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Toward a model of the impact organisation, human and technology factors have on the effectiveness of safety management systems

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Industrial management and organisation

ABSTRACT

Purpose: In this paper, the technology management and safety regulation and implementation challenge are examined by drawing on lessons from local and international events. The 2000-01 unplanned withdrawal from service of Ansett's B767 fleet highlighted the way systemic problems can combine with ageing aircraft issues to rapidly impact the safety or economic viability of a fleet.
Design/methodology/approach: Factors influencing organisational growth and commercial arrangements (e.g. alliancing, global supply chain management), together with human factors considerations in safety management systems such as individual participation in formal and informal knowledge networks, are drawn together to establish the foundation for improved management and regulatory approaches to aerospace technologies throughout their product life cycle. The paper describes the development of a management framework based on knowledge management principles focused on helping meet the combined need of satisfying continuing technical integrity requirements whilst maximising the value obtainable from continuing to operate a fleet of aerospace platforms for the duration of their product life cycle.
Findings: This paper has built on earlier work and drawn these considerations together and proposed a management framework that seeks to allow executive in the broader organisation to better understand where the impact of decisions can spread.
Practical implications: The framework allows those responsible for regulation and safety management to understand the potential context of their risk environment and that the sources of significant risk may well be outside their immediate area. This duality of purpose allows the proposed management framework to be used to enable the inherent value associated with maintaining high cost aircraft in service as long as possible whilst minimising exposure to the risk of unexpected technical issues.
Originality/value: Adoption of alliancing practices that require open communication and mutual cooperative relationships between operators, regulators, type certificate holders etc is recommended within a framework of strategy focused organizational arrangements to achieve the maximum value for all concerned.
Keywords: Safety; Risk management; Aviation; Regulation; Engineering leadership; Organisation

1. Introduction

The challenge of managing aircraft that faces owners, operators and regulators in the aerospace sectors can be aptly summarized in the following quote from the RAND Corporation [1]:

> "Most important, many of the problems associated with aging material have emerged with little or no warning. This raises the concern that an unexpected phenomenon may suddenly jeopardize an entire fleet's flight safety, mission readiness, or support costs."

This highlights the severe impact the unpredictable nature of most of the recognized ageing aircraft issues represent and why so much effort is being expended by the international community in this field. Ansett Australia's experience with the continuing airworthiness of their Boeing 767 fleet in the December 2000 to April 2001 period is a significant illustration of the relevance of this statement in the Australasian region. Wilson and Lockett [2] explored the management dimension needing to be addressed because of the implicit close coupling of actions by owners, operators and regulators. This paper further examines this new dimension and with added insight and proposes a framework for assisting the regulator and industry to assess the impact organisational and technological decisions can have on the effectiveness of safety management systems.

2. The management challenge

2.1. ATSB review of the ansett B767 experience

The Australian Transport Safety Bureau (ATSB) investigated the circumstances surrounding the withdrawal from service of the Ansett B767 as it considered the situation was an indication of a potential safety deficiency. The ATSB investigation [3] found that the Ansett system for the introduction of scheduling of the B767 Airworthiness Limitations Structural Inspections was deficient and vulnerable to human error.

Key deficiencies found by the ATSB in Ansett's engineering and maintenance organization related to:

- Organisational structure and change management.
- Systems for managing work processes and tasks.
- Resource allocation and workload.

The ATSB report commented about the considerable changes Ansett underwent over a number of years and that many of the systems in place had been developed when the company had faced a very different aviation environment. Productivity efficiency measures were introduced over time however, introduction of modern robust systems did not keep pace with the reduction in human resources and loss of corporate knowledge. Inadequate allowance was made for the extra demand on resources in some key areas in the maintenance and engineering organisation during the period of change. A diverse fleet led to some essential aircraft support programs being largely dependent on one or two people and made it possible for an error or omission to go undetected for a number of years. The investigation found that productivity measures were introduced without sufficient regard to the criticality of different work areas and the possible impact resource constraints could have on the core activities of safety critical areas of the organization.

In light of the Ansett experience, the ATSB investigation also found that the Australian system for continuing airworthiness of Class A aircraft was not as robust as it could be because:

- Uncertainty existed about continuing airworthiness regulatory requirements.
- There was inadequate regulatory oversight of a major operator's continuing airworthiness activities.
- Australian major defect report information was not being used to best effect.

Systemic problems that had developed within Ansett's engineering and maintenance organisation went undetected by Ansett's senior management and Civil Aviation Safety Authority (CASA) in the lead up to December 2000. In addition, the ATSB considered there were delays in adapting regulatory oversight of Ansett in response to indications that Ansett was an organisation facing increasing risk. Similarly, the ATSB stated that early 1990s decision by the then Civil Aviation Authority to reduce its involvement in a number of safety-related areas did not adequately allow for possible longer-term adverse effects. Reduction in the work done by Authority specialists in reviewing manufacturer's service bulletins relevant to Australian Class A aircraft, the increased reliance on operators' systems and on action by overseas regulators in some airworthiness matters are quoted as examples of this significant change in robustness.

Delays by the US Federal Aviation Administration (FAA) were also identified by the ATSB as contributing to the lack of awareness by Ansett and CASA of required B767 Airworthiness Limitations Structural Inspections. Associated with the specific deficiencies identified within Ansett, CASA and FAA, the ATSB investigation report outlines where the International Civil Aviation Organisation (ICAO) standards and recommended practices for continuing airworthiness systems could be improved by the application of quality assurance mechanisms to the processing and distribution of safety-related information.

2.2. Post-ansett experiences

In June 2008, Aviation Week [4] reported the FAA is undertaking one of the most concentrated probes of airline Airworthiness Directive (AD) compliance the industry has ever experienced as part of its effort to ensure it is maintaining a strong oversight system. It is reported this program arose from pressure on the FAA by Congress to demonstrate the adequacy of its oversight. Although the audits have indicated compliance is running at around 99%, they have shown how difficult compliance can be and that there is a need for better clarity in AD language.

The AD audit process has caused considerable disruption and cost. For example:

- Delta Airlines announced in March 2008 it had cancelled 275 flights for revalidating a prior AD involving its fleet of 117 MD-88 aircraft.

- United Airlines in April told customers flights would be delayed or cancelled as it performed functional tests on cargo fire suppression system on some 52 Boeing 777s.
- Alaska Airlines cancelled a few dozen flights while it inspected nine MD-80s.
- American Airlines cancelled about 3,500 flights because of the need to re-inspect some 300 MD-80s.

Moving forward, the FAA is reported in [4] as launching a National Safety Inspection Review team to conduct comprehensive safety reviews of air carriers with teams deployed where safety data indicates problems are most likely to occur. Other actions include internal field office tracking with key agency officials being alerted to overdue inspections. The US Department of Transportation has assembled an independent panel of safety experts and other leading industry executives to develop recommendations to improve the aviation system. Legislation is also being pursued in Congress to codify several of the FAA measures already undertaken and most significantly perhaps in comparison to the Ansett experience of those many years earlier, this will include a requirement for the air transportation oversight system to be reviewed for 100% compliance on a five-year cycle with the compliance oversight to include physical inspection.

In Australia, CASA recently reviewed the safety risks the aviation industry may need to address over the next three to five years. In its report arising from the review [5], CASA considers the four key trends currently impacting the industry and expected to do so in the future are:

- Unprecedented global demands for aviation services.
- Developments in aircraft manufacture, systems and technologies that whilst offering potential safety solutions, add to complexity and change.
- Increased security related costs and compliance burdens arising from international instability.
- Global warming and climate change related increased environmental awareness.

New and ageing aircraft, aviation personnel, regulators and administrators are some of the areas of aviation expected to be affected by these influences. Whilst the report seeks to address some of the areas potentially affected, it does note that future work will be needed to address identifying real safety solutions particularly where action is not already underway. Similarly, a number of risk issues addressed in the review are considered by CASA as beyond the scope of one agency and solutions will require an industry wide approach.

New Aircraft Issues. CASA consider the primary passenger risk associated with high capacity aircraft is linked to the introduction of new aircraft since most of the sector is transitioning to new types. New manufacturing techniques and technologies have driven down the cost per seat of aircraft and led in-part to the emergence of low cost carriers. Desirable as it is to have access to the latest aircraft and their technologies, the CASA review considers some of the issues requiring attention include in-part:

- Oversight of low cost carrier concept especially where non-traditional airline models are used relating to operational concepts, aircraft type, passenger demographics and country of origin safety culture.
- The ability of operators and organisations to obtain, train and manage appropriately skilled pilots, engineers and support personnel.
- The potential for unanticipated operational, maintenance and procedural issues associated with the use of new technology.
- The increased complexity of organisations operating multiple aircraft types.

Ageing Aircraft Issues. Whilst the high capacity aircraft risk may be linked to the new technology aspect, outside this sector, concerns relate to the risks associated with an ageing aircraft fleet. Many newer aircraft are too large to be operated economically on low density routes. CASA notes that even if newer aircraft were obtained, attracting qualified personnel to operate and maintain them in competition with larger carriers would prove difficult. Not surprisingly then, the CASA review reports that in the low capacity sector in 2006, for example, almost 70 per cent of single engine aircraft were over 25 years old and 40 per cent were over 40 years old; in addition, 8 per cent of multi-engine fixed wing aircraft were over 40 years old. Apart from continuing to age, the resources boom has seen their operational use intensify. Although it is possible to operate an ageing fleet safely, potential safety issues needing to be considered include:

- Smaller passenger transport organisations operating ageing aircraft will need to deal with ageing aircraft and structural fatigue issues that have not been encountered before. As a consequence, there can be no certainty about the type or quantity of maintenance needed to ensure a high level of safety
- Recruiting sufficient qualified personnel to implement required maintenance may be difficult
- Environment concerns relating to emissions controls and engine and aircraft efficiencies will place greater pressure on operators of ageing aircraft
- Manufacturers may decide to cease support for certain older aircraft and this may result in grounding of aircraft used for passenger transport.

Maintenance Personnel. The CASA review acknowledges that a shortage of maintenance personnel is not an inherent safety risk in itself provided the required standards are maintained and schedules are adjusted to fit the available resource. That said, fatigue and human factor issues do arise when the risk of a shortage in trained personnel leads to them being overworked in order to support current or increased flying levels. Developing and implementing regulations for maintenance personnel duty time along the lines of flying crews may address the individual person risk. However, at an organisation level the availability and sustainment of a pool of qualified personnel requires an appropriate recruitment and training system with the associated lead time and cost involved. Alternative measures also being used more often by larger operators is to place more reliance on offshore maintenance capabilities be they within the organisation or outsourced. Commercially attractive arrangements such as these do however, carry logistic challenges as well as potential quality oversight burdens not experienced when work is done on-shore and/or in-house to say nothing of the impact it can have on sustaining the knowledge base needed for the viability of the in-country maintenance sector.

Management Capability. CASA's review confirms the key role operational and administrative management has in contributing to the overall safety of an organisation. The trend towards outcomes based regulation and safety systems at times when the industry is experiencing sustained commercial and operational instability and growth adds to this significance. During its surveys as part of the review, CASA has identified that the inability of some operators to attract and retain senior people to mentor, guide and direct the less experienced and maintain safety systems is an area of potentially increasing risk. Notably, the period of relative stability in the airline sector post 2001 (i.e. post Ansett) has meant the industry is now not well supplied with managers at the middle and senior level who have had experience in managing risks associated with considerable change. Apart from emphasising the role of senior management in influencing safety outcomes, CASA reports the capabilities and behaviours of industry management to now be an increasing element of its surveillance activity.

Regulation Capability. As in the case of operators, the trends identified in the industry have also been acknowledged by CASA to be impacting the entities involved in administration and regulation of the industry. Some of the issues these organisations now confront or need to address include:

- Employment of less experienced personnel in safety critical organisational areas and the need to ensure the continuity and integrity of safety protocols and outcomes.
- Implementation and management of maintenance schedules for ageing aircraft fleets and liaison with foreign regulatory authorities and manufacturers.
- Integration of new technologies, systems and aircraft into existing operations particularly as operators diversify.
- Systems for entering, storing and disseminating safety critical data for use in electronic, automated and computerised flight systems.

CASA also advises there is a need for all organisations to move beyond simple compliance with a fixed set of regulatory requirements. In a dynamic environment, effective safety management systems are required that monitor, identify and address risks on an ongoing basis. CASA believes these changing dynamics mean its surveillance will increasingly involve not only ensuring organisations are meeting their requirements to enact certain procedures but that judgments are made about how effectively operators are managing their risks in total. The actions by the FAA and Congress relating to increased surveillance reinforce the need to move beyond simple compliance assurance however, the challenge for the industry is perhaps how to bring all the various aspects of safety management together in a coherent and integrated safety based system where the often competing commercial and safety needs can be addressed in a balanced and informed manner.

2.3. Broader impact of aircraft life cycle issues

The Ansett experience, the CASA review and the US based airlines AD compliance audit issues highlight the management challenges relating to the life cycle of aircraft and the direct linkages between safety assurance and commercial outcomes and vice versa. The CASA review emphasis on new aircraft issues being the focus of the high capacity carriers may be relevant in the short term, however, the fleets being now replaced were themselves new many years earlier and the new aircraft will themselves age as part of the normal platform life cycle.

Wilson and Lockett [2] emphasise the importance of work done by RAND researchers [6] which found that deeper maintenance workloads increase six to nine times as aircraft age from 5 to 40 years. Equally serious is the possibility that some fleets may experience sudden, unforeseeable, "runaway" cost increases - i.e., twofold or greater average increases in less than five years. Such precipitous cost increases would not only have grave budgetary implications; they would also constrain an operator’s ability to maintain its fleet structure and availability whilst embarking on modernizing its fleet sometime in the future.

The insidious adverse economic and capability impact of the ageing aircraft problem highlighted by the RAND studies is illustrated in Figure 1.

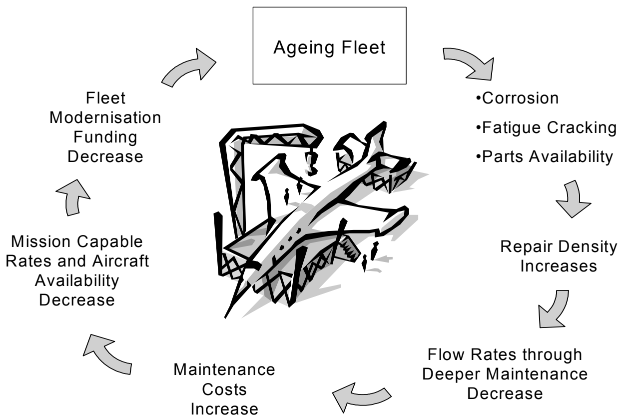

Fig. 1. The ageing aircraft cycle

Most of the ageing aircraft issues revolve around establishing the condition of structure defined as being critical through the original design validation testing and determining other likely critical structural locations arising from service in excess of the design objective and test demonstrated lives. The outcome of activity to date has manifested itself through the revision to maintenance inspections requirements via the aircraft specific Supplemental Structural Inspection Programme (SSIP) in the commercial sector with cross flow to relevant military aircraft programmes [7].

Widespread fatigue damage was often understood to represent the most likely determinant of an aircraft’s structural economic life of type. As the developments regarding a ‘limit of validity’ highlight, the challenge was often considered to lie more in the ability to determine the point in the aircraft’s life that the probability of cracking of this type is sufficiently great to warrant wholesale replacement of large section of structure or retirement of the aircraft. The limited detectability of this type of damage and the apparent rapid onset of its impact make it an area worthy of the considerable focus being applied worldwide. However, corrosion issues are also recognised as an equal, if not more limiting, factor in the economically achievable life of the airframe. Although much effort is being expended in developing predictive tools, full scale fatigue testing, teardown inspection of high life aircraft and fleet condition surveys and data sharing with Original Equipment Manufacturers (OEM) and other operators still represent the most reliable means available to the fleet manager and regulator [8].

To address the cost implications of ageing aircraft, RAND recommends a four-pronged approach:

- First, to enable rapid response in the face of a possible cost runaway, contingency plans should be developed for middle-aged aircraft.
- Second, rather than focusing on individual types of aircraft fleets analysts should assess the costs and risks associated with the full range of aircraft fleets.
- Third, at the same time as investing in engineering research on the ageing of basic materials and potential remedies against the effects of ageing, a tightly structured approach is needed to collecting "heavy maintenance" data to detect and analyse material degradation.
- Finally, insights gained through research and data collection efforts should be used to improve aircraft design and support processes.

Although the above are military derived, the Ansett experience together with the most recent CASA risk issue identification seem to reinforce the ongoing applicability of these considerations and lessons to the overall aviation industry with appropriate tailoring for the relevant sectors.

3. Need for integrated management strategies

Wilson and Lockett [2] identified the following three discrete perspectives needing to be addressed simultaneously when determining the management framework for ageing aircraft structures:

- Cost of ownership of ageing aircraft.
- Risk issues associated with ageing aircraft.
- Value to be gained from continuing to operate ageing aircraft.

It is the way these perspectives combine in a particular fleet and operator's circumstances that will govern the overall effort and investment needing to be applied to meet the business objectives against which the fleet is being retained in-service. The CASA review highlights that regardless of the age of a fleet these perspectives still exist to varying degrees by simply replacing the term 'ageing' with 'current' or 'new'. Similarly, cost of ownership includes the outsourcing of maintenance off-shore, competent maintenance and operating personnel sustainment etc. Furthermore, risk associated with the aircraft relate to the new technologies as well as ageing issues and the capability for the regulator as much as the operating/owning organisation.

CASA's risk review and the recent US based major airline experiences reinforce in many ways, the ATSB's Ansett investigation findings regarding issues of systemic and organisational problems arising and being undetected from a lack of 'mindfulness'.

3.1. Culture of organisational mindfulness

The concept of organisational mindfulness [9] was raised by the ATSB as a means of describing how high reliability organisations operate successfully in a sustainable manner. High reliability organisations are those that operate in an environment where it is not prudent to adopt a strategy of learning from mistakes where those mistakes have severe or even catastrophic consequences. The essence of organisational mindfulness is the idea that no system can guarantee safety at all times. Rather, it is necessary for the organisation to operate with a continuous state of unease, or mindfulness, and be on the alert for the possibility of system failure. The significance of such an organisational culture in the aerospace sector is eminently reinforced by the 1930s comment by Captain A. G Lamlugh of the British Aviation Assurance Group [10]:

> "Aviation is, in itself, not inherently dangerous, but to an even greater extent than the sea it is terribly unforgiving of any carelessness, incapacity, or neglect."

Reason [11] notes that there has been a shift from rule-based to more goal-based regulation—now apparent in most hazardous technologies—and this has brought a number of advantages, most particularly in the need for regulatees to think for themselves (often for the first time) about the dangers that beset their operations. But it has also brought problems—most especially for the regulator. It has, in short, put regulators between a rock and a hard place. The regulator has two tasks: first, to evaluate the Safety Management System (SMS) documentation and its associated programmes; second, if the SMS is approved, to check that the organisation remains in compliance with its documentation and programmes. The difficulty with this is that almost any subsequent accident affecting that organisation will put the regulator in the frame. There are two possibilities. The accident occurred as the result of activities that were in compliance with the SMS—in which case, the regulator should not have approved it in the first place. Alternatively, the contributing factors revealed a lack of compliance with the SMS—in which case, it was a failure of regulatory oversight. Such an observation is reinforced dramatically by CASA's comments in its review relating to the evolving role of the regulator and the very recent action by Congress regarding the FAA's surveillance function.

Appropriately, Reason argues that human and organisational factors will always lie at the heart of any system, regardless of whether or not a bad outcome occurs. In particular, he raises the question - what does it mean to be safe? - and then proposes that a workable definition would be:

> "The ability of organisations and individuals to deal with risks and hazards so as to avoid damage or losses and yet still achieve their goals."

Such a view invokes two overriding principles for safety management: the ALARP principle (keep your risks as low as reasonably practicable); and the ASSIB principle (and still stay in business).

Wood, Dannatt and Marshall [12] in a study for the ATSB explored the application to the aviation industry of a checklist developed by Reason [13] for assessing institutional resilience. This study re-affirms the important role executive and senior management has in establishing and sustaining a safety culture and provides a list of strategies considered important for commitment in action. Apart from these strategies, most of which are linked to the operational aspect of aviation, the study identified a number of concepts that were not addressed in Reason's checklist but which were considered relevant to the theme of institutional resilience and these include, in part:

- Maintenance of standards – how do airlines set standards and the nature of the policies and strategies to support their implementation.

- Networking – although not a formal part of safety management systems, networking is identified as a key factor in gaining essential knowledge and driving performance related behaviour.
- Benchmarking – related somewhat to networking, benchmarking usually occurs formally between alliance partners, however, more notable is the more frequent benchmarking occurring informally by the sharing and using of knowledge gained from colleagues and long term contacts.
- Risk Assessment – the study noted that the concept of risk assessment was referred to rarely and was actually more notable for its absence rather than presence in survey responses and it highlights this as an aspect worthy of further investigation.

These additional institutional resilience concepts accord favourably with the issues identified by CASA's industry level risk review and hence, this raises the need for a broader context to be used when identifying and managing risk particularly as it relates to aircraft technologies.

3.2. Integrating technical and organisational dimensions

Balancing the ALARP and ASSIB principles in a commercial and highly competitive environment invariably leads to the need for strategies to address the ever present contradictory forces between growth and productivity; the latter being increasingly impacted by the evolving airworthiness requirements associated with new technologies or ageing structure. Accordingly, Wilson and Lockett [2] proposed an integrated strategy based approach for organisations involved in managing aircraft that addresses:

- the technical risks they face now and in the future,
- an investment management program to maximize the value associated with retaining ageing aircraft,
- a knowledge management strategy tailored to their business strategy
- people strategies for development and retention of the technical competencies they will need to maintain their aircraft as they move through the various life cycle phases and
- developing and sustaining a high performance organizational culture and its associated mindfulness.

The ATSB investigation into Ansett highlighted the contribution of the local and overseas regulators to the situation. Reason reinforced this in his comments about the regulator approving and monitoring the performance of the SMS of organisations subject to the regulators control. Accordingly, there is an additional dimension that needs to be addressed and this is the recognition that a number of discrete entities combine to become a 'single' organisation that is actually involved in an aircraft's continuing airworthiness assurance. This is illustrated in Ansett's case where the ATSB report indicates that, apart from Ansett itself, CASA, FAA and Boeing were all involved to varying degrees in Ansett's B767 structural airworthiness assurance; the relationship between all these parties varies depending on their commercial situation however, they were in a 'natural' relationship be it driven by the regulations or commercial interest. Regardless of the nature and scope of the various interrelationships, this scenario demonstrates the need for an approach that recognizes the separate organisations' discrete but nonetheless key roles and the information flow necessary for sustaining an effective SMS in a commercially competitive environment.

4. Organisational arrangement impast

4.1. Determining the organisation

Whilst the specific arrangements for an operator will reflect the business model it is employing, Wilson and Lockett [2] concluded there are some minimum knowledge needs which must be satisfied for the operator to manage its risk exposure to aircraft structural issues over the life cycle. In essence, the broad operator needs relate to knowing:

- The demonstrated in-service achievable life of the fleet in the role, structural configuration and manner the aircraft are either used or intended to be used by the operator.
- The actual condition of each aircraft in the fleet.
- The trends in the structural deterioration of the aircraft in the fleet – this includes the type of deterioration and its rate.
- The limits of structural deterioration beyond which either airworthiness will be compromised and/or refurbishment is uneconomical.
- Strategies for recovering from unpredicted structural problems either discovered within the operator's fleet or imposed on the fleet through service bulletins or regulatory requirements.
- The support network that is involved in extending the knowledge boundaries in the aircraft technical risk issues.
- Which tools exist that will assist the operator in value based options analyses for managing the fleet so that the maximum value in retaining the fleet is achieved.

Such critical operator knowledge needs will be satisfied either through internal capability or vide arrangements within the operator's supply chain. Accordingly, a natural set of organisational relationships centred on the operator will develop for supporting an aircraft fleet which reflect these needs either being met explicitly or implicitly and these arrangements may change throughout the life cycle. For example, the regulator's approval of the operator's SMS and the level of oversight provided establish a default set of knowledge needs and levels that will bound the commercial operator's efforts unless there is a business strategy focused at exceeding the minimum effort associated with satisfying the regulator. The Ansett experience seems to be a case at point when one considers the ATSB comments especially those relating to the effect productivity changes had on resourcing of critical areas and this is reinforced by Reason's discussion on human factors influencing the effectiveness of an SMS. Importantly, these combine to highlight that it is the value created by organisational arrangements surrounding the operator and the strategies associated with leveraging these relationships that will largely influence the ongoing viability of the fleet.

Knowledge need gap filling mechanisms often involve the use of alliances by companies to fill single or multiple gaps in their value-added chain. Commercial imperatives associated with maximizing shareholder value often lead to the use of outsourcing and alliances to minimize a company's cost structure whilst maximizing the value created. Malony [14] in a presentation to the Committee for Economic Development of Australia describes the key role of alliancing in extending the boundary of an enterprise to capture organisationally derived value much greater than otherwise achievable from its own organic capability.

When considering the boundaries of the organisation arising from alliances and/or informal networks, it is useful to understand what the term organisation actually embraces and therefore implies must be considered when defining the processes and policies for a safety management system associated with the risk issues and their management. Hall [15] provides a comprehensive but appropriate definition of an organisation as being:

> "..a collectivity with a relatively identifiable boundary, a normative order (rules), ranks of authority (hierarchy), communications system, and membership coordinating systems (procedures); this collectivity exists, on a relatively continuous basis in an environment, and engages in activities that are usually related to a set of goals; the activities have outcomes for organisational members, the organisation itself, and for society."

When one considers the role regulators, type certificate holders, specialist service providers, technology research agencies etc have relative to an operator and their consequent influence on the economics of an ageing fleet, the relevance of this definition of an organisation arising as a consequence of alliancing, outsourcing and informal networking become apparent. In other words, in an 'unconstrained resource world', the operator would have all the capabilities required to meet their knowledge needs for supporting an aircraft fleet however, as the risk profile evolves and realities of commercial imperatives apply, more dependence is placed on the work and support of outside agencies with the operator focusing more and more on activities which are core to its business – for example, it is no surprise that operators do not embark on research programs into the modeling of corrosion effects on structural integrity but they do often require supplementary specialist engineering support from external providers, including the regulator, at times to meet continuing airworthiness requirements associated with inspections and repairs.

The implicit dependence on a broad range of activities outside its immediate control increases the risk of a particular operator being surprised by an unpredicted technology issue. Hence, the operator needs to recognize the extent of the broader organisation that it is the centre of and develop strategies for focusing, accessing and managing the knowledge created within that organisation to meet its needs. Success will require implementation of alliance, outsourcing and risk management processes that will be additional to extant supply chain type arrangements.

5. Developing an integrated management framework

5.1. Strategies for focusing the organisation

In [2], Wilson and Lockett applied Kaplan and Norton strategy focused organisation framework [16] to map the knowledge based strategies an operator needs to implement for effectively managing its ageing aircraft structures at a whole of organisation level. Kaplan and Norton's framework provides a vehicle for encapsulating these integrated strategies by considering the four key perspectives of financial outcome, customer, internal and learning and growth. Associated with this strategy framework, tailored alliance mechanisms need to be implemented to extract the most value from the diverse sub elements of the organisation associated with the regulation and support of an operator's fleet. Together, these will help keep the overall risk to the operator and its customers associated with the structural integrity of an ageing fleet to a minimum.

Figure 2 depicts a relatively high level strategy map showing how these perspectives may be combined in an aerospace enterprise to achieve the balanced ALARP/ASSIB outcome. This model diagram embraces the concepts described in this paper to illustrate how an integrated approach is needed to prevent an operator falling victim to systemic breakdowns of an SMS and at the same time, achieving the value inherent in the continued operation of an otherwise ageing fleet that still meets its overall business model.

5.2. Converting strategies into management framework

Strategy maps alone are not adequate for describing the management framework for a complex system such as that involved in the operation, support and regulation of an aviation enterprise. Kunc [17] describes how strategy maps help formalise business models and as a means of cascading down into the organisation performance metric to implement the model and to verify the content and validity of the strategy. However, the effective implementation of strategies and performance of the organisation is increased when the managers understand the strategy linkages and causal maps are proposed as a means of supporting the development of this understanding throughout the organisation. In addition, emphasis is made about the value cognitive maps can provide to managers to alert them to the path the organisation may likely follow and help them avoid implementing actions which could makes things worse.

Vaughan [18] describes the space shuttle *Challenger* disaster as an organisational-technical system error with the former feeding into the latter and accordingly there are many lessons to be learned. In essence, strategies for control should target causes of the problem and the analysis of the *Challenger* disaster illustrates how decisions of top administrators trickled down through the organisation altering both the structure and culture of the organisation and impacting the official risk engineering risk assessments made at the lowest level of the hierarchy. This key lesson, when combined with the issues described earlier in this paper involving the Ansett, US airlines and CASA experiences, together with technology factor and organisational dimensions, demonstrates the need for a cognitive based management framework that illustrates the interactions and linkages needing to be considered when decision are taken to ensure their impact throughout the whole extended enterprise organisation can be understood and safety risk impact identified.

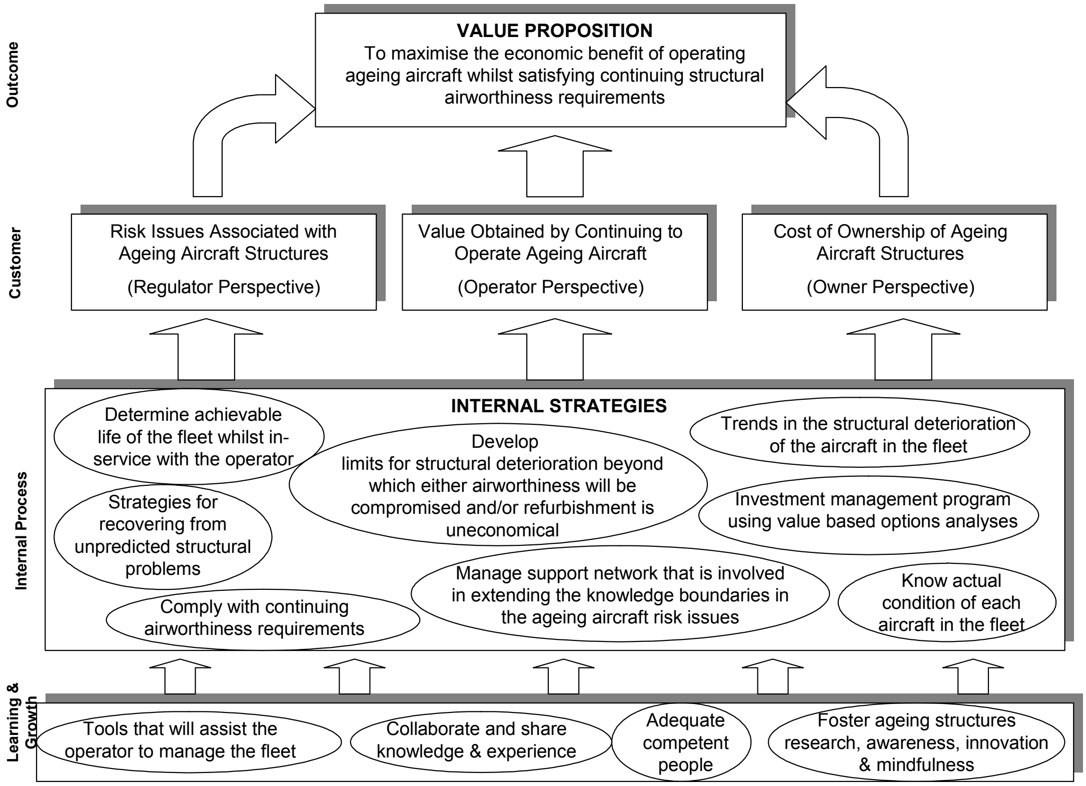

Fig. 2. Strategy map for managing ageing aircraft structures

Applying these considerations to the strategy map in Figure 2 leads to the expanded framework diagram in Figure 3 (an enlarged version is included in Appendix 1). This diagram reflects the issues addressed in the paper and proposes the nature of relationships between the issues that the aviation industry should address in the through life cycle application of aviation technology; the role the regulator has in this broader organisation framework is apparent. Application of the framework as part of the key process of 'Establishing the Context' outlined in the risk management standard AS/NZS 4360:2004 Risk Management [19] is recommended for the operating elements of a aviation industry and perhaps regulators should consider using it for their reviews of how well industry elements are managing their risk as part of the added focus indicated by the CASA review and the FAA/Congress actions. Further development of the framework is progressing as more case studies are investigated.

6. Conclusions and recommendations

The aircraft life cycle issues confronting many commercial and military operators have hitherto been addressed largely by the various technical programs in the international arena. However, organisational considerations associated with the safety and economic viability of operating aircraft has not been addressed to a large extent. These arrangements directly impact the effectiveness of safety management systems that are themselves even more critical for minimizing exposure to unexpected technical issues in aircraft. The Ansett experience of 2001 highlighted the way systemic problems that go beyond a single entity and which embrace the broader enterprise, including the regulator, can combine with aircraft technical issues to rapidly impact the safety or economic viability of a fleet. This paper has built on earlier work and drawn these considerations together and proposed a management framework that seeks to allow executive in the broader organisation to better understand where the impact of decisions can spread. Similarly, the framework allows those responsible for regulation and safety management to understand the potential context of their risk environment and that the sources of significant risk may well be outside their immediate area. This duality of purpose allows the proposed management framework to be used to enable the inherent value associated with maintaining high cost aircraft in service as long as possible whilst minimising exposure to the risk of unexpected technical issues. Contemporary organisational management approaches are applied in the development of the framework to leverage the vast array of capabilities that exist in a diverse support arrangement tailored to the specific needs of operators. Adoption of alliancing practices that require open communication and mutual cooperative relationships between operators, regulators, type certificate holders etc is recommended within a framework of strategy

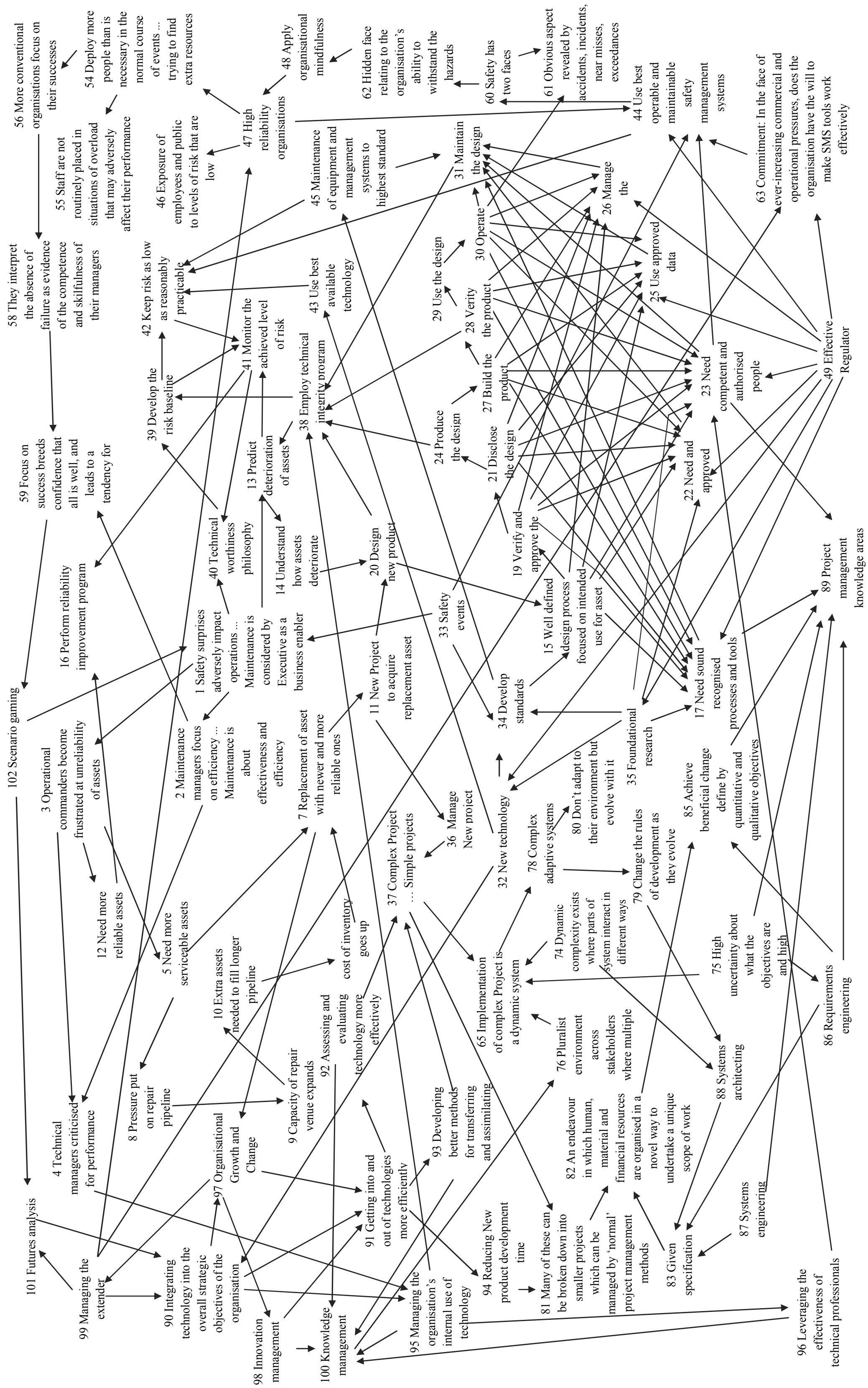

Fig. 3. Framework for managing the impact organisation, technology and human factors have on safety management systems

focused organizational arrangements to achieve the maximum value for all concerned. Underpinning this approach is the need for an increased level of organisational mindfulness so that the evolving risk environment is better understood and safety management systems can be established that are more robust with consequent safety and value benefits to the organisation and society.

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