EUROPEAN ORGANISATION
FOR THE SAFETY OF AIR NAVIGATION

EUROCONTROL

ESARR ADVISORY MATERIAL/GUIDANCE DOCUMENT
(EAM/GUI)

EAM 2 / GUI 8

GUIDELINES ON THE SYSTEMIC OCCURRENCE ANALYSIS METHODOLOGY (SOAM)

Edition	:	1.0
Edition Date	:	17 November 2005
Status	:	Released Issue
Distribution	:	General Public
Category	:	ESARR Advisory Material

SAFETY REGULATION COMMISSION

F.2 DOCUMENT CHARACTERISTICS

TITLE			
EAM 2 / GUI 8 **Guidelines on the Systematic Occurrence Analysis Methodology (SOAM)**			
Document Identifier		**Reference**	EAM 2 / GUI 8
eam2gui8_e10_ri_web		**Edition Number**	1.0
		Edition Date	17-11-2005

Abstract :

These guidelines describe the application of the Systemic Occurrence Analysis Methodology (SOAM) to the investigation of Air Traffic Management (ATM) safety occurrences.

The Safety Occurrence Analysis Methodology (SOAM) developed for EUROCONTROL is one of a number of accident investigation methodologies based on the Reason Model of organisational accidents

Full implementation of the methodology is expected to improve the degree to which the key safety objectives of ESARR 2 are met.

Keywords

ESARR 2	Safety Occurrence	Safety Analysis
Reporting Systems	Severity	Taxonomy
Safety Data Exchange	Risk	Accident
Incident	AST	

Contact Person(s)	Tel	Unit
Charlie GOVAARTS	+32 2 729 31 22	DGOF/SRU

DOCUMENT INFORMATION					
Status		**Distribution**		**Category**	
Working Draft	☐	General Public	☑	Safety Regulatory Requirement	☐
Draft Issue	☐	Restricted EUROCONTROL	☐	Requirement Application Document	☐
Proposed Issue	☐	Restricted SRC	☐	ESARR Advisory Material	☑
Released Issue	☑	Restricted SRC Commissioners	☐	SRC Policy Document	☐
		Restricted SPG	☐	SRC Document	☐
		Restricted SRU	☐	Comment / Response Document	

COPIES OF SRC DELIVERABLES CAN BE OBTAINED FROM

Safety Regulation Unit	Tel: +32 2 729 51 38
EUROCONTROL	Fax: +32 2 729 47 87
Rue de la Fusée, 96	E-mail: sru@eurocontrol.int
B-1130 Bruxelles	Website: www.eurocontrol.int/src

F.3 DOCUMENT APPROVAL

The following table identifies all management authorities who have approved this document.

AUTHORITY	NAME AND SIGNATURE	DATE
Quality Control (SRU)	***signed by Daniel Hartin*** (Daniel HARTIN)	17.11.2005
Head Safety Regulation Unit (SRU)	***signed by Peter Stastny*** (Peter STASTNY)	17.11.2005
Chairman Safety Regulation Commission (SRC)	***signed by Ron Elder*** (Ron ELDER)	17.11.2005

(Space Left Intentionally Blank)

F.4 DOCUMENT CHANGE RECORD

The following table records the complete history of this document.

EDITION NUMBER	EDITION DATE	REASON FOR CHANGE	PAGES AFFECTED
0.01	02-Sep-04	Creation.	All
0.02	10-Nov-04	Document contents completely replaced to focus on providing guidance on the application of SOAM rather than on existing EUROCONTROL best practices.	All
0.03	17-Dec-04	Emphasis of the Rationale, Executive Summary and Background of the project. Update following the AST-FP7 AST-FP meeting feed-back (October 2005).	Section 1 re-drafted
0.04	07-Mar-05	Internal EUROCONTROL review.	All
0.05	29-May-05	Quality control before circulation for formal consultation to AST-FP group.	All
0.06	30-Jun-05	Updates received following internal review meeting.	Section 4
0.07	07-Jul-05	Quality check following AST-FP formal consultation (RFC No.0512).	Section 4
0.1	19-Jul-05	Document sent to SRC for formal consultation.	All
1.0	17-Nov-05	Document released following formal SRC approval.	-

(Space Left Intentionally Blank)

F.5 CONTENTS

Section **Title** **Page**

FOREWORD

CONTENTS

(Space Left Intentionally Blank)

F.6 EXECUTIVE SUMMARY

This document has been prepared to act as a guide for the application of the Systemic Occurrence Analysis Methodology (SOAM) to the investigation of Air Traffic Management (ATM) safety occurrences in support of ESARR 2 implementation.

The Systemic Occurrence Analysis Methodology is a comprehensive process for analysing data collected as part of a safety occurrence investigation, and for generating logical findings and recommendations. The methodology has been designed in accordance with EUROCONTROL specifications, and to integrate with other phases of investigation, as outlined in the *"Guidelines for Investigation of Safety Occurrences in ATM"* (EATMP, 2003). SOAM is one of a number of accident investigation methodologies based on the Reason Model of organisational accidents. Full implementation of the methodology is expected to improve the degree to which the key safety objectives of ESARR 2 are met.

The purpose of a systemic occurrence analysis methodology is to broaden the focus of an investigation from human involvement[1] to include analysis of the latent conditions deeper within the organisation that set the context for the event. Such an approach is consistent with the tenets of Just Culture[2] in which people are encouraged to provide full and open information about how incidents occurred, and are not penalised for errors.

It should also be noted that a truly systemic approach is not simply a means of transferring responsibility for a safety occurrence from front-line employees to senior managers. A consistent philosophy must be applied, where the investigation process seeks to correct deficiencies wherever they may be found, without attempting to apportion blame.

(Space Left Intentionally Blank)

[1] Also known as "active failures" of operational personnel under the original Reason model

[2] For further detail on Just Culture, see: EUROCONTROL. (2004). *EAM2/GUI6: Establishment of "Just Culture" Principles in ATM Safety Data Reporting (Edition 0.1 25 November 2004).* Brussels: Author.

1. INTRODUCTION

The objective of this guidance document is to provide State ATM Safety Regulators and other parties (such as Air Navigation Service Provider [ANSP] safety experts, safety investigation agency and airline safety personnel, etc.) with a Systemic Occurrence Analysis Methodology that will complement the existing range of EUROCONTROL Safety Regulatory Requirement 2 (ESARR 2) supporting materials and packages.

1.1 Rationale

The Systemic Occurrence Analysis Methodology (SOAM) has been developed to support a common approach to the reporting and assessment of ATM safety occurrences as required under ESARR 2. Full implementation of the methodology is expected to improve the degree to which the key safety objectives of ESARR 2 are achieved, i.e.

- A systemic investigation will identify the extent of the ATM system[3] contribution to the cause of all types of safety occurrences, and generate a full complement of corrective measures to address latent organisational deficiencies.
- The findings of a systemic analysis methodology represent key risk areas where appropriate action is required to make safety improvements to the ATM system.
- Safety performance and related trends over time can be better assessed if the fundamental methodology for analysing occurrences is a structured and consistent process.
- The methodology can be applied not only to actual events, but also to generic types of occurrence or hypothetical events. This enables potential enhancements to the ATM system to be identified, even where no safety occurrence has actually taken place.

SOAM will support the objectives of High Level European Action Group for ATM Safety (AGAS) Priority Area 2, Incident Reporting and Data Sharing, by:

- Providing an investigation methodology that can be applied locally by a large number of trained users, across a wide variety of occurrences. Occurrence data collection would then be a dispersed rather than centralised and specialised activity, increasing the potential quantity of data analysed;
- Establishing a dedicated investigation terminology, providing a common language for trained users that facilitates data exchange and understanding;
- Supporting Just Culture principles, which are closely aligned with the philosophy underlying the investigation technique. A comprehensive training program to roll-out the new process would incorporate awareness and education on the benefits of a Just Culture and of open reporting;

[3] From the SOAM perspective the ATM system is understood to be the combination of physical components, procedures and human resources organized to perform the Air Traffic Management function.

- Providing standardised principles for ANSPs, investigators and airspace users on generating valid, effective remedial actions once contributing factors are identified; and
- Providing additional structure and focus to the common taxonomy for reporting and investigating ATM safety occurrences.

Most importantly, SOAM will support one of the most critical [*Harmonisation]* [4] objectives, by providing a common methodology for the identification of causal factors across the aviation industry. This has the potential to enhance *Data Sharing and Lesson Dissemination* by:

- Providing a simple framework (based on principles drawn from the now widely-disseminated and recognised Reason Model) for sharing safety information, covering in particular the contributing factors and remedial actions;
- Standardising the way safety improvement actions are generated; and
- Making it simpler to summarise the outcome of real investigated occurrences for publication, for example in issues of Safety News.

Implementation of the methodology will support AGAS Priority Area 7, Awareness of Safety Matters, by requiring widespread training for ANSPs, which will result in increased safety-related competence amongst both safety experts and operational personnel. The training program envisioned would not only include the core skills involved in occurrence analysis, but link this to the safety management framework and safety culture. The proposed analysis methodology will be integrally linked for example, to a Just Culture, to reporting procedures and practices, and to communication and feedback policies. Embedding these related topics within training in use of the investigation process will have a direct impact on increasing awareness of safety issues.

SOAM will support the AGAS Priority Area 8, Safety Research and Development objective on the conduct of research on learning from occurrence reports and other safety-related events. A systemic investigation methodology such as SOAM will support research by clearly identifying the contributing factors and failed barriers in an occurrence, or sample of occurrences, that need to be corrected. The fact that the basic investigation process is a systematic and standardised one means that contributing factors can be reliably combined and analysed over large samples of incidents investigated over different time periods and locations, by different investigators trained in the technique.

The SOAM technique can also be applied to hypothetical or generic events to provide a systemic analysis of the factors commonly identified in each type of event. The analysis results in a lucid summary of the latent conditions commonly underlying each event, from which generic corrective actions can be developed.

[4] EUROCONTROL. *Strategic Safety Action Plan Work Breakdown Structure.* Requirement 2.15. Brussels: Author. (This document advocates that safety information, notably on cause, lessons learnt and remedial actions shall be shared).

1.2 Overview of SOAM

The Systemic Occurrence Analysis Methodology is a comprehensive process for analysing data collected as part of a safety occurrence investigation, and for generating logical and thorough findings and recommendations. The methodology has been designed to be consistent with EUROCONTROL specifications, and to integrate with other phases of investigation, as outlined in the *"Guidelines for Investigation of Safety Occurrences in ATM"* (EATMP, 2003).[5]

In order to ensure that the SOAM process integrates effectively with existing ESARR 2 philosophy, tools and materials, this manual includes sections on:

- The investigation philosophy, in particular the importance of the analysis process and terminology being consistent with the principles of Just Culture (Section 2);
- Assessing the need for an investigation (Section 3); and
- Factual data gathering (Section 4).

An overview of the investigation process is then provided (Section 5), including background on the Reason Model and explanation of how SOAM fits within the investigation process.

The *Systemic Occurrence Analysis Methodology* is then described in detail within Section 6.

Section 7 explains how findings and recommendations are developed under SOAM.

The document then concludes with References, a Glossary, and three appendices.

(Space Left Intentionally Blank)

[5] EATMP. (2003). *Guidelines for the Investigation of Safety Occurrences in ATM.* (Edition 1.0, 03 March 03). Brussels: EUROCONTROL.

2. INVESTIGATION PHILOSOPHY

2.1 Purpose of Investigations

The principles of this systemic occurrence analysis methodology are founded on an investigation philosophy adapted from ICAO Annex 13, as follows:

"The fundamental objective of the investigation of an occurrence shall be the prevention of accidents or incidents. It is not the purpose of this activity to apportion blame or liability"[6]

2.2 Potential to Learn from Every Safety Occurrence

Safety occurrences are by definition events in which there was a deviation from the desired system state, resulting in loss or damage to equipment or personnel, or increased potential for such outcomes. Every occurrence thus provides an opportunity to study how the deviation occurred, and to identify ways of preventing it from happening again.

It is proposed in principle that the goal of improved system safety will be served by conducting some level of evaluation or investigation into all occurrences. This principle depends on the availability of a simple, systemic analysis methodology that can be applied reliably to all levels of occurrence. While highly competent investigators will always be required for complex, high level investigations, SOAM is suitable for use with all levels of occurrence, and is particularly suitable for use on lower level occurrences by investigators with relatively little training and experience.

2.3 "Just Culture" Investigation Principles

A key objective of the Just Culture perspective[7] is to provide fair treatment for people who have committed "normal" human errors ("honest" slips, lapses, mistakes), and apply sanctions only where actions were intentional violations or in some sense reckless or negligent. This philosophy was designed to counter the very strong natural inclination to blame individuals for errors that contributed to an accident or an incident.

The way in which accidents or incidents are investigated and reported can create an impression of blame, or searching for those "at fault", even when the stated objective includes not apportioning blame. An investigation that does not seek to identify the contextual conditions that influenced human involvement, or deeper systemic factors, will inevitably highlight human error as "the cause".

(Space Left Intentionally Blank)

6 International Civil Aviation Organization. (2001). *Annex 13 to the Convention on International Civil Aviation: Aircraft accident and incident investigation, Ninth edition*, July 2001. Montreal: Author.

7 EUROCONTROL. (2004). *EAM2/GUI6: Establishment of "Just Culture" Principles in ATM Safety Data Reporting* (Edition 0.1 25 November 2004). Brussels: Author.

A systemic occurrence analysis methodology should support the tenets of Just Culture in two ways. First it should clearly broaden the focus of an investigation from the 'active failures' of operational personnel to the *latent conditions* originating from deeper within the organisation that set the context for the event.[8] Second, when referring to the involvement of human operators, it should employ language which as far as possible avoids an imputation of blame. Even terms such as “unsafe acts” as used in Professor James Reason's original modelling of organisational accidents (Reason, 1990, 1991)[9], might be deemed to imply that there was something knowingly unsafe about the person’s action or inaction, when clearly this is not the case in the majority of events.

It should also be noted that a truly systemic approach is not simply a means of transferring responsibility for a safety occurrence from front-line employees to senior managers. A consistent philosophy must be applied, where the investigation process seeks to correct deficiencies wherever they may be found, without attempting to apportion blame. The responsibility for identifying unacceptable or irresponsible behaviour (e.g., wilful rule breaking, negligence) lies outside the bounds of the safety investigation process.

2.4 An Investigation Philosophy

Every safety occurrence is at least subtly different. Every investigation is therefore a discrete process that if conducted properly will identify a unique combination of contributory factors. The investigation should be approached and completed with this philosophy in mind. Neither the process for gathering data, nor the analysis of observations to determine causation should be controlled or bound by findings from prior occurrences.

It is important to distinguish between the actual analysis of an occurrence, and the process of reporting the event, or storing data relating to it. Analysis is a stand-alone, structured problem-solving activity, occurring progressively to develop a picture about what happened. Ideally it is a group activity, concluding in a comprehensive, agreed analysis.

Storing the findings of an occurrence for reporting purposes, trend analysis or other research should occur independently of the analysis phase. There is a danger that *understanding* of the event currently under investigation will be compromised if any part of the analysis involves reference to a database of “factors” found relevant to a body of previous investigations. This type of checklist-driven process, for example selecting items from software lists, may force the analyst to select items that are not totally appropriate to the present investigation, and promotes a reductionist model of accident investigation.

---

[8] Latent Condition: A term popularised by Professor James Reason (1987, 1990, 1991) referring to a workplace condition which usually originates from a decision or action, taken or not taken (by designers, manufacturers, managers, etc.), at a time and place remote from the accident site. This condition usually lies dormant within a system for considerable time, until activated by the actions of operational personnel.

[9] Reason, J. (1990). *Human error.* New York: Cambridge University Press.

Reason, J. (1991). Identifying the latent causes of aircraft accidents before and after the event. *Proceedings of the 22nd ISASI Annual Air Safety Seminar, Canberra, Australia.* Sterling, VA: ISASI.

3. ASSESSING THE LEVEL OF INVESTIGATION

Two decisions are required following a safety occurrence: (1) Should there be a formal investigation?, and if so, (2) What level of investigation should be conducted? Other than events where an investigation is clearly required (see ESARR 2, Appendix A),[10] the decision about the level of investigation conducted typically involves a balance between the competing goals of probable safety payoffs and judicious use of finite investigation resources. It is proposed that a local, limited scale investigation is often worthwhile, provided:

- A simple, systemic analysis methodology is available, appropriate for use in relatively minor safety occurrences; and
- Local personnel are adequately trained in the investigation roles and methods necessary to support the use of such a methodology.

The following model is designed to assist in an initial *a priori* assessment about the level of investigation to be conducted. This framework provides a quick, intuitive basis for this decision. It is not intended to conflict or compete with the comprehensive quantitative method outlined in EAM 2/GUI 5 for assessing severity and risk of recurrence during or after investigation of the occurrence. [11]

The level of investigation chosen for a safety occurrence should be determined by the severity of the occurrence. Aircraft accidents are clearly defined under ICAO Annex 13 [12] and should always be investigated.

ESARR 2 Guidance Document EAM2/GUI1 outlines a severity classification scheme for occurrences according to the severity of their effect on the safe operations of aircraft and occupants.[13] After accidents, the severity levels in this scheme are:

A Serious Incident – "An incident involving circumstances indicating that an accident nearly occurred" (ICAO Annex 13);

B Major Incident – An incident associated with the operation of an aircraft, in which safety of aircraft may have been compromised, having led to a near collision between aircraft, with ground or obstacles;

C Significant Incident – An incident involving circumstances indicating that an accident, a serious or major incident could have occurred, if the risk had not been managed within safety margins, or if another aircraft had been in the vicinity;

E No (immediate) safety effect – An incident which has no (immediate) safety significance; and

D Not determined – insufficient information available to determine the risk involved.

[10] EUROCONTROL. (2000). *ESARR 2: Reporting and Assessment of Safety Occurrences in ATM. (Edition 2.0, 03.11.2000).* Brussels: Author.

[11] EUROCONTROL. (2003). *EAM2/GUI5: Harmonisation of Safety Occurrence Severity and Risk Assessment. (Edition 0.1, 05 June 2003).* Brussels: Author.

[12] International Civil Aviation Organization. (2001). *Annex 13 to the Convention on International Civil Aviation: Aircraft accident and incident investigation, Ninth edition, July 2001.* Montreal: Author.

[13] EUROCONTROL. (1999). *EAM2/GUI1: ESARR 2 Guidance to ATM Safety Regulators, Severity Classification Scheme for Safety Occurrences in ATM (Edition 1.0, 12-11-1999).* Brussels: Author.

Assessment of risk is determined from the matrix below and is based on:

- The **severity** of potential or actual consequences in the event (No (immediate) safety effect; Significant incident, Major incident; or Serious incident) [14], and
- The **probability** of the event recurring (Very Frequent, Frequent, Occasional, Rare or Extremely Rare).

Combining these factors produces one of five risk levels: *Extreme, High, Moderate, Low* or *Minimal*, as depicted in Table 3.1 below:

Table 3.1
Risk Matrix for Safety Occurrences

		ASSESSED RISK LEVELS				
SEVERITY	***A Serious incident***	Extreme	Extreme	High	Moderate	Moderate
	B Major incident	Extreme	High	Moderate	Moderate	Low
	C Significant incident	High	Moderate	Moderate	Low	Minimal
	E No (immediate) safety effect	Moderate	Moderate	Low	Minimal	Minimal
		Very Frequent	***Frequent***	***Occasional***	***Rare***	***Extremely Rare***
		PROBABILITY				

The assessed risk level assists with determining whether an investigation should be conducted, as shown in Table 3.2 below.

Table 3.2
Investigation Requirements for
Assessed Risk Level of Safety Occurrences

Assessed Risk Level	**Investigation Requirement**
Extreme	Required
High	Required
Moderate	Highly Desirable
Low	Optional
Minimal	Not required (in most cases)

It is either required or highly desirable to use SOAM to investigate all accidents and most occurrences rated in the top three severity levels outlined above (*Serious incident, Major incident; Significant incident*). Use of SOAM for safety occurrences of a lesser severity is optional and should be dependent upon a cost/benefit analysis of the potential safety payoff versus the resources necessary to conduct the investigation.

[14] The ESARR 2 severity classification of 'Not determined' is excluded from the Risk Matrix as by definition insufficient information is available to determine the level of risk involved. It is recommended that if this is the case further information is gathered in order to determine whether an investigation is required.

4. FACTUAL DATA GATHERING

4.1 The SHEL Model

In any investigation, sufficient factual data needs to be collected to ensure that a thorough systemic analysis can be conducted.

There is no definitive or prescribed method guiding how investigation data should be gathered. What evidence is sought and what questions are asked of witnesses is, and should be, substantially determined by an appropriately trained and experienced investigation team. It is useful however to gather data within some form of broad descriptive framework, to help with the initial sorting of facts. The SHEL Model (Edwards, 1972)[15] provides such a descriptive framework. This model is already widely referred to in ATM, for example in regard to integration of human factors principles (Airservices Australia, 1996[16]; EATMP, 1999[17]) as well as in the ICAO ADREP 2000 taxonomy.

An adaptation of the SHEL Model is depicted in Figure 4.1 below.

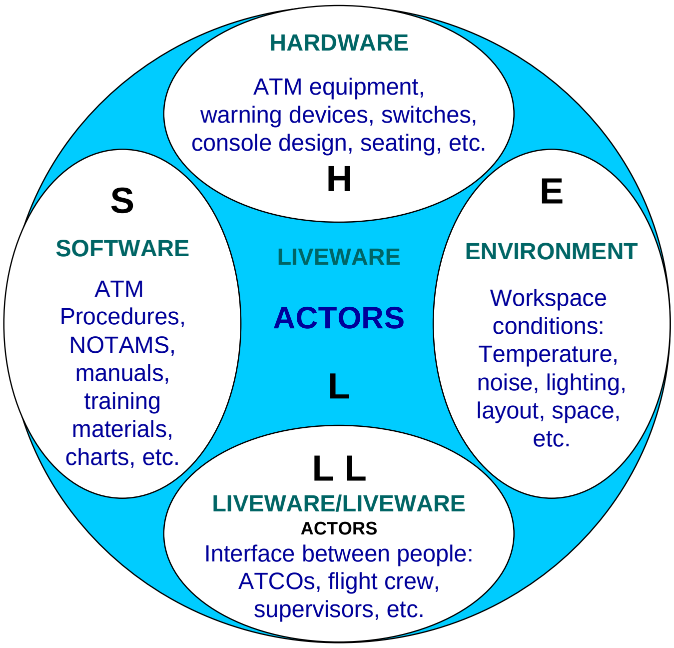


Figure 4.1
The SHEL Model

---

15 Edwards, E. (1972). Man and machine: Systems for safety. In *Proceedings of British Airline Pilots Association Technical Symposium* (pp. 21-36). London: BALPA.

16 Airservices Australia. (1996). *Air Traffic Services Human Factors Guide.* Canberra: Safety and Quality Management Branch, Airservices Australia.

17 EATMP Human Resources Team. (1999). *Human Factors Module – A Business case for Human Factors Investment. (HUM.ET1.ST13.4000-REP-02).* Brussels: EUROCONTROL.

The four components of the original SHEL model are:

- Liveware – the human element (personnel)
- Software – procedures, manuals, symbology, etc.
- Hardware – equipment, workplace layout, etc.
- Environment – weather, terrain or other factors that affect human operators

Importantly, the SHEL Model draws attention not to these different components in isolation, but to the interface between the human elements and the other factors. For example, the L-L interaction would include aspects of communication, cooperation and support; the L-H interaction represents Human/Machine Interface (HMI) issues.

Applying the SHEL Model to safety occurrence investigation suggests that data should be gathered across these four areas. Information gathered should focus on the interaction between the people involved and each element of the SHEL model. Examples of the types of data to be collected under each dimension are shown in Tables 4.1, 4.2, 4.3 and 4.4 below.

Table 4.1
Data Gathering on Liveware[18]

PHYSICAL FACTORS	• Physical characteristics (e.g., height, weight, age) • Sensory limitations (e.g., peripheral vision, hearing)
PHYSIOLOGICAL FACTORS	• Fatigue (e.g., short term, long term, task induced) • Lifestyle, Health, Nutrition, Stress
PSYCHOLOGICAL FACTORS	• Attention (e.g., distraction, boredom, channelised, inattention, monotony) • Information processing (e.g., perception, forgetting, decision making) • Experience/recency (e.g., in position, traffic loads) • Motivation/attitude
PSYCHOSOCIAL FACTORS	• Lifestyle changes (e.g., change in family circumstances)
PERSON-PERSON INTERFACE	• Oral communications o Misinterpretation o Phraseology o Content/rate of speech o Language problems o Readback/hearback • Team interactions o Supervision o Relationships o Morale, make-up (e.g., many inexperienced) • Management o Relations with o Resource allocation o Organisational change o Career path • Labour relations

18 Some items within this table are adapted from Airservices Australia Air Traffic Services Human Factors Guide (Airservices Australia, 1996).

Table 4.2
Data Gathering on Software

PERSON-SYSTEM INTERFACE **(SOFTWARE)**	• What were the nature of the procedures used by people involved in the occurrence, for example in regard to: o Availability o Suitability o Supervisory requirements of procedures or work instructions o Quality/clarity of documentation • What other written materials were relevant to people involved in the occurrence? e.g., maps, charts, checklists, rules, regulations

Table 4.3
Data Gathering on Hardware

HUMAN-MACHINE INTERFACE **(HARDWARE)**	• What were the features of the equipment provided to users in the work place, for example: o Serviceability o Functionality o Usability o Familiarity o Availability o Design, e.g., display quality: colours, illumination, discernability of returns, signal strength, mode confusion, etc. o Reliability, e.g., transmission/reception quality o Interaction with equipment, e.g., affect on workload, skill maintenance, etc. Of, for example: • Navigational aids • Flight information display • Communications equipment • Intercom • Warning devices, e.g., alarms/alerts • Workspace layout

Table 4.4
Data Gathering on Environment

PERSON-ENVIRONMENT INTERFACE	Which features of the environment impacted on the performance of the people involved? For example: • Heat/cold/humidity • Illumination • Spaciousness • Layout • Noise from equipment/people

The SHEL Model can be adapted to incorporate a fifth element, recognising the influence of wider organisational factors on the basic human factors elements. This is entirely consistent with a systemic investigation approach, and with the Reason Model. Data should also be collected on this fifth element, covering the broad areas in which organisational decisions and actions impact on people in the workplace. Examples of organisational topics for data gathering are shown in Table 4.5.

Table 4.5
Data Gathering on Organisation

ORGANISATION	• Training
	  o Design
	  o Delivery
	  o Standardisation
	  o Evaluation
	• Workforce management
	  o Rostering
	  o Staffing levels
	  o Tasking and workload
	• Risk Management
	  o Hazard identification
	  o Risk assessments
	  o Control measures
	  o Effectiveness
	• Organisational and safety culture
	  o Safety management systems
	  o Reporting processes
	  o Response to occurrences
	• Accountability
	  o Management commitment to safety
	  o Responsibility for safety
	• Communication
	  o Information dissemination
	  o Standardised processes
	  o Feedback

While the data gathering and analysis phases in an investigation are typically depicted as distinct, in reality they are part of a recursive process. After an initial data collection phase, a preliminary analysis can be conducted, which will identify gaps that can be filled by further data gathering. This process will continue until the systemic analysis has eliminated unanswered questions and reached a logical conclusion.

4.2 Using SOFIA to Support Factual Data Gathering

The SOFIA methodology incorporated in the Toolkit for ATM Occurrence Investigation (TOKAI) to assist in the assessment and reporting of safety occurrences under ESARR 2, supports the gathering of factual information in an investigation. As such, the data gathering and initial data sorting phase of an investigation, as recommended under SOAM, can be facilitated using the SOFIA methodology.

There are however some underlying differences between the philosophy of SOAM and the present structure of SOFIA[19], such that the steps involved in SOAM do not translate directly into SOFIA. For example, SOFIA integrates the processes of event reconstruction, causal analysis and preparation of recommendations, and ultimately depicts these on a single chart. Under SOAM, these steps are distinct, with the key outputs being the final analysis chart, and a separate list of recommendations.

Work is in progress to modify the existing SOFIA implementation in TOKAI to fully allow the integration of the SOAM steps. Figure 4.2 below illustrates how the existing implementation of SOFIA methodology in TOKAI can help users to design a SOAM chart. The only difference in SOFIA is that the orientation of the layers of contributing factors is displayed horizontally instead of vertically.

---

19 EATMP (2002). *SOFIA Reference Manual. (Edition 1.0, 22 October 2002).* Brussels: EUROCONTROL

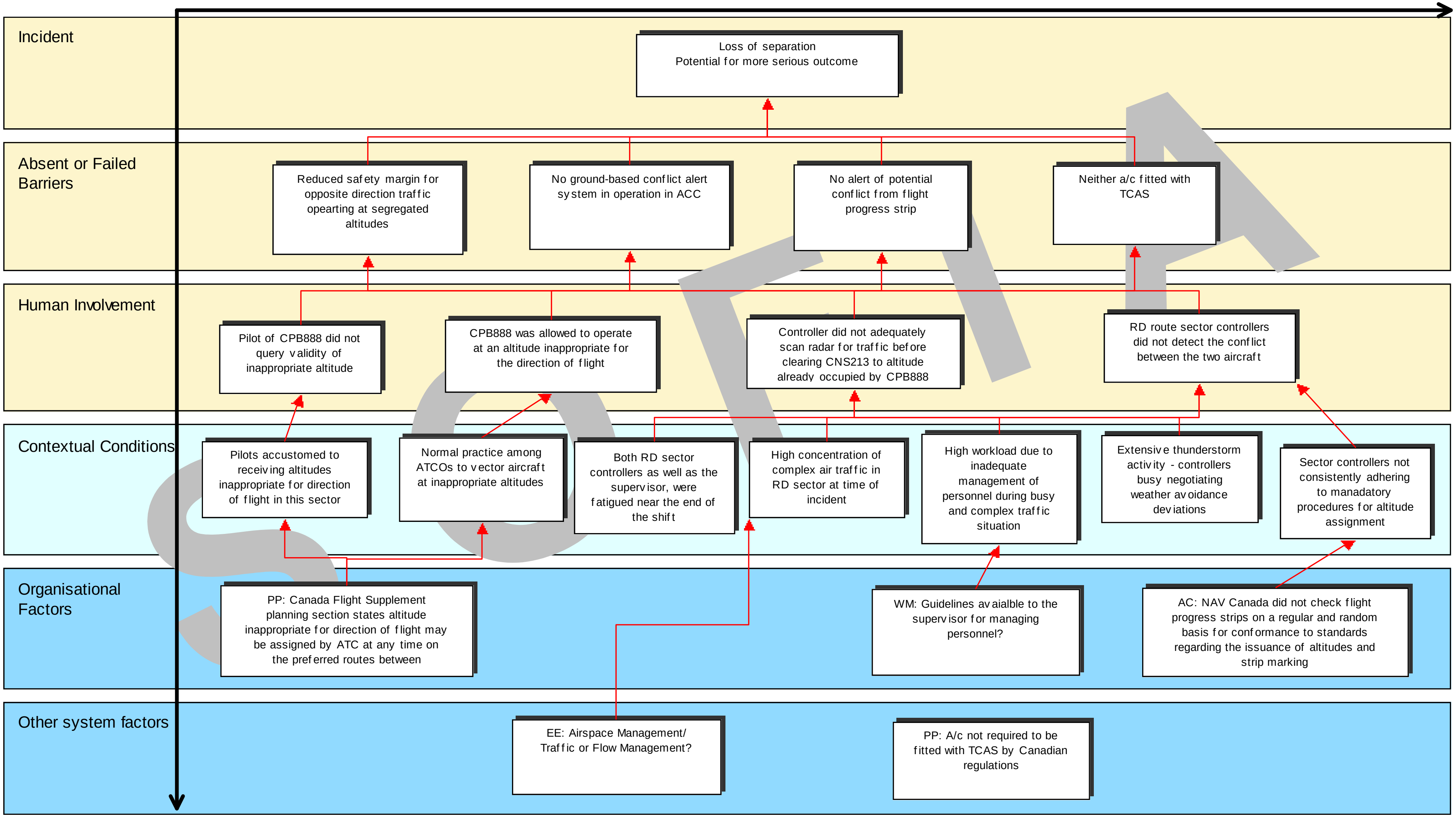


Figure 4.2
SOAM chart representation using SOFIA tool

5. THE INVESTIGATION PROCESS

5.1 Background – The Reason Model

The Systemic Occurrence Analysis Methodology (SOAM) developed for EUROCONTROL is one of a number of accident investigation methodologies based on principles of the well-known "Reason Model" of organisational accidents (Reason, 1990, 1991). This section describes Reason's original model. Adaptations to the model incorporated into SOAM are described in the following section.

As described by Reason, organisational accidents can be characterised by the following elements:

- Deficiencies in the routine processes being carried out by an organisation, as part of its normal operation. These include the *fallible decisions* of senior managers, and *line management deficiencies*;
- A set of task and environmental conditions, that exist in a unique combination on the day of the event, and operate as *psychological precursors* to unsafe acts;
- The *unsafe acts* - errors and violations - committed by individuals or groups of people; and
- *Inadequate defences*, that fail to intervene as intended to protect the system from potential harm once the unsafe act has been committed.

A representation of Reason's original model is depicted in Figure 5.1 below.

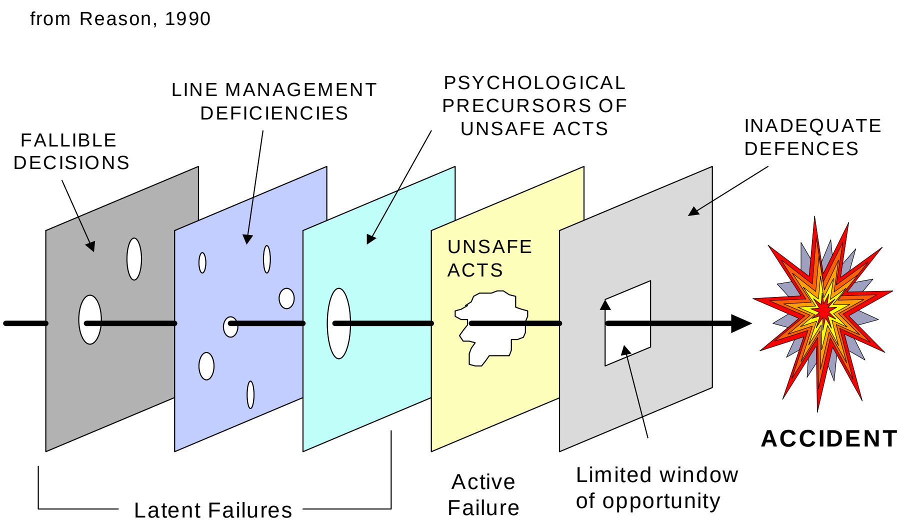


Figure 5.1
Depiction of Reason's Original Model

Reason describes a dynamic relationship between these elements ("the stochastic, organisational and combinatorial nature of aircraft accidents"): Organisational deficiencies allow or create error- or violation-producing conditions, unsafe acts combine with local triggering events, the defences are inadequate, and an accident results.

The Reason Model is commonly referred to as the "Swiss Cheese" model, due to the numerous holes in each layer of the model which represent the deficiencies that allow an occurrence to develop.

According to Reason, this model can be applied reactively by accident investigators, to identify the elements involved in an accident or incident. It can also be used proactively, for example by safety managers, to identify safety deficiencies within an organisation.

5.2 Place of SOAM in the Investigation Process

The **main focus of SOAM is on two key phases** of the investigation process:

- Analysis of factors contributing to the occurrence, and
- Development of recommendations.

These activities are distinct from, but follow logically from:

- Factual information gathering, and
- Graphical reconstruction of the event sequence (e.g., using SOFIA).

In using SOAM, the preparation of a final chart of contributing factors and the development of recommendations are activities which are best conducted "manually" by the investigator(s), rather than with the aid of a software or database tool. However, the output of findings and recommendations produced using SOAM is suitable for subsequent uploading into a tool like SOFIA. This has the benefit of clearly separating the very distinct investigation activities of event reconstruction, causal analysis and preparation of recommendations.

It should also be noted that application of SOAM leaves the analysis of human involvement which may have been implicated in the occurrence to other specialised methodologies. For detailed analysis of human errors there are other tools available on the “market”, such as the HERA-JANUS technique[20], that have been validated for this purpose.

Recommendations from a SOAM-based investigation will be directed towards remediation of contributing systemic factors and failed barriers, a process that is not dependent on an exhaustive analysis of underlying cognitive error mechanisms.

Other techniques may of course be applied at the discretion of the investigator, safety professional or researcher who elects to conduct further analysis of certain aspects of an occurrence.

[20] EATMP (2003). *The Human Error in ATM technique (HERA-JANUS) (Edition 1.0 Feb 2003)*. Brussels. EUROCONTROL

6. SYSTEMIC OCCURRENCE ANALYSIS METHOD

6.1 Methodological Overview

SOAM is a process for conducting a systemic analysis of the data collected in a safety occurrence investigation, and for summarising this information using a structured framework and standard terminology. As with some root-cause analysis investigation methods, SOAM draws on the theoretical concepts inherent in the Reason Model, but also provides a practical tool for analysing and depicting the inter-relationships between all contributing factors in a safety occurrence.

Reason's original model has been adapted and refined within SOAM. The nomenclature has been altered in accordance with a "Just Culture" philosophy, reducing the implication of culpability and blame by both individuals and organisations. In SOAM, Unsafe Acts are referred to simply as *Human Involvement*, Psychological Precursors of Unsafe Acts as *Contextual Conditions*, and Fallible Decisions as *Organisational and System Factors*. The SOAM version of the Reason Model is shown in Figure 6.1 below.

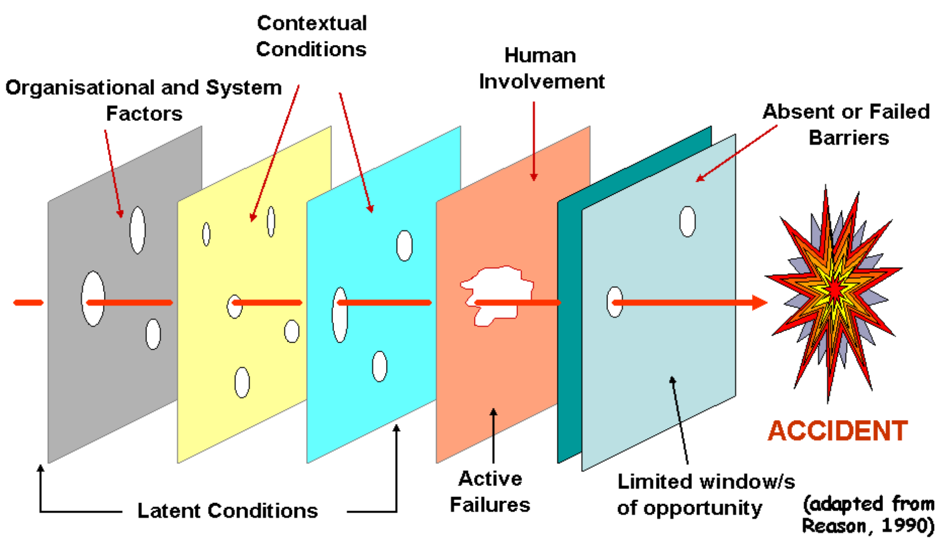


Figure 6.1
SOAM version of the Reason Model

Like other systemic analysis techniques, SOAM forces the investigation to go deeper than a factual report that simply answers basic questions such as “What happened, where and when?" First, data must be collected about the conditions that existed at the time of the occurrence which influenced the actions of the individuals involved. These in turn must be explained by asking what part the organisation played in creating these conditions, or allowing them to remain, thereby increasing the likelihood of a safety occurrence. SOAM thus supports the fundamental purpose of a safety investigation - to understand the factors which contributed to an occurrence and to prevent it from happening again.

SOAM is aligned with and supports "Just Culture" principles by adopting a systemic approach which does not focus on individual error, either at the workplace or management level. It avoids attributing blame by:

- Removing the focus from people's actions, instead seeking explanation for the conditions that shaped their behaviour; and
- Identifying latent organisational factors that allowed less than ideal conditions to exist, under which a safety occurrence could be triggered.

As with the original Reason Model, SOAM can be applied both reactively and proactively.

The process can be applied to any new occurrence, and is also suitable for the retrospective analysis of previously investigated occurrences in an attempt to extract additional learning for the promotion of safety.

SOAM can also be applied proactively to generic occurrences (e.g., level busts, separation minima infringements, runway incursions, etc.) or hypothetical events. These applications result in a comprehensive analysis of the absent barriers and latent conditions that are commonly found to contribute to such events, thereby identifying areas of organisational weakness that require strengthening to improve safety and prevent future occurrences.

SOAM fills a gap evident in most investigation processes by guiding investigators through a structured process for sorting and analysing gathered data. The use of a common terminology, clearly defined concepts and a systematic process makes the findings of the investigation reliable and to the extent possible, independent of the investigators involved.

The SOAM technique is readily understandable by people with minimal previous experience, following a brief period of theoretical training and practice. The technique produces a logical summary chart which utilises the principles of the Reason Model and facilitates straightforward reporting, presentation of findings and dissemination of safety lessons and information.

6.2 Absent or Failed Barriers

The first step in analysing a safety occurrence involves identifying the protective barriers which may have failed or been absent at the time of the occurrence. [21] Typically, complex socio-technical systems contain multiple barriers or defences to protect the system against hazards and undesired events. This is often referred to as the principal of 'defences in depth'. The fact that a safety occurrence has happened indicates that one or more barriers have been ineffective or inoperative.

One objective of the investigation process is to identify barriers that failed to prevent the occurrence or minimise its consequences, or that could have prevented the occurrence had they been in place, and to recommend action to strengthen these. It can be argued that addressing absent or failed barriers is the most productive action following a safety occurrence.

As observed by Hollnagel, barriers can be defined as obstacles that either: "(a) prevent an action from being carried out or an event from taking place, or (b) prevent or lessen the impact of the consequences, for instance by slowing down uncontrolled releases of matter and energy" (Hollnagel, 2003, p.65).[22]

[21] While Reason used the term 'Defences' in his modelling of organisational accidents, 'Barriers' is the preferred terminology within SOAM. For a comprehensive discussion of the concept of barriers see Erik Hollnagel's work, in particular: Hollnagel, E. (2004). *Barriers and accident prevention.* Aldershot, UK: Ashgate.

[22] Hollnagel, E. (2003). Barrier analysis and accident prevention. In G. Edkins & P. Pfister (Eds.), *Innovation and consolidation in aviation.* Aldershot, UK: Ashgate.

According to Reason, defences operate as a final protection against a safety occurrence, by countering the effects of an error or violation, or mitigating their consequences. The holes shown in the defensive layers of the Reason Model (see Figure 5.1 above) can be inadequate either because (a) they failed to work as intended to prevent the occurrence, or (b) defences that reasonably could have been in place were not created or installed by the organisation. Within SOAM, we refer to these elements of an occurrence investigation as **Absent or Failed Barriers**.

The division of barriers according to their function in either preventing an occurrence or containing its consequences can be extended into six barrier types: *Awareness*; *Restriction*; *Detection; Control and Interim Recovery*; *Protection and Containment*; *Escape and Rescue*. These barrier types represent successive lines of defence, beginning with *awareness* and understanding of risks and hazards in the workplace. If this first line of defence is breached, subsequent lines of defence (*restriction*, *detection*, and so on) are designed to contain the situation and limit adverse consequences as control is progressively lost.

It should be noted that while common in many productive industries, the final two barrier types identified above, *Protection and Containment*; and *Escape and Rescue,* will rarely be encountered within typical ATM occurrence investigations.

Applying SOAM to accident analysis can however uncover systemic issues relating to *Protection and Containment,* and *Escape and Rescue* barriers. Extending the analysis to the events after the immediate impact can help to elicit further insights regarding the effectiveness of these types of barriers. One example is the ANSV (Agenzia Nazionale Per La Sicurreza Del Volo) report on the Linate accident [23] in which some of the issues identified relate to the problems that were created by the environmental conditions that faced both controllers and emergency personnel in the aftermath of the collision. *"The reduced visibility not only created the context in which a collision was more likely, it also increased the likelihood of communications failures for any subsequent rescue".*[24]

When all available barriers are breached, safety occurrences transpire. The imperfect fortification structure in Figure 6.2 below (adapted from Reason and Hobbs, 2003) depicts this concept.

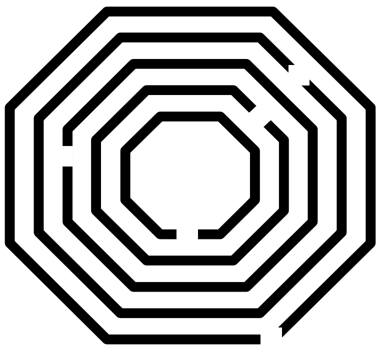


Figure 6.2
Imperfect barriers

[23] Agenzia Nazionale Per La Sicurreza Del Volo (ANSV) (2004). *Final Report, N.A/1/04.* Rome: Author.

[24] Johnson, C. (2005). *Review of ANSV Linate Report. Version 1, 8/02/2005*. Glasgow: Glasgow Accident Analysis Group, University of Glasgow.

Figure 6.3 below depicts the primary applications (Prevention, Resolution and/or Mitigation) of the six barrier types.

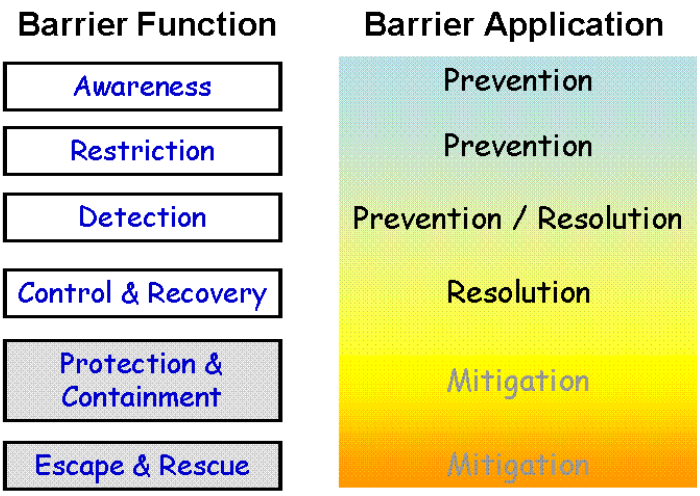


Figure 6.3
Barrier Types and Applications

Check question for Barriers:

Does the item describe a work procedure, aspect of human awareness, physical obstacle, warning or control system, or protection measure designed to prevent an occurrence or lessen its consequences?

The six barrier types are defined in Table 6.1 below.

Table 6.1
Barrier Type Definition

Barrier Type	Definition	Examples
Awareness	Understanding about the system state, risks and hazards, and knowledge of the rules, guidelines, procedures and controls that apply to the task.	• Rules, guidelines • Supervision • Training (initial, OJT, TRM, etc.) • Communication (e.g., shift handover) • Dissemination of lessons learned • Safety briefing
Restriction	Limitation of movement or actions, or establishing pre-conditions for action, through physical, functional or administrative means.	• Work permits, work orders • Instructions, procedures, e.g., readback, hearback, standard phraseology • Deadman systems, interlocks • Software logic

Barrier Type	Definition	Examples
Detection	Indicating systems (human or engineered) that warn about the system status, including the presence of non-normal conditions or imminent dangers.	• Detection by controller • Signage (e.g., , cautions, reminders, etc.) • Signals (visual, auditory) • Warnings, alarms, eg., Area Proximity Warning (APW), Short Term Conflict Alert (STCA), Minimum Safe Altitude Warning (MSAW), TCAS, etc.
Control and interim recovery	Recovering from a non-normal condition and restoring the system to a safe state, with minimal harm or loss.	• Timely and accurate compliance by pilot • Successful recovery action by controller
Protection and containment	Defending people against injury and minimising environmental damage by controlling the accidental release of harmful energy or substances.	• Walls, doors • Filters, containers • Seat belts, harnesses • Personal protective equipment
Escape and rescue	Enabling potential victims to escape out-of-control hazards; treating injuries, restoring the environment.	• Emergency services • First aid

6.3 Human Involvement

Once the relevant absent or failed barriers have been identified, the next stage of the analysis process involves identifying the human actions or non-actions that immediately preceded the safety occurrence. The question at this stage should not be *why* people acted as they did, but simply *what were their actions/inactions* just prior to the event. This provides the starting point for the next stage of the analysis that focuses on trying to understand why people acted as they did, through examination of the contextual conditions in place at the time of the occurrence.

The SOAM approach to identifying areas of human involvement differs from some investigation methodologies that try to explain "why" actions occurred in terms of underlying cognitive error mechanisms. SOAM focuses on error prevention and mitigation through elimination of error-producing conditions and strengthening protective barriers.

Check question for Human Involvement:

Does the item describe an action or non-action taking place immediately prior to and contributing to the occurrence?

This methodology analyses the human involvement in a safety occurrence using an existing model of information processing (see Appendix A). The tasks performed by an Air Traffic Controller (ATCO) involve various forms of information processing, including accurate detection, integration and interpretation of information, as well as planning, projecting and decision making. An information processing model is thus a logical component of an ATM occurrence analysis methodology, enabling a comprehensive representation of the steps that might be performed by a controller as an abnormal event unfolds.

Guiding Interventions

The most effective remedial steps following a safety occurrence will be targeted at the barriers and contextual conditions which allowed the occurrence to take place. Nonetheless, in some circumstances it will be considered necessary to direct remedial efforts toward the errors which are identified using human factors techniques. In developing interventions to address human error it is ineffective to focus on changing human behaviour as errors are part of being human and cannot be eliminated. Interventions are therefore most effective in reducing error if they are directed at the organisational and system level and focus on addressing the contextual conditions that make it more likely that errors will occur.

Appendix A includes examples of some potential causes of errors. The potential causes are described in terms of the contextual conditions that will be discussed in the next stage of the analysis process. Also included are examples of possible interventions based on these potential causes. The suggested interventions are aimed at reducing the probability of error. These lists are **suggestions only** and are by no means intended to be inclusive or prescriptive.

6.4 Contextual Conditions

Contextual conditions describe the circumstances that exist at the time of the safety occurrence. Originally described by Reason (1990, 1991)[25] as "*Psychological precursors of Unsafe Acts*", they have also been variously described as preconditions for unsafe acts, task and environmental conditions, situational factors, conditions, or performance shaping factors.

As indicated by Reason, this category of items constitute *latent conditions*, which may have lain dormant in the system for many days, months or even years prior to the occurrence.[26] They have remained undetected, or perhaps noticed but not recognised as part of a potentially hazardous chain of events. Some of these longstanding contextual conditions may in fact be relatively benign in themselves, or a necessary and accepted part of operating (for example, time pressures or environmental hazards in aviation). It is only when they combine with new, unusual or unique circumstances at a particular time and place that the occurrence is initiated.

As suggested by Reason's original term (psychological precursors of unsafe acts), contextual conditions have the potential to exert a direct and powerful influence on human behaviour. They create an environment that may pre-dispose people to make errors and violations of the type described above. Hollnagel (2000)[27] supports this view by suggesting that "actions at the sharp end" cannot be understood at all without reference to the condition of the people involved, their workplace, tools and equipment, and the organisation in which they work (see Figure 6.4).

[25] Reason, J. (1990). *Human error.* New York: Cambridge University Press.

Reason, J. (1991). Identifying the latent causes of aircraft accidents before and after the event. *Proceedings of the 22nd ISASI Annual Air Safety Seminar, Canberra, Australia.* Sterling, VA: ISASI.

[26] As observed by Hollnagel (2004), the defining characteristic of latent conditions is that they are present within the system well before the onset of a recognisable occurrence sequence.

[27] Hollnagel, E. (2000). *Human Reliability Analysis and Risk Assessment.* Training seminar presented at the Fifth Australian Aviation Psychology Symposium, Manly, November 2000.

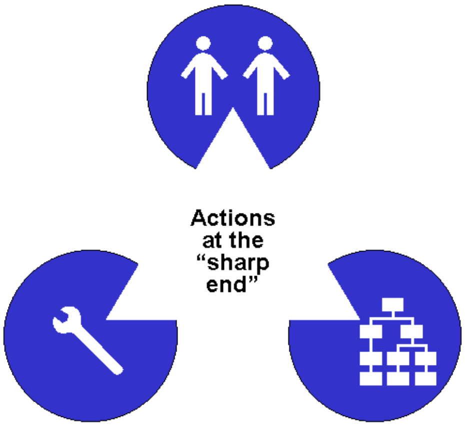


Figure 6.4
Sharp end human action in context
(adapted from Hollnagel, 2000)

In the occurrence investigation process, contextual conditions can be identified by asking "What were the conditions in place at the time of the safety occurrence that help explain why a person acted as they did?".

> **Check question for Contextual Conditions**
>
> Does the item describe an aspect of the workplace, local organisational climate, or a person's attitudes, personality, performance limitations, physiological or emotional state that helps explain their action?

To assist investigators correctly identify contextual conditions, examples are provided in Tables 6.2 to 6.6 below. Five categories of contextual conditions can be distinguished, two relating to the local workplace, and three to people. The categories are:

- Workplace conditions;
- Organisational climate;
- Attitudes and personality;
- Human performance limitations;
- Physiological and emotional factors.

In each table, items are listed according to whether they are most likely to influence errors (left-hand column), violations (right-hand column), or both (middle column). It is apparent from the distribution of items that errors arise primarily from inadequacies in the physical workplace, available resources (including time), and from people's information processing and physiological limitations. Violations in contrast derive most often from the local organisational climate (supervisory behaviour, norms, morale) and from attitude and personality variables.

Many of the items in these tables have been adapted from the *situational and task factors* and *personal factors* described by Reason and colleagues (Maurino, Reason, Johnston, & Lee, 1995) in their book on systemic aviation safety.[28]

[28] Maurino, D.E., Reason, J., Johnston, N., & Lee, R.B. (1995). *Beyond aviation human factors.* Aldershot, UK: Ashgate. (see Tables 1.2 and 1.3).

Table 6.2
Workplace Conditions

WORKPLACE CONDITIONS		
Error Factors	**Common Factors**	**Violation Factors**
• Poor communications • Poor signal/noise ratio • Designer/user mismatch • Poor human/system interface (e.g., mode confusion, poor HMI) display; • Poor mix of "hands on" work & written instruction. (Reliance on informal undocumented knowledge) • Poor shift patterns & overtime working • Hostile work environment (eg., too hot/cold, poor lighting, cramped conditions, noisy, etc.)	• Inadequate supervision • Time pressures • Time shortage • Poor working conditions • Inadequate tools and equipment • Poor access to job • Poor procedures & instructions • Poor supervisor/worker ratio • Poor tasking • Undermanning • Hazards not identified	• Procedures protect the system, but not the individual • Task allows for easy shortcuts

Table 6.3
Organisational Climate

ORGANISATIONAL CLIMATE		
Error Factors	**Common Factors**	**Violation Factors**
• Complacency	• Poor housekeeping	• Violations tolerated • Blame culture • Compliance goes unrewarded • Macho culture • Perceived licence to bend rules • Poor supervisory example • Subjective norms condoning violations • Unfair management sanctions • Little or no autonomy • Low operator status • Adversarial industrial climate

Table 6.4
Attitudes and Personality Factors

ATTITUDES AND PERSONALITY FACTORS		
Error Factors	**Common Factors**	**Violation Factors**
	• Skill overcomes danger • Poor judgement: illusion of control; least effort • Overconfidence	• Attitude to the system • Behavioural beliefs: (gains > risks) • Job dissatisfaction • Learned helplessness • Low self esteem • Personality: unstable extrovert; non-compliant • High risk target • Misperception of hazards

Table 6.5
Human Performance Limitations

HUMAN PERFORMANCE LIMITATIONS		
Error Factors	**Common Factors**	**Violation Factors**
• Negative transfer • Inaccurate knowledge • Attention capture; preoccupation; distraction • Confirmation bias • Error proneness • False perceptions • False sensations • Memory Failures: encoding interference; storage loss; retrieval failure; prospective memory • Perceptual set • Situational awareness • Educational mismatch • Incomplete knowledge • Inference and reasoning	• Inadequate skill • Insufficient ability • Inadequate training • Unfamiliarity with task	

Table 6.6
Physiological and Emotional Factors

PHYSIOLOGICAL AND EMOTIONAL FACTORS		
Error Factors	**Common Factors**	**Violation Factors**
• Disturbed sleep patterns • Domestic problems • Stress and fatigue • Strong motor programmes: frequency bias; similarity bias	• Performance anxiety • Arousal state: monotony & boredom; emotional status	• Bad mood

6.5 Organisational Factors

This section provides guidance in identifying the organisational factors which have contributed to the occurrence. Organisational factors describe circumstances which pre-existed the occurrence and produced or allowed the existence of contextual conditions, which in turn influenced the actions and/or inactions of staff.

A total of 12 organisational factors (ORFs) have been identified as those which frequently contribute to ATM safety occurrences. The factors and their corresponding two-letter codes are summarised in Table 6.7 below.

Table 6.7
Organisational Factors

Code	Organisational Factor
TR	Training
WM	Workforce Management
AC	Accountability
CO	Communication
OC	Organisational Culture
CG	Competing Goals
PP	Policies and Procedures
MM	Maintenance Management
EI	Equipment and Infrastructure
RM	Risk Management
CM	Change Management
EE	External Environment

Check question for Organisational Factors:

Does the item describe an aspect of an organisation's culture, systems [29], processes or decision-making that existed before the occurrence and which resulted in the contextual conditions or allowed those conditions to continue?

The tables below (Table 6.8 through 6.19) provide detail on the characteristics of the 12 organisational factors listed above. For each ORF, the Definition, Indicators, and Consequences are listed, together with details of an illustrative case study. The ORF *Definition* is intended to provide a global picture of the types of characteristics which fall under the particular factor. The *Indicators* are intended to provide a description of the variety of deficiencies which may be classified under the particular ORF. The *Consequences* are intended to provide examples of the visible manifestations of deficiencies which are represented under the particular ORF. Note that for each organisational factor the characteristics listed are indicative only. The listings are intended to be neither exhaustive nor definitive.

It should be noted that the categories of organisational factors are not mutually exclusive and items may sometimes overlap two or more categories. Tables 6.8 to 6.19 below provide guidelines and include examples that can be used as a reference in selecting the appropriate ORF. Where an item could be considered characteristic of more than one category of organisational factor, the investigator should not hesitate to select each relevant category of ORF. Further internal scrutiny of the selected areas will bring only benefits to the organisation. For example the case study in Table 6.8 represents a Training issue that could also be relevant to the Policy and Procedures area. Further investigation of both areas could create relevant recommendations for the organisation.

(Space Left Intentionally Blank)

[29] Includes hardware, administrative, communication and socio-technical systems

Table 6.8
Training Factor Characteristics

TR	Training
Definition	The factors relating to the suitability and quality of training provided by the organisation for staff involved in conducting tasks related directly to the occurrence. These may include issues to do with the design, structure, knowledge content, duration, delivery methods, assessment methods, and recurrence of worker education processes.
Indicators	Indicators of training deficiencies include less than adequate or unsuitable: • Training design (syllabus, structure, content) • Training delivery (methods, devices, duration) • Task/training fit • Training standardisation • Amount of training provided • Competency assessment • Training planning • Assessment of training effectiveness
Consequences	Consequences of training deficiencies may include: • Mismatch between required and actual performance • Lack of required knowledge • Lack of required skill • Inadequate training • Inference or reasoning deficiencies • Misperception of hazards • Inability to perform assigned task/s • Excessive supervision required • Lengthy task completion times • Negative transfer • Unfamiliarity with task • Workload management problems
Case Study	In July 2002 a Boeing 757-200 and a Tupolev TU154M collided mid-air over Überlingen. The B757 crew had received a TCAS RA advising them to descend and the Tupolev crew had received a TCAS RA advising them to climb in order to avoid the collision. Shortly before the Tupolev received the TCAS climb RA, the ATCO noticed the traffic conflict and instructed them to descend to avoid the B757. The Tupolev crew followed the ATCO instruction rather than the TCAS RA and descended directly into the path of the B757. None of the Tupolev crew had received simulator or computer-based training on use of TCAS. Had the crew been provided with 'hands-on' practice at responding to TA and RA alerts, they would have known that their RA to climb would be complemented by a simultaneous descend RA to the other aircraft, and would then have been more likely to give priority to the TCAS RA over the ATC instruction .[30]

[30] Bundesstelle für Flugunfalluntersuchung (2004). *Investigation Report AX001-1-2/02.* Berlin: Author.

Table 6.9
Workforce Management Factor Characteristics

WM	Workforce Management
Definition	The factors relating directly to the management of operational personnel within the organisation. These include HR policies and practices that impact on employee workload, oversight, performance and morale, such as organisational structure, work design, rostering, tasking, manning, experience levels, remuneration and reward systems, but exclude training issues.
Indicators	Indicators of workforce management deficiencies include less than adequate or unsuitable: • Organisational structure • Work design and/or job design • Industrial relations • Staffing levels • Selection methods • Experience of workforce • Rostering practices • Tasking and workload • Supervisor-controller ratio • Team composition • Contractor management • Morale
Consequences	Consequences of workforce management deficiencies may include: • Slow or inadequate response to anomalies • Communication deficiencies • Inappropriate selection (worker/task match) • Undesirable shift patterns • Inadequate supervisor/worker ratio • Improper tasking • Undermanning • Age imbalance • Imbalance of experience and inexperienced workers • Worker autonomy (too little/too much) • Low worker status • Low worker remuneration • Task design encourages shortcuts and/or violations • Inexperience (not lack of training)
Case Study	In the Überlingen mid-air collision, the ATCO did not recognise the conflict between the two aircraft in time to initiate appropriate measures to avoid the collision. He was on duty alone and had to assume the role of radar planning controller, radar executive controller on two different working positions and supervisor all at the same time and thus was unable to safely execute all required tasks. Although two controllers were actually rostered for the night shift it had been common practice at ACC Zurich for many years for one of the controllers to go to the rest facility until being called back on duty in the early morning when traffic became heavier. This longstanding informal arrangement was 'known and tolerated' by company management. It was their responsibility to recognise the inherent safety risks of this arrangement and to take appropriate corrective action to enforce a duty schedule which ensured continuous safe and adequate staffing of the workstations.[31]

[31] Bundesstelle für Flugunfalluntersuchung (2004). *Investigation Report AX001-1-2/02.* Berlin: Author.

Table 6.10
Accountability Factor Characteristics

AC	Accountability
Definition	The factors relating directly to the accountability of key personnel within the organisation and the way in which responsibilities are assigned to these personnel. These include issues such as the assignment of responsibility for safety from senior management levels down, oversight of staff performance with respect to safety-related duties, clear definition and communication of these accountabilities throughout the organisation, and processes to ensure that accountabilities are fulfilled.
Indicators	Indicators of accountability deficiencies include less than adequate: • Demonstrated management commitment to safety • Clearly defined accountabilities for operational safety • Processes to ensure accountabilities are carried through • Response by management to reported or rumoured breaches of rules or procedures by workers • Mechanisms to ensure that the commitment to safety is reflected in everyday actions of managers and workers • Mechanisms to ensure that the importance of safety is embedded within the organisation as a top operational priority
Consequences	Consequences of accountability deficiencies may include: • Lack of conviction regarding the importance of safety • Blurred lines of responsibility for safety within the organisation • Accountability “gaps” for safety critical activities • Action not taken at management level to redress known safety problems • Ambiguity regarding where safety concerns should be directed • Confusion amongst managers over who should take action regarding safety-related concerns or deficiencies • Management commitment to safety not reflected in the beliefs or behaviours of workers
Case Study	Flying Tigers 747 CFIT accident, Kuala Lumpur, 1989: Tiger 66, a scheduled cargo flight from Singapore to Kuala Lumpur, was airborne at 0604 local, with an estimated flight time of 33 minutes. Having discussed an ILS approach to RWY 33, when performing the in-range checklist the response to the "crew briefing" item was “reviewed”. Although both the NOTAMs and ATIS listed the ILS as unserviceable the crew planned for it. After being informed by ATC that the ILS was unserviceable and then cleared for an NDB approach they did not brief for that. The flight was handed off to KL tower and they were descended to 7000 feet and cleared to the Kilo Lima NDB. In several subsequent descent clearances issued by the tower, although not standard, the phraseology used was consistent and clear. The final clearance issued by the tower was “to/two four zero zero”, which the crew interpreted as “descend to four zero zero”. The aircraft descended to 437 feet MSL, ignoring two sets of GPWS alerts, before crashing on a steep slope covered with jungle. The aircraft and cargo were destroyed. There were four fatalities. Both the flight crew and ATCO involved in this event used non-SOP practices and phraseology. In both cases these practices were 'routine violations' which were known of yet not acted on by management. In particular the airline management lacked defined accountability, processes and actions to ensure that flight crew operations were standardised.

Table 6.11
Communication Factor Characteristics

CO	Communication
Definition	The factors relating to the suitability and quality of communication systems and methods within the organisation. This relates to the availability and flow of information within the organisation, whether and how workers are informed about safety critical information, and the clarity and quality of formal and informal communication processes.
Indicators	Indicators of communication deficiencies include less than adequate or unsuitable: • Documented policies and procedures • Clarity of organisational structure and responsibilities • Standardised communication tools • Information flow within the organisation • Communication within the organisation • Communication with other facilities • Coordination within/between work teams, with other sectors • Shift handover procedures
Consequences	Consequences of communication deficiencies may include: • Uncertainty or ambiguity regarding work rules or procedures • Uncertainty or ambiguity regarding organisational structure and responsibilities • Communication breakdowns, misunderstandings • Inadequately informed workforce • Uncertainty about how to obtain information • Lack of management knowledge or understanding regarding worker concerns, behaviour, etc.
Case Study	A de Havilland Dash 8 on an IFR approach to Vancouver International Airport found itself in a hazardous situation, entering a minimum vectoring altitude (MVA) area 2,000ft below the required altitude of 7,000ft. The controller had instructed the aircraft to fly a heading that required further action within minutes to ensure that the required separation from high terrain would be maintained. However, the controller became distracted and forgot the aircraft was on a vector towards high terrain until his coordinator alerted him to the hazardous situation. Inadequate communication about MVA-related safety critical information may have contributed to this incident. Vancouver Area Control Centre management had issued operations bulletins regarding the use of MVA but the distribution was limited to certain departments. The Vancouver terminal unit had not received the bulletin and thus controllers were unaware of the safety issues raised regarding MVAs. The potential safety benefit of wide distribution of lessons learned from occurrences and the resulting change in procedures was lost to the controller involved in this incident. He had received no specific guidance on the type of alternate instructions to issue to aircraft where MVAs are below published minimum IFR altitudes.[32]

[32] Transportation Safety Board of Canada (2000). *Aviation Investigation Report A00P0199.* Canada: Author

Table 6.12
Organisational Culture Factor Characteristics

OC	Organisational Culture
Definition	The factors relating to the shared values and beliefs within an organisation that influence “the way things are done”, and make the organisation different from others. The organisational culture includes safety culture elements such as commitment to safety, awareness, a just approach to errors, wariness about the potential for accidents, and the capacity to learn from past events.
Indicators	Indicators of organisational culture deficiencies include less than adequate: • Values and beliefs relevant to safety and quality • Demonstrated management commitment and concern for safety • Safety Management Systems • Occurrence reporting processes • Examples set by supervisors and management • Management response to occurrences • Management response to individuals reporting safety concerns • Processes for anticipating and protecting against future accidents • Preparedness to admit faults and learn from past experience
Consequences	Consequences of organisational culture deficiencies may include: • Toleration of routine violations • Subjective norms condoning violations • Evidence of a 'blame culture' following safety occurrences • Unfair management sanctions • Compliance with rules not supported • Perceived licence to 'bend the rules' • Risk-taking culture encouraged • Poor example set by management • Defensive response to failures (denial, cover-ups, etc) • Low morale, job dissatisfaction • Lack of pride in work • 'Macho' culture • Adverse industrial climate • Poor housekeeping • Inadequate supervision • Complacency (can't happen here)
Case Study	Columbia Space Shuttle Accident, February 2003: The organisational factors of this accident were entrenched in the Space Shuttle Program's history and culture, including the original compromises that were required to gain approval for the Shuttle program, subsequent years of resource constraints, fluctuating priorities, schedule pressures, and mischaracterisation of the Shuttle program as operational rather than developmental. Cultural traits and organisational practices detrimental to safety were allowed to develop, including: reliance on past success as a substitute for sound engineering practices (such as testing to understand why systems were not performing in accordance with requirements); organisational barriers that prevented effective communication of critical safety information and stifled professional differences of opinion; lack of integrated management across program elements; and the evolution of an informal chain of command and decision-making processes that operated outside the organisation's rules. Significantly, many similar organisational culture factors were cited in the aftermath of the Challenger Space Shuttle Accident in January 1986.

Table 6.13
Competing Goals Factor Characteristics

CG	Competing Goals
Definition	The factors relating to conflicts between competing goals, in particular those of production and safety. These may include conflicts between safety and planning or economic goals, in addition to the vested interests of groups or individuals within the organisation. They are typically characterised by an overemphasis on these goals at the expense of safety.
Indicators	Indicators of competing goals deficiencies include: • High emphasis on productivity to the potential detriment of safety • Discord or tension between production priorities and safe work • Imbalance between budget constraints and safety • Tacit approval of 'short-cuts' that increase productivity • Management priorities and emphasis on goals other than safety • Achievement of productivity, service or other goals is rewarded ahead of safety objectives
Consequences	Consequences of competing goals deficiencies may include: • Budget cuts to safety programs • Workload pressures • Time pressures • Time shortage • Acceptance of routine violations • Pressure to short-cut procedures • Low staffing levels • High workload levels
Case Study	SIMOPS Occurrence at Sydney Airport, August 1991: A Thai Airways DC-10 and an Ansett A320 were involved in a near collision at Sydney Kingsford Smith Airport. The DC-10 was landing on runway 34 at the same time as the A320 was on short final approach for landing on runway 25. Runways 34 and 25 intersect, and SIMOPS were in progress. The Captain of the A320 judged that the DC-10 might not stop before the intersection of the runways (even though it had been instructed to hold short of the intersection of runway 25) and initiated a go-around from about one metre above the runway, subsequently avoiding the DC-10 with 11m vertical and 33m horizontal separation. Contributing to this incident were the competing goals of optimising traffic flow versus aircraft safety. In this case ATC chose to use SIMOPS even though the traffic movement rate did not warrant its use, thus favouring the economic imperative of optimising traffic flow and reducing the safety net for landing aircraft.[33] Further details of this event are included in Appendix B to this document.

[33] Bureau of Air Safety Investigation (1991). *Special Investigation Report B/916/3032.* Canberra: Author.

Table 6.14
Policies and Procedures Factor Characteristics

PP	Policies and Procedures
Definition	The factors relating to the quality and suitability of policies, procedures and operational standards within the organisation. This involves the applicability, clarity, currency, specificity, availability, and standardisation of all written instructions and specifications.
Indicators	Indicators of policies and procedures deficiencies include less than adequate or unsuitable: • Written policies, procedures, checklists and instructions • Relevance or applicability of documentation • Level of detail included in documentation • Standardisation of operational procedures • Feedback loop between document authors and practitioners • Availability of procedures or other documentation • Practicality of procedures and other instructions
Consequences	Consequences of policies and procedures deficiencies may include: • Inaccurate, poorly written, unclear or out of date procedures & instructions • Some key tasks not covered by procedures • Different versions of the same procedure in circulation • Lack of standardisation within or between centres, sectors and/or teams • Different teams or sectors following conflicting procedures • Non-standardised application of procedures and/or requirements • Lack of understanding of policies and procedures amongst staff • Procedures that do not reflect operational practice • Encouragement of procedural short-cuts and violations • Procedures that protect the system not the individual • Poor mix of “hands on” work & written instructions (over-reliance on undocumented knowledge) • Failure to address legal, regulatory and other corporate obligations • Language comprehension problems
Case Study	Bangkok Runway Overrun Occurrence, September 1999: A Boeing 747-438 aircraft overran runway 21L while landing at Bangkok International Airport. The overrun occurred after the aircraft landed long and aquaplaned on a runway which was affected by water following very heavy rain. The crew had used the 'flaps 25/idle reverse thrust' landing procedure (which was the ‘preferred’ company procedure). In such conditions without reverse thrust, there was no prospect of the crew stopping the aircraft in the runway distance remaining after touchdown. During the investigation it became evident that the landing procedure used was not appropriate for operations onto water-affected runways. It was also found that the Company's B747-438 Operations Manual contained no appropriate information about procedures for landing on water-affected runways.[34]

[34] Australian Transport Safety Bureau (2001). *Investigation Report 199904528.* Canberra: Author.

Table 6.15
Maintenance Management Factor Characteristics

MM	Maintenance Management
Definition	The factors relating to management of ATM equipment and facility maintenance activities within the organisation. Typically these will involve factors including the planning, scheduling, resourcing and oversight of maintenance activities. Maintenance management includes the effectiveness with which contracted companies and staff are selected, inducted, trained, supervised and kept informed.
Indicators	Indicators of maintenance management deficiencies include less than adequate or unsuitable: • Scheduling of maintenance activities • Standardisation of maintenance activities • Serviceability of ATM equipment and facilities • Resourcing of maintenance activities • Supervision of maintenance activities • Equipment manuals and documentation • Processes for contractor management
Consequences	Consequences of maintenance management deficiencies may include: • Poorly maintained or unserviceable equipment • Unscheduled shutdowns due to equipment malfunctions or defects attributable to inadequate maintenance • Maintenance activities being conducted at inappropriate times • Low quality work by contractors • Differences in standards of work between employees and contractors • Lack of knowledge or concern by contractors about risks associated with maintenance activities
Case Study	ATC Centre Electrical Power Loss Occurrence: A routine periodic inspection of an uninterruptible power supply for an ATC centre located at a major international airport was commenced at 1800 hrs on a busy weekday. Approximately 20 minutes after work commenced, the centre sustained a total loss of electrical power. All ATC screens failed, the lights in the control room went out, and software switching of voice communications channels, satellite communications, and radar feeds to two other major centres were lost. Controllers were unable to determine the positions of any aircraft under their control for about 10 minutes. During this time controllers used the emergency radio to direct flight crews to maintain a visual lookout for other aircraft and make use of ACAS/TCAS systems where available.[35]

[35] Australian Transport Safety Bureau. (2001). *Air Safety Occurrence Report 200002836.* Canberra: Author.

Table 6.16
Equipment and Infrastructure Factor Characteristics

EI	Equipment and Infrastructure
Definition	The factors relating to the design, quality, availability and serviceability of workplace equipment and other hardware used in support of Air Traffic Management. This element includes Human-Machine Interface issues that impact on usability for operators.
Indicators	Indicators of equipment and infrastructure deficiencies include less than adequate or unsuitable: • Standardisation of equipment design • Equipment purchased 'fit-for-purpose' • Equipment design: Users require additional training or procedures to 'work-around' design deficiencies • Working conditions • HMI • Equipment displays, functions and lay-outs • Work station fit outs • Ergonomics
Consequences	Consequences of equipment and infrastructure deficiencies may include: • Poor HMI • Inadequate tools and equipment • Difficult access to work stations • Negative transfer • Increased workload • Reduced situational awareness • Poor system feedback • Information / task overload • Poor signal to noise ratio • Cramped working conditions • Noisy work environment
Case Study	Runway Collision at Milan Linate, October 2001: An SAS MD-87 collided on take-off with a Cessna Citation II business jet at Milan Linate Airport. The Cessna was cleared to taxi via taxiway Romeo 5 but mistakenly entered taxiway Romeo 6, subsequently entered runway 36R, and was impacted by the MD-87 which had been cleared for takeoff on runway 36R. Both aircraft and part of an airport building were destroyed and there were a total of 118 fatalities. The ATCO was unaware that the Cessna was in the incorrect position. Had the aerodrome had a functioning ground radar system this would have alerted the controller to the incorrect position of the Cessna and the impending collision. The aerodrome had purchased a new 'state of the art' ground radar system six years earlier but it had never been installed.[36] See Section 7 of this document for further details on this occurrence.

[36] Agenzia Nazionale Per La Sicurreza Del Volo (ANSV) (2004). *Final Report, N.A/1/04.* Rome: Author.

Table 6.17
Risk Management Factor Characteristics

RM	Risk Management
Definition	Factors relating to the systems, procedures, accountabilities and activities within the organisation that are designed to identify, analyse, manage and continue to monitor risk. Risk is defined as any aspect of the organisation's operation that has a potential to cause harm to people, equipment, the environment, reputation or the wider community.
Indicators	Indicators of risk management deficiencies include less than adequate or unsuitable: • Management perceptions on the importance of risk management • Risk management policy and documentation • Risk identification processes, eg., hazard reporting systems • Qualitative and quantitative risk measurement methods • Training and competence of personnel involved in risk assessment and compliance activities • Assignment and monitoring of responsibilities and accountabilities for risk identification and control • Safety Cases
Consequences	Consequences of risk management deficiencies may include: • Hazards not identified and managed • Unnecessarily high risk levels • Operational risks not prioritised • Controls do not address high priority risks adequately • Increased incident and accident rates • Unexpected costs / losses • Threats to employee and/or customer welfare • Non-conformance with regulatory requirements
Case Study	Both the Sydney SIMOPS occurrence [37] and the Bangkok runway overrun occurrence [38] as described above are clear examples of deficiencies in organisational risk management. In both cases management implemented and encouraged the employment of procedures oriented towards enhancing efficiency and/or reducing costs without conducting an appropriate analysis of the operational hazards and risks involved.

[37] Bureau of Air Safety Investigation (1991). *Special Investigation Report B/916/3032.* Canberra: Author.

[38] Australian Transport Safety Bureau (2001). *Investigation Report 199904528.* Canberra: Author.

Table 6.18
Change Management Factor Characteristics

CM	Change Management
Definition	Factors associated with the planning, testing, implementation and review of significant modifications to organisational structure or equipment, or major transition from one organisational process or system to another. Change management may also include activities designed to define and instil new values, attitudes, norms, and behaviours within an organisation that support new ways of doing work, adaptation to new technology, and/or overcoming resistance to change.
Indicators	Indicators of change management deficiencies include less than adequate or unsuitable: • Definition of change objectives • Consideration about the scope and consequences of change • Design, management, oversight and review of implementation plans • Communication about objectives, outcomes and implications of change; potential benefits and drawbacks • Change timing and/or timeframes • Concern about of the human impact: effect on employee values, attitudes, morale, performance • Testing and monitoring to compare pre- and post-change performance
Consequences	Consequences of change management deficiencies may include: • Unintended deterioration in safety or other key organisational performance objectives • Gaps in structures, accountabilities or procedures • Intended changes not implemented effectively, or not implemented in a timely manner • Loss of 'corporate knowledge/memory' • Mismatch between tasks and resources • Resistance to change; Staff hostility • Increased worker stress • Uncertainty, confusion about new roles and responsibilities • Reduced morale, increased apathy, low concern for rules, safety, etc. • Increase in safety occurrences
Case Study	Runway Collision at Milan, October 2001: As indicated above, the Linate aerodrome did not have a functioning ground radar system at the time of this accident. The previous ground radar system had been decommissioned some years earlier, and while Milan Linate had purchased a new 'state of the art' system six years prior to this accident, it had never been installed. [39] Change management (oversight of equipment change implementation) is regarded as a significant organisational deficiency amongst the range of factors which contributed to this tragic occurrence.

[39] Agenzia Nazionale Per La Sicurreza Del Volo (ANSV) (2004). *Final Report, N.A/1/04.* Rome: Author.

Table 6.19
External Environment Factor Characteristics

<table>
<tr><th>EE</th><th>External Environment</th></tr>
<tr><td>Definition</td><td>The factors relating to elements of the ATM system which fall outside the direct influence of the organisation yet can be considered to fall within the scope and potential influence of the investigation. Likely to include issues of strategic airspace organisation and management, external air traffic flow management (such as CFMU), regulatory requirements, airport design and maintenance, etc.</td></tr>
<tr><td>Indicators</td><td>Indicators of external environment deficiencies may include less than adequate or unsuitable:
• Consultation between agencies and organisations involved in ATM system regulation and operation
• Safety Management Systems (failing to deal adequately with external supplied services)
• Safety oversight</td></tr>
<tr><td>Consequences</td><td>Consequences of external environment deficiencies may include:
• Ambiguous or conflicting requirements
• Inefficient and/or hazardous movement of air traffic
• Inaccurate/inadequate documentation
• Inadequate aerodrome markings, signage, lighting, etc.
• Inadequate quality assurance
• Reduced situational awareness
• Poor coordination
• Poor communication
• High workload</td></tr>
<tr><td>Case Study</td><td>Runway Collision at Milan, October 2001: Additional contributing factors in the fatal runway collision at Milan's Linate airport included: Published aerodrome documents were out of date and inaccurate; the aerodrome standard did not comply with ICAO Annex 14 regarding required runway markings, lights and signs; documentation regarding taxiway movements was complex and procedures were poorly described; and operational procedures allowed high traffic volume in reduced visibility conditions.

The accident investigation report noted that the absence of a functioning safety management system was the main cause for most of these discrepancies and this was considered one of the main contributing factors to the occurrence.

Three organisations were involved in the management and operations of the airport, one being the regulatory authority. They had established no Quality System Requirements or Operational Manual, and there was no coordination between the organisations to implement new, or review current, systems in place for safe aircraft operations. There was poor communication between the organisations on safety matters, late decisions and slow handling of safety issues, all contributing to the overall lack of safety management of the ATM system.[40]</td></tr>
</table>

[40] Agenzia Nazionale Per La Sicurreza Del Volo (ANSV) (2004). *Final Report, N.A/1/04.* Rome: Author.

6.6 Summary of the Analysis Process

The process for converting the facts gathered about a safety occurrence into logical groupings is summarised in Figure 6.5 below.

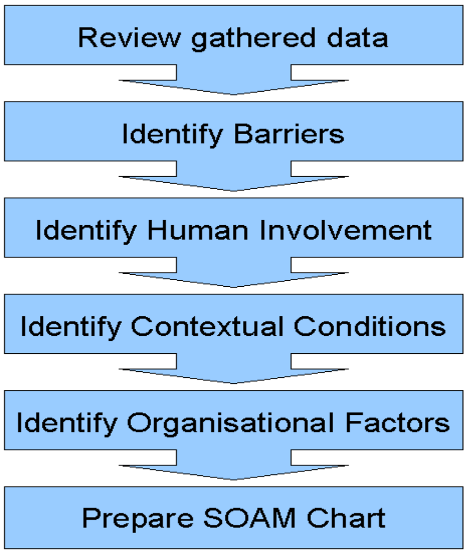


Figure 6.5
SOAM Analysis Process

In practice, this is not a sequential task, but a progressive sorting activity. Each fact is dealt with in turn, and subjected to two tests:

TEST 1 : Does the fact represent a condition or event that contributed to the eventual occurrence, and, if so,

TEST 2 : Does the fact represent a barrier, human involvement, a contextual condition, and/or an organisational factor

Test 1 is designed to exclude information from within the total body of gathered data that may be interesting, but did not have an active role in this particular occurrence. If no causal connection can be found between the fact and an item higher or lower in the error chain (adjacent layers in the Reason Model), the fact is excluded from the SOAM analysis chart.

This does not necessarily mean that the fact is ignored. Investigations often reveal information of interest about an organisation's safety health, but which did not have a direct impact on the occurrence under investigation. These should be detailed in a separate section of the investigation report.

Test 2 is applied to each fact until all gathered data is sorted into one or more of the SOAM categories.[41] Where the investigation is being conducted by a team, this sorting process, which is the essence of the systemic analysis methodology, should be a group activity in which decisions are made by mutual agreement.

[41] A single fact may be represented in more than one of the SOAM categories.

6.7 The SOAM Chart

The final product of the occurrence analysis process is a summary chart depicting:

- The individual contributing factors – grouped according to the layers of the methodology as barriers, human involvement, contextual conditions and organisational factors; and
- Horizontal links representing the association between a contributing factor at one level (e.g., a human action), and its antecedent conditions (e.g., the context in which the action took place).

In completing the links on the SOAM summary chart, facts at different levels should be linked if one is thought to have influenced the other. For example, if a contextual condition (e.g., fatigue) is considered to have influenced an action (e.g., delayed detection of conflict) then a linking line should be drawn between them. Similarly if an organisational factor (e.g., poor workforce management) is considered to have created a contextual condition (e.g., fatigue), or allowed it to continue to exist, then a link should be drawn between them.

An example of a completed SOAM chart is provided in Figure 6.6 below. In this example data from the investigation of the Überlingen mid-air collision [42] has been employed to build a graphical representation of the circumstances surrounding the occurrence using the SOAM technique.

(Space Left Intentionally Blank)

[42] Bundesstelle für Flugunfalluntersuchung (BFU). (2004). *Investigation Report AX001-1-2/02*. Berlin: Author.

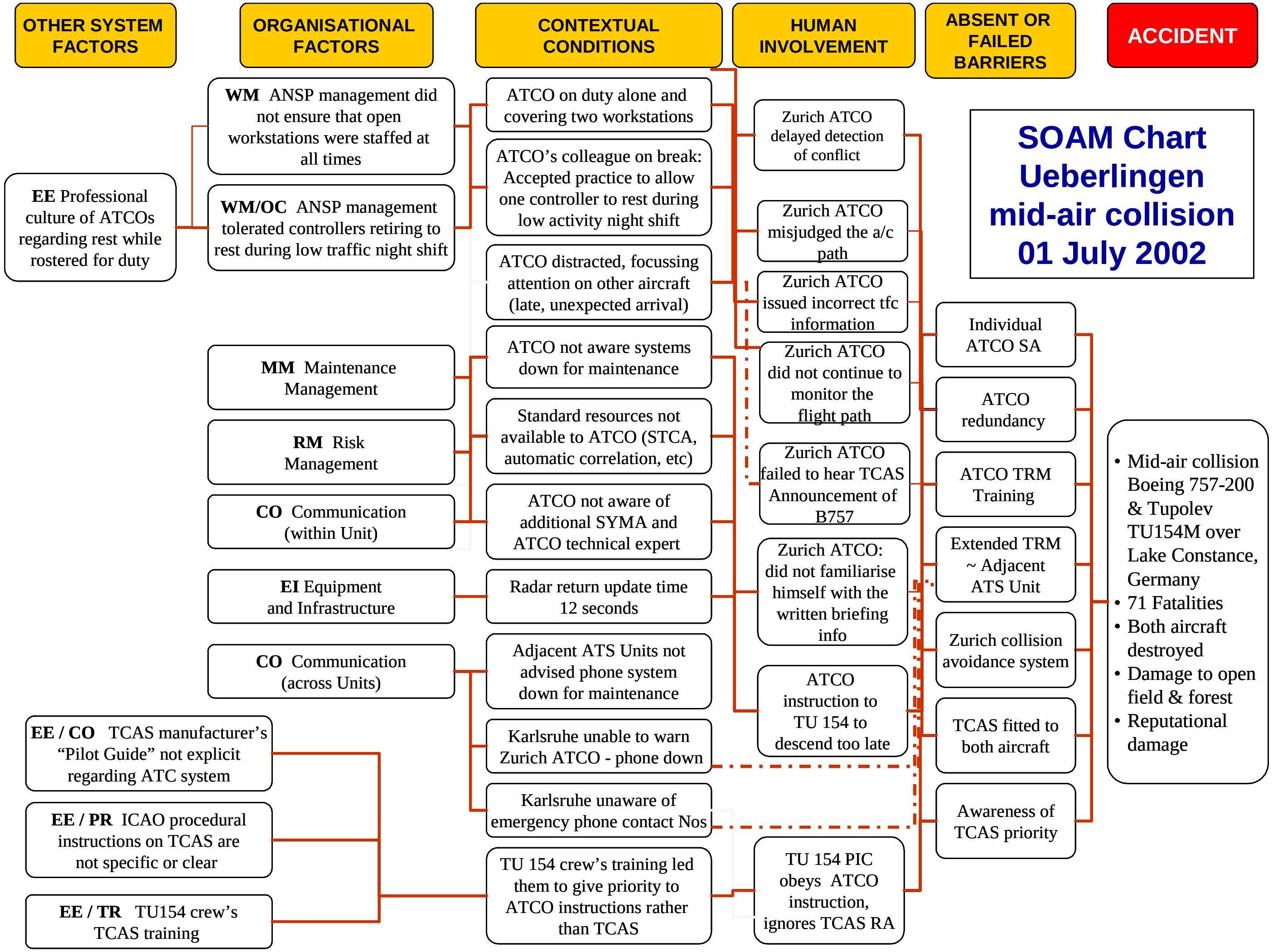


Figure 6.6
SOAM Analysis Chart Example

The SOAM chart provides a clear and effective means of summarising the occurrence using standardised processes and terminology, which:

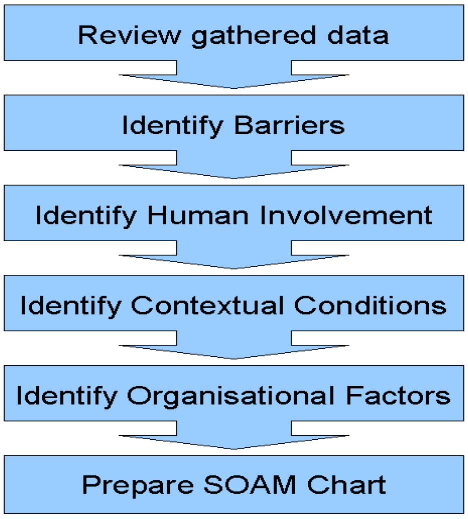
- Facilitates the unambiguous exchange of safety information and learning within and across organisations, and
- Supports executive briefings or presentations on an occurrence, particularly when the time available for this is restricted.

(Space Left Intentionally Blank)

7. EXAMPLE OF SOAM ANALYSIS

This section provides a worked example of how SOAM is applied to an actual investigation. The case study used is the runway collision between a SAS Boeing MD-87 and a Cessna Citation at Milan Linate airport in October 2001. A summary of the occurrence is provided below for reference.[43]

In an actual occurrence investigation, SOAM would be applied once a set of key facts about the event had been collected. The full SOAM process, as described above in Section 6.6, will be demonstrated as follows:



Two additional case studies demonstrating the application of SOAM to lower severity level safety occurrences are provided in Appendices B and C to this document.

(Space Left Intentionally Blank)

[43] The Milan occurrence summary was adapted from an article which originally appeared in the *ICAO Journal*, accessed online in July 2004 at the following site: http://www.airmanshiponline.com/july2004/05-Numerous%20factors_ICAO_J.pdf

7.1 Summary of Occurrence

Occurrence Summary ~ Milan Linate Runway Collision, 8 October 2001

The final report on the runway collision between a Boeing MD-87 and a Cessna Citation at Milan Linate Airport in October 2001 cites a combination of factors, from aerodrome shortcomings to pilot-controller miscommunication, which contributed to a runway incursion which resulted in Italy's worst aviation accident.

The accident took place at 0610 UTC [0710 local time] on 8 October 2001 when an SAS Boeing MD-87, while taking off from Runway 36R at Milan Linate Airport, collided with a Cessna 525-A which had taxied onto the active runway. After the collision the MD-87 became airborne for a short distance then overran the runway and veered slightly right before impacting a building used for baggage handling. The Cessna 525-A remained on the runway and was destroyed by post-impact fire. All occupants of the two aircraft and four ground staff working inside the baggage handling facility (118 people in all) suffered fatal injuries.

Following is a summary of the findings, conclusions and recommendations contained in the English translation of the final report issued by ANSV, the Italian air safety board.

History of flight

The MD-87, operating as SAS Flight 686 (5K 686) with 104 passengers on board, was scheduled to depart Milan Linate for Copenhagen at 0535 UTC. The crew contacted the ground controller at 0541 and was given the slot time of 0616 for take-off. The crew requested taxi clearance at 0554, at which time the controller instructed the crew to taxi from the North apron to the Runway 36 ILS Cat III holding position.

At 0558, the Cessna pilot requested start-up clearance from Linate Ground for a flight to Paris Le Bourget Airport. The pilot was given 0619 as the slot time for take-off. At 0559, the ground controller instructed the pilot of Flight 5K 686 to contact the tower controller on frequency 118.10 megahertz (MHz) when taxiing abeam the fire station. At 0601, the crew of 5K 686 switched to frequency 118.10 and contacted the tower controller. From this moment on, the crews of the MD-87 and the Cessna were tuned to different radio frequencies.

At 0605, the pilots of the Cessna received the following taxi clearance:

"Delta Victor X-ray taxi north via Romeo 5, QNI-I 1013, call me back at the stop bar of the . . . main runway extension.

The Cessna crew acknowledged as follows:

"Roger via Romeo 5 and ... 1013, and call you back before reaching main runway."

The Cessna then left its West apron parking position and followed the yellow guideline until the point where it split into diverging directions, one to the left (northwards) and another to the right, leading south-eastwards. The Cessna followed the latter guideline and entered Taxiway Romeo 6. The pilot turned right instead of left as required by the clearance, and proceeded to Taxiway R6 instead of R5. Taxiway R6 was not marked by identification signs.

Continuing to taxi on R6, the crew made an unsolicited position report at 0608, informing the controller that the aircraft was approaching Sierra 4. It was later established that the S4 marking on the taxiway was not indicated on aeronautical charts and was unknown to the controller, who continued to assume that the Cessna was positioned on Taxiway R5, as previously cleared.

At 0608:36, the ground controller replied with the following instruction:

"Delta Victor X-ray, Roger, maintain the stop bar. I'll call you back."

At 0608:40 the pilot replied: *"Roger. Hold position."*

At 0609:19, the ground controller cleared the Cessna to continue its taxi on the North apron (using the words "main apron"), and to follow the Alpha line. The Cessna pilot responded, *"Roger continue the taxi in main apron, Alpha line the… Delta Victor X-ray.*"

Ground: *“That is correct, and please call me back entering the main taxiway.”*

D—IEVX: *“I’ll call you on the main taxiway.”*

The Cessna continued on R6, crossing a stop marking which was painted on the asphalt, then an ICAO pattern B runway-holding position marking painted on the taxiway, and a unidirectional lighted red stop bar alongside which was a lighted CAT III holding position sign. Immediately before entering the runway by following the green taxiway centerline lights, the Cessna crossed an ICAO pattern A runway-holding position marking painted on the taxiway without communicating with a controller. As the Cessna entered the active runway at the intersection with R6, the tower controller cleared Flight SK 686 for take-off. At 0610:18, the aircraft communications addressing and reporting system (ACARS) installed on the MD-87 communicated with the receiving installation in Copenhagen, which registered the take-off signal. At 0610:21 the two aircraft collided. At the time of collision, the MD-87 was performing a normal take-off rotation. Approximately one second prior to the collision an additional large elevator nose-up command was registered by the MD-87 digital flight data recorder. It is probable that the crew of the MD-87 had a glimpse of the Cessna just prior to the collision (this is suggested by an unintelligible exclamation recorded on the cockpit voice recorder).

Conclusions

The accident investigation report cited a number of deficiencies that played a role in the outcome. While the immediate cause of the accident was identified as the runway incursion by the Cessna pilot, the report stated that this error must be weighed against a range of systemic shortcomings. *“The system in place at Milan Linate airport was not geared to trap misunderstandings, let alone inadequate procedures, blatant human errors and faulty airport layout”* the report concluded. Among its findings, the report stated that:

- The management and operation of Milan Linate Airport was complicated and involved three major organizations. ENAC, the regulatory authority, also held overall responsibility for the management and operations of the aerodrome;
- The aerodrome did not conform with ICAO Annex 14 standards regarding required aerodrome markings, lights and signs;
- No functional safety management system was in place. Its absence prevented each actor at the aerodrome from seeing the "overall picture" regarding safety matters and may have caused: the lack of updates of official documents; the lack of compliance with ICAO Annex 14 standards; the fact that no aerodrome operations manual had been established; and the fact that an effective system for reporting deviations was not in place;
- Fear of sanctions discouraged the self-reporting of incidents and individual mistakes;
- Documentation provided by Aeronautical Information Publication (AIP) Italy and by Jeppesen was not consistent with the Milan Linate Airport layout;
- SAS flight support documentation was not consistent with the airport layout;
- Taxiways had not been designated in a logical manner (in a clockwise direction with north as the starting point, the taxiways had been designated R1, R2, R3, R4, R6 and R5);
- Markings on the West apron dedicated for general aviation were insufficient and not in conformity with ICAO provisions;
- The West apron was without signs: Published aerodrome documents were out of date and inaccurate, so written taxi instructions available to Cessna flight crew differed from verbal instructions issued by controller;
- Aerodrome tower controllers “declared that they ignored the existence” of markings such as S4.
- There was no ground radar system in operation at the aerodrome. The aerodrome had purchased a state of the art Norwegian ground radar system 6 years earlier

but the equipment had never been installed. The previous ground radar system had been uninstalled and had been deactivated for many years;

- Documentation regarding TWY R5 and R6 movements was complex and procedures were poorly described; and
- Required markings, lights and signs either did not exist in the case of Taxiway R6 or were “in dismal order and were hard to recognize especially in low-visibility conditions (R5 and R6)”.

The report also states that equipment which had been installed near the intersection of Runway 18L/36R and Taxiway R6 for the purpose of preventing runway incursions had been deactivated several years previously. The ground controller had no control over the fight cross bars located on Taxiways R5 and R6 and could not adjust taxiway centreline lights to reflect the taxi clearance.

Radiotelephony phraseology used by controllers and pilots did not conform with ICAO phraseologies and it was found that these deviations from standard phraseology were common practice. Analysis indicated that internal quality insurance regarding compliance with standard phraseology was not adequate in the Tower.

The investigation found that the taxi instructions issued to the Cessna by the ground controller were correct, but the readback was incomplete, the controller did not detect the error in the Cessna pilot's readback, and omissions by the pilot were left uncorrected.

In citing causes for the accident, the report indicates that the Cessna crew's situational awareness was diminished by inaccurate charts and a lack of visual aids. Evidence came to light that the Cessna crew were not qualified to operate in conditions where visibility was less than 400m.

The accident investigation report also points out that despite the low-visibility conditions, ranging from 50 to 100 meters at the time of the accident, operational procedures allowed a high volume of aircraft movements.

Controller workload was also very high, with radio communications conducted in more than one language.

7.2 Reviewing Gathered Data

The raw data collected is sorted into categories represented in the SHEL Model, as depicted in Table 7.1 below.

Table 7.1
Data Sorted using SHEL Model

People	Hardware	Software	Environment	Organisation
Cessna crew used the wrong taxiway and entered runway without specific clearance	No signs and incorrect markings TWY R6	AIP Italy and Jeppesen published information not consistent with airport layout	Low visibility at time of accident	Aerodrome standard did not comply with ICAO Annex 14 , required marking, lights and signs
Cessna crew not qualified to takeoff in low visibility conditions present at time of accident	Original equipment for prevention of runway incursions had been deactivated for several years	Operational procedures allowed high traffic volume in reduced visibility conditions	Heavy traffic and low visibility meant high workload situation for controllers	No functional SMS was in operation
Radio communications not performed using standard phraseology	Markings, lights and signs on TWY R6 either did not exist or hard to recognise under conditions	Runway holding positions unknown to ATC as not included in official documents		Aerodrome had not installed new ground radar system that they had received 6 years earlier
ATC did not realise that the Cessna was on TWY R6	New ground radar system received in 1994 had not been installed	Documentation regarding TWY movements complex and procedures poorly described		Internal Quality Assurance re compliance with standard phraseology not adequate
GND controller did not identify the actual Cessna position through radio traffic	Runway guard lights not present on any TWY	Published aerodrome documents out of date and inaccurate		
GND controller issued taxi clearance to main apron even though position reported by Cessna had no meaning to him	Stop bars not controllable			
ATCO did not detect Cessna crew readback error				
Pressure on Cessna crew to commence flight despite prevailing weather				

7.3 Conducting the SOAM Analysis

The facts collected within the investigation are now examined one by one and tested against the definitions of each element of the SOAM analysis process to determine whether and where they may fit in the SOAM Chart. It can be useful to work through the SOAM elements in order (from right to left), beginning with Absent and Failed Barriers, however this is not essential in practice. Less experienced investigators may in fact find it easier to begin with the more obvious elements, such as Contextual Conditions.

Whenever there is uncertainty about how a particular fact should be classified, it is helpful to refer back to the definitions and check questions provided for each SOAM element (see Section 6, and check questions below).

7.3.1 Identifying Absent or Failed Barriers

Check question for Barriers:

Does the item describe a work procedure, aspect of human awareness, physical obstacle, warning or control system, or protection measure designed to prevent an occurrence or lessen its consequences?

The Absent or Failed Barriers which can be identified in the Milan Linate case study are depicted in Table 7.2:

Table 7.2
Absent or Failed Barriers Identified

Absent or Failed Barriers	(Type) [44]
New ground radar system purchased in 1994 had not been installed	Detection
Previous ground radar system had been uninstalled and deactivated for many years	Detection
Runway guard lights not present on any TWY	Detection

7.3.2 Identifying Human Involvement

Check question for Human Involvement:

Does the item describe an action or non-action taking place immediately prior to, and contributing to the occurrence?

Table 7.3 below details the Human Involvement factors identified in the Linate case study.

(Space Left Intentionally Blank)

[44] Note that it is **not essential** to determine the *type* of barrier in each case. This information is provided here for instructional purposes only.

Table 7.3
Human Involvement Identified

Human Involvement	(Type)
Cessna crew used the wrong taxiway and entered runway without specific clearance	Incorrect action plan
GND Controller did not identify Cessna was in the incorrect position from the position report given by Cessna crew	Incorrect interpretation
Controller did not detect error in Cessna pilot's readback of initial taxi instruction	Incorrect interpretation *(ATCO heard the readback but did not interpret it as wrong)*
Cessna crew operated in low visibility conditions without required qualifications	Violation

7.3.3 Identifying Contextual Conditions

Check question for Contextual Conditions:

Does the item describe an aspect of the workplace, local organisational climate, or a person's attitudes, personality, performance limitations, physiological or emotional state that helps explain their actions?

Table 7.3 depicts the Contextual Conditions prevailing in the Linate accident:

Table 7.3
Contextual Conditions Identified

Contextual Conditions	(Type)
Heavy fog - reduced visibility of about 200m	Workplace (Environment)
Lack of location signs and markings on West Apron affected Cessna crew SA	Workplace
Potential pilot confusion over TWY	Human Performance Limitations
Written taxi instructions available to Cessna flight crew differed from ATC instructions	Workplace
Runway holding positions not included in official documents so unknown to ATC	Workplace
High workload situation for controllers due to heavy traffic and low visibility	Human Performance Limitations
Common for controllers not to use standard phraseology	Organisational Climate
Pressure on Cessna crew to commence flight despite prevailing weather	Workplace

7.3.4 Identifying Organisational Factors

Finally, organisational factors are determined from the set of collected facts analysed and sorted to date. Note however that some organisational factors may not have been identified in the initial data gathering phase of the investigation. Each confirmed contextual condition should at this point be reviewed to see if it can be explained by one or more organisational factors. In the Linate case study for example, *"pressure on the Cessna crew to commence flight despite prevailing weather"* is an identified contextual condition. By asking "What would explain this?", an organisational factor involving Competing Goals can be identified to account for time pressure on the crew, and this factor should be added to the list.

Note that the Organisational Factor categories are not mutually exclusive, and that a particular finding may appear to fit under more than one category. The exact classification need not be a matter for undue deliberation or concern, given that all identified organisational factors will be addressed by a specific recommendation for remedial action. For research purposes, for example where organisational factors are being aggregated across a large sample of incidents, a particular finding that overlaps two or more categories can be counted twice.

Check question for Organisational Factors:

Does the item describe an aspect of an organisation's culture, systems, processes or decision-making that existed before the occurrence and which resulted in the contextual conditions or allowed those conditions to continue?

The Organisational Factors identified as relevant to the Linate runway incursion accident are listed in Table 7.4 below.

Table 7.4
Organisational Factors Identified

Organisational Factors	(Type)
Documentation re TWY R5/R6 movements complex and procedures poorly described	(PP) Policies and Procedures
Aerodrome standard did not comply with ICAO Annex 14 required marking, lights and signs	(EI) Equipment and Infrastructure
Published aerodrome documents out of date and inaccurate	(PP/CM) Policies and Procedures & Change Management
Aerodrome had not installed new ground radar system that they had received 6 years earlier	(CG/EI) Competing Goals/ Equipment and Infrastructure
Operational procedures allowed high traffic volume in reduced visibility conditions	(PP/CG) Policies and Procedures & Competing Goals
Internal Quality Assurance re compliance with standard phraseology not adequate in Tower	(AC) Accountability
Lack of centralised Safety Management System	(EE) External Env
Schedule / customer service goals placed ahead of safety (Cessna owners)	(CG) Competing Goals

7.4 The SOAM Analysis Chart

The final step under SOAM is to convert the analysis data generated above into a SOAM Analysis Chart, as depicted in Figure 7.1 below.

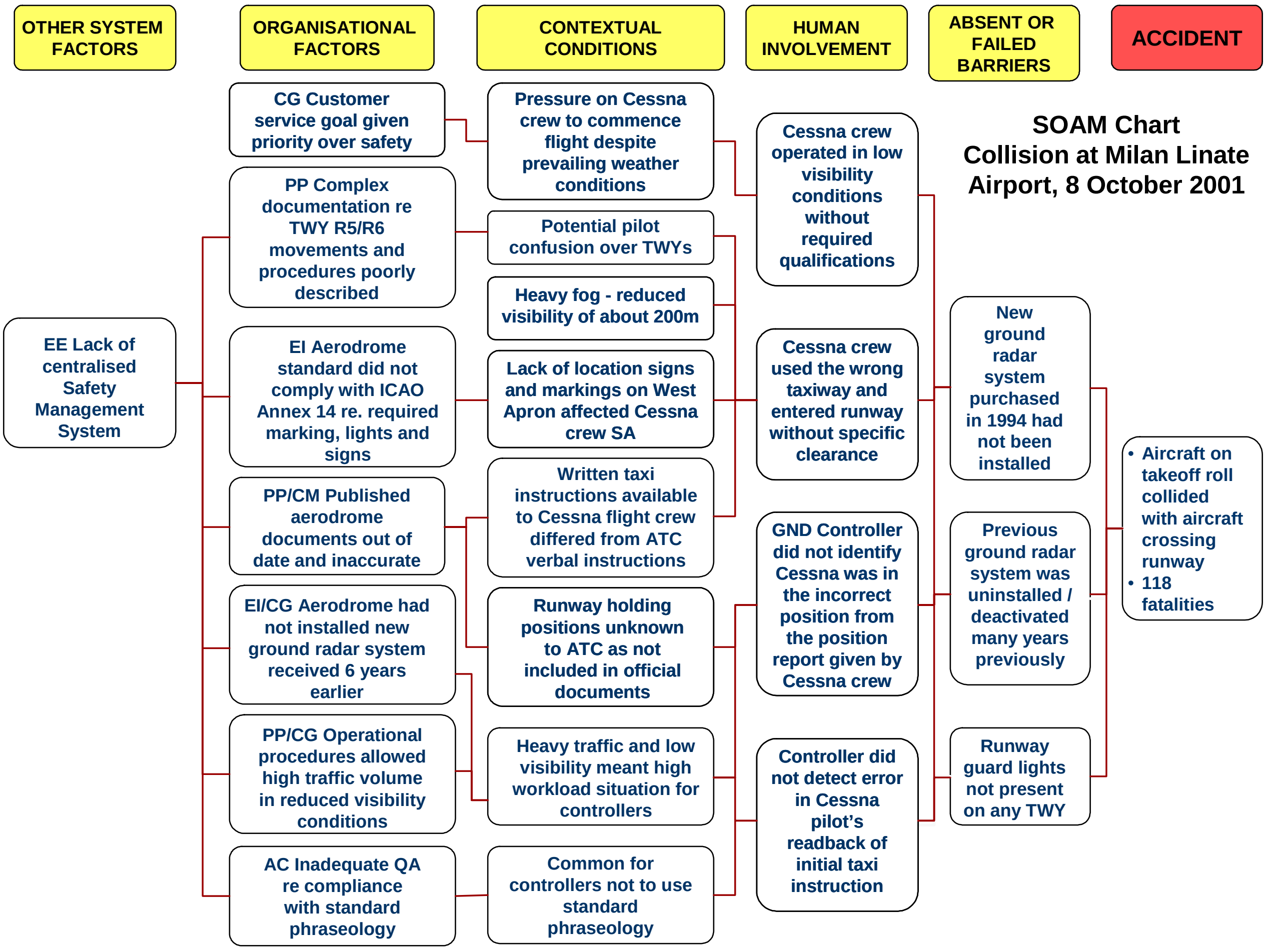


Figure 7.1
SOAM Analysis Chart for Milan Linate accident

As indicated above, two further worked examples of the SOAM analysis process are included at Appendices B and C to this document.

(Space Left Intentionally Blank)

8. FORMULATING RECOMMENDATIONS

8.1 Introduction

The formulation of recommendations for corrective action is a critical element of the occurrence investigation process. The relevance, quality and practicality of the remedial recommendations made at the conclusion of an investigation will determine their acceptability to those in a position to implement safety improvements. This section describes some of the common weaknesses in the way recommendations are formulated during an investigation, and describes the logical process within SOAM for generating recommendations that:

- Are directly and clearly linked to the results of the analysis
- Are focussed on findings that are amenable to corrective action
- Reduce the likelihood of a re-occurrence of the event, and/ or reduce risk

Experience in occurrence investigations across a range of industries suggests that report recommendations are often the weak link in the investigation process, failing to gain credibility or be implemented because they:

- Are focused on individuals and their errors or violations, rather than systemic deficiencies;
- Are too specific and prescriptive, and cover subject matter outside the expertise of the investigators;
- Are too general or vague to be meaningful or practical;
- Are not clearly linked to the facts or conclusions of the investigation about contributing factors, and
- Are perceived to reflect a personal agenda or bias of the investigator(s), rather than objective corrective actions pertinent to the occurrence under investigation.

Therefore, in developing recommendation investigators should make sure they clearly address two elements of the systemic analysis process:

- The barriers that were deficient (absent or failed), and
- The organisational factors

Recommendations should be targeted towards these main elements and include specific reference to the individual, position or organisation to be allocated responsibility for implementing the recommendation. It may also be appropriate to include realistic maximum compliance times for each recommendation.

Targeting recommendations towards organisational factors and deficient barriers is consistent with the logic of the Reason Model and the accepted view of error management. Errors are part of the human condition and cannot be eliminated. As such, attempts to achieve this through additional training, harsher sanctions or more direct supervision will meet with limited success. To paraphrase Reason, errors are like mosquitoes – it is impossible to swat them all. It is far better to “drain the swamps” in which they breed. In the context of corrective safety actions, this means addressing the contextual conditions that precipitate error.

As demonstrated by the Reason Model, contextual conditions are mostly products of organisational influences (the exception being true environmental factors, such as weather, terrain and other natural phenomenon). Addressing organisational factors with corrective actions is designed to change the conditions under which people work, so that the factors which encourage errors and violations are diminished.

There is a further advantage in directing corrective actions to the higher elements of the organisation and system in which occurrences are set. Improvements made to these more global deficiencies will have a much wider impact on future accident prevention than addressing local conditions. Re-designing a company-wide rostering system for example, will potentially have greater total benefit in reducing employee fatigue than implementing local fatigue management strategies such as more frequent breaks or napping.

The SOAM process requires that each failed or absent barrier should be addressed by at least one recommendation for corrective action. Each identified organisational factor should also be addressed by at least one recommendation, unless this factor has already been covered by a recommendation addressing barriers. For example, a warning system that did not operate effectively may be identified as a failed barrier as well as an equipment and infrastructure and/or maintenance management factor at the organisational level, but a single recommendation for corrective action would suffice.

Ensuring that recommendations correspond in this way with the lists of identified barrier failures and organisational factors will ensure that all latent conditions unearthed by the investigation analysis processes are addressed by recommended remedial action/s. It can also help to eliminate the problem of extraneous recommendations being made by exuberant investigators on matters of personal interest which were not identified as contributing factors in the occurrence at hand.

8.2 Assessing the Impact of Recommendations

One means of optimising the effectiveness of recommendations is to conduct a formal analysis of their potential impact. This provides a more detailed picture of considerations such as when and how their impact will be felt, and at what cost. The assessment of impact is typically shown in a matrix relating the degree of effect on safety (see Table 8.1) to the timeframe required to implement the recommended action or change. An example Impact Assessment Matrix is shown in Table 8.2.

Table 8.1
Levels of Potential Benefit

Potential Benefit	Definition
Substantial benefit	Benefits will impact substantially on ATM system safety. Implementation will lead to a measurable reduction in risk and be instrumental in preventing accidents.
Significant benefit	Benefits will be closely related to ATM system safety. Implementation will be closely linked to the prevention of incidents and risk reduction.
Moderate benefit	Benefits will have some effect on ATM system safety and implementation may have some degree of impact on reducing the potential for critical events.
Minimal benefit	Benefits will have limited influence on ATM system safety or effectiveness.
No significant benefit	Recommendations make almost no impact on ATM system safety and can be considered non-essential.

Table 8.2
Example Impact Assessment Matrix

Impact Assessment Matrix					
Potential Benefit	Implementation Timeframe				
	< 5 Days	5 – 30 Days	30 Days - 6 Months	6 Months – 1Year	> 1 Year
Substantial	Substantial	Substantial	Significant	High	Moderate
Significant	Substantial	Significant	High	Moderate	Low
Moderate	Significant	High	Moderate	Low	NSI
Low	High	Moderate	Low	NSI [45]	NSI
No significant benefit	Moderate	Low	Low	NSI	NSI

The Impact Assessment Matrix produces one of five Impact Levels for each combination of Potential Benefits and Implementation Timeframe. The Impact Levels are defined in Table 8.3 below.

Table 8.3
Impact Levels

Impact Assessment	Definition
Substantial	Control measure fully justified
High	Control measure justified
Moderate	Control measure may be justified, however other controls may prove more beneficial
Low	Not justified, other control measures must be considered
No significant impact	Other control measures must be used

The overall cost-benefit or pay-off from introducing changes of particular impact will depend also on the cost of introduction. Cost may be measured in terms of financial commitment and/or other resource-based dimensions, such as the difficulty of making change.

[45] No Significant Impact.

9. REFERENCES

Agenzia Nazionale Per La Sicurreza Del Volo (ANSV) (2004). *Final Report, N.A/1/04.* Rome: Author.

Airservices Australia. (1996). *Air Traffic Services Human Factors Guide.* Canberra: Safety and Quality Management Branch, Airservices Australia.

Australian Transport Safety Bureau. (1999). *Investigation Report 199904528.* Canberra: Author.

Australian Transport Safety Bureau. (2001). *Air Safety Occurrence Report 200002836.* Canberra: Author.

Bundesstelle für Flugunfalluntersuchung (BFU). (2004). *Investigation Report AX001-1-2/02*. Germany: Author.

Bureau of Air Safety Investigation (1991). *Special Investigation Report B/916/3032: Near Collision at Sydney Airport, 12 August 1991.* Canberra: Author.

EATMP Human Resources Team (1999*). Human Factors Module – A Business case for Human Factors Investment.* (HUM.ET1.ST13.4000-REP-02). Brussels: EUROCONTROL.

EATMP (2002). *SOFIA Reference Manual (Edition 1.0, 22 October 2002)*. Brussels: EUROCONTROL.

EATMP. (2003). *Guidelines for the Investigation of Safety Occurrences in ATM. (Edition 1.0, 03 March 03)*. Brussels: EUROCONTROL.

EATMP (2003). *The Human Error in ATM Technique (HERA-JANUS), (Edition 1.0, February 2003)*. Brussels: EUROCONTROL

Edwards, E. (1972). Man and machine: Systems for safety. In *Proceedings of British Airline Pilots' Association Technical Symposium* (pp. 21-36). London: BALPA.

EUROCONTROL. Strategic Safety Action Plan Work Breakdown Structure. Requirement 2.15. Brussels: Author.

EUROCONTROL. (1999). *EAM2/GUI1: ESARR 2 Guidance to ATM Safety Regulators, Severity Classification Scheme for Safety Occurrences in ATM (Edition 12-11-1999)*. Brussels: Author.

EUROCONTROL. (2000). *ESARR 2: Reporting and Assessment of Safety Occurrences in ATM. (Edition 2.0, 03.11.2000).* Brussels: Author.

EUROCONTROL. (2003). *EAM2/GUI5: Harmonisation of Safety Occurrence Severity and Risk Assessment. (Edition 0.1, 05 June 2003).* Brussels: Author.

EUROCONTROL. (2004). *EAM2/GUI6: Establishment of "Just Culture" Principles in ATM Safety Data Reporting (Edition 0.1, 25 November 2004)*. Brussels: Author.

Hollnagel, E. (2000). *Human Reliability Analysis and Risk Assessment*. Training Seminar presented at The Fifth Australian Aviation Psychology Symposium, Manly, November 2000.

Hollnagel, E. (2003). Barrier Analysis and Accident Prevention. In Edkins, G. & Pfister, P. (Eds.) *Innovation and Consolidation in Aviation*. Aldershot, UK: Ashgate.

Hollnagel, E. (2004). *Barriers and accident prevention.* Aldershot, UK: Ashgate.

ICAO Journal (2004). *Numerous factors contributed to fatal runway incursion at Milan Linate Airport.* Accessed online July 2004: http://www.airmanshiponline.com/july2004/05-Numerous%20factors_ICAO_J.pdf

International Civil Aviation Organization. (2001). *Annex 13 to the Convention on International Civil Aviation: Aircraft accident and incident investigation, Ninth edition, July 2001.* Montreal: Author.

Johnson, C. (2005). *Review of ANSV Linate Report. Version 1, 8/02/2005*. Glasgow: Glasgow Accident Analysis Group, University of Glasgow.

Maurino, D.E., Reason, J., Johnston, N., & Lee, R.B. (1995). *Beyond aviation human factors*. Aldershot, UK: Ashgate. (See Tables 1.2 and 1.3).

Rasmussen, J. (1982). Human errors: a taxonomy for describing human malfunction in industrial installations. *Journal of Occupational Accidents, 4,* 311-333.

Reason, J. (1990). *Human error*. New York: Cambridge University Press.

Reason, J. (1991). Identifying the latent causes of aircraft accidents before and after the event. *Proceedings of the 22nd ISASI Annual Air Safety Seminar,* Canberra, Australia. Sterling, VA: ISASI.

Reason, J., & Hobbs, A. (2003). *Managing maintenance error: A practical guide.* Aldershot, UK: Ashgate.

Transportation Safety Board of Canada (2000). *Aviation Investigation Report A00P0199.* Quebec: Author.

Transportation Safety Board of Canada (2002). *Aviation Investigation Report A02W0115: Loss of Separation, Edmonton ACC, 27 June 2002.* Quebec: Author.

(Space Left Intentionally Blank)

10. GLOSSARY

Term	***Definition***
Attitudes and Personality Factors	Factors relating to individual attitudes and personality evident at the time of an occurrence that influence the performance of the operator.
Barriers	Final lines of defence that protect the system against technical and human failures. They are work procedures, aspects of human awareness, physical obstacles, warning or control systems, or protection measures designed to prevent an occurrence, or lessen its consequences. One objective of the investigation process is to identify these absent or failed barriers and take action to strengthen these.
Confirmation bias	The tendency to look for confirming cues or supporting evidence only. In other words, looking for data that *confirms* our initial decision, and overlooking evidence that would show us we are wrong. Because of this so-called “confirmation bias”, it is very difficult to change an initial decision.
Contextual Conditions	The conditions that exist immediately prior to a safety occurrence that directly influence performance in the workplace. These can increase the likelihood of an error or violation being committed. Known in the Reason model as psychological precursors of unsafe acts. SOAM categorises these into: workplace conditions; organisational climate; attitudes and personality factors; human performance limitations; and physiological and emotional factors.
Critical event	Any point during an occurrence at which the operator had the opportunity to detect that the situation was unsafe and/or the operator had the opportunity to recover the situation safely.
Decision ladder	An information processing model that can be used to model the behaviour of an operator and identify their involvement in an occurrence in terms of their observation, diagnosis, choice of goal, planning and decision making, and execution of action.
Error (Human Error)	Definition by James Reason in "Human Error" (1990). "Error is intimately bound up with the notion of intention. The term 'error' can only be meaningfully applied to planned actions that fail to achieve their desired consequences without the intervention of some chance or unforeseeable agency. An error is NOT intentional. You make an error when: what you do differs from what you intended; or your plan was inappropriate."
Human involvement	Refers to the actions or non-actions that immediately contributed to the safety occurrence. Known in the Reason model as active failures and unsafe acts (commonly known as errors and violations).

Term	***Definition***
Human Performance Limitations	Factors relating to the limitations in human information processing that increase the likelihood of an error or violation being committed.
Just Culture	An organisational perspective that discourages blaming the individual for an honest mistake that contributes to an accident or incident. Sanctions are only applied when there is evidence of a violation or intentional reckless or negligent behaviour.
Negative transfer	A condition in which previous experience causes interference with the learning of a new task, usually due to conflicting stimuli or response requirements.
NOTAMs	Notices to Airmen
Organisational Climate	In SOAM this refers to factors relating to organisational issues (such as supervisory behaviour, norms, culture and morale) that exist at the time of an occurrence and influence the performance of the operator.
Organisational Factors	Factors at the organisational level that pre-exist the occurrence and produce, or allow the existence of, conditions that influence the actions of individuals in the workplace. They may go unnoticed for a long period of time until they combine with other conditions and individual actions to breach the barriers of the system and cause an occurrence.
Perceptual set	The tendency to perceive a situation in a particular way due to our past experiences with similar situations.
Physiological and Emotional Factors	One of the categories of Contextual Conditions that exist at the time of an occurrence and influence the performance of the operator.
SHEL Model	The SHEL model provides a descriptive framework of human factors principles that can guide the collection of data in an investigation. The four components of the model are: Liveware (the human element); Software (procedures, manuals, symbology, etc.); Hardware (equipment, workplace layout, etc.); and Environment.
Safety culture	The set of beliefs, norms, attitudes, and practices within an organisation concerned with minimising exposure of the workforce and the general public to dangerous or hazardous conditions. It promotes a shared attitude of concern and responsibility for safety (adapted from ICAO).
Safety occurrence	An accident, serious incident or incident, as well as other defects or malfunctioning of an aircraft, its equipment and any element of the Air Navigation System (from HEIDI).

Term	***Definition***
Situation assessment	Using our experience to assess the whole situation, often recognising it as an instance of a familiar type, a "typical situation". The familiarity of the situation allows you to call up from memory a mental template of how to proceed. If the situation is not familiar, further situation assessment is required in order to make a decision.
Situation awareness	Having a clear and up to date understanding of what is going on around oneself and being able to answer relevant questions at all times.
Violation	A deliberate deviation from rules, regulations or procedures. A person committing a violation fully intends their actions and is aware that they are deviating from rules and procedures.
Workplace conditions	Factors relating to the work environment, HMI issues and procedures that exist at the time of an occurrence and can increase the likelihood of an error or violation being committed.

(Space Left Intentionally Blank)

APPENDIX A

THE DECISION LADDER MODEL AND INTERVENTIONS TO ADDRESS ERROR PROMOTING CONDITIONS

Decision Ladder Model of Rasmussen

The Decision Ladder model of Rasmussen (1982) [46] is an information processing model that can be used in conjunction with SOAM methodology. Like other similar models, it assumes that information is processed in stages, beginning with the detection of information and ending with the execution of an action. The Decision Ladder uses a six-step sequence which has been adapted for use within SOAM to present a simplified view of common ATCO tasks. Using this model, ATCO involvement in a safety occurrence can be analysed in terms of:

- Observation (ie., attention, perception and vigilance)
- Interpretation (ie., situation assessment)
- Choice of goal
- Strategy development
- Choice of action plan
- Execution of action plan

The ATM adaptation of the Decision Ladder technique for use within SOAM is shown in Figure A.1 below.

The Decision Ladder technique facilitates generation of a logical and complete description of the steps that might be performed by a controller when completing routine tasks or dealing with non-standard situations. It guides the investigator by providing check questions at each step against which to map the controller's behaviour. The labels (observation, interpretation, etc.) identify at which point in the behavioural process an error occurred. Although the word "error" is a widely used and accepted term, in this model the underlying information processing breakdowns are labelled "missing detection", "incorrect interpretation" etc., rather than "detection error/failure" or "interpretation error/failure". This is because the words error and failure have negative connotations that often incorrectly encourage the notion of blame toward individuals involved in a safety occurrence.

[46] Rasmussen, J. (1982). Human errors: a taxonomy for describing human malfunction in industrial installations. *Journal of Occupational Accidents, 4,* 311-333.

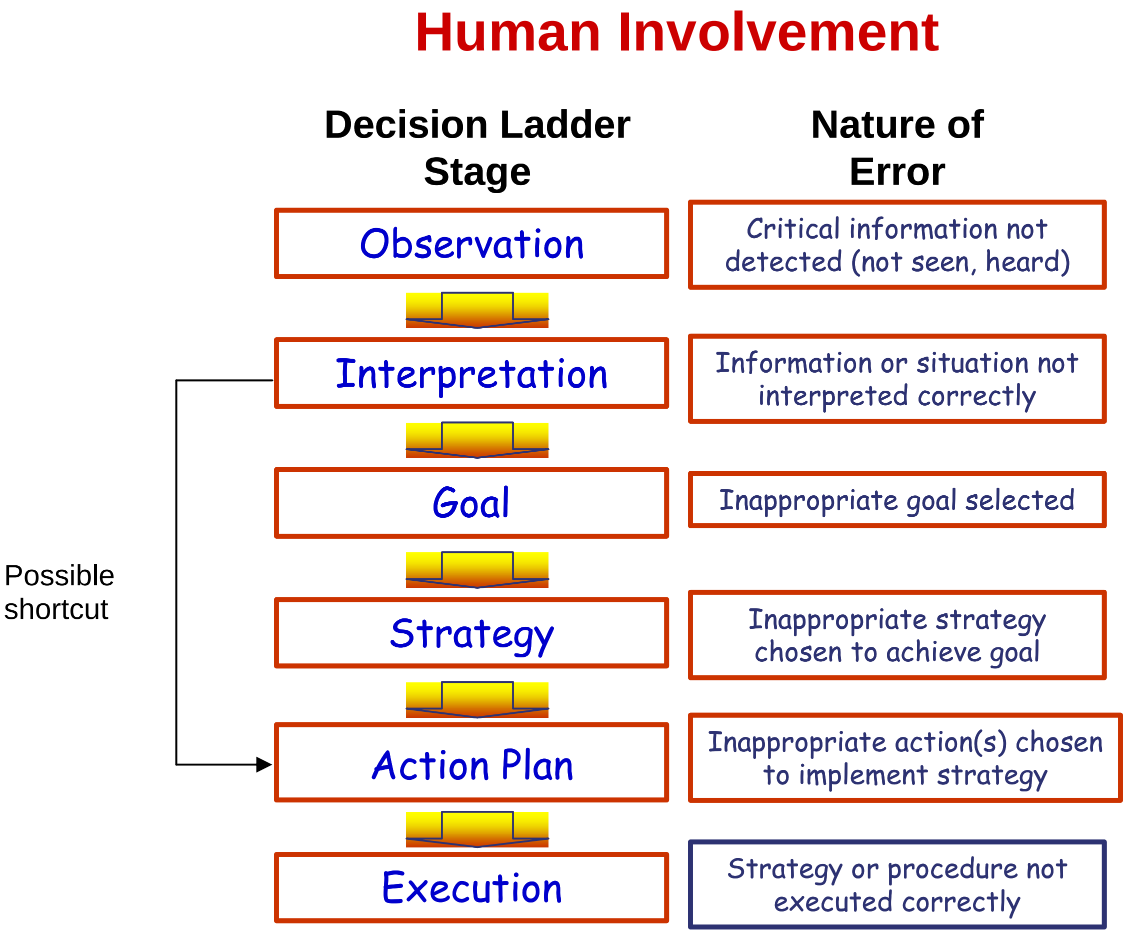


Figure A.1
Decision Ladder for
Identifying Human Involvement in Safety Occurrences

Table A.1 below presents some examples of some potential causes of errors which are described in terms of the contextual conditions that may promote error. Also included are examples of possible interventions based on these potential causes. The suggested interventions are aimed at reducing the probability of error. These lists are **suggestions only** and are by no means intended to be inclusive or prescriptive.

(Space Left Intentionally Blank)

Table A.1
Interventions to Address Error Promoting Conditions

Decision Ladder Stage	Potential Causes	Possible interventions
Observation	Physiological and Emotional Factors, for example: • Stress • Fatigue Workplace Conditions, for example: • Noisy work environment • Interface design issues, e.g., mode confusion, poor display • Time pressures	Interventions could be directed at addressing conditions that increase the possibility that these sorts of attentional failures will occur, for example: • Raising awareness of the importance of vigilance as a defence against system safety excursions • Addressing interface design issues, e.g., displays, communication equipment • Addressing working conditions and the work environment to ensure that controllers are in the best mental and physical shape for work
Interpretation	Human Performance Limitations, for example: • Poor situational awareness • Inaccurate knowledge • Inadequate training • Unfamiliarity with task • Perceptual set (the tendency to perceive a situation in a particular way due to our past experiences with similar situations)	Interventions could be directed at addressing the knowledge shortfalls of controllers, for example: • Specific training to address common gaps in knowledge • Training in situation assessment, in particular for commonly misdiagnosed situations/patterns • Sharing of information, knowledge and experiences from previous incidents
Goal	Workplace Conditions, for example: • Poor task prioritisation • Inadequate risk assessment Human Performance Limitations, for example: • Inadequate training • Inaccurate knowledge • Poor problem solving	Interventions could be directed at improving the controller's ability to handle emergency, abnormal and unfamiliar situations, for example: • Improved training for emergency situations • Training in risk assessment to help controllers consider safe options in such situations

Table A.1 (continued)
Interventions to Address Error Promoting Conditions

Decision Ladder Stage	Potential Causes	Possible interventions
Strategy	Human Performance Limitations, for example: • Inadequate training • Inaccurate knowledge • Poor problem solving	Interventions could be directed at improving knowledge about how to respond in emergency, abnormal and unfamiliar situations and equipping controllers with improved decision making and problem solving skills.
Action Plan	Human Performance Limitations, for example: • Inadequate training • Insufficient knowledge of procedures	Interventions could be directed at: • Improving knowledge of procedures and training in the application of procedures in different situations • Making ambiguous procedures clearer to understand
Execution	Physiological and Emotional Factors, for example: • Stress • Fatigue Workplace Conditions, for example: • Noisy work environment • Time pressures	Interventions should be directed at changing the personal factors or the conditions in the workplace that make it more likely that these sorts of attentional failures will occur, for example: • Addressing shift patterns and working conditions to ensure that controllers are in the best mental and physical shape for work • Making improvements to the work environment to make it as free from distractions and noise as possible.

APPENDIX B

SOAM Case Study – Near Collision at Sydney Airport, August 1991 [47]

Overview

On Monday 12 August 1991, at 1023 hours Eastern Standard Time (EST), a McDonnell Douglas DC-10 Series 30ER aircraft (DC-10) operated by Thai Airways International (THA485) was landing on runway 34 at Sydney (Kingsford Smith) Airport. The DC-10 was carrying 185 persons. At the same time, an Airbus A320-211 aircraft (A320), operated by Ansett Australia (VH-HYC) was on a short final approach for landing on runway 25. The A320 was carrying 110 persons.

Runways 34 and 25 intersect, and at the time of the incident, SIMOPS were in progress with aircraft landing on the intersecting runways. Traffic had been flowing at a rate of approximately 50 movements per hour but had reduced to approximately 20 movements per hour at the time of the occurrence. The Senior Tower Controller (STWR) stated that he considered these traffic conditions to be ‘light’.

The relevant Automatic Terminal Information Service (ATIS) broadcast recording indicated that SIMOPS were in progress and that runway 25 was nominated for departures, while runways 25 and 34 were nominated for arrivals. The ATIS advised aircraft to ‘expect traffic on the crossing runways’. Landing instructions to the crew of the DC-10 included a requirement for the aircraft to be held short of the intersection of runways 34 and 25.

At 10.23:39 EST, THA485 landed on runway 34. With the expectation that THA485 would hold short of the runway intersection as required under SIMOPS procedures, the Aerodrome Controller (ADC 1) had cleared VH-HYC to land on runway 25. At 10.23:57 EST, VH-HYC initiated its landing flare. The progress of THA485’s landing was being monitored by control tower personnel and by the Captain of VH-HYC. At 10.24:02 EST, ADC 1 assessed that THA485 was approaching the runway intersection at an excessive speed. Believing that the DC-10 would not stop before the intersection, the ADC 1 transmitted the instruction ‘Thai 485 stop immediately, stop immediately’. At that time, the Captain of THA485 applied heavy braking.

At 10.24:04 EST, the Captain of VH-HYC, assessing that THA485 might not stop before the intersection and that there was a possibility of a collision between the two aircraft, initiated a go-around from a height of 2 ft above the runway. At 10.24:14 EST, VH-HYC passed through the centreline of runway 34 at a radio altitude of 52 ft (15.85 m). At this time THA485 had almost stopped, with the nose of the aircraft approximately 35 m inside the 07/25 runway strip and approximately 40 (± 20) m from the runway centreline.

At their closest point the separation between VH-HYC and THA485 was 11 (± 2) m vertical distance between the left wingtip of the A320 and the top of the DC-10 fuselage. The horizontal separation at this point was 33 (± 20) m between the left wingtip of the A320 and the nose of the DC-10. This horizontal distance could not be computed as accurately as the vertical due to limitations in the recorded data which required it to be derived. In contrast, the vertical distance is far more precise because it was recorded directly from the aircraft radio altimeter onto the Digital Flight Data Recorder (DFDR).

[47] Material for this case study was adapted from the BASI investigation report: Bureau of Air Safety Investigation (1991). *Special Investigation Report B/916/3032: Near Collision at Sydney Airport, 12 August 1991.* Canberra: Author.

SIMOPS Procedures [48]

The SIMOPS procedures in use at the time of this occurrence suffered from a number of fundamental weaknesses. They relied heavily on near perfect human performance. There was no formal provision in the system to prevent two landing aircraft from arriving at the intersection at the same time, should the aircraft landing on one runway fail to stop, or should both be required to execute simultaneous go-arounds.

Although Australian SIMOPS procedures are based on SOIR procedures used in the USA, they appear to have evolved gradually to meet demands for increased traffic flow. The picture that emerges is one of a system that evolved by "patching on" features in response to outside pressures, rather than a system that was carefully designed and evaluated before it was put in place. No systems analysis was carried out prior to introduction of SIMOPS procedures to identify areas of excessive risk.

Communications and Phraseology

It is significant that although arriving aircraft received SIMOPS instructions on the ATIS with their landing clearance, the crews of A, B and C category aircraft were not required to give a separate acknowledgement of the SIMOPS instructions. In each case, the SIMOPS information was embedded in other information, so as a consequence a flight crew which was not expecting this message was less likely to hear it. The delivery of the SIMOPS hold-short instruction for the Thai Airways DC-10 was embedded in its landing clearance.

ATC Use of SIMOPS

At the time of the incident traffic conditions were light. Yet SIMOPS procedures were still in progress in a situation where the movement rate did not warrant their use. Given that use of SIMOPS added an increment of risk, its use at the time reduced the safety net unnecessarily. This risk, however, was deemed acceptable by the controllers when balanced against the economic imperative of improving traffic flow.

ADSO (AACC)

The AACC ADSO had prepared the FPS for the DC-10 in the early hours of the morning of 12 August. In preparing the FPS she incorrectly recorded the aircraft's PANS/OPS category as 'C' instead of 'D'. The ADSO indicated that in her experience the operation of PANS/OPS Cat D DC-10 aircraft into Sydney was relatively uncommon. At the time of preparing the FPS the ADSO was fatigued (having had 3 hours sleep in the preceding 24 hours) and also reported feeling physically ill. There is a latent condition present in the ADSO training requirements considered to be a safety deficiency: ADSOs are required to check the flight plans received for omissions, but they are not required, and nor are they trained, to interpret or validate flight plan data. In relation to the development of this occurrence the active failures and latent conditions involving the ADSO are not considered critical because, regardless of her incorrect categorisation of the aircraft (which led to the DC-10 crew not receiving LDA information), the DC-10 Captain knew he was required to stop before the runway intersection and had briefed his crew accordingly.

[48] It is noted that the SIMOPS procedures in place at the time of this occurrence were subsequently revised and as such the procedures discussed above do not represent current operational standards at Sydney Airport.

DC-10 Crew

The Captain and First Officer held Airline Transport Pilot Licenses (ATPL) appropriately endorsed for command of the DC-10 aircraft. The pilot trainee held a Commercial Pilot Licence (CPL) appropriately endorsed for co-pilot of the DC-10. There were no issues regarding crew recency or fatigue. The handling pilot was an inexperienced DC-10 co-pilot who had never before flown into Sydney. The crew received advice that SIMOPS were in progress via the ATIS. The Captain included the requirement to stop before the intersection in the pre-landing brief (based on his understanding of Australasian CAA NOTAM C11/89). The crew advised that at no time did they hear any ATC SIMOPS instruction to hold short of the intersection, nor were they aware of the A320 conducting its approach to land on runway 25.

It is possible that the DC-10 crew failed to perceive the SIMOPS transmission because it was embedded in the landing clearance. During the approach the Captain had the task of supervising and monitoring the performance of the inexperienced handling co-pilot. The crew reported they had an autobrake system malfunction on landing, as a result of which the Captain took control from the co-pilot during the landing roll. The crew also advised that they were unaware of the taxiway and intersection MAGS. These signs were small and would have been very difficult to read from an aircraft during the landing roll (at the time of the incident, there were no CAA standards for visual aids to conduct SIMOPS). The crew initially appear to have mistaken the intersection of taxiway C and runway 16/34 for the intersection of runways 25/34. Taxiway C is approximately 180m beyond the runway 25/34 intersection.

The investigation team believes that the combination of an inexperienced co-pilot flying the aircraft, the Captain's distraction by circumstances on the flight deck, and a misperception of the true location of the runway 34/25 intersection led to the aircraft not being stopped before the runway 07/25 flight strip.

A320 Crew

Both the Captain and First Officer held ATPLs appropriately endorsed for command and co-pilot of A320 aircraft respectively. There were no issues regarding crew recency or fatigue. The Captain had been monitoring the DC-10's landing and having advised the FO that the DC-10 was approaching too fast and there was a risk of collision, the Captain took control and initiated the go-around, saying "going around". The go-around was initiated with the A320 only 2ft from the runway with both engines at idle power. The FO indicated that he knew the Captain was taking control of the aircraft and relaxed his grip on the right sidestick. However, the DFDR readout indicated that neutral and nose-down inputs were made for some 12 s although the inputs from the FO's sidestick did not detract from the Captain achieving the desired aircraft attitude. In the A320 the inputs being made by each pilot on his sidestick cannot be sensed through his sidestick by the other. Had there been such a sense of movement between the two sidestick controllers, the co-pilot could have sensed the Captain's input as he initiated the go-around and released any pressure on his sidestick. As the aircraft was achieving the attitude required by the Captain he saw no requirement to activate the 'take-over button' to transfer control authority to his sidestick.

Weather

At the time of the incident there were no problems with visibility, the runways were dry and the crosswind components on runways 25 and 34 were 9 kts and 12 kts respectively.

SOAM Analysis

The following tables (B.1 through B.4) show the results from classification of facts from the Sydney SIMOPS incident into relevant SOAM categories.

Table B.1
Absent or Failed Barriers Identified

Absent or failed Barriers	(Type)
No “safety net” with SIMOPS in place	Restriction
Lack of positive sequencing and co-ordination of aircraft landing on runways 34 and 25	Restriction

Table B.2
Human Involvement Identified

Human Involvement	(Type)
ATC chose to use SIMOPS even though traffic movement rate did not warrant their use	Incorrect action plan
DC-10 Captain did not devote sufficient attention to the landing role	Incorrect execution
DC-10 crew mistook intersection of taxiway C and RWY 16/34 for the intersection of runways 25/34	Incorrect interpretation
DC-10 did not prepare to hold short of the intersection	Incorrect execution

Table B.3
Contextual Conditions Identified

Contextual Conditions	(Type)
Perceived time pressure on ATC	Workplace
Additional workload on Captain of DC-10 supervising an inexperienced co-pilot	Workplace
DC-10 crew had not been informed of the A320 landing simultaneously on RWY 25	Human Performance Limitation
SIMOPS procedures made no allowance for situation where an aircraft landing on RWY 34 did not stop before RWY 25 intersection	Workplace (procedures)
Captain concentrating on brake system malfunction	Human Performance Limitation
SIMOPS procedures deficient in that they required no positive acknowledgement of SIMOPS	Workplace (procedures)
SIMOPS instructions not obvious to DC-10 crew as embedded in other information given by controller in landing clearance	Workplace (procedures)

Table B.4
Organisational Factors Identified

Organisational Factors	(Type)
Economic imperative of improving traffic flow	(CG) Competing Goals
System evolution through 'patching on' features in response to outside pressure	(CM) Change Management
No CAA standards for visual aids to conduct SIMOPS	(PP) Policies and Procedures
No systems analysis carried out prior to introduction of SIMOPS procedures to identify areas of excessive risk	(RM) Risk Management
Inherent risk in SIMOPS procedures fundamentally weak and relied on near perfect human performance	(RM) Risk Management
SIMOPS procedures deficient in not requiring positive communication of information	(PP) Policies and Procedures

Note that factors which are not considered to have contributed directly to the occurrence, have been omitted from the above analysis.

(Space Left Intentionally Blank)

SOAM Analysis Chart

A completed SOAM chart for this occurrence is show below.

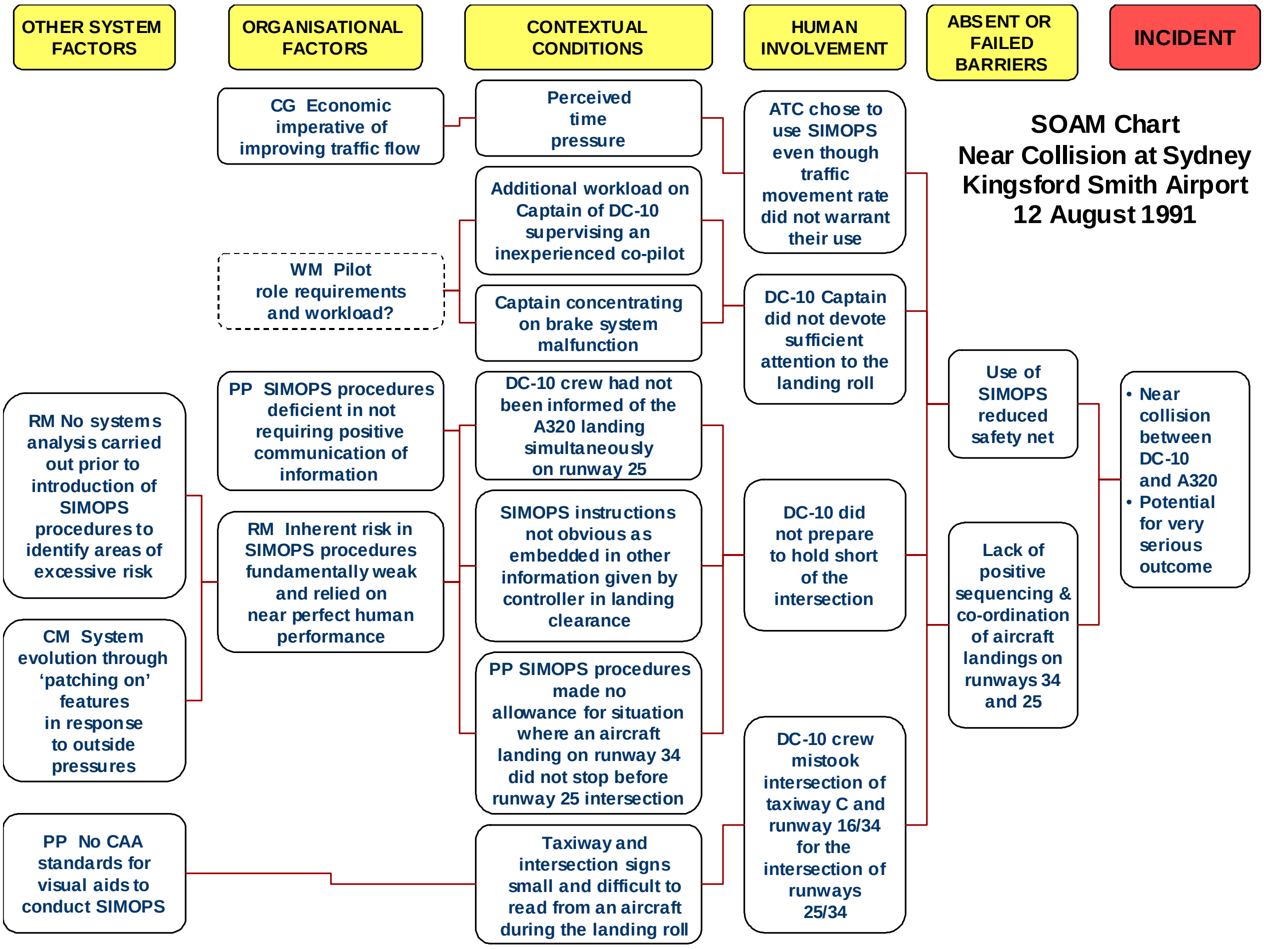


Figure B.1
SOAM Chart of Near Collision, Sydney 1991

(Space Left Intentionally Blank)

APPENDIX C

SOAM Case Study – Loss of Separation, Edmonton, Canada, 27 June 2002 [49]

Overview

This loss of separation occurred on the afternoon of 27 June 2002. At that time, C-GKGM, a BA3112 operating as Corpac Canada Ltd. (Corporate Express) CPB888, was en route under instrument flight rules (IFR) from Fort McMurray, Alberta, to Calgary International Airport, Alberta. C-FDMR, a SA227DC operating as Alta Flights (Charters Inc.) CNS213, was en route, also under IFR from Calgary International Airport to Edmonton City Centre Airport, Alberta. Because of extensive thunderstorm activity between Edmonton and Calgary and restricted airspace associated with the G-8 Conference at Kananaskis, Alberta, both aircraft were diverted east of their flight planned routes. At 1610 mountain daylight time, approximately 60 nautical miles southeast of Edmonton International Airport, the aircraft met on a nearly reciprocal heading at an altitude of 16,000 feet above sea level. They had vertical separation of 200 feet and lateral separation of 1.3 nautical miles in an area where 1,000 feet or five nautical miles is required. The aircraft passed in cloud and neither crew saw the other aircraft.

Factual Information

Both aircraft were being controlled by the Edmonton Area Control Centre (ACC). The loss of separation took place in the Red Deer sector of the Calgary en route specialty.

CPB888 was flight planned at an altitude of 16,000 feet above sea level (ASL) and given a heading of 175º magnetic to intercept the 354º radial of the Calgary VOR. When CPB888 passed from the La Biche, Alberta, en route sector to the Edmonton north terminal sector, its altitude of 16,000 feet was appropriate for the direction of flight. When this heading resulted in a track of about 164º because of westerly winds, 16,000 feet was then inappropriate. Control was handed off to the Edmonton departure sector, and then to the Red Deer en route sector. The aircraft remained at 16,000 feet.

CNS213 was flight planned from Calgary to Edmonton via V112 to the Edmonton VOR at 16,000 feet and proceeded at an initial altitude of 14,000 feet ASL. Five minutes before the occurrence, the Red Deer sector radar controller cleared CNS213 to maintain 16,000 feet. When the two aircraft were about 4.2 nautical miles apart, the Edmonton terminal arrival controller noticed the conflict and drew it to the attention of the Red Deer data controller by landline. The data controller then verbally relayed this information to the Red Deer radar controller who instructed CNS213 to descend immediately to 15,000 feet.

During their scanning of flight progress strips and the radar display, the Red Deer en route sector controllers did not detect the conflict between the aircraft. Neither aircraft was fitted with a traffic alert and collision-avoidance system (TCAS), nor were they required to be by Canadian regulations. There was no ground-based conflict alert system in operation in Edmonton ACC at the time of the occurrence.

For the three-day duration of the G-8 Conference at Kananaskis, Class F restricted airspace (CYR255) was established to prevent unauthorized aircraft from entering the area. Aircraft travelling west from Calgary had to be routed around the northeast corner of CYR255 in the Red Deer en route sector before proceeding west.

[49] Material for this case study was adapted from the TSB Canada investigation report: Transportation Safety Board of Canada (2002). *Aviation Investigation Report A02W0115: Loss of Separation, Edmonton ACC, 27 June 2002.* Quebec: Author.

Controller Workload

A complex traffic situation brought about by the release of aircraft following the Calgary terminal air stop, G-8 airspace restrictions, a 16/17 altitude split, and thunderstorm activity imposed a high workload on air traffic controllers in the Red Deer en route sector. Flow control, as a tool primarily aimed at traffic management in terminal areas, had an adverse effect on the en route sector in this occurrence.

With 13 aircraft operating in the Red Deer sector at the time of the occurrence, the traffic level was considered to be from moderate to high, with high complexity. During the 34 minutes preceding the incident, the Red Deer en route sector radar controller was involved in 311 communications by radio or landline in addition to unrecorded conversations between the two controllers. Flight crews reported that based on the number of radio transmissions, the Red Deer sector was very busy.

Both Red Deer sector controllers, as well as the supervisor, considered themselves to be somewhat tired near the end of their shifts because of the cumulative workload and extra vigilance associated with G-8 airspace activity.

ACC management had increased staffing in anticipation of a higher, more complex workload; however, three of the 11 specialty controllers were on a break. With the supervisor working a control position rather than bringing a controller back from break, personnel were not effectively managed in the Calgary en route specialty during a busy and complex traffic situation. Exercising his option of bringing at least one controller off break would have freed up the supervisor to assume supervisory duties rather than occupy a controller position. He then may have been able to assist the Red Deer controllers in managing traffic in their sector. The radar and data controllers, and the supervisor, indicated that they felt somewhat fatigued because of increased cumulative workload associated with G-8 activities and weather diversions.

Controller Involvement

CPB888 was allowed to operate at an altitude inappropriate for the direction of flight through the Edmonton terminal and Red Deer en route sectors of the Edmonton ACC. This reduced the safety margin required by the *CAR* for opposite direction traffic operating at segregated altitudes. Since much of the traffic in the sector spent a significant amount of time climbing or descending in association with the terminal areas, it had become normal among controllers to vector aircraft toward the TORON intersection at inappropriate altitudes, often without following *MANOPS* guidelines regarding implementation, hand offs, and strip marking.

Flight progress strips were not marked to alert controllers that CPB888 was operating at an inappropriate altitude for the direction of flight. This reduced the likelihood that controllers would detect a potential conflict with opposite direction traffic operating at appropriate altitudes.

The radar controller did not adequately scan the radar display for other traffic prior to clearing CNS213 to the altitude occupied by CPB888, and the conflict between the two aircraft went undetected.

Organisational Issues

The *Canada Flight Supplement* planning section states that altitudes inappropriate for direction of flight may be assigned by ATC at any time on the preferred routes between Edmonton and Calgary. This may also reduce the likelihood of pilots questioning the validity of the use of such altitudes.

The flight progress strips for both aircraft were not marked by the Red Deer en route sector data controller in accordance with *ATC MANOPS* instructions. The marking procedure was designed to alert controllers to potential conflicts arising from aircraft operating at altitudes inappropriate for the direction of flight. NAV CANADA did not check flight progress strips on a regular and random basis for conformance to standards regarding the issuance of altitudes and strip marking, NAV CANADA management personnel in the Edmonton ACC were unaware that Edmonton terminal and Red Deer sector controllers were not consistently adhering to mandatory procedures for altitude assignment.

Crew of CPB888

The crew of CPB888 filed 16,000 feet for the entire route, even though a change in track at the Edmonton VOR would warrant an altitude change. They anticipated remaining at 16,000 feet consistent with previous experience, and the turn to a direction which required a different altitude did not pose any concern. There are indications that pilots in local companies, including those involved in the occurrence, were accustomed to receiving altitudes inappropriate for the direction of flight through the Edmonton terminal and Red Deer en route sectors, and would seldom query controllers on the validity of these altitudes. This was likely due, in part, to the CFS planning section statement that pilots may be cleared at inappropriate altitudes for direction of flight on preferred routes between Edmonton and Calgary.

SOAM Analysis

The following tables (C.1 through C.4) show the results from classification of facts from the Edmonton incident into SOAM categories.

Table C.1
Absent or Failed Barriers Identified

Absent or failed Barriers	(Type)
Neither aircraft fitted with TCAS	Detection
No ground-based conflict alert system in operation at Edmonton ACC	Detection
Reduced safety margin for opposite direction traffic operating at segregated altitudes	Restriction
No alert of potential conflict from flight progress strips	Detection

Table C.2
Human Involvement Identified

Human Involvement	(Type)
Pilot of CPB888 did not query validity of inappropriate altitude	Incorrect action plan
CPB888 was allowed to operate at an altitude inappropriate for the direction of flight	Incorrect action plan
Red Deer route sector controllers did not detect the conflict between the two aircraft	Missed detection
Controller did not adequately scan radar display for traffic before clearing CNS213 to altitude already occupied by CPB888	Incorrect execution

Table C.3
Contextual Conditions Identified

Contextual Conditions	(Type)
Pilots accustomed to receiving altitudes inappropriate for direction of flight in this sector	Workplace
Normal practice among controllers to vector aircraft at inappropriate altitudes	Workplace
Both Red Deer sector controllers, as well as the supervisor, were fatigued near the end of their shifts	Human Performance Limitation
High concentration of complex air traffic in Red Deer sector at time of incident	Workplace
High workload due to inadequate management of personnel during busy and complex traffic situation	Workplace
Sector controllers not consistently adhering to mandatory procedures for altitude assignment	Organisational Climate
Extensive thunderstorm activity – controllers busy negotiating weather avoidance deviations	Workplace (environment)

Table C.4
Organisational Factors Identified

Organisational Factors	(Type)
Aircraft not required to be fitted with TCAS by Canadian regulations	(PP) Policies and Procedures
NAV CANADA management in Edmonton ACC did not check flight progress strips on a regular and random basis for conformance to standards regarding the issuance of altitudes and strip marking	(AC) Accountability
Canada Flight Supplement planning section states altitudes inappropriate for direction of flight may be assigned by ATC at any time on the preferred routes between Edmonton and Calgary	(PP) Policies and Procedures

SOAM Analysis Chart

A completed SOAM chart for this occurrence is show below.

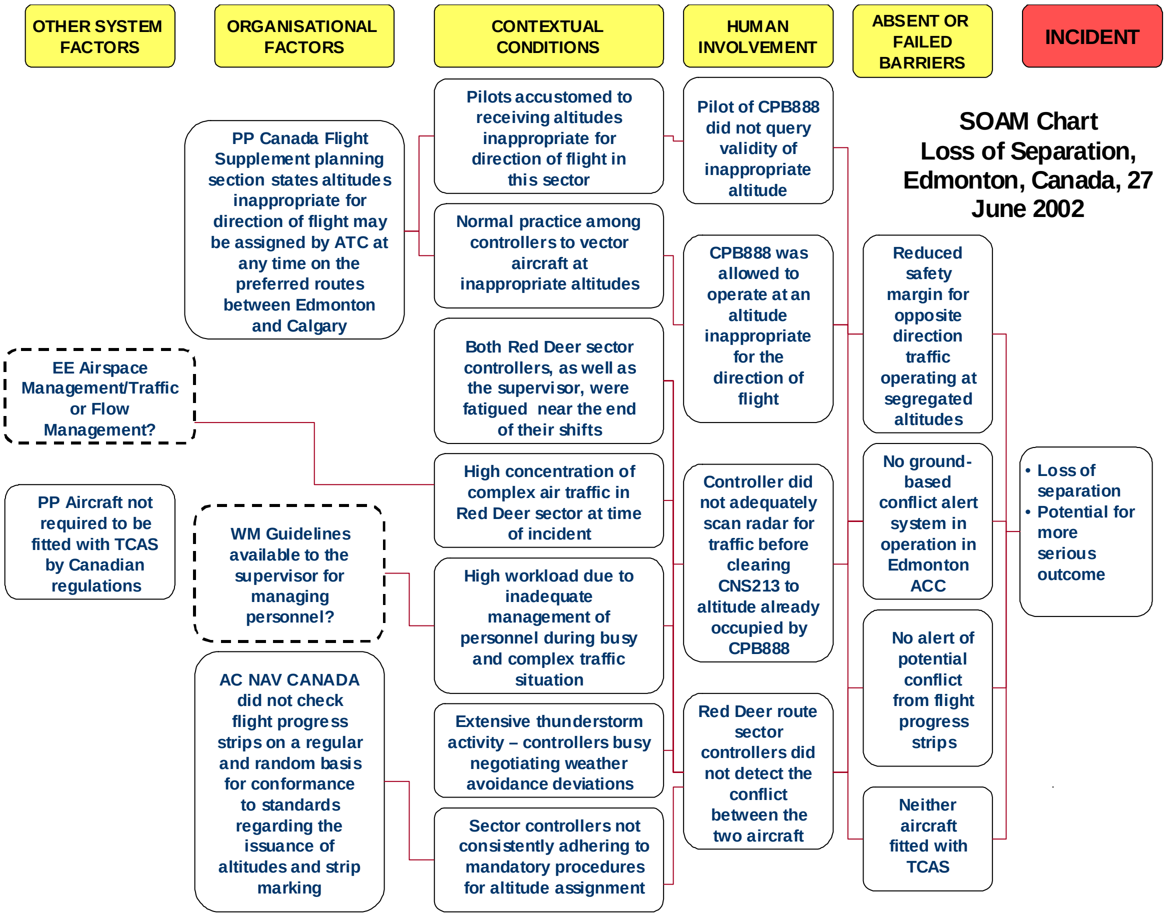


Figure C.1
SOAM Chart of Loss of Separation Incident
Edmonton, Canada, 2002

(End of Document)