Centre for Defence Command, Leadership and Management Studies (CDCLMS)
Australian Defence College, Canberra

COMMAND, LEADERSHIP, MANAGEMENT AND MILITARY ETHICS

CASE STUDIES

- **BLACK HAWKS DOWN –** the leadership, ethical, risk and cultural issues relating to the Australian Army's loss of 18 men in the crash of two Black Hawks in 1996.

- **COLUMBIA AND THE PIG –** the cultural, risk management, ethical and leadership issues associated with NASA's loss of the Space Shuttle Columbia in 2002 and the RAAF F-111 fuel tank deseal/reseal programme that ran for more than 25 years until 2000.

- **MADELEINE'S WAR –** strategic and operational leadership, strategic decision-making and friction in the NATO Operation ***'Allied Force'*** against the former Yugoslavia in 1999. Legal or illegal under international law? Coercive diplomacy and a nineteen member coalition.

- **A CERTAIN MARITIME INCIDENT 2001 –** tactical, operational and strategic leadership in the children overboard affair. An examination of the Select Committee report of October 2002 and the Scrafton perspectives of 2004.

- **THE INQUIRY INTO MILITARY JUSTICE 2004 –** reflection on the parliamentary inquiry into inappropriate behaviour in the ADF. The interim report is due by the end of 2004. The case study also looks at the Joint Standing Committee on Foreign Affairs, Defence and Trade report '*Rough Justice? An Investigation into Allegations of Brutality in the Army's Parachute Battalion*'.

- **THE HMAS WESTRALIA FIRE 1998 –** reflection on the Board of Inquiry findings and the Western Australian Coroner's Report.

- **RAAF AIRCRAFT LOSSES IN THE EARLY 1990's –** reflections on the RAAF leadership and safety culture of the early 1990's.

- **KHOBAR TOWERS (Eliot Cohen) –** leadership, accountability and duty of care in relation to the bombing of the USAF barracks in Saudi Arabia in 1996.

- **FRIENDLY FIRE: TARNAK FARM -** the outcomes of the bombing of Canadian troops by USAF F16 aircraft in Afghanistan in 2002.

- **THE ACQUISITION OF THE SEASPRITE HELICOPTER FOR THE RAN –** an examination of the project and the lessons learned to 2004.

- **PROJECT WEDGETAIL –** innovation, risk management, culture and leadership in the development of Australia's pocket AWACS to 2004.

- **THE BATTLE OF THE 'X' PLANES –** culture, leadership, innovation and risk management; the competition between Boeing and Lockheed Martin for the JSF.

- **THE ADF EXPERIENCE IN RWANDA, 1994-95 –** leadership, ethical decision-making and trauma with the Kibeho massacre and the leadership of the Canadian LTGEN Romeo Dallaire.

- **THE US MARINE CORPS AND THE ITALIAN CABLE CAR DISASTER –** an examination of the crew conspiracy to destroy evidence in 1998.

- **OPERATION *BALI ASSIST* –** exemplary ADF leadership in the evacuation of the Bali bombing victims in 2002.

- **THE USE OF TORTURE IN THE WAR ON TERROR –** reflections on the Afghanistan (2002) and Abu Ghraib (2004) experiences.

- **WAR CRIME: SREBRENICA –** the UN Dutch Battalion and the massacre of Kosovar civilians by the Serbs in 1995.

- **SOMALIA AND DISLOCATION: ETHICS AND THE CANADIAN FORCES –** the fallout from the murder of a Somali youth by the Canadian Airborne Regiment in 1993.

- **TAILHOOK –** US Naval aviators and inappropriate behaviour; the suicide of ADMIRAL Jeremy Boorda in 1996 and a Service 'struggling for its soul'.

- **The DMO and KINNAIRD –** an examination of the ongoing change process in the Defence Materiel Organisation.

CDCLMS
As at NOVEMBER 2004

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www.defence.gov.au/adc/cdclms.htm

CASE STUDIES

The Centre is developing a library of case studies for use on courses incorporating command, leadership and management. These case studies were primarily developed for use on specific components of the Australian Command and Staff Course and the Centre for Defence and Strategic Studies Course. However, the case studies may be used on other Defence courses.

The case studies are currently developed under two categories: strategic leadership and military ethics.

- **MILITARY ETHICS**

Case studies are chosen for their degree of ethical complexity in which the "right" choice is not clear. For each case study, a selection of primary and secondary source information is provided. These include Boards of Inquiry Reports, newspaper articles, interviews with personnel involved and video footage. Students are asked to identify the ethical issues and explain why they are ethical issues. Factors such as leadership, management, command and organisational culture are explored within a military ethics context.

Case studies include:

- The Australian Army Blackhawk Disaster 1996.
- 'Madeleine's War'- Operation Allied Force; the NATO bombing of the Balkans 1999.
- The Khobar Towers Bombing and its aftermath 1996 (Eliot A. Cohen)
- Comparison of organisational culture, leadership, risk management and ethical issues between the RAAF and NASA

leading to the Australian F111 Deseal/Reseal chemical exposure and the Columbia disaster respectively.

- An explanation of a series of RAAF aircraft accidents in the early 1990's

- The ethics of unmanned combat areal vehicles (UCAV's)

- **STRATEGIC LEADERSHIP**

  - Operation Bali Assist.

This case study will facilitate an assessment of the behaviours and actions of the strategic leaders involved in the Bali Bombing of October 2001. The purpose of the case study is to provide a relevant and timely example of the challenges and issues that are associated with being a strategic leader. The Bali example demonstrates these challenges, especially in the aspects of leading a whole-of-government response to an unexpected attack in a foreign nation-state.

As well as collating a range of primary and secondary data for the case study, the Centre has produced a video of interviews with strategic leaders and individuals involved in Operation Bali Assist. Interviews include the aero-medical evacuation doctor and other operational and medical staff from the C130 Wing based at Richmond, the operations and medical staff from Air headquarters and, the Air Commander Australia.

- Joint Strike Fighter (JSF); a case study in corporate culture, risk management and leadership

This case study explores the different corporate cultures, risk management and leadership of Boeing and Lockheed-Martin in relation to the JSF competition.

LEADERSHIP

- The ADF in Rwanda 1994 - 95

Australia deployed two ADF contingents to Rwanda in 1994 and 1995. The contingents experienced a series of traumatic events during their tours. This case study is being developed to highlight the leadership lessons learned and the ethical challenges faced by the deployed Commanders.

Columbia
(Space Shuttle) **and** 'the Pig'
(F111)

A case study in leadership, risk management and the

ethics of organisations

Centre for Defence Command, Leadership and Management Studies

Australian Defence College 2004

Abstract

Columbia

Space flight is known to be risky business, but during the minutes before dawn on February 1 2003, as the doomed shuttle *Columbia* began to descend into the upper atmosphere over the Pacific Ocean, only a handful of people—a few engineers deep inside of NASA—worried that the vehicle and its seven souls might actually come to grief. It was the responsibility of NASA's managers to hear those suspicions, and from top to bottom they failed. But in fairness to those whose reputations have now been sacrificed, seventeen years and eighty-nine shuttle flights have passed since the *Challenger* explosion, and within the agency a new generation had risen that was smart, perhaps, but also unwise—confined by NASA's walls and routines, and vulnerable to the self-satisfaction that inevitably had set in.

The physical cause of the loss of *Columbia* and its crew was a breach in the Thermal Protection System on the leading edge of the left wing, caused by a piece of insulating foam which separated from the left bipod ramp section of the External Tank at 81.7 seconds after launch. The organizational causes of the accident are rooted in the Space Shuttle Program's history and culture, including the original compromises that were required to gain approval for the Shuttle, subsequent years of resource constraints, fluctuating priorities, schedule pressures, mischaracterization of the Shuttle as operational rather than developmental, and lack of an agreed national vision for human space flight. Cultural traits and organizational practices detrimental to safety were allowed to develop, including: reliance on past success as a substitute for sound engineering practices (such as testing to understand why systems were not performing in accordance with requirements); organizational barriers that prevented effective communication of critical safety information and stifled professional differences of opinion; lack of integrated management across program elements; and the evolution of an informal chain of command and decision-making processes that operated outside the organization's rules.

'the Pig'

For more than 20 years RAAF maintenance personnel have been working inside the fuel tanks of F111 aircraft, resealing leaking seams, in an ongoing series of repair programs. They worked in cramped and very unpleasant conditions, sometimes in unbearable heat and sometimes in near freezing temperatures, and they suffered chronic and occasionally acute exposure to the hazardous substances with which they worked. The resulting symptoms include skin rash, gastro-intestinal problems, headaches and loss of memory.

The matter came to a head in early 2000 and the fuel tank repair program was suspended. Since that time the problem of fuel tank leaks has not been adequately addressed and the availability of F111 aircraft has been affected. In short, as

well as causing substantial human suffering, the failure of the fuel tank reseal program has impacted on Defence capability.
Some of those whose health has been damaged believe that certain individuals should be held accountable for allowing things to go on as long as they did. But the scale and duration of the problem indicates that we are dealing with a deep-seated failure for which no single individual or group of individuals can reasonably be held accountable. The 'material made available to the Board… points to ongoing failings at a managerial level to implement a safe system of work and co-ordinate processes within a complex organisation'. If anybody is to be held accountable, therefore, it is the Air Force itself.

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The Columbia Tragedy

This paper on the Columbia tragedy is a combination of edited extracts from:

- The Report of the Columbia Accident Investigation Board, and
- Columbia's Last Flight, by William Lanewiesche in Atlantic Monthly, November 2003

Introduction

The shuttle came into view, on track and on schedule, just after 5:53 Pacific time, crossing the California coast at about 15,000 mph in the superthin air 230,000 feet above the Russian River, northwest of San Francisco.

Two minutes later the *Columbia* neared southwestern Utah. North of the Grand Canyon, in Saint George, Utah, a man and his grown son climbed onto a ridge above the county hospital, hoping for the sort of view they had seen several years before, of a fireball going by. It was a sight they remembered as "really neat". This time was different, though. The son, who was videotaping, started yelling, "Jesus, Dad, there's stuff falling off!" and the father saw it too, with his naked eyes.

The *Columbia* was flying on autopilot, as is usual, and though it continued to lay flares in its wake, the seven astronauts aboard remained blissfully unaware of the trouble they were in. Within five minutes, all seven of the crew were dead. The *Columbia* fell in thousands of pieces along a swath ten miles wide and 300 miles long, across East Texas and into Louisiana. There were many stories later. Some of the debris whistled down through the leaves of trees and smacked into a pond where a man was fishing. Another piece went right through a backyard trampoline, evoking a mother's lament: "Those damned kids …" Still another piece hit the window of a moving car, startling the driver. The heaviest parts flew the farthest. An 800-pound piece of engine hit the ground in Fort Polk, Louisiana, doing 1,400 mph. A 600-pound piece landed nearby.

The Space Shuttle
The Space Shuttle is one of the most complex machines ever devised. Its main elements – the Orbiter, Space Shuttle Main Engines, External Tank, and Solid Rocket Boosters – are assembled from more than 2.5 million parts, 230 miles of wire, 1,060 valves, and 1,440 circuit breakers. Weighing approximately 4.5 million pounds at launch, the Space Shuttle accelerates to an orbital velocity of 17,500 miles per hour – 25 times faster than the speed of sound – in just over eight minutes. Once on orbit, the Orbiter must protect its crew from the vacuum of space while enabling astronauts to conduct scientific research, deploy and service satellites, and assemble the International Space Station. At the end of its mission, the Shuttle uses the Earth's atmosphere as a brake to decelerate from orbital velocity to a safe landing at 220 miles per hour, dissipating in the process all the energy it gained on its way into orbit.

The Orbiter

The Orbiter is what is popularly referred to as "the Space Shuttle." About the size of a small commercial airliner, the Orbiter normally carries a crew of seven, including a Commander, Pilot, and five Mission or Payload Specialists. The Orbiter can accommodate a payload the size of a school bus weighing between 38,000 and 56,300 pounds depending on what orbit it is launched into. The Orbiter's upper flight deck is filled with equipment for flying and maneuvering the vehicle and controlling its remote manipulator arm. The mid-deck contains stowage lockers for food, equipment, supplies, and experiments, as well as a toilet, a hatch for entering and exiting the vehicle on the ground, and – in some instances – an airlock for doing so in orbit. During liftoff and landing, four crew members sit on the flight deck and the rest on the mid-deck.

Different parts of the Orbiter are subjected to dramatically different temperatures during re-entry. The nose and leading edges of the wings are exposed to superheated air temperatures of 2,800 to 3,000 degrees Fahrenheit, depending upon re-entry profile. Other portions of the wing and fuselage can reach 2,300 degrees Fahrenheit. Still other areas on top of the fuselage are sufficiently shielded from superheated air that ice sometimes survives through landing.

To protect its thin aluminum structure during re-entry, the Orbiter is covered with various materials collectively referred to as the Thermal Protection System. The three major components of the system are various types of heat-resistant tiles, blankets, and the Reinforced Carbon-Carbon (RCC) panels on the leading edge of the wing and nose cap. The RCC panels most closely resemble a hi-tech fiberglass – layers of special graphite cloth that are molded to the desired shape at very high temperatures.

The tiles, which protect most other areas of the Orbiter exposed to medium and high heating, are 90 percent air and 10 percent silica (similar to common sand). One-tenth the weight of ablative heat shields, which are designed to erode during re-entry and therefore can only be used once, the Shuttle's tiles are reusable. They come in varying strengths and sizes, depending on which area of the Orbiter they protect, and are designed to withstand either 1,200 or 2,300 degrees Fahrenheit. In a dramatic demonstration of how little heat the tiles transfer, one can place a blowtorch on one side of a tile and a bare hand on the other. The blankets, capable of withstanding either 700 or 1,200 degrees Fahrenheit, cover regions of the Orbiter that experience only moderate heating.

The cause of the loss

The 113th mission of the Space Shuttle Program was called STS-107. It would be the 28th flight of *Columbia*. The physical cause of the loss of *Columbia* and its crew was a breach in the Thermal Protection System on the leading edge of the left wing, caused by a piece of insulating foam.

At 81.7 seconds after launch, when the Shuttle was at about 65,820 feet and traveling at Mach 2.46 (1,650 mph), a large piece of hand-crafted insulating foam came off an area where the Orbiter attaches to the External Tank. At 81.9 seconds, it struck the leading edge of *Columbia*'s left wing. This event was not detected by the crew on board or seen by ground support teams until the next day, during detailed reviews of all launch camera photography and videos. This foam strike had no apparent effect on the daily conduct of the 16-day mission, which met all its objectives.

That conclusion is that *Columbia* re-entered Earth's atmosphere with a pre-existing breach in the leading edge of its left wing in the vicinity of Reinforced Carbon-Carbon (RCC) panel 8. This breach, caused by the foam strike on ascent, was of sufficient size to allow superheated air (probably exceeding 5,000 degrees Fahrenheit) to penetrate the cavity behind the RCC panel. The breach widened, destroying the insulation protecting the wing's leading edge support structure, and the superheated air eventually melted the thin aluminum wing spar. Once in the interior, the superheated air began to destroy the left wing. This destructive process was carefully reconstructed from the recordings of hundreds of sensors inside the wing, and from analyses of the reactions of the flight control systems to the changes in aerodynamic forces.

By the time *Columbia* passed over the coast of California in the pre-dawn hours of February 1, at Entry Interface plus 555 seconds, amateur videos show that pieces of the Orbiter were shedding. The Orbiter was captured on videotape during most of its quick transit over the Western United States. The Board correlated the events seen in these videos to sensor readings recorded during re-entry. Analysis indicates that the Orbiter continued to fly its pre-planned flight profile, although, still unknown to anyone on the ground or aboard *Columbia*, her control systems were working furiously to maintain that flight profile. Finally, over Texas, just southwest of Dallas-Fort Worth, the increasing aerodynamic forces the Orbiter experienced in the denser levels of the atmosphere overcame the catastrophically damaged left wing, causing the Orbiter to fall out of control at speeds in excess of 10,000 mph

Organizational Cause Statement

The organizational causes of this accident are rooted in the Space Shuttle Program's history and culture, including the original compromises that were required to gain approval for the Shuttle Program, subsequent years of resource constraints, fluctuating priorities, schedule pressures, mischaracterizations of the Shuttle as operational rather than developmental, and lack of an agreed national vision. Cultural traits and organizational practices detrimental to safety and reliability were allowed to develop, including: reliance on past success as a substitute for sound engineering practices (such as testing to understand why systems were not performing in accordance with requirements/specifications); organizational barriers which prevented effective

communication of critical safety information and stifled professional differences of opinion; lack of integrated management across program elements; and the evolution of an informal chain of command and decision-making processes that operated outside the organization.s rules.

Understanding Causes

In the Board's view, NASA's organizational culture and structure had as much to do with this accident as the External Tank foam. Organizational culture refers to the values, norms, beliefs, and practices that govern how an institution functions. At the most basic level, organizational culture defines the assumptions that employees make as they carry out their work. It is a powerful force that can persist through reorganizations and the reassignment of key personnel.

Given that today's risks in human space flight are as high and the safety margins as razor thin as they have ever been, there is little room for overconfidence. Yet the attitudes and decision-making of Shuttle Program managers and engineers during the events leading up to this accident were clearly overconfident and often bureaucratic in nature. They deferred to layered and cumbersome regulations rather than the fundamentals of safety. The Shuttle Program's safety culture is straining to hold together the vestiges of a once robust systems safety program.

As the Board investigated the *Columbia* accident, it expected to find a vigorous safety organization, process, and culture at NASA, bearing little resemblance to what the Rogers Commission (which reported after the Challenger disaster in 1986) identified as the ineffective "silent safety" system in which budget cuts resulted in a lack of resources, personnel, independence, and authority. NASA's initial briefings to the Board on its safety programs espoused a risk-averse philosophy that empowered any employee to stop an operation at the mere glimmer of a problem. Unfortunately, NASA's views of its safety culture in those briefings did not reflect reality. Shuttle Program safety personnel failed to adequately assess anomalies and frequently accepted critical risks without qualitative or quantitative support, even when the tools to provide more comprehensive assessments were available.

Similarly, the Board expected to find NASA's Safety and Mission Assurance organization deeply engaged at every level of Shuttle management: the Flight Readiness Review, the Mission Management Team, the Debris Assessment Team, the Mission Evaluation Room, and so forth. This was not the case. In briefing after briefing, interview after interview, NASA remained in denial: in the agency's eyes, "there were no safety-of-flight issues," and no safety compromises in the long history of debris strikes on the Thermal Protection System. The silence of Program-level safety processes undermined oversight; when they did not speak up, safety personnel could not fulfill their stated mission to provide "checks and balances." A pattern of acceptance prevailed throughout the organization that tolerated foam problems without sufficient engineering justification for doing so.

Organizational Causes: Insights from History
NASA's organizational culture is rooted in history and tradition. From NASA's inception in 1958 to the *Challenger* accident in 1986, the agency's Safety, Reliability, and Quality Assurance (SRQA) activities, "although distinct disciplines," were "typically treated as one function in the design, development, and operations of NASA's manned space flight programs." Contractors and NASA engineers collaborated closely to assure the safety of human space flight. Solid engineering practices emphasized defining goals and relating system performance to them; establishing and using decision criteria; developing alternatives; modeling systems for analysis; and managing operations. Although a NASA Office of Reliability and Quality Assurance existed for a short time during the early 1960s, it was funded by the human space flight program. By 1963, the office disappeared from the agency's organization charts. For the next few years, the only type of safety program that existed at NASA was a decentralized "loose federation" of risk assessment oversight run by each program's contractors and the project offices at each of the three Human Space Flight Centers.

Fallout from Apollo – 1967

In January 1967, months before the scheduled launch of *Apollo 1*, three astronauts died when a fire erupted in a ground-test capsule. In response, Congress, seeking to establish an independent safety organization to oversee space flight, created the Aerospace Safety Advisory Panel (ASAP). The ASAP was intended to be a senior advisory committee to NASA, reviewing space flight safety studies and operations plans, and evaluating "systems procedures and management policies that contribute to risk." The panel's main priority was human space flight missions. Although four of the panel's nine members can be NASA employees, in recent years few have served as members. While the panel's support staff generally consists of fulltime NASA employees, the group technically remains an independent oversight body.

Congress simultaneously mandated that NASA create separate safety and reliability offices at the agency.s headquarters and at each of its Human Space Flight Centers and Programs. Overall safety oversight became the responsibility of NASA's Chief Engineer. Although these offices were not totally independent – their funding was linked with the very programs they were supposed to oversee – their existence allowed NASA to treat safety as a unique function. Until the *Challenger* accident in 1986, NASA safety remained linked organizationally and financially to the agency's Human Space Flight Program.

Challenger - 1986

In the aftermath of the *Challenger* accident, the Rogers Commission issued recommendations intended to remedy what it considered to be basic deficiencies in NASA's safety system. These recommendations centered on an underlying theme: the lack of independent safety oversight at NASA. Without independence, the Commission believed, the slate of safety failures that contributed to the *Challenger* accident – such as the undue influence of schedule pressures and the flawed Flight Readiness process – would not be corrected. "NASA should establish an Office of

Safety, Reliability, and Quality Assurance to be headed by an Associate Administrator, reporting directly to the NASA Administrator," concluded the Commission. "It would have *direct authority* for safety, reliability, and quality assurance throughout the Agency. The office should be assigned the workforce to ensure adequate oversight of its functions and should be independent of other NASA functional and program responsibilities" [emphasis added].

In July 1986, NASA Administrator James Fletcher created a Headquarters Office of Safety, Reliability, and Quality Assurance, which was given responsibility for all agency-wide safety-related policy functions. In the process, the position of Chief Engineer was abolished. The new office's Associate Administrator promptly initiated studies on Shuttle in-flight anomalies, overtime levels, the lack of spare parts, and landing and crew safety systems, among other issues. Yet NASA's response to the Rogers Commission recommendation did not meet the Commission's intent: the Associate Administrator did not have direct authority, and safety, reliability, and mission assurance activities across the agency remained dependent on other programs and Centers for funding.

General Accounting Office Review – 1990

A 1990 review by the U.S. General Accounting Office questioned the effectiveness of NASA's new safety organizations in a report titled "Space Program Safety: Funding for NASA's Safety Organizations Should Be Centralized." The report concluded *"NASA did not have an independent and effective safety organization"* [emphasis added]. Although the safety organizational structure may have "appeared adequate," in the late 1980s the space agency had concentrated most of its efforts on creating an independent safety office at NASA Headquarters. In contrast, the safety offices at NASA's field centers "were not entirely independent because they obtained most of their funds from activities whose safety-related performance they were responsible for overseeing." The General Accounting Office worried that "the lack of centralized independent funding may also restrict the flexibility of center safety managers." It also suggested "most NASA safety managers believe that centralized SRM&QA [Safety, Reliability, Maintainability and Quality Assurance] funding would ensure independence." NASA did not institute centralized funding in response to the General Accounting Office report, nor has it since. The problems outlined in 1990 persist to this day.

Space Flight Operations Contract – 1996

The Space Flight Operations Contract was intended to streamline and modernize NASA's cumbersome contracting practices, thereby freeing the agency to focus on research and development. Yet its implementation complicated issues of safety independence. A single contractor would, in principle, provide "oversight" on production, safety, and mission assurance, as well as cost management, while NASA maintained "insight" into safety and quality assurance through reviews and metrics. Indeed, the reduction to a single primary contract simplified some aspects of the NASA/contractor interface. However, as a result, experienced engineers changed jobs, NASA grew dependent on contractors for technical support, contract monitoring requirements increased, and positions were subsequently staffed by less experienced engineers who were placed in management roles.

Collectively, this eroded NASA's in-house engineering and technical capabilities and increased the agency's reliance on the United Space Alliance and its subcontractors to identify, track, and resolve problems. The contract also involved substantial transfers of safety responsibility from the government to the private sector; rollbacks of tens of thousands of Government Mandated Inspection Points; and vast reductions in NASA's in-house safety-related technical expertise. In the aggregate, these mid-1990s transformations rendered NASA's already problematic safety system simultaneously weaker and more complex.

The effects of transitioning Shuttle operations to the Space Flight Operations Contract were not immediately apparent in the years following implementation. In November 1996, as the contract was being implemented, the Aerospace Safety Advisory Panel published a comprehensive contract review, which concluded that the effort "to streamline the Space Shuttle program has not inadvertently created unacceptable flight or ground risks." The Aerospace Safety Advisory Panel's passing grades proved temporary.

Shuttle Independent Assessment Team – 1999

Just three years later, after a number of close calls, NASA chartered the Shuttle Independent Assessment Team to examine Shuttle sub-systems and maintenance practices. The Shuttle Independent Assessment Team Report sounded a stern warning about the quality of NASA's Safety and Mission Assurance efforts and noted that the

Space Shuttle Program had undergone a massive change in structure and was transitioning to “a slimmed down, contractor-run operation.”

The team produced several pointed conclusions: the Shuttle Program was inappropriately *using previous success as a justification* for accepting increased risk; the Shuttle Program’s *ability to manage risk was being eroded* “by the desire to reduce costs;” the size and complexity of the Shuttle Program and NASA/contractor relationships *demanded better communication practices*; NASA’s safety and mission assurance organization was *not sufficiently independent*; and “the workforce has received a conflicting message due to the emphasis on achieving cost and staff reductions, and the *pressures placed on increasing scheduled flights* as a result of the Space Station” [emphasis added]. The Shuttle Independent Assessment Team found failures of communication to flow up from the “shop floor” and down from supervisors to workers, deficiencies in problem and waiver-tracking systems, potential conflicts of interest between Program and contractor goals, and a general failure to communicate requirements and changes across organizations. In general, the Program’s organizational culture was deemed “too insular.”

NASA subsequently formed an Integrated Action Team to develop a plan to address the recommendations from previous Program-specific assessments, including the Shuttle Independent Assessment Team, and to formulate improvements. In part this effort was also a response to program missteps in the drive for efficiency seen in the “faster, better, cheaper” NASA of the 1990s. The NASA Integrated Action Team observed: *“NASA should continue to remove communication barriers and foster an inclusive environment where open communication is the norm.”* The intent was to establish an initiative where *“the importance of communication and a culture of trust and openness permeate all facets of the organization.”* The report indicated that *“multiple processes to get the messages across the organizational structure”* would need to be explored and fostered [emphasis added]. The report recommended that NASA solicit expert advice in identifying and removing barriers, providing tools, training, and education, and facilitating communication processes.

The Shuttle Independent Assessment Team and NASA Integrated Action Team findings mirror those presented by the Rogers Commission. The same communication problems persisted in the Space Shuttle Program at the time of the *Columbia* accident.

Space Shuttle Competitive Source Task Force – 2002

In 2002, a 14-member Space Shuttle Competitive Task Force supported by the RAND Corporation examined competitive sourcing options for the Shuttle Program. In its final report to NASA, the team highlighted several safety-related concerns, which the Board shares:

- Flight and ground hardware and software are obsolete, and safety upgrades and aging infrastructure repairs have been deferred.

- Budget constraints have impacted personnel and resources required for maintenance and upgrades.

- International Space Station schedules exert significant pressures on the Shuttle Program.

- Certain mechanisms may impede worker anonymity in reporting safety concerns.

- NASA does not have a truly independent safety function with the authority to halt the progress of a critical mission element.

Based on these findings, the task force suggested that an Independent Safety Assurance function should be created that would hold one of "three keys" in the Certification of Flight Readiness process (NASA and the operating contractor would hold the other two), effectively giving this function the ability to stop any launch. Although in the Board's view the "third key" Certification of Flight Readiness process is not a perfect solution, independent safety and verification functions are vital to continued Shuttle operations. This independent function should possess the authority to shut down the flight preparation processes or intervene post launch when an anomaly occurs.

Organizational Causes: Insights from Theory

To develop a thorough understanding of accident causes and risk, and to better interpret the chain of events that led to the *Columbia* accident, the Board turned to the contemporary social science literature on accidents and risk and sought insight from experts in High Reliability, Normal Accident, and Organizational Theory. Additionally, the Board held a forum, organized by the National Safety Council, to define the essential characteristics of a sound safety program.

High Reliability Theory argues that organizations operating high-risk technologies, if properly designed and managed, can compensate for inevitable human shortcomings, and therefore avoid mistakes that under other circumstances would lead to catastrophic failures. Normal Accident Theory, on the other hand, has a more pessimistic view of the ability of organizations and their members to manage high-risk technology. **Normal Accident Theory** holds that organizational and technological complexity contributes to failures. Organizations that aspire to failure-free performance are inevitably doomed to fail because of the inherent risks in the technology they operate. Normal Accident models also emphasize systems approaches and systems thinking, while the High Reliability model works from the bottom up: if each component is highly reliable, then the system will be highly reliable and safe.

Though neither High Reliability Theory nor Normal Accident Theory is entirely appropriate for understanding this accident, insights from each figured prominently in the Board's deliberation. Fundamental to each theory is the importance of strong organizational culture and commitment to building successful safety strategies.

The Board selected certain well-known traits from these models to use as a yardstick to assess the Space Shuttle Program, and found them particularly useful in shaping its views on whether NASA's current organization of its Human Space Flight Program is appropriate for the remaining years of Shuttle operation and beyond. Additionally, organizational theory, which encompasses organizational culture, structure, history, and hierarchy, is used to explain the *Columbia* accident, and, ultimately, produce an expanded explanation of the accident's causes. The Board believes the following considerations are critical to understand what went wrong during STS-107. They will become the central motifs of the Board's analysis.

- **Commitment to a Safety Culture:** NASA's safety culture has become reactive, complacent, and dominated by unjustified optimism. Over time, slowly and unintentionally, independent checks and balances intended to increase safety have been eroded in favor of detailed processes that produce massive amounts of data and unwarranted consensus, but little effective communication. Organizations that successfully deal with high-risk technologies create and sustain a disciplined safety system capable of identifying, analyzing, and controlling hazards throughout a technology's life cycle.

- **Ability to Operate in Both a Centralized and Decentralized Manner:** The ability to operate in a centralized manner when appropriate, and to operate in a decentralized manner when appropriate, is the hallmark of a high-reliability organization. On the operational side, the Space Shuttle Program has a highly centralized structure. Launch commit criteria and flight rules govern every imaginable contingency. The Mission Control Center and the Mission Management Team have very capable decentralized processes to solve problems that are not covered by such rules. The process is so highly regarded that it is considered one of the best problem solving organizations of its type. In these situations, mature processes anchor rules, procedures, and routines to make the Shuttle Program.s matrixed workforce seamless, at least on the surface.

  Nevertheless, it is evident that the position one occupies in this structure makes a difference. When supporting organizations try to "push back" against centralized Program direction – like the Debris Assessment Team did during STS-107 – independent analysis generated by a decentralized decision-making process can be stifled. The Debris Assessment Team, working in an essentially decentralized format, was well-led and had the right expertise to work the problem, but their charter was "fuzzy," and the team had little direct connection to the Mission Management Team. This lack of connection to the Mission Management Team and the Mission Evaluation Room is the single most compelling reason why communications were so poor during the debris assessment. In this case, the Shuttle Program was unable to simultaneously manage both the centralized and decentralized systems.

- **Importance of Communication:** At every juncture of STS-107, the Shuttle Program's structure and processes, and therefore the managers in charge, resisted new information. Early in the mission, it became clear that the Program was not going to authorize imaging of the Orbiter because, in the Program's opinion, images were not needed. Overwhelming evidence indicates that Program leaders decided the foam strike was merely a maintenance problem long before any analysis had begun. Every manager knew the party line: "we'll wait for the analysis – no safety-of-flight issue expected." Program leaders spent at least as much time making sure hierarchical rules and processes were followed as they did trying to establish why anyone would want a picture of the Orbiter. These attitudes are incompatible with an organization that deals with high-risk technology.

- **Avoiding Oversimplification:** The *Columbia* accident is an unfortunate illustration of how NASA's strong cultural bias and its optimistic organizational thinking undermined effective decision-making. Over the course of 22 years, foam strikes were normalized to the point where they were simply a "maintenance" issue – a concern that did not threaten a mission's success. This oversimplification of the threat posed by foam debris rendered the issue a low-level concern in the minds of Shuttle managers. Ascent risk, so evident in *Challenger*, biased leaders to focus on strong signals from the Shuttle System Main Engine and the Solid Rocket Boosters. Foam strikes, by comparison, were a weak and consequently overlooked signal, although they turned out to be no less dangerous.

- **Conditioned by Success:** Even after it was clear from the launch videos that foam had struck the Orbiter in a manner never before seen, Space Shuttle Program managers were not unduly alarmed. They could not imagine why anyone would want a photo of something that could be fixed after landing. More importantly, learned attitudes about foam strikes diminished management's wariness of their danger. The Shuttle Program turned "the experience of failure into the memory of success." Managers also failed to develop simple contingency plans for a re-entry emergency. They were convinced, without study, that nothing could be done about such an emergency. The intellectual curiosity and skepticism that a solid safety culture requires was almost entirely absent. Shuttle managers did not embrace safety-conscious attitudes. Instead, their attitudes were shaped and reinforced by an organization that, in this instance, was incapable of stepping back and gauging its biases. Bureaucracy and process trumped thoroughness and reason.

- **Significance of Redundancy:** The Human Space Flight Program has compromised the many redundant processes, checks, and balances that should identify and correct small errors. Redundant systems essential to every high-risk enterprise have fallen victim to bureaucratic efficiency. Years of workforce reductions and outsourcing have culled from NASA's workforce the layers of experience and hands-on systems knowledge that once provided a capacity for safety oversight. Safety and Mission Assurance personnel have been eliminated, careers in safety have lost organizational prestige, and the Program now decides on its own how much safety and engineering oversight it needs. Aiming to align its inspection regime with the International Organization for Standardization 9000/9001 protocol, commonly used in industrial environments – environments very different than the Shuttle Program – the Human Space Flight Program shifted from a comprehensive "oversight" inspection process to a more limited "insight" process, cutting mandatory inspection points by more than half and leaving even fewer workers to make "second" or "third" Shuttle systems checks.

Implications of Theories on Complex Organizations for the Shuttle Program

The Board's investigation into the *Columbia* accident revealed two major causes with which NASA has to contend: one technical, the other organizational. The Board studied the two dominant theories on complex organizations and accidents involving high-risk technologies. These schools of thought were influential in shaping the Board's organizational recommendations, primarily because each takes a different approach to understanding accidents and risk.

The Board determined that **high-reliability theory** is extremely useful in describing the culture that should exist in the human space flight organization. NASA and the Space Shuttle Program must be committed to a strong safety culture, a view that serious accidents can be prevented, a willingness to learn from mistakes, from technology, and from others, and a realistic training program that empowers employees to know when to decentralize or centralize problem-solving. The Shuttle Program cannot afford the mindset that accidents are inevitable because it may lead to unnecessarily accepting known and preventable risks.

The Board believes **normal accident theory** has a key role in human spaceflight as well. Complex organizations need specific mechanisms to maintain their commitment to safety and assist their understanding of how complex interactions can make organizations accident-prone. Organizations cannot put blind faith into redundant warning systems because they inherently create more complexity, and this complexity in turn often produces unintended system interactions that can lead to failure. The Human Space Flight Program must realize that additional protective layers are not always the best choice. The Program must also remain sensitive to the fact that despite its best intentions, managers, engineers, safety professionals, and other employees, can, when confronted with extraordinary demands, act in counterproductive ways.

The challenges to failure-free performance highlighted by these two theoretical approaches will always be present in an organization that aims to send humans into space. What can the Program do about these difficulties? The Board considered three alternatives. First, the Board could recommend that NASA follow traditional paths to improving safety by making changes to policy, procedures, and processes. These initiatives could improve organizational culture. The analysis provided by experts and the literature leads the Board to conclude that although reforming management practices has certain merits, it also has critical limitations. Second, the Board could recommend that the Shuttle is simply too risky and should be grounded. The Board is committed to continuing human space exploration, and believes the Shuttle Program can and should continue to operate. Finally, the Board could recommend a significant change to the organizational structure that controls the Space Shuttle Program's technology. The Board believes this option has the best chance to successfully manage the complexities and risks of human space flight.

Space Shuttle Safety Upgrade Program

NASA presented a Space Shuttle Safety Upgrade Initiative to Congress as part of its Fiscal Year 2001 budget in March 2000. This initiative sought to create a "Pro-active upgrade program to keep Shuttle flying safely and efficiently to 2012 and beyond to meet agency commitments and goals for human access to space."

The planned Shuttle safety upgrades included: Electric Auxiliary Power Unit, Improved Main Landing Gear Tire, Orbiter Cockpit/Avionics Upgrades, Space Shuttle Main Engine Advanced Health Management System, Block III Space Shuttle Main Engine, Solid Rocket Booster Thrust Vector Control/Auxiliary Power Unit Upgrades Plan, Redesigned Solid Rocket Motor – Propellant Grain Geometry Modification, and External Tank Upgrades – Friction Stir Weld.

The plan called for the upgrades to be completed by 2008. However, every proposed safety upgrade – with a few exceptions – was either not approved or was deferred.

The irony of the Space Shuttle Safety Upgrade Program was that the strategy placed emphasis on keeping the "Shuttle flying safely and efficiently to 2012 and beyond," yet the Space Flight Leadership Council accepted the upgrades **only as long as they were financially feasible**. *Funding a safety upgrade in order to fly safely, and then canceling it for budgetary reasons, makes the concept of mission safety rather hollow.*

Echoes of Challenger

As the investigation progressed, Board member Dr. Sally Ride, who also served on the Rogers Commission, observed that there were "echoes" of *Challenger* in *Columbia*. Ironically, the Rogers Commission investigation into *Challenger* started with two remarkably similar central questions: Why did NASA continue to fly with known O-ring erosion problems in the years before the *Challenger* launch, and why, on the eve of the *Challenger* launch, did NASA managers decide that launching the mission in such cold temperatures was an acceptable risk, despite the concerns of their engineers?

Both accidents were "failures of foresight" in which history played a prominent role. First, the history of engineering decisions on foam and O-ring incidents had identical trajectories that "normalized" these anomalies, so that flying with these flaws became routine and acceptable. Second, NASA history had an effect. In response to White House and Congressional mandates, NASA leaders took actions that created systemic organizational flaws at the time of *Challenger* that were also present for *Columbia*.

The constraints under which the agency has operated throughout the Shuttle Program have contributed to both Shuttle accidents. Although NASA leaders have played an important role, these constraints were not entirely of NASA's own making. The

White House and Congress must recognize the role of their decisions in this accident and take responsibility for safety in the future.

Organization, Culture, and Unintended Consequences

A number of changes to the Space Shuttle Program structure made in response to policy decisions had the unintended effect of perpetuating dangerous aspects of pre-*Challenger* culture and continued the pattern of normalizing things that were not supposed to happen. At the same time that NASA leaders were emphasizing the importance of safety, their personnel cutbacks sent other signals. Streamlining and downsizing, which scarcely go unnoticed by employees, convey a message that efficiency is an important goal. The Shuttle/Space Station partnership affected both programs. Working evenings and weekends just to meet the International Space Station Node 2 deadline sent a signal to employees that schedule is important. When paired with the "faster, better, cheaper" NASA motto of the 1990s and cuts that dramatically decreased safety personnel, efficiency becomes a strong signal and safety a weak one. This kind of doublespeak by top administrators affects people's decisions and actions without them even realizing it.

Changes in Space Shuttle Program structure contributed to the accident in a second important way. Despite the constraints that the agency was under, prior to both accidents NASA appeared to be immersed in a culture of invincibility, in stark contradiction to post-accident reality. The Rogers Commission found a NASA blinded by its "Can-Do" attitude, a cultural artifact of the Apollo era that was inappropriate in a Space Shuttle Program so strapped by schedule pressures and shortages that spare parts had to be cannibalized from one vehicle to launch another. This can-do attitude bolstered administrators' belief in an achievable launch rate, the belief that they had an operational system, and an unwillingness to listen to outside experts. The Aerospace Safety and Advisory Panel in a 1985 report told NASA that the vehicle was not operational and NASA should stop treating it as if it were. The Board found that even after the loss of *Challenger*, NASA was guilty of treating an experimental vehicle as if it were operational and of not listening to outside experts. In a repeat of the pre-*Challenger* warning, the 1999 Shuttle Independent Assessment Team report reiterated that "the Shuttle was not an 'operational' vehicle in the usual meaning of the term." Engineers and program planners were also affected by "Can-Do," which, when taken too far, can create a reluctance to say that something cannot be done.

How could the lessons of *Challenger* have been forgotten so quickly? Again, history was a factor. First, if success is measured by launches and landings, the machine appeared to be working successfully prior to both accidents. *Challenger* was the 25th launch. Seventeen years and 87 missions passed without major incident. Second, previous policy decisions again had an impact. NASA's Apollo-era research and development culture and its prized deference to the technical expertise of its working engineers was overridden in the Space Shuttle era by "bureaucratic accountability" – an allegiance to hierarchy, procedure, and following the chain of command. Prior to

Challenger, the can-do culture was a result not just of years of apparently successful launches, but of the cultural belief that the Shuttle Program's many structures, rigorous procedures, and detailed system of rules were responsible for those successes. The Board noted that the pre-*Challenger* layers of processes, boards, and panels that had produced a false sense of confidence in the system and its level of safety returned in full force prior to *Columbia*. NASA made many changes to the Space Shuttle Program structure after *Challenger*. The fact that many changes had been made supported a belief in the safety of the system, the invincibility of organizational and technical systems, and ultimately, a sense that the foam problem was understood.

History as Cause: Two Accidents

NASA's culture of bureaucratic accountability emphasized chain of command, procedure, following the rules, and going by the book. While rules and procedures were essential for coordination, they had an unintended but negative effect. Allegiance to hierarchy and procedure had replaced deference to NASA engineers' technical expertise.

In both cases, engineers initially presented concerns as well as possible solutions – a request for images, a recommendation to place temperature constraints on launch. Management did not listen to what their engineers were telling them. Instead, rules and procedures took priority. For *Columbia*, program managers turned off the Kennedy engineers' initial request for Department of Defense imagery, with apologies to Defense Department representatives for not having followed "proper channels." In addition, NASA administrators asked for and promised corrective action to prevent such a violation of protocol from recurring. Debris Assessment Team analysts at Johnson were asked by managers to demonstrate a "mandatory need" for their imagery request, but were not told how to do that. Both *Challenger* and *Columbia* engineering teams were held to the usual quantitative standard of proof. But it was a reverse of the usual circumstance: instead of having to prove it was safe to fly, they were asked to prove that it was unsafe to fly.

The organizational structure and hierarchy blocked effective communication of technical problems. Signals were overlooked, people were silenced, and useful information and dissenting views on technical issues did not surface at higher levels. What was *communicated to parts of the organization was that O-ring erosion and foam debris were not problems.*

Structure and hierarchy represent power and status. For both *Challenger* and *Columbia*, employees' positions in the organization determined the weight given to their information, by their own judgment and in the eyes of others. As a result, many signals of danger were missed. Relevant information that could have altered the course of events was available but was not presented.

In the more decentralized decision process prior to *Columbia*'s re-entry, structure and hierarchy again were responsible for an absence of signals. The initial request for imagery came from the “low status” Kennedy Space Center, bypassed the Mission Management Team, and went directly to the Department of Defense separate from the all-powerful Shuttle Program. By using the Engineering Directorate avenue to request imagery, the Debris Assessment Team was working at the margins of the hierarchy. But some signals were missing even when engineers traversed the appropriate channels. The Mission Management Team Chair’s position in the hierarchy governed what information she would or would not receive. Information was lost as it traveled up the hierarchy. A demoralized Debris Assessment Team did not include a slide about the need for better imagery in their presentation to the Mission Evaluation Room. Their presentation included the Crater analysis, which they reported as incomplete and uncertain. However, the Mission Evaluation Room manager perceived the Boeing analysis as rigorous and quantitative. The choice of headings, arrangement of information, and size of bullets on the key chart served to highlight what management already believed. The uncertainties and assumptions that signaled danger dropped out of the information chain when the Mission Evaluation Room manager condensed the Debris Assessment Team’s formal presentation to an informal verbal brief at the Mission Management Team meeting.

END OF COLUMBIA PAPER

The F111 Deseal/Reseal Program

This paper on the F111 Deseal/Reseal Program consists of edited extracts from: The Report of the F111 Deseal/Reseal Board of Inquiry, 2 Jul 2001.

Introduction

> *'I have skin cancers or solar skin damage on my scalp, forehead, face and arms. I also have claw toes and my left foot bows out. I have lodged a claim for these impairments with the Department of Veterans Affairs and receive a sixty percent disability pension. … I continue to suffer blood pressure problems which date back to my days at Amberley. I have also suffered haemorrhoids with intermittent bleeding from the bowel. I have a lump on the palm of my left hand and a lump in the throat, which makes it intermittently hard to swallow. Back in my time at Amberley I was referred to an Ear, Nose and Throat Specialist in Brisbane. I still have a sore throat and am always coughing. I have bad breath and my wife is always telling me that I have an awful smell from my body which is not regular body odour. I also get a red rash on my face and suffer from headaches and dizziness, especially when my wife is using any cleaning product around the house. I am at times very depressed and this has put a strain on my relationship with my wife … and with my family. For some years I have not been interested in sex. I get very cranky and yell and snap at my wife for apparently no reason at all. My wife tells me there is something wrong with me and says that I should see a Doctor. She tells me that I am not the same man she knew before our posting to Amberley. I suffer from broken sleep patterns and was always a good eater but now find my appetite is gone. I generally only pick at food. I believe I have lost concentration and my short-term memory is lacking. I seem to be only able to absorb about three to five minutes of information at a time. My wife has noted my short-term memory loss problems, as have some of my friends. I remember when I was first covered in SR51 I felt sick in the stomach that night and had a splitting headache.... I still get headaches frequently'.*

These are the words of one of the workers exposed to toxic chemicals at Amberley. We estimate that in excess of 400 people have suffered long-term damage to their health as a result of such exposure.

For more than 20 years RAAF maintenance personnel have been working inside the fuel tanks of F111 aircraft, resealing leaking seams, in an ongoing series of repair programs. They worked in cramped and very unpleasant conditions, sometimes in unbearable heat and sometimes in near freezing temperatures, and they suffered chronic and occasionally acute exposure to the hazardous substances with which they worked. The resulting symptoms include skin rash, gastro-intestinal problems, headaches and loss of memory.

The matter came to a head in early 2000 and the fuel tank repair program was suspended. Since that time the problem of fuel tank leaks has not been adequately addressed and the availability of F111 aircraft has been affected. In short, as well as causing substantial human suffering, the failure of the fuel tank reseal program has impacted on Defence capability.

Background and Overview to the F111 Deseal/Reseal Programs

The Australian Government ordered 24 General Dynamics (GD) F-111 aircraft (then designated TFX) in October 1963. The aircraft was still 'on the drawing board' when ordered and was not scheduled for delivery until September 1968. Whilst the maiden flight of the F-111C Australian model was achieved in July 1968 and the first aircraft was accepted in October 1968, problems with the Wing Carry Through Box (WCTB) resulted in the Australian aircraft being put immediately into storage. (In March 1968, eight USAF 'Combat Lancer' F-111A aircraft deployed to Thailand to contribute to the 'Rolling Thunder' bombing campaign over North Vietnam. When the third aircraft loss due to mechanical failure occurred on 22 April

1968, operations were suspended and the remaining aircraft returned to the US.) RAAF crews subsequently went to Fort Worth Texas, in December 1969, to take delivery of the aircraft but the loss of another USAF F-111A aircraft caused the Australian aircraft to be returned to storage. By May 1973, the F-111Cs had new WCTBs and were finally cleared for delivery. The first six aircraft arrived at Amberley on 1 June 1973; the twenty-fourth was delivered on 31st October the same year.

The internal fuel tanks on the F-111 are integral to the aircraft's structure. This maximises the fuel that can be carried to give the extended range required of the aircraft. Each available cavity within the fuselage and wings is sealed using a curable sealant applied between mating structural components, for example skin and bulkheads and around fasteners.

Within three months of arrival in Australia, the RAAF found what appeared to be uncured fuel tank sealant when investigating aviation turbine (AVTUR) fuel leak problems. Shortly thereafter, the RAAF became aware of serious fuel leak problems being experienced by the USAF on their F-111 aircraft. Because of the extended time the Australian aircraft had spent in storage, the apparent degrading of the polyester faying surface sealant used at manufacture and the USAF experience, the RAAF became resigned to significant fuel leak problems on the F-111Cs. (As an observation, the polyester sealant does not have a Military Specification which therefore raises questions as to how well the GD material specification, addressing performance, handling and application, and hydrolytic stability, was tested prior to certifying for use in aircraft assembly. It seems the sealant was selected because of its high temperature properties alone.)

The method of sealing the fuselage integral fuel tanks was to apply the polyester adhesive sealant between faying surfaces and in structural voids, complemented by beads of polysulphide fillet sealant (MIL-S-83430) along seams and around the fasteners within the tanks. Unfortunately, the polyester sealant degraded over time and 'reverted' (the common

term used to describe the sealant condition). In essence, the sealant was hydrolytically unstable and the effect was the rupture of the fillet seal by hydraulic action and/or chemical reaction at multiple sites; hence the fuel leaks.

The F-111 was something of a political ‘hot potato’ at the time and every effort was no doubt committed to maximising aircraft availability and in-service performance. The USAF had commenced a ‘deseal/reseal’ program at Sacramento Air Logistics Centre (SM-ALC) and, not surprisingly, the RAAF also decided on the need for a fuselage deseal/reseal program (DSRS), with procedures based on those developed by GD Fort Worth Division (GD/FW) and used by the USAF. This first program (at the time it was hoped to have been the only one needed) was conducted by No 3 Aircraft Depot (3AD) at RAAF Amberley on eleven aircraft between October 1977 and February 1982. The rest of the fleet (nine aircraft - four had been lost in service) was submitted to the program in the USAF facilities at Sacramento, between May 1981 and December 1982, coincident with the first Cold Proof Load Test (CPLT) program.

Perhaps the most notorious aspect of the initial program was the extensive use of a chemical desealant known as SR51. This desealant had a strong, foul odour which directed attention at Amberley to the quarantined work area at the southern end of the Base. Indeed, there were a number of complaints from Ipswich residents about the foul odour emanating from the Base.

> **SR51 Desealant.** The reputation of SR51 came before it. While there was some debate between the manufacturer, the USAF, MRL and the RAAF on toxicity, safe exposure limits, treatment of waste, etc, the clear warning was that the chemical and products of its waste were cause for concern requiring the implementation of special precautions. In theory, the desealant was to be used in a closed system which was to be thoroughly flushed after the SR51 had been used. In practice, the odour, at the very least, was ever present and traces of SR51 were evident even months and years later in aircraft that had been through the first program. A stigma applied to those employed on the deseal process because of the SR51 smell that attended them. They were barred, at least by weight of popular opinion, from many public areas on the Base because of their odour. The cinema and airmen's bar are but two examples.

Employment in the 'rag hangar', a canvas deployable hangar (one of seven RAAF assets and relocated from No 482 Squadron (482SQN)) where the chemical desealing took place, was to be avoided if at all possible. This environment was not dissimilar to that at Sacramento and the advantage of using the desealant was that it was far quicker than desealing by mechanical means only. The process required Air Force tradespeople, many straight from basic trade training, to spend extended periods of their working day in the very cramped and confined spaces of the various fuselage fuel tanks. Because the resealing process relied critically on the removal of as much of the old sealant as possible (complete removal of the faying surface sealant was not possible without completely disassembling the aircraft and careful surface preparation), the desealing work was painstaking. Each aircraft was required in work for about six months.

The wing integral fuel tanks had also been assembled using the same polyester faying surface sealant as in the fuselage tanks, however a silicone sealant rather than the polysulphide sealant was used for the fillet seal because silicone had better heat stability and was more flexible. While the polyester sealant 'reverted' and had the same hydraulic effect on the fillet seal as it had had in the fuselage tanks, it seems there was not the same chemical reaction with silicone as there was with the polysulphide sealant. Nonetheless, almost inevitably, the wing integral fuel tanks also reached the point where ad hoc fuel leak repairs became very time

consuming and relatively ineffective. This collective realisation was documented by 482SQN in July 1981. A wing deseal/reseal program was consequently developed and finally trialed by 3AD in 1985. The wing program then continued at 3AD through to 1992. Wings were worked on in pairs and twenty-four sets were processed through the program. The tanks were able to be completely opened by removing the top skin (one machined piece) hence work was conducted from outside the tank. Chemical desealants were not used in the process because of concern for the D6AC steel wing pivot fittings and the fuel tank paint. In any case, SR51 was not effective on the fluorosilicone fillet sealant therefore an alternative product needed to be proven. The USAF used PR3107 for a period to chemically deseal wings.

First Program

Work on the first program was distinguished by the use of SR51 desealant and the necessary isolation of the 'rag hangar' because of obnoxious odours. Despite the ideal that the SR51 would be contained within a closed system, there were many instances where airmen had to work directly with the chemical, especially during the disposal phase. The fact that exposure had occurred is evidenced by the smell that attended them. Many of the witnesses complained of social isolation because of their smell. The approach to OH&S matters could best be described as casual due to the lack of sound information on the toxicity of the chemicals they used and a macho approach to work generally.

Second Program

The second program is distinguished by the reasonably tight controls that were instigated through the process of contract negotiation. Hazards were significantly reduced by the removal of the SR51 chemical desealing phase. The main concern with this program was with regard to the high-pressure water pick used to remove old sealant, a process which has no long-term implications. The primary concern for this Inquiry is the repetitive use of the solvents within the confined spaces of the fuel tanks. This concern was the subject of ongoing investigation and attention by the contractor through the three years of the program

Spray Seal Program

In 1992, the USAF adopted a process that very much simplified the repair of F-111 fuselage tanks. This process originally specified water pick desealing and cleaning before spray application of the sealant. However, the first couple of applications resulted in many air pockets with consequential time consuming patch-up penalties. Desealing by water pick ceased, and was replaced by patch repairs, thorough alkaline and hot water washes, and drying. Therefore, instead of the laborious task of desealing to remove all of the old sealant, or repairing localised areas with hope that all sealant delaminations had been covered, the task was now simply to spray new flexible polythioether polyurethane sealant (with primer) over the old MIL-S-83430 polysulphide sealant.

The spray seal program was distinguished by the use of the spray sealant and its primer, and the time airmen could spend within the tanks during any one-duty period in very restrictive PPE. Airmen on occasions spent inordinate time in cumbersome PPE and many were at the point of exhaustion when their shift ended. One of the main problems was the lack of a dedicated facility, which forced the section into adopting a tight production schedule. This, plus market testing imperatives on the Wing as a whole, led to constant pressure on all concerned

While there was a level of confidence that this method would prove more effective than previous schemes, the great benefit was that the repair time for each aircraft was reduced to an average of two weeks compared with the previous twenty plus weeks for a full deseal/reseal. The spray seal process was successfully trialed by 501WG in 1996 and subsequently introduced as the approved repair scheme. It has been applied to various tanks of thirteen aircraft, six of which are G models that were acquired from the USAF in 1993/4. It is this process that was suspended in January 2000.

The RAAF is planning to retain the F-111 in service for up to twenty years more and integral fuel tank leaks remain problematic; they continue to represent a significant ongoing threat to aircraft availability. An inherently safe and more effective and enduring means of resealing tanks needs to be developed with some urgency. At point of writing, localised pick and patch repair techniques were being employed to repair leaking fuel tanks and a task has been given to contractors to review the whole fuel leak problem.

The Working Environment

The work in 501WG Fuel Tank Repair Section (FTRS) was dirty, uncomfortable and onerous. The hand cleaning of tanks and finite removal of old sealant using dental picks was a particularly laborious phase of the work. FTRS was not a popular work area although the nature of the work did tend to create quite a bond within the section. Those within the section often felt isolated and ignored. On the three fuselage programs, work is characterised by long periods spent within the confined spaces of the four main fuselage tanks; the A2 tank being particularly restrictive with barely room for one person in the enclosed work area. This confinement was substantially amplified during the spray seal program because of the time it took to suit and rotate the technicians, which invariably discouraged a change other than at the end of a shift. Some airmen therefore spent up to eight hours in the confined spaces of the tanks in claustrophobic protective suits because production schedules were tight and no limits had been set on duty periods.

Some of those whose health has been damaged believe that certain individuals should be held accountable for allowing things to go on as long as they did. We understand this concern. But the scale and duration of the problem indicates that we are dealing with a deep-seated failure for which no single individual or group of individuals can reasonably be held accountable. As we noted at the outset of the hearing, ‘the material made available to the Board… points to ongoing failings at a managerial level to implement a safe system of work and coordinate processes within a complex organisation’. If anybody is to be held accountable, therefore, it is the Air Force itself.

Work Instructions

Knowledge of Instructions. The technical instructions for work on aircraft are comprehensive. The publications were well known to the SNCOs controlling the work, as would be expected. However, the tradespeople on the floor relied heavily on worksheets or their supervisors for information and were generally ignorant of the detail contained in the governing AAPs. In reality, the closer you get to the shop floor the less likely publications are to be read. Tradespeople are, and were, simply interested in their task. A statement under safety instructions in AAP 7214.003-292-3 to the effect: '[p]ractically all materials used in the deseal/reseal operations are toxic and/or flammable … Extreme care should be exercised in the use of these materials … Avoid excessive breathing of fumes and wear protective clothing (gloves, goggles, masks, etc) … ', proved of little utility (as a warning) as it never became evident to the general workforce.

Society Driven Causes

Signs over symptoms

One feature of the inadequate response of the Amberley Medical Section is not related to the lack of an occupational medicine focus but stems from the practice of medicine more generally. A distinction is made in the medical profession between symptoms and signs. Symptoms are those matters of which patients complain; signs are the indications of pathology which are visible or detectable to the medical practitioner. Thus a headache is a symptom but not a sign; an abnormal blood test result may be a sign but not a symptom. An indicator such as a skin rash is both a symptom and a sign.

There is a general tendency in the medical community to give preference to signs when seeking to diagnose problems. From the point of view of the medical observer, signs are objective; reports of symptoms which are not detectable to the medical observer tend to be viewed as less reliable. From the point of view of the patient, the situation is almost the reverse. The symptoms are the objective reality and signs such as blood test results are indirect and abstract.

Medicine faces a dilemma when patients complain of symptoms but there are no signs available to medical observers. There is a risk in these circumstances that medical observers will downplay the significance of the symptoms. Thus, patients with back pain or overuse injuries undetectable to medical observers are often treated with scepticism, particularly when compensation issues are involved.

The medical preference for signs over symptoms appears to have been manifested in early 1999 at Amberley in the following way. When the tests came back negative, the symptoms of which the workers were complaining were dismissed and they were sent back to work with assurances that nothing was amiss. This was a particularly unfortunate outcome, given, as we now know, that the tests were incapable of serving as valid signs.

Air Force Values Driven Causes

The priority of operations over logistics

The distinction between operations and logistics is one of the fundamental cleavage lines of the Air Force. Operations refers to all flying activities of the aircraft squadrons, including training. Logistics supports operations and includes aircraft maintenance work. Some maintenance work is done by personnel attached to the flying squadrons but the more extensive maintenance, including much of the fuel tank repair work, has been done by maintenance organisations with no operational role. The distinction between operations and logistics is therefore not only a conceptual one; it is mirrored in the way the Air Force is organised.

In almost every way, operations take precedence over logistics. It is the needs of the operational squadrons which drive the activities of the logistics squadrons. Operations is what the Air Force is about, and the *raison d'etre* of logistics is to serve operations. The motto on the letterhead of the maintenance wing at Amberley is 'excellent logistics for operations'.

The aim of a maintenance squadron or wing is to produce serviceable aircraft for use by operational squadrons. In this respect, a maintenance organisation within the Air Force is driven by production imperatives in the same way as any private sector producer. It must meet the needs of its client operating squadrons in the same way that private sector producers must supply the needs of their customers. The suspension of the maintenance program at Amberley meant a failure in the supply of serviceable aircraft to the client, just as the disruption of electricity or gas production

results in a failure of supply to customers. This analysis will be important at various stages in this report, in understanding, for example, the production pressures under which the fuel tank repairers worked, the deficiencies exhibited by the Air Force medical service, and the fact that flying safety has received greater attention than ground safety.

The priority of operations over logistics is deep-seated in the culture of the Air Force. The fact that several of the organisational failures which we shall identify stem from this priority means that they will not be easily rectified.

The priority of platforms over people

The recent address by the Secretary to the Department of Defence, Dr Allan Hawke, entitled 'People Power' raised the issue of people versus platforms (weapons platforms, i.e. aircraft, ship etc). 'Defence', he said, was sometimes criticised as being too 'platform-centric' and he argued that there is a need to put people first. He took issue with those who say that equipment must remain the primary focus, and argued that without a 'people first' culture, recruitment and retention rates will decline and with them the ability to sustain operational capability. 'People matter - its people who make the difference', he said. In so saying the Secretary to Defence was seeking to reverse the traditional priorities.

The traditional priority of platforms over people was in evidence at Amberley and we shall show later in this report how it contributed at various times to the failure of the Air Force to protect its maintenance workers. At this point we shall simply illustrate this priority by reference to the case of a worker who was employed to dispose of a chemical used in the first repair program. SR51 was a toxic chemical used to strip away the old and disintegrating sealants inside the tanks, prior to resealing. After use it was disposed of by means of incineration, in a remote corner of the base. This was a lonely and unsupervised activity and the worker whose job this was throughout 1979/80 spent much of his time covered in this chemical. Throughout this period he suffered various ill effects including memory loss, mood swings and vertigo. He complained from time to time about these symptoms but nothing was done about his conditions of work. On one matter, however, the Air Force was particular. He was not to operate the incinerator at any time an F111 was taking off, so as to avoid any possibility that the combustion products from the incinerator might damage the aircraft. We are not suggesting in this case that a deliberate decision was made to give greater importance to an aircraft than to an individual; it is simply that the well-being of the aircraft was attended to while the well-being of the individual was not.

The ‘can do’ problem
The phenomenon of making do with available resources and if necessary deviating from required safety procedures in order to get the job done, so very much in evidence in the fuel tank repair section, is sometimes described as the ‘can do’ philosophy.

The issue has been extensively discussed in the context of airworthiness and the following observations by the Director Airworthiness Coordination and Policy Agency, made in 2000, are worth quoting.

> *‘For some time, there has been general agreement across the RAAF that it is under-resourced (in funding and personnel) and over-tasked. Over the past few years changes have lead to outsourcing, restructuring and reduction in Manpower Required in Uniform (MRU) while retaining capability and levels of tasking. The result has been the strong inculcation of a ‘can do’ mentality within management (at all levels) which largely requires people to do the best they can and to advise management when they cannot meet the task’.*

> *‘Recent surveys indicate that the "can do" mentality is so strong (now perhaps "must do"), that even at the levels where maintenance work is actually being conducted people are extraordinarily reluctant to admit that tasks cannot be achieved. Evidence suggests that short cuts may be being used to achieve tasks in the belief that this is accord with the overall aim of the unit/RAAF (to achieve output - aircraft on line - in the minimum time)….’*

> *‘There is a serious and challenging dichotomy between the views of the practitioners of aircraft maintenance and RAAF management. In effect the troops feel they are doing the right thing, whilst management do not condone at all the range of expedient practices being employed’.*

Production pressures were a major source of the problems of the fuel tank repair section and the analysis provided by the Director Airworthiness Coordination and Policy Agency is entirely

apposite. Moreover, his recommendation about shedding tasks is in line with our thinking. The aim must be to get senior NCOs to abandon their must-do attitude and to ask the question: can this job be done without any compromise to safety? If the answer is no, because of problems with the protective equipment or for any other reason, they must be encouraged to stop the job until the matter is sorted out. The current presumption among senior officers that NCOs should only bring problems to them which they cannot resolve themselves works against this, so the required behaviour will only occur if NCOs are rewarded for stopping work until problems are resolved. The Board is aware of one instance where work stopped because the right respirator canisters were not available, resulting in a speedy resolution of the problem. Such behaviour is to be encouraged.

The Command and Discipline System

Many of the features identified as contributing to the exposure of troops to hazardous chemicals are present in other large organisations. However there is one feature of military organisations which has no counterpart in civilian organisations - the command and discipline system.

The command and discipline system exists for very good reason. Thus, although we shall be identifying ways in which it may have contributed to the problems at Amberley, our recommendations are directed at overcoming the problems which we identify in ways which are consistent with the system.

The threat of disciplinary action

Fuel tank workers worked under the threat of disciplinary action. As one said,

> *'I recall one of the fellows got his brother who worked in a lab in Melbourne to test it (SR51) and he was told to get out of the Section as quickly as possible. We accepted that opinion rather than the medical opinion, but there was little we could do about it because we were under strict orders. If we*

asked to be transferred we were told that we had to do our time, which was two years at that stage'.

Another witness gave the following evidence,

> *'As a junior tradesman I just did what I was told by my NCO and supervisors. I was constantly assured that everything I did with the chemicals was safe and there was no cause for concern. It is my belief that the consequence of not undertaking the tasks that I was given completely would be that I would be subject to contact counseling (that is I would be taken out the back and give a clip under the ear). It was just as though it was a requirement for any new member of the unit whenever posted in to do their time in the Deseal/Reseal section. It was a culture within the unit that you could not bring up and raise any concerns and you simply did what you were told or got a kick in the arse'.*

These perceptions were not unfounded. One worker who refused to re-enter the fuel tanks was charged with an offence, convicted and sentenced to seven days detention at Amberley.

An Air Force review of the maintenance work at Amberley in 1979 expressed some concern about this situation:

> *'In winter this is cold, cheerless, obnoxious and very demanding work…Several psychological problems have already emerged among airmen engaged in this extremely unpopular, but necessary work. There should be no need to reiterate the importance that the nation places on this work and neither is there any reason to doubt the motivation of those employed on it. But when considering the conditions under which they work, for peacetime, it could be argued that their loyalty is being unreasonably tested'.*

The Board has no evidence of disciplinary action being taken in more recent years to compel people to work in the fuel tank repair section, but the threat is always there if they refuse. It is the nature of the service that people are posted to the fuel tank repair section with little option of declining the job.

Organisational Causes

Our thinking about the organisational causes of the exposure of Air Force workers to toxic chemicals is summarised in the diagram at the end of this document. It appears at the end because it is not self-explanatory and will be comprehensible only in the light of the discussion throughout the report.

Investigators are sometimes content to identify the actions or inactions of individuals as the cause of an accident. Human error, carelessness or procedural violations by front line operators are readily apparent in the early stages of most accident investigations, and too often, investigations seem to terminate at this point. The recommendations which follow are for tighter supervision, more training, or perhaps, disciplinary action. But identifying the way in which the actions or inactions of individuals contribute to an accident is only the beginning. Any event has a potentially infinite network of causes or contributing factors, and pushing the investigation some distance back along these causal pathways provides far greater insight into why an event occurred. In particular, when an unwelcome event of any sort occurs in a large organisation, it is important to identify the organisational causes of the event, some of which may be remote in time and place from the event in question. The value of such an analysis is that it may uncover a variety of ways in which accidents can be avoided.

Our analysis adopts this approach and seeks to identify the organisational and cultural factors which led to the failure of the Air Force to protect the health of its F111 fuel tank repair workers. The Board's investigation rapidly revealed numerous incidents of non-compliance by maintenance workers with requirements that they wear personal protective equipment - goggles, respirators and the like - as well as a variety of failures by supervisors, but we treat these as symptomatic of the organisational problems we seek to identify, not in themselves the causes on which it is most useful to focus. Thus while we support better training and tighter supervision of maintenance workers, our principal recommendations concern the way the Air Force does business and they highlight the need for significant cultural and organisational changes.

We should stress that many of the organisational failures which we shall identify are by no means unique to the Air Force. The RAAF is a large organisation with many of the strengths and weaknesses of other large organisations, particularly large industrial organisations. We shall draw these parallels at various points. There are however some features of the Air Force stemming from its military nature, which generate particular weaknesses as well as particular opportunities to provide a safe work place.

Inadequate implementation of previous reports

Safety depends on the capacity to learn from accidents and incidents. It is not enough to investigate their causes; recommendations arising from investigatory reports must be implemented. Otherwise hard won lessons will be to no avail. We identify recommendations from previous reports which, if implemented, would have reduced the exposure of F111 fuel tank workers. In particular, a problem remarkably similar to the F111 problem was identified in 1981 among Air Force surface finishers (roughly, spray painters), some of whom were suffering the ill effects of exposure

to toxic substances. An inquiry produced recommendations, many of which had direct implications for the work of the F111 fuel tank repair section. These recommendations were not implemented for F111 workers. The need to learn the lessons of previous inquiries is a powerful theme.

Contract doctors

Another factor giving rise to difficulty at the Amberley Medical Section is the change in conditions of employment of RAAF doctors in recent years. Decades ago, doctors were salaried. That meant that even though there might be no formal occupational health program at a base, doctors could take time to visit workshops and familiarise themselves with the processes in which workers were involved. Such a familiarity is vital if doctors are to be sensitive to the possible occupational causes of the symptoms which are reported to them.

The drive to limit costs has led the Air Force to outsource services of many sorts, including medical services, and at Amberley today, most patient care is provided by contract doctors. The difficulty of retaining doctors as full time members of the Air Force has also contributed to this shift. Contract doctors are paid to provide office consultations. They are not paid to get out of the office and investigate the workplace. As a result, one doctor who was seeing the men from the fuel tank repair section had never been to visit their workplace. His understanding of the problem he confronted was correspondingly limited. It should be noted, too, that contract doctors are not paid to do the sometimes time-consuming research which may be necessary to identify the nature of the problem.

Some contract doctors may be less likely to feel a sense of belonging to the Air Force community than full time serving medicos. They are not 'members', but simply contractors, and it is not reasonable to expect of them the same commitment to the organisation and willingness to go beyond the call of duty when the need arises that is normally assumed of a member.

The Chain of Command

Responsibility for safety lies ultimately with the chain of command. Our analysis suggests that there were critical failures in the chain of command and many of our recommendations are aimed at rectifying these weaknesses by augmenting the flow of information and ensuring better supervision. The report canvases a number of strategies for achieving this: incident reporting systems, safety committees, audits, etc. We stress that none of these is a substitute for the chain of command. They are simply means of strengthening its capacity to fulfil its function.

The Limitations of the Chain of Command

Research shows that bad news does not move easily up organisational hierarchies. The Air Force is no exception to this rule: there was a great deal of bad news about the reseal program which never made its way to senior commanders. Most striking perhaps was the failure of senior commanders to become aware that workers were suffering symptoms of exposure to toxic chemicals. But there was also a great deal of bad news about the goggles, breathing apparatus and suits which were supposed to protect the workers from exposure. Workers complained frequently about problems with this equipment and chose not to wear it in certain situations, for reasons to be discussed later. But none of this reached the attention of senior commanders.

A related research finding is that, left to themselves, workers develop unapproved ways of doing things in response to difficulties they encounter. Again there is plenty of evidence of this occurring in the reseal programs. For instance, the last program was particularly hazardous because it involved spraying sealant in a confined space, and the design for this program called for the fuel tanks to be ventilated by two supply hoses and two exhaust vents while workers were inside the tanks. However, workers found this impractical and carried out the task without this ventilation. The point here is that although this unapproved practice was followed for more than a year prior to the suspension of the program, senior commanders at no stage became aware of it.

These findings present a considerable challenge to the Air Force. Like any military organisation, the Air Force is highly centralised and it relies heavily on its chain of command to achieve its corporate objectives. It presumes that the chain of command will convey relevant information up the hierarchy to facilitate informed decisions. It also presumes that instructions passed down through the chain of command will be complied with and that the supervisory processes are such as to ensure that instructions are complied with.

Senior Air Force commanders place a great deal of faith in this system. Here are statements provided to the Board by three former commanders of the maintenance wing at Amberley

> *'I expected that, having provided a command and management framework, appropriate direction, priorities and resources to my subordinate commanders and supervisors, they are then responsible and accountable for discharging their duties'.*
>
> *'I feel confident that should a serious safety concern be identified, it would have been raised through the management chain rapidly'.*
>
> *'I have no reason to believe that the procedures developed for the Deseal/Reseal were not generally followed. I consider that the supervisory chain and the Air Force emphasis on supervision was sufficient to ensure compliance with procedures'....*

'At no time was there anything preventing AMSQN members from passing up this information through the Chain of Command (or around the chain of command if they felt it necessary to do so)'.

But despite such convictions it is clear that the chain of command did not function to alert senior commanders to the problems in the fuel tank repair section and conversely that the supervisory processes failed to secure compliance.

The weak link in the chain

Military chains of command are long. There are six ranks between the Leading Aircraftman on the hangar floor and the Group Captain, the highest ranking officer in the maintenance wing at Amerberly. The chain metaphor invites the observation that a chain is only as strong as its weakest link, and the evidence presented to the Board suggests that one link in the chain of command is significantly weaker than the others.

There is a major divide in the Air Force between the commissioned and non-commissioned officers. Non-commissioned officers - Corporals, Sergeants and Warrant Officers - work their way up through the ranks and promotion to Warrant Officer typically comes at a relatively late career point. A few are promoted to the ranks of the commissioned officers. Typically, however, commissioned engineering officers, are tertiary trained and their entry point into the Air Force is above the Warrant Officer rank. The result is that a young engineer may be placed in charge of a sizeable maintenance group with several highly experienced non-commissioned officers reporting to him/her. There is an inherent weakness in the chain of command at this point

since the young engineer is often not in a position to effectively supervise subordinates or to understand their problems.

For example, at Amberley, in July 1999, six months before the spray seal program was suspended, a young engineer took over as officer in charge of the aircraft maintenance section. He was three years out of engineering school and had not previously worked in a maintenance section. His rank at this time was Flight Lieutenant. Although he had not had any significant management experience he now had 170 personnel from seven different sections under his authority. The fuel tank repair section was one of these sections. It was headed by a Flight Sergeant, one of seven Flight Sergeants reporting to the young Flight Lieutenant. This was clearly a situation in which the Flight Lieutenant could give only very limited attention to the fuel tank repair section.

We have focussed here on the six months prior to the cancellation of the spray seal program, but there is evidence that the reseal programs operated for much of their history with relatively little supervision from within the commissioned officer ranks.

This problem is not unique to the Air Force. The Royal Commission into the gas plant explosion at Longford found that the withdrawal of engineers from site as a cost-cutting measure had led to inadequate supervision of trade staff which contributed to the accident. Engineers are a resource which must be available in technically complex environments to provide a back up to those who are more directly involved in the production process. Engineering expertise must be on hand when workers encounter difficulties; otherwise they inevitably resort to unapproved procedures.

The level of staffing necessary to ensure that engineers are on hand when needed involves a degree of redundancy. Where organisations are faced with cost cutting imperatives, engineering staff may be the first to go, but this in the long run is false economy.

This cost-cutting process appears to have been at work in the Air Force. According to one commander,

> *'The Aircraft Maintenance Squadron (AMS) has been through a number of commercialisation-type reviews over a number of years. There are very few officers in the Squadron in comparison to, for example, operational units and there is a substantial reliance on the Flight Sergeants as the team leaders to control the work and the people'.*

He went on:

> *…'(AMS) is a difficult organisation to manage because of the lack of people like Flight Lieutenants; … (we need the) experienced junior officer who is able to get out and about amongst the troops, and provide essentially an external*

oversight of the organisation; or for that matter even be sent to go find out about this, go look into that… So I guess my main comment would be: don't cut out that level of management'.

The differential impact of cost cutting on officers in maintenance squadrons, to which this witness refers, is another manifestation of the priority which the Air Force has given to operations over logistics, to the ultimate detriment of the fuel tank repair section.

The issue of micro-management

The weak link identified above is not the only place in the chain of command where the movement of information upwards can be blocked. We have noted already that in late 1998, information about the symptoms being suffered by personnel of the fuel tank repair section moved up the chain of command as far as the Squadron Leader. He was concerned enough to write to the Medical Section asking them to investigate, and when he drew a blank response from the Medical Section staff he apparently let the matter drop. At no stage did he communicate this information to the Wing Commander to whom he reported, even though the two had daily meetings. This was a critical blockage in the flow of information. A year later, when the same Wing Commander became aware of the symptoms being experienced by the troops in the fuel tank repair section, it was he who took action to suspend the program. There is a possibility that had he become aware of the problem on the earlier occasion, the program might have been halted then.

Why did the movement of information stop at this point? An influential strand of management theory holds that senior managers should not 'micro-manage' those below them. Subordinates have a job to do and should be left alone as far as possible to get on with it. To do otherwise is to undermine them. Thus for example, when a US submarine surfaced under a Japanese fishing vessel, killing nine people, due in part to a failure of a crew member to carry out his usual function, the Commander defended himself by saying,

> *'I depended on my subordinates' to ensure that watches were properly staffed and that provisions were made for working around broken equipment. 'I didn't micro-manage my crew. I empowered them to do their job'.*

A similar presumption against micro-management operated at Amberley. After making reference to this concept, the Wing Commander explained that,

> *'I would try and look at a higher level of dealing with things than the Squadron Leaders. And it is not my job to do the Squadron Leader's job'.*

The other side of this particular coin is that officers are not expected to take matters to their superiors unless they feel unable handle them. As the junior officer quoted above noted,

> *'The system was such that only those problems which could not be rectified at that level (below me) should be brought to my attention'.*

The fact that the Squadron Leader took action about the symptoms of which he had been notified, but did not in turn notify his own superior, is consistent with this style of management. The Wing Commander gave evidence at the Board that although in retrospect he would prefer to have been notified, he believed that the Squadron Leader had handled the matters correctly.

There is of course a competing view about the most effective way to manage. Senior managers need to know what is going on at lower levels in their organisations and, as the Secretary of Defence himself has recently observed:

> *'It is notoriously difficult for the heads of large organisations to get direct, unsanitised feedback from people who do not report directly to them'.*

Managers need to find ways to assure themselves that information about things which are going wrong or procedures which are not being followed is indeed able to find its way up the management chain. There is one simple strategy which management theorists all agree is critical, and that is that senior managers should take the time regularly to walk around workplaces and talk to people in informal ways

which give them the opportunity to voice concerns or grievances. This was certainly an aspect of management strategy at Amberley, in theory, but in practice it seemed to have had a relatively low priority, for according to the evidence of workers on the shop floor, they very rarely saw a senior officer and even more rarely had any opportunity to talk with one. Moreover visits by senior officers tended not to be walk-arounds for the purpose of observation and casual interaction, but occasions for addressing the troops and providing them with information. This is a subtle but important difference.

It seems that the balance struck by management at Amberley between the need to avoid micro-managing and the need to make direct contact with lower ranks was not optimal.

Low priority of industrial medicine

It is estimated that in Australia four times as many people die from diseases caused by exposure to hazardous substances in the workplace as die from traumatic injury on the job. The volume of occupationally caused ill health is of course much greater. The problem is insidious because the full effects of exposure often do not manifest themselves at the time, with the result that management and workers alike fail to have proper regard to the dangers.

A major reason for the failure of the medical section to make any connection between symptoms reported and the workplace practices is that it had no organised occupational medicinal program. Despite the fact that the centre was located in an industrial environment, where workers were using a large variety of potentially harmful chemicals, it functioned for these workers in much the same way as any private medical practice, offering individualised health care, for sporting injuries, viral infections and the like. Some of its medical staff had, at their own initiative, acquired qualifications in occupational medicine, but there was no requirement that doctors at the centre have such qualifications.

Environmental Health Section

The Air Force currently recognises an environmental health specialisation, and major RAAF bases have Environmental Health Sections. These sections are attached to base medical sections and function as an arm of the medical service. Environmental health includes occupational health and safety, but this has not been its primary focus. According to Ross, *'RAAF environmental health has, as its prime focus, preparing for a public health mission in the operational environment. The main tasks are food and water quality, and vector (insect) control. Occupational health or occupational hygiene has been regarded as an additional task not central to this role'.*

This is no accident; it is, or has been RAAF policy. A policy statement issue in 1990 observed that the resources available to Environmental Health Sections were not sufficient to carry out all their responsibilities and that they must act in accordance with the following priorities:

1. Operational health support (including exercises)
2. Disaster health support
3. Training
4. Public health issues, including water supply, food hygiene, disease and insect control
5. Hearing conservation program
6. Annual workplace assessments for the identification and evaluation of workplace hazards
7. Occupational Health Assessment
8. Other duties

This policy document remained in force until December 2000, when it was cancelled, along with a large number of others, for technical reasons. No alternative ranking has been provided and environmental health at Amberley continues to follow these priorities by default. This listing gives top priority to operational health support and a very low priority to occupational health and safety matters. In so doing it reflects the earlier mentioned priority of operations over logistics. Numerous witnesses complained at the Inquiry about an apparent lack of interest shown by the Environmental Health Section in the conditions of the fuel tank repair workers and, given the under-resourcing

of the section and the priorities which had been set for it, this apparent lack of interest was virtually inevitable.

The posting system

Personnel in the Air Force are posted to new positions every two or three years. The reasoning, in part, is that people need to acquire a range of skills so that in an operational environment, where support may be unavailable or limited, they will have the personal competencies necessary to do the job. In particular, an officer needs to be a 'jack of all trades', to be able to cope in extreme circumstances.

One drawback of this philosophy is that a jack of all trades is master of none. Supervisors who are posted into a complex and unfamiliar technical environment, where there are established processes in operation, cannot expect to understand the technicalities or to take responsibility for the processes under their control. They must assume that the processes are being carried out as intended and that it is appropriate to carry on with business as usual, until there is some reason to think otherwise.

Thus, when a Sergeant is posted into the fuel tank repair section to supervise the on-going spray seal program, he is unlikely to realise that the absence of any ventilation inside the tanks is in violation of the approved process. The point is that once a defective procedure becomes entrenched, people rotating through supervisory positions are not likely to question it until something goes wrong.

A new officer commanding makes a similar assumption. One former OC of the maintenance wing at Amberley expressed it this way:

> *'Mature programs running successfully neither demanded nor received more than routine involvement at senior management level. The wing deseal/reseal program fell into this category. It had been going for some years before my arrival, and was not experiencing any major difficulties'.*

Under-resourcing

The inadequate resourcing of the medical service has been implicit in the forgoing but needs to be emphasised. In 1995 the Officer

Commanding the maintenance wing at Amberley participated in a review of the base medical service. He observed that the service was 'an organisation under financial and resource stress'. He notes further that the senior medical officer was a 'young doctor (who) had limited management experience and was distraught with the inability of the under-resourced health services flight to meet customer demand. Representations at the time to improve resourcing were to no avail. We realise that the recommendations which we have made will require additional resources. It is therefore imperative that Air Force recognise these funding requirements.

The Impact of Production Pressures

Investigations of major accidents or industrial health disasters almost invariably reveal that production or operational pressures contributed significantly to the problem. The Air Force is again no exception to the pattern. It delivers Defence capability and this requires, among other things, a large-scale maintenance program to ensure the supply of serviceable aircraft, for use both in regular training exercises and in times of conflict. Thus Air Force maintenance organisations are under production pressures very like those which operate in private industry.

The pressure stemmed quite explicitly from the priority accorded to operations, as another commander noted:

> *'The time constraints were dictated by the operational requirements of the aircraft. The flying squadrons had … very little concept of what F111 servicing involved. Their expectation was that sixteen F111 aircraft would be on line and ready to fly as required…'*

> *'I recall at the time that there was an urgency with the F111 maintenance program. The fuel leaks had meant that the operational flying squadrons had inadequate hours available for training. The problems with the aircraft fuel leaks were well established, resulting in a large number of aircraft being unserviceable'.*

Officers were adamant, however, that these production pressures did not compromise safety. According to one

'I at no time placed any pressure on personnel to forgo safety so as to complete the job on time. In fact, had I been informed that any such thing was happening, I would have taken immediate steps to ensure that the situation was never repeated'.

One OC described two safety matters which had come to his attention during his period of command, one of which had led to the suspension of production until the problem was rectified. From these incidents he drew the conclusion that 'safety came first, the operational and production targets came second'. He went on: 'from the above two examples and other anecdotal evidence offered to me, I believe that this culture of safety-first existed through the management chain.'

He was wrong on this point, and the workforce had a very different perception of just what the priorities were.

The fact that perceptions about the priority accorded to safety depend on one's position in the organisation is a feature of many large industrial organisations. A recent survey of the mining industry in Australia showed that 81 percent of senior managers thought that their company had a positive attitude towards safety, while only 55 per cent of plant operators agreed. It seems that senior managers are generally less aware than the work force of the impact of production pressures on safety.

Pressures on the hangar floor

Members of the fuel tank repair section perceived themselves to be under considerable pressure to get the job done. At times, because of equipment breakdowns, people would have to stay on the job for 12 hours at a stretch to finish what had been scheduled for the day. On one occasion they were asked to do 13 hours overtime in one weekend to complete what they were doing.

Workers on the spray seal program had a five day window of time to carry out the resealing of one aircraft, after which the hangar in which they worked would be needed for other purposes. It was inconceivable that they take

longer. On one occasion delays in getting the sealant delivered meant that they had only three days in which to do the job. They managed, but the job was so rushed that the aircraft needed to be resprayed.

The consequences of pressure

In a high-pressure environment, problems with the personal protective equipment the workers were supposed to wear tended to get brushed aside, particularly in the earlier programs. Gloves disintegrated within five minutes of contact with the chemicals, but rather than continually interrupting the job to get new ones, people worked with bare hands. Moreover, according to one worker,

> *'there were times when the respirator restricted vision in confined areas. In those situations I would simply remove the respirator to get the job done'… Getting the job done was the priority and we just did what we were told'.*

The immediate supervisors were caught up in this compromise. A non-commissioned officer in charge of the first program commented as follows:

> *'I am aware of occasions when troop members removed the respirators from their face because they could not wear them in confined areas in some of the fuselage tanks. Working conditions inside the tanks were always difficult but the job had to be done…'.*

Here are the words of a supervisor at a different period: 'The troops knew the gloves did not work, but the troops had to keep going to get the job done…'.

Production pressures sometimes affected safety in quite complex ways. In the spray seal program, workers inside the tanks were suited out in cumbersome and uncomfortable equipment. As one witness described it: 'imagine yourself dressed up in a couple of overcoats in the middle of summer crawling around in your kitchen cupboards. Its not a real pleasant sort of environment to be in'. Moreover, there was no limit on the time people were required to remain suited up and working

inside tanks. They stayed there till the job was done. Four or five hours was standard and in one case a worker spent eight hours in his protective equipment, unable to consume any fluid or go to the toilet. This was highly stressful work and workers outside the tanks assisted those inside in whatever way they could. Spray guns had to be passed out, cleaned and tested from time to time. Workers who carried out this function were supposed to put on protective gear, but they sometimes didn't because of the pressure of the situation:

> *'The guy inside the fuel tank is under enough stress, so you would be in a hurry to get that gun clean and back to him so that he can keep going doing his job and get out of there with the least amount of stress, because you know how bad it is for him. So sometimes you would forget the mask'.*

This was one of the less obvious forms of exposure for workers in the spray seal program, but it may well have been one of the most significant.

The problem of denial

It needs to be understood that the ways in which production takes precedence over safety are often subtle. It is not that a deliberate choice is made to put people at risk in order to achieve a production target. It is simply that production is a constant imperative and safety is not. Failure to meet production targets has immediate consequences; failure to comply with safety requirements usually has no consequence, either immediate or long term. Safety requirements are precautionary and the failure to take precautions does not lead automatically

to negative outcomes. Where the potentially negative outcomes are as uncertain as the effects of chemical exposure, it is particularly easy for managers to lose focus on safety.

Moreover, organisations sometimes develop a culture of denial, that is, a set of beliefs which enable information about problems to be discounted and production to continue. One such belief which was evident from time to time at Amberley was that people who complain are simply trouble makers who are looking for ways of avoiding work which everyone acknowledged was very unpleasant but which nevertheless had to be done.

A Corporal in the spray seal program who complained numerous times assumed that he had been typed as a troublemaker and ignored for this reason. Workers on the hangar floor were expected to show initiative in overcoming difficulties and it is easy to see how people who complained regularly would have been construed as trouble makers. The Corporal believed that the attitude of his superiors to him was –'You're just a Corporal, don't tell me my job'. He went on:

> *'If you bring these issues up they say you're just being problematic,… you're causing trouble, so just shut up and do your job'.*

He gave the following illustration of how his complaints had been dismissed in this way by a senior officer who once visited the spray seal section. He told the Board that he had explained to the officer:

> *'why we needed more time, more money, more equipment and most of all, more understanding on his behalf so that we can achieve a safe outcome. After an hour of talking straight about all the problems we had, his response to me was 'so can you spray the whole fleet of jets back to back from next week? (ie without any break between sprayings)'.*

It is clear that the idea that complainers were trouble makers at times served as a belief which enabled those who had more pressing things on their minds to discount complaints that protective equipment was inadequate or reports that workers were suffering from headaches or other non-specific ailments.

Immediate Causes

Personal Protective Equipment (PPE) Performance

Respirators. Respirators did not always fit properly. They became uncomfortable and distracting to the wearer after a period of time. Some of the respirators in use, had perished and had therefore lost an element of effectiveness. However, the main issues with respirators were the type of cartridge used and the cartridge life. There are a number of recorded instances when dust cartridges were issued for use in chemical environments. The lack of understanding by the workforce usually lead to these cartridges being used until the chemical odours were detected by the wearer. This obviously raised suspicions.

Gloves. Through the course of the inquiry, evidence was presented and received on the problems with gloves that had been selected as PPE. Light-weight gloves tended to be useless when used with many of the products, especially solvents. The more robust gloves presented significant difficulties where dexterity was necessary for the job at hand. The quotation referred to in paragraph five is an extreme case but nonetheless representative of the problem with gloves, and is worth repeating: ‘We tried out 20 different types of gloves. We never - never got a good glove.’

Coveralls. White cotton coveralls with elastic cuffs were widely used. They were collected and laundered by a civilian contractor. Disposable coveralls were >also available and were commonly worn. The cotton overalls, were usually specified for use within tanks as a precaution against damage to tank linings. The presence of fluids meant that little protection from chemicals was provided. In the case of the Saranex coveralls used in the spray seal program, the ultimate realisation that they provided no protection to toluene was the defining moment for this Inquiry. Subsequent investigations by the 501WG IO found that coveralls that were suitable for chemical protection were not anti-static and were therefore unacceptable. This illustrates the point that OH&S solutions can be elusive and need considered attention.

Organisational Learning

Two contrasting views can be discerned in the literature about how safety is to be achieved in large organisations. The first view is that organisations must strive to perfect their safety management systems. Critics however argue that state-of-the-art safety management systems are not a panacea because they encourage a mechanistic belief that safety is assured once the system is set up.

The Longford gas plant accident near Melbourne in 1998 is testimony to the fallibility of systems. Esso had in place Exxon’s acclaimed Operations Integrity Management System (OIMS) which had, moreover, been audited just six months prior to the explosion and found to be functioning well. However, the Royal Commission was extremely critical of this system.

> *‘OIMS, together with all the supporting manuals, comprised a complex management system. It was repetitive, circular, and contained unnecessary*

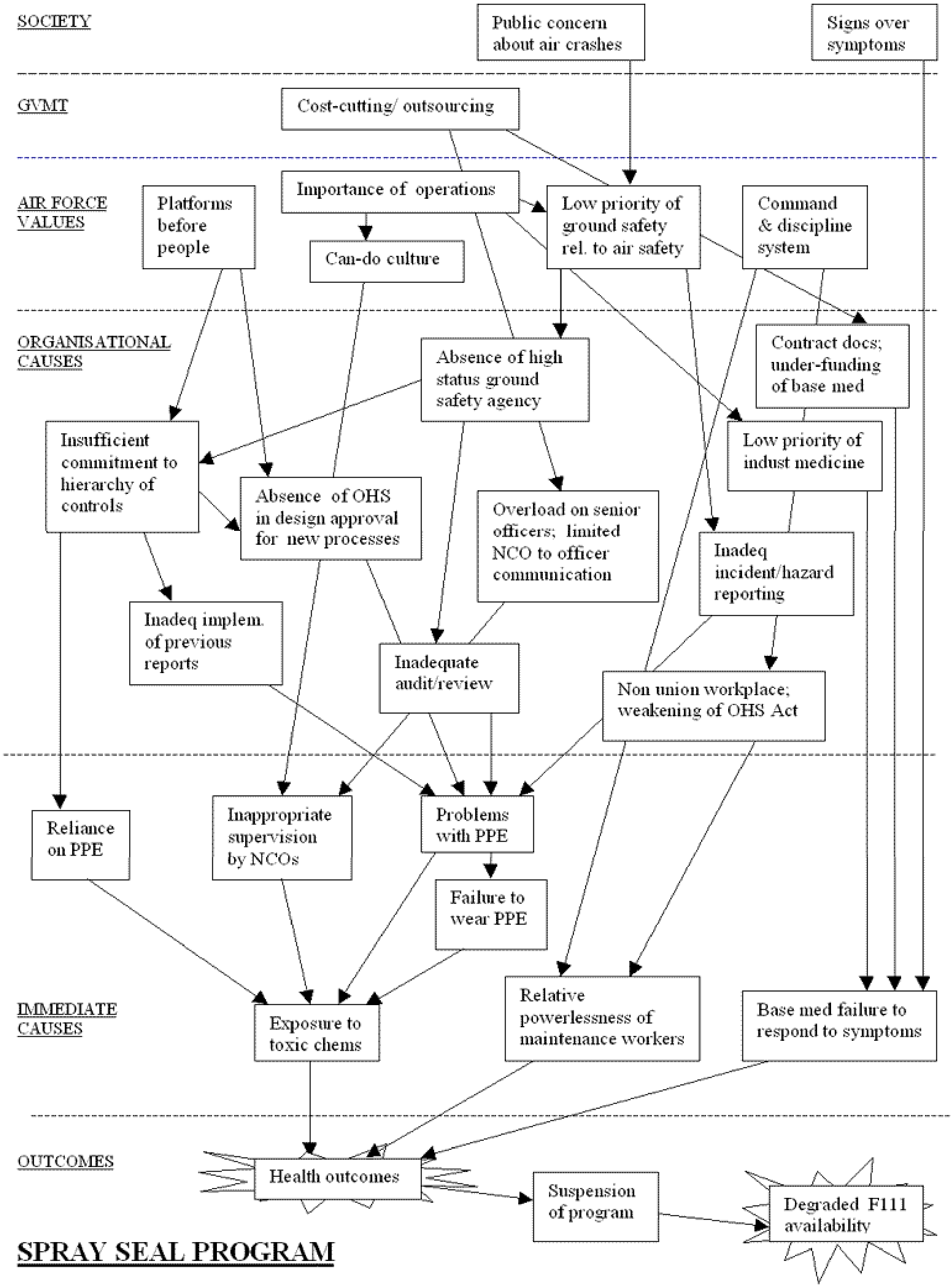
cross-referencing. Much of its language was impenetrable. These characteristics made the system difficult to comprehend by management and by operations personnel'.

'The Commission gained the distinct impression that there was a tendency for the administration of OIMS to take on a life of its own, divorced from operations in the field. Indeed it seemed that in some respects, concentration upon the development and maintenance of the system diverted attention from what was actually happening in the practical functioning of the plants at Longford'.

The Board finds similar characteristics in the Air Force and Defence policies and manuals.

The second view starts from the recognition that systems are never perfect, that things frequently go wrong, and that the most important requirement for safety is that organisations are mindful of the possibility of failure and learn from mistakes, incidents and near misses. The second view, then, is that safety is best achieved by striving to become a learning organisation.

Of course, a systems approach is not incompatible with organisational learning; a safety management system should include the capacity to learn, and lessons learnt may include the need to improve the system. The distinction, therefore, is really a matter of where the emphasis is placed. Nevertheless it is a useful distinction. Research highlights the failure of organisations to learn from their own experiences and those of others as a fundamental cause of accidents. There is a need to promote organisational learning as the most effective way to achieve safe and healthy workplaces.



SPRAY SEAL PROGRAM

RAAF Values Statement

The Air Force stands for:

- Delivery of effective, precision aerospace power;
- Defence of Australia's people, security and interests.

The Air Force aims to:

- Be a professional, highly motivated and dedicated team;
- Develop and support its people;
- Be a safe and equitable place to work.

The Air Force expects that its people will:

- Display honest commitment to the Air Force values.
- Strive for excellence as both leaders and followers.
- Be fair to and respect the rights of others.
- Encourage diversity in all its forms.
- Balance work and personal commitments, including family and relationships, for themselves and those they work with.
- Work together as a team.
- Communicate in an open and honest manner.
- Be capability focussed and operationally ready.
- Be professional and innovative.
- Be recognised for their loyalty, integrity and determination.
- Serve with pride and dedication.

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