CAIB, 2003).

Table 2.5: Volunteer organisations supporting emergency services in London

Emergency Service	**Volunteer Organisation**
London Fire Brigade	Salvation Army
London Ambulance Service	British Association of Immediate Care (BASICS)
	British Red Cross Society
	St John Ambulance
	Salvation Army
Police	Women's Royal Voluntary Service (WRVS)
	First Aid Nursing Yeomanry (FANY)

Source: LESLP, 2007

2.3.2.1.11 Environmental protection agencies

If the accident has damaged the environment or has the potential to do so, environmental protection agencies will have an important role to play at the accident site. Action could include measures such as preventing fuel from leaking into waterways. Particular attention is given to sites of special scientific interest (SSSI) which are of national importance and environmentally very sensitive: in England there are 4,000 SSSIs, covering 7 per cent of the country (Natural England, 2010). Wreckage from a Boeing 747 Freighter that crashed on 22nd December 1999 in the Hatfield Forest SSSI after take off from London Stansted Airport caused substantial environmental damage requiring long-term amelioration.

2.3.2.1.12 Examples of accident sites

Two examples illustrate the unique nature of accident sites and the complexity of the management tasks faced by accident investigators.

The Columbia space-shuttle accident on 1st February 2003 initiated "the largest debris search in history" (CAIB, 2003). The NTSB were brought in by the NASA Mishap Investigation Team (MIT) to provide guidance on the search for wreckage. The search continued until 25th April, and involved more than 3000 people per day in the ground search. There was concern among investigators about the risk to the public health and search personnel caused by human remains, and by hazardous material such as propellants. Over the search period, more than 30,000 people contributed 1.5 million man hours: 700,000 acres of ground were searched manually; and 84,000 pieces of wreckage were collected, weighing a total of 84,900 pounds. Even so, this was only 39 per cent of the weight of the shuttle. Up to 30 items of wreckage were identified as 'hot items', that is, items such as computers, film, camera, and recorders which contained important but highly perishable evidence due to limits on battery life (CAIB, 2003). Had this evidence been delayed in reaching specialist investigators, vital evidence may have been lost.

In Canada, Clitsome (2007) reviewed the TSB response to the A340 runway over-run and fire at the Lester B. Pearson International Airport, Toronto in August 2005. The TSB was notified of the accident by the airport ATC within five minutes of the accident. The TSB immediately called in all available investigators, from which a team of investigators with the most appropriate experience were selected to conduct the investigation. Within three hours of notification, the investigation team met to prepare their equipment and be briefed. The team was on the accident site within twelve hours, and comprised of "35 TSB investigators, supported by accredited representatives from the BEA and the NTSB, and 43 observers from the following entities: Transport Canada, the Federal Aviation Administration of the United States. NAV Canada, Air France, Airbus, General Electric, the UK AAIB, Goodrich Corporation, the Peel Regional Police, and the Greater Toronto Airport Authority (GTAA)" (Clitsome, 2007). The field investigation continued for fourteen days.

2.3.2.2 Notification and deployment

Under *The Civil Aviation (Investigation of Air Accidents and Incidents) Regulations 1996*, it is the official duty of the pilot, or the aerodrome authority if the accident occurs at an aerodrome, to report the accident to the AAIB. In the event, AAIB can be notified of an accident by one or several of a number of sources: the pilot, air traffic control, the police, the aircraft operator or eye witnesses (AAIB, 2008a). On receipt of notification, it is the duty of the Chief Inspector to instigate a investigation. In practice, this is done by a Principal Inspector, acting as duty co-ordinator.

It is the responsibility of the accident investigation agency then to notify any other investigative agency which might be entitled to send an accredited representative, and also ICAO if the aircraft has an MTOW > 2,500kg (ICAO, 2001a). Each organisation will then select an accredited representative and alert any proposed technical advisors.

Annex 13 specifies that the initial notification ideally should include the following information:

> a. "... for accidents the identifying abbreviation ACCID, for serious incidents INCID;
> b. manufacturer, model, nationality and registration marks and serial number of the aircraft;
> c. name of owner, operator and hirer, if any, of the aircraft;
> d. name of the pilot-in-command, and nationality of crew and passengers;
> e. date and time (local time or UTC) of the accident or serious incident;
> f. last point of departure and point of intended landing of the aircraft;
> g. position of the aircraft with reference to some easily defined geographical point and latitude and longitude;

> h. number of crew and passengers; aboard, killed and seriously injured; others, killed and seriously injured;
> i. description of the accident or serious incident and the extent of damage to the aircraft so far as it is known;
> j. an indication to what extent the investigation will be conducted or is proposed to be delegated by the State of Occurrence;
> k. physical characteristics of the accident or serious incident area, as well as an indication of access difficulties or special requirements to reach the site;
> l. identification of the originating authority and means to contact the investigator-in-charge and the aircraft accident investigation authority of the State of Occurrence at any time; and
> m. presence and description of dangerous goods on board the aircraft". (ICAO, 2001a)

It is inevitable that not all the above detail can be provided in the great majority of initial notifications. As noted by the NTSB, investigations commonly begin before all this information is known: "information about the nature of the accident is often incomplete and frequently erroneous at the time of the launch" (NTSB, 2002a). Once the notification is received and the decision to investigate is taken, sufficient investigators with required skills (the 'go team') are selected to attend the accident site from amongst those investigators 'on call'.

When a large aircraft accident occurs in the UK, the Chief Inspector acts as the gold commander; a Principal Inspector acts as silver command (and IIC); and there will be as many operations, engineering and data recorder investigators as are necessary (AAIB, 2008a). For smaller aircraft accidents, such as general aviation accidents, a small field team of an operations inspector and an engineering inspector will be deployed. A Principal Inspector will act as IIC, but will not generally be deployed to the site.

In the USA, the NTSB requires that:

> "... all personnel on call should arrange their personal affairs such that they are able to depart for the scene of an accident with minimum delay. Regardless of when they are notified about an accident, Go Team members should be able to arrive at the airport within approximately two hours of being notified". (NTSB, 2002a)

This is not always practical. The time taken for aircraft accident investigators to arrive on a site will depend on many factors, including the time of the accident, the availability of flights or other travel arrangements to get to the site, the distance to travel, and the ease or difficulty of access to the site. Under *Annex 9* (Facilitation) SARPs, ICAO member states are required to facilitate the arrival of accident investigation teams and equipment from overseas, without delay (ICAO, 2005a).

2.3.2.3 Investigation equipment

The start to any investigation should be expeditious: ICAO states that "Accident investigators should have their investigation field kits and essential personal items packed and ready so that they can proceed without delay to the accident site" (ICAO, 2000). However, as noted by Wood and Sweginnis (2006) "there is no standard investigation kit". NTSB (2002a) similarly observe:

> "Most Go Team members do not have a suitcase pre-packed because there's no way of knowing whether the accident scene will be in Florida or Alaska, but they do have tools of their trade handy - carefully selected wrenches, screwdrivers and devices peculiar to their speciality".

On deployment, the only information the go team might have about an accident site is that given in the initial notification (Section 2.3.2.2). On that limited basis, they must conduct a generic risk assessment: they must select suitable clothing, personal protective equipment, and investigative tools to take with them to the site. The amount of equipment they take will be limited by the size of their vehicle, the baggage allowances on any aircraft in which they travel, and their own physical limitations given potential difficulties of access to the site. It is important that potential hazards at the site are identified as accurately as might be possible beforehand, to ensure that investigators take precisely the right equipment, and avoid taking inappropriate and inadequate equipment which might prevent them from collecting evidence and conducting a thorough investigation.

There are various sources of guidance on the selection of investigative tools (for example ICAO, 2000; Lewis and Burrell, 2004; Wood and Sweginnis, 2006). The equipment finally selected will depend on the personal preferences of the investigator. The only information the accident investigator will have to work with to ascertain what tools, equipment and clothing to take to a site will be the initial notification form.

2.3.2.4 On site activities

The on site work of an aircraft accident investigator is conducted in a high pressure, rapidly changing environment. Time is of the essence - the perishability of evidence, the demanding work environment, the commercial pressures and the often difficult access to sites mean that investigators may have only a short time to collect the evidence needed for thorough investigation. Primary on site evidence is in most investigations critical to discovery of the causal and contributory factors that led to the event.

2.3.2.4.1 Initial actions

On arrival at the site, investigators are likely to be briefed by the police or other emergency services before the site is handed over to the control of the IIC. Ideally, the site will be as undisturbed as possible at this stage. However as it is more than likely that emergency responders would have disturbed the wreckage while recovering passengers and crew from the aircraft, the investigators would seek precise details of their activities, about what their actions were, where they rescued people from, and what, if anything, they moved.

The first action of investigators will be to make an initial assessment of the state of the wreckage and the site conditions they will be working in. They will also make certain that the site is as secure as possible, to ensure that all evidence is adequately protected, whether it be parts of the aircraft or ground scars created along the wreckage trail (ICAO, 1970). Importantly, potential hazards - previously considered generically and off site during preparation for deployment - will be reassessed. This is known as the first dynamic risk assessment: depending on the size of the accident, the dynamic risk assessment will be carried out by the IIC, the safety manager, or an engineering inspector. Generic and dynamic risk assessments are further discussed below (Section 2.4.4).

Further, the investigators must establish a field base from which to operate (NTSB, 2002a; Wood and Sweginnis, 2006). It must provide facilities to make phone calls and access the internet, to meet and interview witnesses, and to store evidence. It should be as close as possible to the accident site, although this proximity will be determined by the local conditions.

Before the investigation can begin in full, the wreckage might need to be made safe. For example, in the accident report on the Boeing 777 accident at London Heathrow airport in January 2008, it is observed that:

> Immediately following the accident, and to make the aircraft safe, the AFS assisted by engineers from the operator accessed the aircraft. The aircraft battery was disconnected, and in the flight deck the Battery switch and the APU switch were moved from ON to OFF". (AAIB, 2010b)

In this case, making the wreckage safe involved co-operation between the AFS and the AAIB. Non-airport fire services might not have known the location of the battery on a Boeing 777, and the necessary supplementary actions to make the aircraft safe. The AAIB inspectors were able to verify the switch positions in the flight deck, and were protected by the AFS in the event of fire outbreak.

Once the likely hazards are identified and safety precautions have been taken, evidence collection begins.

2.3.2.4.2 Evidence collection

Evidence is collected both on site and off site. The two sources complement each other, and both are needed to understand the causal factors of the accident. Evidence collected on site will be re-analysed throughout the investigation.

2.3.2.4.2.1 Evidence collected from accident sites

There is a wide variety of types of evidence: the actual evidence collected at a site will depend on the circumstances of the accident. In some situations, there will be a need for full analysis of the entire airframe and components: in other situations, only certain parts of the aircraft might provide relevant evidence.

Sources such as Wood and Sweginnis (2006), Ellis (1984) and the ICAO *Manual of Aircraft Accident Investigation* (1970), provide guidance on the collection of evidence. The latter sets out procedures for collecting physical evidence in the following categories:

- Flight recorders
- Material failures
- Propellers
- Hydraulic systems
- Electrical systems
- Pressurisation and air conditioning systems
- Ice and rain protection systems
- Instruments
- Radio navigation equipment
- Flight control systems
- Fire detection and protection systems
- Oxygen systems
- Explosives sabotage

(ICAO,1970)

The NTSB collects evidence by dividing the investigation team into eleven groups: air traffic control; human performance; maintenance; operations; airplane performance; powerplants; structures; survival factors; systems; meteorology; and witnesses (NTSB, 2002a). Each group focuses on its own particular aspect of evidence collection, and the evidence and findings are compiled after the on site phase.

In their review of NTSB investigation procedures, Sarsfield *et al.* (2000) observed that: "The need to modernise certain investigative practices and procedures is particularly acute. In some respects, the NTSB's investigative techniques have not kept pace with changes in modern aircraft design, manufacturing, and operation, raising doubts about its ability to expeditiously and conclusively resolve complex accidents".

2.3.2.4.2.2 Perishable evidence

Perishable evidence may be lost unless collected in a short space of time. It includes fuel samples; oil and hydraulic fluid samples; loose papers, maps and charts; evidence of icing; evidence of runway condition; switch positions and instrument readings; control surface and trip tab positions; flight data recorders and cockpit voice recorders; and ground scars (Wood and Sweginnis, 2006).

Guidance documents for the emergency services suggest ways in which evidence might be protected and recorded prior to the arrival of accident investigators: not disturbing wreckage unnecessarily; mapping the location of any runway debris; securing the site; taking photographs; not touching the data recorders; collecting the contact details of witnesses; using fire fighting foam only where necessary; recording the locations where survivors were assisted; and leaving fatalities in place (AAIB, 2008a; AAIU, 2005). The purpose of this guidance is to keep the immediate post-accident site as untouched as possible until the investigators arrive. This allows them to begin investigation immediately, without spending unnecessary time considering whether particular characteristics of the wreckage were caused by the accident or by the emergency rescue.

The NYPD Harbour Unit that responded to the A320 ditching in the Hudson River in January 2009 found that evidence was rapidly being lost due to the flowing tide (NTSB, 2009h). Rescue boats were directed to all floating debris, and the FDNY marine rescue boats tied a cable through the front doors of the aircraft to prevent it from sinking (NTSB, 2009i). This is an extreme example of rapidly perishable evidence.

Given the perishability of evidence, the accident investigation team will begin work as quickly as possible. Light items of wreckage may be blown about, as might documents and papers carried on the aircraft. Fuel and oils may leak into the ground, ice may melt, switch positions move easily, and ground scars fade due to weather or trampling. The more information that can be recorded early on, the better the chance of success. Further, investigators must make early decisions about their own health and safety while collecting the perishable evidence.

2.3.2.4.2.3 Methods of evidence collection

The TSB describes the general tasks that investigators conduct on sites as “secure and examine the occurrence site, examine the equipment, vehicle or wreckage, interview witnesses and company and government personnel, collect pertinent information, select and remove specific wreckage items for further examination, review documentation, and identify potentially unsafe acts and unsafe conditions” (TSB, 2005 p.5).

On site evidence is collected using a variety of techniques, such as photography, diagrams, wreckage distribution plots, and ‘bagging and tagging’ pieces for further analysis. Through experience, each investigator develops favoured techniques: these are important in deciding the equipment and materials to be carried in the ‘go bags’ (Section 2.3.2.3).

The manner in which evidence is collected will depend on the overall management of an accident. For example, if investigators determine that it is important for the purposes of thorough investigation that the wreckage of an aircraft be reconstructed, either wholly or partially - as was the case with TWA 800, the Air France Concorde, and the

Lockerbie aircraft - the major objective will be recording and mapping the location of each part of wreckage, and preserving the wreckage for transport. This is a lengthy and costly task.

The Canadian TSB *Manual of Investigation* (1991) suggests the following factors should be considered before deciding to recover an aircraft back to an investigation base:

- "The likelihood of finding any significant evidence.
- The benefit to the investigation.
- The potential to further advance aviation safety.
- The possibility of organising an effective search.
- The feasibility of recovering the wreckage.
- The extent of public interest.
- The total cost of the search and retrieval process compared to the benefit to aviation safety.
- The likelihood of reliable cost-sharing between the owners, operators, insurance companies, and the TSB".

(TSB, 1991)

Some basic rules have been applied when "bagging and tagging" evidence. For example, anti-static bags should be used for the collection of electrical equipment, to prevent static build up and to avoid potential damage to electrical components and hence stored memory (Pepper, 2005); and any evidence covered in body fluids should be bagged in marked biohazard bags, to prevent investigators handling the wreckage from subsequently being exposed to the hazards present.

Evidence collection within or close to the wreckage potentially exposes investigators to many different health and safety hazards (see Chapter Three).

2.3.2.4.2.4 Quality of evidence collection

The quality of the evidence is of vital importance. Braithwaite and Greaves (2009) note that: "Whilst the no-blame culture approach advocated by *Annex 13* means that evidence does not necessarily need to be collected to the standards of proof required for a criminal prosecution, an investigator that is trying to analyse an accident or draw recommendations from that analysis will struggle to fulfil their role without high quality evidence".

Personal protective requirements differ between aircraft accident investigators and crime scene investigators, due to the different needs for evidence standards and personal protection. On a crime scene, emphasis is placed on preventing contamination of the evidence. Pepper (2005) comments that, by a crime scene investigator wearing incorrect protective clothing, the evidence in a trial can be questioned.

Aircraft accident investigators wear PPE to protect themselves. Since the investigation they are conducting is non-punitive, they can focus on preventing the transfer of evidence onto themselves, rather than preventing the transfer of themselves onto the evidence. There is further discussion of the different needs for PPE in Chapter Six.

2.3.2.5 Completion of site activities

The length of time spent collecting evidence may be affected by the nature of the accident and its location.

The Boeing 777 aircraft that crashed at London Heathrow Airport in January 2008 was moved from the accident site to a secure on-airport compound within three days: flight data recorders had been removed and all available *in situ* evidence had been gathered, recorded or photographed (BBC, 2008). The aircraft remained in the compound for follow-up investigation until April 2009 (Kaminski-Morrow, 2009): in contrast, investigations into general aviation accidents are often completed in one day, and the wreckage then released for immediate removal.

Once all required evidence is collected, the site is returned to the owner, and the aircraft (if not needed for further analysis) is returned to the owner or insurer.

2.3.2.6 Off site activities

Off site evidence collection and analysis can take place at the same time as on site investigation, and subsequently. The TSB lists the activities involved in post-field investigation as follows:

> - examine all pertinent company, vehicle, government and other records;
> - examine selected wreckage in the laboratory and test selected components and systems;
> - read and analyse recorders and other data;
> - create simulations and reconstruct events;
> - review autopsy and toxicological reports;
> - conduct further interviews;
> - determine the sequence of events; and
> - identify safety deficiencies.
>
> (TSB, 2005)

2.3.2.6.1 Evidence collection

Evidence collected at the same time as the field investigation includes maintenance records, operational documents, crew logbooks, radar traces, air traffic control readings, and weather after-casts. Additional evidence may also be gathered from the wreckage removed and stored in a secure wreckage hangar.

Athiniotis, Lombardo and Clark (2010a, 2010b) discussed the problems of recovering a helicopter wreckage from Indonesia to Australia. Australian quarantine regulations required much of the evidence to be washed to remove potential pests and contaminants. The investigation team was particularly interested in split pins from the aircraft, which could have easily been lost in the cleaning process. A method had to be found to comply with the regulations without loss of evidence. Further, it was decided to sterilise evidence which would have been destroyed by washing, such as ash, by using gamma rays or ethylene oxide gas. Once the evidence was secured in this way, health and safety management principles had to be established, to ensure the on-going protection of the laboratory workers sieving through the wreckage for evidence (Athiniotis *et al.* 2010a). This process continued for several months while all the evidence was collected (Athiniotis *et al.*, 2010b).

As in the field, recovered wreckage and off site evidence collection can pose health and safety risks for investigators, but the hazards involved are outside the scope of this research. The particular hazards presented both on and off the site may be the same, but the available measures of posed risk, and the control mechanisms available, may be different. An initial hazards specific training course, in line with ICAO Circular 315 (2008a) guidance, would not instruct investigators and accident site responders in the control of hazards away from an accident site.

2.3.2.6.2 Analysis

As noted in Section 2.1.1 analysis is the evaluation of evidence, and may proceed on the basis of a formal theoretical model or by using an investigator’s own skills and judgements.

Recent work in Australia has sought to add precision in assigning to different factors their relative importance in an accident occurrence. The ATSB analysis standards and framework (Walker and Bills, 2008) has been introduced following criticism of the ATSB’s apparent lack of scientific research methodology, one example of which was criticism by a coronial inquiry into the 2000 Whyalla Airlines crash (Walker and Bills, 2008).

This framework seeks to define terms used to describe the probability of various factors having contributed to an accident, by giving each term a precise probability range (Figure 2.20).

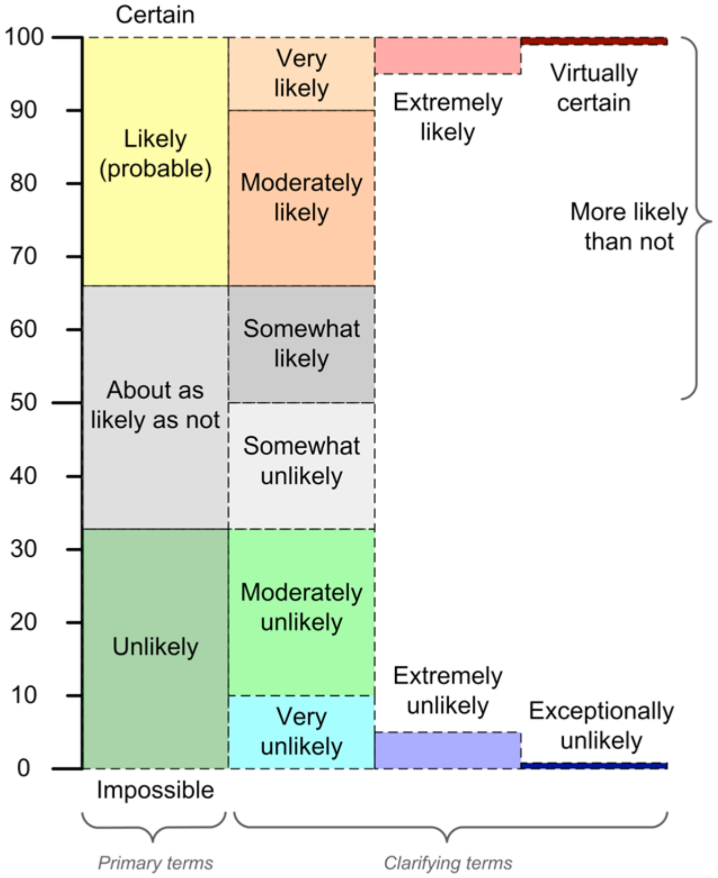


Figure 2.20: ATSB Analysis Framework probability definitions
Source: Walker and Bills, 2008.

These descriptors of probability can then be related to a scale denoting standard of evidence, from low to high (Figure 2.21).

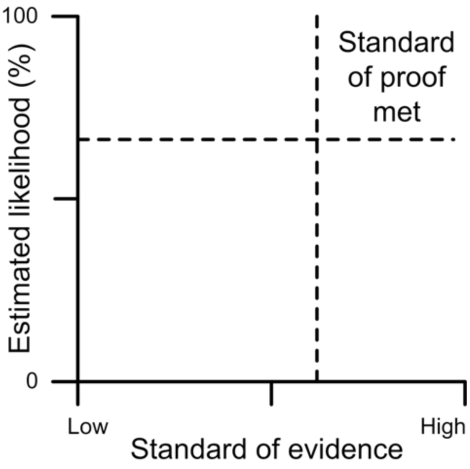


Figure 2.21: ATSB standard of proof requirements
Source: Walker and Bills, 2008.

Both probability and standard of proof are of course subjective assessments: their veracity is dependent only on the judgement of the investigator, drawing on a reservoir of knowledge and skill. The ATSB analysis and standards framework does however mean that no piece of evidence is taken to indicate a possible causal factor in an accident, unless experienced SMEs regard it as a ‘likely’ factor (> 66 per cent probability), and are confident that their evidence is robust (> 66 per cent confidence in the strength of the evidence).

As discussed in Section 2.3.2.4.2.4, the quality of evidence collected by aircraft accident investigators does not need to meet the same standards of proof as that of a police investigation. However, investigators need to understand how the evidence collected affects the level of analysis that can be conducted, and as a direct result the quality of the final report. If hazards encountered on a site affect the evidence collection process, then potentially the quality of analysis may be diminished.

2.3.2.6.3 Reporting and safety recommendations

Accident investigation organisations present the results of investigations in accordance with ICAO reporting requirements , which - amongst other things - require the accident investigation agency to identify “any condition, act or circumstance that was a causal factor in the accident” (ICAO, 2003b, p. IV-1-14).

A full accident report must follow a specific reporting framework, as specified in ICAO *Annex 13* (2001a) and the ICAO *Manual of Aircraft Accident and Incident Investigation Part IV* (2003b). This common framework allows reports on different accidents to be compared directly. As noted previously (Section 2.1.1) full reports are published for major accidents; abbreviated reports on accident report forms may be published for smaller accidents, particularly in general aviation.

Safety recommendations made as a result of the investigation may relate to the causes and contributory factors of the accident, or to any safety deficiencies identified “which did not contribute to the accident but which, nevertheless, are safety deficiencies” (ICAO, 2003b, p. IV-1-15). An example of the latter is the AAIB safety recommendation 2009-098 (AAIB, 2010b, p. 179):

> “It is recommended that the Federal Aviation Administration and the European Aviation Safety Agency, review the qualification testing requirements applied by manufacturers to cabin fittings, to allow for dynamic flexing of fuselage and cabin structure”.

This recommendation was made in response to damage to exit signs and business class seat-back video screens following the crash of the British Airways 777 at London Heathrow Airport in 2008. While these fittings did not cause the accident nor inhibit the evacuation, the damage to them indicates a safety deficiency. Accident investigators look not only for evidence of the cause of an accident, but also for other evidence that might prevent other safety problems from occurring on similar aircraft.

ICAO does not specifically require accident reports to describe the accident site, or to report on hazards or problems found on the site. However, the reports are generally written in such a way that experienced investigators reading them will quickly appreciate the hazards that might have affected the progress of the investigation. The accident reports are therefore one means by which accident investigators communicate information about site hazards to other investigators.

2.3.3 Recovery and site clean-up

As noted in Section 2.3.2.5, when accident investigators have finished with the site, control of is returned to the land owners on completion. Any aircraft wreckage that has not been taken for further analysis is returned to the aircraft owner or insurer, and might be salvaged or repaired for re-entry into service.

2.3.3.1 The purpose of clean-up

There might still be significant wreckage, damage or contamination at the time the land is due to be returned to the owner, and hence there is a need for restoration so far as is possible to the original condition. In Canada, three parties are responsible for the cost of recovering the wreckage and restoring the site: the aircraft owner or insurance company, who bear the major financial responsibility; the coroner, who is responsible for the cost of recovering any bodies from the site; and the TSB, which may be required to pay for any additional cost created by the particular nature of the investigation (although the owner and the insurer might also bear a portion of this cost) (TSB, 1991). The three parties are expected to work together to manage the recovery process. Similar regulations apply in other ICAO member states.

2.3.3.2 The process of clean-up

The participants in aircraft recovery depend on the intended destination of the wreckage. In the UK, the AAIB will usually call on the military for assistance. There are two military units which specialise in such work: the Joint Aircraft Recovery Team (fixed wing), based at St. Athan; and the Joint Aircraft Recovery Team (rotary wing), based at Gosport (MOD DCDC, 2007). Both are experienced in collecting wreckage without loss of evidence.

Private recovery organisations are also used for wreckage collection: sometimes AAIB staff direct the recovery process themselves, using farm equipment and local labour. The level of support needed for recovery will depend on the size of the aircraft, the amount of damage and any need to protect the aircraft from further damage.

If the aircraft is going for salvage, further damage is not a consideration, and the aircraft insurer will be responsible for calling in a salvage organisation. If the aircraft is to be repaired, it will be recovered, with care, by private recovery specialists or by the repair organisation itself. Guidance on the removal of damaged aircraft is set out in the ICAO *Airport Services Manual Part 5 - Removal of Disabled Aircraft* (1996).

The cost of the clean-up of the aircraft accident site is the responsibility of the aircraft owner, and is usually paid through the aircraft insurer. The work is generally carried out by commercial contractors.

Some clean-up operations are major undertakings. For example, it was necessary to remove the entire layer of contaminated surface soil following the clean-up of aircraft wreckage and building rubble left when a Boeing 747 freighter crashed into a building in Amsterdam in 1992 (Uijt de Haag *et al.,*2000). Further, it is often necessary for compensation to be paid to land owners for loss of crops, or damaged property.

Potentially significant hazards may arise during aircraft recovery and site clean-up, but these also fall outside the scope of this research.

2.4 Health and safety

2.4.1 Occupational health and safety

In their text on work-related health and safety, Hughes and Ferrett (2007) define occupational health as: “The protection of the bodies and minds of people from illnesses resulting from the materials, processes or procedures used in the workplace”. They define safety as “the protection of people from physical injury”. In relating the two, they note that “The borderline between health and safety is ill-defined and the two words are usually used together to indicate concern for the physical and mental well-being of the individual at the place of work”. In fundamental terms, health and safety is about protecting people.

The health and safety of UK workers is overseen by the Health and Safety Executive (HSE), which was created by the *Health and Safety at Work Act 1974.* It is a non-departmental public body, which functions as the independent watch-dog for work-related health, safety and illness. Most nations have a comparable organisation: for example WorkCover in Australia, and the Occupational Safety and Health Organisation (OSHA) in the USA.

All employers and employees in the UK are bound by the *Health and Safety at Work Act 1974*, which has been supplemented by *The Management of Health and Safety at Work Regulations 1999* and a number of additional regulations relating to specific types of workplace. The HSE monitors observance of the applicable regulations within workplaces, and enforces compliance through inspections. These might result in the issuing of improvement or prohibition notices, in withdrawing or modifying operational licences, and in extreme cases the prosecution of companies or individuals (HSE, 2009a).

The HSE commonly refers to the ‘safety culture’ within an organisation, which it defines as follows.

> “The safety culture of an organisation is the product of individual and group values, attitudes, perceptions, competencies and patterns of behaviour that determine the commitment to, and the style and proficiency of, an organisation’s health and safety management” (HSE, 1997)

The term ‘safety culture’ is widely used in the same sense within the aviation industry. The safety culture of an airline is an important consideration when investigating an aircraft accident.

The ICAO *Safety Management Manual* (first edition, 2006b) makes the point clearly. It notes that “although compliance with safety regulations is fundamental to safety, contemporary thinking is that much more is required. Organisations that simply comply with the minimum standards set by the regulations are not in a good position to identify emerging safety problems”. ICAO recognises that the safety culture of an organisation is influenced by:

- “management’s actions and priorities;
- policies and procedures;
- supervisory practices;
- safety planning and goals;
- actions in response to unsafe behaviours;
- employee training and motivation; and
- employee involvement or ‘buy-in’”

(ICAO, 2006b).

This research considers the health and safety of accident investigators on accident sites. A critical part of that consideration is the safety culture of investigative organisations. A strong safety culture within an organisation will be reflected in its capacity to maintain the health and secure the safety of its investigators, while satisfying the requirement for thorough investigation. An employer can, through the culture fostered by the organisation, play a strong role in the perceptions that investigators have towards the identification and management of hazards on an accident site.

2.4.2 Hazards

Hazards have been variously defined.

The HSE (1997) defines a hazard as anything with

"... the potential to cause:
- harm including ill health and injury;
- damage to property, plant, products or the environment;
- production losses or increased liability".

The FAA (2006a) defines a hazard as: "Any existing or potential condition that can lead to injury, illness, or death to people; damage to or loss of a system, equipment, or property; or damage to the environment. A hazard is a condition that is a prerequisite to an accident or incident".

ICAO defines a hazard as "Something that has the potential to cause adverse consequences in terms of harm and/or damage" (ICAO, 2008a p.1).

These and other definitions are in agreement that a hazard is something that creates the likelihood of danger or harm to an individual. This research concerns the hazards on aircraft accident sites. The research topic revolves around the basic question: What is a danger to aircraft accident investigators working on accident sites?

If the nature of a hazard is not understood, then the dangers posed to personnel on aircraft accident sites (and other workplaces) can not be properly controlled. Lee (2009) notes that "clear notions of hazards, consequences, and risks, as well as their logical relationships, are necessary for hazards to be correctly identified and effective controls which are 'in sync' with the consequence to be effected. This is evidently lacking in many instances".

2.4.3 Risk

2.4.3.1 Definition

The HSE definition of risk is the following: "A risk is the likelihood that a hazard will actually cause its adverse effects, together with a measure of the effect" (HSE, 2010b). Similarly, ICAO, along with many other bodies, sees risk as the product of consequence and likelihood, and applies this definition in the *Safety Management Manual* (2006a, 2009b). This definition of risk is usually expressed as Risk = Consequence x Likelihood.

There is an extensive body of publications on risk and its definitions (for example Duffey and Saull, 2008; Fischhoff, Watson and Hope, 1984; Hillson and Murray-

Webster, 2005). In reviewing this literature, Aven (2010) identified three common definitions of risk:

1. “Risk is a measure of the probability and severity of adverse effects.
2. Risk is the combination of the probability of an event and its consequences.
3. Risk is equal to the triplet (s_i, p_i, c_i) where s_i is the ith scenario, p_i is the probability of that scenario, and c_i is the consequence of the ith scenario, i=1,2,..., N”

Aven (2010) expressed the common thread between the three definitions in terms of the equation :

$$Risk = (A, C, P)$$

where: “A represents the events (initiating events, scenarios); C the consequences of A; and P the associated probabilities”.

Lee (2009) states that “clear notions of hazards, consequences, and risks, as well as their logical relationships, are necessary for hazards to be correctly identified and effective controls which are ‘in sync’ with the consequence to be effected. This is evidently lacking in many instances”. If the nature of the hazard is not understood, through knowing where it exists, and how it manifests itself, then the dangers posed to personnel on aircraft accident site (or any other workplace) can not be properly controlled.

2.4.3.2 The expression of risk

Risk may be expressed either quantitatively or qualitatively. The quantitative expression of risk is more common. Risk can be presented quantitatively in terms of indices such as the probability of injury to an individual, the recorded number of deaths per unit measure of activity, recorded data on loss of life expectancy, and data on frequency against consequence (Crossland *et al.*, 1992). For example, in Section 2.2.2.3 the risk of a GA air accident in the USA in 2009 (Figure 2.13) was expressed in terms of the number of accidents (7.20) per 100,000 flight hours for different types of aircraft.

Various researchers have expressed in quantitative terms the risks of carrying dangerous goods by rail or road (for example, Purdy, 1993; Bubbico *et al.*, 2004; Oggero *et al.* 2006). These studies have shown that the scale of the hazard caused by an accident is mainly related to the nature of the area of impact, rather than the scale of the accident, which is generally limited by the size of the container holding the dangerous goods (Bubbico *et al.* 2004).

The HSE cautions that there are a number of caveats and issues of which to be aware when reporting OHS risks in quantitative terms, or measuring health and safety performance following risk mitigation:

- "Under-reporting - an emphasis on injury and ill-health rates as a measure, particularly when related to reward systems, can lead to such events not being reported so as to 'maintain' performance.
- Whether a particular event results in an injury is often a matter of chance, so it will not necessarily reflect whether or not a hazard is under control. An organisation can have a low injury rate because of luck or fewer people exposed, rather than good health and safety management.
- Injury rates often do not reflect the potential severity of an event, merely the consequence. For example, the same failing to adequately guard a machine could result in a cut finger or an amputation.
- People can stay off work for reasons which do not reflect the severity of the event.
- There is evidence to show that there is not necessarily a relationship between 'occupational' injury statistics (eg slips, trips and falls) and control of major accident hazards (eg. loss of containment of flammable or toxic material).
- A low injury rate can lead to complacency.
- A low injury rate results in few data points being available.
- There must have been a failure, ie. injury or ill health, in order to get a data point.
- Injury statistics reflect outcomes not causes".

(HSE, 2001)

There are some risks however that cannot be presented numerically as data, ratios and probabilities, and any attempt to do so can be meaningless. These include risks arising in unique situations which cannot be understood by drawing on prior probability data, because no such data exist. In such cases, "there is no alternative to making subjective assessments of the level of risk" (ICAO, 2008a). When a risk can not be objectively quantified, then the risk must be presented subjectively, "based purely on personal judgement, and normally defined as high, medium or low" (Hughes and Ferrett, 2007).

2.4.4 Risk Management

2.4.4.1 Overview

ICAO *Circular 315* (2008a) recognises that the management of safety on an accident site is similar to safety management in other areas of aviation operations. As with all safety management systems, hazard identification and the management of safety risks are the core processes involved in the management of safety on air accident sites.

The health and safety laws governing the safety of accident investigators on accident sites differ between different countries. Accident investigation agencies must comply with national health and safety legislation. While the laws in each country are different, they commonly require employers to conduct a risk assessment before employees begin work.

Figure 2.22 demonstrates the risk assessment process, as set out in *Circular 315* (ICAO, 2008a).

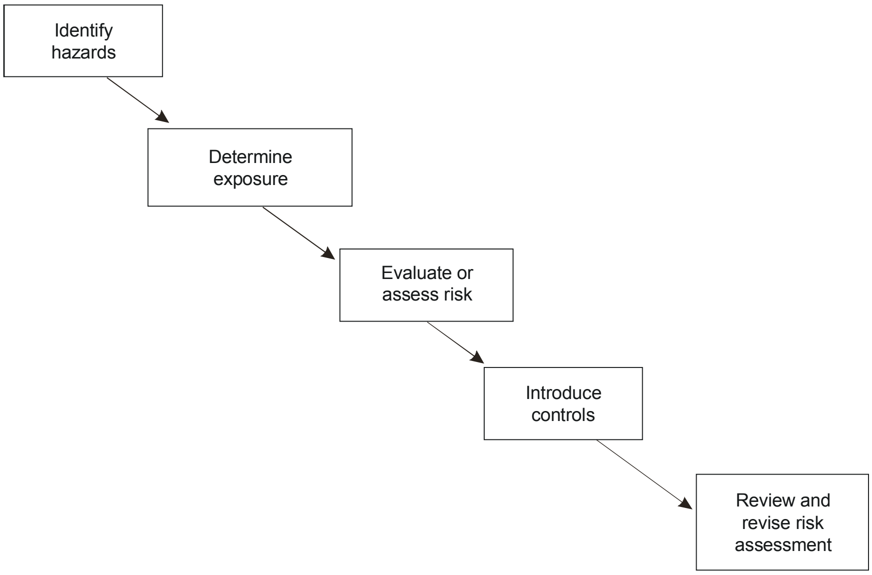


Figure 2.22: Risk assessment process
Source: ICAO, 2008a

This process is not specific to aircraft accident sites: it is the same process in many other industries. What is important to consider in the light of the *Circular* is how this process specifically applies to the aircraft accident site as a workplace. As in other industries, the ultimate purpose of a risk assessment is to reduce the risk to an acceptable level.

Circular 315 (ICAO, 2008a, paragraph 2.3.1) states that "Often, a balance must be struck between the requirements of the task and the need to make the performance of the task safe for investigation and response personnel. This balance may sometimes be difficult to achieve but should always be biased towards safety". To strike and maintain this balance, accident investigators must maintain a level of situational awareness as the accident site changes around them. There are three stages to this: perception of the elements that change; comprehension of the current situation, and projection of the future status (Endsley, 1995). Figure 2.23 shows the decision making process accident investigators need to go through to establish and maintain their situational awareness on the site.

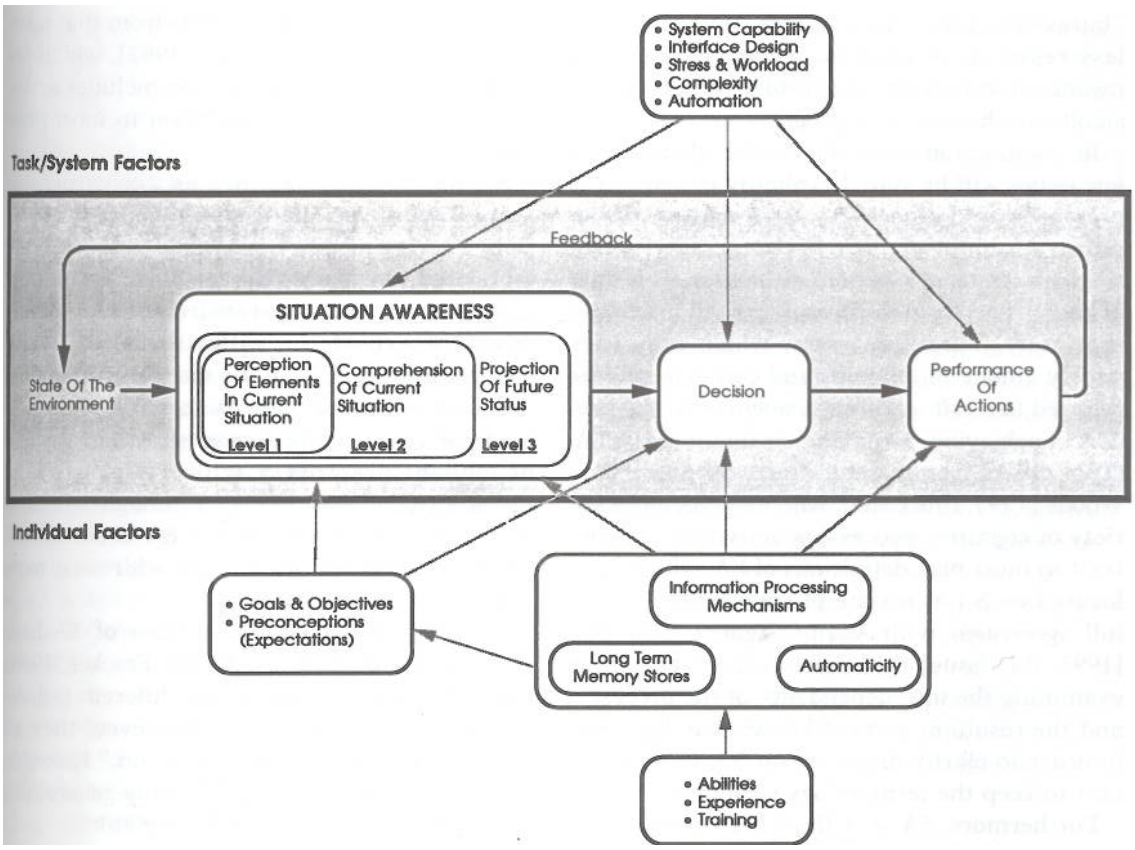


Figure 2.23: Model of situation awareness in dynamic decision making
Source: Endsley, 1995

This model in Figure 2.23 was originally developed to demonstrate the factors affecting situational awareness in occupations such as flying and air traffic control, but can be similarly applied to the work of accident investigators.

As the figure shows, situational awareness is affected by goals and objectives (such as the goal of collecting evidence before it perishes), and by preconceptions and expectations. Knowledge and understanding of potential site hazards is vital to the formation of informed preconceptions and realistic expectations. If accident investigators do not have a sound knowledge of hazards, backed up by solid experience in managing them, then their initial analysis of the situation on arrival at the site could be faulty, and they would be unable accurately to predict further changes.

The key difference between risk assessment for accident investigators, and risk assessment in other industries, is that accident investigators have no way of conducting a complete risk assessment prior to beginning work on an accident site. *Circular 315* notes that "Unlike personnel involved in the more predictable domains within the aviation industry, investigators are required to respond to accident situations that are variable in nature, scale and environment" (ICAO, 2008a, paragraph 2.2.1).

As the situation changes on an accident site, and the investigators' awareness of the situation changes and develops in response (Figure 2.23), so investigators will apply the five stages of the risk assessment process (Figure 2.22) repeatedly and cyclically while on site.

2.4.4.2 Identification of hazards

"Risk assessment is a common sense approach to identifying the hazards and risks associated with a work task or activity" (Perry, 2003 p.2). Under the UK *Management of Health and Safety at Work Regulations 1999* (Regulation 3):

> "Every employer shall make a suitable and sufficient assessment of -
> a. the risks to health and safety of his employees to which they are exposed whilst they are at work; and
> b. the risks to the health and safety of persons not in his employment arising out of or in connection with the conduct by him of his undertaking,
> for the purpose of identifying the measures he needs to take to comply with the requirements and prohibitions imposed upon him or under the relevant statutory provisions".

Perry (2003) describes this regulation as meaning that a risk assessment is 'suitable' for the level and complexity of the job; and 'sufficient' in that it identifies as many of the known hazards and risks as possible based on the knowledge at the time of undertaking the risk assessment.

The initial accident notification will provide the accident investigator with some information on the aircraft type, and ideally about the extent of the damage, the number of passengers and crew, basic information about the accident site, and any dangerous goods carried on board (ICAO, 2001a). From whatever information is provided, a generic risk assessment can be conducted, which will guide investigators on what investigative equipment, personal clothing, and PPE to take.

A generic risk assessment is the only point at which any quantitative assessment of hazards might be possible. In relation to the aircraft, it is likely some basic hazard parameters can be expressed in quantitative terms, such as the volume of fuel on board, oil and hydraulic fluid quantities, tyre pressures, and the weight of the cargo - although access to this information might be slow or difficult. Apart from this, further assessments of the level of risk will be almost entirely subjective.

On large accident sites, a safety officer may be appointed (NTSB, 2002a). It is the duty of either the safety officer or the IIC to conduct the initial risk assessment, which can only be done by inspection on the ground. Potential hazards are identified; the potential exposure of investigators is determined; the level of risk is assessed; control measure sare introduced to mitigate the risk; and the risk assessment is reviewed in the light of the controls (Figure 2.22).

The key requirement for the success of the risk assessment process is that the person conducting the risk assessment has sufficient knowledge and skills in identifying hazards. Investigators build their skills in hazards identification and management through training and experience. It is imperative that investigator training should contain the most up-to-date information about the occurrence and dangers of potential hazards, and about their management and mitigation.

2.4.4.3 Determine exposure

Circular 315 contains very little information about the consequences that hazards may have on aircraft accident investigators. The only guidance it provides is that "identifying the groups of personnel who are likely to be exposed to hazards, the frequency of them being so, and the manner in which they will be exposed and, potentially, harmed is essential to properly determine exposure" (ICAO, 2008a, paragraph 2.3.5). As stated previously (Section 2.4.3.1), risk arises from both the likelihood and the consequence of exposure: where there is no likelihood of a particular substance or condition being present, or no harmful consequence from exposure to it, the substance or condition will pose no risk to an investigator.

Hazards on accident sites may be hazards particular to the worksite, or general hazards that might affect all workers in any workplaces. As with accident sites in general, there are two types of hazards on aircraft accident sites:

1. Particular hazards that arise because of the difficulties of the site, and the nature of the aircraft involved. Their mitigation requires the direct and site-specific management of safety.

2. Health and safety hazards that are not specific to the sites of aircraft accidents, but which can affect workers in other workplaces, such as in muscoskeletal disorders and the risks of working at height. These hazards should be managed under occupational health and safety provisions.

It is immaterial that some hazards fall into more than one of the five categories of hazards (environmental, physical, biological, material and psychological) set out in ICAO *Circular 315* (2008a). The important thing is that the presence of the hazard is identified by investigators at some point during the risk assessment process.

The HSE (2010c) identifies four exposure routes through which hazards may affect accident investigators: through inhalation, through ingestion, through absorption, and through injection (HSE, 2010c). The inhalation of dust, gas or mist can be directly injurious. Lippmann (2000) notes that the systemic uptake of chemicals from inhaled air depends on the physical and chemical properties of the inhaled material, and on the individual's anatomy and pattern of respiration. Thus the risk posed by inhalation depends upon the nature of the inhaled material and the health of the individual investigator. Hazards can be ingested through the mouth, and enter the stomach;

chemical hazards can permeate through the skin and enter the bloodstream. Contamination through injection can occur when a sharp item punctures the skin, causing the hazard to enter the body directly. The same hazards may also affect an investigator by entry through open cuts and wounds.

Different types of hazard attack the body in different ways, as shown in Table 2.6.

Table 2.6: Methods of attack of hazards on humans

Type of Hazard	Target Organ	Reaction / Symptom
Toxic	Kidney, liver, bone marrow	Attacks and affects the functioning of the organ
Carcinogenic	Lungs, liver, bladder	Warts, ulcers, malignant growths
Corrosive	Skin, lungs, stomach	Destroys living tissue
Dermatitic	Skin	Inflammation of the skin (dermatitis)
Irritant	Skin, eyes, lungs	Inflammation, dermatitis, fibrosis of lungs
Flammable	Skin, whole body	Burns
Radioactive	Skin, sensitive organs such as bone marrow, eyes, etc.	Leukaemia, cataracts, loss of fertility

Source: Ridley (2004)

Investigators need to understand the routes of entry and the effects of exposure to different hazards, in order that they can make better risk assessment decisions and protect themselves on accident sites.

In workplaces where quantitative assessments of risk are possible, material safety data sheets (MSDSs) and mandated workplace exposure limits (WELs) can be used to determine and regulate the level of exposure of workers, both over an eight hour working period (long term exposure) and a fifteen minute period (short term exposure). For example, each chemical has a specified short-term and long-term WEL (HSE, 2007). On an aircraft accident site, it is not possible to know exactly how much of a chemical or other hazardous substance is present: accident investigators have no choice but to evaluate the risks of exposure qualitatively rather than quantitatively.

Stolzer *et al.* (2008) describe the qualitative approach to hazards identification as “hazard identification through the analysis of data derived from operational observations”; and the quantitative approach as “hazard identification through process analysis”. There is not much capacity for the latter at aircraft accident sites.

2.4.4.4 Evaluate risk

A risk can be assessed accurately only when it is properly identified and its potential effects are understood. Some organisations attempt to assign values to the likelihood and the consequence of a hazard, so that the risk severity, and therefore acceptability, can be categorised against pre-determined levels. For example, Figures 2.24, 2.25, and 2.26 are risk acceptability evaluation charts from the ICAO *Safety Management Manual* (2009b):

	Meaning	**Value**
Frequent	Likely to occur many times (has occurred frequently)	5
Occasional	Likely to occur sometimes (has occurred infrequently)	4
Remote	Unlikely to occur, but possible (has occurred rarely)	3
Improbable	Very unlikely to occur (not known to have occurred)	2
Extremely improbable	Almost inconceivable that the event will occur	1

Figure 2.24: Probability or likelihood of risk occurrence
Source: ICAO, 2009b

Severity of Consequence	**Meaning**	**Value**
Catastrophic	• Equipment destroyed • Multiple deaths	A
Hazardous	• A large reduction in the safety margins, physical distress or a workload such that the operators cannot be relied upon to perform their tasks accurately or completely • Serious injury • Major equipment damage	B
Major	• A significant reduction in safety margins, a reduction in the ability of the operators to cope with adverse operating conditions as a result of increase in workload, or as a result of conditions impairing their efficiency. • Serious incident • Injury to persons	C
Minor	• Nuisance • Operating limitations • Use of emergency procedures • Minor incident	D
Negligible	• Little consequence	E

Figure 2.25: Severity or consequence of risk
Source: ICAO, 2009b

		Risk Severity				
Risk Probability		**Catastrophic A**	**Hazardous B**	**Major C**	**Minor D**	**Negligible E**
Frequent	5	5A	5B	5C	5D	5E
Occasional	4	4A	4B	4C	4D	4E
Remote	3	3A	3B	3C	3D	3E
Improbable	2	2A	2B	2C	2D	2E
Extremely Improbable	1	1A	1B	1C	1D	1E

Key:

Green	Acceptable risk
Orange	Acceptable based in risk mitigation
Red	Unacceptable under the existing circumstances

Figure 2.26: Risk assessment matrix
Source: ICAO, 2009b

Approaches such as those in Figures 2.24, 2.25 and 2.26 essentially seek to add a degree of precision to a set of descriptors, and are useful to that extent. They remain a qualitative rather than quantitative framework. They have been developed for application in an aviation-specific safety management system, and can also be readily applied in aircraft accident investigation. It is unlikely that there would be much benefit in recording risk in the manner shown in Figure 2.26 on an accident site where the situation is very dynamic, but such taxonomies provide a vocabulary of descriptors of degrees of likelihood and consequence which investigators might find useful.

Glossop, Ioannides and Gould (2000) state “hazard analysis involves the identification of hazards at a facility and evaluating possible scenarios leading to unwanted consequences. “The hazard analysis stage is a very important part of the risk management process, as no action can be made to avoid, or reduce, the effects of unidentified hazards. The hazard analysis stage also has the largest potential for error with little or no feedback of those errors”.

It is of interest that on off-shore rigs and other relatively inaccessible facilities in the petroleum engineering industry, trials are in place to make health and safety assessments by remote means. Both video-conferencing and still photography are in use, and the trials are being overseen by a panel of HSE inspectors (Simon *et al.* 2009). The panel provides expert guidance to enable workers within the facilities to assess the hazards they might encounter.. There might well be potential for this approach to be used on accident sites where there are likely to be hazards of particular concern, and expert health and safety assessment is required.

2.4.4.5 Introduce controls

In the European Union there is now an agreed set of control measures to manage risk to the health and safety of employees. They are mandated by regulation through *EU Council Directive 89/391 EEC 1989* and *The Management of Health and Safety at Work Regulations 1999.* The measures are expressed as a hierarchy of controls to be used when managing identified risks.

> "The employer shall implement the measures referred to ... on the basis of the following general principles of prevention:
> a. avoiding risks;
> b. evaluating the risks which cannot be avoided;
> c. combating the risks at source;
> d. adapting the work to the individual, especially as regards the design of work places, the choice of work equipment and the choice of working at production methods, with a view, in particular, to alleviating monotonous work and work at a predetermined work-rate and to reducing their effect on health;
> e. adapting to technical progress;
> f. replacing the dangerous by the non-dangerous or the less dangerous;
> g. developing a coherent overall prevention policy which covers technology, organisation of work, working conditions, social relationships and the influence of factors related to the working environment;
> h. giving collective protective measures priority over individual protective measures;
> i. giving appropriate instructions to the workers".

This sequence of controls is neatly summarised by Ireland (2000) as "eliminate, substitute, contain, control, protect".

Many of the same principles and sequence underpin the work by Ribak and Froom (1995) on occupational medicine. This sets out three categories of occupational health prevention: primary, secondary and tertiary prevention. Primary prevention methods involve avoiding exposure, and the selection of employees who are not susceptible to particular exposure. Secondary prevention methods prevent exposure from reaching above a certain level, for instance through biological monitoring. Tertiary prevention involves providing care to those who display early symptoms of exposure or injury.

In the UK, accident investigation authorities (as employers) and air accident investigators (as employees) are subject to the EU regulations. Some of the control measures suggested in regulatory guidance are simply not possible on an aircraft accident site, such as complete avoidance of the hazard, or redesigning workplaces. For that reason, ICAO (2008a) has established for all member states a specialised hierarchy of controls for investigators on aircraft accident sites. This is set out in paragraph 2.3.9 of *Circular 315*:

> "A wide range of control measures can be applied to help reduce risks, including:
>
> a. stopping or delaying the task - where the risk is show to be excessive, this may be the only option until alternative methods of work are established;
> b. removal/isolation of the hazards - components can be disconnected, made safe or removed from the site, hazardous materials can be neutralised or covered, dust and fibres can be suppressed with water or fluids, etc.;
> c. limiting exposure - reduce the numbers of personnel within hazardous areas or limit the length of time or frequency of exposure;
> d. modifying tasks or using alternative equipment or materials - this course of action can produce significant reductions in risk;
> e. employing specific work procedures (eg. exposure control plans); and
> f. using protective clothing/equipment."

2.4.4.6 Review and revise risk assessment

Having reviewed and revised their risk assessment following the introduction of controls, investigators will identify any remaining or new hazards; determine the level of exposure to them; assess the remaining or residual risk; implement further controls; and again review and revise the assessment. They will continue to monitor and manage through this process of dynamic risk assessment. As with the initial, and probably off site generic risk assessment, these dynamic risk assessments will be essentially subjective, due to the impossibility of quantitatively measuring the hazards prior to commencing work.

2.4.4.7 Risk 'as low as reasonably practicable'

There are limits to how low any the risk can be reduced, and rarely on an accident site can it be eliminated.

The most common approach is to reduce risk to *As Low As Reasonably Practicable* (ALARP), which is the expression generally used in industry. The same meaning is intended by the alternative expression *So Far As Is Reasonably Practicable*, or SFAIRP, which is used in HSE health and safety regulations (HSE, 2010b).

Figure 2.27 shows three levels of risk, one of which is ALARP (or SFAIRP). This is the region within which risk can be reduced to a tolerable level by applying an acceptable level of effort and cost by way of mitigation. The risk which remains after mitigation is known as the residual risk, being risk which has been reduced but not eliminated. In the region of intolerable risk, the risk must be avoided regardless of cost and effort. In the region of acceptable risk, the risk is so low that any further mitigation would be an unnecessary waste of resource.

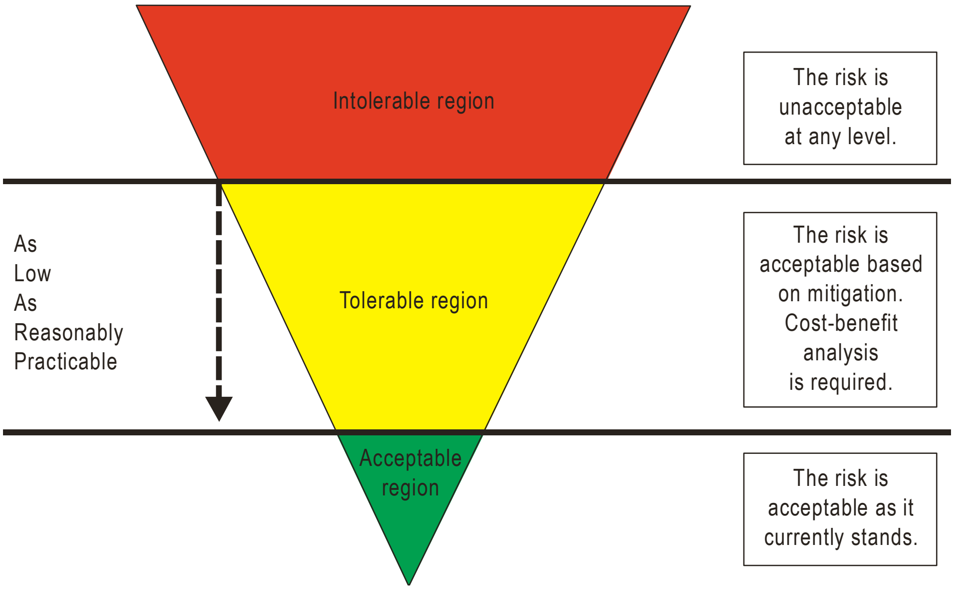


Figure 2.27: Risk management ALARP levels
Source: ICAO, 2009b

Where possible, the upper and lower boundaries of the ALARP zone should be based on a cost-benefit analysis as well as professional judgement (HSE, 2010b). However, many issues of occupational health and safety in air accident investigation are not resolvable simply by cost-benefit analysis, where the cost is expressed simply in monetary terms. The balance to be struck is between taking ‘suitable and sufficient’ measures to reduce risk to the health and safety of an investigator to a tolerable level, in the hope that the investigator will be able to gather evidence to prevent future air accidents; or to reduce the risk to the investigator to a negligible level, at the cost of losing evidence which might have prevented future loss of life.

2.4.5 The communication of risk

The risk management process would be ineffective if the identified hazards, selected control measures and residual risks were not communicated to all those whose work may be affected by them. The manner in which the information is communicated must take account of cultural and language differences, and the backgrounds of those participating in the work (Lee, 2009). Zainal, Farid and Yusoff (2009) suggest that the methods by which information about hazards is communicated may give rise to pre-conceived notions and perceptions of the levels of hazard and risk, which could be counter-productive.

Annex 13 (ICAO, 2001a, paragraph 8.9) urges Member States to “promote the establishment of safety information sharing networks among all users of the aviation system and facilitate the free exchange of information on actual and potential safety deficiencies”. However, beyond incidental and *ad hoc* mention in accident reports, there is currently no formalised and systematic fail-safe method for sharing information between aircraft accident investigators about the hazards they have actually encountered on accident sites.

2.5 Health and safety management on aircraft accident sites

2.5.1 Overview

There is no substantial body of literature and research on the management of health and safety on aircraft accident sites. A preliminary understanding of some of the issues likely to be involved can however be constructed from two sources: knowledge about the management of health and safety issues in the normal operation of the aviation industry as a whole, and knowledge about the management of health and safety issues on disaster sites.

2.5.2 Health and safety management of aircraft operations

Many of the health and safety issues relating to aircraft operations and maintenance are well understood. For many people, an aircraft is their usual working environment, and thorough and complete risk assessments of the hazards they may encounter can be and have been conducted.

Within the UK, the HSE and the CAA have signed an MOU (CAA, 2009) that underlines the responsibilities of each organisation in ensuring the health and safety of airport and airline workers. Under the MOU, the HSE is responsible for the occupational health and safety of all workers on or around an aircraft while it is on the ground; the CAA is responsible for crew from the moment they board the aircraft with the intention of flight, until when they disembark the aircraft (CAA, 2009). The latter is the same period in which national aircraft accident agencies would be responsible for conducting an investigation were an accident to occur (ICAO, 2001a).

The CAA publication *Occupational Health and Safety On-Board Aircraft - Guidance on Good Practice* (CAA, 2007) provides guidance on occupational health and safety on board large commercial aircraft during normal flight operations. Some of the information - in particular that relating to slips, trips and falls, burns, and control of biohazards - is relevant in accident investigation.

Pardo (1995) reviewed the hazards that airline and airport ground staff and maintenance workers may be exposed to during normal working conditions. Table 2.7 sets out some of these occupations, and the hazards identified.

Similarly, Ribak, Malenky and Shain (1995) reviewed the hazards found in military aviation-related workplaces. The hazards they identified are: radiation hazards (lasers and ionising radiation from depleted uranium, and from lights and markings); biomechanical hazards (ejection seats, lifting and carrying, extreme weather and altitude exposure, chemical warfare); and hazards from chemical exposure (hydrazine, liquid oxygen, fuels, chemicals in personal equipment, photographic chemicals, chemicals in the canopy and radome, military aviation fire fighting, batteries, and ammunitions maintenance chemicals). They also drew attention to the hazards posed by pesticides in aerial pesticide application flying. These hazards are also potential hazards in aircraft accident investigation.

Table 2.7: Hazards in the aviation workplace

	Chemical						Physical						
Occupation	**Solvents**	**Oils**	**Inorganic**	**Metals**	**Gases**	**Organic/Polymers**	**Noise**	**Vibration**	**Radiation**	**Heat/cold**	**Biological**	**Ergonomical**	**Psychosocial**
Aircraft body/skin repairer fitter, metal bonders	✓	✓			✓	✓	✓	✓	✓	✓		✓	
Aircraft cleaning, worker / supervisor / inspector	✓				✓	✓	✓				✓	✓	✓
Airframe / power plane mechanic, inspector, assembler	✓	✓		✓	✓	✓	✓	✓	✓			✓	✓
Airplane painter / coverer / painter of transportation equipment	✓			✓	✓	✓	✓					✓	
Electronics repairer, equipment tester / inspector / supervisor, electronics system mechanic / technicians / electrician (electronics shop), field service	✓					✓	✓			✓		✓	✓
Engine tester	✓	✓				✓	✓			✓		✓	✓
Oil filter inspector	✓	✓		✓		✓							
Upholsterer	✓			✓		✓	✓					✓	

Source: Adapted from Pardo, 1995

2.5.3 Health and safety management for emergency responders

In the UK, aircraft accident investigators operate within the framework of health and safety regulations enforced by the HSE. These include *The Health and Safety at Work Act 1974*; *The Management of Health and Safety at Work Regulations 1999*; *Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1995* (RIDDOR); *Control of Major Accident Hazard Regulations 1999* (COMAH); *Control of Substances Hazardous to Health Regulations 1999* (COSHH); *The Personal Protective Equipment at Work Regulations 1992*; and sundry other regulations relating to specific hazards that the investigators might encounter.

As noted in Section 1.2, the HSE has not yet had cause to investigate the working practices of AAIB investigators on accident sites (HSE, 2010a), but this does not mean they might not have reason to do so in the future. The AAIB has to monitor the health and safety of employees on accident sites, in investigation hangars, and in AAIB offices.

The health and safety of emergency responders to natural disasters has been fairly thoroughly explored. The research literature considers the nature of injuries to responders, the management of the response, and the potential improvement of crisis-response practices. Among recent major disasters which have been the subject of such research are the Indian Ocean tsunami (for example Tolentino, 2007), Hurricane Katrina in 2005 (for example Ringel *et al.*, 2007; Sullivent *et a.l*, 2006), and the 2010 Haiti earthquake (for example Piotrowski, 2010).

There were 997 injuries recorded among relief workers responding to Hurricane Katrina. Table 2.8 sets out the types of injuries sustained by these workers; Table 2.9 identifies the activities being undertaken when injury occurred (where recorded).

Table 2.8: Mechanism of non-fatal injuries to relief workers following Hurricane Katrina, 2005

Mechanism of Injury	**Number of Injuries (*n*)**	**Percentage injuries of total (%)**
Cut / pierce / stab	189	19.0
Fall	104	10.4
Struck by / against /crush	125	12.5
Bite / sting	129	12.9
Motor vehicle crash	35	3.5
Carbon monoxide poisoning	6	0.6
Other poisoning / toxic effect	20	2.0
Other	238	23.9
Unknown	151	15.1

Source: Sullivent et al. 2006.

Table 2.9: Activity being conducted by relief workers following Hurricane Katrina when injured

Activity when injured	**Number of Injuries (*n*)**	**Percentage injuries of total (%)**
Cleaning up	185	18.6
Repairing buildings etc.	107	10.7
Operating power tools	26	2.6
Attempting rescue / recovery	67	6.7
Evacuating	1	0.1
Swimming / wading	4	0.4
Operating power generator	4	0.4

Source: Sullivent et al., 2006.

With the exception of ‘repairing buildings’, all the activities set out in Table 2.9 conceivably could be activities undertaken by aircraft accident investigators. Similarly, the types of specified injuries set out in Table 2.8 are known to have occurred in aircraft accident investigation.

There has also been considerable research conducted on the hazards faced by responders to terrorism events, the most documented of which is the 11th September 2001 attacks in the USA, and in particular on the World Trade Centre (WTC) in New York.

Following the collapse of the twin towers of the WTC, a recovery effort took place to clear the site. This began immediately after the emergency life-saving response, and finished on 30th May 2002. OSHA identified over 9,000 hazards on the site, on the basis of more than 24,000 evaluations, including over 6,500 air and material samples. In terms of PPE, over 131,000 dust respirators, 11,000 hard hats, 13,000 pairs of safety glasses and goggles, and 21,000 pairs of gloves were used (OSHA, 2003).

Despite the use of PPE, a large number of injuries occurred. In the one month period following the attacks, 5,222 responders were treated for injury or illness. These responders included firefighters, police, emergency medical services, urban search and rescue (US&R) and construction workers (Berrios-Torres *et al.* 2003). Figure 2.28 shows the number of visits by rescue workers per day to hospital emergency departments or to special Disaster Medical Assistance Team (DMAT) facilities set up near the site. It is noteworthy that more injuries and illnesses were recorded in the weeks following 11th September than in the immediate rescue period.

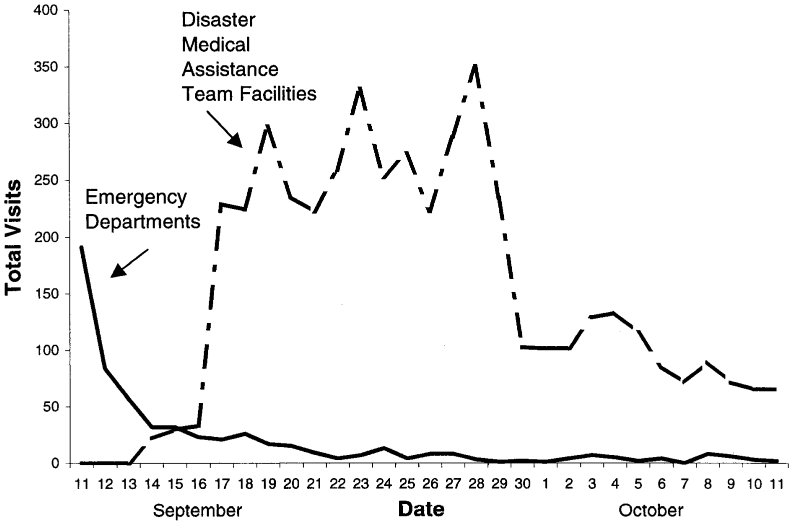


Figure 2.28: WTC rescue worker visits to medical facilities, 11th September - 11th October, 2001
Source: Berrios-Torres et al., 2003.

Table 2.10 gives data on illness and injury among rescue workers at the WTC in the month after the disaster. It shows the types and numbers of injuries and illnesses, and the rate of injury per hundred workers for construction workers and responders from the FDNY, NYPD and US&R (n=3,666). The final column shows the percentage of injuries and illnesses for all workers from all rescue organisations (n=5,222).

Table 2.10: Rescue worker injury and illness categories and rates for workers at the WTC, 11th September - 11th October, 2001

	Construction		**FDNY**		**NYPD**		**US&R**		**All rescue workers**		**Total**
Category	***n***	**Rate**	***n***	**Rate**	***n***	**Rate**	***n***	**Rate**	**N / *n***	**Rate**	**%**
All injury and illness visits	1624	793.7	880	493.7	1117	300.3	45	24.4	3666	390.3	
Musculoskeletal											
Sprain/strain	127	62.1	53	29.7	83	22.3	5	2.7	268	28.5	5.7
Laceration	144	70.4	53	29.7	71	19.1	2	1.1	270	28.7	5.5
Abrasion	34	16.6	21	11.8	33	8.9	-	-	88	9.4	1.9
Contusion	26	12.7	30	11.2	20	5.4	-	-	66	7.0	1.4
Fracture	9	4.4	9	5.0	9	2.4	-	-	27	2.9	0.6
Crush	9	4.4	1	0.6	5	1.3	-	-	15	1.6	0.3
Other musculoskeletal[a]	94	45.9	42	23.6	47	12.6	3	1.6	186	19.8	4.0
Total musculoskeletal	443	217.0	199	111.6	268	72.0	10	5.4	920	97.9	19.3
Respiratory											
Acute respiratory infection[b]	120	58.7	64	35.9	76	20.4	8	4.3	268	28.5	5.5
Cough	105	51.3	60	33.7	62	16.7	2	1.1	229	24.4	4.7
Smoke/dust inhalation	9	4.4	54	30.3	59	15.9	-	-	122	13.0	2.6
Shortness of breath / wheezing	36	17.6	26	14.6	43	11.6	1	0.5	106	11.3	2.3
Other respiratory[c]	6	2.9	2	1.1	9	2.4	1	0.5	18	1.9	0.5
Total respiratory	276	135.0	206	115.6	249	66.9	12	6.5	743	79.1	15.6
Eye											
Eye disorders (irritation / injury)	188	91.9	135	75.7	234	62.9	4	2.2	561	59.7	11.9
Corneal abrasions	15	7.3	13	7.3	14	3.8	1	0.5	43	4.6	0.8
Total eye	203	99.2	148	83.0	248	66.7	5	2.7	604	64.3	12.8
Skin											
Blister	159	77.7	28	15.7	30	8.1	4	2.2	221	23.5	5.0
Irritation / rash	77	37.6	32	18.0	35	9.4	3	1.6	147	15.6	3.3
Burn	72	35.2	17	9.5	20	5.4	-	-	109	11.6	2.3
Other skin[d]	22	10.8	13	7.3	12	3.2	1	0.5	48	5.1	0.9
Total skin	330	161.0	90	50.5	97	26.1	8	4.3	525	55.9	11.5

Table 2.10: Rescue worker injury and illness categories and rates for workers at the WTC, 11th September - 11th October, 2001

	Construction		FDNY		NYPD		US&R		All rescue workers		Total
Category	***n***	**Rate**	***n***	**Rate**	***n***	**Rate**	***n***	**Rate**	**N / *n***	**Rate**	**%**
Neurological											
Headache	183	89.4	129	72.4	123	33.1	5	2.7	440	46.8	9.3
Concussion	4	1.9	4	2.2	1	0.3	-	-	9	1.0	0.2
Other neurological[e]	1	0.4	4	2.8	5	1.3	-	-	11	1.2	0.2
Total neurological	188	91.9	138	77.4	129	34.7	5	2.7	460	49.0	9.7
Gastrointestinal / genitourinary											
Nausea / vomiting / diarrhoea	41	20	14	7.9	31	8.3	2	1.1	88	9.4	1.8
Other gastrointestinal / genitourinary[f]	36	17.6	34	19.1	22	5.9	-	-	92	9.8	1.9
Total gastrointestinal / genitourinary	77	37.6	48	26.9	53	14.2	2	1.1	180	19.2	3.7
Psychological stress	29	14.2	14	7.9	30	8.1	2	1.1	75	8.0	1.6
Cardiovascular											
Chest pain	11	5.3	15	8.4	14	3.8	-	-	40	4.3	0.9
Other cardiovascular[g]	11	5.3	2	1.1	6	1.6	-	-	19	2.0	0.4
Total cardiovascular	22	10.8	17	9.5	20	5.4	-	-	59	6.3	1.3
Environmental											
Heat exhaustion / dehydration	5	2.4	7	3.9	4	1.1	-	-	16	1.7	0.3
Other environmental[h]	9	4.4	3	1.7	8	2.2	1	0.5	21	2.2	0.4
Total environmental	14	6.8	10	5.6	12	3.2	1	0.5	37	3.9	0.8
Endocrine	6	2.9	1	0.6	-	-	-	-	7	0.7	0.2
Other medical[i]	36	17.6	9	5.0	11	3.0	-	-	56	6.0	1.2

[a] Musculoskeletal pain, dislocations, foreign bodies, amputations, inflammatory processes, and trauma not specified.

[b] Symptoms of upper respiratory infection, congestion, sore throat, and influenza-like symptoms.

[c] Allergic rhinitis, peritonsillar abscess, nasal infection, and pneumothorax.

[d] Skin/wound infection, tinea pedis, cellulitis, nail disorder, edema, chapped lips, and cold sores.

[e] Dizziness, seizure, syncope, and relext sympathetic dystrophy.

[f] Renal injury, gastric ulcer, hernia, urinary symptoms, menses, haemorrhoids, heartburn, and abdominal pains.

[g] Hypertension [h] Reduced temperature

[i] Hypoglycaemia, nose irritation, swollen glands, ear disorders, allergic reaction, fever, nose bleed, dental, infection (not specified), and fatigue

Source: Adapted from Berrios-Torres et al., 2003.

Although the cause of the WTC disaster was deliberate terrorism, the disaster itself was the result of two aircraft crashing into buildings in a central city area of high population density. The range and scale of illnesses and injuries in the period of rescue and initial clean-up are unfortunately a quite realistic indication of what conceivably could occur again in a similar environment, whatever the cause of the aircraft accident. The data in Table 2.10 are therefore a very useful basis for understanding the potential health and safety hazards in accident investigation following an aircraft accident in the centre of a major city.

In another study, Wallingford and Snyder (2001) sampled air and debris from the WTC site to identify hazards posed to rescue workers. Examining the composition of the rubble, they determined that "exposure to this type of debris through the air or direct skin contact would result in irritation to the mucous membranes and the skin". All the chemical hazards identified on the site potentially could occur at the site of an aircraft accident .

There is ongoing litigation - supported by a petition to the US Congress - about compensation and ongoing health care provisions for those responders to the WTC disaster who have developed illnesses attributable to their time on the site (Heinrich, 2004; Maloney, 2010). Of particular concern are the respiratory symptoms that have become known as "World Trade Centre cough". Research into the respiratory effects of dust inhaled at the WTC site is on-going (for example Herbstman *et al.*, 2005; Samet, Geyh and Utell, 2007; Wu *et al.* 2010).

Following the London Underground bombings on 7th July 2005, a similar assessment of the hazards posed by airborne chemicals in the tube tunnels was made by Wilson, Murray and Kettle (2009). Negligible levels of hazardous materials were identified from the train carriages. Protection against airborne dust was achieved through the use of P3 respiratory protection, and by placing time limits on work in restricted areas. The researchers noted that "One aspect of major incident response that cannot be easily resolved, is the time required to deploy personnel to the scenes to initiate occupational hygiene or environmental monitoring" (Wilson, Murray and Kettle, 2009).

Although aircraft accident investigators routinely will enter the wreckage of fuselage, it would be rare for them to be working for an extended period in an environment as confined as an underground tunnel. They nevertheless need to be aware of the dangers posed by airborne particulates in small spaces. It would be possible in some circumstances to monitor potential hazards during an investigation, but even without monitoring there are good risk mitigation measures such as the use of PPE and limiting time-on site, which should be implemented.

The health and safety implications of responses to accidents in industries other than aviation have also been fairly widely investigated. For example, Clements and James (2009) discuss the balance that must be achieved following an oil spill, between the need to begin clean-up operations to prevent environmental (and reputational) damage, and the need to conduct a full safety assessment to protect those undertaking the clean-up process. Generic risk assessments and skills in safe work practices are developed within the petrochemical industry, but - as in air accident investigation - local site variables "in terrain, oil type, weather conditions, infrastructure, security and so on" (Clements and James, 2009) will require particular and possibly unique responses.

As noted previously, there is no developed body of knowledge and research on health and safety issues in responding to aircraft accidents, similar to that for accidents in other industries or in responding to natural disasters and acts of terrorism. Air accident reports often demonstrate that initial responders have approached an emergency situation with very little information on what they might encounter. For example, the report on a Boeing 727 runway overrun in Ottawa in 2000, states that "the emergency response services (ERS) vehicles approached the aircraft with no knowledge of the number of passengers, the amount of fuel on board, or whether any dangerous goods were on board. The tower controller did not have that information to pass on to the ERS personnel, potentially delaying or slowing ERS operations and therefore jeopardising ERS and passenger safety" (TSB, 2001). Although potential hazards such as fuel and dangerous goods may be identified as generic factors to be taken into account in an emergency response, it is impossible for any accurate risk assessment to be made without more detailed and precise information. Moreover, if emergency responders do not have such information when first responding to the accident, it is possible that they will still not have the information by the time they hand control of the site to the accident investigators.

2.6 Hazards on aircraft accident sites

2.6.1 Overview

Aircraft accident investigation is, by its nature, a hazardous profession, with a requirement for accident investigators to enter sites where the dangers are largely unknown, with the task of collecting evidence and producing results in a short period of time. As noted by Wood (1998), "Aircraft accident investigation has always been hazardous to some degree, and aircraft accident investigators are routinely exposed to more hazards than they might realise".

The hazards and challenges for investigators are stark:

> "When they reach an accident scene, which can be in just about any type of environment, they may be faced with dead or dying people, pathogens, toxic materials, and other physical hazards. They may also have to deal with jurisdictional disputes, intense media scrutiny, and concerned family members. In the midst of all this, they must act as managers, technologists, and investigators in order to collect and assess evidence to support subsequent efforts to identify the cause of an accident". (Sarsfield *et al.*,2000)

Chapter Three reviews the effects of hazards on evidence collection, and considers each potential hazard at an aircraft accident site, within the framework of ICAO *Circular 315* (2008a). The purpose of this section is to review the literature on hazards, including the guidance on hazards currently available to aircraft accident investigators and accident site responders.

2.6.2 Groups affected by hazards on aircraft accident sites

Section 2.3.2.1 reviewed the range of potential participants at an accident site, and described their various roles and functions; Section 2.5.3 set out the health and safety regulations within which aircraft accident investigators are required to work.

Once the AAIB has control of a site, it is responsible for the health and safety of all personnel present. Good site security is necessary to prevent unauthorised persons from entering, to protect them from injury and to prevent damage to evidence.

Not all parties on site will be equally exposed to hazards. Accident investigators, accredited representatives, technical advisors and representatives of the coroner will spend much time in the wreckage: they will therefore be more exposed to attendant hazards than supplementary attendees such as insurance representatives and witnesses. The media, families and survivors will be kept well away from the immediate vicinity of the wreckage, until all evidence has been collected and the clean-up is well under way: they would be accompanied by AAIB personnel at all times.

2.6.3 Examples of hazards at accident sites

The paucity of research on health and safety issues specifically related to air accident investigation means that there is little systematically documented evidence on the hazards of aircraft accident sites. The primary source of information is thus accident investigation reports, which might or might not report comprehensively on the hazards encountered in each separate investigation.

It was not until the crash of an RAF Harrier in Denmark in 1990 that a hazard at an accident site became the subject of widespread discussion. This was because the investigation had to be delayed, due to the widespread scattering of man-made mineral fibres (MMMF) used to manufacture parts of the airframe (RAF, 1992). As described by Andrews (2008):

> “Within 24 hours of commencing work at the crash site some of the RAF recovery personnel suffered increasingly from painful skin irritations (traumatic dermatitis) and within 36 hours discomfort in breathing”.

Day (2001) reported that accident site responders suffered from respiratory problems, sore throats, and eye and skin irritation, but that when full chemical protection suits with high level respirators were worn, the effects of exposure were reduced. The decontamination process required the removal of all the topsoil from the site (Bath, 1992).

The health and safety concerns about the presence of composite materials during salvage of the Harrier led to the establishment of an Aircraft Crash Recovery Procedures Working Group (MOD*,* 2006a). This work of this group resulted in the *Aircraft Post Crash Management Aide-Memoire* (DARS, 2008).

Andrews (2008) refers to a subsequent Harrier crash in Germany, where firefighters with no knowledge of composite hazards had little protection. RAF investigators arrived at the site shortly after, fully prepared with protective clothing and respirators. This illustrates the need for better communication about hazards, both on site and proactively before an accident occurs (Section 2.4.5).

On 2nd April 2005, a Royal Australian Navy (RAN) Sea King helicopter crashed on Nias Island in Indonesia, while providing humanitarian assistance following a serious earthquake. Athiniotis, Lombardo and Clark wrote a series of papers (2009, 2010a, 2010b) reviewing the accident investigation. They identified a series of issues that affected the investigation process, some of which were hazards present on the accident site.

The investigators had arrived at Nias Island 24 hours after being deployed, and in need of rest. Their trip had required two flights by C130J, and transfer by Chinook, using ‘Combat loading’ improvised seats due to the large amount of emergency aid also being delivered to the area. The roads around the island were badly damaged. On arrival, the team was provided with rooms in the local school as a base of operation, but had no access to food, water or electricity, due to the earthquake damage. Additionally, the entire region was still experiencing earth tremors, measuring up to 6.8 on the Richter scale (Athiniotis *et al.*, 2009).

The investigation team had not been able to obtain any information about the aircraft accident other than that provided by the initial notification (Athiniotis *et al.* 2009). They arrived at the site knowing little about the event.

The working conditions at the accident site were hot and humid, and there was a large amount of burnt carbon fibre. The investigators judged that the best course of action was to wear full personal protective equipment (PPE) while applying a floor wax solution to contain the fibre particles, which would then allow the level of breathing equipment to be reduced to P2 level. Even so, the investigators were restricted to 10 - 40 minutes of effective working time per day, and took almost a week to acclimatise to the environment. One member of the team was treated for heat stress (Athiniotis *et al.*, 2009).

Finally, the investigation team had communication problems due to the lack of mobile phone coverage, and the failure of their satellite phones after two days of exposure to high humidity. The team also struggled with the local language: the accident review highlights the need for a specialist linguist in such circumstances (Athiniotis *et al.*, 2009). While many of the hazards identified in the review of the accident site hazards were exacerbated by the earthquake and resulting local conditions, the problems caused by travel, lack of preparation, climate, and fibres potentially can occur with other aircraft accidents (see Section 3.5).

2.6.4 Injuries to aircraft accident site attendees

As noted previously, the UK HSE has a responsibility to investigate the working practices of AAIB investigators, once a site-related illness or injury has been reported to it. No reports have ever been made. Nor, in Australia, has any illness or injury to an aircraft accident investigator been reported to Workcover by the ATSB, or in the United States by the NTSB to OSHA.

Accidents that occur to UK military personnel on aircraft accident sites do not require reporting to the HSE. The Ministry of Defence (MOD) have their own reporting system. However, injuries to civilian contractors to the military must be reported to the HSE (DASA, 2010). There have not been any recorded civilian injuries on military aircraft accident sites.

Nevertheless, illnesses and injuries do occur. The AAIB itself is very concerned to protect its investigators, and requires any health problems or injuries to be reported on the field investigation forms completed after each investigation. Accident reports can also indicate the occurrence of site-related illnesses and injuries, and there is substantial anecdotal evidence of the dangers of working on air accident sites.

This is acknowledged even at government level. The New Zealand Government has awarded the New Zealand Special Service Medal (Erebus) to those involved in Operation Overdue, the recovery and investigation operation following the crash of Air New Zealand flight TE901 into Mount Erebus, Antarctica, on the 28th November 1979. The reason for the award is set out by the New Zealand Defence Force (2007) in the following terms:

> "The purpose of the New Zealand Special Service Medal (Erebus) is to recognise the extremely difficult and very unpleasant, hazardous, and extreme circumstances associated with Operation Overdue, being the New Zealand Police recovery and identification operation launched in the aftermath of the Erebus crash involving -
>
> a. the following physical risks:
>   i. the debris, wreckage debris, and contaminated wreckage trail from the Erebus crash at the Erebus crash site:
>   ii. the extreme climatic conditions at the crash site:
>   iii. the hazardous physical location of, and conditions at, the crash site:
>
> b. the following psychological risks:
>   i. body recovery:
>   ii. victim identification:
>   iii. the scale of the tragedy of the Erebus crash:
>   iv. the fact that some of the victims of the Erebus crash were personally known to those providing services in the aftermath of the crash."

Illness and injury have also been widely reported in the literature. Following the in-flight breakup and subsequent crash of an F-117A during an airshow in Syracuse, New York in 1997, 23 firefighters became ill from the smoke inhalation and were treated for suspected boron and radiation exposure. These were acute symptoms, but no long term health damage has been recognised. The site investigation took two weeks to complete, which involved the analysis and clean-up of very damaged and burnt debris including radar absorbing material, splintered honeycomb, metal, hydraulic fluid and fuels (Walters and Sumwalt, 2000).

Research conducted by Coarsey-Rader (1995) following the 1994 crash of a DC9 while on approach to Charlotte/Douglas International Airport in North Carolina showed that three of the thirteen investigators who attended the site had symptoms of Post Traumatic Stress Disorder (PTSD). Two of them had developed the same symptoms following attendance at previous accident sites, but the condition had been left undiagnosed. Additionally, another investigator from the group was diagnosed with major depression, and one with phobia.

Slottje *et al.* (2007) researched the health-related quality of life (HRQoL) of emergency responders (firefighters and police officers). The researchers compared the HRQoL scores of responders who attended the 1992 site of the Boeing 747 freighter crash into an apartment building in Amsterdam, against the scores of colleagues who did not attend. The results indicated that in terms of physical health, the HRQoL scores of those who attended the accident site were lower than for those who did not attend the site. It was also found that, among the police officers, the HRQoL scores for mental health were lower for those who attended the site than the scores of other officers.

Hodgkinson and Stewart (1991) outline some of the symptoms known to have been experienced by responders during rescue and recovery operations. These are divided into four categories: physical, cognitive, emotional, and behavioural (Table 2.11).

Table 2.11: Symptoms experienced by responders during rescue and recovery

Category	Symptom
Physical	1. Increased heart rate, respiration, blood pressure 2. Shortness of breath 3. Nausea, upset stomach, diarrhoea 4. Sweating or chills, hot/cold spells, clammy skin 5. Tremors of hands, lips, eyes 6. Muffled hearing 7. Headaches 8. Narrowed field of vision 9. Feelings of weakness, numbness, tingling or heaviness in arms or legs 10. Feeling uncoordinated 11. Soreness of muscles 12. Lower back pains 13. Feeling a 'lump in the throat' 14. Chest pains 15. Faintness of dizziness 16. Exaggerated startle reflex 17. Fatigue 18. Appetite change
Cognitive	1. Memory problems 2. Difficulty in naming objects, eg. when asking to be given important equipment 3. Disorientation 4. Difficulty in comprehending, slowness of thinking 5. Mental confusion 6. Difficulty in making simple calculations eg. in relation to body counts 7. Difficulty in using logic, making judgements and decisions or problem solving 8. Loss of ability to conceptualise alternatives or prioritise tasks 9. Poor concentration, limited attention span 10. Loss of objectivity
Emotional	1. Feeling high, heroic, invulnerable 2. Euphoria, excessive gratitude for being alive 3. Anxiety (both anticipatory, en route and post-incident), fear 4. Strong identification with the victim, perhaps heightened by finding personal effects or photographs 5. Anger (with colleagues, officers, the media), blame 6. Irritability, restlessness, hyper-excitability 7. Sadness, grief, depression, moodiness 8. Recurrent dreams of the event or other traumatic dreams, sleep difficulties 9. Guilt feelings about not having done enough 10. Feelings of isolation, detachment, estrangement 11. Apathy, diminished interest 12. Denial of feelings, numbness 13. Excessive worry about the safety of others

Table 2.11: Symptoms experienced by responders during rescue and recovery

Category	Symptom
Behavioural	1. Difficulty in communicating, verbally or in writing 2. Hyperactivity 3. Decreased efficiency and effectiveness 4. Outbursts of anger, frequent arguments 5. Inability to rest or relax 6. Periods of crying 7. Increased use of alcohol, tobacco and other drugs 8. Social withdrawal, distancing

Source: Hodgkinson and Stewart, 1991

Accident investigators should be aware of these symptoms, and look out for them both in themselves and in other members of the investigative team.

2.6.5 Industry guidance regarding aircraft accident site hazards

Despite no formal reporting of illness or injury to national health and safety watch-dogs, accident investigation authorities clearly recognise and exercise their health and safety responsibilities, and seek to provide guidance and supervision for their investigators.

As noted in Section 1.3.3, the most recent and now key document on accident site hazards is *Circular 315* (ICAO, 2008a), which was produced by the Hazards at Aircraft Accident Sites Study Group. This document identifies twenty different types of hazard potentially present on any aircraft accident site, grouped into five overarching categories: environmental, physical, biological, material and psychological. Chapter three examines each hazard and its impact, and the ways in which exposure to them can be managed.

Previous ICAO documents had gone some way in identifying and categorising hazards on accident sites. The original ICAO *Manual of Aircraft Accident Investigation* (1970) listed hazards for accident investigators on site, and hazards to the investigation process. Table 2.12 gives some examples of the guidance provided by the document (ICAO, 1970).

Table 2.12: Action-specific hazards guidance in ICAO Manual of Aircraft Accident Investigation (1970)		
Actions on the Site	**Potential Hazards**	**Suggested Mitigation Measures**
Initial Walk Around	Fire	• Arrange for fire fighting appliances to remain on site • Defuel the aircraft • Limit use of radio or electrical equipment on the site
	Dangerous cargo	• Check freight manifest
	Radio active material	• Get qualified and equipped persons to remove from site
Wreckage removal from water	Pressure vessels	• Corrosion of metal creates potential 'bombs' - consider deflating tyres, and discharge contents of other pressure vessels
Checking windshield wipers and rain repellant	Chemicals from aerosol-type dispensers	• Bursting hazard, although substance is non-toxic

Source: Adapted from ICAO (1970).

Later ICAO hazards guidance provided a more general overview of potential hazards on the site, but without any task-specific guidance. For example, Part I of the updated *Manual of Aircraft Accident and Incident Investigation* (ICAO, 2000), which replaced the ICAO (1970) manual, discussed hazards that arise in urban accident sites: from fire, dangerous cargo, wreckage hazards, biological hazards (which includes psychological stress), hazards of helicopter operations, and environmental and natural hazards.

Wood and Sweginnis (2006) identify possible site hazards in the following terms:

> - "Chemical hazards: fuel, hydraulic fluids, liquid oxygen, hydrazine.
> - Pressure vessels: hydraulic accumulators, oleo struts, tires, fire extinguishers.
> - Mechanical hazards: springs (ram air turbines, gear doors, drag chute mechanisms.
> - Pyrotechnic hazards: ejection seats, munitions, survival equipment.
> - Hygiene hazards: if there are human remains present in the wreckage, blood-borne pathogens present a serious risk to the investigator.
> - Miscellaneous hazards: radioactivity (instruments, avionics, flight control balance weights), fumes, dusts, and vapours resulting from composite materials or cargo".

Although suggesting that any known hazards should be "removed or neutralised" before the investigation proceeds, the authors provide no guidance in how this should be done.

The ICAO *Circular 298: Training Guidelines for Aircraft Accident Investigators* (2003a) was the most significant ICAO document prior to *Circular 315* (2008a). It states:

> "The safety of personnel at an aircraft accident site is of paramount importance and must be understood by participants of an investigation. An investigator is a valuable resource and it is important that he is protected and well equipped to do his work in the field with as little

> risk as is practicable and with the optimum efficiency. Aircraft accidents frequently occur in adverse weather conditions in areas of inhospitable terrain such as mountainsides, swamps and deserts, or in adverse climatological conditions involving snow and ice or fierce heat. The need to take appropriate measures to protect those on the site against exposure to the elements, to any hazardous cargo or dangerous materials released from the aircraft, and against injury or infection must be understood. There are medical risks and hazards from the aircraft wreckage itself and they must be explained to the investigators. Another subject that must be covered is how to deal with the psychological stress of investigators and other personnel with exposure at an accident site. Disease is an ever-present risk and inoculations against such risks as hepatitis, malaria and tetanus are essential. The use of protective equipment against airborne and blood borne pathogens should be demonstrated. Utilities such as gas mains, electricity transmission lines and main transport routes require special consideration. Finally, a plan for aid and rescue in the event of an accident involving personnel at the site is required by many occupational health and safety organisations and is also dictated by common sense" (ICAO, 2003, p.8)

This paragraph is the basis on which ICAO *Circular 315* (2008a) was developed. By building on the key items referred to above (hazards such as difficult terrain, adverse weather, hazardous cargo, dangerous materials, dangerous wreckage, and biological pathogens), *Circular 315* provides a structured taxonomy of hazards, an operational safety planning guide, a list of necessary PPE equipment list, and a detailed health and safety training programme.

Table 2.13 compares the issues covered by several forms of guidance on site hazards for investigators, against the ICAO *Circular 315* taxonomy of hazards.

Table 2.13: Comparison of accident site hazards identified in guidance to aircraft accident investigators (Note: key at end)

ICAO Circular 315 (2008a) Hazards	**ICAO Training Guidelines for Aircraft Accident Investigators (2003a)**	**ICAO Manual of Aircraft Accident and Incident Investigation Part 1 (2000)**	**Lewis and Burrell (2004)**	**NTSB Accident Investigation Manual: Major Team Investigations (2002a)**	**Wood and Sweginnis (2006)**
Environmental		✓			
Accident location		✓			
Geographical		✓			
Topographical	✓	✓		✓	
Fatigue					
Insects/Wildlife		✓		✓	
Climate	✓	✓		✓	
Security					

Table 2.13: Comparison of accident site hazards identified in guidance to aircraft accident investigators (Note: key at end)

ICAO Circular 315 (2008a) Hazards	**ICAO Training Guidelines for Aircraft Accident Investigators (2003a)**	**ICAO Manual of Aircraft Accident and Incident Investigation Part 1 (2000)**	**Lewis and Burrell (2004)**	**NTSB Accident Investigation Manual: Major Team Investigations (2002a)**	**Wood and Sweginnis (2006)**
Physical Hazards				✓	
Fire and flammable substances		✓		✓	✓
Fuel		✓			✓
Fumes			✓		✓
Stored energy components	✓	✓	✓		
Electrical accumulators		✓		✓	
Hydraulic accumulators		✓			✓
Oleo struts					✓
Wheels and tyres		✓		✓	✓
Fire extinguishing bottles					✓
Pressurised gases		✓	✓		✓
Military and ex-military aircraft		✓		✓	✓
Cockpit escape equipment and ejector seats					✓
Recent safety equipment					
Emergency parachute system				✓	
Airbag restraint system					

Table 2.13: Comparison of accident site hazards identified in guidance to aircraft accident investigators (Note: key at end)

ICAO Circular 315 (2008a) Hazards	**ICAO Training Guidelines for Aircraft Accident Investigators (2003a)**	**ICAO Manual of Aircraft Accident and Incident Investigation Part 1 (2000)**	**Lewis and Burrell (2004)**	**NTSB Accident Investigation Manual: Major Team Investigations (2002a)**	**Wood and Sweginnis (2006)**
Pyrotechnics and explosives		✓	✓		✓
Weapons		✓		✓	✓
Damaged and unstable structures		✓		✓	✓
Biological hazards	✓	✓	✓	✓	✓
General biological hazards and viruses	✓	✓	✓	✓	✓
Local state of hygiene	✓				
Material hazards					
Metals and oxides					✓
Composite materials		✓		✓	✓
Chemicals and other substances		✓	✓		✓
Radioactive materials		✓	✓		✓
Depleted uranium		✓		✓	
Cargo	✓				✓
General cargo	✓				
Dangerous goods	✓	✓		✓	
Psychological hazards	✓	✓			

Table 2.13: Comparison of accident site hazards identified in guidance to aircraft accident investigators (Note: key at end)

ICAO Circular 315 (2008a) Hazards	**ICAO Training Guidelines for Aircraft Accident Investigators (2003a)**	**ICAO Manual of Aircraft Accident and Incident Investigation Part 1 (2000)**	**Lewis and Burrell (2004)**	**NTSB Accident Investigation Manual: Major Team Investigations (2002a)**	**Wood and Sweginnis (2006)**
Additional hazards identified	General reference made to “hazards from the aircraft wreckage itself” and urban accident sites.	Specific mention of hazards of propellors and included springs, aircraft insulation, and helicopter operations.	Reference to general “mechanical hazards” - similar to damaged and unstable structures.	Call physical hazards “mechanical hazards”. Specific mention of propellors, confined spaces, helicopter operations,water operations and urban accident sites.	Like ICAO (1970), most hazards discussed relate to evidence collection rather than site overview.

Key:
Bold: Five major categories of hazards as identified by ICAO (2008a)
Normal: Sub-categories of hazards as identified by ICAO (2008a)
Italics: Specific hazards identified in the sub-categories

It is noteworthy that biological hazards are the only hazards identified by all six sources of guidance. Radioactive materials (or more specifically depleted uranium) are referred to in five of the six references, reflecting concern over radioactive hazards such as those associated with the 1992 Amsterdam B747 Freighter crash .

In addition to ICAO guidance and other guidance referred to above, some accident investigation agencies provide their own guidance for emergency responders. Some examples are *Aircraft Accidents: Guidance for Police, Emergency Services and Airfield Operators* (AAIB, 2008a), *Guidance for An Garda Siochana and the Emergency Services in the aftermath of an Aircraft Accident* (AAIU, 2005) and the *Civil and Military Aircraft Accident Procedures for Police Officers and Emergency Services Personnel* (ATSB, 2006a). These are very informative documents for emergency responders written from the perspective of investigation authorities, but their objective is not to identify all potential hazards for accident investigators, or to set out in detail the processes for managing those hazards.

Some guidance has been prepared specifically for fire fighters (for example Anderson, Hawkins and Gill, 2008; HM Fire Service Inspectorate, 1999). This type of guidance provides information for fire fighters with no specific knowledge about aircraft, and recommends certain rescue techniques. Guidance has also been prepared specifically on risk arising from dangerous goods - *Emergency Response Guidance for Aircraft Incidents Involving Dangerous Goods* (ICAO, 1999, updated annually).

Table 2.14 compares the way in which hazards are identified in guidance documents for emergency responders, against the hazards identified in ICAO *Circular 315* (2008a).

Table 2.14: Comparison of accident site hazards identified in guidance to emergency responders

ICAO Circular 315 (2008a) Hazards	**AAIB (2008a)**	**AAIU (2005)**	**Anderson *et al.* (2008)**	**ATSB (2006a)**	**HM Fire Service (1999)**	**ICAO (1999)**
Environmental						
Accident location						
Geographical						
Topographical						
Fatigue						
Insects/Wildlife						
Climate						
Security						
Physical Hazards						
Fire and flammable substances		✓				
Fuel	✓	✓	✓	✓	✓	
Fumes		✓		✓		
Stored energy components	✓	✓		✓		
Electrical accumulators	✓		✓	✓		
Hydraulic accumulators		✓	✓		✓	
Oleo struts		✓		✓		
Wheels and tyres			✓			
Fire extinguishing bottles		✓		✓		
Pressurised gases	✓	✓	✓	✓	✓	

Table 2.14: Comparison of accident site hazards identified in guidance to emergency responders

ICAO Circular 315 (2008a) Hazards	**AAIB (2008a)**	**AAIU (2005)**	**Anderson *et al.* (2008)**	**ATSB (2006a)**	**HM Fire Service (1999)**	**ICAO (1999)**
Military and ex-military aircraft	✓	✓	✓		✓	
Cockpit escape equipment and ejector seats	✓	✓	✓	✓		
Recent safety equipment				✓		
Emergency parachute system	✓			✓		
Airbag restraint system				✓		
Pyrotechnics and explosives	✓	✓		✓		
Weapons	✓	✓	✓	✓	✓	
Damaged and unstable structures	✓	✓				
Biological hazards						
General biological hazards and viruses	✓	✓				
Local state of hygiene						
Material hazards						
Metals and oxides	✓	✓	✓	✓		
Composite materials	✓	✓	✓	✓	✓	
Chemicals and other substances				✓	✓	
Radioactive materials		✓	✓	✓	✓	✓
Depleted uranium						
Cargo	✓		✓		✓	✓
General cargo	✓		✓		✓	✓
Dangerous goods	✓	✓	✓	✓	✓	✓

Table 2.14: *Comparison of accident site hazards identified in guidance to emergency responders*

ICAO Circular 315 (2008a) Hazards	**AAIB (2008a)**	**AAIU (2005)**	**Anderson *et al.* (2008)**	**ATSB (2006a)**	**HM Fire Service (1999)**	**ICAO (1999)**
Psychological hazards						
Additional hazards identified			Hazards from jet engine intake and propellors	Specifies dangers of portable communications equipment	Hazards of escaping livestock in cargo, running engines	

The differences between *Circular 315* and the other guidance documents reflects the fact that the latter have been written for emergency responders, who attend aircraft accident sites for specific and time-limited purposes, and not as a matter of regular routine. They do not have the career-long exposure to a wide range of potential hazards which is characteristic of the role of an aircraft accident investigator. The question of whether the guidance given in *Circular 315* is adequate for investigators is considered further below.

The UK Police Service uses the mnemonic SAD CHALETS to conduct a risk assessment prior to entering any event (Figure 2.29), and apply this approach in emergency response to aircraft accidents:

Survey (what can I readily see, hear, smell of feel?)

Assess (what do I think is happening and needs to be done?)

Disseminate and Declare (report back to the control room accurately, concisely and clearly, and **Declare a major incident**, if appropriate)

C - Casualties
- Approximate number of all casualties and where they are located.
- What symptoms are present?
- What percentage of casualties are deceased, seriously injured, have minor injuries or are trapped?

H - Hazards
- Present and potential hazards.
- Is there any cloud of gas, smoke or fire present?
- Any debris from any explosion? If so, how widely spread?
- Any other potential hazards?
- Any environmental hazards or potential pollution?
- If a transport accident, are there any Hazchem markings?

A - Access/Egress
- Best access routes for emergency vehicles and suitable provisional points.
- Is the initial access route safe?
- Are likely access and egress routes congested?
- What resources are likely to be needed to maintain clean access and egress routes?
- Is it necessary to remove parked vehicles?
- What egress routes are available, particularly for the removal of casualties?
- Is it necessary to set up ‘Priority’ (Red) routes to key locations (eg. acute hospitals)

L - Location
- The exact location of the incident, using grid references if possible.
- How large is the area affected?
- Does it contain residential properties, shops or offices?
- Are there any venues with large numbers of people nearby?
- Are the vulnerable persons involved or nearby?

E - Emergency Services and Evacuation
- Which emergency services are required?
- Is specialist equipment required, eg. the Fire and Rescue Urban Search and Rescue (USAR) teams?
- Are specialist support organisations required, eg. radiation monitoring, CBRN personnel?
- Is evacuation necessary or is shelter a more viable option?
- Will evacuation of people and/or animals be required, if so approximate numbers?
- Are there vulnerable groups of individuals?
- To where will they be evacuated?
- Is there an identified safe route to use?
- Where will they be taken and are facilities available to receive them?

T - Type
- Type of incident with brief details of types and numbers of vehicles, trains, or buildings involved.
- Are there any early indications if the incident may be an act of terrorism or crime?

S - Start a log / safety
- Consider health and safety, conduct dynamic risk assessments.
- Commence incident log (use pocket note book if necessary).

Figure 2.29: UK Police Service risk assessment mnemonic: SAD CHALETS
Source: ACPO, 2009.

Additionally, the UK Association of Chief Police Officers (ACPO) *Guidance on Emergency Procedures* (2009) warns police that:

> "... as there are health and safety issues relating to aircraft, in particular military aircraft, police officers and staff should not engage directly in the rescue of survivors. This should be left to properly trained and equipped Fire and Rescue Service personnel. In addition, aircraft can contain various hazardous materials, some of which may become airborne. Personnel should, therefore, place themselves upwind of the scene of an aircraft accident, with the cordon extended downwind of the scene to protect people".

It is further suggested that the police consult with the fire and rescue service silver commander about potential hazards on the aircraft accident site (ACPO, 2009).

In January 2010, the UK Department for Communities and Local Government, advised by the Chief Fire and Rescue Adviser for the UK, Sir Ken Knight, published its generic risk assessments for fire response to incidents involving air transport (Communities and Local Government, 2010a). These risk assessments are included in Appendix A.

2.6.6 Hazards specific training for aircraft accident investigators

Training in the identification and management of hazards on aircraft accident sites can be provided as an integrated component of a complete accident investigator course, or as a stand-alone training course.

Accident site safety is one of the 25 areas that ICAO recommend be taught in any basic accident investigation course (ICAO, 2003a). The guidance states:

> "The safety of personnel at an aircraft accident site is of paramount importance and must be understood by participants of an investigation. An investigator is a valuable resource and it is important that he is protected and well equipped to do his work in the field with as little risk as is practicable and with the optimum efficiency. Aircraft accidents frequently occur in adverse weather conditions in areas of inhospitable terrain sounds as mountainsides, swamps and deserts, or in adverse climatological conditions involving snow and ice or fierce heat. The need to take appropriate measures to protect those on the site against exposure to the elements, to any hazardous cargo or dangerous materials released from the aircraft, and against injury or infection must be understood. There are medical risks and hazards from the aircraft wreckage itself and they must be explained to the investigators. Another subject that must be covered is how to deal with psychological stress of investigators and other personnel with exposure at an accident site. Disease is an ever-present risk and inoculations against such risks as hepatitis, malaria and tetanus are essential. The use of protective equipment against airborne and blood borne pathogens should be demonstrated. Utilities such as gas mains, electricity transmission lines and main transport routes require special consideration. Finally, a plan for aid and rescue in the event of an accident involving personnel at site is required by many occupational health and safety organisations and is also dictated by common sense".

ICAO *Circular 315* (2008a) identifies "... common training objectives and standards for aircraft accident investigators and support personnel that are recognised and accepted by Contracting States".

Salazar, DeJohn and Key, (1997) have drawn attention to the requirement within the USA that all employees be provided with training about the hazards posed by blood-borne pathogens. They note the difficulties of implementation in the workplaces of aircraft accident investigators: "an aircraft accident site does not compare in any way to the well-structured environment of a hospital or medical office; therefore, applying (this requirement) to a chaotic and usually isolated site presented a unique dilemma with no clear precedent to build on" (Salazar *et al.* 1997)

They further note that, prior to the requirement, "the Federal government, including the military, had no comprehensive program in place that addressed and mitigated the potential for disease transmission at an aircraft accident site. Infection control was at best a piecemeal effort, usually undertaken by individuals based on their degree of knowledge or interest concerning the subject and personal experience in accident investigation" (Salazar *et al.* 1997). This statement is made specifically in relation to blood-borne pathogens, but there is a risk that the management techniques used to identify other hazards are similarly haphazard.

2.7 Future trends in aircraft accident investigation

Learning about hazards through experience and consideration of past accidents prepares accident investigators for similar accidents. It does not provide the knowledge needed for investigation of accidents of the future. If investigators are to anticipate and respond to the requirements of the future, they need to understanding how the aviation industry, aircraft accident investigation, and health and safety regulations, interact with each other and will change and evolve over time.

In 2000, researchers from the RAND Institute for Civil Justice conducted a review of the NTSB investigation practices and policies (Sarsfield *et al.*, 2000). They noted that:

> "In some respects, the NTSB's investigative techniques have not kept pace with changes in modern aircraft design, manufacturing, and operation, raising doubts about its ability to expeditiously and conclusively resolve complex accidents"

Furthermore, they were very clear about the future:

> "The nature of investigations and the future workload of the NTSB will be heavily influenced by the changing aviation environment, which is characterised by increasing technological complexity, growth in general and commercial aviation air traffic, and important changes in the composition of the air transport fleet. These factors have long challenged aviation accident investigators. Now, the pace of innovation is accelerating rapidly, and some of the developments will put unprecedented strain on the NTSB. Most important, the adequacy of the investigative methods the NTSB has traditionally used will be challenged. These practices have remained largely unchanged since the inception of the NTSB".

As aircraft technology changes, and as aircraft operations also change, accident investigators will need to adapt the methods they use to investigate accidents, and to detect and document their causes.

Sarsfield *et al.* (2000) go on to raise a further important issue:

> "[National Transportation] Safety Board investigators are well prepared for accidents in which the failure mode reveals itself through careful examination of the wreckage and analysis of debris - that is, those accidents in which a "permanent state failure" has occurred. Complex-system events, however, present greater challenges to traditional NTSB investigative practices. Here, failure states can be "reactive", leaving no permanent record to discover in the wreckage".

The investigation which followed the crash of a Boeing 777 at London Heathrow on 17 January 2008 provides an example of a failure state leaving no permanent record in the wreckage. The investigation focussed on the possibility of ice having developed in the fuel system. However the investigators found no ice during the investigation; the only physical evidence was small amounts of cavitation on the left and right high pressure fuel pumps (AAIB, 2010b). There was no evidence of a 'permanent failure state' to be found in the wreckage: the causal factor of the ice, and indeed the possibility of ice development in the Fuel / Oil Heat Exchanger (FOHE) rather than in any other area of the fuel system, could only be determined through tests away from the accident site.

Wood and Sweginnis (2006) reached similar conclusions to Sarsfield *et al.* (2000) in their discussion of the investigation of loads, stresses and strains in aircraft. Importantly, they note that "In any technical area, the knowledge of how to investigate failures always lags behind the development of the technology" (p. 335). They point out that there is a good understanding of metal fatigue in air accident investigation, but very limited knowledge about failure modes of composites in aircraft.

The first major aircraft accident which relied on the investigation of composite damage to understand the reasons for the accident was that of American Airlines flight 587, an A300-600 which crashed in New York on 12th November 2001. The rudder and vertical stabiliser of the aircraft separated in-flight and were found one mile away from the rest of the wreckage (NTSB, 2004b). Airbus indicated that "the fin-box is made of the resin system Hexcel F913 carbon tape and fabric, and the rudder skins are made from F550 carbon fabric in combination with EHG250 fibreglass fabric. The EHG250 fibreglass fabric was used to adhere the Nomex® honeycomb core to the CFRP skin, and was co-cured with the skin (NTSB, 2002b). Different types of composites all possess different properties, and have different purposes.

The increasing use of composites in aircraft manufacture was discussed in Sections 2.2.2.2 and 2.2.2.3. As aircraft design and construction evolves in the future, investigators will need a deeper technical understanding of the properties of composites and the reasons for their failure. At the same time, a new range of investigative techniques will need to be developed.

No investigator, anywhere, has yet been called on to attend a major civil aircraft accident site that contains a large amount of composite. The first major accident involving an A380 or B787 will be a massive learning curve for accident investigators, not only to collect the evidence needed from the site - which may be different from the evidence needed for a traditionally manufactured aircraft - but also in identifying the hazards on the site. Some of the skills needed will transfer from attending other large accident sites; and others will arise from experience in attending GA composite aircraft accidents; but without additional and specific training in the properties of composite materials this is unlikely to be adequate for the purpose of thorough investigation.

Better investigation, and the safety of investigators, also requires the provision of full and timely information. In 1998, following the 1996 in-flight fire and emergency landing of a DC-10 at Newburgh, New York, the NTSB recommended that either the FAA or the Research and Special Programs Administration (RSPA) should require all aircraft operators transporting hazardous material to provide 24 hour access to their cargo details, so that the information could be rapidly retrieved and provided to emergency responders (NTSB, 1998). In 1999, the FAA rejected this recommendation, deferring responsibility for action to the RSPA (NTSB, 1999). In 2003, the safety recommendation was closed without acceptable action, after new hazardous goods shipping regulations were implemented without the urgent response recommendations (NTSB, 2003).

It is interesting to note that the increased safety rate of aviation is leading to a decrease in the currency of accident investigator skills in responding to large aircraft accidents. With the exception of the B777 crash at London Heathrow in 2008, which remained largely intact, with no loss of life and only minimal injury (AAIB, 2010b), there has not been a large scale aircraft accident in the UK since the B747 Freighter crash near Stansted Airport in 1999.

2.8 Concluding note

This chapter has reviewed the extensive body of literature which is the context in which the current the research on hazards awareness for aircraft accident investigators is placed. From this review, it is shown that while there is extensive available material on aircraft accident investigation policies and procedures, and on health and safety best practices, and some measurement of injuries and illnesses to emergency responders, there is very little recorded evidence of actual hazards on aircraft accident sites, and on the mitigation measures used to overcome these hazards and continue with the evidence collection process.

As Jackson (2002) observed:

> "The experiences of others in the field one wishes to research are invaluable. Whether such experiences are other empirical studies, theoretical expressions, or anecdotal accounts, they will contain useful guidance....It is important to plan for which outcome would be more useful to answer any research question: the frequency of an incident or the severity of an incident".

The initial idea from this work sprang from fascinating anecdotal evidence about the hazards accident investigators have encountered on sites, and from the recent emergence of industry guidance on how such hazards might be managed. Together, they have set the scene for this research.

Chapter Three

A Review of Hazards That May Affect Evidence Collection at Aircraft Accident Sites

3.1 Purpose of the study

The intention of ICAO *Circular 315*: *Hazards at Aircraft Accident Sites* (2008a), p.v) is:

> “to assist individuals to consider and apply effective occupational safety management practices both to their own activities and to the activities of the teams that they work with, or for which they are responsible”

Information in the circular is provided for the benefit of both emergency responders and aircraft accident investigators: although on the same accident site, they undertake different tasks, and may be exposed to different hazards and hazard levels.

The *Circular* is not a comprehensive manual of knowledge about hazards, from which accident site attendees might learn about hazards they will be exposed to on an accident site; rather, it is background information which, when combined with an understanding of the tasks to be completed on a site, and consolidated with an accident site health and safety training programme, will assist site attendees to make good risk assessment and management choices.

It is stated in the circular that “given the relative infrequency of accidents, there are few opportunities for the scientific analysis of aircraft debris that is essential for accurate assessment of occupational health risks” (ICAO, 2008a, paragraph 2.2.1). Due to the number of variables involved - the items carried on an aircraft, the potential accident environments, and the crash impacts of an accident - it is simply not possible to predict with accuracy the hazards that might occur on any future accident site. That said, there is a need for scientific assessment to be conducted to the best extent possible.

The purpose of this study is to consider both the evidence collection tasks that may be carried out on an accident site, and the different hazards that may be present on the sites. This information will enable better understanding of where and when hazards may appear on sites, and encourage accident site attendees to consider how better to balance the evidence collection and personal protection tasks.

This study focuses on the hazards faced by accident investigators rather than emergency responders. The benefit of the study lies in the development of extensive task-specific hazards information, which can be applied in further studies. The specific effect of each hazard identified in *Circular 315* is examined across a range of accident sites, as is the aggregate effect of a range of hazards at individual accident sites.

3.2 Context

3.2.1 Overview

This chapter reviews the effects that hazards encountered on an aircraft accident site can have on both accident investigators' personal safety and on their work tasks. There are two predominant documents used to guide this review: ICAO *Circular 315* (2008a), and ICAO *Manual of Aircraft Accident Investigation* (1970, 2000, 2003b and 2008b). These two documents are reviewed in Section 3.2.2 and 3.2.3 respectively.

3.2.2 Background to ICAO *Circular 315*

Following the ICAO Accident Investigation and Prevention (AIG) Divisional Meeting in 1999, the Hazards at Accident Sites Study Group (HASSG) was created. This group was comprised of four SMEs in the field of accident site safety, overseen by a representative from ICAO. The HASSG was created to fulfil ICAO's role of "establishing and maintaining an inventory of hazards peculiar to aircraft accident sites and in the promulgation of related guidance material to states" (ICAO, 2008a, p. v); it was tasked with developing (and maintaining) a list of accident site hazards and specifying necessary training requirements. *Circular 315* (2008a), the outcome of this work, was published in 2008.

As discussed previously (Section 2.6.5), there are a number of other documents which consider factors at accident sites which could be hazardous to aircraft accident investigators and emergency responders. These include, but are not limited to, the ICAO *Training Guidelines for Aircraft Accident Investigators* (2003a), the NTSB *Accident Investigation Manual: Major Team Investigations* (2002a), the AAIB *Aircraft Accidents: Guidance for the Police, Emergency Services and Airfield Operators* (2008a), and the ATSB *Civil and Military Aircraft Accident Procedures for Police Officers and Emergency Services Personnel* (2006a).

However, ICAO *Circular 315* differs from this other guidance in four respects.

First, it recognises that "a balance must be struck between the requirements of the task and the need to make the performance of the task safe for investigation and response personnel" (ICAO, 2008a, paragraph 2.3.1). The work pressures of accident investigation are such that investigators need to begin their investigation activities as soon as possible after they arrive on site, to prevent the loss of perishable evidence. However, health and safety regulations (such as the UK *Health and Safety at Work Act*

1974, paragraph 2) would dictate that accident investigators should not enter an accident site until identified hazards are reasonably mitigated. These two pressures are at odds with each other. Many of the obvious health and safety risk reduction measures that could be undertaken on a site, such as disinfection of surfaces and stabilisation of wreckage, would lead to the destruction of evidence. Therefore, the accident investigator must take responsibility for managing a balance between maintaining personal safety and completing the collection of evidence. Aircraft accident investigators should not be cavalier with their own health and safety, but neither can they be so concerned about the potential risks of hazards that they fail to complete their on site duties.

Second, *Circular 315* (ICAO, 2008a) separates hazards on accident sites into five categories:

1. Environment
2. Physical
3. Biological
4. Materials
5. Psychological

There are other ways in which hazards may be categorised (Section 2.6.5), but this particular taxonomy is useful in that it enables those with no background knowledge of potential hazards to gain an overall appreciation of possible dangers, and to develop a basic framework to which further information about accident site hazards can be added. This framework can be used to build generic and dynamic risk assessments, which will be discussed further in Chapter Six.

Third, *Circular 315* recognises the hazards arising from the changing nature of the materials from which modern aircraft are manufactured, and separates material hazards from general wreckage hazards. Previous ICAO guidance (ICAO, 2000) did not distinguish hazards posed by composite materials from wreckage hazards such as those caused by tyres, propellers, batteries and jagged metal. By separating material hazards from other wreckage hazards, investigators systematically working through the hazard categories are forced to consider specifically the nature of the materials from which the aircraft is manufactured. Importantly, the materials category includes chemicals, which had never before been explicitly included in ICAO site safety guidance.

Finally, the circular provides guidance on the minimum standards to be met by health and safety training for aircraft accident responders. With the exception of one paragraph in *Circular 298: Training Guidelines for Aircraft Accident Investigators* (ICAO, 2003a), no health and safety training guidance has previously been published. This reflects the changing health and safety requirements being implemented by ICAO member states, and fulfils one of the original aims given to the HASSG.

ICAO *Circular 315* (2008a) is laid out in five chapters:

Chapter 1	Terminology
Chapter 2	Managing occupational health risks in aircraft accident investigation
Chapter 3	Hazards
Chapter 4	Generic operational safety planning guide
Chapter 5	Health and safety training

Chapters 1 and 3 of the circular are discussed within this study, Chapters 2 and 4 of the circular are discussed in Chapter Six of this thesis, and the implication the results of studies in Chapters Four, Five and Six of this thesis have on health and safety training (Chapter 5 of the circular) are discussed in Chapter Seven of this thesis. To ensure clarity, this thesis gives thesis chapter titles in words, and *Circular 315* chapter titles in numerals.

3.2.3 Background to ICAO *Manual of Aircraft Accident and Incident Investigation*

In 1994, following the 1992 ICAO Accident Investigation and Prevention (AIG) Divisional Meeting, the Accident Investigation Methodology Study Group (AIMSG) was created. The purpose of this working group was to update the ICAO *Manual of Aircraft Accident Investigation* (Doc 9620) which had not been extensively updated since the 1970 edition.

The AIMSG separated the original single volume manual into four volumes:

Part I	Organisation and planning
Part II	Procedures and checklists
Part III	Investigation
Part IV	Reporting

These four volumes are divided generally in the same way as the first four sections of the original 1970 document. The fifth section of the 1970 manual is now separated between the ICAO *Safety Management Manual* (ICAO, 2006b, 2009b) and the ICAO *Accident Prevention Programme* (2005b). The title of the guidance provided by the four volumes has been changed to the *Manual of Aircraft Accident and Incident Investigation*. This reflects a change in approach in aviation safety: accidents, serious incidents and incidents are now investigated in the same way, the only difference between the events being the outcome (ICAO, 2001a).

The four parts of the manual expand on *Annex 13* (ICAO, 2001a) to provide practical guidance on how to conduct an investigation in a manner required to fulfil the objectives set in *Annex 13*. Part I was published in 2000 (ICAO, 2000); part IV in 2003 (ICAO, 2003b); Part III was published as a draft in 2008 (ICAO, 2008b); and part II is still to be published.

3.3 Methodology

3.3.1 Overview

As stated previously, the purpose of this study is to identify how the hazards set out in ICAO *Circular 315* (2008a) may pose a risk to accident investigators carrying out evidence collection tasks on aircraft accident sites.

The study is in two parts. The first part (Section 3.4) identifies evidence collection methods that accident investigators need to complete on sites. The second part (Section 3.5) is a detailed examination of the hazards identified in Circular 315 (ICAO, 2008a) and how and when they pose risk to an investigator.

3.3.2 Evidence collection activities on aircraft accident sites

The on site activities of accident investigators were introduced in Section 2.3.2.4. There is no definitive list of evidence collection methods to be employed by aircraft accident investigators on accident sites. Indeed, Flaherty (2008, pp. 68-69) noted that accident investigators felt it difficult to work with a "prescriptive methodology"; they preferred to use their own methodologies and the initial information gathered from the site to decide how to proceed with the investigation. However, a framework of evidence collection techniques is helpful in providing some structure and understanding in the review of hazards.

A content analysis methodology was applied to gather the required information. "Content analysis is a research methodology that utilises a set of procedures to make valid inferences from text" (Webster, 1985).

This definition is expanded by Krippendorff (2004, p. 18):

> "Content analysis is a research technique for making replicable and valid inferences from texts (or other meaningful matter) to the contexts of their use"

Similarly Neuendorf (2002):

> "Content analysis is a summarising, quantitative analysis of messages that relies on the scientific method (including attention to objectivity-intersubjectivity, a priori design, reliability, validity, generalisability, replicability, and hypothesis testing) and is not limited as to the types of variables that may be measured or the context in which the messages are created or presented"

The methodology was applied twice to different data sources, and the results of the two analyses compiled into one table.

First, content analysis was applied in reviewing reports published in 2008-2010 on fifteen aircraft accidents which occurred in the years 2006-2009, to identify the sources of evidence used during the investigation. The reporting format set out in *Annex 13* (ICAO, 2001a) was used as a framework to enable comparison between the fifteen reports, to identify where evidence was collected both on and off the site.

Reports selected for inclusion in the analysis were those on recent accidents (rather than serious incidents or incidents), and written in the formal *Annex 13* format. Five reports were selected from each of the AAIB, ATSB and NTSB, to ensure that reported investigations used the most current methodologies. (A review of the fifteen most recent formal AAIB accident reports alone would have required analysis of reports back to 2004, on accidents occurring from 2001.)

Second, content analysis was applied to the ICAO *Manual of Aircraft Accident and Incident Investigation, Part III - Investigation* (2008b). Each section of the manual was systematically reviewed to identify the methods recommended to gather evidence during each aspect of the accident investigation. The content analysis focused on the on site evidence collection techniques.

The two resulting data sets were then combined into a single table against the ICAO *Annex 13* framework. The purpose was to identify the sources of evidence that accident investigators may be looking for both on and off an accident site, and to identify the tasks needed to complete collection of the on site evidence. Development of the table provided a framework for analysis of hazards in the next stage of the research study.

3.3.3 Review of hazards

Each of the hazards identified in Chapter 3 of the ICAO *Circular 315* (2008a) were reviewed to answer five questions:

1. What is the hazard?
2. Why is it hazardous to aircraft accident investigators?
3. Where does the hazard exist on an aircraft accident site?
4. How does the hazard interact with an investigator's work? (Answers to this question involve the use of the results of the previous work into evidence collection techniques used by aircraft accident investigators on site.)
5. What are the recommended practices for aircraft accident investigators to use to protect themselves from exposure to the hazard?

The result of this exercise was to understand how each individual hazard can affect an investigator working on an accident site; how much of a risk is posed by individual hazards to aircraft accident investigators; and which particular hazards may pose most risk, both in terms of prevalence on site and the effect on the investigator.

The literature reviewed included journals, industry papers, and accident investigation guidance. This was supplemented by aircraft accident and incident reports and manuals of fire fighting guidance, to identify sites where particular hazards have arisen or where aircraft specific hazards may occur.

3.4 Evidence collection activities on aircraft accident sites

3.4.1 Overview

The purpose of this study is to provide a structured guide to evidence collection techniques that aircraft accident investigators may use when on an accident site. The ICAO *Manual of Aircraft Accident and Incident Investigation, Part III - Investigation* (2008b, pp. III-1-1 - III-1-2) recommends four areas of investigation: accident particulars; meteorological; technical; and human factors. The same areas of investigation are classified differently by the NTSB (2004a): operations; structures; powerplants; systems; air traffic control; weather; human performance; and survival factors.

3.4.2 Evidence sources used in recent aircraft accident investigation reports

3.4.2.1 Introduction

The reporting requirements of accident investigators are outlined in ICAO *Annex 13* (2001a) and the ICAO *Manual of Aircraft Accident and Incident Investigation, Part IV - Reporting* (2003b), which were discussed previously in Section 2.3.2.6.3.

There are four sections in the standard report format: factual information; analysis, conclusions; and safety recommendations (ICAO, 2001a). As all evidence used in the analysis and determination of causal factors must be introduced initially as factual information, it is with the first section of the reports that this research is most concerned.

Fifteen formal aircraft accident reports, written in accordance with ICAO *Annex 13* reporting guidelines, were reviewed to identify the type of evidence used in each section of the report.

The fifteen reports were comprised of five accident reports from each of the AAIB(2008d,e; 2009c,d; 2010f), ATSB (2010a-e) and the NTSB (2009j,k; 2010c,d,e), representing a range of general aviation, aerial work and commercial air transport operations, and including both fixed-wing and rotary-wing aircraft (as defined in

Section 2.2.1). The full details of each report are listed in Appendix B: in summary, there were eleven fixed-wing aircraft and four rotary-wing aircraft, with twelve aircraft operating commercially, two conducting aerial work, and one private flight.

The skew towards fixed-wing aircraft reflects the larger number of fixed wing aircraft than rotary-wing aircraft currently in operation (see Figure 2.11, Section 2.2.2.3 for UK General Aviation example).

The skew towards commercial aircraft operations over general aviation or aerial work operations is explained by the importance aircraft accident investigation agencies place on investigating accidents which pose the greatest safety risk. The ATSB (2010f) identifies the factors which influence the level of response provided to a safety occurrence as:

- "anticipated safety value of an investigation, including the likelihood of furthering the understanding of the scope and impact of any safety system failures
- likelihood of safety action arising from the investigation, particularly of national or global significance
- existence and extent of fatalities/serious injuries and/or structural damage to transport vehicles/other infrastructure
- obligations or recommendations under international conventions and/or codes
- nature and extent of public, interest, in particular the potential impact on public confidence in the safety of the transport system
- existence of supporting evidence or requirements to conduct a special investigation based on trends
- relevance to an identified and targeted safety program
- the extent of resources available and projected to be available in the event of conflicting priorities
- the risks associated with not investigating including consideration of whether, in the absence of an ATSB investigation, a credible safety investigation by another party is likely
- timeliness of notification
- training benefit for ATSB investigators".

The level of investigation response provided by the ATSB is guided by a hierarchy of aircraft operation types (ATSB, 2010f):

1. "Passenger transport - large aircraft
2. Passenger transport - small aircraft
   i. Regular public transport and charter on small aircraft
   ii. Humanitarian aerial work (for example, RFDS, SAR flights)
3. Commercial (that is, fare paying) recreation (for example, joy flights)
4. Aerial work with participating passengers (for example, news reporters, geological surveys
5. Flying training
6. Other aerial work
   i. Non-passenger carrying aerial work (for example, agriculture, cargo)
   ii. Private transport/personal business
7. High risk personal recreation/sport aviation/experimental aircraft operations

It is for these reasons that most of the aircraft in the sample group are commercial air transport, fixed wing aircraft. Investigations into accidents involving smaller, privately operated aircraft will generally have a report prepared in a less formal structure, such as in a bulletin. This is an acceptable practice under the *Annex 13* (ICAO, 2001a) and ICAO (2003b) guidance.

3.4.2.2 Report analysis

Each section of the fifteen selected aircraft accident reports was analysed to determine the sources or types of evidence used to provide the facts which the accident investigators employed to identify the causal factors of each occurrence. Within the first part of an *Annex 13* (ICAO, 2001a) report, which sets out the factual information, there are nineteen sub-sections. Each of these sections was reviewed for each accident report, and the types of evidence used were classified within the section. Appendix C is a full table of the evidence types identified in each report, both on site and off site. Table 3.1 is a summary of the evidence types used in each report section: the left column lists the nineteen sub-sections against which the investigator must report, and the other two columns the sources of evidence on site and off site.

Table 3.1: Summary of On Site and Off Site Evidence Sources Identified in Fifteen Sample Accident Reports

Report Section	On Site Evidence	Off Site Evidence
1. History of the Flight "A brief narrative giving the following information: * Flight number, type of operation, last point of departure, time of departure (local time or UTC), point of intended landing * Flight preparation, description of the flight and events leading to the accident, including reconstruction of the significant portion of the flight path, if appropriate * Location (latitude, longitude, elevation), time of the accident (local time or UTC), whether day or night" (ICAO, 2001a, Appendix paragraph 1.1)	* CVR data * FDR data * Non-volatile memory (NVM) including ACARS, EPGWS, EICAS and handheld GPS data * Site inspection * Aircraft inspection * Photographs * Review of aircraft manual from on board aircraft	* Witness statements * Crew statements * Emergency responder statements / logs * ATC voice recordings * Flight plans * Meteorological forecasts * ATC statements * Crew flight and duty time records * Review of Standard Operating Procedures (SOPs) * CCTV * Aerodrome information * Weight and balance calculations * Fuel planning documents * Radar traces * Passenger statements
2. Injuries to Persons Standard table for completion (ICAO, 2001a, Appendix paragraph 1.2)	* Site inspection	* Information from emergency services and coroners office

Table 3.1: Summary of On Site and Off Site Evidence Sources Identified in Fifteen Sample Accident Reports

Report Section	On Site Evidence	Off Site Evidence
3. Damage to Aircraft “Brief statement of the damage sustained by aircraft in the accident (destroyed, substantially damaged, slightly damaged, no damage)” (ICAO, 2001a, Appendix paragraph 1.3)	* Site inspection * Aircraft inspection	
4. Other Damage “A brief description of damage sustained by objects other than the aircraft” (ICAO, 2001a, Appendix paragraph 1.4)	* Site inspection	
5. Personnel Information a. “Pertinent information concerning each of the flight crew members include: age, validity of licences, ratings, mandatory checks, flying experience (total and on type) and relevant information on duty time b. Brief statement of qualifications and experience of other crew members c. Pertinent information regarding other personnel, such as air traffic services, maintenance, etc., when relevant” (ICAO, 2001a, Appendix paragraph 1.5)		* Logbook information * Licence type * Operator records * Crew statements * Employment records * Flight and duty time records * ATC movement records * Regulator records * Medical examinations * Statements from families * Statements from colleagues

Table 3.1: Summary of On Site and Off Site Evidence Sources Identified in Fifteen Sample Accident Reports

Report Section	On Site Evidence	Off Site Evidence
6. Aircraft Information a. “Brief statement on airworthiness and maintenance of the aircraft (indication of deficiencies known prior to and during the flight to be included, if having any bearing on the accident). b. Brief statement on performance, if relevant, and whether the mass and centre of gravity were within the prescribed limits during the phase of operation related to the accident. (If not and if of any bearing on the accident give details). c. Type of fuel used”. (ICAO, 2001a, Appendix paragraph 1.6)		* Summary of general aircraft information (including manufacturer, year of manufacture, powerplants fitted, number of hours / cycles operated etc.) * Maintenance records * Certification requirements * Weight and balance charts * Information regarding aircraft structure * Information regarding systems * Information regarding engines * Crew statements * Witness statements (those who had flown the particular aircraft or aircraft type) * Review of checklists * Review of flight manual * Review of operational guidance * Review of performance calculation charts
7. Meteorological Information a. “Brief statement on the meteorological conditions appropriate to the circumstances including both forecast and actual conditions, and the availability of meteorological information to the crew. b. Natural light conditions at the time of the accident (sunlight, moonlight, twilight etc.) (ICAO, 2001a, Appendix paragraph 1.7)	* FDR data	* Meteorological forecasts * Meteorological aftercasts * Meteorological observations * Pilot reports * Witness reports * Emergency responder reports
8. Aids to Navigation “Pertinent information on navigation aids available, including landing aids such as ILS, MLS, NDB, PAR, VOR, visual ground aids, etc., and their effectiveness at the time” (ICAO, 2001a, Appendix paragraph 1.8)	* Equipment fitted in aircraft * Handheld GPS * Charts on aircraft	* Equipment serviceability history * Witness statements * Maintenance records

Table 3.1: Summary of On Site and Off Site Evidence Sources Identified in Fifteen Sample Accident Reports

Report Section	On Site Evidence	Off Site Evidence
9. Communications "Pertinent information on aeronautical mobile and fixed service communications and their effectiveness" (ICAO, 2001a, Appendix paragraph 1.9)	* CVR recordings * Equipment investigation * ELT serviceability	* ATC recordings * ATC statements * SARWATCH timings * Operator statements * Crew statements
10. Aerodrome Information "Pertinent information associated with the aerodrome, its facilities and condition, or with the take-off or landing area if other than an aerodrome" (ICAO, 2001a, Appendix paragraph 1.10)		* Aerodrome location * Runway specifics * Aerodrome facilities * Approach procedure * Aerodrome procedures * ARFFS capabilities * ATC statements * ATC voice recordings * Radar traces * NOTAMS * Maintenance records
11. Flight Recorders "Location of the flight recorder installations in the aircraft, their condition on recovery and pertinent data available therefrom" (ICAO, 2001a, Appendix paragraph 1.11)	* FDR data * CVR data * QAR data * NVM	* Maintenance records * Regulatory requirements * Witness photographs and video * Radar traces * IHUMS data from operator
12. Wreckage and Impact Information "General information on the site of the accident and the distribution pattern of the wreckage; detected material failures or component malfunctions. Details concerning the location and the state of the different pieces of the wreckage are not normally required unless it is necessary to indicate a break-up of the aircraft prior to impact. Diagrams, charts and photographs may be included in this section or attached in the Appendices" (ICAO, 2001a, Appendix paragraph 1.12)	* Site inspection * Aircraft / wreckage inspection * Plot of wreckage, debris and ground damage * Systems inspections	* Records of part numbers * Video footage
13. Medical and Pathological Information "Brief description of the results of the investigation undertaken and pertinent data available therefrom" (ICAO, 2001a, Appendix paragraph 1.13)		* Post-mortem examination * Injury records * Search and rescue records * Witness statements * Passenger statements * Breathalyzer tests on crew

Table 3.1: Summary of On Site and Off Site Evidence Sources Identified in Fifteen Sample Accident Reports

Report Section	On Site Evidence	Off Site Evidence
14. Fire "If fire occurred, information on the nature of the occurrence, and of the fire fighting equipment used and its effectiveness" (ICAO, 2001a, Appendix paragraph 1.14)	* ARFFS laid foam * Inspection for ground or in-flight fire * Damage to surrounds * Thermal camera images	* Emergency fire responders
15. Survival Aspects "Brief description of search, evacuation and rescue, location of crew and passengers in relation to injuries sustained, failure of structures such as seas and seat belt attachments" (ICAO, 2001a, Appendix paragraph 1.15)	* ELT search * Cabin inspection * Aircraft specific emergency card procedures * Wreckage inspection * Exit doors inspection	* Passenger statements * Search and rescue statements * Search and rescue log * Crew statements * Witness statements * Search and rescue SOPs * Witness video * Training procedures
16. Tests and Research "Brief statements regarding the results of tests and research" (ICAO, 2001a, Appendix paragraph 1.16)	* Serviceability tests * Component inspection * Fuel samples * Engine examination * Systems examination * CVR data * Biological matter	* Aircraft simulations * Flight tests * Maintenance records * Tests on comparison components * Engine examinations * Systems examinations * Component simulations * Sound spectrum study * Passenger survey
17. Organisational and Management Operations "Pertinent information concerning the organisations and their management involved in influencing the operation of the aircraft. The organisations include, for example, the operator; the air traffic services; airway, aerodrome and weather agencies; and the regulatory authority. The information could include, but not be limited to, organisational structure and functions, resources, economic status, management policies and practices, and regulatory framework" (ICAO, 2001a, Appendix paragraph 1.17)		* Organisational structure * Operator records * Training requirements * SOPs * Operations manual * Air Operator Certificate * Operator Safety Management System (SMS) * Regulations * Emergency response procedures * Review of previous accidents * Post accident actions * Witness statements * Crew statements * Flight and duty time records * Simulator observations * Maintenance records

Table 3.1: Summary of On Site and Off Site Evidence Sources Identified in Fifteen Sample Accident Reports

Report Section	On Site Evidence	Off Site Evidence
18. Additional Information “Relevant information not already included” (ICAO, 2001a, Appendix paragraph 1.18)	* Switch positions * CVR data	* Review of previous accidents * Review of previous safety recommendations * Review of regulations * Review of SOPs / guidance material * Training oversight * System simulations * Flight simulations * Crew statements * Witness statements * Operator statements * Review of safety studies * Survivability testing
19. Useful of Effective Investigation Techniques “When useful or effective investigation techniques have been used during the investigation, briefly indicate the reason for using these techniques and refer here to the main features as well as describing the appropriate sub-headings” (ICAO, 2001, Appendix paragraph 1.19)	* Not used in sample reports	* Not used in sample reports

Comment on some of the sub-sections listed in the table is useful.

History of the flight provides an overall picture of the accident site and the background to the accident. The sources of evidence, both on site and off site are numerous, and generally also used elsewhere in the report.

The ‘standard table’ referred to in *Injuries to Persons* is shown in Figure 3.1.

Injuries	Crew	Passengers	Others
Fatal			
Serious			
Minor/none			■

Figure 3.1: Table for recording injuries to persons
Source: ICAO, 2001a, Appendix Paragraph 1.2

Of the fifteen accidents in this study, nine were fatal. The table is intended to identify physical injuries, but in one ATSB report (ATSB report AO-2007-070, 2010a) it was noted that psychological trauma was apparent in some of the passengers following the accident. Identification of the number of fatalities and level of injuries to crew and passengers may require collaboration with the emergency services and coroner's office.

Damage to Aircraft and *Other Damage* are answered through site inspection and aircraft inspection, to provide an overview of damage that occurred during the accident sequence. Damage sustained to aircraft in the sample reports ranged from "repairable" to "destroyed". In only two of the fifteen accidents was other damage reported: house and vehicle damage during impact (NTSB AAR10/01, 2010c), and damage to airport lighting and a perimeter fence following a runway overrun (NTSB AAR-10/02, 2010d).

Personnel Information is self explanatory and the evidence entirely off site.

All evidence relating to *Aircraft Information* was obtained off site. However, the evidence sought was guided by on site inspection of damaged components. For example, if an aircraft sustained damage to its landing gear, or particular instruments were found to be in a failed condition, off site evidence would be sought about the landing gear system or the instrumentation system. It is therefore common for some form of site assessment to be required before the evidence needed for this sub-section of the report can be obtained.

The *Meteorological Information* in the sampled reports broke down into three distinct areas: forecasts, aftercasts and observations. Forecasts are the weather information that pilots have on take-off. Aftercast reports are issued by meteorological authorities on the basis of tracked weather patterns but in the absence of direct and real-time observations: one example within the sample reports is an aftercast made of the weather in remote Western Australia, where there were few other sources of actual weather information at the time of the accident (ATSB AO-2007-047, 2010c). Meteorological observations are conditions measured at a certain time, either automatically (such as by an automated surface observing system [ASOS]) or by a trained meteorological observer. Observations generally exist for accidents that have occurred at an air traffic controlled airport. Reports from other pilots flying in the area, or witnesses on the ground, or emergency responders, may also be of assistance.

Although meteorological information is generally collected off site, data gathered on the site may assist in confirmation of the weather conditions at the time of the accident. For example, in one of the reviewed reports, FDR data recovered from the aircraft measured the windspeed and direction during the aircraft landing (ATSB AO-2008-007, 2010d). In another report, the CVR transcript was used to confirm to investigators that the crew had the correct ATIS information for the time.

Aids to Navigation, and *Communications* records are mostly investigated away from the accident site, by using ATC recordings and tapes and independent checks on the functioning on navigation aids. However, an on site check of the serviceability of radios and navigation instruments fitted on the aircraft might be possible.

Much of the *Aerodrome Information* can be obtained through documents and records. However, if the accident occurs on take-off or landing at an airport, then the runway and its surroundings may form part of the accident site to be investigated.

There was extensive reliance in the reports on information contained in the *Flight Recorders* (where fitted). The many different sources of data available on the aircraft include the flight data recorder (FDR), cockpit voice recorder (CVR) and the quick access recorder (QAR). Other data may be recorded as non-volatile memory (NVM) in the electronic memory of systems such as FADEC/ECU, GCU and BPCU, EGPWS, EICAS, and handheld GPS units.

Although the FDR and CVR are crash protected, they may be damaged through fire on impact, or from being exposed to the environment following an accident. In one of the sampled accidents (ATSB 2008-067, 2010e), some parts of the CVR and FDR data were lost following exposure to sea water. Investigators need to balance the special procedures required for recovery of data sources as well as the hazards they may encounter at the site, to ensure that the quality of the data is maintained (see Section 3.4.3)

Wreckage and Impact Information necessarily involves site inspection. Such evidence depends on inspection of damage to the aircraft, and completion of a plot of the wreckage, debris and ground damage. Once an overall appreciation of the site is gathered, then further in-depth inspection of particular systems on the aircraft, such as instruments, electrical systems, propeller, powerplants, landing gear and hydraulics can be carried out. As with *Aircraft Information*, there is little off site evidence about the wreckage and impact that can be gathered without the benefit of on site evidence. Components of the aircraft may be recovered back to a base where further analysis can be carried out, but without the guidance of a site investigation the investigation of failed systems will be difficult.

Medical and Pathological Information generally comes from post-mortem examinations or records of injury to crew and passengers.

The investigation of *Fire* again requires site examination, to determine whether fire occurred pre-impact or post-impact, and to identify its origin. Components will generally be recovered for laboratory analysis. Statements from emergency response personnel, witnesses and the crew and passengers are useful in identifying where to search the accident site.

The report section on *Survival Aspects* calls for identification of factors which might have enhanced the chances of survival for crew and passengers. Some accidents in the sample were considered to be not survivable; for others an inspection of the wreckage suggested evidence whether survival levels had been assisted or hampered. This also is enhanced by statements from crew, passengers, witnesses and emergency responders.

The *Tests and Research* sub-section provides for reporting of the results of tests following the accident. Such tests depend upon the prior recovery of testable aircraft components, or suggestions from the on site inspection about which aircraft systems need further investigation. Items and tests reported on in this section may be linked to the section of *Additional Information.*

Organisational and Management Information allows for identification of any evidence of latent conditions which may have contributed to the accident. Most of this evidence must be collected off site, and includes potential factors such as weaknesses in the organisational structure of the operator, the quality of the maintenance organisation, the capacity of the air traffic control authority, the safety management systems and safety culture of organisations involved, and the SOPs of the groups involved in the accident.

Use of Effective Investigation Techniques, which is the last of the nineteen sub-sections in the *Annex 13* (ICAO, 2001a) report format, is only included in the report when need arises. There was no entry in this sub-section in any of the fifteen sample reports. Only one recent AAIB accident report (Aircraft Accident Report 1/2010, 2010b) included the results of a data mining exercise in this section.

3.4.2.3 Discussion

The purpose of this section of the research has been to identify the on site and off site sources of evidence that aircraft accident investigators commonly use when investigating an aircraft accident.

Through analysis of recent accident reports, it has been identified that evidence must be collected from a variety of different sources, and very little of the report can be completed without both the on and off site components of an investigation.

Off site sources of evidence include statements from crew, passengers, witnesses, and SMEs, recorded aircraft traces, operational guidance, and aircraft specific information. Analysis activities such as simulations, flight tests, and failure tests may also be conducted away from the accident site.

On site sources of evidence include wreckage plotting and examination of the different structures, systems and components which make up the aircraft. The on site activities identified through the reports are summarised in Table 3.2.

Table 3.2: On Site Evidence Collection Tasks Identified from Sampled Accident Reports

On Site Evidence Activities	
Site inspection	Aircraft recovery
Aircraft inspection	Location of accident
Recover FDR/CVR/NVM	Cabin and cargo inspection
Engine inspection	Fuel quantities on aircraft
Systems inspections	Photography
Propeller inspections	Crew materials/paperwork
Flight deck inspection	Bird matter from site

Often components are not analysed on the site, but rather those with identified problems are recovered from the site to a laboratory or headquarters for further examination. Care must be taken by the investigators not to allow further damage to occur to components of interest before laboratory analysis can be conducted.

3.4.3 On Site Evidence Types and Collection Techniques Recommended in ICAO *Manual of Aircraft Accident and Incident Investigation, Part III - Investigation* (2008b)

3.4.3.1 Introduction

In the previous section, the evidence referred to in fifteen recent aircraft accidents was identified. The major forms of on site evidence collection identified were tabled in Table 3.2.

The next stage towards determining the hazards that affect aircraft accident investigators during evidence collection is to identify the techniques used to collect the required evidence on site.

This was conducted through the application of content analysis on Part III of the ICAO *Manual of Aircraft Accident and Incident Investigation* (2008b), ensuring that all evidence sources included in Table 3.2 were included.

3.4.3.2 Review of on site evidence collection techniques

The full results of the content analysis, showing the evidence collection techniques used to collect on site evidence are included as Appendix C.

3.4.4 Discussion and conclusions

Section 3.4.2 showed that, in order to collect all the evidence required for completion of an investigation, both on site and off site evidence collection techniques are needed.

This results of this stage of the research (Section 3.4.3.2, Appendix D) indicate that the techniques required to collect evidence on site require investigators to conduct detailed inspections of different systems and components, which required close contact with many different materials and chemicals. It is during the completion of these tasks that the investigators may become exposed to accident site hazards.

3.5 Review of Hazards

3.5.1 Overview

Within this section of the research, there are five questions to be answered about each hazard:

1. What is the hazard?
2. Why is this hazardous to aircraft accident investigators?
3. Where the hazards exist on an aircraft accident site?
4. How does the hazard interact with an investigators work?
5. What are the recommended practices for aircraft accident investigators to use to protect themselves from exposure to this hazard?

Where possible, an accident site example has been provided for each hazard, to highlight where these hazards have occurred in real world examples. This analysis considers the effects of each hazard as an individual concern on an accident site, rather than the hazards which affect an accident site as a whole.

3.5.2 Environmental Hazards

3.5.2.1 Overview

Environmental hazards are those arising from the location and site characteristics of the aircraft accident. ICAO *Circular 315* (2008a) subdivides environmental hazards into "location (both geographic and topographic), fatigue (effects of travel and transportation), insects/wildlife, climate, security and political situation". These hazards are unrelated to the type of aircraft or the nature of its cargo.

3.5.2.2 Geographic and topographic location

ICAO *Circular 315* (2008a) takes the first of its five subdivisions and observes that:

> "The accident location frequently poses a range of hazards to investigators due to the geographic and topographic location of the site. On land, the site may be located in remote or built-up areas, at altitude, or in very difficult terrain; each of these may pose particular hazards. Marine situations can pose their own problems depending on whether the accident site is in shallow or deep water. Recovery issues pose great risk where divers need to be deployed" (ICAO, 2008a, paragraph 3.2.1)

The analysis which follows is in the terms of this paragraph: the investigation of air accidents in remote areas of high altitude or difficult terrain; in built-up areas; and in marine situations.

Due to the global nature of aviation, aircraft accidents may occur anywhere. Accident investigators in the State of Occurrence might travel only a relatively short distance to an accident site (for example, AAIB accident investigators attending the Boeing 777 crash at London Heathrow Airport on 17th January 2008) or might need to travel comparatively long distances regularly (for example, NTSB investigators attending major incidents across the USA). Accident investigators attending an accident site as an accredited representative or technical advisor can be called anywhere in the world.

The data show that most major accidents have occurred at or near airports, many of which are of course in quite remote locations. Figure 2.4 (in Section 2.2.2.2) gives the percentages of fatal commercial jet aircraft accidents that occurred in different phases of flight over the period 2000-2009 (Boeing, 2010). If the figures for those years are taken to be the norm, 55 per cent of accidents occur during take-off and initial climb or final approach and landing, and an additional 13 per cent occur on the ground at the airport. Thus it would appear from these statistics that in the majority of major accident investigations, aircraft accident investigators will be based either on or near an airport (however remote). The remaining 32 per cent of major aircraft accidents might occur virtually anywhere.

When being deployed to an accident site, there is potentially a large amount of investigative and personal equipment that an investigator may want to take to the site. This might not be difficult on a local deployment, if investigators are able to drive from their base to the site. It is more difficult if flying to a site, or if difficulty of access to the site requires all equipment to be carried in physically. The geographic location of an accident might affect not only the ease of access of investigators, but also the quantity of evidence they can collect and remove from the site.

The location of the accident site affects the response time to the accident, which in turn affects the level of perishable evidence that can be collected (Section 2.3.2.4.2.2). The geographic location of the accident site also affects other hazards, such as fatigue (due to travel distance), bad weather and poor security.

Particular issues with evidence collection arise if the aircraft wreckage is located in a protected site, for example one of the more than 4000 designated Sites of Special Scientific Interest (SSSI) in England (Natural England, 2010). Investigators have a responsibility to prevent further damage to the surroundings within an SSSI, and their work may be supervised by environmental protection officers.

3.5.2.2.1 Remote areas, and areas of high altitude or difficult terrain

The remoteness and site characteristics of the landscape in which aircraft crash may create particular hazards. The topography will affect the ease of access to a site, the difficulty or otherwise of evidence collection, and the level at which site security can be managed. Review of past accidents in similar sites may assist investigators with their generic hazards assessment when these accidents occur.

Khatwa and Roelen (1996) found that around one quarter of the 156 accidents resulting from Controlled Flight Into Terrain (CFIT) during the period 1988-1994 occurred in sites of significant terrain, and 6 per cent occurred in areas of high terrain. The crash conditions were known for 135 aircraft: 97 per cent of them were destroyed, resulting in 3177 fatalities and a mean fatality rate of 91 per cent per aircraft. These statistics suggest that aircraft accident investigators responding to passenger aircraft involved in CFIT accidents in hilly or mountainous terrain, should base their generic risk assessment on a very damaged aircraft with a high level of blood-borne pathogens on the site.

Khatwa and Helmreich (1998-1999) extended this study to review accidents in the period 1980-1998, and found that 67 per cent of the CFIT accidents in this period occurred in hilly or mountainous terrain. The aircraft in this sample can be assumed to have similar site specifics (substantially damaged or destroyed aircraft, high level of fatalities) as the sample for 1988-1994. However, since requirements have now been introduced for Enhanced Ground Proximity Warning Systems (EGPWS) on commercial aircraft, the CFIT accident rate has reduced to almost nil (Matthews, 2004). Figure 2.5 (see Section 2.2.2.2) shows that of the 89 fatal accidents that occurred amongst the western-built commercial jet aircraft fleet in the period 1999-2008, only sixteen were the result of CFIT, although this still resulted in 961 fatalities (Boeing, 2010).

One CFIT accident was an Air Inter A320 which crashed into mountainside while on approach to Strasbourg Airport on 20th January 1992. The area was dense forest, which hampered entry to the site for both rescue workers and accident investigators (Figure 3.2).

Figure 3.2: Air Inter A320 Accident Site, 1992
Source: BEA, 1993

Aircraft accidents which occur in remote areas will take longer for investigators to respond to, which is likely to result in disruptions to the site through time, lack of security, and loss of perishable evidence.

The wreckage of an American Airlines Boeing 757 which crashed near Cali, Columbia in 1995 was located along the top of a mountain ridge at 9000ft above mean sea level (AMSL). The impact site was on the east side of the ridge, and the majority of the wreckage on the west side of the ridge. There was approximately 500ft vertical height between the top of the ridge and the main wreckage point. Only four of the 163 people on board survived the accident. The accident site took eight hours to locate, when emergency responders arrived on site via helicopter (Aeronautica Civil of the Republic of Columbia, 1996).

The danger in investigating accidents in mountainous accident sites comes both from the physiological dangers of working at altitude, and the physical exertion required to access and investigate in areas with steep, unstable terrain.

“High-altitude illness (HAI) occurs when hypoxic stress outstrips acclimatisation. HAI can occur at any altitude above 2100m, but is particularly common above 2750m” (WHO, 2009). When investigators travel to an accident site at high altitude, they might not have time to acclimatise before beginning the investigation tasks. Indeed, aerobic exercise might exacerbate the problem: travellers are advised to avoid overexertion for at least 24 hours after reaching altitude (WHO, 2009). Potential methods of avoiding exertion include limiting working periods, or directing others, who are perhaps better acclimatised, to collect perishable evidence and to photograph the site.

Areas of difficult terrain are not all necessarily remote. The fire service was unable to extinguish the fire caused when a Piper Navajo crashed after take off from Oxford Airport (15th January 2010), as they could not get trucks across a field to the aircraft, nor did they have hoses of sufficient length to reach the site (BBC, 2010). If the fire had been extinguished earlier, less damage would have been caused to the fuselage.

3.5.2.2.2 Built-up areas

The hazards of attending urban accident sites are not directly considered in *Circular 315* (ICAO, 2008a). It refers to other guidance documents, including *ICAO Circular 298 Training Guidelines for Aircraft Accident Investigators* (ICAO, 2003a) and the NTSB *Accident Investigation Manual: Major Team Investigations* (NTSB, 2002a).

Circular 298 (ICAO, 2003a) notes that "utilities such as gas mains, electricity transmission lines and main transport routes require special consideration. The crash of a Colgan Air Dash 8 (12th February 2009) ruptured a natural gas pipeline, causing a fire which took close to twelve hours to extinguish (NTSB, 2009b). Once the site was declared safe, the investigators had to search through burnt aircraft wreckage and house rubble to collect evidence (Figure 3.3).

Figure 3.3: Colgan Air Dash 8 Accident Site (February 2009)
Source: NTSB, 2009b

Built-up areas commonly surround or are near airports. On 17th July 2007, a TAM Airlines A320 overran the runway at Congonhas Airport in Sao Paulo, hitting a fuel service station and an air cargo service building (CENIPA, 2009). As well as dealing with the aircraft hazards, the accident investigators faced additional hazards from fuel (from the service station) and rubble from the building, which was so extensively damaged that it had to be demolished. The El Al B747 freighter crash in Amsterdam on 4th October 1992 also impacted with a building joining two eleven storey apartment buildings (Netherlands Aviation Safety Board, 1994). The hazards created by aircraft impacting with buildings include fire and hazards created by materials from which the buildings are constructed.

Aircraft accidents in urban areas may cause third-party fatalities, as was the case in both the TAM A320 and El-Al Crashes described above. Figure 2.5 (Section 2.2.2.2, Boeing 2010) shows, by CICTT aviation occurrence categories, the number of external (third party) fatalities for commercial jet aircraft accidents 2000-2009. Of the fourteen categories of fatal accident, nine categories included third party fatalities on the ground (excluding mid-air collision). Third party fatalities add to the level of biological hazards on the accident site.

Site security at aircraft accident sites in highly-populated urban areas can be more difficult than on other sites, due to the number of people present around the site. Nearby residents may need to be moved. Figure 3.4 shows two images of the damage following the crash of a TAM Fokker 100 aircraft into housing, following an engine failure on take-off from Congonhas Airport, San Paulo, Brazil on 31st October, 1996. The wreckage is unstable and the buildings damaged, yet there are many people present on the site.

Figure 3.4: Site photographs from TAM 402, 1996
Source: http://www.desatresaeros.net

Examples of aircraft that have crashed on take-off include the collision between a KLM Boeing 747-200 and a Pan-Am Boeing 747-100 at Los Rodeos Airport (now Tenerife North Airport) on 27th March 1977; a Singapore Airways Boeing 747-400 at Taiwan Airport (31st October 2000), and a Spanair MD-82 that crashed while taking off at Madrid Barajas Airport (20th August 2008).

Recent accidents that have occurred during landing include an American Airlines MD-80 at Little Rock, Arkansas (1st June, 1999); a China Airlines MD-11 at Hong Kong International Airport (22nd August 1999); a Garuda Boeing 737-400 at Yogyakarta Airport, Indonesia (7th March 2007); the British Airways Boeing 777-200 at London Heathrow airport (17th January 2008) (Figure 3.5); a Turkish Airlines Boeing 737-800 at Schiphol Amsterdam International Airport (25th February 2009); and a FedEx MD-11 at Tokyo Narita Airport (23rd March 2009).

In most accidents on take-off and landing, the site to be investigated will be within or adjacent to the airport boundary.

Figure 3.5: View of BA777 accident site at LHR, 17 January 2008
Source: AAIB, 2010b

Investigation within an airport boundary reduces the problem of site security, due to the already established airport fences. However, the site will still need to be secured against workers permitted to be within the airport boundaries. Investigators will need to be aware of dangers posed by aircraft operating in the vicinity, such as on taxiways or parallel runways. Additionally, if the location of the wreckage prevents aircraft from operating at the airport, or reduces the number that can operate, then the investigators will be under pressure from the airport operators to move the aircraft as soon as possible.

Airports are in the normal course of events hazardous workplaces, on which the health and safety of the workforce needs to be managed. Some of the hazards are set out in Table 3.3: these would affect aircraft accident investigators at airport sites, in addition to hazards arising from the wreckage. Investigations on airport sites do not however raise issues faced in more remote locations, such as transport to the site (unless the airport is closed by the accident, and an alternate airport is needed), the availability of accommodation, and availability of facilities for interviews and communication.

Table 3.3: Hazards of Working on Airports

Hazard	Possible Sources
Manual handling	Handling cargo and baggage, but also equipment such as vacuum cleaners and catering trolleys
Falls from heights	Falls from aircraft holds, conveyor belt vehicles, catering vehicles and maintenance platforms
Moving vehicles	Vehicles driving up to and away from the aircraft, vehicles passing close to the aircraft on their way to another stand, or crossing pedestrian routes
Fire and explosion	Refuelling of aircraft
Hazardous substances	Exposure to body fluids and sanitary waste, injuries from discarded hypodermic needles (needlestick injuries) during aircraft cleaning, skin exposure to aircraft fuels, fumes from aircraft and vehicle engines
Noise	Aircraft auxiliary power units and engines, ground power units and vehicle engines
Electricity	Ground power units and cables
Machinery	Moving parts of machinery (eg. conveyor belts)
Slips and trips	Badly stowed cables, spillages of fluids (eg. fuel, oil. hydraulic fluid)

Source: HSE, 2000

3.5.2.2.3 Marine situations

Where an investigation occurs in international waters, such as the crash of the A330 on 1st June 2009 in the South Atlantic Ocean, the conduct of the investigation is the responsibility of the State of Registry (ICAO, 2001a), in that case, France. *Annex 13* (ICAO, 2001a, paragraph 5.3.1) provides that: “States nearest the scene of an accident in international waters shall provide assistance as they are able, and shall, likewise, respond to requests by the State of Registry”. In the A330 example, initial search and rescue capabilities were provided by navies from Brazil, France, USA and Spain (BEA, 2009e). Accident investigators from France, accredited representatives, and technical advisors alike all had to travel to the aircraft accident site, involving “...transits of the order of two to four days from ports such as Praia (Cape Verde), Natal (Brazil), or Dakar (Senegal)” (BEA, 2009c, p. 33).

Four factors influence the success of sea recoveries: the depth; the meteorological conditions; the mobilisation times (distance in relation to naval bases); and the political context (BEA, 2004). Accident investigation involves locating the wreckage, and its recovery.

Emergency responders to the A320 landing on the Hudson River lashed cable through the front doors of the aircraft to prevent the fuselage from sinking. This allowed the aircraft to be towed to a dock and recovered from the water two days later (NTSB, 2009g, 2009h, 2009i).

In contrast, the search for wreckage from the A330 crash in the South Atlantic Ocean on 1st June 2009 has taken over a year. In this period there have been three phases of sea search operations: Phase 1 (10th June to 10th July, 2009) which involved five navy vessels (including a submarine), an oceanographic specialist boat, and two tug boats (BEA, 2010a); Phase 2 (27th July to 17th August, 2009) during which the oceanographic boat continued sonar scans of the ocean floor in the expected region of the accident site; and Phase 3 (2nd April to 24th May, 2010) which involved an American ship equipped with a deep water sonar and a remotely operated vehicle (ROV), and a Norwegian ship equipped with six autonomous underwater vehicles (AUV) and one ROV. Over these three search periods, 6300 km^2 was searched without the successful location of more than floating debris (BEA, 2010).

Accident investigators might spend an extended period of time at sea during the search period, or they might be able to return to a land base each night. Whatever the case, accident investigators must be prepared to spend a large amount of time on the water, in sometimes unfavourable weather conditions, without succumbing to the incapacitation of extreme sea sickness. Following the crash of TWA800, a Boeing 747-100 off the New York coast on 17th July, 1996, more than 225 navy divers and 150 civilian divers took part in 4,344 dives lasting 1,733 hours during the recovery period. There were also 2,679 hours of ROV use while locating and recovering the wreckage (US Navy, 1998).

Even once evidence is located on the ocean floor, there is the risk that it might be moved by ocean currents. The search and recovery of the wreckage of a Aerospatiale SA365N Dauphin helicopter which crashed into the North Sea on 27th December 2006 was delayed by inclement weather, and took 19 days to complete. The lower rear fuselage was found removed from the main debris site, and on the basis of further analysis, this separation was considered to have been caused by currents rather than through the accident sequence (AAIB, 2008e).

The Valujet DC-9 crash into the Florida Everglades on 11th May 1996 required divers to work amongst mud and sawgrass to recover aircraft components by hand. Debris was placed on a hovercraft and transported for decontamination, before being taken to a hangar for investigation (NTSB, 1997)

3.5.2.3 Fatigue

> "Extended journey times, circadian desynchronisation resulting from transmeridian travel, lengthy working hours and demanding working conditions can result in reduced performance as an outcome of fatigue. These are significant issues about which individuals should be aware and for which they should be prepared. Investigators should ensure they understand the physical and psychological demands of their work and when confronted with particularly demanding working conditions, seek medical advice at an early stage. It is recommended that investigators undergo a periodic medical examination to check their fitness for work at accident sites. Early provisions must be made for nourishment, rest and counselling of investigators, both during and following their exposure to the accident site" (ICAO, 2008a, paragraph 3.2.2)

Within the field of aviation, and particularly with regard to flight crew and maintenance workers, the potential negative effects of fatigue on job performance are well established. Hobbs (2008, p. 22) suggests that fatigue may "refer to physical weariness, emotional exhaustion, the degradation of skill that results from performing a mentally demanding task over an extended period, chronic fatigue related to weeks of work without an adequate rest, and finally, an unmet need for sleep". Aircraft accident investigators working on an accident site may succumb to all these causes of fatigue.

An aircraft accident may close the airport to which the accident investigators need to travel, thus requiring other and possibly slower means of transportation to be found. This will not only delay evidence collection, but might mean that the investigators are tired or jet lagged before they begin.

The need to begin evidence collection quickly means that unwary investigators might push themselves to collect as much evidence in as short a time as possible, seemingly benefiting the progress of the investigation, but possibly at the cost of their own diminishing efficiency. Added to this are external pressures, such as those from the media or from airport operators to move the aircraft. These pressures, combined with the possible steadily-developing fatigue of the investigator, can lead to mistakes being made. Additionally, if an investigator becomes less vigilant in attention to site hazards due to fatigue, there is an increased risk of injury through exposure.

3.5.2.4 Insects/Wildlife

> "Some sites, particularly in remote areas, will introduce the prospect of exposure to or contact with wildlife. The many insects and larger animals that bite, sting, inject or secrete can cause immediate or long-term health problems, some of which can be life threatening" (ICAO, 2008a, paragraph 3.2.3)

The insects and wildlife hazards posed on accident sites will differ between regions. Advice can be sought from foreign offices or health organisations about the insect or animal borne diseases prevalent in different countries: this information should be sought before an investigator travels to an accident site, so that inoculations or preventative medications, where available, are obtained.

“Rabies is the most important infectious health hazard from animal bites” (WHO, 2009). Rabies is included in a group of diseases called zoonoses, which are transmitted through “animal bites or contact with animals, contaminated body fluids or faeces, or consumption of foods of animal origin, particularly meat and milk products (WHO, 2009a). Animals potentially transmitting these diseases may be drawn to the site: investigators will need to keep distant to protect themselves from bites or other contact, and ensure high levels of hygiene after handling wreckage which might have been contaminated.

Tropical, subtropical and desert regions are home to various poisonous snakes, scorpions and spiders (WHO, 2009). These find shelter amongst aircraft wreckage, particularly if it is providing shade, and can attack unwary investigators. Caution should be taken when moving wreckage, and protective equipment used. Local knowledge will be useful for investigators in becoming aware of poisonous animals potentially present on the site.

Insects can carry a range of different diseases, which are transmitted through bites. Table 3.4 shows the vectors (carriers) and the diseases they can transmit. Protection from insects can be provided by insect repellants or chemicals, or by protecting the skin through layers of clothing. Again, local information should be sought.

Stellman (1998a) estimates that 22 per cent of people may suffer allergic reactions to plants, ranging from skin irritations to respiratory problems. Vegetation can also be sharp; access to the Boeing 747 accident site at Guam in 1997 was hampered by the presence of sword grass (NTSB, 2000).

The hazards from insects and wildlife might not only come from the environment. The MK Airlines 747 Freighter which crashed at Halifax, Nova Scotia on 14th October 2004 was carrying eighteen cargo pallets of fresh seafood (TSB, 2006). Anecdotal stories suggest that the smell the seafood created on the site during investigation was nauseating.

Table 3.4: Principal disease vectors and the diseases they transmit

Vectors	Main diseases transmitted
Aquatic snails	Schistosomiasis (biharziasis)
Blackflies	River blindness (onchocerciasis)
Fleas	Plague (transmitted by fleas from rats to humans)
Mosquitos	
Aedes	Dengue fever Rift Valley fever Yellow fever Chikungunya
Anopheles	Lymphatic filariasis Malaria
Culex	Japanese encepalitis Lymphatic filariasis West Nile fever
Sandflies	Leishmaniasis Sandfly fever (Phlebotomus fever)
Ticks	Crimean-Congo haemorrhagic fever Lyme disease Relapsing fever (borreliosis) Rickettsial diseases including spotted fever and Q fever Tick-borne encephalitis Tularaemia
Triatomine bugs	Chagas disease (American trypanosomiasis)
Tsetse flies	Sleeping sickness (African trypanosomiasis)

Source: WHO, 2009

3.5.2.5 Climate

> "Extremes of climate are likely to pose problems, especially to unprepared investigators, as can locations where changes in weather can occur suddenly. Even relatively small temperature changes can pose problems where wind and rain may also be involved and work is extended through a long day" (ICAO, 2008a, paragraph 3.2.4)

Working in the heat or the cold may reduce investigators' capacities, and put them at personal risk.

Table 3.5 is guidance for fire fighters on how to mitigate stresses from weather conditions (IAFF, 2003) which can similarly affect accident investigators.

Table 3.5: Climate hazards to Fire Fighters

Hazard	Body Area Usually Affected	Examples During Emergency Response	Mitigation Methods
High heat / humidity (ambient)	Entire body	Outdoor response activities involving moderate to high levels of work Response efforts while wearing encapsulating clothing	Provide air conditioning in fire apparatus and vehicles in route to emergency scene Provide increase staffing for controlling work/rest cycles Provide appropriate fire fighter rehabilitation following response efforts Use cooling devices in conjunction with PPE Use 'breathable' PPE
Ambient cold	Entire body Face Hands	Outdoor response activities during winter	Limit cold exposure times Provide heat spaces for rest and rehabilitation Use insulated PPE
Wetness	Entire body Hands	Outdoor response activities during inclement weather	Provide shelter, as possible Use water-resistant PPE
High wind	Entire body	Outdoor response activities during inclement weather	Provide shelter, as possible Use water-resistant PPE
Insufficient or bright light	Eyes (vision)	Outdoor work under bright conditions Response activities wit excessive or insufficient illumination	Provide external lighting Use anti-glare surfaces Provide eyewear with shaded lenses

Source: Adapted from IAFF, 2003

Investigation in hot weather may induce heat related stresses, including heat rash, heat cramps, heat stroke, and heat exhaustion (IAFF, 2003). Investigators must ensure their water intake is sufficient to prevent dehydration. Additionally, irritation from dust may be intensified by the heat (WHO, 2009).

Exposure to cold weather may, depending on severity, reduce manual performance, muscular performance, aerobic performance, reaction time, tracking vigilance, and the ability to perform cognitive tasks (Stellman, 1998b). Opportunity should be provided for investigators to acclimatise to the conditions before beginning work, and shelter should be provided (if possible) to allow breaks away from the site.

The sun, and UVA and UVB rays may, whether in hot or cold weather, result in "sunburn and sunstroke, snow blindness, [and] solar urtica (sun-induced hives)" (WHO, 2009). Wind may blow light pieces of debris away, leading to loss of evidence, and may cause windburn to investigators, causing personal harm.

Precipitation may affect working conditions by destroying perishable evidence by washing it away or covering it (eg. with snow), inhibiting visibility (in fog and mist), making the site slippery, and making the wreckage unstable. News reports suggest that the site search following the crash of an A321 in Islamabad on 28th July 2010 were delayed by heavy rains (eg. Shah, 2010).

3.5.2.6 Security

> "Criminal and terrorist threats are a feature of the social situation in many regions, even in seemingly safe cities. The advice and support of local contacts should be sought to determine security measures that should be adopted. Other political and social advice should be requested in order to not violate local traditions or regulations" (ICAO, 2008a, paragraph 3.2.5)

Security can pose a hazard to accident investigators in two ways: as a risk to themselves from trespassers on the accident site; and as a threat to the investigation, through theft or further damage of evidence. There is no set way of pre-determining how security might pose a hazard to an investigation: investigators must simply be alert to potentially arising situations, and monitor as necessary.

The occurrence of an aircraft accident inevitably creates much local interest. It is necessary to ensure that the site is sufficiently guarded to prevent people from entering. Following the Boeing 757 crash at Cali (20th December 1995), many parts of the wreckage were reportedly stolen from the accident site (Bajak, 1996), despite the difficulty of access to the site. Anecdotal reports suggest that this also occurred on the TAM accident site in San Paulo, Brazil (31st October 1996): Figure 3.5 (Section 3.5.2.2.2) shows the large number of people present around the site. Stolen parts from the accident site might be important evidence which can not be recovered.

In his paper "Investigation Challenges in an Active War Zone", Benzon (2006) discusses the NTSB response to a Boeing 737 crash in Afghanistan in February 2005. The associated hazards included attack from insurgents (investigators were flown to the site and supported by armed military personnel), and land-mines in the wreckage distribution area, which had to be located and disarmed. Along with these security hazards were a range of environment based hazards: travelling into Kabul from the USA, and using makeshift beds in army barracks along the way; and working on an accident site on a mountain ridge, with identified hazards including "the 11,000-foot altitude, the strenuous debarkation from the helicopter, and the snow". Investigators had to leave the site each night and return to Kabul by helicopter, "because of the cold night-time temperatures, the possibility of being weathered in, and the fact that the wreckage was attracting wild animals at night".

3.5.3 Physical Hazards

3.5.3.1 Overview

The *Circular 315* definition of physical hazards is simply:

> "Physical - fire, stored energy, explosives, structures". (ICAO, 2008a, paragraph 3.1.2)

This includes the categories of fire and flammable substances, stored energy components, pressurised gases, military and ex-military aircraft, recent safety equipment, pyrotechnics and explosives, and damaged and unstable structures. The predominant method of exposure to physical hazards is through puncture or damage of the skin surface, however secondary exposure may also be caused through inhalation or ingestion of products of combustion or energy release, and through absorption into the skin.

3.5.3.2 Fire and flammable substances

> "Fuel is likely to be one of the most common hazards encountered at a crash site. Fuel poses problems due to its flammability and its nature as a harmful substance. In practice, it is the flammable aspect that most needs to be guarded against. There are, however, other health hazards presented by inhalation of fumes and prolonged skin contact that should also be considered. Where available, the advice of an experienced fire officer attending the site should be sought in guarding against fire hazards and in securing fuel tanks and containers of other flammable liquids such as hydraulic fluids. Fire may also be the result of aircraft batteries short circuiting; this may be caused by impact damage. Prolonged exposure to fire fighting agents can also cause skin and respiratory injuries. These agents should be washed off skin and clothing as soon as possible". (ICAO, 2008a, paragraph 3.3.1)

A number of different types of fuel are used in the aviation industry, including AVGAS (used in most light piston engines), AVTUR/JET A1 (used in gas turbine engines) and MOGAS (used in some sport aviation aircraft). Other speciality fuels may be used in military aircraft, and will have their own specific properties and associated hazards.

Investigators may come into contact with fuel if is leaking over a site, or when taking a fuel sample. ICAO (2008b) recommends at least two litres of fuel be taken as samples, from a number of locations (if possible) for thorough testing.

The Material Safety Data Sheet (MSDS) for Jet A1 lists potential health hazards as (Shell Australia, 2010a):

> "Slightly irritating to respiratory system. Breathing of high vapour concentrations may cause central nervous system (CNS) depression resulting in dizziness, light-headedness, headache and nausea. Irritating to skin. Harmful: may cause lung damage if swallowed"

The MSDS (Shell Australia, 2010a) also identifies that the "liquid evaporates quickly and can lead to a flash fire or an explosion in a confined space". Investigators should ensure that they collect fuel samples in clean aluminium or steel containers, and check the site for any areas where fuel may be trapped. PPE recommended to be worn in a heavily Jet A1 soaked environment includes chemical resistant gloves, boots and apron, goggles, and a respirator (Shell, 2010a).

The health hazards of exposure to AVGAS differ from those of Jet A1 (Shell Australia, 2010b):

> Harmful by inhalation. Vapours may cause drowsiness and dizziness. Slightly irritating to the respiratory system. Harmful in contact with skin. Irritating to skin. Moderately irritating to eyes. Harmful if swallowed. Harmful: may cause lung damage if swallowed. Possibility of organ or organ system damage from prolonged exposure. Target organ(s): Blood-forming organs. Peripheral nervous system. May cause hereditable genetic damage. Possible risk of harm to the unborn child. Danger of cumulative effects. A component or components of this material may cause cancer. This product contains benzene which may cause leukaemia".

Any part of the body having direct contact with fuel should be immediately washed with water.

While fighting the fire created by an El Al Boeing 747-200 freighter hitting an apartment building in Amsterdam in 1992, firefighters sampled air quality to "determine dangerous concentrations of various gases like carbon monoxide, sulfur dioxide and cyanide, to check for the presence of flammable substances above their lower flammability limit, and to check on dangerous radiation levels". (Uijt de Haag *et al.*, 2000, p. 41).

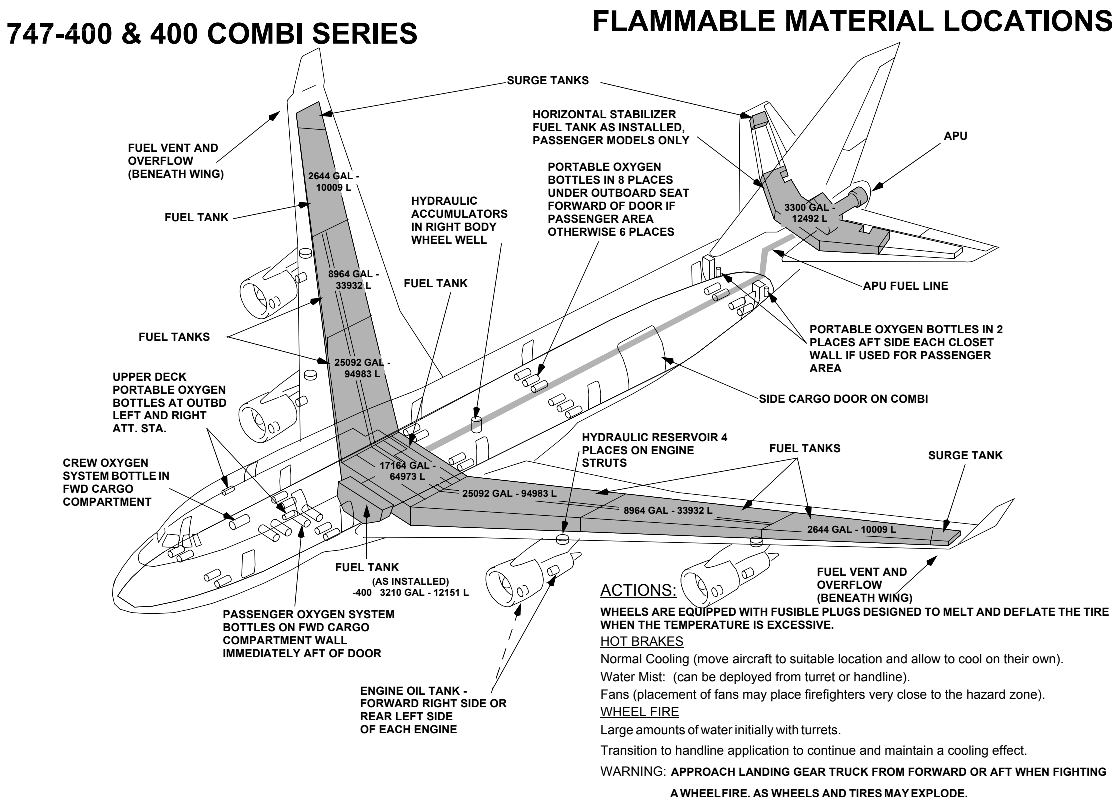
Figure 3.6 shows the locations of flammable substances on a Boeing 747-400 aircraft. The use of fire fighting charts, such as Figure 3.6, assists accident investigators in identifying the locations of flammable materials.

Birch (1988, p.5) identified six ways in which post-crash fires generally occur:

1. "Wing separation due to impact, which is invariably accompanied by massive dynamic fuel spillage;
2. Fuel release from ruptured tank(s) or fuel line(s);
3. Fuel take eruption due to external radiant heating;
4. Ignition of cabin materials, usually as a result of fuel spillage;
5. Engine fires as a result of malfunction;
6. Undercarriage fires often associated with system failure, tyre or impact damage".

Aircraft accident investigators do not generally have to deal with the post-crash fire of an aircraft, as they are rarely on scene at this point. However, having an understanding of these fire breakout mechanisms helps when conducting the site safety assessment to ensure that each of the possible sources of fire break-out are made safe.

Following a fire fighter response to an aircraft, aqueous fire fighting foam (AFFF) may have been laid around the wreckage. A foam layer starves a fire of oxygen, minimising the chance of re-ignition of a fire, but at the same time it can bury or destroy evidence. Investigators directly exposed to foam may experience irritation of the eyes and skin . It is for this reason that the AAIB (2008a) requests that the laying of foam is kept to a minimum.



ACTIONS:

WHEELS ARE EQUIPPED WITH FUSIBLE PLUGS DESIGNED TO MELT AND DEFLATE THE TIRE WHEN THE TEMPERATURE IS EXCESSIVE.

HOT BRAKES

Normal Cooling (move aircraft to suitable location and allow to cool on their own).

Water Mist: (can be deployed from turret or handline).

Fans (placement of fans may place firefighters very close to the hazard zone).

WHEEL FIRE

Large amounts of water initially with turrets.

Transition to handline application to continue and maintain a cooling effect.

WARNING: **APPROACH LANDING GEAR TRUCK FROM FORWARD OR AFT WHEN FIGHTING A WHEEL FIRE. AS WHEELS AND TIRES MAY EXPLODE.**

Figure 3.6: Location of Flammable Materials on a Boeing 747-400
Source: Boeing, 2007.

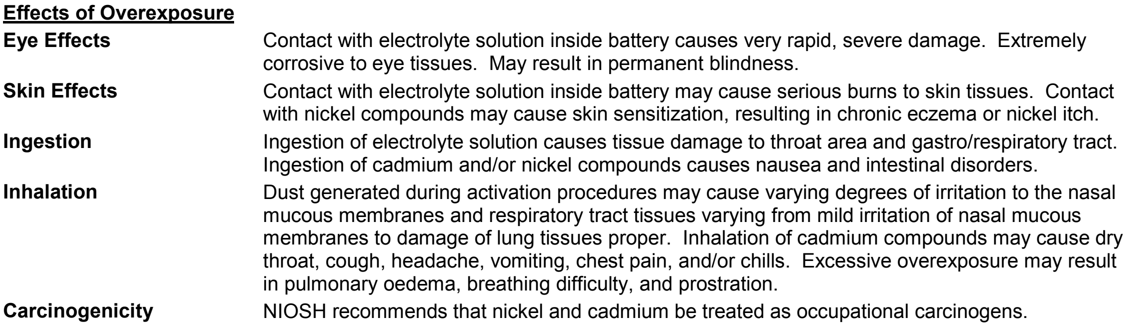
3.5.3.3 Stored energy components

> "Many aircraft structures and systems have the potential to cause injury to personnel. Electrical accumulators or capacitors and emergency power supplies can be hazardous due to their electrical potential and chemical content. Hydraulic accumulators, oleo struts, wheels and fire extinguishing bottles are examples of components that have potential stored energy". (ICAO, 2008a. paragraph 3.3.2)

If a system with stored energy is damaged during an accident or incident, the energy may be inadvertently released. This can occur immediately on damage, or during the movement of wreckage or the inspection of systems. The proximity of an investigator when investigating the system may mean exposure to injury as the potential energy is released.

The pressure within the hydraulic system of an A380 is reportedly 340 bar (5000 psi) (Flight Global, June 2005). Boeing has reported that the pressure in the tyres on many of their aircraft exceeds 200psi; they have records of five separate occasions where maintenance personnel have been killed or lost limbs when tyres have exploded (Boeing, 1999).

The aircraft battery manufacturer Saft reports the effects of exposure to chemicals in a Ni-Cd aircraft battery as shown in Figure 3.7:



Effects of Overexposure	
Eye Effects	Contact with electrolyte solution inside battery causes very rapid, severe damage. Extremely corrosive to eye tissues. May result in permanent blindness.
Skin Effects	Contact with electrolyte solution inside battery may cause serious burns to skin tissues. Contact with nickel compounds may cause skin sensitization, resulting in chronic eczema or nickel itch.
Ingestion	Ingestion of electrolyte solution causes tissue damage to throat area and gastro/respiratory tract. Ingestion of cadmium and/or nickel compounds causes nausea and intestinal disorders.
Inhalation	Dust generated during activation procedures may cause varying degrees of irritation to the nasal mucous membranes and respiratory tract tissues varying from mild irritation of nasal mucous membranes to damage of lung tissues proper. Inhalation of cadmium compounds may cause dry throat, cough, headache, vomiting, chest pain, and/or chills. Excessive overexposure may result in pulmonary oedema, breathing difficulty, and prostration.
Carcinogenicity	NIOSH recommends that nickel and cadmium be treated as occupational carcinogens.

Figure 3.7: Effects of Exposure to Chemicals in Ni-Cd Aircraft Battery
Source: Saft, 2010.

Investigators should visually inspect batteries for leakage before moving them. Leaking batteries should only be touched when wearing very high levels of chemical protective PPE. Care and protection should be used even when the battery does not appear to be leaking.

3.5.3.4 Pressurised gases

> "Some pressurised gases are carried onboard aircraft in containers of various design. The rapid discharge of these can pose a risk of physical injury or of asphyxiation if released on enclosed spaces. Some fire extinguishing agents can also be toxic. Pressurised oxygen can increase the risk of fire or explosion when released". (ICAO, 2008a, paragraph 3.3.3)

The risks posed by pressurised gases are physical injury to investigators due to explosion of the pressure bottle, and to illness or asphyxiation following ingestion of the chemicals within the cylinders.

A Boeing 747-400 carries thirteen steel oxygen cylinders, each pressurised to 12,755kPa/1,850psi (ATSB, 2009b). The damage that pressurised oxygen bottles can do to an aircraft in flight was demonstrated in October 2008 when a passenger emergency oxygen cylinder ruptured in a Qantas Boeing 747-400, and caused rapid decompression of the aircraft. The ATSB's first interim report on the accident (ATSB, 2009b, p.v) states:

> "It was evident that one passenger oxygen cylinder (number 4 from a bank of seven cylinders along the right side of the cargo hold) has sustained a sudden failure and forceful discharge of its pressurised contents, rupturing the fuselage and propelling the cylinder upward, puncturing the cabin floor and entering the cabin adjacent to the second main cabin door. The cylinder had impacted the door frame, door handle and overhead panelling, before presumably falling to the cabin floor and exiting the aircraft through the ruptured fuselage"

On the accident site of an Air France A340 which overran the runway at Toronto International Airport in 2005, the top of one oxygen bottle was blown 84m away from the wreckage in the post-crash fire (TSB, 2007). The bottle top landed across a creek, in an area which was not considered part of the accident site although still within the airport boundary, and could have severely injured anyone who had been standing there.

Protection against these hazards is similar to the protection required against stored energy components: awareness of possible dangers, visual inspection before touching, and personal protective equipment where necessary.

3.5.3.5 Military and ex-military aircraft

> "Current and former military aircraft are now commonly flying with civil registration. Civil aircraft crash investigators and emergency responders may, therefore, commonly come into close proximity with cockpit escape equipment and ejector seats, and, as a result, be subject to associated hazards". (ICAO, 2008a, paragraph 3.3.4)

The specific hazards highlighted by *Circular 315* (ICAO, 2008a) in relation to military and ex-military hazards are the dangers associated with cockpit escape equipment and ejector seats. In the civilian aircraft world, ejector seats are rarely installed.

CAP 632: Operation of 'Permit-to-fly' Ex-military aircraft on the UK Register (CAA, 2009) provides guidance to operators of most ex-military aircraft or replicas thereof (ex-military aircraft with MTWA > 2370kg, with a piston engine greater than 800hp, or with a turbine or turbojet aircraft). This document requires systems in the aircraft to be operated and maintained as they would have been during military service - this may include having ejection seats and canopies fitted.

The Martin Baker Mk 16A seat, as fitted on the Typhoon, ejects at 600 KIAS (Martin Baker, 2010). If this went off unwittingly in the vicinity of an investigator, serious injury at least is likely to occur. Also included within the ejection seat structure are explosive cartridges for the parachute, actuators and oxygen bottles. These may also pose a hazard to investigators. Aircraft with ejection seats fitted should have this clearly marked on the aircraft.

Civilian investigators are responsible for the investigation of accidents involving military aircraft if they occur at civilian airfields. Investigators need to be aware of the risk involved, and of the methods of preventing inadvertent ejection, or have access to specialist expertise.

3.5.3.6 Recent safety equipment

> "Other safety equipment is being introduced into civil aircraft, for example, rocket-deployed emergency parachute systems and airbag restraint systems are being installed across a range of aircraft. Often these systems are not clearly market and may not be marked at all. The armed and unfired rocket of an rocket-deployed recovery parachute system may pose a potential hazard to investigators and rescue personnel". (ICAO, 2008a, paragraph 3.3.5)

Recovery parachutes and airbag systems are becoming increasingly common in new general aviation aircraft.

BRS Aviation, a company that manufacture ballistic recovery systems, claims to have installed over 30,000 aircraft parachute systems (BRS Aviation, 2010). There are three categories of BRS offered: those for experimental aircraft; for sport aircraft; and for certified aircraft. Types of certified aircraft that may be fitted with BRS include the Cirrus SR20, SR22 and SRV aircraft, Cessna 172s and 182s, and the Cessna 182 Katmai-260se STOL. The parachute system is not the same on each of these aircraft (BRS Aviation, 2010).

BRS parachutes are not pre-charged, and if in normal operating conditions the system is purposely initiated, the parachute will not deploy. However in crash conditions, the system may become unstable and unintentional deployment is possible. As with ejector seats, investigators should know the steps required to make the system safe before attending accident sites, or who to contact if they are unable to do so. The system must be made safe before entry into the aircraft or wreckage to begin investigation.

Seat-belt mounted airbags are being introduced into both the general aviation and commercial fleets. Cathay Pacific has fitted these seats-belt airbags to their A340 and Boeing 777 fleet (Amsafe, 2010). Figure 3.8 shows a deployed airbag in a general aviation aircraft. The manner in which airbags deploy in commercial aircraft are similar. If not deployed in the accident sequence, they have the potential to deploy subsequently when the investigator is working within the cockpit or cabin. Investigators should be aware of the direction the airbag could deploy, and steer clear of this area.

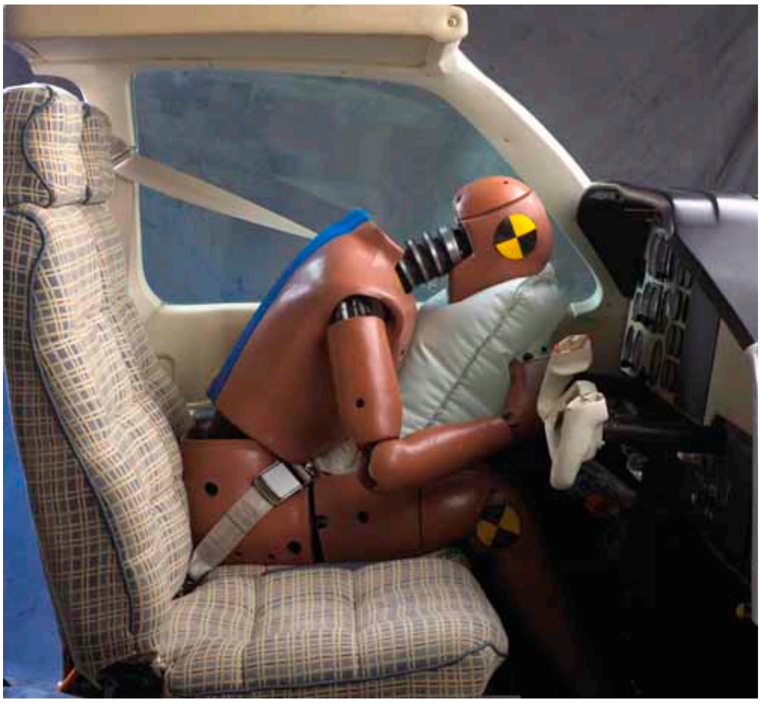


Figure 3.8: Seatbelt fitted airbag on general aviation aircraft
Source: Amsafe, 2010

3.5.3.7 Pyrotechnics and explosives

> "Most commercial and many private aircraft carry custom-built explosive charges to initiate escape slides, parachutes, fire extinguishers, cable cutters, flotation gear, deployable emergency location transmitters, etc. Whilst the activation of these charges may pose only a small direct risk to personnel, the unexpected initiation of the systems that they operate may present a more significant risk. Pyrotechnics are carried by an variety of aircraft, and therefore may discovered amongst the aircraft wreckage. They sometimes sustain impact damage, and, as a result, pose an increase risk of initiation. Weapons may also be carried by passengers or crew as cabin or stored baggage and should be carefully treated. In the early stages of the crash investigation, perhaps at the reporting phase, co-ordination personnel should seek information passed to the Investigator-in-charge. These hazards also support the need for adequate police resources to restrict the pubic and media from access to the accident site for their own protection". (ICAO, 2008a, paragraph 3.3.6)

A wide range of pyrotechnic and explosive hazards are listed in this description. The equipment carried will depend on the aircraft types: for example, escape slides are fitted on large commercial aircraft and emergency flotation devices on helicopters, and parachutes are routinely worn by glider pilots. While these are generally safe in their undamaged state, as are other stored energy components, inadvertent explosion could pose a risk to the physical safety of investigators.

As a safety precaution, escape slides on all commercial aircraft are armed before take off. When deployed, the cartridge fills the slide with compressed carbon dioxide and nitrogen, mixed with air. The process reportedly takes around six seconds (Huber, 2007). Investigators working within these aircraft must determine whether these are still armed when entering the site.

Weapons may be carried on both civil and military aircraft. Most civil aviation regulators have strict guidelines on the ways in which weapons and munitions should be packed. As an example, the CAA (2004) permits firearms to be carried on board aircraft, so long as they are not loaded with ammunition, and are carried in an area inaccessible to passengers during flight, such as in stowed luggage. Up to five kilograms of ammunition may also be carried per passenger.

3.5.3.8 Damaged and unstable structures

> "Generally, the hazards posed by aircraft structures will be obvious and most will be readily identified. Situations sometimes arise, however, when persons on site may be exposed to unexpected hazards, for example, if wreckage moves or gives way underfoot. Modern materials, including composite structures, may appear undamaged externally, but will have lost structural integrity due to impact and/or heat damage. They can also retain significant energy under the stress of impact, which, when released, may suddenly pose a significant hazard. Structural strength may also be reduced by corrosion, for example, seawater may pose a risk to materials such as magnesium in a relatively short period of time". (ICAO 2008a, paragraph 3.3.7)

This category covers the general hazards encountered with aircraft wreckage and debris. Accident investigators may have to walk or climb over aircraft debris to collect evidence from areas of interest, but the wreckage might not be stable. Decisions will have to be made about whether to move the wreckage, find methods of stabilising the wreckage, or working around these conditions. This will be an ongoing process, with constant reassessments needed every time an investigator proceeds to a new part of the site.

In order to access evidence such as large pieces of wreckage from large commercial aircraft, temporary work equipment might be required. The use of this equipment will need to be properly risk assessed, and supervised by experienced personnel. Andrews (2001) identifies types of mobile equipment to include "ladders, step ladders and trestles; general access scaffolds; suspended cradles and chairs; mast-elevated work platforms; power-operated work platforms; and abseiling equipment". He states that the accidents that occur most commonly when using these types of equipment include slips, trips and falls; injuries from moving parts; injuries resulting from failure or collapse of the equipment; and injuries following contact with power-lines and other overhead services (Andrews, 2001). General health and safety lifting procedures should be followed when dealing with heavy wreckage.

3.5.4 Biological hazards

3.5.4.1 Overview

> "Biological - pathogens associated with human remains or cargo consignments and state of local hygiene". (ICAO, 2008a, paragraph 3.1.2).

Circular 315 divides biological hazards into one large category of general biological hazards, and a smaller sub-category of hazards associated with the local state of hygiene.

3.5.4.2 General biological hazards

> "Accident investigators are at risk of exposure to many biological hazards. Biological hazards may exist in the cockpit, cabin and cargo wreckage as well as on the ground where bodies and survivors have lain. Since it is not possible to readily identify contaminated blood and other bodily fluids, it is prudent to take precautions whenever working around and in wreckage, when handling wreckage and when performing off-site examinations and tests on wreckage parts". (ICAO, 2008a, paragraph 3.4.1)

> "Precaution must be take to prevent viruses from entering mucous membranes (such as the eyes, nose and mouth) or non-intact skin such as open cuts or rashes. The accident site may be contaminated with liquid, semi-liquid and dried blood and other bodily fluids, fragmented bones, human or animal tissue and internal organs. In the dried stage, there is a risk that particles of these substances may become airborne and come into contact with the unprotected eyes, nose and mouth". (ICAO, 2008a, paragraph 3.4.2)

The risks posed by biohazards on accident sites are well researched and established. The requirement in the USA for all responders on accident sites to be trained in the management of hazards to 29 CFR 1910.1030 standards reflects this understanding of risk.

Biological pathogens on the accident site may be in blood or other body fluids, or airborne. The predominant blood borne pathogens are hepatitis B, hepatitis C, and HIV (WHO, 2009). There is no accepted figure for how long these pathogens remain viable in the open environment, but the general anecdotal consensus is that HIV lasts no longer that a few minutes in dried blood in the outside atmosphere. The hepatitis viruses appear to last longer, up to around four days.

With specific reference to HIV, Sherertz (1992) notes that clinical studies conducted by Resnick (1985) show that "common household bleach in 10% concentration in water and 70% alcohol each inactivated infectious viruses within 1 minute. Exposure of HIV to nonionic detergent also resulted in inactivation of virus within 1 minute".

Salazar, DeJohn and Key (1997, 1999) observed that the instigation of nine site protocols on several large aircraft accident sites in the USA minimised the risks posed to investigators by blood borne pathogens. They were:

> 1. "Adequate immunisation against tetanus and a recent booster were made mandatory.
> 2. Hepatitis B immunisations were made readily available to personnel; most of the personnel entering the sites chose to be immunised against hepatitis B.
> 3. Use of contact lenses was forbidden due to increased risk for eye infection.
> 4. Persons with skin conditions that interrupted to integrity of the skin (eg. psoriasis, open sores, cuts, burns, skin lesions) were advised against entering the accident site.
> 5. Persons with eye or ear infections were advised against entering the site.
> 6. Any leakage of protective clothing was dealt with as soon as possible to prevent contamination.
> 7. If contaminated water, dirt, or mud entered the mouth, eyes or ears, individuals affects were requested to leave the area immediately, and report to medical personnel for examination and irrigation of the affected area with clean water.
> 8. Briefings were given on blood-borne pathogen hazards, universal precautions, and preventative measures.
> 9. At the ValuJet site, persons at greater risk for infection were not exposed to water and muck from the accident site; possible conditions included diabetes mellitus, those with concomitant infections or any other underlying condition likely to encourage infection due to lowered immunological defences".

Salazar, DeJohn and Key suggest that post-crash fires may kill biohazards (1997).

There are two ways that airborne diseases may be transferred: airborne transmissions and droplet transmission. "Airborne transmission occurs when droplet nuclei (evaporated droplets) < 5 micron in size are disseminated in the air... Diseases spread by this mode include open / active pulmonary tuberculosis (TB), measles, chicken pox, pulmonary plague and haemorrhaging fever with pneumonia" (WHO, 2009, p.54). "Droplet transmission occurs when there is adequate contact between the mucous membranes of the nose and mouth or conjunctavae of a susceptible person and large particle droplets (> 5 microns)... Diseases transmitted by this route include pneumonias, pertussis, diptheria, SARS, mumps and meningitis" (WHO, 2009, p.55). Awareness of the potential airborne hazards around the accident site will assist in protecting against the risks posed.

3.5.4.3 Local state of hygiene

> "Low levels of hygiene can pose health risks. Even relatively minor complaints can become serious when personnel cannot access medical treatment. Care should be taken when eating and drinking in remote locations or where hygiene levels are of concern. Guidance on essential hygiene should be sought from experts prior to undertaking foreign travel". (ICAO, 2008a, paragraph 3.4.11)

Many important infectious diseases (such as cholera, cryptosporidioisis, giardiasis, hepatitis A and E, listeriosis and typhoid fever) are transmitted by contaminated food and water (WHO, 2009).

Investigators should be aware of the local conditions, and adapt for them. Investigators travelling to sites should seek medical advice from international health agencies or local authorities, on what steps may be taken to prevent illness.

3.5.5 Material hazards

3.5.5.1 Overview

> "Materials - exposure to and contact with materials and substances at the site". (ICAO 2008a, paragraph 3.1.2)

Material hazards on a site are in part determined by the materials and substances used by aircraft manufacturers to build and operate the aircraft. The materials carried in the payload of the aircraft might also contribute to the presence of material hazards. Following an aircraft accident, investigators might immediately obtain the aircraft manufacturer fire fighting charts, and the cargo manifest of the aircraft, to assist with their initial hazards identification process.

3.5.5.2 Metals and oxides

> "Many of the metals and their respective oxides are hazardous to health when ingested into the body. However, all dusts and particles are considered hazardous when encountered in sufficient concentrations. It requires only relatively small quantities of some metals to pose risks to health and to have a significant effect on the body. These metals and oxides are accordingly classified as high risk. These substances may adversely react with chemicals, such as fire fighting agents, so any indication of chemical reaction should be treated with the greatest care and reported to the Investigator-in-charge". (ICAO, 2008a, paragraph 3.5.4)

> "The products of combustion of many materials are hazardous when inhaled, ingested or absorbed and exposure to them is restricted by national safety authorities. In practice, however, due to the type of damage created in an aircraft accident, it is almost impossible to separately identify and quantify safe limits of exposure to these substances during emergency response and accident investigation activities. Furthermore, accidents in industrial areas may introduce entirely new chemicals that may adversely react with each other or with the aircraft and prove more harmful to rescue or investigative personnel". (ICAO, 2008a, paragraph 3.5.6).

Most of the aircraft currently in operation have been manufactured using aluminium alloys. The behaviours of these alloys in impacts and fires has been well researched and understood.

Metals, and other materials in aircraft, start to burn at different temperatures. Ashes may contain any variety of chemicals and oxides of metals, and inhalation of these products should be protected against using appropriate PPE.

3.5.5.3 Composite materials

> "The use of fibre-based composites on aircraft is now extensive, with aircraft structures commonly consisting of more than 15 per cent be weight of these materials. A broad range of fibrous materials is used in the construction of composite materials, including carbon, glass, kevlar and boron, with these and others often combined to form a hybrid fibre. The resin matrix binding the fibre generally accounts for around 40 per cent of the manufactured composite material. These different fibres, not surprisingly, behave differently when subjects to the forces and effects of aircraft accidents". (ICAO, 2008a, paragraph 3.5.7)

> "Reports indicate that when subjected to fire or impact alone, composite structures are likely to release around 1 per cent of their base material as free fibres. When subjected to both fire and impact damage, structures can release up to 10 - 12 per cent of material as free fibres". (ICAO, 2008a, paragraph 3.5.8)

> "Particular concern has been raised about the potential hazard posed by damaged composite structures. Research into these hazards has been conducted at carious times following the early use of composites on aircraft, although it is acknowledged that more research on the health hazards posed is required. Research on carbon fibre indicates that this material exhibits minimal fibrogenic activity and little evidence of lung toxicity in tests. The studies show that carbon fibre is different from asbestos and mineral fibre, and less toxic that silica. As a result of recent unrelated research, some States have proposed that all synthetic mineral fibres under 6 microns (mean diameter) should be classified as irritates, and that some ceramic and mineral woods (types generally not used on aircraft) should be classified as carcinogenic (i.e. capable of causing cancer)". (ICAO, 2008a, paragraph 3.5.9)

> "Other research suggests that exposure to the dusts of burnt composites may pose more of a problem that exposure to free fibres. What is clear at the present is that more research is required to be sure of the hazards and levels of risk posed by the range of materials". (ICAO, 2008a, paragraph 3.5.10)

> "There are other short term health effects resulting from exposure to the fibres and debris from impacted and combusted composites. Most notably, the fibres are highly irritant, particularly to the eyes, and also to the nose, throat and lungs. There is also still concern that partially burnt debris will cause contact hazards, such as dermatitis. Substances which are taken into the lungs with fibre and dust may also cause sensitisation (allergies), which is a significant concern". (ICAO, 2008a, paragraph 3.5.11)

> "As with other hazards, appropriate procedures to limit expose and reduce disturbance will prevent dusts and fibres from becoming airborne and minimise their hazardous nature when they do. Consideration may be given to entering the accident site from an up-wind direction so hazardous exposure is reduced as much as possible, and if encountered, provides a known exit direction with reduced risk of further exposure". (ICAO, 2008a, paragraph 3.5.12)

The description provided about composite material hazards in ICAO *Circular 315* (2008a) is the most comprehensive description in the *Circular* about any of the identified hazards. This reflects the growing use of composites in the aviation industry, and the growing concern about the hazards these materials may pose in crash conditions.

The Boeing 787 contains more composite material than other commercial aircraft in operation. Fire fighting guidance provided by Boeing (2009) states that "... from a toxicity perspective, the composite structure during fire testing poses no greater hazards than an aluminium fuselage aircraft. Also, note that the burn through time on the composite structure is significantly longer than with the aluminium fuselage which may inherently provide greater safety to both the rescue fire responders and passengers in some scenarios". This guidance is based on an intact fuselage, and the advice does not necessarily extend to aircraft that contain damaged composites.

Taylor (2008) describes the composites used in aircraft as including:

- "Carbon/epoxy (CFRP) - used as a primary structural and skin material;
- Kevlar/epoxy - mostly used in military applications, in primary structures and amour plating;
- Glass fibre - used as a structural and skin material (on amateur-built and GA aircraft);
- Glass/phenolic (GRFP) - used in interior fittings, furnishings and structures;
- Boron/epoxy - used in composite repair patches, older composed structures"

Taylor (2008) also advises that the initial actions of investigators on sites should be to protect electrical equipment on site, as released fibres may be conductive, and hence destroy the equipment and any evidence contained within.

In reference to the dangers posed by aircraft composites in fires, Day (2001, p.3) notes that:

> "Highly toxic fumes are given off by the resins and bonding agents used in the manufacture of composite materials. Many resins contain hydrogen, chlorine, nitrogen and oxygen. As a result Hydrogen Cyanide, Hydrogen Chloride and Nitrogen Dioxide are given off which are extremely toxic. Other poisonous products of combustion include Formaldehyde, Ammonia, Toluene and Carbon Monoxide and isocyanates from polyurethane based resins. Whilst it can be argued that the majority of these gases will be taken away in the smoke plume of the main fire, they may still be present in the post crash scenario where the pose a severe threat to firefighters".

Investigators may also be affected by these chemical by-products of composites in fires, especially if investigating in enclosed spaces.

Day (2001) also recommends that:

> "The risk of composite material fibres and particles can be reduced in the following ways:
>
> - The application of a fine water spray to the area
> - The application of a water base suppressant. This will consolidate the top 3-4mm of the crash site debris.
> - Application of a foam blanket. This does have the disadvantage of covering holes in aircraft floors and other obstructions.
> - Small areas can be covered by polythene sheeting.
> - Sections of composite materials may be separated from other debris and secured in polythene bags for future disposal
>
> NB: Removal of crash debris would only be considered in the post crash scenario and having consulted the AAIB first".

3.5.5.4 Chemicals and other substances

> “Aircraft contain many chemical compounds, some of which may be hazardous in their natural state and other which can become hazardous when exposed to heat and other substances. For example:
>
> - Viton ® is a synthetic rubber-like material containing fluorine used for ‘O’ rings and gaskets in engines and hydraulic systems. If exposed to high temperatures and moisture, the material may degrade and produce a corrosive substance.
> - Batteries contain chemicals such as lithium that reacts vigorously with water, and thionyl chloride that decomposes in air to form hydrochloric acid and sulphur dioxide.
> - Hydraulic fluids may become hazardous in their normal state, perhaps being classed as irritants. Some also become acidic when exposed to temperatures above a certain threshold.
> - Used mineral oils from engines are widely known to be carcinogenic and are identified in specific legislation in some States.
> - Partially combusted fuels and lubricants are known to produce a range of hazardous substances.
> - Asbestos, although not frequently used in aircraft construction, has been used in heat shielding materials on and around engines and in various gaskets”.
>
> (ICAO, 2008a, paragraph 3.5.13)

There are many different chemicals on aircraft, contained within different systems and components of the aircraft structure. Aircraft manufacturers’ fire fighting charts will assist in identifying the location of these chemicals.

Considering hydraulic fluids alone, ICAO (1970) states: “When heated, Skydrol (a Trade Name hydraulic fluid commonly used in present aircraft) gives off a white misty vapour which is acrid and choking. When burned, the residue is first dark coloured and viscous, then it changes to a dark charred material, then a white fluffy deposit appears after prolonged heat. When burned, it has a yellowish flame with white smoke. If Skydrol is heated and a piece of aluminium is placed in it, an acetylene-type odour is evident”. Investigators must be cautious when working in these situations. Solutia (2010), the manufacturer of Skydrol, advises that contact with the skin will cause the skin to dry out, causing dermatitis and secondary infections; they recommend that gloves impervious to fluids, goggles, and a respirator should be worn when working in an area where Skydrol could be splashed.

Indeed, working in an area where chemicals are present, investigators may need to used high levels of PPE, including chemical protective suits, eye protection and powered respirators to prevent inhalation of, or contact with, the chemicals.

3.5.5.5 Radioactive materials

> "Radioactive materials are often used in small volumes in some aircraft components and are frequently carried as cargo in commercial operations, particularly substances for medical use. Generally, specific radioactivities of these are low, and half lives are short. However, higher activity material is regularly carried on-board aircraft. Restrictions on packaging these are, however, very strict, ensuring that in the majority of cases, packaged contents will remain effectively inert in the event of an accident.
>
> - Several radioactive materials have been used in the construction of aircraft. These are mainly materials with a low specific radioactivity, and therefore pose a low risk in their normal state. However, when reduced to dust after fire, they are likely to pose a hazard to health if ingested or inhaled. Depleted uranium has been used in ballast weights for control surfaces in a range of civil and military aircraft. It was fitted in several hundred early versions of the Boeing 747, in Lockheed aircraft, and in stretched versions of the Hercules C130 aircraft. This materials has also been used to manufacture tip weights for helicopter main rotor blades.
> - Radiologically, depleted uranium is not classes as a significant risk in its undamaged form. Where particulate is produced, however, e.g. by machining or fire damage, depleted uranium may be ingested, inhaled, or absorbed and, once in the body, the material poses a significant chemical hazard.
> - Thorium. This material has been used extensively in components for aircraft engines, both piston and turbine, and is often alloyed with magnesium, although at relatively low concentrations. It has also been used in other components such as gearbox casings on helicopters and fixed wing aircraft. Its use has been reduced significantly in recent years, however, there are significant stocks of thoriated components available and these are, presumably, still to be used.
> - Tritium. Beta lights are used extensively on some civil aircraft to indicate emergency exits and also in instrument lights on some military aircraft. Typical beta lights each contain a total of about 20 curies of tritium gas. Exposure to the contents of a single broken beta light could result in a dose of up to 1/10th of the current acceptable annual limit.
> - Other nuclides. Americium is used in some forward looking infrared (FLIR) systems, Krypton is used within oil level indication systems, and Strontium 90 can be found within ice detection systems and in helicopter rotor crack indicating systems".
>
> (ICAO, 2008a, paragraph 3.5.14)

Following the 1992 crash of a Boeing 747-200 freighter into an apartment building in Amsterdam, there was much concern from bystanders about their possible exposure to uranium as a result of the accident. Uijt de Haag *et al.* (2000) conducted an investigation into these claims, and determined that, despite 152kg of depleted uranium being missing from the site following the site clean-up, it was highly improbable that the health of any bystanders were affected by inhalation, external irradiation or ingestion of depleted uranium.

Environmental protection agencies may need to respond to accident sites where radioactive materials are thought to be present.

3.5.5.6 Cargo

> "There are immense difficulties associated with identifying and assessing risks posed by cargo. A huge variety of freight is carried by air, most of which is identified in some way, although a significant volume carries only a general description. Dangerous Goods are usually well identified and documented, and information may be gathered (using dangerous goods manifests) at a very early stage to help determine the degree of hazard. While general cargo, by definition, is considered non-dangerous (in transport classification terms), in general health and safety terms, it is quite capable of posing significant hazards. It should be noted at cargo containing dangerous goods and general cargo many include the chemicals and substances mentioned above (NOTE: Paragraph 3.5.14). Neither mail, not private goods, both carried by air in large volumes, carry any indication of contents on their packaging". (ICAO, 2008a, paragraph 3.5.15).

> "When carrying out early site assessment work, it is essential to obtain full information about the complete load of cargo as soon as possible, Dangerous Goods manifests may usually be obtained quickly, but general cargo manifests should also be obtained and reviewed at a very early stage. A wide range of information is contained within the manifests/cargo documents, including descriptions of packaging, general description of cargo, and contact details of consignors/consignees, etc.". (ICAO, 2008a, paragraph 3.5.16)

Cargo on an aircraft may be categorised as either general cargo, or designated dangerous goods.

Dangerous goods are defined as: "Articles or substances which are capable if posing a risk to health, safety, property or the environment and which are shown in the list of dangerous goods in the Technical Instructions or which are classified according to those Instructions". The SARPs in *Annex 18: The Safe Transport of Dangerous Goods by Air* (ICAO, 2001d) provide guidance about what can be transported by air, how it must be packed and labelled, and the responsibilities of the shipping and aircraft operator.

A dangerous goods manifest is required to be left at the place of departure. This information can be requested by investigators following an accident, but may take some time to receive. The TSB (2006) reported that, following the MK Airlines 747 Freighter crash at Halifax, Nova Scotia in 2004:

> "Since all the dangerous goods carried on MK1602 had been loaded at the previous stop, Bradley International Airport, no one in Halifax had any information regarding the dangerous goods. It was not until 10 hours after the accident that ARFF received a listing of the dangerous goods that had been loaded at Bradley. A lack of timely information concerning dangerous goods could have jeopardised the safety of the ARFF personnel and other responding personnel. In the case of a survivable aircraft accident, knowledge of the number of occupants could be critical to successful rescue efforts".

The NTSB has made numerous safety recommendations for manifests to be held at both the departure and intended arrival airports (including in 1990, 1998 and 2005), but these have not been accepted (TSB, 2006).

No manifests exist to provide information about cargo that passengers are carrying with them, or the undeclared cargo on an aircraft. Aviation regulators publish guidelines about the goods that can be carried on board aircraft. The CAA (2010) classifies goods suitable for carriage in four categories: carry on baggage, checked baggage, on the person, or requiring operator approval.

In March 2000, a Malaysia Airways A330-300 had to be written off following a spill of oxalyl chloride which was mis-declared as another non-toxic substance. The chemical corroded the aircraft, and caused five baggage loaders, who entered the aircraft hold, to become ill (FSF ASN Database, 2010). Investigators must be aware that the information they are provided with on the dangerous goods manifest might not be accurate and reliable.

In May 2004, spilt mercury was discovered in a Flybe BAe 146 aircraft at Belfast City Airport. Three baggage handlers, two cargo handlers, and a fire fighter were hospitalised as a precautionary measure (BBC, 2004). In this instance no damage was done to the aircraft, but this mis-packed cargo is another cautionary example of a cargo manifest not providing accurate information.

3.5.6 Psychological hazards

> "Accident investigations frequently require personnel to work in close proximity to disaster and trauma. This work involved dealing not just with the fatally or seriously injures, but with survivors, relatives and colleagues of the victims. The intensity, scale, and (frequently) long duration of the task can present significant potential for adverse psychological impact on investigation teams. After past disasters, there have been reports of rescue workers suffering from Post-traumatic Stress Disorder (PTSD), causing sleep disturbance, intrusive thoughts and flashbacks. There is little available evidence to confirm such symptoms amongst accident investigators, suggesting that the psychological impact poses less of a risk to investigators that once thought. However, this more satisfactory outcome may be due to the establishment of professionalism at both an individual and team level (including good work practices) and effective peer support". (ICAO, 2008a, paragraph 3.6.1)

The psychological hazards that affect an investigator are not necessarily recognisable on the site, and might not affect the evidence collection, but can have longer lasting repercussions after the event. Conversely, investigators might be affected immediately by horrific conditions at an accident site, and be distracted from the tasks they are intending to carry out.

Following such an experience, responders may develop Critical Incident Stress (CIS). Leonhardt and Vogt (2006) define CIS as: "The psychological and physical changes which a person experiences after a critical incident. These reactions are normal reactions to an abnormal event". A list of recognised symptoms of CIS are summarised by Leonhardt and Vogt (2006, pp. 47-48) as:

"Cognitive:
- General confusion
- Difficulty in decision making
- Difficulty in identifying people known to the individual
- Disorientation in terms of time and place
- Change in readiness to react to situations
- Changed perception of surroundings
- Distrust
- Nightmares
- Disorientation in ability to concentrate and being alert
- Memory lapses, blanks

Emotional:
- Fear and insecurity
- Feelings of guilt
- Feelings of being overwhelmed/helplessness
- Anxiety
- Irritability/aggression
- Fits of anger
- Increased excitability
- Panic attacks
- Over exaggerated expressions of grief
- Suppression of feelings/elusive behaviour
- Lack of emotion or outbreaks of emotions
- Depression

Physical:
- Sudden dizziness/feelings of faintness
- Dizziness/numbness
- Sleeping disorder
- Faster pulse of higher blood pressure
- Breathing difficulties
- Dimness of vision
- Chills and fevers
- Teeth grinding
- Increased fluid intake
- Drowsiness
- Nausea and vomiting
- Muscle twitching/nervous twitching/paralysis
- Headaches and chest pains
- Shock

Behavioural:
- Disturbed appetite
- Speech changes
- Changes in social behaviour
- Isolation
- Over sensibility
- Hurry, restlessness
- Uncontrollable movements (for example ticks)
- Increased substance use
- Anger expression
- Increased excitability
- Panic attacks
- Over exaggerated expressions of grief
- Suppression of feelings/elusive behaviour
- Lack of emotion or outbreaks of emotions
- Retreat, immobility, hyper mobility"

If CIS remains untreated, or intervention methods are poor and ineffective, then Post Traumatic Stress Disorder (PTSD) may develop. Kersey (2001) recommends that to reduce the risk of Post Traumatic Stress Disorder (PTSD), organisations should implement procedures such as "defusing sessions soon after the event where pent up feelings can be released; mentoring or "buddy" sessions with colleagues; professional counselling; or long-term psychiatric assistance".

3.6 Discussion and conclusions

The purpose of this study was to consider on site evidence collection tasks, and the hazards that investigators may encounter when collecting evidence on a site. This information might assist investigators in considering the the evidence collection methods to be employed on sites, and how each task might potentially be affected by the presence of different hazards.

As noted in Section 2.4.4.1, *Circular 315* (ICAO, 2008a) is specific in its guidance on where trade-offs between the job requirements and the safety of the investigator should be made. Where the frequently difficult balance must be struck between the requirements of the task and the safety of the personnel, the decisions "should always be biased towards safety" (ICAO, 2008a, paragraph 2.3.1).

Every accident site will pose different hazards or combinations of hazards. Given the diversity of aircraft operations and the variety of hazards that have been identified and considered, it is impossible to construct "across the board" generic risk assessments to provide investigators with comprehensive knowledge in advance of the hazards they are about to encounter on a site. As an investigator gains experience attending accident sites that have similarities in terms of aircraft type, accident type, or location, he will begin intuitively to develop generic assessments of the likely presence of particular hazards on particular sites. However, the individual investigator must remain open to the consideration that such an assessment might prove not to be correct, and that on site dynamic risk assessment will identify different hazards from those which might have been expected. Prediction of likely site hazards is a matter for the individual investigator entering a particular site. Investigators within an organisation, and across organisations, should be encouraged to report and discuss hazards they have encountered in different circumstances so that others can learn from their experiences, and improve their own personal generic risk assessments.

While a thorough understanding of all possible hazards is a necessary condition for success and safety as an investigator, it is not in itself a sufficient condition to ensure either. The key essential is the capacity to assess the risks, and the degree of each risk, not just generically, but at the specific unique accident site, considering all other factors, and to decide on appropriate mitigation. This inevitably involves making decisions about trade-offs between the requirements of the job and the degree of risk being faced in that particular location.

It is therefore not sufficient to have a knowledge of the full range of hazards described in *Circular 315* (ICAO, 2008a). It is also essential to be able to apply the risk assessment process set out in the *Circular*, as discussed in Section 2.4.4.1 and shown in Figure 2.22. If the investigator is to gather all relevant evidence within a possibly limited time-span, and to remain safe, he must almost innately follow the discipline of identifying the hazards, determining his degree of exposure to them, evaluating the risks arising from that exposure, introducing controls by way of mitigating the hazards, and reviewing the residual risks and revising the risk assessment in response. Situational awareness (Endsley, 1995; Figure 2.23) is critical, given the dynamic nature of an accident site. Training in routine use of the *Circular 315* risk assessment methodology - which it will commonly be necessary to apply under difficult physical conditions and immense time pressures at an accident site - is perhaps more important than a comprehensive knowledge of all possible risks, including those encountered only infrequently.

The culture of the investigation organisation must be such that when investigators encounter a hazard they have not encountered before, and are uncertain about its nature and impact, they feel able to suspend the investigation until this is determined. This may jeopardise the evidence collection process, but will allow the investigator to maintain personal safety. By advancing awareness of different hazards that may occur on sites, the chance of evidence being lost through through suspension of the investigation process will be diminished.

Chapter Four

Novice Accident Investigators' Perception of Aircraft Accident Site Hazards

4.1 Purpose of the study

The objective of Chapter Four is to identify the hazards that novice accident investigators perceive to pose most risk when they attend an aircraft accident site. In Chapter Five, the hazards identified by experienced accident investigators on real accident sites will be reviewed, and a comparison made between the perceptions of the novices and the real experiences of the experts. This knowledge will assist in improving hazards specific training for aircraft accident investigators (Chapter Seven).

Using the framework set out in *ICAO Circular 315* (2008a) as a guide, Chapter Three systematically analysed the hazards that potentially occur on aircraft accident sites, the conditions under which they occur, and the consequences they may have on the personal safety of an aircraft accident investigator and on the integrity of the evidence collection process.

It is evident from Chapter Three and the literature reviewed in Section 2.6.5 that current industry guidance focuses on the risks to accident site responders through hazards such as fire, biological materials, composites, radioactive hazards, and dangerous goods. There is little mention of general health and safety concerns such as trip hazards and personal security. The hypothesis of the research in this chapter is that novice investigators will have a greater concern about general health and safety hazards, such as slips, trips and falls and biological hazards, than particular aircraft specific hazards such as pressurised vessels. Consideration is also given to whether the novice investigators' perceptions of risk are likely to be realised on the actual sites.

4.2 Context

4.2.1 Overview

This research study draws on three aspects previously discussed: evidence collection tasks on an accident site (Section 2.3.2.4.2); hazards identification as a process of risk management (Section 2.4.4); and health and safety management on an accident site (Section 2.5).

The identification and assessment of hazards on an accident site is an essentially subjective judgement. A full quantitative analysis of potential hazards before entry is simply not possible. Aircraft accident investigators make a thorough inspection of the site, and make professional judgements about risk on the basis of their knowledge and previous experience. Because of the variety and scale of hazards that may appear on different accident sites, this is the only effective and available way of conducting an assessment: a full quantitative analysis of potential hazards before entry to site is simply not possible.

Although accident investigators are trained in identifying potential site hazards, and are guided in doing so by their knowledge of aircraft and aircraft operations, there will be differences in the assessments of risk made by different individuals. This is inevitable with subjective assessment. There is a theoretical basis for explaining these differences in perception, and in the behaviours which follow from the identification of risk.

4.2.2 Perception of hazards

"Many decisions are based on beliefs concerning the likelihood of uncertain events" (Tversky and Kahneman, 1974, pp. 1124). The way in which an investigator conducts a hazards assessment on an accident site is largely determined by that individual's view of the risk posed by particular hazards.

Fischoff, Watson and Hope (1984, p.124) consider the differences between objective assessment and subjective assessment of risk. They see the term 'objective risk measurement' as referring "to the product of scientific research, primarily public health statistics, experimental studies, epidemiological surveys, and probabilistic risk assessments". In contrast, 'subjective risk measurement' refers to "non-expert perceptions of that research, embellished by whatever other considerations seize the public mind". They further note that "this distinction is controversial in how it characterises both the public and the experts". On an accident site there is little opportunity, especially in the initial hazards assessments, for objective measurements of on site risks; rather, an investigator will survey the site to determine, subjectively, what he or she deems to be the major risks and the best mitigation measures.

On large scale accident sites, risk assessment would normally be carried out by a safety inspector (Section 2.4.4). This might be done in consultation with fire service responders and environmental protection agency representatives, who could be expected to have different perspectives on the nature and magnitude of the potential site risks, based on their own experiences and priorities.

Work on risk perception (for example Alhakami and Slovic, 1994; Fischhoff *et al.*, 1978; Pidgeon *et al.*, 1992; Slovic, Fischoff and Lichtenstein, 1979; Slovic, 1987; Weyman and Kelly, 1999) suggests an inverse relationship between perceived risk and perceived benefit when reviewing the outcome of a hazard. That is, the greater the perceived benefit, the lower the risk is perceived to be, and vice versa" (Alhakami and Slovic, 1994, p. 1085). If that is so, it suggests that if an investigator perceives the need to proceed immediately with the collection of rapidly perishable evidence, he will perceive the risk in doing so as lower than he might perceive it to be were the need not so urgent. In contrast, if an investigator perceives a particular hazard to pose a high risk to personal safety, he will take extra precautions for protection against exposure to the hazard, whether the perception of the risk is valid or not.

Siegrist and Cvetkovich (2000) analysed the link between the perception of hazards and trust in expert judgement. They determined that an individual with little previous knowledge of a particular hazard,he was more likely to trust others about the risks posed by the hazard, than individuals with previous knowledge of the hazard. This conclusion has relevance for the design of instruction for investigators coming from a wide range of backgrounds.

4.3 Methodology

4.3.1 Survey design

A simple, one question survey instrument was developed to conduct this research. Sampled investigators were asked:

Please identify five hazards that you believe you are at greatest risk from when attending an accident site.

Prior to distribution, the survey was piloted with a number of responders, including expert and novice accident investigators and experts in research methods, to ensure that the language of the question was understood, and that the meaning of the question elicited valid responses for analysis. For many of the targeted responders, English was a second language, so the question had to be clear and concise, and the intended meaning quite explicit.

Each responder was provided with a sheet of A4 paper with the written question. Below the question, numbered spaces were provided for the five requested answers.

The survey design was developed using a free listing technique, described by Bernard (2006, p.301) as "a deceptively simple, but powerful technique ... to get informants to list as many items as they can in a domain". In this study, the domain of the research was explicitly hazards on aircraft accident sites.

For practical reasons, the free listing methodology was slightly modified. Rather than asking investigators to list all possible hazards they could identify, they were asked to provide a list of their perceived five greatest hazards. This was for practical survey administration reasons, as the researcher had only ten minutes to introduce and distribute the survey to investigators prior to a hazards-specific training programme, and for the practicality of analysing the responses from the large number of participants.

This limitation is not considered to have had an effect on the results of the survey. The nature of the research question was to identify the hazards that novice investigators perceive as posing most risk on an aircraft accident site, rather than identifying all hazards that pose any risk on a site. Any potential problems created by this enforced limitation were overcome by sampling a large number of responders. By using a large number of responders, a variety of hazards known by investigators from different backgrounds were identified, rather than using a smaller sample of investigators to identify a larger number of hazards.

4.3.2 Participants

The survey was administered to investigators attending a basic investigation course (as categorised by ICAO *Circular 298* [2003a], Section 2.1.4). All responders were novice accident site attendees.

Participants were from a range of employment and cultural backgrounds, and included employees of national aircraft accident investigation agencies, military accident investigators and recovery specialists, aircraft insurers, engine manufacturers, aviation regulators and aircraft operators.

The survey was distributed before any ICAO *Circular 315* (2008a) or *Circular 298* (2003a) hazard-specific training was undertaken. This ensured that the novice perception of site risks was elicited, rather than perceptions informed by a training course. Individuals may have had previous training from within their own organisation. However, because this background training would have been given from a different perspective than aircraft accident site hazards, it was not considered to significantly affect the results of the survey. Each individual was still considered a novice in terms of the research, as they were only beginning careers in aircraft accident investigation.

4.3.3 Ethical considerations

Prior to distribution of the survey, the researcher introduced the survey to each sample group. This introduction served to inform participants of the nature of the survey, and the overall research, and provided an opportunity to confirm that participation in the survey was voluntary, anonymous, and confidential.

Participants had approximately ten minutes to complete the survey. Although the survey was distributed by the researcher, the responses were collected either by a third party person (not involved in the research), or from an anonymous drop-box. This assured participants of their anonymity. No person other than the researcher had access to the completed survey forms after collection.

The content of the survey question was not considered to breach any ethical guidelines, as all participants were voluntarily attending a course in which they knew they were to learn about all aspects of aircraft accident investigation, including site hazards.

4.3.4 Analysis methodology

Analysis was conducted using a card sort methodology, as described by Rugg and McGeorge (1997). The card sort methodology is a commonly applied methodology in psychology and social sciences. The sort was conducted against a template developed using the hazards taxonomy identified in ICAO *Circular 315* (2008a), and as applied in Chapter Three (Section 3.5).

Circular 315 (ICAO, 2008a) was selected it is currently the most recent and comprehensive taxonomy of potential hazards (see Table 2.13, Section 2.6.5); it is the most recent international document on hazards, produced for accident investigators; and little benefit was seen in developing a new taxonomy simply for the purposes of this study. Further, use of this standard taxonomy allows for comparisons to be made against the results in this chapter and the study presented in Chapter Five.

Two raters (a psychologist, and the researcher) completed the card sort, by sorting all the cards into the pre-assigned categories. The purpose of using two raters was to improve reliability in the manner in which the cards were sorted.

Each individual hazard identified by a participant in the survey was printed on an individual index card. Each card was numbered on the back, in a place where it would not influence the rater’s decision on how to sort the card. Each number, and the corresponding hazard it identified, was recorded in a master document for analysis purposes.

A verbal briefing accompanied a written instruction sheet detailing the instructions of the exercise. The raters were provided with a copy of Chapter 3 of ICAO *Circular 315* (2008a) which outlines each hazard category, and provided the framework for the analysis. The raters were asked to read the hazard identified on each card, and place in in the appropriate category.

The name of each hazard identified in *Circular 315* (2008a), including the overarching groups (environmental hazards, physical hazards, biological hazards, and materials hazards) were each written on a separate envelope. This created 24 envelopes, and 24 categories:

1. Accident Location
2. Fatigue
3. Insects/wildlife
4. Climate
5. Security
6. Fire and flammable substances
7. Stored energy components
8. Pressurised gases
9. Military and ex-military aircraft
10. Recent safety equipment
11. Pyrotechnics and explosives
12. Damaged and unstable structures
13. General biological hazards
14. Local state of hygiene
15. Metals and oxides
16. Composite materials
17. Chemicals and other substances
18. Radioactive materials
19. Cargo
20. Psychological hazards
21. Environmental hazards (including categories 1-5)
22. Physical hazards including categories (6-12)
23. Biological hazards (including categories 13 and 14)
24. Material hazards (including categories 15-19)

The raters were asked to, where possible, assign each card to just one category by placing the card in the appropriate envelope. Where this was not thought possible, raters were permitted to assign the card to two or more categories, up to a maximum of five categories. They did this by creating a “dummy card” (using spare index cards provided) with the name of the hazard, and its corresponding hazard written on the card.

Where the rater decided that the hazard could appropriately fit in more than five categories, they were asked to identify the card as “too general” and place it in an envelope marked as such.

Placing cards in more than one category was not considered detrimental to the research, as hazards do not have to fit into mutually exclusive categories. Indeed, if a hazard does fit into more than one category, this may provide more than one opportunity for an investigator to consider whether the hazard is present on a site, during the initial hazard identification process. Additionally, the freedom to assign cards to multiple categories prevented cards from being falsely assigned to categories. This increased the reliability of the analysis.

If the raters believed a card did not fit into any of the ICAO *Circular 315* (2008a) hazards categories, then they were permitted to place this card in a separate envelope. They were then asked to suggest possible category names for this group of cards.

There was no time limit assigned to the rating exercise. On completion of the card sort exercise by each rater, the way in which the cards were sorted was recorded on a standard marking form, identifying the cards by number.

When both raters completed the task, the card numbers that were placed in each category by each rater were compared. A comparison between the raters' scores was used to measure inter-rater reliability. This was done through calculating the level of agreement between the raters on the particular cards assigned to that group.

For the purposes of analysis, only the cards which both raters agreed as belonging in a category were included in the results.

4.4 Results

4.4.1 Participants

The survey was administered to five course groups over the period of 2006-2010. A total of 121 survey responses were received (n=121), providing 604 identified hazards. Some participants listed up to seven hazards on the response form, and some listed only one. All responses were included in the analysis.

Table 4.1 provides details of the course groups surveyed, the response rates, and the average number of hazards identified per responder.

Table 4.1: Responses to novice investigator hazards survey

Course Number	Number of Surveys Distributed	Number of Responses Received	Response Rate (%)	Total Number of Hazards Identified	Average Number of Hazards Identified Per Responder
1	34	25	73.5	124	4.96
2	31	30	96.8	149	4.97
3	25	21	84.0	105	5.00
4	28	26	92.9	130	5.00
5	21	19	90.5	96	5.05
Total	***139***	***121***	***87.1***	***604***	***4.99***

4.4.2 Card sort analysis

4.4.2.1 Overview

The card sort exercise took the raters between two and a half and four hours to complete. Following recording of each rater's sort, the results were tabulated, and the categories assigned to each card sorted. These are listed in Appendix E.

The agreement scores between raters on the cards in each categories ranged between 50 per cent and 90 per cent.

Cards were included in a category when was agreement between the two raters that they should be assigned to that category. 422 cards were assigned to one category only, 51 cards to two categories, six cards to three categories, and one card to four categories. It is these cards that are included in the analysis in Sections 4.4.2.2 to 4.4.2.6 below.

Both raters created an additional category to which to assign some cards. Twenty eight cards were considered by the raters to suggest hazards on site that did not fit into any of the pre-assigned categories, in that they were either hazards that prevented evidence collection (for example disturbance to evidence, damage to evidence) or arose from poor accident site management (for example uncoordinated investigation activities, complacency, co-ordination and communications between site attendees). They also both created a category for cards containing responses not relevant to the research. For the purpose of considering hazards identified by ICAO *Circular 315* (2008a), these 28 cards were amongst a total of 124 cards which were excluded from the analysis due to either no applicability to the research, or differences in coding between raters.

Each hazard is discussed separately. The tables included are summaries of the cards in each category which had complete rater agreement about belonging in that category. The full list of cards identified in each category is in Appendix F.

4.4.2.2 Environmental hazards

4.4.2.2.1 General environmental hazards

There were only four cards which were sorted by both raters as belonging in the overarching "environment" hazard category (No. 21). These cards simply said "environment" or "environmental", and therefore no further analysis was possible .

4.4.2.2.2 Aircraft location

There were 58 cards assigned to the category of aircraft location. These are shown in Table 4.2, grouped by similarity of response.

Table 4.2: Novice -identified hazards attributable to aircraft location

Hazard Identified	**Number**
Terrain	
Terrain	7
Terrain: geographical; difficult terrain path clearance; very steep slopey terrain; terrain - steep slopes, mountains, ravines; terrain hazard; physical (terrain); site terrain	7
	14
Terrain and weather combined	
Terrain and weather	1
Terrain and weather (site location and environment)	1
Local weather conditions and terrain	1
Availability of wreckage (terrain, climate etc)	1
Environment: cold, rough terrain, steep climbs, rolling rocks, snow ravines; hot and high, cold (military - desert, jungle, arctic); weather, terrain	3
	7
Environment more broadly	
Natural environment: of the crash site; steep slope, forest; terrain, weather, wildlife; terrain, weather, confined space; mountain, swamp	6
Environment of the crash: electric wires, other vehicles, weather; natural environment; smoke, fire, environment	2
	8
Slips, trips and falls	
Slips, trips and falls - various but specific descriptions	15
More general descriptions: uneven ground; underfoot conditions; ground conditions - uneven and cluttered; unsteady ground/surfaces	4
	19
Overhead hazards and power	
Overhead hazards and power lines	4
Electricity	3
	7
Other	
Organic (plant vegetation)	1
Site risks	1
“The scene can be not easy to be in, and difficult to reach”	1
	3
Total	***58***

ICAO *Circular 315* (2008a, paragraph 3.2.1) classes accident location hazards as hazards "due to the geographic and topographic location of the site". The responses given identify a range of different topographic site hazards, with the type of terrain or environment (mountains, slopes, difficult access to the site) a primary consideration. No responses identified hazards associated with marine-based investigations. Fifteen cards related to slips, trips and falls - a common health and safety problem not only associated with accident sites, but with all work sites. Another four cards alluded to slips, trips and falls through mention of uneven underfoot conditions.

Many the responses linked aircraft location hazards with climate hazards, or insect/ wildlife hazards that many environmental hazards are perceived to be closely related.

4.4.2.2.3 Fatigue

Only five hazards were assigned to the fatigue category (Table 4.3).

Table 4.3: Novice-identified hazards attributable to fatigue

Hazard Identified	**Number**
Fatigue: accumulating tiredness and long hours	4
Fatigue (long hours / many time zones away)	1
Total	***5***

The ICAO *Circular 315* (2008a, paragraph 3.2.2) describes fatigue as resulting from "extended journey times, circadian desyncronisation resulting from transmeridian travel, lengthy working hours and demanding working conditions". The cards are consistent with this, although the effect of working conditions is implied rather than explicit.

4.4.2.2.4 Insects/wildlife

Twelve cards were assigned to Insects/Wildlife hazards (Table 4.4).

Table 4.4: Novice-identified hazards attributable to insects/wildlife

Hazard Identified	**Number**
Animal or Insects	9
Environment of the crash site	1
Weather / nature	1
Smoke / fire / environment	1
Total	***12***

Of the nine cards grouped as 'animals and insects' most identified at least two different animal or insect hazards. Four cards referred to snakes, three to other reptiles, and two to wild animals generally. Four cards referred to insects. Only three of the nine cards specifically mentioned a method by which these animals or insects attack - all as bites. Only one card referred to a specific disease - in this case Weils disease (a zoonose carried by rats, as discussed in Section 3.5.2.4). The type of animal and insect hazards present on an accident sites will of course depend on the location and nature of that site. The three in Table 4.4 which are not grouped with other cards were also assigned to other categories.

4.4.2.2.5 Climate

Thirty cards were assigned to hazards attributed to climate (Table 4.5).

Weather, and its elements of temperature and precipitation in a range of forms, was referred to on 28 of the 30 cards assigned to this category, although only one card referred to wind as a hazard. As with aircraft location hazards (Section 3.4.2.2.2), the perception was one of a strong association between weather extremes and other environmental hazards.

Table 4.5: Novice-identified hazards attributable to climate

Hazard Identified	Number
Weather	
Weather	7
Weather, various descriptions (temperature and precipitation, exposure, dehydration): inclement weather; snow, rain; rain, heat, cold; hot/cold/wind; hot/cold/wet-exposure; dehydration and illness from exposure too the weather; hot and high, cold (military - desert, jungle, arctic)	10
	17
Weather and terrain	
Weather and terrain, various descriptions: cold, rough terrain, steep climbs, rolling rocks, snow ravines; local weather conditions and terrain; availability of wreckage (terrain, climate etc)	6
Weather, and environment more generally: weather/nature; natural environment; natural environmental hazards - terrain, weather, wildlife etc; terrain, weather, confined space; environmental - electric wires, other vehicles, weather	5
	11
Other	
Environment of the crash site	1
Smoke / fire / environment	1
	2
Total	***30***

4.4.2.2.6 Security

Five cards related to security hazards on accident sites (Table 4.6).

Table 4.6: Novice-identified hazards attributable to security

Hazards Identified	Number
Local conditions	1
Insecure site	1
Hostile action (from enemy or terrorism)	3
Total	***5***

The consequences of an insecure site could be both personal threat to the investigators, and loss of evidence - both of which were recognised in these cards.

4.4.2.3 Physical hazards

4.4.2.3.1 General physical hazards

The raters did not assign any cards to the overarching category of physical hazards (No. 22). Most cards which referred to physical hazards fell within hazards-specific categories (Nos. 6-12)

4.4.2.3.2 Fire and flammable substances

Fire and flammable substances was the third largest category following the card sort. There were 75 cards assigned to this category (Table 4.7).

Table 4.7: Novice-identified hazards attributable to fire and flammable substances

Hazards Identified	Number
Fire and products of fire	
Fire	27
Fire/ash	1
Fire (if very early on)/hot surfaces	1
Fire explosion from fuel and electrical short circuits	1
Fire/highly volatile materials	1
Fire (fuel)	3
Fires/fumes (chemicals)	1
Fire/smoke/gases	1
Fire/explosion (e.g. rescue equipment)	1
Fire and heat	1
Fire/combustibles/fuel	1
Fire or re-ignition	1
Fire risk/fuel	1
Fire from kerosene	1
Burn	2

Table 4.7: Novice-identified hazards attributable to fire and flammable substances	
Hazards Identified	**Number**
Flammable materials and sources of ignition	1
	45
Fuel hazards	
Fuel	5
Fuel ignition	2
Fuel and other fluids (fire!)	1
Various fluids - fuel/hydraulic/extinguishants	1
Dangerous materials (fuel, hydraulic fluid etc)	1
Fuel pooling and fire	1
Fuel, hydraulic fluids, batteries on site	1
Fluids (fuel/hydraulic/oil)	7
	19
Fumes, smoke and vapours	
Fumes/vapours	5
Smoke	2
Smoke/fire/environment	1
Smoke/fibres/radioactive	1
Smoke/fibres/resin	1
Airborne pathogens and burnt synthetics	1
	11
Total	***75***

The responses fell into three related groups within the fire and flammable substances category: fire hazards; fuel hazards; and fume, smoke and vapour hazards. The majority (44 cards out of 75) were about the direct risk of fire and the resulting heat and fumes: a large risk when arriving on site early on (as noted by one respondent), but one which can be better managed after the emergency response. The initial risk assessment conducted by investigators should take into account the potential hazards of re-ignition or combustion, and take steps to prevent this from occurring. Only one response referred to the hazards posed by the physical product of fire, ash. The toxicity of fumes at an accident site will depend on the nature of the cargo, the materials from which the aircraft and its various components have been manufactured, and the ground cover at the accident site.

4.4.2.3.3 Stored energy components

Six cards were identified as belonging in this category (Table 4.8).

Table 4.8: Novice identified hazards attributable to stored energy components

Hazard Identified	Number
Electrical	2
Fires explosion from fuel and electrical circuits	1
Equipment under pressure or mechanically pre-charged	1
Aircraft parts (tyres, hydraulics etc)	2
Total	***6***

The cards in this category covered the range of hazards arising from stored energy components (as discussed in Section 3.5.4.3). However the few novice investigators who perceived stored energy components to be one of their five major hazards appeared to be more concerned with the electrical potential and explosive risks posed by these components, rather than with the risk arising from their potential chemical content risk, as described in ICAO *Circular 315* (2008a).

4.4.2.3.4 Pressurised gases

Fourteen hazards were categorised as pressurised gases (Table 4.9).

Responders identifying hazards in this category labelled the hazards as either oxygen, gas or general pressure hazards. ICAO *Circular 315* (2008a, paragraph 3.3.3) describes the risk posed to investigators from pressurised gases as arising from either “physical injury or asphyxiation”. Both of these outcomes were included in these cards.

Table 4.9: Novice-identified hazards attributable to pressurised gases

Hazards Identified	Number
Gas	
Gas supplies or cylinders	1
Gases - pressure/poisonous	1
	2
Pressurised vessels	
Pressurised vessels	2
Explosion from pressurised containers	1
Pyrotechnics and pressurised bottles	1
Explosive materials/bottles	1
Compressed cylinders	1
Equipment under pressure or mechanically pre-charged	1
Items under pressure (oxygen bottles, fire extinguishers, tyres)	1
	8
Oxygen	
Oxygen bottles	1
Liquid oxygen leaks	1
Explosion of oxygen bottles and cylinders	1
Detonation of gas or oxygen bottles	1
	4
Total	***14***

4.4.2.3.5 Military and ex-military aircraft

There was no agreement between raters that any cards belonged in this category, and very few cards that could potentially have been included.

The category definition for hazards associated with military and ex-military aircraft in *Circular 315* ICAO, 2008a, paragraph 3.3.4) refers specifically only to the cockpit escape equipment and ejector seats. There are other hazards associated with military and ex-military aircraft, such as weapons carried and the systems on board, which can be categorised elsewhere in the taxonomy.

4.4.2.3.6 Recent safety equipment

There was only one card that raters assigned this category: “On board explosives/rocket propellants”. The card was also assigned to the category off pyrotechnics and explosives. There was no perception of hazards associated with ballistic recovery systems or airbag systems amongst the responders to the survey - or at least they did not see them as a significant threat on accident sites.

4.4.2.3.7 Pyrotechnics and explosives

There were nineteen cards in this category (Table 4.10).

Table 4.10: Novice-identified hazards attributable to pyrotechnics and explosives

Name of Hazard	Number
Explosives	7
Explosive materials	1
Explosive cartridges	2
Unexploded munitions	6
On board explosives / rocket propellants	1
Pyrotechnics	2
Total	***19***

Explosives are used in emergency equipment, including escape slides and fire extinguishers (which are also a stored energy hazard). Cards within this category also showed some awareness of the risk posed by weapons carried on board military aircraft and civil also aircraft (subject to packing requirements).

4.4.2.3.8 Damaged and unstable wreckage

This was the largest category of perceived hazards, with 109 cards (Table 4.11).

ICAO *Circular 315* (2008a, paragraph 3.3.7) states that “generally, the hazards posed by damaged aircraft structures will be obvious and most will be readily identified”. Certainly, these were the most obvious hazards for the novice investigators. More than half the cards saw sharp debris resulting in cuts and wounds as the major hazard arising from damaged structures; there was also concern about falling objects, unstable footholds, slip and falls and other forms of direct personal injury.

Table 4.11: Novice-identified hazards attributable to damaged and unstable wreckage

Hazards Identified	**Number**
Sharp debris	
Sharp objects (glass/fuselage); sharp objects cuts; sharp matters; cuts from metal parts; sharps; sharp edges - broken airframe); torn metal; wound with a cutting part; shrapnel injury; sharp objects (metal/non-metals); sharp edges from wreckage; sheared metal/glass; glass/shrapnel; cuts from jagged wreckage; cuts as a result of sharp aluminium	57
Unstable wreckage	
Mechanical (sharp edges, falling objects); object falls in case of large aircraft; loose debris - broken seats, loose baggage etc; loose surrounding aircraft structure; unstable parts of the wreckage; unsafe supports; unsecured objects e.g. derailed train; falling objects; moving parts; loose objects/unstable; loose wreckage falling onto rescuers/investigators; free fall of damaged spares; unstable equipment - topple hazard; physical risk through instability of wreckage	17
Slips, trips, falls	
Tripping; trip hazards; slips and trips - hydraulic and other fluids; trip and fall; slips, trips, falls; slips, trips, cuts; trip hazards - uneven surfaces, wreckage	14
Personal injury from wreckage (without specifying sharps, instability or slips etc)	
Personal injury from wreckage; wreckage itself; accident debris; injury while lifting or moving wreckage); injury from debris; physical hazards in accident area; structures/wreckage/fire/ smoke; crash generated debris; manual handling/wreckage	14
Chemicals and other hazardous materials	
Chemical hazards (bio etc), mechanical hazards; sharp objects and biohazards; biohazards; hazardous materials on board the aircraft; hazardous materials from damage to structure	5
Injury from moving equipment	
Rotating or reciprocating equipment; moving mechanics	2
Total	***109***

4.4.2.4 Biological hazards

4.4.2.4.1 Overview of biological hazards

The overarching category of biological hazards in *Circular 315* (2008a) encompasses all biological hazards, with a sub-category pertaining to *local state of hygiene*. As responses were quite specific there were no hazards assigned to the overall category of biological hazards (No.23):

4.4.2.4.2 General biological hazards

Eighty four cards were assigned to the category of biological pathogens (Table 4.12).

Table 4.12: Novice-identified hazards attributable to general biological hazards

Name of Hazard	Number
General biological hazards	
Biohazards	17
Biological substances and materials	8
Blood borne pathogens	23
Bloods	4
Body fluids and parts	12
Disease	4
Hepatitis and HIV	5
Infection	2
Contamination	2
	77
Other	
Airborne particles / pathogens	2
Effluent and waste materials	3
Biochemical	2
	7
Total	***84***

Of the 84 cards, 77 referred to biohazards generally or focused on blood-borne pathogens and body fluids. Although descriptions varied and were imprecise - blood, blood borne pathogens, biological substances - it was clear that there was a common perception of the link between body fluids and infection. Hepatitis A to C and HIV were the only infections specifically mentioned.

4.4.2.4.3 Local state of hygiene

Only one card - ‘local conditions/awareness’ - was sorted into this category. This card also appeared as a *Security* hazard.

4.4.2.5 Material hazards

4.4.2.5.1 General material hazards

Two responses were assigned to the general category of material hazards - ‘dangerous goods/materials from aircraft’ and ‘hazardous materials’.

4.4.2.5.2 Metals and oxides

The five responses categorised as metal and oxides hazards are summarised in Table 4.13.

Table 4.13: Novice identified hazards attributable to metals and oxides

Name of Hazard	Number
Ash / products of combustion	3
Toxic substances (gas, solid, liquid)	1
Other toxic aircraft materials	1
Total	***5***

ICAO *Circular 315* (2008a, paragraph 3.5.4) notes that metals and oxides are dangerous when ingested. Three of the five responses in this category showed an understanding of how ash and other products of combustion can affect investigators, but as the responses were so few this is obviously not generally perceived by novice investigators as a major issue.

4.4.2.5.3 Composite materials

Table 4.14 shows the hazards perceived to arise from composite materials.

Table 4.14: Novice identified hazards attributable to composite materials

Name of Hazard	Number
Airborne fibres	6
Airborne pathogens / burnt synthetics / fuel smoke	2
Carbon fibre	9
Man Made Mineral Fibres (MMMF)	4
Materials (fluids, carbons, etc.)	1
Other toxic aircraft materials	1
Total	***23***

Of the 23 responses, nine refer to carbon fibres and four to MMMF. Carbon fibre is one of the most commonly known composites, particularly in the aircraft manufacturing industry, but possible composites described in ICAO *Circular 315* (2008a) include "carbon, glass, kevlar and boron, with these and other often combined to form a hybrid fibre".

4.4.2.5.4 Chemicals and other substances

The number of cards identifying hazards resulting from chemicals and other substances is shown in Table 4.15.

Of the 48 cards assigned to this category, 38 identify chemicals in general as the hazard. A range of exposure methods is identified in the cards, including inhalation and through skin contact. Five of the cards refer directly to hydraulic fluid: one refers to the slip hazards produced by hydraulic fluids, the others imply their chemical irritancy properties. Hydrazine, a chemical used in F16 aircraft, is the only specific chemical identified.

Table 4.15: Novice identified hazards attributable to chemicals and other substances

Name of Hazard	Number
Chemicals	29
Chemicals (combined with toxic goods, dangerous goods, solvents, radioactive materials, fuel)	9
Loose normally-contained materials eg. Hydrazine	1
Inhalation of Chemical gases/fumes	3
Other toxic aircraft material	1
Hydraulic fluid, lubricants	4
Slips and trips - hydraulic and other fluids	1
Total	***48***

4.4.2.5.5 Radioactive materials

Table 4.16 summarises the perceived hazards related to radioactive materials.

Table 4.16: Novice identified hazards attributable to radioactive materials

Name of Hazard	Number
Radioactive materials	8
Radiation	3
Radiological (beta lights, etc.)	1
Nuclear contamination	1
Total	***13***

Twelve of the thirteen cards refer to radioactive materials in general. Only one card specifically identifies a source of radiation, in beta lights. This is one of the specific hazards identified in the description of radioactive materials in ICAO *Circular 315* (2008a).

4.4.2.5.6 Cargo

Table 4.17 gives the number of cards identifying cargo-related hazards.

Table 4.17: Novice identified hazards attributable to cargo

Name of Hazard	Number
Dangerous goods / cargo	12
Unknown cargo	2
Hazardous materials	1
Total	***15***

Dangerous goods are the predominant hazard identified in this category (12/15 cards), ICAO (2008a) refers to the health and safety hazards that general cargo may pose, but these have not been perceived as a risk by the novice investigators.

4.4.2.6 Psychological hazards

Seventeen cards were assigned to the category of psychological hazards (Table 4.18).

Table 4.18: Novice identified hazards attributed to psychological hazards

Name of Hazard	Number
Psychological trauma	7
Personal and psychological trauma from witnessing post accident events	3
Psychological - mental trauma / stress	1
Stress	4
The smell / stench of the accident site	1
Family, next of kin	1
Total	***17***

Psychological trauma suggests a hazard which might persist - or even initially develop - well after the time spent on site. Some form of debriefing should take place to ensure that this trauma is managed. Stress may be a short term psychological hazard, brought on from the pressures of being on site, or may develop into a deeper psychological trauma. The stress of dealing with the family of fatalities from the accident may increase the risk of stress and trauma.

4.5 Discussion

The tables in Section 4.4 summarise the perceived hazards described on cards on which there was agreement between raters, in terms of the *Circular 315* (ICAO, 2008a) hazards category to which the card should be assigned.

The excluded cards were spread across the range of categories, and could not significantly affect the rank order of categories were they to be included. Some of the cards (58) were assigned to multiple categories, leading to a total of 546 cards being assigned. Six of these 546 cards were assigned to the overarching categories, which are not included in the rank order shown in Table 4.19.

The sample of novice investigators as a whole perceived the five greatest hazards they face on accident sites as arising from damaged and unstable wreckage; biological hazards; fire and flammable substances; accident location; and chemicals and other substances. These five categories accounted for 68 per cent of the total 546 cards categorised. The inter-rater agreement in classifying cards into these categories stood at 85 per cent, indicating that the cards so assigned are a true representation of those groups.

The perceived five greatest hazards are spread across four of the five overarching hazards groups in ICAO *Circular 315* (2008a). The novice investigators therefore recognise the risk posed by environmental hazards, physical hazards, biological hazards and material hazards. The fifth hazard category, psychological hazards, is ranked only 9th in terms of risk perceived by novice investigators, and is perceived to be one of their five greatest hazards by only three per cent of novice investigators (17/546 cards).

Table 4.19: Rank order of hazards categories identified by novice accident investigators		
Rank Order	**Category of Hazards**	**Number of Cards**
1	Damaged and unstable structures	109
2	Biological hazards	84
3	Fire and flammable substances	75
4	Accident location	58
5	Chemicals and other substances	48
6	Climate	30
7	Composite materials	23
8	Pyrotechnics and explosives	19
9	Psychological hazards	17
10	Cargo hazards	15
11	Pressurised gases	14
12/13	Insects/wildlife	13
12/13	Radioactive materials	13
14	Stored energy components	6
15/16/17	Fatigue	5
15/16/17	Security	5
15/16/17	Metals and oxides	5
18/19	Recent safety equipment	1
18/19	Local state of hygiene	1
20	Military and ex-military aircraft	0

Novice investigators did not perceive fatigue, security, metals and oxides, recent safety equipment and local state of hygiene to be significant hazards. No investigators perceived the hazards of military and ex-military escape equipment and ejector seats to be a high risk.

Of the 109 investigators who perceived damaged and unstable wreckage to be one of their five most serious hazards, 57 perceived the danger to be laceration from sharp objects in the wreckage; 17 from unstable debris and falling objects; and 28 from slips, trips, falls and other forms of personal injury. The ranking of damaged and unstable wreckage hazards as the number one hazard would appear to be evidence in support of the hypothesis that novice investigators might have a greater concern about general health and safety hazards than about aircraft specific hazards.

The effects of the second-ranked category, biological hazards were much less precisely described on the cards than the responses to the damaged and unstable wreckage category, which referred directly to mechanisms of injury. Rather, there were various descriptions of the hazards such as ‘blood borne pathogens’, ‘body fluids’ and ‘human remains’. There was no specific mention of the methods of exposure to these hazards. However, 77 of the 84 cards were in some way related to infection or illness arising from exposure to blood or bodily fluids. Again, this would appear to support the hypothesis of identification of general health and safety hazards over aircraft specific hazards, as does the ranking of fire and flammable substances as the third-ranked perceived hazard among novice investigators.

Accident location is a very general definition for a category which can encapsulate a wide and varied range of hazards, but to the novice investigators it signified difficult terrain and the natural environment as well as surrounding man-made hazards. Many of the cards in this category were closely linked with climate hazards. If the 30 cards identifying climate hazards (rank order six) are considered in terms of the broader environment of the site, the location of the site might be seen as a more significant hazard by novice investigators than the rank order suggests.

Responses assigned to the category of chemicals and other substances (48 cards; 9 per cent of responders) are undifferentiated by respondents as responses to biological hazards, suggesting that novice investigators are aware of the broad risks but not the precise mechanisms by which the hazards are presented.

4.6 Conclusions

All the novice investigators surveyed for this study had obviously made a deliberate career choice to become accident investigators, and to undergo a course of training to that end. They therefore had an apparent interest in and commitment to this field. At the time of the survey, they had undertaken the syllabus for the basic accident investigation course (ICAO, 2003a), as set out in Section 2.1.4. This is a very wide overview of the field of accident investigation including, amongst other things, the responsibilities of the various jurisdictions involved in investigation, accident site considerations, the available range of personal equipment and protective clothing, the likely sources of evidence, the design of aircraft systems and likely modes of failure, aerodynamics and aircraft performance, and report writing. However, the basic investigation course does not include attendance or training at an accident site.

The hypothesis to be tested by the research was that novice investigators will have greater concern about general health and safety hazards - such as slips, trips and falls and biological hazards - than particular aircraft specific hazards such as pressurised vessels. This hypothesis would appear to be proven: the top five ranked categories all identify general safety hazards. Categories which include aircraft-specific hazards (including stored-energy components, pressurised gases, recent safety equipment, composite materials, metals and oxides, and military and ex-military aircraft) were ranked much further down the scale.

The implication of this finding is that the basic investigation course - as presently structured by ICAO - does not give a balanced understanding of the realities likely to be encountered on an accident site. This is partly understandable given that there is no real substitute for experience. Nevertheless, it is clear that the basic course would be enriched by a greater focus on case studies and on accident reports prepared by experienced accident investigators. Case studies of major and complex aircraft accident investigations carried out by highly skilled investigators from the national investigation authorities - such as Lockerbie (AIB, 1990), Heathrow (AAIB, 2009c), and Buffalo (NTSB, 2009a-e) - would give trainee investigators a less theoretical and much more realistic understanding of the situations they are likely to encounter. Similarly, as discussed in Section 4.2.2, there are real benefits in including simulated accident sites in investigator training.

The methodology employed for this study allowed the trainee investigators to have open scope to name hazards they felt posed a personal risk on sites. While this made the sorting of cards into the hazard categories assigned by ICAO *Circular 315* (2008a) difficult, leading to the repetition of some cards in multiple categories, it ensured that all ideas that the novice investigators had about potential site hazards could be included in the scope of the research.

Chapter Five

An Assessment of the Occurrence of Hazards on Aircraft Accident Sites

5.1 Purpose of the study

Chapter Five analysed the hazards that novice aircraft accident investigators perceive to be the greatest risks on accident sites. The purpose of this chapter is to analyse the hazards identified on accident sites by experienced aircraft accident investigators.

The methodology used - the analysis of historical data on health and safety forms completed by investigators from a national aircraft accident investigation agency - also enabled review of the process of site investigation, providing an overview of the tasks completed and the PPE used by investigators.

5.2 Context

The health and safety regulations of several countries which require employers to maintain records of the working environments of their employees, have been considered above. The difficulties associated with pro-active risk assessments and quantitative risk assessments have also been discussed. The only accurate way in which employers of aircraft accident investigators can monitor the exposure of their employees to hazards on accident sites is through retrospective review following accident site attendance.

5.3 Methodology

5.3.1 Overview

This study is based on analysis of health and safety forms which are completed routinely by investigators employed by a national aircraft investigation agency, following an investigation. The sample of forms collected were for attendances at the sites of accidents, serious incidents, and incidents between February 2003 and July 2009.

5.3.2 Research design

The researcher had no influence over the design of the form. Two different forms were used over the period of analysis, the first from February 2003 to the end of 2006, the other from January 2007 onwards.

Both versions of the form asked for general information about the accident, including aircraft type, registration, and location; and site safety information, including details of the activities undertaken, the safety hazards identified, and the PPE used. The later version of the form included additional questions about the deployment and aircraft recovery process.

5.3.3 Ethical considerations

The health and safety forms are completed by aircraft accident investigators as part of their standard investigation tasks. Permission to use the forms for this research was granted by the investigation agency.

As part of the data analysis, all identifying information was removed from the forms. No person, other than the researcher, had access to the forms.

5.3.4 Analysis methods

Information from the health and safety forms was entered into a database. The standard database format called for all the information included on the newer version of the health and safety form. When information from the earlier version of the health and safety form was entered, sections not included in the original form were left blank. The differences in the forms were taken into consideration during analysis. There was no information collected on the first version of the form which was not included on the second version of the form.

The information in the database was recorded in .csv format. This is a common data storage format which allowed portability of information between programmes.

Once the information from the forms was entered into the database, some additional fields were created to assist with analysis. These included whether the form was completed by an investigator specialising in either operational, engineering, or flight data recorders investigation; whether the aircraft was operating as a commercial flight, a general aviation flight, or a sport aviation flight; and whether the aircraft was of fixed wing or rotary wing design.

The analysis then considered the range of different events attended, the deployment process, and the aircraft recovery process. The information regarding the event was predominantly categorical; the information regarding the deployment and aircraft recovery process was predominantly nominal. A simple count was used to look at this information.

The tasks completed on site were analysed by content analysis, as applied in review of site tasks in Section 3.4.3. These tasks were considered in relation to the specialisation of the investigator completing the form.

The hazards on site were analyses using a template analysis methodology (King, 1998). The coding scheme applied for analysis was based on the categories of hazards identified in ICAO *Circular 315* (2008a), as discussed in Chapter Three, and applied in the research in Chapter Four. Additionally, the responses given to the perception survey used in Chapter Five were used as additional probes to ensure that the responses on the health and safety forms were categorised in the same way as the novice risk perception study.

Content analysis was again applied in considering the PPE used by investigators. The PPE used on each site was then compared to the hazards identified on the site, to identify the minimum levels of protective equipment used for different hazards.

5.4 Results

5.4.1 Overview

In this study, 392 field investigation health and safety forms were reviewed. These covered 208 events, occurring between February 2003 and July 2009. The majority of forms were from late 2005 onwards: there were 180 forms (96 occurrences) on the original version of the form, and 212 forms (112 occurrences) on the newer report format. Between one and eight forms were received per event.

Forms are required to be submitted by each investigator who attends a site, although there were more site attendances during the specified period than the number of forms received by the researcher. This sample is not seen to cause a problem for the analysis.

Of the forms received and analysed, it is unknown whether each of the events were accidents, serious incidents, or incident.

Table 5.1 gives the number of forms analysed for each different type of investigator or responder (engineering, operations, FDM, health and safety and engineering support [HS&E], other) in the sample, and the number of events that these forms covered.

Table 5.1: Number of health and safety forms analysed by investigator type

Type of Investigator	Number of Forms Analysed	Number of Sites Analysed
Engineering	149	142
Operations	186	177
Flight Data Monitoring	37	35
HS&E	15	12
Other	5	4

5.4.2 Deployment

5.4.2.1 Aircraft type

Table 5.2 shows the operation type and category of aircraft involved in the events to which investigators were deployed.

Table 5.2: Number of health and safety forms analysed by operation and aircraft category

Category of Operation	Number of Forms Completed	Number of Sites Inspected
Commercial (fixed wing)	186	101
Commercial (rotary wing)	25	9
General Aviation (fixed wing)	100	54
General Aviation (rotary wing)	22	10
Sport Aviation / Balloons	64	35
Total	397	209

Note: One accident site attended by five investigators was a mid-air collision between a commercial fixed wing aircraft and a sport aviation aircraft. This means there are (397-5=392) forms and (209-1=208) accident sites in total.

Four of the aircraft accidents involved military aircraft. These are included by the investigation organisation under the commercial (fixed wing) category.

5.4.2.2 Method of travel on deployment

The later version of the form sought information about deployment, including the time of deployment, the time on the task, and the method of travel. In most responses the time of deployment and time on task were given only approximately or not at all, but the method of travel is clear: of the 212 investigators who completed the later version of the form, 141 had deployed to the site by vehicle, including their own vehicles and agency vehicles.

Of the 141 investigators who deployed by vehicle, the average time from base to deployment was about 5 hours 30 minutes. This included 24 deployments for which notification was received late at night, and the investigators arrived on site the following morning. Removing these 24 deployments from the calculation, the average time to deploy to a site by road was 3 hours 15 minutes.

The majority of investigators reported no problem with the deployment, or had no comment. In one circumstance the investigator was provided with incorrect details of the aircraft location; one chose to deploy using a company four-wheel-drive vehicle, due to the initial but incorrect notification that the site was on a "remote, high elevation field". Six investigators commented on the heavy traffic encountered, and four on conditions during the drive (either darkness, fog or rain). One investigator specifically noted that they "arrived fatigued on site with many hours of work ahead", while another commented that the deployment was "a long drive at the end of the day".

A total of 61 investigators deployed to the site by air. Approximate times between deployment and arrival were given for 47 of these deployments: the average was almost 13 hours. Of these deployments, eleven were to international sites, of which there were eight; eleven were to offshore sites (two sites); the remainder were to locations which were too remote or too distant to access by road.

Comments from investigators who deployed by air focussed on the limited amounts of equipment that could be carried on board aircraft, or problems about airport congestion and delayed flights.

Ten investigators did not provide details of their time or method of deployment. In four of these cases, deployment was not necessary because the work of investigation was undertaken while remaining at base. Nevertheless, completion of a health and safety form remained a requirement.

5.4.2.3 Organisation of the site investigation

In the 212 completed later versions of the form, only eight investigators reported problems in responding to the accident occurrence (by answering "yes" to response issues). Three of these commented on the timeliness of deployment (one early, one late, and one questioning whether deployment was even necessary). One investigator reported problems with security and gaining entry to the site, and one reported that access to the site was difficult. One investigator, responding to an accident involving an ex-military aircraft, noted that assistance was required to make the aircraft safe. Two investigators did not provide further details.

A total of 18 investigators answered "yes" when asked whether there were issues with police: difficulties included 'over-enthusiasm' of police on site, and difficulties in getting the police to secure the site. One investigator reported that three shotguns were found on the site.

Four investigators reported problems with accommodation. Two were related to the quality of the hotel, one to difficulty in finding accommodation, and one that the hotel was closed on arrival. One investigator suggested that hotels should be booked for the night following the site investigation, not just the one before it, because investigators are commonly too tired to travel home.

Aircraft were recovered back to base from sites on which 133 of the investigators had worked. In 52 of these cases, the investigator played a major role in recovering the wreckage. A total of 34 aircraft were recovered with military assistance, and 42 required other organisations to assist in wreckage recovery. The recovery organisations included private recovery contractors, sea salvage organisations, and local fire and police services.

5.4.3 Activities on site

As expected, different tasks were carried out by engineering investigators and operations investigators in response to accidents.

Table 5.3 shows the tasks that engineering specialist investigators report as having undertaken, in the 149 forms they submitted. The tasks most commonly identified are listed along the top line.

Table 5.3: Tasks identified by engineering investigators during site activity

Activities Identified by Engineering Investigators		
Recovery of aircraft	Examination of aircraft	Examination of wreckage
Site examination	Site survey	Plotting of wreckage / witness marks
Examine components	Runway inspection	Interviews
Functional tests on aircraft	Collect floating debris	Examine wreckage in hangar
Record damage on aircraft	Recover bodies	Examine documents
Observations on procedures	Investigate 3rd party damage	Recover data recorders
Assist other investigators	Search for missing parts	Fuel sampling
Wreckage sift	Writing field notes	Police liaison
Review flight data	Co-ordinate security	Co-ordinate recovery of bodies
Make the aircraft safe	Meeting with relatives	Brief coroner
Take chemical samples from toilets	Photography	Investigate burst tyres

Phrases such as “standard field investigation”, “straightforward deployment” and “standard GA deployment” were also used in some of the forms.

Table 5.4 gives the investigation activities identified by 186 operations inspectors, with the most commonly identified tasks along the top line.

Table 5.4: Tasks identified by operations investigators during deployment

Activities Identified by Operations Inspectors		
Interviews	Attend site	Liaise with emergency responders
Inspect aircraft	Examine wreckage	Gather documents
Recover wreckage	Visit airfield (if different to accident site)	Collect ATC tapes / radar traces etc.
Family liaison	Meetings with operator etc.	Visit ATC - interviews/review procedures
Inspect runway	Collect wreckage	Office based work
Initial scene preservation	Data recorder recovery	Helicopter flights to survey scene
Recover bodies	Fuel sampling	

As in the forms completed by engineering inspectors, some of the operations inspectors used phrases like “normal on site and post site” and “normal field investigation”.

FDM investigators deployed to sites recover recorders directly from the aircraft, or from maintenance organisations or operators who may have already recovered them. There are only two instances in the sample of forms (out of 37) of FDM investigators having to search through wreckage to recover the recorders.

Health and safety support staff provide support for the investigators by conducting risk assessments, and facilitating the recovery of wreckage.

5.4.4 Hazards identified by experienced accident investigators

5.4.4.1 Overview

The separate lists of hazards identified by operations, engineering and FDM investigators, and by HS&E responders, are included as Appendix G. Table 5.5 shows the number of hazards identified by the different categories of investigators.

Table 5.5: Number of hazards identified by investigators on accident sites

Investigator Type	Number of Sites Attended	Number of Sites with no Hazards Identified	Number of Sites with Hazards	Total Number of Hazards Identified
Engineering	149	46	103	207
Operations	186	114	72	115
FDM	37	29	8	10
HS&E	15	1	14	32

The differences in the number of hazards reflect the difference in the tasks completed by investigators on sites: engineering investigators are much more involved in the wreckage sift, whereas operations and FDM investigators may not need to be involved in the site search to the same depth.

These hazards were then combined and categorised using the definitions in ICAO *Circular 315* (2008a), and compared to the hazards attributed to each category in Chapter Four. These are discussed in Sections 5.4.4.2 - 5.4.4.6.

5.4.4.2 Environmental hazards

5.4.4.2.1 Aircraft location

The hazards identified by accident investigators as arising from the aircraft location are shown in Table 5.6.

Table 5.6: Hazards identified by experienced accident investigators as attributable to aircraft location

Hazard	Number
Airside / hanger operations / noise from other aircraft	30
Slope of earth / steep terrain / difficult access due to slope	12
Wet and slippery ground / icy ground / slippery seaweed on ground	6
Trip hazards	4
Hazards working on a ship / offshore	6
Working on high platforms	3
Field surface / uneven terrain	5
Working in and around unstable buildings	5
Marsh / waterlogged or swampy ground / mud	11
Wreckage in trees / broken branches in trees	9
Access to site / aircraft	5
Total	***96***

Airside hazards account for a third of the hazards identified in this category. This is not a location hazard specifically mentioned in the definition provided by ICAO *Circular 315* (2008a), but it is clearly a significant hazard during investigation of accidents and incidents at an operating airfield.

5.4.4.2.2 Fatigue

Four investigators identified fatigue as a hazard they had encountered during the investigation.

5.4.4.2.3 Insects/wildlife

Seven investigators identified hazards categorised as insects/wildlife. Of these seven, four were insect hazards (specifically mosquitos and horse flies). One investigator had to deal with livestock (both dead and alive) on the site. Two investigators identified hazards arising from the vegetation on the site: one had to investigate on a site covered with gorse bushes, and extremely sharp bush; the other developed hay fever while on site.

5.4.4.2.4 Climate

Table 5.7 summarises the climate related hazards which were identified by investigators.

Table 5.7: Hazards identified by experienced accident investigators as attributable to climate

Hazard	Number
Cold weather / freezing windchill	10
Dehydration	1
Hot weather	3
Rain / Snow	5
Weather	2
Sun exposure	1
Total	***22***

While cold weather was the predominant hazard, a number of other hazards arising from extremes of temperature and precipitation were recorded.

5.4.4.2.5 Security

Four security related hazards were recorded: one being poor access control on the site; one with protecting third parties while they were on the site; and two (the same site, but identified by different investigators) where stones were thrown at them by bystanders while they were conducting the investigation.

5.4.4.3 Physical hazards

5.4.4.3.1 Fire and flammable substances

There were 28 hazards attributed to this category, 26 were associated with fuel and the remainder with oil.

5.4.4.3.2 Stored energy components

Table 5.8 summarises the hazards identified as relating to stored energy component hazards.

Table 5.8: Hazards identified by experienced accident investigators as attributable to stored energy components

Hazard	Number
Battery	3
High voltage power supply	1
Exploding nose wheel	1
Power to systems	1
Total	***6***

Five of these six hazards referred to potential electrical inputs when the investigator is working on the site.

5.4.4.3.3 Pressurised gases

Two investigators identified hazards posed by pressurised cylinders on sites attended.

5.4.4.3.4 Military and ex-military aircraft

Four investigators identified armed ejection seats or escape systems on sites to which they deployed .

5.4.4.3.5 Recent safety equipment

No hazards related to recent safety equipment were identified in this sample of health and safety forms.

5.4.4.3.6 Pyrotechnics and explosives

On three separate accident sites, investigators identified either ammunition, flares, or a fire extinguisher posing a hazard during the investigation.

5.4.4.3.7 Damaged and unstable structures

Table 5.9 gives details of hazards related to damaged and unstable structures.

Table 5.9: Hazards identified by experienced accident investigators as attributable to damaged and unstable structures

Hazard	Number
Sharp wreckage / debris / sharps / sharp metal	30
Unstable wreckage	3
Medical kit left remaining by ambulance services (may contain sharps)	4
Broken perspex	1
Cabin environment	1
Total	***39***

By far the most common hazard encountered in this category was sharp wreckage. The broken perspex and the medical kit can also be considered in that context. Unstable wreckage may hamper access to evidence, and the cabin environment might also be unstable or difficult to access.

5.4.4.4 Biological hazards

5.4.4.4.1 General biological hazards

Of the 77 hazards attributed to this category, 73 related directly to biohazards, pathogens, blood, or human remains, and one other investigator identified ‘decontamination’ as a hazard. Three investigators reported animal manure on the site.

5.4.4.4.2 Local state of hygiene

No hazards associated with the local state of hygiene were identified on the sampled forms.

5.4.4.5 Material hazards

5.4.4.5.1 Metals and oxides

Seven investigation forms identified metals and oxides hazards: four identified fire residue/ash/dust; and three identified the hazards from more intact but still fire damaged materials.

5.4.4.5.2 Composite materials

Table 5.10 summarises the composite-related hazards identified by investigators.

Table 5.10: Hazards identified by experienced accident investigators as attributable to composite materials

Hazard	Number
Damaged composites / carbon fibre / glass reinforced plastic / carbon fibre shards	14
Burnt composites / burnt carbon fibre	10
Composite dust / Carbon fibre dust	3
Asbestos	2
Total	***29***

Fourteen of these hazards arise from impact damaged composites, and ten from fire damaged composites. The three composite dust hazards could come from either impact damage or, more likely, fire damage. Asbestos was located in a building into which an aircraft crashed.

5.4.4.5.3 Chemicals and other substances

Ten hazards were identified on the sample group of sites (Table 5.11).

Table 5.11: Hazards identified by experienced accident investigators as attributable to chemicals and other substances

Hazard	Count
Fire extinguisher powder	3
Hydraulic fluid / Skydrol	4
Chemical weed killer	2
Chemicals	1
Total	***10***

Only one investigator identified ‘chemicals’ as a general hazard, the others were more specific about the particular chemical encountered.

5.4.4.5.4 Radioactive materials

Two investigators identified radioactive material hazards. The first one was radioactive dust, following an accident involving an ex-military aircraft; the second a damaged forward looking infrared (FLIR) system on a current military aircraft.

5.4.4.5.5 Cargo

Two cases of cargo hazards were identified, both from dangerous goods on board the aircraft.

5.4.4.6 Psychological hazards

One investigator developed stress following interviews with relatives of the deceased in an accident.

5.4.4.7 Hazards due to working conditions

Some of the hazards identified by investigators do not fit into the ICAO *Circular 315* (2008a) taxonomy of hazards. These are identified in Table 5.12.

Table 5.12: Hazards identified by investigators as associated with working conditions

Hazard	Number
Driving conditions to site	6
Lifting heavy wreckage	4
Working at night	4
Working with cranes / lifting equipment	2
Lack of food/water supply	1
Carrying kit	1
Total	***18***

Working at night, the driving conditions to the site, and lack of food and water can lead to early onset of fatigue and dehydration. This will reduce the performance of investigators and possibly be detrimental to the investigation. Driving in itself may be a danger if investigators are distracted by incoming information about the accident to which they they are responding. Lifting heavy wreckage and carrying kit can lead to muscoskeletal injuries.

Working with cranes and lifting equipment may be necessary when stabilising wreckage, or when recovering wreckage for further investigation. Investigators may need to consult the crane operator for safety advice.

The investigators also identified the hazards that arose from powering up an aircraft and operating flight controls. Investigators must ensure that the area is clear of other workers before these tasks are undertaken.

5.4.5 Personal protective equipment used on accident sites

The personal protective equipment accident investigators identified as wearing on accident sites in listed in Table 5.13.

Table 5.13: PPE used by investigators on accident sites

PPE	ENG	OPS	FDM	HS&E	Total
Footwear					
Safety Boots/Shoes	28	25	2	3	***58***
Walking Boots	2	1	-	-	***3***
Wellington Boots	5	8	-	-	***13***
Overshoes (booties)	-	1	-	-	***1***
Clothing					
Cold weather clothing	16	3	1	1	***21***
Wet/foul weather clothing	10	9	1	6	***26***
Waterproof clothing	6	6	1	-	***13***
Ski clothing	-	2	-	-	***2***
High visibility vest/jacket	23	9	4	-	***36***
Protective Coveralls					
Coveralls	28	5	1	2	***36***
Hearing Protection					
Ear defenders	7	1	-	1	***9***
Eye Protection					
Safety Glasses	7	1	1	-	***9***
Safety Goggles	3	1	1	-	***5***
Visor	-	-	-	1	***1***
Respiratory Protection					
Disposable mask	15	4	-	1	***20***
Half face mask	1	-	-	1	***2***
Gloves					
Gloves (unspecified)	43	39	2	6	***90***
Nitrile gloves	11	14	-	6	***31***
Heavy duty/leather wreckage gloves	12	1	-	6	***19***
Warm gloves	1	-	-	-	***1***
Waterproof gloves	-	1	-	-	***1***

Table 5.13: PPE used by investigators on accident sites

PPE	ENG	OPS	FDM	HS&E	Total
Head Protection					
Hard Hat	8	5	4	3	***20***
Hat	4	1	-		***5***
Other PPE					
Safety harness	2	-	-	-	***2***
Life jacket	-	1	1	-	***2***
Immersion suit	-	1	-	-	***1***
Other					
Sunscreen	3	1	-	-	***4***
Insect repellent	1	-	-	-	***1***
Antiseptic / Disinfectant / Sterilisation sprays and wipes	4	1	-	-	***5***
Torch	-	1	-	-	***1***
Trolley	-	-	1	-	***1***

This list shows that a wide range of PPE was used by investigators responding to accidents. All the major types of PPE are included. In addition items shown in the table, a number of investigators reported wearing ‘standard PPE’ or ‘full protective clothing’. Upon questioning some of the sampled investigators, this term was taken to mean, at a minimum, coveralls, nitrile gloves, wreckage gloves and a respirator.

Wearing PPE comes with the job of investigation. A question arises from the above table about whether all types of PPE have been reported whenever they have been used. For example, it would seem certain that more than 58 investigators wore safety shoes on sites, as safety shoes or boots are a standard part of an investigator’s kit. It might well be that unless they were specifically required for particular sites, their use was simply not recorded.

5.5 Discussion

5.5.1 Review of investigator deployment

Amongst the sample group, the method of deployment depended on the distance to the site. The average time taken to get to a site by car was 3 hours 15 minutes, the average time taken to get to a site by air was almost 13 hours. Delay in arriving at a site creates the potential for loss of evidence.

Both methods of deployment had drawbacks: investigators deploying by car complained of traffic, which potentially leads to fatigue and lack of focus when they arrive on site; investigators deploying by air complained of airport congestion and delay, and limits on baggage allowances. If investigators are unable to carry all necessary equipment with them, they might be unable to collect all the evidence required, or might have inadequate PPE for protection.

After arrival, some investigators experienced difficulties in gaining access to the site, or in liaising with other organisations on the site. Because aircraft accidents are so rare, other organisations appear not to be aware of the protocols and legal rights of an accident investigation agency, and of how they might best assist the investigation.

5.5.2 Activities on the investigation site

The activities that investigators carry out on an accident site vary according to purpose: engineering investigators get involved in the wreckage, possibly inspecting and collecting every piece of debris for evidence about the causes of the accident; while operations inspectors, following initial site inspections and wreckage collection, might investigate in detail a smaller part of the aircraft or wreckage, such as the cockpit, before conducting interviews and gathering other sources of evidence.

5.5.3 Hazards identified on accident sites

Evidence collection and hazards management are integrally linked task, and vary according to the specialisation of the investigator. Regardless of the specialisation, all investigators need to strike a balance between “the requirements of the task and the need to make the performance of the task safe” (ICAO, 2008a, paragraph 2.3.1).

The rank order of hazards identified by experienced accident investigators in the data provided by the health and safety forms is shown in Table 5.14.

The top five hazard categories were aircraft location, biological hazards, damaged and unstable structures, composite materials, and fire and flammable substances. These hazards represent four of the five overarching categories of hazards in *Circular 315* (ICAO, 2008a), psychological hazards being the only one not included.

Table 5.14: Rank order of hazard categories identified by experienced accident investigators

Rank Order	Category of Hazards	Number of Reports
1	Aircraft location	96
2	Biological hazards	77
3	Damaged and unstable structures	39
4	Composite materials	29
5	Fire and flammable substances	28
6	Climate	22
7	Chemicals and other substances	10
8/9	Insects/wildlife	7
8/9	Metals and oxides	7
10	Stored energy components	6
11/12/13	Fatigue	4
11/12/13	Security	4
11/12/13	Military and ex-military aircraft	4
14	Pyrotechnics and explosives	3
15/16/17	Pressurised gases	2
15/16/17	Radioactive hazards	2
15/16/17	Cargo	2
18	Psychological hazards	1
19/20	Recent safety equipment	0
19/20	Local state of hygiene	0

5.6 Conclusion

Examination of the 392 health and safety reports covering 208 accidents and incidents over more than six years has allowed a comprehensive and detailed analysis of the realities faced by accident investigators in the field. This reveals a great range and diversity of experiences and situations in the life of an accident investigator.

The number and range of tasks undertaken are numerous: 33 different activities were reported by engineering investigators (Table 4.1), and twenty were reported by operations inspectors. For the former, recovery of the aircraft and examination of the wreckage are the most common activities; for the latter, the most frequent activities are interviews, site attendance and liaison with other responders.

The 208 sites were attended by 387 investigators in various specialisations (Table 5.5). They identified a total of 364 hazards. Engineering investigators reported hazards at the great majority of sites they attended (hazards at 103 of 149 sites); far fewer sites with hazards were encountered by operations engineers (72 of 186 sites) and FDM engineers (8 of 37 sites). This reflects the different sorts of activities undertaken by each specialisation, with the greatest exposure to hazards being faced by engineering investigators. In contrast, HS&E investigators identified hazards at 14 of the 15 sites they attended, which is explained by the fact that HS&E expertise is normally called in when other inspectors have encountered potential hazards about which they require specialist advice.

The most frequently reported hazards arising from aircraft location were airside hazards (30 of 96 reported hazards), although on-site terrain hazards relating to steepness, slipperiness, trip hazards and uneven ground and swampy ground amount to 38 of 96 reported hazards (Table 5.6). Cold weather was more commonly a source of hazards than hot weather (Table 5.7), although this was an expected consequence of the nature of the climate in the jurisdiction of the national investigation agency to which the investigators belonged. Sharp wreckage was a common hazard (Table 5.9); damaged and burnt composite materials (Table 5.10) were almost three times as frequently encountered as chemical hazards (Table 5.11).

It is clear that over a working lifetime an investigator will encounter a very wide range of hazards, but some of them will be met very infrequently. As four of the five major categories of hazards - arising from the location of the aircraft, biological hazards, damaged and unstable structures, and fire and flammable substances - will be encountered almost routinely, investigators must have high level skills in identifying and managing these hazards while at the same time collecting the necessary evidence and maintaining its integrity.

Investigators also need to have the knowledge and skill necessary to identify and manage the less-frequently encountered hazards, even though they might come across hazards such as those arising from cargo, pyrotechnics, lack of security and recent safety equipment on only a handful of occasions during a career. It is inevitable that such knowledge and skill must largely be acquired at second hand - through updated briefings on the identification and mitigation of such hazards - rather than be honed to a high level of practical experience in the field. This means that there needs to be ongoing specialised research into the detection and management of infrequently encountered hazards, and the prompt and regular dissemination of this information to all investigators, through publication and in-service training. Preferably, the latter should include training for experienced accident investigators on simulated accident sites involving the presence of infrequently encountered hazards. There also needs to be a capacity for investigators to call upon personnel engaged in such specialist research, in the event of uncertainty about the existence of a particular hazard at an accident site, or about how to deal with it.

The results of this study can not be directly compared to the results of the previous study (Chapter Four), as one study compares perception of risk and the other actual hazards, without consideration of the level of risk however, it is interesting to compare the relative rankings of the hazards (Table 4.19 and Table 5.14).

Although given in a different order, four of the five hazards that novice investigators perceive as most risk on site (aircraft location, damaged and unstable structures, biological hazards, and fire and flammable substances) are the ones experienced investigators identify most commonly on a site.

Novice accident investigators included risks from chemicals and other substances within their five perceived highest risk hazards, where the experienced investigators identified it only seventh most commonly found on sites. Hazards associated with composite materials were reported by the experienced investigators as the fourth most common hazard, but only seventh by the novice accident investigators.

The risk arising from cargo is identified by novices as quite high, but identified by experienced investigators infrequently. Conversely, novice investigators did not identify any risk associated with military and ex-military aircraft, whereas experienced investigators identified this in equal eleventh ranking out of twenty hazards categories. The hazards posed by metals and oxides are listed by experienced investigators as the eight most common hazard, while novice investigators responses rank these hazards as fifteenth most hazardous. Potential hazards arising from recent safety equipment and local state of hygiene are not recognised as greatly significant by either novice or experienced accident investigators, despite recent safety equipment being one of the common inclusions in aircraft accident site hazards literature.

Chapter Six

Observations of the Identification and Assessment of Hazards, and the Selection and Use of Personal Protective Equipment by Accident Investigators on Simulated and Real Accident Sites

6.1 Purpose of the study

This study answers question four of the research questions: How do accident investigators identify and manage the hazards?

This study looks at the processes investigators use in the field to identify hazards, and at the methods employed to protect themselves against the effects of those hazards. The research was conducted by observing investigators on simulated accident sites during both initial and advanced investigator training, and on a real accident site.

6.2 Context

6.2.1 Overview

This study builds upon the research set out in the previous chapters, and brings together the work on the training of aircraft accident investigators, generic and dynamic risk assessment, the potential hazards which may occur on accident sites, and on site evidence collection methods (Chapter Three).

6.2.2 Training investigators on simulated accident sites

The benefits of using simulated accidents for training in accident investigation have been demonstrated and are widely recognised (for example, Braithwaite and Greaves, 2009; Siewert and Stephens, 2007; Woodcock *et al*., 2005). As noted by Braithwaite and Greaves (2009):

> "Simulation is not the same as instruction – the aim is not to walk investigators through an accident site tutorial (though such tutorials are a useful introduction). Instead, simulation requires full participation by the investigators under training and observation and feedback from experienced instructors".

Simulating an accident site gives investigators an opportunity to practice the theories and techniques they have been taught during formal training, in a 'safe' environment where their mistakes will not lead to a loss of vital evidence. More importantly for this research, a simulation allows investigators to practice the skills needed to identify and mitigate site hazards while collecting evidence, in a training environment.

Simulated accident sites are virtual crash scenes created in the field in great detail by subject matter experts (SMEs): they are laid out so that they resemble 'real' accident sites as closely as possible. Accident investigators working on these sites in a training exercise are required to operate under time pressures to collect evidence both on and off the site. However, the simulated environment allows close monitoring of the way in which the investigators conduct themselves, so that they can learn from later analysis of any deficiencies in their behaviour, which on a real accident site could result in loss of evidence, or direct personal harm.

6.2.3 Personal protective equipment

6.2.3.1 Types of personal protective equipment

The personal protective equipment used by investigators on aircraft accident sites was reviewed in Section 5.4.5. This chapter considers the findings of Chapter Four in in the light of this further study and the available guidance on PPE.

General health and safety guidelines suggest that PPE be used only as a final risk mitigation measure (Section 2.4.4.5). However, in achieving the necessary balance between evidence collection and personal safety, investigators may often need to turn to PPE before other risk mitigation measures.

The PPE recommended by *Circular 315* (ICAO, 2008a, p.19) for an investigators 'go-kit' is shown in Table 6.1. In addition, *Circular 315* (ICAO, 2008a, p.20) notes that investigators working in marine environments may require: "life vest; suitable footwear for deck operations; hard hat or, if permitted, peaked waterproof hat; pair of neoprene gloves; sun protective screen; and motion sickness medication if recommended".

Table 6.1: Suggested PPE and equipment for Accident Investigators (ICAO, 2008a)
Half-face respirator complete with spare set of broad range of chemical/dust cartridges (the set should be effective for organic vapour, acid gas and P100). If space permits, a full-face piece respirator complete with spare set of cartridges should be included
Several disposable dust/mist HEPA/P3 masks
Two or more disposable coveralls
Several pairs of disposable nitrile gloves
Several pairs of disposable heavy duty gloves
One pair of Kevlar cut-resistant gloves with lined palm and fingers
Protective footwear with sole and toe protection
Hard hat
Eye protection: either safety glasses or safety goggles
Hearing protection: either ear muffs or ear plugs
Hand and equipment wipes
High visibility vest
Chemical or duct tape
Cleaning/disinfection chemicals and supplies
Bio-disposal bags
Drinking water
First aid kit
Foul-weather clothing
Insect protective solutions and medication, if recommended
Extra batteries and power supply adaptors for electronic equipment

The PPE that investigators choose to wear on an accident site will depend not only on the nature of the site, but also on the specific tasks to be carried out.

In the literature on aircraft accident investigation, there are various recommendations on PPE in addition to those given in *Circular 315.* These are compared in Appendix H.

6.2.3.2 Standards of personal protective equipment

When PPE is the most appropriate risk mitigation measure, it is important to ensure that the equipment is of the appropriate standard, and is fitted properly. It is also important that the guidelines for use are followed. Each type of PPE has been tested to sustain a certain level of use, beyond which the equipment will fail to function as designed, and will not provide protection for the investigator. Each individual pack of different PPE should contain an information leaflet with the limits of use on it. PPE selected should be comfortable for the wearer, and compatible with other selected PPE.

Head Protection

Hard hats should provide protection to meet standards EN397 (Europe)/ ANSI Z89.1-1986 (USA). The hard hats should be marked as either class A or B.

A hard hat should be selected provide a gap of between 1 and 1 ¼ inches (2.54cm to 3.18cm) between the top of the head and the top of the cap. This provides the optimal level of impact absorbency if required.

All hard hats should have a chinstrap point, to ensure the hat stays on the head when manoeuvring around wreckage. In some industries and some working environments, such as on the railways, the wearing of a hard hat is compulsory. In other situations, it may be the choice of the investigator. Accessories such as face visors, ear defenders, radios, torches and cameras may be attached to the hard hat.

If a hard hat is is judged not to be necessary, the investigator may instead choose to wear a ‘bump cap’ – a baseball style plastic cap, that provides some protection for the wearer against impact, but not the same level as a hard hat. The bump cap uses padding rather than a suspension system and space to provide protection. The advantage of bump caps is that they are lighter and less bulky. They provide sun or rain protection as well as as head impact protection.

Hard hats should be cleaned with hot water and a standard disinfectant solution such as Virkon, with all detergent rinsed off at the end of the cleaning process. Hats should be inspected regularly for their condition, and disposed of as soon as they show any signs of damage, such as cuts, cracking, loss of gloss colour and flaking, when they will no longer provide sufficient protection. Bump caps may not be able to be cleaned to a sufficient level if they are covered with cotton.

Eye Protection

Safety goggles should meet at least standard EN166.1 – B.3.4.9. This means that they are goggles with the highest level of lens (166.1), that withstand being hit by high speed particles at medium level impact (B), are resistant to liquid droplets (3), coarse dust particles (4) and molten metals and hot solids (9). Face shields are available that meet, and exceed these standards, although a full face shield can be cumbersome to wear for extended periods.

Safety goggles should fit over glasses, and have a malleable seal that forms around the arm of the glasses. Prescription safety goggles are available, although costly. Goggles must be properly cleaned after each use, or contaminants could be introduced into the eyes.

Safety goggles come with the option of having vents or no vents on the top of the goggle. Vents are designed to prevent the goggles from steaming up inside, but it must be ensured that the vents are indirect, otherwise dusts and other particles may get into the goggles, thus defeating their purpose.

Most safety goggles comes with an anti-fog coating, but it wears off with use. Many ways of reducing this problem have been found, including wetting the goggles before use, or lightly smearing the inside of the goggle with dish washing liquid.

Safety glasses provide less protection against hazards than safety goggles, but are lighter and less burdening to wear.

Safety goggles and safety glasses are considered disposable PPE. Unless they have prescription lenses, they are generally fairly cheap, and can be disposed of with other PPE after a few uses. It is possible to wash the goggles in a disinfectant solution if necessary, but this will greatly affect the anti-fog lens. Any safety goggles that show signs of damage should immediately be replaced.

Hearing Protection

For protecting hearing, investigators have the choice of either ear defenders or ear plugs. Both types of hearing protection must meet standard EN 352.

Ear defenders can be mounted on a hard hat, or used as a stand alone pair. The equipment must be compatible: stand alone ear defenders cannot be used with a hard hat. Advanced ear defenders may have an active noise cancelling system, or may be attached to radio input. This is important on a large site, where communication is required. Ear defenders should be cleaned with a disinfectant wipe when necessary.

Ear plugs can be either disposable or reusable. In a hazardous accident investigation situation, the disposable option is generally recommended. Some pairs of ear plugs are available with a cord, band, or plastic grips to hold when handling the plugs. The benefit is that the investigator does not then need to handle the part of the ear plug being placed into the ear, thus preventing dust from being forced into the ear canal.

Respiratory Protection

A variety of different types of respiratory protection is available to accident investigators. The differences between them should be considered carefully to ensure appropriate selection for the hazards being encountered.

Paper dust masks (EN 149) provide a basic level of protection for investigators. These masks are available in a variety of filtration levels (FFP1 (lowest) to FFP3 (highest), with or without an inbuilt valve and filter. These are disposable masks, and should be replaced often, as the integrity of the mask is reduced by increase in moisture. Additionally, touching the mask will reduce its effectiveness.

Care should be taken to fit the mask properly to the face, by adjusting the metal bar across the nose, and adjusting the elastic around the face as required. These types of mask are not suitable for investigators with facial hair that affects the closeness of fit of the mask to the face.

Half-face masks (EN 140) and full-face masks (EN 136) can have different filters fitted, to suit the working environment. These filters simply click on to the basic face mask unit. Each individual should have both half- and full-face masks, and these should be fit tested, to ensure that no air can leak in or out of the mask through poor seals. The mask can be washed in disinfectant solution. The filters which attach are disposable PPE, and each comes with a recommended maximum time of usefulness, which is marked on the filter packaging.

In high dust situations, requiring a longer working time, investigators may wear a fan assisted, fully enclosed helmet (EN 146). To use this equipment requires training. However the potential filtration levels are higher; with experience, investigators may find the helmet more comfortable than a full face mask.

The highest level of respiratory protection available is through the use of a forced air breathing apparatus. This provides either fresh air (EN 138) or compressed air (EN 14594).

Body Protection (including skin)

Disposable ‘paper’ overalls (required standard EN 340) provide some protection for investigators against dusts and fibres. They offer limited protection against fluids. These suits do not breathe, and add extra warmth for the investigator.

Fluid resistant overalls (EN 368) provide protection greater protection against fluids. These suits can be washed down and disinfected if necessary, although for greater precaution they should be disposed of if a lot of pathogens have been encountered.

Whatever type of suit is selected for use, it is important that the size chosen takes account of the types of clothing that may be worn underneath. An investigator may find that they need a different sized suit, depending on whether they have their summer or winter layers of clothing on.

If coveralls are not required for the investigation activities, then the investigators may need to use sun screen or insect repellent on areas of bare skin.

Hand and Arm Protection

Gloves protect against either chemical hazards or mechanical hazards. An appropriate size glove should be selected by each investigator, to maintain maximum dexterity for evidence collection.

The simplest glove for use is the pathogen resistant glove (EN 374, EN 388 and EN 455 requirements). This is the standard nitrile glove, that provides barrier resistance to biological hazards, light fluids and dusts. These gloves offer no protection against sharps, and will tear easily, in which case they must be replaced immediately. Fuels and oils will be protected against for a short time, but gloves should be replaced as soon as is practicable after contact. Nitrile gloves have increasingly replaced latex gloves, due to common latex irritations. These gloves are for single use only.

A leather palmed glove (EN 388 – followed by a number between 0 and 4, from lowest to highest levels of protection) provides protection against mechanical hazards, such as sharps. However, as they are not impervious to fluids, nitrile gloves will still be required to be worn underneath. These gloves are again disposable.

Heavy duty chemical resistant gloves (EN 388, EN 374 and EN 420) will provide protection against chemicals. However, these gloves should be replaced regularly as they may absorb the chemicals which could seep through the material onto the skin. Nitrile gloves should be worn underneath these gloves.

The highest level of protection is provided by a knitted Kevlar glove, which gives both mechanical and chemical resistance. They are expensive, and will need to be replaced if they absorb a high level of chemicals.

In performing some tasks, investigators might need a glove with a longer length sleeve, that stretches to the elbow or higher. This will ensure that no fluids get around the end of the glove.

Foot and Leg Protection

Boots should meet the equivalent standards of:

- EN 345 (Europe)
- ANSI Standard Z41-1991 (USA)
- CSA Standard CAN/CSA-Z199-M92 (Canada)

The boots selected should be waterproof, with a reinforced, impact resistant toe (steel or composite cap). The boot should have a non-slip, puncture resistant sole, running along the length of the boot, that protects the wearer from injuries if standing on sharp wreckage. They should provide ankle support to the investigator, for walking over rough terrain. There should be no direct route of entry for hazards to penetrate the boot, including through the eyes. In addition to these requirements, consideration should be given to comfort, as the investigator may be required to wear the boots for many long days on end.

In particularly wet, dusty, or fibrous environments, wellington boots (rubber boots, gumboots) may be a better option. These boots can be more easily cleaned than other work boots, due to the simple design. Selected wellington boots should meet the same standards as other work boots, with a reinforced sole and toe cap. However, working a full day in wellington boots may be more strenuous than wearing working boots, increasing the fatigue.

After finishing work on a site, footwear should be thoroughly cleaned, using a disinfectant, such as Virkon. Ideally, this should be done in a dedicated cleaning area, not used for other purposes. Depending on the working environment, dusts and fibres may become embedded in the laces, which will need to be replaced if they cannot be cleaned by standard disinfectant techniques.

In addition to footwear, investigators may find use for knee pads and/or shin guards on the site. Knee pads are useful when the investigation task requires much kneeling, such as collecting evidence. Shin guards may be useful when moving pieces of wreckage, to stop cuts and bruises.

6.3 Methodology

6.3.1 Overview

This research was based on observations of the actions of trainee/novice investigators during the on site investigation phase of a simulated accident investigation. Some of the trainees were attending the basic accident investigation course at Cranfield University, and others the advanced course. The observations were focussed specifically on the hazard identification and assessment process conducted by trainee investigators when first entering the site; on the ways in which they managed the hazards encountered during specific evidence collection tasks; and on the selection and use of PPE.

An investigation on the site of a real accident was also observed, with the same focus on the identification and assessment of hazards, the management of those hazards during evidence collection, and the selection and use of PPE. The objective was to determine whether the observations on simulated sites approximated reality in the field.

6.3.2 Simulated accident scenarios

Investigations were observed at three sites: one simulated incident site and two simulated accident sites.

Each simulation was developed by SMEs The sources of evidence and the necessary methodologies for evidence collection were representative of the range of sources and methodologies in Sections 3.4.2 and 3.4.3.

The observations were made in 2008 and 2009. The investigation of the incident simulation was undertaken by attendees at a basic investigation course; the two aircraft accident simulations were developed for investigators on advanced aircraft accident investigation courses.

6.3.3 Observations

Observation of the actions of investigators on accident sites enables analysis of the practical application in the field of published guidance on risk assessment and management, such as that in *Circular 315* (ICAO, 2008a, Chapters 2,4). The various stages in the identification, assessment and mitigation of hazards can be identified, and the selection and correct use of appropriate PPE can be evaluated. The adequacy of the theoretical advice given in the guidance can be tested in the field; the understanding and skill of the trainee in applying that advice is also demonstrated, so that further training needs can be identified.

At each of accident simulations, the researcher acted as a ‘participating observer’, a role which Bernard (2006) describes as “outsiders who participate in some aspects of life around them and record what they can”. Trainee investigators were told that the observer was a member of the staff assisting with the day, and would be on the site in a supervisory capacity. The researcher did not participate in the investigation, but her presence on the site was accepted as normal by the trainees.

The simulations were each on different days, so all of them could be observed by the one researcher. SMEs were also present on the site. They were aware of the researcher’s research objectives, and provided guidance at stages during the investigation when particular events were occurring. However, only the researcher recorded the actions and events, thus minimising the potential effect of observational biases such as selective attention and selective coding (Robson, 2002).

In preparation for this work, the researcher had attended a number of similar previously simulated accidents, in order to determine the best positions from which to make the observations at various stages in the investigation, and to review some of the location hazards involved in the simulation. This ensured that, during the observation process, the focus could remain on recording the actions of the investigators.

Three elements of each investigation were observed and recorded at each simulation: the site hazards, which included both the hazards identified by the trainee investigators and the hazards identified by the SMEs; the conduct of the hazard assessment process by the investigators; and their selection and use of PPE.

The observations were recorded as notes or field jottings (Bernard, 2006): given the pace at which it was necessary for some parts of the investigation to proceed, it was impractical for long descriptive field notes to made at the time. Field notes were supplemented by photographs taken to record site hazards, the evidence available for use by investigators, and the actions taken by investigators on site. Immediately after the investigation concluded, full notes were prepared from the field jottings and photographs.

6.3.4 Participants

6.3.4.1 Participants in the observations

The participants were assigned to investigation teams, comprised of a balance of backgrounds and experience. This ensured that each team had an equal opportunity of succeeding in the simulation task.

Investigators on each simulation site were provided with a tent or sheltered environment large enough for entire team. In the tent was a wide selection of PPE, covering all possible needs.

6.3.4.2 Ethical considerations

Participation in the simulated investigation was an expected part of attendance at one of the investigator training courses. The simulations were designed primarily as a learning tool for the trainee investigators, rather than for the purpose of this research.

Before participating in the site simulation, all investigators had - at a minimum - completed training in hazards awareness and site safety, and had been on another simulated accident site during a site appreciation tutorial. Many of the investigators on the advanced investigation courses had more extensive site experience.

A safety briefing was provided to each investigation team before site entry. This briefing alerted investigators to the fact that the health and safety hazards they faced on the site were real, but that all the equipment necessary to protect themselves from any hazard was provided. The briefing also introduced the investigators to the SMEs present on the site (including the researcher), who would be monitoring both their progress with the investigation and their safety. Each of the SMEs had a whistle which, if blown, would signal that investigators were to cease whatever task they were doing immediately, because of a safety problem. Such a situation did not arise during any of the observed simulations.

6.3.5 Analysis of observations

The recorded notes for all groups across each accident site, and for all groups across all accident sites, were compared across the range of observed investigations. Investigator actions and any SME opinions on those actions were considered. The theoretical guidance on the identification and assessment of hazards, on the management of those hazards during evidence collection and on the selection and use of PPE, was considered against the reality of what actually happened in the field.

6.4 Results

6.4.1 Overview

This section reviews each of the accident sites separately. The aircraft incident site (investigated by attendees of the basic investigation course) is discussed first, followed by the two simulated aircraft accident investigations. Observations of the work of accident investigators on the real accident site is discussed subsequently.

The review is presented as a narrative covering the nature of the simulation, the hazards present on site, the hazards assessment process, and the PPE worn during site tasks.

6.4.2 Simulation 1: Aircraft incident on take-off

The first simulation was an investigation of a runway over-run following an aborted take-off in a Jetstream 200 aircraft. The simulation scenario was akin to an incident investigation rather than an accident investigation. The investigation however was complicated by the ground handlers having dropped one of the cargo boxes from the conveyor and it breaking open, to reveal batteries being carried as undeclared cargo.

This simulation was conducted in November on a cold day (< 5ºC) beginning with fog, followed by intermittent rain throughout the day. The exercise was conducted at Cranfield University, on a runway no longer in use (for the purpose of this exercise, it was considered an operational runway). The rest of the airfield was operational. Figure 6.1 shows the aircraft under investigation.

In terms of site hazards, this investigation was the most benign of the simulations. With the exception of the weather, which made being on the site for more than a couple of hours quite uncomfortable, the only real concerns on the site were three batteries, which on inspection were undamaged, and therefore not a high risk; and access to the aircraft, which required the investigators to climb up a baggage conveyor (Figure 6.2). There were no injuries in the event.

Figure 6.1: Simulation 1: Jetstream 200 aborted take-off and runway over-run

Figure 6.2: Simulation 1: Damaged cargo box and conveyor providing access to the aircraft

At this site, the process of investigation was observed for one group. Initially, they were very hesitant in entering the site: they did not approach the aircraft until 45 minutes after the initial safety briefing and a briefing from the fire services. Instead, they briefed as an entire group on the possible hazards they could identify from a distance of around 20m from the aircraft. They then began a very wide walk around the site, before sending in two investigators in high level PPE to assess the site closely. The PPE selected for the two investigators included paper coveralls, eye and respiratory protection (one with a full face mask, the other with safety goggles and a disposable dust mask).

The site survey recognised that:

- The thermal plugs of the tyres had melted, removing the risk of tyre explosion. No action was necessary.
- The batteries had been stood upright (by the fire services), and were not leaking. They were therefore not posing any immediate threat to the investigators. The investigators elected, after photographing and documenting the evidence, to move the batteries onto a drop sheet away from the aircraft.
- Access to the inside of the aircraft should be limited to only two investigators, working together, to prevent too many people from climbing on the baggage loader.

This group did not initially consider the issue of site security. They believed the perimeter fence of the airport would prevent intruders from accessing the site, but this proved not to be the case. Each of the simulations had a number of ‘witnesses’ written into the scenario, who could provide background information to the investigators. The aircraft was visible from the airport gate, and a number of these witnesses entered the accident site to speak to the investigators. One ‘reporter’ was able to walk up to the aircraft before being stopped by any of the investigators. Following these intrusions, a cordon was established around the aircraft, the airport gate was secured, and a single path of entry in and out of the site was established. Lack of site security may lead to a loss of evidence, or may delay the investigation process when people not involved in the investigation enter the site.

Investigators entered the site wearing appropriate footwear for the site, and clothing to protect themselves from the weather. Other than the standard airport requirement to wear high visibility vests, no comprehensive PPE requirements were set by the team. All team members opted to wear nitrile gloves, and some covered these with heavy duty gloves. The investigators who documented the contents of the broken cargo crate, and moved the batteries, wore the same high level PPE as during the site safety assessment. Although mismatched, the SMEs on the site deemed their PPE selection to be appropriate, if not a little too high for the task of moving the batteries (considering they had assessed the batteries as not a high risk hazard).

Towards the end of the investigation, some of the investigators became lax with their use of PPE, including one investigator who worked with coveralls undone (Figure 6.3). Although there were no major site hazards in this simulation, it was noted that investigators did not change gloves at any stage during the investigation process, or during the different tasks such as taking photographs, making notes and moving the cargo.

Figure 6.3: Investigator with coveralls not zipped up

6.4.3 Simulation 2: Mid-air accident

6.4.3.1 Overview of the site investigation

This simulation created a mid-air collision between a Cessna 152 and a Aerospatiale Socata TB10 aircraft in the circuit at Cranfield Airport. The two aircraft crashed separately, creating two sites to be investigated. Three groups each undertook an investigation.

The first site, the Cessna 152 (Figure 6.4) was on open grass on the airport. The pilot of the aircraft was fatally injured in the accident. During the crash sequence, the aircraft cart-wheeled along the ground, before stopping in an upright position facing backwards along the direction of flight. The wreckage trail was approximately 100m long. The aircraft was severely damaged in the accident sequence, and access into the aircraft was limited.

Figure 6.4: Simulation 2: C152 accident site

The second site, containing the TB10 (Figure 6.5) was in a small clearing within a forested area inside the airport boundary. This aircraft flew through trees before coming to rest in the clearing. One occupant suffered fatal injuries, the other was able to escape. A post-impact fire occurred, causing substantial damage to the airframe. There was also substantial damage to the surrounding vegetation, with parts of the aircraft lodged in the trees overhead. The ground around the aircraft was muddy.

A third site, located below the estimated position of the mid-air collision, contained some pieces of wreckage from both aircraft. This was located approximately 500m from the C152 wreckage, and 240m from the TB10 wreckage. This site was in open grass near the airport VOR.

The investigation took place in mid-June, with the weather ranging between 15ºC and 20ºC. There was rain overnight before the investigation began, but no rain during the site investigation (although rain threatened). There was a slight wind of up to 10kts, which was not sufficient to disturb any of the larger wreckage from the C152 site. The TB10 site was protected from any wind disturbance by the surrounding vegetation.

Figure 6.5: Simulation 2: TB10 accident site

The hazards of the C152 site were mainly restricted to damaged wreckage (sharps, broken perspex etc.). The hazards on the TB10 site were more numerous, and therefore the investigation of this site became the focus of the observations. Three groups were observed at work on the TB10 site.

6.4.3.2 Simulation 2: Group 1

The first group summarised their activities for completion on the TB10 site as: the search for physical evidence, moving of structures and components, and sample collection. Their initial site survey involved a long look around the site, including the forest area. They wore no PPE during this initial assessment. The hazards they identified were:

- fire damage (dust/fibres) - the hazard these posed was reduced as they had been dampened down by the overnight rain;
- biohazards around the cabin area;
- sharp objects from the wreckage;
- the weather, and the physical environment around the aircraft;
- aircraft debris in the trees;
- a strong smell of fuel on the site.

In dealing with these hazards, the team decided that all investigators on the site would wear, as a minimum, gloves (both heavy duty rigger gloves and nitrile gloves) and sturdy footwear. In addition disposable masks were to be worn when working close to the wreckage.

Despite a whole team briefing on PPE requirements, members of the group adopted a casual attitude towards the use of PPE, particularly gloves. Heavy duty gloves were rarely worn: most of the investigators put a single pair of nitrile gloves on at the beginning, and did not change them during the investigative process. Two of the investigators in the group were observed to move sharp wreckage wearing only nitrile gloves, despite having heavy duty gloves.

6.4.3.3 Simulation 2: Group 2

Group 2 had a designated site safety surveyor complete a full assessment of the site before anyone else entered. The hazards they identified in the area included:
- fire damage;
- man made mineral fibres;
- biohazards in the cockpit area;
- wreckage in the trees overhead;
- stinging nettles and brambles;
- fire fighting foam on the ground around the aircraft.

These hazards were managed through the use of PPE: a standard was created requiring all team members to wear coveralls, face mask, nitrile gloves and heavy duty gloves while on the site. Investigators working near, or retrieving wreckage from, the trees were required to wear hard hats.

In response to the potential stinging nettle hazard, all investigators were required to wear long trousers and a long sleeve shirt underneath their coveralls. This was intended to provide an extra level of protection against the vegetation. Some investigators found this too warm, and took shortcuts with the PPE such as pushing up their sleeves.

The biohazard danger was overcome not only with the use of PPE to protect those who were in the contaminated area, but also by limiting the number of investigators who entered the site. The number of investigators potentially exposed to the hazard was kept at a minimum.

Group 2 was the only group on this site to recognise the potential for fire fighting foam to create a slip hazard. The team considered the possibility of hazard caused by the use of mobile phones near fuel, and restricted the use of phones to a distance away from the site. They were also one of the few teams amongst all groups observed on all sites to implement a clean/dirty line on the site, from the clean side of which used PPE would be removed and bagged in standard bags or biohazard disposal bags.

6.4.3.4 Simulation 2: Group 3

The third group sent two investigators to conduct a survey of the site wearing coveralls, safety boots, heavy duty gloves and disposable masks. They did not wear eye protection. Major hazards identified included:

- debris at the tops of the trees;
- fuel tanks of the aircraft burnt out;
- possible fibres from the aircraft structure.

Following the site inspection, it was decided that only wet weather gear was required, unless working in the direct vicinity of the aircraft. The same PPE as worn for the site briefing was worn when working within the aircraft cockpit. The group also specified heavy duty gloves when working around the engine, due to the potential for sharps.

The use of masks by this group was fairly haphazard, with masks being worn on top of the head when they became overbearing, or when not required. While removal of an object causing discomfort may be an instinctive reaction, the masks should have been disposed of when not required, rather than being reused after being placed on the forehead or hair. Such reuse allows contamination by dust, which the mask is designed to prevent: when the investigator places the mask back over the nose and mouth, the dust is directly inhaled. It was observed that following the initial site safety briefing for this group, there was no further discussion about PPE, or PPE briefings for other investigators who went onto the site.

6.4.4 Simulation 3: Aircraft accident on landing

6.4.4.1 Overview of the site investigation

This simulation was a crash of a Piper Saratoga whilst conducting an instrument approach into Cranfield Airport (Figure 6.6). The aircraft cart-wheeled on impact with the ground and came to rest inverted. The pilot (the sole occupant) died in the accident sequence.

The accident site was in the open fields parallel to, but spaced away from, the active runway. The site was located some distance away from any airport gates or fences. Being inverted, the wreckage itself was quite unstable; the wings were detached, but almost resting on the fuselage (Figure 6.7). The space inside the aircraft had been compromised during the impact sequence (Figure 6.8).

Figure 6.6: Simulation 3: Piper Saratoga accident on landing

The simulation took place in June, on overcast days with temperatures of 10- 15ºC. The early mornings were foggy, and there was light intermittent rain during the investigation. Wind speed built to 10-15kts throughout the day.

Two groups were observed working on the site, on two days.

Figure 6.7: Simulation 3: instability of the wreckage

Figure 6.8: Simulation 3: inside the Saratoga cockpit

6.4.4.2 Simulation 3: Group 1

Group 1 conducted a ten-minute walk-around of the site as a whole group, discussing the hazards they identified as they proceeded. They then proceeded to gather equipment, both to protect themselves and to collect evidence. The group appeared hesitant about how to start the investigation: they did not begin until 30 minutes after being briefed by the fire service.

The first hazard they were concerned with was the aircraft battery. Before any further investigation, they took tools to find the battery and ensure it was disconnected. They also immediately appointed a security guard to man the closest access gate, to prevent intruders from entering the site and also so they would know when witnesses or others came to speak to them. The security guard was to record all people entering the site.

For the purpose of the investigation, the team of seven split into three groups of two (with the IIC floating between the groups) to cover different parts of the site. One group initially walked around the site and back along the flight-path; one group surveyed the wreckage trail; and the third group went inside the inner cordon (set up by the fire fighters) around the aircraft wreckage, to investigate within the wreckage itself.

Initially, no PPE other than nitrile gloves and high visibility vests were worn. The team working on the wreckage trail were simply measuring, photographing and recording the wreckage trail and ground markings, without yet touching any of the evidence. The team working within the inner cordon chose not to touch the wreckage, and photographed the wreckage without entering it. They carried heavy duty gloves with them for later use in moving small pieces of wreckage from the outside of the aircraft. One investigator entered the cockpit area to take photographs with no PPE other than nitrile gloves.

On the second day, the team began to move wreckage and bag evidence. They worked in a larger group, all wearing nitrile gloves under heavy duty wreckage gloves, at a minimum. Those who entered or worked near the cabin area, wore coveralls, nitrile gloves, goggles and a disposable respirator. The group worked as a team to to ensure they were all using appropriate PPE before entering the aircraft, but there was no discussion about the stability of the wreckage or whether it was safe to enter.

The group did not consider what to do with the PPE when it had been used, and kept their disposal bags in their work/rest tent, which meant that they wore contaminated clothing into the area where they ate and drank.

6.4.4.3 Simulation 3: Group 2

The second group on the site began their investigation with the IIC being briefed by the responding fire crew, while the rest of the team wandered along the path parallel to the wreckage (although some distance away), towards the VOR and back along the aircraft direction of flight. When the group returned and were briefed by the IIC, they then conducted another walk-around and site assessment. No PPE was worn by any member of the group during this process.

The group appeared distracted while walking around the aircraft itself, and began individually photographing the wreckage from within the cordon. At this stage, the body (a fire services dummy) was still in the aircraft. One investigator put on nitrile gloves at this point.

The team slowly decided that investigators entering the aircraft should wear coveralls, goggles, nitrile gloves, and a dust respirator. They dressed individually in this PPE at the rest tent, and walked to the site - a distance of approximately 500m. They took a disposal bag with them to the site so they could remove contaminated equipment once used. A fuel sample was collected in an appropriate container, by an investigator wearing nitrile gloves.

On the second day, the PPE was carried to the site before being put on. Team members helped each other with putting on the coveralls, but not the other equipment needed. Before entering the site, they reviewed the fire services briefing they received the previous day, and reviewed the hazards. They then began work on the site, initially in a large group, and then breaking down into separate tasks.

One investigator had problems with the arms and legs of the coveralls riding up and exposing skin, particularly his arms. When questioned, he said he was unaware that different sizes of coveralls were available. This problem was eventually overcome by taping the legs of the coveralls to the investigator’s boots, and the arms of the suit to his gloves.

Apart from this case, all other PPE was initially fitted appropriately, with the exception of disposable respirators. Many of the investigators failed to open the respirator fully, and to position the elastic bands securely, which meant that they were not protected by the filter. Over time however, shortcuts around other items of PPE were found as it got uncomfortable or seemed to impede the task being completed: goggles were placed on the head, and respirators were placed on the head or hung around the neck.

Unlike Group 1, this group did recognise the potential instability of the wreckage on this site, and ensured that the fuselage was stabilised by an investigator on either side before any other member of their team crawled into the cabin space. The investigator inside the aircraft wore a hard hat as additional protection.

6.4.5 General aviation aircraft accident: Christen Eagle II, Seething Airfield, Norfolk UK, 2008

On 29th October 2008, a Christen Eagle II aircraft, registration G-EGUL (Figure 6.9) crashed after impact with a crop spraying vehicle while on landing at Seething Airfield, Norfolk, UK. The impact killed one occupant immediately; the other occupant later died in hospital.

Figure 6.9: Christen Eagle II, G-EGUL (Note: picture in previous colours)
Source: CAA (2010c)

The aircraft accident was investigated by the AAIB. The researcher was invited to attend the site as an observer, due to the unusual hazards presented by impact with a crop sprayer.

The Christen Eagle is an aerobatic biplane with a steel tube fuselage, wooden spars and ribs, covered with an alloy skin from firewall to rear seat, and polyester fabric skin elsewhere (Jane's, 1987-1988). The aircraft can be purchased as a kit, or in a fully assembled state. This particular aircraft (G-EGUL) was built in 1980.

The purpose of G-EGUL's flight was to take photographs to accompany a story on the aircraft in a general aviation enthusiasts magazine. The flight plan was to complete some general airwork before conducting some circuits around the airfield, so that a ground based photographer could take some photographs of the aircraft on approach. On the second approach to the airfield, the aircraft collided with a crop spraying vehicle which was tending a field in the undershoot area of the runway (AAIB, 2009e). Figure 6.10 shows the site layout.

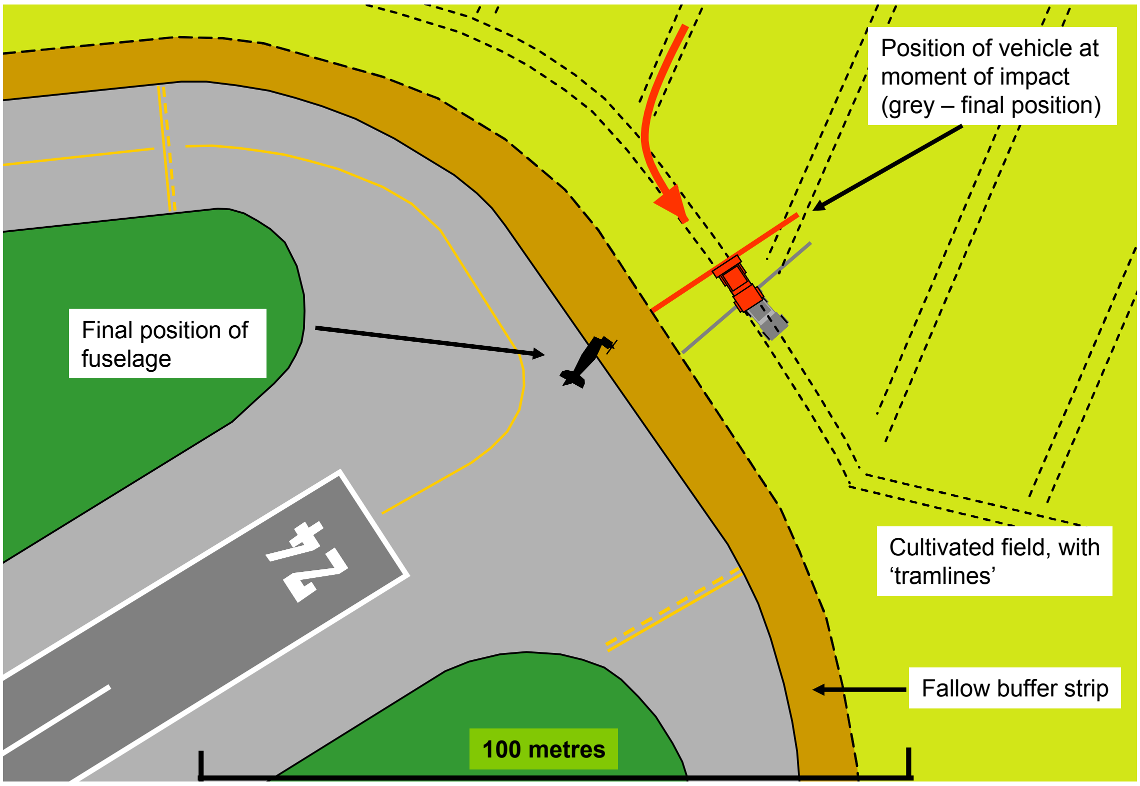


Figure 6.10: Site diagram for Christen Eagle II, G-EGUL crash, 2008
Source: AAIB, 2009e

Two investigators arrived on the site after dark on the evening of the accident. The site was protected by the police overnight, and the investigation resumed around 0800 hours on 30th October. The site investigation was complete and the aircraft recovered onto a truck by 1700 hours.

The accident occurred at the far extreme of an airfield. The gate to the airfield was guarded by police, and the adjoining farm and row of trees along the roadside provided some natural security on the site. The investigators did not need to cordon off the aircraft beyond what had been done by the responding emergency services.

The weather for the investigation was cold but dry. Cold weather clothing, including coat, hat and scarf, were needed as a minimum. The fuselage of the aircraft came to rest on the edge of the tarmac surface of the airport, but with the exception of a thin strip of grass (the ‘fallow buffer strip’ in Figure 6.10), the rest of the wreckage site was a very muddy, freshly ploughed field. Walking across the field was laborious, and the rapid accretion of mud on the bottom of boots made them very heavy. This mud had to be removed each time an investigator returned to the tarmac.

The nose of the aircraft shattered the fibreglass tank of the crop sprayer (Figure 6.11) before crashing, and being engulfed in a post-impact fire. The main fuselage of the aircraft was extensively damaged (Figure 6.12), and parts of the wreckage (from both the aircraft and the sprayer) were scattered around the site, on both sides of the crop spraying vehicle.

Figure 6.11: Damage to the crop spraying vehicle

Figure 6.12: View of G-EGUL wreckage, looking from the crop spraying vehicle in the direction of flight

The debris had absorbed the yellow colour of the chemical being used in the crop spray (Figure 6.13). There was also yellow liquid pooling beneath the crop spraying vehicle.

It took approximately 3 hours for a farm worker to be located who could provide the investigators with the MSDS for the chemical being used. The chemical was a herbicide (containing pendimethalin and flufenacet), which has only a low toxicological effect in humans. However, it may still be an irritant to skin: a PPE requirement for coveralls, two pairs of nitrile gloves, and heavy duty gloves (on top of cold weather clothing and safety boots) was decided upon.

Figure 6.13: Yellow discolouration to the wing from the herbicide

There was a large amount of blood around the aircraft. This was covered by placing a tarpaulin over the affected area, although it caused some difficulty when removing objects from within the aircraft. The remains of the fuselage were supported by mobile supports straps left in place by the ambulance services, and this provided the required additional stability. As is standard practice, the medical supplies used by the ambulance responders and the fire extinguishers used by the airport fire crew were left on the scene.

During the investigation, it was discovered that some fuel remained within the fuel tank. During the post-crash fire, the metal of the tank had melted; there were some deposits of metal within the fuel, but it had not all combusted (Figure 6.14). Disposable masks were used in addition to other PPE when moving the remains of the tank away from the rest of the wreckage.

Figure 6.14: Fuel and tank deposits remaining in tank

For recovery of the wreckage, all debris pieces had to be retrieved. Collecting and bagging all visible pieces of wreckage carrying them across the muddy field to a central location was a physically exerting task, despite the relatively small distance involved. The aircraft was recovered onto a truck, along with the bags of debris, and the burnt aircraft ashes were scraped up and bagged for further investigation at the AAIB.

The report into the accident was published in September 2009 (AAIB, 2009e).

6.5 Discussion

6.5.1 Comparison between simulated and real accident sites

The real accident site and the simulated sites, particularly the two accident sites, were comparable sites for the purposes of this research. The scale of the accidents, the size of the sites, the wreckage distribution, the hazards present, and the external pressures clear the site, were all similar. The most apparent difference was that the wreckage trail of the real site was much smaller than in the simulated sites - a matter which has no bearing on the research or on the method of investigation.

The two accident simulations were created using aircraft which had been involved in real accidents. From the wreckage, realistic scenarios were developed, which would explain the existing damage to the wreckage, using expert knowledge and experience in accident investigation.

One difference between the real accident site and the simulated sites was the number of investigators present at the investigations. On the real accident site, one investigator conducted most of the wreckage survey. A second investigator was present, but had other investigative tasks to complete. Because of health and safety concerns raised by the initially unknown chemical covering the site, a health and safety advisor was also called. These three AAIB investigators comprised the complete investigation team. On the simulated sites, there were up to seven investigators in a team, because the essential purpose was investigator training.

6.5.2 Hazard assessment and mitigation

In each of the observed investigations, the site assessment was conducted by means of an initial walk-around and visual inspection of the site. This assessment was a subjective appraisal of potential hazards, as discussed in Section 3.2.1.

The number of investigators involved in the hazards assessment varied between groups, from one to seven (the entire group). At the upper limit, the entire group evidently wanted the experience of conducting the site assessment: the lower limit might be explained by curiosity to enter the site rather than participate in a preliminary group assessment. It is of interest that the advanced course investigators in Simulations 2 and 3, many of whom have previous investigation experience, carried out the hazards assessments in larger groups.

Some of the groups were initially hesitant about entering the site. Potentially, the recency of their prior hazards-specific training might have affected the way in which trainee investigators conducted the site safety survey and identified site hazards. The team on Simulation 1 had completed their hazards training only a week before the simulation, which might account for their taking 45 minutes to enter the site. However, other groups who had completed their hazards training longer ago seemed equally as hesitant. Alternative explanations might be wariness about encountering the hazards, or less than proactive leadership by the IIC. The training guidelines in *Circular 315* (ICAO, 2008a, paragraph 5.5.1) suggest that recurrent health and safety training should occur every 24-36 months: compliance with this would ensure that all investigators are equally aware of the hazards, both the well-known hazards and those which are newly emerging.

There was also variation in the use of PPE during the initial assessment. One group (Simulation 1) conducted the assessment in full PPE with high level breathing protection from a full face mask; another group wore no PPE whatsoever for the assessment. In Simulation 3, the problem of balancing personal safety and evidence collection was demonstrated by Group 2, who became distracted while conducting the site survey and began photographing the aircraft wreckage. As noted in Section 3.2.2, alerting investigators to the importance of this balance is one of the primary objectives of ICAO *Circular 315* (2008a). It was the opinion of SMEs on the simulated sites that a group of two investigators - in safety boots, coveralls, nitrile gloves with heavy duty gloves over the top, goggles, and disposable respiratory protection - would be a sufficient deployment and level of PPE for the initial assessment, provided they did not enter any enclosed cabins or spaces during the assessment.

The observations indicated that the communication of hazards between investigators within groups was poor. The site assessment process carried out at the beginning of each investigation was rarely discussed again. Only Group 2 in Simulation 3 reassessed the site hazards on the second day of site investigation: this group had struggled with managing the site survey and the use of PPE the day before, and probably understood the need to make improvements. No other group overtly communicated or discussed any hazards amongst themselves after the initial assessment, even when team members arrived who had not been present for the initial assessment.

The behaviours and actions of the groups observed in this research can be analysed in terms of the five step risk management process set out in ICAO *Circular 315* (2008a, paragraph 2.3.2). Except in the case of the real accident and accident investigation, the identification of hazards, the determination of exposure and the assessment of risk were carried out casually; the introduced controls relied on the use of PPE rather than any other risk mitigation measure, and indeed introduced further risk (through incorrect use of PPE, and potential contamination from used PPE); and there was no deliberate review and revision of risk assessments, to renew and maintain the cyclical five step process. Only one group (Group 2 in Simulation 2) specifically restricted the number of people conducting a task in order to limit exposure to an identified hazard. The group in Simulation 1 was the only group to remove a hazard to a remote location after photographing and recording the evidence *in situ* - which was precisely the technique used by investigators on the real accident site following identification of the hazardous fuel tank.

6.5.3 Hazards on the accident site

The hazards on each of the simulated sites ranged from limited and minor to abundant and serious. The simulated incident presented hazards in the form of access to the aircraft, and stored chemical and potential energy in the batteries. The simulated fatal accidents presented possible biohazards, unstable wreckage, fuel, and debris in trees. The potential for a slippery surface due to the fire-fighting foam was (correctly) considered by one group. All groups recognised the potential of sharp wreckage. The real accident site had wreckage completely covered in a mild irritant chemical.

Chapter Four suggested that novice accident investigators were aware of the majority of hazards suggested by ICAO *Circular 315* (2008a); indeed, in this study they managed to identify most of the hazards on the different simulated accident sites. The simulations all involved traditional GA aircraft. It would be of real benefit in identifying future training needs, to simulate an accident involving a more advanced GA aircraft such as a Cirrus SR22, with a composite fuselage and ballistic recovery system. Such a simulation would introduce a range of hazards of which novice investigators are unaware, but for which they need to be prepared.

6.5.4 Selection and use of personal protective equipment

Reliance on PPE was the most common way in which investigators on the simulated sites chose to protect themselves. They had a broad understanding of the PPE needed to protect against different hazards, but did not fully understand the limitations of the PPE and its correct use.

At no point did any of the observed trainee investigators change their PPE when changing task, or when the effectiveness of the equipment was compromised (such as coveralls after kneeling in mud in Simulation 2). On the real accident site, the investigators went through a number of changes in PPE throughout the day.

There were deficiencies also in the way in which the PPE was worn. Full protection is achieved only when PPE is worn correctly, despite any discomfort. Wearing coveralls of an incorrect size, failing to zip them up and to fasten the hood (which prevents them from coming unzipped), wearing respirators incorrectly, and placing goggles and masks on the head and then back again over the eyes, are common practices which increase risk rather than reduce it. Clearly, there are messages here for investigator training.

6.6 Conclusion

The research has a number of implications for the training of accident investigators.

First, there is a need for trainee investigators to be taught to think and work as a team. This means training in leadership and direction, training in the strategic allocation of roles and tasks according to purpose, and training in the exercise of those roles as an accountable member of the team. The aimlessness, loss of time and lack of co-ordination demonstrated by some of the groups of trainees suggests that training in teamwork and team management should be an essential component of investigator training. Although each individual might have a very good understanding of the identification and management of hazards, and of the techniques for the collection of evidence, an investigation could be ineffective and wasteful without explicit direction and co-ordination.

Second, greater attention needs to be given to teaching about the importance of effective and timely communication between members of the investigation team, at all points during the investigation process. It might well be that the communication problems among trainee investigators was due to the fact that they did not know each other very well, or that - being all at a similar stage of learning - there was no clear authority gradient based on seniority or experience. However, this could also well be the situation in a real investigation: although the investigators from a single national investigation agency would know each other and their respective roles in the organisation, there are many participants in a major investigation, including ICAO recognised investigators, technical advisers and other responders (Section 2.3.2.1). These people, who will certainly not know all each other and might come from very different cultural backgrounds, must nevertheless have the skills to accept and work within a co-ordinated structure, and to communicate effectively.

Third, greater emphasis perhaps needs to be given early in the training programme to the management and mitigation of risk by means other than the use of PPE: such as limiting the number of investigators potentially exposed to a hazard, and rotating them; implementing a clean/dirty line; properly disposing of potentially contaminated material; and recognising unstable structures and dealing with them. Although the experienced investigators at the real accident site used PPE and did so appropriately, they first set out to manage the accident site to make it as safe as possible for the collection of evidence: they sought the MSDS for the chemical, and then decided on the PPE; they covered the blood with a tarpaulin to prevent slippage; they stabilised the fuselage by using mobile support straps; and they removed the remains of the fuel tank away from the wreckage. They used no more and no less PPE than was necessary, and they used it properly.

Fourth, and consistent with the above, training in the correct selection, use and disposal of PPE must remain a core objective of training programmes. The purpose and limitations of the various items of PPE must be fully understood, and PPE must be selected so that it is really fit for purpose. Not all safety gloves are the same, nor will all of them provide similar protection against a range of hazards. An investigator must choose PPE that is appropriate for each investigation task, and dispose of the used equipment appropriately.

Finally, more emphasis must be placed on basing the core syllabus for all training for accident investigators soundly and centrally on the practical application in the field of the risk assessment process (Figure 2.22) set out in *Circular 315* (ICAO, 2008a). The five stage iterative process - identify hazards, determine exposure, assess risk, introduce controls, review and revise risk assessment - is the foundation on which both the mitigation of risk and the maximisation of evidence is built.

Chapter Seven

Conclusion: The Implications of the Research on Hazards Specific Training for Aircraft Accident Investigators

7.1 Overview

The research has explored areas of accident site hazards, investigator awareness of hazards, hazards assessment and management, and the use of personal protective equipment. Four distinct but related studies have been used to answer four research questions:

1. What hazards may arise for investigators collecting evidence on aircraft accident sites?
2. What site hazards do novice aircraft accident investigators perceive to be a risk?
3. What hazards are experienced accident investigators identifying on sites?
4. How do accident investigators identify and manage the hazards?

The findings and conclusions of each study have been set out at the end of each of Chapters Three, Four, Five and Six.

This concluding chapter draws together the implications of each study for the design of hazards specific training for aircraft accident investigators. These implications are advanced not as a criticism of existing training programmes, but as a reaffirmation of good practice where it exists, and as advice where it does not. This chapter also considers the limitations of the research, and proposes some future directions for further work.

ICAO *Circular 315* (2008a) is the first document to specify training aims for aircraft accident investigators and emergency responders to accident sites.

The training aims are (ICAO, 2008a, paragraph 5.2.1):

> - "detailing the potential variable nature and scale of occupational health hazards experienced at aircraft accident sites;
> - outlining any applicable State occupational health and safety legislation and its applicability to accident investigation activities undertaken by the State's aircraft accident investigators;
> - providing an understanding of the occupational health risk management, risk assessment, and risk control processes associated with aircraft accident investigation operations;
> - provide an understanding of the hazards and means of prevention of exposure to blood-borne pathogens that meets the requirements of the State training standards;
> - provide an awareness of the selection and use of personal protective equipment to meet the risks posed in aircraft accident investigation tasks; and

- provide an awareness of the effects and symptoms of psychological hazards associated with aircraft accident response activities".

Circular 315 (ICAO, 2008a) recommends that training be conducted by "trainers who are knowledgeable and experienced in their subject as it applies to accident site operations". There needs to be awareness of a potential risk of bias towards teaching about particular hazards: training should give a balanced view of all potential current, and emerging site hazards.

7.2 Implications of Study One: What hazards may arise for investigators collecting evidence on aircraft accident sites?

The study reviewed the nature of evidence collection activities by examining - against the nineteen subsections of ICAO *Annex 13: Aircraft Accident and Incident Investigation* (ICAO, 2001a) - the sources of on site and off site evidence reported in fifteen selected aircraft accident reports.

It then reviewed the techniques used for on site collection of evidence, by content analysis of the ICAO *Manual of Aircraft Accident and Incident Investigation, Part III Investigation* (ICAO, 2008b). Consideration of the detailed range of techniques set out in this document against the on site evidence collection activities which were necessary to prepare reports on the fifteen specific accidents, revealed the extent to which it is necessary for investigators to conduct detailed inspections of different systems and components, which requires close contact with many different materials and chemicals. It is during this process that the investigators are exposed to accident site hazards.

On that basis, each potential hazard was then reviewed, using the framework given in ICAO *Circular 315: Hazards at Aircraft Accident Sites* (ICAO, 2008a), to answer five questions: about the precise nature of the hazard; about the specific danger it poses for investigators; about the conditions under which the hazard will exist; about the way in which the hazard will affect the work of the investigator; and about how investigators might manage the risk and protect themselves from exposure.

The study has three clear implications for the training of accident investigators.

First, in using ICAO *Circular 315* as a basis for training programmes, emphasis should be placed at least as much on processes for the management of risk, as on the nature and taxonomy of the hazards themselves. Whatever the specific nature of the site hazards, and whatever the nature of the conditions in which an investigation must be carried out, the investigator must have the mental discipline to follow systematically and routinely the iterative risk assessment process set out in *Circular 315*: identify the hazards; determine the degree of exposure to them; assess the risk; introduce mitigation; and review and revise the risk assessment. Ongoing situational awareness at an accident site where different elements are in a state of dynamic change is the key to both personal protection and the effective collection of evidence.

Second, although the work of accident investigation inevitably raises the question of trade-offs between the requirements of the investigation and the health and safety of the investigator, the decision "should always be biased towards safety" (ICAO, 2008a). That basic tenet should be the foundation of any hazards-specific training programme.

Third, the ultimate objective of training programmes - and of future research on the detection and management of hazards - should be to ensure that for an accident investigator at an accident site, the personal risk is no greater that for any other worker in any other workplace. The systems and components from which aircraft are manufactured are widely used and managed in other walks of life with absolute safety. Except in the most extreme cases, the range of environments in which aircraft crash are environments in which people have adapted to live and work healthy and productive lives.

If aircraft accident investigators have the mental discipline to manage hazards at an accident site on the basis of the *Circular 315* risk assessment process, a thorough understanding of hazards of all types, the skills to identify them, and knowledge of the mitigation measures needed for protection, there would seem to be no reason why a particular risk on an aircraft accident site should pose any more risk to the workers than in other workplaces. While an accident site is a unique workplace, it is a workplace comprised of the same hazards as occur in many other workplaces.

The significant difference between aircraft accident sites and most other workplaces is that it is not possible at an accident site to undertake a generic workplace risk assessment in advance of the event. Hence the assessment of risk is the task of the investigator, and must be done in real time.

7.3 Implications of Study Two: What site hazards do novice aircraft accident investigators perceive to be a risk?

The study was a survey of novice aircraft accident investigators. These investigators may have prior hazards identification and risk management training, but not in an aircraft accident investigation context. None of the participants surveyed were experienced aircraft accident investigators.

The surveyed novice accident investigators identified damaged and unstable structures; biological hazards; fire and flammable substances; accident location; and chemicals and other substances as the five hazards they perceived to pose most risk on aircraft accident sites.

The group showed little knowledge regarding the hazards posed by stored energy components; fatigue; security; metals and oxides; recent safety equipment; local state of hygiene and ex-military aircraft. Of the 604 hazards identified during the survey of novices, each of these categories was identified fewer than ten times.

The indication from these results is that novice aircraft accident investigators are well aware of general health and safety hazards, as would affect a person in any workplace, but they are not as aware of the aircraft-specific hazards that may occur on an accident site.

One theory behind perception of hazards (Siegrist and Cvetkovich, 2000; Section 4.2.2) suggests that individuals are more accepting of guidance about the risk posed by hazards if they do not have previous knowledge of the hazard. Almost every person training to become an aircraft accident investigator has an aviation related background, and as such, will carry with them some knowledge about hazards posed by aircraft. Use of a survey instrument to identify preconceptions will allow training course designers to understand the backgrounds of the participants on a course, and the biases they may have towards identifying the risks of particular hazards - thus allowing hazards specific training courses to be tailored to get the most relevant information to new investigators in a limited time frame.

7.4 Implications of Study Three: What hazards are experienced accident investigators identifying on sites?

This study analysed the health and safety reports submitted by investigators employed by a national air accident investigation authority over the period February 2003 - July 2009. There were 392 reports covering 208 accidents and incidents, which allowed comprehensive and detailed analysis of the realities faced by accident investigators in the field.

The study showed that within the sample, almost all the hazards identified in the *Circular 315* (ICAO, 2008a) taxonomy were identified. Some of these hazards will be encountered only infrequently, some will be found more commonly, possibly on almost every site. The implication of these results is that investigators should have knowledge about the broad range of hazards to ensure that any exposure to the hazard will be met with appropriate and timely mitigation measures. Investigators need to have the knowledge and skill necessary to identify and manage all hazards, including those they come across only rarely.

By alerting novice and inexperienced accident site investigators to the results of this study, individual investigators can begin to tailor their personal generic risk assessments to suit the types of accidents they may be involved in investigating, and the tasks they will be completing on a site. Learning from others' experiences will assist new investigators in managing the hazards assessment process.

This study did not consider the consequences of each of the hazards identified, merely their presence on a site. Some of the hazards frequently identified, such as noise from other aircraft and cold weather, may prove to be a low risk to an investigator, while less frequently identified hazards, such as an exploding nose-wheel and chemicals, might create a much higher personal risk for an investigator. Further research could be conducted into a measure of the possible risks posed by different hazards in different accident scenarios.

There appears to be little sharing of information about hazards encountered on accident sites between investigators, and especially not between investigators from different organisations. Accessibility to more of the data used in this study will assist not only new accident investigators in training courses, but experienced investigators alike.

By considering the findings of Study two and Study Three - the hazards that novice accident investigators perceive as a risk on an accident site, and the hazards that experienced investigators actually encounter - we can better identify the needs of training programmes and design them accordingly. The novice accident investigators identified damaged and unstable structures; biological hazards; fire and flammable substances; accident location; and chemicals and other substances as the five hazards they perceived to pose most risk on aircraft accident sites. The experienced aircraft accidents identified aircraft location; biological hazards; damaged and unstable structures; composite materials; and fire and flammable substances as the five most common hazards occurring on accident sites.

Although given in a different order, four of the five hazards that investigators perceive as most risk on a site, are the ones experienced investigators identify most commonly. It would appear that novice investigators place high consideration on the risks posed by general health and safety hazards potentially present in other environments. Where there is a difference between the risk perceived by novice investigators and identified by experienced investigators, it is regarding aircraft specific hazards, for example metals and oxides and composite materials. Novice investigators did not identify any risk associated with military and ex-military aircraft, whereas experienced investigators identified this in equal eleventh ranking out of the twenty hazards. The hazards included as recent safety equipment or local state of hygiene are not recognised as greatly significant by either novice or experienced investigators. Within each of the categories, the hazards identified by novice investigators were quite general, where the hazards identified by experienced investigators were quite specific. It is suggested that training be tailored to cover the details of specific hazards within each of the categories, to provide better awareness of the range of hazards that may be encountered.

7.5 Implications of Study Four: How do accident investigators identify and manage the hazards?

This study was based on observation of the actions and behaviours of trainee investigators at simulated accident sites, and AAIB investigators at the site of a genuine fatal accident. There are four implications for training programmes.

First, investigators need to be trained to think and work as members of a team. The mental discipline of the risk assessment process, and a knowledge and understanding of the identification and management of hazards, are both necessary requirements for a successful investigator, but they are not sufficient requirements: an investigator must be able - as the situation requires - to lead a team, to be a member of a team, to accept accountability for specific functions within the team, and to subordinate individual preferences to the objectives of the team.

Second, effective and timely communication is the key to effective teamwork, and should be a central element of investigator training.

Third, greater emphasis need to be given early in training programmes to the management of risk by means other than PPE. In the simulations there was a strong reliance on PPE to protect investigators from hazards while they collected evidence. For the PPE to work effectively, the investigators must understand the reasons they are using the PPE to protect against certain hazards, and the correct methods for its use. This was not evident through the observations. There are alternative strategies for the mitigation of risk on the accident site which are far more effective than the donning of inappropriate protective clothing, as demonstrated at the real accident site by AAIB investigators.

Fourth, training in the correct selection, use and disposal of PPE must remain a core objective of training programmes. Fitness for purpose is the key.

7.6 Limitations of the research

The boundaries of the current research are clear. As the number of potential hazards on aircraft accident sites is almost limitless, restrictions were placed on the dimensions of the research problem.

First, the research focus is on hazards of aircraft accident sites, and not on hazards posed by wreckage analysis off site.

Second, it focuses only on hazards and processes which affect aircraft accident investigators and technical advisors during the evidence collection process, and not on other participants at other stages of the response to an accident. Emergency responders and wreckage recovery organisations perform different functions, and may face different risks from those encountered in the accident investigation phase.

Third, the research is limited to hazards potentially occurring on accident sites investigated by civilian accident investigation agencies. Accidents involving military aircraft may create additional hazards: their investigation requires specialist military knowledge of systems and operations. The research does however draw on examples of hazards identified when civilian accident investigators have been involved with the investigation of military aircraft accidents.

Within this thesis, discussion of ICAO Circular 315 (2008a) compliant training course design has focussed on the design of general courses suitable for investigators who will investigate a wide range of accidents. When a course is to be designed for a specific group of investigators who will investigate only a specific type of accident or incident (such as general aviation only), the discussion of hazards should be focussed more specifically.

7.7 Conclusions of the research

Four questions were asked in the beginning of the research:

1. What hazards may arise for investigators collecting evidence on aircraft accident sites?
2. What site hazards do novice aircraft accident investigators perceive to be a risk?
3. What hazards are experienced accident investigators identifying on sites?
4. How do accident investigators identify and manage the hazards?

The four studies have answered these questions.

1. The risks posed to accident investigators are broad in range and variable in nature, with consequences ranging from minor to extreme. However, with a developed awareness of the hazards - what they are called, how they become apparent, where they are located, how they affect an investigator, and how to protect against them - the risks can be made no greater than in other workplaces. Experienced aircraft accident investigators referred to ‘usual hazards’ and ‘usual PPE’, indicating a level of accepted risk as part of the job.

2. Novice aircraft accident investigators perceive damaged and unstable structures; biological hazards; fire and flammable substances; accident location; and chemicals and other substances as the five hazards which pose most risk on aircraft accident sites. This

reflects an understanding of many general health and safety hazards, but of few aircraft specific hazards.

3. Experienced aircraft accidents identified aircraft location; biological hazards; damaged and unstable structures; composite materials; and fire and flammable substances as the five most common hazards occurring on accident sites. It is significant that experienced accident investigators list composite hazards as one of the top five hazards: composites are becoming more common in aircraft manufacture, but it is still an emerging technology with emerging hazards of which investigators are becoming increasingly aware. These results also suggest that composite hazards are not yet a hazard accepted by experienced investigators as ‘standard’.

The commonality between the other four hazards listed by novice and experienced investigators suggest that novice investigators are right to be wary of the general health and safety hazards which are commonplace on accident sites.

4. Identification of hazards on accident sites relies on subjective visual assessment. In order to achieve this, the investigators assessing the site must have a rich awareness of all potential site hazards. However, results of observations on training investigators showed a high reliance on personal protective equipment for protection against hazards, rather than on any other mitigation measures. Other methods for hazards management should be explored before PPE use.

Without this developed hazards awareness, aircraft accident investigators will be affected by the hazards, not be able to collect evidence, and not advance aviation safety through accident investigation.

7.8 Future Research

This piece of research focused directly on the hazards encountered by aircraft accident investigators investigating civil aircraft accidents on accident sites. There are a number of possible extensions for this work.

1. Consideration as to whether training is the best method of increasing aircraft accident investigator awareness of accident site hazards. This is the method suggested by ICAO Circular 315 (2008a), and currently adopted throughout the world, but not the only possibility.

2. A review of the hazards to accident investigators collecting evidence after recovery of the aircraft from the site. The environmental hazards and biological hazards will be limited, but the time spent handling the equipment will increase, potentially increasing exposure to physical and material hazards.

3. A subsequent review of hazards on aircraft accident sites encountered by other responders to the site, including emergency responders and aircraft recovery personnel. While all groups have different tasks on the accident site, many may overlap, and a combination of techniques to mitigate the hazards may benefit all parties.

4. A review of the hazards of investigating military aircraft, from the perspective of a civilian investigator. Civilian investigators may be required to investigate military accidents, and while they might do this in conjunction with investigators with specialist military knowledge, sometimes this might not be the case. In this event, they will be investigating a site with no hazards awareness.

5. Extension of the review into considering hazards on the accident sites of other transport modes. Investigators across different transportation modes may encounter many of the same hazards, but manage them differently. A comparison of the hazards awareness and risk management techniques used may assist in developing a best practice model for all industries.

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Transport Safety Investigation Act 2003

European Union

Council Directive 94/56 EC of 21 November 1994 establishing the fundamental principles governing the investigation of civil aviation accidents and incidents.

Council Directive 89/391/EEC of 12 June 1989 on the introduction of measures to encourage improvements in the safety and health of workers at work.

The Treaty on the Functioning of the European Union.

United Kingdom

Civil Contingencies Act 2004.

Health and Safety at Work Act 1974.

The Civil Aviation (Investigation of Air Accidents and Incidents) Regulations 1996.

The Civil Aviation (Investigation of Military Air Accidents at Civil Aerodromes) Regulations 2005.

The Management of Health and Safety at Work Regulations 1999

Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1995 (RIDDOR)

Control of Major Accident Hazard Regulations 1999 (COMAH)

Control of Substances Hazardous to Health Regulations 1999 (COSHH)

The Personal Protective Equipment at Work Regulations 1992

United States

29 CFR 1910.1030 Bloodborne Pathogens

Aircraft Accident Databases:

RGW Cherry and Associates (current to 2009)
Warwick Air Accident Database (current to 1997)
World Aircraft Accident Summary (current to 2009) ASCEND
AOPA Air Safety Foundation Accident Database (current to 2009)
Aviation Safety Network Database (current to 2009) Flight Safety Foundation

Appendix A

Fire Fighter Generic Risk Assessment for Response to Aircraft Accident

Source: Adapted from Communities and Local Government (2010).
This is a document published in conjunction with the Chief Fire and Rescue Adviser for the UK, providing general risk assessment guidelines for fire fighters responding to an aircraft accident or incident.

Note: '7.2d familiarisation visit' is a preparatory visit to a site, in line with 7.2d of the UK *Fire and Rescue Services Act, 2004*.

Ref No.	Activity	Hazard	Risk	Persons at risk	Control Measures
1	• All tasks on crash site • Fire Service operations	• Material used in aircraft construction	• Injury / illness caused by corrosive / toxic materials	• Operational personnel • Members of public • Other responding emergency services	• Training and supervision • Provision of risk critical information in relation to hazardous materials • Provision of risk critical information in relation to aircraft construction • Adequate and appropriate PPE to include respiratory protection and chemical protection where necessary • Facility for decontamination or disposal of PPE and equipment • Limited exposure of personnel wherever possible. As low as reasonable practicable by strict cordon control • 7.2d familiarisation visits • Safety Officers • Liaison with military command centres and on scene advisors

Ref No.	Activity	Hazard	Risk	Persons at risk	Control Measures
2	• All tasks on crash site • Fire Service operations	• Smoke, flames and toxic gases • Reactive components, burning fuel etc	• Injury / illness caused by burns, inhalation of smoke and gases	• Operational personnel • Members of public • Other responding emergency services	• Training and supervision • Safe approach • Adequate and appropriate PPE • Adequate and appropriate respiratory protection • Firefighting procedures and equipment • Limited exposure of personnel wherever practicable by strict cordon control • Provision of risk critical information in relation to aircraft construction and associated hazards •Safety Officers •Liaison with military command centres and on scene advisors.
3	• Post fire hazards	• Hazardous materials used in the construction of aircraft such as polymers composites, fluoroelastomer, hydrofluoric, hydrofluoric acid	• Injury / illness caused by toxic materials	• Operational personnel • Members of public • Other responding emergency services	• Training and supervision • Safe approach • Adequate and appropriate PPE • Adequate and appropriate respiratory protection • Firefighting procedures and equipment • Limited exposure of personnel wherever practicable by strict cordon control • Provision of risk critical information in relation to aircraft construction and associated hazards • Safety Officers • Liaison with military command centres and on scene advisors
4	• Fire Service operations working on / in/around damaged structures	• Collapse of weakened structures • Sharp jagged edges • Weak and unstable structures •Top-heavy aircraft eg. helicopters	• Injury caused by collapsed structures, and aircraft components	• Operational personnel • Members of public • Other responding emergency services	• Training and supervision • Adequate and suitable PPE • Safety Officers • Communications systems • Fire fighting procedures and equipment • Limited exposure of personnel wherever possible. As low as reasonably practicable by strict cordon control • Liaison with military command centres and on scene advisors

Ref No.	Activity	Hazard	Risk	Persons at risk	Control Measures
5	• Fire Service operations in the vicinity of aircraft engines	• Spinning propellers / rotors	• Injury caused by direct contact / propeller wash	• Operational personnel • Members of public • Other emergency services	• Training and supervision • Safe approach • Adequate and appropriate PPE • Adequate and appropriate respiratory protection • Firefighting procedures and equipment • Limited exposure of personnel wherever possible. As low as reasonably practicable by strict cordon control. • Safety Officers • Liaison with military command centres and on scene advisors
6	• Fire Service operations in the vicinity of aircraft engines	• Exhaust areas	• Injury caused by noise / hot-expelled gases	• Operational personnel • Members of public • Other emergency services	• Training and supervision • Safe approach • Adequate and appropriate PPE • Adequate and appropriate respiratory protection • Firefighting procedures and equipment • Exclusion zones to the rear of jet engines • Limited exposure of personnel wherever possible. As low as reasonable practicable by strict cordon control •Liaison with military command centres and on scene advisors
7	• Fire Service operations in the vicinity of aircraft engines	• Induction into turbines	• Injury caused to personnel by direct induction or the induction of equipment • Noise	• Operational personnel • Members of public • Other emergency services	• Training and supervision • Safe approach • Adequate and appropriate PPE • Adequate and appropriate respiratory protection • Firefighting procedures and equipment • Exclusion zones forward of engine intakes • Limited exposure of personnel wherever possible. As low as reasonably practicable by strict cordon control • Liaison with military commend centres and on scene advisors

Ref No.	Activity	Hazard	Risk	Persons at risk	Control Measures
8	• Fire service operations - aircraft fuel spillages	• Highly flammable, explosive, corrosive, irritant and toxic	• Injury / illness caused by exposure and contact		• Training and supervision • Safe approach • Adequate and appropriate PPE • Adequate and appropriate respiratory protection • Firefighting procedures and equipment • Limited exposure of personnel wherever possible. As low as reasonable practicable by strict cordon control • Provision of risk critical information in relation to aircraft fuel and associated hazards • Safety Officers • Liaison with military command centres and on scene advisors
9	• Internal rescue and fire fighting	• Pressurise systems, fixtures and fittings, electrical system, hydraulic systems, confined working conditions	• Injury / illness cased by exposure and contact	• Operational personnel • Other emergency services • Members of public	• Training and supervision • Adequate and appropriate PPE • Adequate and appropriate respiratory protection • Firefighting procedures and equipment • Communication systems • Limited exposure of personnel wherever possible. As low as reasonably practicable by strict cordon control. • Provision of risk critical information in relation to aircraft construction and associated hazards • 7.2d familiarisation visits • Safety Officers • Liaison with military command centres and on scene advisors

Ref No.	Activity	Hazard	Risk	Persons at risk	Control Measures
10	• Fire service operation on or around aircraft fitted with ballistic recovery systems	• Ballistic pyrotechnics	• Injury caused by uncontrolled actuation	• Operational personnel • Other emergency services • Members of public	• Training and supervision • Safe approach • Adequate and appropriate PPE • Firefighting procedures and equipment • Provision of risk critical information in relation to ballistic recovery systems • Limited exposure of personnel wherever possible. As low as reasonably practicable by strict cordon control • Safety Officers • Liaison with military command centres and on scene advisors
11	• Fire Service operations / External hazards	• Exploding tyres, wheel assembly / collapsing undercarriage	• Injury / illness projectile wheel/ undercarriage components	• Operational personnel • Members of public • Other emergency services	• Training and supervision • Safe approach • Adequate and appropriate PPE • Firefighting procedures and equipment • Controlled use of radio • Limited exposure of personnel wherever possible. As log as reasonably practicable by strict cordon control • Provision of risk critical information in relation to aircraft systems and associated hazards • Safety Officers • Liaison with military command centres • On scene advisors • 7.2d familiarisation visits • Liaison with military command centres and on scene advisors

Ref No.	Activity	Hazard	Risk	Persons at risk	Control Measures
12	• Hazard specific to military aircraft and ex-military aircraft • Fire Service operations	• Pyrotechnics, explosives and aircraft armaments • Radar systems and high electromagnetic radiation	• Injury and illness caused by exposure or contact, cased by uncontrolled/ controlled actuation	• Operational personnel • Members of public • Other emergency services	• Training and supervision • Safe approach • Adequate and appropriate PPE • Firefighting procedures and equipment • Controlled use of radio • Time distance shielding • Limited exposure of personnel wherever possible. As low as reasonable practicable by strict cordon control. • Provision of risk critical information in relation to aircraft systems and associated hazards • Safety Officers • Liaison with military command centres • On scene military advisers • 7.2d familiarisation visits • Liaison with military command centres and on scene advisors
13	• Hazard specific to military aircraft and ex-military aircraft • Fire Service operations	• Lasers and defensive aid suits	• Injury resulting from uncontrolled actuation	• Operational personnel • Members of public • Other emergency services	• Training and supervision • Safe approach • Adequate and appropriate PPE • Adequate and appropriate respiratory protection • Firefighting procedures and equipment • Limited exposure of personnel wherever possible. As low as reasonable practicable by strict cordon control • Provision of risk critical information in relation to helicopter construction and associated hazards • Safety Officers • 7.2d familiarisation visits • Liaison with military command centres and on scene advisors

Ref No.	Activity	Hazard	Risk	Persons at risk	Control Measures
14	• Additional hazards associated with helicopters and military aircraft • Fire Service operations	• Water actuated buoyance bags • Automatic deployable emergency locator transmitters	• Injury resulting from uncontrolled actuation	• Operational personnel • Members of public • Other emergency services	• Training and supervision • Safe approach • Adequate and appropriate PPE • Adequate and appropriate respiratory protection • Firefighting procedures and equipment • Limited exposure of personnel wherever possible. As low as reasonably practicable by strict cordon control • Provision of risk critical information in relation to helicopter construction and associated hazards • Safety Officers • 7.2d familiarisation visits • Liaison with military command centres and on scene advisors
15	• Fire service operations around cargo holds	• Large variety of different cargoes ranging from livestock to military hardware • Confined space of cargo areas incorporating trip hazards and crush hazards	• Injury / illness due to contact or exposure to cargo and cargo handling systems	• Operational personnel • Members of public • Other emergency services	• Training and supervision • Safe approach • Adequate and appropriate PPE • Adequate and appropriate respiratory protection • Firefighting procedures and equipment • Limited exposure of personnel wherever possible. As low as reasonable practicable by strict cordon control • Provision of risk critical information in relation to aircraft manifests • Provision of risk critical information from chemical databases • Liaison with military command centres and on scene advisors • Safety Officers • Liaison with military command centres and on scene advisors

Ref No.	Activity	Hazard	Risk	Persons at risk	Control Measures
16	• Rescue and fire fighting operations involving aircraft accidents	• Blood borne pathogens	• Illness as a result of direct contamination or cross contamination to other casualties	• Fire service personnel • Members of public • Other emergency services	• Training and supervision • Safe approach • Adequate and appropriate PPE • Adequate and appropriate respiratory protection • Firefighting procedures and equipment • Facility for decontamination or disposal of PPE and equipment • Limited exposure of personnel wherever possible. As low as reasonably practicable by strict cordon control • Safety Officers
17	• Use of Fire Service equipment to undertake firefighting and rescues	• Manual handling • Failure of equipment causing sudden collapse or movement of loads • Cuts/nips/ trap or entanglement hazard from moving parts • Noise and vibration • High-pressure hydraulic systems • Burns	• Injury / illness resulting from exposure or contact	• Fire service personnel • Members of public • Other emergency services	• Training and supervision • Safe approach • Adequate and appropriate PPE • Adequate and appropriate respiratory protection • Firefighting procedures and equipment • Manual handing training • Adequate and appropriate PPE • Adequate and appropriate respiratory protection • Firefighting procedures and equipment • Limited exposure of personnel wherever possible. As low as reasonably practicable by strict cordon control • Safety Officers
18	• All crash sites	• Site conditions, debris lubricants etc strewn down around the incident ground • Foam blanket coverage hiding any of above	• Potential slip, trip and falls	• Fire service personnel • Members of public • Other emergency services	• Adequate lighting where necessary • Secure site reasonable practical to do so, establish cordons • Safety brief for attending personnel

Ref No.	Activity	Hazard	Risk	Persons at risk	Control Measures
19	• Rescue of casualties from aircraft accidents	• Stress reaction	• Illness as a result of direct or indirect exposure to incident	• Fire service personnel • Members of public • Other emergency services	• Training and supervision • Limited exposure of personnel wherever possible. As low as reasonable practicable by strict cordon control • Safety Officers • Incident debriefs • Liaison with military command centres and on scene advisors
20	• Attending aircraft accidents • Fire Service operations	• Limited experience	• Injury / illness caused by lack of knowledge or poor safe systems of work	• Fire service personnel • Members of public • Other emergency services	• Training and supervision • Limited exposure of personnel wherever possible. As low as reasonable practicable by strict cordon control • Safety Officers • Incident debriefs • Limited exposure of personnel wherever possible. As low as reasonable practicable by strict cordon control • Liaison with military command centres and on scene advisors

Appendix B

Reports used in Evidence Analysis

Air Accident Investigation Branch

1. Aircraft Accident Report No: 5/2008 (EW/C2006/06/04) Report on the accident to Boeing 7370300, registration OO-TND at Nottingham East Midlands Airport on 15 June 2006 (AAIB, 2008d).

2. Aircraft Accident Report No: 7/2008 (EW/C2006/12/03) Report on the accident to Aerospatiale SA365N, registration G-BLUN, near the North Morecambe gas platform, Morecambe Bay on 27 December 2006 (AAIB, 2008e).

3. Aircraft Accident Report No: 2/2009 (EW/2007/02/07) Report on the accident to Boeing 777-222, registration N786UA at London Heathrow Airport on 26 February 2007 (AAIB, 2009c).

4. Aircraft Accident Report No: 6/2009 (EW/C2007/09/08) Report on the accident to Hawker Hurricane Mk XII (IIb), G-HURR, 1 nm north-west of Shoreham Airport, West Sussex on 15 September 2007 (AAIB, 2009d).

5. Aircraft Accident Report No: 2/2010 (EW/C2007/02/08) Report on the accident to beech 200C Super King Air, VQ-TIU at 1 nm south-east of North Caicos Airport, Turks and Caicos Islands, British West Indies on 6 February 2007 (AAIB, 2010f).

Australian Transport Safety Bureau

1. AO-2007-070 - Leading edge device failure - Norfolk Island - 29 December 2007 - VH-OBN, Boeing 737-229. Publication Date: 8 February 2010 (ATSB, 2010a).

2. AO-2009-018 - Midair collision - 15km SE Springvale Station, WA - 5 May 2009 - VH-PHT, Robinson Helicopter Company R22 Beta II and VH-HCB, Robinson Helicopter Company R22 Beta II. Publication Date: 17 February 2010 (ATSB, 2010b).

3. AO-2007-047 - Aircraft loss of control - 255km SW of Warburton, Western Australia - 17 October 2007 - VH-WXC, Cessna Aircraft Company 210M. Publication Date: 22 April 2010 (ATSB, 2010c).

4. AO-2008-007 - Hand landing - Darwin Airport, Northern Territory - 7 February 2008 - VH-NXE, Boeing Company 717-200. Publication Date: 14 May 2010 (ATSB, 2010d)

5. AO-2008-067 - Total power loss - Talbot Bay, Western Australia - 25 September 2008 - VH-NSH, Bell Helicopter Co. 407. Publication Date: 28 June 2010 (ATSB, 2010e)

National Transportation Safety Board

1. AAR-09/06 (PB2009-910406) - Loss of Control and Crash - Marlin Air - Cessna Citation 550, N550BP - Milwaukee, Wisconsin - June 4, 2007 - Adopted: October 14, 2009 (NTSB, 2009j).

2. AAR-09/07 (PB2009-901407) - Crash During Approach to Landing of Maryland State Police - Aerospatiale S365N1, N92MD - District Heights, Maryland - September 27. 2008 - Adopted: October 27, 2009 (NTSB, 2009k).

3. AAR-10/01 (PB2010-910401) - Loss of Control on Approach - Colgan Air, Inc. - Operating as Continental Connection Flight 3407 - Bombardier DHC-8-400, N200WQ - Clarence Centre, New York - February 12, 2009 - Adopted: February 2, 2010 (NTSB, 2010c).

4. AAR-10/02 (PB2010-910402) - Runway Overrun During Rejected Takeoff - Global Exec Aviation - Bombardier Learjet 60, N999LJ - Columbia, South Carolina - September 19, 2008 - Adopted April 6, 2010 (NTSB, 2010d).

5. AAR-10/03 (PB2010-910403) - Loss of Thrust in Both Engines After Encountering a Flock of Birds and Subsequent Ditching on the Hudson River - US Airways Flight 1549 - Weehawken, New Jersey - January 15, 2009 - Adopted: May 4, 2010 (NTSB, 2010e).

Appendix C

Evidence Sources Used In Recent Aircraft Accident Investigation Reports

Report Section	Sample Report	On Site Evidence	Off Site Evidence
1.1 History of the flight	AAIB1	* Aircraft manual * FDR data * CVR data * ACARS data * EPGWS computer	* Crew statements * Flight plan * Weather forecast * ATC recordings * ATC statements * CCTV * ARFFS statements
	AAIB2	* FDR data * CVR data * GPS data	* Helicopter landing deck information * Oil rig information * Crew duty times * Flight plan * Weight and balance * SOPs * Witness statements * Emergency responder statements
	AAIB3	* EICAS data * FDR data	* Crew statements * Witness statements * ARFFS statement
	AAIB4		* Witness statements
	AAIB5		* Witness statements * Fuel documents * Passenger statements
	ATSB1	* Photographs * Engineering inspection	* Crew statements
	ATSB2		* Witness statements
	ATSB3		* Witness statements * Flight plan * ATC recordings
	ATSB4	* FDR data	* ATC recordings * Crew statements
	ATSB5		* Witness statements
	NTSB1	* CVR data * Wreckage examination	* Flight plan * Meteorological observations * Witness statements

Report Section	Sample Report	On Site Evidence	Off Site Evidence
	NTSB2		* Radar track * ATC recordings
	NTSB3	* Site inspection * ACARS data * CVR data * FDR data	* Crew schedules * Operational records
	NTSB4	* Site inspection * CVR data	*ATC statements
	NTSB5	* CVR data	* Emergency response log * Crew statements
1.2 Injuries to Persons	AAIB1		* 2 crew, minor/none
	AAIB2		* 2 crew fatal * 4 passengers fatal
	AAIB3		* 20 crew minor/none * 185 passengers minor/none
	AAIB4		* 1 crew fatal
	AAIB5		* 1 crew fatal * 4 passengers serious * 1 passenger minor
	ATSB1		* No physical injuries * Psychological injuries identified through passenger statements after accident
	ATSB2		* 2 crew fatal
	ATSB3		* 1 crew fatal
	ATSB4		* None reported
	ATSB5		* 1 crew minor/none * 6 passengers minor/none
	NTSB1		* 2 crew fatal * 4 passengers fatal
	NTSB2		* 3 crew fatal * 1 passenger fatal * 1 passenger serious
	NTSB3		* 4 crew fatal * 45 passengers fatal * 1 ground fatal
	NTSB4		* 2 crew fatal * 2 passenger fatal * 2 passengers serious

Report Section	Sample Report	On Site Evidence	Off Site Evidence
	NTSB5		* 1 crew serious * 1 passenger serious * 95 passengers minor * 4 crew none * 51 passengers none
1.3 Damage to aircraft	AAIB1	* Site inspection * Aircraft inspection	
	AAIB2	* Aircraft destroyed * Recovered from marine environment	
	AAIB3	* Aircraft inspection	
	AAIB4	* Site inspection * Aircraft destroyed through impact and fire	
	AAIB5	* Site inspection - aircraft in shallow marine environment * Aircraft destroyed	
	ATSB1	* Site inspection	
	ATSB2	* Site inspection * Aircraft seriously damaged	
	ATSB3	* Site inspection * Aircraft seriously damaged	
	ATSB4	* Inspection of damaged aircraft	
	ATSB5	* Aircraft recovered from marine environment	
	NTSB1	* Aircraft recovered from marine environment	
	NTSB2	* Site inspection * Extensive structural damage	
	NTSB3	* Site inspection * Aircraft destroyed	
	NTSB4	* Site inspection * Aircraft destroyed	
	NTSB5	* Aircraft recovered from marine environment * Aircraft substantially damaged	
1.4 Other damage	AAIB1	* No other damage	
	AAIB2	* No other damage	
	AAIB3	* No other damage	

Report Section	Sample Report	On Site Evidence	Off Site Evidence
	AAIB4	* No other damage	
	AAIB5	* No other damage	
	ATSB1	* No statement	
	ATSB2	* No statement	
	ATSB3	* No statement	
	ATSB4	* No statement	
	ATSB5	* No statement	
	NTSB1	* No other damage	
	NTSB2	* No other damage	
	NTSB3	* Site inspection * House and vehicle damage from impact and fire	
	NTSB4	* Site inspection * Damage to aerodrome lighting, fence and a road	
	NTSB5	* No other damage	
1.5 Personnel Information	AAIB1		* Logbook information * Licence information * Operator records * Crew statements
	AAIB2		* Logbook information * Licence information * Job role records * Background history of crew * Safety training records
	AAIB3		* Logbook information * Licence information * Rest periods
	AAIB4		* Logbook information * Licence information * Employment information * ATC aircraft movement records * Formal training records * Witness statements * Display authorisation records

Report Section	Sample Report	On Site Evidence	Off Site Evidence
	AAIB5		* Logbook information * Licence information * Operation records * Flying history * Training records * Employment status
	ATSB1		* Employment record * Licence information * Logbook information
	ATSB2		* Licence information * Logbook information * Flight and duty times
	ATSB3		* Licence information * Logbook information * Operator records * Flight and duty times
	ATSB4		* Licence information * Logbook information * Training records
	ATSB5		* Licence information * Logbook information * Training records
	NTSB1		* Employment records * Regulator records * Logbook information * Licence information * Witness statements * Training records
	NTSB2		* Licence information * Logbook information * Training records * Witness statements * Flight and duty times * Medical examination
	NTSB3		* Licence information * Logbook information * Flight and duty times * Witness statements * Operator records * Regulator records * Training records
	NTSB4		* Employment records * Licence information * Logbook information * Flight and duty times * Witness statements * Regulator records

Report Section	Sample Report	On Site Evidence	Off Site Evidence
	NTSB5		* Employment records * Licence information * Logbook information * Flight and duty times * Crew statements * Operator records
1.6 Aircraft Information	AAIB1		* General aircraft information * Weight and balance * Engine specifics * Systems information * Structures information * Maintenance records
	AAIB2		* General aircraft information * Systems information * Maintenance records
	AAIB3		* General aircraft information * Maintenance records * Systems information
	AAIB4		* General aircraft information * Maintenance/restoration records * Weight and balance calculations * Registration details
	AAIB5		* General aircraft information * Weight and balance information * Pilot’s operating handbook * Airplane flight manual * Performance calculations * Checklists
	ATSB1		* General aircraft information * Maintenance records
	ATSB2		* General aircraft information * Maintenance records
	ATSB3		* General aircraft information * Maintenance records * Systems information * Operational information
	ATSB4		* General aircraft information * Aircraft damage inspection in laboratory

Report Section	Sample Report	On Site Evidence	Off Site Evidence
	ATSB5		* General aircraft information * Weight and balance information * Engine information * Crew statements * Maintenance records
	NTSB1		* General aircraft information * Weight and balance information * Systems information * Checklists * Witness statements * Operations manual
	NTSB2		* General aircraft information * Instrument information * Maintenance records * Weight and balance information * Witness statements
	NTSB3		* General aircraft information * Weight and balance information * Performance data * Operators flight manual * Witness statements * Company memos * Instrument information * Systems information * Maintenance records * Airplane logbook
	NTSB4		* General aircraft information * Engine information * Aircraft logbook information * Maintenance records * Systems information
	NTSB5		* General aircraft information * Weight and balance information * Systems information * Instrument information * Engine information * Certification requirements * Maintenance records

Report Section	Sample Report	On Site Evidence	Off Site Evidence
1.7 Meteorological Information	AAIB1		* Meteorological forecasts * Meteorological observations
	AAIB2		* Meteorological aftercast * Meteorological forecast * Meteorological observations * Witness statements * Regulations * Celestial records
	AAIB3		* Meteorological observations
	AAIB4		* Meteorological observations
	AAIB5		* Meteorological observations
	ATSB1		* Meteorological forecast * Meteorological observations
	ATSB2		* Meteorological observations * Sun position
	ATSB3		* Meteorological aftercast
	ATSB4	* FDR data	* Meteorological observations * Crew statements
	ATSB5		* Witness observations
	NTSB1		* Meteorological forecasts * Meteorological observations
	NTSB2		* Meteorological observations * Emergency response statements * Witness statements * Meteorological forecasts
	NTSB3	* Meteorological forecasts carried in aircraft	* Meteorological observations * Pilot reports * ATC transcript * Witness statements
	NTSB4	* CVR data	* Meteorological observations
	NTSB5		* Meteorological observations * Tidal records
1.8 Aids to Navigation	AAIB1	* Charts on aircraft	* Maintenance records * Service inspection
	AAIB2	* GPS data * On board radar data	* Review of available aids
	AAIB3		* Not applicable
	AAIB4		* Not applicable

Report Section	Sample Report	On Site Evidence	Off Site Evidence
	AAIB5		* Not applicable
	ATSB1		* No statement
	ATSB2	* Equipment fitted * Handheld GPS data	
	ATSB3		* Equipment serviceability check
	ATSB4		* No statement
	ATSB5		* No statement
	NTSB1		* No problems reported
	NTSB2		* Equipment serviceability check
	NTSB3		* Witness statements * Equipment serviceability check
	NTSB4		* No problems reported
	NTSB5		* No problems reported
1.9 Communications	AAIB1	* Site inspection	* ATC recordings * ATC statements
	AAIB2	* On board communications recordings	* ATC recordings
	AAIB3	* CVR recordings	* Crew statements * Witness statements
	AAIB4		* Not applicable
	AAIB5		* No ATC transmissions
	ATSB1		* Crew statements
	ATSB2	* Equipment investigation * ELT serviceability	* Witness statements * Regulations review
	ATSB3		* ATC recordings * SARWATCH timings * Operator statements
	ATSB4		* No statement
	ATSB5		* No statement
	NTSB1		* No problems reported
	NTSB2		* No problems reported

Report Section	Sample Report	On Site Evidence	Off Site Evidence
	NTSB3		* No problems reported
	NTSB4		* No problems reported
	NTSB5		* Crew statements * ATC statements
1.10 Aerodrome Information	AAIB1	* Location of accident site	* Maintenance records * Runway specifics * Airport facilities information
	AAIB2		* Regulations for use * Landing area inspection records
	AAIB3		* Not applicable
	AAIB4		* Aerodrome location * Runway specifics
	AAIB5		* Runway specifics * Runway facilities * Aerodrome procedures
	ATSB1		* Runway specifics * Terrain information * Approach procedure
	ATSB2		* No statement
	ATSB3		* No statement
	ATSB4		* Runway specifics * Aerodrome facilities * Approach procedure
	ATSB5		* No statement
	NTSB1		* Aerodrome location * Runway specifics
	NTSB2		* ATC operations * Aerodrome location * Runway specifics * Runway facilities * Approach procedure
	NTSB3		* Aerodrome location * Runway specifics * Approach procedure * ATC operations * ATC statements

Report Section	Sample Report	On Site Evidence	Off Site Evidence
	NTSB4		* Aerodrome location * Runway specifics * NOTAMS * ARFFS capabilities
	NTSB5		* Aerodrome information * Regulator guideance * Aerodrome procedures * ATC SOPs * ATC recordings * Radar track
1.11 Flight Recorders	AAIB1	* CVR * FDR * EPGWS computer	
	AAIB2	* IHUMS * CVFDR * MDR * DIGITAS unit * Instrument readings	* IHUMS data from operator * Maintenance records * Ground radar * Flight test * Data simulation (using unmeasured variables with known parameters) *Note: Sea water corroded some of the CVFDR tape*
	AAIB3	* FDR data * CVR data * QAR data * NVM from GCU and BPCU	
	AAIB4		* Witness photographs and videos
	AAIB5	* CVR data	
	ATSB1	* DFDR data * CVR data	
	ATSB2	* No recorders fitted	* Requirements for recorders
	ATSB3		* No statement
	ATSB4	* QAR data * FDR data * CVR data	
	ATSB5	* FADEC/ECU data	* Witness video
	NTSB1	* No recorders fitted	* Requirements for recorders
	NTSB2	* No recorders fitted	* Requirements for recorders
	NTSB3	* CVR data * FDR data	
	NTSB4	* CVR data	

Report Section	Sample Report	On Site Evidence	Off Site Evidence
	NTSB5	* CVR data * FDR data	
1.12 Wreckage and Impact Information	AAIB1	* Site size and location * Ground marks * Debris plot * Aircraft inspection * Fuel ‘dipstick’ readings * Cargo inspection * Weight and balance calculation	* CCTV
	AAIB2	* Floating debris location * Sonar scans of underwater * Structure recovery location plotting * Recovery of wreckage from seabed * Engine inspection * Main and tail rotor inspection * Flight control inspection * Instrument inspection	
	AAIB3	* Aircraft examination * Fire examination * Structural examination * Conductivity measurements * Wiring inspection * Insulation blanket inspection * Systems inspections	* Part number records * Tests on specimen parts
	AAIB4	* Site investigation * Ground impact marks * Propeller inspection * Wreckage inspection * Systems inspection * Instrument inspection * Engine investigation	* Video footage
	AAIB5	* Site examination * Wreckage plotting * Structures examination * Instruments examination * Engine examination * Propeller examination	
	ATSB1	* Structures investigation	
	ATSB2	* Site investigation * Debris plotting * Fire investigation * Structures investigation * Impact marks investigation * Systems investigation * Engine investigation	

Report Section	Sample Report	On Site Evidence	Off Site Evidence
	ATSB3	* Site investigation * Ground witness marks * Debris plotting * Structures investigation * Propeller investigation * Systems investigation * Instrument investigation	
	ATSB4	* Structures investigation	
	ATSB5	* Site investigation * Structures investigation * Engine examination	
	NTSB1	* Site investigation * Debris recovery * Systems investigation * Structures investigation	
	NTSB2	* Site investigation * Instrument examination * Structures investigation * Approach charts * Wreckage plotting	
	NTSB3	* Site investigation * Wreckage plotting * Tree damage * Systems inspection * Structures investigation * Engine investigation	
	NTSB4	* Site investigation * Debris trail * Wreckage plotting * Structures investigation * Engine investigation	
	NTSB5	* Structures investigation * Engine investigation	
1.13 Medical and pathological information	AAIB1		* No injuries to consider
	AAIB2		* SAR records * Post-mortem examination
	AAIB3		* Not applicable
	AAIB4		* Post-mortem examination
	AAIB5		* Post-mortem examination * Injury records
	ATSB1		* No statement
	ATSB2		* Impact not survivable

Report Section	Sample Report	On Site Evidence	Off Site Evidence
	ATSB3		* Impact not survivable
	ATSB4		* No statement
	ATSB5		* No statement
	NTSB1		* Post-mortem examination
	NTSB2		* Post-mortem examination * Medical history * Witness statements * Injury records
	NTSB3		* Post-mortem examination
	NTSB4		* Post-mortem examination
	NTSB5		* Breathalyzer tests * Injury records * Passenger interviews
1.14 Fire	AAIB1	* Foam blanket laid around aircraft	* ARFFS statement
	AAIB2		* There was no fire
	AAIB3	* Thermal camera images	* ARFFS statements
	AAIB4	* Site inspection - severe post-impact fire	
	AAIB5	* No evidence of fire	
	ATSB1		* No statement
	ATSB2	* Site inspection - grass fire	* SAR statements
	ATSB3		* No statement
	ATSB4		* No statement
	ATSB5		* No statement
	NTSB1	* Site inspection - no evidence of fire	
	NTSB2		* No fire occurred
	NTSB3	* Site inspection - no evidence of in-flight fire, ground fire occurred	
	NTSB4	* Site inspection	* Passenger statements * Witness statements * ARFFS statements

Report Section	Sample Report	On Site Evidence	Off Site Evidence
	NTSB5		* No fire occurred
1.15 Survival Aspects	AAIB1		* None to consider
	AAIB2	* PLB search	* SAR response incident log * SAR statements * PLB search * Immersion suit survivability conditions
	AAIB3		* Not applicable
	AAIB4		* Accident was not survivable
	AAIB5	* Cabin inspection	* Passenger statements * SAR statements
	ATSB1	* Aircraft specific emergency procedures card	* Operations manual * Passenger statements * Crew statements * Maintenance records
	ATSB2		* Impact not survivable
	ATSB3		* Impact not survivable
	ATSB4		* No statement
	ATSB5		* Crew SOPs * Crew statements * Witness statements * Passenger statements
	NTSB1		* Impact not survivable
	NTSB2	* Wreckage inspection	* Emergency responder statements * Witness statements * SAR SOPs * SAR log
	NTSB3		* Emergency responder statements * Natural gas emergency responder statements
	NTSB4	* Cabin inspection * Exit door inspections	* Passenger statements
	NTSB5		* Certification regulations * Crew training procedures * Witness video * Crew statements * Passenger statements * Emergency response log

Report Section	Sample Report	On Site Evidence	Off Site Evidence
1.16 Tests and Research	AAIB1	* Aircraft navaid checks for serviceability * Instruments checked for serviceability and accuracy	* Records of navigation aid calibrations
	AAIB2		* Flight tests
	AAIB3	* Components removed for examination	* Removal of comparison parts from other aircraft * Flammability tests * Review of past accidents * Endurance tests * Maintenance records
	AAIB4		* Not applicable
	AAIB5		* Not applicable
	ATSB1		* Passenger survey
	ATSB2		* No statement
	ATSB3	* Fuel sample	* Testing of sample components
	ATSB4		* No statement
	ATSB5		* Passenger survey * Review of past accidents * Engine manufacturer research
	NTSB1		* Aircraft simulation and performance tests
	NTSB2	* Engine examination * Avionics equipment	* Engine examination * Avionics examinations * Aircraft performance studies * TAWS simulations
	NTSB3		* Aircraft performance simulation
	NTSB4	* CVR data	* Sound spectrum study * Aircraft performance simulation with map overlay
	NTSB5	* Biological material collection (bird matter)	* Aircraft performance study * Biological material testing * Flight simulation
1.17 Organisational and management information	AAIB1		* Operator AOC * Operations manual * SOPs * Operator training and recency requirements * ATC SOPs

Report Section	Sample Report	On Site Evidence	Off Site Evidence
	AAIB2		* Operator records * Operator training and recency records * Operations manual * Operators safety management system
	AAIB3		* Organisational structure * Management structure
	AAIB4		* Organisational control manual * Training records * Safety review
	AAIB5		* Operator information * Review of Regulations * Emergency response procedures
	ATSB1		* AOC inspection * Review of operator emergency response plan * Crew statements
	ATSB2		* Flight and duty times management procedures * Mustering procedures
	ATSB3		* No statement
	ATSB4		* Review of regulation * Training review
	ATSB5		* No statement
	NTSB1		* Operational oversight review * Witness statements * Organisation history
	NTSB2		* Organisation overview * Training procedures * SOPs * Review of previous accidents * Post accident actions * Regulatory oversight
	NTSB3		* Organisation overview * Training manual * Training records * Witness interviews * Simulator observations * Flight manuals * SOPs * Employment policies * Safety management programmes * Post accident actions

Report Section	Sample Report	On Site Evidence	Off Site Evidence
	NTSB4		* Organisation overview * Maintenance records * Pilots training procedures * SOP * Regulatory oversight
	NTSB5		* Pilot Handbook * SOPs * Checklists * Evacuation SOPs * Training requirements and records * Regulatory oversight
1.18 Additional Information	AAIB1		* Crew statements
	AAIB2	* Automatic Voice Alert Device * Instrument panel switch positions * CVR records	* System simulation * Operator statements * Previous accident analysis
	AAIB3		* Crew checklists * Failure condition simulations * Review of previous safety recommendations
	AAIB4		* Legal requirements * Manoeuvre simulation * Previous display accidents * Historic aircraft operation guidelines
	AAIB5		* Review of regulations * Human factors research * Witness statements
	ATSB1		* No statement
	ATSB2		* Mustering procedures
	ATSB3		* Review of regulations
	ATSB4		* Training oversight * Advisory material * Operators route manual
	ATSB5		* Review of previous events
	NTSB1		* CRM review * Review of safety recommendations
	NTSB2		* Safety of EMS operations * SOPs * Review of previous safety recommendations

Report Section	Sample Report	On Site Evidence	Off Site Evidence
	NTSB3		* Previous safety recommendations * Review of previous accidents * Witness statements
	NTSB4		* Training safety studies * Post accident action reviews * Review of changes to flight manual from manufacturer * Review of previous safety recommendations * Tyre requirements
	NTSB5		* Wildlife safety studies * Review of previous accidents * Review of safety recommendations * Survivability testing
1.19 Useful or effective investigation techniques	AAIB1		* Not included
	AAIB2		* Not included
	AAIB3		* Not included
	AAIB4		* Not included
	AAIB5		* Not included
	ATSB1		* Not included
	ATSB2		* Not included
	ATSB3		* Not included
	ATSB4		* Not included
	ATSB5		* Not included
	NTSB1		* Not included
	NTSB2		* Not included
	NTSB3		* Not included
	NTSB4		* Not included
	NTSB5		* Not included

Appendix D

Evidence Types and Collection Methodologies Recommended in ICAO *Manual of Aircraft Accident and Incident Investigation, Part III - Investigation* (2008b)

Source of Evidence	Evidence Type	Evidence Collection Method	Reference Section in ICAO (2008b)	Description
Location of aircraft	Physical location of aircraft wreckage	* "Global Positioning Satellite (GPS) receiver and aeronautical charts or aerial photographs" * "Plotting the bearing and distances from known positions on a large-scale map or by using aerial photography"	2.1	Determination of the aircraft location is the first stage of developing a wreckage plot.
Site inspection	Examination of impact marks and debris	* "Careful examination of ground marks, or scars upon trees, shrubs, rocks, poles, power lines, buildings etc." * "Measurement and documentation of ground scars, as well as impact marks on analogue instruments etc."	2.4 6.3.7	* "It is usually possible to form a preliminary mental picture of: a. the direction, angle and speed of descent; b. whether it was a controlled or uncontrolled descent; c. whether the engines were under power at the time of impact; d. whether the aircraft was structurally intact at the point of first impact"

Source of Evidence	Evidence Type	Evidence Collection Method	Reference Section in ICAO (2008b)	Description
Site inspection	Wreckage distribution chart	* Staking the wreckage * Use a GPS receiver to identify individual components on the accident site * Build a wreckage distribution chart of the accident site	2.3.2 2.3.3 2.3.4	* "As each stake is placed, it should be identified with a unique number and significance noted in a log. A master log can be assembled by the investigator-in-charge so that return to specific locations or identification of distribution can be made" * Combine the initial wreckage debris identification and staking effort with an associated position entered into a GPS systems database" * The chart should record the locations of all major components, parts and accessories, freight and locations at which the accident victims were found, or survivors located, and if available, their identities. The initial contact markings and other ground markings should also be indicated on the chart with suitable reference to identify the part of the aircraft or component responsible for the marking. When terrain features appear to have bearing on the accident or on the type of damage they too should be noted on the wreckage distribution chart. Pertinent dimensions, descriptive notes and also the locations from which photographs were taken add to the completeness of the chart"

Source of Evidence	Evidence Type	Evidence Collection Method	Reference Section in ICAO (2008b)	Description
Photography	Accident site and wreckage photography (both still and video)	Photograph: * “Aerial view of the site * The site ground view from each cardinal compass position * The site from the direction the aircraft was travelling in at impact * Ground scars * Damage to trees and foliage * Skid marks * Photo inventory of major wreckage components * Flight control surfaces and actuators * Landing gear and other hydraulic components * Cockpit switch positions * Fire/heat damage and discolouration * Human remains, injuries, blood/tissue smears on wreckage * Extra items or items adjacent to items not accounted for * Close ups from fracture surfaces * Close ups of any other items you suspect may have contributed to the mishap * Private property damage * Steps in removing, opening or cutting apart components * Any other photos deemed necessary”	2.2	* “Clear will composed photographs allow the investigator to preserve perishable evidence, substantiate the information in the report, and illustrate the investigator’s conclusions” * “The general rule in accident site photography is to start with the most perishable evidence and work to the least perishable evidence”
Airframe examination	“Structural integrity and damage on wings, fuselage, tail, landing gear, flight controls, and cockpit	* Visual inspection and photography * Close examination of all components * Recordings the position of switches etc	9.3.2 - 9.3.5	* Investigators should identify any damage to the airframe components, and identify any missing pieces
Airframe examination	Fatigue of materials	* Wreckage inspection to identify fatigue in components	9.4	* Fatigue may manifest in many ways. including as bending fatigue, tension fatigue failures and torsion fatigue failures
Airframe examination	Smears and scoring	* Inspection of smears (deposits of one material on another, eg. paint, oil etc.) or score marks (from one surface or object scraping on another)	9.3.1	* This investigation should be done before any components are moved, as the evidence can be easily damaged

Source of Evidence	Evidence Type	Evidence Collection Method	Reference Section in ICAO (2008b)	Description
Airframe examination	Static failures	* Visual inspection to identify static failures - "this failure is characterised by permanent distortion or rupture of the member"	9.5	* Fractures in metals differ in look depending on whether they are the result of tensile, compression, bending, shear, torsion or tearing failures. * Fabrics may fail through tensile, tearing, or teasing stresses. * Polymers may deform through tensile, bending or tearing forces. * Different static failures will appear slightly different.
Airframe examination	Corrosion	* Visual inspection of corrosion in metals or composites	9.11	* Corrosion may occur either chemically or electrochemically. The source of corrosion should be investigated.
Airframe examination	Composite material damage	* Inspection of failed composite materials - these behave differently to metals	9.8	* Macroscopic analysis of composites will not provide sufficient evidence on site, and selected composite panels will need to be recovered for laboratory review. Care should be taken as composite panels can be easily damaged in transit
Airframe / wreckage examination	Reconstruction of broken or damaged parts	* "Parts are collected, identified, and arranged on the ground in their relative positions"	8.4	* After the site is photographed and wreckage plot diagrams made, it may be beneficial or identify components of the aircraft to determine whether all parts are contained within the wreckage. Further, more complicated reconstructions, can be completed away from the accident site
Airframe / wreckage examination	Fire damage from either ground or in-flight fires (or both)	* The fire investigator must gain an overall assessment of the fire damage caused by the post impact fire. This will assist in knowing if the ground fire may have damaged the parts from the aircraft zone suspected to cause the in-flight fire" * Identify ignition sources: either chemical, thermal or electrical * Identification of discolouration of paint * Photograph the evidence	11.1 - 11.10	* "Supporting fire evidence for the scenario will be masked by the post impact fire and subsequent fire fighting response before the investigator arrives on site" * "This is where knowledge of fluid flammability enters into the investigation. The commercial phosphate ester base fluids, such as Skydrol, are not readily flammable. Mineral oil base fluids are, however, quite flammable in the atomised spray release mode" * Different materials will burn at different rates, as do ground and in-flight fires

Source of Evidence	**Evidence Type**	**Evidence Collection Method**	**Reference Section in ICAO (2008b)**	**Description**
Airframe examination	Evidence of explosive damage	* Inspect for pieces of shrapnel * Testing for chemical residue * Inspection of metallurgical surface characteristics	19.2	* Use evidence collected on site in conjunction with information from data recorders
Flight Recorders	Recovery of recorded flight data, possibly including: * Flight Data Recorders * Cockpit Voice Recorders * Quick Access Recorders * Airborne Image Recorder * Non-Volatile Memory in printed circuit boards	* Retrieval of all available recorded media from the aircraft wreckage for analysis away from the site * Special retrieval processes may be required depending on the location of the recorders, and the extent of damage sustained in the impact/fire. * If a recorder is found submerged in water they "should be rinsed in fresh (distilled or de-ionized) water and placed in the watertight container. They should be transported fully submerged in fresh water (or water from the site if clean water is not available" * "It is important to note the location of the flight recorders and to document the conditions to which they were subject at the accident site".	2.3.1 7.1	* "Irrespective of the type of recording system no attempt should be made to conduct a read-out at the accident site; instead the recorder should be hand carried in a timely manner to an adequate playback and analysis facility where suitable processing by qualified personnel can take place"
Cockpit inspection	Personal equipment of crew - inspection of the "effectiveness and appropriateness" of equipment available to the crew	Investigate: * "If used, did the equipment function as designed, or were there factors which prevented them from providing the protection necessary" * "The ability of a crew member to have access to the required controls" * "The crew members ability to see objects if their presence is part of the accident scenario" * "The ability of a crew member to see instruments, warning lights or switch positions across the cockpit"	4.6	* This is an investigation into how the crew were operating within the flight deck environment, and whether they were limited in their operational capabilities by any extenuating factors.
Cockpit inspection	Flight planning	* Review a copy of the flight plan to identify the "particular circumstances of the intended flight" * The flight plan may be logged with an external agency, or may be carried on the aircraft.	4.7	* "It will often be useful, especially in the case of light aircraft flights operated on demand and training flights to ascertain what the crew's intentions regarding the flight and various manoeuvres planned"

Source of Evidence	Evidence Type	Evidence Collection Method	Reference Section in ICAO (2008b)	Description
Cockpit inspection	Maps, charts and navigational databases	“The investigator should check: * Plotting charts * Radio navigation charts * Terminal area charts * Instrument approaches * Aeronautical charts (topographical) * Visual approach charts * Landing charts * Aerodrome charts * Aeronautical navigation charts * Charts from the internet * Electronic flight bags * RAMS and navigation aid availability * GPS databases”	4.9	* Investigators should confirm the accuracy of materials being carried by the pilots on the flight
Cockpit inspection	Calculated weight and balance of the aircraft in the flight circumstances	* The planned weight and balance charts (possibly carried amongst pilot paperwork) should be checked against the set of up the aircraft: “The setting in the cockpit and the position of the variable tailplane, or the trim tabs, if appropriate, should be checked”	4.8	* The purpose of this investigation is to consider the variation between the planned weight and balance of the aircraft and the actual weight and balance configuration
Cockpit inspection	Instrument conditions and readings	* “All instruments should be recovered, their readings and conditions documented and their connections examined”	13.6	* Readings on instruments may be determined through either: 1. visual examination 2. microscopic examination of dial and pointer for evidence of impact marks 3. internal examination of operating gears and mechanisms for evidence of impact marks or capture 4. electrical synchro readout.
Cockpit inspection	Switch positions	* “All switches should be documented as to position when found”	13.3.2	* “When switch position becomes a factor in the investigation, the position of nearby switches should also be considered. Crew members reaching for a particular switch without correctly identifying the switch may inadvertently select the incorrect switch”

Source of Evidence	Evidence Type	Evidence Collection Method	Reference Section in ICAO (2008b)	Description
Power plant investigation	Functionality of the engine	* "Assess potential issues such as in-flight fire, uncontained rotor parts and the visible condition of the entrance and exit stages of the engine" * Conduct an inventory of the components (eg. "inlet, nacelle, fan, compressors, burner, turbines, exhaust, externals")	12.2	* If evidence is not obvious through a visual inspection, the a complete engine teardown in a laboratory may be required. * Investigators are looking for answers to: a. "what thrust power was being commanded b. what thrust power was being produced c. what malfunctions occurred d. what were the indications to crew"
Power plant investigation	Propeller examination	* "The first step in propeller examination is to account for all the blades, particularly the integrity of the tips. If any portion of the blade is missing, the fractures on the recovered portion should be examined with a magnifying glass to determine whether the break occurred in flight or at impact. Evidence of fatigue or tension breaks should be carefully noted"	12.4	* "When properly correlated with evidence obtained from the engine, examination of the propeller can produce valuable evidence such as: a. revealing whether power was being produced at the time of impact b. rpm of the engine (in some cases) c. propeller blade angle d. ground speed of the aircraft (in some cases)"
Power plant investigation	Type and quality of fuel	* Collection of oil and fuel samples * Samples of smoke or soot smears * Recovery of chip detectors in the oil system	12.6 - 12.8	* "At least 2 litres should be obtained if proper assessment of fuel is to be made" * "Fuel samples should be in suitably sealed times. (Glass or plastic containers let in light which may spoil the sample; fuel may also absorb some of the constituents of the plastic)
Systems investigations	Hydraulic system	* Samples of hydraulic fluids * Examination of the hydraulic pumps * Establish system pressure * Inspect operation of the pressure release valves	13.2	* "Most large aircraft have at least two independent hydraulic systems" * "Investigators should obtain hydraulic fluid samples from as many sources as possible, eg. reservoirs, filters, actuators and trapped line sections"
Systems investigations	Electrical system	* Inspection of components in the system to identify any failures * Check quality and charge of the battery * Light bulb analysis	13.3	* "The external evidence, crew statements, on-board recordings, witness reports, air traffic control communications recording etc, will generally provide the initial direction for the electrical system investigation"

Source of Evidence	Evidence Type	Evidence Collection Method	Reference Section in ICAO (2008b)	Description
Systems investigations	Damage to aircraft wiring	* Visual inspection of the wiring * "A magnifying glass and multimeter will be about the best tools for this work. The purpose of this examination is to identify any wiring that should be removed for laboratory analysis"	9.11.3 13.3.9	* "Considering the more than 200km of wiring that snakes through the typical wide-body transport, it is apparent that many sections of wiring will not be inspected"
Systems investigations	Pressurisation and air conditioning systems	* Physical inspection of superchargers and compressors, turbine bleed air systems, air conditioning systems, valves in the system and ducting * Inspect function of crew oxygen masks * Account for all portable oxygen cylinders carried * Check for activation of the passenger oxygen system * Check function of the chemical oxygen generators	13.4 13.10	* The integrity and functionality of all components in the systems should be investigated. Certain signs, such as soot in the turbine engine bleed air system, suggest certain causes (in this example, possible carbon dioxide contamination) * Check the system as a whole to ensure valves in the system are set as necessary, gases contained are oxygen and not a toxic material
Systems investigations	Ice and rain protection systems	* Inspection of "pneumatics and thermal de-icing equipment, windshield wipers and rain repellant"	13.5	* Check control settings in cockpit against the function on the aircraft
Systems investigations	Navigation systems	* Examine selected settings on equipment * Examine antennas and cables * Examine on-board self-contained systems	13.7	* Different equipment may be fitted to different aircraft. Confirm with maintenance records etc. the equipment fitted to the particular aircraft
Systems investigations	Flight control system	* Identify, recover and inspect all flight control components	13.8	* "Identify, tag, and photograph, as is, as much of the system as possible. During this part of the investigation, be sure to document, both in your notes and with photographs, any observations which appear to be unusual * If you must disconnect portions of the system, index by marking each side of the connection so that you can reconstruct. Document such disconnects. * Mark the position of any component that might be free to move during wreckage recovery"

Source of Evidence	Evidence Type	Evidence Collection Method	Reference Section in ICAO (2008b)	Description
Systems investigations	Fire detection and protection systems	* Physical inspection of the systems * "Fire extinguisher bottles should be recovered and examined for their state of charge"	13.9	* "Fire detection and extinguisher systems are becoming increasingly complex, therefore consideration may need to be given to using specialised knowledge and test equipment of the manufacturer"
Systems investigations	Landing gear systems	* Inspect the extension and retraction functions, and switch positions and indicator lights in the cockpit * Check for correct installation of bolts in landing gear * Check that the two wheel halves match * Check pressure in the brake systems * Check the fuseable plugs * Check tire quality and inflation	13.11	* This is a general investigation of all the components in the system, and how they fit together * Consideration should be given to how the system functioned for a take-off or landing accident, if hydroplaning occurred, or whether the anti-skid or spin-up protection systems worked as intended
Systems investigations	Fuel system	* Inspect quality and quantity of the fuel * Inspect fuel tank selectors and valves * Inspect feed tank fuel gauges * Analysis of low-level and low-pressure indicators * Physical inspection of the components and connection in the systems	13.11	* "Fuel system problems may occur very early in some mishap sequences although under different circumstances the even would barely be an incident. This is the aspect of mishap investigations which frequently requires a complete evaluation of the fuel system to disclose problems which provoked a set of events which lead to a mishap"
Cabin inspection	Position of fatalities	* Label and photograph bodies *in situ* before movement * Collection of body fluids on site * Compare injuries of fatalities to aircraft wreckage	18.4 - 18.6	* Recovery of bodies is not carried out by accident investigators, but they should be aware of the pathology procedures, and know the practices of collecting evidence from around the bodies
Cabin inspection	Survivability factors	* Inspect the condition of the cockpit * Inspect the condition of the passenger cabin * Inspect the use of exits * Identify the positions and condition of slides or rafts used * Identify the location and condition of fitted cabin crew emergency equipment * Record locations of cabin baggage inside aircraft * Identify cargo locations * Test functionality of emergency communication systems	17.2	* Within the process of the site and aircraft examination, consideration should be given to factors which may influence the survivability of the accident.

Source of Evidence	**Evidence Type**	**Evidence Collection Method**	**Reference Section in ICAO (2008b)**	**Description**
Bird/wildlife examination	Physical presence of bird or wildlife remains	* Inspect the point of impact and surrounding evidence, plus collect remains	5.6	“Investigators should attempt to collect the following: * all feather material from aircraft * all feathers found on the ground * non-fleshy remains (beaks, talons, feathers, fur, teeth)”
Meteorological conditions	Presence of icing on site	* Investigate local weather conditions for possible presence of ground icing, in-flight icing, or engine icing.	5.4	* Physical inspection of icing on an accident site is difficult if the investigator, or an emergency responder, can not immediately record its presence at the site, so investigation of surrounding factors are necessary
Witness interviews	Interviews with eyewitnesses	* Interviews: “Statements should be taken as soon as possible after the accident; they can always be amplified later if necessary, but first statements are usually the most accurate” * Interviews with eye witnesses may have to be conducted on the site when witnesses come forward rather than be arranged for a later time	4.11	“The following information should be recorded where relevant: * Personal data regarding witness * Time of observation * Location of witness at time of observation * Anything heard or observed concerning the aircraft itself, and, if relevant, other nearby aircraft according to the stage of flight, such as: position of flaps, trim, taxiing, run-up, brakes on start, initiation of rotation, climb angle, estimated speed, estimated altitude, points overflown by the aircraft, headings, manoeuvres, position of flight controls, landing gear, falling objects, flames from exhaust, fire or smoke, light signals, anti-collision and cabin lights, landing lights, touchdown point, use of brakes, reverse thrust, any seemingly abnormal noise, phenomena or movement etc. * Position of the main and and any scattered wreckage * Position of bodies * Any sketches that the witnesses may be able to provide to illustrate his statement * Any photographs or videos taken * Rescue operations reports * If witness knows of other witnesses, their names and addresses * Signature on one copy of the statement and of any sketches made”

Appendix E

Rater Assigned Categories Per Card in Novice Investigator Perception Survey

The following list shows the hazard category or categories assigned to each card in the novice investigator perception survey.

Key:

Number	**Hazard Category**
1.	Aircraft location
2.	Fatigue
3.	Insects/wildlife
4.	Climate
5.	Security
6.	Fire and flammable substances
7.	Stored energy components
8.	Pressurised gases
9.	Military and ex-military aircraft
10.	Recent safety equipment
11.	Pyrotechnics and explosives
12.	Damaged and unstable structures
13.	General biological hazards
14.	Local state of hygiene
15.	Metals and oxides
16.	Composite materials
17.	Chemicals and other substances
18.	Radioactive materials
19.	Cargo
20.	Psychological hazards
21.	All environmental hazards (categories 1-5)
22.	All physical hazards (categories 6-12)
23.	All biological hazards (categories 13-14)
24.	All material hazards (categories 15-19)
25.	Impede gathering of evidence (rater assigned category)
26.	Not relevant to research (rater assigned category)
27.	Personal safety hazard (rater assigned category)
28.	Investigation management (rater assigned category)
29.	Working conditions (rater assigned category)
30.	More than five categories relevant (rater assigned category)

Appendix E: Hazards Identified in Novice Investigator Perception Study

Card No.	**Hazard identified (as written by survey responders)**	**Rater A (category numbers assigned)**					**Rater B (category numbers assigned)**				
1	Fuel (ignition)	6					6				
2	Safety	25					26				
3	Other toxic aircraft materials	15	16	17			15	16	17		
4	Sharp objects (glass / fuselage)	12					12				
5	Biohazards	13					13				
6	Fire	6					6				
7	Aircraft fluids (hydraulic fluid / fuel)	6					17				
8	Aviation fuel	6					6				
9	Body parts / fluids	13					13				
10	Metals / possible injury	12					15				
11	Biohazards	13					13				
12	Ash	13	16				6	15			
13	Fuel and other fluids (fire!!!)	6					6				
14	Sharp debris	12					12				
15	Dangerous goods / materials from aircraft	24					24				
16	Biohazards	13					13				
17	Contaminants	13					17				
18	Various fluids - fuel / hydraulic / extinguishants	6	7				6	17			
19	Fire	6					6				
20	Hazardous materials	30					24				
21	Hazards materials on the aircraft	8	11	13	17	19	24				
22	Sharp objects, cuts	12	13				12				
23	Post-accident fire	6					6				
24	Media	20					28				
25	Ash	15					6	15			
26	Mechanical (items dropping or falling apart)	25					12				
27	Dangerous materials (fuel, hydraulic fluid, etc.)	6					6	24			
28	Biohazards	13					13				
29	Pressure left in systems / firing squibs	11					7	8	11		
30	Mechanical (sharp edges, falling objects)	12					12				
31	Personal injury from wreckage	12	13				12				
32	Chemical hazard	17					17				
33	Fire	6					6				
34	Biological substances	13					13				
35	Radiation (radioactive materials)	18					18				
36	Sharp matters	12					12				
37	Fume	6					6				
38	Chemical substances	17					17				
39	Biological hazards	13					13				
40	Object falls in case of large aircraft	12					12				
41	Disturbance of evidence	25					28				
42	Media intrusion	20					28				
43	Hazardous substances	30					24				

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Card No.	Hazard identified (as written by survey responders)	Rater A (category numbers assigned)					Rater B (category numbers assigned)				
44	Hazardous ashes	15					15	16	17		
45	Hazards due to lubricants	6	11	17			17				
46	Fire hazards	6					6				
47	Hazardous fuels	6					6				
48	Hazardous fumes	6					15	16	17		
49	Fatigue	2					2				
50	Personal trauma (psychological)	20					20				
51	Losing objectivity	25					28				
52	Destroying evidence	25					28				
53	Fire	6					6				
54	Fumes / vapours	6					6	15	16	17	
55	Sharp objects	12					12				
56	Pressurised vessels	8					8				
57	Chemicals	17					17				
58	Fire	6					6				
59	Personal psychological trauma from witnessing post accident events	20					20				
60	Uncoordinated investigation activities	25					28				
61	Fire	6					6				
62	Blood related diseases	13					13				
63	Tripping	12					1	12			
64	Cuts from metal parts	12	13				12				
65	Mental distress	20					20				
66	Sharps	12					12				
67	Fire / explosions	6	11				22				
68	Dangerous air cargo	19					19				
69	Loose normally-contained materials eg. Hydrazine	17					17				
70	Media	20					28				
71	Fuel pooling and fire	6					6				
72	Loose debris - broken seats, loose baggage, etc.	12	13				12				
73	Sharp edges - broken airframe	12					12				
74	Blood borne pathogens	13					13				
75	Chemicals	17					17				
76	Fumes / invisible poisonous gas	6					17				
77	Fire / ash	6					6	15			
78	Terrain condition / environment	21					1	4			
79	Loose surrounding and aircraft structure	12					12				
80	Airborne particles	13	16				13	15	16	17	
81	Weather	4					4				
82	Dangerous goods if the aircraft has	19					19				
83	Fuel, hydraulic fluids, batteries on the site	6	17				6	7	17		
84	Wreckage itself	12					12				
85	Public	20					28				

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Card No.	**Hazard identified (as written by survey responders)**	**Rater A (category numbers assigned)**					**Rater B (category numbers assigned)**				
86	Biohazards	13					13				
87	Terrain and weather	1	4				1	4			
88	COSHH and material hazards	6	11	13	16	17	24				
89	Fire	6					6				
90	Myself and my team	26					28				
91	Fuel fire	6					6				
92	Terrain dangerous	5					1				
93	Explosives	11					11				
94	Biological	13					13				
95	Physical	27					22				
96	Terrain (geographical)	1					1				
97	Trauma	20					20				
98	Explosive risk (fuel / weapons?)	6	11				22				
99	Chemical hazards (bio etc.), mechanical hazards	12	13	17			12	13	17		
100	Environment of the crash site	1	3	4	5		1	3	4		
101	Biohazards	13					13				
102	Moving / lifting operations	12					29				
103	Physical injury	25					22				
104	Contamination	13					13				
105	Environment	21					21				
106	Fire	6					6				
107	Weather	4					4				
108	Inadvertent damage of evidence	25					28				
109	Unknown chemical, radioactive or biohazard cargo	13	17	18	19		19				
110	Sharp objects	12					12				
111	Fire	6					6				
112	Hazardous material on board aircraft	8	11	13	17	19	24				
113	Body fragments	13					13				
114	Materials "physical parts" and equipments	26					22	24			
115	Chemicals	17					17				
116	COSHH hazards	6	11	13	16	17	28				
117	Weather	4					4				
118	Biohazards	13					13				
119	Unintentional movement of evidence	25					28				
120	Slips / trips / falls	1	12				1	12			
121	Chemicals / toxic goods	17					17				
122	Carbon fibre	16					16				
123	Sharp objects	12					12				
124	Protecting evidence	25					28				
125	Blood borne pathogens (biohazards)	13					13				
126	Communicable disease Hepatitis B	13					13				
127	Organic (plant vegetation)	1					1				
128	Accident debris	12					12				

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Card No.	**Hazard identified (as written by survey responders)**	**Rater A (category numbers assigned)**					**Rater B (category numbers assigned)**				
129	Hazchem	17					17				
130	Animal / insect (Weils disease, bites)	3					3				
131	Fire	6					6				
132	Sharp objects (torn metal etc.)	12					12				
133	Environment (cold, rough terrain, steep climbs, rolling rocks, snow ravines)	1	4				1	4			
134	Explosive materials / systems (from cargo, from aircraft systems, pressurised containers, etc.)	7	8	11	19		30				
135	Toxic material (both from cargo and aircraft systems)	13	16	19			24				
136	Reptiles and or insects	3					3				
137	Being cut on pieces of wreckage	12	13				12				
138	Blood borne health contamination	13					13				
139	Explosions	11					11				
140	Sharp objects	12					12				
141	Sharp objects	12					12				
142	Bodies / pathogens	13					13				
143	Weather - hot / cold / wet - exposure	4					4				
144	Rough ground / damaged buildings - slips / trips / falls	1	12				1	12			
145	Chemicals	17					17				
146	Fumes / vapours from fuel	6					6	17			
147	Sharp edges	12					12				
148	Unstable parts of the wreckage	12					12				
149	Equipments under pressure or mechanically pre-charged	7	8				7	8			
150	Fire (if very early on site) / hot surfaces	6					6	15			
151	Fatalities - trauma	20					20				
152	Fuel	6					6				
153	Fire out break	6					6				
154	Radioactive radiation	18					18				
155	Explosion from pressurised containers	8					8				
156	Cuts from sharp (wreckage) objects	12	13				12				
157	Snake and other bites	3					3				
158	Blood borne pathogens	13					13				
159	Injury on the body caused by high temperature of some material	6					15				
160	Wound with a cutting part	12	13				12				
161	Injury caused by some explosions	11					11				
162	Inhale some toxic gas	6					17				
163	Ability to gain the most of any debrief, before and after going on site	25					28				
164	Exposition by radiation	18					18				
165	Immediate and subsequent personal stress	20					20				
166	Remaining focused during time on site	25					28				

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Card No.	Hazard identified (as written by survey responders)	Rater A (category numbers assigned)					Rater B (category numbers assigned)				
167	Accumulating tiredness and fatigue	2					2				
168	The smell / stench of the accident site	20					13	15	16	17	20
169	Hazardous materials	30					24				
170	Burn	6					6	17			
171	Snake or harmful animal	3					3				
172	Cut from sharp tool	12	13				29				
173	Infection	13					13				
174	Blood	13					13				
175	Influenza (fever)	27					13				
176	Cuts as a result of sharp aluminium	12					12				
177	Explosion of oxygen bottles and cylinders	8					8				
178	Infection	13					26				
179	Chemical	17					17				
180	Radiation	18					18				
181	Snake, reptiles, wild animals, etc.	3					3				
182	Fire	6					6				
183	Chemicals	17					17				
184	Self injuries	27					26				
185	Terrain	1					1				
186	Shrapnel injury	12	13				12				
187	Contact with pathogenic materials	13					13				
188	Inhalation of poisonous gases	6					17				
189	Fire, explosion	6	11				22				
190	Hazard material (including smoke)	30					24				
191	Environmental (eg. steep slope, forest, etc.)	1					1				
192	Cut by sharp edges of debris	12	13				12				
193	Inclement weather	4					4				
194	Toxic substances (gas, solid, liquid)	6	15	17			15	16	17		
195	Fire hazards	6					6				
196	Sharp objects	12					12				
197	Overhead hazards	1					1				
198	Trip hazards	1	12				1	12			
199	Slips and trips - hydraulic and other fluids	1	12	17			1	12	17		
200	Chemical hazards	17					17				
201	Flammable materials and sources of ignition	6					6				
202	Sharp objects and biohazards	12	13				12	13			
203	Rotating or reciprocating equipment	12					12				
204	Bio	13					13				
205	Toxin / chemical	17					17				
206	Sharps	12					12				
207	Environmental	21					21				
208	Impact	20					26				
209	Detonation of gas or oxygen bottles	8					8				

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Card No.	Hazard identified (as written by survey responders)	Rater A (category numbers assigned)					Rater B (category numbers assigned)				
210	Sharp objects	12					12				
211	Fire	6					6				
212	Unsafe supports	12					12				
213	Sharp objects (metal / non metals)	12					12				
214	Pyrotechnics and pressurised bottles	8	11				8	11			
215	Radioactive materials / fumes and smoke	18					6	18			
216	Bites (insects), etc. in accident site	3					3				
217	Chemical from passenger luggage or aircraft	17					17				
218	Fire	6					6				
219	Metal pieces from the aircraft	12					15				
220	Biological material and snakes	3	13				3	13			
221	Blood	13					13				
222	Hazardous materials	30					24				
223	Body fluids	13					13				
224	Sharp edges	12					12				
225	Tripping hazards	1	12				1	12			
226	Underfoot conditions	1	12				1				
227	Explosive materials / bottles	8					8				
228	Dangerous reptiles and flies	3					3				
229	Toxic gases / fumes / smoke	6					6	17			
230	Difficult terrain path clearance	1					1				
231	Biohazards	13					13				
232	Sharp debris	12					12				
233	Fuel	6					6				
234	Gas	6					8				
235	Health	27					26				
236	Dust / fibres from damaged wreckage made from man made mineral fibres	16					16				
237	Radiological (beta lights etc.)	18					18				
238	Contamination from leaking fuel, oils and greases, as well as from bio contamination from bodily fluids	6	13				6	13	17		
239	Injury whilst lifting or moving wreckage	12					12				
240	Sharp edges (sheared metal / glass)	12					12				
241	Biohazard (blood borne, tetanus etc.)	13					13				
242	Chemical spill (cargo or fluids)	17					17				
243	Fuel	6					6				
244	Electrical	7					7				
245	Explosion	11					22				
246	Chemical / dangerous goods	17	19				17	19			
247	Blood borne pathogens	13					13				
248	Sharp objects	12					12				
249	Fire	6					6				
250	Pathogens from body fluids	13					13				
251	Items under pressure (oxygen bottles, fire extinguishers, tyres)	8	11				7	8			

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Card No.	Hazard identified (as written by survey responders)	Rater A (category numbers assigned)					Rater B (category numbers assigned)				
252	Hydraulic oil and fuel (liquid and gas)	6	8	17			6	17			
253	Human remains (blood etc.)	13					13				
254	Sharp edges from wreckage	12					12				
255	Availability of wreckage (terrain, climate, etc.)	1	3	4	5		1	4			
256	Smoke	6					6				
257	Chemicals (fuel, hydraulic fluids, etc.)	6	17				6	17			
258	Sharp objects	12					12				
259	Bio-hazards	13					13				
260	Biohazards	13					13				
261	Injuries from jagged metals	12					12				
262	Possible explosions from on board materials	11					11				
263	Possibilities of falling over / hazardous materials on board the craft	12	13	17	19		1	12	24		
264	Cut by sharp edges	12	13				12				
265	Trip and fall	12					1	12			
266	Contact with radioactive materials	18					18				
267	Fire hazards	6					6				
268	Sharp metal pieces	12					12				
269	Wild life attack	3					3				
270	Fall from height	1	12				29				
271	Radioactive substance	18					18				
272	Toxic	6	13	16	17	18	26				
273	Explosion	11					11				
274	Metal pieces from the aircraft	12					15				
275	Chemical / solvents	17					17				
276	Trip hazards	12					1	12			
277	Sharp edges	12					12				
278	Depends on the accident	26					28				
279	Chemical from contamination gases	17					17				
280	Hostile environment eg. terrain	5					1	4			
281	Elements such as rain, heat, cold	4					4				
282	Unaware of the location based hazards eg. live electrical equipment	1					1				
283	Unaware of the safety rules at site and violates it	25					28				
284	Unsecured objects eg. derailed train	12					12				
285	Spilt chemical, toxic gas etc.	17					17				
286	Hurt by unexpected rescue / recovery operation	25					29				
287	MMMF - man made mineral fibres	16					16				
288	Insecure site	5					5				
289	Electrical discharge	7					7				
290	Slip / trip hazards	1	12				1	12			
291	Enemy fire (I'm military!)	5					5				
292	Biological	13					13				

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Card No.	Hazard identified (as written by survey responders)	Rater A (category numbers assigned)					Rater B (category numbers assigned)				
293	Chemical	17					17				
294	Risk of injury, wounds	13					12				
295	Nuclear contamination	18					18				
296	Emotional impressed by the accident	20					20				
297	Injury from debris - metallic	12	13				12				
298	Fire explosion from fuel and electrical short circuits	6	7				6	7			
299	Driving to the accident site	1					29				
300	Working at height / on / through the wreckage	1	12				29				
301	Falling objects / unstable wreckage	12					12				
302	Ignorance of the total environment	25					14	21			
303	Lack of adequate risk assessment	25					28				
304	Inadequate safety brief	25					28				
305	Lack of co-ordination / liaison / command / planning	25					28				
306	Failure to follow procedures / human error	25					28				
307	Chemical fumes / ingestion	17					17				
308	Explosive cartridges	11					11				
309	Fire (from fuel)	6					6				
310	Fumes (from fuel)	6					6				
311	Terrain	1					1				
312	Sharp bits	12					12				
313	Munitions (if military aircraft)	11					9	11			
314	Train movements	12					1				
315	Emergency service vehicle movements	25					29				
316	Overhead lines	1					1				
317	Lone working	25					29				
318	Slips, trips, falls	1	12				1	12			
319	Hazardous gases	8					15	16	17		
320	Fire	6					6				
321	Injury from debris	12	13				12				
322	Mineral oil	6					17				
323	Terrain	1					1				
324	Explosions	11					22				
325	Toxic substances	6	13	16			17				
326	Bio hazards	13					13				
327	Physical hazards in accident area	1	3	4	5	12	12				
328	Slip, fall etc. when getting to the place	1					1	12			
329	Working at height	25					29				
330	Electrical hazard	1					7				
331	Falling objects	12					12				
332	Insufficient illumination	25					29				
333	Confined space	1					29				
334	Blood born pathogens	13					13				

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Card No.	**Hazard identified (as written by survey responders)**	**Rater A (category numbers assigned)**					**Rater B (category numbers assigned)**				
335	Hazardous materials (cargo, materials, effects of fire)	24					24				
336	Hazardous materials from vehicle’ s damage - structure	12					12	24			
337	Terrain	1					1				
338	Stability of accident vehicle and site	12					12				
339	Sharp objects	12					12				
340	Blood / disease	13					13				
341	Glass / shrapnel	12					12				
342	Toxic waste	6	13	16	17		13				
343	Moving parts	12					12				
344	Physical (slips, trips, cuts, etc.)	1	12				1	12			
345	Chemical and fuel (contact and inhalation)	6	17				17				
346	Body fluids (contact and skin exposure)	13					13				
347	Mechanical (if machinery is to be operated)	12					29				
348	Elements (sun, wind, dehydration, etc)	4					4				
349	Physical injury	27					22				
350	Electricity	1					1				
351	Chemical	17					17				
352	Falls	1	12				1	12			
353	Press	20					28				
354	Hours of work - fatigue	2	20				2				
355	Ground conditions - uneven and cluttered	1					1				
356	Overhead power	1					1				
357	Crainage (*sic*) - lifting equipment	12					29				
358	Light conditions - night?	25					29				
359	Fire / highly volatile materials	6					6				
360	Compressed cylinders	8					7	8			
361	Sharp objects	12					12				
362	Pathogens / toxic chemicals	13	17				13	17			
363	Airborne fibres	16					15	16	17	23	
364	Sharp objects	12					12				
365	Chemicals	17					17				
366	Loose objects / unstable	12					12				
367	Overhead power lines	1					1				
368	Gas supplies or cylinders	8					8				
369	Fire	6					6				
370	Volatile / highly flammable fluids	6					6				
371	Sharp broken metal parts	12					12				
372	Very steep slopey terrain	1					1				
373	Explosives / dangerous goods on board	11	18	19			9	10	11	19	
374	Fire (spontaneous combustion)	6					6				
375	Hazardous materials (chemicals, etc.)	17					17				

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Card No.	Hazard identified (as written by survey responders)	Rater A (category numbers assigned)					Rater B (category numbers assigned)				
376	Terrain (eg steep slopes / mountains, ravines)	1					1				
377	Complacency (eg. over-confidence, carelessness of others)	25					28				
378	Environmental (hot, cold, wind, etc.)	4					4				
379	Physical - structures / wreckage / fire / smoke	12	13				6	12			
380	Psychological - mental trauma / stress	20					20				
381	Biological - disease, chemical hazards	13	17				13	17			
382	Environmental - hot and high, cold, (military - desert, jungle, arctic)	1	3	4	5		1	4			
383	Hostile action: if it's in military conflict / dangerous air cargo / weapons	5	19				5	11	19		
384	The incident aircraft, parts and debris (carbon fibres)	16					15	16	17	19	22
385	Chemical and biological + toxic agents (carbon fibres)	13	17				13	16	17		
386	Weapons, explosives, dangerous cargo	11	17	18	19		11	19			
387	Environmental (weather, terrain)	1	4				1	4			
388	Personnel (yourself, your team, responders, media)	25					28				
389	Dead / injured people lying about	13	20				13	20			
390	Local climatic conditions prevailing	4					4				
391	Infection whilst conducting investigation	13					13				
392	Getting injured whilst conducting investigation	25					29				
393	Correct immunisation and correct PPE required	27					28				
394	Fire	6					6				
395	Toxic chemical	17					17				
396	Harmful radiation	18					18				
397	Moving mechanics	12					12				
398	Terrorist	5					5				
399	Cuts from jagged wreckage / sharps	12	13				12				
400	Trip hazards - uneven surfaces, wreckage	1	12				1	12			
401	Chemical - dangerous goods / substances	17	19				17	19			
402	Disease - blood / effluent, etc.	13					13				
403	Risk of explosion or fire	6	11				22				
404	Pathogens / carcinogens	13	16				13	15	16	17	
405	Hazardous materials	30					24				
406	Waste materials	13					13				
407	Sharp objects	12					12				
408	Live electrical currents	1					1				
409	Biohazards / blood borne pathogens	13					13				
410	Fire (fuel)	6					6				
411	Sharps	12					12				
412	Burnt carbon fibre	16					16				

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Card No.	Hazard identified (as written by survey responders)	Rater A (category numbers assigned)					Rater B (category numbers assigned)				
413	Trip hazards	12					1	12			
414	Sharp wreckage	12					12				
415	Unsteady ground / surfaces	1					1				
416	Chemicals and other substances exposure	17					17				
417	Inhalation of fibres	16					15	16			
418	Dehydration and illness from exposure to weather	4					4				
419	To act when I see the scene	20					28				
420	Fires / fumes (chemicals)	6					6	17			
421	Fit for the job (physically)	2					28				
422	Torn up parts can hurt you	12					12				
423	The scene can be not easy to be in, not easy to reach	1					1	3	4	5	
424	Sharp edges - cut	12	13				12				
425	Uneven walking surface - trip	1					1				
426	Loose wreckage falling onto rescuers / investigators	12					12				
427	Environmental - electric wires, other vehicles, weather	1	4				1	4	29		
428	Contaminants - chemicals, fuel, waste containers, body decay	9	13	17			6	13	17		
429	HAZMAT	17					24				
430	Explosives (I'm with the air force)	11					9	11			
431	Sharp objects and wreckage	12					12				
432	Terrain	1					1				
433	Bio hazards (blood borne pathogens)	13					13				
434	Inhalation of particles or gas	6	16				15	16	17		
435	Explosion	11					22				
436	Sharp object	12					12				
437	Falling down object (trees, avalanche, wreckage)	1					1	12			
438	Contact with dangerous goods (hydraulic oil, liquid, blood)	13	17				13	17	19		
439	Possible explosion / flammables	11					22				
440	Fuel ignition	6					6				
441	Toxic gas	6					17				
442	Free fall of damaged spares	12					12				
443	Sharp edges	12					12				
444	Wreckage / debris	12					12				
445	Effluent	13					13				
446	Dangerous goods	11	19				19				
447	Smoke / fire / environment	1	3	4	6	12	1	3	4	6	15
448	Body parts	13					13				
449	Contamination	13					13				
450	Sharp edges	12					12				
451	Explosions - fuel - fire hazards	6	11				22				

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Card No.	Hazard identified (as written by survey responders)	Rater A (category numbers assigned)					Rater B (category numbers assigned)				
452	Falling objects (non stable objects), moving objects	12					12				
453	Weather (snow, rain)	4					4				
454	Biological factors	13					13				
455	Chemical / radioactive agents	17	18				17	18			
456	Debris	12					12				
457	Natural environment	1	4				1	3	4		
458	Other on scene people activities	25					28				
459	The wreckage	12					12				
460	Biological	13					13				
461	Biochemical	13					13				
462	Fluids (fuel / hydraulic / oil …)	6					6	17			
463	The media! My self!	20					28				
464	Inhalation hazard - including toxic fumes from combustion, released chemical vapours, composite fibre dust	16	17				15	16	17		
465	Blood borne pathogens, hepatitis (long term), HIV (shorter term)	13					13				
466	Fires and explosions (heat, concussion effects from over pressure effects, projectiles)	6	8	11			22				
467	Crash generated debris	12					12				
468	Natural environmental hazards - terrain, weather, wildlife, etc.	1	3	4			1	4			
469	Unexploded ordnance	11					9	11			
470	Unstable equipment - i. topple hazard	12					12				
471	Uneven ground - often in the middle of nowhere	1					1				
472	Sharp objects	12					12				
473	Hazardous substances	30					19				
474	Dangerous goods	19					19				
475	Exploding things	11					6	15	17		
476	Fire / smoke / gases	6					13				
477	Human "fluids" - hepatitis A - Z, HIV	13					13				
478	Weather / nature	3	4				1	3	4		
479	Toxic air / carbons	6	16				15	16	17		
480	Fire / explosion (eg. rescue equipment)	6	12				6	9	10	11	
481	Sharp edges	12					12				
482	Biological hazards (eg. HIV)	13					13				
483	Psychological trauma	20					20				
484	Injuries from damage parts etc.	12	13				12				
485	Toxic material and gas	6	16				24				
486	Biological material	13					13				
487	Stress	20					20				
488	Fatigue	2					2				
489	Man made mineral fibres / composite material	16					16				

Appendix E: Hazards Identified in Novice Investigator Perception Study

Card No.	Hazard identified (as written by survey responders)	Rater A (category numbers assigned)					Rater B (category numbers assigned)				
490	Fluids - fuel / oil / hydraulic	6					6	17			
491	Gases - pressure / poisonous	6	8				8	17			
492	Slips / trips	1	12				1	12			
493	Sharp edges / impact hazards	12					12				
494	Fire and wreckage	5	12				22				
495	Chemical and fuel	6	17				6	17			
496	Biological	13					13				
497	Sabotage	25					5				
498	Environment - terrain, weather, confined space	1	4				1	4			
499	Unexploded munitions	11					9	11			
500	On board explosives / rocket propellants	10	11				9	10	11		
501	Liquid oxygen leaks	8					8				
502	Poisonous substances from AIM-9 seeker head (Indium Antimonide)	17					9	18			
503	Carbon fibre ingestion	16					16				
504	Terrain hazard	1	3	4	5		1				
505	Fire hazard	6					6				
506	Chemical hazards	17					17				
507	Biological hazards (blood / fluids)	13					13				
508	Composite material hazard	16					16				
509	Parts pressure loaded	11					7	8			
510	Blood borne	13					13				
511	Terrain, environment	21					1	3	4		
512	Sharp and jagged objects	12					12				
513	Aircraft parts (tyres, hydraulic, etc.)	7					7				
514	Airborne pathogens / vapours	13					15	16	17	23	
515	Unknown substances COSHH	30					17				
516	Blood pathogens	13					13				
517	Manual handling / wreckage	12					12				
518	Sharps' cuts PPE	12					12				
519	Survivors / general public / security services	20					28				
520	Blood borne pathogens	13					13				
521	Sharp hazards (metals)	12					12				
522	Composites	16					16				
523	Pressure vessels	8					8				
524	Family, next of kin	20					20				
525	Terrain	1					1				
526	Weather	4					4				
527	Radioactive materials	18					18				
528	Explosive materials	11					11				
529	Oxygen bottles	8					8				
530	Hydraulic pressure	7					7	8			
531	MMMF - dusts / fibres / puncture risks	16					16				
532	Products of combustion	15					6	15			

Appendix E: Hazards Identified in Novice Investigator Perception Study

Card No.	Hazard identified (as written by survey responders)	Rater A (category numbers assigned)					Rater B (category numbers assigned)				
533	Human remains - pathogens, etc.	13					13				
534	Physical risk through stability of wreckage	12					12				
535	Site risks	1	12				1	3	4	5	
536	Blood borne pathogens / disease	13					13				
537	MMF / materials	16					16				
538	Psychological effects	20					20				
539	Vehicle movements, etc.	12					29				
540	Environmental hazards	21					21				
541	Poisonous smoke	6					6	17			
542	Explosives	11					11				
543	Fire and heat	6					6				
544	Corrosives	12					17				
545	Environment / landscape	21					1	3	4		
546	Wreckage	12					12				
547	Weather	4					4				
548	Co-ordination and communication between site attendees	25					28				
549	Fluids, fuel, hydraulic, cargo	6	17	19			6	17	19		
550	Terrain	1					1				
551	Fire / combustibles / fuel	6					6				
552	Weather conditions	4					4				
553	Local conditions / awareness	5	14				5	14			
554	Unknown cargo	19					19				
555	Bio (Hep A, B, C)	13					13				
556	Materials (fluids, carbons, etc.)	6	16				15	16	17		
557	Weather	4					4				
558	Physical (terrain)	1					1				
559	Stress (pressure)	2	20				20				
560	Blood borne pathogens	13					13				
561	Skin breaks (cuts, grazes)	13					12				
562	Fire or re-ignition	6					6				
563	Unknown hazards (what are we dealing with?)	27					28				
564	Site terrain	1					1				
565	Dangerous goods	19					19				
566	Pyrotechnics	11					11				
567	Bloods	13					13				
568	Debris / wreckage	12					12				
569	Site location / mountain / swamp	1					1				
570	Blood borne pathogens	13					13				
571	Chemical hazards	17					17				
572	Fire	6					6				
573	Fire risk / fuel	6					6				
574	Toxic aircraft fluids / hydraulics	6					17				

Appendix E: Hazards Identified in Novice Investigator Perception Study

Card No.	**Hazard identified (as written by survey responders)**	**Rater A (category numbers assigned)**					**Rater B (category numbers assigned)**				
575	Airborne pathogens / burnt synthetics / fuel smoke	6	13	16			6	13	15	16	17
576	Bio hazards / passenger remains - HIV …	13					13				
577	Terrain and weather (site location) (site environment)	1	3	4	5		1	4			
578	Chemicals	17					17				
579	Disease	13					13				
580	Dangerous goods and cargo	13	18	19			19				
581	Fire	6					6				
582	Radio active materials	18					18				
583	Disease from bodily fluid	13					13				
584	Chemicals	17					17				
585	Dangerous goods - cargo	19					19				
586	Fire from kerosene	6					6				
587	Hazards arising from parts used in construction of aircraft ie. gas canisters for slides, etc.	11					11				
588	Environmental (hot / cold)	4					1	4			
589	Psychological (loss of life)	20					20				
590	Physical (sharp edges)	12					12				
591	Blood borne pathogens	13					13				
592	Fatigue (long hours / many time zones away)	2					2				
593	Slip / trip / fall	1	12				1	12			
594	Chemical	17					17				
595	Pathogen / blood based	13					13				
596	Burn	6					6	17			
597	Psychological	20					20				
598	Environment	21					21				
599	Smoke / fibres / radioactive	6	16	18			6	15	16	17	18
600	HAZ MAT	17					24				
601	Blood borne	13					13				
602	Smoke, fumes, resin	6					6	15	16	17	
603	Fibres (micro fibre)	16					16				
604	Local weather conditions and terrain	1	4				1	4			

Appendix F

Novice Investigator Perception Survey: Cards Per Category with Complete Rater Agreement

1. Aircraft Location		
	Card Number	**Name of Hazard**
1	87	Terrain and weather
2	96	Terrain (geographical)
3	100	Environment of the crash site
4	120	Slips / trips / falls
5	127	Organic (plant vegetation)
6	133	Environment (cold, rough terrain, steep climbs, rolling rocks, snow ravines)
7	144	Rough ground / damaged buildings - slips / trips / falls
8	185	Terrain
9	191	Environmental (eg. steep slope, forest, etc.)
10	197	Overhead hazards
11	198	Trip hazards
12	199	Slips and trips - hydraulic and other fluids
13	225	Tripping hazards
14	226	Underfoot conditions
15	230	Difficult terrain path clearance
16	255	Availability of wreckage (terrain, climate, etc.)
17	282	Unaware of the location based hazards eg. live electrical equipment
18	290	Slip / trip hazards
19	311	Terrain
20	316	Overhead lines
21	318	Slips, trips, falls
22	323	Terrain
23	328	Slip, fall etc. when getting to the place

1. Aircraft Location		
	Card Number	**Name of Hazard**
24	337	Terrain
25	344	Physical slips, trips, cuts, etc.)
26	350	Electricity
27	352	Falls
28	355	Ground conditions - uneven and cluttered
29	356	Overhead power
30	367	Overhead power lines
31	372	Very steep slopey terrain
32	376	Terrain (eg. steep slopes / mountains, ravines)
33	382	Environmental - hot and high, cold, (military - desert, jungle, arctic)
34	387	Environmental (weather, terrain)
35	400	Trip hazards - uneven surfaces, wreckage
36	408	Live electrical currents
37	415	Unsteady ground / surfaces
38	423	The scene can be not easy to be in, not easy to reach
39	425	Uneven walking surface - trip
40	427	Environmental - electric wires, other vehicles, weather
41	432	Terrain
42	437	Falling down object (trees, avalanche, wreckage)
43	447	Smoke / fire / environment
44	457	Natural environment
45	468	Natural environmental hazards - terrain, weather, wildlife, etc.
46	471	Uneven ground - often in the middle of nowhere
47	492	Slips / trips
48	498	Environment - terrain, weather, confined space
49	504	Terrain hazard
50	525	Terrain
51	535	Site risks

1. Aircraft Location		
	Card Number	**Name of Hazard**
52	550	Terrain
53	558	Physical (terrain)
54	564	Site terrain
55	569	Site location / mountain / swamp
56	577	Terrain and weather (site location) (site environment)
57	593	Slip / trip / fall
58	604	Local weather conditions and terrain

2. Fatigue		
	Card Number	**Name of Hazard**
1	49	Fatigue
2	167	Accumulating tiredness and fatigue
3	354	Hours of work - fatigue
4	488	Fatigue
5	592	Fatigue (long hours / many time zones away)

3. Insects/Wildlife

	Card Number	Name of Hazard
1	100	Environment of the crash site
2	130	Animal / insect (Weils disease, bites)
3	136	Reptiles and or insects
4	157	Snake and other bites
5	171	Snake or harmful animal
6	181	Snake, reptiles, wild animals, etc.
7	216	Bites (insects), etc. in accident site
8	220	Biological material and snakes
9	228	Dangerous reptiles and flies
10	269	Wild life attack
11	447	Smoke / fire / environment
12	478	Weather / nature

4. Climate

	Card Number	Name of Hazard
1	81	Weather
2	87	Terrain and weather
3	100	Environment of the crash site
4	107	Weather
5	117	Weather
6	133	Environment (cold, rough terrain, steep climbs, rolling rocks, snow ravines)
7	143	Weather - hot / cold / wet - exposure
8	193	Inclement weather
9	255	Availability of wreckage (terrain, climate, etc)
10	281	Elements such as rain, heat, cold
11	348	Elements (sun, wind, dehydration, etc.)
12	378	Environmental (hot, cold, wind, etc.)
13	382	Environmental - hot and high, cold, (military - desert, jungle, arctic)
14	387	Environmental (weather, terrain)
15	390	Local climatic conditions prevailing
16	418	Dehydration and illness from exposure to weather
17	427	Environmental - electric wires, other vehicles, weather
18	447	Smoke / fire / environment
19	453	Weather (snow, rain)
20	457	Natural environment
21	468	Natural environmental hazards - terrain, weather, wildlife, etc.
22	478	Weather / nature
23	498	Environment - terrain, weather, confined space
24	526	Weather
25	547	Weather
26	552	Weather conditions
27	557	Weather

4. Climate		
	Card Number	**Name of Hazard**
28	577	Terrain and weather (site location) (site environment)
29	588	Environmental (hot / cold)
30	604	Local weather conditions and terrain

5. Security		
	Card Number	**Name of Hazard**
1	288	Insecure site
2	291	Enemy fire (I’m military!)
3	383	Hostile action: if it’s in military conflict / dangerous air cargo / weapons
4	398	Terrorist
5	553	Local conditions / awareness

6. Fire and Flammable Substances		
	Card Number	**Name of Hazard**
1	1	Fuel (ignition)
2	6	Fire
3	8	Aviation fuel
4	13	Fuel and other fluids (fire!!!)
5	18	Various fluids - fuel / hydraulic / extinguishants
6	19	Fire
7	23	Post-accident fire
8	27	Dangerous materials (fuel, hydraulic fluid, etc.)
9	33	Fire
10	37	Fume
11	46	Fire hazards
12	47	Hazardous fuels
13	53	Fire
14	54	Fumes / vapours
15	58	Fire
16	61	Fire
17	71	Fuel pooling and fire
18	77	Fire / ash
19	83	Fuel, hydraulic fluids, batteries on the site
20	89	Fire
21	91	Fuel fire
22	106	Fire
23	111	Fire
24	131	Fire
25	146	Fumes / vapours from fuel
26	150	Fire (if very early on site) / hot surfaces
27	152	Fuel

6. Fire and Flammable Substances

	Card Number	Name of Hazard
28	153	Fire out break
29	170	Burn
30	182	Fire
31	195	Fire hazards
32	201	Flammable materials and sources of ignition
33	211	Fire
34	218	Fire
35	229	Toxic gases / fumes / smoke
36	233	Fuel
37	238	Contamination from leaking fuel, oils and greases, as well as from bio contami
38	243	Fuel
39	249	Fire
40	252	Hydraulic oil and fuel (liquid and gas)
41	256	Smoke
42	257	Chemicals (fuel, hydraulic fluids, etc.)
43	267	Fire hazards
44	298	Fire explosion from fuel and electrical short circuits
45	309	Fire (from fuel)
46	310	Fumes (from fuel)
47	320	Fire
48	359	Fire / highly volatile materials
49	369	Fire
50	370	Volatile / highly flammable fluids
51	374	Fire (spontaneous combustion)
52	394	Fire
53	410	Fire (fuel)
54	420	Fires / fumes (chemicals)
55	440	Fuel ignition

6. Fire and Flammable Substances

	Card Number	**Name of Hazard**
56	447	Smoke / fire / environment
57	462	Fluids (fuel / hydraulic / oil ...)
58	476	Fire / smoke / gases
59	480	Fire / explosion (eg. rescue equipment
60	490	Fluids - fuel / oil / hydraulic
61	495	Chemical and fuel
62	505	Fire hazard
63	541	Poisonous smoke
64	543	Fire and heat
65	549	Fluids, fuel, hydraulic, cargo
66	551	Fire / combustibles / fuel
67	562	Fire or re-ignition
68	572	Fire
69	573	Fire risk / fuel
70	575	Airborne pathogens / burnt synthetics / fuel smoke
71	581	Fire
72	586	Fire from kerosene
73	596	Burn
74	599	Smoke / fibres / radioactive
75	602	Smoke, fumes, resin

7. Stored Energy Components

	Card Number	Name of Hazard
1	149	Equipment under pressure or mechanically pre-charged
2	244	Electrical
3	289	Electrical discharge
4	298	Fires explosion from fuel and electrical short circuits
5	513	Aircraft parts (tyres, hydraulics, etc.)
6	530	Hydraulic pressure

8. Pressurised gases

	Card Number	Name of Hazard
1	56	Pressurised vessels
2	149	Equipment under pressure or mechanically pre-charged
3	155	Explosion from pressurised containers
4	177	Explosion of oxygen bottles and cylinders
5	209	Detonation of gas or oxygen bottles
6	214	Pyrotechnics and pressurised bottles
7	227	Explosive materials / bottles
8	251	Items under pressure (oxygen bottles, fire extinguishers, tyres)
9	360	Compressed cylinders
10	368	Gas supplies or cylinders
11	491	Gases - pressure / poisonous
12	501	Liquid oxygen leaks
13	523	Pressure vessels
14	529	Oxygen bottles

9. Military and Ex-Military Aircraft - No agreement between raters

10. Recent Safety Equipment		
	Card Number	**Name of Hazard**
1	500	On board explosives / rocket propellants

11. Pyrotechnics and Explosives		
	Card Number	**Name of Hazard**
1	29	Pressure left in systems / firing squibs
2	93	Explosives
3	139	Explosions
4	161	Injury caused by some explosions
5	214	Pyrotechnics and pressurised bottles
6	262	Possible explosions from on board materials
7	308	Explosive cartridges
8	313	Munitions (if military aircraft)
9	373	Explosives / dangerous goods on board
10	386	Weapons, explosives, dangerous cargo
11	430	Explosives (I'm with the air force)
12	469	Unexploded ordnance
13	475	Exploding things
14	499	Unexploded munitions
15	500	On board explosives / rocket propellants
16	528	Explosive materials
17	542	Explosives
18	566	Pyrotechnics
19	587	Hazards arising from parts used in construction of aircraft ie. gas canisters for slides, etc.

12. Damaged and Unstable Structures

	Card Number	**Name of Hazard**
1	4	Sharp objects (glass / fuselage)
2	14	Sharp debris
3	22	Sharp objects cuts
4	30	Mechanical (sharp edges, falling objects)
5	31	Personal injury from wreckage
6	36	Sharp matters
7	40	Object falls in case of large aircraft
8	55	Sharp objects
9	63	Tripping
10	64	Cuts from metal parts
11	66	Sharps
12	72	Loose debris - broken seats, loose baggage, etc.
13	73	Sharp edges - broken airframe
14	79	Loose surrounding and aircraft structure
15	84	Wreckage itself
16	99	Chemical hazards (bio etc.), mechanical hazards
17	110	Sharp objects
18	123	Sharp objects
19	128	Accident debris
20	132	Sharp objects (torn metal, etc.)
21	140	Sharp objects
22	141	Sharp objects
23	147	Sharp edges
24	148	Unstable parts of the wreckage
25	156	Cuts from sharp (wreckage) objects
26	160	Wound with a cutting part
27	176	Cuts as a result of sharp aluminium
28	186	Shrapnel injury

12. Damaged and Unstable Structures		
	Card Number	**Name of Hazard**
29	192	Cut by sharp edges of debris
30	196	Sharp objects
31	198	Trip hazards
32	199	Slips and trips - hydraulic and other fluids
33	202	Sharp objects and biohazards
34	203	Rotating or reciprocating equipment
35	206	Sharps
36	210	Sharp objects
37	212	Unsafe supports
38	213	Sharp objects (metal / non metals)
39	224	Sharp edges
40	225	Tripping hazards
41	232	Sharp debris
42	239	Injury whilst lifting or moving wreckage
43	240	Sharp edges (sheared metal / glass)
44	248	Sharp objects
45	254	Sharp edges from wreckage
46	258	Sharp objects
47	261	Biohazards
48	263	Possibilities of falling over / hazardous materials on board the craft
49	264	Cut by sharp edges
50	265	Trip and fall
51	268	Sharp metal pieces
52	276	Trip hazards
53	277	Sharp edges
54	284	Unsecured objects eg. derailed train
55	290	Slip / trip hazards
56	297	Injury from debris - metallic

12. Damaged and Unstable Structures		
	Card Number	**Name of Hazard**
57	301	Falling objects / unstable wreckage
58	312	Sharp bits
59	318	Slips, trips, falls
60	321	Injury from debris
61	327	Physical hazards in accident area
62	331	Falling objects
63	336	Hazardous materials from vehicle’s damage - structure
64	338	Stability of accident vehicle and site
65	339	Sharp objects
66	341	Glass / shrapnel
67	343	Moving parts
68	344	Physical (slips, trips, cuts, etc.)
69	352	Falls
70	361	Sharp objects
71	364	Sharp objects
72	366	Loose objects / unstable
73	371	Sharp broken metal parts
74	379	Physical - structures / wreckage / fire / smoke
75	397	Moving mechanics
76	399	Cuts from jagged wreckage / sharps
77	400	Trip hazards - uneven surfaces, wreckage
78	407	Sharp objects
79	411	Sharps
80	413	Trip hazards
81	414	Sharp wreckage
82	422	Torn up parts can hurt you
83	424	Sharp edges - cut
84	426	Loose wreckage falling onto rescuers / investigators

12. Damaged and Unstable Structures

	Card Number	Name of Hazard
85	431	Sharp objects and wreckage
86	436	Sharp object
87	442	Free fall of damaged spares
88	443	Sharp edges
89	444	Wreckage / debris
90	450	Sharp edges
91	452	Falling objects (non stable objects), moving objects
92	456	Debris
93	459	The wreckage
94	467	Crash generated debris
95	470	Unstable equipment - ie. topple hazard
96	472	Sharp objects
97	481	Sharp edges
98	484	Injuries from damage parts, etc.
99	492	Slips / trips
100	493	Sharp edges / impact hazards
101	512	Sharp and jagged objects
102	517	Manual handling / wreckage
103	518	Sharps’ cuts PPE
104	521	Sharp hazards (metals)
105	534	Physical risk through stability of wreckage
106	546	Wreckage
107	568	Debris / wreckage
108	590	Physical (sharp edges)
109	593	Slip / trip / fall

13. General Biological Hazards

	Card Number	Name of Hazard
1	5	Biohazards
2	9	Body parts / fluid
3	11	Biohazards
4	16	Biohazards
5	28	Biohazards
6	34	Biological substances
7	39	Biological hazards
8	62	Blood related diseases
9	74	Blood borne pathogens
10	80	Airborne particles
11	86	Biohazards
12	94	Biological
13	99	Chemical hazards (bio etc.), mechanical hazards
14	101	Biohazards
15	104	Contamination
16	113	Body fragments
17	118	Biohazards
18	125	Blood borne pathogens (biohazards)
19	126	Communicable disease Hepatitis B
20	138	Blood borne health contamination
21	142	Bodies / pathogens
22	158	Blood borne pathogens
23	173	Infection
24	174	Blood
25	187	Contact with pathogenic materials
26	202	Sharp objects and biohazards
27	204	Bio
28	220	Biological material and snakes

13. General Biological Hazards		
	Card Number	**Name of Hazard**
29	221	Blood
30	223	Body fluids
31	231	Biohazards
32	238	Contamination from leaking fuel, oils and greases, as well as from bio contamination from bodily fluids
33	241	Biohazard (blood borne, tetanus, etc.)
34	247	Blood borne pathogens
35	250	Pathogens from body fluid
36	253	Human remains (blood, etc.)
37	259	Biohazards
38	260	Biohazards
39	292	Biological
40	326	Biohazards
41	334	Blood borne pathogens
42	340	Blood / disease
43	342	Toxic waste
44	346	Body fluids (contact and skin exposure)
45	362	Pathogens / toxic chemicals
46	381	Biological - disease, chemical hazards
47	385	Chemical and biological + toxic agents (carbon fibres)
48	389	Dead / injured people lying about
49	391	Infection whilst conducting investigation
50	402	Disease - blood / effluent, etc.
51	404	Pathogens / carcinogens
52	406	Waste materials
53	409	Biohazards / blood borne pathogens
54	428	Contaminants - chemicals, fuel, waste containers, body decay
55	433	Biohazards (blood borne pathogens

13. General Biological Hazards		
	Card Number	**Name of Hazard**
56	438	Contact with dangerous goods (hydraulic oil, liquid, blood)
57	445	Effluent
58	448	Body parts
59	449	Contamination
60	454	Biological factors
61	460	Biological
62	461	Biochemical
63	465	Blood borne pathogens, hepatitis (long term), HIV (shorter term)
64	477	Human “fluids” - hepatite A - Z, HIV
65	482	Biological hazards (eg. HIV)
66	486	Biological material
67	496	Biological
68	507	Biological hazards (blood / fluids)
69	510	Blood borne
70	516	Blood pathogens
71	520	Blood borne pathogens
72	533	Human remains - pathogens, etc.
73	536	Blood borne pathogens / disease
74	555	Bio (Hep. A, B, C)
75	560	Blood borne pathogens
76	567	Bloods
77	570	Blood borne pathogens
78	575	Airborne pathogens / burnt synthetics / fuel smoke
79	576	Biohazards / passenger remains - HIV ...
80	579	Disease
81	583	Disease from bodily fluid
82	591	Blood borne pathogens
83	595	Pathogen / blood based

13. General Biological Hazards		
	Card Number	**Name of Hazard**
84	601	Blood borne

14. Local State of Hygiene		
	Card Number	**Name of Hazard**
1	553	Local conditions / awareness

15. Metals and Oxides		
	Card Number	**Name of Hazard**
1	3	Other toxic aircraft materials
2	25	Ash
3	44	Hazardous ashes
4	194	Toxic substances (gas, solid, liquid)
5	532	Products of combustion

16. Composite Materials		
	Card Number	**Name of Hazards**
1	3	Other toxic aircraft materials
2	80	Airborne particles
3	122	Carbon fibre
4	236	Dust / fibres from damaged wreckage made from man made mineral fibres
5	287	MMMF - man made mineral fibres
6	363	Airborne fibres
7	384	The incident aircraft, parts and debris (carbon fibres)
8	404	Pathogens / carcinogens
9	412	Burnt carbon fibre
10	417	Inhalation of fibres
11	434	Inhalation of particles or gas
12	464	Inhalation hazard - including toxic fumes from combustion, released chemical vapours, composite fibre dust
13	479	Toxic air / carbons
14	489	Man made mineral fibres / composite material
15	503	Carbon fibre ingestion
16	508	Composite material hazard
17	522	Composites
18	531	MMMF - dusts / fibres / puncture risks
19	537	MMF / materials
20	556	Materials (fluids, carbons, etc.)
21	575	Airborne pathogens / burnt synthetics / fuel smoke
22	599	Smoke / fibres / radioactive
23	603	Fibres (micro fibre)

17. Chemicals and Other Substances

	Card Number	Name on Card
1	3	Other toxic aircraft material
2	32	Chemical hazard
3	38	Chemical substances
4	45	Hazards due to lubricants
5	57	Chemicals
6	69	Loose normally-contained materials eg. Hydrazine
7	75	Chemicals
8	83	Fuel, hydraulic fluids, batteries on the site
9	99	Chemical hazards (bio etc.), mechanical hazards
10	115	Chemicals
11	121	Chemicals / toxic goods
12	129	Hazchem
13	145	Chemicals
14	179	Chemical
15	183	Chemicals
16	199	Slips and trips - hydraulic and other fluids
17	205	Toxin / chemical
18	217	Chemical from passenger luggage or aircraft
19	242	Chemical spill (cargo or fluids)
20	246	Chemical / dangerous goods
21	252	Hydraulic oil and fuel (liquid and gas)
22	257	Chemicals (fuel, hydraulic fluids, etc)
23	275	Chemicals / solvents
24	279	Chemical from contamination gases
25	285	Spilt chemical, toxic gas, etc.
26	293	Chemical

17. Chemicals and Other Substances		
	Card Number	**Name on Card**
27	307	Chemical fumes / ingestion
28	345	Chemical and fuel (contact and inhalation)
29	351	Chemical
30	362	Pathogens / toxic chemicals
31	365	Chemicals
32	375	Hazardous materials (chemicals, etc.)
33	381	Biological - disease, chemical hazards
34	385	Chemical and biological + toxic agents (carbon fibres)
35	395	Toxic chemical
36	401	Chemical - dangerous goods / substances
37	416	Chemicals and other substances exposure
38	428	Contaminants - chemicals, fuel, waste containers, body decay
39	438	Contact with dangerous goods (hydraulic oil, liquid, blood)
40	455	Chemical / radioactive agents
41	464	Inhalation hazard - including toxic fumes from combustion, released chemical vapours, composite fibre dust
42	495	Chemical and fuel
43	506	Chemical hazards
44	549	Fluids, fuel, hydraulic, cargo
45	571	Chemical hazards
46	578	Chemicals
47	584	Chemicals
48	594	Chemical

18. Radioactive Materials		
	Card Number	**Name of Hazard**
1	35	Radiation (radioactive materials)
2	154	Radioactive radiation
3	164	Exposition by radiation
4	180	Radiation
5	215	Radioactive materials / fumes and smoke
6	237	Radiological (beta lights, etc.)
7	266	Contact with radioactive materials
8	271	Radioactive substance
9	295	Nuclear contamination
10	396	Harmful radiation
11	455	Chemical / radioactive agents
12	527	Radioactive materials
13	582	Radio active materials

19. Cargo		
	Card Number	**Name of Hazard**
1	68	Dangerous air cargo
2	82	Dangerous goods if the aircraft has
3	109	Unknown chemical, radioactive or biohazard cargo
4	246	Chemical / dangerous goods
5	263	Possibilities of falling over / hazardous materials on board the craft
6	383	Hostile action: if it’s in military conflict / dangerous air cargo / weapons
7	386	Weapons, explosives, dangerous cargo
8	401	Chemical - dangerous goods / substances
9	446	Dangerous goods
10	474	Dangerous goods
11	549	Fluids, fuel, hydraulic, cargo
12	554	Unknown cargo
13	565	Dangerous goods
14	580	Dangerous goods and cargo
15	585	Dangerous goods - cargo

20. Psychological Hazards		
	Card Number	**Name of Hazard**
1	50	Personal trauma (psychological)
2	59	Personal psychological trauma from witnessing post accident events
3	65	Mental distress
4	97	Trauma
5	151	Fatalities - trauma
6	165	Immediate and subsequent personal stress
7	168	The smell / stench of the accident site
8	296	Emotional impressed by the accident
9	380	Psychological - mental trauma / stress
10	389	Dead / injured people lying about
11	483	Psychological trauma
12	487	Stress
13	524	Family, next of kin
14	538	Psychological effects
15	559	Stress (pressure)
16	589	Psychological (loss of life)
17	597	Psychological

21. Environmental Hazards		
	Card Number	**Name of Hazard**
1	105	Environmental
2	207	Environmental
3	540	Environmental hazards
4	598	Environmental

22. Physical Hazards - No agreement between raters

23. Biological Hazards - No agreement between raters

24. Material Hazards

	Card Number	**Name of Hazard**
1	15	Dangerous goods / materials from aircraft
2	335	Hazardous materials (cargo, materials, effects of fire)

Appendix G

Hazards Identified On Sites by Experienced Aircraft Accident Investigators

Hazards Identified by Engineering Investigators

Hazard	Count
None	46
Airside / hangar operations / noise from other aircraft	25
Fuel	16
Slope of earth / steep terrain / difficult access due to slope	7
Biohazards / body parts / Human tissue / Human remains / Body fluids / Blood / Biohazard in toilet / Biological contamination / Bloodborne pathogens	36
Damaged composites / carbon fibre / glass reinforced plastic / carbon fibre shards	6
Burnt composites / burnt carbon fibre /	5
Wet and slippery ground / icy ground / slippery seaweed on ground	6
Unstable wreckage	2
Medical kit left remaining by ambulance services (may contain sharps)	4
Trip hazards	3
Hazards working on a ship / offshore	3
Working with cranes / lifting equipment	2
Sharp wreckage / debris / sharps / sharp metal	13
Oil	2
Dry powder extinguishant	2
Battery	2
Working on high platforms	3
Broken perspex	1
Field surface / uneven terrain	3
Lifting heavy wreckage	3
Cold weather / freezing windchill	5
Asbestos	1
Working in and around unstable buildings	3

Hazards Identified by Engineering Investigators

Hazard	Count
Marsh / waterlogged or swampy ground / mud	4
Hazardous cargo	1
Hydraulic fluid / Skydrol	2
Powering up aircraft	1
Hay fever	1
Dehydration	1
Access to the aircraft	1
Operation of flying controls	1
Mosquitos / Insects / Horse flies	3
Working at night	2
Wet weather	1
Livestock (both dead and alive)	1
Composite dust / Carbon fibre dust	3
Radioactive dust	1
Wreckage in trees	2
Gorse bushes	1
Broken branches and trees	3
Chemical weed killer	1
Snow - “white out”	1
Hot weather	2
Cow pats	1
Ammunition	1
Personal safety / locals throwing stones	2
Pressurised cylinders	2
Fire residue / dust from charred wreckage	3
High voltage power supply	1
Flares	1
Poor access control	1

Hazards Identified by Engineering Investigators

Hazard	Count
Fatigue	1
Cabin environment	1
Live cartridges in ejection seat / armed escape system / cartridge starter system	3
Protecting the safety of third parties on the site	1
Driving conditions to site	2
Fire extinguisher	1

Hazards Identified by Operations Investigators	
Hazard	**Count**
None	114
Mountain / steep terrain	5
Slippery / wet / muddy ground	6
Biological hazards / pathogens	27
Aircraft debris / sharp metal / wreckage / sharps	12
Access to site	4
Rain / Snow	3
Cold weather	4
Fuel	8
Wooded areas / falling loose wood	2
Airside hazards	5
Ship hazards	2
Products of composite combustion	5
Damaged buildings	1
Uneven terrain	1
Composites / carbon fibre / fibreglass	8
Fire extinguisher powder	1
Asbestos	1
Dangerous goods	1
Hot weather	1
Toxic hazards	1
Trip hazards	1
Working at night	4
Hydraulic fluid	2
Horse flies	1
Damaged FLIR	1
Driving	1
Fatigue	1

Hazards Identified by Operations Investigators

Hazard	Count
Lack of food / water supply	1
Weedkiller	1
Exploding nosewheel	1
Stress from conducting interviews	1
Manure	1
Ejector seat and canopy	1

Hazards Identified by HS&E Responders	
Hazard	**Count**
None	1
Debris / Sharps / general wreckage	5
Blood / pathogens / tissue	10
Fire damaged or burnt materials	4
Wet, slippery ground	1
Lifting wreckage	1
Working in and around an unsafe building	1
Fuel	2
Damaged trees	1
Unstable wreckage	1
Terrain surface	1
Chemicals	1
Weather	2
Animal slurry	1
Battery	1

Hazards Identified by FDM Investigators	
Hazard	**Count**
None	29
Carrying kit	2
Power to systems	1
Fatigue	2
Sun exposure	1
Decontamination	1
Falling branches	1
Driving	1
Ship operations	1

Appendix H

Recommended PPE for Investigators During Site Investigation

Recommended PPE for Investigators During Site Investigation

ICAO Circular 315 (2008a)	Lewis and Burrell (2004)	NTSB (2002a)
Half-face respirator complete with spare set of broad range chemical/dust cartridges (the set should be effective for organic vapour, acid gas and P100). If space permits, a full-face piece respirator complete with spare set of cartridges should be included.	Appropriate severe weather clothing including sturdy boots	Summer and winter weight uniforms (BDU)
Several disposable dust/mist HEPA/P3 masks	Heavy gloves	Winter weight jacket with hood
Two or more disposable coveralls	Latex Gloves	Rain suit
Several pairs of disposable nitrile gloves	Sun protection	Work boots with steel toes and shanks
Several pairs of disposable heavy duty gloves	Insect repellent	Boots suitable for mountainous terrain
One pair of Kevlar cut-resistant gloves with lined palm and fingers	Small first aid kit	Head cover (baseball cap, winter hat or protective helmet)
Protective footwear with sole and toe protection	Signalling device	Sunglasses
Hard hat	Ear protection	Personal Protective Equipment (PPE)
Eye protection: either safety glasses or safety goggles	Food and water	Tyvek coveralls
Hearing protection: either ear muffs or ear plugs		Goggles
Hand and equipment wipes		Leather gloves
High visibility vest		Latex examination gloves
Chemical or duct tape		Boot covers
		Particulate mask