Australian Government
Australian Transport Safety Bureau

Collision with water involving Yakovlev Aircraft Factories Yak-52, VH-PAE

near South Stradbroke Island, Queensland, on 5 June 2019

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Addendum

Page	Change	Date

Safety summary

What happened

On the morning of 5 June 2019, the pilot and passenger of a Yakovlev Aircraft Factories Yak-52 aircraft, registered VH-PAE, were conducting a private aerobatic flight from Southport Airport, Queensland. During the flight, while near South Stradbroke Island, the aircraft collided with water. The occupants were fatally injured and the aircraft was destroyed.

What the ATSB found

The ATSB found that, during the flight, a number of aerobatic manoeuvres were conducted below 500 ft above ground level. However, in the absence of recorded data or witnesses to the collision with water, it could not be determined with certainty that the pilot was conducting an aerobatic manoeuvre immediately prior to the impact, but it was considered a possibility. Despite this, for reasons undetermined, the aircraft collided with water at high speed.

It was also established that, during the accident flight and previous flights, the pilot conducted low-level aerobatics without completing the required training or having the appropriate endorsement. This would have potentially limited the pilot's appreciation of the risks associated with low-level aerobatics.

Some of the pilot's low-level aerobatic flights had been witnessed by people with aviation experience and knowledge. While the pilot did receive some warnings about this, there were other opportunities and means for people to formally communicate and escalate their concerns that were not used.

Although not contributory to the accident, a pre-existing fatigue crack was found in the elevator bellcrank, which had the potential to fail in-flight, leading to a loss of control. In addition, the manufacturer could provide airworthiness information upon request for Yak-52 aircraft in Russia and overseas as long as they had not exceeded their prescribed airframe life. However, aircraft such as VH-PAE had exceeded their airframe life and therefore were no longer able to be supported. As a result, significant changes to the scheduled maintenance program relating to the elevator bellcrank were not known or included in local maintenance schedules.

Further, the ATSB established that VH-PAE, along with other Yak-52 aircraft, had exceeded their prescribed airframe life limit. Until 2007, permit index assessments were conducted by the Civil Aviation Safety Authority and included aircraft that had exceeded their life limits. While not related to the accident, when the Australian Warbirds Association Limited conducted the assessments, they did not consider Yak-52 aircraft to have an airframe life. Subsequently, these aircraft were assigned a permit index that allowed flight over populous areas without consideration of the risk to the aircraft occupants and general public.

What's been done as a result

In November 2020, the ATSB issued a safety advisory notice to Yak-52 maintainers and owners emphasising the importance of dye penetrant inspections to remove defective elevator bellcranks from service. The notice also noted that Russia, as the aircraft's state of design, increased the frequency for inspections of the bellcranks to 25 ± 5 flying hours. Further, aluminium alloy bellcranks were no longer approved for use on Yak-52s operating in Russia.

Safety message

This accident highlights the inherent risks associated with performing low-level aerobatics and the reduced safety margins when recovering from manoeuvres. Even more so, it demonstrates the importance of being suitably trained and qualified to conduct these operations. It also provides an opportunity to encourage witnesses, particularly those within the aviation industry, to report any

concerns regarding unsafe behaviours through mechanisms such as confidential reporting systems.

Further, as the Yak-52 aluminium elevator bellcranks have a propensity to crack, it emphasises the need to conduct more frequent dye penetrant inspections to identify and remove defective bellcranks from service, and to consider replacing them with steel bellcranks.

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The occurrence

On 5 June 2019, at about 0945 Eastern Standard Time,[1] the pilot and passenger of a Yakovlev Aircraft Factories Yak-52 aircraft, registered VH-PAE, were conducting a private flight from Southport Airport, Queensland. The flight was intended to take about 30 minutes and included a scenic flight north along the coast from Broadbeach to the Jumpinpin channel, and then seawards off Jumpinpin to conduct aerobatic manoeuvres over water, before returning to Southport (Figure 2). A second passenger was waiting at the airport to complete a similar flight once the aircraft had returned.

Prior to take-off, the pilot told a witness that a low-level turn over the trees would be more exciting for the passenger. The pilot also discussed taking off downwind on runway 01 and that the aircraft could accept the tailwind component. The second passenger provided video footage showing the aircraft departing Southport from runway 01 and conducting a left turn shortly after take-off. The ATSB's analysis of that video estimated the turn was conducted at about 200 ft above ground level (AGL) (Figure 1). This departure was described by a witness at Southport as being 'normal' for the pilot. The aircraft was held close to the ground after take-off to build up airspeed, which allowed a left turn to be performed just past the runway boundary.

Figure 1: Take-off from Southport Airport and left turn (inset)

At 0950, Airservices Australia surveillance data identified a radar return for an aircraft tracking in a southerly direction from the airport. On reaching Broadbeach, the aircraft then turned left to commence tracking to the north along the coast. This was consistent with the timing of departure and proposed flight plan for VH-PAE.

Shortly after, the pilot was heard broadcasting on the common traffic advisory frequency by another pilot who departed Southport Airport at around the same time indicating they were overhead Pacific Fair (a shopping centre located at Broadbeach) at an altitude of 500 ft, northbound.

[1] Eastern Standard Time (EST): Coordinated Universal Time (UTC) + 10 hours.

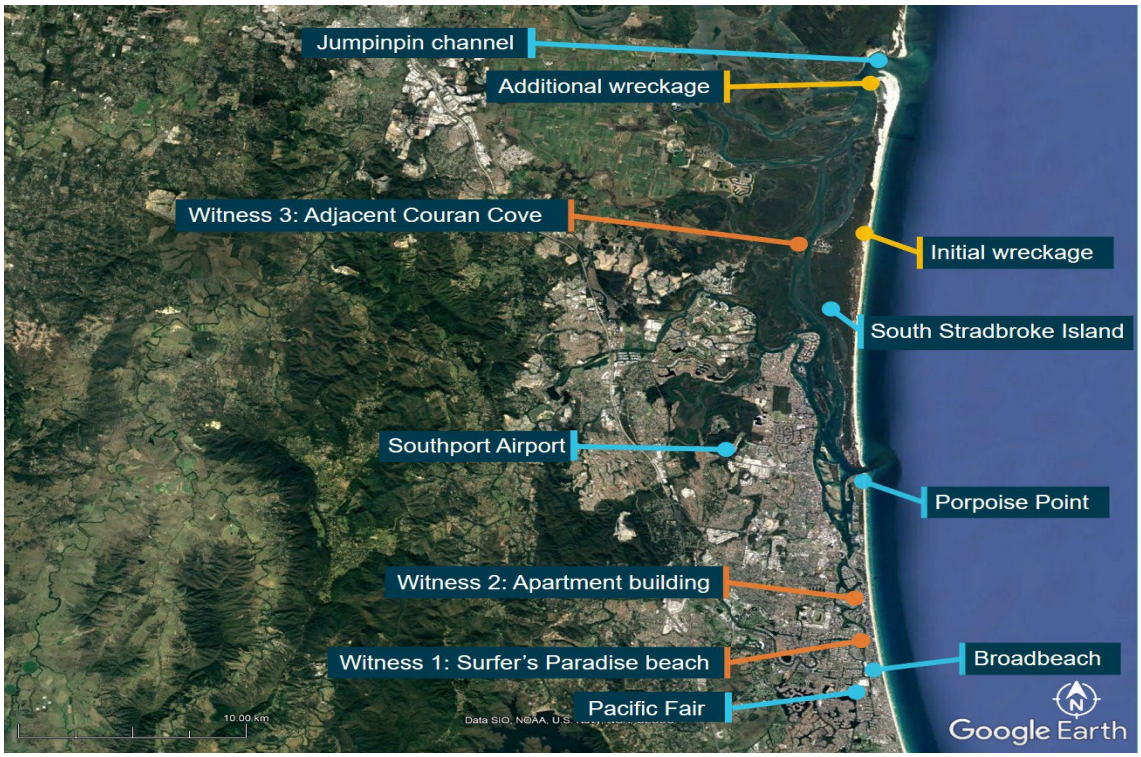
Two witnesses reported observing the aircraft tracking on the planned scenic route. The first witness was at Surfers Paradise beach (Figure 2) and observed the aircraft flying from west to east, then northbound along the coast (refer to section titled Witness observations). The second witness was near South Stradbroke Island on the 12th floor of an apartment building. That witness saw the track north along the beach towards South Stradbroke Island with two people on board.

Another pilot who recently departed Southport Airport, heard the pilot of VH-PAE broadcast on the common traffic advisory frequency that they were at Porpoise Point and heading seaward for aerobatics at 3,500 ft.

At about 0958, Department of Defence surveillance data recorded an aircraft over South Stradbroke Island, conducting operations with significant track and speed fluctuations, consistent with aerobatic manoeuvres. Altitude data was not available (refer to section titled Recorded information). About 7 minutes later, no further radar returns were recorded. Witnesses on the western side of South Stradbroke Island adjacent to Couran Cove, reported that they observed an aircraft consistent with VH-PAE conduct a 'loop, cut right, and dive below the tree line', but did not recall anything else unusual about the aircraft.

When the aircraft had not returned to Southport after an hour, the second passenger became concerned and asked members of the Southport Flying Club if they had heard anything. At about 1310, a representative from the club contacted Airservices Australia about the overdue aircraft and at 1400, the Australian Maritime Safety Authority's Joint Rescue Coordination Centre initiated search and rescue operations. At about 1630, part of the propeller (initial wreckage) was located on the eastern side of South Stradbroke Island (Figure 2). In the following days, the pilot and passenger, who sustained fatal injuries were recovered, along with additional wreckage.

Figure 2: Location of areas of interest for the flight (blue), witness locations (orange), and aircraft wreckage locations (yellow)



Context

Pilot information

Licence and experience

The pilot held a current Private Pilot Licence (Aeroplane) initially issued under Civil Aviation Regulations 5[2] in 4 July 2014 and transferred to the Part 61 licencing system on 23 May 2016. The pilot's general aviation logbook showed a total flying experience of 412.4 hours to the last recorded flight on 31 May 2019, of which 39.4 hours were in VH-PAE.

The pilot had last completed a single-engine aeroplane flight review on 17 January 2019, which included an aerobatic flight activity endorsement. This qualified the pilot to conduct spins and aerobatics at no less than 3,000 ft AGL. After obtaining this endorsement, the flying instructor discussed the requirements for obtaining a low-level aerobatic endorsement (below 3,000 ft) with the pilot. However, the pilot did not obtain this endorsement nor hold an operational rating for low-level flying.

The Civil Aviation Safety Authority's (CASA) *Part 61 Manual of Standards* outlined that, aerobatic flight activity endorsements require pilots to operate no lower than the minimum authorised height of 3,000 ft AGL. Once proficient, and then checked for competency to the requirements of the standards, there is a progressive reduction in the minimum authorised height to 1,500 ft AGL, 1,000 ft AGL, 500 ft AGL, and then unlimited.[3] This process requires pilots to demonstrate competence at, or above each level before attempting the next level.

The pilot also held a Recreational Aviation Australia (RAAus) pilot certificate, issued in February 1999, and had accumulated a total of 413.3 hours up to 29 May 2015 with this certificate. There was no logbook for the pilot's RAAus flying available and no further update of flying hours was noted on the RAAus pilot licence file after this date.

Medical and pathological information

The pilot held a Class 2 Aviation Medical Certificate, valid until 1 May 2021, and was required to have vision correction available for reading while exercising the privileges of the licence. A review of the pilot's aviation medical records found there was no information that indicated a medical event may have contributed to the accident.

The nature of the pilot's and passenger's injuries limited the information that could be obtained from a post-mortem examination. Due to the disruption to the aircraft, the accident was not considered survivable.

Pilot's flying history

An acquaintance described the pilot as initially 'being disciplined', but this had slipped as the pilot became more familiar with the accident aircraft and began 'pushing limits too fast and too soon'. Another acquaintance mentioned having concerns about the height the pilot flew aerobatics and attempted to communicate these concerns. There were also a number of occasions in the years prior to the accident where the pilot was observed performing low-level flying and aerobatic manoeuvres without holding the required qualifications:

- In October 2013, the pilot received a written warning from RAAus about performing aerobatics in an RAAus registered aircraft, which was not permitted.
- In November 2018, the pilot was observed to conduct low-level aerobatic manoeuvres in the accident aircraft at about 500 ft over a residential area near Southport Airport, which was

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[2] Licences issued under the previous Civil Aviation Regulations 5 were transferred to the new licencing system Part 61 from 1 September 2014.

[3] Unlimited: Aerobatics can be conducted at any height.

counter to the 'flying neighbourly'[4] policy. As a result, the pilot was issued with a verbal warning by the Southport Flying Club and advised that a repeat incident would result in a revoked membership from the club.

- A friend of the pilot went for a flight in late April 2019. The friend reported flying low-level as they were at the same height as the buildings along the beach and conducting aerobatic manoeuvres. An analysis of the passenger's video footage showed that the aerobatics were conducted below 1,000 ft and that elements of the flight were conducted as low as 260 ft based on the buildings in the area. The friend recalled that the pilot had commented about knowing how to safely do a barrel roll[5] while flying low-level. The pilot had also mentioned not being approved to conduct this manoeuvre at a low height and that if too much height was lost, it would be 'impossible' to recover.
- About a week prior to the accident, the pilot was observed to enter the circuit at Boonah airfield inverted, estimated to be at about 1,300 ft by a witness.
- Three days prior to the accident, another passenger who flew with the pilot reported the flight was lower than the height of the buildings on the Gold Coast. Images provided showed the flight was conducted below the height of numerous well-known buildings at that location, which was below 500 ft.

A review of the ATSB and CASA databases found no safety reports relating to the pilot. In addition, aside from the verbal warning, the Southport Flying Club had not received any other safety reports regarding the pilot's flying.

Aircraft information

General

The Yakovlev Aircraft Factories Yak-52 is an all-metal, two-seat, low-wing aircraft, powered by an air-cooled M-14P radial engine driving a two-bladed, variable-pitch wooden propeller. The aircraft was manufactured with front and rear flight controls. The primary flight controls are located in the front cockpit and the secondary flight controls in the rear cockpit. About 1,800 Yak-52 aircraft were produced between 1977 and 1998, which was designed as a military trainer. In 2020, there were 51 Yak-52s registered in Australia.

The accident aircraft was manufactured in 1982 by Aerostar in Bacău, Romania. In 2002, the aircraft reached the end of its airframe life and was disposed of.[6] In about 2004, the aircraft was disassembled in Russia and imported to Australia. The aircraft was first registered with the Civil Aviation Safety Authority on 5 April 2017, and was registered to the pilot on 5 July 2018. The last periodic and associated inspections were carried out on 31 October 2018. The most recent entry on the maintenance release was 5 days prior to the accident (on 31 May 2019) and showed that the aircraft had accumulated 1,164.2 hours total time-in-service.

A review of the weight and balance found that the aircraft was within centre of gravity limits at the time of take-off. Further, the aircraft was not fitted with a transponder, nor was it required to be.

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[4] The Southport Flying Club information kit stated that 'All pilots should remember that flying neighbourly within the vicinity of Mason field [Southport Airport] is important to the future tenure of the club members. Breaches of CASA regulations, poor Airmanship and recklessness will not be tolerated by the management committee.'

[5] Barrel roll: An aerobatic manoeuvre in which an aircraft follows a single turn of a spiral while rolling once about its longitudinal axis.

[6] Yak-52s were subject to an overhaul life, and separately an airframe life. The airframe life of Yak-52s was considered in hours, landings, or years, whichever was the sooner. In this case, the aircraft had reached 20 years since being manufactured. The initial airframe life could be extended by implementing an approved maintenance and inspection program.

Airworthiness

The majority of ex-military (commonly referred to as warbirds) or replica aircraft in Australia were not designed and manufactured to any known civil aviation standard. These aircraft have been allowed to operate in Australia under a special certificate of airworthiness in the limited category.[7] The special certificate of airworthiness, issued for VH-PAE on 19 September 2017, indicated the aircraft was to be operated in day visual flight rules[8] conditions.

As an ex-military aircraft, under *Civil Aviation Safety Regulation 1998* (CASR) Part 132 it was required to be administered by the Australian Warbirds Association Limited (AWAL). AWAL is a self-administering recreational aviation administering organisation operating under CASR Part 132. Part of their role was to provide oversight of this sector of warbird, ex-military and replica aircraft. As such, aircraft operated under CASR Part 132 must conform to the requirements of the AWAL exposition and self-administration manual. All persons who fly an AWAL administered aircraft are to be members of AWAL.

The AWAL contacted the ATSB shortly after the accident and stated that the aircraft was purchased in about May 2018 and that the aircraft's annual renewal with AWAL subsequently expired. Sometime later, the aircraft was observed to be operating and after attempts to contact the new owner, this was reported to CASA. The aircraft's annual AWAL renewal was subsequently paid and the new owner became a member of AWAL, in order to operate the aircraft.

There were different design and manufacturing standards of warbird aircraft in Australia. The aircraft was maintained in accordance with AWAL's maintenance schedule, which included the applicable airworthiness directives. In addition, the AWAL maintenance schedule included structural integrity inspection requirements, carried out every 3 years. This specified that engine mount and landing gear welds be inspected by using a 10 times magnifying glass or with dye penetrant. Other listed inspection requirements were to be carried out to a depth that the maintenance organisation performing the work deemed necessary.

Airframe life and permit index

Airframe life limits for Yak-52s as defined by the Yakovlev Design Bureau were conditional on the aircraft being maintained in accordance with Yakovlev's scheduled maintenance program. The airframe life for Yak-52s of the same specification as VH-PAE, was 1,000 flight hours or 5,000 landings in 20 years. In 2005, the Russian Central Aerohydrodynamic Institute (ЦАГИ) established an extension to the Yak-52 airframe life to 2,000 flight hours or 10,000 landings in 30 years. To support this extension, Yakovlev issued amendment 2 of the scheduled maintenance program for the Yak-52 on 9 September 2009 and the extension was conditional on the aircraft continuing to be maintained in accordance with the revised schedule. As VH-PAE and other imported Yak-52s stopped being maintained in accordance with any of the Yakovlev schedules when they were disposed of, the life extension did not apply.

Warbird aircraft in Australia, as part of their introduction to service, underwent a permit index (PI) assessment. CASA advisory circular *Limited category aircraft - permit index* (AC 21-25) outlined that this was a risk assessment procedure to:

> …ensure that the risk is confined to the occupants of the aircraft, while protecting the general public from risk of harm or property damage.

PI assessments were initially carried out by CASA, who performed about two-thirds of these prior to their administration being transferred to AWAL in May 2007. At the time of its registration in

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[7] A warbird, historic or replica aircraft could be issued with a limited certificate if the Australian Warbirds Association Limited (AWAL) was satisfied that the aircraft could operate at an acceptable level of safety if flown in accordance with any limitations or conditions placed upon the aircraft's limited certificate.

[8] Visual flight rules (VFR): A set of regulations that permit a pilot to operate an aircraft only in weather conditions generally clear enough to allow the pilot to see where the aircraft is going.

Australia, VH-PAE was 15 years over its 20-year airframe life. A review of the other Yak-52s in Australia found that 40 per cent were over their airframe life limit at the time of registration. At the time of publication, and with the exception of some aircraft that have been modified to a tail-wheel configuration, the remaining Yak-52s registered in Australia had exceeded their airframe life.

PI numbers are issued to individual aircraft ranging from '0' with no airport or populous area[9] restrictions (other than the normal airspace and air traffic control requirements), to '3' where operations over populous areas were prohibited.

The assessment procedure takes into account a range of risk categories including fatigue history, repairs and modifications, installed equipment (i.e. ejection seats or external fuel), engine type, fuel capacity, stall speed, etc. The assessment adds or subtracts points against risk category elements. The total score determines the PI number. The risk category for fatigue history had the following elements:

- history not known – deduct 130 points
- airframe life exceeded – deduct 130 points
- not applicable or airframe life within limits – no addition or subtraction of points.

Deducting 130 points, such as if the aircraft had an expired airframe life, would result in a PI assessment that would prevent operations of aircraft over populous areas.

The AWAL exposition and self-administration manual included a procedure for issuing a certificate stating an airframe life different to the aircraft's currently approved airframe life.[10] It required the aircraft owner or registered operator to apply with the following information:

- the name of the applicant or registered operator
- the make, model and registration of the aircraft
- the approved airframe (fatigue) life of the aircraft
- the expired fatigue life of the aircraft
- how the fatigue has been measured
- the operational history of the aircraft
- the maintenance history of the aircraft
- the proposed future use of the aircraft
- whether it is proposed to use the aircraft for adventure flights
- if a detailed inspection has been made of the aircraft structure, the reports of that inspection.

An assessment of the application by an AWAL approved person considered the following:

- the existing approved airframe life and the factors and assumptions on which it is based
- the intended future operations of the aircraft
- the operational and airworthiness history of the aircraft
- the service history of:
  - other aircraft of the same type and model; and
  - other aircraft and structures of similar design

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[9] Populous area: An area that is substantially used for, or is in use for, residential, commercial, industrial or recreational purposes.

[10] CASR Part 132 defines the approved airframe life as the latter of the aircraft's approved design, a variation (if any) of the airframe life by the national aviation authority of the country of the aircrafts manufacture, if the aircraft is an ex-armed forces aircraft - a variation (if any) of the airframe life by the armed force that operated the aircraft or for which the aircraft was manufactured, and a certificate (if any) stating an airframe life for the aircraft's airframe given by the administering authority for the aircraft. In this case, the administering authority is AWAL.

- maintenance program findings
- an assessment of the structure of the aircraft.

The AWAL approved person could issue a certificate stating a new approved airframe life if they were satisfied it would maintain an acceptable level of safety of flight.

In carrying out the PI assessment for VH-PAE, the risk category for fatigue history was recorded against the risk element 'not applicable or airframe life within limits', and included in the comment 'No, fatigue life'. VH-PAE was assigned a PI of '0' in 2017, and there was no record of a certificate stating an airframe life different to the existing approved airframe life being issued.

AWAL advised the ATSB that they did not regard the Yak-52 as having an airframe life as they had not been presented with documentation suitable to AWAL to define it, and from their experience they did not consider it to be an issue. AWAL further advised that, for this reason, a certificate to extend the airframe life of VH-PAE was not required, and that the PIs for other Yak-52s were assessed as '0'.

In 1998, the United Kingdom (UK) Civil Aviation Authority (CAA) issued Mandatory Permit Directive[11] (MPD) 1998-017 to detail airframe life limitations and the overhaul life of the Yak-52 in the UK. It stated that:

> Correspondence with the Design Authority, Yakovlev Design Bureau, has confirmed that there is an initial airframe life limit, which varies with the Series of the aeroplane.
>
> The initial airframe life limit can be extended by the implementation of an approved maintenance and inspection programme.

The MPD defined the airframe life for Yak-52s as 1,000–1,500 flight hours or 5,000–7,000 landings in 15–20 years, depending on the modification status of the aircraft. AWAL advised they did not regard MPD 1998-017 as suitable data to define Yak-52 airframe life limits as they were not required to comply with data published by foreign authorities.

Fuel

The aircraft operated on aviation gasoline (AvGas) 100LL (91/96 octane) and had the capacity to carry 120 L in two 60 L wing tanks, with about 12 L being unusable. Southport Airport fuel records indicated that the pilot uplifted 75.22 L of AvGas prior to departure. A test of the fuel bowser found no issues with the fuel quality.

Meteorological information

Bureau of Meteorology

The nearest Bureau of Meteorology automatic weather station was located at the Gold Coast Seaway, about 12 km south from the last witness observation. At 1000 on the day of the accident, the station recorded the wind at 11 kt from a southerly direction and a temperature of 19.5°C.

Witness observations

Witnesses located near Couran Cove on South Stradbroke Island, at time of sighting the aircraft, described the conditions as 'good' visibility, with no cloud. There were light winds at the time, but wind gusts increased over the day.

Recorded information

Surveillance data was obtained from Airservices Australia (Mount Hargrave radar) and the Department of Defence (Mount Hargrave, Somerville and Amberley radars). As the aircraft was

[11] In the UK, a MPD is the equivalent of an airworthiness directive, but for aircraft operated on a permit to fly. Both are issued by the UK CAA, and like an airworthiness directive, the requirements of an MPD must be complied with.

not fitted with a transponder, only primary radar returns[12] were available. The coverage will detect aircraft at, or above heights depending on the aircraft's proximity to radar coverage and terrain shielding. Due to the limitations of primary radar and terrain shielding, there were gaps in the radar recording. An analysis of this data showed:

- the aircraft was detected at 0946:43 departing Southport Airport and heading in a southerly direction
- between 0952:13 and 0953:56, the aircraft was tracking in an easterly direction towards the coast
- at 0955:27, the aircraft was tracking in a northerly direction towards South Stradbroke Island
- until 0958:30, the aircraft had a relatively constant speed of around 120 kt, consistent with straight-and-level flight in a northerly direction along the beach
- after 0958:30, the aircraft's speed varied between 70 kt and 160 kt
- between 1003:44 and 1004:30, the aircraft's speed further reduced from 130 kt to 72 kt, and it was at or above 1,200 ft overhead South Stradbroke Island
- the last detections between 1005:36 and 1005:48 were 'tightly grouped' indicating the aircraft was either at very low speeds or in a steep dive; the speed was below 60 kt, which could be attributed to the aircraft being in a vertical manoeuvre.

Department of Defence analysis of the aircraft's recorded speed and heading variations indicated the manoeuvring was consistent with the conduct of aerobatics.

Witness observations

Several witnesses who observed the aircraft on the accident flight were interviewed by the ATSB. A summary of their recollections is provided below.

Surfers Paradise beach

At around 1000, a witness located at Surfers Paradise beach observed the aircraft turn and track along the beach in a northerly direction, conducting a manoeuvre consistent with a 'split S'[13] turn. While tracking along the beach, the pilot then conducted another manoeuvre likened to an aileron roll.[14]

From the witness' location, it appeared the aircraft was flying below the height of the buildings and was lower than other aircraft they had observed flying along the beach. Based on this, and a comparison of another aircraft present at the time of interview, VH-PAE was estimated to be flying between 200-300 ft.

The witness also recalled that the aircraft's speed and engine sound was constant and there did not appear to be anything unusual. Further, the weather was described as 'fine', with a southerly wind.

Apartment building near South Stradbroke Island

Between 1000-1100, a witness on the 12th floor balcony of their apartment saw the aircraft tracking in a northerly direction along the coast, flying straight-and-level. The aircraft was at the same height as their floor, at an estimated 100-200 ft, which was lower than aircraft usually flying in that area and direction.

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[12] Primary radar is a system where a ground-based antenna transmits a radar pulse, then listens for the small amount of return energy that is reflected from an aircraft. The time delay between the transmission of the pulse and the receipt of the reflected return is a measure of the range. This is effective within a short range from the radar head. Regardless of whether an aircraft has a transponder, primary radar will detect an aircraft's position, height and approximate airspeed.

[13] Split S turn: A flight manoeuvre comprising a half flick (snap) roll followed by a second half of loop, resulting in loss of height and 180° change in heading.

[14] Aileron roll: an aerobatic manoeuvre in which an aircraft does a 360° revolution about its longitudinal axis.

Couran Cove

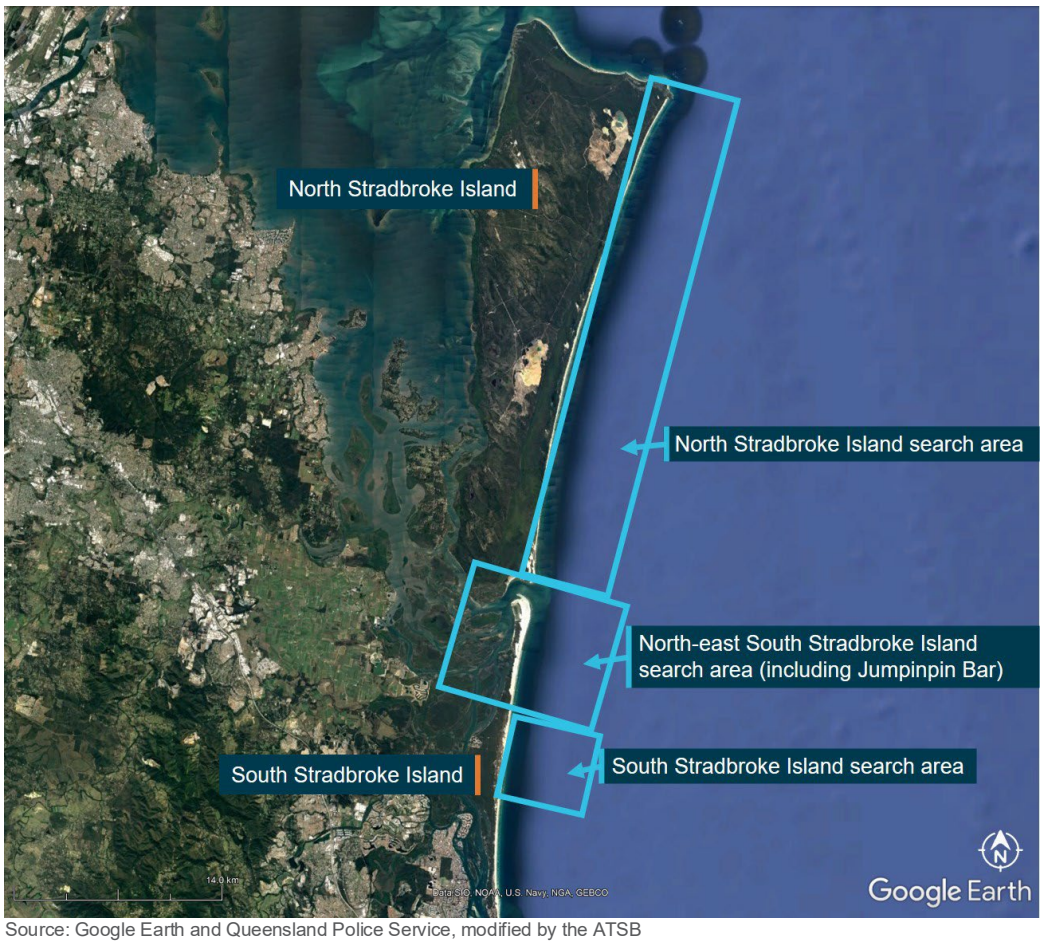
Around 1100,[15] witnesses were on their houseboat on the western side of South Stradbroke Island near Couran Cove, about 5 km south of the Jumpinpin channel. On the south-east side of the island, they observed an aircraft consistent with the accident aircraft conduct a 'loop', 'roll', then 'cut' right, and then dived behind the tree line. The aircraft did not appear to lose height after conducting the loop. The witnesses did not recall any unusual engine noises, nor did they see or hear anything that suggested the aircraft had collided with water.

Wreckage and impact information

Search area and recovered wreckage

The Australian Maritime Safety Authority and Gold Coast Water Police initiated a search for the aircraft and occupants. The search zones were around North Stradbroke Island and to the north-east coastline of South Stradbroke Island, including the Jumpinpin channel (Figure 3). The search was interrupted for several days due to poor weather conditions. When the search resumed, it focussed on the South Stradbroke Island area, where most of the recovered wreckage was found.

Figure 3: Search area



Source: Google Earth and Queensland Police Service, modified by the ATSB

The recovered wreckage, depicted in Figure 4, included:

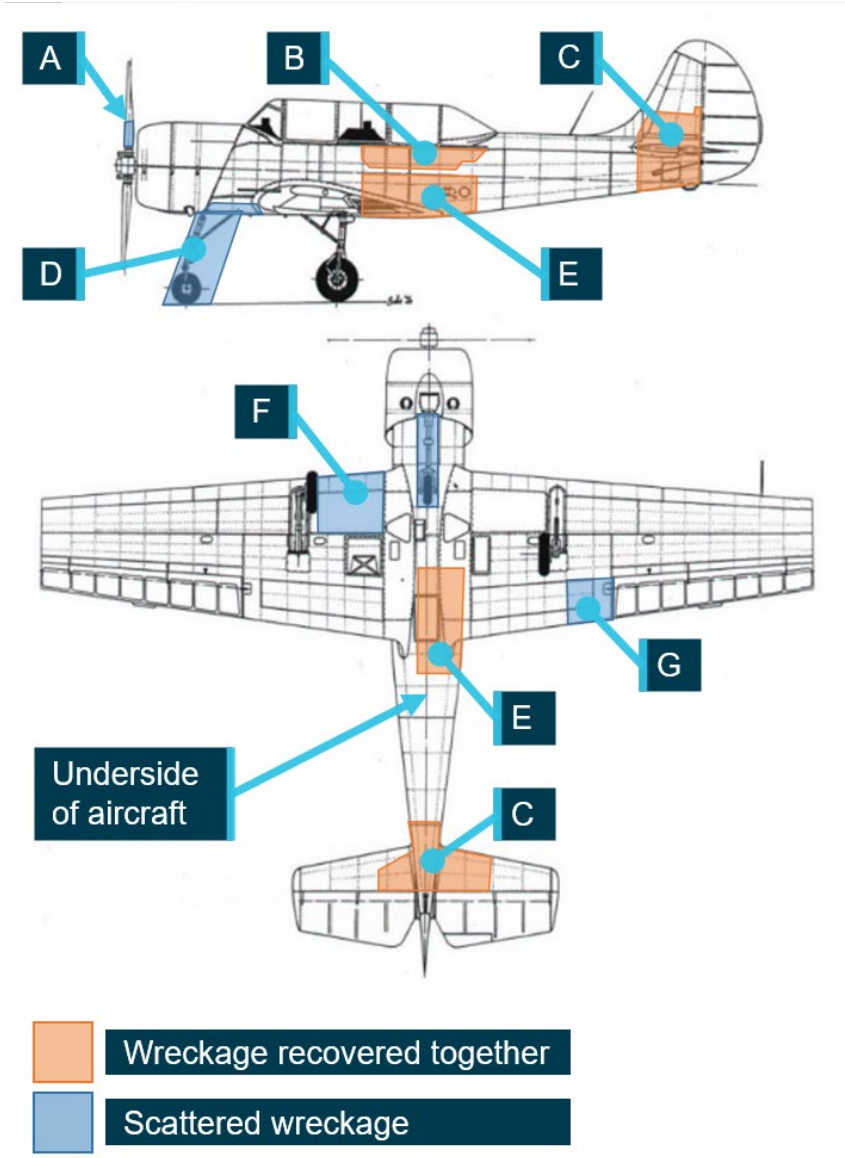
- a number of wooden propeller blade fragments (A)

[15] The witnesses reported sighting the aircraft more than 1 hour after the aircraft's last radar return and other witness sightings. However, their description of the aircraft and the location was consistent with VH-PAE.

- the fuselage skin and structure from the left side of the rear cockpit (B)
- the tail section consisting of the rear fuselage and the inboard sections of the horizontal and vertical stabilisers (the tail section was found attached to the rear cockpit by the flight control cables) (C)
- the nose landing gear, its associated components and mounting structure (this structure formed the floor of the front cockpit and included the front cockpit rudder pedals) (D)
- a number of components from the front and rear cockpits, with the rear cockpit in place but significantly disrupted (E)
- a section of the right wing inboard leading edge (F)
- a section of the left-wing trailing edge adjacent to the aileron (G).

In addition, a seat cushion base and back, and the pneumatic system main and emergency storage tanks were also recovered.

Figure 4: Shaded areas showing the wreckage recovered from VH-PAE



Source: www.yakuk.com, modified by the ATSB

Wreckage examination

The recovered wreckage was transported to secure facilities at the Gold Coast Water Police station for examination by the ATSB. That examination identified that the left-wing rear mount was present with a section of the wing structure.[16] The failure of the wing structure was likely to have been due to overstress and the failure surfaces had been eroded during their time in the ocean prior to recovery.

The left-wing trailing edge included the hinge point for the left aileron and the hinge bracket from the left aileron. The cut-out for the left flap was present along with a section of the wing upper surface skin. The inboard section of the upper surface was torn in an irregular fashion. The outboard section of the upper surface was torn along a rivet line.

The right-wing skin had been torn away from the spar. There was significant disruption to the leading edge. The right-wing fuel tank had been ejected from this section. Remnants of its mounting frames and straps were present. The impact damage to the aircraft meant it was not possible to determine the quantity or quality of the fuel on board prior to the accident. The majority of the lower surface of the recovered wreckage was the right-wing fuel tank access panel. This panel showed evidence of surface hydraulicing,[17] likely resulting from the impact with the water.

Examination of the tail section of the aircraft found the right horizontal stabiliser was extensively damaged with its forward and rear spars bent rearwards and stabiliser skin torn away from the structure (Figure 5). The centre hinge for the elevator was bent inboard. The left horizontal stabiliser had tearing mid-span, but otherwise it retained its original form. The vertical stabiliser was extensively damaged with most of its upper section missing. Further, the wreckage examination identified two small cracks on either side of the elevator bellcrank at a change in section (refer to section titled *Bellcrank examination*).

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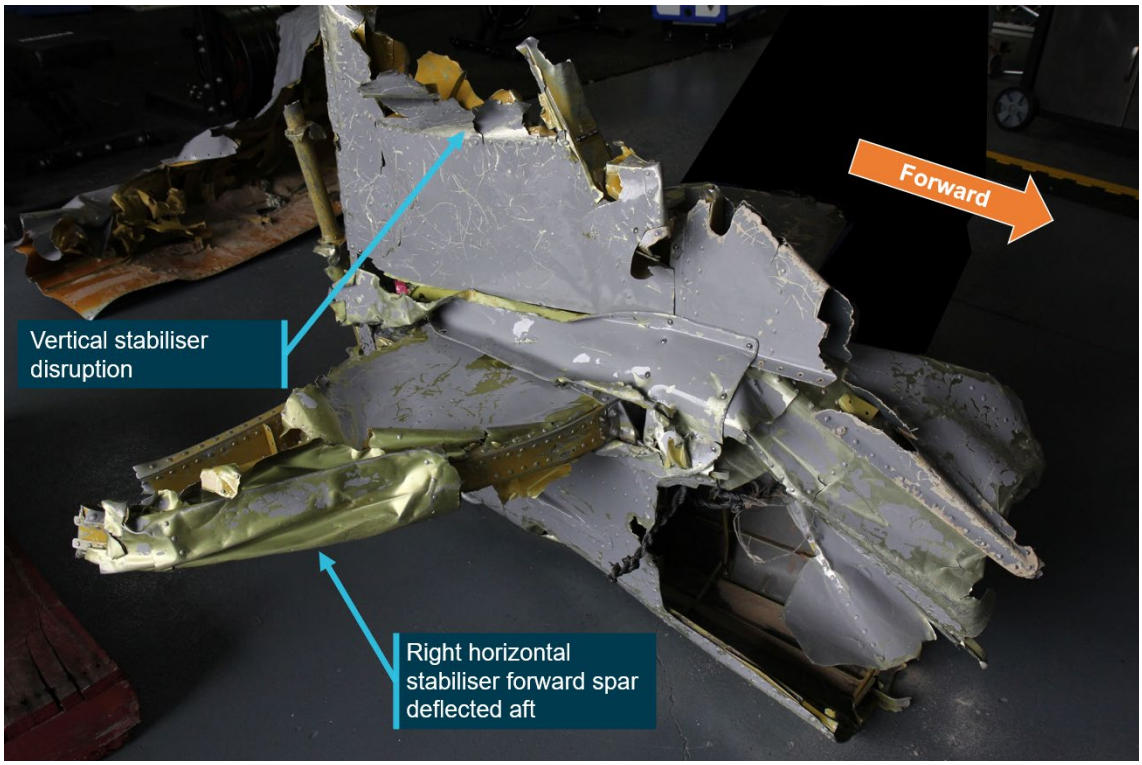
[16] The wings of VH-PAE were replaced with examples modified to service bulletin 59-R and 107-BD specifications by the original owner during its re-assembly in Australia. The wing carry-through spar had been previously modified to service bulletin 60-R specification.

[17] 'Hydraulicing' in this context is the deformation of the aircraft skin around its structural members (such as ribs). This deformation occurs by the action of water on the aircraft skin during the accident sequence.

Figure 5: Tail section damage



Source: ATSB

A significant amount of the aircraft structure and systems were not recovered. However, from the wreckage available for examination, there was no evidence of any pre-impact failures. The significant disruption to the aircraft was indicative of a high-speed impact with significant impact forces, which were not considered survivable.

Elevator bellcrank assembly

Bellcrank examination

The elevator bellcrank is primarily loaded in the vertical plane and transmits the forward and rearward pilot inputs on the control column through the cables to control elevator movement. The ATSB's initial examination of the elevator bellcrank identified two small cracks on either side at the location identified in previously published airworthiness directives (refer to section titled *Airworthiness requirements*) (Figure 6). The larger crack on the right side (aft looking forward) was relatively straight and extended about 3 mm across the rear face of the bellcrank and 10 mm along the side. A number of small indents were observed in the region of the crack. Closer examination of the crack on the left side revealed that it was two smaller cracks. One crack was located on the rear face corner, extending about 1 mm each direction, and the other followed the machined radius and extended for about 7.5 mm.

In order to perform further analysis on the cracking, the bellcrank was fractured to examine and categorise the cracks. This examination identified that the smaller cracks on the left (aft looking forward) showed features consistent with fatigue and were likely present prior to the accident. The larger crack's features were predominantly consistent with overstress as a result of the accident.

A chemical analysis of the bellcrank found it had been manufactured from AK-4 aluminium alloy, which may have been an earlier specification due to the age of the aircraft. The most recent design specification was for the bellcranks to be manufactured from AK-6 aluminium alloy. The radius at the change in thickness from the inner to the outer section of the bellcrank was relatively consistent with that specified on the supplied engineering drawings from the manufacturer.

Figure 6: Elevator bellcrank cracks observed on VH-PAE

Source: ATSB

Previous Yak-52 elevator bellcrank failure

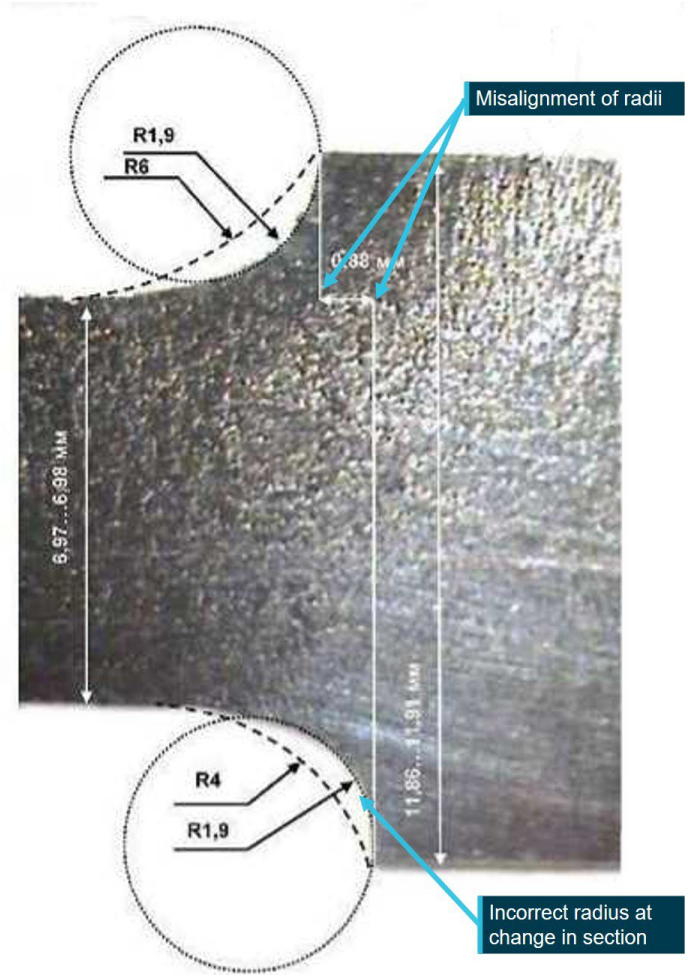
On 19 September 2010, in Yekaterinburg, Russia, a Yak-52 conducting aerobatics was observed by witnesses to enter a steep descent. The pilot reported a broken cable within the aircraft. The pilot was unable to regain control and the aircraft collided with terrain. The pilot was fatally injured and the aircraft was destroyed in a post-impact fire. The investigation outcomes were detailed in a paper published by the Russian Association of Independent Aviation Accident Investigators.

An examination of the wreckage found that the elevator bellcrank had fractured through the inner section, adjacent to the change in section from the inner to the outer section (see *Appendix - Photographs of the elevator bellcrank from the 2010 accident*). Examination of the fracture surface showed it was consistent with a fatigue failure. The bellcrank was found to have been correctly manufactured from AK-6 aluminium alloy according to the design specification for this aircraft having been manufactured in 1990. The paper concluded that high operational cyclic stresses had influenced the development of the fatigue crack, along with multiple aspects relating to the manufacture of the elevator bellcrank including:

- a radius at the change in section (thickness) on the bellcrank was smaller than that specified in the engineering drawings
- when manufactured, the radii on either side of the bellcrank were incorrectly aligned (Figure 7)
- an unfavourable (lateral) microstructure orientation[18]
- rough machining surface at the crack origin.

[18] The preferred orientation of aluminium alloys and other non-ferrous alloys is related to the internal grain structure within the bulk material. A preferred orientation is dependent on the manufacturing method and it influences many properties of the bulk material, including, strength, ductility and resistance to fatigue environmental cracking.

Figure 7: The bellcrank from the Yak-52 involved in the 2010 Yekaterinburg accident showing misalignment of the radii and incorrect radius at the change in section



Source: Society of Independent Air Accident Investigations, modified by the ATSB

The Russian investigation examined an elevator bellcrank from an exemplar aircraft that was manufactured around 1985. This bellcrank was cracked in the same area, had manufacturing defects, and was manufactured from AK-4 specification aluminium alloy. It was noted this may have been an earlier specification due to the age of the aircraft.

Airworthiness requirements

While the presence of the pre-existing cracks did not contribute to the accident involving VH-PAE, they were coincident with the location identified in the airworthiness directives and a service bulletin issued by Lithuania and the UK. Mandatory Permit Directive MPD 2000-004 was issued by the UK Civil Aviation Authority in July 2000 and was based on the Lithuanian airworthiness directive CAI-TSD-007/2000 issued in May 2000. The Lithuanian directive was prompted by the identification of a 19 mm crack found in the elevator control pulley of a Yak-52 during an inspection. The CAA of New Zealand also had an airworthiness directive (DCA/YAK/5) related to elevator bellcrank inspections based on the UK document.

The MPD 2000-004 directive was listed as a special inspection in the AWAL Yak-52 maintenance schedule, which required the bellcrank to be inspected using dye penetrant at every periodic inspection (100 flying hours or 12 months). If cracks were identified, no further flight was permitted until the bellcrank was replaced. The aircraft was inspected in accordance with MPD 2000-004 on 31 October 2018, and since then flew about 35 hours prior to the accident.

In 2009, Yakovlev issued amendment 2 of the scheduled maintenance program for the Yak-52, which extended the airframe life of the aircraft. Among the changes was the requirement for the elevator bellcrank to be inspected at intervals of 25 ± 5 flying hours, and if cracks were detected, then no further flight was permitted until the bellcrank was replaced.

As a result of the Yekaterinburg fatal accident in 2010, Yakovlev issued a letter in 2011 reiterating the requirement for dye penetrant inspections of the elevator bellcrank every 25 ± 5 flying hours, and for the aluminium alloy bellcranks to be replaced with bellcranks manufactured from 30KhGSA (30ХГСА) specification steel.

In 2012, Yakovlev issued service bulletin 121-BD (121-БД), which required all remaining aircraft with aluminium alloy bellcranks to be replaced with steel bellcranks no later than December 2012. The dye penetrant inspection interval of 25 ± 5 flying hours, as specified by amendment 2 of the Yak-52 scheduled maintenance program, remained in place for steel bellcranks.

Despite the significance of these changes in response to the accident in 2010, AWAL was not aware of these changes and therefore had not been incorporated into maintenance schedules in Australia.

Accessing airworthiness information

The Yakovlev Design Bureau provided upon request, airworthiness information such as maintenance requirements, the airframe life, and general support for Yak-52 aircraft both within Russia and overseas. Some Yak-52 aircraft, such as VH-PAE, being operated outside of Russia had reached the end of their prescribed airframe life and were no longer supported by Yakovlev. Therefore owners, operators and maintainers of these aircraft relied on local formal requirements such as MPD 2000-004, their peers, and unofficial sources such as the internet for maintenance information.

The ATSB asked representatives from the UK CAA, CAA of New Zealand, CASA, AWAL, and maintenance organisations about their knowledge of service bulletin 121-BD. They indicated that:

- The UK CAA advised the ATSB they were aware of the service bulletin and associated documents. One of which was taken as the basis for the acceptability of steel bellcranks as replacements for the original aluminium in the Yak-52s operating in the UK. They also advised that some UK operators were continuing with the inspections in MPD 2000-004 even with the steel component fitted.[19] Furthermore, they had no plans to withdraw MPD 2000-004 as there may be aircraft in the UK for which the requirements remained applicable, but were updating it to align with the service bulletin, including acknowledgement of the steel replacement.
- The CAA of New Zealand were unaware of the service bulletin. Prior to the issue of airworthiness directive, DCA/YAK/5 in 2012, they contacted the UK CAA and adopted the requirements of MPD 2000-004.
- The Civil Aviation Safety Authority advised they were unaware of the requirements of the bulletin and there were challenges in obtaining information for Russian aircraft.
- The AWAL advised they were also unaware of the requirements but would consider incorporating them into the AWAL Yak-52 maintenance schedule.
- Similarly, two aircraft maintenance engineers who specialised in maintaining warbird aircraft advised they were unaware of the requirements but were aware that some Yak-52 aluminium bellcranks were being replaced with steel bellcranks.

In consideration of the minimal awareness of the service bulletin, the ATSB issued a safety advisory notice (AO-2019-027-SAN-024) on 25 November 2020. The purpose of the notice was to remind maintainers and operators of the importance of dye penetrant inspections to identify and remove defective bellcranks from service. The notice also noted that Russia, as the aircraft's state

[19] In Russia, dye penetrant inspections continue to be required after the elevator bellcrank has been replaced with one manufactured from steel.

of design, increased their inspection frequency to 25 ± 5 flying hours and that aluminium alloy bellcranks were no longer approved for use on Yak-52s operating in Russia.

Operational information

Pre-flight briefings and informed participation

Warbirds can be used for private operations provided that any passengers who are carried are given a safety briefing. *Civil Aviation Safety Regulation Part 132* required a safety briefing to ensure that a person flying in the aircraft was fully informed of the risks associated with the aircraft and given the opportunity to make a properly informed decision to accept the risks.

According to the CASA advisory circular *Limited category aircraft - operation* (AC 132-01), all limited category aircraft were required to clearly display the word 'limited' on the outside near the entry to the aircraft. In addition, a further safety warning was required to be displayed in a position visible to the pilot and passenger:

WARNING

PERSONS FLY IN THIS AIRCRAFT AT THEIR OWN RISK

THIS AIRCRAFT WAS NOT DESIGNED FOR AIR TRANSPORT OPERATIONS AND IS NOT REQUIRED TO BE OPERATED TO THE SAME SAFETY STANDARDS AS AN AIRCRAFT USED FOR AIR TRANSPORT OPERATIONS

The aircraft had both these displayed in the required areas.

The basis of informed participation in Australia relies on the premise that passengers make themselves aware of the potential risks of undertaking the planned activity, are briefed on the risks, and are given ample time to consider the consequences of accepting these risks. Warbird aircraft are not designed to meet civil aviation airworthiness standards and were constructed for role specific military purposes, therefore, it is important that pilots and passengers of these aircraft are aware that they do not meet conventional airworthiness standards.

The Yak-52 flight manual also specified that a pre-flight briefing must be conducted before any passenger-carrying flight. This should include, explanation of the flight controls and instruments, fitment and operation of the harness, demonstration of the operation of the canopy, and use of the in-cockpit communications system. The second passenger confirmed that the passenger was briefed by the pilot prior to departing on harness operation, remaining clear of the flight controls, and the risk of loose articles in the cockpit. The detail included in the passenger's briefing met the requirements of being informed.

Cost sharing

The flight was conducted under a private cost sharing arrangement, whereby operating costs for the aircraft where shared between the passenger and pilot towards the running of the aircraft for the flight. This was to be the same arrangement for the second passenger, awaiting the return of the aircraft back to Southport Airport.

Yak-52 aerobatic manoeuvring warnings

The aircraft had G load[20] limits of +7g to -5g and a never exceed speed (V_{NE}) of 227 kt. The pilot's operating handbook stated that all aerobatic manoeuvres 'must be conducted at a safe height, not over built up areas and with a pre-determined lower limit for leaving the aircraft [if a parachute is worn] if the manoeuvre cannot be recovered from'. The handbook also contained several warnings regarding specific aerobatic manoeuvres:

[20] The nominal value for acceleration. In flight, g load represents the combined effects of flight manoeuvring loads and turbulence and can have a positive or negative value. A value of 1g is representative of level unaccelerated flight.

> [Dynamic stall][21] Achieved usually through mishandling in tight turns or a too abrupt pull up. A buffet precedes the stall, and the stall is characterized by the aircraft sharply breaking to an unusual flight attitude.
>
> All spinning must be done at a safe altitude with a predetermined bail out height…All spinning must be carried out at an altitude where recovery can be made by 1000m agl (3300 ft agl).
>
> It is not difficult to get into a flat spin through a mishandled stall turn particularly when, as is normally the case, power is kept on. …some aircraft, after a fully developed flat spin…will NOT recover with the conventional spin recovery [techniques].
>
> If practicing spinning, total height loss can be dramatic and even with absolutely correct recovery procedures, height loss can be in excess of 2000 ft and a bit more to level regain flight.

The manual further stated that, irrespective of how many flying hours a pilot had on other aircraft types, it was advisable to receive 'proper instruction' from an experienced instructor who was 'completely familiar' with the Yak-52, particularly in relation to flat spin recovery.

Risks associated with aerobatics

Low-level aerobatics

Conducting manoeuvres at low-level significantly increases the risk of collision with terrain if the manoeuvre is not correctly executed. For example, the Yak-52 pilot's operating handbook indicated that greater than 2,000 ft may be required to recover from a spin. The CASA Civil Aviation Advisory Publication (CAAP) 155-1(0), *Aerobatics*, provided guidance on the rules relating to aerobatic flights and information about the safety risks involved when performing such operations.

As well as detailing the minimum height aerobatics shall be conducted, the CAAP also discusses the risks of low-level aerobatics. Specifically, the CAAP stated that:

> Aerobatics at low-level obviously entail a higher degree of risk because of the reduced safety margins for recovery from manoeuvres. A low-level aerobatics permission should be issued not just because the holder has appropriate aerobatic skills, but because he or she has the ability to assess and manage the risks involved in low-level aerobatics, particularly the risks to third parties.
>
> …It is highly probable that the consequence of an error or failure during low-level aerobatics will be fatal to the participants…

Physiological effects

As highlighted in CAAP 155-1(0), 'Aerobatic manoeuvres involve rapid changes in speed and direction which impose significant accelerative forces on the aircraft and pilot. The physiological effects of these G forces can range from minor discomfort to loss of consciousness'. Such effects may include:

- Grey-out: Loss of colour perception and clarity, possibly accompanied with a loss of peripheral vision during high positive G loads.
- Tunnel vision: A concentric narrowing of the field of vision following grey-out.
- Black-out: The field of vision narrows completely and vision is lost.
- G-induced loss of consciousness: Occurs when the blood flow to the brain, and therefore the supply of oxygen, is sufficiently reduced by the positive G forces being experienced. A high negative G for a significant period may also have a similar effect.
- G incapacitation: There will be a short period of total incapacitation where the pilot is completely unconscious. This is followed by a recovery period of relative incapacitation where the pilot regains consciousness but is in a confused state and unable to control the aircraft.

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[21] Aerodynamic stall: occurs when airflow separates from the wing's upper surface and becomes turbulent. A stall occurs at high angles of attack, typically 16˚ to 18˚, and results in reduced lift.

Unless the aircraft has sufficient height for the pilot to reduce G, and recover vision and/or consciousness, there is a risk of collision with terrain (United States Federal Aviation Administration n.d.).

Risk perception and interventions for unsafe behaviour

Unsafe acts are an error or violation committed in the presence of a potential hazard, that if not properly controlled, could cause injury or damage (Reason 1990). Examples of unsafe acts include violations, which are deviations from practices to maintain safe operations. Research conducted by Shuch (1992) reported that pilot perception of risk may decrease with repeated successful outcomes. Shuch (1992) found that if a pilot has a history of flights without incident, then they may perceive that they have a lower likelihood of an adverse outcome based on their prior incident-free experiences.

If there are concerns about a pilot's behaviour from a safety perspective, there are formal reporting systems available to industry people and the general public. These include:

- Reporting to the local flying club or aerodrome operator.
- Reporting to the ATSB using the voluntary and confidential reporting scheme (REPCON). This scheme allows any person who has an aviation safety concern to report it to the ATSB confidentially. Safety concerns include an incident or circumstance that affects or might affect the safety of aircraft operations. Once submitted, the report is de-identified to protect the reporter and forwarded to the relevant organisation that is best placed to address the issue.
- Reporting unsafe behaviour to CASA using their confidential and anonymous reporting scheme. When a report is made, CASA is obliged to act on valid reported safety related information.

Similar occurrences

A search of the ATSB's occurrence database found the following investigations relating to low-level aerobatics.

ATSB investigation (AO-2018-066)

On 5 October 2018, a BRM Aero Bristell light sport aircraft, registered VH-YVX, departed Moorabbin Airport, Victoria, with a pilot and passenger on board. The purpose of the flight was a navigation exercise in support of the pilot's commercial pilot training requirements. Following an overfly of the intended waypoint at Stawell Airport, the aircraft was observed by witnesses to conduct a number of aerobatic-type manoeuvres before control was lost. The pilot was unable to recover control of the aircraft before it impacted terrain. The occupants sustained significant injuries and the aircraft was destroyed.

The ATSB determined that, contrary to the aircraft's limitations and the pilot's qualifications, aerobatic manoeuvres were conducted during the flight, and immediately prior to the loss of control. During one of these manoeuvres, the aircraft experienced an accelerated aerodynamic stall and entered into an upright spin at an altitude of about 1,650 ft AGL, which then progressed into a fully-developed spin. Although the pilot did not consistently apply the manufacturer's recommended spin recovery technique, recovery from a fully-developed spin may not have been possible in the aircraft type.

ATSB investigation (AO-2018-061)

On 7 September 2018, the pilot of a Yakovlev 9-UM (YAK 9) aircraft, registered VH-YIX, departed Latrobe Airport, Victoria for a local private flight. The aircraft was observed by witnesses to the north of Moe performing aerobatic maneuvers. A short time later, the aircraft impacted the ground in a steep nose-down attitude, fatally injuring the pilot and destroying the aircraft.

The ATSB found that the aircraft entered a spin at low altitude (below 1,000 ft) from which it was not possible to recover. There was no evidence of pilot incapacitation, or a mechanical fault with the aircraft that contributed to the accident. Although possessing an aerobatic endorsement, the pilot did not hold the endorsement to conduct aerobatics below 3,000 ft. The pilot had limited experience and recency in the YAK 9 and had not previously conducted aerobatics in the aircraft. The pilot was therefore likely unaware of its unique handling characteristics and not adequately prepared to conduct the solo aerobatic flight.

ATSB investigation (AO-2015-074)

On the afternoon of 8 July 2015, the pilot of an amateur-built Pitts Model 12, registered VH-JDZ, took off from Maitland Airport, New South Wales. Witnesses observed the aircraft at the top of what appeared to be a vertical climb. The aircraft slid backwards, tail first, before entering a horizontal spin. Shortly after, the witnesses lost sight of the aircraft below the tree line and some reported hearing a loud bang. The aircraft had collided with terrain in thick bushland. The pilot was fatally injured and the aircraft was destroyed.

Radar data and witness reports were consistent with the aircraft being used for aerobatic manoeuvres in the minutes prior to the accident, with some of the flight being conducted below 200 ft AGL. The ATSB found that, for reasons that could not be determined, VH-JDZ entered a vertical manoeuvre from which the pilot did not regain control before colliding with terrain. The pilot had trained for aerobatics, but did not hold an aerobatic endorsement and the aircraft was being flown at a height that reduced the time available to recover from a loss of control, if required.

Safety analysis

Introduction

In the morning, the pilot and passenger departed Southport Airport, Queensland, on a private aerobatic flight in VH-PAE. During the flight, while near South Stradbroke Island, the aircraft collided with water. Both occupants sustained fatal injuries and the aircraft was destroyed.

While the aircraft in its entirety could not be located, examination of the recovered wreckage did not identify any pre-existing defects that would have contributed to the accident. Similarly, witness observations shortly before the accident suggested that there no mechanical issues with the aircraft at that time.

This analysis will examine the known events leading up to the accident, the pilot's previous history conducting low-level aerobatic flights, and the opportunities available for aviation industry personnel to provide intervention. Further, the fatigue cracking of the elevator bellcrank, the availability of updated airworthiness information for Yak-52 aircraft operating outside Russia, and the aircraft life limits and assigned permit index will also be discussed.

Flight prior to the collision with water

The plan was to conduct a scenic flight along the coast with some aerobatics. This was consistent with witness comments, where a number of aerobatic manoeuvres was observed being conducted below 500 ft during the accident flight. In addition, Department of Defence surveillance data recorded an aircraft manoeuvring over South Stradbroke Island in a manner consistent with aerobatics and with the timing for VH-PAE. No altitude data was detected, which was consistent with the fact that the aircraft was not fitted with a transponder. However, as the aircraft was not detected by the radar numerous times, this indicated it was either below the radar coverage of three local radar sites and/or due to terrain shielding. Despite this, in the absence of recorded data or witnesses to the collision with water, it could not be determined with certainty that the pilot was conducting an aerobatic manoeuvre immediately prior to impact, but it was considered possible.

The significant amount of disruption to the aircraft, and the limited wreckage recovered, indicated the aircraft impacted the water at high speed. The damage to the right horizontal stabiliser and the vertical stabiliser suggested the aircraft entered the water inverted with its right wing down. However, in contrast, the hydraulicing found on the lower surface of the right wing suggested an upright attitude. In light of this conflicting evidence, the exact orientation of the aircraft when it collided with the water could not be determined.

However, due to the limited evidence available at the time of the accident, the ATSB was unable to consider a number of potential factors that could explain why the aircraft collided with the water. These included inadvertent passenger interference with the flight controls, loose articles interfering with the flight controls, an engine failure, partial or full pilot incapacitation possibly due to the physiological effects of conducting aerobatics, an aerodynamic stall, or otherwise mishandled manoeuvre.

Pilot's history with low-level aerobatics

The pilot had obtained an endorsement to conduct aerobatics and spinning above 3,000 ft about 6 months prior to the accident. However, the pilot did not hold a low-level aerobatic endorsement or an operational rating for low-level flying. Despite this, witnesses and previous passengers had observed the pilot conduct aerobatics below the endorsed height, including on the accident flight. It was also noted that one of these flights had been conducted prior to the pilot receiving the endorsement. Research has shown that the perception of risk can decrease with repeated successful outcomes, which, in this case, may have reinforced the pilot's behaviour.

In addition, while the pilot was made aware of the requirements for low-level aerobatic training by a flying instructor, the investigation found no evidence that the pilot had received any training toward this. The aerobatic endorsement process outlined in the Civil Aviation Safety Authority's (CASA) Manual of Standards provided the means for the pilot to conduct training and be assessed for aerobatics at lower heights. If this process had been followed, the pilot would have had further opportunities to learn how to identify and manage the risks specific to low-level aerobatic manoeuvres.

As previously discussed, it could not be determined whether low-level aerobatics was being conducted at the time of the accident. Irrespective, performing these manoeuvres reduces the safety margins to recover from mishandled manoeuvres and adverse physiological effects, which substantially increases the risk of an accident.

Interventions for unsafe acts

Despite not being appropriately qualified, the pilot was observed conducting low-level aerobatics on several occasions prior to the accident by different people from within the aviation industry. While some people attempted to communicate their concerns about risk-taking behaviour to the pilot, there was no evidence found that the pilot's behaviour had been reported to the ATSB or CASA. Direct intervention with a person observed to be engaged in unsafe flying behaviour can be challenging. For example, it can lead to defensive behaviour and an adversarial situation with a negative outcome for both parties. Therefore, confidential reporting systems such as that provided by the ATSB and CASA provide a means to escalate concerns about pilot behaviour and provide protection for the source of the report.

Elevator bellcrank fatigue crack

Examination of the elevator bellcrank found two small pre-existing fatigue cracks located adjacent to a change in thickness from the inner to the outer section of the bellcrank. The location of these cracks was coincident with the location identified in the United Kingdom Civil Aviation Authority Mandatory Permit Directive MPD 2000-004. As per the Australian Warbirds Association Limited maintenance schedule for the aircraft, which included the requirement to carry out MPD 2000-004, a dye penetrant inspection had been performed on the bellcrank about 35 hours prior to the accident. However, the ATSB was unable to determine when the cracking initiated.

While the cracking did not contribute to the accident, if it had not been identified during subsequent inspections, the crack would have eventually progressed to failure and almost certainly resulted in a loss of control.

Access to information for continued airworthiness

As some Yak-52 aircraft being operated outside of Russia had reached the end of their prescribed airframe life, they were no longer supported by Yakovlev. Therefore, the airworthiness requirements for these aircraft were determined independently by owners, operators and maintainers who relied on local formal requirements such as MPD 2000-004, their peers, and unofficial sources such as the internet for maintenance information. Consequently, these airworthiness requirements had remained relatively unchanged since 2000. This was evident from discussions with a number of relevant parties, including CASA, the Australian Warbirds Association Limited, maintainers, and operators who were not aware of service bulletin 121-BD and the preceding documentation relevant to the elevator bellcrank. In addition, it was not clearly understood that after replacing an aluminium elevator bellcrank with one manufactured from steel, the requirement for dye penetrant inspections still applied.

In accordance with the Australian airworthiness requirements at the time, the aircraft's elevator bellcrank was inspected about 35 hours prior to the accident. The manufacturer's most recent requirements had a shorter inspection interval, which would have resulted in the bellcrank being

inspected again about 10 hours prior. However, as it could not be determined when the cracking initiated, it was unknown if the cracks would have been identified had that inspection occurred.

Despite this, not having a formal communication mechanism outside of Russia for those aircraft no longer supported, increased the risk that important information about the continued airworthiness of the Yak-52 aircraft might not be identified, which could potentially lead to in-service failures.

Airframe life and permit index assessment

At the time the permit index assessment for VH-PAE was carried out by the Australian Warbirds Association Limited (AWAL), the aircraft was 15 years older than its prescribed airframe life of 20 years. A further 40 per cent of Yak-52s registered with AWAL had also exceeded their airframe life at the time of registration. Despite this, the aircraft, including VH-PAE, were assigned a permit index of '0', which meant that they could be operated over populous areas.

While AWAL had a life extension procedure that could be applied to an aircraft that exceeded its airframe life, they did not regard the Yak-52 as having an airframe life as they had not been presented with documentation they considered suitable to define it, and from their experience they did not consider it to be an issue. However, the United Kingdom Civil Aviation Authority Mandatory Permit Directive (MPD) 1998-017 defining Yak-52 airframe life limits had been produced with the assistance of Yakovlev. Although Yak-52 aircraft in Australia were not required to comply with the airworthiness requirements of foreign authorities, the existence of an airframe life limit could be established from this directive to guide the AWAL permit index assessment.

The AWAL exposition and self-administration manual permit index assessment procedure, and if needed, the airframe life extension procedure, partly depended on the extent and quality of information provided by the aircraft owner to the approved person carrying out the assessment. However, the procedures were intended to ensure that the risk in operating warbird aircraft such as VH-PAE was confined to the occupants of the aircraft, while protecting the general public from risk of harm or property damage. By not formally considering risk elements contained within the permit index assessment, an acceptable level of safety could not be assured.

Findings

ATSB investigation report findings focus on safety factors (that is, events and conditions that increase risk). Safety factors include 'contributing factors' and 'other factors that increased risk' (that is, factors that did not meet the definition of a contributing factor for this occurrence but were still considered important to include in the report for the purpose of increasing awareness and enhancing safety). In addition 'other findings' may be included to provide important information about topics other than safety factors.

These findings should not be read as apportioning blame or liability to any particular organisation or individual.

From the evidence available, the following findings are made with respect to the collision with water involving Yakovlev Aircraft Industries Yak-52, VH-PAE, near South Stradbroke Island, Queensland, on 5 June 2019.

Contributing factors

- While conducting an aerobatic flight, which included low-level manoeuvres, for reasons undetermined, the aircraft collided with the water at high speed.

Other factors that increased risk

- The pilot was not trained or endorsed for low-level aerobatics, but conducted them on the accident flight and previous flights. This behaviour increased the risk of an accident from either a mishandled manoeuvre or adverse physiological effects.
- The pilot had previously performed unsafe acts that were witnessed by people from the aviation industry. While the pilot did receive previous warnings, there were other opportunities and means for people to formally communicate and escalate their concerns that were not used.
- A pre-existing fatigue crack was found in the elevator bellcrank, which had the potential to fail in-flight and lead to a loss of control.
- There was no formal mechanism for the state of design to provide airworthiness information for Yak-52 aircraft that had reached the end of their prescribed airframe life. This resulted in updated information regarding the elevator bellcrank inspection interval and design not being known or included in local maintenance schedules.
- The Australian Warbirds Association Limited did not consider Yak-52 aircraft to have an airframe life, and therefore, they were assigned a permit index of zero, which allowed flight over populous areas. However, there was information available from Yakovlev via the United Kingdom Civil Aviation Authority that detailed airframe life limits.

Safety issues and actions

Central to the ATSB's investigation of transport safety matters is the early identification of safety issues. The ATSB expects relevant organisations will address all safety issues an investigation identifies.

Depending on the level of risk of a safety issue, the extent of corrective action taken by the relevant organisation(s), or the desirability of directing a broad safety message to the aviation industry, the ATSB may issue a formal safety recommendation or safety advisory notice as part of the final report.

All of the directly involved parties are invited to provide submissions to this draft report. As part of that process, each organisation is asked to communicate what safety actions, if any, they have carried out or are planning to carry out in relation to each safety issue relevant to their organisation.

The initial public version of these safety issues and actions will be provided separately on the ATSB website on release of the final investigation report, to facilitate monitoring by interested parties. Where relevant, the safety issues and actions will be updated on the ATSB website after the release of the final report as further information about safety action comes to hand.

Safety action not associated with an identified safety issue

Safety advisory notice to owners and maintainers of Yak-52 aircraft

SAN number:	AO-2019-027-SAN-024
SAN release date:	25 November 2020

In November 2020, the Australian Transport Safety Bureau issued a safety advisory notice to owners and maintainers of Yak-52 aircraft:

> Given the known fatigue cracking and potential failure of Yakovlev Aircraft Factories Yak-52 elevator bellcranks manufactured from aluminium alloy, the ATSB reminds maintainers and operators of the importance of dye penetrant inspections to remove defective bellcranks from service. The ATSB would also like to ensure that operators and maintainers of Yak-52 aircraft are aware that Russia, the aircraft's state of design, increased the inspection frequency for the bellcranks to 25 ± 5 flying hours. Further, aluminium alloy bellcranks are no longer approved for use on Yak-52s operating in Russia.

General details

Occurrence details

Date and time:	5 June 2019 – 1000 EST	
Occurrence category:	Accident	
Primary occurrence type:	Collision with terrain	
Location:	near South Stradbroke Island, Queensland	
	Latitude: 27°52'48.0"S	Longitude: 153°24'36.0"E

Aircraft details

Manufacturer and model:	Yakovlev Aircraft Factories Yak-52	
Registration:	VH-PAE	
Serial number:	822001	
Type of operation:	Private	
Departure:	Southport Airport, Queensland	
Destination:	Southport Airport, Queensland	
Persons on board:	Crew – 1	Passengers – 1
Injuries:	Crew – 1 (fatal)	Passengers – 1 (fatal)
Aircraft damage:	Destroyed	

Glossary

AGL	Above Ground Level
AWAL	Australian Warbirds Association Limited
CAAP	Civil Aviation Advisory Publication
CAA	Civil Aviation Authority
CASR	Civil Aviation Safety Regulation
CASA	Civil Aviation Safety Authority
MPD	Mandatory Permit Directive
PI	Permit index

Sources and submissions

Sources of information

The sources of information during the investigation included the:

- Airservices Australia
- Department of Defence
- Queensland Police Service
- Civil Aviation Safety Authority
- witnesses
- maintenance organisation for VH-PAE
- Interstate Aviation Committee (MAK)
- Yakovlev Design Bureau
- Australian Warbirds Association Limited
- Recreational Aviation Australia
- Bureau of Meteorology
- previous owner of VH-PAE
- United Kingdom Air Accidents Investigation Branch
- Civil Aviation Authority of New Zealand.

References

Civil Aviation Safety Authority 2017, *AC 21-25 Limited category aircraft - permit index.* Civil Aviation Safety Authority.

Civil Aviation Safety Authority 2007, *Civil Aviation Advisory Publication CAAP 155-1(0), Aerobatics.* Civil Aviation Safety Authority.

Federal Aviation Administration n.d. *Acceleration in Aviation: G-Force.* Federal Aviation Administration.

Schuch, HP 1992, The influence of flight experience on midair collision risk perception. *Accident Analysis & Prevention,* vol. 24, pp. 655-660.

Submissions

Under section 26 of the *Transport Safety Investigation Act 2003*, the ATSB may provide a draft report, on a confidential basis, to any person whom the ATSB considers appropriate. That section allows a person receiving a draft report to make submissions to the ATSB about the draft report.

A draft of this report was provided to the following directly involved parties:

- Civil Aviation Safety Authority
- witnesses
- maintenance organisation for VH-PAE
- Interstate Aviation Committee (MAK)
- Yakovlev Design Bureau
- Department of Defence
- Airservices Australia
- Australian Warbirds Association Limited
- Southport Flying Club

- United Kingdom Air Accidents Investigation Branch
- Civil Aviation Authority of New Zealand
- Dutch Safety Board.

Responses were received from the:

- Civil Aviation Safety Authority
- Interstate Aviation Committee (MAK)
- United Kingdom Air Accidents Investigation Branch
- Australian Warbirds Association Limited.

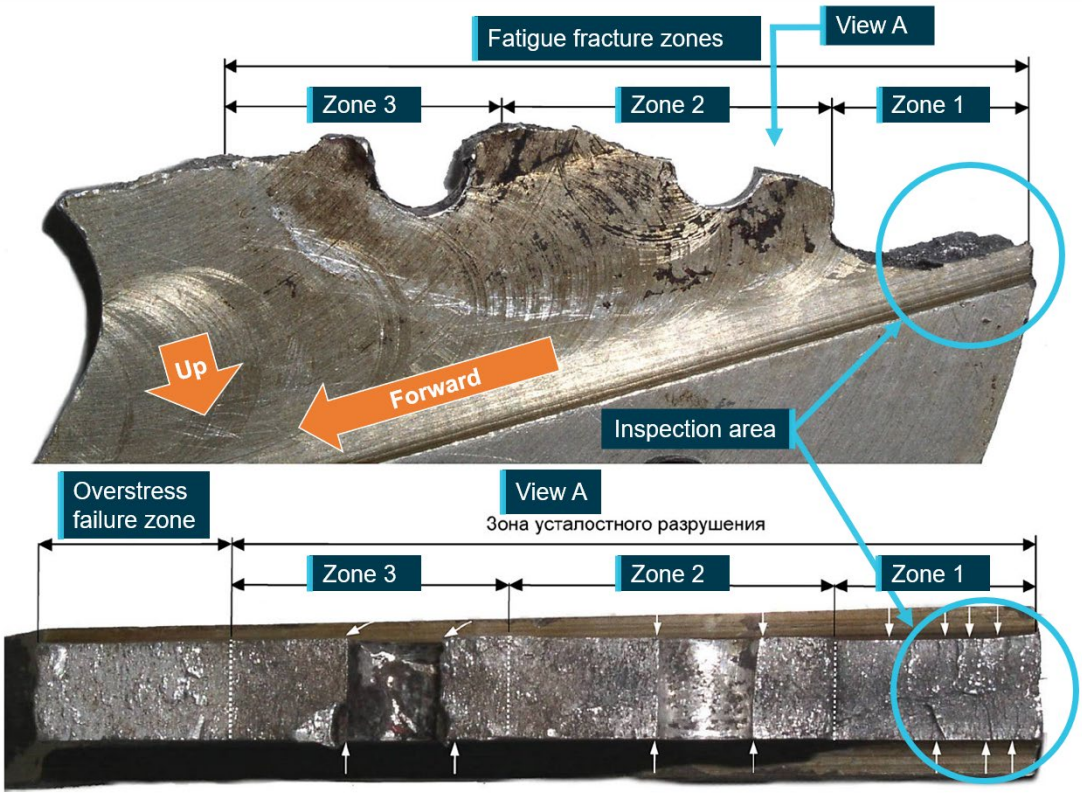
The submissions were reviewed and, where considered appropriate, the text of the report was amended accordingly.

Appendix - Photographs of elevator bellcrank from the 2010 accident

Figure 8: Yak-52 elevator bellcrank from the 2010 Yekaterinburg accident

Source: Society of Independent Air Accident Investigators, modified by the ATSB

Figure 9: Fatigue fracture zones on the elevator



Note: The various zones indicate the different fatigue fracture characteristics.
Source: Society of Independent Air Accident Investigators, modified by the ATSB

Australian Transport Safety Bureau

About the ATSB

The ATSB is an independent Commonwealth Government statutory agency. It is governed by a Commission and is entirely separate from transport regulators, policy makers and service providers.

The ATSB's purpose is to improve the safety of, and public confidence in, aviation, rail and marine transport through:

- independent investigation of transport accidents and other safety occurrences
- safety data recording, analysis and research
- fostering safety awareness, knowledge and action.

The ATSB is responsible for investigating accidents and other transport safety matters involving civil aviation, marine and rail operations in Australia, as well as participating in overseas investigations involving Australian-registered aircraft and ships. It prioritises investigations that have the potential to deliver the greatest public benefit through improvements to transport safety.

The ATSB performs its functions in accordance with the provisions of the *Transport Safety Investigation Act 2003* and Regulations and, where applicable, international agreements.

Purpose of safety investigations

The objective of a safety investigation is to enhance transport safety. This is done through:

- identifying safety issues and facilitating safety action to address those issues
- providing information about occurrences and their associated safety factors to facilitate learning within the transport industry.

It is not a function of the ATSB to apportion blame or provide a means for determining liability. At the same time, an investigation report must include factual material of sufficient weight to support the analysis and findings. At all times the ATSB endeavours to balance the use of material that could imply adverse comment with the need to properly explain what happened, and why, in a fair and unbiased manner. The ATSB does not investigate for the purpose of taking administrative, regulatory or criminal action.

Terminology

An explanation of terminology used in ATSB investigation reports is available on the ATSB website. This includes terms such as occurrence, contributing factor, other factor that increased risk, and safety issue.