Air Force 2021
Large-scale risk management

Cargo ramp entanglement
Multi-role harness saves the day

Explosion over Darwin
Sabre breaks up in flight

01 2022 EDITION

Spotlight

SPACE SAFETY

Developing the safety regulations and policies for our future projects and missions

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FOREWORD

WELCOME TO THE first edition of *Spotlight* for 2022 which is also the first time that we've published *Spotlight* under the Defence Aviation Safety Authority (DASA) banner.

I'd like to acknowledge the excellent and continued work of the Defence Flight Safety Bureau's (DFSB) Publishing and Multimedia team in having created such a well-read and highly respected publication over many decades. DFSB forms an important part of the DASA and along with the other DASA Directorates is embracing the spirit of One-DASA as we evolve as an authority. *Spotlight* will not fundamentally change its style or influential reach and in time will expand to contain a wider range of articles that cover the vast scope of all DASA activities.

This edition presents a particularly interesting read and I commend it to you. As with previous editions, there is something in here for every reader. We take a forward look into space safety and what challenges that may hold for us following the recent decision that DASA will become a regulator for Defence space activities. And we look back through the rear-vision mirror in exploring some historical accidents involving aircraft we no longer operate such as the Meteor and Kittyhawk. There are also some great articles that analyse some contemporary safety events, explain human factors or non-technical skills; and those ever-important stories that capture what our people have learnt from their own experiences and mistakes.

Please read on. I trust you will enjoy this edition of *Spotlight*.

Regards,

Joe Medved
Air Commodore
Director General
Defence Aviation Safety Authority

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Here's a hint: SPEAK UP

By SQNLDR William Harwood

AN AIRLINER IS on its final approach after a long, overnight sector. The captain is the pilot flying, but things aren't going to plan. They're getting overloaded, and the rest of the crew knows it. One pilot tells them that they're in the wrong flight-director mode. Another tells them to watch their rate of descent. Nobody is sure if they've received a landing clearance, and the landing checklist isn't completed until the aircraft alerts them to it. Nothing about this approach is stable, yet nobody says the words that you're thinking – 'go around!' Instead, the captain continues the approach to landing without objection. How could this happen?

Speaking up in high-risk contexts is defined as an upward voice, directed from lower- to higher-status individuals within and across teams that challenges the status quo, to avert or mitigate errors (Bienefeld and Grote, 2012). You might think this would come easily for aircrew, especially after several decades of crew resource management, and now aviation non-technical skills training and the long-established and well-practiced just culture in aviation safety. However, in the example above, pilots commented that while they had no trouble speaking up, it was much harder to do in real life compared to the classroom.

They're not alone – a 2012 study of a 1751 crew members at a European airline found that while 100 per cent agreed they needed to speak up for flight safety, only 52 per cent did so in ambiguous situations where, in hindsight, they felt it was necessary to do so (for example, observed errors or violations of procedures) (Bienefeld and Grote, 2012).

The study found the most common reasons for silence was an apparent desire to maintain a good team climate. Forty-three per cent of first officers feared that speaking up would damage their relationships with captains. Captains were similar, with 53 per cent indicating that speaking up about problems or issues could damage their relationships with other crew members and that they wanted to maintain a positive team climate (Bienefeld and Grote, 2012).

A pilot in the above example commented that they felt like they were the only one speaking up, and that the rest of the crew was comfortable with the approach. This was not the case – several crew members were speaking up during the approach, so why wasn't the message getting through?

The effectiveness of speaking up is defined by how it is done. Researchers at NASA found that while captains often chose the clearest form of communication – a command – co-pilots overwhelmingly chose the most indirect method of speaking up when trying to alert the captain to a problem – hinting. This is referred to as mitigated speech, and we often use it anytime that we are ashamed, embarrassed, or deferring to authority (Stone and Heen, 2009). The above example is a classic case of mitigated speech.

In aviation, many tasks and operations are team affairs – no single person or organisation can be responsible for the safe outcome of all tasks. However, if someone is not contributing to the team effort there can be unsafe outcomes. (Civil Aviation Safety Authority, 2018)

So how do we best contribute when things are going wrong? As a captain, actions speak louder than words; your crew is watching how you react when others speak up. If you are distracted, busy, dismissive, or immediately explain why their concern isn't a problem, you can bet they won't take the risk again. (Stone and Heen, 2009)

As a co-pilot, you must speak up in an assertive rather than submissive or aggressive manner. (Bienefeld and Grote, 2012) Rather than saying 'the checklist isn't complete', say 'unstable – go around!' The biggest hint is not to hint at all – speak up!

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AUTHORITY GRADIENT

Defence employs approximately 170,000 people across a range of diverse groups, services and professions. The chain of command is the basis of the leadership structure in Defence. The power distance between team members due to rank is referred to as the authority gradient.

A steep authority gradient can occur when a member of the team is of a greater rank and when there is a perception by team members that the higher ranked team member is dominant or overly-controlling in his or her use of authority. Steep authority gradients limit input from team members, reducing the shared mental model of the team.

Steep gradients are especially challenging when a person of lower rank is required to take up a leadership position within the team. This situation not only creates tension between the team leader and senior team member but can create confusion for the other team members who may be unsure where direction is coming from.

A shallow authority gradient can occur when there is low power distance between team members or when the team leader encourages an overly democratic approach to team decision-making. If the gradient is too shallow, it can take a long time to make decisions because all members are encouraged to provide input, regardless of knowledge and experience.

Australia may be a new space-faring nation and the ADF only beginning its star-ward journey, but space flight safety needs to be as much a part of our business today as aviation or workplace safety.

To boldly go ... safely

By WGCDR Nikki Olsen, PhD

'BRAZILIAN ROCKET EXPLODES ON PAD: MANY DEAD' read one online article to announce the explosion of the VLS-1 rocket at Alcåntara Launch Centre in 2003. The accident, caused by inadvertent propellant ignition, resulted in the destruction of the 10-storey-high launch structure, a wildfire in the nearby jungle and 21 deaths – all scientists and engineers who worked on the program. The subsequent investigation criticised the Brazilian Space Agency for using solid-propellant rockets and the lack of throttle controls and emergency shut-offs. But what has this got to do with the ADF?

On 19 September 2020, the first rocket launched from Australia to the edge of space blasted off from Koonibba Rocket Range in South Australia. The 34 kg, 3.4 m DART rocket was carrying a RAAF payload of prototype miniature radio frequency receivers. The receivers were designed, made and launched by Australian companies Southern Launch and DEWC Systems, both sponsored by RAAF's Plan Jericho.

Likewise, on 23 March 2021 the RAAF, in partnership with UNSW, successfully launched its third satellite payload to low Earth orbit, signalling a significant advancement in the development of sovereign space communications and ISR technologies. Furthermore, in December 2020, RAAF Woomera Range Complex played host to the recovery of a Japanese scientific payload, carrying precious mineral samples from the asteroid *Ryugu*.

These recent steps towards a space-faring ADF capability should come as no surprise. Indeed, the *2016 Defence Whitepaper* flagged the strengthening of the ADF's space surveillance and situational awareness capabilities and the vital role of space-based systems for intelligence collection, communications, navigation, targeting and surveillance.

Then, the 2020 Defence Strategic Update outlined key initiatives to establish an independent and sovereign communications network, an enhanced space control program and a sovereign space-based imagery capability providing coverage of the Indo-Pacific region. The establishment of an ADF Space Command from January 2022 was also a giant step for Defence-kind. The ADF is well and truly positioning itself as a space-faring capability for the future.

However, imagine if the rocket at Koonibba Rocket Range had exploded on the launch pad or veered off course towards the town of Ceduna? Suppose the RAAF/UNSW payload collided with an ISR satellite in low Earth orbit, preventing real-time imagery of a mission in progress and unnecessarily endangering soldiers' lives? What if the returning Japanese payload broke up in the atmosphere, raining debris over towns in the Aussie outback?

What is space flight safety?

While the well-publicised fatalities of astronauts are the first to come to mind when we talk about space flight safety (recall the *Challenger* and *Columbia* space shuttle disasters), manned missions have not been the only risk to human life in our pursuit of harnessing the fourth domain of commerce, exploration and warfare. In 1980, 48 people in the USSR lost their lives when a rocket exploded during refuelling and in 2007, three people died in California from an explosion during a rocket systems test.

Then there's the launch part of the mission – in 1996 an Ariane 501 rocket was detonated in mid-air to protect public settlements when it flew off course in French Guiana, and in 2017 debris from a Kazakhstani launch failure caused a wildfire, killing two members of the public. Furthermore, and depending on your source, between six and 100+ people were killed in 1996 when a Long March rocket veered off course and crashed into the nearby village of Mayelin, China – the village was obliterated as if it never existed (Zak, 2013).

According to experts in space and science law Joseph Pelton and Ram Jakhu (2010), space flight safety is the protection of human life and/or spacecraft during all phases of a space mission, regardless of whether it is a 'manned' or 'unmanned' activity. This includes all aspects of the space mission from pre-launch, launch, orbital or sub-orbital operations, through to re-entry and landing. It also includes the protection of ground and flight facilities, the population surrounding the launch site and, more broadly, the environmental impact of space safety, in so far as to its impact to human life on Earth. 'Space safety is not only about astronaut safety', writes Pelton, 'upon achieving the status of a spacefaring nation, a key responsibility that devolves is to establish the technology and

We need to start asking how we will develop safety regulations and policies for our projects and missions and in what way the human factors or non-technical skills involved in space operations are similar or different to those in aviation operations.

processes to protect (national and foreign) life and property against the consequences of malfunctioning rockets and re-entry space systems.' (Pelton et al, 2015).

The hazards and risks are numerous. At the launch site alone there are risks associated with explosions, toxins and radioactivity. Then there's the risk to people on the ground due to rocket excursions from planned trajectories or from debris generated from in-flight termination. We must also consider the risk to maritime and air transportation – currently managed on a mission-to-mission basis, yet the number of launches each week grow and air traffic continues to increase exponentially. In fact, it is estimated that debris from the re-entry destruction of the Columbia shuttle in 2003 resulted in a one-in-100 risk that there would be a fatal collision with GA aircraft. Thus we must ask, 'how do we effectively and safety integrate space traffic with air traffic in an ever congested air space?'

Assuming we can get our space asset to orbital space, its chances of surviving up there are dwindling. As of April 2021, there are approximately 128 million pieces of orbital debris less than 1 cm, 900,000 pieces between 1 and 10 cm and 34,000 pieces greater than 10 cm, all travelling at approximately 36,000 km/h in low Earth orbit (ESA, 2021). Considering that orbital debris as small as 1 cm can make a satellite inoperable and another as small as 3 cm can destroy a space shuttle, the exponential increase in debris over the short-term future should be concerning to all. Even the International Space Station has had to move out of its planned orbit 29 times in its 10-year history to avoid debris (NASA, 2021).

Of course, destruction of an 'unmanned' space asset on its own may not necessarily constitute a major catastrophe worthy of space safety recognition. But think of the second- and third-order effects: our communications, transport, power and computer systems worldwide heavily depend on satellites. Depending on what and how much we lose, global business could grind to a halt, food supply chains could break down, essential weather forecasting information would not supply air transport providers or the agriculture sector and worldwide communications may be disrupted. And for the ADF – imagine losing contact with soldiers in sensitive areas, leaving them vulnerable to attack, not being able to operate our advanced fifth-generation fleet or the isolation of being on the high seas in areas of tension without secure position, navigation and timing systems.

Then there is the re-entry phase. Satellites that are not actually in perpetual orbital motion around the Earth but rather in constant free-fall, will eventually make their way to re-entering the Earth's atmosphere. While defunct satellites and spent launch stages usually fragment and, sometimes explode, due to the high aerodynamic forces and fiction-generated heat of atmosphere re-entry, some parts designed to withstand such pressure survive and come crashing down to Earth intact. These surviving elements are a risk to people and property, air and maritime traffic. Worryingly, predicting the exact re-entry time and location of randomly re-entering debris is extremely difficult.

Space flight safety in the ADF

Australia may be a new space-faring nation and the ADF only beginning its star-ward journey, but the extreme dangers, catastrophic effects of getting it wrong and the cascading negative effect of our use of the heavens is already a problem for today.

There are many parallels and differences between aviation safety and space flight safety. Aviation safety is underpinned by the Convention on International Civil Aviation and the standards and regulations promulgated by ICAO that provide a minimum level of safety assurance across all 193 ICAO states. In pursuit of adhering to international best practice where possible (and deviating only where required for military purpose), the Defence Aviation Community implements a series of aviation safety regulations and safety management practices that are consistent with these obligations. Additionally, we benefit from a century of lessons learnt across the entire globe and can draw on the multitude of aviation safety experts and researchers to implement a robust and effective aviation safety management system.

In contrast, there are no space treaties, nor obligatory subscription to international regulatory or safety organisations, that define or require uniform safety-management methods or standards across space-faring nations. Instead space safety, like space programs themselves, are managed at the national level with widely inconsistent benchmarks across different nations.

While there are voluntary international standards in space systems safety, launch-site operations and space risk management recently developed, the international community is still at the beginning of its journey with regards to its own national standards of space flight safety and no-where near mandatory international standards. To top it off, the experiences of most other states are as new as our own and research in the domain is still in its early stages.

There is a lot we don't yet know about how we will manage space flight safety in the ADF and we'll have to rely on the experiences of partner space-faring nations, like the US, to develop our own standards and practices in space-flight-safety management.

We need to start asking how we will develop safety regulations and policies for our projects and missions and in what way the human factors or non-technical skills involved in space operations are similar or different to those in aviation operations. We also need to consider how to prepare to investigate and conduct investigations of space flight occurrences, what is needed to develop subject matter expertise and experts and how we might educate the future Defence Space Community to promote space flight safety.

Then there is the added complication that ADF space missions will almost certainly be joint ventures with civilian industry and/or other nations. This raises uncertainties concerning what our jurisdiction to manage space flight safety will be and how we will effectively influence and co-ordinate safety management in an increasingly multi-national, whole-of-government and whole-of-nation space domain.

Finally we will also need to consider our safety obligations on the international stage. Pelton and Jakhu (2010) write, 'space debris mitigation and space traffic management will constitute the two most important international space safety standards and regulatory issues to be faced in the next few years'. However note that they wrote that statement in 2010 and yet, despite the considerable risk to capability, reputation and human life, there is still no significant international action on this front. How will the ADF contribute to this discussion? And how will we fulfil our obligations to the safety of the international community in carrying out our space missions?

Conclusion

When we think about space flight safety we tend to think about the safety that NASA and Russia's Roscosmos manages to send their astronauts and cosmonauts to space and to return them safely to Earth. However space flight safety encompasses more than that – it applies to all stages of space flight from launch preparation to re-entry and landing and to both manned and unmanned space assets. In a wider sense it also involves public safety at the launch/landing sites and under the flight path as well as the environment, both on Earth and in space.

The ADF is well and truly on its way to developing its space-based and space-enabled capabilities. Thus, it is not unreasonable to believe that our part in this game will increase significantly over the next few decades, as we shore up our sovereign design, manufacturing and launch capabilities in pursuit of national space resilience. However, our responsibility to protect human life, infrastructure and both terrestrial and space-based assets from the risks associated with our latest endeavour is paramount. Therefore, space flight safety needs to be as much a part of our business today as aviation or workplace safety.

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DASA update:

Defence Space Command has recently agreed to the need for a Defence space regulator and that DASA is best placed to fulfil this role. Looking forward, we will work closely with the Australian Space Agency (ASA) to establish a Defence space framework that will allow DASA to independently assure Defence space activities comply with the ***Australian Space (Launches and Returns) Act 2018***. DASA also plans to expand its investigatory capability, independent of the ASA, for accidents and incidents involving Defence space activities.

WIRES! 'COME UP, COME UP!'

By WO2 Bradd Shelton

DURING EXERCISE SWIFT EAGLE 2004, I was part of a Blackhawk crew working out of Cowley Beach near Innisfail. We had been on exercise for about two weeks doing a variety of tasks from day airmobile operations to recon inserts by night vision devices (NVD).

The morning of the incident our crew was tasked to conduct an admin move starting with an hour-long transit to a Navy ship off the coast at Ingham. I was the right-side loadmaster with a more senior loadie on the left, an experienced aircraft captain (AC) and a relatively new co-pilot (CP) up front. The transit there went smoothly with our crew members quite relaxed and happy to be doing a low-drag task.

We conducted a deck landing, took on eight pax (passengers), then, while on return to the regiment, we received a new task to take four Special Forces members from the regiment location to the Innisfail Airport. The Special Forces members had a plane to catch and we realised that while we had enough time, we couldn't muck around too much.

We landed back at the regiment, took on fuel via a hot refuel, the four pax boarded and we departed for the Innisfail Airport. In the lead up to the exercise a low-flying area had been approved for the five miles around the regiment location. This approval included a wire recce conducted by a Kiowa squadron and approval to fly Nap of Earth (NOE).

During the exercise, if wires were spotted by crews that weren't marked on the wire map, ops would already be notified and add them to the master wire map. Crews would then update their individual maps prior to each sortie.

After departing the regiment we flew via a low-level route at about 50 ft, climbing and descending over the known wires on our track. Approximately four miles from base we encountered a set of wires that weren't marked on the wire map. We noted them and decided to climb to 100 ft in case of more unmarked wires.

As we continued on we made a right-hand turn into a small valley. On my side of the aircraft the terrain was about 200 ft above us and I noticed a tower at the peak of the ridge parallel to us. I scanned forward and saw a set of wires running down from the tower directly in our path and at our level. I immediately called 'Wires, come up, come up!' At the same time the left-hand loadie called 'Come up, come up!' The CP who was on the controls at the time reacted immediately and raised the collective.

Although we climbed about 15 ft we collected one of the wires which stuck to the right main landing gear and wire cutter. The wire was dragged along by the aircraft for about 50 ft until it finally broke in a shower of sparks. As it broke it contacted two of the main rotor blades causing the blade tip caps to separate from the blade.

The AC made a PAN call back to the ops team, the left loadie called 'Brace, brace, brace' to the passengers while the CP and I identified a clear field to land in. An emergency landing was conducted in a sugarcane field without any further damage to the aircraft or injury to pax and crew.

Looking back on this incident there were a number of contributing factors to consider. With regards to Individual/team actions (from the DSAM taxonomy) there were potential issues around Information Utilisation (ITA02). The crew on a sortie the previous night had identified the wires we later struck.

The information was passed to ops on return to base but not updated on the master wire map until after we had departed on our sortie the following morning. External Communication (ITA04) deficiencies could have contributed to increasing risk as the ops team didn't pass the change to all aircraft currently on tasks.

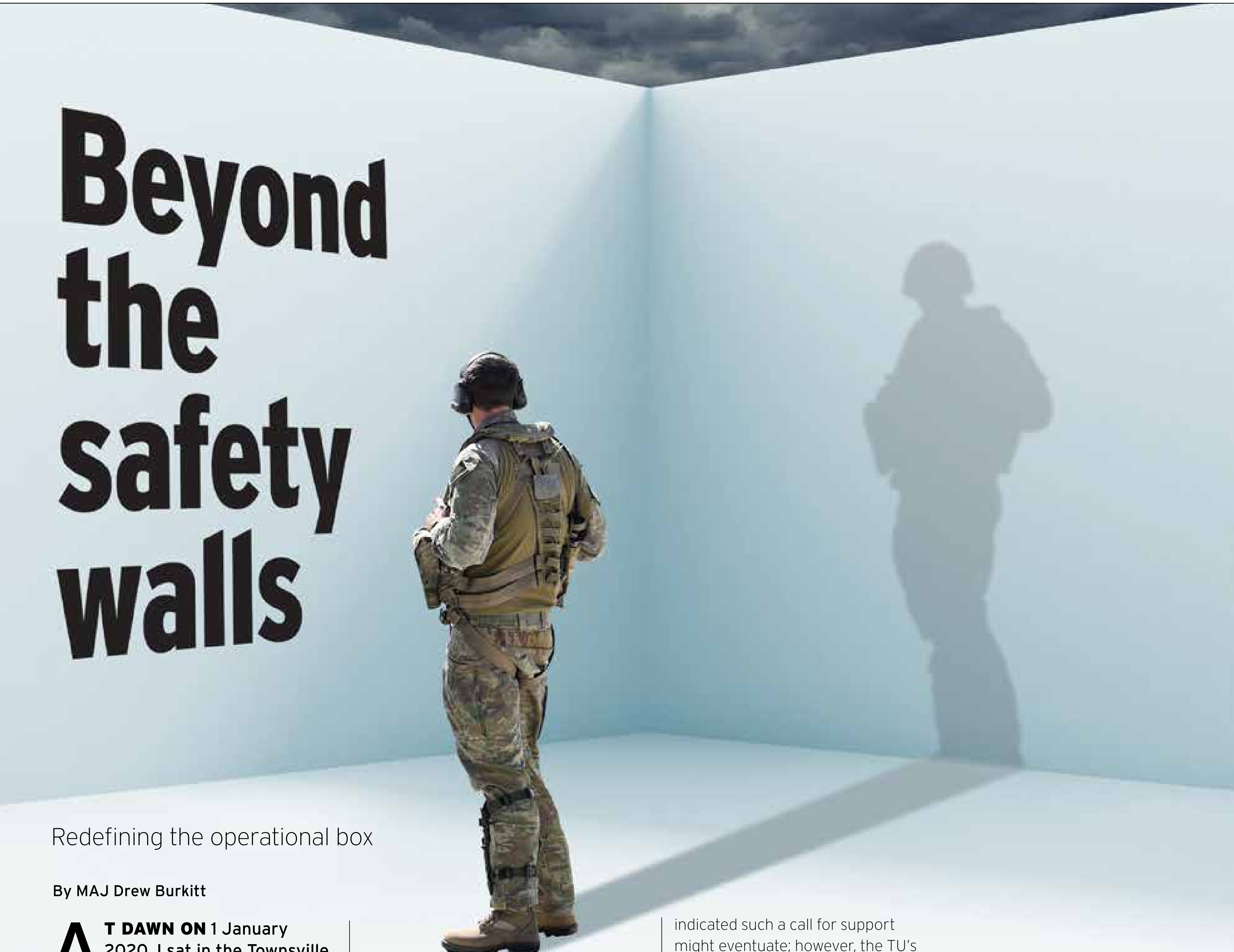
Contributing local conditions that may have included Fatigue/Alertness (LC2.02) and Attention (LC2.03). The ops team had been working at a higher-than-usual tempo for the preceding two weeks and it is reasonable to attribute some fatigue-related performance decline. This would also have had an impact on the attention each ops member was able to devote to routine tasks. Task/Job Factors (LC3) such as distractions and high workload, felt across the aircrew and ops, in the lead up to the incident could also have been a contributing factor.

In terms of deficiencies in risk controls, there appeared to be a deficiency in active supervision/control (RC5.01) within the ops team regarding the conduct of routine/mundane tasks. There also appeared to be a deficiency in the workplace instructions/orders/procedures (RC3.02) from the aircrew perspective. Although the decision was made to climb after finding the first set of unmarked wires, perhaps the procedures at the time should have called for the cessation of low flying, particularly on an admin move. The procedure could also have been changed to mandate that the ops team contact any flying aircraft with changes within the AO.

Regarding classifying this incident, although there were no injuries to personnel there was a moderate amount of damage to the aircraft. The right landing gear required replacement while two of the blades required replacement tip caps. The maintenance liability was in excess of two days making it a Class C incident. In considering the perceived risk level, the flight ops safety outcome could be judged to be major while the risk controls could be judged as mostly effective. This lead to an overall classification of Class C.

When I look back at this incident I think the biggest take away is that when conducting routine or low-priority tasks, there is no need to risk safety for cool flying such as low flying. There was no tactical need to be low and the experience was not worth the outcome or potential worst-case scenario. Additionally, when conducting routine tasks, it is easy to become complacent and switch off to risks. A simple radio call from us could have prevented this incident and reduced the exposure to a potentially serious accident.

As a side note, the passengers were picked up by road and transported to the airport where they made their flight.



Beyond the safety walls

Redefining the operational box

By MAJ Drew Burkitt

AT DAWN ON 1 January 2020, I sat in the Townsville Qantas Club enjoying an airline portion of scrambled eggs while considering the operational unknowns the team was venturing in to.

C Squadron (minus) from 5th Aviation Regiment was being deployed as Task Unit (TU) Chinook in response to the Victorian Government's request for support with bushfires sweeping the state's south-east. The three Australian CH-47F Chinooks would take over from Blackhawk crews from the 6th Aviation Regiment who'd been based at RAAF Base East Sale. Another two CH-47D+ from the Republic of Singapore Air Force (RSAF), would later attach to the TU, as well as a surge in Australian Chinooks.

Watching the media coverage of the Victorian fires in late December indicated such a call for support might eventuate; however, the TU's preparedness concerned me. The deployment plan was ready, but it was just that – a deployment plan and not a detailed concept of how the following support to the operation would be conducted. Were the missions and tasks similar to what we had trained for? Would we have to adapt our procedures to suit the situations? What rules were we about to knowingly or unknowingly break?

Uncertain of the answers to my questions, the idea of the operational 'box' came to mind. I was introduced to the 'stay safe and stay inside the box'[1] messaging in 2014 with a poster showing the 'danger zone' outside the box: a little too reminiscent of a certain movie. Admittedly, I do not recall much of the associated briefing apart from a mixed acceptance by the audience. Some members took the opportunity to add additional comical, yet edgy clauses such as 'don't go near the edge of the box' and 'don't even look at the edge of the box'. Others took a more pessimistic view, showing frustration with a perceived command insurance policy towards risk within aviation operations.

I can appreciate that the concept was based on concerns Army Aviation had about decision-making and the application of written rules. These concerns were likely heightened during that decade following the two Chinook accidents in Afghanistan during 2011 and 2012. The box concept was; therefore, a valid means of communicating a simple safety message designed to calibrate members' adherence to rules and regulations. Although by potentially over-simplifying the message, the value of contextualisation of rules and regulations took a subservient position.

Before I could adapt the concept to the operations at hand, I needed to understand why such a concept was considered so valuable. At a fundamental level, I was against such an initiative-constraining idea that being inside a box promoted. I wrestled with how the metaphorical walls must enable safe operations. I didn't feel comfortable placing all my faith in these mythical barriers. With the box in a different position (like on operations) the walls may no longer remain as solid, may bend or become permeable. What then?

My thinking progressed to an annoyance in not knowing what the box actually was. I revisited the danger zone – this was the area where prescribed rules and regulations were not directly specified, and where I thought the TU might stray. Three questions quickly developed. What were the rules or regulations that we were at risk of finding unsuitable? Could we anticipate approaching these situations, and finally, were we trained to deal with finding ourselves in the danger zone?

Unsuitable walls

The walls of the box were well known in training. They were rarely, if ever, challenged, with only a cursory look required to understand they were still there. Challenging some of these rules was now at the forefront of my mind.

As I compared likely tasks and rule sets, I quickly realised most were firmly within the box and was initially relieved. However, upon further consideration, I found some areas were definitely either not constrained within the box or had the ability to push against the walls given the circumstances.

The two main areas of concern centred on operating at minimum visibility requirements and the carriage of civilian passengers. On their own, these two areas are easily manageable yet layered with additional pressures, would they push the TU against and through the box wall? I considered whether the walls regarding these could be moved to facilitate our operations but the extant rules and regulations were clear and generous. Therefore, the question was not about re-writing these rules, rather identifying how they would apply to the new context.

Anticipation

From our comfortable TU setup at East Sale, we began formalising our plan for the operation. With such a short turn around, I admit some formal aspects were still underway but they were happening. The risk management plan (RMP) was being updated, an SOP was being rapidly developed and robust, honest communication was occurring across the TU and into the headquarters.

Through our standard mechanisms, especially risk management, we were addressing the box with our best judgment. Nevertheless, this did not mean that we were being pro-active.

The context of operations was now becoming clear. Operating in low visibility (at the limit of the rules) was becoming normalised, as was carrying civilians. The operation's success to date had focused my attention towards complacency in risk and decision-making. I could see the confidence in the crews building as each successful mission promoted an apparent ease of operating against the bounds of the box.

As tasking changed to include VIP missions, it seemed that to some people the walls were becoming permeable with a clear focus on impressing VIPs over safe operations. This was the situation I was awaiting; a pressure point that would deliberately push the TU into the danger zone.

Trained in the danger zone

Before the deployment I considered the initial and continuation training undertaken by the TU, particularly the aircrews. I recalled the continuum was sound, with growth of experience part of the individual and collective development. But the question of context now reappeared as I became nervous that this training might not have focused on pushing crews towards the box walls, let alone into the danger zone.

Discussing my concern with the TU Operations Officer, our shared view was that our preparatory training could in fact be considered dangerously safe as it had not stretched crews to operate within the dynamic operational context we were now facing. The training mindset was easily within the defined box walls. However, now we questioned if this training allowed for an expansion of experiences outside of purely training. Were our training objectives focused incorrectly, resulting in dangerously safe training that was not relevant to tasking? What were the unknown unknowns that we are now committing to? Unfortunately, the time for training was now gone and yet the box remained.

WO1 Darrel Rowe, searches the ground from a CH-47F Chinook during the flight to evacuate local civilian residents during Operation Bushfire Assist 2019-20.

Burning the box

The single change that sparked my own realisation about how complex the box can become, was the inclusion of the RSAF Chinook detachment from Oakey, Queensland. The detachment's professional work ethic and enthusiasm was warmly welcomed, as was its two CH-47D+ aircraft.

It was easy to draw parallels between the Australian and Singaporean Chinook capabilities, yet there were also many differences. To include the RSAF members in the joint force, we needed an appreciation of their operational box. Did they have the same walls? With such a rushed integration, we would never fully match the two operational boxes. However, the complexity I was largely concerned with was resolved through careful integration into a common operational box that suited both elements.

The TU was now operating as a joint unit in weather conditions – namely visibility – at or below the minimums for safe flight. While several unique taskings were approved, several captaincy decisions were knowingly not in accordance with standing instructions. As such, we'd started to burn small holes in the box.

The associated Aviation Safety Reports (ASRs) would explain to what extent we'd strayed into the danger zone. A number of ASR events were a result of deliberate decisions to deal with challenging situations, some were not. However, all events were being reported openly and honestly.

Some TU members did question the repercussions of such extensive reporting but there was minimal negative feedback. On the contrary, the feedback was very positive. TU members were talking, listening (and hearing) but most of all, learning. They were no longer stuck in a training mindset, rather they were adapting to an operation mindset. Collectively we were redefining the box by actively setting up new safe and approved limits for operating. The team was also standing its ground when challenged to go further.

This learning and innovation culture was a major highlight of the operation. The tasking was difficult, challenging and rewarding but collectively we learnt the box was flexible to allow for unknown-unknowns. It allowed the TU to know the rules and enabled mission decision-making at the lowest level.

Mindset, planning and communication were the key enablers. Firstly, a readiness mindset allowed team members to transition their thinking from a training state to an operation state. While deliberate training does foster this mindset, the importance of command's willingness to challenge the status quo will open opportunities suited to that environment. Secondly, a robust method of analysis and decision-making allowed for the TU to respond rather than react to situations. This may be considered risk management; however, I'd contend that this was nothing more than good planning prior to execution. To enable this execution the third aspect, communication, became imperative both at a small-group level and across organisations.

Conclusion

When I was first briefed the box metaphor, I did not consider the danger zone that lay beyond the walls. I thought the concept was over-simplified and protected those who created the walls.

Operation Bushfire Assist 2020 challenged my approach to this concept. I still think it is overly simple and nauseatingly dramatic; however, it did help me consider the operational stresses of the deployment, albeit not as originally intended.

The walls were not always suitable but provided a restraint that enabled me to consider why they were there. Approaching the walls was alarmingly easy, yet the knowledge of their presence allowed for deliberate, risk-based decisions.

Training may not extend to include pushing against the walls. Maybe it should. Regardless, I consider the success of the TU was not in the flying, it was the combination of the collective mindset, planning and communication. Through these three aspects, safe operations were still possible in a newly defined box.

An Australian Army Chinook supports the evacuations of people and animals during Operation Bushfire Assist 2019-20.

Endnote

1 Lawler, GM, '*The Australian Army 'Combat Aviation Newsletter'* August-September 2014, Director General of Aviation opening comments paragraph 3.

Large-scale activity risk management

By SQNLDR Bruce Chalmers

SAFETY OF OUR personnel is the top priority for Air Force, and The Air Force 2021 (AF2021) project placed safety high on its list of priorities during commemorative activities over the 12-month centenary period.

The largest activity undertaken for the centenary was the 60-ship flypast over Canberra in support of the presentation of the new Queen's Colour for the RAAF at Government House.

This magnificent spectacle, honouring the 350,000 who have served, the 11,191 who gave their lives and the 3143 who have no known grave was an undertaking that took months to plan and co-ordinate. Its successful completion with a live telecast (no pressure), testament to the exceptional work done by the Air Operations cell of the Air Force Air Show Team.

Under the guidance of Director Air Operations, GPCAPT Tim Sloane, all safety requirements were planned and met. It began with the development of a risk management plan for specific flypast hazards. The plan then guided the supporting activities to eliminate or mitigate risks.

'As the planning progressed we ensured all stakeholders were identified and notified of the areas affected by the flypast,' says GPCAPT Sloane.

'As you would appreciate we ensured a very large block of airspace was reserved for the flypast aircraft exclusive use.

'It was also critically important that specific communication links were established given the number of aircraft we had in the space.'

The Air Shows Team repeatedly, over weeks, conducted simulations of the entire flypast and adjusted planning to ensure separation between the aircraft, during the holding, the flypast itself and the departure to home bases.

In addition, trained observers were situated at specific points around Lake Burley Griffin to look for unauthorised traffic. The resources of Surveillance and Response Group were marshalled to monitor all aircraft movements by employment of an E-7A Wedgetail aircraft positioned overhead, bringing the latest technology to ensure the safety of all involved.

On the ground, extra rescue and firefighting assets were deployed to Canberra to assist with any aircraft-related emergencies, completing the mitigation processes of the plan.

All these actions were employed to reduce hazards to as low as reasonably practicable.

Air Force had other events in the week leading up to and on 31 March, 2021 at bases across Australia and in Canberra where a number of business-as usual-activities took on the Air Force 2021 persona for the centenary year. In the middle of a global pandemic this meant for every one of those an additional list of compliance and risk-management activities had to be undertaken.

Potential risks were identified and analysed to ensure elimination, substitution, isolation, engineering, administration and PPE controls could occur.

Potential risks were identified and analysed to ensure elimination, substitution, isolation, engineering, administration and PPE controls could occur.

As Air Force 2021 activities were generally business as usual annual RAAF birthday activities, risks were generally assessed as very low as they had been conducted on numerous previous occasions and had controls in place thanks to lessons learnt.

The additional activities based in Canberra surrounding the presentation of the Queen's Colour created considerable public interest, especially for the mass flypast. This required risk plans to be submitted to the National Capital Authority to ensure COVID compliance, as large numbers of the public would occupy public spaces to observe the proceedings.

ACT Police LSC Jason Byrne, ACT Fire and Rescue CMDR Paul Thorpe and No. 1 Security Forces Squadron CPL Tyren Hones, at the Regatta Point Venue Control Centre, Canberra.

On the ground, extra rescue and firefighting assets were deployed to Canberra to assist with any aircraft-related emergencies, completing the mitigation processes of the plan.

Risk plans were prepared for the commemorative service, centennial fly past, flag-raising ceremonies, Queen's Colour parade, Rond Terrace and welcome to country sites.

The application of risk analysis applied to all AF2021 events used the following methodology: risk-management identification, evaluation, and prioritisation of risks (defined in ISO 31000 2018 as the effect of uncertainty on objectives) followed by co-ordinated and economical application of resources to minimise, monitor, and control the probability or impact of unfortunate events or to maximise the realisation of opportunities.

Due to the scale and complexity of AF2021 events, a hybrid tool for risk/hazard identification and management was developed. The tool was broken into three parts:

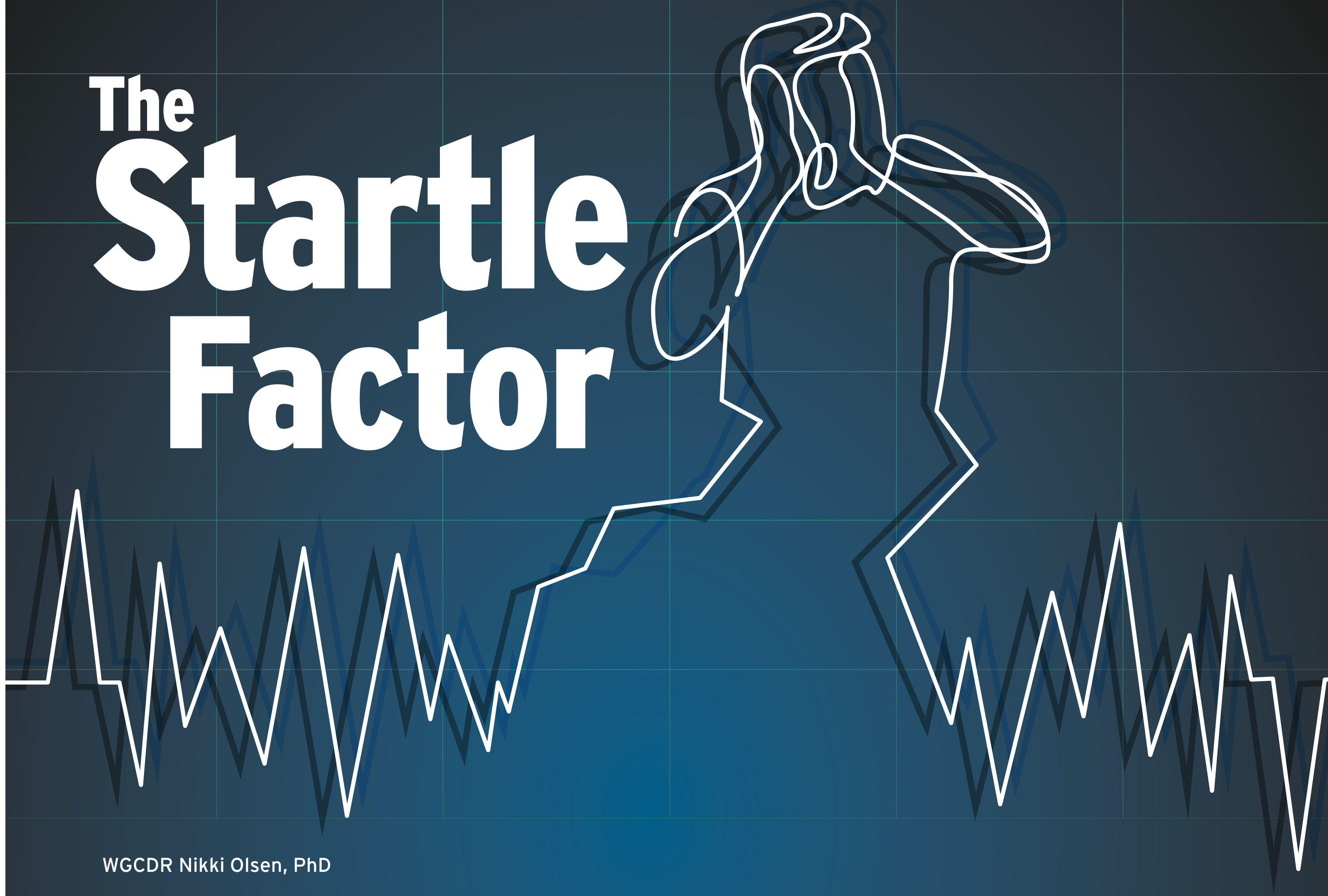
Part One. The overall risk title documenting every plausible risk/hazard identified and was given a title and a number. The numbering system correlated to that particular risk/hazard throughout the remainder of the document to match the analysis and the mitigation phases of the process.

Part Two. Each identified risk title was further broken down and each sub-risk within that title was given a letter. Again the assigned letter remains pertinent to that particular title and sub-risk for the remainder of the document.

Part Three. Incorporated the analysis of the risk and the identification of existing controls (elimination, substitution, isolation, engineering administration and PPE) as well as the likelihood versus consequence matrix (Defence Work Health and Safety Risk Matrix) providing the risk level (very low, low, medium, high and very high). The document stated level of authority required to accept the risk and finally who had accepted the risk.

As the Air Force 2021 program drew to a close the robustness of it safety planning and execution was evident with a successful year of commemorative activities completed safely.

The Startle Factor



WGCDR Nikki Olsen, PhD

IT IS LIKELY the pilot's inability to maintain directional control resulted from a period of impaired cognitive performance caused by an acute stress response.

This was one of the findings of DFSB's recent runway excursion investigation.

Just over a year earlier, a Hawk pilot successfully executed an abort on the runway when their aircraft experienced an engine failure on take-off. Despite what must have been an intense and rapidly evolving situation the pilot was 'surprised at how well muscle memory from simulator emergencies filtered through to their actions' during the malfunction.

We are becoming increasingly aware of accidents and incidents in which pilots experience acute stress in response to an emergency or otherwise surprising situation. In most cases, the outcome is positive. In others, pilots have responded ineffectively or inappropriately, often exacerbating the dangerous situation in which they found themselves.

This appears to be the case for Air France Flight 447, Colgan Air Flight 3407 and West Caribbean Airlines flight 708 in which pilots failed to diagnose and correctly manage surprising aircraft situations and were subsequently unable to prevent their aircraft stalling and crashing.

The contributing factor attributed to all of these cases: an acute stress response known as the startle reaction.

What is the startle reaction?

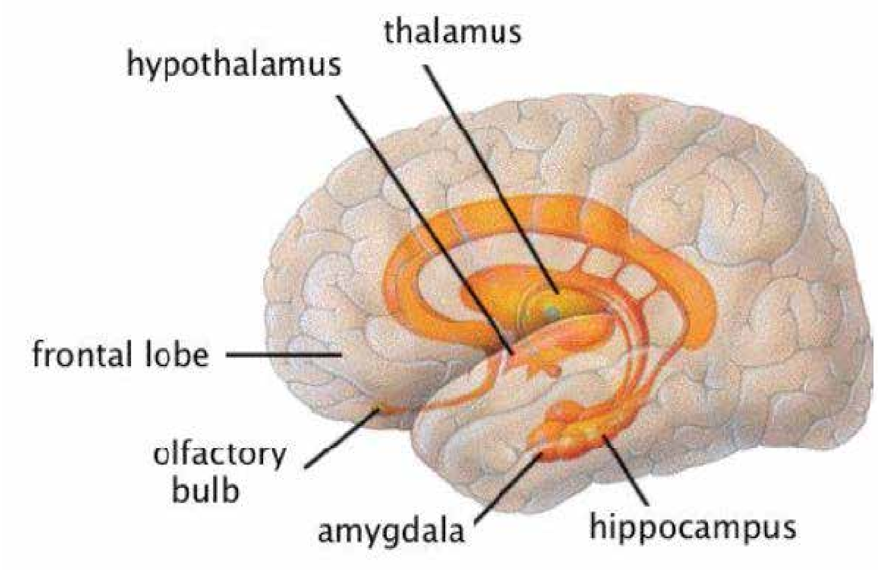
Remember back to the last time you were in a café and the waiter dropped a glass or a plate. You may recall the feeling of your body jumping out of your skin or that you at least turned in the direction of the ruckus, perhaps imperceptibly leaning away from it. Furthermore, you probably paused your conversation mid-sentence and, after not more than a second or two before realising that you were in no danger, you returned to your conversation hesitatingly, requiring a moment to remember where you were before the interruption.

… the pilot may become task focused, causing them to focus on irrelevant information at the expense of more critical information.

According to Martin (2013), startle is a reflex physical reaction that intuitively moves someone away from a stimulus (for example, a startling sound or sight) while also focussing the person's attention on that stimulus. However, while most people recover from false alarm startle situations within 1.5 sec, a stimulus that is perceived to be threatening tends to result in a significantly worse reaction – this enhanced reaction is referred to as fear-potentiated startle.

To fully understand the startle reaction we need to start at the thalamus, the area of the brain that receives input from the senses. Martin explains that the thalamus projects these sensory inputs to the attentional processing centre, the amygdala, where a rapid matching process compares the sensory input with stored memory to appraise the usefulness and emotional relevance of the information. If the information is found to be both surprising and potentially threatening, both the startle circuits and the fight-or-flight circuits (the sympathetic nervous system) activate within about 14 ms.

At the same time, a signal is sent to the prefrontal cortex where a more in-depth analysis of the information occurs. This slower process explains why we may suffer from false alarms – that is, upon realising that the information is not threatening, extinction circuits are activated to lower our arousal, though this is some time after the initial startle (500 ms for this realisation vs 14 ms for the initial startle).



On the other hand, if the information is confirmed to be threatening, a reinforcing signal is sent back to the amygdala, which enhances the stress response, and turns a simple startle into a fear-potentiated startle reaction (Martin, 2013).

Startle and performance

Considering the effect of a startling stimulus on the attentional and information-processing systems of our brain, we can begin to see how someone's capacity for effective information processing can be significantly compromised during startle, causing issues for problem solving and decision-making. For example, the pilot may become task focused, causing them to focus on irrelevant information at the expense of more critical information (Martin and Murray, 2013).

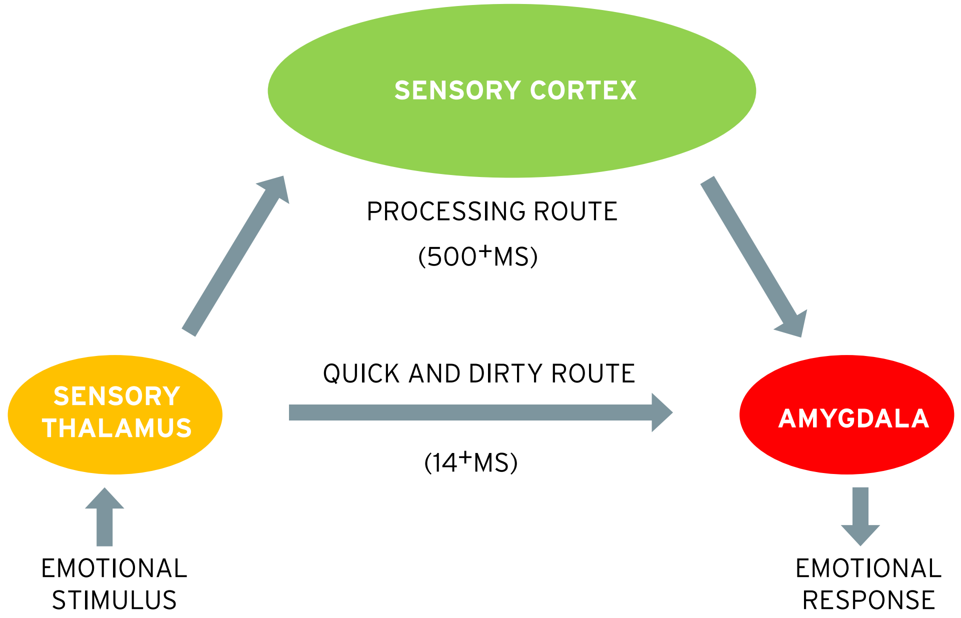
Alternatively, the pilot may experience a significant deterioration in psychomotor skills (for example, inconsistent handling or inadvertent switch selection) or disruption to working memory, resulting in a loss of situational awareness (Thackray, 1983).

Not all startle events are equal

Martin (2013) writes that the intensity of the startle depends on the type of stimulus (how loud, unexpected, terrifying or improbable the stimulus is), the environment (how dark, frightening or dangerous the setting) and the person experiencing the startle (their level of preoccupation or vigilance and any predisposed anxiousness in their character).

Ideally, while pilots would be low reactors to startle, his research found that fear-potentiated startle impaired the decision-making of 33 per cent of pilots (n=5) for up to 30 sec when exposed to a startling stimulus in a simulator.

In a similar experiment, 78 per cent of participants (n=14) reported noticing a physiological reaction to the startling stimulus and 61 per cent of participants (n=11) reported a period of confusion or indecision.



Other research suggests that true startle events resulting in responses severe enough to cause negative consequences are actually quite rare (Talone et al, 2015). Indeed, a systematic search of the ADF's reporting database returned only five reports since 2004 in which startle or surprise was reported and a search of the ATSB aviation reporting database returned only four reports since 1954.

Training and procedures for startle

Reducing the effects of startle reaction in aviators has begun to receive a lot of attention in the past decade. In 2014, the European Aviation Safety Agency issued a Notice of Proposed Amendment to incorporate surprise and startle effect into CRM (NTS) training and the US Federal Aviation Administration issued a promotional flyer on the benefits of chair-flying and simulation to prepare for startle situations (available in the Human Factors Resources section of the DFSB website).

Many researchers have suggested other strategies that can be incorporated into any unit's training or daily business. These include:

1. Using positive experiences to develop a sense of mastery

Martin and Murray (2013) highlight that startle reaction is significantly greater when people experience an element of fear from the situation. Therefore they recommend strategies to develop a sense of mastery over critical events (such as managing a stall) to reduce the negative associations that could lead to heightened fear during startle. For example, they suggest:

- changing the language used in the training environment 'by creating a "challenging but fun" exercise with repetitions to competence, which are verbally reinforced and praised, stall warning events downstream can possibly be appraised more positively'
- using personal reflection to develop mental schemas for managing surprising events through meditation, visualisation, whiteboard scenarios, chair flying (pilots) or Ben Hur (ATC)
- computer-based and simulator training during which learners can experience

Startle in ATC

Pilots are not the only aviation actors who are susceptible. Research conducted on university students performing simple ATC radar-monitoring tasks showed that, while the mean response time of startled and non-startled participants was similar, those who were exposed to a startling stimulus made significantly more errors in the 30-60 seconds following the stimulus than the non-startled group (Thackray, 1983).

Later research conducted on experienced air traffic controllers also demonstrated a negative effect to startling stimuli, though this was significantly less than the non-ATC control group, suggesting that recruitment, training or experience may have some positive effect on startle reaction (Cosic et al, 2019).

Experts argue that, with increasing technological advancement, the potential for startle in ATC is growing (Thackray, 1998, Ciseau, 2017). As automation in ATC systems increases, the role of the air traffic controller will continue to transition from active control to system monitoring, increasing the potential for complacency and then surprise, when things go wrong.

Moreover, pilots and passengers are not alone in experiencing fear during a sudden aviation emergency – the psychological (and sometimes physiological) response is also shared by ATC. Thus surprise, coupled with feelings of fear or anxiety, can equally result in impaired decision-making in ATC, with disastrous consequences.

emergency scenarios repeatedly in a safe environment and eventually build a base of many successful, positive experiences.

2. **Developing automatic skills and rules to combat reduced brain function**

Research has demonstrated that in 80-90 per cent of decisions made during safety-critical scenarios, pilots utilise incremental actions to adaptively react to dynamic and challenging situations (*Aviation Non-Technical Skills Guidebook, 2018*). That is, by developing automatic skills through repetition (such as in a simulator) and being able to easily access rule-based decision-making (knowing your orders, instructions and procedures), practitioners can apply honed skills and rules with little thought to the same or similar situations outside of training. This form of recognition-primed decision-making was likely a key factor in the Hawk engine failure Class B of 2019.

3. **Enhancing NTS training**

Dismukes et al. (2018) suggest developing training in non-technical skills to help practitioners:

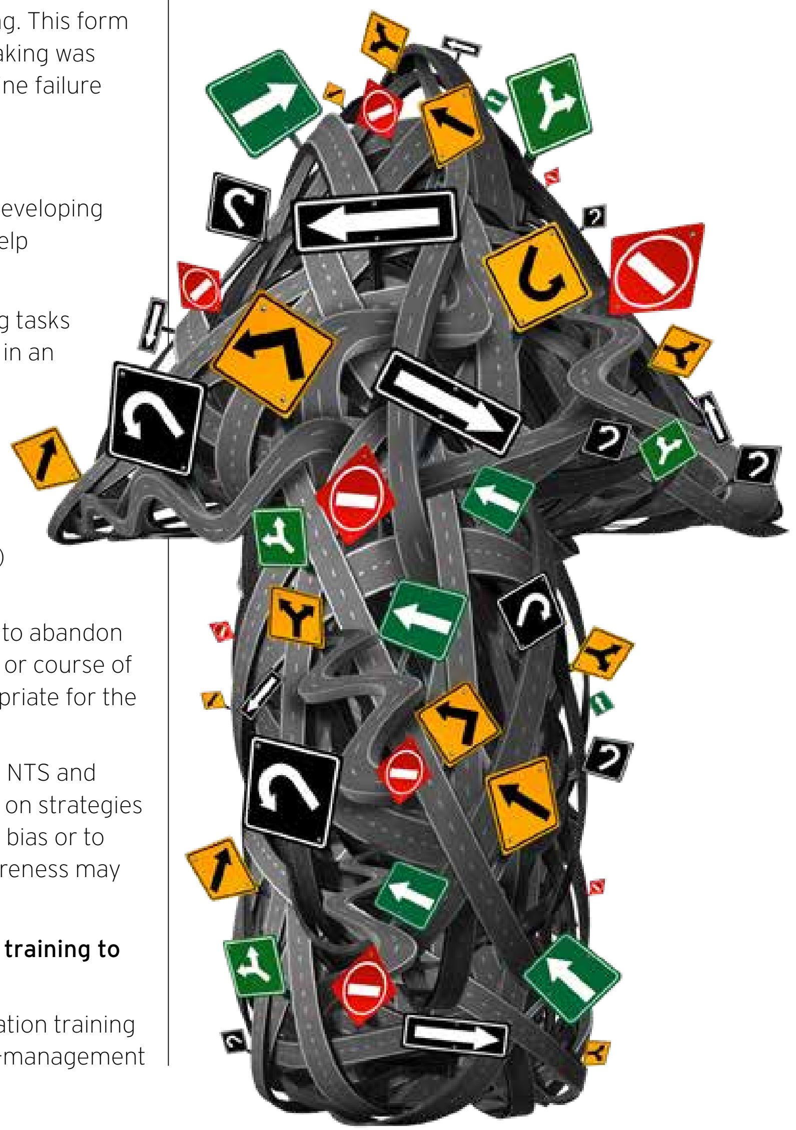
- shift attention among competing tasks to avoid fixating on a single task in an emergency
- step back mentally from a situation to establish a high-level mental model as the situation unfolds (and to continuously update that model) and
- maintain the cognitive flexibility to abandon a previously selected procedure or course of action that has become inappropriate for the developing situation.

Therefore enhancing your unit's NTS and other safety packages by focusing on strategies to avoid task fixation, continuation bias or to strengthen skills in situational awareness may be useful.

4. **Adapting stress-management training to the aviation context**

Also referred to as stress inoculation training or stress exposure training, stress-management training is designed to promote transfer of skills to the combat environment (Cooper, 2009) and NASA (2015) has since promoted its use for professionals in the aviation sphere. A complex and holistic training framework, it involves a preparation phase (in which learners gain knowledge about stress and their particular stress-inducing environment), skill acquisition and rehearsal (thought-monitoring strategies, tension-reduction techniques, overlearning and mental rehearsal) and an application phase under simulated stress conditions.

Thus, it is a template for training to mitigate acute stress response in any high-stress situation. For more detail refer to Cooper's full article in the Human Factors Resources section of the DFSB website.



5. **Incorporating mnemonics into procedures**

While some research suggests that enunciating actions or mantras may not be possible for those who are under significant startle (Martin and Murray, 2013), Landman et al. (2020) found that for those experiencing a moderate level of startle, the use of mnemonics (for example, aviate/navigate/communicate/administrate) positively influenced decision-making. It was important to incorporate a step to manage the stress (for example, breath or calm down) and one to observe the overall situation (for example, observe) before any steps to analyse the situation. Mnemonics need to be automatic so require repetition (such as when chair flying or in the simulator) and can be incorporated into pre-take-off emergency briefs to ensure they are fresh in the mind.

6. **Stress resilience assessment**

As stress affects everyone individually, it may be possible to assess for stress resilience during recruitment. Cosic et al. (2019) suggest that technologically assisted stress-resilience assessment during recruitment could incorporate metrics for startle reaction, startle habituation and fear-potentiated startle, strengthening admission assessments for pilots, air traffic controllers and other professionals in high-hazard industries.

Conclusion

Startle is a normal and natural human response to surprising events; however, when combined with fear-inducing conditions, can create a prolonged and detrimental startle response.

In high-hazard industries such as aviation, this can have a significant effect on safety. In hindsight, there are many such accidents where startle reaction is likely to have been a contributing factor.

Promisingly, researchers are gaining a better understanding of startle in general when applied to aviation and have tested and recommended several strategies for mitigating negative startle reaction in pilots and air traffic controllers in particular.

However, as in most things, awareness and understanding is the first step. To find out more about startle reaction refer to the references at right or to DFSB's *Aviation Non-Technical Skills Guidebook* (Chapter 8 – *Managing Stress* and Chapter 11 (pp 188) – *Surprise and Startle*).

You can order copies for your unit by emailing DFSB.

So, why not create an awareness activity for your unit's next safety day?

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QF32 vs AF447

Flying over Indonesia, QF32 experienced an uncontained engine failure due to the breaking of a poorly manufactured sub oil pipe, which subsequently resulted in damage to flight controls, landing gear, the fuel system and the wing, among other aircraft components. Despite this severe damage, QF32 managed to make an emergency landing at Singapore's Changi Airport.

Conversely, while flying over the Atlantic Ocean, AF477 entered an aerodynamic stall after the aircrew responded poorly to the autopilot disconnecting. The disconnection occurred due to airspeed measurement inconsistencies caused by icing on the aircraft's pitot tubes (pressure measurement instrument). There were no fatalities of QF32 and no survivors of AF447. The major difference: in the Qantas flight deck the experienced captain immediately pressed the altitude hold button which attenuated the adverse thrust effects and allowed immediate control of the flight path; in the Air France flight deck, the inexperienced first officer, exhibiting strong indications of startle, immediately pulled up, exacerbating the (survivable) flight control problem.

The subsequent differences in immediate workload allowed the QF32 crew to make a considered analysis and work through the problem, while the AF447 crew continued to reactively deal with the ambiguous environmental cues in an uncontrolled and unco-ordinated manner.

Adapted from the ***Aviation Non-Technical Skills Guidebook***, DFSB

Welcome return to the classroom

Aviation safety training

> Teaching in a classroom adds another dimension to facilitating that provides a better feel and improved participation.

By SQNLDR John-John Rozells

THERE WOULD BE few people not affected in some way by COVID-19 or the restrictions it caused in the past two years. The very serious health risks aside, it affected our ability to go about our daily lives, see family and friends, and travel.

From a professional perspective, it impacted jobs. Despite the worldwide pandemic, Defence employees – military and civilian – had work to do and quickly adapted to alternative working arrangements.

One example was the DFSB Education and Training team, whose members, in very quick time, had to rethink the way training could be delivered in the new world of travel restrictions, quarantines and isolations.

As a result of the challenges of 2020 and 2021 the team has shown significant growth, adjusting its courses to ensure they evolved and remained effective, best supporting the training needs of the Defence Aviation Community.

Cancelling courses such as Non-Technical Skills (NTS) training, Aviation Safety Officer (ASO) Initial (I) and ASO Advanced (A) training would not have been popular or viable.

Move to remote learning

In early 2020, DFSB reacted to the changing environment by delivering courses via remote means – but this did not come easily.

Training team members experimented with a number of platforms including, Zoom and GovTeams before determining that delivery could be best achieved by the Australian Defence Education Learning Environment (ADELE). Using ADELE, DFSB was able to deliver training for the ASO(I) in two parts. Part A saw students complete a week of self-paced learning before participating in the facilitative and syndicate activities in Part B. While COVID restrictions were in place this was done via a virtual classroom in ADELE.

On 4 April 2022 the team was able to return to face-to-face delivery in a classroom at RAAF Base Wagga after almost a year of virtual delivery. The course was attended by students with a broad range of aviation backgrounds from across Navy, Army and Air Force.

The return to the classroom has seen greater interaction and robust and meaningful discussions of aviation safety topics.

Feedback from attendees has been positive and getting back into the classroom with students incredibly rewarding for members of DFSB's Training Team, Research and Intelligence Reporting and Safety Investigators who were delivering the aviation safety training.

Course 3/2022 was the first time in more than 12 months that the Part B component was achieved without students dialling in, and instead filling the classroom at the School of Post Graduate Studies in RAAF Base Wagga. As the home for a number of training institutions, RAAF Wagga was the ideal location, providing the necessary facilities to deliver the course.

'Teaching in a classroom adds another dimension to facilitating that provides a better feel and improved participation,' DFSB Trainer WOFF Jonathan Durrant says.

DFSB Trainer FSGT Aaron Beattie added that being in the classroom allowed the training team to better focus on the needs of each syndicate.

DFSB will continue to utilise opportunities to deliver its suite of courses in a blended or face-to-face environment throughout 2022 and beyond. ASO(I) and NTS courses were delivered in Amberley in May.

AVIATION SAFETY TRAINING – 2022

Course	COURSE AIM:	PREREQUISITES:	COURSE DESCRIPTION:
ASO (I) Aviation Safety Officer (Initial) Course	To graduate Unit ASOs, Maintenance ASOs and Flight Senior Maintenance Sailors.	Personnel who are required to perform the duties of an ASO.	The course is delivered as two separate weekly components (the first is self-paced online; the second is face-to-face) with a one-week break in between. The course provides theory and practical exercises in the broad topics of the Defence Aviation Safety Management System, Risk Management, Human Factors, the Defence Safety Analysis model, safety event investigation and reporting.
ASO (A) Aviation Safety Officer (Advanced) Course	To graduate Base, Wing, Regiment, Fleet, Group and Command ASOs.	ASO (I) Practical and applied experience as an ASO (or equivalent)	The course provides theory and practical exercises in the broad topics of the Defence Aviation Safety Management System, human factors and risk management, and base/unit emergency response.
NTS Non-Technical Skills Trainer	To graduate students with the knowledge and skills to deliver non-technical skills training.	A solid background in Crew/Maintenance Resource Management and/or Human Factors.	The course provides the theoretical background of aviation non-technical skills and trains students in the skills and knowledge for delivering non-technical skills training. The course also introduces students to scenario-based training and assessment techniques.
AIIC Aviation Incident Investigator Course *Available upon request	To develop members with the skills to conduct aviation incident-level investigations in support of their ASOs.	Any personnel who are involved with Defence aviation. There is no restriction on rank, Defence civilians and contractor staff are also welcome to attend.	This one-day course provides theory (taken from the ASO(I) course) on the topics of; the Defence Aviation Safety Management System; generative safety culture; error and violation; the Defence Aviation Safety Analysis Model; aviation safety event investigation and reporting. Interested personnel should contact their ASO.

For details on course dates and locations visit the DFSB intranet site or email dfsbet@dpe.protected.mil.au

All courses are generally oversubscribed, dates provided are for planning purposes and are subject to change due to operational requirements, nominations from individual units or candidates will not be accepted, nominations are to be forwarded with Commanding Officer's endorsement to:

- **Air Force:** the relevant Wing Aviation Safety Officer, or for CSG, Staff Officer Safety HQCSG
- **Navy:** the Fleet Aviation Safety Officer
- **Army:** ASDC Aviation Safety, Aviation Branch, HQ FORCOMD.

Lessons learnt from MUAS crash in Timor Leste

By WO2 Craig Jackson

A SKYLARK MINIATURE UNMANNED Aerial System (MUAS) experienced technical issues and crashed into a private residence in Dili, Timor Leste in 2007 and as flight instructor for the MUAS at the time, I was involved in the ensuing investigation.

The investigation was a first because of the nature of the incident, the air vehicle involved and as the incident occurred while supporting peacekeeping operations.

Several factors were highlighted in the investigation:

- the personnel involved had little experience operating from a densely populated area
- the equipment was not optimised to operate in a hot, humid environment
- the age of the equipment, spares shortages and the chain of command's attitude at the time being can-do and that you must achieve the task.

Lack of experience

The Skylark IV Analog Miniature UAS was procured from Elbit Systems to support efforts in the Middle East Area of Operations (MEAO). It was conducting its second deployment in Iraq with 20 STA Regt when, at short notice, the regiment was tasked to support the election process in East Timor.

At the time of the incident the unit supporting this operation was spread thin because it was supporting several theaters at once (Iraq, Afghanistan and Timor). This resulted in external units being asked to provide personnel to undertake the training and deploy at short notice to conduct these operations in Timor. Even the chain of command had never deployed on a UAS deployment and was reliant on the limited publications at the time.

Flight operations were being conducted from the heliport in the center of town and this was a challenge in itself, due to the different contingents operating there and limited airspace control. Previous deployments of this system were in remote regions of the Iraqi desert, which permitted a more managed approach to operating the system.

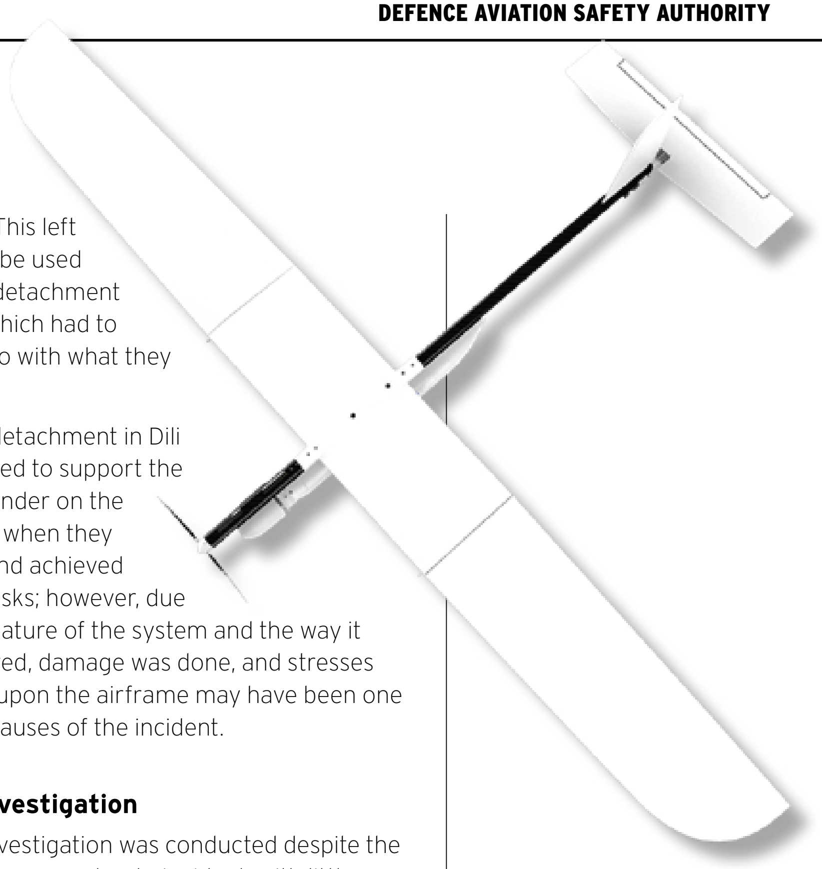
Impact of hot, humid environment

The unit had only operated in the MEAO and had not flown in a humid environment, which was a challenge. Procedures had to be amended as and when required to continue flight operations and at one point it had been identified that the wing-locking system would not secure fully because of the moisture, and crews had to improvise to secure the wing sections.

This modification was passed to the maintenance support unit which authorised the change to procedures prior to any further flights.

Other challenges

At the start of the operation there was a shortage of equipment due to the MUAS being acquired under a rapid acquisition process and all available spares were being sent to the detachment in Iraq or supporting training at home. This left little to be used by the detachment in Dili which had to make do with what they had.



The detachment in Dili continued to support the commander on the ground when they could and achieved most tasks; however, due to the nature of the system and the way it recovered, damage was done, and stresses placed upon the airframe may have been one of the causes of the incident.

The investigation

An investigation was conducted despite the fact it was a moderate incident, with little or no damage done or injuries on the ground. It found that a wing section had not locked in resulting in separation and the UAS hit a civilian structure.

Recommendations were made that this section be taped to a point where it would not separate during launch and flight but due to the force of landing on the airbag could detach as required in the recovery process.

Public opinion of the use of these systems was noted and privacy issues were answered; however, Army reputation was not tarnished and in some respects a better environment was provided for the residents.

Lessons learnt

Although I was a minor contributor to the investigation, by witnessing the process I learnt the purpose of investigation was not to apportion blame, rather identify causes and fixes that can be used to further develop an emerging capability and educate others.

In the course of my career this incident has been referred to on numerous occasions as one of the starting points for the UAS Aviation Safety construct, and shows even though it was a minor incident in the scheme of things, it could have been a lot worse.

Cargo ramp entanglement

IN MID-JUNE 2020, a C-130J Hercules was conducting simulated Air Sea Rescue Kit (ASRK) dispatch training in Jervis Bay. During the deployment of an ASRK from the cargo ramp and door, one of the loadmasters became entangled in the deployment rope. The multi-role harness (MRH) restrained the entangled loadmaster, preventing them from being dragged out of the aircraft.

The loadmasters immediately debriefed the event and elected to continue the ASRK serial without reporting the event to the aircraft captain. The flight continued without further incident.

The entanglement was recorded as a Class-B event in Sentinel's Aviation Safety Reporting system and the Defence Flight Safety Bureau duty officer was notified. Commander Air Mobility Group subsequently appointed an Aviation Safety Investigation Team (ASIT) to investigate the entanglement.

The event flight was programmed as an instructional C-130J SAR techniques-and-procedures sortie. The aircraft had three pilots on-board – the aircraft captain and two co-pilots conducting SAR training from the right-hand seat. There were six loadmasters on-board the aircraft for the event flight. Their role/disposition in the rear cabin space during the event sequence was:

- two loadmasters conducting their final assessment as part of the Loadmaster SAR Course (LMs 1 and 2)
- one loadmaster who had recently finished Loadmaster IQ Course and undertaking progression to IQ training (LM 3)
- an ITP loadmaster seeking to regain their CQ, IQ and loadmaster categorisation (SPVR 1)
- a CQ-qualified loadmaster assessing supervisor 1 and ultimately, LMs 1 and 2 (SPVR 2)
- an IQ-qualified loadmaster who was supervising LM 3 (SPVR 3).

Flight authorisation

During the authorisation brief, it was established that the aircraft captain would fly the sortie from the left-hand seat while the other two under-instruction QFIs would rotate through the right-hand seat. When discussing sortie conduct, the authorising officer reiterated the importance of the aircraft captain ensuring it was clear to all who was supervising whom, and who was in charge of the cargo compartment for each evolution.

Given the number of people in the cargo compartment conducting different elements of loadmaster training, a breakdown in command and control posed the biggest threat to flight safety. Loadmaster 3 was to be supervising one of the two loadmasters under assessment (LMs 1 or 2) while either SPVRs 2 or 3 was supervising LM 3. The supervisor not supervising LM 3 was to supervise the other loadmaster under assessment. SPVR 1 was to be acting as a passenger only.

The authorising officer stated to the aircraft captain 'Make sure you know who's checking who checking who, or that whoever is at the top of the tree, that they are on the hook to make sure it all is safe'.

During the authorisation brief, the authorising officer reinforced that command and supervision needed to be specifically discussed at the crew ramp brief.

The event

Approximately three minutes prior to the first ASRK drop, LMs 1 and 2 started the drop checklist. This included removing the restraints from the ASRK (except for the vertical restraint) and opening the cargo ramp and door. When the one-minute warning was given, LM 1 removed the vertical restraint and safely secured it in the aircraft before moving the ASRK aft with LM 2. LM 1 remained kneeling beside the ASRK. When the green light was activated, indicating the release, LM 2 began to dispatch the ASRK.

As the last segment of the ASRK departed the aircraft, LM 1 was believed to have tripped, receiving a sudden jolt aft towards the open cargo ramp and door. This trip/jolt was caused by the static line from Container No. 5 of the ASRK becoming entangled around the lower part of their leg. LM 1's rearwards movement was halted by their MRH while their legs were over the end of the ramp. The force of the departing ASRK caused the remainder of the ASRK static line to untangle as it departed the aircraft.

SPVR 1 and LM 2 helped LM 1 back to their feet before the cargo ramp and door were closed. The event had been filmed by SPVR 2 while they remained seated in the loadmaster crashworthy seat.

After the entanglement event occurred, the supervisors/loadmasters discussed what they thought had happened. The supervisors thought LM 1 had slipped on a tie-down ring while on the ramp.

SPVRs 1 and 2 said to LM 1 that the MRH system is designed to ensure there is no risk of departing the aircraft in flight and that tripping over a tie-down ring can happen. LM 1 said that the trip had left them with a sore leg but they were able to continue with the serial. SPVR 2 clarified with LM 1, that if they were not up to it, then the remaining serials should be cancelled.

'Make sure you know who's checking who checking who, or that whoever is at the top of the tree, that they are on the hook to make sure it all is safe'.

LM 1 confirmed they were able to proceed with the rest of the serials. None of the loadmasters discussed the event with the aircraft captain at any point during the mission.

During the return flight, SPVR 2 remained in the rear of the cabin, while the other loadmasters went forward to the cockpit to witness the coastal flight home. During this transit, SPVR 2 reviewed the film of the event sequence that they had taken on their personal phone and realised that LM 1 had, in fact, been dragged to the cabin floor by the ASRK's static line and had not tripped as originally thought.

Upon realisation of the seriousness of the event, SPVR 2 suffered a vasovagal reaction, feeling nauseous and lightheaded. The aircraft captain was not informed of the film footage, nor the symptoms experienced by SPVR 2 during the transit flight.

While the aircraft taxied-in, SPVR 2 remembered they were to attend a squadron executive meeting that was about to start. SPVR 2 understood that this event was a lot more serious than the crew initially thought but prioritised attending the meeting over discussing the matter with the aircraft captain. SPVR 2 left the aircraft to attend the meeting, with the intent of informing the aircraft captain about the film at a later time.

The pilots finished shutting down the aircraft and conducted a debrief of the pilot-specific aspects of the mission on the flight-deck. Thereafter, no formal crew-debrief took place.

SPVR 3 mentioned to one of the co-pilots that LM 1 had fallen over on a tie-down ring, which was later relayed to the aircraft captain. The aircraft captain believed the tripping event to be minor and that the matter did not require any further discussion.

Post-flight activities

SPVR 2 was unable to meet with the aircraft captain to discuss the entanglement before the aircraft captain departed the workplace at the end of the day. SPVR 2 believed the event should be discussed in person, as opposed to over the phone and elected to go home with the intent of discussing the event the next day. Once home, SPVR 2 reviewed the video numerous times in order to make sense of what had happened and how it had happened.

The next day, SPVR 2 met with the flight's authorising officer and showed them the footage. The authorising officer directed SPVR 2 to immediately find the aircraft captain to de-brief them about the event. Once the aircraft captain was fully briefed on the entanglement event, an Aviation Safety Report (ASR) was raised.

Injuries to LM 1

LM 1 sustained minor soft-tissue injury during the entanglement. Clinical examination and ultrasound investigation confirmed that a subcutaneous haematoma did not extend to any underlying blood vessels or nerves. There was no damage to the limb muscles and no deep vein thrombosis.

Upon realisation of the seriousness of the event, Supervisor 2 suffered a vasovagal reaction, feeling nauseous and lightheaded.

Human factors and situational awareness in dynamic environments

By SGTs Rob McGavock and Josh Baker

AIRBORNE OPERATIONS, BOTH cargo and personnel, are inherently complex and dynamic. During these operations it's vitally important for everyone involved to understand their roles and the other duties being conducted by all personnel on board. Having a technical understanding of all sequences being flown in the mission and all equipment used will allow the crews involved to recognise second- and third-order effects should a situation arise. The nature and complexity of airborne operations will usually mean that when emergency situations begin they are extremely dynamic.

Human factors

Recognising confidence, body language and other indicators in personnel involved will help build better situational awareness of the mission about to take place. Aircrew are taught to recognise human factors within themselves and the crew at the start of their aviation careers. It's important to carry that over to all personnel working in the aviation environment.

From ground support staff to special operations personnel, recognising indicators that may affect performance could be the difference in preventing a dynamic situation from becoming a fatality.

The following three incidents took place during an exchange program a few years ago with loadmasters attached to US Army Special Operations Command (USASOC). USASOC operates C-27J Spartans to conduct personnel and cargo airdrop for US Army Special Operations units.

Incident One

RAAF Loadmaster (LM) right door, US Army LM left door. The Safety Jump Master (SJM) was new and had about five passes in the door before – none of which were on a C-27J Spartan. The standard exit sequence for training was left door first followed by right door.

That day it was hot and bumpy, which was typical for summer. The SJM was struggling to keep their feet while conducting checks on the jumpers prior to exit. The first pass of the afternoon the

RAAF LM called a 'STOP DROP' due to incorrect routing of the static line that wasn't picked up. We performed a race track and recommenced the drops.

During the drop sequence the fifth jumper was a little hesitant. The static line was passed off further away than normal and as the SJM raked the static line it broke the rubber bands on the back of the parachute and payed out a large length. Once the static line hit the airflow of the door, it looped around over the head of the SJM.

The RAAF LM instantly pushed the jumpers in the RHS door forward calling a 'STOP DROP'. The RAAF LM rushed to the LHS of the aircraft and grabbed the static line that had looped over the SJM's head. The jumper then proceeded to exit the aircraft causing the static line to tighten. While the RAAF LM was holding the static line, the US Army LM dragged the SJM downwards to pull their head back through the tightening loop. As their head was coming through the loop the RAAF LM was unable to keep the loop open and it tightened on their helmet, pulling the helmet off.

Once the situation was under control, the aircraft captain was notified and recommended we land the plane immediately to debrief the situation. On the ground the SJM, who was noticeably shaken, was not giving true and accurate information about what had happened. The RAAF LM spoke up to the commanders to notify them of the actual events that took place.

The static line was passed off further away than normal and as the Safety raked the static line it broke the rubber bands on the back of the parachute and payed out a large length. Once the static line hit the airflow of the door, it looped around over the head of the Safety Jump Master.

Incident Two

RAAF LM left door, US Army LM right door. SJM on the left door didn't look confident during the pre-drop check sequences. As soon as the left-door jumpers began to exit the SJM was struggling to keep up with raking the static lines and was starting the shuffle forward to keep up.

At this time a static line was dropped early by a jumper and started to swing and roll in the air passing between the para doors. The SJM attempted to catch it but missed, causing the static line to wrap around their arm above the elbow. As the jumper exited it violently pulled the SJM towards and out the left para door. The RAAF LM caught the SJM around the waist on the jump step at the door and then unwrapped their arm from the static line in the airflow before the US Army LM could help pull them completely back inside the aircraft with the 'STOP DROP' being called at this time. The SJM was shaken by what had occurred, we debriefed the aircraft captain who also saw parts of the incident as he looked back. We then landed and further briefed the group of the importance of static line management.

Incident Three

RAAF LM left door, US Army LM right door. First jumper was in the door at STANDBY awaiting the green light with the SJM managing his static line. Approximately five seconds prior to green light the SJM let go of the first jumper's static line and started reaching forward for the second and third static lines. The first static line immediately began rolling in the airflow and went over the SJM's head, at this time the SJM pulled their head back to clear the static line but that caused the static line to complete the loop around their neck and under their chin as the green light came on and the first jumper exited the aircraft.

The RAAF LM immediately grabbed the static line to take weight off the SJM's neck as the jumper exited. The RAAF LM held the weight through the break-tie sequence of the parachute deployment and pinned himself between the door and the SJM in an effort to keep them inside the aircraft and prevent injury. The US Army LM had moved over to assist in clearing the static line around the SJM's neck.

A 'STOP DROP' was called and the SJM was assessed for injury. With no injuries found and the situation under control the aircraft captain was debriefed.

Take away

Situational awareness is key to recognising human factors and indicators in personnel involved and in understanding the follow-on effects in a dynamic emergency. Make the effort to grow your understanding of all equipment on board your aircraft, including their operating sequences. Conducting detailed pre-briefs with all personnel involved and building that situational awareness early can and did prevent injuries and possible fatalities during these three incidents.

Explosion over Darwin Harbour

By AIRCDRE Mark Lax

HOW DOES A perfectly serviceable fighter aircraft explode in mid-air? This is the story of an inexperienced young fighter pilot and a detailed technical investigation that ultimately revealed what happened.

At 1335 hours local time on Wednesday 1 November 1961, a Mk 32 Sabre, A94-360, disintegrated in mid-air and the scattering wreckage crashed into Darwin Harbour. The debris fell in sections into the water approximately five miles from RAAF Base Darwin on a bearing of 237°T. The pilot, PLTOFF Robin Irvine of No. 75(F) Squadron, RAAF Base Williamtown, was killed.

Pilots of two Canberra aircraft flying behind the incident aircraft reported seeing a pinpoint of light like a Verey pistol cartridge followed by a large explosion with a ball of flame. Next, three large pieces of aircraft were seen to fall into the water.

But how could a Sabre just blow up?

The circumstances

PLTOFF Irvine was flying number two in a pair of Sabres engaged in an intercept mission during an air-defence exercise over the Top End. The pilot of the leading Sabre had been directed by controllers in No. 2 CRU to attack a flight of Canberra aircraft that were at 2000 ft and running in from the SW in a mock attack on RAAF Base Darwin. He led PLTOFF Irvine in a dive from 25,000 ft to 3000 ft for a rear-on attack on the leading pair of the approaching Canberra aircraft. The leader then directed PLTOFF Irvine to attack the right-hand Canberra while he attacked the left.

After completing his attack, the leader began a turn to port and looked back at PLTOFF Irvine who was about 400 m to his right in the five o'clock position.

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He followed the rear section down and watched it plunge into the water. Two other large sections then fell into the water behind the rear fuselage. A few smaller pieces and some fuel drifted onto the Darwin foreshore. The leader immediately called a Mayday and circled the wreck while No. 2 CRU pin-pointed the exact crash position.

Eyewitness accounts

Back at the RAAF base, there was an immediate response to the emergency and one of the first things was to seek eyewitness accounts of what happened. The most reliable eyewitness accounts were expected to be the Canberra crews who were in the second wave of the attack between one and two miles behind the two Sabre aircraft. The pilots; however, said they were unable to shed any light on what happened.

Reports from other eyewitnesses on the harbour foreshore also provided little information other than the fact they had seen pieces of the aircraft falling, with smoke and flames emanating from the wreckage.

The accident investigation

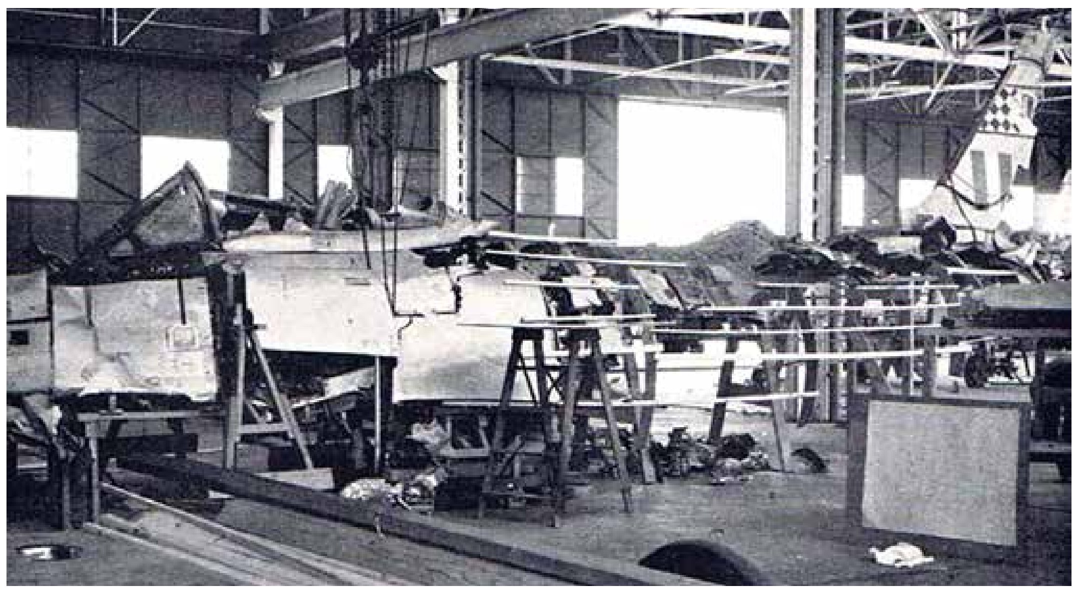
As is usual procedure, an accident investigation began almost immediately, and the investigating officers followed a regimented checklist for their examination.

Medical condition of the pilot, his proficiency, weather, examination of the wreckage, airworthiness of the aircraft and witness statements were part of the routine. Any other factors pertinent to the case were also canvassed.

The first issue the investigating team considered was the medical condition and proficiency of the pilot. PLTOFF Irvine was fit and healthy at the time of the accident and had recently completed the Sabre Operational Conversion at Williamtown. His total flying was 495.40 hrs and he had flown 102.10 hrs on Sabre aircraft.

The weather was next on the list. It was fine and clear with a few scattered nimbus clouds in the area. The meteorological section reported that some slight turbulence might have been encountered in the area, but the Canberra pilots reported that there was no turbulence that afternoon.

The investigation now turned to recovering and examining the wreckage for technical failure. The wreckage was spread over an area of about 1500 m long and 200 m wide.



Reconstruction of the Sabre's fuselage.

Recovery of the wreckage began immediately after the accident. The rear fuselage including the engine and empennage was recovered the next day. Most of the port wing, both flaps, both ailerons and sections of the starboard wing/trailing edge were recovered the following week. Assorted pieces of fuselage and numerous small items were also recovered during this period. A few days later, Navy divers recovered the pilot's body together with the forward part of the fuselage. Unfortunately for the investigation, the wing centre section and inboard starboard wing were not found.

Examination of the wreckage

At RAAF Base Darwin, preliminary examination of the wreckage led to the conclusion that the cause of the accident and the mode of disintegration would not become apparent until a thoroughly detailed technical examination had been made. It was therefore decided that all wreckage recovered should be air-transported to RAAF Base Laverton where it would be pieced together for study.

Research officers from the Aeronautical Research Laboratories were asked to help with the wreckage analysis. The fuselage was painstakingly pieced together around a wooden frame and parts of the wings were spread out on trestles.

Analysis work started two weeks later. The first thing investigators noticed was that the engine was intact. There was no evidence of compressor or turbine failure that may have caused an explosion. Detailed study of the wreckage disclosed that the port wing had failed in upwards bending; the failure occurred along a chordwise line of the lower surface of the wing at an average distance of about 25 cm outboard from the joint which secures the wing to its centre section.The wing lower skin between the front and rear spars was pulled away in tension and shear. Study of these fractures satisfied investigators that they were clean static failures without evidence of fatigue cracking or previous tensile failure. In other words, there was no evidence of corrosion or metal fatigue.

The upper surface of the port wing also failed under compression loading, between the front and rear spars. This upper surface area had fractured into several pieces, characteristic of compression failure in such a type of panel.

Then came an examination of the comparatively small pieces of the starboard wing which had been recovered. The pieces of wing skin were heavily deformed by tearing, impact and gouging. This indicated that outboard from about mid-span, the starboard wing had slammed violently against a comparatively solid part of the structure. Importantly for investigators, they found the reverse of black lettering clearly imprinted on pieces of the upper wing skin of the starboard wing towards the trailing edge and in the vicinity of the roundel.

The lettering was normally on the upper forward surface of the port wing near the wingtip. The imprints on the starboard wing provided conclusive evidence that the two wings' upper surfaces had slammed together near their tips. For the wings to have slammed together and with the force necessary to imprint the black lettering on the starboard wing skin, high G loading was required at the time of break-up.

The investigators now sought technical advice from the USAF which confirmed that when one wing breaks off a Sabre, the other wing with centre section still attached tears away from the fuselage almost immediately (a time difference of microseconds only) because of rapid rolling acceleration caused by asymmetric lift. Such a break-up is almost invariably accompanied by fire and what witnesses generally describe as an explosion.

The conclusion was that the port wing of A94-360 struck the fuselage. The wing's leading edge lodged heavily against the canopy, just behind its rearward edge. As it passed rearwards the port wing tip struck the tip of the tailfin but did not carry away any part of the empennage. The starboard wing, probably with the centre section still attached, struck the starboard side of the fuselage, and carried away most of the starboard horizontal tailplane.

After the wings had failed in positive bending (that is, upwards) and had struck the fuselage, the fuselage failed. The extensive shattering of panels and supporting structure and the secondary damage in this region made it impossible to determine exactly where the failure began. As the wings dragged over this region of the fuselage, fuel from the wings was spilled along the top and sides of the fuselage. This spilled fuel ignited after the fuselage separated.

This accident highlighted the danger of uncontrolled pilot-induced oscillations as an aircraft approached the transonic region where control effectiveness becomes less responsive. The Sabre flight manual was amended to warn pilots of the seriousness of PIOs and how to recover from one.

The investigators concluded that given the very high G created by the wing failure and subsequent roll, and given the early design of ejection seats in the 1960s, the pilot would not have been able to eject.

Instruments and panel

Examination of the instruments recovered provided investigators with additional information. Differences in internal construction of the various instruments resulted in different forms of internal damage being caused by the inordinately high rolling G as the port wing failed. Some instruments seized at the readings they were showing when the wings failed, and others did not.

The summary of conclusions drawn from examination of the instruments was that the aircraft was flying at an indicated Mach number of 0.96 and an indicated airspeed of 600 kts when the port wing failed. The aircraft was subjected to a reversal of G forces between +9.1 G and -4.4 G.

Examination for fire and explosion

With the technical assessment of the failure of the airframe complete, the next issue to resolve was the fire and explosion. On the fuselage, the only evidence of burning was on the outer fuselage skin. There was no evidence that there had been fire anywhere else. The fuselage front fuel-cell bay and the fuselage rear fuel cell showed no signs of fire or sooting. All these regions were examined for any signs that an explosion had occurred, but none was found.

Two of the five main fuel cells were recovered. These were the port wing fuel cell and the rear fuselage fuel cell. There was no evidence of burning in the rear fuselage fuel cell but charring and sooting inside the port wing fuel cell indicated that there had been burning inside this cell. There had not been an explosion, at least of significant force, within this fuel cell and none of the fractures in the lower and upper metal skins of the port wing could be attributed to an explosion within the tank.

Without an internal fire or explosion, investigators speculated that the fire in the port wing fuel cell could have been ignited by sparks caused by abrasion between metal as the wings scraped along the fuselage. It was known that fuel fires invariably accompany this type of structural break-up.

Likely reasons for structural failure

So why did a perfectly serviceable Sabre break up and explode? The conclusive evidence suggested that Sabre A94-360 disintegrated because of failure of the wings in positive bending. This required consideration of the reasons that could have caused wing failure. Investigators decided there were four:

- aero-elastic instability (wing flutter)
- significant air turbulence
- tailplane actuator malfunction
- pilot-imposed dynamic loading.

First cause to be dismissed was flutter. There was no evidence that aero-elastic instability of the wings or control surfaces had occurred to the extent to cause or contribute to the break-up of the aircraft.

Next, turbulence. From reports by the Canberra crews and the pilot of the Sabre that was leading A94-360, there was no noticeable air turbulence just preceding the accident; therefore, this factor was also eliminated.

A tailplane actuating mechanism malfunction could have imposed enough dynamic loading on the wings to break them. The Sabre tailplane is moved by a hydraulic actuating jack which changes the tailplane incidence at the same angular rate as it would if connected by direct mechanical linkage to the pilot's control column.

If the fidelity of the tailplane rate of change was upset, so that the tailplane led the pilot's control movement, or if a spurious response caused the tailplane hydraulic jack to move so as to impose heavy positive G on the aircraft, the ultimate strength of the wings could have been exceeded. However, examination of the hydraulic actuating mechanism did not disclose any signs of malfunction. Given the above, the investigators finally turned to excessive G loading imposed by the pilot as to the possible cause of the accident.

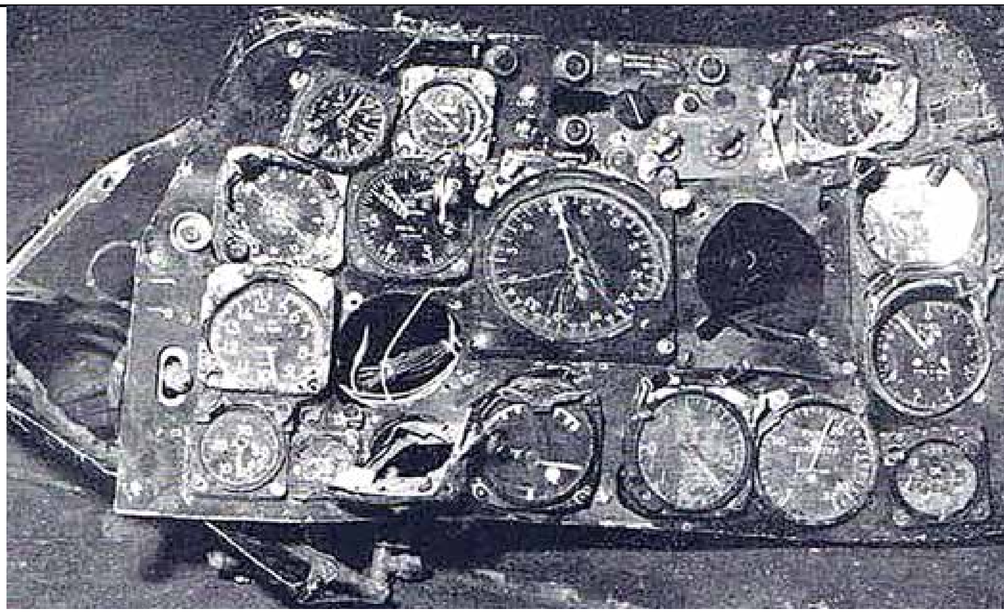
What was known

At about 600 m astern of the Canberras, the pilot leading the Sabre pair instructed his Number 2 to attack the starboard Canberra. The pilot of A94-360 had to manoeuvre his aircraft to attack his target. At a speed around about M0.93, the tailplane effectiveness of the Sabre reduces rapidly and the aircraft damping in pitch becomes much less than at lower mach numbers.

Any pitching disturbance, such as a stick movement, can cause a pitching oscillation that is only lightly damped. If the pilot attempts to stop this oscillation by chasing it with stick movement, he only succeeds in increasing the oscillation, because the time or cycle of about one second between oscillations is too short for a pilot to be able to follow it. Such an out-of-cycle stick movement by the pilot quickly results in violent porpoising of the aircraft which imposes high G forces. This is also called a pilot-induced oscillation or PIO.

The accelerometer recovered from A94-360 had recorded 9.1 maximum positive G and 4.4 maximum negative G. The accelerometer had seized at the time of wing failure and therefore the readings were not caused when the front fuselage fell into the water. The range of G loading is typical of porpoising, which increased in amplitude very rapidly.

It is conceivable that the reading of +9.1 G was recorded sometime before the break-up, but this was not thought likely from the leader's account of the flight and the fact that a pilot would regard such a reading as overstressing and would return to base before completing his sortie. Also, none of the controlled manoeuvres, which he had flown during the sortie was likely to impose anything like +9.1 to -4.4 G. The readings were; therefore, almost certainly recorded during porpoising of the aircraft just before it broke up.



Sabre's instrument panel.

Aircraft G loading necessary to cause it to break-up

The G loading at which structural failure will occur depends upon several factors. Some of these are aircraft design, weight, airspeed and type of manoeuvre. During porpoising there is the possibility that the bending flex frequency of the wings may coincide with the frequency of the aircraft oscillation. If this happens, the wings will likely bend or deflect downwards under negative G. With rapid application of loading, such as occurs during violent porpoising, the bending wing overshoots or bends further than to the position which it would take up under the same steady G. Then if positive G is applied rapidly as the wing is beginning to spring back, a further overshoot occurs, and so the wing will again be subjected to a greater strain than under the same steady G.

The findings

The accident was caused by failure of the port wing in positive bending. This failure resulted from enough G loading being imposed upon the aircraft to exceed the ultimate breaking strength for which the structure was designed.

The airspeed and mach number at which the aircraft was flying when the port wing failed and the accelerometer recording of G reversals at this time, indicate that pitching oscillations, commonly described as porpoising, caused the wing failure.

There was no evidence that fire or explosion caused the failure of the port wing. The severity with which the wings came together and their chordwise positions relative to each other when they did so, provided reliable testimony that high G loading was applied when the port wing failed.

Fuel from a ruptured fuel cell or cells spilled over the fuselage skin. After the fuselage had broken, this fuel ignited and burned along the fuselage, mainly on the upper areas of skin and a rapid ignition of fuel vapour due to sparks caused the apparent explosion.

This accident highlighted the danger of uncontrolled pilot-induced oscillations as an aircraft approached the transonic region where control effectiveness becomes less responsive. The Sabre flight manual was amended to warn pilots of the seriousness of PIOs and how to recover from one.

Author note

This review was largely based upon the *DFS Crash Critique No. 69 of 11 January 1962*. Many additional technical details of the nine-page report have been omitted for brevity, but the essence of the investigation remains.

Capture, codify and control innovative violations

Maintaining positive imbalance

By Tony Bannister-Tyrell, PhD

BEING INNOVATIVE; LOOKING for smarter ways to do things; having a can-do attitude is how many of us see ourselves. These are indeed worthy attributes for improving business processes and task outcomes. But in highly regulated, high-consequence endeavours uncontrolled innovation can induce unintended outcomes and increase exposure to risk. Regardless of the innovative intent, action without approval is a violation – in some instances, significantly so. The challenge is to identify where innovations are occurring, then capture, codify and control them.

My doctoral research explored drivers of innovative decision-making and the willingness of aviation maintenance personnel to walk the very fine line between innovation and violation. That fine line is routinely breached, either inadvertently or, in some instances, intentionally.

Evident from the research is that individuals continue to innovate maintenance processes and practices, many of which are unapproved; some undertaken to improve maintenance outcomes, to make the process better, more effective, improve efficiencies, or indeed to make the process safer. Such actions are what I've termed Innovative violations. They are the product of positive deviance behaviours where the overriding aim is to benefit task or organisational performance, as opposed to individual gain.

Figure 1 identifies the key drivers of innovative decision-making.

Positive deviance behaviour

Evidence of positive deviance behaviours has been recorded in aviation maintenance research dating back 30 years. Research presented by the Australian Transport Safety Bureau (Aircraft Maintenance Safety Survey, 1997) revealed that 69 per cent of respondents felt the need to bend the rules to get the job done.

In the section pertaining to unsafe acts in aircraft maintenance; not referring to the approved procedure for performance of a familiar task was listed as one of two most reported behaviours.

Results from my most recent research demonstrate that little has changed since 1997, despite substantial changes in aviation governance, compliance, and regulatory requirements, not the least of which was the introduction of CASR Part 145 for Approved Maintenance Organisations in 2011. Hence, a dichotomy exists between perceived and actual behaviour.

The perceived behaviour is that of compliance with rules and regulations; however, interviews discovered that actual behaviour revolves around intent to do a better job, to look for innovative maintenance solutions, and the desire to demonstrate technical acumen.

Innovation influencing factors

Participants defined innovation as doing a task better, more effective, more efficient, or a safer way, or just tweaking it slightly. Violations were mostly defined as doing it however you want, or as breaking the rules and being contrary to the publication. So, we are left asking:

- Is doing it a better way the same as doing it however you want?
- Is being contrary to the publication the same as tweaking it slightly?
- Is being more effective, or more efficient the same as breaking the rules?

The analysis revealed that age and aviation experience were dominant factors for innovative behaviour and willingness to deviate.

Younger, less experienced participants indicated greater support for doing a task a better way, for relying on past experiences when performing current maintenance activity and having to take maintenance shortcuts when dealing with facility repairs and upgrades.

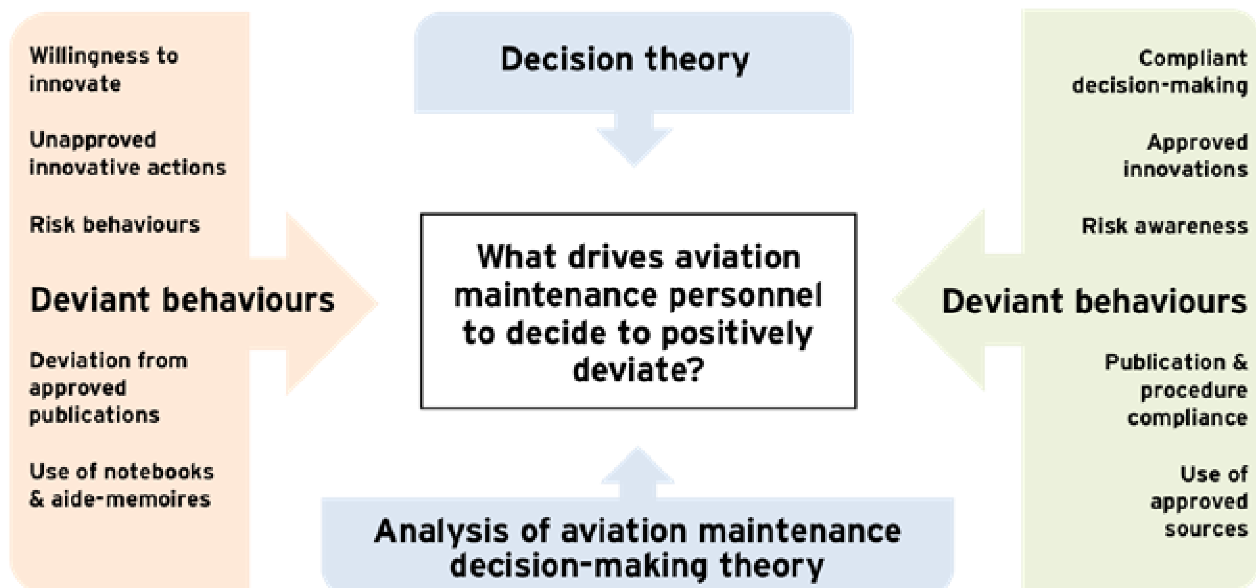


Figure 1: Drivers of innovative decision-making

Furthermore, while younger participants indicated a willingness to accept risks, they also appeared unclear of where they sat on the regulatory continuum. They were more willing to support innovative actions and scored higher for items that measured innovation, innovative approaches to maintenance and imaginative thinking. They exhibited a higher acceptance for violating behaviours, indicated a willingness to work outside of published procedures, and were accepting of shortcuts and workarounds. However, they scored lower for critical thinking.

The rationale for such behaviour appears to be driven by a desire and intent to exercise technical acumen, of which, paradoxically, they don't have a great deal, due to their lack of experience. This can result in a miscalculation of their self-assessed level of technical competency and therefore lead to poorer decisions.

Figure 2 depicts the Creativity Compliance Curve. This conceptualised model provides a prediction of where an innovator would be positioned within a rule-abider/violator continuum. This concept of thinking as a creative endeavour was previously espoused by Sir Frederic Bartlett (Bartlett, 1958) in his chapter on the artist's thinking. He describes the artist as not always conforming to the norms, but rather adapting and manipulating the conventions and rules to fit the ideas and actions towards an outcome that best serves.

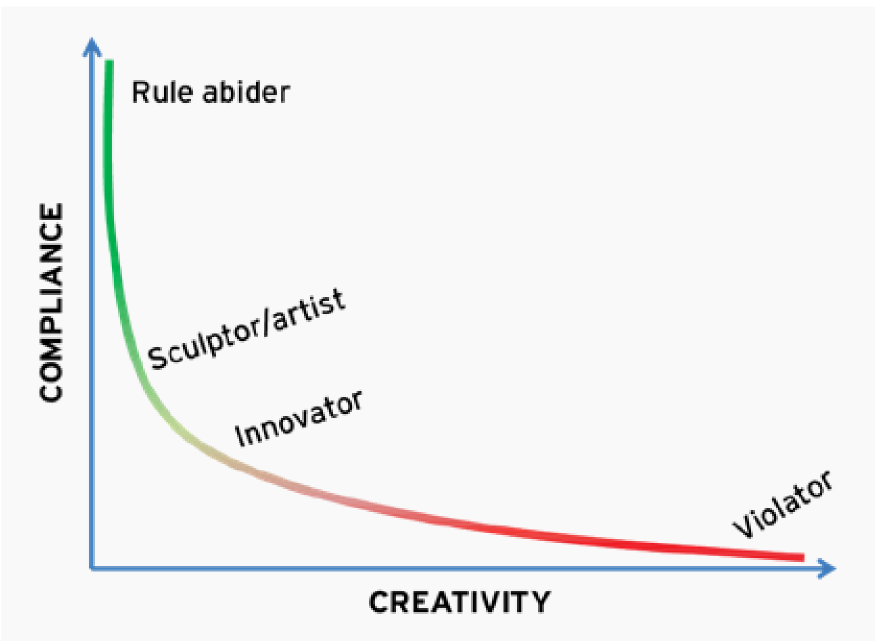


Figure 2: The Creativity Compliance Curve

The model, derived from analysed results from the present study and in reference to the previous work of Bartlett (1958), depicts the delineation between compliance and creativity and through positioning of the innovator identifies the need for effective barriers to prevent decisions to positively deviate (potentially resulting in creative or innovative behaviours) from becoming violations.

The impact of this new awareness should provide no comfort for regulatory and governance authorities. The dilemma that confronts them – indeed any person responsible for aviation-safety compliance – is where to position innovation barriers to support innovative behaviours, but restrict innovations from becoming violations. Alarmingly, as is evident from the current research, willingness to pursue innovative approaches to maintenance is a penchant of the inexperienced.

Where do we install an innovative barrier – would you play it safe and place the barrier above Sculptor, or take a more risk-acceptance approach and place it below Innovator?

There's no correct answer. The decision of where to place it is entirely dependent on your circumstances and what is an acceptable level of risk for you and the organisation. What is important; however, is that a barrier is created somewhere along the continuum and that barrier actively prevents innovations from becoming violations.

Innovative intent

In the domain of aviation maintenance, unapproved innovations are potential, if not actual, violations. Performing an unapproved innovation, in essence, is a violation of the procedure. Despite this assertion there is clear evidence of maintenance personnel being willing to pursue acts of innovative maintenance.

What is the answer? Should we insist, rigidly, on strict conformance to the approved processes? 'We have always done it this way', so it must be the best way, right? Surely no one still thinks like that. How do we encourage innovative thought, discover new, better, safer methods and products without compromising the safety of the public, the equipment and the environment?

Many references were made by interviewees to doing something in a better way, with most participants able to enunciate a perceived difference between an innovation and a violation. Common among the definitions of innovation and violation is the delineating factor of intent.

Being innovative and creative received positive affirmations by many interviewees and it could likely be expected that some innovative intent was directed towards positive deviance behaviour.

Maintainer attitudes towards innovative maintenance was reported as being routine; indeed, one interviewee conceded innovations were a daily occurrence.

Noting that most participants felt they were innovative maintainers, then statements like 'daily occurrence' are perhaps unsurprising. This is despite substantial agreement in survey and interview responses attesting to rule abidance and always complying with the approved procedures.

The safety management fulcrum identifies the interplay between compliance and violating behaviours. Correct positioning of the fulcrum is vital in overcoming the impact of deviant behaviour.

Maintaining a positive imbalance towards regulatory framework and safety culture ensures a mechanical advantage continues to exist over the potential impost of poor procedures and process violations.

The positive imbalance also ensures that good behaviours, such as event reporting, learning from our mistakes, and compliance are given more leverage to overcome violation-outcome events.

Capturing, codifying, and controlling positive deviance behaviours facilitates the raising of the bar and provides opportunities to deal with and effectively manage increasing workloads. In so doing it ensures continuing regulatory compliance and reduces the organisation's exposure to the risk of latent defects.

Conclusion

While aviation was the subject of my research, the findings are relevant and applicable to other highly regulated or high-consequence domains and industries.

The finding that younger participants, those with the least aviation industry experience and least on-type experience, were more likely to pursue innovative maintenance outcomes is significant given this same cohort of participants scored lower for critical thinking and understanding risk.

In dealing with this research outcome, it is important to not simply generate more procedures or apply tighter restrictions. Such actions, would in all likelihood, be nugatory. The exhibited willingness of some aviation maintenance personnel to push current boundaries, by-pass defences, and to ignore warning and caution signs suggests the need for a different approach.

From an organisational perspective – we need to create an environment where innovative behaviours do not go unrecorded, unchallenged, and unassessed. Rather, these behaviours and actions need to be accurately captured so that any good ideas are shared and that benefits gained are maximised.

Direct engagement, where organisational participants are encouraged to be innovative, where trusted decision-makers are authorised for innovation, and where action is taken to capture, codify and control innovative behaviours can generate required levels of self-regulation towards compliance.

This arrangement ensures that innovations are shared, risks are understood and any weakness in critical thinking is mitigated through effective peer or supervisor review of positively deviant decision intentions.

About the author

Tony commenced his RAAF career as an airframe fitter in 1979, and was commissioned into the Engineer Branch in 1987. Between 2005 and 2014 he was the Australian Aerospace P-3 Senior Maintenance Manager. His PhD (completed in 2020) focused on positive deviance behaviour by aviation maintenance personnel and explored maintainer attitudes towards innovative maintenance practices. Tony is very much a practitioner rather than a theorist.

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In trouble from the moment he started to dive

By Andrew Curtis, Researcher, Mildura 2OTU Heritage Inc

ON 12 NOVEMBER 1944, student pilot SGT Bernard O'Keeffe of No. 2 Operational Training Unit (2OTU) was detailed to carry out a high dive-bombing exercise at the Wentworth Bombing Ranges (NSW). The exercise consisted of six dives with one 11½ lb practice bomb dropped in each dive. The first three dives were to start from 12,000 ft, dive vertically and pull out at a minimum of 6000 ft. The next three dives were to start from 6000 ft, dive at a 70-degree angle and pull out at a minimum of 3000 ft.

SGT O'Keeffe, in P-40E Kittyhawk A29-115, was leading a pairs formation with fellow student pilot FSGT Alfred Thomas also in a Kittyhawk. At 1340, when at 12,000 ft, SGT O'Keeffe turned on his back to commence his first vertical dive with FSGT Thomas following 100 yards behind. SGT O'Keeffe started his turn at 160 mph and during the dive in which he dropped his practice bomb, was pulling away from SGT Thomas whose speed reached 490 mph. SGT O'Keeffe was seen to turn slightly in a spiral on the way down and was noticed by the range safety officer to be still spiralling slightly when he hit the ground at a 30 degree angle and an estimated speed of 400 mph. He was killed on impact.

This was the first of four fatal dive-bombing accidents that occurred between this time and August 1945; and all were at the Wentworth Bombing Ranges. In fact, from the time 2OTU was based at RAAF Mildura in May 1942 until SGT O'Keeffe's accident, only one bombing-training accident occurred on any of the unit's four bombing ranges. That was a non-fatal accident on 25 February 1944 between FLGOFF Gordon Horace White in Kittyhawk A29-319 and SGT L Collins in Kittyhawk A29-146 who collided after completing a dive-bombing exercise. FLGOFF White crashed on the range while SGT Collins managed to make it back to base.

Five bombing-training accidents is a relatively small number compared to the more-than 330 attributed to 2OTU aircraft found in records by the author. However, they account for four of the unit's 53 deaths from aircraft accidents. The findings of the Courts of Inquiry (COI) for three of the fatal dive-bombing training accidents are available online via the National Archives of Australia.

The most useful COI of the three available is that of SGT O'Keeffe's accident in P-40E Kittyhawk A29-115. The findings of the court note that there wasn't any concrete evidence that the pilot departed from the exercise as briefed and that it was not known what caused the accident, with structural and engine failure ruled out.

Known facts of the accident from witnesses

The COI for SGT O'Keeffe's accident was very lucky to have FSGT Thomas as an eyewitness along with ground eyewitnesses and expert witnesses with considerable flying experience. FSGT Thomas not only observed the dive and was doing the same exercise, but he was also on the same Wirraway course at 8OTU (Parkes) as SGT O'Keeffe before being posted to 2OTU and could describe the training there.

SGT O'Keeffe was in trouble from the moment he turned on his back to commence his dive. The following points are likely to have affected his dive and efforts to recover from it:

- The 160 mph dive turn-in speed was higher than the recommended maximum starting speed of 140 mph.
- It was estimated that A29-115 reached a speed of at least 500 mph in the dive

… classes pilot fixation into three primary causes: equipment problems, abnormal situations and target fixation. An equipment problem is where equipment does not work as per normal and the pilot is preoccupied with it. An abnormal situation is where an event occurs out of the normal sequence of events and the pilot focuses on this situation that is out of the norm rather than concentrating on flying. Target fixation is the pilot's fixation on performing a secondary task rather than on flying the aircraft.

(based on the fact it was pulling away from FSGT Thomas who was at 490 mph). *RAAF Technical Order – Kittyhawk Instruction No. 1* (Issue 3) states the maximum permissible IAS speed in a dive without a belly tank is 485 mph.

- There was no attempt to pull out of the dive at 6000 ft as instructed (was seen at an 80-degree dive at this height), rather it was attempted at 2000 ft when he pulled away in a 50-degree turn.

The aircraft was seen to spiral during the dive until the crash. Witnesses stated that, in high speeds, the Kittyhawk tends to roll to the left and is more accentuated the higher the speed.

Other factors that may have played a part in the accident

Possible failure to reduce the throttle prior to the dive. Student pilots were instructed that the throttle speed for climbing was 28 in and to reduce this to 24 in for the dive, along with ensuring the maximum dive turn-in speed was 140 mph.

FSGT Thomas mentions in his statement they were climbing immediately before the dive but not what the setting was – if the throttle was at 28 in or had been backed off. If not, this could account for the excessive speed.

Low hours on type

SGT O'Keeffe had a total of 287 hrs 50 min total flying time (all types) of which 24 hrs 30 min was on Kittyhawks, including 14 hrs 25 min in the previous week.

This was SGT O'Keeffe's first high dive-bombing in a Kittyhawk and first vertical high dive-bombing. SGT O'Keeffe had dual instruction in Wirraways at 8OTU in dives that were from 6000 ft to 3000 ft at a 60-degree angle. No. 2OTU did not carry out check dives when student pilots reached the unit.

SGT O'Keeffe is likely to have greyed out or blacked out when recovering from the dive. FSGT Thomas himself greyed out when recovering from the dive which he started at 2000 ft and was level at 1000 ft.

New to the syllabus

In late 1944 and prior to the accident, this particular type of dive had been added to the 2OTU Kittyhawk training syllabus. As experience was gained in conducting exercises, refinements, such as the previously mentioned addition of check dives, could be made to future training.

Target fixation

FSGT Thomas stated that SGT O'Keeffe 'stayed on target' too long with part of the COI's supposition that he concentrated on the target after he went below 6000 ft and, as he was at a high speed, discounted the eight seconds it would take to reach ground level.

Insight into the Kittyhawk P40-E

SQNLDR Glen Cooper (OC 2 Kittyhawk Squadron, 2OTU), FLGOFF Clive Roy Briggs (Staff Instructor, D Flight, 2 Kittyhawk Squadron, 2OTU) and SQNLDR Ian Loudon (Chief Flying Instructor) made expert witness statements in the Inquiry about the Kittyhawk P40-E's tendency to roll to the left at high speeds in a dive.

In short, the combined statements suggest that from speeds above 300 mph, P-40E Kittyhawks were known to roll to the left and had to be trimmed correctly; between 350 and 400 mph the roll would become more accentuated if not trimmed correctly; and from 450 and 480 mph it required 'great physical strength to keep the aircraft level'. SQNLDR Loudon himself said that in dives above 450 mph, he had to use the aircraft's electric aileron trimming device to keep the left wing up as the control stick loading was equal to the strength he could apply on it.

Fatal dive-bombing accidents

The three other fatal dive-bombing accidents can be examined for similar causal factors. A summary of each follows.

On 14 December 1944 FSGT Kenneth Edward Hepburn in Kittyhawk A29-176 P40-K was engaged in a dive-bombing exercise.

Kittyhawk A29-176 of No. 2 OTU on fighter affiliation exercises with Liberators from No. 7 OTU, October to December 1944. Source: Tocumwal Aviation Museum, original source unknown.

The findings note that A29-176 was seen to spiral dive from 2000 ft, struck the ground and disintegrated on impact. The full COI report is not available, therefore no other information is known.

On 30 March 1945 SGT Alan Joseph Worboys Saunders in Kittyhawk A29-146 was on a 60-70 degree dive exercise from 6000 ft with one 250 lb high-explosive bomb. A29-146 flicked after pulling out of the dive, SGT Saunders was unable to regain control and was killed in the crash.

The findings surmised that SGT Saunders pulled up in a steep climbing turn in an effort to see where his bomb had fallen; however, this was too soon after recovering from the dive and the aircraft stalled. It was also against the instruction to make a tactical withdrawal after the dive by flying straight along the ground away from the target.

Thirteen days after Victory over Japan Day, on 27 August 1945, WOFF John Campbell Higgins in Kittyhawk A29-190 was on a formation dive-bombing exercise from 8000 ft with practice bombs with three other aircraft.

WOFF Higgins was observed at 1500 ft at an 80-degree angle, in a slow aileron turn and was heard to shout over the R/T at this time.

He was killed when A29-190 dived straight into the ground.

The COI's opinion was that WOFF Higgins was concentrating on sighting and misjudged his height and angle of attack. WOFF Higgins was 2OTU's second-last flying-accident fatality before it changed to a Care & Maintenance Unit in February 1946.

The end of bombing training at 2OTU

Bombing exercises were removed from 2OTU's training syllabus shortly after, along with the removal of rocket-projectile exercises. A number of other changes were made to other exercises and night flying. This was recorded in a Department of Air Minute Paper (*Air Accident and Flying Discipline – policy*) dated 2 October 1945 which was reporting what was being done to reduce flying accidents post-war at operational training units.

Pilot fixation and target fixation

Kreisha Ballantyne in her 2015 article *The Fatal Five* discusses five psychological traps that pilots and others in aviation may fall into. In defining task fixation, Ballantyne mentions Timothy N Timmons' research paper that classes pilot fixation into three primary causes: equipment problems, abnormal situations and target fixation.

An equipment problem is where equipment does not work as per normal and the pilot is preoccupied with it. An abnormal situation is where an event occurs out of the normal sequence of events and the pilot focuses on this situation that is out of the norm rather than concentrating on flying. Target fixation is the pilot's fixation on performing a secondary task rather than on flying the aircraft.

A29-176 and A29-115 were both seen to spiral dive during their exercises. Should a spiral dive be classed as an equipment problem or an abnormal situation? Is the known tendency of the Kittyhawk P40-E to roll to the left in a dive at speed an equipment problem? Or is it an abnormal situation that presents itself after 300 mph and in varying degrees, as the higher the dive speed, the greater the amount of effort is required to keep the aircraft level to stay on target?

Three of the four accidents had an element of target fixation in their inquiry findings and it is unknown if it was an element of the fourth accident due to the full report being unavailable. SGT Saunders in A29-146 pulled up too quickly in an attempt to see where his bomb fell even though instructed not to do so; WOFF Higgins in A29-190 was concentrating on sighting; and SGT O'Keeffe concentrated on the target for too long.

Timmons cites a modern-day example of target fixation involving a pilot of a USAF F-16 Fighting Falcon that occurred in Iraq in 2006. In providing close air support, the F-16 successfully made one ground strafing run using 20 mm cannon and then proceeded on a second run. On this run, the pilot became so fixated on the target that he flew into the target area killing himself on impact.

The Investigation's summary stated the cause was due to the pilot's 'channelized attention manifested by his (the pilot's) desire to maintain a constant visual positive identification of targeted enemy vehicles and subsequent target fixation on these vehicles while they were travelling at high speed' leading him to begin and carry out his second run 'below a recoverable altitude'.

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