Using Incident Investigation Tools Proactively for Incident Prevention

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"Our investigation and correction activities tend to be based on the amount of damage and injury – which is random. We don't really have prevention programs; we have accident correction programs."

Richard Wood (1997). Aviation Safety Programs – A Management Handbook.

INTRODUCTION

Can simply correcting the deficiencies found through incident investigations reduce error? Modern safety theory would suggest that relying on correcting deficiencies found through incident investigation as a means to reduce error is somewhat restrictive (Wiegmann & Shappell 2003, Reason 2000, Wood 1997, Kleitz 1994).

Significant factors leading to the incident, and the subsequent actions necessary to prevent recurrence, do not always emerge from the physical evidence of the case alone. Many incidents occur, not because they could not be prevented, but because the organisation did not appreciate the gaps in their safety systems, nor learn from, or retain the lessons from past incidents within or outside their organisation.

The future direction for incident prevention lies in using investigation methodologies as a tool that both integrates and compliments pre-existing processes such as risk management and audit. Using investigative tools to identify and resolve the precursors to error and learning from past incidents can assist organisations to gain an appreciation of the strengths and limitations of their safety systems and reduce errors that lead to incidents.

This paper will focus on the benefit of using an investigation framework proactively to manage exposure and risks across organisations, then apply one such framework – the Incident Cause Analysis Method (ICAM) – to review an aviation accident and judge if proactive application of the framework may have identified the precursors, effectively preventing the adverse outcome.

INVESTIGATION TOOLS / FRAMEWORKS

The principle objective of incident investigation is to prevent recurrence, reduce risk and advance health and safety performance. It is not the purpose of this activity to apportion blame or liability. The use of established investigation methodologies guide the investigation team in following a structured, logical path during the course of an investigation. Investigation methodologies provide guidance in gathering investigative data and a framework for organising and analysing the data.

Modern investigation methodologies not only identify how an incident occurred, but also identify why it occurred. Most importantly, corrective actions and key learnings arise from the investigation aimed at preventing similar incidents from occurring again. However, the effectiveness of corrective actions and key learnings in reducing error is clearly an area which needs to be improved upon, evidenced by repeat incidents seen through-out many industries.

IMPROVING SAFETY AT AN ORGANISATIONAL LEVEL

Standard investigation methodologies examine the physical evidence at an incident site, the defences that failed to prevent or mitigate the incident, the actions of people involved, the conditions that existed and the pertinent organisational factors. While this is usually effective at determining why a particular accident occurred, the investigation methodology is not focused on, and therefore is not very effective at, making organisations safer.

In order to improve safety at an organisational level and identify and reduce the precursors to error, a more holistic tool is required which examines the full range of organisational elements from a proactive stance. While a number of tools can be used for this purpose, this paper will focus on the Incident Cause Analysis Method.

INCIDENT CAUSE ANALYSIS METHOD (ICAM)

The principles of the Incident Cause Analysis Method (ICAM), stem from the work of organisational psychologist and human error expert, Professor James Reason and his modelling of organisational accidents. Reason and his colleagues from the University of Manchester in the United Kingdom, developed a conceptual and theoretical approach to the safety of large, complex, socio-technical systems, of which aviation and mining are excellent examples.

Reason defines organisational accidents as those in which *latent conditions* (arising mainly from management decisions, practices or cultural influences), combine adversely with local triggering conditions (weather, location etc.) and with *active failures* (errors and/or procedural violations) committed by individuals or teams at the front line or "sharp end" of an organisation, to produce an accident (Reason, 1990; 1997).

A fundamental concept of ICAM is acceptance of the inevitability of human error. Human factors research and operational experience, has shown that human error is a normal characteristic of human behaviour, and although it can be reduced, it cannot be completely eliminated (Helmreich & Merritt, 2000). ICAM is designed to ensure that the investigation is not restricted to the errors and violations of operational personnel. It identifies the local factors that contributed to the incident and the latent hazards within the system and the organisation (Gibb & De Landre, 2002). Through the analysis of this information, ICAM provides the ability to identify what really went wrong and to make recommendations on what needs to be done to prevent recurrence. It is directed towards building error-tolerant defences against future incidents.

SPECIFIC OBJECTIVES OF ICAM

The specific objectives of investigations using ICAM are:

1. To establish all the relevant and material facts surrounding the event.

2. To ensure the investigation is not restricted to the errors and violations of operational personnel.

3. To identify underlying or latent causes of the event.

4. To review the adequacy of existing controls and procedures.

5. To recommend corrective actions which when applied can:
   - reduce risk,
   - prevent recurrence;
   - and by default, improve operational efficiency.

6. Detect developing trends that can be analysed to identify specific or recurring problems.

7. To ensure that it is not the purpose of the investigation to apportion blame or liability. Where a criminal act or an act of willful negligence is discovered, the information will be passed to the appropriate authority.

8. To meet relevant statutory requirements for incident investigation and reporting.

APPLYING ICAM

ICAM is an analysis tool that sorts the findings of an investigation into a structured framework. An adaptation of the *Reason Model* with the ICAM terminology is shown at Figure 1 below:

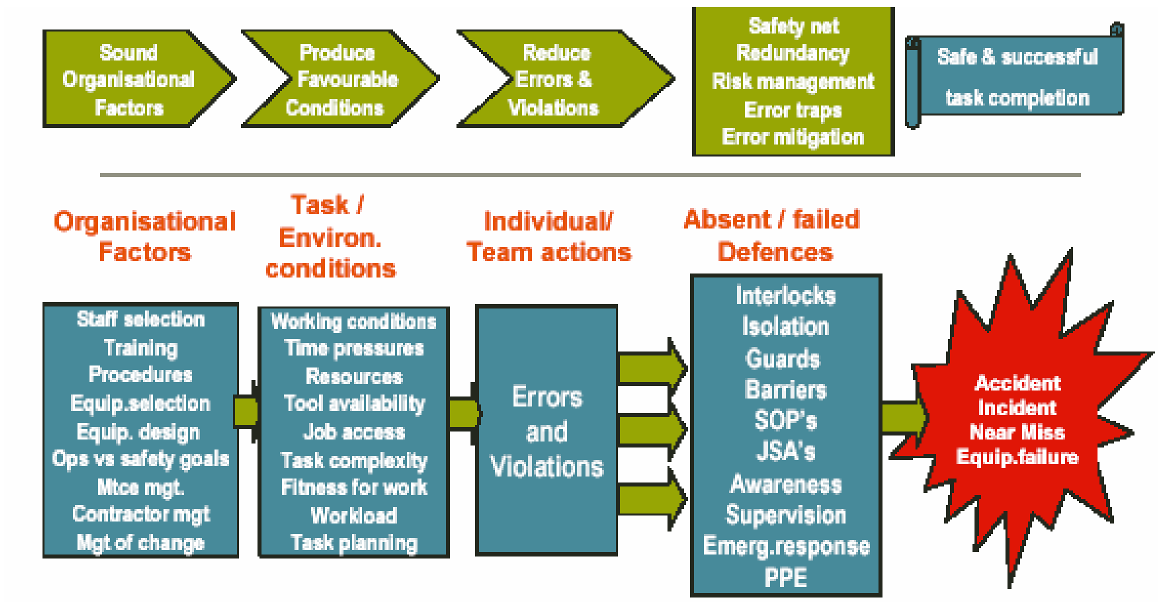

Figure 1. **ICAM Model of Accident Causation**

The ICAM model organises occurrence causal factors into four elements which are briefly explained on the following page:

- **Absent / Failed Defences**

  These contributing factors result from inadequate or absent defences that failed to detect and protect the system against technical and human failures. These are the control measures which did not prevent the incident or limit its consequences.

- **Individual / Team Actions**

  These are the errors or violations that led directly to the incident and are typically associated with personnel having direct contact with the equipment, such as operators or maintenance personnel.

- **Task / Environmental Conditions**

  These are the conditions in existence immediately prior to, or at the time of the incident that directly influence human and equipment performance in the workplace. These are the circumstances under which the errors and violations took place and can be embedded in task demands, the work environment, individual capabilities and human factors.

- **Organisational Factors**

  These are the underlying organisational factors that produce the conditions that affect performance in the workplace. They may lie dormant or undetected for a long time within an organisation and only become apparent when they combine with other contributing factors that led to the incident. ICAM classifies the organisational factors into 14 Organisational Factor Types (OFT's) as seen in Table 1 below:

Table 1
ICAM Organisational Factor Types

HW	Hardware
TR	Training
OR	Organisation
CO	Communication
IG	Incompatible Goals
PR	Procedures
MM	Maintenance Management
DE	Design
RM	Risk Management
MC	Management of Change
CM	Contractor Management
OC	Organisational Culture
RI	Regulatory Influence
OL	Organisational Learning

APPLYING ICAM PROACTIVELY

While ICAM has proved to be an extremely effective reactive tool with the results of ICAM investigations being used for the development of safety performance improvement strategies, the future direction for incident prevention lies in the proactive use of the model. Proactive use of the model provides safety learnings to the organisation without the costs associated with an occurrence. Additional benefit is gained by applying the model to a number of similar type, low consequence events, to assess what would otherwise be a set of unrelated safety concerns and to develop strategic recommendations for safety improvements (Gibb & De Landre, 2003).

For incident reduction to ultimately occur, the precursors to error must be identified and rectified. While reactive investigation tools are required, they do not necessarily describe how the precursors to incidents are to be identified in the first place. To address this quandary, error management systems are needed that will reduce error, mitigate their consequences and therefore, proactively prevent incidents.

The facets of the ICAM error management strategy encompass error prevention, error containment and error mitigation. Figure 2 below page illustrates how the elements of ICAM Model can be used for a 3-way strategy to manage workplace errors, with the defences within an organisation directed towards error containment and error mitigation and the organisational factors aimed at error prevention.

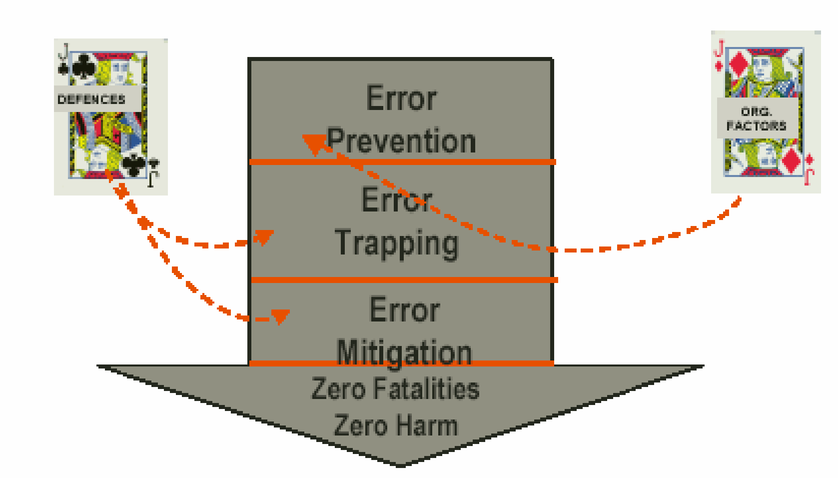

Figure 2. **ICAM 3-way strategy to manage workplace errors**

In using the ICAM methodology proactively, the terminology alters and the sequence of examining the elements changes. As a reactive tool, the Investigator arrives at the incident site and works back through the elements (shown in Figure 1 on Page 3) starting from the right-hand side. Firstly the Absent / Failed Defences are identified then the Individual / Team Actions, then the Task / Environmental Conditions and finally the Organisational Factors.

However, as Figure 1 displays with the appearance of arrows, the actual incident originates back in the Organisational Factors. When using the ICAM methodology proactively as a risk management model to enhance safety, the terminology changes as indicated on the following page in Table 2:

Table 2.
Titles of Elements for Reactive and Proactive Use of ICAM

REACTIVE ICAM ELEMENT	PROACTIVE ICAM ELEMENT
• Absent / Failed Defences	• Risk Controls
• Individual / Team Actions	• Risk Taking Behaviour
• Task / Environmental Conditions	• Risk and Behavioural Influences
• Organisational Factors	• Management Controls

Figure 3 below, displays the proactive and reactive direction of use of the model. Proactive application starts on the left-hand side of the model with Management Controls and works through the Risk and Behavioural Influences, Risk Taking Behaviour, concluding with the Risk Controls.

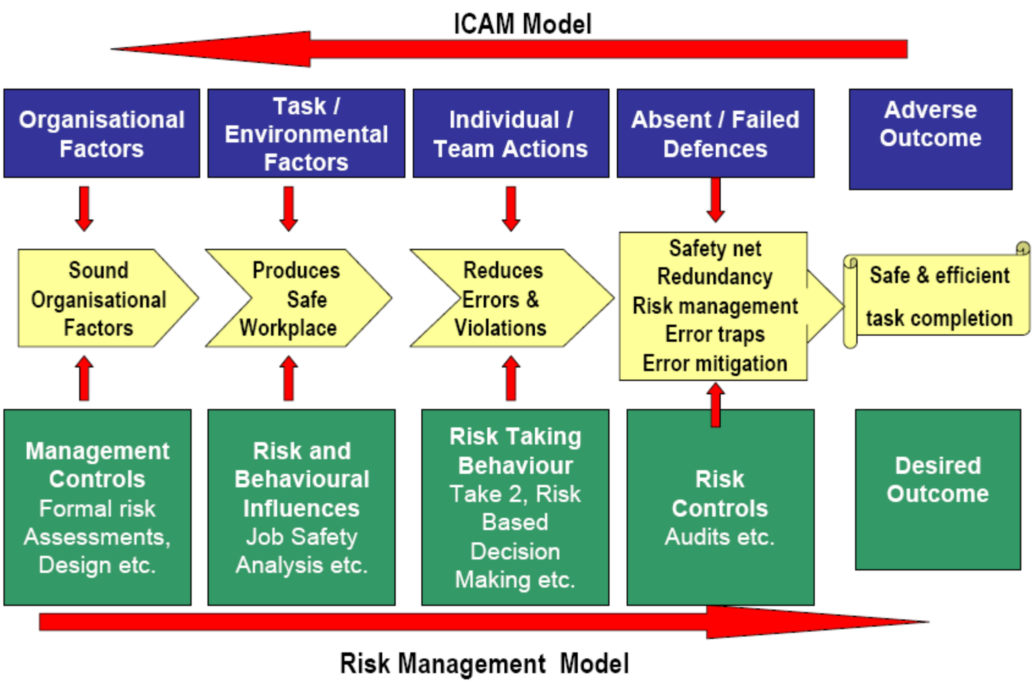

Figure 3. **Reactive vs Proactive Direction of Use of the ICAM Model**

As an example of this approach - given a new operation, acquisition of new equipment, staff selection etc. the use of the Risk Management Model would start by identifying the types of Management Controls that should be in place aimed at risk reduction and error prevention. Examples could include: change management strategies, formal risk assessments and training needs assessments.

The next step would be to identify the influences on personnel to maintain a safe workplace. This could include the fact that a Job Safety Analysis is required to be done for a particular task. Following this tools that are available or should be provided to personnel, aimed at minimising the possibility of errors are identified. These could include training in risk based decision making or Take 2 type tools. Finally the risk controls that are, or should be, in place to either trap or mitigate errors are identified.

Where the Risk Management Model identifies specific issues that do not currently exist, such as lack of appropriate change management processes or scheduled audits etc. then these gaps obviously need to be rectified to maintain an appropriate level of safety for the new operation / process.

CASE STUDY – 1999 LEARJET ACCIDENT, ABERDEEN,USA.

From a purely theoretical stance, a Case Study will be examined to demonstrate how the proactive use of ICAM may have identified precursors to error and identified deficiencies in the safety system, effectively breaking the links that led to the accident. (It should be noted that this case study analysis is a subjective view that has been applied after the event and is based on existing documentation and reports only).

The Case Study selected involved a Learjet Model 35 (N47BA) that crashed on 25th October 1999 near Aberdeen, South Dakota in the USA. Summary details of the accident appear below:

SUMMARY REPORT ON THE LEARJET INCIDENT

Excerpt from the National Transportation Safety Board (NTSB) Aircraft Accident Brief

On October 25, 1999, about 1213 central daylight time (CDT), a Learjet Model 35, N47BA, operated by Sunjet Aviation, Inc., of Sanford, Florida, crashed near Aberdeen, South Dakota. The airplane departed Orlando, Florida, for Dallas, Texas, at about 0920 eastern daylight time (EDT). Radio contact with the flight was lost north of Gainesville, Florida, after air traffic control (ATC) cleared the airplane to flight level (FL) 390.

The airplane was intercepted by several U.S. Air Force (USAF) and Air National Guard (ANG) aircraft as it proceeded northwestbound at approximately 45,000 feet. The military pilots in a position to observe the accident airplane at close range stated (in interviews or via radio transmissions) that the forward windshields of the Learjet seemed to be frosted or covered with condensation. The military pilots could not see into the cabin. They did not observe any structural anomaly or other unusual condition.

At approximately 1326 (eastern daylight time) the military pilots observed the airplane depart controlled flight and spiral to the ground, impacting an open field. All occupants on board the airplane (the captain, first officer, and four passengers - including professional golfer, Payne Stewart) were killed, and the airplane was destroyed (NTSB, 2001; 2005).

Applying ICAM to this accident, it is possible, for illustrative purposes to identify latent conditions and factors that could have been identified prior to the accident. Due to the nature of the accident, with the speed of impact described as near supersonic, much of the physical evidence was destroyed preventing a more definitive analysis of technical and human causal factors.

The NTSB (2005) noted the challenges and difficulties with the investigation by stating:

"This investigation took 13 months to complete and was hampered by several factors:

- *Because the aircraft impacted at nearly supersonic speed and at an extremely steep angle, none of its components remained intact. Therefore, investigators had to painstakingly examine the fragmented valves, connectors, and portions of other aircraft parts before they could draw any conclusions about the accident's cause.*

- *The airplane was not equipped with a flight data recorder, an invaluable tool in most major investigations, and it had only a 30-minute cockpit voice recorder, which was of limited use during this investigation.*

- *And, all of the investigators involved in this investigation were also investigating other accidents. The Investigator-in-Charge was working on four other investigations in addition to this one."*

APPLICATION OF ICAM TO THE CASE STUDY

Absent / Failed Defences

Absent or failed defences are those contributing factors that failed to detect and protect the system against technical and human factors. These are the control measures that did not prevent the incident or limit its consequences. Some of the Absent / Failed Defences identified in the accident included:

- Cabin pressurisation (inability to maintain)
- Bleed air supply to the cabin (lack of)
- Flow control valve - supplying warm air to windshield (closed)
- Timeliness/warning for donning oxygen masks (adequacy ?)
- Oxygen quality/quantity
- Incomplete standardised manual and procedures
  - Ambiguous maintenance procedures, some verbal, some written, some not signed off.
  - Poor written reporting relationship between aircrew and maintenance staff
  - Non adherence to company policy for maintenance reporting/signoff
  - Inadequate procedures for emergency oxygen supply
  - Unclear whether guidance provided for procedures anomaly – switching to auto pilot
  - Procedures for reporting maintenance issues inadequate
  - Written records for maintenance reports incomplete
- Application of SOP's (previous inconsistencies)
- Crew pairing (Inexperienced Captain with First Officer)
- Flying time on type (Captain limited)

Individual / Team Actions

Individual / Team Actions are the errors or violations that led directly to the incident. They are typically associated with personnel having direct contact with the equipment, such as operators or maintenance personnel. They are always committed actively (someone did or did not do something) and have a direct relation with the incident. Some of the Individual / Team Actions identified in the accident included:

- Timeliness in donning oxygen masks
- Descending to a lower, safe altitude
- Lack of verbal response from crew to ATC radio contact

Task / Environmental Conditions

These are the conditions in existence immediately prior to or at the time of the incident that directly influence human and equipment performance in the workplace. These are the circumstances under which the errors and violations took place and can be embedded in task demands, the work environment, individual capabilities and human factors. Some of the Task / Environmental Conditions identified in the accident included:

- Loss of cabin pressurisation
- Flow control valve closed
- Limited time on type
- High altitude
- Low pressure evident in cabin (via alarm)
- Ambiguity surrounding effectiveness of alarm system
- Lack of supplemental oxygen
- Hypoxia / Incapacitation

Organisational Factors

These are the underlying organisational factors that produce the conditions that affect performance in the workplace. They may lie dormant or undetected for a long time within an organisation and only become apparent when they combine with other contributing factors that led to the incident. Some of the Organisational Factors identified in the accident included:

- Deficient monitoring/ auditing of maintenance item completion
- Equipment not fit for purpose- suspected valve problems with closure of flow control valve.
- Process of (managing) introduction of new aircraft
- Incident reporting system deficiencies
- Inadequate procedures for checking quality and quantity of on board emergency oxygen bottle
- Deficiencies in maintenance control – use of MEL etc.
- No evidence of risk appreciation process used
- Ambiguous monitoring by management of resources, climate and processes of a safe working environment
- Incomplete corporate commitment to safety
- Failure to revise maintenance strategy
- Failure to appreciate the risk exposure or vulnerability within the organisation
- No follow-up from previously failed defenses – identification, tracking and resolving maintenance items and adverse trends

IDENTIFYING THE PRECURSORS

The lack of physical evidence at the crash site, the lack of complete documentation, data and records left sufficient doubt about the exact cause of this accident. The NTSB determined that the probable cause was incapacitation of the flight crew members as a result of their failure to receive supplemental oxygen following a loss of cabin pressurisation, for undetermined reasons (NTSB 2001).

The application of a proactive tool prior to the accident, may have been able to identify the precursors to the accident and broken the error chain. Given some of the contributing factors identified during the investigation and the type of issues that are typically found during the proactive application of ICAM, factors that were judged as being precursors to error that may well have been identified include:

- Poor follow through on work procedures regarding maintenance reporting, identification, tracking and resolving of maintenance items and adverse trends.

- Incomplete standardised manual and procedures.

- Monitoring / auditing processes.

- Change management issues with the purchase of a new aircraft.

- Adequacy of procedures for checking quality and quantity of on-board emergency oxygen bottle.

- Condition of equipment (highlighting ventilation issues previously identified and repaired).

- Anomaly of practices regarding the timing of switching to auto pilot.

- Crew pairing (given experience/hours on type)

- Risk Management

BENEFIT OF PROACTIVE APPROACHES

There is no doubt that a proactive error management strategy that leads to overall incident reduction is beneficial for all organisations and can be measured in both tangible and intangible means. The proactive use of tools such as ICAM, can provide safety learnings to an organisation without the costs associated with an incident. Applying ICAM as a preventive tool allows an organisation to shift its focus from investigation findings to preventative safety. By designing error tolerant workplaces that will reduce error, organisations have the potential to mitigate error consequences and therefore, proactively prevent incidents.

Adopting this approach for all levels of work operations, processes etc. can be beneficial. If preventive efforts are applied only to events with the 'highest' likelihood of disaster, the opportunity is missed to prevent a regularly recurring event of 'low' probability, which may have latent effects, for example in the case study - the maintenance reporting and follow through procedures.

CONCLUSION

Correcting the deficiencies found using standard reactive incident investigation methods should reduce and manage the errors that led to a particular incident, but in order to reduce the precursors to error and fundamentally improve the safety of an organisation, a more holistic, proactive approach is required.

ICAM is one such method, which demonstrates commitment to continual improvement in performance and safety by addressing the latent conditions and hazards in the system that produce human error. The proactive use of ICAM as a tool that both integrates with and compliments proactive processes such as risk management and audit, expands the utility of ICAM and may enable the precursors to occurrences to be identified and remedied prior to an actual occurrence saving time, money and perhaps lives.

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