NEW DIRECTIONS IN AIR SAFETY

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Over many years the aviation industry, often as a result of bitter experience, has developed elaborate systems and procedures to maintain and ensure the safety of operations. Many of the changes have resulted from the comprehensive investigation of aircraft accidents and incidents.

As a result, aviation has long been, and continues to be, the leader in the field of transportation safety, and many of the lessons learned and methods developed in aviation have been applied in areas ranging from marine, road and rail transport to medicine.

At the outset let me offer a brief comment on one ongoing, and often controversial, aspect of air safety, that of cost. It has been argued that the level of safety in aviation is a direct function of the amount of money spent on safety. In other words, safety has a price and the more you spend, the more safety you get.

However, the assumption that air safety is a matter of money alone is false.

To illustrate the point, it is possible to have two airlines, both with identical fleets, facilities and resources, with the same experience and age profile of operational personnel, working out of the same airports and covering the same routes at the same times with the same load factors and fare structures. In other words, their overall 'cost' baselines on any index are the same. Yet, one organisation may have a high level of safety, and the other a very poor safety record. If safety were solely a matter of cost, how could this be so?

The ‘safety health’ concept

The difference lies in what is termed the ‘safety health’ of the two companies, and this state of health is primarily a function of the management and organisational factors in each company. In the terms of this example, it is clearly quite possible for the ‘unsafe’ company to increase the safety health of its organisation to match that of its competition, and thereby increase its operational safety, for minimal, or nil, cost. It can do this by rectifying deficiencies in organisational factors such as communication, people management, personnel selection, and in local factors such as ‘safety consciousness’ in the workplace.

A central proposition of this argument is that while air safety clearly does have a cost, the greatest source of variance in the safety of operations is not necessarily the equipment, or the category of operation (there are some very safe commuter/charter operators and some very unsafe airline operators around the world), rather it is the nature of the organisations involved and sometimes that of the various aviation systems in which they operate.

A small aviation company operating on a limited budget with the most basic of equipment, does not have to be any less 'safe' than a major airline, nor does it have to spend large amounts of money to achieve this high level of safety and thereby price itself out of business.

This paper will outline one important area critical to aviation safety air safety investigation. First, some information on the Australian Bureau of Air Safety Investigation, or BASI, as it is generally known, will be provided. Secondly, the new ‘safety health’ concepts being applied to improve the safety of world aviation will be described.

The Bureau of Air Safety Investigation

The Bureau of Air Safety Investigation is the agency of the Australian Government which is responsible for the investigation of accidents and incidents occurring to civil aircraft in Australia and its territories. BASI operates in accordance with Annex 13 of the Chicago Convention, (ICAO). This annex sets out the international standards and recommended practices for the investigation of accidents and serious incidents. Australia has incorporated the provisions of this Annex into our domestic Air Navigation Regulations.

The objective of the Bureau is to promote safe aviation by disseminating information and safety recommendations based on the investigation of selected accidents and incidents, and on the results of research. In accordance with Annex 13 it is not the purpose of BASI's investigations to apportion blame or liability. The Bureau exists purely for the purpose of air safety.

Australia is fortunate in that, unlike some other countries, most of the key elements of the air safety investigation function are within the one organisation – BASI has only minimal reliance on other agencies. It is the legal recipient of air safety incident reports (both mandatory and confidential), it investigates accidents and incidents, it conducts analysis and research, it develops proactive accident prevention programs, it maintains Australia's computerised aviation accident and incident data base, and it publishes its own reports. Each year the Bureau receives an average of 5000 incident and 270 accident reports.

The results of BASI investigations are presented in terms of 'findings' and 'significant factors'. The Bureau does not utilise the term 'cause', and nor does it, as some other countries do, identify any one factor as the most important in a particular occurrence. In the Bureau's experience, to nominate any one factor – for example, as a single 'most probable cause' – results in most attention being concentrated on that factor alone, when the majority of air safety occurrences are the result of a complex interaction of many factors. Every one of these should be addressed for purposes of accident prevention, otherwise the effectiveness of the investigation process can be greatly reduced.

Like its overseas equivalents, BASI has no power to implement its recommendations. However, approximately ninety percent are accepted, normally by the regulatory authority – the Civil Aviation Safety Authority (CASA). If CASA chooses not to accept a BASI recommendation it must state its reasons for not doing so and these are published by the Bureau.

Selective investigation

In recent years, the Bureau has adopted a policy of selective investigation, similar to many of our equivalent organisations in other countries. The traditional approach in Australia had been to investigate everything, no matter how minor. However, many categories of air safety occurrence are repetitive in nature, such as ground loops involving aircraft with tailwheel undercarriages, and no new prevention knowledge is gained by continuing to investigate such events. However, the law requires that all accidents and incidents must be reported. Because BASI receives all these reports, it retains the ability to monitor trends, and can initiate an investigation into safety issues raised – for example, by a number of relatively minor occurrences. While these events individually would not warrant full investigation, considered as a group they may be indicative of broader systemic safety deficiencies – a topic which will be addressed later in this paper.

In practice the Bureau does not distinguish operationally between accidents and incidents – they are all 'safety occurrences'. The objective of selective investigation is to concentrate the Bureau's resources on in-depth investigations which offer the greatest potential to enhance air safety. BASI has developed and refined various criteria to decide which events will be looked at most closely – one of these is a primary emphasis on the safety of fare-paying passengers in any category of operation – high capacity regular public transport (RPT), low capacity RPT and charter, and other commercial operations involving fare paying passengers.

In addition, in part enabled by the redeployment of resources as a result of the selective investigation policy, BASI is placing a much stronger emphasis on applied systems safety studies. This is aimed at identifying and rectifying underlying factors within the aviation system which can impact upon safety at the 'sharp end' – that is, in the cockpit, cabin, control tower, maintenance workshop, or on the ramp. This systemic safety aspect of the Bureau's operations will be discussed in detail later in this paper.

BASI's structure

BASI is a relatively small organisation, with a total of 80 employees. The Bureau has a Central Office in Canberra, with five field offices located in state capitals around the country. The field offices each have a small number of staff, the investigators located in them being either pilots or licensed aircraft maintenance engineers (LAMEs), or sometimes both.

Central Office contains all the Bureau's technical specialist facilities, such as flight data recorder readout, computer graphics, engineering and audio laboratories, radar recording, and computing. Members of all categories of investigator are located in Central Office. There is a single employment category of 'air safety investigator', within which there are seven different categories – operations (pilots), air traffic services (ATS), human performance, engineer, maintenance (LAME), cabin safety and technical officer (e.g. avionics, communications).

Contemporary aviation safety is no longer primarily the province of pilots and engineers alone – it is now a multi-disciplinary endeavour, often requiring input from many diverse fields. Aviation is going through a process of rapid change in its operational, technical, commercial, economic, regulatory, and political dimensions. Developments in each of these dimensions can impact directly or indirectly on air safety. As an organisation the Bureau must therefore maintain a current awareness of these changes so that all staff fully understand the context within which they carry out their tasks, and the Bureau possesses or has access to the appropriate specialist expertise.

BASI employs a team approach to investigations. An investigation of a serious ATS incident, for example, could be carried out by a team made up of investigators in the categories of air traffic services, operations (pilot), and human performance. All these specialists work together as an integrated group to apply their different fields of professional expertise to the identification of the significant factors in the occurrence.

BASI's aims

The Bureau's overriding concern is with maximising the safety of aviation as a transportation system. BASI shares this primary concern with all elements of the Australian and international aviation communities, and cooperates closely with them towards that safety goal, while maintaining complete objectivity and independence in its operations.

BASI is an adviser to the Safety Committee of the International Air Transport Association (IATA) and the Flight Operations and Safety Working Group of the Association of Asia-Pacific Airlines which represents eighteen of the major airlines in our region. The latter is especially important because Asia Pacific is the world's fastest growing region of aviation.

Because the Bureau is completely independent of the regulatory authority, CASA, it is able to operate its own Confidential Aviation Incident Reporting (CAIR) system in-house. The CAIR program has been most successful and has the support of the aviation industry.

Communicating safety information

Since its establishment in 1988, the scope of CAIR has been expanded to cover not only flight crews, but also air traffic services personnel, maintenance and ground handling staff and cabin crew. Each of these groups is provided with a special purpose form contained within the CAIR reporting package. The purpose of the extension of the CAIR program was to obtain the full air safety picture, not just that from the perspective of one particular professional group. For example, cabin crew are uniquely placed to provide certain kinds of critical information on passenger safety and emergency procedures affecting survival which may not be available from any other source.

In addition to occurrence investigation and research reports, the Bureau publishes quarterly its own high quality safety magazine, *Asia-Pacific AIR SAFETY* With the exception of 1987, BASI and its predecessors have been producing an air safety magazine continuously since July 1953, a period of 43 years.

Circulated to over 60,000 readers throughout the industry in Australia and overseas, *Asia-Pacific AIR SAFETY* is a key element in the Bureau's high level of communication with the aviation community in the region. It disseminates information on the Bureau's operations, raises safety issues, educates the entire aviation community, and provides an essential feedback element of the CAIR program, as well as including a CAIR reporting package in each issue.

BASI is a highly computerised organisation. As well as our central computing facilities, every staff member has a powerful PC, and the whole system is networked throughout Australia. BASI has an integrated system to provide information support for all of its operations – from investigation, research and analysis, occurrence reporting, financial and project management, production of reports, to office automation. The main component of the system is called OASIS – Occurrence Analysis and Safety Information System – and is in a continuous process of evolutionary development to provide even greater capability for safety analysis of the aviation system, and to adapt to changes in that system.

Accident investigation and prevention: the BASI perspective

In its first form the Bureau was established as the 'Accident Investigation and Analysis Branch' of the Department of Civil Aviation in 1952. Perhaps the single most important change in the Bureau's recent operations is the shift from a primarily reactive organisation, investigating accidents and incidents after they occur, to an organisation which is also proactive and equally concerned operationally with the prevention of air safety occurrences. The Bureau now dedicates considerable resources to the identification of deficiencies in the aviation system which have the potential, given the right combination of events and circumstances, to become significant factors in accidents or incidents.

Similarly, for the Bureau's accident and incident investigations, as well as finding out what went wrong at the 'sharp end' – in the cockpit, control tower, cabin or maintenance area – BASI aims to identify any underlying factors in the aviation system which might have contributed to the occurrence.

For example, if passengers are killed or injured because of problems of evacuation following a survivable accident, it is essential to determine what actually went wrong in the cabin, and to ascertain the immediate reasons why the cabin crew were unable to ensure the survivability of all occupants. But of even greater importance is the identification of any latent organisational factors which may have contributed to the failure of the cabin crew to achieve a successful evacuation – factors such as poor communication, inadequate supervision, or inappropriate training. Experience has shown that if such underlying systemic factors are not detected in investigations, and therefore remain unchanged, sooner or later the same kinds of failures will occur again. The Bureau's Systems Safety Branch, is dedicated to the critical task of identifying these underlying latent deficiencies in the aviation system, both before and after accidents or incidents.

A proactive approach

From the proactive perspective, BASI promotes active communication with the industry at all levels – for example, it is an important role of BASI investigators to act as 'intelligence gatherers', as well as conveying

information to the industry on the Bureau and its operations. This provides an early warning system to enable BASI to become aware of safety issues as they develop, so that we may recommend remedial action without waiting for an accident. The CAIR program described earlier also plays a key role in the achievement of this objective.

In conjunction with a major regional airline, the Bureau has developed, trialed and evaluated an innovative, cost-effective proactive safety program called INDICATE (Identifying Needed Defences In the Civil Aviation Transport Environment). INDICATE is an airline self-management safety tool which encourages regular passenger transport operators to critically evaluate and continually improve the strength of their safety system. INDICATE also provides a formal communication channel for airline operators to regularly identify and report current weaknesses in aviation regulations, policies and standards to the Bureau of Air Safety Investigation, before they result in an accident. As a result of its success, other airlines have adopted INDICATE which is also attracting overseas interest.

A central factor driving the adoption of a new conceptual approach to aviation safety by the world's aviation community is that although the world airline accident rate is very low, it has effectively plateaued. This means that if the accident rate does not change, and the increases in air traffic occur as projected, then early in the next century the number of airline accidents will increase to a level which will be completely unacceptable to the industry and the travelling public – approximately one hull-loss every fortnight. Such a situation would also be financially unsustainable to the industry.

In many other categories of aviation, accident rates have also remained comparatively steady for many years, with little statistically significant change in either direction.

It is therefore imperative that if the industry is to break away from this steady state, and achieve substantial improvement in what is already an excellent safety record, it cannot afford simply to recycle its present well established safety philosophies and procedures. It must do more to achieve significant change to the ‘status quo’. By adopting new systems safety ideas and practical proactive approaches to air safety, BASI aims to enhance the safety of aviation operations in all areas.

The Reason model of systems safety

Fundamental to the Bureau and the international aviation community's contemporary safety philosophy

is the work of Professor James Reason, of the University of Manchester, UK, and his colleagues. Reason and his team have developed a conceptual and theoretical approach to the safety of large, complex socio-technical systems, of which aviation is an excellent example. As part of the development of his model Reason analysed major accidents in aviation, shipping, rail, nuclear power, aerospace and so on. All of these case studies represented catastrophic failures of such systems.

Details of the Reason model can be found in his book *Human Error* published in 1991. Descriptions of the model more specifically related to the aviation context can be found in Reason (1991a, 1991b). The concepts are further developed and applied to aviation case studies in the book *Beyond Aviation Human Factors* (Reason, Johnston, Maurino, and Lee, 1995).

The model has been translated into successful operational corporate safety programs by Shell (TRIPOD), British Rail (PRISM) British Airways Engineering (MESH), and, most recently, Singapore Airlines.

Most importantly, significant changes to ICAO Annex 13 which came into effect in late 1994 mean that it is now an international requirement that organisational and management information be formally addressed in accident and incident reports. This information should be provided for any organisation which influences the operation of the aircraft. ICAO has recommended that the Reason Model be used for this purpose. Major BASI investigations such as the Monarch airlines report and the B747 VH-INH report are structured in accordance with the Reason model. Both have had substantial impacts in redressing deficiencies in the aviation system in both the corporate and regulatory areas.

The Reason model: some basic concepts

The Reason model has many dimensions, and space permits only a brief outline of some of the concepts.

Reason stresses the fundamental need always to adopt a total systems approach to safety. While this in itself is certainly not new, it is the manner in which Reason addresses and analyses the system that is of special interest.

Reason (1991a) describes two kinds of failures in complex systems –‘active’ and ‘latent’:

> *Active failures* are defined as those errors or violations having an immediate adverse effect. These are generally associated with the activities of 'front line' operators... control room personnel, ships' crew, train drivers, signalmen, pilots, air traffic controllers, cabin crews etc.
>
> *Latent failures:* these are decisions or actions, the damaging consequences of which may lie dormant for a long time, only becoming evident when they combine with local triggering factors (such as, active failures, technical faults, atypical environmental conditions, and so on) to breach the system's defences. Their defining feature is that they were present within the system well before the onset of a recognisable accident sequence. They are most likely to be generated by people whose activities are removed in both time and space from the direct human-machine interface: designers, high-level decision makers, regulators, line managers.

Active failures have long been the 'traditional' concern of air safety specialists, – the focus has been on the behaviour of people at the 'sharp end', that is, those personnel most directly involved at the time of the occurrence – flying the aircraft, controlling air traffic, evacuating passengers, or carrying out maintenance.

Understanding the Reason model

In considering the nature of active failures, Reason (1990) has developed the Generic Error Modelling System (GEMS), which incorporates the classification of errors into skill-based, rule-based and knowledge-based categories. In aviation, the knowledge-based category is the primary target of crew resource management and judgement training courses.

Reason (1991b) explains some fundamental ideas of his systems approach as follows.

> Like many other high-hazard, low risk systems, modern aircraft have acquired such a high degree of technical and procedural protection that they are largely proof against single failures, either human or mechanical. They are much more like to fall prey to an 'organisational' accident. That is, a situation in which *latent failures*, arising mainly in the managerial and organisational spheres,

combine adversely with local triggering events (weather, location etc.) and with the *active failures* of individuals at the 'sharp end' (errors and procedural violations).

Reason argues that all large socio-technical systems contain a core group of generic *general failure types* (GFTs), examples being incompatible goals; organisational deficiencies; inadequate communications; poor planning; inadequate control and monitoring, design failures; inadequate defences; poor procedures; poor training; inadequate regulations.

Active failures can be regarded not only as separate entities in themselves, but also as 'tokens' of one or more GFTS. To illustrate, a company may experience a number of air safety incidents, each one being quite different on the surface, and apparently unrelated to the others. However, careful systemic investigation and analysis may reveal that all these incidents are tokens of an underlying GFT in the company, such as poor training.

Identification of the functional relationship between these 'types' and 'tokens' is a critical objective of the proactive corporate safety programs referred to earlier.

These proactive safety programs involve the regular input of information from staff, both workers and managers. The programs identify and continuously monitor the GFT profile for the organisation, which thereby enables management and staff to develop and focus remedial action upon those specific organisational deficiencies which are of greatest concern. The programs also identify local latent failures in the workplace.

Reason: looking further

Reason (1991b) identified a number of stages in the development of a system failure, such as an accident. This schematic model also shows the information feedback loops involved. Please see Figure 1 below.

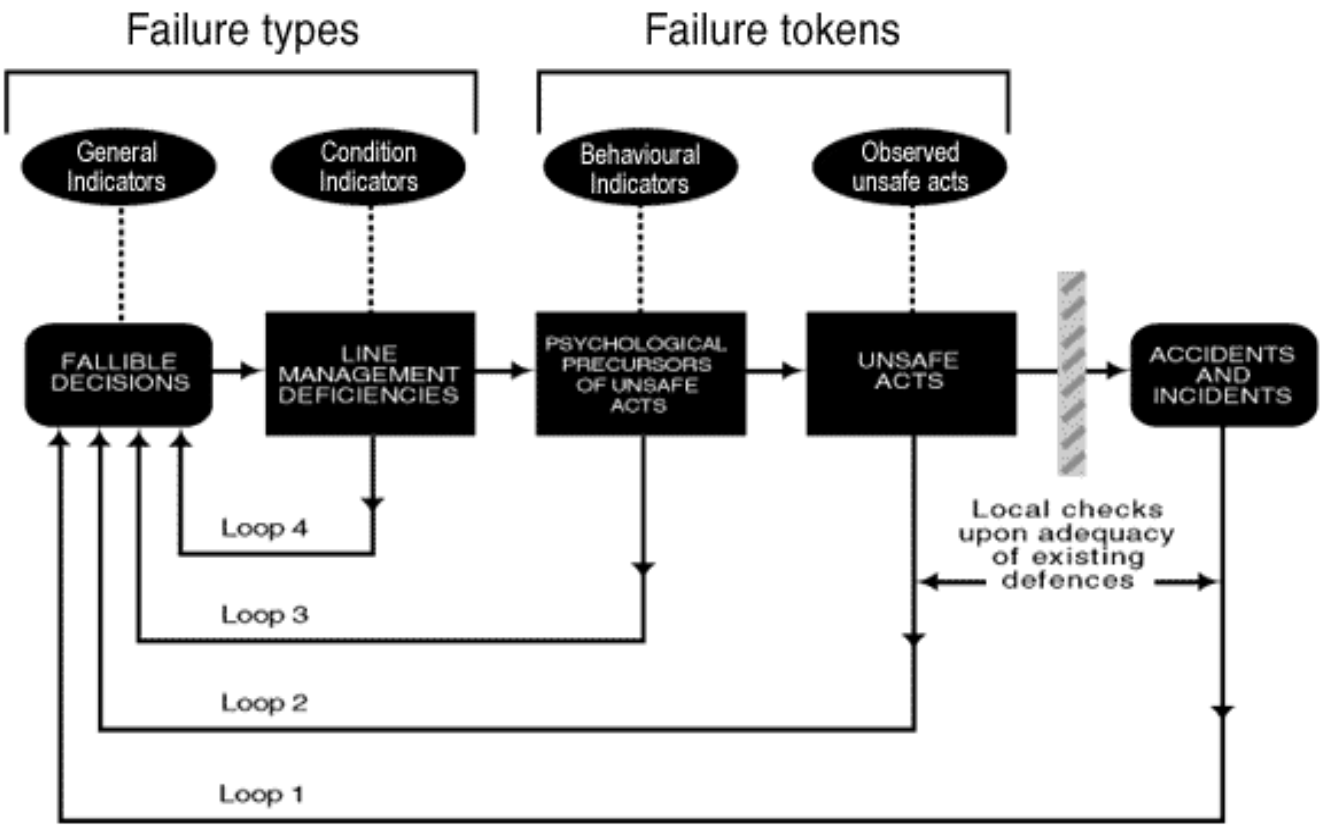

Figure 1

To be specific: referring to Figure 1, an example of a fallible policy decision made by corporate management might be to maximise the profitability of an airline regardless of any other considerations. This decision then places great pressure on the company's line managers to translate this policy into effect. A consequence is the development in the workplace of a psychological climate in which staff under pressure, and perhaps in fear of losing their jobs, constantly try and cut corners to save money, and thereby commit unsafe acts – both unintended errors and deliberate violations – such as inadequate maintenance work, sub-standard emergency procedures training, and so on. When the defences of the system fail – for example, the final inspection of

maintenance work by supervisors is not properly carried out, – a ‘window of opportunity’ for a system failure such as an accident or a failed evacuation may result, given the right set of circumstances.

Referring to Figure 1, the traditional approach of air safety investigation agencies has been to move around the outer of the feedback loops (loop 1).

However, it is obvious that on this basis an incident or accident has to actually occur before the information necessary for the prevention of similar occurrences in future could be obtained.

What we are doing

In the wide-body era, the industry cannot afford to continue in this vein – that is, to wait for the loss of aircraft or the occurrence of serious incidents to identify significant system deficiencies, or latent failures, which were already present and which could, and should, have been addressed before these events.

The real challenge for future air safety investigation is to penetrate more effectively the ‘inner loops’ of the Reason model diagram – to detect and to rectify the fallible decisions by corporate managers, the line management deficiencies, the psychological precursors of unsafe acts – sometimes referred to as the ‘organisational climate’ – and the unsafe acts themselves, together with any deficiencies in the defences of the system, before a catastrophic system failure results.

The CAIR system plays an important role in providing information on latent failures before they contribute to accidents. The Bureau’s magazine, *Asia-Pacific AIR SAFETY* provides the continuous feedback to reporters which is essential to the success of any confidential reporting system.

As well as conveying information on BASI’s systems safety approach through our magazine, Bureau staff make numerous personal presentations on the systems safety approach to the domestic and international aviation communities. James Reason himself has visited BASI on several occasions. For example, in 1991 he was an invited keynote speaker to the International Society of Air Safety Investigators (ISASI) Seminar in Canberra, which was attended by over two hundred and fifty delegates.

Systems safety

A good example of a significant conceptual change incorporated in the systems safety approach is the way in which BASI now regards an accident.

In contrast to the traditional view, Reason argues that accidents should not be considered as isolated, infrequent one-off events, but instead should be regarded as the consequences of particular sets of circumstances in which active and latent factors, sometimes acting in combination with external environmental factors, facilitate a failure of the system.

‘Normal’ errors made by humans in the system, which, as Reason emphasises, are occurring all the time, may not be always detected by the system's defences and thereby become significant factors in an accident. The point is that such errors are characteristic of human performance; they do not occur only in accident or incident situations. As a result, accident and incident data alone are not valid indicators of the degree of errors made by people in the system, and therefore do not provide a true index of system safety. In other words, if an operator has had no accidents over a given period, this does not mean that performance by the company's personnel has been error free during this time. For management to conclude that it has can create an extremely dangerous state of affairs for the company. For instance, management might decide that because the company is not actually having accidents, the safety department can be eliminated to save some money.

With the invaluable assistance of CAIR, together with its industry awareness program and research, the Bureau is increasingly able to interrogate the inner feedback loops of Figure 1. Thus we gain access to critical safety information without having to wait for accidents and incidents to occur.

In Reason’s terms, the proactive corporate systems safety programs described earlier measure organisational ‘health’ rather than organisational ‘illness’, and, among other things, aim to detect latent failures, or ‘resident pathogens’ and to remedy these, in this way reducing the system’s overall vulnerability to failure.

BASI and information technology

The Bureau's OASIS facility is being further developed in accordance with the fundamental concepts of the Reason approach. The already successful operational applications of the Reason model by several large corporations have provided a firm foundation upon which to work, even though the BASI perspective is somewhat different because of the Bureau's role as a government air safety investigation agency.

SIAM – a new accident prevention tool

Traditional means of collecting and recording air safety occurrence information, particularly of high volume low detail air safety incidents (referred to by BASI as Category 5 occurrences), severely limit the degree to which this information can be effectively used for systemic analysis. The international aviation community has recognised that such analysis is essential to accident prevention and safety enhancement.

Even the most advanced aviation accident and incident data bases currently available are primarily 'ad hoc' in nature. They are not structured on the basis of an integrated model of systems safety. The hundreds of descriptive and explanatory factors typically contained in such systems, together with their modifiers, tend to do little more than model the spoken language, rather than offer any real insights into system safety.

In the light of all these considerations, BASI has substantially modified its existing Occurrence Analysis and Safety Information System (OASIS). The Bureau has developed and introduced SIAM – the Systemic Incident Analysis Model. SIAM is a fully integrated system based upon the theoretically sound and practically proven systems safety approach developed by James Reason and recommended by ICAO.

How SIAM works

As well as collecting the normal factual information regarding air safety occurrences, SIAM takes a completely new approach by adding information and value to each report specifically from a systems safety perspective.

SIAM provides new safety information in terms of real, potential and apparent outcomes. what defences in the aviation system failed to allow each occurrence to happen; what were the latent and active failures in the system; and, where appropriate, what were the recovery measures that prevented an incident becoming an accident.

The model has been designed for capturing basic statistical information on systems safety from high volume, low detail occurrences. In the Australian system, this is the only category of occurrence which has sufficient numbers to make in-depth statistical analysis possible and productive. Australia has had a comprehensive mandatory aviation incident reporting system since the 1950s and the Bureau receives around four to five thousand reports each year. All of these are entered into the OASIS database. Most of these reports are what BASI terms 'Category 5', or relatively minor occurrences.

OASIS, like many similar systems focused on *events* only. In contrast, the primary emphasis of SIAM is upon *outcomes*, as well as events.

Outcomes

An outcome is the primary reason why a safety body such as BASI would be interested in an air safety occurrence. Ultimately, this means aircraft crashing into the ground or colliding with each other, or breaking up in flight, although the model allows more detail than this.

A significant innovation in the SIAM system is that the outcome attached to an occurrence is not necessarily what actually happened, but also what could potentially have happened, or appeared to have happened. In very basic terms, the fact that a serious outcome could have happened, but did not, is the difference between an incident and an accident, and the assumption is that a recovery measure was successful in controlling the potential consequences.

Occasionally, an outcome only appears to have happened – in other words there is a false alarm. These typically arise either from a breakdown in a warning or monitoring system (that is, failing safe), or from the threshold sensitivity of some warning systems. These are integrated into SIAM and the failures modelled as either technical breakdowns or latent failures respectively.

Defence failures

Defences are in place in the aviation system to prevent negative outcomes. Examples include such engineered safety features as engine monitoring systems and navigation equipment, and procedural defences such as flight rules and maps and charts. At the very least, it ought to be possible to determine that a given defence failed in some way in even a minor occurrence, although this may occasionally require a limited degree of further investigation of such occurrences than has occurred in the past.

In many instances, the type of defence failure can also be specified. This falls into essentially three categories: technical breakdown, latent failure and active failure. Technical breakdowns are obvious. A latent failure of a defence is when a general, pre-existing weakness of the defence is responsible. An active failure is when an otherwise perfectly good defence is somehow bypassed or defeated by the action of a person or persons – for example, a mistake, error or violation.

Recovery measures are very much like defences, differing only by the point in an occurrence at which they operate. The aviation system is such that the failure of a single defence alone rarely results in an outcome, rather two or three defences typically have to fail in sequence. In this way, the system can be described as defended in depth. In effect, recovery measures are a special class of defence in that by the time they are needed, the system has already become unsafe – in other words, they often represent the last level of protection.

An example

Take the outcome of ‘mid-air collision’. Such an event might become likely if the defence of ‘navigation’ fails, and a loss of separation occurs. This only becomes a *collision* if the pilot fails to recover the situation, aided by such recovery measures as TCAS or a warning by air traffic control. In SIAM it is intended that occurrences are tagged with the recovery measure which ‘saved the day’. By this method, clear indications can be obtained of what particular elements of the aviation system are being most relied upon to maintain the safe operation of the total system, and which areas are most vulnerable.

SIAM: the story so far

SIAM was extensively trialed by a small number of line investigators within the Bureau. This was followed by a comprehensive staff training program, prior to its operational introduction throughout BASI in October 1996. As noted previously, SIAM has been designed with the maximum potential for evolutionary development as operational experience with it accumulates.

SIAM generates a weekly statistical summary. As had been hoped, when SIAM was envisaged, this information clearly identifies areas of the aviation system on which attention needs to be focused.

A most interesting feature of the SIAM data is that, while human factors are identified as significant contributors to the majority of air safety occurrences, it is also the case that in by far the greatest number of cases it is also humans who prevent incidents from becoming accidents. In other words, while active failures by people are involved in the majority of accidents and incidents, it is also the humans in the system who play the primary role in accident prevention, that is in keeping the system safe. This provides a perspective on the aviation system rather different to the more traditional view, which has tended to emphasise the negative aspects of human performance.

The use of a 'potential outcome' category in SIAM indicates the seriousness of various categories of occurrence, should the aviation system fail or be degraded in some way. If the provisions in the system which prevent these potential occurrences becoming real are absent or deficient, then the aviation industry will clearly be in very serious difficulty. SIAM provides a basis on which to take remedial measures.

Although still in its development stages, SIAM offers a major advance on previous data systems because it incorporates a proven model of systems safety, and provides new kinds of information on air safety occurrences. Already SIAM is proving its worth in adding value to high volume, low detail occurrence reports, and represents a major advance in accident prevention. BASI believes SIAM shows great promise and is actively continuing its development.

Accident prevention strategies: the Boeing approach

Complementing the Reason approach is important work being carried out by Boeing (Russell, 1994).

Boeing has re-analysed 232 major airline accidents occurring between 1981 and 1992. The objective was to determine how many opportunities existed for intervention to stop the accident before it occurred. Boeing has identified a number of 'intervention strategies' and found that these are often several of these for each accident – in one example up to 20. In other words, there were always a number of opportunities to prevent the accident. Of real concern is the fact that non-adherence to procedures by the flying pilot and other operational procedural considerations consistently emerge as the most significant factors.

The critical question now is to determine what are the factors within the world aviation system which consistently deliver this picture year after year. The combination of the Boeing and Reason approaches offers great safety enhancement potential.

Conclusion

New legislation passed through the Australian Parliament in late 1995 gave BASI additional powers to investigate safety deficiencies in the aviation system without the need for such investigations to be triggered by an accident or incident. This was a major step forward in accident prevention, and substantially increased the Bureau's pro-active safety capabilities.

In the dawning era of the 800 passenger airliner, the loss of just one of these aircraft, let alone a mid-air collision between two of them in crowded airspace over a major city, would constitute a disaster of unthinkable proportions.

A final sobering point to consider is that such a large airliner can also easily be brought down through collision with a light aircraft. Consequently, because many categories of aircraft operation share parts of the same airspace, the aviation system as a whole needs to operate safely.

Fortunately, the aviation community is well-endowed with dedicated professionals in all areas who are dedicated to meeting the safety challenges that lie ahead. Their outstanding record of achievements to date indicates that they will be successful in the future.

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